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Enhanced Web Tool Speeds IGBT Selection, Matching Device To The Application

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Design tools are becoming more and more available from all manufacturers. They can shorten the design cycle, reduce bill of materials (BOM) cost, and mitigate the issue of "suboptimal performance." Overtime, they will gradually become application-specific and encompass thermal models.

Some of the design tools offered by manufacturers would be better described as device-selection tools. These tools can be particularly helpful when searching for a power semiconductor device. Because transistor development entails multiple tradeoffs in device characteristics, vendors have developed large portfolios of these components to serve the needs of different applications. A vendor's device-selection tool enables the system designer to navigate through the various part numbers more easily, in order to locate the most suitable components.

However, these device-selection tools are still evolving to enable more optimal device selection. This article discusses the recent enhancements made by International Rectifier in its IGBT selection tool. The first version of the tool, which was released two years ago, permitted users to enter critical application parameters and then calculate a device's junction temperature under a set of representative operating conditions. But recently, the functionality of this tool was expanded to take into account heatsink thermal resistance as well as the thermal resistance for surface-mounted parts.

In addition to describing tool features, this article presents a device selection example that illustrates how this tool can be used to compare alternative solutions in the design of a small motor drive. Some of the limitations of this tool are also discussed as these are leading to the development of more-powerful, application-specific tools.

Selecting The Low-Cost Component For The Application

Every component has a price, a simple number expressed in currency terms. But there is also another cost metric associated with each component: the cost of system failures. The two numbers can be widely divergent because the failure of a one-cent diode has the same ultimate result as the failure of a power component costing several dollars. In some fields of application, like telecom and automotive, failures are monitored and the true cost of a component can be ascertained, if desired. In consumer products, price and cost tend to merge due to the short lifetime of the product.

But there are other indirect component costs that are difficult to measure and impossible to track, even in design-intensive sectors. These are the costs related to the suboptimal performance of a component. An older and less-efficient power device may be designed into a new application for reasons of convenience or availability or because it's already qualified. That power device may require a heatsink that is manually assembled, while a newer, more-efficient device would not need the heatsink and could be surface-mounted directly on the board. We will go through one such example in a later section.

Over the last few years the design cycle has become shorter while the product offerings have become more numerous and more tailored to one application or the other. In a parallel development, a larger share of the design resources are being redirected towards compliance issues, at the expense of the power-stage design work. As a result, the designer has limited opportunities to work in the lab to optimize the device selection. His natural inclination is to stay with the "tried and proven" or to select the component with the lowest sticker price.

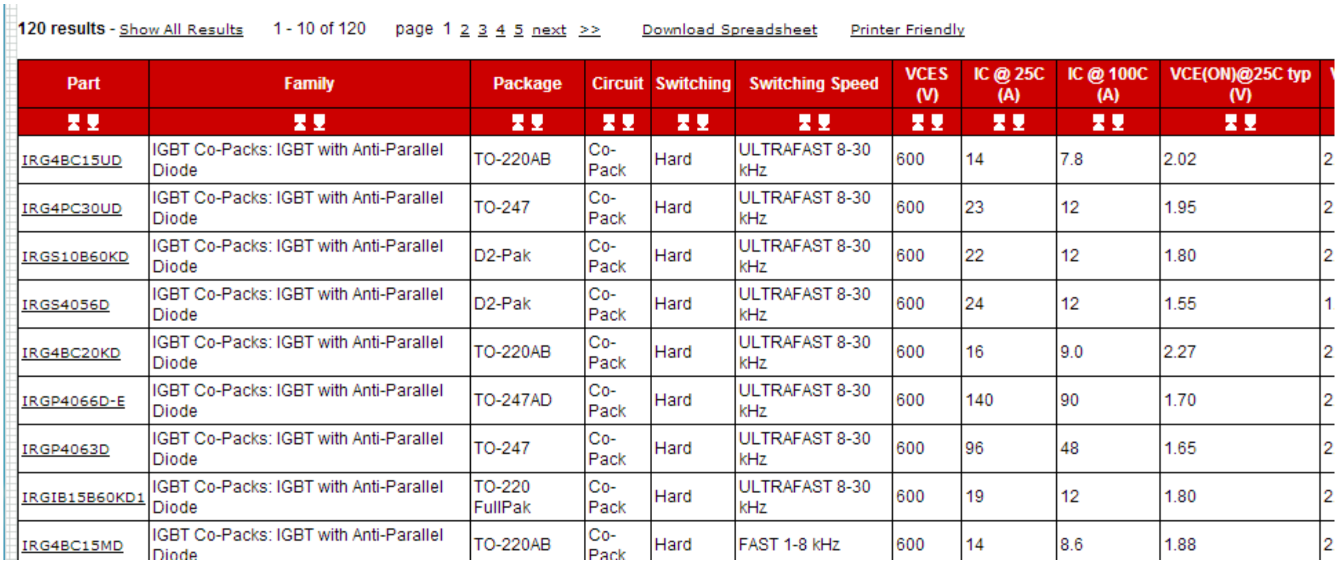
If there is a good customer-supplier relationship, the designer works with the field application engineer to select the best component. This can be a satisfactory solution if the preferred supplier—and not one of his competitors—has the right device in his portfolio of products.

In the end, the selection of a critical component remains a key design task and the engineer can use all the help he or she can get.

The Case Of The Power Devices

Component suppliers are acutely aware of this need and have been trying to simplify the selection process by presenting their product line in a web format, with key parameters in sortable columns. They are all slightly different from each other, but a typical example is shown in Fig. 1.

This is good, as far as it goes, but does not bridge the gap between component and application. Power components, from resistors to RF transistors, operate in a thermo-mechanical environment that is at least as important as the electrical operating conditions, like voltage, current and frequency. The device selector shown in Fig. 1 lists a number of key parameters but no mention is made of the thermal environment (nor frequency, for that matter.)



120 results - Show All Results   1 - 10 of 120   page 1 2 3 4 5 next >>   Download Spreadsheet   Printer Friendly

Part	Family	Package	Circuit	Switching	Switching Speed	VCES (V)	IC @ 25C (A)	IC @ 100C (A)	VCE(ON)@25C typ (V)	
IRG4BC15UD	IGBT Co-Packs: IGBT with Anti-Parallel Diode	TO-220AB	Co-Pack	Hard	ULTRAFAST 8-30 kHz	600	14	7.8	2.02	2
IRG4PC30UD	IGBT Co-Packs: IGBT with Anti-Parallel Diode	TO-247	Co-Pack	Hard	ULTRAFAST 8-30 kHz	600	23	12	1.95	2
IRGS10B60KD	IGBT Co-Packs: IGBT with Anti-Parallel Diode	D2-Pak	Co-Pack	Hard	ULTRAFAST 8-30 kHz	600	22	12	1.80	2
IRGS4056D	IGBT Co-Packs: IGBT with Anti-Parallel Diode	D2-Pak	Co-Pack	Hard	ULTRAFAST 8-30 kHz	600	24	12	1.55	1
IRG4BC20KD	IGBT Co-Packs: IGBT with Anti-Parallel Diode	TO-220AB	Co-Pack	Hard	ULTRAFAST 8-30 kHz	600	16	9.0	2.27	2
IRGP4066D-E	IGBT Co-Packs: IGBT with Anti-Parallel Diode	TO-247AD	Co-Pack	Hard	ULTRAFAST 8-30 kHz	600	140	90	1.70	2
IRGP4063D	IGBT Co-Packs: IGBT with Anti-Parallel Diode	TO-247	Co-Pack	Hard	ULTRAFAST 8-30 kHz	600	96	48	1.65	2
IRGIB15B60KD1	IGBT Co-Packs: IGBT with Anti-Parallel Diode	TO-220 FullPak	Co-Pack	Hard	ULTRAFAST 8-30 kHz	600	19	12	1.80	2
IRG4BC15MD	IGBT Co-Packs: IGBT with Anti-Parallel Diode	TO-220AB	Co-Pack	Hard	FAST 1-8 kHz	600	14	8.6	1.88	2

Fig. 1. A typical example of a web-based product selector. There are many more columns than what is shown in the picture and they are sortable. Unfortunately, all these parameters are device-related based on a standardized set of test conditions. They are not application-related and do not take into account the thermal environment of the applications.

This problem of device selection is particularly acute if the component is an IGBT, on account of the multiple tradeoffs that the device designers have made. Well known is the tradeoff between conduction losses and switching losses. Less known are the tradeoffs between short-circuit capability and conduction losses or cost versus diode performance and power density, not to mention hard-switching versus soft-switching performance.

These tradeoffs are made to improve the figure of merit that is the key to the success of the IGBTs: amps per dollar. Needless to say, different manufacturers strike the balance in different places of the tradeoff curve to accommodate the inputs from their key customers. To make matters even-more complicated, advances in the applications and newer silicon technologies conspire to reposition this optimal point into more-advanced territory.

All these devices are different and behave in different ways in a specific application. Not only in terms of junction temperature, but also in terms of switching waveforms, short-circuit capability and EMI. Even if the difference in performance between two IGBTs is not significant, the pressure to reduce product cost does not leave much room for the suboptimal performance mentioned in the previous section.

Web Tools Can Help

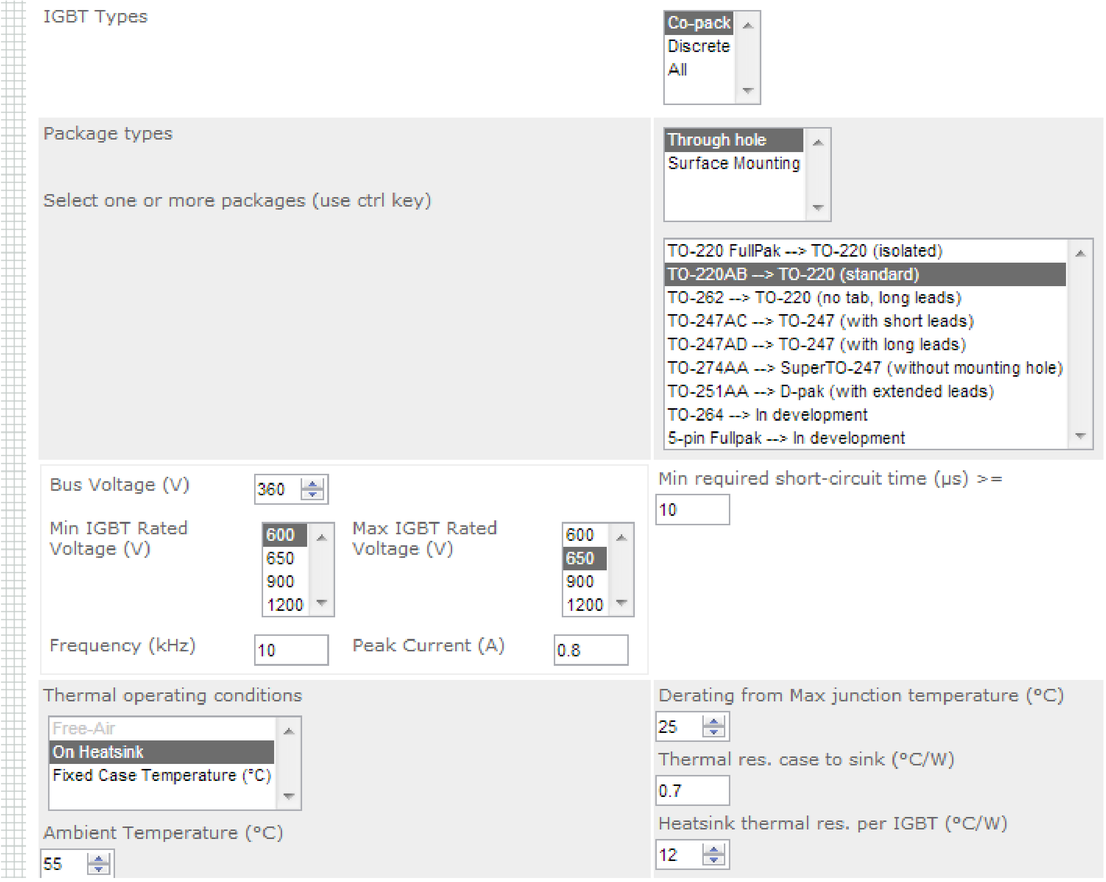
Back in 2011, International Rectifier introduced a web tool to narrow down the list of potential candidates to a handful of part numbers, thus making the IGBT selection process much simpler. It took into account the most-critical application parameters including frequency. An engine in the background calculated the operating junction temperature under a set of operating conditions that were simple but representative. The tool was useful and became quite popular but did not go far enough in bridging that critical gap between the thermal environment and the device itself.

The functionality of that tool has now been expanded to take into account the heatsink thermal resistance as well as the thermal resistance for surface-mounted parts. The figures in this section show how this tool can be used to compare alternative solutions to the design of a small motor drive, as it could be used in a home appliance.

After selecting the package characteristics, we enter the electrical operating conditions. As is customary for motor drives, we enter the requirement of 10-µs short-circuit rating in the appropriate box. We mount the three-phase bridge on a small heatsink that could be individual (a simple clip) or common to all the devices. We enter the thermal resistance of the individual clip: 12°C/W.

The tool uses this data to calculate power losses in the specified application conditions and only those devices that would operate at a junction temperature lower than a preset limit are returned as potential candidates. The temperature limit is equal to the max rated junction temperature, less the derating entered in Fig. 2. A disclaimer: as explained in the last section, power losses and temperature are not specific to the application and they are only used to compare potential candidates.

The IGBTs that meet the requirements entered in Fig. 2 are the four shown in Fig. 3. They are ranked according to operating junction temperature, a number that is closely related to efficiency.



IGBT Types
Co-pack
Discrete
All

Package types
Through hole
Surface Mounting

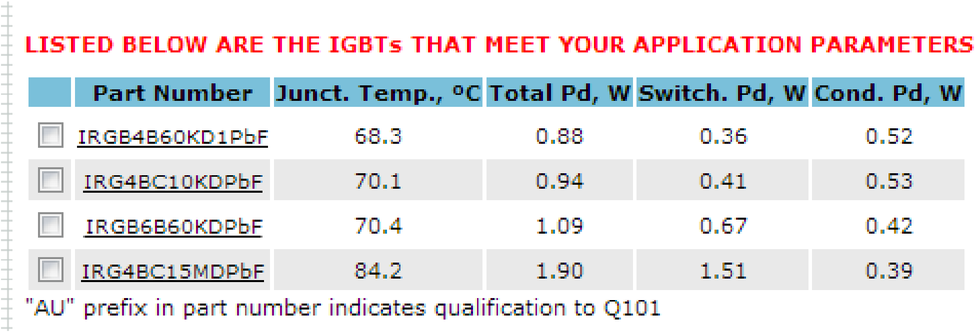
Select one or more packages (use ctrl key)
TO-220 FullPak --> TO-220 (isolated)
TO-220AB --> TO-220 (standard)
TO-262 --> TO-220 (no tab, long leads)
TO-247AC --> TO-247 (with short leads)
TO-247AD --> TO-247 (with long leads)
TO-274AA --> SuperTO-247 (without mounting hole)
TO-251AA --> D-pak (with extended leads)
TO-264 --> In development
5-pin Fullpak --> In development

Bus Voltage (V): 360
Min IGBT Rated Voltage (V): 600, 650, 900, 1200
Max IGBT Rated Voltage (V): 600, 650, 900, 1200
Frequency (kHz): 10
Peak Current (A): 0.8
Min required short-circuit time (µs) >=: 10

Thermal operating conditions
Free-Air
On Heatsink
Fixed Case Temperature (°C)

Ambient Temperature (°C): 55
Derating from Max junction temperature (°C): 25
Thermal res. case to sink (°C/W): 0.7
Heatsink thermal res. per IGBT (°C/W): 12

Fig. 2. The information entered in this screen is used by the evaluation engine to eliminate all devices that exceed the stipulated junction temperature in the operating conditions stated above.



LISTED BELOW ARE THE IGBTs THAT MEET YOUR APPLICATION PARAMETERS

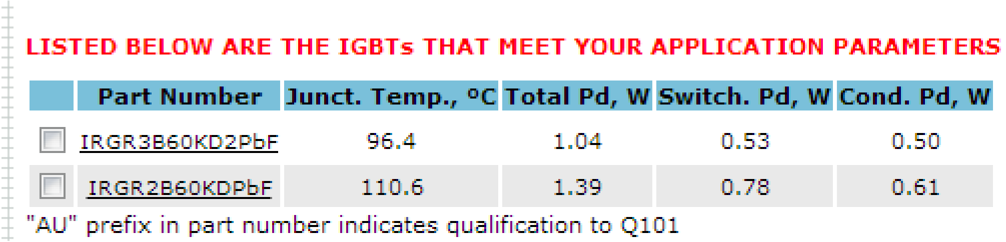
	Part Number	Junct. Temp., °C	Total Pd, W	Switch. Pd, W	Cond. Pd, W
☐	IRGB4B60KD1PbF	68.3	0.88	0.36	0.52
☐	IRG4BC10KDPbF	70.1	0.94	0.41	0.53
☐	IRGB6B60KDPbF	70.4	1.09	0.67	0.42
☐	IRG4BC15MDPbF	84.2	1.90	1.51	0.39

"AU" prefix in part number indicates qualification to Q101

Fig. 3. Four IGBTs meet the criteria entered in Fig. 2. They are ranked according to operating junction temperature—a number that is closely related to efficiency. The data sheet for each part can be downloaded by clicking on the part number.

The tool can be used to explore alternative solutions like surface mounting without a heatsink. We chose D-Paks with a thermal resistance-to-ambient of 40°C/W, a reasonable number if the board is a 4- to 6-oz copper laminate with some vias underneath the IGBTs. All the other operating conditions are the same.

This time the tool returns the two IGBTs shown in Fig. 4. Power dissipation is close to that of the IGBTs in Fig. 3 but, since package and die are both smaller, these IGBTs are likely to be less expensive than those listed in Fig. 3. The junction temperature may be a bit higher, but it's still within the constraints of the junction rating and of the PCB capability.



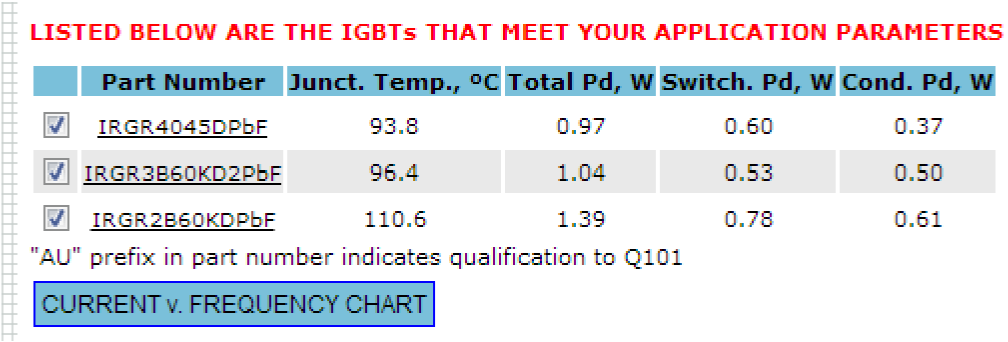
LISTED BELOW ARE THE IGBTs THAT MEET YOUR APPLICATION PARAMETERS

	Part Number	Junct. Temp., °C	Total Pd, W	Switch. Pd, W	Cond. Pd, W
☐	IRGR3B60KD2PbF	96.4	1.04	0.53	0.50
☐	IRGR2B60KDPbF	110.6	1.39	0.78	0.61

"AU" prefix in part number indicates qualification to Q101

Fig. 4. The input shown in Fig. 2 has been changed to request surface-mounted IGBTs. A thermal resistance-to-ambient of 40°C/W has been entered. All other operating conditions are the same. The tool returns the two IGBTs shown above. Power dissipation is close to that of the IGBTs in Fig. 3 but these IGBTs are likely to be less expensive. Junction temperature is higher than the IGBTs in Fig. 3, due to the different thermal environment.

Let's make a further attempt at device optimization by reducing the short-circuit requirement from 10 µs to 5 µs, well within the response time of the current-sensing ICs normally employed in this type of application. This time the tool returns the same two IGBTs shown in Fig. 4, plus a new one (Fig. 5), with lower power dissipation and lower junction temperature. Not surprisingly, this more-efficient IGBT is of a newer generation, trench design, while the other two are built in planar technology.



LISTED BELOW ARE THE IGBTs THAT MEET YOUR APPLICATION PARAMETERS

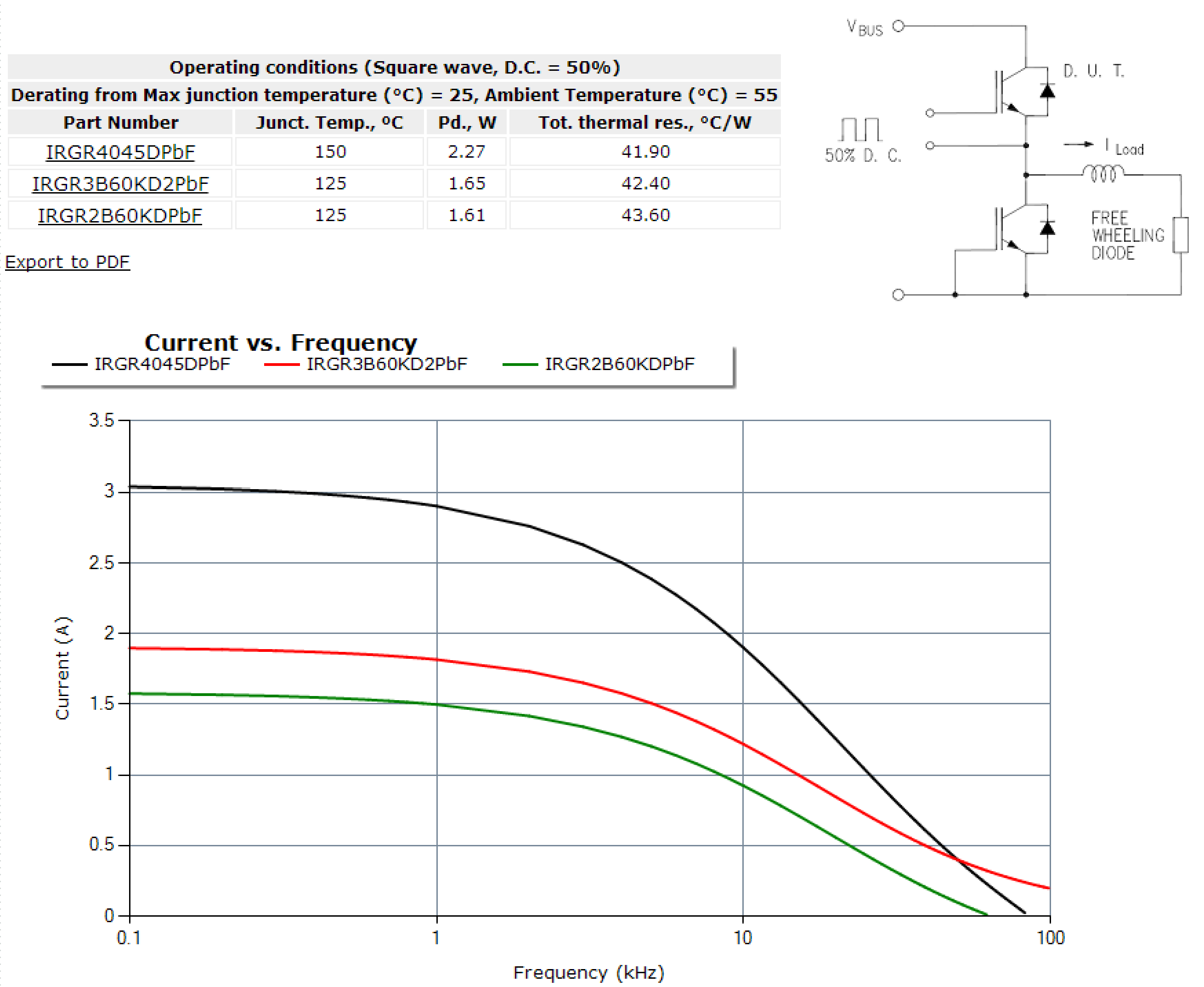
	Part Number	Junct. Temp., °C	Total Pd, W	Switch. Pd, W	Cond. Pd, W
☑	IRGR4045DPbF	93.8	0.97	0.60	0.37
☑	IRGR3B60KD2PbF	96.4	1.04	0.53	0.50
☑	IRGR2B60KDPbF	110.6	1.39	0.78	0.61

"AU" prefix in part number indicates qualification to Q101

Fig. 5. Same input as Fig. 4 with a short-circuit capability reduced from 10 µs to 5 µs. A new IGBT shows up with lower power dissipation and lower junction temperature. More-efficient and less-expensive devices become available if the short-circuit requirement is decreased.

Let’s take this analysis a step further and compare the relative performance of these three IGBTs. Up to this point we have been asking the tool to gives some candidates that meet the application parameters. We have three such devices and we have an indication of losses and junction temperature in the application. We would like to know more about their capabilities.

We click on the box to the left of each part number and on the button “Current v. Frequency Chart”. The tool returns the graph shown in Fig. 6. In the previous figures the current and frequencies were fixed, in this graph the junction temperature is fixed, frequency is swept and current is the end result.



Operating conditions (Square wave, D.C. = 50%)			
Derating from Max junction temperature (°C) = 25, Ambient Temperature (°C) = 55			
Part Number	**Junct. Temp., ºC**	**Pd., W**	**Tot. thermal res., °C/W**
IRGR4045DPbF	150	2.27	41.90
IRGR3B60KD2PbF	125	1.65	42.40
IRGR2B60KDPbF	125	1.61	43.60

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Fig. 6. The Current vs. Frequency curve gives a snapshot of conduction and switching performance and can be used to mitigate the issue of “suboptimal performance.” Clearly the IRGR4045 (trench) has much superior conduction characteristics than the other two IGBTs: at low frequency it can carry much more current. It’s also clear that its current-carrying capability degrades more rapidly as frequency increases, a sign of higher switching losses. The tabular information supplies some additional information.

Character Connotations

A picture is worth a thousand words and Fig. 6 alone is worth at least that much. It’s clear that the IRGR4045 has conduction characteristics that are much superior to those of the other two IGBTs, as indicated by the ability of the IRGR4045 to carry much more current at low frequency. It’s also clear that its current-carrying capability degrades more rapidly as frequency increases, a sign of higher switching losses. As seasoned designers are painfully aware, fast switching frequently translates into EMI problems and, particularly in motor drives, higher frequencies do not necessarily translate into tangible benefits.

The table in Fig. 6 supplies some additional information: operating junction temperature and power dissipation. The plots are for a junction temperature that is derated from maximum rating by the entry we have made in the first screen, 25°C in this case. The IRGR4045 is rated at 175°C while the others are rated at 150°C. This is one of the reasons its curve is so much higher than the other two.

The motor drive application we have explored could not take advantage of this higher temperature rating because of the limitations of the PCB. But, as we have seen in Fig. 5, the IRGR4045 has the lowest operating temperature in the specific application. This gives us another optimization hint: eliminate the vias on the PCB and go to 4-oz copper, thus shaving some cost from the BOM. At this point we have learned the trick: we go back to the device selector, increase the thermal resistance from 40°C/W to, say, 50°C/W and see what effects it has on losses and temperature.

As mentioned in the first section, suboptimal performance cannot be quantified, nor eliminated. But it can be greatly reduced with the help of web tools that are becoming more and more available.

Where Do We Go From Here?

Useful as it might be, this tool is still far from answering all the design issues of a typical development. It falls short on two accounts, as explained below. Let’s review these limitations and look at them as challenges and opportunities for more-advanced tools.

The first limitation is shown in the schematic of Fig. 6. The losses are calculated for a buck converter operated at 50% duty cycle in continuous-current mode. In this operating mode, the diode co-packaged with the IGBT does not conduct. Its complementary IGBT does and its losses are not calculated.

The junction temperature calculated by the tool for the upper device is still formally correct because its diode does not conduct, but the calculation is not representative of a real-life application. In a real-life application the duty cycle could be higher or lower and losses would change accordingly.

To overcome this limitation, application-specific tools are in development. Using the example of the motor drive, the present tool does not take into account the fact that an IGBT only conducts for half of the cycle of the motor current, while its diode conducts during the other half. Nor does it take into account different modulation strategies.

A tool specifically crafted for motor drives would take all these factors in consideration without neglecting the thermal environment. It would calculate the duty cycle based on the modulation index and power factor entered by the user.

The second limitation poses a bigger challenge: the thermal environment cannot be properly characterized with thermal resistance numbers. Heat does not flow linearly from point A to point B; it flows in all directions driven by the temperature differential. There is no such thing as a “heatsink temperature” or a “junction temperature.” There is a temperature distribution on the surface of a junction and there is a 3-D temperature distribution within a heatsink.

Let’s consider again the example of the motor drive implemented with surface-mounted IGBTs. The power dissipation is known and is the same for all six devices. We also know the thermal resistances and, supposedly, we have all the data to calculate case temperature and PCB temperature.

If we were to take a thermal image of the bridge under the stipulated conditions, we would be in for a shock: the temperature of the two devices in the center leg could be 5°C to 15°C higher than that of the other two legs. The problem is that the very concept of “case temperature” becomes particularly shaky when we are dealing with surface-mounted power devices.

This is the next challenge: factor-in an accurate model of the thermal environment. The analytical tools are already available in the form of FEA engines that can be embedded into the IGBT selection tool itself. What is needed is a set of heatsink models in standardized form. Such models are being developed by the more sophisticated users, particularly in the automotive field, but they are laborious and not accessible to every designer. They need to be standardized to be made available to a larger population of users.

In the end, despite the availability of tools, there is an aspect of device performance that is still left to oscilloscope investigation: switching waveforms. These waveforms are the result of the interaction between device characteristics, board layout and stray parameters. They have significant implications for one of the most difficult design challenges: EMI conformance to regulations. Available tools are still unable to bridge this gap.

About The Author

Steve Clemente joined International Rectifier (IR) in 1980, after working in the Numerical Control Division of General electric and the Corporate R&D of Westinghouse. In his 30+ years at IR, Clemente has held several managerial positions in Applications, R&D and Systems Engineering.

For further reading on IGBT selection, see the How2Power Design Guide, select the Advanced Search option, go to Search by Design Guide Category and select "Power Transistors" in the Component category.