

IGBT losses in hard switching

Energy Saving Products BU
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International
IOR Rectifier



The IGBT Selector calculates the losses



IGBTs are ranked by junction temperature

Switching and conduction losses

LISTED BELOW ARE THE IGBTs THAT MEET YOUR APPLICATION PARAMETERS

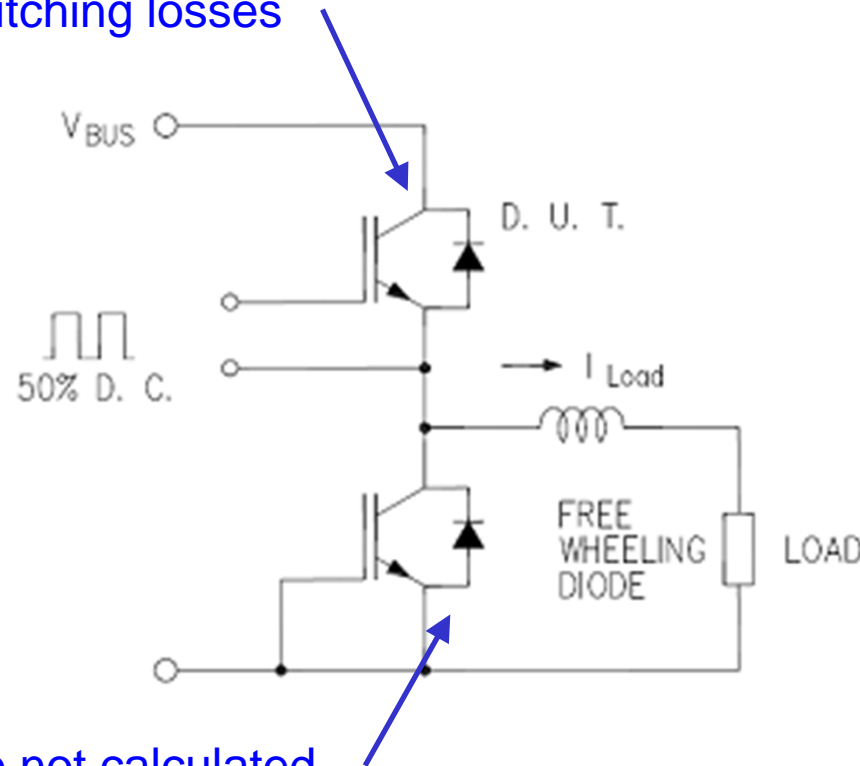
	Part Number	Junct. Temp., °C	Total Pd, W	Switch. Pd, W	Cond. Pd, W
<input checked="" type="checkbox"/>	<u>IRGB4056DPBF</u>	105.6	13.41	4.76	8.65
<input checked="" type="checkbox"/>	<u>IRGB4064DPbF</u>	111.6	13.51	3.83	9.68
<input checked="" type="checkbox"/>	<u>IRGB4060DPbF</u>	116.8	14.69	4.17	10.52
<input checked="" type="checkbox"/>	<u>IRGB10B60KDPBF</u>	116.2	17.48	7.12	10.36
<input type="checkbox"/>	<u>IRGB4045DPbF</u>	142.4	18.84	5.06	13.78

For detailed conditions, see next page

Circuit and conditions – 1



1. Buck (or Boost) converter operating at 50% duty cycle, single switch
- 2 Losses are calculated for the operating temperature indicated in the results
3. Hard switching. IGBT turn-on losses due to diode reverse recovery are included in the switching losses



Diode losses are not calculated

Conduction losses scale with duty cycle, switching losses do not change.

Circuit and conditions – 2



Switching losses are calculated at:

- this voltage
- this current
- this frequency

The screenshot shows the IOR IGBT calculator interface. Annotations with blue arrows point to specific fields:

- Switching losses are calculated at:**
 - this voltage:** Points to the **Bus voltage (V)** field, which contains the value 400.
 - this current:** Points to the **Peak Current (A)** field, which contains the value 1.5.
 - this frequency:** Points to the **Frequency (kHz)** field, which contains the value 100.
- Conduction losses are calculated at this current:** Points to the **Peak Current (A)** field, which contains the value 1.5.
- Ambient temperature:** Points to the **Ambient temperature (°C)** field, which contains the value 55.
- Thermal resistances:** Points to the **Thermal res. case to sink (°C/W)** and **Heatsink thermal res. per IGBT (°C/W)** fields, which contain the values 0.7 and 2 respectively.

Other visible fields include:

- Min IGBT rated voltage (V):** A dropdown menu with values 600, 650, 900, and 1200.
- Max IGBT rated voltage (V):** A dropdown menu with values 600, 650, 900, and 1200.
- Min required short-circuit time (μs) >=:** A field containing the value 0.
- Thermal operating conditions:** A dropdown menu with options **Free-Air**, **On Heatsink** (selected), and **Fixed Case temperature (°C)**.
- Derating from max junction temperature:** A field containing the value 25.

Ambient temperature

Thermal resistances

All losses are calculated at the temperature indicated in the results.

What if you don't know the thermal resistance of the sink? (see later)

Topologies with variable current and duty cycle **IOR**

PFC, continuous current

Enter boost voltage

The screenshot shows a software interface for PFC design. A green arrow points to the 'Bus voltage (V)' input field, which contains the value '400'. Another green arrow points from the text 'Use the rms value of the line current' to the 'Peak Current (A)' input field, which contains the value '1.5'. The interface includes several other input fields and dropdown menus for configuring the PFC design.

Bus voltage (V)	400	Min required short-circuit time (μ s) \geq	0
Min IGBT rated voltage (V)	600	Max IGBT rated voltage (V)	600
	650		650
	900		900
	1200		1200
Frequency (kHz)	100	Peak Current (A)	1.5
Thermal operating conditions		Derating from max junction temperature ($^{\circ}$ C)	
Free-Air		40	
On Heatsink		Thermal res. case to sink ($^{\circ}$ C/W)	
Fixed Case temperature ($^{\circ}$ C)		0.7	
Ambient temperature ($^{\circ}$ C)		Heatsink thermal res. per IGBT ($^{\circ}$ C/W)	
55		4	

Use the rms value of the line current

PFCs operate at a duty cycle that is less than 50%.

Scale the conduction losses from 50% to the average duty cycle

Some PFCs operate in discontinuous mode with triangular waveforms. Losses cannot be calculated with this tool

Topologies with variable current and duty cycle **IR**

Buss voltage

Motor drives

Bus voltage (V) 400

Min IGBT rated voltage (V) 600

Max IGBT rated voltage (V) 600

Frequency (kHz) 100

Peak Current (A) 1.5

Thermal operating conditions

Free-Air

On Heatsink

Fixed Case temperature (°C)

Ambient temperature (°C) 55

Min required short-circuit time (µs) >= 0

Derating from max junction temperature (°C) 40

Thermal res. case to sink (°C/W) 0.7

Heatsink thermal res. per IGBT (°C/W) 4

Use the rms value of the motor current

“per IGBT”: heatsink for 6 IGBTs would be 1.3

Results are not accurate because diode losses are not included. They provide a good indication of what they are likely to be and they are very useful to compare alternative IGBTs. Tools dedicated to motor drives are available. Some are already on the web (follow link below).

<https://ec.irf.com/v6/en/US/direct/ir?cmd=dclpowirHome&action=simConfig.do&appNode=iSine>

What if you don't know the heatsink size?



Select "Fixed case temperature"

Thermal operating conditions

Free-Air
On Heatsink
Fixed Case temperature (°C)

Fixed Case temperature (°C)

100

Derating from max junction temperature (°C)

40

See Results

Enter a reasonable operating temperature for the stated conditions.

A lower temperatures requires a bigger heatsink

For SM applications remember that FR4 is limited to 110-125°C

LISTED BELOW ARE THE IGBTs THAT MEET YOUR APPLICATION PARAMETERS

Part Number	Junct. Temp., °C	Total Pd, W	Switch. Pd, W	Cond. Pd, W
<input type="checkbox"/> IRG4PC50UPbF	102.3	3.59	2.90	0.69
<input type="checkbox"/> IRG4PC40WPbF	103.1	4.02	3.20	0.83

The losses in the table can be used to calculate a first approximation for the heatsink thermal resistance

$$R_{th} = \frac{(T_{jmax} - \text{Derating from } T_{jmax}) - T_{ambient}}{\text{Total Pd}}$$

Now you can enter the thermal resistance of the heatsink and do a finer selection with a second (and third) iteration