Email: powersolutions@dynexsemi.com
Main switchboard: +44 (0)1522 500 500
Website: www.dynexsemi.com

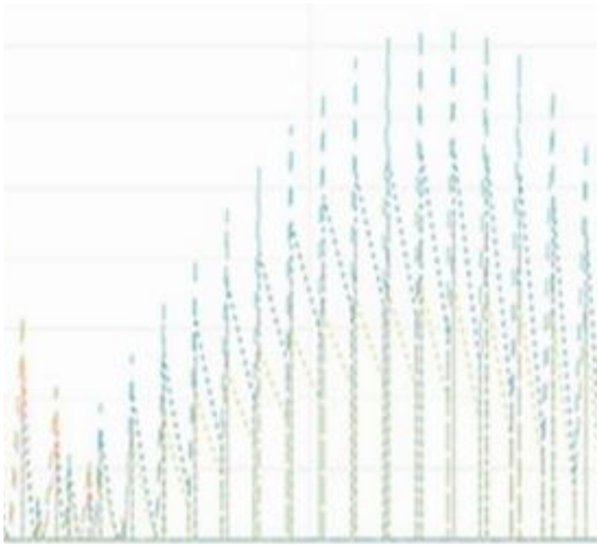
AN6156
Calculating Power Losses in an IGBT Module
Application Note

Replaces AN6156-1 AN6156-2 February 2021 LN40671

Introduction

The Insulated Gate Bipolar Transistor (IGBT) is an active power semiconductor switch which is well suited for high power active front end rectifiers, motor drives, traction drives, converters, wind turbine applications. This application note demonstrates both analytical and simulation-based methods for determining device power losses and junction temperatures for standard topologies

Refer to AN5700 for a complete explanation of Dynex's IGBT naming convention.



Types of Power Loss

Power losses in IGBTs are comprised primarily of steady – state conduction losses and switching losses. The total average power loss in the IGBT is given by:

$$P_{IGBT(AV)} = P_{cond} + P_{sw}$$

Whereas, the Diode is given by the forward conduction losses and reverse recovery losses.

$$P_{Diode(AV)} = P_{cond} + P_{rec}$$

This application note describes the theory behind the calculation and shows how to calculate the power losses for the IGBT and Diode and the junction temperatures respectively.

In an IGBT module there are many IGBT die and diode die depending on the module and requirements of the application (re Figure 1). All chips dissipate power when they are conducting or switching from one state to another

The conduction losses for the IGBT and freewheeling diode are the product of the current flowing through the collector or anode and saturation voltage (on state voltage) over the conducting period. In contrast, the switching

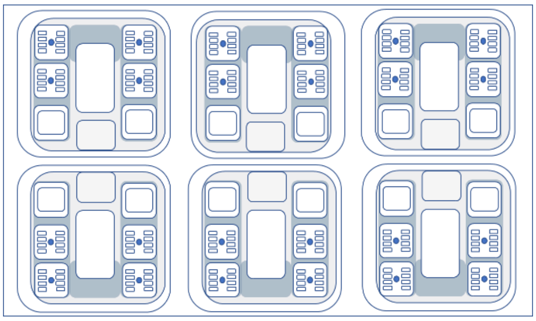


Figure 1. 190mm x 140mm IGBT Module Layout

losses occur as a result of energy loss during the on/off transition and are function of the switching frequency.

IGBT Power Loss Composition

An IGBT is a voltage-controlled device which combines the advantages of a MOSFET and a BJT. It is a three-terminal device; collector, emitter and gate terminal. It is a four-layer semiconductor that uses the drive characteristics of a MOSFET and voltage characteristics of BJT. For high power IGBT modules it is necessary to provide a suitable heatsink, in order to mitigate thermal runaway.

IGBT losses are comprised of two categories:

-Conduction
-Switching (E_{SW})

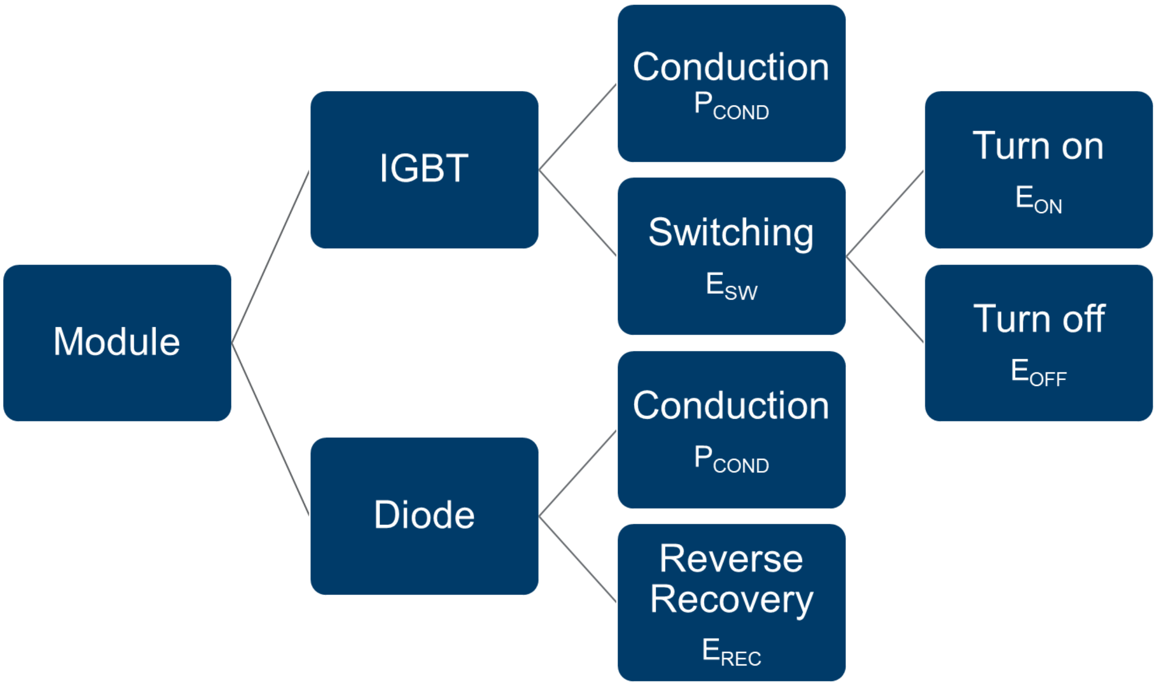


Figure 2. IGBT Module Loss Hierarchy

Conduction Losses

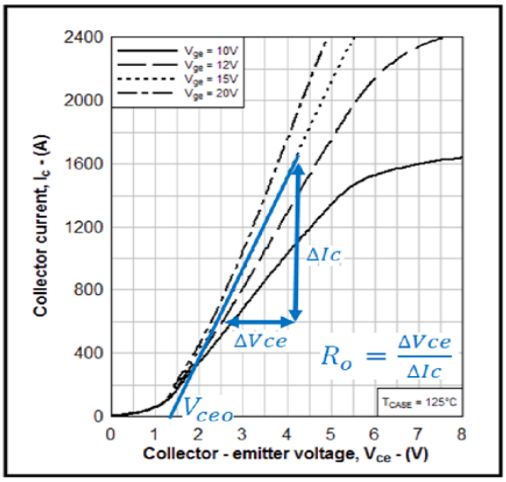


Figure 3. IGBT Output Characteristics with on-state parameters

Conduction losses are the losses that occur while the IGBT or freewheeling diode is on and conducting current, the total power dissipation during conduction is computed by multiplying the on-state voltage and the on-state current. In PWM applications the conduction loss must be multiplied by the duty factor to obtain average power dissipation. A first order approximation of conduction losses can be obtained by multiplying the IGBT's rated V_{CESAT} by the expected average device current.

The average conduction loss dissipated by the IGBT is given by the following equation.

$$Pcond(IGBT) = \frac{1}{T}\int_0^T [V_{CE}(t) * I_{CE}(t)]dt$$

In order to connect datasheet values to the above equation; we need to linearize the equation to a more common on-state loss equation seen in several semiconductor devices.

$$Pcond(IGBT) = V_{CE0} * i + R_0 * i^2$$

$$Pcond(Diode) = V_{Do} * i + R_{Do} * i^2$$

The new linearized equation introduces two new terms:

-V_{CE0}, On-state voltage threshold voltage, temperature dependent

-R_0, On-state resistance, temperature dependent

Figure 3, illustrates how the On-state characteristic terms V_{CE0} and R_0 are obtained; a best practice is to utilise Output Characteristic figure at $T_{VJ(max)}$, as this will use the worst case condition.

Note: Most Dynex switching loss curves utilise ±15V; therefore, when estimating/calculating V_{CE0} and R_0, use the 15V V_{GE} curve.

The On-state characteristics can be determined by first establishing two points of V_{CE} and Collector Current I_C. Then simply calculate the inverse slope of the Vge = 15V curve.

$$R_0 = \frac{V_{CE2} - V_{CE1}}{I_{C2} - I_{C1}}$$

V_{CE0}, can be calculated by establishing a line on the Output Characteristics figure (re Figure 3) and determining the X-intercept or by drawing a straight line to the X-axis and verifying a couple points with the following equation:

$$V_{CE(sat)} = V_{CE0} + R_0 * I_C$$

A similar process is done with the IGBTs antiparallel FRD as shown in Figure 4.

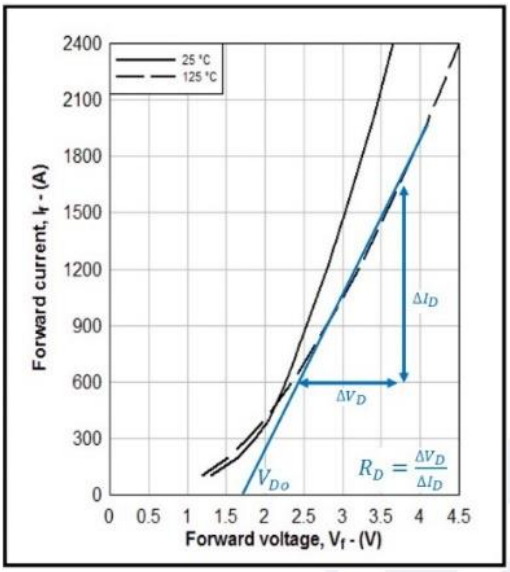


Figure 4. FRD R_D and V_{Do} derivation

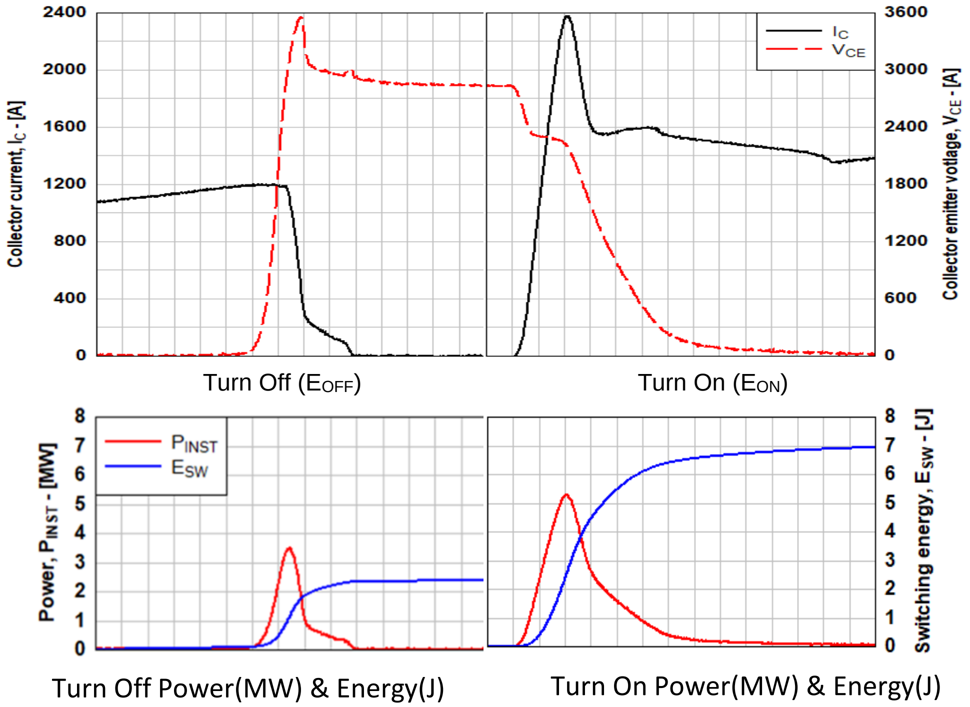


Figure 5. Switching waveforms, instantaneous power curve and energy integral (DIM1200ASM45-TF000)

Switching Losses E_{SW}

Switching losses can be the major source of device losses, this is highly dependent on the application's switching frequency. Voltage source inverters, active front end rectifiers and Buck/Boost converters are highly dependent on applied switching frequency; whereas, lower frequency applications, such MMCs are less susceptible to switching losses.

During the transition interval both the current through and the voltage across the device are substantially larger than zero, which leads to large instantaneous power loss. The curves show the simplified current and voltage waveforms and the dissipated power during one switching cycle of an IGBT in an inverter leg.

The integral of the instantaneous power yields the switching energy for one transition at the applied collector current. Most IGBT datasheets express the derived switching energies as a function of collector current.

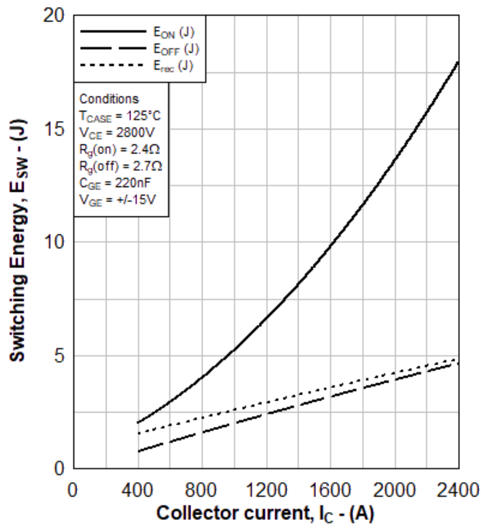


Figure 6. Switching Energy Curve DIM1200ASM45-TF000

The FRD's reverse recovery losses are a similar mechanism to the IGBT in which during the FRD turn off period there is a temporary non-zero reverse current and voltage. Dynex datasheets typically depict all incorporated device switching energies on the same curve; however, some devices do have dedicated IGBT and FRD switching energy curves.

The basic principal to determining the switching power loss for an IGBT is with following equation:

$$P_{SW(IGBT)} = (E_{ON} + E_{OFF}) * f_{SW}$$

$$P_{SW(Diode)} = (E_{REC}) * f_{SW}$$

The switching power loss needs to be normalized with the conditions provided for any application with the nominal values from the datasheet.

$$P_{SW(IGBT)} = \frac{(E_{ON} + E_{OFF}) * f_{SW}}{\pi} * \frac{I_{pk}}{I_{NOM}} * \frac{V_{DC\ Link}}{V_{NOM}}$$

$$P_{SW(Diode)} = \frac{(E_{REC}) * f_{SW}}{\pi} * \frac{I_{pk}}{I_{NOM}} * \frac{V_{DC\ Link}}{V_{NOM}}$$

f_{SW} = Switching Frequency
I_{PK} = Peak collector current
I_{NOM} = Nominal rated current of device
$V_{DC\ Link}$ = DC Link Voltage
V_{NOM} = Datasheet dynamic Vline
E_{ON} = Turn on energy loss @ I_{PK}
E_{OFF} = Turn off energy loss @ I_{PK}
E_{REC} = Diode reverse recovery energy loss @ I_{PK}

Total Losses

By determining the switching and conduction losses it is possible to obtain reasonable characterizations of the system's efficiency, thermal load and most importantly the junction temperature of the devices.

$$P_{Total} = P_{Cond(IGBT)} + P_{SW(IGBT)} + P_{Cond(Diode)} + P_{SW(Diode)}$$

The previous equations for switching and conduction losses are general purpose and not suited for specific applications.

ANNEX 1 of this application note contains common application specific analytical equations for the determination of module losses for the following topologies:

-2 Level Half Bridge
-3 Level I Type Converter
-3 Level T Type Converter
-Buck / Boost DC Converter

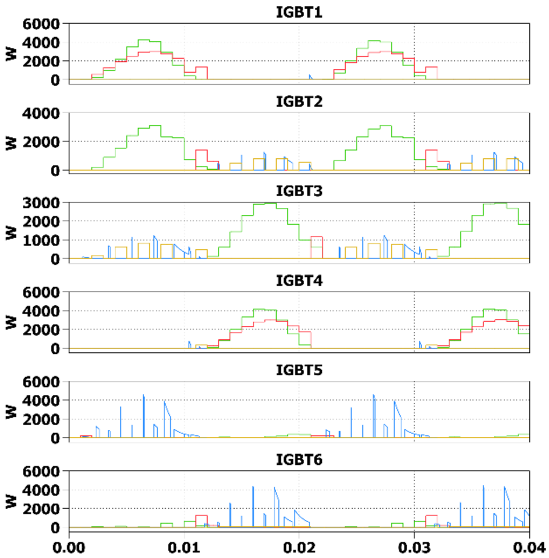


Figure 7. Example ANPC Instantaneous Losses

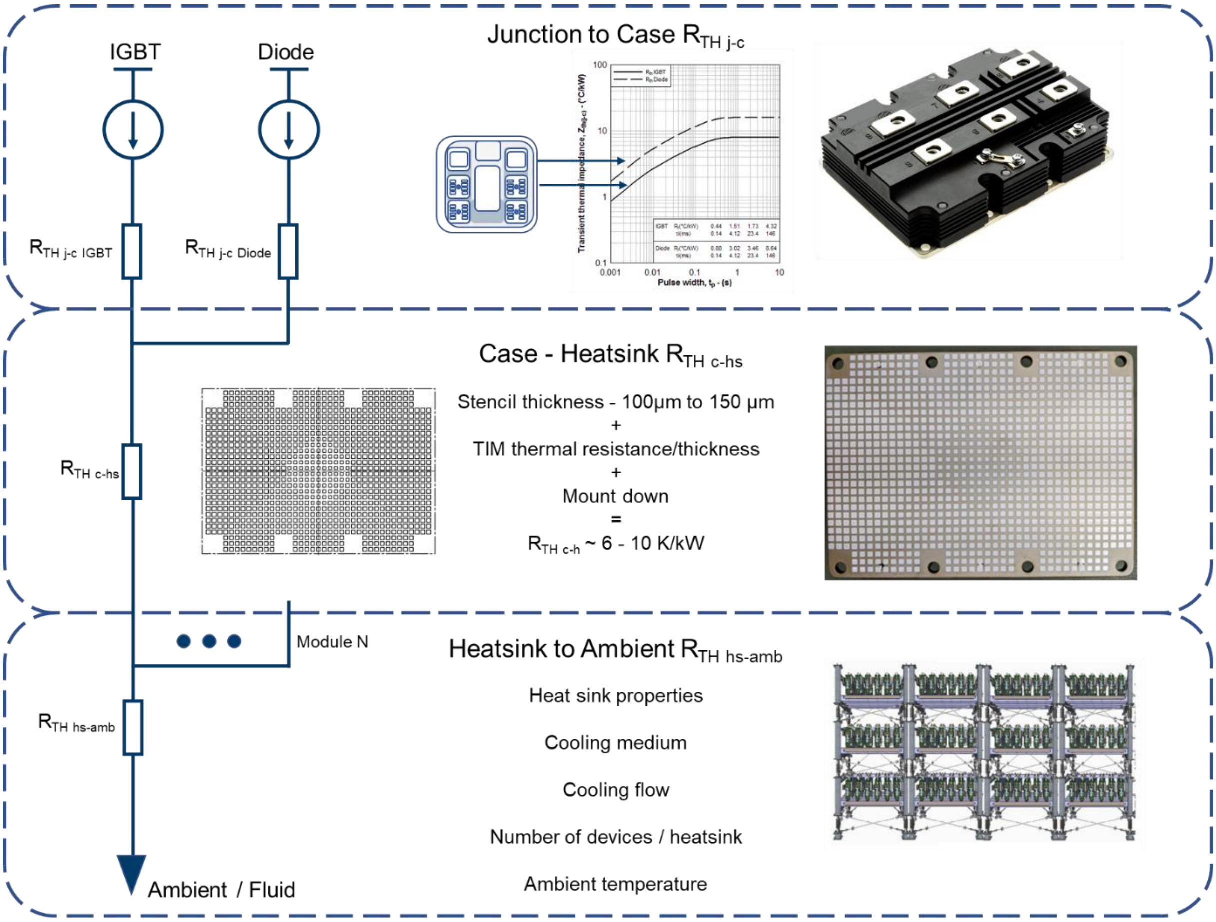


Figure 8. Thermal circuit for junction temperature estimation

Junction Temperature Estimation

For IGBT modules Figure 8 demonstrates a one-dimensional approximation allowing for the estimation of junction temperature.

A tabulated calculation using a spreadsheet or offline calculation requires the temperature rises be calculated for each junction.

$$T_{j(IGBT)} = \Delta T_{IGBT} + \Delta T_{ch} + \Delta T_{hs} + T_a$$

$$T_{j(Diode)} = \Delta T_{Diode} + \Delta T_{ch} + \Delta T_{hs} + T_a$$

IGBT Temp rise:

$$P_{Total(IGBT)} = P_{SW(IGBT)} + P_{Cond(IGBT)}$$

$$\Delta T_{j(IGBT)} = R_{TH\ j-c(IGBT)} * (P_{Total(IGBT)})$$

Diode Temp rise:

$$P_{Total(Diode)} = P_{SW(Diode)} + P_{Cond(Diode)}$$

$$\Delta T_{j(Diode)} = R_{TH\ j-c(Diode)} * (P_{Total(Diode)})$$

Case – heatsink temp rise:

$$P_{Module} = P_{Total(IGBT)} + P_{Total(Diode)}$$

$$\Delta T_{ch} = R_{TH\ c-hs} * P_{Module}$$

Heatsink – temp

$$P_{Heatsink} = P_{Module1} + \cdots + P_{ModuleN}$$

$$\Delta T_{hs} = R_{TH\ hs} * P_{Heatsink}$$

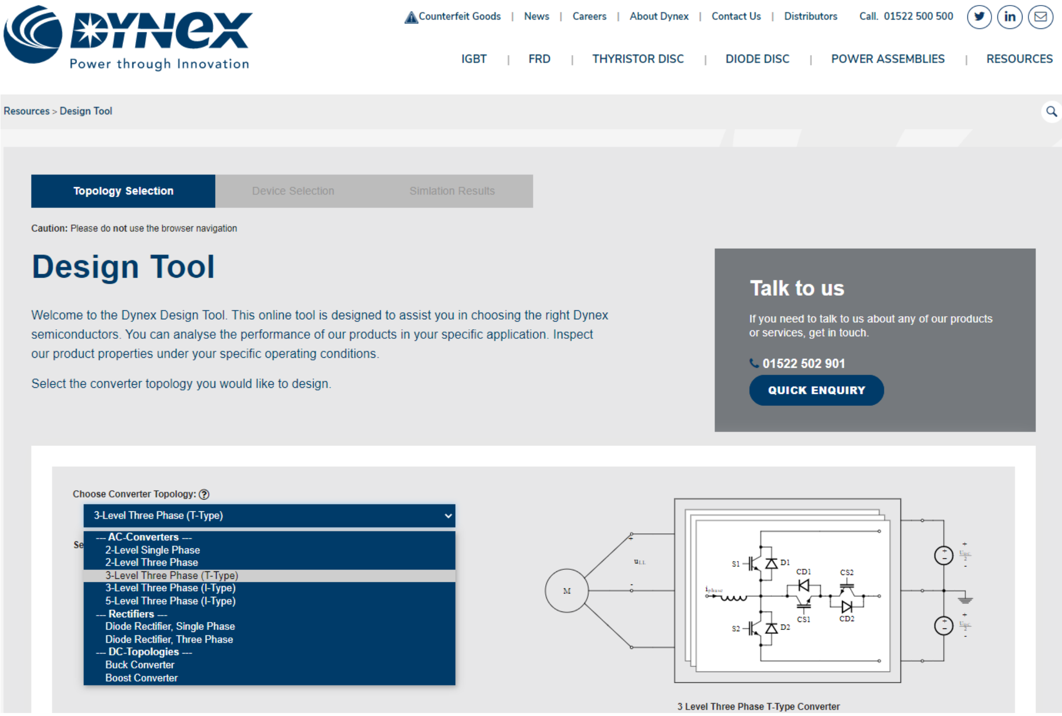


Figure 9. Design Tool topology selection page

Simulation Platforms

Utilising the analytical methods described in the previous sections requires considerable effort and time to implement, the analytical methods are suitable for conservative calculations, however, simulation tools offer superior characterization and efficiency.

Dynex offers two simulation methods:

Design Tool
PLECS thermal descriptions

Both PLECS thermal models and the Design Tool utilize the same data sets that are contained in published datasheets.

Design Tool

The Design Tool is Dynex's online platform that can offer up to three simultaneous component evaluations for a number of topologies.

Another feature of the Design Tool is interactive data sheets in which two operating points can evaluated on the Switching Energy and Output Characteristics.

In the Application Examples section, a Design Tool simulation is provided using the integrated report publisher.

Figure 10. Design Tool interactive datasheet

PLECS Thermal Descriptions

Dynex also provides PLECS thermal descriptions for detailed and bespoke simulations.

Design Tool Application Example

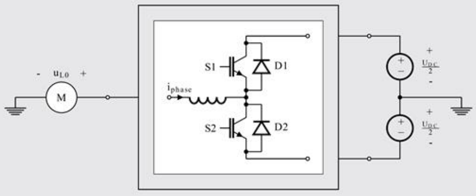
2 Level Converter

Design A: DIM750ASM65-TF000
Design B: DIM750ASM65-TS000
Design C: DIM750ASM65-TL000

The Design Tool is utilized in this example to simultaneously evaluate Dynex's 6500V / 750A IGBT modules in a simple 2 Level Converter. In one simulation a design is capable of determining which 6500V part offering is most suitable for the application. Note: Negative power factor is required for rectifier applications.

Design Tool

On this page you can simulate the electrical system behaviour and the resulting semiconductor losses and thermal behaviour. In order to achieve the ideal results for your application you can vary several system parameters below. If you can't find a satisfactory result you might need to exchange the selected semiconductors.



2-Level Single Phase

Design A:	Design B:	Design C:
Switching Devices:	Switching Devices:	Switching Devices:
DIM750ASM65-TF000	DIM750ASM65-TS000	DIM750ASM65-TL000

Parameters for System Simulation:

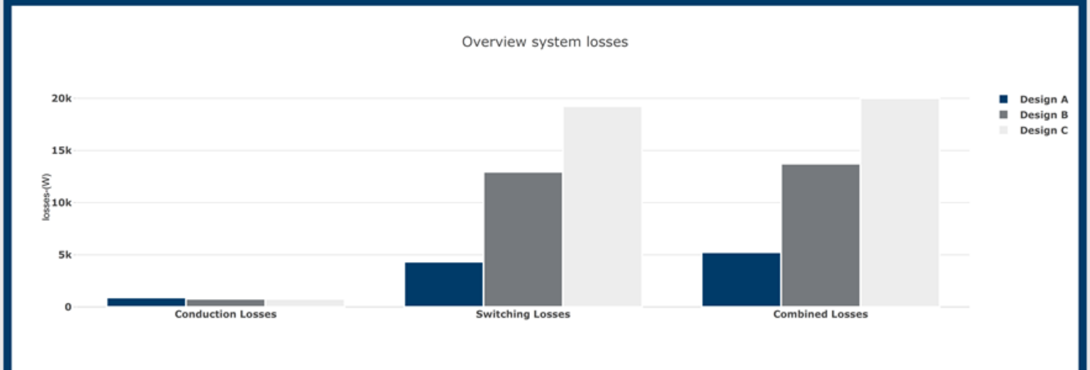
Parameter	Value	Parameter	Value	Parameter	Value
Nominal voltage-(V)	1100.0	Nominal current-(A)	300.0	Nominal Electrical Frequency	50
DC-Link voltage-(V)	3700.0	Motor Phase Inductance	0.001401	Average ambient temperature-(°C)	25
Switching frequency-(Hz)	700	Power factor	-0.9	Average junction temperature-(°C)	115
		Reactive power	Inductive		

Export Simulation Results to PDF

UPDATE SYSTEM SIMULATION

DESIGN A DESIGN B DESIGN C

Calculated System Losses

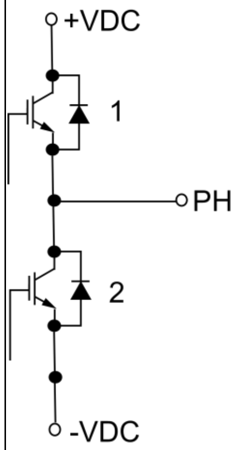


	Conduction Losses-(W)			Switching Losses-(W)			Combined Losses-(W)		
	A	B	C	A	B	C	A	B	C
System	909.17	787.09	766.05	4342.85	12948.91	19240.16	5252.01	13736.01	20006.21
Switch S1	370.3	298.27	275.36	1718.54	5904.06	9059.38	2088.83	6202.33	9334.75
Diode D1	83.87	94.93	107.33	436.58	491.43	541.23	520.45	586.36	648.56
Switch S2	370.96	298.78	275.83	1755.18	5995.06	9106.93	2126.14	6293.84	9382.76
Diode D2	84.04	95.11	107.53	432.55	558.37	532.62	516.59	653.49	640.15

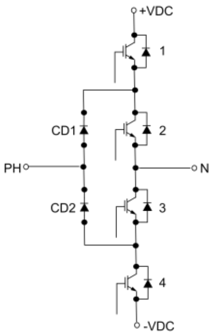
Calculated System Parameters

Apparent Power-(VA)	Efficiency-(%)			Grid Voltage-(V)	Current-(A)	Current Ripple -(%)	Modulation Index M_a	Maximally Allowed Thermal Resistance $R_{th\text{-}CA}$-(K/W)		
	A	B	C					A	B	C
330000.0	98.77	96.83	95.45	1100.0	300.0	163.3	0.89	0.033	0.005	0.001

Annex 1 – Analytical Loss Equations

Topology	Loss Estimation Equation
2 Level Half Bridge 	**Conduction Loss** Modulation index, $m = \frac{V_{out(pk)}}{0.5*V_{DC(LINK)}}$ Power factor, typically $\cos(\varphi)_{INVERTER}$ = 0.8 to 0.95 & $\cos(\varphi)_{RECTIFIER}$ = -0.9 to -0.99 IGBT conduction losses: $V_{CEsat} = V_{CE0} + I.R_0$ where $R_0 = \frac{V_{CE2}-V_{CE1}}{I_{C2}-I_{C1}}$ V_{CE0} – refer to Conduction Losses Section Diode conduction losses: $V_F = V_{D0} + I.R_{D0}$ where $R_{Do} = \frac{V_{Do2}-V_{Do1}}{I_{f2}-I_{f1}}$ V_{Do} – refer to Conduction Losses Section **IGBT:** $P_{cond(I)} = \left(\frac{1}{2\pi} + \frac{m*\cos(\varphi)}{8}\right) * V_{CE0} * I_{pk} + \left(\frac{1}{8} + \frac{m*\cos(\varphi)}{3\pi}\right) * R_0 * I_{pk}^2$ **FRD:** $P_{cond(D)} = \left(\frac{1}{2\pi} - \frac{m*\cos(\varphi)}{8}\right) * V_{Do} * I_{pk} + \left(\frac{1}{8} - \frac{m*\cos(\varphi)}{3\pi}\right) * R_{Do} * I_{pk}^2$ **Switching Loss** **IGBT:** $P_{SW(I)} = \left(E_{ON(@I_{NOM})} + E_{OFF(@I_{NOM})}\right) * f_{SW} * \frac{\sqrt{2}}{\pi} * \frac{I_{out}}{I_{NOM}} * \frac{V_{DC\,Link}}{V_{NOM}}$ **FRD:** $P_{SW(D)} = \left(E_{REC(@I_{NOM})}\right) * f_{SW} * \frac{\sqrt{2}}{\pi} * \frac{I_{out}}{I_{NOM}} * \frac{V_{DC\,Link}}{V_{NOM}}$ I_{out} = RMS output current hence $I_{pk} = \sqrt{2}\,.I_{out}$

3 Level I Type



Conduction Loss

Modulation index, $m = \frac{V_{out(pk)}}{0.5*\sqrt{3}*V_{DC(LINK)}}$

IGBT 1, 4: $P_{cond(IGBT1,4)} = \frac{m*I_{PK}}{12\pi} * (3 * V_{CE0} * [(\pi - \varphi) * \cos\varphi + \sin\varphi] + 2 * R_0 * I_{PK} * [1 + \cos\varphi]^2)$

IGBT 2, 3: $P_{cond(IGBT2,3)} = \frac{I_{PK}}{12\pi} * (V_{CE0} * [12 + 3m(\varphi\cos\varphi - \sin\varphi)] + R_0 * I_{PK} * [3\pi - 2m(1 - \cos\varphi)^2])$

CD1, CD2: $P_{cond(CD1,2)} = \frac{I_{PK}}{12\pi} * \left(V_{Do}\left[12 + 3m[(2\varphi - \pi)\cos\varphi - 2\sin\varphi]\right] + R_{Do} * I_{PK}[3\pi - 4m(1 + \cos^2\varphi)]\right)$

Diode 1, 4: $P_{cond(Diode1,4)} = \frac{m*I_{PK}}{12\pi}(3 * V_{Do}[-\varphi\cos\varphi + \sin\varphi] + 2R_{Do} * I_{PK}[1 - \cos\varphi]^2)$

Diode 2, 3: $P_{cond(Diode2,3)} = \frac{m*I_{PK}}{12\pi}(3 * V_{Do}[-\varphi\cos\varphi + \sin\varphi] + 2R_{Do} * I_{PK}[1 - \cos\varphi]^2)$

Switching Loss

IGBT 1, 4: $P_{SW(IGBT1,4)} = f_{SW} * \left(E_{ON(@I_{NOM})} + E_{OFF(@I_{NOM})}\right) * \frac{I_{pk}}{I_{NOM}} * \frac{0.5V_{DC\,Link}}{V_{NOM}} * \left(\frac{1}{2\pi} * [1 + \cos\varphi]\right)$

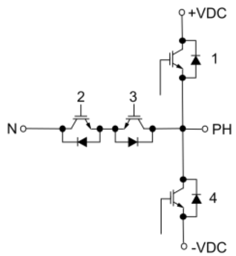
IGBT 2, 3: $P_{SW(IGBT2,3)} = f_{SW} * \left(E_{ON(@I_{NOM})} + E_{OFF(@I_{NOM})}\right) * \frac{I_{pk}}{I_{NOM}} * \frac{0.5V_{DC\,Link}}{V_{NOM}} * \left(\frac{1}{2\pi} * [1 - \cos\varphi]\right)$

CD1, CD2: $P_{SW(CDiode2,3)} = f_{SW} * E_{REC(@I_{NOM})} * \frac{I_{pk}}{I_{NOM}} * \frac{0.5V_{DC\,Link}}{V_{NOM}} * \left(\frac{1}{2\pi} * [1 + \cos\varphi]\right)$

Diode 1, 4: $P_{SW(Diode1,4)} = f_{SW} * E_{REC(@I_{NOM})} * \frac{I_{pk}}{I_{NOM}} * \frac{0.5V_{DC\,Link}}{V_{NOM}} * \left(\frac{1}{2\pi} * [1 - \cos\varphi]\right)$

Diode 2, 3: $P_{SW(Diode2,3)} = 0$

3 Level T Type



Modulation index, $m = \frac{V_{out(pk)}}{0.5*\sqrt{3}*V_{DC(LINK)}}$

Conduction Loss

IGBT 1, 4: $P_{cond(IGBT1,4)} = \frac{m*I_{pk}}{12\pi} * (3 * V_{CE0} * [(\pi - \varphi) * \cos\varphi + \sin\varphi] + 2 * R_0 * I_{PK} * [1 + \cos\varphi]^2)$

IGBT 2, 3: $P_{cond(IGBT2,3)} = \frac{I_{pk}}{12\pi} * (V_{CE0} * [12 + 6m(\varphi\cos - \sin\varphi) - 3m\pi\cos\varphi] + R_0 * I_{PK} * [3\pi - 4m(1 + \cos^2\varphi)])$

Diode 1, 4: $P_{cond(Diode1,4)} = \frac{m*I_{pk}}{12\pi}(3 * V_{Do}[-\varphi\cos\varphi + \sin\varphi] + 2R_{Do} * I_{PK}[1 - \cos\varphi]^2)$

Diode 2, 3: $P_{cond(Diode2,3)} = \frac{I_{pk}}{12\pi}(V_{Do}[12 + 3m[2\varphi\cos\varphi - 2\sin\varphi] - 3m\pi\cos\varphi] + R_{Do} * I_{PK}[3\pi - 4m(1 + \cos^2\varphi)])$

Switching Loss

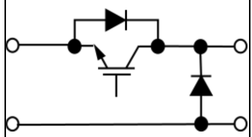
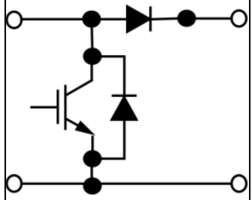
IGBT 1, 4: $P_{SW(IGBT1,4)} = f_{SW} * \left(E_{ON(@I_{NOM})} + E_{OFF(@I_{NOM})}\right) * \frac{I_{pk}}{I_{NOM}} * \frac{V_{DC\,Link}}{V_{NOM(IGBT1\&4)}} * \left(\frac{1}{2\pi} * [1 + \cos\varphi]\right)$

IGBT 2, 3: $P_{SW(IGBT2,3)} = f_{SW} * \left(E_{ON(@I_{NOM})} + E_{OFF(@I_{NOM})}\right) * \frac{I_{pk}}{I_{NOM}} * \frac{0.5*V_{DC\,Link}}{V_{NOM(IGBT2\&3)}} * \left(\frac{1}{2\pi} * [1 - \cos\varphi]\right)$

Diode 1, 4: $P_{SW(Diode1,4)} = f_{SW} * E_{REC(@I_{NOM})} * \frac{I_{pk}}{I_{NOM}} * \frac{0.5*V_{DC\,Link}}{V_{NOM(Diode2\&3)}} * \left(\frac{1}{2\pi} * [1 - \cos\varphi]\right)$

Diode 2, 3: $P_{SW(Diode2,3)} = f_{SW} * E_{REC(@I_{NOM})} * \frac{I_{pk}}{I_{NOM}} * \frac{V_{DC\,Link}}{V_{NOM(Diode1\&4)}} * \left(\frac{1}{2\pi} * [1 + \cos\varphi]\right)$

Note: IGBT 1/4, IGBT 2/3 may have different V_{NOM} as they may utilize different V_{CES} devices.

Buck Converter 	**Conduction** **IGBT:** $P_{cond} = \frac{V_{out}}{V_{in}}(I_{out} * V_{CE0} + I_{out}^2 * R_0)$ **Diode:** $P_{cond} = \frac{V_{in}-V_{out}}{V_{in}}(I_{out} * V_{Do} + I_{out}^2 * R_{Do})$ **Switching** **IGBT:** $P_{SW} = \left(E_{ON(@I_{NOM})} + E_{OFF(@I_{NOM})}\right) * f_{SW} * \frac{I_{out}}{I_{NOM}} * \frac{V_{in}}{V_{NOM}}$ **Diode:** $P_{SW} = \left(E_{REC(@NOM)}\right) * f_{SW} * \frac{I_{out}}{I_{NOM}} * \frac{V_{in}}{V_{NOM}}$
Boost Converter 	**Conduction** **IGBT:** $P_{cond} = \left(1 - \frac{V_{in}}{V_{out}}\right)(I_{in} * V_{CE0} + I_{in}^2 * R_0)$ **Diode:** $P_{cond} = \left(\frac{V_{in}}{V_{out}}\right)(I_{in} * V_{Do} + I_{in}^2 * R_{Do})$ **Switching** **IGBT:** $P_{SW} = \left(E_{ON(@I_{NOM})} + E_{OFF(@I_{NOM})}\right) * f_{SW} * \frac{I_{in}}{I_{NOM}} * \frac{V_{out}}{V_{NOM}}$ **Diode:** $P_{SW} = \left(E_{REC(@NOM)}\right) * f_{SW} * \frac{I_{in}}{I_{NOM}} * \frac{V_{out}}{V_{NOM}}$

IMPORTANT INFORMATION:

This publication is provided for information only and not for resale.

The products and information in this publication are intended for use by appropriately trained technical personnel.

Due to the diversity of product applications, the information contained herein is provided as a general guide only and does not constitute any guarantee of suitability for use in a specific application. The user must evaluate the suitability of the product and the completeness of the product data for the application. The user is responsible for product selection and ensuring all safety and any warning requirements are met. Should additional product information be needed please contact Customer Service.

Although we have endeavoured to carefully compile the information in this publication it may contain inaccuracies or typographical errors. The information is provided without any warranty or guarantee of any kind.

This publication is an uncontrolled document and is subject to change without notice. When referring to it please ensure that it is the most up to date version and has not been superseded.

The products are not intended for use in applications where a failure or malfunction may cause loss of life, injury or damage to property. The user must ensure that appropriate safety precautions are taken to prevent or mitigate the consequences of a product failure or malfunction.

The products must not be touched when operating because there is a danger of electrocution or severe burning. Always use protective safety equipment such as appropriate shields for the product and wear safety glasses. Even when disconnected any electric charge remaining in the product must be discharged and allowed to cool before safe handling using protective gloves.

Extended exposure to conditions outside the product ratings may affect reliability leading to premature product failure. Use outside the product ratings is likely to cause permanent damage to the product. In extreme conditions, as with all semiconductors, this may include potentially hazardous rupture, a large current to flow or high voltage arcing, resulting in fire or explosion. Appropriate application design and safety precautions should always be followed to protect persons and property.

Product Status & Product Ordering:
We annotate datasheets in the top right-hand corner of the front page, to indicate product status if it is not yet fully approved for production. The annotations are as follows: -

Target Information:	This is the most tentative form of information and represents a very preliminary specification. No actual design work on the product has been started.
Preliminary Information:	The product design is complete and final characterisation for volume production is in progress. The datasheet represents the product as it is now understood but details may change.
No Annotation:	The product has been approved for production and unless otherwise notified by Dynex any product ordered will be supplied to the **current version of the data sheet prevailing at the time of our order acknowledgement.**

All products and materials are sold and services provided subject to Dynex's conditions of sale, which are available on request.

HEADQUARTERS OPERATIONS
DYNEX SEMICONDUCTOR LIMITED
Doddington Road, Lincoln, Lincolnshire, LN6 3LF
United Kingdom.
Phone: +44 (0) 1522 500500
Fax: +44 (0) 1522 500550
Web: http://www.dynexsemi.com

CUSTOMER SERVICE
Phone: +44 (0) 1522 502753 / 502901
Fax: +44 (0) 1522 500020
e-mail: powersolutions@dynexsemi.com