UNIVERSIDADE FEDERAL DO CEARÁ
CENTRO DE TÉCNOLOGIA
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RÚBEN NUNES DA SILVA

REVISÃO DOS DISPOSITIVOS IGBT’s COMERCIAIS UTILIZADOS EM TRABALHOS ACADÊMICOS E ANÁLISE DA VARIAÇÃO DOS PREÇOS DE MOSFET’s NO CONTEXTO DE PANDEMIA DA COVID 19

FORTALEZA
2022

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Trabalho de Conclusão de Curso apresentado ao Programa de Graduação em Engenharia Elétrica da Universidade Federal do Ceará, como requisito parcial à obtenção do título de Engenheiro Eletricista.

Orientador: Prof. Dr. Sergio Daher

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Aprovada em ___ / ___ / _______.

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Ao meu Deus e meu Senhor Jesus Cristo.

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“Gravity explains the motions of the planets, but it cannot explain who sets the planets in motion.”

Isaac Newton

RESUMO

Este trabalho apresenta uma análise da evolução de especificações de dispositivos IGBT's discretos utilizados em trabalhos acadêmicos nacionais e internacionais ao longo das duas últimas décadas. Além disso, foi realizado o estudo da evolução local dos preços de dispositivos MOSFET ao longo dos últimos quatro anos com o pano de fundo da pandemia da COVID-19 e levando em consideração o histórico de cotação do dólar em reais para o mesmo período. Para o primeiro estudo, considerou-se três fontes para compilação de artigos acadêmicos: o Repositório de Trabalhos Acadêmicos da Universidade Federal de Santa Catarina (UFSC), a Revista de Eletrônica de Potência da Sociedade Brasileira de Eletrônica de Potência (SOBRAEP) e a Revista de Eletrônica de Potência (*Journal of Power Electronics)* do Instituto Coreano de Eletrônica de Potência. Das referências de IGBT's compiladas, coletou-se as principais especificações de *datasheet* a fim de descrever os dispositivos e analisar os parâmetros de tensão coletor-emissor em condução ($V_{CE(ON)}$) e de perda total por comutação (E_T). Ambas as especificações são menores em dispositivos mais eficientes. Os dispositivos estudados apresentam tensão de bloqueio ($V_{CE(BR)}$) entre $400\ V$ e $1200\ V$ e corrente de coletor (I_C) entre $6\ A$ e $105\ A$ a $25°\ C$. As referências de IGBT's totalizam 73. Observou-se, que houve melhoramento da queda de tensão, $V_{CE(ON)}$, para os dispositivos que apresentam tensões, $V_{CE(BR)} = 1{,}2\ kV$. Já para dispositivos com tensões de bloqueio menores, constatou-se que não houve melhora do parâmetro $V_{CE(ON)}$. Na especificação de perda total de energia por comutação, E_T, observou-se que para dispositivos de até $650\ V$ de tensão de bloqueio, houve um descréscimo do parâmetro nos anos de 2008 e 2009 em relação a anos prévios, o que sugere que houve melhoramento nesse período. Já para transistores com tensão de bloqueio máxima de $1{,}2\ kV$, observou-se diminuição de valores ao longo das duas últimas décadas, indicando que houve melhoramento do parâmetro. Na análise de preços dos MOSFET's, constatou-se que os preços dos semicondutores subiram mais que a cotação do dólar para o mesmo período. Isso evidencia que a principal causa foi a escassez de semicondutores causada pela pandemia da COVID-19, apesar do preço do dólar ainda ser um importante fator.

Palavras-Chave: IGBT. Evolução tecnológica. Variação de preço. COVID-19.

ABSTRACT

This work reports an evolution analysis of specifications of discrete IGBT devices used in national and international academic works over the last two decades. In addition, it comprises the study of the local development of prices for MOSFET devices over the last four years against the backdrop of the COVID-19 pandemic and considering the historical exchange rate of the dollar in reais over the same period. In the first study, three sources were considered to compile the academic articles: the Repository of Academic Works from the Federal University of Santa Catarina (UFSC), the Power Electronics Magazine from the Brazilian Society of Power Electronics (SOBRAEP) and the Journal of Power Electronics from the Korean Institute of Power Electronics. From the compiled IGBT references, the main *datasheet* specifications were collected in order to characterize the devices and analyze the on-state collector- emitter voltage parameters $(V_{CE(ON)})$ and total switching loss (E_T). Both specs are lower on more efficient devices. The studied devices have the blocking voltage $(V_{CE(BR)})$ between $400\ V$ and $1200\ V$, and collector current (I_C) between $6\ A$ and $105\ A$ in $25\ °C$. The references of IGBT's add up to 73. It was noticed that there was improvement for the voltage drop specification, $V_{CE(ON)}$, for devices that present voltages, $V_{CE(BR)} = 1.2\ kV$. Whereas for devices with lower blocking voltages, there was no improvement in the $V_{CE(ON)}$ parameter. In the specification of total loss of energy per switching, E_T, it was observed that for devices with up to 650 V of blocking voltage, there was a decrease in the specification in the years 2008 and 2009 compared to previous years, which suggests that there was an improvement in this period. Where as for transistors with a maximum blocking voltage of 1.2 kV, a decrease in values was observed over the last two decades, indicating that there was improvement in the parameter. In the MOSFET price analysis, it was noticed that the prices of semiconductors rose more than the dollar exchange rate for the same period. This reveals that the main cause was the semiconductors shortage caused by the COVID-19 pandemic, despite the dollar price still being an important factor.

Keywords: IGBT. Technological evolution. Price variation. COVID-19.

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LISTA DE ABREVIATURAS E SÍMBOLOS

IGBT	*Insulated Gate Bipolar Transistor*
MOSFET	*Metal-Oxide-Semiconductor Field-Effect Transitor*
TBJ	Transistor Bipolar de Junção
SOBRAEP	Sociedade Brasileira de Eletrônica de Potência
UFSC	Universidade Federal de Santa Catarina
INEP	Instituto de Eletrônica de Potência
PT	*Punch through*
NPT	*Non Punch Through*
FS	*Field Stop*

SUMÁRIO

1 INTRODUÇÃO

A eletrônica de potência se encontra em diversas aplicações cotidianas: ar-condicionados, fogões de indução, computadores pessoais, nobreaks (UPS), fontes e carregadores de bateria, dentre outros.

Durante as três últimas décadas, a eletrônica de potência tem contribuído para o desenvolvimento e inovação de um grande número de aplicações e áreas de estudo, como, robótica, satélites, automação industrial, internet das coisas, indústria automotiva e aeronáutica, dentre outros (LANNUZZO, 2020).

Além desses usos, a eletrônica de potência tem atuações em processos eletromecânicos, controle de temperatura e luminosidade, aplicações médicas, comunicação, rede de computadores, sistemas de geração, transmissão e distribuição de energia elétrica, transporte e aplicações militares (MARI, 2020).

A pandemia da COVID-19, que teve início em 2020, dentre as muitas consequências, trouxe um profundo impacto na cadeia de suprimentos mundial, especialmente, no setor de semicondutores levando a uma escassez de chips eletrônicos em escala global nos últimos quatro anos.

Segundo, o CEO da empresa de semicondutores GlobalFoundries, Tom Caulfield, a escassez não é dos chips mais avançados, mas os chamados "*legacy nodes*" (nós de legado), que são os chips de tecnologia mais antiga que atuam em funções como, gerenciamento de energia, conexão de telas ou habilitação de conexões sem fio. (CNBC, 2021).

Tal escassez foi consequência de um acumulo de fatores como, o aumento da demanda por eletrônicos como resultado das campanhas de "*homeoffice*" durante os chamados "*lockdowns*" na pandemia, ao mesmo tempo que as empresas do setor de semicondutores previram diminuição da demanda devido as restrições econômicas. Além disso, houve uma escassez mundial de contêiners que afetou amplamente a cadeia de suprimentos em vários setores, incluindo a indústria de semicondutores. (PACHHANDARA, 2022)

1.1 Objetivos

Este presente trabalho tem como primeira proposta a pesquisa bibliográfica de IGBT's discretos de Si utilizados em trabalhos acadêmicos brasileiros e internacionais, na área de Eletrônica de Potência, desenvolvidos ao longo dos últimos 24 anos. Fazendo uma análise comparativa de evolução de desempenho e eficiência no decorrer dos anos.

Os trabalhos foram compilados de três fontes: o Repositório de Trabalhos Acadêmicos da Universidade Federal de Santa Catarina (UFSC), a Revista de Eletrônica de Potência da Sociedade Brasileira de Eletrônica de Potência (SOBRAEP) e a Revista de Eletrônica de Potência (*Journal of Power Electronics)* do Instituto Coreano de Eletrônica de Potência (*The Korean Institute of Power Electronics*). A escolha das fontes foi feita levando em conta a tradição da UFSC na área de Eletrônica de Potência com o seu Instituto de Eletrônica de Potência (INEP), a Revista de Eletrônica de Potência da SOBRAEP contém um acervo de artigos publicados, na área em estudo, que são reconhecidos nacional e mundialmente e, além disso, o Instituto Coreano de Eletrônica de Potência promove diversificação dos trabalhos escolhidos, já que eles publicam trabalhos acadêmicos de diversas partes do mundo.

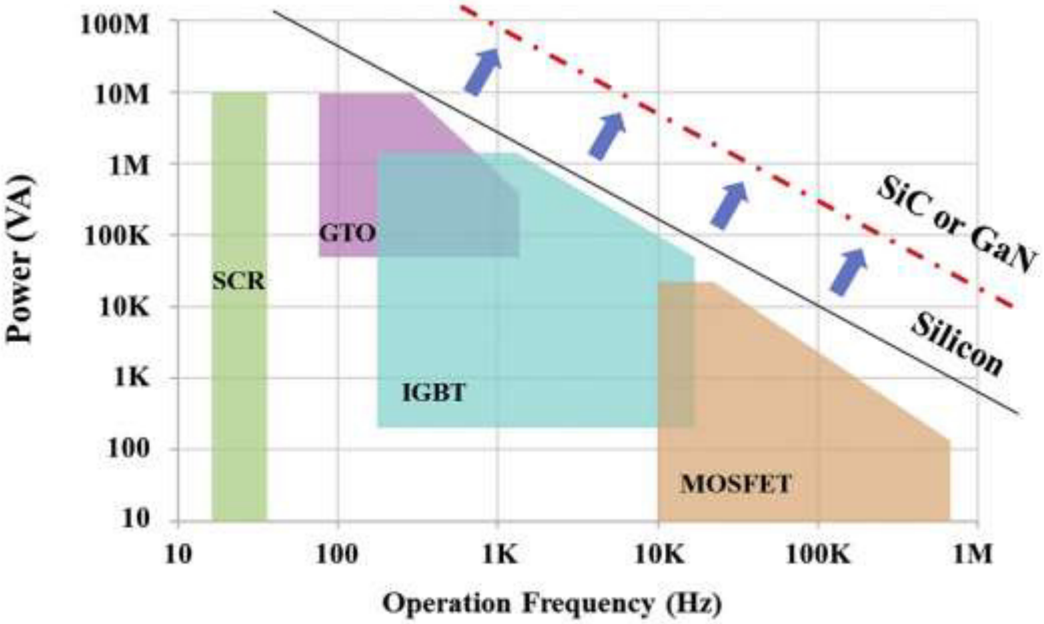
A segunda parte do trabalho visa avaliar o desenvolvimento de preços de dispositivos semicondutores de potência ao longo dos últimos quatro anos no mercado local, tendo em vista o pano de fundo da escassez global de semicondutores na pandemia da COVID-19 e o aumento do preço do dólar no mercado brasileiro no mesmo período. Para isso, tomou-se catálogos de preços de componentes eletrônicos, que datam desde o início de 2019 até o final de 2022, fornecidos periodicamente por um distribuidor local: COMPIMEX. Devido a indisponibilidade de IGBT's nos catálogos, considerou-se os dispositivos MOSFET para o estudo.

2 TRANSISTOR BIPOLAR DE PORTA ISOLADA (IGBT)

As aplicações de eletrônica de potência se dão nos mais variados ranges de potência e de frequência (de mW a GW e 60Hz a 100MHz), desde aparelhos domésticos portáteis até equipamentos eletrônicos utilizados em grandes infraestruturas das redes de energia das concessionárias (CHOW e GUO, 2019).

Os transistores de potência são construídos de modo que cada tipo abranja uma faixa de frequência e de potência de operação, como pode-se verificar no gráfico da Figura 1. Ainda segundo o gráfico a seguir, verifica-se que os dispositivos MOSFET são a melhor escolha quando a aplicação é de alta frequência e baixa potência. Em adição, verifica-se que os IGBT's são aplicados quando a potência e a frequência de operação são intermediárias. Já para as aplicações em alta potência, os dispositicos SCR e GTO se destacam.

Figura 1 - Potência versus frequência de chaveamento em transistores de potência.



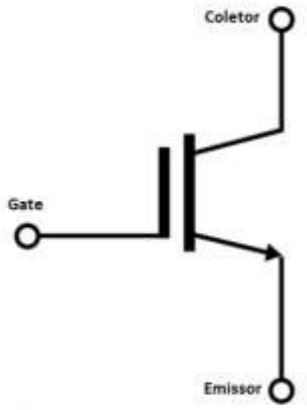
Fonte: Chow, Guo (2019, p. 159).

Materiais semicondutores de banda larga (WGB – *Wide Bandgap*) como carbeto de silício (SiC) e nitreto de gálio (GaN) têm sido cada vez mais empregados em chaves semicondutoras de potência apesar de ainda possuirem alto custo comparado a dispositivos de silício. A Figura 1 mostra, indicado pelo tracejado vermelho, o potencial de expansão da capacidade de potência e frequência com os dispositivos de banda larga.

O transistor bipolar de porta isolada ou IGBT (*Insulated Gate Bipolar Transistor*) é um dispositivo que combina as facilidades de acionamento do dispositivo MOSFET, devido à alta impedância de entrada, com as baixas perdas de condução de um transistor bipolar de junção (TBJ). A simbologia do IGBT está apresentada na Figura 5. Ela é uma combinação da simbologia dos dispositivos MOSFET e TBJ.

Os IGBT's são atualmente empregados em diversas aplicações em eletrônica de potência com alguns dispositivos sendo capaz de bloquear tensões de até 6500V, operar com correntes na ordem de milhares de amperes e frequências de até 20 kHz. Sistemas de tração automotivos e ferroviários, conversores de energia e acionamento industrial são exemplos de aplicações dos IGBT's (LANNUZZO, 2020).

Figura 2 - Simbologia do IGBT.

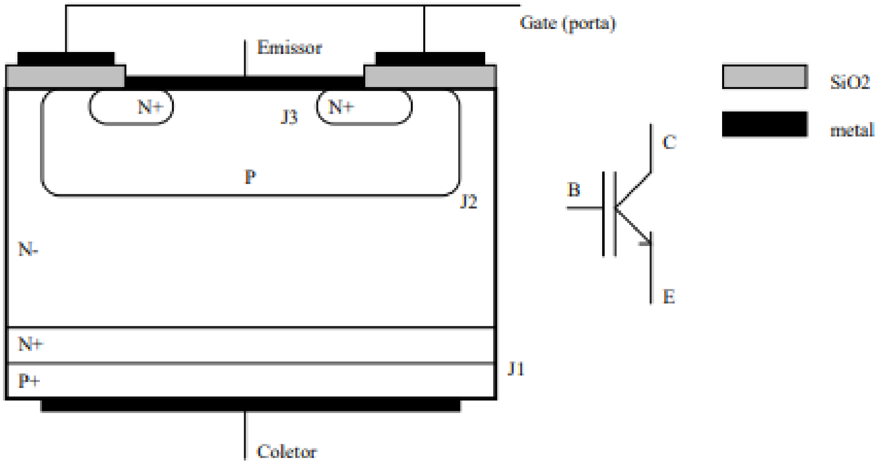


Fonte: FREITAS (2017).

2.1 Estrutura Básica

A estrutura básica de um IGBT é apresentada na Figura 7. Os terminais de um IGBT são chamados de *gate, collector* e *emitter,* ou, porta, coletor e emissor respectivamente. Os terminais coletor e emissor são equivalentes ao *drain* e *source* dos dispositivos MOSFET.

Figura 3 - Estrutura básica de um IGBT.



Fonte: Pomilio (2014, p. 41).

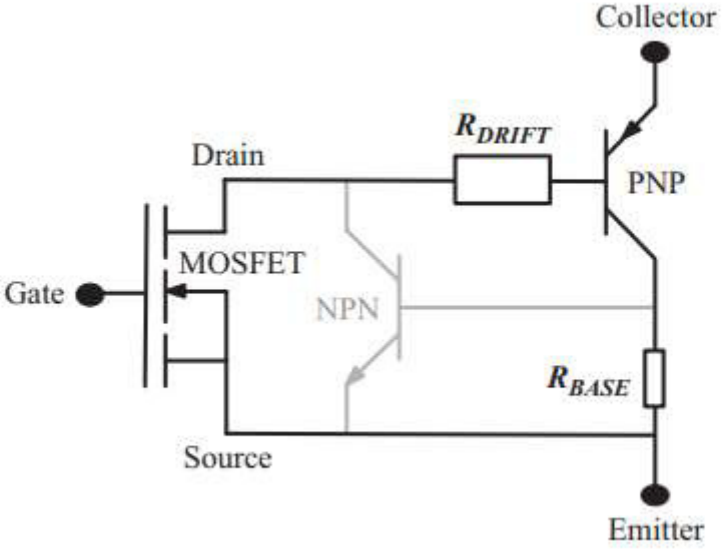
A estrutura do dispositivo é bastante similar a de um MOSFET, porém, com a adição de uma camada extra altamente dopada, p^+, na região do coletor que equivale ao dreno, *drain,* do MOSFET.

Assim como os dispositivos MOSFET's, os IGBT são chaves com porta isolada, onde a porta é isolada por uma camada de dióxido de silício (SiO_2). Isso torna o acionamento do IGBT bastante similar ao do MOSFET, sendo que ambos possuem alta impedância de entrada e são controlados pela tensão V_{GE} (tensão porta-emissor) ou V_{GS}, (tensão porta-fonte).

Diferentemente do MOSFET, o dispositivo IGBT não possui diodo intrínseco para fluxo de corrente reversa. Sendo isso, portanto, em muitos casos, uma vantagem já que se pode utilizar um diodo externo ou ainda projetar um diodo interno ao encapsulamento, processo conhecido como "*co-pak*", que atende melhor as especificações requeridas pela aplicação.

A Figura 7 apresenta um circuito equivalente do IGBT, representado por um MOSFET conectado a um Transistor Bipolar de Junção (TBJ) do tipo NPN e um do tipo PNP. Porém, o TBJ do tipo NPN pode ser desprezado devido ao fato da resistência conectada em paralelo com a sua base ser muito pequena. Isso implica em uma corrente muito baixa na base sendo insuficiente para acionar o dispositivo.

Figura 4 - Circuito equivalente de um IGBT.



Fonte: Lannuzzo (2020, p. 115)

2.2 Princípio de Funcionamento

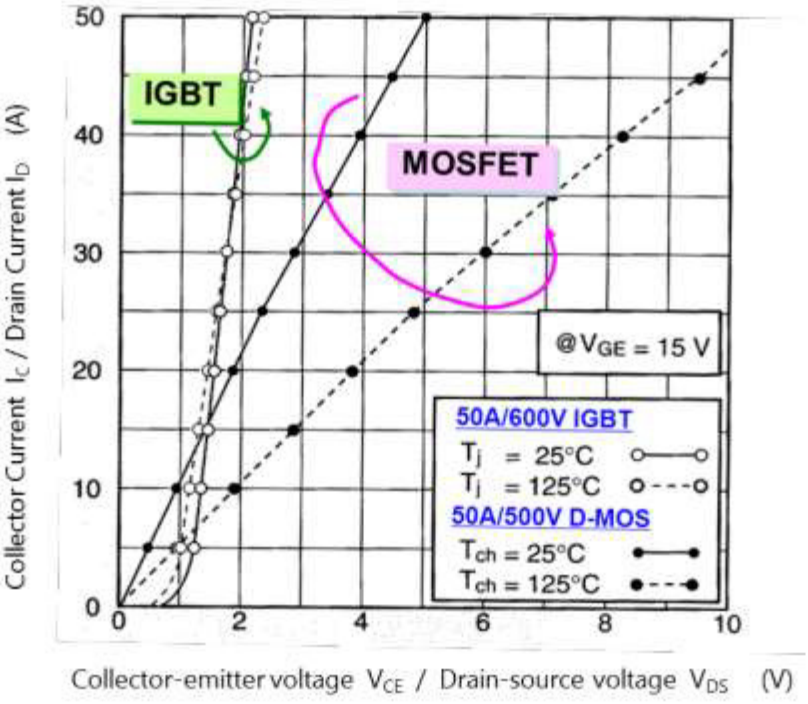
O acionamento dos dispositivos IGBT’s é bastante similar ao dos MOSFET’s. Ele é feito através da aplicação de uma tensão porta-emissor $V_{GE} > V_{TH}$, sendo V_{TH} a tensão de limiar (*threshold voltage*) do dispositivo. Ao aplicar-se uma tensão suficientemente alta na entrada do transistor bipolar de porta isolada, um canal n é gerado na camada p próxima ao terminal emissor, permitindo a circulação de elétrons entre o emissor e o coletor.

Geralmente, os IGBT’s de silício são acionados com 15 V para a entrada em condução, já para o bloqueio, entre -15 V e -5 V em dispositivos com alta corrente de operação e 0 V em dispositivos com baixa corrente de operação (SEMIKRON, 2021).

A adição da camada p^+ na região do coletor faz com que, quando em condução, portadores minoritários, lacunas, sejam injetados na camada n- aumentando assim a condução do transistor e, portanto, diminuindo a resistência e tensão no estado ligado. A diminuição da resistência de condução permite que o IGBT seja capaz de conduzir correntes superiores ao MOSFET. Esse processo é conhecido como efeito de modulação de condutividade (*conductivity modulation effect*).

A Figura 5, a seguir, apresenta um gráfico tensão versus corrente no estado ligado, tanto do IGBT quanto do MOSFET, para temperaturas de junção de 25°C e 125°C. Verifica-se, segundo o gráfico, que a resistência em condução do IGBT é consideravelmente menor que a resistência de um MOSFET equivalente devido ao efeito de modulação de condutividade. Além disso, constata-se que a resistência do dispositivo MOSFET é bastante sensível a variação da temperatura, havendo uma elevação com o aumento da temperatura. Enquanto isso, a resistência do IGBT permaneceu relativamente constante.

Figura 5 - Características de operação em regime de condução – IGBT versus MOSFET.



Fonte: Toshiba (2022, p. 22).

Já em relação ao chaveamento, os transistores IGBT's possuem um maior tempo durante a comutação em relação aos dispositivos de efeito de campo devido a um fenômeno que ocorre no bloqueio, chamado de corrente de cauda (*tail current*). Essa característica ocorre devido a injeção de portadores minoritários da camada p^+ para camada n. Tais portadores são recombinados após o bloqueio do dispositivo, o que gera uma corrente remanescente que permanece mesmo após a tensão V_{CE} atingir seu valor máximo em regime de bloqueio. O fenômeno da corrente de cauda é um dos principais fatores relacionados a maiores perdas no chaveamento e menor frequência de operação em relação ao dispositivo MOSFET.

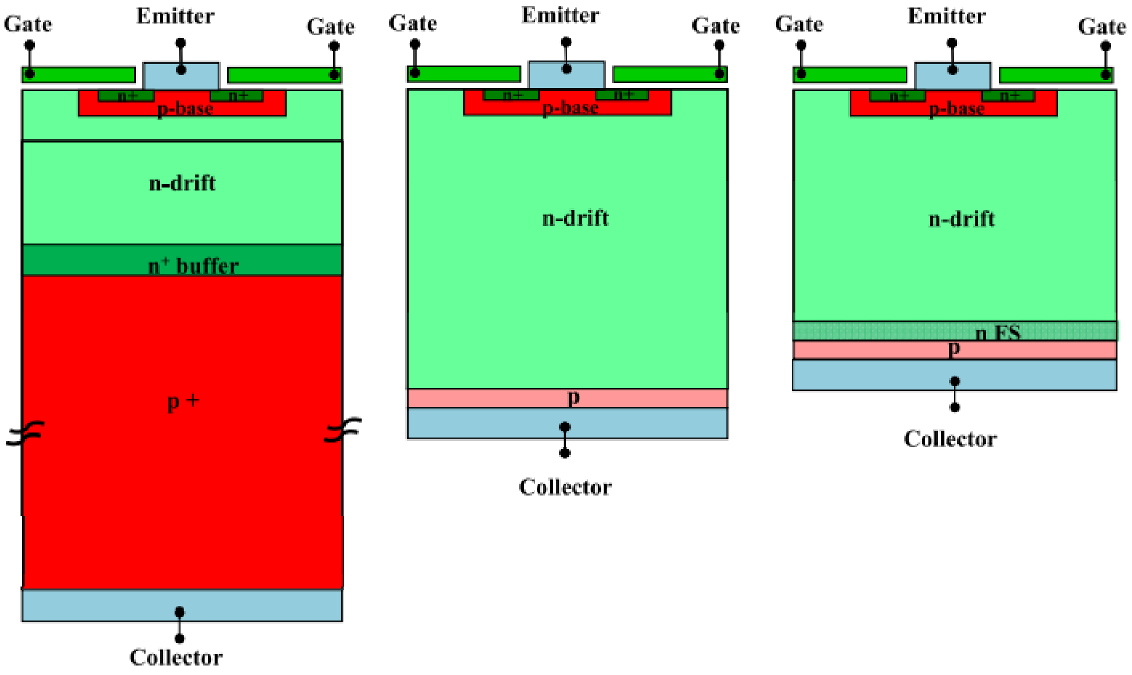
2.3 Principais Tecnologias

As principais tecnologias que compõem a estrutura dos dispositivos IGBT’s são: o IGBT PT (*Punch Through*), o IGBT NPT (Non *Punch Through*) e o IGBT FS (*Field Stop*). Eles podem ainda ser divididos em duas categorias: dispositivos simétricos e assimétricos. o IGBT NPT pertece a primeira categoria (simétricos), já os IGBT’s PT e FS pertencem a segunda categoria (assimétrico).

Neste trabalho as tecnologias dos IGBT’s compilados são apresentadas conforme disponibilidade de tal informação nos *datasheets*. A seguir é apresentado um resumo de cada um desses tipos de estrutura.

A Figura 6, a seguir, apresenta as estruturas empregadas das três tecnologias que são descritas nos próximos tópicos.

Figura 6 - Estruturas de IGBT's. (a) PT. (b) NPT. (c) FS.



(a) (b) (c)

(IWAMURO, 2017).

2.3.1 Punch Through – PT

Os dispositivos do tipo PT vêm sendo empregados desde a inserção do IGBT no mercado de chaves de potência. Como é ilustrado na Figura 6 (a), suas principais características são: estrutura assimétrica, presença de uma camada p^+ bastante espessa na região do coletor e uma camada *buffer* ou *stop field* n^+ entre a camada p^+ e a camada n^- (*drift region*).

A camada n^+ tem a função de absorver os portadores minoritários, que são injetados pela camada p^+ durante a entrada em condução, quando o dispositivo entra em bloqueio. Isso faz com que o bloqueio seja mais rápido do que se não houvesse a presença da camada *buffer*. Porém, pelo fato da camada *buffer* n ser altamente dopada, há um aumento na queda de tensão em condução do dispositivo.

A presença da camada *buffer*, também faz com que o dispositivo não suporte tensões V_{CE} simétricas de mesma magnitude. Ou seja, em comparação a tensões positivas, o IGBT do tipo PT não suporta elevadas tensões negativas. Isso faz com que o uso de tais dispositivos seja, em geral, a aplicações CC e/ou CA com baixas tensões de bloqueio.

Outra característica marcante da estrutura *Punch Through* é que os dispositivos apresentam coeficiente de temperatura, para $V_{CE(ON)}$, negativo. Isso significa que para um aumento de temperatura, permanecendo a corrente I_C constante, ocorre a diminuição da tensão coletor-emissor em condução. Em geral, tal atributo é positivo, já que implica em menores perdas por condução com o aumento da temperatura. Entretanto, isso faz com que dispositivos com tecnologia PT sejam inadequados para paralelismo, pois geram uma má distribuição de corrente na operação (BASCOPÉ, 1997).

2.3.2 Non Punch Through – NPT

Os dispositivos IGBT's do tipo *non punch through* (NPT) ou assimétrico surgiram posteriormente aos dispositivos do tipo PT como uma alternativa as limitações destes. Como é apresentado na Figura 6 (b), suas principais características são: estrutura simétrica, presença de uma camada n (*drift region*) bastante espessa e a ausência da camada *buffer n.*

A ausência da camada *buffer* faz com que algumas das limitações presentes na estrutura PT sejam ausentes na NPT. A capacidade de operação tanto com elevadas tensões positivas quanto negativas e coeficiente de temperatura, para $V_{CE(ON)}$, positivo são exemplos de melhorias da tecnologia NPT em relação a PT.

Além disso, devido a presença de uma camada n (*drift region*) mais espessa, há uma maior capacidade de bloqueio de tensão nos dispositivos NPT. Portanto, eles são mais adequados para aplicações em potências mais elevadas.

2.3.3 Field Stop - FS

Os dispositivos do tipo *field stop* (FS) ou também conhecidos como *soft punch through* (SPT) surgiram posteriormente aos tipos PT e NPT. Eles apresentam aspectos que são comuns a ambas estruturas (PT e NPT). Como é ilustrado na Figura 6 (c), suas principais características são: estrutura assimétrica, camada n (*drift region)* mais espessa em relação a camada p no coletor e presença de uma camada *buffer n* levemente dopada.

Ambos os dispositivos IGBT's, tipo FS e PT, apresentam uma camada *buffer* em comum como já foi descrito. Porém, tal camada na estrutura FS é dopada optimizadamente de modo a impedir a penetração do campo elétrico durante o estado de bloqueio enquanto ainda permite a modulação de condutividade durante a condução. Portanto, o IGBT do tipo FS combina as vantagens de baixas perdas de dispositivos PT e coeficiente de temperatura positivo e bloqueio suave dos dispositivos NPT (LANNUZZO, 2020).

2.4 Análise de Perdas de Condução e Comutação – IGBT versus MOSFET

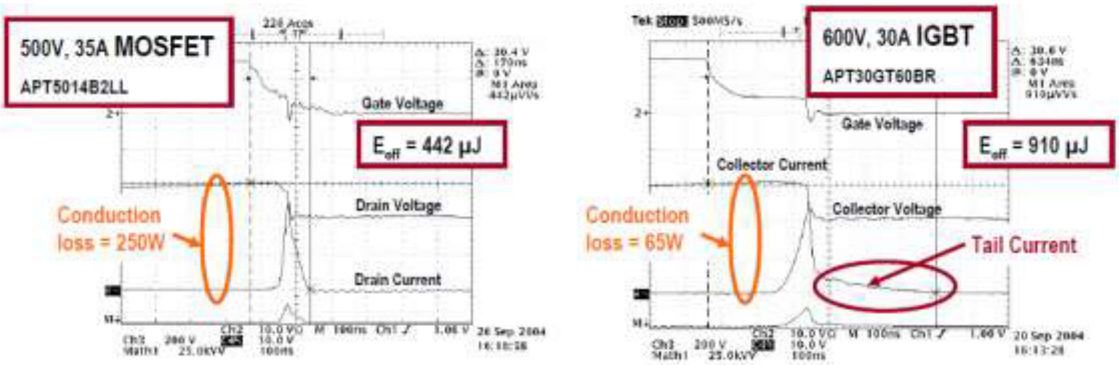
Nos tópicos anteriores foram discutidas algumas das principais características dos transistores de potência IGBT e MOSFET. Porém, as duas principais características que fazem distinção entre ambos os dispositivos são as perdas de condução e comutação. Em geral, nos MOSFET's há maiores perdas de condução e comutação encontradas nos dispositivos MOSFET's e IGBT's respectivamente.

As perdas de condução nos dispositivos de efeito de campo se destacam devido à resistência de condução ser relativamente alta, em contraste com as perdas nos dispositivos IGBT's que são amenizadas devido ao efeito de modulação de condutividade. Maiores perdas de condução implicam em menor capacidade de condução de corrente, além de menor capacidade de bloqueio de tensão, já que as camadas do MOSFET são menos espessas a fim de reduzir a resistência de condução, porém, geram uma menor capacidade de bloqueio de tensão.

Já as perdas de comutação são notórias nos transistores bipolares de porta isolada (IGBT) devido ao fenômeno de corrente de cauda que se encontra presente no bloqueio do dispositivo.

A Figura 7 foi retirada de uma apresentração de slides da fabricante de dispositivos semicondutores Advanced Power Technology (APT) e apresenta uma comparação entre as perdas de condução e de comutação de um dispositivo MOSFET (APT5014B2LL) e um IGBT (APT30GT60BR) com especificações parecidas e sobre as mesmas condições de teste. As condições de teste são: tensão de bloqueio de $400\ V$, corrente de operação de $30\ A$, temperatura de junção de $125\ °C$, resistência conectada a porta de $10\ \Omega$ e tensão na porta de $15\ V$.

Figura 7 - Características de condução e bloqueio – IGBT versus MOSFET.



Fonte: Dodge (2004, p. 3).

Observa-se pela Figura 7 que no bloqueio o IGBT apresenta um tempo maior para que a corrente do coletor chegue ao valor nulo em relação a corrente de dreno no MOSFET, o que implica em uma perda no bloqueio (E_{OFF}), em μJ, cerca de duas vezes superior ao dispositivo de efeito de campo em questão.

Já as perdas de condução verificadas no experimento foram de $65\ W$ para o dispositivo IGBT e de $250\ W$ para o dispositivo MOSFET. Isso corresponde a um valor de perda quase quatro vezes superior no MOSFET em relação ao IGBT.

3 PRINCIPAIS DADOS DE *DATASHEET* DO IGBT

Este trabalho tem como um dos objetivos a análise de parâmetros de *datasheet* de referências de IGBT's. Neste tópico tais parâmetros são definidos e detalhados.

3.1 Tensão Coletor-Emissor em Condução ($\boldsymbol{V_{CE(ON)}}$)

Este parâmetro é definido como o valor de queda de tensão entre os terminais coletor e emissor do dispositivo em estado ligado. Ele é o principal parâmetro para o cálculo de perdas de condução. Este parâmetro é dependente da temperatura e é feita a comparação para valor de temperatura de junção de 25 °C, pois é o valor de temperatura comum a todos os *datasheets*. Os valores apresentados neste trabalho são valores típicos apresentados pelos dispositivos e estão em *Volts*.

3.2 Corrente no Coletor ($\boldsymbol{I_C}$)

É defindo como a corrente de coletor máxima que o dispositivo suporta. Assim como o parâmetro anterior, este é dependente da temperatura na junção e a comparação é feita considerando operação na temperatura de 25 °C. Os valores são apresentados em *amperes*.

3.3 Tensão Coletor-Emissor de Breakdown ($\boldsymbol{V_{CE(BR)}}$)

Define-se como a tensão de bloqueio máxima entre os terminais emissor e coletor e não pode ser excedida para que não ocorra o efeito de ruptura do semicondutor (*breakdown*). Os valores são apresentados em *Volts*.

3.4 Perdas por entrada em condução ($\boldsymbol{E_{ON}}$)

Correspondem a quantidade da energia total perdida durante a entrada em condução do dispositivo quando acionando uma carga indutiva. Tal energia corresponde ao período desde quando a corrente, I_C, atinge 10% do seu valor final até quando a tensão, V_{CE}, atinge 10% do seu valor inicial, como é representado na Figura 8. Este parâmetro é apresentado neste trabalho em *microjoules.*

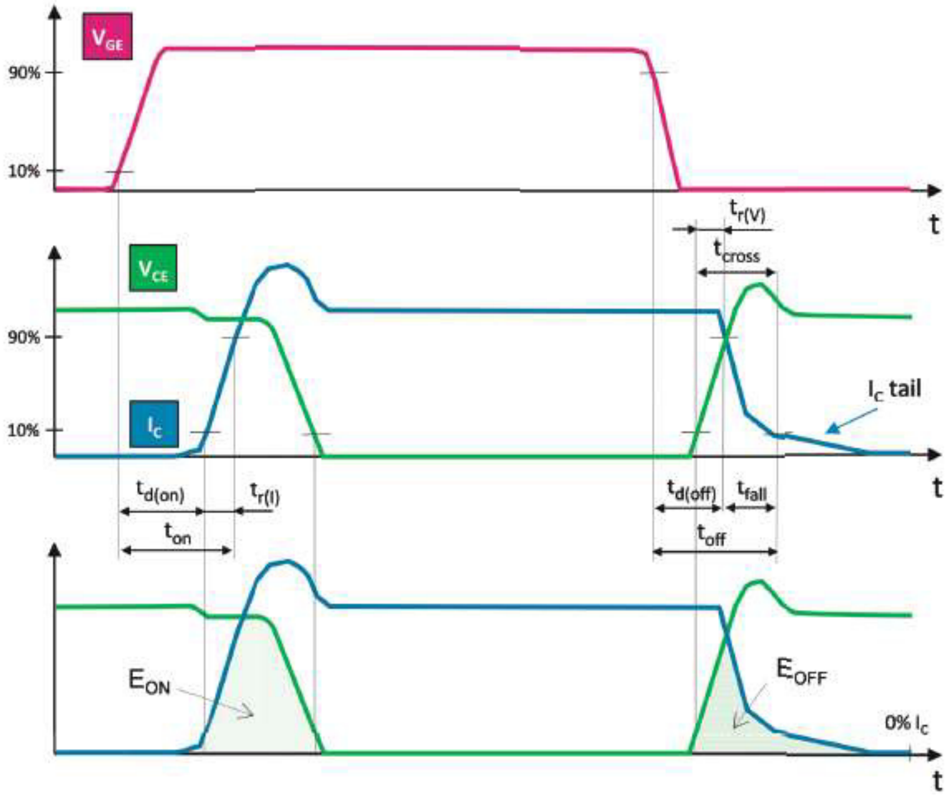
3.5 Perdas por Bloqueio (E_{OFF})

Análogo às perdas na entrada em condução, as perdas no bloqueio correspondem a quantidade de energia gasta durante a bloqueio do transistor quando uma carga indutiva é alimentada através dele. Tal perda abrange desde o momento que a tensão, V_{CE}, cresce a 10% do seu valor final até o instante que a corrente, I_C, decresce ao seu valor final, aproximadamente 0% do valor inicial, como é representado na Figura 8. Este parâmetro é apresentado neste trabalho em *microjoules.*

3.6 Perda Total por Comutação (E_T)

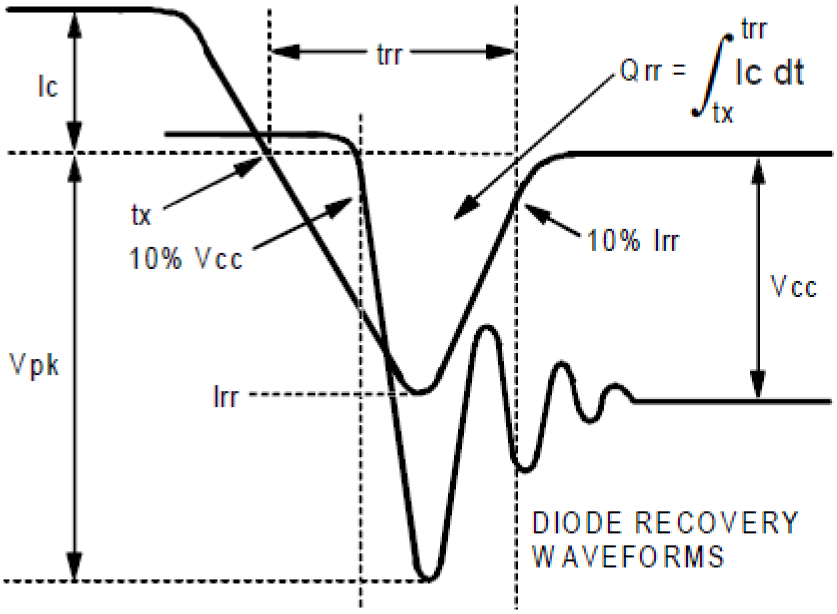
Este parâmetro corresponde a soma das perdas por entrada em condução e bloqueio do dispositivo. Para os dispositivos que apresentam diodo interno ao encapsulamento, esse parâmetro considera a energia gasta na recuperação reversa do diodo. A recuperação reversa está presente no diodo quando ele sai do estado de condução direta para o estado de bloqueio, período que o diodo passa a conduzir reversamente antes de desligar por completo, como é ilustrado na Figura 9. Os valores para este parâmetro são apresentados neste trabalho em *microjoules.*

Figura 8 - Formas de onda na entrada em condução e bloqueio do IGBT.



Fonte: ST Microeletronics (2014, p. 26).

Figura 9 - Formas de onda na recuperação reversa do diodo.



Fonte: IR - *Datasheet* IRG4BC15UD (2001).

4 REFERÊNCIAS DE DISPOSITVOS IGBT DISCRETOS DE TRABALHOS ACADÊMICOS

As referências compiladas de trabalhos acadêmicos tanto nacionais quanto internacionais totalizam 73 dispositivos e estão apresentadas a seguir com informações básicas de capacidade de corrente de coletor, I_C, e tensão de bloqueio, $V_{CE(BR)}$. Além disso, é refenciado o trabalho acadêmico em que o dispositivo é utilizado. As primeiras folhas dos *datasheets* dos semicondutores consultados encontram-se no anexo A.

Os dispositivos são divididos em quatro categorias de acordo com informações de tensão, $V_{CE(BR)}$, e corrente, I_C: 1ª - $V_{CE(BR)} \leq 650V$ e $I_C \leq 40A$; 2ª - $V_{CE(BR)} \leq 650V$ e $I_C > 40A$; 3ª - $900 < V_{CE(BR)} \leq 1000V$ e 4ª - $1000 < V_{CE(BR)} \leq 1200V$. Na primeira categoria, há 24 dispositivos; na segunda, 22; na terceira, 5; e na quarta, 22.

Para as comparações que são feitas neste trabalho, a categoria de dispositivos com tensão de bloqueio entre $900\ V$ e $1000\ V$ é descartada, tendo em vista o baixo número de dispositivos presentes nela.

4.1 Dispositivos IGBT's: $V_{CE(BR)} \leq 650V$ e $I_C \leq 40A$

A seguir, estão listados os 24 dispositivos IGBT's utilizados nos trabalhos acadêmicos compilados, que têm as seguintes especificações: $V_{CE(BR)} \leq 650V$ e $I_C \leq 40A$.

HGTP3N60C3D

- *Fabricante:* Intersil;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 6A$ (25°C) e 3A (110°C);
- *Encapsulamento:* TO-220AB;
- *Tecnologia:* Não disponível;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (HEY, 1998).

HGTP7N60C3D

- *Fabricante:* Fairchild;

- *Tensão coletor-emissor (Breakdown):* $\mathrm{V_{CE(BR)}} = 600\mathrm{V}$;
- *Corrente coletor:* $\mathrm{I_C} = 14\mathrm{A}$ (25°C) e 7A (110°C);
- *Tecnologia:* Não disponível;
- *Presença de diodo no encapsulamento:* Sim;
- *Encapsulamento:* TO-220AB;
- *Trabalho acadêmico (mais antigo):* (HEY, 2000).

IRGBC40U

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $\mathrm{V_{CE(BR)}} = 600\mathrm{V}$;
- *Corrente coletor:* $\mathrm{I_C} = 40\mathrm{A}$ (25°C) e 20A (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (BARBI, 2001)

IRG4PC40U

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (HANG-SEOK, 2001).

IRG4BC30UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 23A$ (25°C) e $12A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;

- *Trabalho acadêmico (mais antigo):* (HANG-SEOK, 2001).

IRG4PC40W

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (MOISSEEV, 2002).

IRG4PC30W

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):*$V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 23A$ (25°C) e $12A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (BRAGA, 2002).

IRG4BC30U

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 23A$ (25°C) e $12A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (NETO, 2005).

IRG4BC15UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;

- *Corrente coletor:* $I_C = 14A$ (25°C) e $7{,}8A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (GONÇALVES, 2006).

IRGB20B60PD1

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $22A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (MORAIS, 2008).

IRG4BC10KD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 9A$ (25°C) e $5A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (PERAÇA, 2008).

IRG4BC20UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 13A$ (25°C) e $6{,}5A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (OLIVEIRA, 2009).

IRGP20B60PD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $22A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (WADA, 2009).

IRG4BC20SD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 19A$ (25°C) e $10A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (BASKARAN, 2010).

IGP15N60T

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 30A$ (25°C) e $15A$ (100°C);
- *Tecnologia:* FS;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (RYU, 2011).

IRG4PC40UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);

- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (BELTRAME, 2011).

FGH20N60SFD

- *Fabricante:* Fairchild;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);
- *Tecnologia:* SF;
- *Encapsulamento TO-247*;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (SHIN, 2014).

HGTP10N40C1D

- *Fabricante:* Intersil;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 400V$;
- *Corrente coletor:* $I_C = 17{,}5A$ (25°C) e 10 (90°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (LAALI, 2014).

IRGB4064DPbF

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 20A$ (25°C) e 10 (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (ARJONA, 2015).

IRG4PC30UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 23A$ (25°C) e $12A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (BARBI, 2015).

BUP400D

- *Fabricante:* Siemens;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 22A$ (25°C) e 14 (90°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (ALI, 2015).

FGP20N60UFD

- *Fabricante:* Fairchild;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);
- *Tecnologia:* SF;
- *Encapsulamento:* TO-220;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (MANOHARAN, 2016).

HGTG7N60A4D

- *Fabricante:* Onsemi;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 34A$ (25°C) e $18A$ (100°C);
- *Tecnologia:* Não disponível;

- *Encapsulamento:* TO-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (ALVES, 2017).

IKW20N60T

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);
- *Tecnologia:* FS;
- *Encapsulamento:* TO-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (ZHOU, 2019).

4.2 Dispositivos IGBT's: $V_{CE(BR)} \leq 650V$ e $I_C > 40A$

Neste item, estão listados os dispositivos IGBT's utilizados nos trabalhos acadêmicos compilados, que têm as seguintes especificações: $V_{CE(BR)} \leq 650V$ e $I_C > 40A$.

IRG4PSC71U

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 85A$ (25°C) e $60A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* SUPER-247;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (SANTOS, 2001).

IRG4PC50UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 55A$ (25°C) e $27A$ (100°C);
- *Tecnologia:* Não disponível;

- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (MARAFÃO, 2002).

IRG4PC50W

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 55A$ (25°C) e $27A$ (125°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (MARTINS, 2004).

IRG4PSC71UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 85A$ (25°C) e $60A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* SUPER-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (GOMES, 2007).

IRG4PC50KD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 52A$ (25°C) e $30A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (PIAZZA, 2008).

IRGP50B60PD1

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 75A$ (25°C) e $45A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (VIDAL, 2008).

APT15GP60BDF1

- *Fabricante:* Advanced Power Technology;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 56A$ (25°C) e $27A$ (110°C);
- *Tecnologia:* PT;
- *Encapsulamento:* TO-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (SALAM, 2009).

IRG4PC40FD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 49A$ (25°C) e $27A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (SALAM, 2009).

APT30GT60BRD

- *Fabricante:* Advanced Power Technology;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 55A$ (25°C) e $30A$ (110°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AC;

- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (GREFF, 2008).

IRGP30B60KD-E

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 60A$ (25°C) e $30A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AD;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (BELTRAME, 2010).

IKW75N60T

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 80A$ (25°C) e $75A$ (100°C);
- *Tecnologia:* FS
- *Encapsulamento:* TO-220AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (ZHANG, 2010).

IGW30N60T

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 60A$ (25°C) e $30A$ (100°C);
- *Tecnologia:* FS;
- *Encapsulamento:* TO-220AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (RYU, 2011).

IRGPC40S

- *Fabricante:* International Rectifier;

- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 50A$ (25°C) e $31A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (COSTA, 2012).

STGW35HF60WD

- *Fabricante:* ST;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 60A$ (25°C) e $35A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (KIM, 2012).

IRGP50B60PD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 75A$ (25°C) e $42A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (BORGES, 2012).

IKW30N60T

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 60A$ (25°C) e $30A$ (125°C);
- *Tecnologia:* FS;
- *Encapsulamento:* TO-220AC;
- *Presença de diodo no encapsulamento:* Sim;

- *Trabalho acadêmico (mais antigo):* (DARMIAN, 2012).

SGH80N60UFD

- *Fabricante:* Fairchild;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 80A$ (25°C) e $40A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (CHEN, 2012).

IRGP50B60PD1PBF

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 75A$ (25°C) e $45A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (COSTA, 2012).

IXGH72N60A3

- *Fabricante:* IXYS;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 75A$ (25°C) e $72A$ (110°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (LIU, 2017).

IRG4PC40K

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;

- *Corrente coletor:* $I_C = 42A$ (25°C) e $25A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (JUNIOR, 2018).

IRGPC40F

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 600V$;
- *Corrente coletor:* $I_C = 49A$ (25°C) e $27A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (JUNIOR, 2018).

IKP40N65F5

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 650V$;
- *Corrente coletor:* $I_C = 74A$ (25°C) e $46A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* PG-TO247-3;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (MEZAROBA, 2020).

4.3 Dispositivos IGBT's: $900 \leq V_{CE(BR)} \leq 1000V$

Neste item, estão listados os dispositivos IGBT's utilizados nos trabalhos acadêmicos compilados, que têm a seguinte especificação: $900 \leq V_{CE(BR)} \leq 1000V$.

CT90AM-18

- *Fabricante:* Mitsubishi Electric;

- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 900V$;
- *Corrente coletor:* $I_C = 60A$ (25°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-3PL;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (OGURA, 2002).

FGL60N100BNTD

- *Fabricante:* Fairchild;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1000V$;
- *Corrente coletor:* $I_C = 60A$ (25°C) e $42A$ (100°C) ;
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-264;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (NGHIA, 2009).

IRG4PF50WPBF

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 900V$;
- *Corrente coletor:* $I_C = 51A$ (25°C) e $28A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (ANDERSEN, 2010).

IRG4PF50WD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 900V$;
- *Corrente coletor:* $I_C = 51A$ (25°C) e $28A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;

- *Trabalho acadêmico (mais antigo):* (REINERT, 2011)

BUP304

- *Fabricante:* Siemens;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1000V$;
- *Corrente coletor:* $I_C = 35A$ (25°C) e $23A$ (90°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-218AB;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (JEDIDI, 2017).

4.4 Dispositivos IGBT's: $\boldsymbol{V_{CE(BR)} = 1200V}$

Neste item, estão listados os dispositivos IGBT's, utilizados nos trabalhos acadêmicos compilados, que têm a seguinte especificação: $V_{CE(BR)} = 1200V$.

IRG4PH50UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 45A$ (25°C) e $24A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (CANESIN, 2002).

IRGP20B120UD-E

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AD;
- *Presença de diodo no encapsulamento:* Sim;

- *Trabalho acadêmico (mais antigo):* (BUTTENDORF, 2003).
- *Volume:* Não se aplica.

IRG4PH40K

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 30A$ (25°C) e $15A$ (125°C) ;
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (SALAM, 2009).

BUP306D

- *Fabricante:* Siemens;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 23A$ (25°C) e $15A$ (125°C) ;
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-218AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (BABAEI, 2010).

IXRP15N120

- *Fabricante:* IXYS;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 25A$ (25°C) e $15A$ (90°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-220AB;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (JABBARI, 2010).

IRG4PH50U

- *Fabricante:* International Rectifier;

- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 45A$ (25°C) e $24A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (SALAM, 2011).

IRG4PH40UD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 41A$ (25°C) e $21A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (AGARWAL, 2012).

IRG4PH20KD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 11A$ (25°C) e $5A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (ALMEIDA, 2013).

IRGP20B120U-E

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):*$V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AD;
- *Presença de diodo no encapsulamento:* Não;

- *Trabalho acadêmico (mais antigo):* (RAIHAN, 2013).

IGW40T120

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 75A$ (25°C) e $40A$ (125°C);
- *Tecnologia:* FS;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (ZHANG, 2014).

IKW40N120H3

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 80A$ (25°C) e $40A$ (100°C);
- *Tecnologia:* FS;
- *Encapsulamento:* TO-220AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (KRISHNAMOORTHY, 2014).

SKW25N120

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 50A$ (25°C) e $25A$ (100°C);
- *Tecnologia:* NPT;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (WANG, 2015).

IRG7PH35UD1PbF

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;

- *Corrente coletor:* $I_C = 50A$ (25°C) e $25A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (JASSIM, 2015).

FGA15N120AND

- *Fabricante:* Fairchild;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 24A$ (25°C) e $15A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (RAJ, 2016).

FGA25N120ANTD

- *Fabricante:* Fairchild;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 50A$ (25°C) e $25A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (CHENG, 2016).

BUP314

- *Fabricante:* Siemens;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 52A$ (25°C) e $33A$ (90°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-218AB;
- *Presença de diodo no encapsulamento:* Não;
- *Trabalho acadêmico (mais antigo):* (MEJDAR, 2016).

IKW40N120T2

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 75A$ (25°C) e $40A$ (110°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-220AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (XU, 2016).

IKW40T120

- *Fabricante:* Infineon;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 75A$ (25°C) e $40A$ (100°C);
- *Tecnologia:* FS;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (WANG, 2016).

FGA20N120FTD

- *Fabricante:* Fairchild;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 40A$ (25°C) e $20A$ (100°C);
- *Tecnologia:* FS;
- *Encapsulamento:* TO-3PN;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (GUAN, 2018).

FGH40T120SMD

- *Fabricante:* Onsemi;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;

- *Corrente coletor:* $I_C = 80A$ (25°C) e $40A$ (125°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO−247−3LD;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (FAHMY, 2018).

IRG4PH50KDPbF

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 45A$ (25°C) e $24A$ (100°C);
- *Tecnologia:* Não disponível;
- *Encapsulamento:* TO-247AC;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (FREDDY, 2019).

IRGPS60B120KD

- *Fabricante:* International Rectifier;
- *Tensão coletor-emissor (Breakdown):* $V_{CE(BR)} = 1200V$;
- *Corrente coletor:* $I_C = 45A$ (25°C) e $24A$ (100°C) ;
- *Tecnologia:* NPT;
- *Encapsulamento:* SUPER-247;
- *Presença de diodo no encapsulamento:* Sim;
- *Trabalho acadêmico (mais antigo):* (GUERRERO-GUERRERO, 2019).

5 EVOLUÇÃO DO DESEMPENHO DE IGBT's DISCRETOS

Analisou-se os dispositivos listados anteriormente, com base nos parâmetros coletados de seus respectivos *datasheets*, a fim de verificar a evolução dos dispositivos IGBT's comerciais, que operam com tensões de até $1{,}2\ kV$, durante os últimos vinte anos.

A seguir temos uma análise comparativa de dois parâmetros dos dados coletados e apresentação dos resultados observados de acordo com a divisão por especificação feita no capítulo 4.

As tabelas seguintes, deste capítulo, estão ordenadas do trabalho mais antigo ao trabalho mais novo, de modo a facilitar a visualização do desenvolvimento dos parâmetros com o decorrer dos anos.

5.1 Evolução da Tensão Coletor-Emissor em Condução ($\boldsymbol{V_{CE(ON)}}$)

O parâmetro de tensão coletor-emissor apresenta dependência com a corrente nominal do dispositivo, I_C. Dispositivos que operam em corrente maiores apresentam, em geral, queda de tensão em condução maior, apesar de existir outros fatores como temperatura de operação. Portanto, considerou-se necessário dividir o parâmetro pela corrente nominal do dispositivo, a fim de diminuir a influência da corrente no parâmetro, e depois multiplicá-lo por 100 para remover algumas casas decimais. A Equação 1 apresenta o cálculo feito, onde $K_{CE(ON)}$ é o novo parâmetro resultante.

$$K_{CE(ON)} = 100 \cdot V_{CE(ON)}/I_C \qquad [1]$$

Os valores de $K_{CE(ON)}$ cálculados estão apresentados na quarta coluna das tabelas a seguir. Na análise dos dados, foram desconsiderados valores de $K_{CE(ON)}$ que estivessem muito dispersos dos outros valores dos dispositivos da faixa de tempo em análise.

5.1.1 Dispositivos IGBT's: $\boldsymbol{V_{CE(BR)} \leq 650V}$ *e* $\boldsymbol{I_C \leq 40A}$

A tabela 1 apresenta os parâmetros de tensão coletor-emissor no condução, $V_{CE(ON)}$, em 25 °C dos dispositivos IGBT's listados no item 4.1 ($V_{CE(BR)} \leq 650V$ e $I_C \leq 40A$), assim como os respectivos valores $K_{CE(ON)}$ calculados conforme a equação 1.

A tensão coletor-emissor em condução é um parâmetro que está diretamente associado as perdas de condução do dispositivo, como já discutido no item 3.1. Sendo assim, o dispositivo mais eficiente, em geral, é o que possui menor tensão de condução e que, por sua vez, implica menor parâmetro $K_{CE(ON)}$.

Observou-se que na quarta coluna alguns valores estão dispersos dos demais e, portanto, decidiu-se não considera-los para a análise seguinte. Estes valores são $27{,}50\ V/A$ e $26{,}56\ V/A$, que correspondem aos dipositivos HGTP3N60C3D e IRG4BC10KD, respectivamente.

Tabela 1 - Tensão coletor-emissor em condução dos IGBT's com $V_{CE(BR)} \leq 650V\ e\ I_C \leq 40A$.

IGBT - Referência	Ic (A) (25 °C)	Vceon (typ) (V) (25°C)	Kce(on) (V/A) (25°C)	Ano de publicação
HGTP3N60C3D	6	1,65	27,50	1998
HGTP7N60C3D	14	1,6	11,43	2000
IRG4PC40U	40	1,72	4,30	2001
IRG4BC30UD	23	1,95	8,48	2001
IRGBC40U	40	2,2	5,50	2001
IRG4PC40W	40	2,05	5,13	2002
IRG4PC30W	23	2,1	9,13	2002
IRG4BC30U	23	1,95	8,48	2005
IRG4BC15UD	14	2,02	14,43	2006
IRGB20B60PD1	40	2,05	5,13	2008
IRG4BC10KD	9	2,39	26,56	2008
IRG4BC20UD	13	1,85	14,23	2009
IRGP20B60PD	40	2,5	6,25	2009
IRG4BC20SD	19	1,85	9,74	2010
IGP15N60T	30	1,5	5,00	2011
IRG4PC40UD	40	1,72	4,30	2011
FGH20N60SFD	40	2,2	5,50	2014
HGTP10N40C1D	17,5	2,5	14,29	2014
IRGB4064DPbF	20	1,6	8,00	2015
IRG4PC30UD	23	1,95	8,48	2015
BUP400D	22	2,1	9,55	2015
FGP20N60UFD	40	1,8	4,50	2016
HGTG7N60A4D	34	1,9	5,59	2017
IKW20N60T	40	1,5	3,75	2019

Fonte: Próprio autor com base nos *datasheets*.

Para a análise a seguir, os dados da Tabela 1 são divididos em duas faixas: a primeira de 1998 a 2008 e a segunda de 2009 a 2019. As faixas foram escohidas de modo a dividir os dados em quantidades semelhantes por faixa.

Considere os dois menores valores de $K_{CE(ON)}$, que aparecem pelo menos uma vez, do primeiro período (1998 a 2008) e os dois menores valores para o segundo período (2009 a 2019). No primeiro período, os dois menores valores de tensão em condução sobre a corrente foram $4{,}30\,V/A$ e $5{,}13\,V/A$. Já no segundo período, tem-se os valores de $3{,}75\,V/A$ e $4{,}50\,V/A$.

Agora, segue a mesma análise, porém, para os dois maiores valores de cada período. Na primeira faixa de tempo, os dois maiores valores foram $14{,}43\,V/A$ e $11{,}43\,V/A$. Em contrapartida, os valores da segunda faixa foram $14{,}29\,V/A$ e $14{,}23\,V/A$.

A média aritimética dos valores na primeira faixa foi $8{,}00\,V/A$ e na segunda faixa, 7,63 V/A, diminuição de 4,64 % em relação a primeira faixa.

Com base em tais dados, constata-se que não houve diferença significativa em relação aos valores presentes em ambas as faixas. Porém, percebe-se o aumento de dispositivos com valores mais baixos de $K_{CE(ON)}$

Portanto, verifica-se pela Tabela 1 que os valores de $K_{CE(ON)}$ dos IGBT's permaneceram na mesma faixa entre 1998 e 2019. Sendo assim, constata-se que não houve aprimoramento significativo em relação a tensão coletor-emissor em condução nas últimas duas décadas. Porém, percebe-se no segundo período o aumento do uso de dispositivos mais eficientes (valores $K_{CE(ON)}$ menores), o que pode indicar que tais dispositivos se tornaram mais acessíveis com os anos.

5.1.2 Dispositivos IGBT's: $V_{CE(BR)} \leq 650V$ *e* $I_C > 40A$

A Tabela 2 contém os valores de tensão emissor-coletor em condução para as referências de IGBT's listadas no item 4.2 ($V_{CE(BR)} \leq 650V$ e $I_C > 40A$), assim como os respectivos valores $K_{CE(ON)}$ calculados conforme a equação 1.

O dispositivo IRG4PC40K é excluído da análise, pois seu valor de $K_{CE(ON)}$ foi considerado disperso em relação aos valores mais próximos. O valor de $K_{CE(ON)}$, na quarta coluna, para esse dispositivo é $5{,}00\,V/A$. Na mesma coluna, o valor mais próximo ao do dispositivo é $4{,}17\,V/A$ e o segundo mais próximo $3{,}97\,V/A$.

Tabela 2 - Tensão coletor-emissor em condução dos IGBT's com $V_{CE(BR)} \leq 650V\ e\ I_C > 40A.$

IGBT - Referência	Ic (A) (25 °C)	Vceon (typ) (V) (25°C)	Kce(on) (V/A)	Ano de publicação
IRG4PSC71U	85	1,67	1,96	2001
IRG4PC50UD	55	1,65	3,00	2002
IRG4PC50W	55	1,93	3,51	2004
IRG4PSC71UD	85	1,67	1,96	2007
IRG4PC50KD	52	1,84	3,54	2008
IRGP50B60PD1	75	2	2,67	2008
IRG4PC40FD	49	1,85	3,78	2009
APT30GT60BRD	55	2	3,64	2009
APT15GP60BDF1	56	2,2	3,93	2009
IRGP30B60KD-E	60	1,95	3,25	2010
IKW75N60T	80	1,5	1,88	2010
IGW30N60T	60	1,5	2,50	2011
IRGPC40S	50	1,6	3,20	2012
STGW35HF60WD	60	2,5	4,17	2012
IRGP50B60PD	75	2	2,67	2012
IKW30N60T	60	1,5	2,50	2014
SGH80N60UFD	80	2,1	2,63	2016
IRGP50B60PD1PBF	75	2	2,67	2017
IXGH72N60A3	75	1,35	1,80	2017
IRG4PC40K	42	2,1	5,00	2018
IRGPC40F	49	1,7	3,47	2018
IKP40N65F5	74	1,6	2,16	2020

Fonte: Próprio autor com base nos *datasheets*.

Para a análise a seguir, os dados da Tabela 2 são divididos em duas faixas: a primeira de 2001 a 2010 e a segunda 2011 a 2020. As faixas foram escolhidas de modo a dividir os dados em quantidades semelhantes por faixa.

Da mesma forma que no caso anterior, para verificação da evolução do parâmetro nos IGBT's, toma-se os dois menores valores de $K_{CE(ON)}$ entre os anos de 2001 a 2010 e entre 2011 e 2020. Para o primeiro período, os dois menores valores são 1,88 V/A e 1,96 V/A. Já para a segunda faixa, são 1,80 V/A e 2,16 V/A.

Analogamente, considerou-se os dois maiores valores de $K_{CE(ON)}$ da primeira faixa, assim como, também, os da segunda faixa. Os dois maiores valores no primeiro período são 3,93 V/A e 3,78 V/A. Em contraste, no segundo período foram 4,17 V/A e 3,47 V/A.

Além disso, a média aritimética dos valores no primeiro período foi 3,01 V/A e no segundo, 2,78 V/A, diminuição de 7,78 % em relação à primeira faixa.

A partir de tais dados, percebe-se que não houve uma clara tendência à melhora do parâmetro de tensão emissor-coletor em condução dos dispositivos do item 4.2 ($V_{CE(BR)} \leq 650V$ e $I_C > 40A$) durante o período avaliado, pois, apesar da diminuição da média dos valores de $K_{CE(ON)}$ do segundo período, as faixas de valores permanecem aproximadamente constantes.

5.1.3 Dispositivos IGBT's: $V_{CE(BR)} = 1200V$

A Tabela 3 apresenta os valores de tensão emissor-coletor em condução para as referências de IGBT's listadas no item 4.4 ($V_{CE(BR)} = 1200\,V$), assim como os respectivos valores $K_{CE(ON)}$ calculados conforme a equação 1.

Para a avaliação a seguir, são desconsiderados valores que sejam dispersos em relação aos demais. O dispositivo IRG4PH20KD apresenta valor igual a 28,82 V/A que é bastante superior ao valor mais próximo, que é de 12,17 V/A. Portanto, é desconsiderado na análise.

Tabela 3 - Tensão coletor-emissor em condução dos IGBT's com $V_{CE(BR)} = 1200V$.

IGBT - Referência	Ic (A) (25 °C)	Vceon (typ) (V) (25°C)	Kce(on) (V/A)	Ano de publicação
IRG4PH50UD	45	2,78	6,18	2002
IRGP20B120UD-E	40	3,05	7,63	2003
IRG4PH40K	30	3,29	10,97	2009
BUP306D	23	2,8	12,17	2010
IXRP15N120	25	2,5	10,00	2010
IRG4PH50U	45	3,2	7,11	2011
IRG4PH40UD	41	2,43	5,93	2012
IRG4PH20KD	11	3,17	28,82	2013
IRGP20B120U-E	40	3,05	7,63	2013
IGW40T120	75	1,8	2,40	2014
IKW40N120H3	80	2,05	2,56	2014
SKW25N120	46	3,1	6,74	2015
IRG7PH35UD1PbF	50	1,9	3,80	2015
FGA15N120AND	24	2,4	10,00	2016
FGA25N120ANTD	50	2	4,00	2016
BUP314	52	2,7	5,19	2016
IKW40N120T2	75	1,75	2,33	2016
IKW40T120	75	1,8	2,40	2016
FGA20N120FTD	40	1,6	4,00	2018

FGH40T120SMD	80	1,8	2,25	2018
IRG4PH50KDPbF	45	2,77	6,16	2019
IRGPS60B120KD	105	2,33	2,22	2019

Fonte: Próprio autor com base nos *datasheets*.

Para a análise da evolução do parâmetro nos IGBT’s, dividiu-se a tabela em dois períodos. O primeiro período compreende os anos de 2002 a 2014 e o segundo entre 2015 e 2019. Para o primeiro período, os dois menores valores são $2{,}40\ V/A$ e $2{,}56\ V/A$. Já para a segunda faixa, são $2{,}22\ V/A$ e $2{,}25\ V/A$.

Do mesmo modo, considerou-se os dois maiores valores da primeira faixa, assim como, também, os da segunda faixa. Os dois maiores valores no primeiro período são $12{,}17\ V/A$ e $10{,}97\ V/A$. Em contraste, no segundo período são $10{,}00\ V/A$ e $6{,}74\ V/A$.

Em adição, a média aritimética dos valores na primeira faixa foi $7{,}26\ V/A$, já na segunda, $4{,}46\ V/A$. Portanto, há uma queda de cerca de $38{,}51\ \%$ em relação à primeira faixa.

A partir dessas análises, percebe-se que houve uma clara tendência a melhora do parâmetro, tendo em vista os menores valores apresentados no segundo período tanto no limiar inferior quanto superior dos dados, e a média no segundo período ser consideravelmente menor.

Portanto, constata-se que houve uma clara evolução do parâmetro de tensão emissor-coletor em condução dos dispositivos do item 4.4 durantre o período em questão.

5.2 Perda Total por Comutação (E_T)

Para análise do parâmetro, são considerados os valores típicos (*typical*) de E_T dividido pela corrente I_C dos dispositivos na temperatura de $25\ °C$. A equação 2 apresenta o cálculo realizado, onde K_T é o novo parâmetro resultante.

$$K_T = E_T/I_C \qquad [2]$$

Os valores de K_T cálculados estão apresentados na quarta coluna das tabelas a seguir.

Como já descrito em 3.6, E_T engloba as perdas pelo diodo interno ao encapsulamento quando ele entra no modo de recuperação reversa, também definido em 3.6. Portanto, para fins de comparação, são considerados apenas os dispositivos que apresentam diodo interno. Nas tabelas subsequentes, a segunda coluna informa se há diodo interno ou não.

Na análise dos dados, foram desconsiderados valores de K_T que estivessem muito dispersos dos outros valores dos dispositivos da faixa de tempo em análise e que apresentam dados em temperatura diferente de 25°C.

5.2.1 Dispositivos IGBT's: $V_{CE(BR)} \leq 650V$ *e* $I_C \leq 40A$

A tabela 4 a seguir apresenta os parâmetros de perda total por comutação, E_T, dos dispositivos IGBT's listados no item 4.1 ($V_{CE(BR)} \leq 650V$ e $I_C \leq 40A$), assim como os respectivos valores K_T calculados conforme a equação 2.

O IGBT HGTP10N40C1D não contém informações de E_T no *datasheet* e o dispositivo IRGB4064DPbF apresenta esse parâmetro apenas para a temperatura de $175\ °C$. Portanto, eles não são considerados para análise.

Os IGBT's IRG4BC20SD e BUP400D apresentam valores de K_T bastante dispersos em relação aos demais, $152{,}63\ \mu J/A$ e $77{,}27\ \mu J/A$, respectivamente, como pode ser verificado na Tabela 4. Portanto, não são considerados na análise seguinte.

A Tabela 5 apresenta os valores que são considerados para a análise do parâmetro nos dispositivos com $V_{CE(BR)} \leq 650V$ e $I_C \leq 40A$.

Tabela 4 - Perdas totais por comutação dos IGBT's com $V_{CE(BR)} \leq 650V$ e $I_C \leq 40A$.

IGBT - Referência	Diodo	Ic (A) (25 °C)	Et (µJ) (typ)	Kt (µJ/A)	Ano de publicação
HGTP3N60C3D	Sim	6	330	55,00	1998
HGTP7N60C3D	Sim	14	765	54,64	2000
IRG4PC40U	Não	40	670	16,75	2001
IRG4BC30UD	Sim	23	540	23,48	2001
IRGBC40U	Não	40	750	18,75	2001
IRG4PC40W	Não	40	340	8,50	2002
IRG4PC30W	Não	23	260	11,30	2002
IRG4BC30U	Não	23	360	15,65	2005
IRG4BC15UD	Sim	14	500	35,71	2006
IRGB20B60PD1	Sim	40	195	4,88	2008
IRG4BC10KD	Sim	9	390	43,33	2008
IRG4BC20UD	Sim	13	290	22,31	2009
IRGP20B60PD	Sim	40	315	7,88	2009
IRG4BC20SD	Sim	19	2900	152,63	2010
IGP15N60T	Não	30	570	19,00	2011
IRG4PC40UD	Sim	40	1060	26,50	2011
FGH20N60SFD	Sim	40	530	13,25	2014
HGTP10N40C1D	Sim	17,5	-	-	2014

IRGB4064DPbF	Sim	20	415 (175°C)	20,75	2015
IRG4PC30UD	Sim	23	540	23,48	2015
BUP400D	Sim	22	1700	77,27	2015
FGP20N60UFD	Sim	40	640	16,00	2016
HGTG7N60A4D	Sim	34	180	5,29	2017
IKW20N60T	Sim	40	770	19,25	2019

Fonte: Próprio autor com base nos *datasheets*.

Em 3.6, apresentou-se o parâmetro E_T como sendo a perda total de energia da chave de potência durante comutação e, por consequência, a soma das perdas por entrada em condução, E_{ON}, e as perdas bloqueio, E_{OFF}. Portanto, quanto menor for esse parâmetro, mais eficiente será a conversão, principalmente, para dispositivos que operam em frequências mais elevadas. Tal fato, se aplica também a K_T, pois ele é diretamente proporcional a E_T.

Considere os dois menores valores de K_T, na Tabela 5, que aparecem pelo menos uma vez, no período entre 1998 e 2009 e os dois menores valores entre 2010 e 2019. No primeiro período, os dois menores valores foram 4,88 $\mu J/A$ e 7,88 $\mu J/A$. Já no segundo período, tem-se os valores de 5,29 $\mu J/A$ e 13,25 $\mu J/A$.

Agora, segue a mesma análise, porém, para os dois maiores valores de K_T para cada período. Na primeira faixa de tempo, os dois maiores valores foram 55,00 $\mu J/A$ e 54,64 $\mu J/A$. Em contrapartida, os valores da segunda faixa foram 26,50 $\mu J/A$ e 23,48 $\mu J/A$.

A média aritimética dos valores de K_T na primeira faixa foi aproximadamente 30,90 $\mu J/A$ e na segunda faixa, 17,30 $\mu J/A$, diminuição de 44,04 % em relação a primeira faixa.

Com esse dados, é possível constatar que os dispositivos mais eficientes se tornaram mais comumente utilizados com o decorrer dos anos, já que a média da segunda faixa é menor. Na primeira faixa, porém, percebe-se que em 2008 e 2009 dois transistores (IRGB20B60PD1 e IRGP20B60PD) se destacam por baixo valor do parâmetro em análise. Porém, não se consta o mesmo decréscimo nos valores nos anos seguintes. Isso indica que houve um aprimoramento das perdas de comutação nos dispositivos da década de 2000.

Tabela 5 - Perdas totais por comutação dos IGBT's analisados com $V_{CE(BR)} \leq 650V\ e\ I_C \leq 40A$.

IGBT - Referência	Diodo	Ic (A) (25 °C)	Et (µJ) (typ)	Et/Ic (µJ/A)	Ano de publicação
HGTP3N60C3D	Sim	6	330	55,00	1998
HGTP7N60C3D	Sim	14	765	54,64	2000

IRG4BC30UD	Sim	23	540	23,48	2001
IRG4BC15UD	Sim	14	500	35,71	2006
IRGB20B60PD1	Sim	40	195	4,88	2008
IRG4BC10KD	Sim	9	390	43,33	2008
IRG4BC20UD	Sim	13	290	22,31	2009
IRGP20B60PD	Sim	40	315	7,88	2009
IRG4PC40UD	Sim	40	1060	26,50	2011
FGH20N60SFD	Sim	40	530	13,25	2014
IRG4PC30UD	Sim	23	540	23,48	2015
FGP20N60UFD	Sim	40	640	16,00	2016
HGTG7N60A4D	Sim	34	180	5,29	2017
IKW20N60T	Sim	40	770	19,25	2019

Fonte: Próprio autor com base nos *datasheets*.

5.2.2 Dispositivos IGBT's: $V_{CE(BR)} \leq 650V$ *e* $I_C > 40A$

A Tabela 6 apresenta os valores de perdas totais por comutação para as referências de IGBT's listadas no item 4.2 ($V_{CE(BR)} \leq 650V$ e $I_C > 40A$), assim como os respectivos valores K_T calculados conforme a equação 2.

Tabela 6 - Perdas totais por comutação dos IGBT's com $V_{CE(BR)} \leq 650V$ e $I_C > 40A$.

IGBT - Referência	Diodo	Ic (A) (25 °C)	Et (µJ) (typ)	Kt (µJ/A)	Ano de publicação
IRG4PSC71U	Não	85	2410	28,35	2001
IRG4PC50UD	Sim	55	1580	28,73	2002
IRG4PC50W	Não	55	400	7,27	2004
IRG4PSC71UD	Sim	85	5530	65,06	2007
IRG4PC50KD	Sim	52	2450	47,12	2008
IRGP50B60PD1	Sim	75	630	8,40	2008
IRG4PC40FD	Sim	49	2960	60,41	2009
APT30GT60BRD	Sim	55	1700 (150°C)	30,91(150°C)	2009
APT15GP60BDF1	Sim	56	251	4,48	2009
IRGP30B60KD-E	Sim	60	1175	19,58	2010
IKW75N60T	Sim	80	4500	56,25	2010
IGW30N60T	Não	60	1460	24,33	2011
IRGPC40S	Não	50	13000	260,00	2012
STGW35HF60WD	Sim	60	475	7,92	2012
IRGP50B60PD	Sim	75	940	12,53	2012
IKW30N60T	Sim	60	1460	24,33	2014
SGH80N60UFD	Sim	80	1160	14,50	2016
IRGP50B60PD1PBF	Sim	75	630	8,40	2017
IXGH72N60A3	Não	75	4880	65,07	2017

IRG4PC40K	Não	42	950	22,62	2018
IRGPC40F	Não	49	3650	74,49	2018
IKP40N65F5	Sim	74	460	6,22	2020

Fonte: Próprio autor com base nos *datasheets*.

Para a análise a seguir, os dados da Tabela 7 são divididos em duas faixas: a primeira de 2002 a 2009 e a segunda 2010 a 2020. As faixas foram escolhidas de modo a dividir os dados em quantidades semelhantes por faixa.

Da mesma forma que no caso anterior, para verificação da evolução do parâmetro nos IGBT's, toma-se os dois menores valores de K_T para o primeiro período e para o segundo período. Para a primeira faixa, os dois menores valores são $4{,}88\ \mu J/A$ e $8{,}40\ \mu J/A$. Já para a segunda faixa, são $6{,}22\ \mu J/A$ e $7{,}92\ \mu J/A$.

Analogamente, considerou-se os dois maiores valores de K_T da primeira faixa, assim como, também, os da segunda faixa. Os dois maiores valores no primeiro período são $65{,}06\ \mu J/A$ e $60{,}41\ \mu J/A$. Em contraste, no segundo período foram $56{,}25\ \mu J/A$ e $24{,}33\ \mu J/A$.

Além disso, a média aritimética dos valores de K_T no primeiro período foi $35{,}70\ \mu J/A$ e no segundo, $18{,}72\ \mu J/A$, diminuição de 47,6 % em relação a primeira faixa.

A partir de tais dados, percebe-se que assim como no caso anterior, houve uma clara melhora nas perdas de comutação nos anos de 2008 e 2009 (IRGP50B60PD1 e APT15GP60BDF1) em comparação a anos prévios. Isso indica, assim como na análise anterior, que nos anos 2000 ocorreu uma diminuição das perdas por comutação de dispositivos de IGBT's da categoria em estudo. A diminuição da média foi bastante significativa, o que indica o aumento do uso de transistores mais eficientes ao longo dos anos.

Tabela 7 - Perdas totais por comutação dos IGBT's analisados com $V_{CE(BR)} \leq 650V\ e\ I_C > 40A$.

IGBT - Referência	Diodo	Ic (A) (25 °C)	Et (μJ) (typ)	Kt (μJ/A)	Ano de publicação
IRG4PC50UD	Sim	55	1580	28,73	2002
IRG4PSC71UD	Sim	85	5530	65,06	2007
IRG4PC50KD	Sim	52	2450	47,12	2008
IRGP50B60PD1	Sim	75	630	8,40	2008
IRG4PC40FD	Sim	49	2960	60,41	2009
APT15GP60BDF1	Sim	56	251	4,48	2009
IRGP30B60KD-E	Sim	60	1175	19,58	2010
IKW75N60T	Sim	80	4500	56,25	2010
STGW35HF60WD	Sim	60	475	7,92	2012

IRGP50B60PD	Sim	75	940	12,53	2012
IKW30N60T	Sim	60	1460	24,33	2014
SGH80N60UFD	Sim	80	1160	14,50	2016
IRGP50B60PD1PBF	Sim	75	630	8,40	2017
IKP40N65F5	Sim	74	460	6,22	2020

Fonte: Próprio autor com base nos *datasheets*.

5.2.3 Dispositivos IGBT's: $V_{CE(BR)} = 1200V$

A Tabela 8 apresenta os valores de perda total por comutação para as referências de IGBT's listadas no item 4.4. Para as comparações, são considerados os valores de perda total típicos (*typical*) dos dispositivos, na temperatura de 25°C, sobre a corrente. Tais dados estão dispostos na quarta coluna.

Os transistores que foram excluídos somente por apresentarem valores dispersos são: FGA15N120AND, IRG4PH50KDPbF e FGA25N120ANTD. Os dados de K_T para esses dispositivos foram $161{,}25\ \mu J/A$, $127{,}33\ \mu J/A$ e $101{,}20\ \mu J/A$, respectivamente.

Tabela 8 - Perdas totais por comutação IGBT's com $V_{CE(BR)} = 1200V$.

IGBT - Referência	Diodo	Ic (A) (25 °C)	Et (µJ) (typ)	Kt (µJ/A)	Ano de publicação
IRG4PH50UD	Sim	45	3600	80,00	2002
IRGP20B120UD-E	Sim	40	1275	31,88	2003
IRG4PH40K	Não	30	1260	42,00	2009
BUP306D	Sim	23	-	-	2010
IXRP15N120	Sim	25	3100 (125°C)	124,00 (125°C)	2010
IRG4PH50U	Não	45	1940	43,11	2011
IRG4PH40UD	Sim	41	3730	90,98	2012
IRG4PH20KD	Sim	11	920	83,64	2013
IRGP20B120U-E	Não	40	1960	49,00	2013
IGW40T120	Não	75	6500	86,67	2014
IKW40N120H3	Sim	80	4400	55,00	2014
SKW25N120	Sim	46	3700	80,43	2015
IRG7PH35UD1PbF	Não	50	-	-	2015
FGA15N120AND	Sim	24	3870	161,25	2016
FGA25N120ANTD	Sim	50	5060	101,20	2016
BUP314	Não	52	8250 (125°C)	158,65 (125°C)	2016
IKW40N120T2	Sim	75	5250	70,00	2016
IKW40T120	Sim	75	6500	86,67	2016
FGA20N120FTD	Sim	40	1130	28,25	2018
FGH40T120SMD	Sim	80	3800	47,50	2018

IRG4PH50KDPbF	Sim	45	5730	127,33	2019
IRGPS60B120KD	Sim	105	7997	76,16	2019

Fonte: Próprio autor com base nos *datasheets*.

A Tabela 9 apresenta os dispositivos da Tabela 8 que foram efetivamente utilizados na análise feita.

Para a análise a seguir, os dados da Tabela 9 são divididos em duas faixas: a primeira de 2002 a 2015 e a segunda 2016 a 2019. As faixas foram escolhidas de modo a dividir os dados em quantidades semelhantes por faixa.

Da mesma forma que no caso anterior, para verificação da evolução do parâmetro nos IGBT's, toma-se os dois menores valores de K_T para o primeiro período e para o segundo período. Para o primeiro período, os dois menores valores são $31{,}88\ \mu J/A$ e $55{,}00\ \mu J/A$. Já para a segunda faixa, são $28{,}25\ \mu J/A$ e $47{,}50\ \mu J/A$.

Analogamente, considerou-se os dois maiores valores de K_T da primeira faixa e, também, os da segunda faixa. Os dois maiores valores no primeiro período são $90{,}98\ \mu J/A$ e $83{,}64\ \mu J/A$. Em contraste, no segundo período foram $86{,}67\ \mu J/A$ e $76{,}16\ \mu J/A$.

Além disso, a média aritimética dos valores de K_T no primeiro período foi $70{,}32\ \mu J/A$ e no segundo, $61{,}72\ \mu J/A$, diminuição de 12,2 % em relação à primeira faixa.

A partir de tais dados, percebe-se que houve uma clara melhora nos parâmetros, apesar de não ter sido tão grande a evolução dos limites de cada faixa.

Tabela 9 - Perdas totais por comutação dos IGBT's analisados com $V_{CE(BR)} = 1200V$.

IGBT - Referência	Diodo	Ic (A) (25 °C)	Et (µJ) (typ)	Et/Ic (µJ/A)	Ano de publicação
IRG4PH50UD	Sim	45	3600	80,00	2002
IRGP20B120UD-E	Sim	40	1275	31,88	2003
IRG4PH40UD	Sim	41	3730	90,98	2012
IRG4PH20KD	Sim	11	920	83,64	2013
IKW40N120H3	Sim	80	4400	55,00	2014
SKW25N120	Sim	46	3700	80,43	2015
IKW40N120T2	Sim	75	5250	70,00	2016
IKW40T120	Sim	75	6500	86,67	2016
FGA20N120FTD	Sim	40	1130	28,25	2018
FGH40T120SMD	Sim	80	3800	47,50	2018
IRGPS60B120KD	Sim	105	7997	76,16	2019

Fonte: Próprio autor com base nos *datasheets*.

6 EVOLUÇÃO DE PREÇOS DE MOSFET's NO MERCADO LOCAL - 2019 À 2022

O estudo a seguir leva em consideração o desenvolvimento dos preços de MOSFET's no mercado local ao longo dos últimos quatro anos, tomando tabelas de preço para a análise. A análise consistirá em comparar o crescimento dos preços dos semicondutores ao crescimento da cotação do dólar no mesmo período avaliado. A tabela de preços foi retirada de uma distribuidora de componentes eletrônicos chamada COMPIMEX, sediada em Fortaleza, CE.

Foram considerados sete dispositivos MOSFET para o estudo. A Tabela 10 apresenta tais dispositivos e seus principais parâmetros.

Tabela 10 - MOSFET's para análise de preços.

Referências MOSFET	Fabricante	VDSS (V)	ID (A) (100° C)	ID (A) (25° C)	RDSon (OHM)
IRF540N	International Rectifier	100	23	33	0,040
IRF640N	International Rectifier	200	13	18	0,15
IRF840	International Rectifier	500	5,1	8,0	0,85
IRF1404	International Rectifier	40	75	75	0,004
IRFP460N	International Rectifier	500	13	20	0,24
IRFB4227	International Rectifier	200	46	65	0,024
IRFZ48N	International Rectifier	55	45	64	0,014

Fonte: Próprio autor com base nos *datasheets*.

As Tabelas 11 e 12 mostram o desenvolvimento de preços unitários dos transistores MOSFET ao longo do período entre 2019 e 2022. Na Tabela 12, os dados que estam marcados com asterisco foram estimados, devido a ausencia do dado nas tabelas de preços no período. Os valores foram estimados linearmente com base nos dados mais próximos e no período de tempo decorrido, segundo a equação 3.

$$V_{ESTIMADO} = V_A + (V_B - V_A) \cdot \frac{T_{EA}}{T_{AB}} \qquad [3]$$

Onde,

$V_{ESTIMADO}$ – Valor a ser estimado;

V_A – Valor do período A, imediatamente anterior ao período do valor estimado;

V_B - Valor do período B, imediatamente posterior ao período do valor estimado;

T_{EA} – Período entre valor anterior e valor estimado;

T_{AB} – Período entre valor anterior e valor posterior.

Tabela 11 - Preços unitários dos MOSFET's em 2019 e 2020.

Referências MOSFET	Preço Unitário (mai/19)	Preço Unitário (ago/19)	Preço Unitário (nov/19)	Preço Unitário (fev/20)	Preço Unitário (set/20)
IRF540N	R$ 2,00	R$ 2,80	R$ 2,35	R$ 2,35	R$ 3,60
IRF640N	R$ 2,30	R$ 2,75	R$ 2,75	R$ 2,75	R$ 3,75
IRF840	R$ 3,35	R$ 3,35	R$ 3,70	R$ 3,65	R$ 4,50
IRF1404	R$ 5,75	R$ 5,75	R$ 5,50	R$ 5,50	R$ 6,95
IRFP460N	R$ 11,60	R$ 15,60	R$ 15,60	R$ 15,60	R$ 16,95
IRFB4227	R$ 11,80	R$ 13,60	R$ 13,60	R$ 10,45	R$ 12,80
IRFZ48N	R$ 2,80	R$ 2,80	R$ 2,80	R$ 2,80	R$ 3,90
Preço Unitário Total	**R$ 39,60**	**R$ 46,65**	**R$ 46,30**	**R$ 43,10**	**R$ 52,45**

Fonte: Próprio autor com base nas tabelas de preços.

Tabela 12 - Preços unitários dos MOSFET's em 2021 e 2022.

Referências MOSFET	Preço Unitário (mar/21)	Preço Unitário (ago/21)	Preço Unitário (nov/21)	Preço Unitário (mai/22)	Preço Unitário (nov/22)
IRF540N	R$ 3,70	R$ 4,40	R$ 4,40	R$ 3,65	R$ 3,30
IRF640N	R$ 3,50	R$ 3,50	R$ 4,28 *	R$ 5,25	R$ 5,25
IRF840	R$ 4,50	R$ 4,50	R$ 4,15	R$ 4,15	R$ 6,40
IRF1404	R$ 8,20	R$ 8,20	R$ 8,20	R$ 9,50	R$ 8,35
IRFP460N	R$ 16,95	R$ 16,95	R$ 20,15 *	R$ 24,15	R$ 24,15
IRFB4227	R$ 13,35	R$ 13,35	R$ 13,35	R$ 18,75 *	R$ 24,15
IRFZ48N	R$ 3,60	R$ 3,60	R$ 4,65	R$ 4,85	R$ 3,50
Preço Unitário Total	**R$ 53,80**	**R$ 54,50**	**R$ 59,18**	**R$ 70,30**	**R$ 75,10**
(*) - Valor estimado					

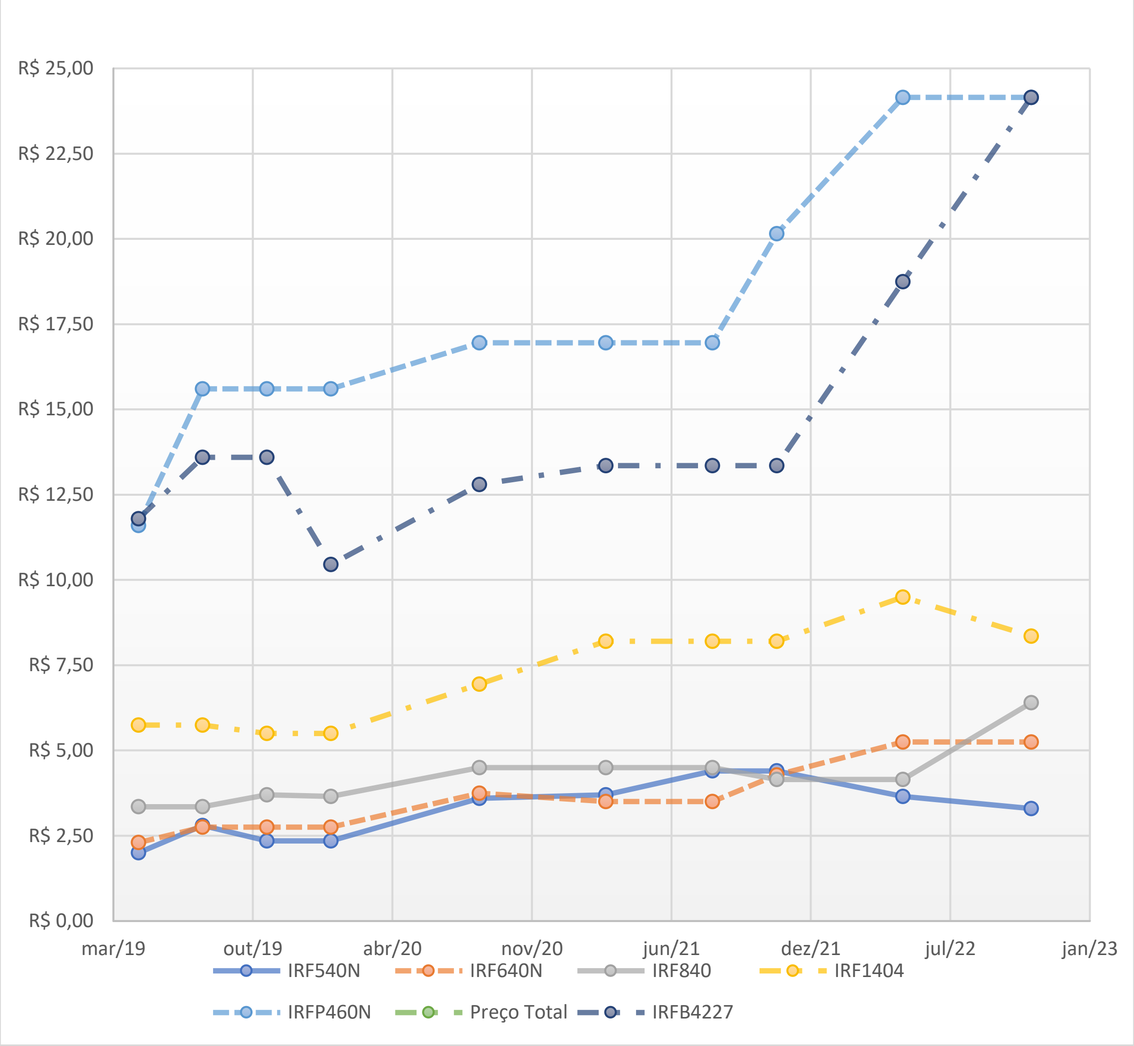
Fonte: Próprio autor com base nas tabelas de preços.

Pelas Tabelas 11 e 12, verifica-se que houve um aumento no final do ano de 2019 em relação ao início, saindo de $R\$$ 39,60, em maio de 2019, para $R\$$ 46,65, em agosto de 2019, e permaneceu-se aproximadamente constante até fevereiro de 2020. Esse aumento foi de cerca de 17,8 %. Entre fevereiro de 2020 e setembro de 2020, houve um aumento de $R\$$ 43,10 para

$R\$$ 52,45, cerca de 21,7 %. Entre setembro de 2020 e novembro de 2021, houve um aumento de 12,8 %. Entre novembro de 2021 e maio de 2022, houve uma elevação de preços de $R\$$ 59,18 para $R\$$ 70,30, que corresponde a 18,8 % de diferença. De maio de 2022 a novembro de 2022 houve uma variação percentual positiva de 6,82 %. Desde o primeiro período houve aumento médio de 89, 6 % nos preços.

O Gráfico 1 ilustra o desenvolvimento dos preços dos MOSFET's ao longo dos últimos anos e dá uma noção das proporções dos aumentos.

Gráfico 1 - Desenvolvimento dos preços de MOSFET's entre 2019 e 2022.



Fonte: Próprio autor com base nas tabelas de preços.

A Tabela 13 apresenta o valor da soma dos preços unitários dos dispositivos MOSFET's para cada período registrado, além apresentar a variação percentual total ao final entre maio de 2019 e novembro de 2022.

Tabela 13 - Preços unitários totais dos MOSFET’s entre 2019 e 2022.

Período	Preço Unitário Total (R$)	Variação em relação ao período anterior (%)
mai/19	39,60	-
ago/19	46,65	17,80
nov/19	46,30	-0,75
fev/20	43,10	-6,91
set/20	52,45	21,69
mar/21	53,80	2,57
ago/21	54,50	1,30
nov/21	59,18	8,58
mai/22	70,30	18,79
nov/22	75,10	6,83
Variação Percentual Total		**89,65**

Fonte: Próprio autor com base nas tabelas de preços.

A Tabela 14, apresenta a cotação do dólar em reais desde maio de 2019 até novembro de 2022, assim como a variação percentual de cada período em relação ao período anterior e no final da tabela a variação percentual total da cotação do dólar entre maio de 2019 e novembro de 2022.

Tabela 14 - Cotação dólar em reais de 2019 a 2022.

Mês/Ano	Cotação dólar (R$)	Variação em relação ao período anterior (%)
mai/19	R$ 3,78	-
ago/19	R$ 3,83	1,32
nov/19	R$ 3,98	3,92
fev/20	R$ 4,25	6,78
set/20	R$ 5,36	26,12
mar/21	R$ 5,58	4,10
ago/21	R$ 5,14	-7,89
nov/21	R$ 5,67	10,31
mai/22	R$ 5,03	-11,29
nov/22	R$ 5,15	2,39
Variação Percentual Total		**36,24**

Fonte: Próprio autor com base em dados do IPEA.

Verifica-se, pela Tabela 14 que a maior variação do preço do dólar foi de 26,12 %. Em contraste, na Tabela 13, para o mesmo período, o preço unitário total variou cerca de 21,7 %, que também foi a maior variação entre períodos consecutivos. Constata-se que ambas variações se deram em magnitudes semelhantes.

No mesmo período da segunda maior variação positiva do dólar, 10,3 %, que ocorreu entre agosto de 2021 e novembro de 2021, observou-se que o aumento dos preços unitários totais foi de 8,6 %.

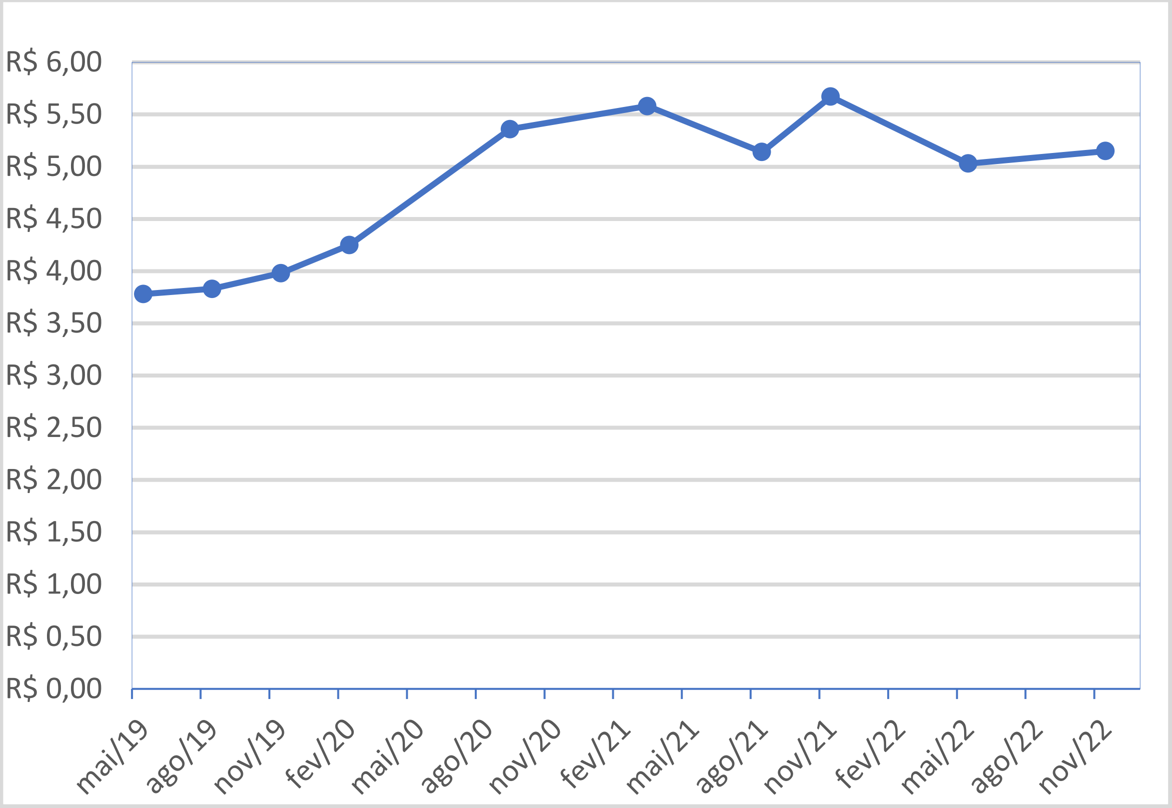
Porém, em variações negativas, os dois parâmetros se comportam de maneira diferente. Entre novembro de 2021 e maio de 2022, o dólar caiu cerca de 11,3 %. Entretanto, os preços unitários totais subiram 18,8 % para o mesmo período.

Além disso, o aumento do preço do dólar para todo o período foi de 36,2 %, já para os preço unitários totais foi de 89,6 %.

Tais fatos indicam dependência entre os fatores, porém, também demonstram que houveram outros fortes fatores que influenciaram o aumento dos preços dos semicondutores. Fatores esses como a escassez global de semicondutores, que já foi discutida anteriormente neste trabalho.

O Gráfico 2 ilustra a evolução da cotação do dólar em reais entre 2019 e 2022, dando uma noção das proporções das variações.

Gráfico 2 - Desenvolvimento da cotação do dólar entre 2019 e 2022.



Fonte: Próprio autor com base em dados do IPEA.

7 CONCLUSÃO

A análise da evolução de especificações de dispositivos IGBT’s discretos de trabalhos acadêmicos ao longo das duas últimas décadas obteve resultados interessantes e satisfatórios. Os parâmetros analisados foram a tensão emissor-coletor em condução, $V_{CE(ON)}$ e as perdas totais por comutação dos transistores, E_T.

Em ambos os parâmetros, devido a influência da corrente I_C dos transistores, considerou-se necessário dividi-los pela corrente de coletor nominal a fim de diminuir a influencia da variação de corrente entre os dispositivos, resultando nos parâmetros $K_{CE(ON)}$ e K_T.

Para dispositivos com tensão $V_{CE(BR)} \leq 650\ V$ e corrente $I_C \leq 40\ A$, o parâmetro ($V_{CE(ON)}$), não apresentou aprimoramento significativo ao longo dos anos, apesar da redução da média do valores em 4,64 %. Tal conclusão ocorre devido ao fato que a faixa de valores de $K_{CE(ON)}$ permanece praticamente inalterada ao longo das duas décadas.

Ainda para os mesmos níveis de tensão e corrente, mas, em relação ao parâmetro (E_T), a análise dos dados revelou que houve um aprimoramento do parâmetro na década de 2000, pois percebe-se uma diminuição significativa dos valores de K_T nos anos de 2008 e 2009. Entretanto, não observou-se melhora considerável na década de 2010.

Para dispositivos com tensão $V_{CE(BR)} \leq 650\ V$ e corrente $I_C > 40\ A$, o parâmetro ($V_{CE(ON)}$), não teve melhora significativa, assim como na categoria anterior. Apesar da diminuição da média em cerca de 7,8 %, as faixas permaneceram praticamente inalteradas.

Considerando ainda as mesmas faixas de tensão e corrente, o parâmetro E_T apresentou resultados semelhantes ao ocorrido para os dispositivos do caso anterior. Observou-se uma diminuição significativa de K_T nos anos de 2008 e 2009. O que indica que houve uma evolução na década de 2000. Não se constatou evolução significativa da especificação durante a década de 2010.

Dispositivos que operam em até 1,2 kV de tensão de bloqueio apresentaram notório aprimoramento da tensão em condução entre a década de 2000 e 2010. As faixas de valores de $K_{CE(ON)}$, apresentaram diminuição e a média teve um decréscimo considerável de 38,5 %.

Já em relação as perdas de comutação, houve também um aprimoramento da especificação, já que as faixas de valores de K_T e a média caíram do primeiro para o segundo período de tempo.

Os IGBT's compilados de $1{,}2\ kV$ de tensão foram em sua maioria de trabalhos acadêmicos da década de 2010, o que limitou a análise. Ainda assim, os resultados são considerados satisfatórios.

Em todas as análises, houve redução da média dos valores do segundo período em relação ao primeiro. Nos casos em que as faixas de valores permaneceram constantes, tal redução indica o aumento do uso de transistores mais eficientes e, consequentemente, que tais dispositivos se tornaram mais acessíveis no decorrer dos anos.

Os resultados apresentados mostra que dispositivos IGBT's com tensões de bloqueio maiores (1,2 kV) apresentaram maior evolução dos parâmetros analisados em comparação a dispositivos com tensões menores. Tal conclusão é similar a feita por Takata (1996), onde, constatou-se que os dispositivos IGBT's da época haviam quase alcançado um estado de maturidade em baixas tensões.

Em relação a análise dos preços de MOSFETs, observou-se que a evolução dos preços se deu de forma similar ao preço do dólar para variações positivas deste. Entretanto, em variações negativas da cotação do dólar, os preços dos dispositivos continuaram a crescer de forma considerável. O aumento dos preços dos MOSFET's para o período analisado foi de $89{,}6\ \%$. Em contraste, o aumento da cotação do dólar para o mesmo período foi de $36{,}2\ \%$.

Tal análise indica que há relação entre o preço do dólar e dos dispositivos semicondutores, apesar de que não é o fator mais determinante. Como discutido anteriormente, o principal fator no aumento dos preços de semicondutores foi a escassez global de chips eletrônicos decorrentes dos efeitos da pandemia da COVID-19.

7.1 Trabalhos Futuros

Para trabalhos futuros, sugere-se a análise mais aprofundada do fato de não se haver tantos transistores IGBT's de tensão de $1{,}2\ kV$ em trabalhos acadêmicos antes da década de 2010, investigando o desenvolvimento das aplicações de tensão dos dispositivos IGBT's nas últimas duas décadas e descrevendo as novas tecnologias por trás delas.

Recomenda-se, ainda, a análise mais aprofundada do desenvolvimento dos preços de dispositivos semicondutores de potência, como IGBT's, MOSFET's e tiristores, comparando informações de preços de múltiplos distribuidores locais e/ou nacionais para investigação mais ampla.

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ANEXO A – FOLHAS DE DADOS DE DISPOSITIVOS (INFORMAÇÕES PRINCIPAIS)

International
IOR Rectifier

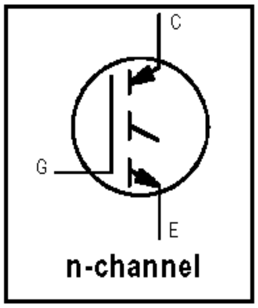
PD- 95230

IRG4PF50WPbF

INSULATED GATE BIPOLAR TRANSISTOR

Features

- Optimized for use in Welding and Switch-Mode Power Supply applications
- Industry benchmark switching losses improve efficiency of all power supply topologies
- 50% reduction of Eoff parameter
- Low IGBT conduction losses
- Latest technology IGBT design offers tighter parameter distribution coupled with exceptional reliability
- Lead-Free



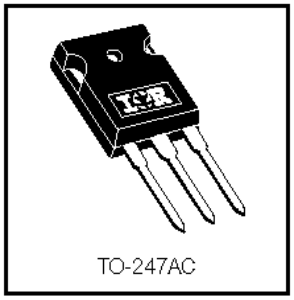
V_{CES} = 900V

$V_{CE(on)\ typ.}$ = 2.25V

@V_{GE} = 15V, I_C = 28A

Benefits

- Lower switching losses allow more cost-effective operation and hence efficient replacement of larger-die MOSFETs up to 100kHz
- Of particular benefit in single-ended converters and Power Supplies 150W and higher
- Reduction in critical Eoff parameter due to minimal minority-carrier recombination coupled with low on-state losses allow maximum flexibility in device application



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	900	V
I_C @ T_C = 25°C	Continuous Collector Current	51	A
I_C @ T_C = 100°C	Continuous Collector Current	28	
I_{CM}	Pulsed Collector Current ①	204	
I_{LM}	Clamped Inductive Load Current ②	204	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	186	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm from case)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	0.64	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	40	
Wt	Weight	6 (0.21)	——	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	900	—	—	V	V_{GE} = 0V, I_C = 250µA
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	18	—	—	V	V_{GE} = 0V, I_C = 1.0A
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.295	—	V/°C	V_{GE} = 0V, I_C = 3.5mA
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	2.25	2.7	V	I_C = 28A V_{GE} = 15V
		—	2.74	—		I_C = 60A See Fig.2, 5
		—	2.12	—		I_C = 28A , T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-13	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA
g_{fe}	Forward Transconductance ⑤	26	39	—	S	$V_{CE} \geq$ 15V, I_C = 28A
I_{CES}	Zero Gate Voltage Collector Current	—	—	500	µA	V_{GE} = 0V, V_{CE} = 900V
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C
		—	—	5.0	mA	V_{GE} = 0V, V_{CE} = 900V, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	160	240	nC	I_C = 28A V_{CC} = 400V See Fig. 8 V_{GE} = 15V
Q_{ge}	Gate - Emitter Charge (turn-on)	—	19	29		
Q_{gc}	Gate - Collector Charge (turn-on)	—	53	80		
$t_{d(on)}$	Turn-On Delay Time	—	29	—	ns	T_J = 25°C I_C = 28A, V_{CC} = 720V V_{GE} = 15V, R_G = 5.0Ω Energy losses include "tail" See Fig. 10, 11, 13, 14
t_r	Rise Time	—	26	—		
$t_{d(off)}$	Turn-Off Delay Time	—	110	170		
t_f	Fall Time	—	150	220		
E_{on}	Turn-On Switching Loss	—	0.19	—	mJ	
E_{off}	Turn-Off Switching Loss	—	1.06	—		
E_{ts}	Total Switching Loss	—	1.25	1.7		
$t_{d(on)}$	Turn-On Delay Time	—	28	—	ns	T_J = 150°C, I_C = 28A, V_{CC} = 720V V_{GE} = 15V, R_G = 5.0Ω Energy losses include "tail" See Fig. 13, 14
t_r	Rise Time	—	26	—		
$t_{d(off)}$	Turn-Off Delay Time	—	280	—		
t_f	Fall Time	—	90	—		
E_{ts}	Total Switching Loss	—	3.45	—	mJ	
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	3300	—	pF	V_{GE} = 0V V_{CC} = 30V See Fig. 7 ƒ = 1.0MHz
C_{oes}	Output Capacitance	—	200	—		
C_{res}	Reverse Transfer Capacitance	—	45	—		

Notes:

① Repetitive rating; V_{GE} = 20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC} = 80%(V_{CES}), V_{GE} = 20V, L = 10µH, R_G = 5.0Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0µs, single shot.

International
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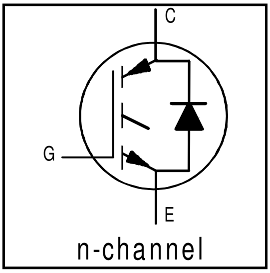
PD- 91788

IRG4PF50WD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Features

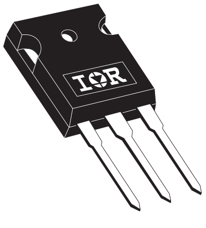
- Optimized for use in Welding and Switch-Mode Power Supply applications
- Industry benchmark switching losses improve efficiency of all power supply topologies
- 50% reduction of Eoff parameter
- Low IGBT conduction losses
- Latest technology IGBT design offers tighter parameter distribution coupled with exceptional reliability
- IGBT co-packaged with HEXFRED^{TM} ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package



V_{CES} = 900V

$V_{CE(on)}$ typ. = 2.25V

@V_{GE} = 15V, I_C = 28A



TO-247AC

Benefits

- Lower switching losses allow more cost-effective operation and hence efficient replacement of larger-die MOSFETs up to 100kHz
- HEXFRED^{TM} diodes optimized for performance with IGBTs. Minimized recovery characteristics reduce noise, EMI and switching losses

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	900	V
I_C @ T_C = 25°C	Continuous Collector Current	51	A
I_C @ T_C = 100°C	Continuous Collector Current	28	
I_{CM}	Pulsed Collector Current ①	204	
I_{LM}	Clamped Inductive Load Current ②	204	
I_F @ T_C = 100°C	Diode Continuous Forward Current	16	
I_{FM}	Diode Maximum Forward Current	204	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	–––	–––	0.64	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	–––	–––	0.83	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	–––	0.24	–––	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	–––	–––	40	
Wt	Weight	–––	6 (0.21)	–––	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	900	—	—	V	V_{GE} = 0V, I_C = 250µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.295	—	V/°C	V_{GE} = 0V, I_C = 3.5mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.25	2.7	V	I_C = 28A	V_{GE} = 15V
		—	2.74	—		I_C = 60A	See Fig. 2, 5
		—	2.12	—		I_C = 28A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-13	—	mV/°C	V_{CE} = V_{GE}, I_C = 250µA	
g_{fe}	Forward Transconductance ④	26	39	—	S	V_{CE} = 50V, I_C = 28A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	500	µA	V_{GE} = 0V, V_{CE} = 900V	
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C	
		—	—	6.5	mA	V_{GE} = 0V, V_{CE} = 900V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	2.5	3.5	V	I_C = 16A	See Fig. 13
		—	2.1	3.0		I_C = 16A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	—	160	240	nC	I_C = 28A	
Qge	Gate - Emitter Charge (turn-on)	—	19	29		V_{CC} = 400V	See Fig. 8
Q_{gc}	Gate - Collector Charge (turn-on)	—	53	80		V_{GE} = 15V	
$t_{d(on)}$	Turn-On Delay Time	—	71	—	ns	T_J = 25°C	
t_r	Rise Time	—	50	—		I_C = 28A, V_{CC} = 720V	
$t_{d(off)}$	Turn-Off Delay Time	—	150	220		V_{GE} = 15V, R_G = 5.0Ω	
t_f	Fall Time	—	110	170		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	—	2.63	—	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	—	1.34	—		See Fig. 9, 10, 18	
E_{ts}	Total Switching Loss	—	3.97	5.3			
$t_{d(on)}$	Turn-On Delay Time	—	69	—	ns	T_J = 150°C,	See Fig. 11, 18
t_r	Rise Time	—	52	—		I_C = 28A, V_{CC} = 720V	
$t_{d(off)}$	Turn-Off Delay Time	—	270	—		V_{GE} = 15V, R_G = 5.0Ω	
t_f	Fall Time	—	190	—		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	—	6.0	—	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	—	3300	—	pF	V_{GE} = 0V	
C_{oes}	Output Capacitance	—	200	—		V_{CC} = 30V	See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	45	—		f = 1.0MHz	
t_{rr}	Diode Reverse Recovery Time	—	90	135	ns	T_J = 25°C See Fig.	
		—	164	245		T_J = 125°C 14	I_F = 16A
I_{rr}	Diode Peak Reverse Recovery Current	—	5.8	10	A	T_J = 25°C See Fig.	
		—	8.3	15		T_J = 125°C 15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	260	675	nC	T_J = 25°C See Fig.	
		—	680	1838		T_J = 125°C 16	di/dt = 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery During t_b	—	120	—	A/µs	T_J = 25°C See Fig.	
		—	76	—		T_J = 125°C 17	

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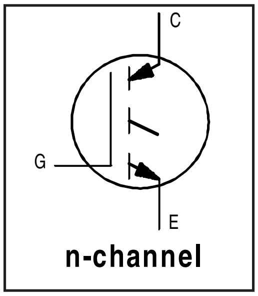
PD - 91657B

IRG4PC50W

INSULATED GATE BIPOLAR TRANSISTOR

Features

- Designed expressly for Switch-Mode Power Supply and PFC (power factor correction) applications
- Industry-benchmark switching losses improve efficiency of all power supply topologies
- 50% reduction of Eoff parameter
- Low IGBT conduction losses
- Latest-generation IGBT design and construction offers tighter parameters distribution, exceptional reliability



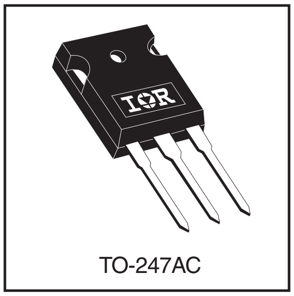
$V_{CES} = 600V$

$V_{CE(on)}$ max. = 2.30V

$@V_{GE} = 15V, I_C = 27A$

Benefits

- Lower switching losses allow more cost-effective operation than power MOSFETs up to 150 kHz ("hard switched" mode)
- Of particular benefit to single-ended converters and boost PFC topologies 150W and higher
- Low conduction losses and minimal minority-carrier recombination make these an excellent option for resonant mode switching as well (up to >300 kHz)


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	55	A
I_C @ T_C = 100°C	Continuous Collector Current	27	
I_{CM}	Pulsed Collector Current ①	220	
I_{LM}	Clamped Inductive Load Current ②	220	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	170	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	0.64	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	40	
Wt	Weight	6 (0.21)	——	g (oz)

2/7/2000

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 250μA
$V_{(BR)CES}$	Emitter-to-Collector Breakdown Voltage ④	18	—	—	V	V_{GE} = 0V, I_C = 1.0A
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.41	—	V/°C	V_{GE} = 0V, I_C = 5.0mA
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	1.93	2.3	V	I_C = 27A V_{GE} = 15V
		—	2.25	—		I_C = 55A See Fig.2, 5
		—	1.71	—		I_C = 27A , T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250μA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-11	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA
g_{fe}	Forward Transconductance ⑤	27	41	—	S	V_{CE} = 100 V, I_C = 27A
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	μA	V_{GE} = 0V, V_{CE} = 600V
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C
		—	—	5000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	180	270	nC	I_C = 27A V_{CC} = 400V See Fig.8 V_{GE} = 15V
Q_{ge}	Gate - Emitter Charge (turn-on)	—	24	36		
Q_{gc}	Gate - Collector Charge (turn-on)	—	63	95		
$t_{d(on)}$	Turn-On Delay Time	—	46	—	ns	T_J = 25°C I_C = 27A, V_{CC} = 480V V_{GE} = 15V, R_G = 5.0Ω Energy losses include "tail" See Fig. 9, 10, 14
t_r	Rise Time	—	33	—		
$t_{d(off)}$	Turn-Off Delay Time	—	120	180		
t_f	Fall Time	—	57	86		
E_{on}	Turn-On Switching Loss	—	0.08	—	mJ	
E_{off}	Turn-Off Switching Loss	—	0.32	—		
E_{ts}	Total Switching Loss	—	0.40	0.5		
$t_{d(on)}$	Turn-On Delay Time	—	31	—	ns	T_J = 150°C, I_C = 27A, V_{CC} = 480V V_{GE} = 15V, R_G = 5.0Ω Energy losses include "tail" See Fig. 10,11, 14
t_r	Rise Time	—	43	—		
$t_{d(off)}$	Turn-Off Delay Time	—	210	—		
t_f	Fall Time	—	62	—		
E_{ts}	Total Switching Loss	—	1.14	—	mJ	
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	3700	—	pF	V_{GE} = 0V V_{CC} = 30V See Fig. 7 ƒ = 1.0MHz
C_{oes}	Output Capacitance	—	260	—		
C_{res}	Reverse Transfer Capacitance	—	68	—		

Notes:

① Repetitive rating; V_{GE} = 20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC} = 80%(V_{CES}), V_{GE} = 20V, L = 10μH, R_G = 5.0Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80μs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0μs, single shot.

International
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PD 91471B

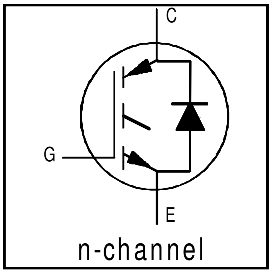
IRG4PC50UD

UltraFast CoPack IGBT

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Features

- UltraFast: Optimized for high operating frequencies 8-40 kHz in hard switching, >200 kHz in resonant mode
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- IGBT co-packaged with HEXFRED^{TM} ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package



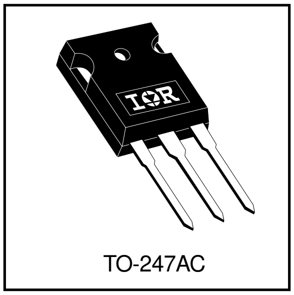
V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.65V

@V_{GE} = 15V, I_C = 27A

Benefits

- Generation 4 IGBT's offer highest efficiencies available
- IGBT's optimized for specific application conditions
- HEXFRED diodes optimized for performance with IGBT's . Minimized recovery characteristics require less/no snubbing
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBT's


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	55	A
I_C @ T_C = 100°C	Continuous Collector Current	27	
I_{CM}	Pulsed Collector Current ①	220	
I_{LM}	Clamped Inductive Load Current ②	220	
I_F @ T_C = 100°C	Diode Continuous Forward Current	25	
I_{FM}	Diode Maximum Forward Current	220	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	------	------	0.64	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	------	------	0.83	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	------	0.24	------	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	-----	-----	40	
Wt	Weight	------	6 (0.21)	------	g (oz)

12/30/00

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	600	----	----	V	V_{GE} = 0V, I_C = 250μA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	----	0.60	----	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	----	1.65	2.0	V	I_C = 27A	V_{GE} = 15V
		----	2.0	----		I_C = 55A	See Fig. 2, 5
		----	1.6	----		I_C = 27A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	----	6.0		V_{CE} = V_{GE}, I_C = 250μA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	----	-13	----	mV/°C	V_{CE} = V_{GE}, I_C = 250μA	
g_{fe}	Forward Transconductance ④	16	24	----	S	V_{CE} = 100V, I_C = 27A	
I_{CES}	Zero Gate Voltage Collector Current	----	----	250	μA	V_{GE} = 0V, V_{CE} = 600V	
		----	----	6500		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	----	1.3	1.7	V	I_C = 25A	See Fig. 13
		----	1.2	1.5		I_C = 25A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	----	----	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

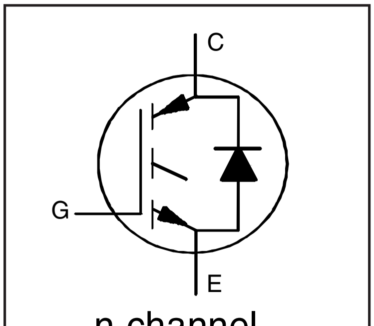
	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	----	180	270	nC	I_C = 27A	
Qge	Gate - Emitter Charge (turn-on)	----	25	38		V_{CC} = 400V See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	----	61	90		V_{GE} = 15V	
$t_{d(on)}$	Turn-On Delay Time	----	46	----	ns	T_J = 25°C	
t_r	Rise Time	----	25	----		I_C = 27A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	140	230		V_{GE} = 15V, R_G = 5.0Ω	
t_f	Fall Time	----	74	110		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	----	0.99	----	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	----	0.59	----		See Fig. 9, 10, 11, 18	
E_{ts}	Total Switching Loss	----	1.58	1.9			
$t_{d(on)}$	Turn-On Delay Time	----	44	----	ns	T_J = 150°C, See Fig. 9, 10, 11, 18	
t_r	Rise Time	----	27	----		I_C = 27A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	240	----		V_{GE} = 15V, R_G = 5.0Ω	
t_f	Fall Time	----	130	----		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	----	2.3	----	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	----	13	----	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	----	4000	----	pF	V_{GE} = 0V	
C_{oes}	Output Capacitance	----	250	----		V_{CC} = 30V See Fig. 7	
C_{res}	Reverse Transfer Capacitance	----	52	----		f = 1.0MHz	
t_{rr}	Diode Reverse Recovery Time	----	50	75	ns	T_J = 25°C See Fig.	
		----	105	160		T_J = 125°C 14	I_F = 25A
I_{rr}	Diode Peak Reverse Recovery Current	----	4.5	10	A	T_J = 25°C See Fig.	
		----	8.0	15		T_J = 125°C 15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	----	112	375	nC	T_J = 25°C See Fig.	
		----	420	1200		T_J = 125°C 16	di/dt 200A/μs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery During t_b	----	250	----	A/μs	T_J = 25°C	
		----	160	----		T_J = 125°C	

PD - 94626

SMPS IGBT

IRGP20B60PD

WARP2 SERIES IGBT WITH ULTRAFAST SOFT RECOVERY DIODE



n-channel

V_{CES} = 600V
$V_{CE(on)}$ typ. = 2.05V
@ V_{GE} = 15V I_C = 13.0A

Equivalent MOSFET Parameters ①
$R_{CE(on)}$ typ. = 158mΩ
I_D (FET equivalent) = 20A

Applications

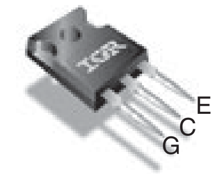
- Telecom and Server SMPS
- PFC and ZVS SMPS Circuits
- Uninterruptable Power Supplies
- Consumer Electronics Power Supplies

Features

- NPT Technology, Positive Temperature Coefficient
- Lower V_{CE}(SAT)
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability

Benefits

- Parallel Operation for Higher Current Applications
- Lower Conduction Losses and Switching Losses
- Higher Switching Frequency up to 150kHz



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	40	A
I_C @ T_C = 100°C	Continuous Collector Current	22	
I_{CM}	Pulse Collector Current (Ref. Fig. C.T.4)	80	
I_{LM}	Clamped Inductive Load Current ②	80	
I_F @ T_C = 25°C	Diode Continous Forward Current	31	
I_F @ T_C = 100°C	Diode Continous Forward Current	12	
I_{FRM}	Maximum Repetitive Forward Current ③	42	
V_{GE}	Gate-to-Emitter Voltage	±20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	220	W
P_D @ T_C = 100°C	Maximum Power Dissipation	86	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$ (IGBT)	Thermal Resistance Junction-to-Case-(each IGBT)	—	—	0.58	°C/W
$R_{\theta JC}$ (Diode)	Thermal Resistance Junction-to-Case-(each Diode)	—	—	2.5	
$R_{\theta CS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	—	0.24	—	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	—	—	40	
	Weight	—	6 (0.21)	—	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 500µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.32	—	V/°C	V_{GE} = 0V, I_C = 1mA (25°C-125°C)	
R_G	Internal Gate Resistance	—	4.3	—	Ω	1MHz, Open Collector	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.05	2.35	V	I_C = 13A, V_{GE} = 15V	4, 5,6,8,9
		—	2.50	2.80		I_C = 20A, V_{GE} = 15V	
		—	2.65	3.00		I_C = 13A, V_{GE} = 15V, T_J = 125°C	
		—	3.30	3.70		I_C = 20A, V_{GE} = 15V, T_J = 125°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	4.0	5.0	V	I_C = 250µA	7,8,9
$\Delta V_{GE(th)}/\Delta TJ$	Threshold Voltage temp. coefficient	—	-11	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA	
gfe	Forward Transconductance	—	19	—	S	V_{CE} = 50V, I_C = 40A, PW = 80µs	
I_{CES}	Collector-to-Emitter Leakage Current	—	1.0	250	µA	V_{GE} = 0V, V_{CE} = 600V	
		—	0.1	—	mA	V_{GE} = 0V, V_{CE} = 600V, T_J = 125°C	
V_{FM}	Diode Forward Voltage Drop	—	1.4	1.7	V	I_F = 12A, V_{GE} = 0V	10
		—	1.3	1.6		I_F = 12A, V_{GE} = 0V, T_J = 125°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V, V_{CE} = 0V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
Qg	Total Gate Charge (turn-on)	—	68	102	nC	I_C = 13A	17
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	24	36		V_{CC} = 400V	CT1
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	10	15		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	—	95	140	µJ	I_C = 13A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	100	145		V_{GE} = +15V, R_G = 10Ω, L = 200µH	
E_{total}	Total Switching Loss	—	195	285		T_J = 25°C ④	
$t_{d(on)}$	Turn-On delay time	—	20	26	ns	I_C = 13A, V_{CC} = 390V	CT3
t_r	Rise time	—	5.0	7.0		V_{GE} = +15V, R_G = 10Ω, L = 200µH	
$t_{d(off)}$	Turn-Off delay time	—	115	135		T_J = 25°C ④	
t_f	Fall time	—	6.0	8.0			
E_{on}	Turn-On Switching Loss	—	165	215	µJ	I_C = 13A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	150	195		V_{GE} = +15V, R_G = 10Ω, L = 200µH	11,13
E_{total}	Total Switching Loss	—	315	410		T_J = 125°C ④	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	19	25	ns	I_C = 13A, V_{CC} = 390V	CT3
t_r	Rise time	—	6.0	8.0		V_{GE} = +15V, R_G = 10Ω, L = 200µH	12,14
$t_{d(off)}$	Turn-Off delay time	—	125	140		T_J = 125°C ④	WF1,WF2
t_f	Fall time	—	13	17			
C_{ies}	Input Capacitance	—	1570	—	pF	V_{GE} = 0V	16
C_{oes}	Output Capacitance	—	130	—		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	20	—		f = 1Mhz	
C_{oes} eff.	Effective Output Capacitance (Time Related) ⑤	—	94	—		V_{GE} = 0V, V_{CE} = 0V to 480V	15
C_{oes} eff. (ER)	Effective Output Capacitance (Energy Related) ⑤	—	76	—			
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T_J = 150°C, I_C = 80A	3
						V_{CC} = 480V, Vp =600V	CT2
						Rg = 22Ω, V_{GE} = +15V to 0V	
t_{rr}	Diode Reverse Recovery Time	—	42	60	ns	T_J = 25°C I_F = 12A, V_R = 200V,	19
		—	80	120		T_J = 125°C di/dt = 200A/µs	
Q_{rr}	Diode Reverse Recovery Charge	—	80	180	nC	T_J = 25°C I_F = 12A, V_R = 200V,	21
		—	220	600		T_J = 125°C di/dt = 200A/µs	
I_{rr}	Peak Reverse Recovery Current	—	3.5	6.0	A	T_J = 25°C I_F = 12A, V_R = 200V,	19,20,21,22
		—	5.6	10		T_J = 125°C di/dt = 200A/µs	CT5

Notes:

① $R_{CE(on)}$ typ. = equivalent on-resistance = $V_{CE(on)}$ typ. / I_C, where $V_{CE(on)}$ typ. = 2.05V and I_C = 13A. I_D (FET Equivalent) is the equivalent MOSFET I_D rating @ 25°C for applications up to 150kHz. These are provided for comparison purposes (only) with equivalent MOSFET solutions.

② V_{CC} = 80% (V_{CES}), V_{GE} = 15V, L = 28µH, R_G = 22Ω.

③ Pulse width limited by max. junction temperature.

④ Energy losses include "tail" and diode reverse recovery. Data generated with use of Diode 8ETH06.

⑤ C_{oes} eff. is a fixed capacitance that gives the same charging time as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.
C_{oes} eff.(ER) is a fixed capacitance that stores the same energy as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.

International
IOR Rectifier

PD - 9.683A

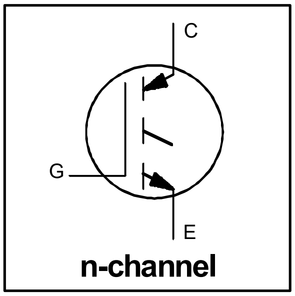
IRGBC40U

INSULATED GATE BIPOLAR TRANSISTOR

UltraFast IGBT

Features

- Switching-loss rating includes all "tail" losses
- Optimized for high operating frequency (over 5kHz) See Fig. 1 for Current vs. Frequency curve



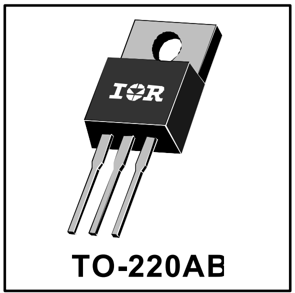
V_{CES} = 600V

$V_{CE(sat)} \leq 3.0V$

@V_{GE} = 15V, I_C = 20A

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher usable current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of high-voltage, high-current applications.



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	40	A
I_C @ T_C = 100°C	Continuous Collector Current	20	
I_{CM}	Pulsed Collector Current ①	160	
I_{LM}	Clamped Inductive Load Current ②	160	
V_{GE}	Gate-to-Emitter Voltage	±20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	—	0.77	°C/W
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	—	0.50	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	—	80	
Wt	Weight	—	2.0 (0.07)	—	g (oz)

Revision 0

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 250μA	
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	20	—	—	V	V_{GE} = 0V, I_C = 1.0A	
$\Delta V_{(BR)CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	—	0.63	—	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.2	3.0	V	I_C = 20A	V_{GE} = 15V
		—	2.7	—		I_C = 40A	See Fig. 2, 5
		—	2.3	—		I_C = 20A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	5.5		V_{CE} = V_{GE}, I_C = 250μA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-13	—	mV/°C	V_{CE} = V_{GE}, I_C = 250μA	
g_{fe}	Forward Transconductance ⑤	11	18	—	S	V_{CE} = 100V, I_C = 20A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	μA	V_{GE} = 0V, V_{CE} = 600V	
		—	—	1000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	51	67	nC	I_C = 20A
Q_{ge}	Gate - Emitter Charge (turn-on)	—	8.9	11		V_{CC} = 400V See Fig. 8
Q_{gc}	Gate - Collector Charge (turn-on)	—	20	33		V_{GE} = 15V
$t_{d(on)}$	Turn-On Delay Time	—	25	—	ns	T_J = 25°C
t_r	Rise Time	—	21	—		I_C = 20A, V_{CC} = 480V
$t_{d(off)}$	Turn-Off Delay Time	—	96	190		V_{GE} = 15V, R_G = 10Ω
t_f	Fall Time	—	43	120		Energy losses include "tail"
E_{on}	Turn-On Switching Loss	—	0.34	—	mJ	
E_{off}	Turn-Off Switching Loss	—	0.41	—		See Fig. 9, 10, 11, 14
E_{ts}	Total Switching Loss	—	0.75	1.6		
$t_{d(on)}$	Turn-On Delay Time	—	25	—	ns	T_J = 150°C,
t_r	Rise Time	—	23	—		I_C = 20A, V_{CC} = 480V
$t_{d(off)}$	Turn-Off Delay Time	—	174	—		V_{GE} = 15V, R_G = 10Ω
t_f	Fall Time	—	140	—		Energy losses include "tail"
E_{ts}	Total Switching Loss	—	1.4	—	mJ	See Fig. 10, 14
L_E	Internal Emitter Inductance	—	7.5	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	1500	—	pF	V_{GE} = 0V
C_{oes}	Output Capacitance	—	190	—		V_{CC} = 30V See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	17	—		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC}=80%(V_{CES}), V_{GE}=20V, L=10μH, R_G= 10Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

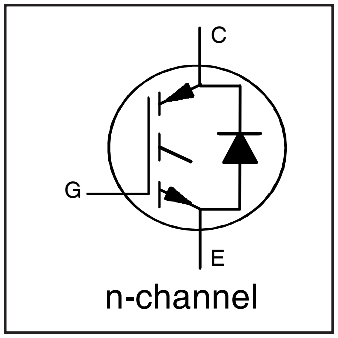
④ Pulse width ≤ 80μs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0μs, single shot.

PD - 97113

IRGB4064DPbF

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE



V_{CES} = 600V

I_C = 10A, T_C = 100°C

t_{sc} > 5µs, T_{jmax} = 175°C

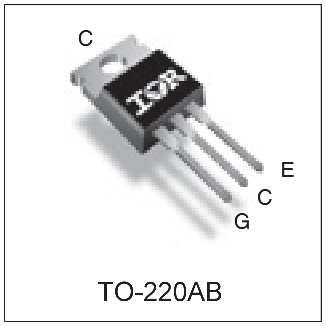
$V_{CE(on)\ typ.}$ = 1.6V

Features

- Low $V_{CE\ (on)}$ Trench IGBT Technology
- Low Switching Losses
- Maximum Junction temperature 175 °C
- 5µs SCSOA
- Square RBSOA
- 100% of The Parts Tested for I_{LM}
- Positive $V_{CE\ (on)}$ Temperature Coefficient.
- Ultra Fast Soft Recovery Co-pak Diode
- Tighter Distribution of Parameters
- Lead-Free Package

Benefits

- High Efficiency in a Wide Range of Applications
- Suitable for a Wide Range of Switching Frequencies due to Low $V_{CE\ (ON)}$ and Low Switching Losses
- Rugged Transient Performance for Increased Reliability
- Excellent Current Sharing in Parallel Operation
- Low EMI



TO-220AB

G	C	E
Gate	Collector	Emitter

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	600	V
I_C@ T_C = 25°C	Continuous Collector Current	20	A
I_C@ T_C = 100°C	Continuous Collector Current	10	
I_{CM}	Pulsed Collector Current	40	
I_{LM}	Clamped Inductive Load Current ①	40	
I_F@T_C=25°C	Diode Continuous Forward Current	20	
I_F@T_C=100°C	Diode Continuous Forward Current	10	
I_{FM}	Diode Maximum Forward Current ②	40	
V_{GE}	Continuous Gate-to-Emitter Voltage	±20	V
	Transient Gate-to-Emitter Voltage	±30	
P_D @ T_C =25°	Maximum Power Dissipation	101	W
P_D @ T_C =100°	Maximum Power Dissipation	50	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 175	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT ③	——	——	1.49	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode ③	——	——	3.66	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.50	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount ③	——	——	62	
Wt	Weight		1.44		g

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 100μA ④	CT6
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.47	—	V/°C	V_{GE} = 0V, I_C = 500μA (-55°C-175°C)	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	1.6	1.91	V	I_C = 10A, V_{GE} = 15V, T_J = 25°C	
		—	1.9	—		I_C = 10A, V_{GE} = 15V, T_J = 150°C	5,6,7,9,
		—	2.0	—		I_C = 10A, V_{GE} = 15V, T_J = 175°C	10 ,11
$V_{GE(th)}$	Gate Threshold Voltage	4.0	—	6.5	V	$V_{CE} = V_{GE}$, I_C = 275μA	9,10,11,12
$\Delta V_{GE(th)}/\Delta TJ$	Threshold Voltage temp. coefficient	—	-11	—	mV/°C	$V_{CE} = V_{GE}$, I_C = 1.0mA (25°C - 175°C)	
gfe	Forward Transconductance	—	6.9	—	S	V_{CE} = 50V, I_C = 10A, PW = 80μs	
I_{CES}	Collector-to-Emitter Leakage Current	—	—	25	μA	V_{GE} = 0V, V_{CE} = 600V	8
		—	328	—		V_{GE} = 0V, V_{CE} = 600V, T_J = 175°C	
V_{FM}	Diode Forward Voltage Drop	—	2.5	3.1	V	I_F = 10A	
		—	1.7	—		I_F = 10A, T_J = 175°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
Q_g	Total Gate Charge (turn-on)	—	21	32	nC	I_C = 10A	24
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	5.3	8.0		V_{GE} = 15V	CT1
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	8.9	13		V_{CC} = 400V	
E_{on}	Turn-On Switching Loss	—	29	71	μJ	I_C = 10A, V_{CC} = 400V, V_{GE} = 15V	CT4
E_{off}	Turn-Off Switching Loss	—	200	308		R_G = 22Ω, L = 1.0mH, T_J = 25°C	
E_{total}	Total Switching Loss	—	229	339		Energy losses include tail & diode reverse recovery	
$t_{d(on)}$	Turn-On delay time	—	27	37	ns	I_C = 10A, V_{CC} = 400V, V_{GE} = 15V	CT4
t_r	Rise time	—	15	23		R_G = 22Ω, L = 1.0mH, T_J = 25°C	
$t_{d(off)}$	Turn-Off delay time	—	79	90			
t_f	Fall time	—	21	30			
E_{on}	Turn-On Switching Loss	—	99	—	μJ	I_C = 10A, V_{CC} = 400V, V_{GE} = 15V	13,15
E_{off}	Turn-Off Switching Loss	—	316	—		R_G=22Ω, L=1.0mH, T_J = 175°C ④	CT4
E_{total}	Total Switching Loss	—	415	—		Energy losses include tail & diode reverse recovery	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	27	—	ns	I_C = 10A, V_{CC} = 400V, V_{GE} = 15V	14,16
t_r	Rise time	—	16	—		R_G = 22Ω, L = 1.0mH, T_J = 175°C	CT4
$t_{d(off)}$	Turn-Off delay time	—	98	—			WF1,WF2
t_f	Fall time	—	33	—			
C_{ies}	Input Capacitance	—	594	—	pF	V_{GE} = 0V	22
C_{oes}	Output Capacitance	—	49	—		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	17	—		f = 1.0Mhz	
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T_J = 175°C, I_C = 40A V_{CC} = 480V, Vp =600V Rg = 22Ω, V_{GE} = +15V to 0V	4 CT2
SCSOA	Short Circuit Safe Operating Area	5	—	—	μs	V_{CC} = 400V, Vp =600V Rg = 22Ω, V_{GE} = +15V to 0V	22, CT3 WF4
Erec	Reverse Recovery Energy of the Diode	—	191	—	μJ	T_J = 175°C	17,18,19
t_{rr}	Diode Reverse Recovery Time	—	62	—	ns	V_{CC} = 400V, I_F = 10A	20,21
I_{rr}	Peak Reverse Recovery Current	—	16	—	A	V_{GE} = 15V, Rg = 22Ω, L=1.0mH	WF3

Notes:

① V_{CC} = 80% (V_{CES}), V_{GE} = 15V, L = 28 μH, R_G = 22 Ω.

② Pulse width limited by max. junction temperature.

③ R_θ is measured at T_J approximately 90°C

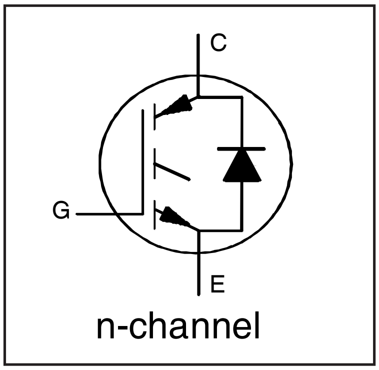
④ Refer to AN-1086 for guidelines for measuring $V_{(BR)CES}$ safely

International
IOR Rectifier

PD - 94613A

SMPS IGBT IRGB20B60PD1

WARP2 SERIES IGBT WITH ULTRAFAST SOFT RECOVERY DIODE



V_{CES} = 600V
$V_{CE(on)}$ typ. = 2.05V
@ V_{GE} = 15V I_C = 13.0A

Equivalent MOSFET Parameters ①
$R_{CE(on)}$ typ. = 158mΩ
I_D (FET equivalent) = 20A

Applications

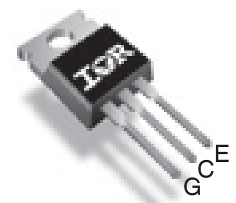
- Telecom and Server SMPS
- PFC and ZVS SMPS Circuits
- Uninterruptable Power Supplies
- Consumer Electronics Power Supplies

Features

- NPT Technology, Positive Temperature Coefficient
- Lower V_{CE}(SAT)
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability

Benefits

- Parallel Operation for Higher Current Applications
- Lower Conduction Losses and Switching Losses
- Higher Switching Frequency up to 150kHz



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	40	A
I_C @ T_C = 100°C	Continuous Collector Current	22	
I_{CM}	Pulse Collector Current (Ref. Fig. C.T.4)	80	
I_{LM}	Clamped Inductive Load Current ②	80	
I_F @ T_C = 25°C	Diode Continous Forward Current	10	
I_F @ T_C = 100°C	Diode Continous Forward Current	4	
I_{FRM}	Maximum Repetitive Forward Current ③	16	
V_{GE}	Gate-to-Emitter Voltage	±20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	215	W
P_D @ T_C = 100°C	Maximum Power Dissipation	86	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$ (IGBT)	Thermal Resistance Junction-to-Case-(each IGBT)	–––	–––	0.58	°C/W
$R_{\theta JC}$ (Diode)	Thermal Resistance Junction-to-Case-(each Diode)	–––	–––	5.0	
$R_{\theta CS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	–––	0.50	–––	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	–––	–––	80	
	Weight	–––	2 (0.07)	–––	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 500µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.32	—	V/°C	V_{GE} = 0V, I_C = 1mA (25°C-125°C)	
R_G	Internal Gate Resistance	—	4.3	—	Ω	1MHz, Open Collector	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.05	2.35	V	I_C = 13A, V_{GE} = 15V	4, 5,6,8,9
		—	2.50	2.80		I_C = 20A, V_{GE} = 15V	
		—	2.65	3.00		I_C = 13A, V_{GE} = 15V, T_J = 125°C	
		—	3.30	3.70		I_C = 20A, V_{GE} = 15V, T_J = 125°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	4.0	5.0	V	I_C = 250µA	7,8,9
$\Delta V_{GE(th)}/\Delta TJ$	Threshold Voltage temp. coefficient	—	-11	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA	
gfe	Forward Transconductance	—	19	—	S	V_{CE} = 50V, I_C = 40A, PW = 80µs	
I_{CES}	Collector-to-Emitter Leakage Current	—	1.0	250	µA	V_{GE} = 0V, V_{CE} = 600V	
		—	0.1	—	mA	V_{GE} = 0V, V_{CE} = 600V, T_J = 125°C	
V_{FM}	Diode Forward Voltage Drop	—	1.5	1.8	V	I_F = 4.0A, V_{GE} = 0V	10
		—	1.4	1.7		I_F = 4.0A, V_{GE} = 0V, T_J = 125°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V, V_{CE} = 0V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
Qg	Total Gate Charge (turn-on)	—	68	102	nC	I_C = 13A	17
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	24	36		V_{CC} = 400V	CT1
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	10	15		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	—	95	140	µJ	I_C = 13A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	100	145		V_{GE} = +15V, R_G = 10Ω, L = 200µH	
E_{total}	Total Switching Loss	—	195	285		T_J = 25°C ④	
$t_{d(on)}$	Turn-On delay time	—	20	26	ns	I_C = 13A, V_{CC} = 390V	CT3
t_r	Rise time	—	5.0	7.0		V_{GE} = +15V, R_G = 10Ω, L = 200µH	
$t_{d(off)}$	Turn-Off delay time	—	115	135		T_J = 25°C ④	
t_f	Fall time	—	6.0	8.0			
E_{on}	Turn-On Switching Loss	—	165	215	µJ	I_C = 13A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	150	195		V_{GE} = +15V, R_G = 10Ω, L = 200µH	11,13
E_{total}	Total Switching Loss	—	315	410		T_J = 125°C ④	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	19	25	ns	I_C = 13A, V_{CC} = 390V	CT3
t_r	Rise time	—	6.0	8.0		V_{GE} = +15V, R_G = 10Ω, L = 200µH	12,14
$t_{d(off)}$	Turn-Off delay time	—	125	140		T_J = 125°C ④	WF1,WF2
t_f	Fall time	—	13	17			
C_{ies}	Input Capacitance	—	1560	—	pF	V_{GE} = 0V	16
C_{oes}	Output Capacitance	—	95	—		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	20	—		f = 1Mhz	
C_{oes} eff.	Effective Output Capacitance (Time Related) ⑤	—	83	—		V_{GE} = 0V, V_{CE} = 0V to 480V	15
C_{oes} eff. (ER)	Effective Output Capacitance (Energy Related) ⑤	—	61	—			
RBSOA	Reverse Bias Safe Operating Area		FULL SQUARE			T_J = 150°C, I_C = 80A	3
						V_{CC} = 480V, Vp =600V	CT2
						Rg = 22Ω, V_{GE} = +15V to 0V	
t_{rr}	Diode Reverse Recovery Time	—	28	42	ns	T_J = 25°C I_F = 4.0A, V_R = 200V,	19
		—	38	57		T_J = 125°C di/dt = 200A/µs	
Q_{rr}	Diode Reverse Recovery Charge	—	40	60	nC	T_J = 25°C I_F = 4.0A, V_R = 200V,	21
		—	70	105		T_J = 125°C di/dt = 200A/µs	
I_{rr}	Peak Reverse Recovery Current	—	2.9	5.2	A	T_J = 25°C I_F = 4.0A, V_R = 200V,	19,20,21,22
		—	3.7	6.7		T_J = 125°C di/dt = 200A/µs	CT5

Notes:

① $R_{CE(on)}$ typ. = equivalent on-resistance = $V_{CE(on)}$ typ. / I_C, where $V_{CE(on)}$ typ. = 2.05V and I_C = 13A. I_D (FET Equivalent) is the equivalent MOSFET I_D rating @ 25°C for applications up to 150kHz. These are provided for comparison purposes (only) with equivalent MOSFET solutions.

② V_{CC} = 80% (V_{CES}), V_{GE} = 15V, L = 28µH, R_G = 22Ω.

③ Pulse width limited by max. junction temperature.

④ Energy losses include "tail" and diode reverse recovery. Data generated with use of Diode 8ETH06.

⑤ C_{oes} eff. is a fixed capacitance that gives the same charging time as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.
C_{oes} eff.(ER) is a fixed capacitance that stores the same energy as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.

International
IOR Rectifier

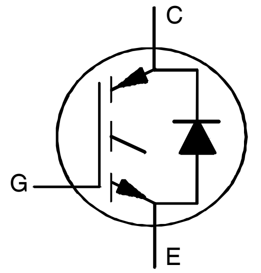
PD - 97455

IRG7PH35UD1PbF
IRG7PH35UD1-EP

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRA-LOW VF DIODE FOR INDUCTION HEATING AND SOFT SWITCHING APPLICATIONS

Features

- Low $V_{CE\ (ON)}$ trench IGBT Technology
- Low Switching Losses
- Square RBSOA
- Ultra-Low V_F Diode
- 1300Vpk Repetitive Transient Capacity
- 100% of the Parts Tested for I_{LM} ①
- Positive $V_{CE\ (ON)}$ Temperature Co-Efficient
- Tight Parameter Distribution
- Lead Free Package



n-channel

V_{CES} = 1200V

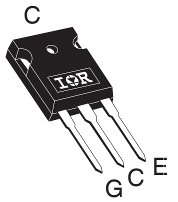
$I_{NOMINAL}$ = 20A

$T_{J(max)}$ = 150°C

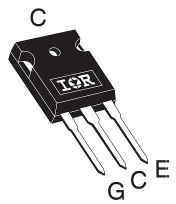
$V_{CE(on)}$ typ. = 1.9V

Benefits

- Device optimized for induction heating and soft switching applications
- High Efficiency due to Low $V_{CE(on)}$, low switching losses and Ultra-low V_F
- Rugged transient performance for increased reliability
- Excellent current sharing in parallel operation
- Low EMI



TO-247AC
IRG7PH35UD1PbF



TO-247AD
IRG7PH35UD1-EP

G	C	E
Gate	Collector	Emitter

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current	50	A
I_C @ T_C = 100°C	Continuous Collector Current	25	
$I_{NOMINAL}$	Nominal Current	20	
I_{CM}	Pulse Collector Current, V_{GE}=15V ④	60	
I_{LM}	Clamped Inductive Load Current, V_{GE}=20V ①	80	
I_F @ T_C = 25°C	Diode Continous Forward Current	50	
I_F @ T_C = 100°C	Diode Continous Forward Current	25	
I_{FM}	Diode Maximum Forward Current ②	80	
V_{GE}	Continuous Gate-to-Emitter Voltage	±30	V
P_D @ T_C = 25°C	Maximum Power Dissipation	179	W
P_D @ T_C = 100°C	Maximum Power Dissipation	71	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$ (IGBT)	Thermal Resistance Junction-to-Case-(each IGBT) ⑤	–––	–––	0.70	°C/W
$R_{\theta JC}$ (Diode)	Thermal Resistance Junction-to-Case-(each Diode) ⑤	–––	–––	1.35	
$R_{\theta CS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	–––	0.24	–––	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	–––	40	–––	

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	1200	—	—	V	V_{GE} = 0V, I_C = 100µA ③
$V_{(BR)Transient}$	Repetitive Transient Collector-to-Emitter Voltage	—	—	1300	V	V_{GE} = 0V, T_J = 75°C, PW ≤ 10µs ③
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	1.2	—	V/°C	V_{GE} = 0V, I_C = 1mA (25°C-150°C)
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	1.9	2.2	V	I_C = 20A, V_{GE} = 15V, T_J = 25°C
		—	2.3	—		I_C = 20A, V_{GE} = 15V, T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0	V	V_{CE} = V_{GE}, I_C = 600µA
gfe	Forward Transconductance	—	22	—	S	V_{CE} = 50V, I_C = 20A, PW = 30µs
I_{CES}	Collector-to-Emitter Leakage Current	—	1.0	100	µA	V_{GE} = 0V, V_{CE} = 1200V
		—	120	—		V_{GE} = 0V, V_{CE} = 1200V, T_J = 150°C
V_{FM}	Diode Forward Voltage Drop	—	1.15	1.26	V	I_F = 20A
		—	1.08	—		I_F = 20A, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±30V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	85	130	nC	I_C = 20A
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	15	20		V_{GE} = 15V
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	35	50		V_{CC} = 600V
E_{off}	Turn-Off Switching Loss	—	620	850	µJ	I_C = 20A, V_{CC} = 600V, V_{GE} = 15V R_G = 10Ω, L = 200µH,L_S = 150nH, T_J = 25°C Energy losses include tail
$t_{d(off)}$	Turn-Off delay time	—	160	180	ns	I_C = 20A, V_{CC} = 600V, V_{GE} = 15V
t_f	Fall time	—	80	105		R_G = 10Ω, L = 200µH,L_S = 150nH, T_J = 25°C
E_{off}	Turn-Off Switching Loss	—	1120	—	µJ	I_C = 20A, V_{CC} = 600V, V_{GE}=15V R_G = 10Ω, L = 200µH,L_S = 150nH, T_J = 150°C Energy losses include tail
$t_{d(off)}$	Turn-Off delay time	—	190	—	ns	I_C = 20A, V_{CC} = 600V, V_{GE} = 15V
t_f	Fall time	—	210	—		R_G = 10Ω, L = 200µH,L_S = 150nH, T_J = 150°C
C_{ies}	Input Capacitance	—	1940	—	pF	V_{GE} = 0V
C_{oes}	Output Capacitance	—	120	—		V_{CC} = 30V
C_{res}	Reverse Transfer Capacitance	—	40	—		f = 1.0Mhz
RBSOA	Reverse Bias Safe Operating Area		FULL SQUARE			T_J = 150°C, I_C = 80A V_{CC} = 960V, Vp =1200V Rg = 10Ω, V_{GE} = +20V to 0V

Notes:

① V_{CC} = 80% (V_{CES}), V_{GE} = 20V, R_G = 10Ω.
② Pulse width limited by max. junction temperature.
③ Refer to AN-1086 for guidelines for measuring $V_{(BR)CES}$ safely.
④ Rating for Hard Switching conditions. Rating is higher in Soft Switching conditions.
⑤ R_θ is measured at T_J approximately 90°C.

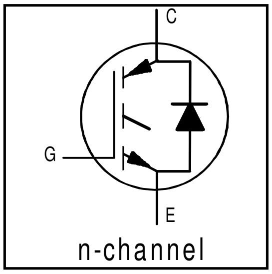
International
IOR Rectifier

PD - 91682A

IRG4PSC71UD

UltraFast CoPack IGBT

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE



V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.67V

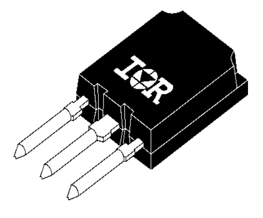
@V_{GE} = 15V, I_C = 60A

Features

- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency (minimum switching and conduction losses) than prior generations
- IGBT co-packaged with HEXFRED ultrafast, ultrasoft recovery anti-parallel diodes for use in bridge configurations
- Industry-benchmark Super-247 package with higher power handling capability compared to same footprint TO-247
- Creepage distance increased to 5.35mm

Benefits

- Generation 4 IGBT's offer highest efficiencies available
- Maximum power density, twice the power handling of TO-247, less space than TO-264
- IGBTs optimized for specific application conditions
- HEXFRED diodes optimized for performance with IGBTs
- Cost and space saving in designs that require multiple, paralleled IGBTs



SUPER - 247

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	85⑤	A
I_C @ T_C = 100°C	Continuous Collector Current	60	
I_{CM}	Pulsed Collector Current ①	200	
I_{LM}	Clamped Inductive Load Current ②	200	
I_F @ T_C = 100°C	Diode Continuous Forward Current	60	
I_{FM}	Diode Maximum Forward Current	350	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	350	W
P_D @ T_C = 100°C	Maximum Power Dissipation	140	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	

Thermal Resistance\ Mechanical

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	——	——	0.36	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	——	——	0.69	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	——	38	
	Recommended Clip Force	20.0(2.0)	——	——	N (kgf)
	Weight	——	6 (0.21)	——	g (oz)

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Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	600	—	—	V	$V_{GE} = 0V$, $I_C = 250\mu A$	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.39	—	V/°C	$V_{GE} = 0V$, $I_C = 10mA$	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	1.67	2.0	V	$I_C = 60A$	$V_{GE} = 15V$
		—	1.95	—		$I_C = 100A$	See Fig. 2, 5
		—	1.71	—		$I_C = 60A$, $T_J = 150°C$	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		$V_{CE} = V_{GE}$, $I_C = 250\mu A$	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-13	—	mV/°C	$V_{CE} = V_{GE}$, $I_C = 1.5mA$	
g_{fe}	Forward Transconductance ④	47	70	—	S	$V_{CE} = 50V$, $I_C = 60A$	
I_{CES}	Zero Gate Voltage Collector Current	—	—	500	µA	$V_{GE} = 0V$, $V_{CE} = 600V$	
		—	—	13	mA	$V_{GE} = 0V$, $V_{CE} = 600V$, $T_J = 150°C$	
V_{FM}	Diode Forward Voltage Drop	—	1.4	1.7	V	$I_C = 60A$	See Fig. 13
		—	1.3	—		$I_C = 60A$, $T_J = 150°C$	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	$V_{GE} = \pm 20V$	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	—	340	520	nC	$I_C = 60A$	
Qge	Gate - Emitter Charge (turn-on)	—	44	66		$V_{CC} = 400V$ See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	—	160	240		$V_{GE} = 15V$	
$t_{d(on)}$	Turn-On Delay Time	—	90	—	ns	$T_J = 25°C$	
t_r	Rise Time	—	94	—		$I_C = 60A$, $V_{CC} = 480V$	
$t_{d(off)}$	Turn-Off Delay Time	—	245	368		$V_{GE} = 15V$, $R_G = 5.0\Omega$	
t_f	Fall Time	—	110	167		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	—	3.26	—	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	—	2.27	—		See Fig. 9, 10, 11, 18	
E_{ts}	Total Switching Loss	—	5.53	7.2			
$t_{d(on)}$	Turn-On Delay Time	—	91	—	ns	$T_J = 150°C$, See Fig. 9, 10, 11, 18	
t_r	Rise Time	—	88	—		$I_C = 60A$, $V_{CC} = 480V$	
$t_{d(off)}$	Turn-Off Delay Time	—	353	—		$V_{GE} = 15V$, $R_G = 5.0\Omega$	
t_f	Fall Time	—	150	—		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	—	7.1	—	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	—	7500	—	pF	$V_{GE} = 0V$	
C_{oes}	Output Capacitance	—	720	—		$V_{CC} = 30V$ See Fig. 7	
C_{res}	Reverse Transfer Capacitance	—	93	—		$f = 1.0MHz$	
t_{rr}	Diode Reverse Recovery Time	—	82	120	ns	$T_J = 25°C$ See Fig.	
		—	140	210		$T_J = 125°C$ 14	$I_F = 60A$
I_{rr}	Diode Peak Reverse Recovery Current	—	8.2	12	A	$T_J = 25°C$ See Fig.	
		—	13	20		$T_J = 125°C$ 15	$V_R = 200V$
Q_{rr}	Diode Reverse Recovery Charge	—	364	546	nC	$T_J = 25°C$ See Fig.	
		—	1084	1625		$T_J = 125°C$ 16	$di/dt = 200A/\mu s$
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	—	328	—	A/µs	$T_J = 25°C$ See Fig.	
During t_b		—	266	—		$T_J = 125°C$ 17	

PD - 91681A

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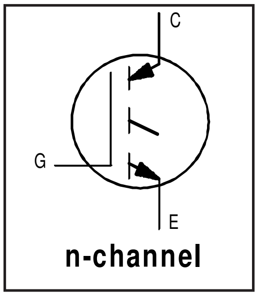
IRG4PSC71U

INSULATED GATE BIPOLAR TRANSISTOR

UltraFast Speed IGBT

Features

- UltraFast switching speed optimized for operating frequencies 8 to 40kHz in hard switching, 200kHz in resonant mode soft switching
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency (minimum switching and conduction losses) than prior generations
- Industry-benchmark Super-247 package with higher power handling capability compared to same footprint TO-247
- Creepage distance increased to 5.35mm



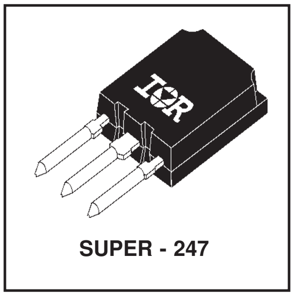
V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.67V

@V_{GE} = 15V, I_C = 60A

Benefits

- Generation 4 IGBT's offer highest efficiencies available
- Maximum power density, twice the power handling of the TO-247, less space than TO-264
- IGBTs optimized for specific application conditions
- Cost and space saving in designs that require multiple, paralleled IGBTs


SUPER - 247

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	85⑥	A
I_C @ T_C = 100°C	Continuous Collector Current	60	
I_{CM}	Pulsed Collector Current ①	200	
I_{LM}	Clamped Inductive Load Current ②	200	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	180	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	350	W
P_D @ T_C = 100°C	Maximum Power Dissipation	140	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm from case)	

Thermal Resistance\ Mechanical

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	——	0.36	°C/W
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	——	38	
	Recommended Clip Force	20.0(2.0)	——	——	N (kgf)
	Weight	——	6 (0.21)	——	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 250µA	
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	18	—	—	V	V_{GE} = 0V, I_C = 1.0A	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.45	—	V/°C	V_{GE} = 0V, I_C = 5.0mA	
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	1.67	2.0	V	I_C = 60A	V_{GE} = 15V
		—	1.95	—		I_C = 100A	See Fig.2, 5
		—	1.71	—		I_C = 60A , T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-10	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA	
g_{fe}	Forward Transconductance ⑤	47	70	—	S	V_{CE} = 50V, I_C = 60A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	500	µA	V_{GE} = 0V, V_{CE} = 600V	
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C	
		—	—	5.0	mA	V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	340	520	nC	I_C = 60A
Q_{ge}	Gate - Emitter Charge (turn-on)	—	44	66		V_{CC} = 400V See Fig. 8
Q_{gc}	Gate - Collector Charge (turn-on)	—	160	240		V_{GE} = 15V
$t_{d(on)}$	Turn-On Delay Time	—	34	—	ns	
t_r	Rise Time	—	50	—		T_J = 25°C
$t_{d(off)}$	Turn-Off Delay Time	—	56	84		I_C = 60A, V_{CC} = 480V
t_f	Fall Time	—	86	130		V_{GE} = 15V, R_G = 5.0Ω
E_{on}	Turn-On Switching Loss	—	0.42	—	mJ	Energy losses include "tail"
E_{off}	Turn-Off Switching Loss	—	1.99	—		See Fig. 10, 11, 13, 14
E_{ts}	Total Switching Loss	—	2.41	3.2		
$t_{d(on)}$	Turn-On Delay Time	—	30	—	ns	T_J = 150°C,
t_r	Rise Time	—	49	—		I_C = 60A, V_{CC} = 480V
$t_{d(off)}$	Turn-Off Delay Time	—	129	—		V_{GE} = 15V, R_G = 5.0Ω
t_f	Fall Time	—	175	—		Energy losses include "tail"
E_{ts}	Total Switching Loss	—	4.5	—	mJ	See Fig. 13, 14
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	7500	—	pF	V_{GE} = 0V
C_{oes}	Output Capacitance	—	720	—		V_{CC} = 30V See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	93	—		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE} = 20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC} = 80%(V_{CES}), V_{GE} = 20V, L = 10µH, R_G = 5.0Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0µs, single shot.

⑥ Current limited by the package, (Die current = 100A)

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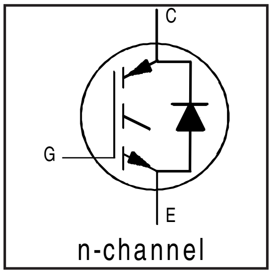
PD 91573A

IRG4PH50UD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

UltraFast CoPack IGBT



$V_{CES} = 1200V$

$V_{CE(on)\ typ.} = 2.78V$

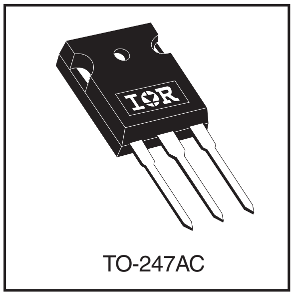
$@V_{GE} = 15V, I_C = 24A$

Features

- UltraFast: Optimized for high operating frequencies up to 40 kHz in hard switching, >200 kHz in resonant mode
- New IGBT design provides tighter parameter distribution and higher efficiency than previous generations
- IGBT co-packaged with HEXFRED^{TM} ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package

Benefits

- Higher switching frequency capability than competitive IGBTs
- Highest efficiency available
- HEXFRED diodes optimized for performance with IGBT's . Minimized recovery characteristics require less/no snubbing



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current	45	A
I_C @ T_C = 100°C	Continuous Collector Current	24	
I_{CM}	Pulsed Collector Current ①	180	
I_{LM}	Clamped Inductive Load Current ②	180	
I_F @ T_C = 100°C	Diode Continuous Forward Current	16	
I_{FM}	Diode Maximum Forward Current	180	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	——	——	0.64	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	——	——	0.83	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	——	40	
Wt	Weight	——	6 (0.21)	——	g (oz)

7/7/2000

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	1200	—	—	V	V_{GE} = 0V, I_C = 250µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	1.20	—	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.56	3.5	V	I_C = 20A	V_{GE} = 15V
		—	2.78	3.7		I_C = 24A	
		—	3.20	—		I_C = 45A	See Fig. 2, 5
		—	2.54	—		I_C = 24A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-13	—	mV/°C	V_{CE} = V_{GE}, I_C = 250µA	
g_{fe}	Forward Transconductance ④	23	35	—	S	V_{CE} = 100V, I_C = 24A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 1200V	
		—	—	6500		V_{GE} = 0V, V_{CE} = 1200V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	2.5	3.5	V	I_C = 16A	See Fig. 13
		—	2.1	3.0		I_C = 16A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q_g	Total Gate Charge (turn-on)	—	160	250	nC	I_C = 24A		
Qge	Gate - Emitter Charge (turn-on)	—	27	40		V_{CC} = 400V	See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	—	53	80		V_{GE} = 15V		
$t_{d(on)}$	Turn-On Delay Time	—	47	—	ns	T_J = 25°C		
t_r	Rise Time	—	24	—		I_C = 24A, V_{CC} = 800V		
$t_{d(off)}$	Turn-Off Delay Time	—	110	170		V_{GE} = 15V, R_G = 5.0Ω		
t_f	Fall Time	—	180	260		Energy losses include "tail" and		
E_{on}	Turn-On Switching Loss	—	2.10	—	mJ	diode reverse recovery.		
E_{off}	Turn-Off Switching Loss	—	1.50	—		See Fig. 9, 10, 18		
E_{ts}	Total Switching Loss	—	3.60	4.6				
$t_{d(on)}$	Turn-On Delay Time	—	46	—	ns	T_J = 150°C,	See Fig. 11, 18	
t_r	Rise Time	—	27	—		I_C = 24A, V_{CC} = 800V		
$t_{d(off)}$	Turn-Off Delay Time	—	240	—		V_{GE} = 15V, R_G = 5.0Ω		
t_f	Fall Time	—	330	—		Energy losses include "tail" and		
E_{ts}	Total Switching Loss	—	6.38	—	mJ	diode reverse recovery.		
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package		
C_{ies}	Input Capacitance	—	3600	—	pF	V_{GE} = 0V		
C_{oes}	Output Capacitance	—	160	—		V_{CC} = 30V	See Fig. 7	
C_{res}	Reverse Transfer Capacitance	—	31	—		ƒ = 1.0MHz		
t_{rr}	Diode Reverse Recovery Time	—	90	135	ns	T_J = 25°C	See Fig.	
		—	164	245		T_J = 125°C	14	I_F = 16A
I_{rr}	Diode Peak Reverse Recovery Current	—	5.8	10	A	T_J = 25°C	See Fig.	
		—	8.3	15		T_J = 125°C	15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	260	675	nC	T_J = 25°C	See Fig.	
		—	680	1838		T_J = 125°C	16	di/dt = 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	—	120	—	A/µs	T_J = 25°C	See Fig.	
	During t_b	—	76	—		T_J = 125°C	17	

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PD - 91574B

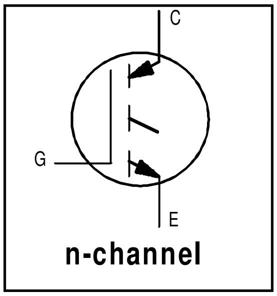
IRG4PH50U

INSULATED GATE BIPOLAR TRANSISTOR

Ultra Fast Speed IGBT

Features

- UltraFast: Optimized for high operating frequencies up to 40 kHz in hard switching, >200 kHz in resonant mode
- New IGBT design provides tighter parameter distribution and higher efficiency than previous generations
- Optimized for power conversion; SMPS, UPS and welding
- Industry standard TO-247AC package



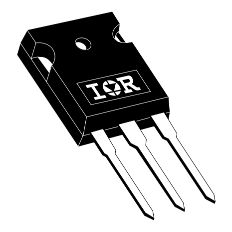
$V_{CES} = 1200V$

$V_{CE(on)\ typ.} = 2.78V$

$@V_{GE} = 15V, I_C = 24A$

Benefits

- Higher switching frequency capability than competitive IGBTs
- Highest efficiency available
- Much lower conduction losses than MOSFETs
- More efficient than short circuit rated IGBTs



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current	45	A
I_C @ T_C = 100°C	Continuous Collector Current	24	
I_{CM}	Pulsed Collector Current ①	180	
I_{LM}	Clamped Inductive Load Current ②	180	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	170	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	0.64	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.24	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	40	
Wt	Weight	6 (0.21)	—	g (oz)

01/14/02

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	1200	—	—	V	V_{GE} = 0V, I_C = 250µA
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	18	—	—	V	V_{GE} = 0V, I_C = 1.0A
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	1.20	—	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	2.56	3.5	V	I_C = 20A V_{GE} = 15V See Fig.2, 5
		—	2.78	3.7		I_C = 24A
		—	3.20	—		I_C = 45A
		—	2.54	—		I_C = 24A , T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		$V_{CE} = V_{GE}$, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-13	—	mV/°C	$V_{CE} = V_{GE}$, I_C = 250µA
g_{fe}	Forward Transconductance ⑤	23	35	—	S	V_{CE} = 100V, I_C = 24A
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 1200V
		—	—	2.0		V_{GE} = 0V, V_{CE} = 24V, T_J = 25°C
		—	—	5000		V_{GE} = 0V, V_{CE} = 1200V, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	160	250	nC	I_C = 24A V_{CC} = 400V See Fig. 8 V_{GE} = 15V
Q_{ge}	Gate - Emitter Charge (turn-on)	—	27	40		
Q_{gc}	Gate - Collector Charge (turn-on)	—	53	83		
$t_{d(on)}$	Turn-On Delay Time	—	35	—	ns	T_J = 25°C I_C = 24A, V_{CC} = 960V V_{GE} = 15V, R_G = 5.0Ω Energy losses include "tail" See Fig. 9, 10, 14
t_r	Rise Time	—	15	—		
$t_{d(off)}$	Turn-Off Delay Time	—	200	350		
t_f	Fall Time	—	290	500		
E_{on}	Turn-On Switching Loss	—	0.53	—	mJ	
E_{off}	Turn-Off Switching Loss	—	1.41	—		
E_{ts}	Total Switching Loss	—	1.94	2.6		
$t_{d(on)}$	Turn-On Delay Time	—	31	—	ns	T_J = 150°C I_C = 24A, V_{CC} = 960V V_{GE} = 15V, R_G = 5.0Ω Energy losses include "tail" See Fig. 11, 14
t_r	Rise Time	—	18	—		
$t_{d(off)}$	Turn-Off Delay Time	—	320	—		
t_f	Fall Time	—	280	—		
E_{ts}	Total Switching Loss	—	5.40	—	mJ	
E_{on}	Turn-On Switching Loss	—	0.35	—	mJ	T_J = 25°C, V_{GE} = 15V, R_G = 5.0Ω I_C = 20A, V_{CC} = 960V Energy losses include "tail"
E_{off}	Turn-Off Switching Loss	—	1.43	—		
E_{ts}	Total Switching Loss	—	1.78	2.9		
		—	4.56	—		See Fig. 9, 10, 11, 14, T_J = 150°C
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	3600	—	pF	V_{GE} = 0V V_{CC} = 30V See Fig. 7 f = 1.0MHz
C_{oes}	Output Capacitance	—	160	—		
C_{res}	Reverse Transfer Capacitance	—	31	—		

Notes:

① Repetitive rating; V_{GE} = 20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC} = 80%(V_{CES}), V_{GE} = 20V, L = 10µH, R_G = 5.0Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0µs, single shot.

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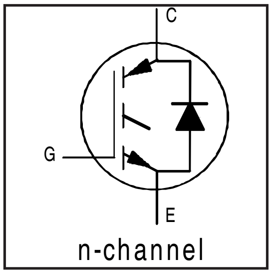
IRG4PH50KDPbF

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Short Circuit Rated
UltraFast IGBT

Features

- High short circuit rating optimized for motor control, t_{sc} =10µs, V_{CC} = 720V , T_J = 125°C, V_{GE} = 15V
- Combines low conduction losses with high switching speed
- Tighter parameter distribution and higher efficiency than previous generations
- IGBT co-packaged with HEXFRED™ ultrafast, ultrasoft recovery antiparallel diodes
- Lead-Free



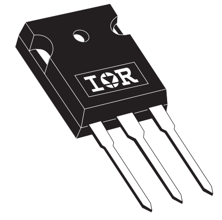
V_{CES} = 1200V

$V_{CE(on)\ typ.}$ = 2.77V

@V_{GE} = 15V, I_C = 24A

Benefits

- Latest generation 4 IGBT's offer highest power density motor controls possible
- HEXFRED™ diodes optimized for performance with IGBTs. Minimized recovery characteristics reduce noise, EMI and switching losses
- This part replaces the IRGPH50KD2 and IRGPH50MD2 products
- For hints see design tip 97003



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current	45	A
I_C @ T_C = 100°C	Continuous Collector Current	24	
I_{CM}	Pulsed Collector Current ①	90	
I_{LM}	Clamped Inductive Load Current ②	90	
I_F @ T_C = 100°C	Diode Continuous Forward Current	16	
I_{FM}	Diode Maximum Forward Current	90	
t_{sc}	Short Circuit Withstand Time	10	µs
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	–––	–––	0.64	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	–––	–––	0.83	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	–––	0.24	–––	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	–––	–––	40	
Wt	Weight	–––	6 (0.21)	–––	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	1200	—	—	V	V_{GE} = 0V, I_C = 250µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.91	—	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.77	3.5	V	I_C = 24A	V_{GE} = 15V
		—	3.28	—		I_C = 45A	See Fig. 2, 5
		—	2.54	—		I_C = 24A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-10	—	mV/°C	V_{CE} = V_{GE}, I_C = 250µA	
g_{fe}	Forward Transconductance ④	13	19	—	S	V_{CE} = 100V, I_C = 24A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 1200V	
		—	—	6500		V_{GE} = 0V, V_{CE} = 1200V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	2.5	3.5	V	I_C = 16A	See Fig. 13
		—	2.1	3.0		I_C = 16A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q_g	Total Gate Charge (turn-on)	—	180	270	nC	I_C = 24A		
Q_{ge}	Gate - Emitter Charge (turn-on)	—	25	38		V_{CC} = 400V	See Fig.8	
Q_{gc}	Gate - Collector Charge (turn-on)	—	70	110		V_{GE} = 15V		
$t_{d(on)}$	Turn-On Delay Time	—	87	—	ns			
t_r	Rise Time	—	100	—		T_J = 25°C		
$t_{d(off)}$	Turn-Off Delay Time	—	140	300		I_C = 24A, V_{CC} = 800V		
t_f	Fall Time	—	200	300		V_{GE} = 15V, R_G = 5.0Ω		
E_{on}	Turn-On Switching Loss	—	3.83	—	mJ	Energy losses include "tail"		
E_{off}	Turn-Off Switching Loss	—	1.90	—		and diode reverse recovery		
E_{ts}	Total Switching Loss	—	5.73	7.9		See Fig. 9,10,18		
t_{sc}	Short Circuit Withstand Time	10	—	—	µs	V_{CC} = 720V, T_J = 125°C V_{GE} = 15V, R_G = 5.0Ω		
$t_{d(on)}$	Turn-On Delay Time	—	67	—	ns	T_J = 150°C,	See Fig. 10,11,18	
t_r	Rise Time	—	72	—		I_C = 24A, V_{CC} = 800V		
$t_{d(off)}$	Turn-Off Delay Time	—	310	—		V_{GE} = 15V, R_G = 5.0Ω,		
t_f	Fall Time	—	390	—		Energy losses include "tail"		
E_{ts}	Total Switching Loss	—	8.36	—	mJ	and diode reverse recovery		
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package		
C_{ies}	Input Capacitance	—	2800	—	pF	V_{GE} = 0V		
C_{oes}	Output Capacitance	—	140	—		V_{CC} = 30V	See Fig. 7	
C_{res}	Reverse Transfer Capacitance	—	53	—		ƒ = 1.0MHz		
t_{rr}	Diode Reverse Recovery Time	—	90	135	ns	T_J = 25°C	See Fig.	
		—	164	245		T_J = 125°C	14	I_F = 16A
I_{rr}	Diode Peak Reverse Recovery Current	—	5.8	10	A	T_J = 25°C	See Fig.	
		—	8.3	15		T_J = 125°C	15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	260	675	nC	T_J = 25°C	See Fig.	
		—	680	1838		T_J = 125°C	16	di/dt = 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	—	120	—	A/µs	T_J = 25°C	See Fig.	
	During t_b	—	76	—		T_J = 125°C	17	

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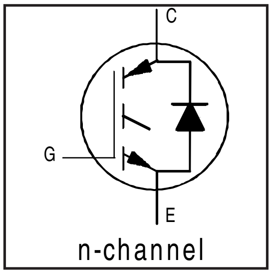
PD- 91621B

IRG4PH40UD

UltraFast CoPack IGBT

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE



V_{CES} = 1200V

$V_{CE(on)\ typ.}$ = 2.43V

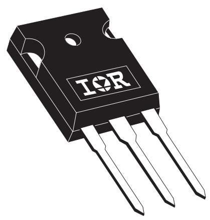
@V_{GE} = 15V, I_C = 21A

Features

- UltraFast: Optimized for high operating frequencies up to 40 kHz in hard switching, >200 kHz in resonant mode
- New IGBT design provides tighter parameter distribution and higher efficiency than previous generations
- IGBT co-packaged with HEXFRED^{TM} ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package

Benefits

- Higher switching frequency capability than competitive IGBTs
- Highest efficiency available
- HEXFRED diodes optimized for performance with IGBT's . Minimized recovery characteristics require less/no snubbing


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current	41	A
I_C @ T_C = 100°C	Continuous Collector Current	21	
I_{CM}	Pulsed Collector Current ①	82	
I_{LM}	Clamped Inductive Load Current ②	82	
I_F @ T_C = 100°C	Diode Continuous Forward Current	8.0	
I_{FM}	Diode Maximum Forward Current	130	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	——	——	0.77	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	——	——	1.7	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	——	40	
Wt	Weight	——	6 (0.21)	——	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	1200	—	—	V	V_{GE} = 0V, I_C = 250μA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.43	—	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.43	3.1	V	I_C = 21A	V_{GE} = 15V
		—	2.97	—		I_C = 41A	See Fig. 2, 5
		—	2.47	—		I_C = 21A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250μA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-11	—	mV/°C	V_{CE} = V_{GE}, I_C = 250μA	
g_{fe}	Forward Transconductance ④	16	24	—	S	V_{CE} = 100V, I_C = 21A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	μA	V_{GE} = 0V, V_{CE} = 600V	
		—	—	5000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	2.6	3.3	V	I_C = 8.0A	See Fig. 13
		—	2.4	3.1		I_C = 8.0A, T_J = 125°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	—	86	130	nC	I_C = 21A	
Qge	Gate - Emitter Charge (turn-on)	—	13	20		V_{CC} = 400V	See Fig. 8
Q_{gc}	Gate - Collector Charge (turn-on)	—	29	44		V_{GE} = 15V	
$t_{d(on)}$	Turn-On Delay Time	—	46	—	ns	T_J = 25°C	
t_r	Rise Time	—	35	—		I_C = 21A, V_{CC} = 800V	
$t_{d(off)}$	Turn-Off Delay Time	—	97	150		V_{GE} = 15V, R_G = 10Ω	
t_f	Fall Time	—	240	360		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	—	1.80	—	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	—	1.93	—		See Fig. 9, 10, 18	
E_{ts}	Total Switching Loss	—	3.73	4.6			
$t_{d(on)}$	Turn-On Delay Time	—	42	—	ns	T_J = 150°C,	See Fig. 11, 18
t_r	Rise Time	—	32	—		I_C = 21A, V_{CC} = 800V	
$t_{d(off)}$	Turn-Off Delay Time	—	240	—		V_{GE} = 15V, R_G = 10Ω	
t_f	Fall Time	—	510	—		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	—	7.04	—	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	—	1800	—	pF	V_{GE} = 0V	
C_{oes}	Output Capacitance	—	120	—		V_{CC} = 30V	See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	18	—		f = 1.0MHz	
t_{rr}	Diode Reverse Recovery Time	—	63	95	ns	T_J = 25°C See Fig.	
		—	106	160		T_J = 125°C 14	I_F = 8.0A
I_{rr}	Diode Peak Reverse Recovery Current	—	4.5	8.0	A	T_J = 25°C See Fig.	
		—	6.2	11		T_J = 125°C 15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	140	380	nC	T_J = 25°C See Fig.	
		—	335	880		T_J = 125°C 16	di/dt = 200A/μs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery During t_b	—	133	—	A/μs	T_J = 25°C See Fig.	
		—	85	—		T_J = 125°C 17	

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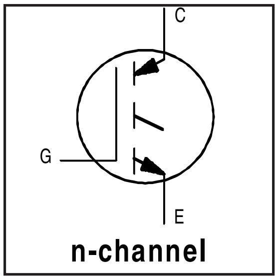
INSULATED GATE BIPOLAR TRANSISTOR

IRG4PH40K

Short Circuit Rated
UltraFast IGBT

Features

- High short circuit rating optimized for motor control, t_{sc} =10µs, V_{CC} = 720V , T_J = 125°C, V_{GE} = 15V
- Combines low conduction losses with high switching speed
- Latest generation design provides tighter parameter distribution and higher efficiency than previous generations



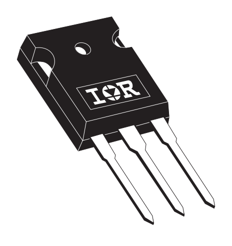
V_{CES} = 1200V

$V_{CE(on)\ typ.}$ = 2.74V

@V_{GE} = 15V, I_C = 15A

Benefits

- As a Freewheeling Diode we recommend our HEXFRED^{TM} ultrafast, ultrasoft recovery diodes for minimum EMI / Noise and switching losses in the Diode and IGBT
- Latest generation 4 IGBT's offer highest power density motor controls possible
- This part replaces the IRGPH40K and IRGPH40M devices



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current	30	A
I_C @ T_C = 100°C	Continuous Collector Current	15	
I_{CM}	Pulsed Collector Current ①	60	
I_{LM}	Clamped Inductive Load Current ②	60	
t_{sc}	Short Circuit Withstand Time	10	µs
V_{GE}	Gate-to-Emitter Voltage	±20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	180	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	0.77	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	40	
Wt	Weight	6 (0.21)	——	g (oz)

2/7/2000

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	1200	—	—	V	V_{GE} = 0V, I_C = 250µA	
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	18	—	—	V	V_{GE} = 0V, I_C = 1.0A	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.37	—	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	2.54	—	V	I_C = 10A	V_{GE} = 15V See Fig.2, 5
		—	2.74	3.4		I_C = 15A	
		—	3.29	—		I_C = 30A	
		—	2.53	—		I_C = 15A , T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-3.3	—	mV/°C	V_{CE} = V_{GE}, I_C = 250µA	
g_{fe}	Forward Transconductance ⑤	8.0	12	—	S	V_{CE} = 100 V, I_C = 15A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 1200V	
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C	
		—	—	3000		V_{GE} = 0V, V_{CE} = 1200V, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	94	140	nC	I_C = 15A
Q_{ge}	Gate - Emitter Charge (turn-on)	—	14	22		V_{CC} = 400V See Fig.8
Q_{gc}	Gate - Collector Charge (turn-on)	—	37	55		V_{GE} = 15V
$t_{d(on)}$	Turn-On Delay Time	—	30	—	ns	
t_r	Rise Time	—	22	—		T_J = 25°C
$t_{d(off)}$	Turn-Off Delay Time	—	200	300		I_C = 15A, V_{CC} = 960V
t_f	Fall Time	—	150	230		V_{GE} = 15V, R_G = 10Ω
E_{on}	Turn-On Switching Loss	—	0.73	—	mJ	Energy losses include "tail"
E_{off}	Turn-Off Switching Loss	—	1.66	—		See Fig. 9,10,14
E_{ts}	Total Switching Loss	—	2.39	2.9		
t_{sc}	Short Circuit Withstand Time	10	—	—	µs	V_{CC} = 720V, T_J = 125°C V_{GE} = 15V, R_G = 10Ω
$t_{d(on)}$	Turn-On Delay Time	—	29	—	ns	T_J = 150°C,
t_r	Rise Time	—	24	—		I_C = 15A, V_{CC} = 960V
$t_{d(off)}$	Turn-Off Delay Time	—	870	—		V_{GE} = 15V, R_G = 10Ω
t_f	Fall Time	—	330	—		Energy losses include "tail"
E_{ts}	Total Switching Loss	—	4.93	—	mJ	See Fig. 10,11,14
E_{on}	Turn-On Switching Loss	—	0.37	—	mJ	T_J = 25°C, V_{GE} = 15V, R_G = 10Ω
E_{off}	Turn-Off Switching Loss	—	0.89	—		I_C = 10A, V_{CC} = 960V
E_{ts}	Total Switching Loss	—	1.26	—		Energy losses include "tail"
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	1600	—	pF	V_{GE} = 0V
C_{oes}	Output Capacitance	—	77	—		V_{CC} = 30V See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	26	—		f = 1.0MHz

Details of note ① through ⑤ are on the last page

PD- 91777

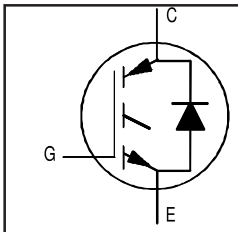
IRG4PH20KD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Short Circuit Rated
UltraFast IGBT

Features

- High short circuit rating optimized for motor control, t_{sc} =10µs, V_{CC} = 720V , T_J = 125°C, V_{GE} = 15V
- Combines low conduction losses with high switching speed
- Tighter parameter distribution and higher efficiency than previous generations
- IGBT co-packaged with HEXFRED^{TM} ultrafast, ultrasoft recovery antiparallel diodes



n-channel

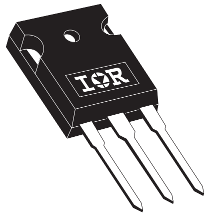
V_{CES} = 1200V

$V_{CE(on)\ typ.}$ = 3.17V

@V_{GE} = 15V, I_C = 5.0A

Benefits

- Latest generation 4 IGBT's offer highest power density motor controls possible
- HEXFRED^{TM} diodes optimized for performance with IGBTs. Minimized recovery characteristics reduce noise, EMI and switching losses



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current	11	A
I_C @ T_C = 100°C	Continuous Collector Current	5.0	
I_{CM}	Pulsed Collector Current ①	22	
I_{LM}	Clamped Inductive Load Current ②	22	
I_F @ T_C = 100°C	Diode Continuous Forward Current	5.0	
I_{FM}	Diode Maximum Forward Current	22	
t_{sc}	Short Circuit Withstand Time	10	µs
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	60	W
P_D @ T_C = 100°C	Maximum Power Dissipation	24	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	—	—	2.1	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	—	—	3.5	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	—	0.24	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	—	40	
Wt	Weight	—	6 (0.21)	—	g (oz)

6/25/98

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	1200	—	—	V	V_{GE} = 0V, I_C = 250µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	1.13	—	V/°C	V_{GE} = 0V, I_C = 2.5mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	3.17	4.3	V	I_C = 5.0A	V_{GE} = 15V
		—	4.04	—		I_C = 11A	See Fig. 2, 5
		—	2.84	—		I_C = 5.0A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.5	—	6.5		V_{CE} = V_{GE}, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-10	—	mV/°C	V_{CE} = V_{GE}, I_C = 1mA	
g_{fe}	Forward Transconductance ④	2.3	3.5	—	S	V_{CE} = 100V, I_C = 5.0A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 1200V	
		—	—	1000		V_{GE} = 0V, V_{CE} = 1200V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	2.5	2.9	V	I_C = 5.0A	See Fig. 13
		—	2.2	2.6		I_C = 5.0A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q_g	Total Gate Charge (turn-on)	—	28	43	nC	I_C = 5.0A		
Q_{ge}	Gate - Emitter Charge (turn-on)	—	4.4	6.6		V_{CC} = 400V	See Fig.8	
Q_{gc}	Gate - Collector Charge (turn-on)	—	12	18		V_{GE} = 15V		
$t_{d(on)}$	Turn-On Delay Time	—	50	—	ns			
t_r	Rise Time	—	30	—		T_J = 25°C		
$t_{d(off)}$	Turn-Off Delay Time	—	100	150		I_C = 5.0A, V_{CC} = 800V		
t_f	Fall Time	—	250	380		V_{GE} = 15V, R_G = 50Ω		
E_{on}	Turn-On Switching Loss	—	0.62	—	mJ	Energy losses include "tail"		
E_{off}	Turn-Off Switching Loss	—	0.30	—		and diode reverse recovery		
E_{ts}	Total Switching Loss	—	0.92	1.2		See Fig. 9,10,18		
t_{sc}	Short Circuit Withstand Time	10	—	—	µs	V_{CC} = 720V, T_J = 125°C V_{GE} = 15V, R_G = 50Ω		
$t_{d(on)}$	Turn-On Delay Time	—	50	—	ns	T_J = 150°C,	See Fig. 10,11,18	
t_r	Rise Time	—	30	—		I_C = 5.0A, V_{CC} = 800V		
$t_{d(off)}$	Turn-Off Delay Time	—	110	—		V_{GE} = 15V, R_G = 50Ω,		
t_f	Fall Time	—	620	—		Energy losses include "tail"		
E_{ts}	Total Switching Loss	—	1.6	—	mJ	and diode reverse recovery		
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package		
C_{ies}	Input Capacitance	—	435	—	pF	V_{GE} = 0V		
C_{oes}	Output Capacitance	—	44	—		V_{CC} = 30V	See Fig. 7	
C_{res}	Reverse Transfer Capacitance	—	8.3	—		ƒ = 1.0MHz		
t_{rr}	Diode Reverse Recovery Time	—	51	77	ns	T_J = 25°C	See Fig.	
		—	68	102		T_J = 125°C	14	I_F = 5.0A
I_{rr}	Diode Peak Reverse Recovery Current	—	6.0	9.0	A	T_J = 25°C	See Fig.	
		—	7.0	11		T_J = 125°C	15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	183	274	nC	T_J = 25°C	See Fig.	
		—	285	427		T_J = 125°C	16	di/dt = 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery During t_b	—	380	—	A/µs	T_J = 25°C	See Fig.	
		—	307	—		T_J = 125°C	17	

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PD - 9.693A

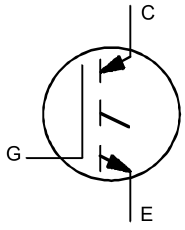
IRGPC40F

INSULATED GATE BIPOLAR TRANSISTOR

Fast Speed IGBT

Features

- Switching-loss rating includes all "tail" losses
- Optimized for medium operating frequency (1 to 10kHz) See Fig. 1 for Current vs. Frequency curve



n-channel

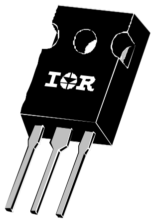
$V_{CES} = 600V$

$V_{CE(sat)} \leq 2.0V$

$@V_{GE} = 15V, I_C = 27A$

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher usable current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of high-voltage, high-current applications.



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	49	A
I_C @ T_C = 100°C	Continuous Collector Current	27	
I_{CM}	Pulsed Collector Current ①	200	
I_{LM}	Clamped Inductive Load Current ②	200	
V_{GE}	Gate-to-Emitter Voltage	±20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	—	0.77	°C/W
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	—	0.24	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	—	40	
Wt	Weight	—	6 (0.21)	—	g (oz)

Revision 0

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	$V_{GE} = 0V$, $I_C = 250\mu A$
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	20	—	—	V	$V_{GE} = 0V$, $I_C = 1.0A$
$\Delta V_{(BR)CES}/\Delta T_J$	Temp. Coeff. of Breakdown Voltage	—	0.70	—	V/°C	$V_{GE} = 0V$, $I_C = 1.0mA$
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	1.7	2.0	V	$I_C = 27A$ $V_{GE} = 15V$
		—	2.2	—		$I_C = 49A$ See Fig. 2, 5
		—	1.9	—		$I_C = 27A$, $T_J = 150°C$
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	5.5		$V_{CE} = V_{GE}$, $I_C = 250\mu A$
$\Delta V_{GE(th)}/\Delta T_J$	Temp. Coeff. of Threshold Voltage	—	-12	—	mV/°C	$V_{CE} = V_{GE}$, $I_C = 250\mu A$
g_{fe}	Forward Transconductance ⑤	9.2	12	—	S	$V_{CE} = 100V$, $I_C = 27A$
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	μA	$V_{GE} = 0V$, $V_{CE} = 600V$
		—	—	1000		$V_{GE} = 0V$, $V_{CE} = 600V$, $T_J = 150°C$
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	$V_{GE} = \pm 20V$

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	59	80	nC	$I_C = 27A$
Q_{ge}	Gate - Emitter Charge (turn-on)	—	8.6	10		$V_{CC} = 400V$ See Fig. 8
Q_{gc}	Gate - Collector Charge (turn-on)	—	25	42		$V_{GE} = 15V$
$t_{d(on)}$	Turn-On Delay Time	—	25	—	ns	$T_J = 25°C$
t_r	Rise Time	—	37	—		$I_C = 27A$, $V_{CC} = 480V$
$t_{d(off)}$	Turn-Off Delay Time	—	240	410		$V_{GE} = 15V$, $R_G = 10\Omega$
t_f	Fall Time	—	230	420		Energy losses include "tail"
E_{on}	Turn-On Switching Loss	—	0.65	—	mJ	
E_{off}	Turn-Off Switching Loss	—	3.0	—		See Fig. 9, 10, 11, 14
E_{ts}	Total Switching Loss	—	3.65	6.0		
$t_{d(on)}$	Turn-On Delay Time	—	28	—	ns	$T_J = 150°C$,
t_r	Rise Time	—	37	—		$I_C = 27A$, $V_{CC} = 480V$
$t_{d(off)}$	Turn-Off Delay Time	—	380	—		$V_{GE} = 15V$, $R_G = 10\Omega$
t_f	Fall Time	—	460	—		Energy losses include "tail"
E_{ts}	Total Switching Loss	—	6.0	—	mJ	See Fig. 10, 14
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	1500	—	pF	$V_{GE} = 0V$
C_{oes}	Output Capacitance	—	190	—		$V_{CC} = 30V$ See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	20	—		$f = 1.0MHz$

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC}=80%(V_{CES}), V_{GE}=20V, L=10μH, R_G= 10Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80μs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0μs, single shot.

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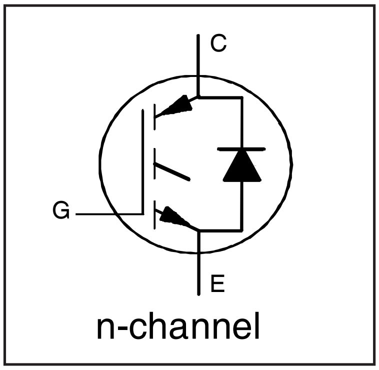
SMPS IGBT

PD - 95330A

IRGP50B60PD1PbF

WARP2 SERIES IGBT WITH ULTRAFAST SOFT RECOVERY DIODE



n-channel

V_{CES} = 600V
$V_{CE(on)}$ typ. = 2.00V
@ V_{GE} = 15V I_C = 33A

Equivalent MOSFET Parameters①
$R_{CE(on)}$ typ. = 61mΩ
I_D (FET equivalent) = 50A

Applications

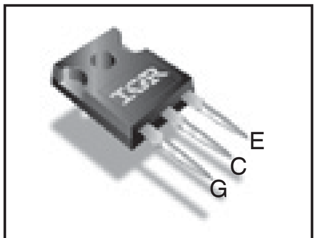
- Telecom and Server SMPS
- PFC and ZVS SMPS Circuits
- Uninterruptable Power Supplies
- Consumer Electronics Power Supplies
- Lead-Free

Features

- NPT Technology, Positive Temperature Coefficient
- Lower V_{CE}(SAT)
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability

Benefits

- Parallel Operation for Higher Current Applications
- Lower Conduction Losses and Switching Losses
- Higher Switching Frequency up to 150kHz



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	75	A
I_C @ T_C = 100°C	Continuous Collector Current	45	
I_{CM}	Pulse Collector Current (Ref. Fig. C.T.4)	150	
I_{LM}	Clamped Inductive Load Current ②	150	
I_F @ T_C = 25°C	Diode Continous Forward Current	40	
I_F @ T_C = 100°C	Diode Continous Forward Current	15	
I_{FRM}	Maximum Repetitive Forward Current ③	60	
V_{GE}	Gate-to-Emitter Voltage	±20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	390	W
P_D @ T_C = 100°C	Maximum Power Dissipation	156	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$ (IGBT)	Thermal Resistance Junction-to-Case-(each IGBT)	–––	–––	0.32	°C/W
$R_{\theta JC}$ (Diode)	Thermal Resistance Junction-to-Case-(each Diode)	–––	–––	1.7	
$R_{\theta CS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	–––	0.24	–––	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	–––	–––	40	
	Weight	–––	6.0 (0.21)	–––	g (oz)

7/25/08

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 500μA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.31	—	V/°C	V_{GE} = 0V, I_C = 1mA (25°C-125°C)	
R_G	Internal Gate Resistance	—	1.7	—	Ω	1MHz, Open Collector	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.00	2.35	V	I_C = 33A, V_{GE} = 15V	4, 5,6,8,9
		—	2.45	2.85		I_C = 50A, V_{GE} = 15V	
		—	2.60	2.95		I_C = 33A, V_{GE} = 15V, T_J = 125°C	
		—	3.20	3.60		I_C = 50A, V_{GE} = 15V, T_J = 125°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	4.0	5.0	V	I_C = 250μA	7,8,9
$\Delta V_{GE(th)}/\Delta TJ$	Threshold Voltage temp. coefficient	—	-10	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA	
gfe	Forward Transconductance	—	41	—	S	V_{CE} = 50V, I_C = 33A, PW = 80μs	
I_{CES}	Collector-to-Emitter Leakage Current	—	5.0	500	μA	V_{GE} = 0V, V_{CE} = 600V	
		—	1.0	—	mA	V_{GE} = 0V, V_{CE} = 600V, T_J = 125°C	
V_{FM}	Diode Forward Voltage Drop	—	1.30	1.70	V	I_F = 15A, V_{GE} = 0V	10
		—	1.20	1.60		I_F = 15A, V_{GE} = 0V, T_J = 125°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V, V_{CE} = 0V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
Qg	Total Gate Charge (turn-on)	—	205	308	nC	I_C = 33A	17
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	70	105		V_{CC} = 400V	CT1
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	30	45		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	—	255	305	μJ	I_C = 33A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	375	445		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	
E_{total}	Total Switching Loss	—	630	750		TJ = 25°C ④	
$t_{d(on)}$	Turn-On delay time	—	30	40	ns	I_C = 33A, V_{CC} = 390V	CT3
t_r	Rise time	—	10	15		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	
$t_{d(off)}$	Turn-Off delay time	—	130	150		T_J = 25°C ④	
t_f	Fall time	—	11	15			
E_{on}	Turn-On Switching Loss	—	580	700	μJ	I_C = 33A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	480	550		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	11,13
E_{total}	Total Switching Loss	—	1060	1250		T_J = 125°C ④	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	26	35	ns	I_C = 33A, V_{CC} = 390V	CT3
t_r	Rise time	—	13	20		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	12,14
$t_{d(off)}$	Turn-Off delay time	—	146	165		T_J = 125°C ④	WF1,WF2
t_f	Fall time	—	15	20			
C_{ies}	Input Capacitance	—	3648	—	pF	V_{GE} = 0V	16
C_{oes}	Output Capacitance	—	322	—		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	56	—		f = 1Mhz	
C_{oes} eff.	Effective Output Capacitance (Time Related) ⑤	—	215	—		V_{GE} = 0V, V_{CE} = 0V to 480V	15
C_{oes} eff. (ER)	Effective Output Capacitance (Energy Related) ⑤	—	163	—			
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T_J = 150°C, I_C = 150A V_{CC} = 480V, Vp =600V Rg = 22Ω, V_{GE} = +15V to 0V	3 CT2
t_{rr}	Diode Reverse Recovery Time	—	42	60	ns	T_J = 25°C I_F = 15A, V_R = 200V,	19
		—	74	120		T_J = 125°C di/dt = 200A/μs	
Q_{rr}	Diode Reverse Recovery Charge	—	80	180	nC	T_J = 25°C I_F = 15A, V_R = 200V,	21
		—	220	600		T_J = 125°C di/dt = 200A/μs	
I_{rr}	Peak Reverse Recovery Current	—	4.0	6.0	A	T_J = 25°C I_F = 15A, V_R = 200V,	19,20,21,22
		—	6.5	10		T_J = 125°C di/dt = 200A/μs	CT5

Notes:

① $R_{CE(on)}$ typ. = equivalent on-resistance = $V_{CE(on)}$ typ./ I_C, where $V_{CE(on)}$ typ.= 2.00V and I_C =33A. I_D (FET Equivalent) is the equivalent MOSFET I_D rating @ 25°C for applications up to 150kHz. These are provided for comparison purposes (only) with equivalent MOSFET solutions.

② V_{CC} = 80% (V_{CES}), V_{GE} = 15V, L = 28 μH, R_G = 22 Ω.

③ Pulse width limited by max. junction temperature.

④ Energy losses include "tail" and diode reverse recovery, Data generated with use of Diode 30ETH06.

⑤ C_{oes} eff. is a fixed capacitance that gives the same charging time as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.
C_{oes} eff.(ER) is a fixed capacitance that stores the same energy as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.

International
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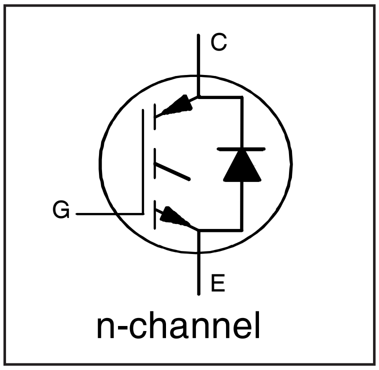
SMPS IGBT

IRGP50B60PD

WARP2 SERIES IGBT WITH ULTRAFAST SOFT RECOVERY DIODE



V_{CES} = 600V
$V_{CE(on)}$ typ. = 2.00V
@ V_{GE} = 15V I_C = 33A

Equivalent MOSFET Parameters①
$R_{CE(on)}$ typ. = 61mΩ
I_D (FET equivalent) = 50A

Applications

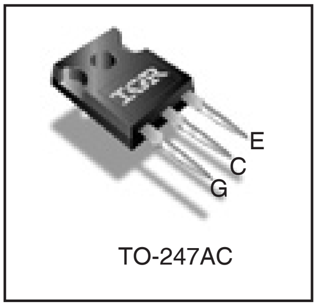
- Telecom and Server SMPS
- PFC and ZVS SMPS Circuits
- Uninterruptable Power Supplies
- Consumer Electronics Power Supplies

Features

- NPT Technology, Positive Temperature Coefficient
- Lower V_{CE}(SAT)
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability

Benefits

- Parallel Operation for Higher Current Applications
- Lower Conduction Losses and Switching Losses
- Higher Switching Frequency up to 150kHz



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	75	A
I_C @ T_C = 100°C	Continuous Collector Current	42	
I_{CM}	Pulse Collector Current (Ref. Fig. C.T.4)	150	
I_{LM}	Clamped Inductive Load Current ②	150	
I_F @ T_C = 25°C	Diode Continous Forward Current	50	
I_F @ T_C = 100°C	Diode Continous Forward Current	25	
I_{FRM}	Maximum Repetitive Forward Current ③	100	
V_{GE}	Gate-to-Emitter Voltage	±20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	370	W
P_D @ T_C = 100°C	Maximum Power Dissipation	150	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$ (IGBT)	Thermal Resistance Junction-to-Case-(each IGBT)	—	—	0.34	°C/W
$R_{\theta JC}$ (Diode)	Thermal Resistance Junction-to-Case-(each Diode)	—	—	0.64	
$R_{\theta CS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	—	0.24	—	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	—	—	40	
	Weight	—	6.0 (0.21)	—	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 500μA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.61	—	V/°C	V_{GE} = 0V, I_C = 1mA (25°C-125°C)	
R_G	Internal Gate Resistance	—	1.2	—	Ω	1MHz, Open Collector	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.0	2.2	V	I_C = 33A, V_{GE} = 15V	4, 5,6,8,9
		—	2.4	2.6		I_C = 50A, V_{GE} = 15V	
		—	2.6	2.9		I_C = 33A, V_{GE} = 15V, T_J = 125°C	
		—	3.2	3.6		I_C = 50A, V_{GE} = 15V, T_J = 125°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	4.0	5.0	V	I_C = 250μA	7,8,9
$\Delta V_{GE(th)}/\Delta TJ$	Threshold Voltage temp. coefficient	—	-7.07	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA	
gfe	Forward Transconductance	—	42	—	S	V_{CE} = 50V, I_C = 33A, PW = 80μs	
I_{CES}	Collector-to-Emitter Leakage Current	—	5.0	500	μA	V_{GE} = 0V, V_{CE} = 600V	
		—	1.0	—	mA	V_{GE} = 0V, V_{CE} = 600V, T_J = 125°C	
V_{FM}	Diode Forward Voltage Drop	—	1.3	1.7	V	I_F = 25A, V_{GE} = 0V	10
		—	1.5	2.0		I_F = 50A, V_{GE} = 0V	
		—	1.3	1.7		I_F = 25A, V_{GE} = 0V, T_J = 125°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V, V_{CE} = 0V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
Qg	Total Gate Charge (turn-on)	—	240	360	nC	I_C = 33A	17
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	41	82		V_{CC} = 400V	CT1
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	84	130		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	—	360	590	μJ	I_C = 33A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	380	420		V_{GE} = +15V, R_G = 3.3Ω, L = 210μH	
E_{total}	Total Switching Loss	—	740	960		TJ = 25°C ④	
$t_{d(on)}$	Turn-On delay time	—	34	44	ns	I_C = 33A, V_{CC} = 390V	CT3
t_r	Rise time	—	26	36		V_{GE} = +15V, R_G = 3.3Ω, L = 210μH	
$t_{d(off)}$	Turn-Off delay time	—	130	140		T_J = 25°C ④	
t_f	Fall time	—	43	56			
E_{on}	Turn-On Switching Loss	—	610	880	μJ	I_C = 33A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	460	530		V_{GE} = +15V, R_G = 3.3Ω, L = 210μH	11,13
E_{total}	Total Switching Loss	—	1070	1410		T_J = 125°C ④	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	33	43	ns	I_C = 33A, V_{CC} = 390V	CT3
t_r	Rise time	—	26	36		V_{GE} = +15V, R_G = 3.3Ω, L = 200μH	12,14
$t_{d(off)}$	Turn-Off delay time	—	140	160		T_J = 125°C ④	WF1,WF2
t_f	Fall time	—	50	65			
C_{ies}	Input Capacitance	—	4750	—	pF	V_{GE} = 0V	16
C_{oes}	Output Capacitance	—	390	—		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	58	—		f = 1Mhz	
C_{oes} eff.	Effective Output Capacitance (Time Related) ⑤	—	280	—		V_{GE} = 0V, V_{CE} = 0V to 480V	15
C_{oes} eff. (ER)	Effective Output Capacitance (Energy Related) ⑤	—	190	—			
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T_J = 150°C, I_C = 150A V_{CC} = 480V, Vp =600V Rg = 22Ω, V_{GE} = +15V to 0V	3 CT2
t_{rr}	Diode Reverse Recovery Time	—	50	75	ns	T_J = 25°C I_F = 25A, V_R = 200V,	19
		—	105	160		T_J = 125°C di/dt = 200A/μs	
Q_{rr}	Diode Reverse Recovery Charge	—	112	375	nC	T_J = 25°C I_F = 25A, V_R = 200V,	21
		—	420	4200		T_J = 125°C di/dt = 200A/μs	
I_{rr}	Peak Reverse Recovery Current	—	4.5	10	A	T_J = 25°C I_F = 25A, V_R = 200V,	19,20,21,22
		—	8.0	15		T_J = 125°C di/dt = 200A/μs	CT5

Notes:

① $R_{CE(on)}$ typ. = equivalent on-resistance = $V_{CE(on)}$ typ./ I_C, where $V_{CE(on)}$ typ.= 2.00V and I_C =33A. I_D (FET Equivalent) is the equivalent MOSFET I_D rating @ 25°C for applications up to 150kHz. These are provided for comparison purposes (only) with equivalent MOSFET solutions.

② V_{CC} = 80% (V_{CES}), V_{GE} = 20V, L = 28 μH, R_G = 22 Ω.

③ Pulse width limited by max. junction temperature.

④ Energy losses include "tail" and diode reverse recovery, Data generated with use of Diode 30ETH06.

⑤ C_{oes} eff. is a fixed capacitance that gives the same charging time as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.
C_{oes} eff.(ER) is a fixed capacitance that stores the same energy as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.

International
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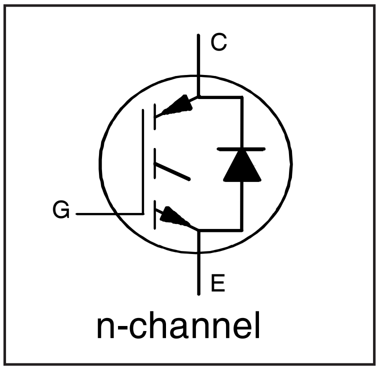
SMPS IGBT

IRGP50B60PD1

WARP2 SERIES IGBT WITH ULTRAFAST SOFT RECOVERY DIODE

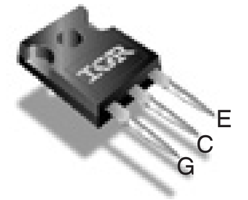


V_{CES} = 600V
$V_{CE(on)}$ typ. = 2.00V
@ V_{GE} = 15V I_C = 33A

Equivalent MOSFET Parameters①
$R_{CE(on)}$ typ. = 61mΩ
I_D (FET equivalent) = 50A

Applications
- Telecom and Server SMPS
- PFC and ZVS SMPS Circuits
- Uninterruptable Power Supplies
- Consumer Electronics Power Supplies

Features
- NPT Technology, Positive Temperature Coefficient
- Lower V_{CE}(SAT)
- Lower Parasitic Capacitances
- Minimal Tail Current
- HEXFRED Ultra Fast Soft-Recovery Co-Pack Diode
- Tighter Distribution of Parameters
- Higher Reliability



TO-247AC

Benefits
- Parallel Operation for Higher Current Applications
- Lower Conduction Losses and Switching Losses
- Higher Switching Frequency up to 150kHz

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	75	A
I_C @ T_C = 100°C	Continuous Collector Current	45	
I_{CM}	Pulse Collector Current (Ref. Fig. C.T.4)	150	
I_{LM}	Clamped Inductive Load Current ②	150	
I_F @ T_C = 25°C	Diode Continous Forward Current	40	
I_F @ T_C = 100°C	Diode Continous Forward Current	15	
I_{FRM}	Maximum Repetitive Forward Current ③	60	
V_{GE}	Gate-to-Emitter Voltage	±20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	390	W
P_D @ T_C = 100°C	Maximum Power Dissipation	156	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf·in (1.1 N·m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$ (IGBT)	Thermal Resistance Junction-to-Case-(each IGBT)	—	—	0.32	°C/W
$R_{\theta JC}$ (Diode)	Thermal Resistance Junction-to-Case-(each Diode)	—	—	1.7	
$R_{\theta CS}$	Thermal Resistance, Case-to-Sink (flat, greased surface)	—	0.50	—	
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient (typical socket mount)	—	—	40	
	Weight	—	6.0 (0.21)	—	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 500µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.31	—	V/°C	V_{GE} = 0V, I_C = 1mA (25°C-125°C)	
R_G	Internal Gate Resistance	—	1.7	—	Ω	1MHz, Open Collector	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.00	2.35	V	I_C = 33A, V_{GE} = 15V	4, 5,6,8,9
		—	2.45	2.85		I_C = 50A, V_{GE} = 15V	
		—	2.60	2.95		I_C = 33A, V_{GE} = 15V, T_J = 125°C	
		—	3.20	3.60		I_C = 50A, V_{GE} = 15V, T_J = 125°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	4.0	5.0	V	I_C = 250µA	7,8,9
$\Delta V_{GE(th)}/\Delta TJ$	Threshold Voltage temp. coefficient	—	-10	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA	
gfe	Forward Transconductance	—	41	—	S	V_{CE} = 50V, I_C = 33A, PW = 80µs	
I_{CES}	Collector-to-Emitter Leakage Current	—	5.0	500	µA	V_{GE} = 0V, V_{CE} = 600V	
		—	1.0	—	mA	V_{GE} = 0V, V_{CE} = 600V, T_J = 125°C	
V_{FM}	Diode Forward Voltage Drop	—	1.30	1.70	V	I_F = 15A, V_{GE} = 0V	10
		—	1.20	1.60		I_F = 15A, V_{GE} = 0V, T_J = 125°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V, V_{CE} = 0V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig
Qg	Total Gate Charge (turn-on)	—	205	308	nC	I_C = 33A	17
Q_{gc}	Gate-to-Collector Charge (turn-on)	—	70	105		V_{CC} = 400V	CT1
Q_{ge}	Gate-to-Emitter Charge (turn-on)	—	30	45		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	—	255	305	µJ	I_C = 33A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	375	445		V_{GE} = +15V, R_G = 3.3Ω, L = 200µH	
E_{total}	Total Switching Loss	—	630	750		TJ = 25°C ④	
$t_{d(on)}$	Turn-On delay time	—	30	40	ns	I_C = 33A, V_{CC} = 390V	CT3
t_r	Rise time	—	10	15		V_{GE} = +15V, R_G = 3.3Ω, L = 200µH	
$t_{d(off)}$	Turn-Off delay time	—	130	150		T_J = 25°C ④	
t_f	Fall time	—	11	15			
E_{on}	Turn-On Switching Loss	—	580	700	µJ	I_C = 33A, V_{CC} = 390V	CT3
E_{off}	Turn-Off Switching Loss	—	480	550		V_{GE} = +15V, R_G = 3.3Ω, L = 200µH	11,13
E_{total}	Total Switching Loss	—	1060	1250		T_J = 125°C ④	WF1,WF2
$t_{d(on)}$	Turn-On delay time	—	26	35	ns	I_C = 33A, V_{CC} = 390V	CT3
t_r	Rise time	—	13	20		V_{GE} = +15V, R_G = 3.3Ω, L = 200µH	12,14
$t_{d(off)}$	Turn-Off delay time	—	146	165		T_J = 125°C ④	WF1,WF2
t_f	Fall time	—	15	20			
C_{ies}	Input Capacitance	—	3648	—	pF	V_{GE} = 0V	16
C_{oes}	Output Capacitance	—	322	—		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	56	—		f = 1Mhz	
C_{oes} eff.	Effective Output Capacitance (Time Related) ⑤	—	215	—		V_{GE} = 0V, V_{CE} = 0V to 480V	15
C_{oes} eff. (ER)	Effective Output Capacitance (Energy Related) ⑤	—	163	—			
RBSOA	Reverse Bias Safe Operating Area	FULL SQUARE				T_J = 150°C, I_C = 150A V_{CC} = 480V, Vp =600V Rg = 22Ω, V_{GE} = +15V to 0V	3 CT2
t_{rr}	Diode Reverse Recovery Time	—	42	60	ns	T_J = 25°C I_F = 15A, V_R = 200V,	19
		—	74	120		T_J = 125°C di/dt = 200A/µs	
Q_{rr}	Diode Reverse Recovery Charge	—	80	180	nC	T_J = 25°C I_F = 15A, V_R = 200V,	21
		—	220	600		T_J = 125°C di/dt = 200A/µs	
I_{rr}	Peak Reverse Recovery Current	—	4.0	6.0	A	T_J = 25°C I_F = 15A, V_R = 200V,	19,20,21,22
		—	6.5	10		T_J = 125°C di/dt = 200A/µs	CT5

Notes:

① $R_{CE(on)}$ typ. = equivalent on-resistance = $V_{CE(on)}$ typ./ I_C, where $V_{CE(on)}$ typ.= 2.00V and I_C =33A. I_D (FET Equivalent) is the equivalent MOSFET I_D rating @ 25°C for applications up to 150kHz. These are provided for comparison purposes (only) with equivalent MOSFET solutions.

② V_{CC} = 80% (V_{CES}), V_{GE} = 20V, L = 28 µH, R_G = 22 Ω.

③ Pulse width limited by max. junction temperature.

④ Energy losses include "tail" and diode reverse recovery, Data generated with use of Diode 30ETH06.

⑤ C_{oes} eff. is a fixed capacitance that gives the same charging time as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.
C_{oes} eff.(ER) is a fixed capacitance that stores the same energy as C_{oes} while V_{CE} is rising from 0 to 80% V_{CES}.

International
IOR Rectifier

PD- 94117

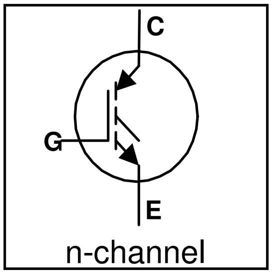
IRGP20B120U-E

INSULATED GATE BIPOLAR TRANSISTOR

UltraFast IGBT

Features

- UltraFast Non Punch Through (NPT) Technology
- 10 µs Short Circuit capability
- Square RBSOA
- Positive V_{CE}(on) Temperature Coefficient
- Extended lead TO-247 package



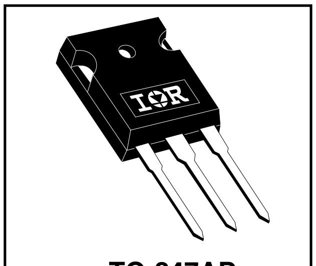
V_{CES} = 1200V

$V_{CE(on)\ typ.}$ = 3.05V

V_{GE} = 15V, I_C = 20A, 25°C

Benefits

- Benchmark efficiency above 20KHz
- Optimized for Welding, UPS, and Induction Heating applications
- Rugged with UltraFast performance
- Low EMI
- Significantly Less Snubber required
- Excellent Current sharing in Parallel operation
- Longer leads for easier mounting


TO-247AD

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current (Fig.1)	40	A
I_C @ T_C = 100°C	Continuous Collector Current (Fig.1)	20	
I_{CM}	Pulsed Collector Current (Fig.3, Fig. CT.5)	120	
I_{LM}	Clamped Inductive Load Current(Fig.4, Fig. CT.2)	120	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
E_{AS} @ T_C =25°C	Avalanche Energy, single pulse I_C = 25A, V_{CC} = 50V, R_{GE} = 25ohm L = 200µH (Fig. CT.6)	65	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation (Fig.2)	300	W
P_D @ T_C = 100°C	Maximum Power Dissipation (Fig.2)	120	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300, (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	—	—	0.42	°C/W
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	—	0.24	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	—	40	
Wt	Weight	—	6 (0.21)	—	g (oz)
$Z_{\theta JC}$	Transient Thermal Impedance Junction-to-Case (Fig.18)				

Electrical Characteristics @ TJ = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Fig.
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	1200			V	V_{GE} = 0V,I_c =250 µA	
$\Delta V_{(BR)CES} / \Delta Tj$	Temperature Coeff. of Breakdown Voltage		+1.2		V/°C	V_{GE} = 0V, I_c = 1 mA (25 -125 °C)	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage		3.05	3.45	V	I_C = 20A, V_{GE} = 15V	5, 6
			3.37	3.80		I_C = 25A, V_{GE} = 15V	7, 8
			4.23	4.85		I_C = 40A, V_{GE} = 15V	9
			3.89	4.50		I_C = 20A, V_{GE} = 15V, T_J = 125°C	10
			4.31	5.06		I_C = 25A, V_{GE} = 15V, T_J = 125°C	
$V_{GE(th)}$	Gate Threshold Voltage	4.0	5.0	6.0	V	V_{CE} = V_{GE}, I_C = 250 µA	8,9,10,11
$\Delta V_{GE(th)} / \Delta Tj$	Temperature Coeff. of Threshold Voltage		- 1.2		mV/°C	V_{CE} = $V_{GE,}$ I_C = 1 mA (25 -125 °C)	
g_{fe}	Forward Transconductance	13.6	15.7	17.8	S	V_{CE} = 50V, I_C = 20A, PW=80µs	
I_{CES}	Zero Gate Voltage Collector Current			250	µA	V_{GE} = 0V, V_{CE} = 1200V	
			420	750		V_{GE} = 0V, V_{CE} = 1200V, T_J =125°C	
			1482	2200		V_{GE} = 0V, V_{CE} = 1200V, T_J =150°C	
I_{GES}	Gate-to-Emitter Leakage Current			±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Fig.
Q_g	Total Gate charge (turn-on)		169	254	nC	I_C = 20A	17
Q_{ge}	Gate - Emitter Charge (turn-on)		24	36		V_{CC} = 600V	CT1
Q_{gc}	Gate - Collector Charge (turn-on)		82	126		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss *		850	1050	µJ	I_C = 20A, V_{CC} = 600V	CT4
E_{off}	Turn-Off Switching Loss *		425	650		V_{GE} = 15V, Rg = 5Ω, L = 200µH	WF1
E_{tot}	Total Switching Loss *		1275	1800		T_J = 25°C, Energy losses include tail and diode reverse recovery	WF2
E_{on}	Turn-on Switching Loss *		1350	1550	µJ	Ic = 20A, V_{CC} = 600V	12, 14
E_{off}	Turn-off Switching Loss *		610	875		V_{GE} = 15V, Rg = 5Ω, L = 200µH	CT4
E_{tot}	Total Switching Loss *		1960	2425		T_J = 125°C, Energy losses include tail and diode reverse recovery	WF1 & 2
td(on)	Turn - on delay time		50	65	ns	Ic = 20A, V_{CC} = 600V	13, 15
tr	Rise time		20	30		V_{GE} = 15V, Rg = 5Ω, L = 200µH	CT4
td(off)	Turn - off delay time		204	230		T_J = 125°C	WF1
tf	Fall time		24	35			WF2
C_{ies}	Input Capacitance		2200		pF	V_{GE} = 0V	
C_{oes}	Output Capacitance		210			V_{CC} = 30V	16
C_{res}	Reverse Transfer Capacitance		85			f = 1.0 MHz	
RBSOA	Reverse bias safe operating area	FULL SQUARE				T_J = 150°C, Ic = 120A V_{CC} = 1000V, V_P = 1200V Rg = 5Ω, V_{GE} = +15V to 0V	4 CT2
SCSOA	Short Circuit Safe Operating Area	10	----	----	µs	T_J = 150°C V_{CC} = 900V, V_P = 1200V Rg = 5Ω, V_{GE} = +15V to 0V	CT3 WF3
Le	Internal Emitter Inductance		13		nH	Measured 5 mm from the package.	

* Used Diode HF40D120ACE

PD- 93817

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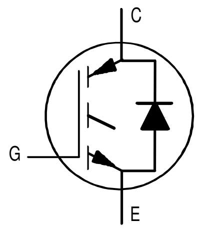
IRGP20B120UD-E

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

UltraFast CoPack IGBT



N-channel

V_{CES} = 1200V

$V_{CE(on)\ typ.}$ = 3.05V

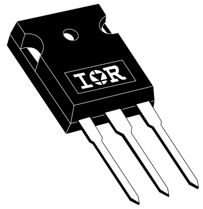
V_{GE} = 15V, I_C = 20A, 25°C

Features

- UltraFast Non Punch Through (NPT) Technology
- Low Diode V_F (1.67V Typical @ 20A & 25°C)
- 10 µs Short Circuit Capability
- Square RBSOA
- UltraSoft Diode Recovery Characteristics
- Positive $V_{CE(on)}$ Temperature Coefficient
- Extended Lead TO-247AD Package

Benefits

- Benchmark Efficiency Above 20KHz
- Optimized for Welding, UPS, and Induction Heating Applications
- Rugged with UltraFast Performance
- Low EMI
- Significantly Less Snubber Required
- Excellent Current Sharing in Parallel Operation
- Longer Leads for Easier Mounting



TO-247AD

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current (Fig.1)	40	A
I_C @ T_C = 100°C	Continuous Collector Current (Fig.1)	20	
I_{CM}	Pulsed Collector Current (Fig.3, Fig. CT.5)	120	
I_{LM}	Clamped Inductive Load Current(Fig.4, Fig. CT.2)	120	
I_F @ T_C = 100°C	Diode Continuous Forward Current	20	
I_{FM}	Diode Maximum Forward Current	120	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation (Fig.2)	300	W
P_D @ T_C = 100°C	Maximum Power Dissipation (Fig.2)	120	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300, (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	–––	–––	0.42	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	–––	–––	0.83	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	–––	0.24	–––	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	–––	–––	40	
W_t	Weight	–––	6 (0.21)	–––	g (oz)
$Z_{\theta JC}$	Transient Thermal Impedance Junction-to-Case (Fig.24)				

Electrical Characteristics @ TJ = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Fig.
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	1200			V	V_{GE} = 0V, I_c = 250 µA	
$\Delta V_{(BR)CES} / \Delta T_j$	Temperature Coeff. of Breakdown Voltage		+1.2		V/°C	V_{GE} = 0V, I_c = 1 mA (25 -125 °C)	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage		3.05	3.45	V	I_C = 20A, V_{GE} = 15V	5, 6
			3.37	3.80		I_C = 25A, V_{GE} = 15V	7, 9
			4.23	4.85		I_C = 40A, V_{GE} = 15V	10
			3.89	4.50		I_C = 20A, V_{GE} = 15V, T_J = 125°C	11
			4.31	5.06		I_C = 25A, V_{GE} = 15V, T_J = 125°C	
$V_{GE(th)}$	Gate Threshold Voltage	4.0	5.0	6.0	V	V_{CE} = V_{GE}, I_C = 250 µA	9,10,11,12
$\Delta V_{GE(th)} / \Delta T_j$	Temperature Coeff. of Threshold Voltage		- 1.2		mV/°C	V_{CE} = V_{GE}, I_C = 1 mA (25 -125 °C)	
g_{fe}	Forward Transconductance	13.6	15.7	17.8	S	V_{CE} = 50V, I_C = 20A, PW=80µs	
I_{CES}	Zero Gate Voltage Collector Current			250	µA	V_{GE} = 0V, V_{CE} = 1200V	
			420	750		V_{GE} = 0V, V_{CE} = 1200V, T_J =125°C	
			1482	2200		V_{GE} = 0V, V_{CE} = 1200V, T_J =150°C	
V_{FM}	Diode Forward Voltage Drop		1.67	1.96	V	I_C = 20A	8
			1.76	2.06		I_C = 25A	
			1.73	2.03		I_C = 20A, T_J = 125°C	
			1.87	2.18		I_C = 25A, T_J = 125°C	
I_{GES}	Gate-to-Emitter Leakage Current			±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Fig.
Q_g	Total Gate charge (turn-on)		169	254	nC	I_C = 20A	23
Q_{ge}	Gate - Emitter Charge (turn-on)		24	36		V_{CC} = 600V	CT1
Q_{gc}	Gate - Collector Charge (turn-on)		82	126		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss		850	1050	µJ	I_C = 20A, V_{CC} = 600V	CT4
E_{off}	Turn-Off Switching Loss		425	650		V_{GE} = 15V, Rg = 5Ω, L = 200µH	WF1
E_{tot}	Total Switching Loss		1275	1800		T_J = 25°C, Energy losses include tail and diode reverse recovery	WF2
E_{on}	Turn-on Switching Loss		1350	1550	µJ	Ic = 20A, V_{CC} = 600V	13, 15
E_{off}	Turn-off Switching Loss		610	875		V_{GE} = 15V, Rg = 5Ω, L = 200µH	CT4
E_{tot}	Total Switching Loss		1960	2425		T_J = 125°C, Energy losses include tail and diode reverse recovery	WF1 & 2
td(on)	Turn - on delay time		50	65	ns	Ic = 20A, V_{CC} = 600V	14, 16
tr	Rise time		20	30		V_{GE} = 15V, Rg = 5Ω, L = 200µH	CT4
td(off)	Turn - off delay time		204	230		T_J = 125°C	WF1
tf	Fall time		24	35			WF2
C_{ies}	Input Capacitance		2200		pF	V_{GE} = 0V	
C_{oes}	Output Capacitance		210			V_{CC} = 30V	22
C_{res}	Reverse Transfer Capacitance		85			f = 1.0 MHz	
RBSOA	Reverse bias safe operating area	FULL SQUARE				T_J = 150°C, Ic = 120A V_{CC} = 1000V, V_P = 1200V Rg = 5Ω, V_{GE} = +15V to 0V	4 CT2
SCSOA	Short Circuit Safe Operating Area	10	----	----	µs	T_J = 150°C V_{CC} = 900V, V_P = 1200V Rg = 5Ω, V_{GE} = +15V to 0V	CT3 WF4
E_{rec}	Reverse recovery energy of the diode		1600	2100	µJ	T_J = 125°C	17,18,19
trr	Diode Reverse recovery time		300		ns	V_{CC} = 600V, Ic = 20A	20, 21
Irr	Peak Reverse Recovery Current		32	36	A	V_{GE} = 15V, Rg = 5Ω, L = 200µH	CT4, WF3
Le	Internal Emitter Inductance		13		nH	Measured 5 mm from the package.	

STGW35HF60WD

35 A, 600 V ultra fast IGBT

Features

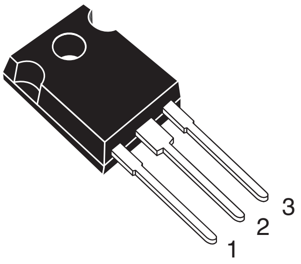
- Improved E_{off} at elevated temperature
- Minimal tail current
- Low conduction losses
- $V_{CE(sat)}$ classified for easy parallel connection
- Ultra fast soft recovery antiparallel diode

Applications

- Welding
- High frequency converters
- Power factor correction

Description

The STGW35HF60WD is based on a new advanced planar technology concept to yield an IGBT with more stable switching performance (E_{off}) versus temperature, as well as lower conduction losses. The device is tailored to high switching frequency operation (over 100 kHz).



TO-247

Figure 1. Internal schematic diagram

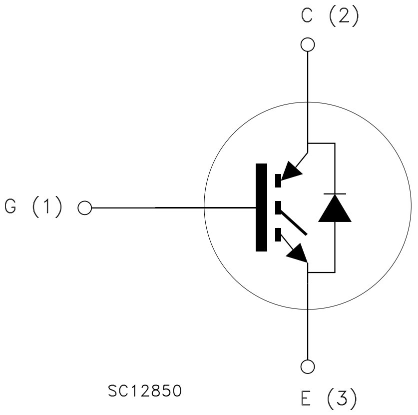


Table 1. Device summary

Order code	Marking[(1)]	Package	Packaging
STGW35HF60WD	GW35HF60WDA	TO-247	Tube
	GW35HF60WDB		
	GW35HF60WDC		

1. Collector-emitter saturation voltage is classified in group A, B and C, see *Table 5: VCE(sat) classification*. STMicroelectronics reserves the right to ship from any group according to production availability.

1 Electrical ratings

Table 2. Absolute maximum ratings

Symbol	Parameter	Value	Unit
V_{CES}	Collector-emitter voltage (V_{GE} = 0)	600	V
I_C (1)	Continuous collector current at T_C = 25 °C	60	A
I_C (1)	Continuous collector current at T_C = 100 °C	35	A
I_{CP}(2)	Pulsed collector current	150	A
I_{CL} (3)	Turn-off latching current	80	A
V_{GE}	Gate-emitter voltage	± 20	V
I_F	Diode RMS forward current at T_C = 25 °C	30	A
I_{FSM}	Surge non repetitive forward current t_p= 10 ms sinusoidal	120	A
P_{TOT}	Total dissipation at T_C = 25 °C	200	W
T_{stg}	Storage temperature	– 55 to 150	°C
T_j	Operating junction temperature		

1. Calculated according to the iterative formula:

$$I_C(T_C) = \frac{T_{j(max)} - T_C}{R_{thj-c} \times V_{CE(sat)(max)}(T_{j(max)}, I_C(T_C))}$$

2. Pulse width limited by maximum junction temperature and turn-off within RBSOA
3. V_{CLAMP} = 80% (V_{CES}), V_{GE} = 15 V, R_G = 10 Ω, T_J = 150 °C

Table 3. Thermal data

Symbol	Parameter	Value	Unit
$R_{thj-case}$	Thermal resistance junction-case IGBT	0.63	°C/W
	Thermal resistance junction-case diode	1.5	°C/W
$R_{thj-amb}$	Thermal resistance junction-ambient	50	°C/W

2 Electrical characteristics

(T_J = 25 °C unless otherwise specified)

Table 4. Static

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)CES}$	Collector-emitter breakdown voltage (V_{GE} = 0)	I_C = 1 mA	600			V
$V_{CE(sat)}$	Collector-emitter saturation voltage	V_{GE} = 15 V, I_C= 20 A			2.5	V
		V_{GE} = 15V, I_C = 20 A,T_J= 125 °C		1.65		
$V_{GE(th)}$	Gate threshold voltage	V_{CE} = V_{GE}, I_C = 1 mA	3.75		5.75	V
I_{CES}	Collector cut-off current (V_{GE} = 0)	V_{CE} = 600 V V_{CE} = 600 V, T_J = 125 °C			250 1	µA mA
I_{GES}	Gate-emitter leakage current (V_{CE} = 0)	V_{GE} = ±20 V			± 100	nA

Table 5. $V_{CE(sat)}$ classification

Symbol	Parameter	Group	Value		Unit
			Min.	Max.	
$V_{CE(sat)}$	Collector-emitter saturation voltage V_{GE} = 15 V, I_C= 20 A	A	1.68	1.92	V
		B	1.88	2.17	
		C	2.13	2.50	

Table 6. Dynamic

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{ies} C_{oes} C_{res}	Input capacitance Output capacitance Reverse transfer capacitance	V_{CE} = 25 V, f = 1 MHz, V_{GE} = 0	-	2400 235 50	-	pF pF pF
Q_g Q_{ge} Q_{gc}	Total gate charge Gate-emitter charge Gate-collector charge	V_{CE} = 400 V, I_C = 20 A, V_{GE} = 15 V, *(see Figure 17)*	-	140 13 52	-	nC nC nC

Table 7. Switching on/off (inductive load)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$ t_r $(di/dt)_{on}$	Turn-on delay time Current rise time Turn-on current slope	V_{CC} = 400 V, I_C = 20 A R_G = 10 Ω, V_{GE} = 15 V, *(see Figure 16)*	-	30 15 1650	-	ns ns A/µs
$t_{d(on)}$ t_r $(di/dt)_{on}$	Turn-on delay time Current rise time Turn-on current slope	V_{CC} = 400 V, I_C = 20 A R_G = 10 Ω, V_{GE} = 15 V, T_J = 125 °C *(see Figure 16)*	-	30 15 1600	-	ns ns A/µs
$t_r(V_{off})$ $t_d(_{off})$ t_f	Off voltage rise time Turn-off delay time Current fall time	V_{CC} = 400 V, I_C = 20 A, R_{GE} = 10 Ω, V_{GE} = 15 V *(see Figure 16)*	-	30 175 40	-	ns ns ns
$t_r(V_{off})$ $t_d(_{off})$ t_f	Off voltage rise time Turn-off delay time Current fall time	V_{CC} = 400 V, I_C = 20 A, R_{GE} = 10 Ω, V_{GE} =15 V, T_J = 125 °C *(see Figure 16)*	-	50 225 70	-	ns ns ns

Table 8. Switching energy (inductive load)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}[1] E_{off} E_{ts}	Turn-on switching losses Turn-off switching losses Total switching losses	V_{CC} = 400 V, I_C = 20 A R_G = 10 Ω, V_{GE} = 15 V, *(see Figure 18)*	-	290 185 475		µJ µJ µJ
E_{on}[1] E_{off} E_{ts}	Turn-on switching losses Turn-off switching losses Total switching losses	V_{CC} = 400 V, I_C = 20 A R_G = 10 Ω, V_{GE} = 15 V, T_J = 125 °C *(see Figure 18)*	-	420 350 770	 530 	µJ µJ µJ

1. Eon is the tun-on losses when a typical diode is used in the test circuit in Figure 18. If the IGBT is offered in a package with a co-pak diode, the co-pack diode is used as external diode. IGBTs and diode are at the same temperature (25 °C and 125 °C). Eon include diode recovery energy.

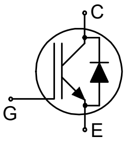
Table 9. Collector-emitter diode

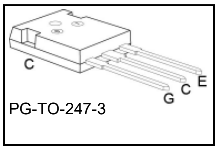
Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_F	Forward on-voltage	I_F = 20 A I_F = 20 A, T_J = 125 °C	-	1.8 1.4	2.25	V V
t_{rr} Q_{rr} I_{rrm}	Reverse recovery time Reverse recovery charge Reverse recovery current	I_F = 20 A,V_R = 50 V, di/dt = 100 A/µs *(see Figure 19)*	-	50 90 3	-	ns nC A
t_{rr} Q_{rr} I_{rrm}	Reverse recovery time Reverse recovery charge Reverse recovery current	I_F = 20 A,V_R = 50 V, T_J =125 °C, di/dt = 100 A/µs *(see Figure 19)*	-	135 375 5.5	-	ns nC A

SKW25N120

Fast IGBT in NPT-technology with soft, fast recovery anti-parallel Emitter Controlled Diode

- 40lower E_{off} compared to previous generation
- Short circuit withstand time – 10 µs
- Designed for:
  - Motor controls
  - Inverter
  - SMPS
- NPT-Technology offers:
  - very tight parameter distribution
  - high ruggedness, temperature stable behaviour
  - parallel switching capability
- Pb-free lead plating; RoHS compliant
- Qualified according to JEDEC[1] for target applications
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/





Type	V_{CE}	I_C	E_{off}	T_j	Marking	Package
SKW25N120	1200V	25A	2.9mJ	150°C	K25N120	PG-TO-247-3

Maximum Ratings

Parameter	Symbol	Value	Unit
Collector-emitter voltage	V_{CE}	1200	V
DC collector current T_C = 25°C T_C = 100°C	I_C	 46 25	A
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	84	
Turn off safe operating area $V_{CE} \leq$ 1200V, $T_j \leq$ 150°C	-	84	
Diode forward current T_C = 25°C T_C = 100°C	I_F	 42 25	
Diode pulsed current, t_p limited by T_{jmax}	I_{Fpuls}	80	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[2] V_{GE} = 15V, 100V$\leq V_{CC} \leq$1200V, $T_j \leq$ 150°C	t_{SC}	10	µs
Power dissipation T_C = 25°C	P_{tot}	313	W
Operating junction and storage temperature	T_j , T_{stg}	-55...+150	°C
Soldering temperature, wavesoldering, 1.6mm (0.063 in.) from case for 10s	T_s	260	

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[1] J-STD-020 and JESD-022

[2] Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		0.4	K/W
Diode thermal resistance, junction – case	R_{thJCD}		1.15	
Thermal resistance, junction – ambient	R_{thJA}		40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	$V_{GE}=0V$, $I_C=1500\mu A$	1200	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, I_C=25A T_j=25°C T_j=150°C	2.5 -	3.1 3.7	3.6 4.3	
Diode forward voltage	V_F	V_{GE}=0V, I_F=25A T_j=25°C T_j=150°C	 -	2.0 1.75	2.5	
Gate-emitter threshold voltage	$V_{GE(th)}$	$I_C=1000\mu A$, $V_{CE}=V_{GE}$	3	4	5	
Zero gate voltage collector current .	I_{CES}	V_{CE}=1200V,V_{GE}=0V T_j=25°C T_j=150°C	- -	- -	350 1400	µA
Gate-emitter leakage current	I_{GES}	V_{CE}=0V,V_{GE}=20V	-	-	100	nA
Transconductance	g_{fs}	V_{CE}=20V, I_C=25A		20	-	S
Dynamic Characteristic						
Input capacitance	C_{iss}	V_{CE}=25V, V_{GE}=0V, f=1MHz	-	2150	2600	pF
Output capacitance	C_{oss}		-	260	310	
Reverse transfer capacitance	C_{rss}		-	110	130	
Gate charge	Q_{Gate}	V_{CC}=960V, I_C=25A V_{GE}=15V	-	225	300	nC
Internal emitter inductance Measured 5mm (0.197 in.) from case	L_E		-	13	-	nH
Short circuit collector current 1)	$I_{C(SC)}$	$V_{GE}=15V, t_{SC}\leq 10\mu s$ $100V \leq V_{CC} \leq 1200V$, $T_j \leq$ 150°C	-	240	-	A

1) Allowed number of short circuits: <1000; time between short circuits: >1s

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	Symbol	Conditions	Value			Unit
			Min.	typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=800V,I_C=25A, V_{GE}=15/0V, R_G=22Ω, $L_\sigma{}^{1)}$=180nH, $C_\sigma{}^{1)}$=40pF Energy losses include "tail" and diode reverse recovery.	-	45	60	ns
Rise time	t_r		-	40	52	
Turn-off delay time	$t_{d(off)}$		-	730	950	
Fall time	t_f		-	30	39	
Turn-on energy	E_{on}		-	2.2	2.9	mJ
Turn-off energy	E_{off}		-	1.5	2.0	
Total switching energy	E_{ts}		-	3.7	4.9	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=25°C, V_R=800V, I_F=25A, di_F/dt=650A/µs	-	90		ns
	t_S		-			
	t_F		-			
Diode reverse recovery charge	Q_{rr}		-	1.0		µC
Diode peak reverse recovery current	I_{rrm}		-	20		A
Diode peak rate of fall of reverse recovery current during t_F	di_{rr}/dt		-	470		A/µs

Switching Characteristic, Inductive Load, at T_j=150 °C

Parameter	Symbol	Conditions	Value			Unit
			Min.	typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=150°C V_{CC}=800V,I_C=25A, V_{GE}=15/0V, R_G=22Ω, $L_\sigma{}^{1)}$=180nH, $C_\sigma{}^{1)}$=40pF Energy losses include "tail" and diode reverse recovery.	-	50	60	ns
Rise time	t_r		-	36	43	
Turn-off delay time	$t_{d(off)}$		-	820	990	
Fall time	t_f		-	42	50	
Turn-on energy	E_{on}		-	3.8	4.6	mJ
Turn-off energy	E_{off}		-	2.9	3.8	
Total switching energy	E_{ts}		-	6.7	8.4	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=150°C V_R=800V, I_F=25A, di_F/dt=750A/µs	-	280		ns
	t_S		-			
	t_F		-			
Diode reverse recovery charge	Q_{rr}		-	4.3		µC
Diode peak reverse recovery current	I_{rrm}		-	32		A
Diode peak rate of fall of reverse recovery current during t_F	di_{rr}/dt		-	130		A/µs

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1) Leakage inductance L_σ and stray capacity C_σ due to dynamic test circuit in figure E.

FAIRCHILD
SEMICONDUCTOR®

IGBT

SGH80N60UFD

Ultrafast IGBT

General Description

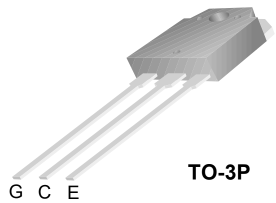
Fairchild's UFD series of Insulated Gate Bipolar Transistors (IGBTs) provides low conduction and switching losses. The UFD series is designed for applications such as motor control and general inverters where high speed switching is a required feature.

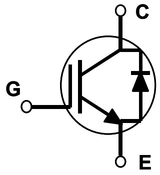
Features

- High speed switching
- Low saturation voltage : $V_{CE(sat)}$ = 2.1 V @ I_C = 40A
- High input impedance
- CO-PAK, IGBT with FRD : t_{rr} = 50ns (typ.)

Applications

AC & DC motor controls, general purpose inverters, robotics, and servo controls.





Absolute Maximum Ratings

T_C = 25°C unless otherwise noted

Symbol	Description	SGH80N60UFD	Units
V_{CES}	Collector-Emitter Voltage	600	V
V_{GES}	Gate-Emitter Voltage	± 20	V
I_C	Collector Current @ T_C = 25°C	80	A
	Collector Current @ T_C = 100°C	40	A
$I_{CM\ (1)}$	Pulsed Collector Current	220	A
I_F	Diode Continuous Forward Current @ T_C = 100°C	25	A
I_{FM}	Diode Maximum Forward Current	280	A
P_D	Maximum Power Dissipation @ T_C = 25°C	195	W
	Maximum Power Dissipation @ T_C = 100°C	78	W
T_J	Operating Junction Temperature	-55 to +150	°C
T_{stg}	Storage Temperature Range	-55 to +150	°C
T_L	Maximum Lead Temp. for Soldering Purposes,/8” from Case for 5 Seconds	300	°C

Notes :
(1) Repetitive rating : Pulse width limited by max. junction temperature

Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Units
$R_{\theta JC}$(IGBT)	Thermal Resistance, Junction-to-Case	--	0.64	°C/W
$R_{\theta JC}$(DIODE)	Thermal Resistance, Junction-to-Case	--	0.83	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	--	40	°C/W

Electrical Characteristics of the IGBT T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Off Characteristics						
BV_{CES}	Collector-Emitter Breakdown Voltage	V_{GE} = 0V, I_C = 250uA	600	--	--	V
$\Delta B_{VCES}/\Delta T_J$	Temperature Coefficient of Breakdown Voltage	V_{GE} = 0V, I_C = 1mA	--	0.6	--	V/°C
I_{CES}	Collector Cut-Off Current	$V_{CE} = V_{CES}$, V_{GE} = 0V	--	--	250	uA
I_{GES}	G-E Leakage Current	$V_{GE} = V_{GES}$, V_{CE} = 0V	--	--	± 100	nA
On Characteristics						
$V_{GE(th)}$	G-E Threshold Voltage	I_C = 40mA, $V_{CE} = V_{GE}$	3.5	4.5	6.5	V
$V_{CE(sat)}$	Collector to Emitter Saturation Voltage	I_C = 40A, V_{GE} = 15V	--	2.1	2.6	V
		I_C = 80A, V_{GE} = 15V	--	2.6	--	V
Dynamic Characteristics						
C_{ies}	Input Capacitance	V_{CE} = 30V, V_{GE} = 0V, f = 1MHz	--	2790	--	pF
C_{oes}	Output Capacitance		--	350	--	pF
C_{res}	Reverse Transfer Capacitance		--	100	--	pF
Switching Characteristics						
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 300 V, I_C = 40A, R_G = 5Ω, V_{GE} = 15V, Inductive Load, T_C = 25°C	--	23	--	ns
t_r	Rise Time		--	50	--	ns
$t_{d(off)}$	Turn-Off Delay Time		--	90	130	ns
t_f	Fall Time		--	50	150	ns
E_{on}	Turn-On Switching Loss		--	570	--	uJ
E_{off}	Turn-Off Switching Loss		--	590	--	uJ
E_{ts}	Total Switching Loss		--	1160	1500	uJ
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 300 V, I_C = 40A, R_G = 5Ω, V_{GE} = 15V, Inductive Load, T_C = 125°C	--	30	--	ns
t_r	Rise Time		--	55	--	ns
$t_{d(off)}$	Turn-Off Delay Time		--	150	200	ns
t_f	Fall Time		--	160	250	ns
E_{on}	Turn-On Switching Loss		--	630	--	uJ
E_{off}	Turn-Off Switching Loss		--	940	--	uJ
E_{ts}	Total Switching Loss		--	1580	2000	uJ
Q_g	Total Gate Charge	V_{CE} = 300 V, I_C = 40A, V_{GE} = 15V	--	175	250	nC
Q_{ge}	Gate-Emitter Charge		--	25	40	nC
Q_{gc}	Gate-Collector Charge		--	60	90	nC
L_e	Internal Emitter Inductance	Measured 5mm from PKG	--	14	--	nH

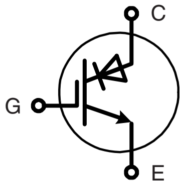
Electrical Characteristics of DIODE T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Units
V_{FM}	Diode Forward Voltage	I_F = 25A	T_C = 25°C	--	1.4	1.7	V
			T_C = 100°C	--	1.3	--	
t_{rr}	Diode Reverse Recovery Time	I_F = 25A, di/dt = 200A/us	T_C = 25°C	--	50	95	ns
			T_C = 100°C	--	105	--	
I_{rr}	Diode Peak Reverse Recovery Current		T_C = 25°C	--	4.5	10	A
			T_C = 100°C	--	8.5	--	
Q_{rr}	Diode Reverse Recovery Charge		T_C = 25°C	--	112	375	nC
			T_C = 100°C	--	420	--	

IXYS Advanced Technical Information **IXRP 15N120**
IXRA 15N120

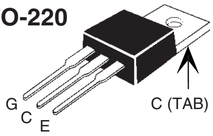
IGBT with Reverse Blocking capability

V_{CES} = ±1200 V
I_{C25} = 25 A
$V_{CE(sat)}$ = 2.5 V typ.

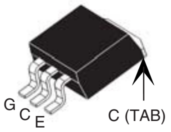


IXRP 15N120

TO-220



IXRA 15N120



TO-263

G = Gate, C = Collector,
E = Emitter, TAB = Collector

IGBT			
Symbol	**Conditions**	**Maximum Ratings**	
V_{CES}	T_{VJ} = 25°C to 150°C	±1200	V
V_{GES}	Continuous	± 20	V
I_{C25}	T_C = 25°C	25	A
I_{C90}	T_C = 90°C	15	A
I_{CM}	V_{GE} = 0/15 V; R_G = 47 Ω; T_{VJ} = 125°C	30	A
V_{CEK}	RBSOA; Clamped inductive load; L = 100 µH	600	V
SCSOA	600 V	10	µs
P_{tot}	T_C = 25°C	300	W

Symbol	**Conditions**	**Characteristic Values** (T_{VJ} = 25°C, unless otherwise specified) **min.**	**typ.**	**max.**	
$V_{CE(sat)}$	I_C = 10 A; V_{GE} = 15 V; T_{VJ} = 25°C		2.5	2.95	V
	T_{VJ} = 125°C		3.3		V
$V_{GE(th)}$	I_C = 1 mA; V_{GE} = V_{CE}	3		6	V
I_{CES}	V_{CE} = V_{CES}; V_{GE} = 0 V; T_{VJ} = 25°C			50	µA
	T_{VJ} = 125°C		1.0		mA
I_{GES}	V_{CE} = 0 V; V_{GE} = ± 20 V			500	nA
Q_{Gon}	V_{CE} = 120 V; V_{GE} = 15 V; I_C = 10 A		36		nC

Features

- IGBT with NPT (non punch through) structure
- reverse blocking capability
  - function of series diode monolithically integrated, no external series diode required
  - soft reverse recovery
- positive temperature coefficient of saturation voltage
- Epoxy of TO-247 package meets UL 94V-0

Applications

Converters requiring reverse blocking capability:

- current source inverters
- matrix converters
- bi-directional switches
- resonant converters
- induction heating
- auxiliary switches for soft switching in the main current path

0539

IGBT

Symbol	Conditions	Characteristic Values (T_{VJ} = 25°C, unless otherwise specified) typ.	
	External diode DSEP 30-12 - diagramm see Fig. 1		
$t_{d(on)}$	Inductive load; T_{VJ} = 125°C V_{CE} = 600 V; I_C = 10 A V_{GE} = ±15 V; R_G = 47 Ω	22	ns
t_r		18	ns
$t_{d(off)}$		210	ns
t_f		32	ns
E_{on}		1.1	mJ
E_{off}		0.13	mJ
	Internal diode - diagramm see Fig. 2		
$t_{d(on)}$	Inductive load; T_{VJ} = 125°C V_{CE} = 600 V; I_C = 10 A V_{GE} = ±15 V; R_G = 47 Ω	17.5	ns
t_r		16	ns
$t_{d(off)}$		212	ns
t_f		41	ns
E_{on}		3.0	mJ
E_{off}		0.1	mJ
$E_{rec\ int}$		0.65	mJ
I_{RM}	I_F = 10 A; di_C/dt = -800 A/µs; T_{VJ} = 125°C V_{CE} = -600 V; V_{GE} = 15 V	25	A
t_{rr}		300	ns
R_{thJC}		0.65	K/W

Component

Symbol	Conditions	Maximum Ratings	
T_{VJ}		-55...+150	°C
T_{stg}		-55...+125	°C
M_d	mounting torque	0.8 - 1.2	Nm
F_C	mounting force with clip	20...120	N

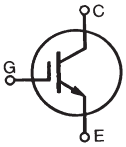
Symbol	Conditions	Characteristic Values typ.	
R_{thCH}	with heatsink compound	0.25	K/W
Weight		6	g

0539

GenX3™ 600V IGBT

IXGH72N60A3
IXGT72N60A3

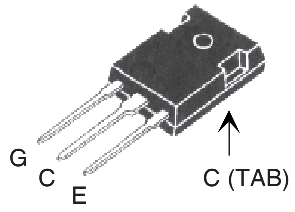
Ultra Low Vsat PT IGBT for
up to 5kHz switching



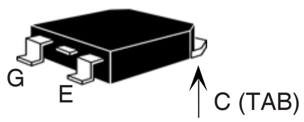
V_{CES} = 600V
I_{C110} = 72A
$V_{CE(sat)} \leq$ 1.35V
$t_{fi(typ)}$ = 250ns

Symbol	Test Conditions	Maximum Ratings	
V_{CES}	T_C = 25°C to 150°C	600	V
V_{CGR}	T_J = 25°C to 150°C, R_{GE} = 1MΩ	600	V
V_{GES}	Continuous	± 20	V
V_{GEM}	Transient	± 30	V
I_{C25}	T_C = 25°C (limited by leads)	75	A
I_{C110}	T_C = 110°C	72	A
I_{CM}	T_C = 25°C, 1ms	400	A
SSOA **(RBSOA)**	V_{GE} = 15V, T_{VJ} = 125°C, R_G = 3Ω Clamped inductive load @ ≤ 600V	I_{CM} = 150	A
P_C	T_C = 25°C	540	W
T_J		-55 ... +150	°C
T_{JM}		150	°C
T_{stg}		-55 ... +150	°C
T_L	1.6mm (0.062 in.) from case for 10s	300	°C
T_{SOLD}	Plastic body for 10 seconds	260	°C
M_d	Mounting torque (TO-247)	1.13/10	Nm/lb.in.
Weight	TO-247	6	g
	TO-268	4	g

TO-247 (IXGH)



TO-268 (IXGT)



G	= Gate	C	= Collector
E	= Emitter	TAB	= Collector

Features

- Optimized for low conduction losses
- Square RBSOA
- International standard packages

Advantages

- High power density
- Low gate drive requirement

Applications

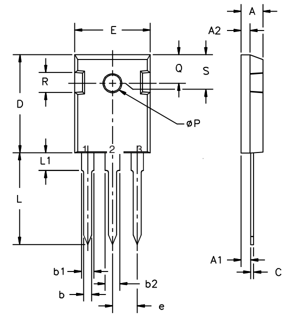
- Power Inverters
- UPS
- Motor Drives
- SMPS
- PFC Circuits
- Battery Chargers
- Welding Machines
- Lamp Ballasts
- Inrush Current Protection Circuits

Symbol	Test Conditions (T_J = 25°C unless otherwise specified)	Characteristic Values Min.	 Typ.	 Max.	
BV_{CES}	I_C = 250µA, V_{GE} = 0V	600			V
$V_{GE(th)}$	I_C = 250µA, V_{CE} = V_{GE}	3.0		5.0	V
I_{CES}	V_{CE} = V_{CES}			75	µA
	V_{GE} = 0V T_J = 125°C			750	µA
I_{GES}	V_{CE} = 0V, V_{GE} = ± 20V			±100	nA
$V_{CE(sat)}$	I_C = 60A, V_{GE} = 15V, Note 1			1.35	V

Symbol	Test Conditions (T_J = 25°C unless otherwise specified)	Characteristic Values Min.	Typ.	Max.	
g_{fs}	I_C = 60A, V_{CE} = 10V, Note 1	48	76		S
C_{ies}	V_{CE} = 25V, V_{GE} = 0V, f = 1MHz		6600		pF
C_{oes}			360		pF
C_{res}			80		pF
Q_g	$I_C = I_{C110}$, V_{GE} = 15V, $V_{CE} = 0.5 \bullet V_{CES}$		230		nC
Q_{ge}			40		nC
Q_{gc}			78		nC
$t_{d(on)}$	**Inductive load, T_J = 25°C** I_C = 50A, V_{GE} = 15V V_{CE} = 480V, R_G = 3Ω		31		ns
t_{ri}			34		ns
E_{on}			1.38		mJ
$t_{d(off)}$			320		ns
t_{fi}			250		ns
E_{off}			3.5		mJ
$t_{d(on)}$	**Inductive load, T_J = 125°C** I_C = 50A, V_{GE} = 15V V_{CE} = 480V, R_G = 3Ω		29		ns
t_{ri}			32		ns
E_{on}			2.6		mJ
$t_{d(off)}$			510		ns
t_{fi}			375		ns
E_{off}			6.5		mJ
R_{thJC}				0.23	°C/W
R_{thCS}			0.15		°C/W

Note 1: Pulse test, t ≤ 300μs, duty cycle, d ≤ 2%.

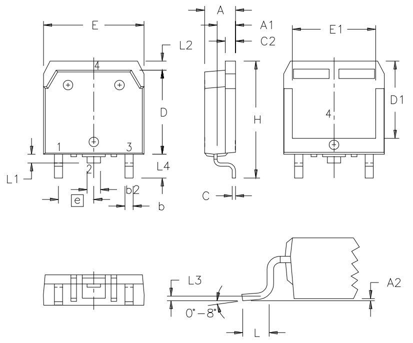
TO-247 AD Outline



Terminals: 1 - Gate 2 - Drain

Dim.	Millimeter Min.	Max.	Inches Min.	Max.
A	4.7	5.3	.185	.209
A_1	2.2	2.54	.087	.102
A_2	2.2	2.6	.059	.098
b	1.0	1.4	.040	.055
b_1	1.65	2.13	.065	.084
b_2	2.87	3.12	.113	.123
C	.4	.8	.016	.031
D	20.80	21.46	.819	.845
E	15.75	16.26	.610	.640
e	5.20	5.72	0.205	0.225
L	19.81	20.32	.780	.800
L1		4.50		.177
∅P	3.55	3.65	.140	.144
Q	5.89	6.40	0.232	0.252
R	4.32	5.49	.170	.216

TO-268 Outline



Terminals: 1 - Gate 2 - Drain

SYM	INCHES MIN	MAX	MILLIMETERS MIN	MAX
A	.193	.201	4.90	5.10
A1	.106	.114	2.70	2.90
A2	.001	.010	0.02	0.25
b	.045	.057	1.15	1.45
b2	.075	.083	1.90	2.10
C	.016	.026	0.40	0.65
C2	.057	.063	1.45	1.60
D	.543	.551	13.80	14.00
D1	.488	.500	12.40	12.70
E	.624	.632	15.85	16.05
E1	.524	.535	13.30	13.60
e	.215 BSC		5.45 BSC	
H	.736	.752	18.70	19.10
L	.094	.106	2.40	2.70
L1	.047	.055	1.20	1.40
L2	.039	.045	1.00	1.15
L3	.010 BSC		0.25 BSC	
L4	.150	.161	3.80	4.10

IXYS reserves the right to change limits, test conditions and dimensions.

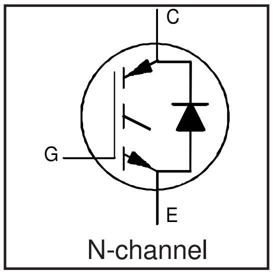
International
IOR Rectifier

PD- 94239A

IRGPS60B120KD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Motor Control Co-Pack IGBT



V_{CES} = 1200V

$V_{CE(on)}$ typ. = 2.50V

@ V_{GE} = 15V,

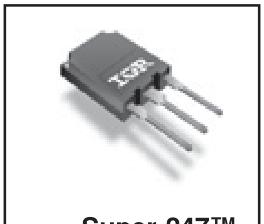
I_{CE} = 60A, Tj=25°C

Features

- Low VCE (on) Non Punch Through IGBT Technology.
- Low Diode VF.
- 10µs Short Circuit Capability.
- Square RBSOA.
- Ultrasoft Diode Reverse Recovery Characteristics.
- Positive VCE (on) Temperature Coefficient.
- Super-247 Package.

Benefits

- Benchmark Efficiency for Motor Control.
- Rugged Transient Performance.
- Low EMI.
- Significantly Less Snubber Required
- Excellent Current Sharing in Parallel Operation.



Super-247™

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	1200	V
I_C @ T_C = 25°C	Continuous Collector Current	105②	A
I_C @ T_C = 100°C	Continuous Collector Current	60	
I_{CM}	Pulsed Collector Current	240	
I_{LM}	Clamped Inductive Load Current ①	240	
I_F @ T_C = 25°C	Diode Continuous Forward Current	120	
I_F @ T_C = 100°C	Diode Continuous Forward Current	60	
I_{FM}	Diode Maximum Forward Current	240	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	595	W
P_D @ T_C = 100°C	Maximum Power Dissipation	238	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	—	—	0.20	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	—	—	0.41	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	—	0.24	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	—	40	
	Recommended Clip Force	20 (2)	—	—	N(kgf)
Wt	Weight	—	6.0 (0.21)	—	g (oz)
Le	Internal Emitter Inductance (5mm from package)	—	13	—	nH

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig.
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	1200	——	——	V	V_{GE} = 0V, I_C = 500µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	——	0.40	——	V/°C	V_{GE} = 0V, I_C = 1.0mA, (25°C-125°C)	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	——	2.33	2.50	V	I_C = 50A V_{GE} = 15V	5, 6
		——	2.50	2.75		I_C = 60A	7, 9
		——	2.79	3.1		I_C = 50A, T_J = 125°C	10
		——	3.04	3.5		I_C = 60A, T_J = 125°C	11
$V_{GE(th)}$	Gate Threshold Voltage	4.0	5.0	6.0		V_{CE} = V_{GE}, I_C = 250µA	9,10
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	——	-12	——	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA, (25°C-125°C)	11 ,12
g_{fe}	Forward Transconductance	——	34.4	——	S	V_{CE} = 50V, I_C = 60A, PW=80µs	
I_{CES}	Zero Gate Voltage Collector Current	——	——	500	µA	V_{GE} = 0V, V_{CE} = 1200V	
		——	650	1350		V_{GE} = 0V, V_{CE} = 1200V, T_J = 125°C	
V_{FM}	Diode Forward Voltage Drop	——	1.82	2.10	V	I_C = 50A	8
		——	1.93	2.20		I_C = 60A	
		——	1.96	2.20		I_C = 50A, T_J = 125°C	
		——	2.13	2.40		I_C = 60A, T_J = 125°C	
I_{GES}	Gate-to-Emitter Leakage Current	——	——	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig.
Qg	Total Gate Charge (turn-on)	——	340	510	nC	I_C = 60A	23
Qge	Gate - Emitter Charge (turn-on)	——	40	60		V_{CC} = 600V	CT1
Q_{gc}	Gate - Collector Charge (turn-on)	——	165	248		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	——	3214	4870	µJ	I_C = 60A, V_{CC} = 600V	CT4
E_{off}	Turn-Off Switching Loss	——	4783	5450		V_{GE} = 15V,R_G = 4.7Ω, L =200µH	WF1
E_{tot}	Total Switching Loss	——	8000	10320		Ls = 150nH T_J = 25°C	WF2
E_{on}	Turn-On Switching Loss	——	5032	6890	µJ	T_J = 125°C	13,15
E_{off}	Turn-Off Switching Loss	——	7457	8385		Energy losses include "tail" and	
E_{tot}	Total Switching Loss	——	12500	15275		diode reverse recovery.	
$t_{d(on)}$	Turn-On Delay Time	——	72	94	ns	I_C = 15A, V_{CC} = 600V	14, 16
t_r	Rise Time	——	32	45		V_{GE} = 15V, R_G = 4.7Ω L =200µH	CT4
$t_{d(off)}$	Turn-Off Delay Time	——	366	400		Ls = 150nH, T_J = 125°C	WF1
t_f	Fall Time	——	45	58			WF2
C_{ies}	Input Capacitance	——	4300	——	pF	V_{GE} = 0V	22
C_{oes}	Output Capacitance	——	395	——		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	——	160	——		f = 1.0MHz	
RBSOA	Reverse Bias Safe Operting Area		FULL SQUARE			T_J = 150°C, I_C = 240A, Vp =1200V V_{CC} = 1000V, V_{GE} = +15V to 0V R_G = 4.7Ω	4 CT2
SCSOA	Short Circuit Safe Operting Area	10	——	——	µs	T_J = 150°C, Vp =1200V V_{CC} = 900V, V_{GE} = +15V to 0V, R_G = 4.7Ω	CT3 WF4
Erec	Reverse Recovery energy of the diode	——	3346	——	µJ	T_J = 125°C	17,18,19
t_{rr}	Diode Reverse Recovery time	——	180	——	ns	V_{CC} = 600V, I_F = 60A, L =200µH	20, 21
I_{rr}	Diode Peak Reverse Recovery Current	——	50	——	A	V_{GE} = 15V,R_G = 4.7Ω, Ls = 150nH	CT4,WF3

International
IOR Rectifier

PD - 9.692

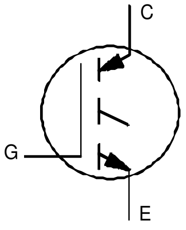
IRGPC40S

INSULATED GATE BIPOLAR TRANSISTOR

Standard Speed IGBT

Features

- Switching-loss rating includes all "tail" losses
- Optimized for line frequency operation (to 400Hz) See Fig. 1 for Current vs. Frequency curve



n-channel

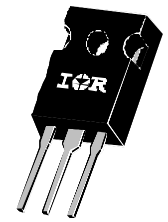
$V_{CES} = 600V$

$V_{CE(sat)} \leq 1.8V$

$@V_{GE} = 15V, I_C = 31A$

Description

Insulated Gate Bipolar Transistors (IGBTs) from International Rectifier have higher usable current densities than comparable bipolar transistors, while at the same time having simpler gate-drive requirements of the familiar power MOSFET. They provide substantial benefits to a host of high-voltage, high-current applications.



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	50	A
I_C @ T_C = 100°C	Continuous Collector Current	31	
I_{CM}	Pulsed Collector Current ①	240	
I_{LM}	Clamped Inductive Load Current ②	240	
V_{GE}	Gate-to-Emitter Voltage	±20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	------	------	0.77	°C/W
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	------	0.24	------	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	------	------	40	
Wt	Weight	------	6 (0.21)	------	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	----	----	V	V_{GE} = 0V, I_C = 250µA
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	20	----	----	V	V_{GE} = 0V, I_C = 1.0A
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	----	0.75	----	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	----	1.6	1.8	V	I_C = 31A, V_{GE} = 15V
		----	2.2	----		I_C = 60A, See Fig. 2, 5
		----	1.7	----		I_C = 31A, T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	----	5.5		V_{CE} = V_{GE}, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	----	-9.3	----	mV/°C	V_{CE} = V_{GE}, I_C = 250µA
g_{fe}	Forward Transconductance ⑤	12	21	----	S	V_{CE} = 100V, I_C = 31A
I_{CES}	Zero Gate Voltage Collector Current	----	----	250	µA	V_{GE} = 0V, V_{CE} = 600V
		----	----	1000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	----	----	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	----	62	90	nC	I_C = 31A
Q_{ge}	Gate - Emitter Charge (turn-on)	----	10	15		V_{CC} = 400V See Fig. 8
Q_{gc}	Gate - Collector Charge (turn-on)	----	27	40		V_{GE} = 15V
$t_{d(on)}$	Turn-On Delay Time	----	28	----	ns	T_J = 25°C
t_r	Rise Time	----	50	----		I_C = 31A, V_{CC} = 480V
$t_{d(off)}$	Turn-Off Delay Time	----	1100	1500		V_{GE} = 15V, R_G = 10Ω
t_f	Fall Time	----	620	1100		Energy losses include "tail"
E_{on}	Turn-On Switching Loss	----	1.0	----	mJ	
E_{off}	Turn-Off Switching Loss	----	12	----		See Fig. 9, 10, 11, 14
E_{ts}	Total Switching Loss	----	13	20		
$t_{d(on)}$	Turn-On Delay Time	----	29	----	ns	T_J = 150°C,
t_r	Rise Time	----	53	----		I_C = 31A, V_{CC} = 480V
$t_{d(off)}$	Turn-Off Delay Time	----	1600	----		V_{GE} = 15V, R_G = 10Ω
t_f	Fall Time	----	1200	----		Energy losses include "tail"
E_{ts}	Total Switching Loss	----	22	----	mJ	See Fig. 10, 14
L_E	Internal Emitter Inductance	----	7.5	----	nH	Measured 5mm from package
C_{ies}	Input Capacitance	----	1600	----	pF	V_{GE} = 0V
C_{oes}	Output Capacitance	----	140	----		V_{CC} = 30V See Fig. 7
C_{res}	Reverse Transfer Capacitance	----	20	----		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE}=20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC}=80%(V_{CES}), V_{GE}=20V, L=10µH, R_G= 10Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

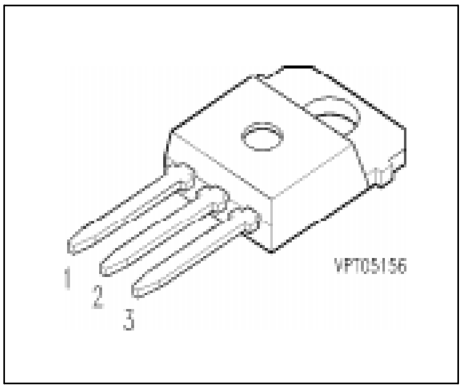
④ Pulse width ≤ 80µs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0µs, single shot.

IGBT With Antiparallel Diode

Preliminary data

- Low forward voltage drop
- High switching speed
- Low tail current
- Latch-up free
- Including fast free-wheel diode



Pin 1	Pin 2	Pin 3
G	C	E

Type	V_{CE}	I_C	Package	Ordering Code
BUP 306D	1200V	23A	TO-218 AB	Q67040-A4222-A2

Maximum Ratings

Parameter	Symbol	Values	Unit
Collector-emitter voltage	V_{CE}	1200	V
Collector-gate voltage	V_{CGR}		
R_{GE} = 20 kΩ		1200	
Gate-emitter voltage	V_{GE}	± 20	
DC collector current	I_C		A
T_C = 25 °C		23	
T_C = 90 °C		15	
Pulsed collector current, t_p = 1 ms	I_{Cpuls}		
T_C = 25 °C		46	
T_C = 90 °C		30	
Diode forward current	I_F		
T_C = 90 °C		18	
Pulsed diode current, t_p = 1 ms	I_{Fpuls}		
T_C = 25 °C		108	
Power dissipation	P_{tot}		W
T_C = 25 °C		165	
Chip or operating temperature	T_j	-55 ... + 150	°C
Storage temperature	T_{stg}	-55 ... + 150	

Maximum Ratings

Parameter	Symbol	Values	Unit
DIN humidity category, DIN 40 040	-	E	-
IEC climatic category, DIN IEC 68-1	-	55 / 150 / 56	

Thermal Resistance

Thermal resistance, chip case	R_{thJC}	0.63	K/W
Diode thermal resistance, chip case	R_{thJCD}	1.25	

Electrical Characteristics, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Values			Unit
		min.	typ.	max.	
Static Characteristics					
Gate threshold voltage $V_{GE} = V_{CE}$, I_C = 0.7 mA	$V_{GE(th)}$	4.5	5.5	6.5	V
Collector-emitter saturation voltage	$V_{CE(sat)}$				
V_{GE} = 15 V, I_C = 10 A, T_j = 25 °C		-	2.8	3.3	
V_{GE} = 15 V, I_C = 10 A, T_j = 125 °C		-	3.8	4.3	
Zero gate voltage collector current V_{CE} = 1200 V, V_{GE} = 0 V, T_j = 25 °C	I_{CES}	-	-	0.4	mA
Gate-emitter leakage current V_{GE} = 20 V, V_{CE} = 0 V	I_{GES}	-	-	100	nA
AC Characteristics					
Transconductance V_{CE} = 20 V, I_C = 10 A	g_{fs}	3.5	5.5	-	S
Input capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{iss}	-	1300	1750	pF
Output capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{oss}	-	100	150	
Reverse transfer capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{rss}	-	50	75	

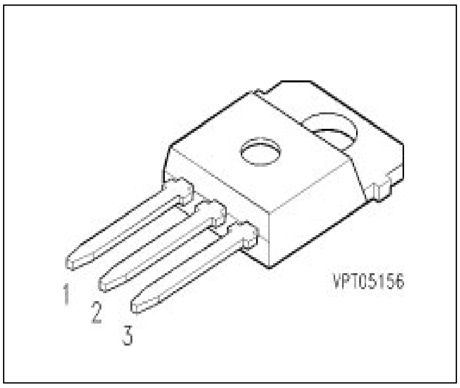
Electrical Characteristics, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Values			Unit
		min.	typ.	max.	
Switching Characteristics, Inductive Load at T_j = 125 °C					
Turn-on delay time V_{CC} = 600 V, V_{GE} = 15 V, I_C = 10 A R_{Gon} = 47 Ω	$t_{d(on)}$	-	40	60	ns
Rise time V_{CC} = 600 V, V_{GE} = 15 V, I_C = 10 A R_{Gon} = 47 Ω	t_r	-	30	50	
Turn-off delay time V_{CC} = 600 V, V_{GE} = -15 V, I_C = 10 A R_{Goff} = 47 Ω	$t_{d(off)}$	-	200	300	
Fall time V_{CC} = 600 V, V_{GE} = -15 V, I_C = 10 A R_{Goff} = 47 Ω	t_f	-	20	30	
Total turn-off loss energy V_{CC} = 600 V, V_{GE} = -15 V, I_C = 10 A R_{Goff} = 47 Ω	E_{off}	-	1.3	-	mWs
Free-Wheel Diode					
Diode forward voltage	V_F				V
I_F = 15 A, V_{GE} = 0 V, T_j = 25 °C		-	2.4	2.9	
I_F = 15 A, V_{GE} = 0 V, T_j = 125 °C		-	1.9	-	
Reverse recovery time I_F = 15 A, V_R = -600 V, V_{GE} = 0 V di_F/dt = -800 A/µs	t_{rr}				ns
T_j = 25 °C		-	-	-	
T_j = 125 °C		-	100	150	
Reverse recovery charge I_F = 15 A, V_R = 0 V, di_F/dt = -800 A/µs	Q_{rr}				µC
I_F = 15 A, V_{GE} = 0 V, T_j = 25 °C		-	1	1.8	
V_R = 0 V, di_F/dt = -800 A/µs, T_j = 125 °C		-	3	5.4	

IGBT

Preliminary data

- Low forward voltage drop
- High switching speed
- Low tail current
- Latch-up free
- Avalanche rated



Pin 1	Pin 2	Pin 3
G	C	E

Type	V_{CE}	I_C	Package	Ordering Code
BUP 304	1000V	35A	TO-218 AB	Q67078-A4200-A2

Maximum Ratings

Parameter	Symbol	Values	Unit
Collector-emitter voltage	V_{CE}	1000	V
Collector-gate voltage R_{GE} = 20 kΩ	V_{CGR}	1000	
Gate-emitter voltage	V_{GE}	± 20	
DC collector current	I_C		A
T_C = 25 °C		35	
T_C = 90 °C		23	
Pulsed collector current, t_p = 1 ms	I_{Cpuls}		
T_C = 25 °C		70	
T_C = 90 °C		46	
Avalanche energy, single pulse I_C = 15 A, V_{CC} = 50 V, R_{GE} = 25 Ω L = 200 µH, T_j = 25 °C	E_{AS}	23	mJ
Power dissipation T_C = 25 °C	P_{tot}	310	W
Chip or operating temperature	T_j	-55 ... + 150	°C
Storage temperature	T_{stg}	-55 ... + 150	

Maximum Ratings

Parameter	Symbol	Values	Unit
DIN humidity category, DIN 40 040	-	E	-
IEC climatic category, DIN IEC 68-1	-	55 / 150 / 56	

Thermal Resistance

Thermal resistance, chip case	R_{thJC}	≤ 0.4	K/W

Electrical Characteristics, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Values			Unit
		min.	typ.	max.	
Static Characteristics					
Gate threshold voltage	$V_{GE(th)}$				V
$V_{GE} = V_{CE}$, I_C = 0.1 mA		4.5	5.5	6.5	
Collector-emitter saturation voltage	$V_{CE(sat)}$				
V_{GE} = 15 V, I_C = 15 A, T_j = 25 °C		-	2.8	3.3	
V_{GE} = 15 V, I_C = 15 A, T_j = 125 °C		-	3.8	4.3	
V_{GE} = 15 V, I_C = 15 A, T_j = 150 °C		-	4	4.5	
Zero gate voltage collector current	I_{CES}				µA
V_{CE} = 1000 V, V_{GE} = 0 V, T_j = 25 °C		-	1	250	
V_{CE} = 1000 V, V_{GE} = 0 V, T_j = 125 °C		-	-	1000	
Gate-emitter leakage current	I_{GES}				nA
V_{GE} = 20 V, V_{CE} = 0 V		-	0.1	100	
AC Characteristics					
Transconductance	g_{fs}				S
V_{CE} = 20 V, I_C = 15 A		5.5	8	-	
Input capacitance	C_{iss}				pF
V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz		-	2000	2700	
Output capacitance	C_{oss}				
V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz		-	160	240	
Reverse transfer capacitance	C_{rss}				
V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz		-	65	100	

Electrical Characteristics, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Values			Unit
		min.	typ.	max.	
Switching Characteristics, Inductive Load at T_j = 125 °C					
Turn-on delay time V_{CC} = 600 V, V_{GE} = 15 V, I_C = 15 A R_{Gon} = 33 Ω	$t_{d(on)}$	-	30	45	ns
Rise time V_{CC} = 600 V, V_{GE} = 15 V, I_C = 15 A R_{Gon} = 33 Ω	t_r	-	22	35	
Turn-off delay time V_{CC} = 600 V, V_{GE} = -15 V, I_C = 15 A R_{Goff} = 33 Ω	$t_{d(off)}$	-	230	310	
Fall time V_{CC} = 600 V, V_{GE} = -15 V, I_C = 15 A R_{Goff} = 33 Ω	t_f	-	20	28	
Total turn-off loss energy V_{CC} = 600 V, V_{GE} = -15 V, I_C = 15 A R_{Goff} = 33 Ω	E_{off}	-	1.7	-	mWs

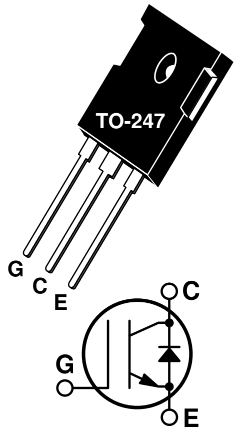
ADVANCED POWER TECHNOLOGY®

APT30GT60BRD

600V 55A

Thunderbolt IGBT™ & FRED

The Thunderbolt IGBT™ is a new generation of high voltage power IGBTs. Using Non-Punch Through Technology the Thunderbolt IGBT™ combined with an APT free-wheeling ultraFast Recovery Epitaxial Diode (FRED) offers superior ruggedness and ultrafast switching speed.



- **Low Forward Voltage Drop**
- **Low Tail Current**
- **RBSOA and SCSOA Rated**
- **Ultrafast Soft Recovery Antiparallel Diode**
- **High Freq. Switching to 150KHz**
- **Ultra Low Leakage Current**

MAXIMUM RATINGS (IGBT) All Ratings: $T_C = 25°C$ unless otherwise specified.

Symbol	Parameter	APT30GT60BRD	UNIT
V_{CES}	Collector-Emitter Voltage	600	Volts
V_{CGR}	Collector-Gate Voltage ($R_{GE} = 20K\Omega$)	600	
V_{GE}	Gate-Emitter Voltage	±20	
I_{C1}	Continuous Collector Current @ $T_C = 25°C$	55	Amps
I_{C2}	Continuous Collector Current @ $T_C = 110°C$	30	
I_{CM1}	Pulsed Collector Current ① @ $T_C = 25°C$	110	
I_{CM2}	Pulsed Collector Current ① @ $T_C = 110°C$	60	
P_D	Total Power Dissipation	200	Watts
T_J,T_{STG}	Operating and Storage Junction Temperature Range	-55 to 150	°C
T_L	Max. Lead Temp. for Soldering: 0.063" from Case for 10 Sec.	300	

STATIC ELECTRICAL CHARACTERISTICS (IGBT)

Symbol	Characteristic / Test Conditions	MIN	TYP	MAX	UNIT
BV_{CES}	Collector-Emitter Breakdown Voltage ($V_{GE} = 0V$, $I_C = 0.5mA$)	600			Volts
$V_{GE}(TH)$	Gate Threshold Voltage ($V_{CE} = V_{GE}$, $I_C = 700\mu A$, $T_j = 25°C$)	3	4	5	
$V_{CE}(ON)$	Collector-Emitter On Voltage ($V_{GE} = 15V$, $I_C = I_{C2}$, $T_j = 25°C$)	1.6	2.0	2.5	
	Collector-Emitter On Voltage ($V_{GE} = 15V$, $I_C = I_{C2}$, $T_j = 150°C$)			2.8	
I_{CES}	Collector Cut-off Current ($V_{CE} = V_{CES}$, $V_{GE} = 0V$, $T_j = 25°C$)			250	μA
	Collector Cut-off Current ($V_{CE} = V_{CES}$, $V_{GE} = 0V$, $T_j = 150°C$)			2000	
I_{GES}	Gate-Emitter Leakage Current ($V_{GE} = ±20V$, $V_{CE} = 0V$)			±100	nA

CAUTION: These Devices are Sensitive to Electrostatic Discharge. Proper Handling Procedures Should Be Followed.

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DYNAMIC CHARACTERISTICS (IGBT)

Symbol	Characteristic	Test Conditions	MIN	TYP	MAX	UNIT
C_{ies}	Input Capacitance	**Capacitance** $V_{GE} = 0V$ $V_{CE} = 25V$ f = 1 MHz		1600		pF
C_{oes}	Output Capacitance			250		
C_{res}	Reverse Transfer Capacitance			90		
Q_g	Total Gate Charge ②	**Gate Charge** $V_{GE} = 15V$ $V_{CC} = 0.5V_{CES}$ $I_C = I_{C2}$		140		nC
Q_{ge}	Gate-Emitter Charge			60		
Q_{gc}	Gate-Collector ("Miller") Charge			12		
t_d(on)	Turn-on Delay Time	**Resistive Switching (25°C)** $V_{GE} = 15V$ $V_{CC} = 0.8V_{CES}$ $I_C = I_{C2}$ $R_G = 10\Omega$		14		ns
t_r	Rise Time			55		
t_d(off)	Turn-off Delay Time			200		
t_f	Fall Time			140		
t_d(on)	Turn-on Delay Time	**Inductive Switching (150°C)** V_{CLAMP}(Peak) = $0.66V_{CES}$ $V_{GE} = 15V$ $I_C = I_{C2}$ $R_G = 10\Omega$ $T_J = +150°C$		18		ns
t_r	Rise Time			30		
t_d(off)	Turn-off Delay Time			300		
t_f	Fall Time			25		
E_{on}	Turn-on Switching Energy ③			.5		mJ
E_{off}	Turn-off Switching Energy			1.2		
E_{ts}	Total Switching Losses ③			1.7		
t_d(on)	Turn-on Delay Time	**Inductive Switching (25°C)** V_{CLAMP}(Peak) = $0.66V_{CES}$ $V_{GE} = 15V$ $I_C = I_{C2}$ $R_G = 10\Omega$ $T_J = +25°C$		18		ns
t_r	Rise Time			30		
t_d(off)	Turn-off Delay Time			260		
t_f	Fall Time			20		
E_{ts}	Total Switching Losses ③			1.3		mJ
gfe	Forward Transconductance	$V_{CE} = 20V$, $I_C = I_{C2}$	6			S

THERMAL AND MECHANICAL CHARACTERISTICS (IGBT and FRED)

Symbol	Characteristic	MIN	TYP	MAX	UNIT
$R_{\Theta JC}$	Junction to Case (IGBT)			0.63	°C/W
	Junction to Case (FRED)			0.90	
$R_{\Theta JA}$	Junction to Ambient			40	
W_T	Package Weight		0.22		oz
			6.1		gm
Torque	Mounting Torque using a 6-32 or 3mm Binding Head Machine Screw			10	lb•in
				1.1	N•m

① Repetitive Rating: Pulse width limited by maximum junction temperature.

② See MIL-STD-750 Method 3471

③ Switching losses include the FRED and IGBT.

APT Reserves the right to change, without notice, the specifications and information contained herein.

ULTRAFAST SOFT RECOVERY PARALLEL DIODE

MAXIMUM RATINGS (FRED)

All Ratings: T_C = 25°C unless otherwise specified.

Symbol	Characteristic / Test Conditions	APT30GT60BRD	UNIT
V_R	Maximum D.C. Reverse Voltage	600	Volts
V_{RRM}	Maximum Peak Repetitive Reverse Voltage		
V_{RWM}	Maximum Working Peak Reverse Voltage		
$I_F(AV)$	Maximum Average Forward Current (T_C = 100°C, Duty Cycle = 0.5)	30	Amps
$I_F(RMS)$	RMS Forward Current	70	
I_{FSM}	Non-Repetitive Forward Surge Current (T_J = 45°C, 8.3ms)	320	

STATIC ELECTRICAL CHARACTERISTICS (FRED)

Symbol	Characteristic / Test Conditions		MIN	TYP	MAX	UNIT
V_F	Maximum Forward Voltage	I_F = 30A			1.8	Volts
		I_F = 60A		1.5		
		I_F = 30A, T_J = 150°C			1.6	
I_{RM}	Maximum Reverse Leakage Current	$V_R = V_R$ Rated			250	μA
		$V_R = V_R$ Rated, T_J = 125°C			500	
L_S	Series Inductance (Lead to Lead 5mm from Base)			10		nH

DYNAMIC CHARACTERISTICS (FRED)

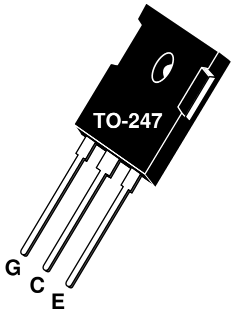
Symbol	Characteristic		MIN	TYP	MAX	UNIT
t_{rr1}	Reverse Recovery Time, I_F = 1.0A, di_F/dt = -15A/μs, V_R = 30V, T_J = 25°C			50	65	ns
t_{rr2}	Reverse Recovery Time	T_J = 25°C		50		
t_{rr3}	I_F = 30A, di_F/dt = -240A/μs, V_R = 350V	T_J = 100°C		80		
t_{fr1}	Forward Recovery Time	T_J = 25°C		155		
t_{fr2}	I_F = 30A, di_F/dt = 240A/μs, V_R = 350V	T_J = 100°C		155		
I_{RRM1}	Reverse Recovery Current	T_J = 25°C		4	10	Amps
I_{RRM2}	I_F = 30A, di_F/dt = -240A/μs, V_R = 350V	T_J = 100°C		7.5	15	
Q_{rr1}	Recovery Charge	T_J = 25°C		100		nC
Q_{rr2}	I_F = 30A, di_F/dt = -240A/μs, V_R = 350V	T_J = 100°C		300		
V_{fr1}	Forward Recovery Voltage	T_J = 25°C		5		Volts
V_{fr2}	I_F = 30A, di_F/dt = 240A/μs, V_R = 350V	T_J = 100°C		5		
diM/dt	Rate of Fall of Recovery Current	T_J = 25°C		400		A/μs
	I_F = 30A, di_F/dt = -240A/μs, V_R = 350V (See Figure 10)	T_J = 100°C		200		

ADVANCED POWER TECHNOLOGY®

APT15GP60BDF1

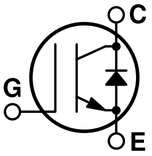
600V

POWER MOS 7® IGBT



The POWER MOS 7® IGBT is a new generation of high voltage power IGBTs. Using Punch Through Technology this IGBT is ideal for many high frequency, high voltage switching applications and has been optimized for high frequency switchmode power supplies.

- **Low Conduction Loss**
- **Low Gate Charge**
- **Ultrafast Tail Current shutoff**
- **100 kHz operation @ 400V, 19A**
- **200 kHz operation @ 400V, 12A**
- **SSOA rated**



MAXIMUM RATINGS

All Ratings: T_C = 25°C unless otherwise specified.

Symbol	Parameter	APT15GP60BDF1	UNIT
V_{CES}	Collector-Emitter Voltage	600	Volts
V_{GE}	Gate-Emitter Voltage	±20	
V_{GEM}	Gate-Emitter Voltage Transient	±30	
I_{C1}	Continuous Collector Current @ T_C = 25°C	56	Amps
I_{C2}	Continuous Collector Current @ T_C = 110°C	27	
I_{CM}	Pulsed Collector Current ① @ T_C = 25°C	65	
SSOA	Switching Safe Operating Area @ T_J = 150°C	65A @ 600V	
P_D	Total Power Dissipation	250	Watts
T_J,T_{STG}	Operating and Storage Junction Temperature Range	-55 to 150	°C
T_L	Max. Lead Temp. for Soldering: 0.063" from Case for 10 Sec.	300	

STATIC ELECTRICAL CHARACTERISTICS

Symbol	Characteristic / Test Conditions	MIN	TYP	MAX	UNIT
BV_{CES}	Collector-Emitter Breakdown Voltage (V_{GE} = 0V, I_C = 500μA)	600			Volts
$V_{GE(TH)}$	Gate Threshold Voltage (V_{CE} = V_{GE}, I_C = 1mA, T_j = 25°C)	3	4.5	6	
$V_{CE(ON)}$	Collector-Emitter On Voltage (V_{GE} = 15V, I_C = 15A, T_j = 25°C)		2.2	2.7	
	Collector-Emitter On Voltage (V_{GE} = 15V, I_C = 15A, T_j = 125°C)		2.1		
I_{CES}	Collector Cut-off Current (V_{CE} = 600V, V_{GE} = 0V, T_j = 25°C) ②			500	μA
	Collector Cut-off Current (V_{CE} = 600V, V_{GE} = 0V, T_j = 125°C) ②			3000	
I_{GES}	Gate-Emitter Leakage Current (V_{GE} = ±20V)			±100	nA

CAUTION: These Devices are Sensitive to Electrostatic Discharge. Proper Handling Procedures Should Be Followed.

APT Website - http://www.advancedpower.com

DYNAMIC CHARACTERISTICS

Symbol	Characteristic	Test Conditions	MIN	TYP	MAX	UNIT
C_{ies}	Input Capacitance	**Capacitance** $V_{GE} = 0V$, $V_{CE} = 25V$ f = 1 MHz		1685		pF
C_{oes}	Output Capacitance			210		
C_{res}	Reverse Transfer Capacitance			15		
V_{GEP}	Gate-to-Emitter Plateau Voltage	**Gate Charge** $V_{GE} = 15V$ $V_{CE} = 300V$ $I_C = 15A$		7.5		V
Q_g	Total Gate Charge ③			55		nC
Q_{ge}	Gate-Emitter Charge			12		
Q_{gc}	Gate-Collector ("Miller") Charge			15		
SSOA	Switching Safe Operating Area	$T_J = 150°C$, $R_G = 5\Omega$, $V_{GE} =$ 15V, L = 100µH, $V_{CE} = 600V$	65			A
$t_{d(on)}$	Turn-on Delay Time	**Inductive Switching (25°C)** $V_{CC} = 400V$ $V_{GE} = 15V$ $I_C = 15A$ $R_G = 5\Omega$ $T_J = +25°C$		8		ns
t_r	Current Rise Time			12		
$t_{d(off)}$	Turn-off Delay Time			29		
t_f	Current Fall Time			58		
E_{on1}	Turn-on Switching Energy ④			130		µJ
E_{on2}	Turn-on Switching Energy (Diode)⑤			152		
E_{off}	Turn-off Switching Energy ⑥			121		
$t_{d(on)}$	Turn-on Delay Time	**Inductive Switching (125°C)** $V_{CC} = 400V$ $V_{GE} = 15V$ $I_C = 15A$ $R_G = 5\Omega$ $T_J = +125°C$		8		ns
t_r	Current Rise Time			12		
$t_{d(off)}$	Turn-off Delay Time			69		
t_f	Current Fall Time			88		
E_{on1}	Turn-on Switching Energy ④			130		µJ
E_{on2}	Turn-on Switching Energy (Diode) ⑤			267		
E_{off}	Turn-off Switching Energy ⑥			268		

THERMAL AND MECHANICAL CHARACTERISTICS

Symbol	Characteristic	MIN	TYP	MAX	UNIT
$R_{\Theta JC}$	Junction to Case (IGBT)			.50	°C/W
$R_{\Theta JC}$	Junction to Case (DIODE)			1.31	
W_T	Package Weight			5.90	gm

① Repetitive Rating: Pulse width limited by maximum junction temperature.

② For Combi devices, I_{ces} includes both IGBT and FRED leakages

③ See MIL-STD-750 Method 3471.

④ E_{on1} is the clamped inductive turn-on-energy of the IGBT only, without the effect of a commutating diode reverse recovery current adding to the IGBT turn-on loss. (See Figure 24.)

⑤ E_{on2} is the clamped inductive turn-on energy that includes a commutating diode reverse recovery current in the IGBT turn-on switching loss. A Combi device is used for the clamping diode as shown in the E_{on2} test circuit. (See Figures 21, 22.)

⑥ E_{off} is the clamped inductive turn-off energy measured in accordance with JEDEC standard JESD24-1. (See Figures 21, 23.)

Data Sheet **January 2000** **File Number 4140.2**

6A, 600V, UFS Series N-Channel IGBT with Anti-Parallel Hyperfast Diodes

The HGTP3N60C3D, and HGT1S3N60C3DS are MOS gated high voltage switching devices combining the best features of MOSFETs and bipolar transistors. These devices have the high input impedance of a MOSFET and the low on-state conduction loss of a bipolar transistor. The much lower on-state voltage drop varies only moderately between 25^{o}C and 150^{o}C. The IGBT used is the development type TA49113. The diode used in anti-parallel with the IGBT is the development type TA49055.

The IGBT is ideal for many high voltage switching applications operating at moderate frequencies where low conduction losses are essential.

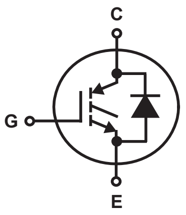
Formerly Developmental Type TA49119.

Ordering Information

PART NUMBER	PACKAGE	BRAND
HGTP3N60C3D	TO-220AB	G3N60C3D
HGT1S3N60C3DS	TO-263AB	G3N60C3D

NOTE: When ordering, use the entire part number. Add the suffix 9A to obtain the TO-263AB variant in tape and reel, i.e., HGT1S3N60C3DS9A.

Symbol

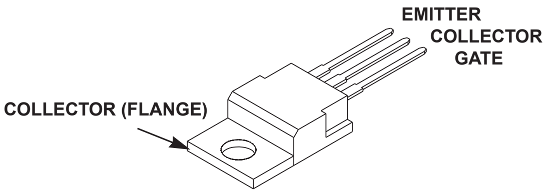


Features

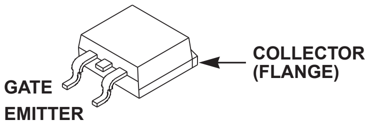
- 6A, 600V at T_C = 25^{o}C
- 600V Switching SOA Capability
- Typical Fall Time. . . . . 130ns at T_J = 150^{o}C
- Short Circuit Rating
- Low Conduction Loss
- Hyperfast Anti-Parallel Diode

Packaging

JEDEC TO-220AB



JEDEC TO-263AB



INTERSIL CORPORATION IGBT PRODUCT IS COVERED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS

4,364,073 4,417,385 4,430,792 4,443,931 4,466,176 4,516,143 4,532,534 4,587,713
4,598,461 4,605,948 4,620,211 4,631,564 4,639,754 4,639,762 4,641,162 4,644,637
4,682,195 4,684,413 4,694,313 4,717,679 4,743,952 4,783,690 4,794,432 4,801,986
4,803,533 4,809,045 4,809,047 4,810,665 4,823,176 4,837,606 4,860,080 4,883,767
4,888,627 4,890,143 4,901,127 4,904,609 4,933,740 4,963,951 4,969,027

CAUTION: These devices are sensitive to electrostatic discharge; follow proper ESD Handling Procedures.

Absolute Maximum Ratings $T_C = 25^oC$, Unless Otherwise Specified

		HGTP3N60C3D, HGT1S3N60C3DS	UNITS
Collector to Emitter Voltage	BV_{CES}	600	V
Collector Current Continuous			
At $T_C = 25^oC$	I_{C25}	6	A
At $T_C = 110^oC$	I_{C110}	3	A
Collector Current Pulsed (Note 1)	I_{CM}	24	A
Gate to Emitter Voltage Continuous	V_{GES}	±20	V
Gate to Emitter Voltage Pulsed	V_{GEM}	±30	V
Switching Safe Operating Area at $T_J = 150^oC$ (Figure 14)	SSOA	18A at 480V	
Power Dissipation Total at $T_C = 25^oC$	P_D	33	W
Power Dissipation Derating $T_C > 25^oC$		0.27	W/^oC
Operating and Storage Junction Temperature Range	T_J, T_{STG}	-40 to 150	^oC
Maximum Lead Temperature for Soldering	T_L	260	^oC
Short Circuit Withstand Time (Note 2) at $V_{GE} = 10V$ (Figure 6)	t_{SC}	8	μs

CAUTION: Stresses above those listed in “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTES:

1. Repetitive Rating: Pulse width limited by maximum junction temperature.
2. $V_{CE(PK)} = 360V$, $T_J = 125^oC$, $R_G = 82\Omega$.

Electrical Specifications $T_C = 25^oC$, Unless Otherwise Specified

PARAMETER	SYMBOL	TEST CONDITIONS		MIN	TYP	MAX	UNITS
Collector to Emitter Breakdown Voltage	BV_{CES}	$I_C = 250\mu A$, $V_{GE} = 0V$		600	-	-	V
Collector to Emitter Leakage Current	I_{CES}	$V_{CE} = BV_{CES}$	$T_C = 25^oC$	-	-	250	μA
		$V_{CE} = BV_{CES}$	$T_C = 150^oC$	-	-	2.0	mA
Collector to Emitter Saturation Voltage	$V_{CE(SAT)}$	$I_C = I_{C110}$, $V_{GE} = 15V$	$T_C = 25^oC$	-	1.65	2.0	V
			$T_C = 150^oC$	-	1.85	2.2	V
Gate to Emitter Threshold Voltage	$V_{GE(TH)}$	$I_C = 250\mu A$, $V_{CE} = V_{GE}$	$T_C = 25^oC$	3.0	5.5	6.0	V
Gate to Emitter Leakage Current	I_{GES}	$V_{GE} = \pm 25V$		-	-	±250	nA
Switching SOA	SSOA	$T_J = 150^oC$ $R_G = 82\Omega$ $V_{GE} = 15V$ L = 1mH	$V_{CE(PK)} = 480V$	18	-	-	A
			$V_{CE(PK)} = 600V$	2	-	-	A
Gate to Emitter Plateau Voltage	V_{GEP}	$I_C = I_{C110}$, $V_{CE} = 0.5\ BV_{CES}$		-	8.3	-	V
On-State Gate Charge	$Q_{G(ON)}$	IC = IC110, VCE = 0.5 BVCES	$V_{GE} = 15V$	-	10.8	13.5	nC
			$V_{GE} = 20V$	-	13.8	17.3	nC
Current Turn-On Delay Time	$t_{d(ON)I}$	$T_J = 150^oC$ $I_{CE} = I_{C110}$ $V_{CE(PK)} = 0.8\ BV_{CES}$ $V_{GE} = 15V$ $R_G = 82\Omega$ L = 1mH		-	5	-	ns
Current Rise Time	t_{rI}			-	10	-	ns
Current Turn-Off Delay Time	$t_{d(OFF)I}$			-	325	400	ns
Current Fall Time	t_{fI}			-	130	275	ns
Turn-On Energy	E_{ON}			-	85	-	μJ
Turn-Off Energy (Note 3)	E_{OFF}			-	245	-	μJ
Diode Forward Voltage	V_{EC}	$I_{EC} = 3A$		-	2.0	2.5	V
Diode Reverse Recovery Time	t_{RR}	$I_{EC} = 3A$, $dI_{EC}/dt = 200A/\mu s$		-	22	28	ns
		$I_{EC} = 1A$, $dI_{EC}/dt = 200A/\mu s$		-	17	22	ns
Thermal Resistance	$R_{\theta JC}$	IGBT		-	-	3.75	^oC/W
		Diode		-	-	3.0	^oC/W

NOTE:

3. Turn-Off Energy Loss (E_{OFF}) is defined as the integral of the instantaneous power loss starting at the trailing edge of the input pulse and ending at the point where the collector current equals zero ($I_{CE} = 0A$). The HGTP3N60C3D and HGT1S3N60C3DS were tested per JEDEC standard No. 24-1 Method for Measurement of Power Device Turn-Off Switching Loss. This test method produces the true total Turn-Off Energy Loss. Turn-On losses include diode losses.

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SMPS Series N-Channel IGBT with Anti-Parallel Hyperfast Diode

600 V

HGTG7N60A4D, HGTP7N60A4D, HGT1S7N60A4DS

The HGTG7N60A4D, HGTP7N60A4D and HGT1S7N60A4DS are MOS gated high voltage switching devices combining the best features of MOSFETs and bipolar transistors. These devices have the high input impedance of a MOSFET and the low on−state conduction loss of a bipolar transistor. The much lower on−state voltage drop varies only moderately between 25°C and 150°C. The IGBT used is the development type TA49331. The diode used in anti−parallel is the development type TA49370.

This IGBT is ideal for many high voltage switching applications operating at high frequencies where low conduction losses are essential. This device has been optimized for high frequency switch mode power supplies.

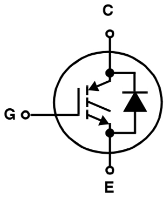
Formerly Developmental Type TA49333.

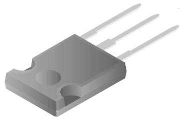
Features

- >100 kHz Operation at 390 V, 7 A
- 200 kHz Operation at 390 V, 5 A
- 600 V Switching SOA Capability
- Typical Fall Time: 75 ns at $T_J = 125°C$
- Low Conduction Loss
- Temperature Compensating SABER™ Model www.onsemi.com
- These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant

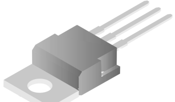
ON Semiconductor®

www.onsemi.com

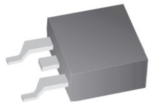




TO−247−3LD
CASE 340CK

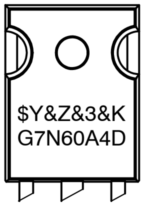


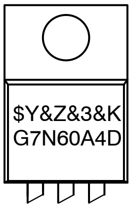
TO−220−3LD
CASE 340AT

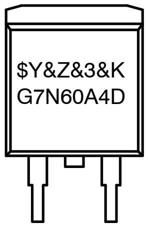


D2PAK−3
CASE 418AJ

MARKING DIAGRAMS







&Y = ON Semiconductor Logo
&Z = Assembly Plant Code
&3 = 3−Digit Date Code
&K = 2−Digit Lot Traceability Code
G7N60A4D = Specific Device Code

ORDERING INFORMATION

See detailed ordering and shipping information on page 2 of this data sheet.

ORDERING INFORMATION

PART NUMBER	PACKAGE	BRAND
HGTG7N60A4D	TO−247	G7N60A4D
HGTP7N60A4D	TO−220AB	G7N60A4D
HGT1S7N60A4DS	TO−263AB	G7N60A4D

NOTE: When ordering, use the entire part number. Add the suffix 9A to obtain the TO−263AB variant in tape and reel, e.g., HGT1S7N60A4DS9A.

PACKAGING

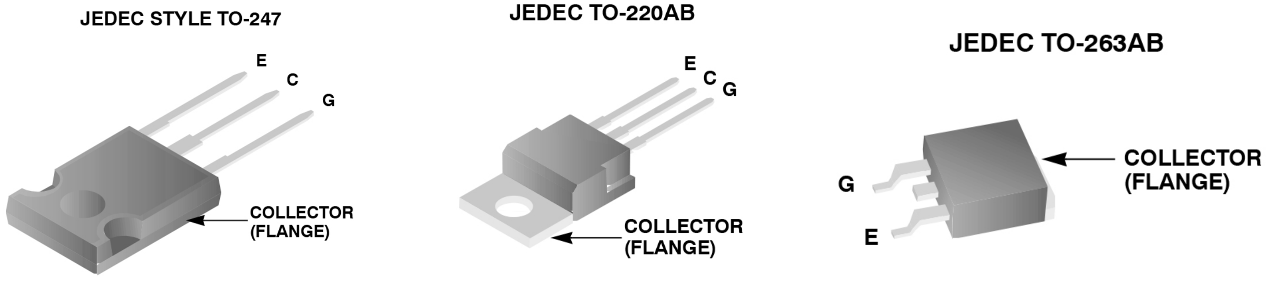


Figure 1.

ABSOLUTE MAXIMUM RATINGS T_C = 25°C Unless Otherwise Specified

Description	Symbol	All Types	Units
Collector to Emitter Voltage	BV_{CES}	600	V
Collector Current Continuous			
At T_C = 25°C	I_{C25}	34	A
At T_C = 110°C	I_{C110}	14	A
Collector Current Pulsed (Note 1)	I_{CM}	56	A
Gate to Emitter Voltage Continuous	V_{GES}	±20	V
Gate to Emitter Voltage Pulsed	V_{GEM}	±30	V
Switching Safe Operating Area at T_J = 150°C (Figure 1)	SSOA	35 A at 600 V	
Power Dissipation Total at T_C = 25°C	P_D	125	W
Power Dissipation Derating T_C > 25°C		1.0	W/°C
Operating and Storage Junction Temperature Range	T_J, T_{STG}	−55 to 150	°C
Maximum Lead Temperature for Soldering			
Leads at 0.063 in (1.6 mm) from case for 10 s	T_L	300	
Package Body for 10 s, see Tech Brief 334	T_{PKG}	260	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Pulse width limited by maximum junction temperature.

ELECTRICAL SPECIFICATIONS T_J = 25 °C Unless Otherwise Specified

PARAMETER	SYMBOL	TEST CONDITIONS		MIN	TYP	MAX	UNITS
Collector to Emitter Breakdown Voltage	BV_{CES}	I_C = 250 μA, V_{GE} = 0 V		600	–	–	V
Collector to Emitter Leakage Current	I_{CES}	V_{CE} = 600 V	T_C = 25°C	–	–	250	μA
			T_C = 125°C	–	–	2	mA
Collector to Emitter Saturation Voltage	$V_{CE(SAT)}$	I_C = 7 A, V_{GE} = 15 V	T_C = 25°C	–	1.9	2.7	V
			T_C = 150°C	–	1.6	2.2	V
Gate to Emitter Threshold Voltage	$V_{GE(TH)}$	I_C = 250 μA, V_{CE} = 600 V		4.5	5.9	7	V
Gate to Emitter Leakage Current	I_{GES}	V_{GE} = ±20 V		–	–	±250	nA
Switching SOA	SSOA	T_J = 150°C, R_G = 25 Ω, V_{GE} = 15 V, L = 100 μH, V_{CE} = 600 V		35	–	–	A
Gate to Emitter Plateau Voltage	V_{GEP}	I_C = 7 A, V_{CE} = 300 V		–	9	–	V
On−State Gate Charge	$Q_{G(ON)}$	I_C = 7 A, V_{CE} = 300 V	V_{GE} = 15 V	–	37	45	nC
			V_{GE} = 20 V	–	48	60	nC
Current Turn−On Delay Time	$t_{d(ON)I}$	IGBT and Diode at T_J = 25°C, I_{CE} = 7 A, V_{CE} = 390 V, V_{GE} = 15 V, R_G = 25 Ω, L = 1 mH, Test Circuit (Figure 24)		–	11	–	ns
Current Rise Time	t_{rI}			–	11	–	ns
Current Turn−Off Delay Time	$t_{d(OFF)I}$			–	100	–	ns
Current Fall Time	t_{fI}			–	45	–	ns
Turn−On Energy	E_{ON1}			–	55	–	μJ
Turn−On Energy	E_{ON2}			–	120	150	μJ
Turn−Off Energy (Note 3)	E_{OFF}			–	60	75	μJ
Current Turn−On Delay Time	$t_{d(ON)I}$	IGBT and Diode at T_J = 150°C, I_{CE} = 7 A, V_{CE} = 390 V, V_{GE} = 15 V, R_G = 25 Ω, L = 1 mH, Test Circuit (Figure 24)		–	10	–	ns
Current Rise Time	t_{rI}			–	7	–	ns
Current Turn−Off Delay Time	$t_{d(OFF)I}$			–	130	150	ns
Current Fall Time	t_{fI}			–	75	85	ns
Turn−On Energy	E_{ON1}			–	50	–	μJ
Turn−On Energy	E_{ON2}			–	200	215	μJ
Turn−Off Energy (Note 3)	E_{OFF}			–	125	170	μJ
Diode Forward Voltage	V_{EC}	I_{EC} = 7 A		–	2.4	–	V
Diode Reverse Recovery Time	t_{rr}	I_{EC} = 7 A, dI_{EC}/dt = 200 A/μs		–	34	–	ns
		I_{EC} = 1 A, dI_{EC}/dt = 200 A/μs		–	22	–	ns
Thermal Resistance Junction To Case	$R_{\theta JC}$	IGBT		–	–	1.0	°C/W
		Diode		–	–	2.2	°C/W

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

2. Values for two Turn−On loss conditions are shown for the convenience of the circuit designer. E_{ON1} is the turn−on loss of the IGBT only. E_{ON2} is the turn−on loss when a typical diode is used in the test circuit and the diode is at the same T_J as the IGBT. The diode type is specified in Figure 24.
3. Turn−Off Energy Loss (E_{OFF}) is defined as the integral of the instantaneous power loss starting at the trailing edge of the input pulse and ending at the point where the collector current equals zero (I_{CE} = 0 A). All devices were tested per JEDEC Standard No. 24−1 Method for Measurement of Power Device Turn−Off Switching Loss. This test method produces the true total Turn−Off Energy Loss.

International
IOR Rectifier

PD - 94388B

IRGP30B60KD-E

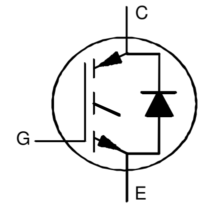
INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Features

- Low $V_{CE\ (on)}$ Non Punch Through IGBT Technology.
- Low Diode V_F.
- 10µs Short Circuit Capability.
- Square RBSOA.
- Ultrasoft Diode Reverse Recovery Characteristics.
- Positive $V_{CE\ (on)}$ Temperature Coefficient.
- TO-247AD Package

Benefits

- Benchmark Efficiency for Motor Control.
- Rugged Transient Performance.
- Low EMI.
- Excellent Current Sharing in Parallel Operation.



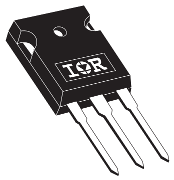
n-channel

V_{CES} = 600V

I_C = 30A, T_C=100°C

t_{sc} > 10µs, T_J=150°C

$V_{CE(on)}$ typ. = 1.95V



TO-247AD

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	60	A
I_C @ T_C = 100°C	Continuous Collector Current	30	
I_{CM}	Pulsed Collector Current	120	
I_{LM}	Clamped Inductive Load Current ①	120	
I_F @ T_C = 25°C	Diode Continuous Forward Current	60	
I_F @ T_C = 100°C	Diode Continuous Forward Current	30	
I_{FM}	Diode Maximum Forward Current	120	
V_{GE}	Gate-to-Emitter Voltage	±20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	304	W
P_D @ T_C = 100°C	Maximum Power Dissipation	122	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	——	——	0.41	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	——	——	1.32	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	——	40	
Wt	Weight	——	6.0	——	g

02/27/06

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig.
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 500µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.4	—	V/°C	V_{GE} = 0V, I_C = 1.0mA, (25°C-150°C)	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	1.95	2.35	V	I_C = 30A, V_{GE} = 15V	5,6,7
		—	2.40	2.75		I_C = 30A, V_{GE} = 15V, T_J = 150°C	9,10,11
$V_{GE(th)}$	Gate Threshold Voltage	3.5	4.5	5.5	V	V_{CE} = V_{GE}, I_C = 250µA	9,10,11
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-10	—	mV/°C	V_{CE} = V_{GE}, I_C = 1.0mA, (25°C-150°C)	12
g_{fe}	Forward Transconductance	—	18	—	S	V_{CE} = 50V, I_C = 50A, PW=80µs	
I_{CES}	Zero Gate Voltage Collector Current	—	5.0	250	µA	V_{GE} = 0V, V_{CE} = 600V	
		—	1000	2000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	1.30	1.55	V	I_F = 30A	8
		—	1.25	1.50		I_F = 30A T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	Ref.Fig.
Qg	Total Gate Charge (turn-on)	—	102	153	nC	I_C = 30A	23
Qge	Gate - Emitter Charge (turn-on)	—	14	21		V_{CC} = 400V	CT.1
Qgc	Gate - Collector Charge (turn-on)	—	44	66		V_{GE} = 15V	
E_{on}	Turn-On Switching Loss	—	350	620	µJ	I_C = 30A, V_{CC} = 400V	CT.4
E_{off}	Turn-Off Switching Loss	—	825	955		V_{GE} =15V, R_G = 10Ω, L=200µH,	
E_{tot}	Total Switching Loss	—	1175	1575		L_S = 150nH T_J = 25°C ②	
$t_{d(on)}$	Turn-On Delay Time	—	46	60	ns	I_C = 30A, V_{CC} = 400V	CT.4
t_r	Rise Time	—	28	39		V_{GE} = 15V, R_G = 10Ω L =200µH	
$t_{d(off)}$	Turn-Off Delay Time	—	185	200		L_S = 150nH, T_J = 25°C	
t_f	Fall Time	—	31	40			
E_{on}	Turn-On Switching Loss	—	635	1085	µJ	I_C = 30A, V_{CC} = 400V	CT.4
E_{off}	Turn-Off Switching Loss	—	1150	1350		V_{GE} = 15V,R_G = 10Ω, L =200µH	13,15
E_{tot}	Total Switching Loss	—	1785	2435		L_S = 150nH T_J = 150°C ②	WF1,WF2
$t_{d(on)}$	Turn-On Delay Time	—	46	60	ns	I_C = 30A, V_{CC} = 400V	CT.4
t_r	Rise Time	—	28	39		V_{GE} = 15V, R_G = 10Ω L =200µH	14,16
$t_{d(off)}$	Turn-Off Delay Time	—	205	235		L_S = 150nH, T_J = 150°C	WF1,WF2
t_f	Fall Time	—	32	42			
C_{ies}	Input Capacitance	—	1750	—	pF	V_{GE} = 0V	22
C_{oes}	Output Capacitance	—	160	—		V_{CC} = 30V	
C_{res}	Reverse Transfer Capacitance	—	60	—		f = 1.0MHz	
RBSOA	Reverse Bias Safe Operting Area	FULL SQUARE				T_J = 150°C, I_C = 120A, Vp =600V V_{CC} = 500V, V_{GE} = +15V to 0V, R_G=10Ω	4 CT.2
SCSOA	Short Circuit Safe Operting Area	10	—	—	µs	T_J = 150°C, Vp =600V, R_G = 10Ω V_{CC} = 360V, V_{GE} = +15V to 0V	CT.3 WF.4
Erec	Reverse Recovery energy of the diode	—	925	1165	µJ	T_J = 150°C	17,18,19
t_{rr}	Diode Reverse Recovery time	—	125	—	ns	V_{CC} = 400V, I_F = 30A, L = 200µH	20,21
I_{rr}	Diode Peak Reverse Recovery Current	—	43	48	A	V_{GE} = 15V,R_G = 10Ω, L_s = 150nH	CT.4,WF.3

Notes: ① V_{CC} = 80% (V_{CES}), V_{GE} = 15V, L = 28µH, R_G = 22Ω. ② Energy losses include "tail" and diode reverse recovery.

March 2015

FGP20N60UFD

600 V, 20 A Field Stop IGBT

Features

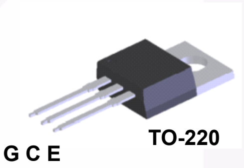
- High Current Capability
- Low Saturation Voltage: $V_{CE(sat)}$ = 1.8 V @ I_C = 20 A
- High Input Impedance
- Fast Switching
- RoHS Compliant

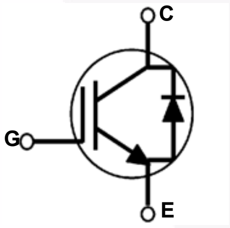
Applications

- Solar Inverter, UPS, Welder, PFC

General Description

Using novel field stop IGBT technology, Fairchild's field stop IGBTs offer the optimum performance for solar inverter, UPS, welder and PFC applications where low conduction and switching losses are essential.





Absolute Maximum Ratings

Symbol	Description		Ratings	Unit
V_{CES}	Collector to Emitter Voltage		600	V
V_{GES}	Gate to Emitter Voltage		±20	V
	Transient Gate-to-Emitter Voltage		±30	
I_C	Collector Current	@ T_C = 25°C	40	A
	Collector Current	@ T_C = 100°C	20	A
$I_{CM\ (1)}$	Pulsed Collector Current	@ T_C = 25°C	60	A
P_D	Maximum Power Dissipation	@ T_C = 25°C	165	W
	Maximum Power Dissipation	@ T_C = 100°C	66	W
T_J	Operating Junction Temperature		-55 to +150	°C
T_{stg}	Storage Temperature Range		-55 to +150	°C
T_L	Maximum Lead Temp. for soldering Purposes, 1/8" from case for 5 seconds		300	°C

Notes:
1: Repetitive rating: Pulse width limited by max. junction temperature

Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Unit
$R_{\theta JC}$(IGBT)	Thermal Resistance, Junction to Case	-	0.76	°C/W
$R_{\theta JC}$(Diode)	Thermal Resistance, Junction to Case	-	2.51	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	-	62.5	°C/W

Package Marking and Ordering Information

Device Marking	Device	Package	Reel Size	Tape Width	Quantity
FGP20N60UFD	FGP20N60UFDTU	TO-220	-	-	50ea

Electrical Characteristics of the IGBT

T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Off Characteristics						
BV_{CES}	Collector to Emitter Breakdown Voltage	V_{GE} = 0V, I_C = 250μA	600	-	-	V
$\Delta BV_{CES} / \Delta T_J$	Temperature Coefficient of Breakdown Voltage	V_{GE} = 0 V, I_C = 250 μA	-	0.6	-	V/°C
I_{CES}	Collector Cut-Off Current	$V_{CE} = V_{CES}$, V_{GE} = 0 V, T_C = 25°C	-	-	250	μA
		$V_{CE} = V_{CES}$, V_{GE} = 0 V, T_C = 125°C	-	-	1	mA
I_{GES}	G-E Leakage Current	$V_{GE} = V_{GES}$, V_{CE} = 0V	-	-	±400	nA
On Characteristics						
$V_{GE(th)}$	G-E Threshold Voltage	I_C = 250 μA, $V_{CE} = V_{GE}$	4.0	5.0	6.5	V
$V_{CE(sat)}$	Collector to Emitter Saturation Voltage	I_C = 20 A, V_{GE} = 15 V	-	1.8	2.4	V
		I_C = 20 A, V_{GE} = 15 V, T_C = 125°C	-	2.0	-	V
Dynamic Characteristics						
C_{ies}	Input Capacitance	V_{CE} = 30 V, V_{GE} = 0 V, f = 1 MHz	-	940	-	pF
C_{oes}	Output Capacitance		-	110	-	pF
C_{res}	Reverse Transfer Capacitance		-	40	-	pF
Switching Characteristics						
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 400 V, I_C = 20 A, R_G = 10 Ω, V_{GE} = 15 V, Inductive Load, T_C = 25°C	-	13	-	ns
t_r	Rise Time		-	17	-	ns
$t_{d(off)}$	Turn-Off Delay Time		-	87	-	ns
t_f	Fall Time		-	32	64	ns
E_{on}	Turn-On Switching Loss		-	0.38	-	mJ
E_{off}	Turn-Off Switching Loss		-	0.26	-	mJ
E_{ts}	Total Switching Loss		-	0.64	-	mJ
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 400 V, I_C = 20 A, R_G = 10 Ω, V_{GE} = 15 V, Inductive Load, T_C = 125°C	-	13	-	ns
t_r	Rise Time		-	16	-	ns
$t_{d(off)}$	Turn-Off Delay Time		-	92	-	ns
t_f	Fall Time		-	63	-	ns
E_{on}	Turn-On Switching Loss		-	0.41	-	mJ
E_{off}	Turn-Off Switching Loss		-	0.36	-	mJ
E_{ts}	Total Switching Loss		-	0.77	-	mJ
Q_g	Total Gate Charge	V_{CE} = 400 V, I_C = 20 A, V_{GE} = 15 V	-	63	-	nC
Q_{ge}	Gate to Emitter Charge		-	7	-	nC
Q_{gc}	Gate to Collector Charge		-	32	-	nC

Electrical Characteristics of the Diode T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions		Min.	Typ.	Max	Unit
V_{FM}	Diode Forward Voltage	I_F = 10 A	T_C = 25°C	-	1.9	2.5	V
			T_C = 125°C	-	1.7	-	
t_{rr}	Diode Reverse Recovery Time	I_F = 10 A, dI_F/dt = 200 A/µs	T_C = 25°C	-	35	-	ns
			T_C = 125°C	-	57	-	
Q_{rr}	Diode Reverse Recovery Charge		T_C = 25°C	-	41	-	nC
			T_C = 125°C	-	96	-	

FAIRCHILD
SEMICONDUCTOR®

IGBT

FGL60N100BNTD

NPT-Trench IGBT

General Description

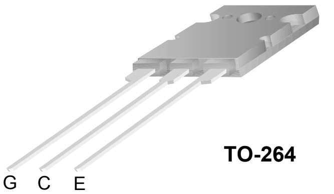
Trench insulated gate bipolar transistors (IGBTs) with NPT technology show outstanding performance in conduction and switching characteristics as well as enhanced avalanche ruggedness. These devices are well suited for Induction Heating (I-H) applications

Features

- High Speed Switching
- Low Saturation Voltage : $V_{CE(sat)}$ = 2.5 V @ I_C = 60A
- High Input Impedance
- Built-in Fast Recovery Diode

Application

Micro- Wave Oven, I-H Cooker, I-H Jar, Induction Heater, Home Appliance



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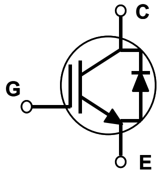

Absolute Maximum Ratings

T_C = 25°C unless otherwise noted

Symbol	Description	FGL60N100BNTD	Units
V_{CES}	Collector-Emitter Voltage	1000	V
V_{GES}	Gate-Emitter Voltage	± 25	V
I_C	Collector Current @ T_C = 25°C	60	A
	Collector Current @ T_C = 100°C	42	A
$I_{CM\ (1)}$	Pulsed Collector Current	120	A
I_F	Diode Continuous Forward Current @ T_C = 100°C	15	A
P_D	Maximum Power Dissipation @ T_C = 25°C	180	W
	Maximum Power Dissipation @ T_C = 100°C	72	W
T_J	Operating Junction Temperature	-55 to +150	°C
T_{stg}	Storage Temperature Range	-55 to +150	°C
T_L	Maximum Lead Temp. for soldering Purposes, 1/8” from case for 5 seconds	300	°C

Notes :
(1) Repetitive rating : Pulse width limited by max. junction temperature

Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Units
$R_{\theta JC}$(IGBT)	Thermal Resistance, Junction-to-Case	--	0.69	°C/W
$R_{\theta JC}$(DIODE)	Thermal Resistance, Junction-to-Case	--	2.08	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	--	25	°C/W

Electrical Characteristics of IGBT

T_C = 25°C unless otherwise noted

Off Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
BV_{CES}	Collector Emitter Breakdown Voltage	V_{GE} = 0V, I_C = 1mA	1000	--	--	V
I_{CES}	Collector Cut-Off Current	V_{CE} = 1000V, V_{GE} = 0V	--	--	1.0	mA
I_{GES}	G-E Leakage Current	V_{GE} = ± 25, V_{CE} = 0V	--	--	± 500	nA

On Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
$V_{GE(th)}$	G-E Threshold Voltage	I_C = 60mA, V_{CE} = V_{GE}	4.0	5.0	7.0	V
$V_{CE(sat)}$	Collector to Emitter Saturation Voltage	I_C = 10A, V_{GE} = 15V	--	1.5	1.8	V
		I_C = 60A, V_{GE} = 15V	--	2.5	2.9	V

Dynamic Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
C_{ies}	Input Capacitance	V_{CE}=10V, V_{GE} = 0V, f = 1MHz	--	6000	--	pF
C_{oes}	Output Capacitance		--	260	--	pF
C_{res}	Reverse Transfer Capacitance		--	200	--	pF

Switching Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 600 V, I_C = 60A, R_G = 51Ω, V_{GE}=15V, Resistive Load, T_C = 25°C	--	140	--	ns
t_r	Rise Time		--	320	--	ns
$t_{d(off)}$	Turn-Off Delay Time		--	630	--	ns
t_f	Fall Time		--	130	250	ns
Q_g	Total Gate Charge	V_{CE} = 600 V, I_C = 60A, V_{GE} = 15V , , T_C = 25°C	--	275	350	nC
Q_{ge}	Gate-Emitter Charge		--	45	--	nC
Q_{gc}	Gate-Collector Charge		--	95	--	nC

Electrical Characteristics of DIODE

T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
V_{FM}	Diode Forward Voltage	I_F = 15A	--	1.2	1.7	V
		I_F = 60A	--	1.8	2.1	V
t_{rr}	Diode Reverse Recovery Time	I_F = 60A di/dt = 20 A/us		1.2	1.5	us
I_R	Instantaneous Reverse Current	V_{RRM} = 1000V	--	0.05	2	uA

IGBT - Field Stop, Trench

1200 V, 40 A

FGH40T120SMD, FGH40T120SMD-F155

Description

Using innovative field stop trench IGBT technology, ON Semiconductor's new series of field stop trench IGBTs offer the optimum performance for hard switching application such as solar inverter, UPS, welder and PFC applications.

Features

- FS Trench Technology, Positive Temperature Coefficient
- High Speed Switching
- Low Saturation Voltage: $V_{CE(sat)} = 1.8$ V @ $I_C = 40$ A
- 100% of the Parts tested for I_{LM}(1)
- High Input Impedance
- These Devices are Pb−Free and are RoHS Compliant

Applications

- Solar Inverter, Welder, UPS & PFC applications

ON Semiconductor®

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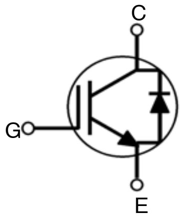
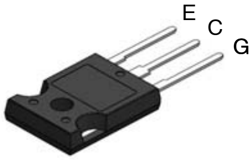
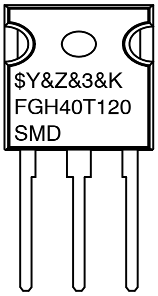




TO−247−3LD
CASE 340CK

TO−247−3LD
CASE 340CH

MARKING DIAGRAM



$Y = ON Semiconductor Logo
&Z = Assembly Plant Code
&3 = Numeric Date Code
&K = Lot Code
FGH40T120SMD = Specific Device Code

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 2 of this data sheet.

ABSOLUTE MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Description		Symbol	Ratings	Unit
Collector to Emitter Voltage		V_{CES}	1200	V
Gate to Emitter Voltage		V_{GES}	±25	V
Transient Gate to Emitter Voltage			±30	V
Collector Current	T_C = 25°C	I_C	80	A
Collector Current	T_C = 100°C		40	A
Clamped Inductive Load Current	T_C = 25°C	I_{LM} (Note 1)	160	A
Pulsed Collector Current		I_{CM} (Note 2)	160	A
Diode Continuous Forward Current	T_C = 25°C	I_F	80	A
Diode Continuous Forward Current	T_C = 100°C		40	A
Diode Maximum Forward Current		I_{FM}	240	A
Maximum Power Dissipation	T_C = 25°C	P_D	555	W
Maximum Power Dissipation	T_C = 100°C		277	W
Operating Junction Temperature		T_J	−55 to +175	°C
Storage Temperature Range		T_{stg}	−55 to +175	°C
Maximum Lead Temp. for soldering Purposes, 1/8” from case for 5 seconds		T_L	300	°C

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Vcc = 600 V,V_{GE} = 15 V, I_C = 160 A, R_G = 10 W , Inductive Load
2. Limited by Tjmax

THERMAL CHARACTERISTICS

Parameter	Symbol	Typ	Max	Unit
Thermal Resistance, Junction to Case	$R_{\theta JC}$(IGBT)	–	0.27	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$(Diode)	–	0.89	°C/W
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	–	40	°C/W

PACKAGE MARKING AND ORDERING INFORMATION

Device Marking	Device	Package	Reel Size	Tape Width	Quantity
FGH40T120SMD	FGH40T120SMD	TO−247−3 (PB−Free)	–	–	30
FGH40T120SMD	FGH40T120SMD−F155	TO−247−3 (Pb−Free)	–	–	30

ELECTRICAL CHARACTERISTICS OF THE IGBT (T_C = 25°C unless otherwise noted)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
OFF CHARACTERISTICS						
Collector to Emitter Breakdown Voltage	BV_{CES}	V_{GE} = 0 V, I_C = 250 μA	1200	–	–	V
Collector Cut−Off Current	I_{CES}	V_{CE} = V_{CES}, V_{GE} = 0 V	–	–	250	μA
G−E Leakage Current	I_{GES}	V_{GE} = V_{GES}, V_{CE} = 0 V	–	–	±400	nA
ON CHARACTERISTICs						
G−E Threshold Voltage	$V_{GE(th)}$	I_C = 40 mA, V_{CE} = V_{GE}	4.9	6.2	7.5	V
Collector to Emitter Saturation Voltage	$V_{CE(sat)}$	I_C = 40 A, V_{GE} = 15 V, T_C = 25°C	–	1.8	2.4	V
		I_C = 40 A, V_{GE} = 15 V, T_C = 175°C	–	2.0	–	V

ELECTRICAL CHARACTERISTICS OF THE IGBT (T_C = 25°C unless otherwise noted) (continued)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
DYNAMIC CHARACTERISTICS						
Input Capacitance	C_{ies}	V_{CE} = 30 V, V_{GE} = 0 V, f = 1 MHz	–	4300	–	pF
Output Capacitance	C_{oes}		–	180	–	pF
Reverse Transfer Capacitance	C_{res}		–	100	–	pF
SWITCHING CHARACTERISTICS						
Turn−On Delay Time	$t_{d(on)}$	V_{CC} = 600 V, I_C = 40 A, R_G = 10 Ω, V_{GE} = 15 V, Inductive Load, T_C = 25°C	–	40	–	ns
Rise Time	t_r		–	47	–	ns
Turn−Off Delay Time	$t_{d(off)}$		–	475	–	ns
Fall Time	t_f		–	10	–	ns
Turn−On Switching Loss	E_{on}		–	2.7	–	mJ
Turn−Off Switching Loss	E_{off}		–	1.1	–	mJ
Total Switching Loss	E_{ts}		–	3.8	–	mJ
Turn−On Delay Time	$t_{d(on)}$	V_{CC} = 600 V, I_C = 40 A, R_G = 10 Ω, V_{GE} = 15 V, Inductive Load, T_C = 175°C	–	40	–	ns
Rise Time	tr		–	55	–	ns
Turn−Off Delay Time	$t_{d(off)}$		–	520	–	ns
Fall Time	t_f		–	50	–	ns
Turn−On Switching Loss	E_{on}		–	3.4	–	mJ
Turn−Off Switching Loss	E_{off}		–	2.5	–	mJ
Total Switching Loss	E_{ts}		–	5.9	–	mJ
Total Gate Charge	Q_g	V_{CE} = 600 V, I_C = 40 A, V_{GE} = 15 V	–	370	–	nC
Gate to Emitter Charge	Q_{ge}		–	23	–	nC
Gate to Collector Charge	Q_{gc}		–	210	–	nC

ELECTRICAL CHARACTERISTICS OF THE DIODE (T_J = 25°C unless otherwise noted)

Parametr	Symbol	Test Conditions	Min	Typ	Max	Unit
Diode Forward Voltage	V_{FM}	I_F = 40 A, T_C = 25°C	–	3.8	4.8	V
		I_F = 40 A, T_C = 175°C	–	2.7	–	V
Diode Reverse Recovery Time	t_{rr}	V_R = 600 V, I_F = 40 A, di_F/dt = 200 A/μs, T_C = 25°C	–	65	–	ns
Diode Peak Reverse Recovery Current	I_{rr}		–	7.2	–	A
Diode Reverse Recovery Charge	Q_{rr}		–	234	–	nC
Diode Reverse Recovery Time	t_{rr}	V_R = 600 V, I_F = 40 A, di_F/dt = 200 A/μs, T_C = 175°C	–	200	–	ns
Diode Peak Reverse Recovery Current	I_{rr}		–	18.0	–	A
Diode Reverse Recovery Charge	Q_{rr}		–	1800	–	nC

FAIRCHILD
SEMICONDUCTOR®

September 2008

FGH20N60SFD

600V, 20A Field Stop IGBT

Features

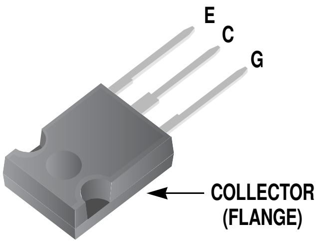
- High current capability
- Low saturation voltage: $V_{CE(sat)}$ =2.2V @ I_C = 20A
- High input impedance
- Fast switching
- RoHS compliant

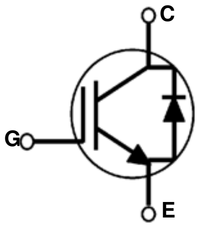
Applications

- Induction Heating, UPS, SMPS, PFC

General Description

Using Novel Field Stop IGBT Technology, Fairchild's new series of Field Stop IGBTs offer the optimum performance for Induction Heating, UPS, SMPS and PFC applications where low conduction and switching losses are essential.





Absolute Maximum Ratings

Symbol	Description		Ratings	Units
V_{CES}	Collector to Emitter Voltage		600	V
V_{GES}	Gate to Emitter Voltage		± 20	V
I_C	Collector Current	@ T_C = 25°C	40	A
	Collector Current	@ T_C = 100°C	20	A
$I_{CM\ (1)}$	Pulsed Collector Current	@ T_C = 25°C	60	A
P_D	Maximum Power Dissipation	@ T_C = 25°C	165	W
	Maximum Power Dissipation	@ T_C = 100°C	66	W
T_J	Operating Junction Temperature		-55 to +150	°C
T_{stg}	Storage Temperature Range		-55 to +150	°C
T_L	Maximum Lead Temp. for soldering Purposes, 1/8" from case for 5 seconds		300	°C

Notes:
1: Repetitive rating: Pulse width limited by max. junction temperature

Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Units
$R_{\theta JC}$(IGBT)	Thermal Resistance, Junction to Case	-	0.76	°C/W
$R_{\theta JC}$(Diode)	Thermal Resistance, Junction to Case	-	2.51	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	-	40	°C/W

Package Marking and Ordering Information

Device Marking	Device	Package	Packaging Type	Qty per Tube	Max Qty per Box
FGH20N60SFD	FGH20N60SFDTU	TO-247	Tube	30ea	-

Electrical Characteristics of the IGBT T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Off Characteristics						
BV_{CES}	Collector to Emitter Breakdown Voltage	V_{GE} = 0V, I_C = 250μA	600	-	-	V
$\frac{\Delta BV_{CES}}{\Delta T_J}$	Temperature Coefficient of Breakdown Voltage	V_{GE} = 0V, I_C = 250μA	-	0.6	-	V/°C
I_{CES}	Collector Cut-Off Current	$V_{CE} = V_{CES}$, V_{GE} = 0V	-	-	250	μA
I_{GES}	G-E Leakage Current	$V_{GE} = V_{GES}$, V_{CE} = 0V	-	-	±400	nA
On Characteristics						
$V_{GE(th)}$	G-E Threshold Voltage	I_C = 250μA, $V_{CE} = V_{GE}$	4.0	5.0	6.5	V
$V_{CE(sat)}$	Collector to Emitter Saturation Voltage	I_C = 20A, V_{GE} = 15V	-	2.2	2.8	V
		I_C = 20A, V_{GE} = 15V, T_C = 125°C	-	2.4	-	V
Dynamic Characteristics						
C_{ies}	Input Capacitance	V_{CE} = 30V, V_{GE} = 0V, f = 1MHz	-	940	-	pF
C_{oes}	Output Capacitance		-	110	-	pF
C_{res}	Reverse Transfer Capacitance		-	40	-	pF
Switching Characteristics						
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 400V, I_C = 20A, R_G = 10Ω, V_{GE} = 15V, Inductive Load, T_C = 25°C	-	13	-	ns
t_r	Rise Time		-	16	-	ns
$t_{d(off)}$	Turn-Off Delay Time		-	90	-	ns
t_f	Fall Time		-	24	48	ns
E_{on}	Turn-On Switching Loss		-	0.37	-	mJ
E_{off}	Turn-Off Switching Loss		-	0.16	-	mJ
E_{ts}	Total Switching Loss		-	0.53	-	mJ
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 400V, I_C = 20A, R_G = 10Ω, V_{GE} = 15V, Inductive Load, T_C = 125°C	-	12	-	ns
t_r	Rise Time		-	16	-	ns
$t_{d(off)}$	Turn-Off Delay Time		-	95	-	ns
t_f	Fall Time		-	28	-	ns
E_{on}	Turn-On Switching Loss		-	0.4	-	mJ
E_{off}	Turn-Off Switching Loss		-	0.28	-	mJ
E_{ts}	Total Switching Loss		-	0.69	-	mJ
Q_g	Total Gate Charge	V_{CE} = 400V, I_C = 20A, V_{GE} = 15V	-	65	-	nC
Q_{ge}	Gate to Emitter Charge		-	7	-	nC
Q_{gc}	Gate to Collector Charge		-	33	-	nC

Electrical Characteristics of the Diode T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions		Min.	Typ.	Max	Units
V_{FM}	Diode Forward Voltage	I_F = 10A	T_C = 25°C	-	1.9	2.5	V
			T_C = 125°C	-	1.7	-	
t_{rr}	Diode Reverse Recovery Time	I_{ES} =10A, dI_{ES}/dt = 200A/µs	T_C = 25°C	-	34	-	ns
			T_C = 125°C	-	57	-	
Q_{rr}	Diode Reverse Recovery Charge		T_C = 25°C	-	41	-	nC
			T_C = 125°C	-	96	-	

FAIRCHILD
SEMICONDUCTOR®

November 2013

FGA25N120ANTD

1200 V, 25 A NPT Trench IGBT

Features

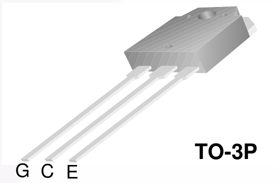
- NPT Trench Technology, Positive Temperature Coefficient
- Low Saturation Voltage: $V_{CE(sat),\ typ} = 2.0$ V @ $I_C = 25$ A and $T_C = 25°C$
- Low Switching Loss: $E_{off,\ typ} = 0.96$ mJ @ $I_C = 25$ A and $T_C = 25°C$
- Extremely Enhanced Avalanche Capability

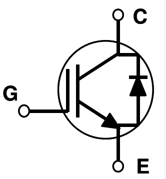
Applications

- Induction Heating, Microwave Oven

Description

Using Fairchild's proprietary trench design and advanced NPT technology, the 1200V NPT IGBT offers superior conduction and switching performances, high avalanche ruggedness and easy parallel operation. This device is well suited for the resonant or soft switching application such as induction heating, microwave oven.





Absolute Maximum Ratings

Symbol	Description		Ratings	Unit
V_{CES}	Collector-Emitter Voltage		1200	V
V_{GES}	Gate-Emitter Voltage		± 20	V
I_C	Collector Current	@ T_C = 25°C	50	A
	Collector Current	@ T_C = 100°C	25	A
$I_{CM\ (1)}$	Pulsed Collector Current		90	A
I_F	Diode Continuous Forward Current	@ T_C = 25°C	50	A
	Diode Continuous Forward Current	@ T_C = 100°C	25	A
I_{FM}	Diode Maximum Forward Current		150	A
P_D	Maximum Power Dissipation	@ T_C = 25°C	312	W
	Maximum Power Dissipation	@ T_C = 100°C	125	W
T_J	Operating Junction Temperature		-55 to +150	°C
T_{stg}	Storage Temperature Range		-55 to +150	°C
T_L	Maximum Lead Temp. for soldering Purposes, 1/8” from case for 5 seconds		300	°C

Notes:

(1) Repetitive rating: Pulse width limited by max. junction temperature

Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Unit
$R_{\theta JC}$(IGBT)	Thermal Resistance, Junction-to-Case	--	0.4	°C/W
$R_{\theta JC}$(DIODE)	Thermal Resistance, Junction-to-Case	--	2.0	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	--	40	°C/W

Package Marking and Ordering Information

Part Number	Top Mark	Package	Packing Method	Reel Size	Tape Width	Quantity
FGA25N120ANTDTU	FGA25N120ANTD	TO-3P	Tube	N/A	N/A	30

Electrical Characteristics of the IGBT T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
Off Characteristics						
I_{CES}	Collector Cut-Off Current	$V_{CE} = V_{CES}$, $V_{GE} = 0$ V	--	--	3	mA
I_{GES}	G-E Leakage Current	$V_{GE} = V_{GES}$, $V_{CE} = 0$ V	--	--	± 250	nA
On Characteristics						
$V_{GE(th)}$	G-E Threshold Voltage	$I_C = 25$ mA, $V_{CE} = V_{GE}$	3.5	5.5	7.5	V
$V_{CE(sat)}$	Collector to Emitter Saturation Voltage	$I_C = 25$ A, $V_{GE} = 15$ V	--	2.0	--	V
		$I_C = 25$ A, $V_{GE} = 15$ V, $T_C = 125$°C	--	2.15	--	V
		$I_C = 50$ A, $V_{GE} = 15$ V	--	2.65	--	V
Dynamic Characteristics						
C_{ies}	Input Capacitance	$V_{CE} = 30$ V, $V_{GE} = 0$ V, f = 1 MHz	--	3700	--	pF
C_{oes}	Output Capacitance		--	130	--	pF
C_{res}	Reverse Transfer Capacitance		--	80	--	pF
Switching Characteristics						
$t_{d(on)}$	Turn-On Delay Time	$V_{CC} = 600$ V, $I_C = 25$ A, $R_G = 10\ \Omega$, $V_{GE} = 15$ V, Inductive Load, $T_C = 25$°C	--	50	--	ns
t_r	Rise Time		--	60	--	ns
$t_{d(off)}$	Turn-Off Delay Time		--	190	--	ns
t_f	Fall Time		--	100	--	ns
E_{on}	Turn-On Switching Loss		--	4.1	--	mJ
E_{off}	Turn-Off Switching Loss		--	0.96	--	mJ
E_{ts}	Total Switching Loss		--	5.06	--	mJ
$t_{d(on)}$	Turn-On Delay Time	$V_{CC} = 600$ V, $I_C = 25$ A, $R_G = 10\ \Omega$, $V_{GE} = 15$ V, Inductive Load, $T_C = 125$°C	--	50	--	ns
t_r	Rise Time		--	60	--	ns
$t_{d(off)}$	Turn-Off Delay Time		--	200	--	ns
t_f	Fall Time		--	154	--	ns
E_{on}	Turn-On Switching Loss		--	4.3	--	mJ
E_{off}	Turn-Off Switching Loss		--	1.5	--	mJ
E_{ts}	Total Switching Loss		--	5.8	--	mJ
Q_g	Total Gate Charge	$V_{CE} = 600$ V, $I_C = 25$ A, $V_{GE} = 15$ V	--	200	--	nC
Q_{ge}	Gate-Emitter Charge		--	15	--	nC
Q_{gc}	Gate-Collector Charge		--	100	--	nC

Electrical Characteristics of DIODE T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
V_{FM}	Diode Forward Voltage	I_F = 25 A	T_C = 25°C	--	2.0	3.0	V
			T_C = 125°C	--	2.1	--	
t_{rr}	Diode Reverse Recovery Time	I_F = 25 A di_F/dt = 200 A/µs	T_C = 25°C	--	235	350	ns
			T_C = 125°C	--	300	--	
I_{rr}	Diode Peak Reverse Recovery Current		T_C = 25°C	--	27	40	A
			T_C = 125°C	--	31	--	
Q_{rr}	Diode Reverse Recovery Charge		T_C = 25°C	--	3130	4700	nC
			T_C = 125°C	--	4650	--	

December 2007

FGA20N120FTD

1200V, 20A Trench IGBT

Features

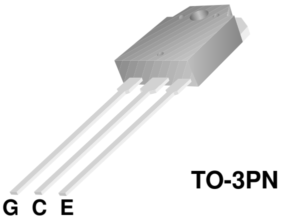
- Field stop trench technology
- High speed switching
- Low saturation voltage: $V_{CE(sat)}$ =1.6V @ I_C = 20A
- High input impedance
- RoHS compliant

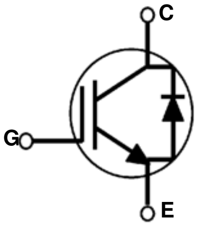
Applications

- Induction heating and Microvewave oven
- Soft switching applications

General Description

Using advanced field stop trench technology, Fairchild's 1200V trench IGBTs offer superior conduction and switching performances, and easy parallel operation with exceptional avalanche ruggedness. This device is designed for soft switching applications.





Absolute Maximum Ratings

Symbol	Description		Ratings	Units
V_{CES}	Collector to Emitter Voltage		1200	V
V_{GES}	Gate to Emitter Voltage		± 25	V
I_C	Continuous Collector Current	@ T_C = 25°C	40	A
	Continuous Collector Current	@ T_C = 100°C	20	A
$I_{CM\ (1)}$	Pulsed Collector Current		60	A
I_F	Diode Continuous Forward Current	@ T_C = 25°C	20	A
P_D	Maximum Power Dissipation	@ T_C = 25°C	298	W
	Maximum Power Dissipation	@ T_C = 100°C	119	W
T_J	Operating Junction Temperature		-55 to +150	°C
T_{stg}	Storage Temperature Range		-55 to +150	°C
T_L	Maximum Lead Temp. for soldering Purposes, 1/8" from case for 5 seconds		300	°C

Notes:
1: Repetitive rating, Pulse width limited by max. junction temperature

Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Units
$R_{\theta JC}$(IGBT)	Thermal Resistance, Junction to Case	-	0.42	°C/W
$R_{\theta JC}$(Diode)	Thermal Resistance, Junction to Case	-	2.0	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient	-	40	°C/W

Package Marking and Ordering Information

Device Marking	Device	Package	Reel Size	Tape Width	Quantity
FGA20N120FTD	FGA20N120FTDTU	TO-3PN	-	-	30

Electrical Characteristics of the IGBT

T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Off Characteristics						
BV_{CES}	Collector to Emitter Breakdown Voltage	V_{GE} = 0V, I_C = 1mA	1200	-	-	V
I_{CES}	Collector Cut-Off Current	V_{CE} = V_{CES}, V_{GE} = 0V	-	-	1	mA
I_{GES}	G-E Leakage Current	V_{GE} = V_{GES}, V_{CE} = 0V	-	-	±250	nA
On Characteristics						
$V_{GE(th)}$	G-E Threshold Voltage	I_C = 20mA, V_{CE} = V_{GE}	3.5	5.9	7.5	V
$V_{CE(sat)}$	Collector to Emitter Saturation Voltage	I_C = 20A, V_{GE} = 15V T_C = 25°C	-	1.60	2.00	V
		I_C = 20A, V_{GE} = 15V, T_C = 125°C	-	1.85	-	V
Dynamic Characteristics						
C_{ies}	Input Capacitance	V_{CE} = 30V, V_{GE} = 0V, f = 1MHz	-	3080	-	pF
C_{oes}	Output Capacitance		-	95	-	pF
C_{res}	Reverse Transfer Capacitance		-	60	-	pF
Switching Characteristics						
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 600V, I_C = 20A, R_G = 10Ω, V_{GE} = 15V, Resistive Load, T_C = 25°C	-	30	-	ns
t_r	Rise Time		-	79	-	ns
$t_{d(off)}$	Turn-Off Delay Time		-	143	-	ns
t_f	Fall Time		-	217	320	ns
E_{on}	Turn-On Switching Loss		-	0.42	-	mJ
E_{off}	Turn-Off Switching Loss		-	0.71	1.05	mJ
E_{ts}	Total Switching Loss		-	1.13	-	mJ
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 600V, I_C = 20A, R_G = 10Ω, V_{GE} = 15V, Resistive Load, T_C = 125°C	-	29	-	ns
t_r	Rise Time		-	93	-	ns
$t_{d(off)}$	Turn-Off Delay Time		-	147	-	ns
t_f	Fall Time		-	259	-	ns
E_{on}	Turn-On Switching Loss		-	0.47	-	mJ
E_{off}	Turn-Off Switching Loss		-	0.86	-	mJ
E_{ts}	Total Switching Loss		-	1.33	-	mJ
Q_g	Total Gate Charge	V_{CE} = 600V, I_C = 20A, V_{GE} = 15V	-	137	-	nC
Q_{ge}	Gate to Emitter Charge		-	23	-	nC
Q_{gc}	Gate to Collector Charge		-	65	-	nC

Electrical Characteristics of the Diode

T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions		Min.	Typ.	Max	Units
V_{FM}	Diode Forward Voltage	I_F = 20A	T_C = 25°C	-	1.3	1.7	V
			T_C = 125°C	-	1.3	-	
t_{rr}	Diode Reverse Recovery Time	I_{ES} =20A, dI/dt = 200A/µs	T_C = 25°C	-	447	-	ns
			T_C = 125°C	-	485	-	
I_{rr}	Diode Peak Reverse Recovery Current		T_C = 25°C	-	48	-	A
			T_C = 125°C	-	50	-	
Q_{rr}	Diode Reverse Recovery Charge		T_C = 25°C	-	10.8	-	µC
			T_C = 125°C	-	12	-	

FAIRCHILD
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IGBT

FGA15N120AND

General Description

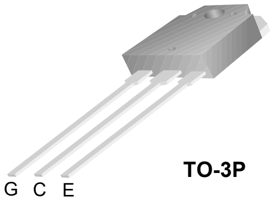
Employing NPT technology, Fairchild's AND series of IGBTs provides low conduction and switching losses. The AND series offers solutions for applications such as induction heating (IH), motor control, general purpose inverters and uninterruptible power supplies (UPS).

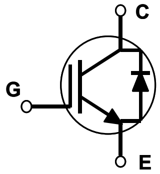
Features

- High speed switching
- Low saturation voltage : $V_{CE(sat)}$ = 2.4 V @ I_C = 15A
- High input impedance
- CO-PAK, IGBT with FRD : t_{rr} = 210ns (typ.)

Applications

Induction Heating, UPS, AC & DC motor controls and general purpose inverters.





Absolute Maximum Ratings

T_C = 25°C unless otherwise noted

Symbol	Description		FGA15N120AND	Units
V_{CES}	Collector-Emitter Voltage		1200	V
V_{GES}	Gate-Emitter Voltage		± 20	V
I_C	Collector Current	@ T_C = 25°C	24	A
	Collector Current	@ T_C = 100°C	15	A
$I_{CM\ (1)}$	Pulsed Collector Current		45	A
I_F	Diode Continuous Forward Current	@ T_C = 100°C	15	A
I_{FM}	Diode Maximum Forward Current		45	A
P_D	Maximum Power Dissipation	@ T_C = 25°C	200	W
	Maximum Power Dissipation	@ T_C = 100°C	80	W
T_J	Operating Junction Temperature		-55 to +150	°C
T_{stg}	Storage Temperature Range		-55 to +150	°C
T_L	Maximum Lead Temp. for soldering Purposes, 1/8" from case for 5 seconds		300	°C

Notes :
(1) Repetitive rating : Pulse width limited by max. junction temperature

Thermal Characteristics

Symbol	Parameter	Typ.	Max.	Units
$R_{\theta JC}$(IGBT)	Thermal Resistance, Junction-to-Case	--	0.63	°C/W
$R_{\theta JC}$(DIODE)	Thermal Resistance, Junction-to-Case	--	2.88	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction-to-Ambient	--	40	°C/W

Electrical Characteristics of the IGBT T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Off Characteristics						
BV_{CES}	Collector-Emitter Breakdown Voltage	V_{GE} = 0V, I_C = 3mA	1200	--	--	V
$\Delta B_{VCES}/\Delta T_J$	Temperature Coefficient of Breakdown Voltage	V_{GE} = 0V, I_C = 3mA	--	0.6	--	V/°C
I_{CES}	Collector Cut-Off Current	V_{CE} = V_{CES}, V_{GE} = 0V	--	--	3	mA
I_{GES}	G-E Leakage Current	V_{GE} = V_{GES}, V_{CE} = 0V	--	--	± 100	nA
On Characteristics						
$V_{GE(th)}$	G-E Threshold Voltage	I_C = 15mA, V_{CE} = V_{GE}	3.5	5.5	7.5	V
$V_{CE(sat)}$	Collector to Emitter Saturation Voltage	I_C = 15A, V_{GE} = 15V	--	2.4	3.2	V
		I_C = 15A, V_{GE} = 15V, T_C = 125°C	--	2.9	--	V
		I_C = 24A, V_{GE} = 15V	--	3.0	--	V
Dynamic Characteristics						
C_{ies}	Input Capacitance	V_{CE} = 30V, V_{GE} = 0V, f = 1MHz	--	1150	--	pF
C_{oes}	Output Capacitance		--	120	--	pF
C_{res}	Reverse Transfer Capacitance		--	56	--	pF
Switching Characteristics						
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 600 V, I_C = 15A, R_G = 20Ω, V_{GE} = 15V, Inductive Load, T_C = 25°C	--	90	--	ns
t_r	Rise Time		--	70	--	ns
$t_{d(off)}$	Turn-Off Delay Time		--	310	--	ns
t_f	Fall Time		--	60	120	ns
E_{on}	Turn-On Switching Loss		--	3.27	4.9	mJ
E_{off}	Turn-Off Switching Loss		--	0.6	0.9	mJ
E_{ts}	Total Switching Loss		--	3.68	5.8	mJ
$t_{d(on)}$	Turn-On Delay Time	V_{CC} = 600 V, I_C = 15A, R_G = 20Ω, V_{GE} = 15V, Inductive Load, T_C = 125°C	--	80	--	ns
t_r	Rise Time		--	60	--	ns
$t_{d(off)}$	Turn-Off Delay Time		--	310	--	ns
t_f	Fall Time		--	50	--	ns
E_{on}	Turn-On Switching Loss		--	3.41	--	mJ
E_{off}	Turn-Off Switching Loss		--	0.84	--	mJ
E_{ts}	Total Switching Loss		--	4.25	--	mJ
Q_g	Total Gate Charge	V_{CE} = 600 V, I_C = 15A, V_{GE} = 15V	--	120	180	nC
Q_{ge}	Gate-Emitter Charge		--	9	14	nC
Q_{gc}	Gate-Collector Charge		--	63	95	nC
L_e	Internal Emitter Inductance	Measured 5mm from PKG	--	14	--	nH

Electrical Characteristics of DIODE T_C = 25°C unless otherwise noted

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Units
V_{FM}	Diode Forward Voltage	I_F = 15A	T_C = 25°C	--	1.7	2.7	V
			T_C = 125°C	--	1.8	--	
t_{rr}	Diode Reverse Recovery Time	I_F = 15A dI/dt = 200 A/µs	T_C = 25°C	--	210	330	ns
			T_C = 125°C	--	280	--	
I_{rr}	Diode Peak Reverse Recovery Current		T_C = 25°C	--	27	40	A
			T_C = 125°C	--	31	--	
Q_{rr}	Diode Reverse Recovery Charge		T_C = 25°C	--	2835	6600	nC
			T_C = 125°C	--	4340	--	

PD 91453B

International
IOR Rectifier

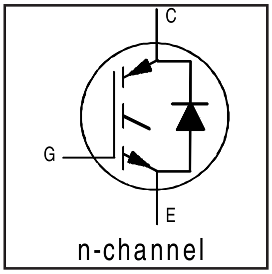
IRG4BC30UD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

UltraFast CoPack IGBT

Features

- UltraFast: Optimized for high operating frequencies 8-40 kHz in hard switching, >200 kHz in resonant mode
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- IGBT co-packaged with HEXFRED^{TM} ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-220AB package



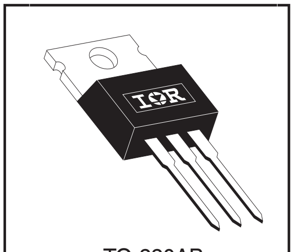
$V_{CES} = 600V$

$V_{CE(on)\ typ.} = 1.95V$

$@V_{GE} = 15V, I_C = 12A$

Benefits

- Generation -4 IGBT's offer highest efficiencies available
- IGBTs optimized for specific application conditions
- HEXFRED diodes optimized for performance with IGBTs . Minimized recovery characteristics require less/no snubbing
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBTs



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ $T_C = 25°C$	Continuous Collector Current	23	A
I_C @ $T_C = 100°C$	Continuous Collector Current	12	
I_{CM}	Pulsed Collector Current ①	92	
I_{LM}	Clamped Inductive Load Current ②	92	
I_F @ $T_C = 100°C$	Diode Continuous Forward Current	12	
I_{FM}	Diode Maximum Forward Current	92	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ $T_C = 25°C$	Maximum Power Dissipation	100	W
P_D @ $T_C = 100°C$	Maximum Power Dissipation	42	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	------	------	1.2	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	------	------	2.5	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	------	0.50	------	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	-----	-----	80	
Wt	Weight	------	2 (0.07)	------	g (oz)

4/17/00

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	600	----	----	V	V_{GE} = 0V, I_C = 250µA
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	----	0.63	----	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	----	1.95	2.1	V	I_C = 12A V_{GE} = 15V
		----	2.52	----		I_C = 23A See Fig. 2, 5
		----	2.09	----		I_C = 12A, T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	----	6.0		$V_{CE} = V_{GE}$, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	----	-11	----	mV/°C	$V_{CE} = V_{GE}$, I_C = 250µA
g_{fe}	Forward Transconductance ④	3.1	8.6	----	S	V_{CE} = 100V, I_C = 12A
I_{CES}	Zero Gate Voltage Collector Current	----	----	250	µA	V_{GE} = 0V, V_{CE} = 600V
		----	----	2500		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
V_{FM}	Diode Forward Voltage Drop	----	1.4	1.7	V	I_C = 12A See Fig. 13
		----	1.3	1.6		I_C = 12A, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	----	----	±100	nA	V_{GE} = ±20V

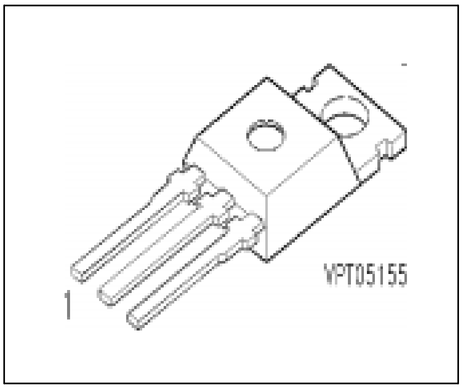
Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	----	50	75	nC	I_C = 12A	
Qge	Gate - Emitter Charge (turn-on)	----	8.1	12		V_{CC} = 400V See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	----	18	27		V_{GE} = 15V	
$t_{d(on)}$	Turn-On Delay Time	----	40	----	ns	T_J = 25°C	
t_r	Rise Time	----	21	----		I_C = 12A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	91	140		V_{GE} = 15V, R_G = 23Ω	
t_f	Fall Time	----	80	130		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	----	0.38	----	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	----	0.16	----		See Fig. 9, 10, 11, 18	
E_{ts}	Total Switching Loss	----	0.54	0.9			
$t_{d(on)}$	Turn-On Delay Time	----	40	----	ns	T_J = 150°C, See Fig. 9, 10, 11, 18	
t_r	Rise Time	----	22	----		I_C = 12A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	120	----		V_{GE} = 15V, R_G = 23Ω	
t_f	Fall Time	----	180	----		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	----	0.89	----	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	----	7.5	----	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	----	1100	----	pF	V_{GE} = 0V	
C_{oes}	Output Capacitance	----	73	----		V_{CC} = 30V See Fig. 7	
C_{res}	Reverse Transfer Capacitance	----	14	----		ƒ = 1.0MHz	
t_{rr}	Diode Reverse Recovery Time	----	42	60	ns	T_J = 25°C See Fig.	
		----	80	120		T_J = 125°C 14	I_F = 12A
I_{rr}	Diode Peak Reverse Recovery Current	----	3.5	6.0	A	T_J = 25°C See Fig.	
		----	5.6	10		T_J = 125°C 15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	----	80	180	nC	T_J = 25°C See Fig.	
		----	220	600		T_J = 125°C 16	di/dt 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery During t_b	----	180	----	A/µs	T_J = 25°C See Fig.	
		----	120	----		T_J = 125°C 17	

IGBT With Antiparallel Diode

Preliminary data

- Low forward voltage drop
- High switching speed
- Low tail current
- Latch-up free
- Including fast free-wheel diode



Pin 1	Pin 2	Pin 3
G	C	E

Type	V_{CE}	I_C	Package	Ordering Code
BUP 400D	600V	22A	TO-220 AB	Q67040-A4423-A2

Maximum Ratings

Parameter	Symbol	Values	Unit
Collector-emitter voltage	V_{CE}	600	V
Collector-gate voltage R_{GE} = 20 kΩ	V_{CGR}	600	
Gate-emitter voltage	V_{GE}	± 20	
DC collector current T_C = 25 °C T_C = 90 °C	I_C	 22 14	A
Pulsed collector current, t_p = 1 ms T_C = 25 °C T_C = 90 °C	I_{Cpuls}	 44 28	
Diode forward current T_C = 90 °C	I_F	11	
Pulsed diode current, t_p = 1 ms T_C = 25 °C	I_{Fpuls}	72	
Power dissipation T_C = 25 °C	P_{tot}	100	W
Chip or operating temperature	T_j	-55 ... + 150	°C
Storage temperature	T_{stg}	-55 ... + 150	

Maximum Ratings

Parameter	Symbol	Values	Unit
DIN humidity category, DIN 40 040	-	E	-
IEC climatic category, DIN IEC 68-1	-	55 / 150 / 56	

Thermal Resistance

Thermal resistance, chip case	R_{thJC}	≤ 1.25	K/W
Diode thermal resistance, chip case	R_{thJCD}	≤ 2.5	

Electrical Characteristics, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Values			Unit
		min.	typ.	max.	
Static Characteristics					
Gate threshold voltage $V_{GE} = V_{CE}$, I_C = 0.35 mA	$V_{GE(th)}$	4.5	5.5	6.5	V
Collector-emitter saturation voltage	$V_{CE(sat)}$				
V_{GE} = 15 V, I_C = 10 A, T_j = 25 °C		-	2.1	2.7	
V_{GE} = 15 V, I_C = 10 A, T_j = 125 °C		-	2.2	2.8	
V_{GE} = 15 V, I_C = 20 A, T_j = 25 °C		-	3	-	
V_{GE} = 15 V, I_C = 20 A, T_j = 125 °C		-	3.3	-	
Zero gate voltage collector current V_{CE} = 600 V, V_{GE} = 0 V, T_j = 25 °C	I_{CES}	-	-	160	µA
Gate-emitter leakage current V_{GE} = 25 V, V_{CE} = 0 V	I_{GES}	-	-	100	nA
AC Characteristics					
Transconductance V_{CE} = 20 V, I_C = 10 A	g_{fs}	2	-	-	S
Input capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{iss}	-	570	760	pF
Output capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{oss}	-	80	120	
Reverse transfer capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{rss}	-	50	75	

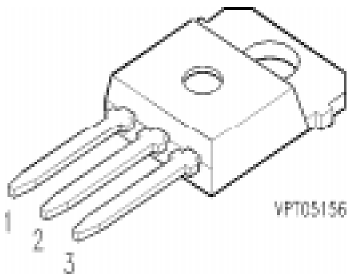
Electrical Characteristics, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Values			Unit
		min.	typ.	max.	
Switching Characteristics, Inductive Load at T_j = 125 °C					
Turn-on delay time	$t_{d(on)}$				ns
V_{CC} = 300 V, V_{GE} = 15 V, I_C = 10 A					
R_{Gon} = 100 Ω		-	45	70	
Rise time	t_r				
V_{CC} = 300 V, V_{GE} = 15 V, I_C = 10 A					
R_{Gon} = 100 Ω		-	60	90	
Turn-off delay time	$t_{d(off)}$				
V_{CC} = 300 V, V_{GE} = -15 V, I_C = 10 A					
R_{Goff} = 100 Ω		-	250	340	
Fall time	t_f				
V_{CC} = 300 V, V_{GE} = -15 V, I_C = 10 A					
R_{Goff} = 100 Ω		-	500	680	
Free-Wheel Diode					
Diode forward voltage	V_F				V
I_F = 10 A, V_{GE} = 0 V, T_j = 25 °C		-	1.65	-	
I_F = 10 A, V_{GE} = 0 V, T_j = 125 °C		-	-	-	
Reverse recovery time	t_{rr}				ns
I_F = 10 A, V_R = -300 V, V_{GE} = 0 V					
di_F/dt = -100 A/µs					
T_j = 25 °C		-	60	100	
T_j = 125 °C		-	100	150	
Reverse recovery charge	Q_{rr}				µC
I_F = 10 A, V_R = -300 V, V_{GE} = 0 V					
di_F/dt = -100 A/µs					
T_j = 25 °C		-	0.2	0.37	
T_j = 125 °C		-	0.4	0.74	

IGBT

Preliminary data

- Low forward voltage drop
- High switching speed
- Low tail current
- Latch-up free
- Avalanche rated



Pin 1	Pin 2	Pin 3
G	C	E

Type	V_{CE}	I_C	Package	Ordering Code
BUP 314	1200V	52A	TO-218 AB	Q67040-A4206-A2

Maximum Ratings

Parameter	Symbol	Values	Unit
Collector-emitter voltage	V_{CE}	1200	V
Collector-gate voltage R_{GE} = 20 kΩ	V_{CGR}	1200	
Gate-emitter voltage	V_{GE}	± 20	
DC collector current	I_C		A
T_C = 25 °C		52	
T_C = 90 °C		33	
Pulsed collector current, t_p = 1 ms	I_{Cpuls}		
T_C = 25 °C		104	
T_C = 90 °C		66	
Avalanche energy, single pulse I_C = 25 A, V_{CC} = 50 V, R_{GE} = 25 Ω L = 200 µH, T_j = 25 °C	E_{AS}	65	mJ
Power dissipation T_C = 25 °C	P_{tot}	300	W
Chip or operating temperature	T_j	-55 ... + 150	°C
Storage temperature	T_{stg}	-55 ... + 150	

Maximum Ratings

Parameter	Symbol	Values	Unit
DIN humidity category, DIN 40 040	-	E	-
IEC climatic category, DIN IEC 68-1	-	55 / 150 / 56	

Thermal Resistance

Thermal resistance, chip case	R_{thJC}	≤ 0.42	K/W

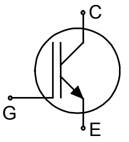
Electrical Characteristics, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Values			Unit
		min.	**typ.**	**max.**	
Static Characteristics					
Gate threshold voltage $V_{GE} = V_{CE}$, I_C = 0.35 mA	$V_{GE(th)}$	4.5	5.5	6.5	V
Collector-emitter saturation voltage	$V_{CE(sat)}$				
V_{GE} = 15 V, I_C = 25 A, T_j = 25 °C		-	2.7	3.2	
V_{GE} = 15 V, I_C = 25 A, T_j = 125 °C		-	3.3	3.9	
V_{GE} = 15 V, I_C = 42 A, T_j = 25 °C		-	3.4	-	
V_{GE} = 15 V, I_C = 42 A, T_j = 125 °C		-	4.3	-	
Zero gate voltage collector current V_{CE} = 1200 V, V_{GE} = 0 V, T_j = 25 °C	I_{CES}	-	-	0.25	mA
Gate-emitter leakage current V_{GE} = 25 V, V_{CE} = 0 V	I_{GES}	-	-	100	nA
AC Characteristics					
Transconductance V_{CE} = 20 V, I_C = 25 A	g_{fs}	8.5	20	-	S
Input capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{iss}	-	1650	2200	pF
Output capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{oss}	-	250	380	
Reverse transfer capacitance V_{CE} = 25 V, V_{GE} = 0 V, f = 1 MHz	C_{rss}	-	110	160	

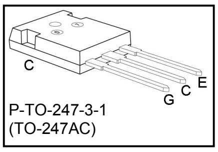
Electrical Characteristics, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Values			Unit
		min.	typ.	max.	
Switching Characteristics, Inductive Load at T_j = 125 °C					
Turn-on delay time V_{CC} = 600 V, V_{GE} = 15 V, I_C = 25 A R_{Gon} = 47 Ω	$t_{d(on)}$	-	75	110	ns
Rise time V_{CC} = 600 V, V_{GE} = 15 V, I_C = 25 A R_{Gon} = 47 Ω	t_r	-	65	100	
Turn-off delay time V_{CC} = 600 V, V_{GE} = -15 V, I_C = 25 A R_{Goff} = 47 Ω	$t_{d(off)}$	-	420	560	
Fall time V_{CC} = 600 V, V_{GE} = -15 V, I_C = 25 A R_{Goff} = 47 Ω	t_f	-	45	60	

Low Loss IGBT in Trench and Fieldstop technology



- Short circuit withstand time – 10µs
- Designed for :
    - Frequency Converters
    - Uninterrupted Power Supply
- Trench and Fieldstop technology for 1200 V applications offers :
    - very tight parameter distribution
    - high ruggedness, temperature stable behavior
- NPT technology offers easy parallel switching capability due to positive temperature coefficient in $V_{CE(sat)}$
- Low EMI
- Low Gate Charge
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/



P-TO-247-3-1
(TO-247AC)

Type	V_{CE}	I_C	$V_{CE(sat),Tj=25°C}$	$T_{j,max}$	**Package**	**Ordering Code**
IGW40T120	1200V	40A	1.8V	150°C	TO-247AC	Q67040-S4519

Maximum Ratings

Parameter	**Symbol**	**Value**	**Unit**
Collector-emitter voltage	V_{CE}	1200	V
DC collector current	I_C		A
T_C = 25°C		75	
T_C = 100°C		40	
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	105	
Turn off safe operating area $V_{CE} \leq$ 1200V, $T_j \leq$ 150°C	-	105	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[1)] V_{GE} = 15V, $V_{CC} \leq$ 1200V, $T_j \leq$ 150°C	t_{SC}	10	µs
Power dissipation T_C = 25°C	P_{tot}	270	W
Operating junction temperature	T_j	-40...+150	°C
Storage temperature	T_{stg}	-55...+150	
Soldering temperature, 1.6mm (0.063 in.) from case for 10s	-	260	

[1)] Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		0.45	K/W
Thermal resistance, junction – ambient	R_{thJA}	TO-247AC	40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	V_{GE}=0V, I_C=1.5mA	1200	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, I_C=40A T_j=25°C T_j=125°C T_j=150°C	- - -	1.8 2.1 2.3	2.3 - -	
Gate-emitter threshold voltage	$V_{GE(th)}$	I_C=1.5mA, V_{CE}=V_{GE}	5.0	5.8	6.5	
Zero gate voltage collector current	I_{CES}	V_{CE}=1200V, V_{GE}=0V T_j=25°C T_j=150°C	- -	- -	0.4 4.0	mA
Gate-emitter leakage current	I_{GES}	V_{CE}=0V, V_{GE}=20V	-	-	600	nA
Transconductance	g_{fs}	V_{CE}=20V, I_C=40A	-	21	-	S
Integrated gate resistor	R_{Gint}			6		Ω

Dynamic Characteristic

Input capacitance	C_{iss}	V_{CE}=25V, V_{GE}=0V, f=1MHz	-	2500	-	pF
Output capacitance	C_{oss}		-	130	-	
Reverse transfer capacitance	C_{rss}		-	110	-	
Gate charge	Q_{Gate}	V_{CC}=960V, I_C=40A V_{GE}=15V	-	203	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E	TO-247AC	-	-	13	nH
Short circuit collector current[1]	$I_{C(SC)}$	V_{GE}=15V, t_{SC}≤10µs V_{CC} = 600V, T_j = 25°C	-	210	-	A

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	**Symbol**	**Conditions**	**Value**			**Unit**
			min.	**typ.**	**max.**	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=600V, I_C=40A, V_{GE}=0/15V, R_G=15Ω, L_σ[2]=180nH, C_σ[2]=39pF Energy losses include "tail" and diode reverse recovery.	-	48	-	ns
Rise time	t_r		-	34	-	
Turn-off delay time	$t_{d(off)}$		-	480	-	
Fall time	t_f		-	70	-	
Turn-on energy	E_{on}		-	3.3	-	mJ
Turn-off energy	E_{off}		-	3.2	-	
Total switching energy	E_{ts}		-	6.5	-	

Switching Characteristic, Inductive Load, at T_j=150 °C

Parameter	**Symbol**	**Conditions**	**Value**			**Unit**
			min.	**typ.**	**max.**	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=150°C V_{CC}=600V, I_C=40A, V_{GE}=0/15V, R_G= 15Ω, L_σ[2]=180nH, C_σ[2]=39pF Energy losses include "tail" and diode reverse recovery.	-	52	-	ns
Rise time	t_r		-	40	-	
Turn-off delay time	$t_{d(off)}$		-	580	-	
Fall time	t_f		-	120	-	
Turn-on energy	E_{on}		-	5.0	-	mJ
Turn-off energy	E_{off}		-	5.4	-	
Total switching energy	E_{ts}		-	10.4	-	

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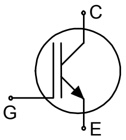
[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

[2] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

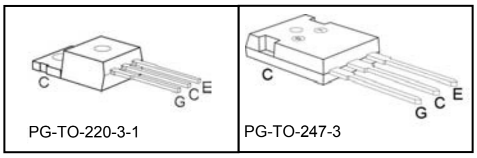
TrenchStop® Series

IGP30N60T
IGW30N60T

Low Loss IGBT in TrenchStop® and Fieldstop technology



- Very low $V_{CE(sat)}$ 1.5 V (typ.)
- Maximum Junction Temperature 175 °C
- Short circuit withstand time – 5µs
- Designed for :
  - Frequency Converters
  - Uninterruptible Power Supply
- TrenchStop® and Fieldstop technology for 600 V applications offers :
  - very tight parameter distribution
  - high ruggedness, temperature stable behavior
  - very high switching speed
- Positive temperature coefficient in $V_{CE(sat)}$
- Low EMI
- Low Gate Charge
- Qualified according to JEDEC[1] for target applications
- Pb-free lead plating; RoHS compliant
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/



Type	V_{CE}	I_C	$V_{CE(sat),Tj=25°C}$	$T_{j,max}$	Marking Code	Package
IGP30N60T	600V	30A	1.5V	175°C	G30T60	PG-TO-220-3-1
IGW30N60T	600V	30A	1.5V	175°C	G30T60	PG-TO-247-3

Maximum Ratings

Parameter	Symbol	Value	Unit
Collector-emitter voltage	V_{CE}	600	V
DC collector current, limited by T_{jmax}	I_C		A
$T_C = 25°C$		60	
$T_C = 100°C$		30	
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	90	
Turn off safe operating area ($V_{CE} \leq 600V$, $T_j \leq 175°C$)	-	90	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[2)] $V_{GE} = 15V$, $V_{CC} \leq 400V$, $T_j \leq 150°C$	t_{SC}	5	µs
Power dissipation $T_C = 25°C$	P_{tot}	187	W
Operating junction temperature	T_j	-40...+175	°C
Storage temperature	T_{stg}	-55...+175	
Soldering temperature, 1.6mm (0.063 in.) from case for 10s	-	260	

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[1] J-STD-020 and JESD-022

2) Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		0.80	K/W
Thermal resistance, junction – ambient	R_{thJA}	PG-TO-220-3-1 PG-TO-247-3-21	62 40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	V_{GE}=0V, I_C=0.2mA	600	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, I_C=30A T_j=25°C T_j=175°C	 - -	 1.5 1.9	 2.05 -	
Gate-emitter threshold voltage	$V_{GE(th)}$	I_C=0.43mA, V_{CE}=V_{GE}	4.1	4.9	5.7	
Zero gate voltage collector current	I_{CES}	V_{CE}=600V, V_{GE}=0V T_j=25°C T_j=175°C	 - -	 - -	 40 1000	µA
Gate-emitter leakage current	I_{GES}	V_{CE}=0V,V_{GE}=20V	-	-	100	nA
Transconductance	g_{fs}	V_{CE}=20V, I_C=30A	-	16.7	-	S
Integrated gate resistor	R_{Gint}			-		Ω

Dynamic Characteristic

Input capacitance	C_{iss}	V_{CE}=25V,	-	1630	-	pF
Output capacitance	C_{oss}	V_{GE}=0V,	-	108	-	
Reverse transfer capacitance	C_{rss}	f=1MHz	-	50	-	
Gate charge	Q_{Gate}	V_{CC}=480V, I_C=30A V_{GE}=15V	-	167	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E	PG-TO-220-3-1 PG-TO-247-3-21	- -	7 13	- -	nH
Short circuit collector current1)	$I_{C(SC)}$	V_{GE}=15V,t_{SC}≤5µs V_{CC} = 400V, T_j = 150°C	-	275	-	A

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[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=400V, I_C=30A, V_{GE}=0/15V, R_G=10.6 Ω, L_σ[1]=136nH, C_σ[1]=39pF Energy losses include "tail" and diode reverse recovery. [2]	-	23	-	ns
Rise time	t_r		-	21	-	
Turn-off delay time	$t_{d(off)}$		-	254	-	
Fall time	t_f		-	46	-	
Turn-on energy	E_{on}		-	0.69	-	mJ
Turn-off energy	E_{off}		-	0.77	-	
Total switching energy	E_{ts}		-	1.46	-	

Switching Characteristic, Inductive Load, at T_j=175 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=175°C, V_{CC}=400V, I_C=30A, V_{GE}=0/15V, R_G= 10.6 Ω L_σ[1]=136nH, C_σ[1]=39pF Energy losses include "tail" and diode reverse recovery.[2]	-	24	-	ns
Rise time	t_r		-	26	-	
Turn-off delay time	$t_{d(off)}$		-	292	-	
Fall time	t_f		-	90	-	
Turn-on energy	E_{on}		-	1.0	-	mJ
Turn-off energy	E_{off}		-	1.1	-	
Total switching energy	E_{ts}		-	2.1	-	

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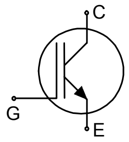
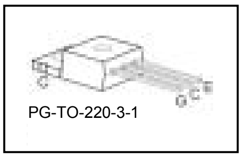
[1] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

[2] Includes Reverse Recovery Losses from IKW30N60T due to dynamic test circuit in Figure E.

Low Loss IGBT in TrenchStop® and Fieldstop technology



- Very low $V_{CE(sat)}$ 1.5 V (typ.)
- Maximum Junction Temperature 175 °C
- Short circuit withstand time – 5µs
- Designed for :
  - Frequency Converters
  - Uninterrupted Power Supply
- TrenchStop® and Fieldstop technology for 600 V applications offers :
  - very tight parameter distribution
  - high ruggedness, temperature stable behavior
  - very high switching speed
- Positive temperature coefficient in $V_{CE(sat)}$
- Low EMI
- Pb-free lead plating; RoHS compliant
- Qualified according to JEDEC[1] for target applications
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/



Type	V_{CE}	I_C	$V_{CE(sat),Tj=25°C}$	$T_{j,max}$	**Marking Code**	**Package**
IGP15N60T	600V	15A	1.5V	175°C	G15T60	PG-TO-220-3-1

Maximum Ratings

Parameter	**Symbol**	**Value**	**Unit**
Collector-emitter voltage	V_{CE}	600	V
DC collector current, limited by T_{jmax}	I_C		A
T_C = 25°C		30	
T_C = 100°C		15	
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	45	
Turn off safe operating area ($V_{CE} \leq$ 600V, $T_j \leq$ 175°C)	-	45	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[2]	t_{SC}	5	µs
V_{GE} = 15V, $V_{CC} \leq$ 400V, $T_j \leq$ 150°C			
Power dissipation T_C = 25°C	P_{tot}	130	W
Operating junction temperature	T_j	-40...+175	°C
Storage temperature	T_{stg}	-55...+175	
Soldering temperature wavesoldering, 1.6 mm (0.063 in.) from case for 10s		260	

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[1] J-STD-020 and JESD-022

[2] Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		1.15	K/W
Thermal resistance, junction – ambient	R_{thJA}		62	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	V_{GE}=0V, I_C=0.2mA	600	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, I_C=15A				
		T_j=25°C	-	1.5	2.05	
		T_j=175°C	-	1.9	-	
Gate-emitter threshold voltage	$V_{GE(th)}$	I_C=210µA, V_{CE}=V_{GE}	4.1	4.9	5.7	
Zero gate voltage collector current	I_{CES}	V_{CE}=600V, V_{GE}=0V				µA
		T_j=25°C	-	-	40	
		T_j=175°C	-	-	1000	
Gate-emitter leakage current	I_{GES}	V_{CE}=0V, V_{GE}=20V	-	-	100	nA
Transconductance	g_{fs}	V_{CE}=20V, I_C=15A	-	8.7	-	S
Integrated gate resistor	R_{Gint}			-		Ω

Dynamic Characteristic

Input capacitance	C_{iss}	V_{CE}=25V, V_{GE}=0V, f=1MHz	-	860	-	pF
Output capacitance	C_{oss}		-	55	-	
Reverse transfer capacitance	C_{rss}		-	24	-	
Gate charge	Q_{Gate}	V_{CC}=480V, I_C=15A V_{GE}=15V	-	87	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E		-	7	-	nH
Short circuit collector current[1]	$I_{C(SC)}$	V_{GE}=15V, t_{SC}≤5µs V_{CC} = 400V, T_j = 150°C	-	137.5	-	A

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[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	**Symbol**	**Conditions**	**Value**			**Unit**
			min.	**Typ.**	**max.**	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=400V,I_C=15A, V_{GE}=0 /15V, R_G=15Ω, L_σ[1]=154nH, C_σ[1]=39pF Energy losses include “tail” and diode reverse recovery.	-	17	-	ns
Rise time	t_r		-	11	-	
Turn-off delay time	$t_{d(off)}$		-	188	-	
Fall time	t_f		-	50	-	
Turn-on energy	E_{on}		-	0.22	-	mJ
Turn-off energy	E_{off}		-	0.35	-	
Total switching energy	E_{ts}		-	0.57	-	

Switching Characteristic, Inductive Load, at T_j=175 °C

Parameter	**Symbol**	**Conditions**	**Value**			**Unit**
			min.	**Typ.**	**max.**	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=175°C, V_{CC}=400V,I_C=15A, V_{GE}=0/15V, R_G= 15 Ω L_σ[1]=154nH, C_σ[1]=39pF Energy losses include “tail” and diode reverse recovery.	-	17	-	ns
Rise time	t_r		-	15	-	
Turn-off delay time	$t_{d(off)}$		-	212	-	
Fall time	t_f		-	79	-	
Turn-on energy	E_{on}		-	0.34	-	mJ
Turn-off energy	E_{off}		-	0.47	-	
Total switching energy	E_{ts}		-	0.81	-	

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[1] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

HGTP10N40C1D, HGTP10N40E1D, HGTP10N50C1D, HGTP10N50E1D

10A, 400V and 500V N-Channel IGBTs with Anti-Parallel Ultrafast Diodes

April 1995

Features

- **10A, 400V and 500V**
- **$V_{CE(ON)}$: 2.5V Max.**
- **T_{FALL}: 1µs, 0.5µs**
- **Low On-State Voltage**
- **Fast Switching Speeds**
- **High Input Impedance**
- **Anti-Parallel Diode**

Applications

- **Power Supplies**
- **Motor Drives**
- **Protective Circuits**

Description

The HGTP10N40C1D, HGTP10N40E1D, HGTP10N50C1D, and HGTP10N50E1D are n-channel enhancement-mode insulated gate bipolar transistors (IGBTs) designed for high voltage, low on-dissipation applications such as switching regulators and motor drivers. They feature a discrete anti-parallel diode that shunts current around the IGBT in the reverse direction without introducing carriers into the depletion region. These types can be operated directly from low power integrated circuits.

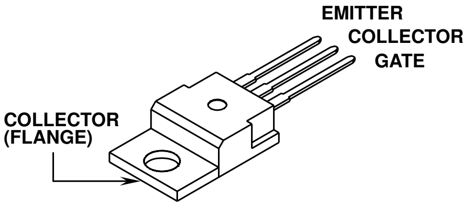
PACKAGING AVAILABILITY

PART NUMBER	PACKAGE	BRAND
HGTP10N40C1D	TO-220AB	10N40C1D
HGTP10N40E1D	TO-220AB	10N40E1D
HGTP10N50C1D	TO-220AB	10N50C1D
HGTP10N50E1D	TO-220AB	10N50E1D

NOTE: When ordering, use the entire part number.

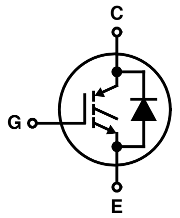
Package

JEDEC TO-220AB



Terminal Diagram

N-CHANNEL ENHANCEMENT MODE



Absolute Maximum Ratings $T_C = +25^oC$, Unless Otherwise Specified

		HGTP10N40C1D HGTP10N40E1D	HGTP10N50C1D HGTP10N50E1D	UNITS
Collector-Emitter Voltage	V_{CES}	400	500	V
Collector-Gate Voltage $R_{GE} = 1M\Omega$	V_{CGR}	400	500	V
Gate-Emitter Voltage	V_{GE}	±20	±20	V
Collector Current Continuous at $T_C = +25^oC$	I_{C25}	17.5	17.5	A
at $T_C = +90^oC$	I_{C90}	10	10	
Power Dissipation Total at $T_C = +25^oC$	P_D	75	75	W
Power Dissipation Derating $T_C > +25^oC$		0.6	0.6	W/^{o}C
Operating and Storage Junction Temperature Range	T_J, T_{STG}	-55 to +150	-55 to +150	^{o}C

CAUTION: These devices are sensitive to electrostatic discharge; follow proper IC Handling Procedures.

Electrical Specifications T_C = +25°C, Unless Otherwise Specified

PARAMETERS	SYMBOL	TEST CONDITIONS	LIMITS				UNITS
			HGTP10N40C1D, HGTP10N40E1D		HGTP10N50C1D, HGTP10N50E1D		
			MIN	MAX	MIN	MAX	
Collector-Emitter Breakdown Voltage	BV_{CES}	I_C = 1mA, V_{GE} = 0	400	-	500	-	V
Gate Threshold Voltage	$V_{GE(TH)}$	V_{GE} = V_{CE}, I_C = 1mA	2.0	4.5	2.0	4.5	V
Zero Gate Voltage Collector Current	I_{CES}	V_{CE} = 400V, T_C = +25°C	-	250	-	-	μA
		V_{CE} = 500V, T_C = +25°C	-	-	-	250	μA
		V_{CE} = 400V, T_C = +125°C	-	1000	-	-	μA
		V_{CE} = 500V, T_C = +125°C	-	-	-	1000	μA
Gate-Emitter Leakage Current	I_{GES}	V_{GE} = ±20V, V_{CE} = 0	-	100	-	100	nA
Collector-Emitter On Voltage	$V_{CE(ON)}$	I_C = 10A, V_{GE} = 10V	-	2.5	-	2.5	V
		I_C = 17.5A, V_{GE} = 20V	-	3.2	-	3.2	V
Gate-Emitter Plateau Voltage	V_{GEP}	I_C = 5A, V_{CE} = 10V	-	6 (Typ)	-	6 (Typ)	V
On-State Gate Charge	$Q_{G(ON)}$	I_C = 5A, V_{CE} = 10V	-	19 (Typ)	-	19 (Typ)	nC
Turn-On Delay Time	$t_{D(ON)I}$	I_C = 10A, $V_{CE(CLP)}$ = 300V, L = 50μH, T_J = +100°C, V_{GE} = 10V, R_G = 50Ω	-	50	-	50	ns
Rise Time	t_{RI}		-	50	-	50	ns
Turn-Off Delay Time	$t_{D(OFF)I}$		-	400	-	400	ns
Fall Time	t_{FI}						
40E1D, 50E1D			680 (Typ)	1000	680 (Typ)	1000	ns
40C1D, 50C1D			400 (Typ)	500	400 (Typ)	500	ns
Turn-Off Energy Loss per Cycle (Off Switching Dissipation = W_{OFF} x Frequency)	W_{OFF}	I_C = 10A, $V_{CE(CLP)}$ = 300V, L = 50μH, T_J = +100°C, V_{GE} = 10V, R_G = 50Ω					
40E1D, 50E1D			1810 (Typ)				μJ
40C1D, 50C1D			1070 (Typ)				μJ
Thermal Resistance Junction-to-Case	$R_{\theta JC}$		-	1.67	-	1.67	°C/W
Diode Forward Voltage	V_{EC}	I_{EC} = 10A	-	2	-	2	V
Diode Reverse Recovery Time	t_{RR}	I_{EC} = 10A, di/dt = 100A/μs	-	100	-	100	ns

INTERSIL CORPORATION IGBT PRODUCT IS COVERED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS:

4,364,073	4,417,385	4,430,792	4,443,931	4,466,176	4,516,143	4,532,534	4,567,641
4,587,713	4,598,461	4,605,948	4,618,872	4,620,211	4,631,564	4,639,754	4,639,762
4,641,162	4,644,637	4,682,195	4,684,413	4,694,313	4,717,679	4,743,952	4,783,690
4,794,432	4,801,986	4,803,533	4,809,045	4,809,047	4,810,665	4,823,176	4,837,606
4,860,080	4,883,767	4,888,627	4,890,143	4,901,127	4,904,609	4,933,740	4,963,951
4,969,027							

FAIRCHILD
SEMICONDUCTOR®

September 2005

HGTP7N60C3D, HGT1S7N60C3DS, HGT1S7N60C3D

14A, 600V, UFS Series N-Channel IGBT with Anti-Parallel Hyperfast Diodes

General Description

The HGTP7N60C3D, HGT1S7N60C3DS and HGT1S7N60C3D are MOS gated high voltage switching devices combining the best features of MOSFETs and bipolar transistors. These devices have the high input impedance of a MOSFET and the low on-state conduction loss of a bipolar transistor. The much lower on-state voltage drop varies only moderately between 25°C and 150°C. The IGBT used is developmental type TA49115. The diode used in anti-parallel with the IGBT is developmental type TA49057.

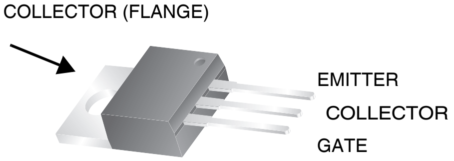
The IGBT is ideal for many high voltage switching applications operating at moderate frequencies where low conduction losses are essential, such as: AC and DC motor controls, power supplies and drivers for solenoids, relays and contactors.

Formerly Developmental Type TA49121.

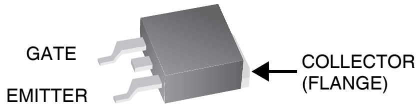
Features

- 4A, 600V at $T_C = 25^oC$
- 600V Switching SOA Capability
- Typical Fall Time..................140ns at $T_J = 150^oC$
- Short Circuit Rating
- Low Conduction Loss
- Hyperfast Anti-Parallel Diode

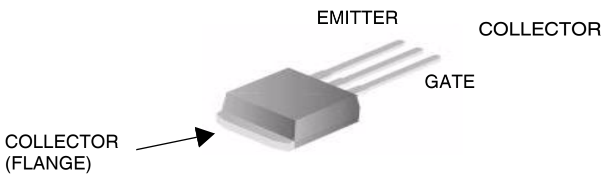
JEDEC TO-220AB

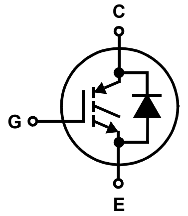


JEDEC TO-263AB



JEDEC TO-262





FAIRCHILD SEMICONDUCTOR IGBT PRODUCT IS COVERED BY ONE OR MORE OF THE FOLLOWING U.S. PATENTS

4,364,073	4,417,385	4,430,792	4,443,931	4,466,176	4,516,143	4,532,534	4,587,713
4,598,461	4,605,948	4,620,211	4,631,564	4,639,754	4,639,762	4,641,162	4,644,637
4,682,195	4,684,413	4,694,313	4,717,679	4,743,952	4,783,690	4,794,432	4,801,986
4,803,533	4,809,045	4,809,047	4,810,665	4,823,176	4,837,606	4,860,080	4,883,767
4,888,627	4,890,143	4,901,127	4,904,609	4,933,740	4,963,951	4,969,027	

Absolute Maximum Ratings $T_A = 25°C$ unless otherwise noted

Symbol	Parameter	Ratings	Units
BV_{CES}	Collector to Emitter Voltage	600	V
I_{C25}	Collector Current Continuous At $T_C = 25^oC$	14	A
I_{C110}	Collector Current Continuous At $T_C = 110^oC$	7	A
I(AVG)	Average Diode Forward Current at 110^{o}C	8	A
I_{CM}	Collector Current Pulsed (Note 1)	56	A
V_{GES}	Gate to Emitter Voltage Continuous	±20	V
V_{GEM}	Gate to Emitter Voltage Pulsed	±30	V
SSOA	Switching Safe Operating Area at $T_J = 150^oC$ (Figure 14)	40A at 480V	
P_D	Power Dissipation Total at $T_C = 25^oC$	60	W
	Power Dissipation Derating $T_C > 25^oC$	0.487	W/^{o}C
T_J, T_{STG}	Operating and Storage Junction Temperature Range	-40 to 150	^{o}C
T_L	Maximum Lead Temperature for Soldering	260	^{o}C
t_{SC}	Short Circuit Withstand Time (Note 2) at $V_{GE} = 15V$	1	µs
	Short Circuit Withstand Time (Note 2) at $V_{GE} = 10V$	8	µs

CAUTION: Stresses above those listed in “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

NOTES:

1. Repetitive Rating: Pulse width limited by maximum junction temperature.
2. $V_{CE(PK)} = 360V$, $T_J = 125^oC$, $R_G = 50W$.

Thermal Characteristics

$R_{\theta JC}$	Thermal Resistance IGBT	2.1	^{o}C/W
	Thermal Resistance Diode	2.0	^{o}C/W

Package Marking and Ordering Information

Part Number	Package	Brand
HGTP7N60C3D	TO-220AB	G7N60C3D
HGT1S7N60C3DS	TO-263AB	G7N60C3D
HGT1S7N60C3D	TO-262	G7N60C3D

NOTES:When ordering, use the entire part number. Add the suffix 9A to obtain the TO-263AB variant in tape and reel, i.e. HGT1S7N60C3DS9A.

Electrical Characteristics T_A = 25°C unless otherwise noted

Off Characteristics

Symbol	Parameter	Test Conditions		Min	Typ	Max	Units
BV_{CES}	Collector to Emitter Breakdown Voltage	$I_C = 250\mu A$, $V_{GE} = 0V$		600	-	-	V
I_{CES}	Collector to Emitter Leakage Current	$V_{CE} = BV_{CES}$, $T_C = 25^oC$ $V_{CE} = BV_{CES}$, $T_C = 150^oC$		-	-	250 2.0	µA mA
I_{GES}	Gate-Emitter Leakage Current	$V_{GE} = \pm 25V$		-	-	±250	nA
$V_{CE(SAT)}$	Collector to Emitter Saturation Voltage	$I_C = I_{C110}$, $V_{GE} = 15V$	$T_C = 25^oC$	-	1.6	2.0	V
			$T_C = 150^oC$	-	1.9	2.4	V

On Characteristics

Symbol	Parameter	Test Conditions		Min	Typ	Max	Units
$V_{GE(TH)}$	Gate-Emitter Threshold Voltage	$I_C = 250\mu A$, $V_{CE} = V_{GE}$, $T_C = 25^oC$		3.0	5.0	6.0	V
SSOA	Switching SOA	$T_J = 150^oC$, $R_G = 50\Omega$, $V_{GE} = 15V$, L = 1mH	$V_{CE(PK)} = 480V$	40	-	-	A
			$V_{CE(PK)} = 600V$	60	-	-	A
V_{GEP}	Gate to Emitter Plateau Voltage	$I_C = I_{C110}$, $V_{CE} = 0.5\ BV_{CES}$		-	8	-	V

Switching Characteristics

Symbol	Parameter	Test Conditions		Min	Typ	Max	Units
$t_{d(ON)I}$	Current Turn-On Delay Time	$T_J = 150^oC$ $I_{CE} = I_{C110}$ $V_{CE(PK)} = 0.8\ BV_{CES}$ $V_{GE} = 15V$ $R_G = 50\Omega$ L = 1mH		-	8.5	-	ns
t_{rI}	Current Rise Time			-	11.5	-	ns
$t_{d(OFF)I}$	Current Turn-Off Delay Time			-	350	400	ns
t_{fI}	Current Fall Time			-	140	275	ns
E_{ON}	Turn-On Energy			-	165	-	µJ
E_{OFF}	Turn-Off Energy (Note 3)			-	600	-	µJ
$Q_{G(ON)}$	On-State Gate Charge	$I_C = I_{C110}$, $V_{CE} = 0.5\ BV_{CES}$	$V_{GE} = 15V$	-	23	30	nC
			$V_{GE} = 20V$	-	30	38	nC

Drain-Source Diode Characteristics and Maximum Ratings

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
V_{EC}	Diode Forward Voltage	$I_{EC} = 7A$	-	1.9	2.5	V
t_{rr}	Diode Reverse Recovery Time	$I_{EC} = 7A$, $dI_{EC}/dt = 200A/\mu s$	-	25	37	ns
		$I_{EC} = 1A$, $dI_{EC}/dt = 200A/\mu s$	-	18	30	ns

NOTES:

3.Turn-Off Energy Loss (E_{OFF}) is defined as the integral of the instantaneous power loss starting at the trailing edge of the input pulse and ending at the point where the collector current equals zero (I_{CE} = 0A). The HGTP7N60C3D and HGT1S7N60C3DS were tested per JEDEC standard No. 24-1 Method for Measurement of Power Device Turn-Off Switching Loss. This test method produces the true total Turn-Off Energy Loss. Turn-On losses include diode losses.

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PD -91582B

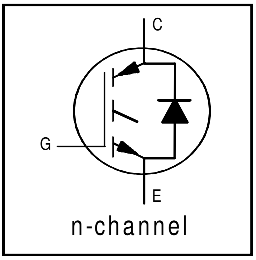
IRG4PC50KD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Short Circuit Rated
UltraFast IGBT

Features

- Short Circuit Rated UltraFast: Optimized for high operating frequencies >5.0 kHz, and Short Circuit Rated to 10µs @125°C, V_{GE} = 15V
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- IGBT co-packaged with HEXFRED™ ultrafast, ultra-soft recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package



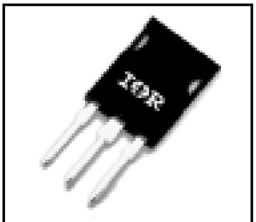
V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.84V

@V_{GE} = 15V, I_C = 30A

Benefits

- Generation 4 IGBTs offer highest efficiencies available
- HEXFRED diodes optimized for performance with IGBTs. Minimized recovery characteristics require less/no snubbing
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBTs



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	52	A
I_C @ T_C = 100°C	Continuous Collector Current	30	
I_{CM}	Pulsed Collector Current ①	104	
I_{LM}	Clamped Inductive Load Current ②	104	
I_F @ T_C = 100°C	Diode Continuous Forward Current	25	
I_{FM}	Diode Maximum Forward Current	280	
t_{sc}	Short Circuit Withstand Time	10	µs
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	200	W
P_D @ T_C = 100°C	Maximum Power Dissipation	78	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	—	—	0.64	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	—	—	0.83	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	—	0.24	—	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	—	—	40	
Wt	Weight	—	6 (0.21)	—	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage ③	600	—	—	V	V_{GE} = 0V, I_C = 250µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.47	—	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	1.84	2.2	V	I_C = 30A	V_{GE} = 15V
		—	2.19	—		I_C = 52A	see figures 2, 5
		—	1.79	—		I_C = 25A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		$V_{CE} = V_{GE}$, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-12	—	mV/°C	$V_{CE} = V_{GE}$, I_C = 250µA	
g_{fe}	Forward Transconductance ④	17	24	—	S	V_{CE} = 100V, I_C = 30A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 600V	
		—	—	6500		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	1.3	1.7	V	I_C = 25A	see figure 13
		—	1.2	1.5		I_C = 25A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q_g	Total Gate Charge (turn-on)	—	200	300	nC	I_C = 30A		
Q_{ge}	Gate - Emitter Charge (turn-on)	—	25	38		V_{CC} = 400V	see figure 8	
Q_{gc}	Gate - Collector Charge (turn-on)	—	85	127		V_{GE} = 15V		
$t_{d(on)}$	Turn-On Delay Time	—	63	—	ns			
t_r	Rise Time	—	49	—		T_J = 25°C		
$t_{d(off)}$	Turn-Off Delay Time	—	150	220		I_C = 30A, V_{CC} = 480V		
t_f	Fall Time	—	95	140		V_{GE} = 15V, R_G = 5.0Ω		
E_{on}	Turn-On Switching Loss	—	1.61	—	mJ	Energy losses include "tail"		
E_{off}	Turn-Off Switching Loss	—	0.84	—		and diode reverse recovery		
E_{ts}	Total Switching Loss	—	2.45	3.0		see figures 9,10,18		
t_{sc}	Short Circuit Withstand Time	10	—	—	µs	V_{CC} = 360V, T_J = 125°C V_{GE} = 15V, R_G = 10Ω , V_{CPK} < 500V		
$t_{d(on)}$	Turn-On Delay Time	—	61	—	ns	T_J = 150°C,	see figures 11,18	
t_r	Rise Time	—	46	—		I_C = 30A, V_{CC} = 480V		
$t_{d(off)}$	Turn-Off Delay Time	—	310	—		V_{GE} = 15V, R_G = 5.0Ω		
t_f	Fall Time	—	170	—		Energy losses include "tail"		
E_{ts}	Total Switching Loss	—	3.53	—	mJ	and diode reverse recovery		
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package		
C_{ies}	Input Capacitance	—	3200	—	pF	V_{GE} = 0V		
C_{oes}	Output Capacitance	—	370	—		V_{CC} = 30V	see figure 7	
C_{res}	Reverse Transfer Capacitance	—	95	—		ƒ = 1.0MHz		
t_{rr}	Diode Reverse Recovery Time	—	50	75	ns	T_J = 25°C	see figure	
		—	105	160		T_J = 125°C	14	I_F = 25A
I_{rr}	Diode Peak Reverse Recovery Current	—	4.5	10	A	T_J = 25°C	see figure	
		—	8.0	15		T_J = 125°C	15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	112	375	nC	T_J = 25°C	see figure	
		—	420	1200		T_J = 125°C	16	di/dt 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	—	250	—	A/µs	T_J = 25°C	see figure	
	During t_b	—	160	—		T_J = 125°C	17	

PD 9.1467D

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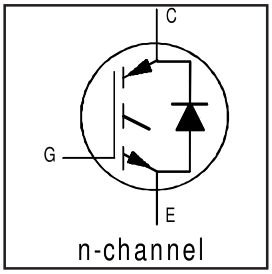
IRG4PC40UD

UltraFast CoPack IGBT

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE



V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.72V

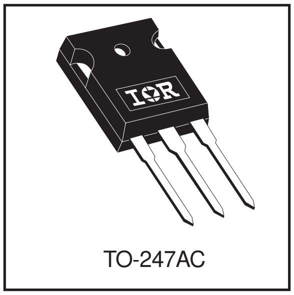
@V_{GE} = 15V, I_C = 20A

Features

- UltraFast: Optimized for high operating frequencies 8-40 kHz in hard switching, >200 kHz in resonant mode
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- IGBT co-packaged with HEXFRED^{TM} ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package

Benefits

- Generation -4 IGBT's offer highest efficiencies available
- IGBT's optimized for specific application conditions
- HEXFRED diodes optimized for performance with IGBT's . Minimized recovery characteristics require less/no snubbing
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBT's


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	40	A
I_C @ T_C = 100°C	Continuous Collector Current	20	
I_{CM}	Pulsed Collector Current ①	160	
I_{LM}	Clamped Inductive Load Current ②	160	
I_F @ T_C = 100°C	Diode Continuous Forward Current	15	
I_{FM}	Diode Maximum Forward Current	160	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	------	------	0.77	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	------	------	1.7	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	------	0.24	------	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	-----	-----	40	
Wt	Weight	------	6 (0.21)	------	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	600	----	----	V	V_{GE} = 0V, I_C = 250µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	----	0.63	----	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	----	1.72	2.1	V	I_C = 20A	V_{GE} = 15V
		----	2.15	----		I_C = 40A	See Fig. 2, 5
		----	1.7	----		I_C = 20A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	----	6.0		V_{CE} = V_{GE}, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	----	-13	----	mV/°C	V_{CE} = V_{GE}, I_C = 250µA	
g_{fe}	Forward Transconductance ④	11	18	----	S	V_{CE} = 100V, I_C = 20A	
I_{CES}	Zero Gate Voltage Collector Current	----	----	250	µA	V_{GE} = 0V, V_{CE} = 600V	
		----	----	3500		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	----	1.3	1.7	V	I_C = 15A	See Fig. 13
		----	1.2	1.6		I_C = 15A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	----	----	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q_g	Total Gate Charge (turn-on)	----	100	150	nC	I_C = 20A		
Qge	Gate - Emitter Charge (turn-on)	----	16	25		V_{CC} = 400V	See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	----	40	60		V_{GE} = 15V		
$t_{d(on)}$	Turn-On Delay Time	----	54	----	ns	T_J = 25°C		
t_r	Rise Time	----	57	----		I_C = 20A, V_{CC} = 480V		
$t_{d(off)}$	Turn-Off Delay Time	----	110	165		V_{GE} = 15V, R_G = 10Ω		
t_f	Fall Time	----	80	120		Energy losses include "tail" and		
E_{on}	Turn-On Switching Loss	----	0.71	----	mJ	diode reverse recovery.		
E_{off}	Turn-Off Switching Loss	----	0.35	----		See Fig. 9, 10, 11, 18		
E_{ts}	Total Switching Loss	----	1.10	1.5				
$t_{d(on)}$	Turn-On Delay Time	----	40	----	ns	T_J = 150°C,	See Fig. 9, 10, 11, 18	
t_r	Rise Time	----	52	----		I_C = 20A, V_{CC} = 480V		
$t_{d(off)}$	Turn-Off Delay Time	----	200	----		V_{GE} = 15V, R_G = 10Ω		
t_f	Fall Time	----	130	----		Energy losses include "tail" and		
E_{ts}	Total Switching Loss	----	1.6	----	mJ	diode reverse recovery.		
L_E	Internal Emitter Inductance	----	13	----	nH	Measured 5mm from package		
C_{ies}	Input Capacitance	----	2100	----	pF	V_{GE} = 0V		
C_{oes}	Output Capacitance	----	140	----		V_{CC} = 30V	See Fig. 7	
C_{res}	Reverse Transfer Capacitance	----	34	----		ƒ = 1.0MHz		
t_{rr}	Diode Reverse Recovery Time	----	42	60	ns	T_J = 25°C	See Fig.	
		----	74	120		T_J = 125°C	14	I_F = 15A
I_{rr}	Diode Peak Reverse Recovery Current	----	4.0	6.0	A	T_J = 25°C	See Fig.	
		----	6.5	10		T_J = 125°C	15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	----	80	180	nC	T_J = 25°C	See Fig.	
		----	220	600		T_J = 125°C	16	di/dt 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	----	190	----	A/µs	T_J = 25°C		
	During t_b	----	160	----		T_J = 125°C		

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PD - 9.1585B

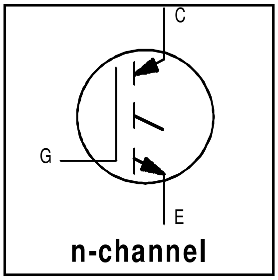
IRG4PC40K

Short Circuit Rated
UltraFast IGBT

INSULATED GATE BIPOLAR TRANSISTOR

Features

- Short Circuit Rated UltraFast: Optimized for high operating frequencies >5.0 kHz , and Short Circuit Rated to 10µs @ 125°C, V_{GE} = 15V
- Generation 4 IGBT design provides higher efficiency than Generation 3
- Industry standard TO-247AC package



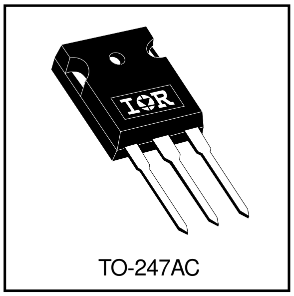
V_{CES} = 600V

$V_{CE(on)}$ typ. = 2.1V

@V_{GE} = 15V, I_C = 25A

Benefits

- Generation 4 IGBTs offer highest efficiency available
- IGBTs optimized for specified application conditions


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	42	A
I_C @ T_C = 100°C	Continuous Collector Current	25	
I_{CM}	Pulsed Collector Current ①	84	
I_{LM}	Clamped Inductive Load Current ②	84	
t_{sc}	Short Circuit Withstand Time	10	µs
V_{GE}	Gate-to-Emitter Voltage	±20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	15	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	——	0.77	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.24	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	40	
Wt	Weight	6 (0.21)	——	g (oz)

4/15/2000

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 250µA
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	18	—	—	V	V_{GE} = 0V, I_C = 1.0A
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.46	—	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	2.10	2.6	V	I_C = 25A V_{GE} = 15V
		—	2.70	—		I_C = 42A See Fig.2, 5
		—	2.14	—		I_C = 25A , T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-13	—	mV/°C	V_{CE} = V_{GE}, I_C = 250µA
g_{fe}	Forward Transconductance ⑤	7.0	14	—	S	V_{CE} = 100 V, I_C = 25A
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 600V
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C
		—	—	2000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	120	180	nC	I_C = 25A
Q_{ge}	Gate - Emitter Charge (turn-on)	—	16	24		V_{CC} = 400V See Fig.8
Q_{gc}	Gate - Collector Charge (turn-on)	—	51	77		V_{GE} = 15V
$t_{d(on)}$	Turn-On Delay Time	—	30	—	ns	
t_r	Rise Time	—	15	—		T_J = 25°C
$t_{d(off)}$	Turn-Off Delay Time	—	140	210		I_C = 25A, V_{CC} = 480V
t_f	Fall Time	—	140	210		V_{GE} = 15V, R_G = 10Ω
E_{on}	Turn-On Switching Loss	—	0.62	—	mJ	Energy losses include "tail"
E_{off}	Turn-Off Switching Loss	—	0.33	—		See Fig. 9,10,14
E_{ts}	Total Switching Loss	—	0.95	1.4		
t_{sc}	Short Circuit Withstand Time	10	—	—	µs	V_{CC} = 400V, T_J = 125°C V_{GE} = 15V, R_G = 10Ω , V_{CPK} < 500V
$t_{d(on)}$	Turn-On Delay Time	—	30	—	ns	T_J = 150°C,
t_r	Rise Time	—	18	—		I_C = 25A, V_{CC} = 480V
$t_{d(off)}$	Turn-Off Delay Time	—	190	—		V_{GE} = 15V, R_G = 10Ω
t_f	Fall Time	—	150	—		Energy losses include "tail"
E_{ts}	Total Switching Loss	—	1.9	—	mJ	See Fig. 11,14
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	1600	—	pF	V_{GE} = 0V
C_{oes}	Output Capacitance	—	130	—		V_{CC} = 30V See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	55	—		f = 1.0MHz

Notes:

① Repetitive rating; V_{GE} = 20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC} = 80%(V_{CES}), V_{GE} = 20V, L = 10µH, R_G = 10Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0µs, single shot.

PD 91464B

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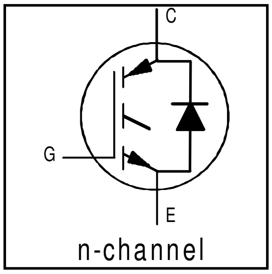
IRG4PC40FD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Fast CoPack IGBT



V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.50V

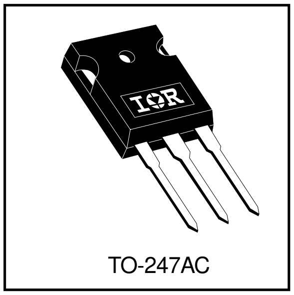
@V_{GE} = 15V, I_C = 27A

Features

- Fast: Optimized for medium operating frequencies (1-5 kHz in hard switching, >20 kHz in resonant mode).
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- IGBT co-packaged with HEXFRED™ ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package

Benefits

- Generation -4 IGBT's offer highest efficiencies available
- IGBT's optimized for specific application conditions
- HEXFRED diodes optimized for performance with IGBT's . Minimized recovery characteristics require less/no snubbing
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBT's



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	49	A
I_C @ T_C = 100°C	Continuous Collector Current	27	
I_{CM}	Pulsed Collector Current ①	200	
I_{LM}	Clamped Inductive Load Current ②	200	
I_F @ T_C = 100°C	Diode Continuous Forward Current	15	
I_{FM}	Diode Maximum Forward Current	200	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	160	W
P_D @ T_C = 100°C	Maximum Power Dissipation	65	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	------	------	0.77	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	------	------	1.7	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	------	0.24	------	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	-----	-----	40	
Wt	Weight	------	6 (0.21)	------	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	600	----	----	V	V_{GE} = 0V, I_C = 250µA
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	----	0.70	----	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	----	1.50	1.7	V	I_C = 27A V_{GE} = 15V
		----	1.85	----		I_C = 49A See Fig. 2, 5
		----	1.56	----		I_C = 27A, T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	----	6.0		V_{CE} = V_{GE}, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	----	-12	----	mV/°C	V_{CE} = V_{GE}, I_C = 250µA
g_{fe}	Forward Transconductance ④	9.2	12	----	S	V_{CE} = 100V, I_C = 27A
I_{CES}	Zero Gate Voltage Collector Current	----	----	250	µA	V_{GE} = 0V, V_{CE} = 600V
		----	----	3500		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
V_{FM}	Diode Forward Voltage Drop	----	1.3	1.7	V	I_C = 15A See Fig. 13
		----	1.2	1.6		I_C = 15A, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	----	----	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	----	100	150	nC	I_C = 27A	
Qge	Gate - Emitter Charge (turn-on)	----	15	23		V_{CC} = 400V See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	----	35	53		V_{GE} = 15V	
$t_{d(on)}$	Turn-On Delay Time	----	63	----	ns	T_J = 25°C	
t_r	Rise Time	----	32	----		I_C = 27A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	230	350		V_{GE} = 15V, R_G = 10Ω	
t_f	Fall Time	----	170	250		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	----	0.95	----	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	----	2.01	----		See Fig. 9, 10, 11, 18	
E_{ts}	Total Switching Loss	----	2.96	4.0			
$t_{d(on)}$	Turn-On Delay Time	----	63	----	ns	T_J = 150°C, See Fig. 9, 10, 11, 18	
t_r	Rise Time	----	33	----		I_C = 27A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	350	----		V_{GE} = 15V, R_G = 10Ω	
t_f	Fall Time	----	310	----		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	----	4.7	----	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	----	13	----	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	----	2200	----	pF	V_{GE} = 0V	
C_{oes}	Output Capacitance	----	140	----		V_{CC} = 30V See Fig. 7	
C_{res}	Reverse Transfer Capacitance	----	29	----		ƒ = 1.0MHz	
t_{rr}	Diode Reverse Recovery Time	----	42	60	ns	T_J = 25°C See Fig.	
		----	74	120		T_J = 125°C 14	I_F = 15A
I_{rr}	Diode Peak Reverse Recovery Current	----	4.0	6.0	A	T_J = 25°C See Fig.	
		----	6.5	10		T_J = 125°C 15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	----	80	180	nC	T_J = 25°C See Fig.	
		----	220	600		T_J = 125°C 16	di/dt 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	----	188	----	A/µs	T_J = 25°C See Fig.	
	During t_b	----	160	----		T_J = 125°C 17	

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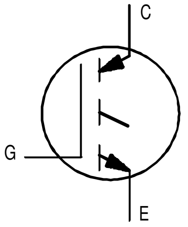
PD - 91628A

IRG4PC30W

INSULATED GATE BIPOLAR TRANSISTOR

Features

- Designed expressly for Switch-Mode Power Supply and PFC (power factor correction) applications
- Industry-benchmark switching losses improve efficiency of all power supply topologies
- 50% reduction of Eoff parameter
- Low IGBT conduction losses
- Latest-generation IGBT design and construction offers tighter parameters distribution, exceptional reliability



n-channel

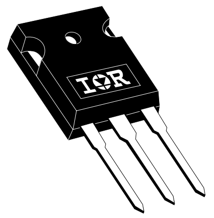
$V_{CES} = 600V$

$V_{CE(on)}$ max. = 2.70V

@V_{GE} = 15V, I_C = 12A

Benefits

- Lower switching losses allow more cost-effective operation than power MOSFETs up to 150 kHz ("hard switched" mode)
- Of particular benefit to single-ended converters and boost PFC topologies 150W and higher
- Low conduction losses and minimal minority-carrier recombination make these an excellent option for resonant mode switching as well (up to >>300 kHz)



TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Breakdown Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	23	A
I_C @ T_C = 100°C	Continuous Collector Current	12	
I_{CM}	Pulsed Collector Current ①	92	
I_{LM}	Clamped Inductive Load Current ②	92	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
E_{ARV}	Reverse Voltage Avalanche Energy ③	180	mJ
P_D @ T_C = 25°C	Maximum Power Dissipation	100	W
P_D @ T_C = 100°C	Maximum Power Dissipation	42	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to + 150	°C
	Soldering Temperature, for 10 seconds	300 (0.063 in. (1.6mm from case)	
	Mounting torque, 6-32 or M3 screw.	10 lbf•in (1.1N•m)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	–––	1.2	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.24	–––	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	–––	40	
Wt	Weight	6 (0.21)	–––	g (oz)

4/15/2000

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage	600	—	—	V	V_{GE} = 0V, I_C = 250µA
$V_{(BR)ECS}$	Emitter-to-Collector Breakdown Voltage ④	18	—	—	V	V_{GE} = 0V, I_C = 1.0A
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.34	—	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(ON)}$	Collector-to-Emitter Saturation Voltage	—	2.1	2.7	V	I_C = 12A V_{GE} = 15V
		—	2.45	—		I_C = 23A See Fig.2, 5
		—	1.95	—		I_C = 12A , T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		V_{CE} = V_{GE}, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-11	—	mV/°C	V_{CE} = V_{GE}, I_C = 250µA
g_{fe}	Forward Transconductance ⑤	11	16	—	S	V_{CE} = 100 V, I_C = 12A
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 600V
		—	—	2.0		V_{GE} = 0V, V_{CE} = 10V, T_J = 25°C
		—	—	1000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
Q_g	Total Gate Charge (turn-on)	—	51	76	nC	I_C = 12A
Q_{ge}	Gate - Emitter Charge (turn-on)	—	7.6	11		V_{CC} = 400V See Fig.8
Q_{gc}	Gate - Collector Charge (turn-on)	—	18	27		V_{GE} = 15V
$t_{d(on)}$	Turn-On Delay Time	—	25	—	ns	
t_r	Rise Time	—	16	—		T_J = 25°C
$t_{d(off)}$	Turn-Off Delay Time	—	99	150		I_C = 12A, V_{CC} = 480V
t_f	Fall Time	—	67	100		V_{GE} = 15V, R_G = 23Ω
E_{on}	Turn-On Switching Loss	—	0.13	—	mJ	Energy losses include "tail"
E_{off}	Turn-Off Switching Loss	—	0.13	—		See Fig. 10, 11, 13, 14
E_{ts}	Total Switching Loss	—	0.26	0.35		
$t_{d(on)}$	Turn-On Delay Time	—	24	—	ns	T_J = 150°C,
t_r	Rise Time	—	17	—		I_C = 12A, V_{CC} = 480V
$t_{d(off)}$	Turn-Off Delay Time	—	150	—		V_{GE} = 15V, R_G = 23Ω
t_f	Fall Time	—	150	—		Energy losses include "tail"
E_{ts}	Total Switching Loss	—	0.55	—	mJ	See Fig. 13, 14
L_E	Internal Emitter Inductance	—	13	—	nH	Measured 5mm from package
C_{ies}	Input Capacitance	—	980	—	pF	V_{GE} = 0V
C_{oes}	Output Capacitance	—	71	—		V_{CC} = 30V See Fig. 7
C_{res}	Reverse Transfer Capacitance	—	18	—		ƒ = 1.0MHz

Notes:

① Repetitive rating; V_{GE} = 20V, pulse width limited by max. junction temperature. (See fig. 13b)

② V_{CC} = 80%(V_{CES}), V_{GE} = 20V, L = 10µH, R_G = 23Ω, (See fig. 13a)

③ Repetitive rating; pulse width limited by maximum junction temperature.

④ Pulse width ≤ 80µs; duty factor ≤ 0.1%.

⑤ Pulse width 5.0µs, single shot.

PD 91462B

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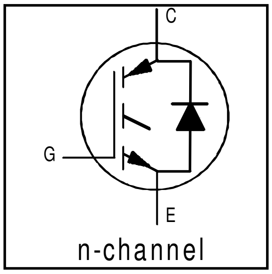
IRG4PC30UD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

UltraFast CoPack IGBT

Features

- UltraFast: Optimized for high operating frequencies 8-40 kHz in hard switching, >200 kHz in resonant mode
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- IGBT co-packaged with HEXFRED™ ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-247AC package



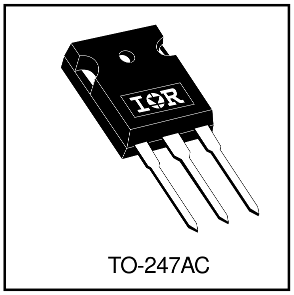
V_{CES} = 600V

$V_{CE(on)\,typ.}$ = 1.95V

@V_{GE} = 15V, I_C = 12A

Benefits

- Generation -4 IGBT's offer highest efficiencies available
- IGBT's optimized for specific application conditions
- HEXFRED diodes optimized for performance with IGBT's . Minimized recovery characteristics require less/no snubbing
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBT's


TO-247AC

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	23	A
I_C @ T_C = 100°C	Continuous Collector Current	12	
I_{CM}	Pulsed Collector Current ①	92	
I_{LM}	Clamped Inductive Load Current ②	92	
I_F @ T_C = 100°C	Diode Continuous Forward Current	12	
I_{FM}	Diode Maximum Forward Current	92	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	100	W
P_D @ T_C = 100°C	Maximum Power Dissipation	42	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	------	------	1.2	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	------	------	2.5	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	------	0.24	------	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	-----	-----	40	
Wt	Weight	------	6 (0.21)	------	g (oz)

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	600	----	----	V	V_{GE} = 0V, I_C = 250µA
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	----	0.63	----	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	----	1.95	2.1	V	I_C = 12A V_{GE} = 15V
		----	2.52	----		I_C = 23A See Fig. 2, 5
		----	2.09	----		I_C = 12A, T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	----	6.0		V_{CE} = V_{GE}, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	----	-11	----	mV/°C	V_{CE} = V_{GE}, I_C = 250µA
g_{fe}	Forward Transconductance ④	3.1	8.6	----	S	V_{CE} = 100V, I_C = 12A
I_{CES}	Zero Gate Voltage Collector Current	----	----	250	µA	V_{GE} = 0V, V_{CE} = 600V
		----	----	2500		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
V_{FM}	Diode Forward Voltage Drop	----	1.4	1.7	V	I_C = 12A See Fig. 13
		----	1.3	1.6		I_C = 12A, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	----	----	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	----	50	75	nC	I_C = 12A	
Qge	Gate - Emitter Charge (turn-on)	----	8.1	12		V_{CC} = 400V See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	----	18	27		V_{GE} = 15V	
$t_{d(on)}$	Turn-On Delay Time	----	40	----	ns	T_J = 25°C	
t_r	Rise Time	----	21	----		I_C = 12A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	91	140		V_{GE} = 15V, R_G = 23Ω	
t_f	Fall Time	----	80	130		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	----	0.38	----	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	----	0.16	----		See Fig. 9, 10, 11, 18	
E_{ts}	Total Switching Loss	----	0.54	0.9			
$t_{d(on)}$	Turn-On Delay Time	----	40	----	ns	T_J = 150°C, See Fig. 9, 10, 11, 18	
t_r	Rise Time	----	22	----		I_C = 12A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	120	----		V_{GE} = 15V, R_G = 23Ω	
t_f	Fall Time	----	180	----		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	----	0.89	----	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	----	13	----	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	----	1100	----	pF	V_{GE} = 0V	
C_{oes}	Output Capacitance	----	73	----		V_{CC} = 30V See Fig. 7	
C_{res}	Reverse Transfer Capacitance	----	14	----		ƒ = 1.0MHz	
t_{rr}	Diode Reverse Recovery Time	----	42	60	ns	T_J = 25°C See Fig.	
		----	80	120		T_J = 125°C 14	I_F = 12A
I_{rr}	Diode Peak Reverse Recovery Current	----	3.5	6.0	A	T_J = 25°C See Fig.	
		----	5.6	10		T_J = 125°C 15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	----	80	180	nC	T_J = 25°C See Fig.	
		----	220	600		T_J = 125°C 16	di/dt 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	----	180	----	A/µs	T_J = 25°C See Fig.	
	During t_b	----	120	----		T_J = 125°C 17	

PD 91449B

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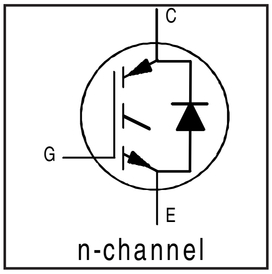
IRG4BC20UD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

UltraFast CoPack IGBT

Features

- UltraFast: optimized for high operating frequencies 8-40 kHz in hard switching, >200 kHz in resonant mode
- Generation 4 IGBT design provides tighter parameter distribution and higher efficiency than Generation 3
- IGBT co-packaged with HEXFRED® ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-220AB package



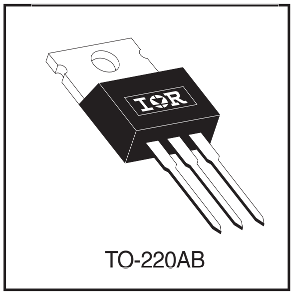
V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.85V

@V_{GE} = 15V, I_C = 6.5A

Benefits

- Generation -4 IGBTs offer highest efficiencies available
- IGBTs optimized for specific application conditions
- HEXFRED diodes optimized for performance with IGBTs. Minimized recovery characteristics require less/no snubbing
- Designed to be a "drop-in" replacement for equivalent industry-standard Generation 3 IR IGBTs



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	13	A
I_C @ T_C = 100°C	Continuous Collector Current	6.5	
I_{CM}	Pulsed Collector Current ①	52	
I_{LM}	Clamped Inductive Load Current ②	52	
I_F @ T_C = 100°C	Diode Continuous Forward Current	7.0	
I_{FM}	Diode Maximum Forward Current	52	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	60	W
P_D @ T_C = 100°C	Maximum Power Dissipation	24	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	------	------	2.1	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	------	------	3.5	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	------	0.50	------	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	-----	-----	80	
Wt	Weight	------	2 (0.07)	------	g (oz)

3/21/2000

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	600	----	----	V	V_{GE} = 0V, I_C = 250µA
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	----	0.69	----	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	----	1.85	2.1	V	I_C = 6.5A V_{GE} = 15V
		----	2.27	----		I_C = 13A See Fig. 2, 5
		----	1.87	----		I_C = 6.5A, T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	----	6.0		V_{CE} = V_{GE}, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	----	-11	----	mV/°C	V_{CE} = V_{GE}, I_C = 250µA
g_{fe}	Forward Transconductance ④	1.4	4.3	----	S	V_{CE} = 100V, I_C = 6.5A
I_{CES}	Zero Gate Voltage Collector Current	----	----	250	µA	V_{GE} = 0V, V_{CE} = 600V
		----	----	1700		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
V_{FM}	Diode Forward Voltage Drop	----	1.4	1.7	V	I_C = 8.0A See Fig. 13
		----	1.3	1.6		I_C = 8.0A, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	----	----	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	----	27	41	nC	I_C = 6.5A	
Qge	Gate - Emitter Charge (turn-on)	----	4.5	6.8		V_{CC} = 400V See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	----	10	16		V_{GE} = 15V	
$t_{d(on)}$	Turn-On Delay Time	----	39	----	ns	T_J = 25°C	
t_r	Rise Time	----	15	----		I_C = 6.5A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	93	140		V_{GE} = 15V, R_G = 50Ω	
t_f	Fall Time	----	110	170		Energy losses include "tail" and	
E_{on}	Turn-On Switching Loss	----	0.16	----	mJ	diode reverse recovery.	
E_{off}	Turn-Off Switching Loss	----	0.13	----		See Fig. 9, 10, 11, 18	
E_{ts}	Total Switching Loss	----	0.29	0.3			
$t_{d(on)}$	Turn-On Delay Time	----	38	----	ns	T_J = 150°C, See Fig. 9, 10, 11, 18	
t_r	Rise Time	----	17	----		I_C = 6.5A, V_{CC} = 480V	
$t_{d(off)}$	Turn-Off Delay Time	----	100	----		V_{GE} = 15V, R_G = 50Ω	
t_f	Fall Time	----	220	----		Energy losses include "tail" and	
E_{ts}	Total Switching Loss	----	0.49	----	mJ	diode reverse recovery.	
L_E	Internal Emitter Inductance	----	7.5	----	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	----	530	----	pF	V_{GE} = 0V	
C_{oes}	Output Capacitance	----	39	----		V_{CC} = 30V See Fig. 7	
C_{res}	Reverse Transfer Capacitance	----	7.4	----		ƒ = 1.0MHz	
t_{rr}	Diode Reverse Recovery Time	----	37	55	ns	T_J = 25°C See Fig.	
		----	55	90		T_J = 125°C 14	I_F = 8.0A
I_{rr}	Diode Peak Reverse Recovery Current	----	3.5	5.0	A	T_J = 25°C See Fig.	
		----	4.5	8.0		T_J = 125°C 15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	----	65	138	nC	T_J = 25°C See Fig.	
		----	124	360		T_J = 125°C 16	di/dt 200A/µs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery During t_b	----	240	----	A/µs	T_J = 25°C See Fig.	
		----	210	----		T_J = 125°C 17	

International
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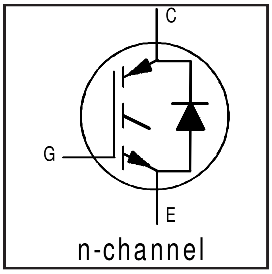
IRG4BC20SD

Standard Speed IGBT

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Features

- Extremely low voltage drop 1.4Vtyp. @ 10A
- S-Series: Minimizes power dissipation at up to 3 KHz PWM frequency in inverter drives, up to 4 KHz in brushless DC drives.
- Very Tight Vce(on) distribution
- IGBT co-packaged with HEXFRED^{TM} ultrafast, ultra-soft-recovery anti-parallel diodes for use in bridge configurations
- Industry standard TO-220AB package



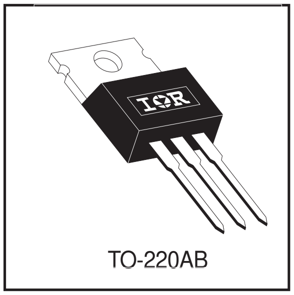
V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 1.4V

@V_{GE} = 15V, I_C = 10A

Benefits

- Generation 4 IGBT's offer highest efficiencies available
- IGBT's optimized for specific application conditions
- HEXFRED diodes optimized for performance with IGBT's . Minimized recovery characteristics require less/no snubbing
- Lower losses than MOSFET's conduction and Diode losses



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	19	A
I_C @ T_C = 100°C	Continuous Collector Current	10	
I_{CM}	Pulsed Collector Current ①	38	
I_{LM}	Clamped Inductive Load Current ②	38	
I_F @ T_C = 100°C	Diode Continuous Forward Current	7.0	
I_{FM}	Diode Maximum Forward Current	38	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	60	W
P_D @ T_C = 100°C	Maximum Power Dissipation	24	
T_J	Operating Junction and	-55 to +150	°C
T_{STG}	Storage Temperature Range		
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	——	——	2.1	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	——	——	3.5	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.50	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	——	80	
Wt	Weight	——	2 (0.07)	——	g (oz)

9/23/98

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltageƒ	600	—	—	V	V_{GE} = 0V, I_C = 250µA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.75	—	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	1.40	1.6	V	I_C = 10A	V_{GE} = 15V
		—	1.85	—		I_C = 19A	See Fig. 2, 5
		—	1.44	—		I_C = 10A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.0		$V_{CE} = V_{GE}$, I_C = 250µA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-11	—	mV/°C	$V_{CE} = V_{GE}$, I_C = 250µA	
g_{fe}	Forward Transconductance ④	2.0	5.8	—	S	V_{CE} = 100V, I_C = 10A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	µA	V_{GE} = 0V, V_{CE} = 600V	
		—	—	1700		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	1.4	1.7	V	I_C = 8.0A	See Fig. 13
		—	1.3	1.6		I_C = 8.0A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q_g	Total Gate Charge (turn-on)	—	27	40	nC	I_C = 10A		
Qge	Gate - Emitter Charge (turn-on)	—	4.3	6.5		V_{CC} = 400V	See Fig. 8	
Q_{gc}	Gate - Collector Charge (turn-on)	—	10	15		V_{GE} = 15V		
$t_{d(on)}$	Turn-On Delay Time	—	62	—	ns	T_J = 25°C		
t_r	Rise Time	—	32	—		I_C = 10A, V_{CC} = 480V		
$t_{d(off)}$	Turn-Off Delay Time	—	690	1040		V_{GE} = 15V, R_G = 50Ω		
t_f	Fall Time	—	480	730		Energy losses include "tail" and		
E_{on}	Turn-On Switching Loss	—	0.32	—	mJ	diode reverse recovery.		
E_{off}	Turn-Off Switching Loss	—	2.58	—		See Fig. 9, 10, 11,18		
E_{ts}	Total Switching Loss	—	2.90	4.5				
$t_{d(on)}$	Turn-On Delay Time	—	64	—	ns	T_J = 150°C,	See Fig. 10,11, 18	
t_r	Rise Time	—	35	—		I_C = 10A, V_{CC} = 480V		
$t_{d(off)}$	Turn-Off Delay Time	—	980	—		V_{GE} = 15V, R_G = 50Ω		
t_f	Fall Time	—	800	—		Energy losses include "tail" and		
E_{ts}	Total Switching Loss	—	4.33	—	mJ	diode reverse recovery.		
L_E	Internal Emitter Inductance	—	7.5	—	nH	Measured 5mm from package		
C_{ies}	Input Capacitance	—	550	—	pF	V_{GE} = 0V		
C_{oes}	Output Capacitance	—	39	—		V_{CC} = 30V	See Fig. 7	
C_{res}	Reverse Transfer Capacitance	—	7.1	—		ƒ = 1.0MHz		
t_{rr}	Diode Reverse Recovery Time	—	37	55	ns	T_J = 25°C	See Fig.	
		—	55	90		T_J = 125°C	14	I_F = 8.0A
I_{rr}	Diode Peak Reverse Recovery Current	—	3.5	5.0	A	T_J = 25°C	See Fig.	
		—	4.5	8.0		T_J = 125°C	15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	65	138	nC	T_J = 25°C	See Fig.	
		—	124	360		T_J = 125°C	16	di/dt = 200Aµs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	—	240	—	A/µs	T_J = 25°C	See Fig.	
	During t_b	—	210	—		T_J = 125°C	17	

PD - 94082A

International
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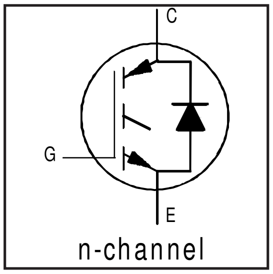
IRG4BC15UD

UltraFast CoPack IGBT

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE



V_{CES} = 600V

$V_{CE(on)}$ typ. = 2.02V

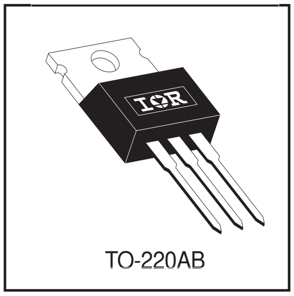
@V_{GE} = 15V, I_C = 7.8A

Features

- UltraFast: Optimized for high frequencies from10 to 30 kHz in hard switching
- IGBT Co-packaged with ultra-soft-recovery antiparallel diode
- Industry standard TO-220AB package

Benefits

- Best Value for Appliance and Industrial Applications
- High noise immune "Positive Only" gate drive- Negative bias gate drive not necessary
- For Low EMI designs- requires little or no snubbing
- Single Package switch for bridge circuit applications
- Compatible with high voltage Gate Driver IC's
- Allows simpler gate drive



TO-220AB

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	14	A
I_C @ T_C = 100°C	Continuous Collector Current	7.8	
I_{CM}	Pulsed Collector Current ①	42	
I_{LM}	Clamped Inductive Load Current ②	42	
I_F @ T_C = 100°C	Diode Continuous Forward Current	4.0	
I_{FM}	Diode Maximum Forward Current	16	
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	49	W
P_D @ T_C = 100°C	Maximum Power Dissipation	19	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	——	——	2.7	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	——	——	7.0	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	——	0.50	——	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	——	——	80	
Wt	Weight	——	2 (0.07)	——	g (oz)

03/20/01

Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltage③	600	——	——	V	V_{GE} = 0V, I_C = 250µA
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	——	0.63	——	V/°C	V_{GE} = 0V, I_C = 1.0mA
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	——	2.02	2.4	V	I_C = 7.8A V_{GE} = 15V
		——	2.56	——		I_C = 14A
		——	2.21	——		I_C = 7.8A, T_J = 150°C
$V_{GE(th)}$	Gate Threshold Voltage	3.0	——	6.0		V_{CE} = V_{GE}, I_C = 250µA
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	——	-10	——	mV/°C	V_{CE} = V_{GE}, I_C = 250µA
g_{fe}	Forward Transconductance ④	4.1	6.2	——	S	V_{CE} = 100V, I_C = 7.8A
I_{CES}	Zero Gate Voltage Collector Current	——	——	250	µA	V_{GE} = 0V, V_{CE} = 600V
		——	——	1400		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C
V_{FM}	Diode Forward Voltage Drop	——	1.5	1.8	V	I_C = 4.0A
		——	1.4	1.7		I_C = 4.0A, T_J = 150°C
I_{GES}	Gate-to-Emitter Leakage Current	——	——	±100	nA	V_{GE} = ±20V

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
Q_g	Total Gate Charge (turn-on)	——	23	35	nC	I_C = 7.8A V_{CC} = 400V V_{GE} = 15V	
Qge	Gate - Emitter Charge (turn-on)	——	4.0	6.0			
Q_{gc}	Gate - Collector Charge (turn-on)	——	9.6	14			
$t_{d(on)}$	Turn-On Delay Time	——	17	——	ns	T_J = 25°C I_C = 7.8A, V_{CC} = 480V V_{GE} = 15V, R_G = 75Ω Energy losses include "tail" and diode reverse recovery.	
t_r	Rise Time	——	20	——			
$t_{d(off)}$	Turn-Off Delay Time	——	160	240			
t_f	Fall Time	——	83	120			
E_{on}	Turn-On Switching Loss	——	0.24	——	mJ		
E_{off}	Turn-Off Switching Loss	——	0.26	——			
E_{ts}	Total Switching Loss	——	0.50	0.63			
$t_{d(on)}$	Turn-On Delay Time	——	16	——	ns	T_J = 150°C, I_C = 7.8A, V_{CC} = 480V V_{GE} = 15V, R_G = 75Ω Energy losses include "tail" and diode reverse recovery.	
t_r	Rise Time	——	21	——			
$t_{d(off)}$	Turn-Off Delay Time	——	180	——			
t_f	Fall Time	——	220	——			
E_{ts}	Total Switching Loss	——	0.76	——	mJ		
L_E	Internal Emitter Inductance	——	7.5	——	nH	Measured 5mm from package	
C_{ies}	Input Capacitance	——	410	——	pF	V_{GE} = 0V V_{CC} = 30V ƒ = 1.0MHz	
C_{oes}	Output Capacitance	——	37	——			
C_{res}	Reverse Transfer Capacitance	——	5.3	——			
t_{rr}	Diode Reverse Recovery Time	——	28	42	ns	T_J = 25°C	I_F = 4.0A V_R = 200V di/dt 200A/µs
		——	38	57		T_J = 125°C	
$_{rr}$	Diode Peak Reverse Recovery Current	——	2.9	5.2	A	T_J = 25°C	
		——	3.7	6.7		T_J = 125°C	
Q_{rr}	Diode Reverse Recovery Charge	——	40	60	nC	T_J = 25°C	
		——	70	110		T_J = 125°C	
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery During t_b	——	280	——	A/µs	T_J = 25°C	
		——	240	——		T_J = 125°C	

PD -91734B

International
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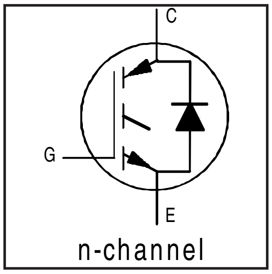
IRG4BC10KD

INSULATED GATE BIPOLAR TRANSISTOR WITH ULTRAFAST SOFT RECOVERY DIODE

Short Circuit Rated
UltraFast IGBT

Features

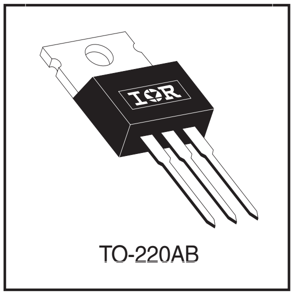
- High short circuit rating optimized for motor control, t_{sc} =10µs, @360V V_{CE} (start), T_J = 125°C, V_{GE} = 15V
- Combines low conduction losses with high switching speed
- Tighter parameter distribution and higher efficiency than previous generations
- IGBT co-packaged with HEXFRED™ ultrafast, ultrasoft recovery antiparallel diodes



V_{CES} = 600V

$V_{CE(on)\ typ.}$ = 2.39V

@V_{GE} = 15V, I_C = 5.0A


TO-220AB

Benefits

- Latest generation 4 IGBTs offer highest power density motor controls possible
- HEXFRED™ diodes optimized for performance with IGBTs. Minimized recovery characteristics reduce noise, EMI and switching losses

Absolute Maximum Ratings

	Parameter	Max.	Units
V_{CES}	Collector-to-Emitter Voltage	600	V
I_C @ T_C = 25°C	Continuous Collector Current	9.0	A
I_C @ T_C = 100°C	Continuous Collector Current	5.0	
I_{CM}	Pulsed Collector Current ①	18	
I_{LM}	Clamped Inductive Load Current ②	18	
I_F @ T_C = 100°C	Diode Continuous Forward Current	4.0	
I_{FM}	Diode Maximum Forward Current	16	
t_{sc}	Short Circuit Withstand Time	10	µs
V_{GE}	Gate-to-Emitter Voltage	± 20	V
P_D @ T_C = 25°C	Maximum Power Dissipation	38	W
P_D @ T_C = 100°C	Maximum Power Dissipation	15	
T_J T_{STG}	Operating Junction and Storage Temperature Range	-55 to +150	°C
	Soldering Temperature, for 10 sec.	300 (0.063 in. (1.6mm) from case)	
	Mounting Torque, 6-32 or M3 Screw.	10 lbf•in (1.1 N•m)	

Thermal Resistance

	Parameter	Min.	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case - IGBT	----	----	3.3	°C/W
$R_{\theta JC}$	Junction-to-Case - Diode	----	----	7.0	
$R_{\theta CS}$	Case-to-Sink, flat, greased surface	----	0.50	----	
$R_{\theta JA}$	Junction-to-Ambient, typical socket mount	----	----	80	
Wt	Weight	----	2 (0.07)	----	g (oz)

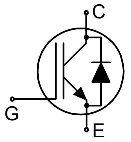
Electrical Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions	
$V_{(BR)CES}$	Collector-to-Emitter Breakdown Voltageƒ	600	—	—	V	V_{GE} = 0V, I_C = 250μA	
$\Delta V_{(BR)CES}/\Delta T_J$	Temperature Coeff. of Breakdown Voltage	—	0.58	—	V/°C	V_{GE} = 0V, I_C = 1.0mA	
$V_{CE(on)}$	Collector-to-Emitter Saturation Voltage	—	2.39	2.62	V	I_C = 5.0A	V_{GE} = 15V
		—	3.25	—		I_C = 9.0A	See Fig. 2, 5
		—	2.63	—		I_C = 5.0A, T_J = 150°C	
$V_{GE(th)}$	Gate Threshold Voltage	3.0	—	6.5		V_{CE} = V_{GE}, I_C = 250μA	
$\Delta V_{GE(th)}/\Delta T_J$	Temperature Coeff. of Threshold Voltage	—	-11	—	mV/°C	V_{CE} = V_{GE}, I_C = 250μA	
g_{fe}	Forward Transconductance „	1.2	1.8	—	S	V_{CE} = 50V, I_C = 5.0A	
I_{CES}	Zero Gate Voltage Collector Current	—	—	250	μA	V_{GE} = 0V, V_{CE} = 600V	
		—	—	1000		V_{GE} = 0V, V_{CE} = 600V, T_J = 150°C	
V_{FM}	Diode Forward Voltage Drop	—	1.5	1.8	V	I_C = 4.0A	See Fig. 13
		—	1.4	1.7		I_C = 4.0A, T_J = 150°C	
I_{GES}	Gate-to-Emitter Leakage Current	—	—	±100	nA	V_{GE} = ±20V	

Switching Characteristics @ T_J = 25°C (unless otherwise specified)

	Parameter	Min.	Typ.	Max.	Units	Conditions		
Q_g	Total Gate Charge (turn-on)	—	19	29	nC	I_C = 5.0A		
Q_{ge}	Gate - Emitter Charge (turn-on)	—	2.9	4.3		V_{CC} = 400V	See Fig.8	
Q_{gc}	Gate - Collector Charge (turn-on)	—	9.8	15		V_{GE} = 15V		
$t_{d(on)}$	Turn-On Delay Time	—	49	—	ns			
t_r	Rise Time	—	28	—		T_J = 25°C		
$t_{d(off)}$	Turn-Off Delay Time	—	97	150		I_C = 5.0A, V_{CC} = 480V		
t_f	Fall Time	—	140	210		V_{GE} = 15V, R_G = 100Ω		
E_{on}	Turn-On Switching Loss	—	0.25	—	mJ	Energy losses include "tail"		
E_{off}	Turn-Off Switching Loss	—	0.14	—		and diode reverse recovery		
E_{ts}	Total Switching Loss	—	0.39	0.48		See Fig. 9,10,14		
t_{sc}	Short Circuit Withstand Time	10	—	—	μs	V_{CC} = 360V, T_J = 125°C		
						V_{GE} = 15V, R_G = 100Ω , V_{CPK} < 500V		
$t_{d(on)}$	Turn-On Delay Time	—	46	—	ns	T_J = 150°C,	See Fig. 10,11,14	
t_r	Rise Time	—	32	—		I_C = 5.0A, V_{CC} = 480V		
$t_{d(off)}$	Turn-Off Delay Time	—	100	—		V_{GE} = 15V, R_G = 100Ω		
t_f	Fall Time	—	310	—		Energy losses include "tail"		
E_{ts}	Total Switching Loss	—	0.56	—	mJ	and diode reverse recovery		
L_E	Internal Emitter Inductance	—	7.5	—	nH	Measured 5mm from package		
C_{ies}	Input Capacitance	—	220	—	pF	V_{GE} = 0V		
C_{oes}	Output Capacitance	—	29	—		V_{CC} = 30V	See Fig. 7	
C_{res}	Reverse Transfer Capacitance	—	7.5	—		ƒ = 1.0MHz		
t_{rr}	Diode Reverse Recovery Time	—	28	42	ns	T_J = 25°C	See Fig.	
		—	38	57		T_J = 125°C	14	I_F = 4.0A
I_{rr}	Diode Peak Reverse Recovery Current	—	2.9	5.2	A	T_J = 25°C	See Fig.	
		—	3.7	6.7		T_J = 125°C	15	V_R = 200V
Q_{rr}	Diode Reverse Recovery Charge	—	40	60	nC	T_J = 25°C	See Fig.	
		—	70	105		T_J = 125°C	16	di/dt = 200A/μs
$di_{(rec)M}/dt$	Diode Peak Rate of Fall of Recovery	—	280	—	A/μs	T_J = 25°C	See Fig.	
	During t_b	—	235	—		T_J = 125°C	17	

Low Loss DuoPack : IGBT in Trench and Fieldstop technology with soft, fast recovery anti-parallel EmCon HE diode



- Very low $V_{CE(sat)}$ 1.5 V (typ.)
- Maximum Junction Temperature 175 °C
- Short circuit withstand time – 5µs
- Positive temperature coefficient in $V_{CE(sat)}$
- very tight parameter distribution
- high ruggedness, temperature stable behaviour
- very high switching speed
- Low EMI
- Very soft, fast recovery anti-parallel EmCon HE diode
- Qualified according to JEDEC[1] for target applications
- Pb-free lead plating; RoHS compliant
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/

PG-TO-247-3-21

Applications:

- Frequency Converters
- Uninterrupted Power Supply

Type	V_{CE}	I_C	$V_{CE(sat),Tj=25°C}$	$T_{j,max}$	Marking	Package
IKW75N60T	600V	75A	1.5V	175°C	K75T60	PG-TO-247-3-21

Maximum Ratings

Parameter	Symbol	Value	Unit
Collector-emitter voltage	V_{CE}	600	V
DC collector current, limited by T_{jmax}	I_C		A
T_C = 25°C		80[2]	
T_C = 100°C		75	
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	225	
Turn off safe operating area ($V_{CE} \leq$ 600V, $T_j \leq$ 175°C)	-	225	
Diode forward current, limited by T_{jmax}	I_F		
T_C = 25°C		80[2]	
T_C = 100°C		75	
Diode pulsed current, t_p limited by T_{jmax}	I_{Fpuls}	225	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[3] V_{GE} = 15V, $V_{CC} \leq$ 400V, $T_j \leq$ 150°C	t_{SC}	5	µs
Power dissipation T_C = 25°C	P_{tot}	428	W
Operating junction temperature	T_j	-40...+175	°C
Storage temperature	T_{stg}	-55...+175	
Soldering temperature, 1.6mm (0.063 in.) from case for 10s	-	260	

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[1] J-STD-020 and JESD-022

[2] Value limited by bondwire

[3] Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		0.35	K/W
Diode thermal resistance, junction – case	R_{thJCD}		0.6	
Thermal resistance, junction – ambient	R_{thJA}		40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	V_{GE}=0V, I_C=0.2mA	600	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, I_C=75A T_j=25°C T_j=175°C	 - -	 1.5 1.9	 2.0 -	
Diode forward voltage	V_F	V_{GE}=0V, I_F=75A T_j=25°C T_j=175°C	 - -	 1.65 1.6	 2.0 -	
Gate-emitter threshold voltage	$V_{GE(th)}$	I_C=1.2mA, V_{CE}=V_{GE}	4.1	4.9	5.7	
Zero gate voltage collector current	I_{CES}	V_{CE}=600V, V_{GE}=0V T_j=25°C T_j=175°C	 - -	 - -	 40 1000	µA
Gate-emitter leakage current	I_{GES}	V_{CE}=0V, V_{GE}=20V	-	-	100	nA
Transconductance	g_{fs}	V_{CE}=20V, I_C=75A	-	41	-	S
Integrated gate resistor	R_{Gint}			-		Ω

Dynamic Characteristic

Parameter	Symbol	Conditions	min.	Typ.	max.	Unit
Input capacitance	C_{iss}	V_{CE}=25V, V_{GE}=0V, f=1MHz	-	4620	-	pF
Output capacitance	C_{oss}		-	288	-	
Reverse transfer capacitance	C_{rss}		-	137	-	
Gate charge	Q_{Gate}	V_{CC}=480V, I_C=75A V_{GE}=15V	-	470	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E		-	13	-	nH
Short circuit collector current[1]	$I_{C(SC)}$	V_{GE}=15V, $t_{SC}\leq 5\mu$s V_{CC} = 400V, $T_j \leq$ 150°C	-	687.5	-	A

---

[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	**Symbol**	**Conditions**	**Value**			**Unit**
			min.	**typ.**	**max.**	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=400V, I_C=75A, V_{GE}=0/15V, R_G=5Ω, L_σ[1]=100nH, C_σ[1]=39pF Energy losses include "tail" and diode reverse recovery.	-	33	-	ns
Rise time	t_r		-	36	-	
Turn-off delay time	$t_{d(off)}$		-	330	-	
Fall time	t_f		-	35	-	
Turn-on energy	E_{on}		-	2.0	-	mJ
Turn-off energy	E_{off}		-	2.5	-	
Total switching energy	E_{ts}		-	4.5	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=25°C, V_R=400V, I_F=75A, di_F/dt=1460A/µs	-	121	-	ns
Diode reverse recovery charge	Q_{rr}		-	2.4	-	µC
Diode peak reverse recovery current	I_{rrm}		-	38.5	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	921	-	A/µs

Switching Characteristic, Inductive Load, at T_j=175 °C

Parameter	**Symbol**	**Conditions**	**Value**			**Unit**
			min.	**typ.**	**max.**	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=175°C, V_{CC}=400V, I_C=75A, V_{GE}=0/15V, R_G= 5Ω L_σ[1]=100nH, C_σ[1]=39pF Energy losses include "tail" and diode reverse recovery.	-	32	-	ns
Rise time	t_r		-	37	-	
Turn-off delay time	$t_{d(off)}$		-	363	-	
Fall time	t_f		-	38	-	
Turn-on energy	E_{on}		-	2.9	-	mJ
Turn-off energy	E_{off}		-	2.9	-	
Total switching energy	E_{ts}		-	5.8	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=175°C V_R=400V, I_F=75A, di_F/dt=1460A/µs	-	182	-	ns
Diode reverse recovery charge	Q_{rr}		-	5.8	-	µC
Diode peak reverse recovery current	I_{rrm}		-	56.2	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	1013	-	A/µs

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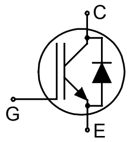
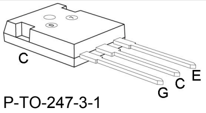
[1] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

Low Loss DuoPack : IGBT in Trench and Fieldstop technology with soft, fast recovery anti-parallel EmCon HE diode



- Best in class TO247
- Short circuit withstand time – 10µs
- Designed for :
  - - Frequency Converters
  - - Uninterrupted Power Supply
- Trench and Fieldstop technology for 1200 V applications offers :
  - - very tight parameter distribution
  - - high ruggedness, temperature stable behavior
- NPT technology offers easy parallel switching capability due to positive temperature coefficient in $V_{CE(sat)}$
- Low EMI
- Low Gate Charge
- Very soft, fast recovery anti-parallel EmCon HE diode
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/



P-TO-247-3-1
(TO-247AC)

Type	V_{CE}	I_C	$V_{CE(sat),Tj=25°C}$	$T_{j,max}$	**Package**	**Ordering Code**
IKW40T120	1200V	40A	1.8V	150°C	TO-247AC	Q67040-S4520

Maximum Ratings

Parameter	**Symbol**	**Value**	**Unit**
Collector-emitter voltage	V_{CE}	1200	V
DC collector current	I_C		A
$T_C = 25°C$		75	
$T_C = 100°C$		40	
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	105	
Turn off safe operating area $V_{CE} \leq 1200V$, $T_j \leq 150°C$	-	105	
Diode forward current	I_F		
$T_C = 25°C$		80	
$T_C = 100°C$		40	
Diode pulsed current, t_p limited by T_{jmax}	I_{Fpuls}	105	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[1)] $V_{GE} = 15V$, $V_{CC} \leq 1200V$, $T_j \leq 150°C$	t_{SC}	10	µs
Power dissipation $T_C = 25°C$	P_{tot}	270	W
Operating junction temperature	T_j	-40...+150	°C
Storage temperature	T_{stg}	-55...+150	
Soldering temperature, 1.6mm (0.063 in.) from case for 10s	-	260	

[1)] Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		0.45	K/W
Diode thermal resistance, junction – case	R_{thJCD}		0.81	
Thermal resistance, junction – ambient	R_{thJA}	TO-247AC	40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{\mathrm{(BR)CES}}$	V_{GE}=0V, I_{C}=1.5mA	1200	-	-	V
Collector-emitter saturation voltage	$V_{\mathrm{CE(sat)}}$	V_{GE} = 15V, I_{C}=40A				
		T_j=25°C	-	1.8	2.3	
		T_j=125°C	-	2.1	-	
		T_j=150°C	-	2.3	-	
Diode forward voltage	V_{F}	V_{GE}=0V, I_{F}=40A				
		T_j=25°C	-	1.75	2.3	
		T_j=125°C	-	1.75	-	
		T_j=150°C	-	1.75	-	
Gate-emitter threshold voltage	$V_{\mathrm{GE(th)}}$	I_{C}=1.5mA, V_{CE}=V_{GE}	5.0	5.8	6.5	
Zero gate voltage collector current	I_{CES}	V_{CE}=1200V, V_{GE}=0V				mA
		T_j=25°C	-	-	0.4	
		T_j=150°C	-	-	4.0	
Gate-emitter leakage current	I_{GES}	V_{CE}=0V, V_{GE}=20V	-	-	600	nA
Transconductance	g_{fs}	V_{CE}=20V, I_{C}=40A	-	21	-	S
Integrated gate resistor	R_{Gint}			6		Ω

Dynamic Characteristic

Input capacitance	C_{iss}	V_{CE}=25V, V_{GE}=0V, f=1MHz	-	2500	-	pF
Output capacitance	C_{oss}		-	130	-	
Reverse transfer capacitance	C_{rss}		-	110	-	
Gate charge	Q_{Gate}	V_{CC}=960V, I_C=40A V_{GE}=15V	-	203	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E	TO-247AC	-	-	13	nH
Short circuit collector current[1]	$I_{C(SC)}$	V_{GE}=15V,$t_{SC}\leq$10µs V_{CC} = 600V, T_j = 25°C	-	210	-	A

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=600V,I_C=40A, V_{GE}=0/15V, R_G=15Ω, L_σ[2]=180nH, C_σ[2]=39pF Energy losses include "tail" and diode reverse recovery.	-	48	-	ns
Rise time	t_r		-	34	-	
Turn-off delay time	$t_{d(off)}$		-	480	-	
Fall time	t_f		-	70	-	
Turn-on energy	E_{on}		-	3.3	-	mJ
Turn-off energy	E_{off}		-	3.2	-	
Total switching energy	E_{ts}		-	6.5	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=25°C, V_R=600V, I_F=40A, di_F/dt=800A/µs	-	240	-	ns
Diode reverse recovery charge	Q_{rr}		-	3.8		µC
Diode peak reverse recovery current	I_{rrm}		-	28		A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	370	-	A/µs

---

[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

[2] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

Switching Characteristic, Inductive Load, at T_j=150 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=150°C V_{CC}=600V, I_C=40A, V_{GE}=0/15V, R_G= 15Ω, L_σ[1]=180nH, C_σ[1]=39pF Energy losses include “tail” and diode reverse recovery.	-	52	-	ns
Rise time	t_r		-	40	-	
Turn-off delay time	$t_{d(off)}$		-	580	-	
Fall time	t_f		-	120	-	
Turn-on energy	E_{on}		-	5.0	-	mJ
Turn-off energy	E_{off}		-	5.4	-	
Total switching energy	E_{ts}		-	10.4	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=150°C V_R=600V, I_F=40A, di_F/dt=800A/µs	-	410	-	ns
Diode reverse recovery charge	Q_{rr}		-	8.8	-	µC
Diode peak reverse recovery current	I_{rrm}		-	36	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	330		A/µs

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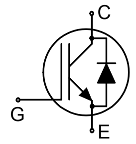
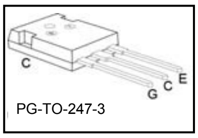
[1] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

Low Loss DuoPack : IGBT in 2nd generation **TrenchStop**® with soft, fast recovery anti-parallel EmCon diode



- Best in class TO247
- Short circuit withstand time – 10µs
- Designed for :
  - Frequency Converters
  - Uninterrupted Power Supply
- **TrenchStop**® 2nd generation for 1200 V applications offers :
  - very tight parameter distribution
  - high ruggedness, temperature stable behavior
- Easy paralleling capability due to positive temperature coefficient in $V_{CE(sat)}$
- Low EMI
- Low Gate Charge
- Very soft, fast recovery anti-parallel EmCon HE diode
- Qualified according to JEDEC[1] for target applications
- Pb-free lead plating; RoHS compliant
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/



Type	V_{CE}	I_C	$V_{CE(sat),Tj=25°C}$	$T_{j,max}$	Marking Code	Package
IKW40N120T2	1200V	40A	1.75V	175°C	K40T1202	PG-TO-247-3

Maximum Ratings

Parameter	Symbol	Value	Unit
Collector-emitter voltage	V_{CE}	1200	V
DC collector current (T_j=150°C)	I_C		A
T_C = 25°C		75[2]	
T_C = 110°C		40	
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	160	
Turn off safe operating area	-	160	
$V_{CE} \leq$ 1200V, $T_j \leq$ 175°C			
DC Diode forward current (T_j=150°C)	I_F		
T_C = 25°C		75[2]	
T_C = 110°C		40	
Diode pulsed current, t_p limited by T_{jmax}	I_{Fpuls}	160	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time(3)	t_{SC}	10	µs
V_{GE} = 15V, $V_{CC} \leq$ 600V, $T_{j,start} \leq$ 175°C			
Power dissipation	P_{tot}	480	W
T_C = 25°C			
Operating junction temperature	T_j	-40...+175	°C
Storage temperature	T_{stg}	-55...+150	
Soldering temperature, 1.6mm (0.063 in.) from case for 10s	-	260	
Wavesoldering only, temperature on leads only			

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[1] J-STD-020 and JESD-022
[2] Limited by bond wire
(3) Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	**Symbol**	**Conditions**	**Max. Value**	**Unit**
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}		0.31	K/W
Diode thermal resistance, junction – case	R_{thJCD}		0.53	
Thermal resistance, junction – ambient	R_{thJA}		40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	**Symbol**	**Conditions**	**Value**			**Unit**
			min.	**typ.**	**max.**	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	V_{GE}=0V, I_C=500µA	1200	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, I_C=40A				
		T_j=25°C	-	1.75	2.2	
		T_j=150°C	-	2.25	-	
		T_j=175°C	-	2.3	-	
Diode forward voltage	V_F	V_{GE}=0V, I_F=40A				
		T_j=25°C	-	1.75	2.2	
		T_j=150°C	-	1.80	-	
		T_j=175°C	-	1.80	-	
Gate-emitter threshold voltage	$V_{GE(th)}$	I_C=1.5mA, V_{CE}=V_{GE}	5.2	5.8	6.4	
Zero gate voltage collector current	I_{CES}	V_{CE}=1200V, V_{GE}=0V				mA
		T_j=25°C	-	-	0.4	
		T_j=150°C	-	-	4.0	
		T_j=175°C	-	-	20	
Gate-emitter leakage current	I_{GES}	V_{CE}=0V, V_{GE}=20V	-	-	200	nA
Transconductance	g_{fs}	V_{CE}=20V, I_C=40A	-	21	-	S

Dynamic Characteristic

Input capacitance	C_{iss}	V_{CE}=25V, V_{GE}=0V, f=1MHz	-	2360	-	pF
Output capacitance	C_{oss}		-	230	-	
Reverse transfer capacitance	C_{rss}		-	125	-	
Gate charge	Q_{Gate}	V_{CC}=960V, I_C=40A V_{GE}=15V	-	192	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E		-	13	-	nH
Short circuit collector current[1]	$I_{C(SC)}$	V_{GE}=15V,t_{SC}≤10µs V_{CC} = 600V, $T_{j,start}$ = 25°C $T_{j.start}$ = 175°C	-	220 156	-	A

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=600V,I_C=40A, V_{GE}=0/15V, R_G=12Ω, $L_\sigma{}^{2)}$=80nH, $C_\sigma{}^{2)}$=67pF Energy losses include “tail” and diode reverse recovery.	-	33	-	ns
Rise time	t_r		-	28	-	
Turn-off delay time	$t_{d(off)}$		-	314	-	
Fall time	t_f		-	94	-	
Turn-on energy	E_{on}		-	3.2	-	mJ
Turn-off energy	E_{off}		-	2.05	-	
Total switching energy	E_{ts}		-	5.25	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=25°C, V_R=600V, I_F=40A, di_F/dt=950A/µs	-	258	-	ns
Diode reverse recovery charge	Q_{rr}		-	3.3		µC
Diode peak reverse recovery current	I_{rrm}		-	23		A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	350	-	A/µs

---

[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

[2] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

Switching Characteristic, Inductive Load, at T_j=175 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=175°C V_{CC}=600V, I_C=40A, V_{GE}=0/15V, R_G= 12Ω, L_σ[1]=180nH, C_σ[1]=67pF Energy losses include "tail" and diode reverse recovery.	-	32	-	ns
Rise time	t_r		-	28	-	
Turn-off delay time	$t_{d(off)}$		-	405	-	
Fall time	t_f		-	195	-	
Turn-on energy	E_{on}		-	4.5	-	mJ
Turn-off energy	E_{off}		-	3.8	-	
Total switching energy	E_{ts}		-	8.3	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=175°C V_R=600V, I_F=40A, di_F/dt=950A/µs	-	480	-	ns
Diode reverse recovery charge	Q_{rr}		-	6.6	-	µC
Diode peak reverse recovery current	I_{rrm}		-	31	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	200		A/µs

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[1] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

IGBT

High speed DuoPack: IGBT in Trench and Fieldstop technology with soft, fast recovery anti-parallel diode

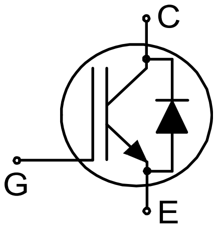
IKW40N120H3

1200V high speed switching series third generation

Data sheet

Industrial Power Control

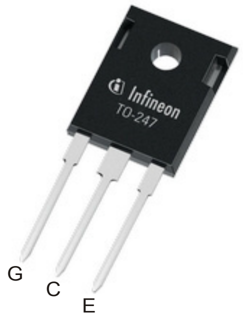
High speed DuoPack: IGBT in Trench and Fieldstop technology with soft, fast recovery anti-parallel diode



Features:

TRENCHSTOP™ technology offering
- very low V_{CEsat}
- low EMI
- Very soft, fast recovery anti-parallel diode
- maximum junction temperature 175°C
- qualified according to JEDEC for target applications
- Pb-free lead plating; RoHS compliant
- complete product spectrum and PSpice Models:

http://www.infineon.com/igbt/



Applications:

- uninterruptible power supplies
- welding converters
- converters with high switching frequency

Key Performance and Package Parameters

Type	V_{CE}	I_C	V_{CEsat}, T_{vj}=25°C	T_{vjmax}	Marking	Package
IKW40N120H3	1200V	40A	2.05V	175°C	K40H1203	PG-TO247-3

Table of Contents

Maximum Ratings

For optimum lifetime and reliability, Infineon recommends operating conditions that do not exceed 80% of the maximum ratings stated in this datasheet.

Parameter	Symbol	Value	Unit
Collector-emitter voltage	V_{CE}	1200	V
DC collector current, limited by T_{vjmax} T_C = 25°C T_C = 100°C	I_C	80.0 40.0	A
Pulsed collector current, t_p limited by T_{vjmax}	I_{Cpuls}	160.0	A
Turn off safe operating area $V_{CE} \leq 1200V$, $T_{vj} \leq 175°C$	-	160.0	A
Diode forward current, limited by T_{vjmax} T_C = 25°C T_C = 100°C	I_F	40.0 20.0	A
Diode pulsed current, t_p limited by T_{vjmax}	I_{Fpuls}	160.0	A
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time V_{GE} = 15.0V, $V_{CC} \leq 600V$ Allowed number of short circuits < 1000 Time between short circuits: ≥ 1.0s T_{vj} = 175°C	t_{SC}	10	µs
Power dissipation T_C = 25°C Power dissipation T_C = 100°C	P_{tot}	483.0 220.0	W
Operating junction temperature	T_{vj}	-40...+175	°C
Storage temperature	T_{stg}	-55...+150	°C
Soldering temperature, wave soldering 1.6mm (0.063in.) from case for 10s		260	°C
Mounting torque, M3 screw Maximum of mounting processes: 3	M	0.6	Nm

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction - case	$R_{th(j-c)}$		0.31	K/W
Diode thermal resistance, junction - case	$R_{th(j-c)}$		1.11	K/W
Thermal resistance junction - ambient	$R_{th(j-a)}$		40	K/W

Electrical Characteristic, at T_{vj} = 25°C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	V_{GE} = 0V, I_C = 0.50mA	1200	-	-	V
Collector-emitter saturation voltage	V_{CEsat}	V_{GE} = 15.0V, I_C = 40.0A T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 175°C	- - -	2.05 2.50 2.70	2.40 - -	V
Diode forward voltage	V_F	V_{GE} = 0V, I_F = 20.0A T_{vj} = 25°C T_{vj} = 175°C	- -	1.80 1.85	2.35 -	V
Diode forward voltage	V_F	V_{GE} = 0V, I_F = 40.0A T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 175°C	- - -	2.40 2.60 2.60	3.05 - -	V
Gate-emitter threshold voltage	$V_{GE(th)}$	I_C = 1.00mA, V_{CE} = V_{GE}	5.0	5.8	6.5	V
Zero gate voltage collector current	I_{CES}	V_{CE} = 1200V, V_{GE} = 0V T_{vj} = 25°C T_{vj} = 175°C	- -	- -	250.0 2500.0	µA
Gate-emitter leakage current	I_{GES}	V_{CE} = 0V, V_{GE} = 20V	-	-	600	nA
Transconductance	g_{fs}	V_{CE} = 20V, I_C = 15.0A	-	20.0	-	S

Electrical Characteristic, at T_{vj} = 25°C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Dynamic Characteristic						
Input capacitance	C_{ies}	V_{CE} = 25V, V_{GE} = 0V, f = 1MHz	-	2330	-	pF
Output capacitance	C_{oes}		-	185	-	
Reverse transfer capacitance	C_{res}		-	130	-	
Gate charge	Q_G	V_{CC} = 960V, I_C = 40.0A, V_{GE} = 15V	-	185.0	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E		-	13.0	-	nH
Short circuit collector current Max. 1000 short circuits Time between short circuits: ≥ 1.0s	$I_{C(SC)}$	V_{GE} = 15.0V, V_{CC} ≤ 600V, t_{SC} ≤ 10µs T_{vj} = 175°C	-	139	-	A

Switching Characteristic, Inductive Load

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic, at T_{vj} = 25°C						
Turn-on delay time	$t_{d(on)}$	T_{vj} = 25°C, V_{CC} = 600V, I_C = 40.0A, V_{GE} = 0.0/15.0V, $R_{G(on)}$ = 12.0Ω, $R_{G(off)}$ = 12.0Ω, $L\sigma$ = 70nH, $C\sigma$ = 67pF $L\sigma$, $C\sigma$ from Fig. E Energy losses include “tail” and diode reverse recovery.	-	30	-	ns
Rise time	t_r		-	57	-	ns
Turn-off delay time	$t_{d(off)}$		-	290	-	ns
Fall time	t_f		-	16	-	ns
Turn-on energy	E_{on}		-	3.20	-	mJ
Turn-off energy	E_{off}		-	1.20	-	mJ
Total switching energy	E_{ts}		-	4.40	-	mJ

Diode Characteristic, at T_{vj} = 25°C

Diode reverse recovery time	t_{rr}	T_{vj} = 25°C, V_R = 600V, I_F = 40.0A, di_F/dt = 500A/µs	-	355	-	ns
Diode reverse recovery charge	Q_{rr}		-	1.90	-	µC
Diode peak reverse recovery current	I_{rrm}		-	12.8	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	-150	-	A/µs

Switching Characteristic, Inductive Load

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic, at T_{vj} = 175°C						
Turn-on delay time	$t_{d(on)}$	T_{vj} = 175°C, V_{CC} = 600V, I_C = 40.0A, V_{GE} = 0.0/15.0V, $R_{G(on)}$ = 12.0Ω, $R_{G(off)}$ = 12.0Ω, $L\sigma$ = 70nH, $C\sigma$ = 67pF $L\sigma$, $C\sigma$ from Fig. E Energy losses include “tail” and diode reverse recovery.	-	29	-	ns
Rise time	t_r		-	49	-	ns
Turn-off delay time	$t_{d(off)}$		-	366	-	ns
Fall time	t_f		-	48	-	ns
Turn-on energy	E_{on}		-	4.40	-	mJ
Turn-off energy	E_{off}		-	2.60	-	mJ
Total switching energy	E_{ts}		-	7.00	-	mJ

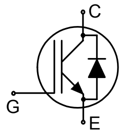
Diode Characteristic, at T_{vj} = 175°C

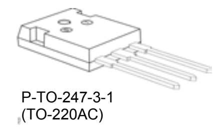
Diode reverse recovery time	t_{rr}	T_{vj} = 175°C, V_R = 600V, I_F = 40.0A, di_F/dt = 500A/µs	-	639	-	ns
Diode reverse recovery charge	Q_{rr}		-	4.30	-	µC
Diode peak reverse recovery current	I_{rrm}		-	16.0	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	-105	-	A/µs

IKW30N60T

TrenchStop Series

Low Loss DuoPack : IGBT in Trench and Fieldstop technology with soft, fast recovery anti-parallel EmCon HE diode





- Very low $V_{CE(sat)}$ 1.5 V (typ.)
- Maximum Junction Temperature 175 °C
- Short circuit withstand time – 5µs
- Designed for :
  - Frequency Converters
  - Uninterruptible Power Supply
- Trench and Fieldstop technology for 600 V applications offers :
  - very tight parameter distribution
  - high ruggedness, temperature stable behavior
  - very high switching speed
  - low $V_{CE(sat)}$
- Positive temperature coefficient in $V_{CE(sat)}$
- Low EMI
- Low Gate Charge
- Very soft, fast recovery anti-parallel EmCon HE diode
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/

Type	V_{CE}	I_C	$V_{CE(sat),Tj=25°C}$	$T_{j,max}$	Marking Code	Package	Ordering Code
IKW30N60T	600V	30A	1.5V	175°C	K30T60	TO-247	Q67040S4717

Maximum Ratings

Parameter	**Symbol**	**Value**	**Unit**
Collector-emitter voltage	V_{CE}	600	V
DC collector current, limited by T_{jmax}	I_C		A
T_C = 25°C		60	
T_C = 100°C		30	
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	90	
Turn off safe operating area ($V_{CE} \leq$ 600V, $T_j \leq$ 175°C)	-	90	
Diode forward current, limited by T_{jmax}	I_F		
T_C = 25°C		60	
T_C = 100°C		30	
Diode pulsed current, t_p limited by T_{jmax}	I_{Fpuls}	90	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[1] V_{GE} = 15V, $V_{CC} \leq$ 400V, $T_j \leq$ 150°C	t_{SC}	5	µs
Power dissipation T_C = 25°C	P_{tot}	187	W
Operating junction temperature	T_j	-40...+175	°C
Storage temperature	T_{stg}	-55...+175	
Soldering temperature, 1.6mm (0.063 in.) from case for 10s	-	260	

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[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}	TO-247	0.80	K/W
Diode thermal resistance, junction – case	R_{thJCD}	TO-247	1.05	
Thermal resistance, junction – ambient	R_{thJA}	TO-247 AC	40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	$V_{GE}=0V$, $I_C=0.2mA$	600	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, $I_C=30A$				
		$T_j=25°C$	-	1.5	2.05	
		$T_j=175°C$	-	1.9	-	
Diode forward voltage	V_F	$V_{GE}=0V$, $I_F=30A$				
		$T_j=25°C$	-	1.65	2.05	
		$T_j=175°C$	-	1.6	-	
Gate-emitter threshold voltage	$V_{GE(th)}$	$I_C=0.43mA$, $V_{CE}=V_{GE}$	4.1	4.9	5.7	
Zero gate voltage collector current	I_{CES}	$V_{CE}=600V$, $V_{GE}=0V$				µA
		$T_j=25°C$	-	-	40	
		$T_j=175°C$	-	-	1000	
Gate-emitter leakage current	I_{GES}	$V_{CE}=0V$, $V_{GE}=20V$	-	-	100	nA
Transconductance	g_{fs}	$V_{CE}=20V$, $I_C=30A$	-	16.7	-	S
Integrated gate resistor	R_{Gint}			-		Ω

Dynamic Characteristic

Parameter	Symbol	Conditions	min.	typ.	max.	Unit
Input capacitance	C_{iss}	$V_{CE}=25V$, $V_{GE}=0V$, $f=1MHz$	-	1630	-	pF
Output capacitance	C_{oss}		-	108	-	
Reverse transfer capacitance	C_{rss}		-	50	-	
Gate charge	Q_{Gate}	$V_{CC}=480V$, $I_C=30A$ $V_{GE}=15V$	-	167	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E	TO-247-3-1	-	7	-	nH
Short circuit collector current[1]	$I_{C(SC)}$	$V_{GE}=15V$, $t_{SC}\leq5\mu s$ V_{CC} = 400V, T_j = 150°C	-	275	-	A

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[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=400V,I_C=30A, V_{GE}=0/15V, R_G=10.6 Ω, L_σ1)=136nH, C_σ1)=39pF Energy losses include "tail" and diode reverse recovery.	-	23	-	ns
Rise time	t_r		-	21	-	
Turn-off delay time	$t_{d(off)}$		-	254	-	
Fall time	t_f		-	46	-	
Turn-on energy	E_{on}		-	0.69	-	mJ
Turn-off energy	E_{off}		-	0.77	-	
Total switching energy	E_{ts}		-	1.46	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=25°C, V_R=400V, I_F=30A, di_F/dt=910A/µs	-	143	-	ns
Diode reverse recovery charge	Q_{rr}		-	0.92	-	µC
Diode peak reverse recovery current	I_{rrm}		-	16.3	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	603	-	A/µs

Switching Characteristic, Inductive Load, at T_j=175 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=175°C, V_{CC}=400V,I_C=30A, V_{GE}=0/15V, R_G= 10.6 Ω L_σ1)=136nH, C_σ1)=39pF Energy losses include "tail" and diode reverse recovery.	-	24	-	ns
Rise time	t_r		-	26	-	
Turn-off delay time	$t_{d(off)}$		-	292	-	
Fall time	t_f		-	90	-	
Turn-on energy	E_{on}		-	1.0	-	mJ
Turn-off energy	E_{off}		-	1.1	-	
Total switching energy	E_{ts}		-	2.1	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=175°C V_R=400V, I_F=30A, di_F/dt=910A/µs	-	225	-	ns
Diode reverse recovery charge	Q_{rr}		-	2.39	-	µC
Diode peak reverse recovery current	I_{rrm}		-	22.3	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	310	-	A/µs

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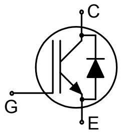
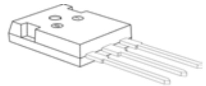
1) Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

IKP20N60T, IKB20N60T
TrenchStop Series IKW20N60T

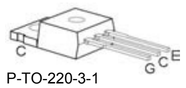
Low Loss DuoPack : IGBT in Trench and Fieldstop technology with soft, fast recovery anti-parallel EmCon HE diode



- Very low $V_{CE(sat)}$ 1.5 V (typ.)
- Maximum Junction Temperature 175 °C
- Short circuit withstand time – 5µs
- Designed for :
  - Frequency Converters
  - Uninterrupted Power Supply
- Trench and Fieldstop technology for 600 V applications offers :
  - very tight parameter distribution
  - high ruggedness, temperature stable behavior
  - very high switching speed
  - low $V_{CE(sat)}$
- Positive temperature coefficient in $V_{CE(sat)}$
- Low EMI
- Low Gate Charge
- Very soft, fast recovery anti-parallel EmCon HE diode
- Complete product spectrum and PSpice Models : http://www.infineon.com/igbt/



P-TO-247-3-1
(TO-220AC)



P-TO-220-3-1
(TO-220AB)

P-TO-263-3-2 (D²-PAK)
(TO-263AB)

Type	V_{CE}	I_C	$V_{CE(sat), Tj=25°C}$	$T_{j,max}$	Marking Code	Package	Ordering Code
IKP20N60T	600V	20A	1.5V	175°C	K20T60	TO-220	Q67040S4715
IKB20N60T	600V	20A	1.5V	175°C	K20T60	TO-263	Q67040S4713
IKW20N60T	600V	20A	1.5V	175°C	K20T60	TO-247	Q67040S4716

Maximum Ratings

Parameter	Symbol	Value	Unit
Collector-emitter voltage	V_{CE}	600	V
DC collector current, limited by T_{jmax} T_C = 25°C T_C = 100°C	I_C	 40 20	A
Pulsed collector current, t_p limited by T_{jmax}	I_{Cpuls}	60	
Turn off safe operating area ($V_{CE} \leq$ 600V, $T_j \leq$ 175°C)	-	60	
Diode forward current, limited by T_{jmax} T_C = 25°C T_C = 100°C	I_F	 40 20	
Diode pulsed current, t_p limited by T_{jmax}	I_{Fpuls}	60	
Gate-emitter voltage	V_{GE}	±20	V
Short circuit withstand time[1)] V_{GE} = 15V, $V_{CC} \leq$ 400V, $T_j \leq$ 150°C	t_{SC}	5	µs
Power dissipation T_C = 25°C	P_{tot}	166	W
Operating junction temperature	T_j	-40...+175	°C
Storage temperature	T_{stg}	-55...+175	
Soldering temperature, 1.6mm (0.063 in.) from case for 10s	-	260	

[1)] Allowed number of short circuits: <1000; time between short circuits: >1s.

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction – case	R_{thJC}	TO-220-3-1 TO-247-3-1 TO-263-3-2	0.9	K/W
Diode thermal resistance, junction – case	R_{thJCD}	TO-220-3-1 TO-247-3-1 TO-263-3-2	1.5	
Thermal resistance, junction – ambient	R_{thJA}	TO-220-3-1 TO-247-3-1 TO-263-3-2 (6cm² Cu)	62 40 40	

Electrical Characteristic, at T_j = 25 °C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	$V_{GE}=0V$, $I_C=0.2mA$	600	-	-	V
Collector-emitter saturation voltage	$V_{CE(sat)}$	V_{GE} = 15V, $I_C=20A$ $T_j=25°C$ $T_j=175°C$	 - -	 1.5 1.9	 2.05 -	
Diode forward voltage	V_F	$V_{GE}=0V$, $I_F=20A$ $T_j=25°C$ $T_j=175°C$	 - -	 1.65 1.6	 2.05 -	
Gate-emitter threshold voltage	$V_{GE(th)}$	$I_C=290\mu A, V_{CE}=V_{GE}$	4.1	4.9	5.7	
Zero gate voltage collector current	I_{CES}	$V_{CE}=600V$, $V_{GE}=0V$ $T_j=25°C$ $T_j=175°C$	 - -	 - -	 40 1000	µA
Gate-emitter leakage current	I_{GES}	$V_{CE}=0V, V_{GE}=20V$	-	-	100	nA
Transconductance	g_{fs}	$V_{CE}=20V$, $I_C=20A$	-	11	-	S
Integrated gate resistor	R_{Gint}			-		Ω

Dynamic Characteristic

Input capacitance	C_{iss}	V_{CE}=25V, V_{GE}=0V, f=1MHz	-	1100	-	pF
Output capacitance	C_{oss}		-	71	-	
Reverse transfer capacitance	C_{rss}		-	32	-	
Gate charge	Q_{Gate}	V_{CC}=480V, I_C=20A V_{GE}=15V	-	120	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E	TO-220-3-1 TO-247-3-1 TO-263-3-2	-	7	-	nH
Short circuit collector current[1]	$I_{C(SC)}$	V_{GE}=15V,t_{SC}≤5µs V_{CC} = 400V, T_j ≤ 150°C	-	183.3	-	A

Switching Characteristic, Inductive Load, at T_j=25 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=25°C, V_{CC}=400V,I_C=20A, V_{GE}=0/15V, R_G=12 Ω, L_σ[2]=131nH, C_σ[2]=31pF Energy losses include "tail" and diode reverse recovery.	-	18	-	ns
Rise time	t_r		-	14	-	
Turn-off delay time	$t_{d(off)}$		-	199	-	
Fall time	t_f		-	42	-	
Turn-on energy	E_{on}		-	0.31	-	mJ
Turn-off energy	E_{off}		-	0.46	-	
Total switching energy	E_{ts}		-	0.77	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=25°C, V_R=400V, I_F=20A, di_F/dt=880A/µs	-	41	-	ns
Diode reverse recovery charge	Q_{rr}		-	0.31	-	µC
Diode peak reverse recovery current	I_{rrm}		-	13.3	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	711	-	A/µs

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[1] Allowed number of short circuits: <1000; time between short circuits: >1s.

[2] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

Switching Characteristic, Inductive Load, at T_j=175 °C

Parameter	Symbol	Conditions	Value			Unit
			min.	Typ.	max.	
IGBT Characteristic						
Turn-on delay time	$t_{d(on)}$	T_j=175°C, V_{CC}=400V,I_C=20A, V_{GE}=0/15V, R_G= 12 Ω L_σ[1]=131nH, C_σ[1]=31pF Energy losses include “tail” and diode reverse recovery.	-	18	-	ns
Rise time	t_r		-	18	-	
Turn-off delay time	$t_{d(off)}$		-	223	-	
Fall time	t_f		-	76	-	
Turn-on energy	E_{on}		-	0.51	-	mJ
Turn-off energy	E_{off}		-	0.64	-	
Total switching energy	E_{ts}		-	1.15	-	
Anti-Parallel Diode Characteristic						
Diode reverse recovery time	t_{rr}	T_j=175°C V_R=400V, I_F=20A, di_F/dt=880A/µs	-	176	-	ns
Diode reverse recovery charge	Q_{rr}		-	1.46	-	µC
Diode peak reverse recovery current	I_{rrm}		-	18.9	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	467	-	A/µs

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[1] Leakage inductance L_σ and Stray capacity C_σ due to dynamic test circuit in Figure E.

IGBT

High speed 5 FAST IGBT in TRENCHSTOP^{TM} 5 technology copacked with RAPID 1 fast and soft anti parallel diode

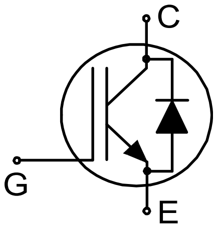
IKP40N65F5, IKW40N65F5

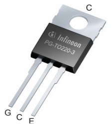
650V DuoPack IGBT and Diode
High speed switching series fifth generation

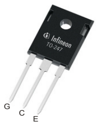
Data sheet

Industrial Power Control

High speed 5 FAST IGBT in TRENCHSTOP™ 5 technology copacked with RAPID 1 fast and soft anti parallel diode







Features and Benefits:

High speed F5 technology offering
- Best-in-Class efficiency in hard switching and resonant topologies
- 650V breakdown voltage
- Low Q_g
- IGBT copacked with RAPID 1 fast and soft antiparallel diode
- Maximum junction temperature 175°C
- Qualified according to JEDEC for target applications
- Pb-free lead plating; RoHS compliant
- Complete product spectrum and PSpice Models: http://www.infineon.com/igbt/

Applications:

- Solar converters
- Uninterruptible power supplies
- Welding converters
- Mid to high range switching frequency converters

Package pin definition:

- Pin 1 - gate
- Pin 2 & backside - collector
- Pin 3 - emitter

Key Performance and Package Parameters

Type	V_{CE}	I_C	V_{CEsat}, T_{vj}=25°C	T_{vjmax}	Marking	Package
IKW40N65F5	650V	40A	1.6V	175°C	K40F655	PG-TO247-3
IKP40N65F5	650V	40A	1.6V	175°C	K40F655	PG-TO220-3

Table of Contents

Maximum ratings

Parameter	Symbol	Value	Unit
Collector-emitter voltage	V_{CE}	650	V
DC collector current, limited by T_{vjmax} $T_C = 25°C$ $T_C = 100°C$	I_C	 74.0 46.0	A
Pulsed collector current, t_p limited by T_{vjmax}	I_{Cpuls}	120.0	A
Turn off safe operating area $V_{CE} \leq 650V$, $T_{vj} \leq 175°C$	-	120.0	A
Diode forward current, limited by T_{vjmax} $T_C = 25°C$ $T_C = 100°C$	I_F	 36.0 21.0	A
Diode pulsed current, t_p limited by T_{vjmax}	I_{Fpuls}	120.0	A
Gate-emitter voltage Transient Gate-emitter voltage ($t_p \leq 10µs$, D < 0.010)	V_{GE}	±20 ±30	V
Power dissipation $T_C = 25°C$ Power dissipation $T_C = 100°C$	P_{tot}	255.0 120.0	W
Operating junction temperature	T_{vj}	-40...+175	°C
Storage temperature	T_{stg}	-55...+150	°C
Soldering temperature, wave soldering 1.6 mm (0.063 in.) from case for 10s	PG-TO247-pinGCE PG-TO220-3	260 260	°C
Mounting torque, M3 screw Maximum of mounting processes: 3	M	0.6	Nm

Thermal Resistance

Parameter	Symbol	Conditions	Max. Value	Unit
Characteristic				
IGBT thermal resistance, junction - case	$R_{th(j-c)}$		0.60	K/W
Diode thermal resistance, junction - case	$R_{th(j-c)}$		1.80	K/W
Thermal resistance junction - ambient	$R_{th(j-a)}$	PG-TO247-pinGCE PG-TO220-3	40 62	K/W

Electrical Characteristic, at T_{vj} = 25°C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Static Characteristic						
Collector-emitter breakdown voltage	$V_{(BR)CES}$	V_{GE} = 0V, I_C = 0.20mA	650	-	-	V
Collector-emitter saturation voltage	V_{CEsat}	V_{GE} = 15.0V, I_C = 40.0A T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 175°C	- - -	1.60 1.80 1.90	2.10 - -	V
Diode forward voltage	V_F	V_{GE} = 0V, I_F = 20.0A T_{vj} = 25°C T_{vj} = 125°C T_{vj} = 175°C	- - -	1.45 1.40 1.40	1.80 - -	V
Gate-emitter threshold voltage	$V_{GE(th)}$	I_C = 0.40mA, V_{CE} = V_{GE}	3.2	4.0	4.8	V
Zero gate voltage collector current	I_{CES}	V_{CE} = 650V, V_{GE} = 0V T_{vj} = 25°C T_{vj} = 175°C	- -	- -	40.0 4000.0	µA
Gate-emitter leakage current	I_{GES}	V_{CE} = 0V, V_{GE} = 20V	-	-	100	nA
Transconductance	g_{fs}	V_{CE} = 20V, I_C = 40.0A	-	50.0	-	S

Electrical Characteristic, at T_{vj} = 25°C, unless otherwise specified

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
Dynamic Characteristic						
Input capacitance	C_{ies}	V_{CE} = 25V, V_{GE} = 0V, f = 1MHz	-	2500	-	pF
Output capacitance	C_{oes}		-	50	-	
Reverse transfer capacitance	C_{res}		-	9	-	
Gate charge	Q_G	V_{CC} = 520V, I_C = 40.0A, V_{GE} = 15V	-	95.0	-	nC
Internal emitter inductance measured 5mm (0.197 in.) from case	L_E	PG-TO247-pinGCE PG-TO220-3	-	13.0	-	nH

Switching Characteristic, Inductive Load

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	
IGBT Characteristic, at T_{vj} = 25°C						
Turn-on delay time	$t_{d(on)}$	T_{vj} = 25°C, V_{CC} = 400V, I_C = 20.0A, V_{GE} = 0.0/15.0V, r_G = 15.0Ω, $L\sigma$ = 30nH, $C\sigma$ = 30pF $L\sigma$, $C\sigma$ from Fig. E Energy losses include “tail” and diode reverse recovery.	-	19	-	ns
Rise time	t_r		-	13	-	ns
Turn-off delay time	$t_{d(off)}$		-	160	-	ns
Fall time	t_f		-	16	-	ns
Turn-on energy	E_{on}		-	0.36	-	mJ
Turn-off energy	E_{off}		-	0.10	-	mJ
Total switching energy	E_{ts}		-	0.46	-	mJ

Turn-on delay time	$t_{d(on)}$	T_{vj} = 25°C, V_{CC} = 400V, I_C = 5.0A, V_{GE} = 0.0/15.0V, r_G = 15.0Ω, $L\sigma$ = 30nH, $C\sigma$ = 30pF $L\sigma$, $C\sigma$ from Fig. E Energy losses include “tail” and diode reverse recovery.	-	20	-	ns
Rise time	t_r		-	4	-	ns
Turn-off delay time	$t_{d(off)}$		-	175	-	ns
Fall time	t_f		-	10	-	ns
Turn-on energy	E_{on}		-	0.07	-	mJ
Turn-off energy	E_{off}		-	0.03	-	mJ
Total switching energy	E_{ts}		-	0.10	-	mJ

Diode Characteristic, at T_{vj} = 25°C

Diode reverse recovery time	t_{rr}	T_{vj} = 25°C, V_R = 400V, I_F = 20.0A, di_F/dt = 1000A/μs	-	60	-	ns
Diode reverse recovery charge	Q_{rr}		-	0.45	-	μC
Diode peak reverse recovery current	I_{rrm}		-	12.4	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	-280	-	A/μs

Diode reverse recovery time	t_{rr}	T_{vj} = 25°C, V_R = 400V, I_F = 5.0A, di_F/dt = 1000A/μs	-	33	-	ns
Diode reverse recovery charge	Q_{rr}		-	0.22	-	μC
Diode peak reverse recovery current	I_{rrm}		-	10.6	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	-1030	-	A/μs

Switching Characteristic, Inductive Load

Parameter	Symbol	Conditions	Value			Unit
			min.	typ.	max.	

IGBT Characteristic, at T_{vj} = 150°C

Turn-on delay time	$t_{d(on)}$	T_{vj} = 150°C, V_{CC} = 400V, I_C = 20.0A, V_{GE} = 0.0/15.0V, r_G = 15.0Ω, $L\sigma$ = 30nH, $C\sigma$ = 30pF $L\sigma$, $C\sigma$ from Fig. E Energy losses include “tail” and diode reverse recovery.	-	20	-	ns
Rise time	t_r		-	14	-	ns
Turn-off delay time	$t_{d(off)}$		-	185	-	ns
Fall time	t_f		-	15	-	ns
Turn-on energy	E_{on}		-	0.50	-	mJ
Turn-off energy	E_{off}		-	0.16	-	mJ
Total switching energy	E_{ts}		-	0.66	-	mJ

Turn-on delay time	$t_{d(on)}$	T_{vj} = 150°C, V_{CC} = 400V, I_C = 5.0A, V_{GE} = 0.0/15.0V, r_G = 15.0Ω, $L\sigma$ = 30nH, $C\sigma$ = 30pF $L\sigma$, $C\sigma$ from Fig. E Energy losses include “tail” and diode reverse recovery.	-	18	-	ns
Rise time	t_r		-	5	-	ns
Turn-off delay time	$t_{d(off)}$		-	220	-	ns
Fall time	t_f		-	12	-	ns
Turn-on energy	E_{on}		-	0.14	-	mJ
Turn-off energy	E_{off}		-	0.05	-	mJ
Total switching energy	E_{ts}		-	0.19	-	mJ

Diode Characteristic, at T_{vj} = 150°C

Diode reverse recovery time	t_{rr}	T_{vj} = 150°C, V_R = 400V, I_F = 20.0A, di_F/dt = 1000A/µs	-	85	-	ns
Diode reverse recovery charge	Q_{rr}		-	1.00	-	µC
Diode peak reverse recovery current	I_{rrm}		-	17.0	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	-220	-	A/µs

Diode reverse recovery time	t_{rr}	T_{vj} = 150°C, V_R = 400V, I_F = 5.0A, di_F/dt = 1000A/µs	-	50	-	ns
Diode reverse recovery charge	Q_{rr}		-	0.50	-	µC
Diode peak reverse recovery current	I_{rrm}		-	14.0	-	A
Diode peak rate of fall of reverse recovery current during t_b	di_{rr}/dt		-	-500	-	A/µs