Introduction:

This note will guide you through the Dynex Semiconductor IGBT Module data sheet format and discuss fully its contents. For the purpose of discussion and illustration Dynex IGBT Module part number DIM1500ESM33-TS000 is chosen and explained in sequence starting from the first page.

An IGBT datasheet generally includes tables and graphs of data regarding device ratings and characteristics. In order to use an IGBT Module datasheet properly it is important that the user has a good understanding of the information presented in the datasheet. The aim of this article is to explain the ratings and characteristics of Dynex range of high power IGBT Modules. Hopefully this will promote an efficient and reliable use of the device and also help the user to make a correct choice of device for the intended application.

Dynex IGBT Module Nomenclature:

The module designation for the Dynex as shown below;

D = Dynex Semiconductor Identifier

I = Prime Technology

M = Module Generic Identifier

1500 = Nominal current rating

E = Package outline/power terminal layout

S = Module electrical circuit

M = Baseplate Material Identifier

33 = Voltage rating divided by 100

(-)

TS = Silicon Technology Identifier

000 = Special Selection Number (defaults to 000 for standard product)

EXAMPLES:

DIM1500ESM33-TL000: *IGBT Module, E package outline, 1500A single switch, MMC baseplate, 3300V Enhanced soft punch through IGBT Silicon, low V_{ce} variant.*

DIM800DDM17-A000: *IGBT Module, D package outline, 800A dual switch, MMC baseplate, 1700V NPT DMOS IGBT silicon.*

DFM300WXS18-A000: *FRD Module, W package outline, 300A Diode, copper baseplate, 1800V "A" series diode silicon.*

Part Number: DIM1500ESM33-TS000

The DIM1500ESM33-TS000 has been chosen for explaining the characteristic and parameters step by step in this note.

This is followed by the description of the module type such as: “Single Switch IGBT Module”

This means that the module is an independent switch made up of IGBT/anti-parallel diode. The actual circuit configuration is given in Fig. 1.

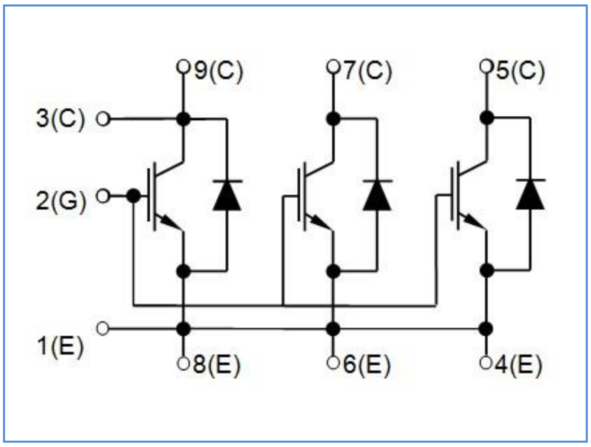


Figure 1: Circuit configuration

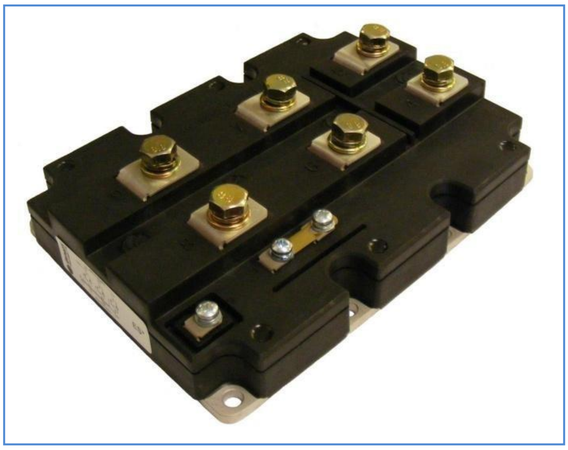


Figure 2: Outline type code E package

Dynex datasheets are controlled documents with a specific document number, issue number and date. This information appears in a small print. Dynex reserves the right to change the datasheets without notice and so the users are advised to refer to the latest version by visiting Dynex web site: *http://www.dynexsemi.com*

Features:
The features section outlines specific key attributes of the device and technologies. The picture/photograph of the actual module is given in Fig. 2.

Applications:

A few examples of possible application are indicated here, followed by a brief description of the module and its capability. It should be noted that inclusion in this section does not imply that Dynex has fully tested the device under all application conditions. The suitability of a device for a given application rests solely with the user.

Ordering Information:
Order as: **DIM1500ESM33-TS000**
This specifies the correct part number for ordering the device.

Key Parameters:
This is a summary of main parameters unique to the part number. The full description of these parameters is found with appropriate test conditions in the main body of the datasheet. It is important that when comparing with other similar product a full description of the parameters should be consulted as manufacturers often specify different test conditions.

Absolute Maximum Ratings:

T_{case} = 25°C unless stated otherwise

Symbol	Parameter	Test Conditions	Max.	Units
V_{CES}	Collector-emitter voltage	V_{GE} = 0V	3300	V
V_{GES}	Gate-emitter voltage		±20	V
I_C	Continuous collector current	T_{case} = 110°C	1500	A
$I_{C(PK)}$	Peak collector current	1ms, T_{case} = 140°C	3000	A
P_{max}	Max. transistor power dissipation	T_{case} = 25°C, T_j = 150°C	15.6	kW
I^2t	Diode I^2t value	V_R = 0, t_p = 10ms, T_j = 150ºC	720	kA^2s
V_{isol}	Isolation voltage – per module	Commoned terminals to base plate. AC RMS, 1 min, 50Hz	6000	V
Q_{PD}	Partial discharge – per module	IEC1287, V_1 = 3500V, V_2 = 2600V, 50Hz RMS	10	pC

Table 1: Absolute maximum ratings

The ratings of the device are divided into the electrical, thermal and mechanical ratings. The parameters are given in a tabulated form. The applied stresses above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied. Exposure to Absolute Maximum Ratings for extended periods may affect device reliability.

VCES - Collector - Emitter Voltage:

V_{CES} is defined as the maximum continuous DC collector-to-emitter blocking voltage with gate-to-emitter terminals shorted and case temperature. It is important not to exceed the stated value as it is possible to damage the forward blocking junction leading to catastrophic failure of the device.

Most IGBTs are designed to operate directly from the rectified commercial and industrial mains supply voltages. Dynex offers IGBT modules which are rated at 1200V, 1700V, 3300V, 4500V and 6500V. The circuit designer has to ensure that the choice of voltage grade device is such that the operating DC line voltage, any variation of this voltage, and overvoltage transients generated due to device switching, is less than V_{CES}.

For example, for a 750V DC line voltage the overhead room to allow for the voltage variation and switching transients is 450V for 1200V IGBT. If this is not enough then one chooses the next higher voltage grade IGBT (e.g. 1700V). However, this device will have higher power losses. The user can:

a) Account for increased losses by designing the appropriate thermal circuit.
b) Minimise circuit inductance by careful layout of the circuit thus reducing the switching transients.
c) Consider using an external snubber circuit to suppress the over-voltage transients. The final decision is based on the efficiency and the cost of the system.

Most semiconductor devices are susceptible to cosmic radiation and using high DC voltage will induce higher failure rate. Therefore the operating dc voltage should be kept much lower than the maximum V_{CES}.

VGES - Gate-Emitter Voltage:

V_{GES} is defined as the maximum gate-emitter voltage. This voltage is a function of thickness and characteristics of the gate oxide layer. For long term reliability it is necessary not to exceed the specified value. V_{GE} controls the maximum collector current and the family of output characteristics as a function of V_{GE} ranging from ±10V to ±20V is included in the datasheet graph section.

IC - Continuous Collector Current:

This is a temperature dependant continuous collector current rating. It is defined as the maximum DC current that can flow through the device while its case temperature (T_C) is held at the specified level and the junction temperature is allowed to rise to the maximum permitted value ($T_{j\,max}$) due to the power dissipation (P) in the device. I_C is determined from the following relationship:

$$I_C = \frac{(T_{j\,max} - T_C)}{V_{ce\,sat} \times R_{th\,(j-C)}} \quad (1)$$

$R_{th\,(j-C)} =$ Junction to case thermal resistance of the device.
$V_{ce\,sat} =$ Collector − Emitter saturation voltage at I_C.
Where;

This is essentially a current rating based on the thermal rating of the package. That is with fixed $T_{j\,max}$ = 150°C the current rating varies with the choice of T_C. Usually T_C is chosen to give the headline DC current rating. For example T_C = 110°C is chosen to give 1500A DC current rating for the module DIM1500ESM33-TS000. When comparing with other similar product from different manufacturer it is important to note under what condition the DC current rating is specified.

IC(pk) - Peak Collector Current:
This is the maximum pulsed collector current rating and it is specified at 1ms pulse duration. It is partly based on the device thermal rating as per Eqn.1 with 1ms transient thermal resistance value and partly on other factors. In most cases $I_{C(pk)} = 2 \times I_C$. The case temperature T_C is adjusted to give this value. For DIM1500ESM33-TS000, T_C =140°C.

Pmax – Maximum IGBT Power Dissipation:
P_{max} is the maximum continuous power dissipation in the IGBT part of the module and it is calculated from Eqn.2.

$$P_{max} = \frac{(T_j - T_C)}{R_{th\,(j-C)\,IGBT}} \qquad (2)$$

In the datasheet it is specified with the T_C = 25°C and T_j = 150°C which results in $P_{max} = 15.6\text{kW}$ for DIM1500ESM33-TS000.

I²t – Diode I²t value:
This rating is the diode surge current rating and is given by the integral of a half-sine wave defined in the Eqn.3.

$$\int_0^{t_p} I^2(t)\,dt = \frac{1}{2} \times {I_{FSM}}^2 \times t_p \qquad (3)$$

This rating is derived by test and measurements. I^2t is specified in the datasheet with reverse voltage $V_R = 0, t_p\ 10\text{ms (50Hz)}$ and T_j = 150°C. This rating is important for dimensioning the diode for fault current tolerance.

Visol – Isolation voltage – per module:

This is the maximum isolation voltage between all module terminals and the insulated base plate. The value is given for the conditions of AC RMS voltage (50Hz) for 1min. The isolation voltage of each voltage range is defined by the equation

$$V_{isol} = \frac{2V_{CES}}{\sqrt{2}} + 1000 \tag{4}$$

QPD – Partial discharge – per module:
Partial discharge is a two-stage test, where an electrical potential is placed between the terminals of the module and baseplate. To pass, there must be a charge of <10pC between the terminals and the baseplate during the last 10 seconds of the profile. The test is intended to expose impurities in the module's dielectric material. Over extended periods during operation, these impurities could propagate and form conductive paths between the live areas of the module and the heatsink. The modules are tested between the terminals and the baseplate as per IEC1287 Standard. Applied voltages are 50Hz RMS AC.

Thermal and Mechanical Ratings:

Internal insulation material:	AlN
Baseplate material:	AlSiC
Creepage distance:	33mm
Clearance:	20mm
CTI (Comparative Tracking Index):	>600

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Units
$R_{th(j-c)}$	Thermal resistance – transistor	Continuous dissipation - junction to case	-	-	8	°C/kW
$R_{th(j-c)}$	Thermal resistance – diode	Continuous dissipation - junction to case	-	-	16	°C/kW
$R_{th(c-h)}$	Thermal resistance – case to heatsink (per module)	Mounting torque 5Nm (with mounting grease)	-	-	6	°C/kW
T_j	Junction temperature	Transistor	-	-	150	°C
		Diode	-	-	150	°C
T_{stg}	Storage temperature range	-	-40	-	125	°C
	Screw torque	Mounting – M6	-	-	5	Nm
		Electrical connections – M4	-	-	2	Nm
		Electrical connections – M8	-	-	10	Nm

Table 2: Thermal and mechanical ratings

Internal insulation material:
This gives information about the material used for the substrate which provides the electrical insulation between the active device and the base-plate. This could be alumina $(Al_2 O_3)$ or aluminium-nitride (AlN).

Base-plate material:
This provides the information about the base-plate material.

The insulating substrate material is chosen to match the base-plate material to reduce stresses caused by thermal expansion. For copper base-plates, alumina $(Al_2 O_3)$ substrates are used and for metal matrix composite $(AlSiC)$base-plates aluminium-nitride (AlN) substrates are used. For applications requiring enhanced temperature cycling capability (AlN) substrates and $(AlSiC)$ base-plate are used.

Creepage distance:
This is the minimum surface creepage distance between any two electrical terminals.

Clearance:
This is the minimum direct air strike distance between any two electrical terminals.

CTI – Comparative Tracking Index:
This is the comparative value of resistance to surface tracking or erosion of the case material (plastic) under an electrical stress.

Rth(j-c) - Thermal Resistance: $R_{th\,(j-c)}$is the steady state thermal resistance between junction and case. This is made up of thermal resistance of silicon chip, isolation material, solder interfaces and base-plate. Two values of $R_{th\,(j-c)}$are specified, one for the IGBT switch and another for the anti-parallel diode.

Rth(c-h) - Contact Thermal Resistance: $R_{th\,(c-h)}$is the contact thermal resistance between the case (base-plate) of the device and the heatsink. This resistance is a function of the fixing screw mounting torque, quality of the mounting surfaces and the interface compound or material used. The user should follow the recommended mounting procedure to obtain the optimum results (see application note AN4505).

Tj - Junction Temperature:
Junction temperature defines the maximum permissible operating junction temperature, $(T_{j\,max})$for the IGBT and diode to give reliable operation.

Tstg - Storage Temperature Range:
This is defined as the minimum and maximum storage temperature range. Note that degradation of materials used in the module can occur due to temperature variation and this process can be accelerated outside the specified storage range.

Mounting Torque:

These are the maximum limits for the screw torques applied to the busbar connections and the base-plate fastening to the heatsink. It should be emphasised that insufficient torque applied to the mounting screws may result in poor contact thermal resistance to the heatsink and excessive applied torque can result in the damage to the module. For further information please see application note AN4505, ‘Heatsink Issues for IGBT Modules’.

Electrical Characteristics:

The electrical characteristics of the module are divided into tables listing the static and the dynamic parameters.

T_{case} = 25°C unless stated otherwise.

Symbol	Parameter	Test Conditions	Min	Typ	Max	Units
I_{CES}	Collector cut-off current	V_{GE} = 0V, V_{CE} = V_{CES}			5	mA
		V_{GE} = 0V, V_{CE} = V_{CES}, T_{case} = 125°C			90	mA
		V_{GE} = 0V, V_{CE} = V_{CES}, T_{case} = 150°C			150	mA
I_{GES}	Gate leakage current	V_{GE} = ± 20V, V_{CE} = 0V			1	µA
$V_{GE(TH)}$	Gate threshold voltage	I_C = 120mA, V_{GE} = V_{CE}		5.7		V
$V_{CE(sat)}$ †	Collector-emitter saturation voltage	V_{GE} = 15V, I_C = 1500A		2.2		V
		V_{GE} = 15V, I_C = 1500A, T_j = 125°C		2.8		V
		V_{GE} = 15V, I_C = 1500A, T_j = 150°C		3.0		V
I_F	Diode forward current	DC		1500		A
I_{FM}	Diode maximum forward current	t_p = 1ms		3000		A
V_F †	Diode forward voltage	I_F = 1500A		2.4		V
		I_F = 1500A, T_j = 125°C		2.5		V
		I_F = 1500A, T_j = 150°C		2.4		V
C_{ies}	Input capacitance	V_{CE} = 25V, V_{GE} = 0V, f = 1MHz		260		nF
Q_g	Gate charge	±15V Including external C_{ge}		25		µC
C_{res}	Reverse transfer capacitance	V_{CE} = 25V, V_{GE} = 0V, f = 1MHz		6		nF
L_M	Module inductance			10		nH
R_{INT}	Internal transistor resistance			90		µΩ
SC_{Data}	Short circuit current, I_{SC}	T_j = 150°C, V_{CC} = 2500V t_p ≤ 10µs, V_{GE} ≤ 15V $V_{CE(max)}$ = V_{CES} – L^* x dI/dt IEC 60747-9		5500		A

Note:
† Measured at the auxiliary terminals
* L is the circuit inductance + L_M

Table 3: Electrical characteristics

Static Characteristics:
These characteristics describe the behaviour of device in steady state conditions either in the "off-state" or "on-state" (conduction-state). These characteristics are measured at the case temperature of 25°C unless stated otherwise.

ICES - Collector Cut-off Current:
I_{CES} is the collector to emitter blocking (or cut-off) current specified at the rated collector to emitter blocking voltage V_{CES} with gate-emitter shorted.

IGES - Gate Leakage Current:

I_{GES} is the current that flows between gate to emitter terminals with collector emitter shorted $(\text{i.e.}\, V_{CE} = 0)$ when a specified voltage (V_{GE}) is applied across gate-emitter terminals.

VGE (TH) - Gate Threshold Voltage:

$V_{GE(TH)}$ is the gate to emitter threshold voltage and it is the minimum gate-emitter voltage required to turn-on the IGBT at specified I_C ,V_{CE} and case temperature.

VCE (sat) - Collector-Emitter Saturation Voltage:

$V_{CE(sat)}$ is the collector to emitter saturation voltage. This is the on-state voltage of the IGBT at rated collector current and specified gate-emitter voltage. Note that this voltage can be measured at the busbars terminals and hence includes the internal resistance R_{INT} (separately specified). In some modules it is measured using the auxiliary terminals (i.e. at chip level) and hence does not include R_{INT}. When calculating power dissipation in the IGBT it may be prudent to deduct the power dissipation due to internal resistance where $V_{CE(sat)}$ is measured at the busbar level.

IF - Diode forward current:

This is the maximum DC forward current of the diode part in the module.

IFM - Diode maximum forward current:

This the maximum peak forward current of the diode specified at 1ms pulse duration.

VF – Diode forward voltage:

V_F is the forward voltage drop of the diode when I_F flows through it. Note again that this is specified at the busbar level unless specified otherwise.

Cies – Input capacitance:

The input capacitance Cies is defined as the capacitance between the gate and the emitter terminals with the collector terminal shorted to the emitter terminal. This capacitance needs to be charged before turning the IGBT on. It also has influence on the rise time of the collector current. This is measured at $V_{CE} = 25\text{V}, V_{GE} = 0\text{V and f} = 1\text{MHz}$.

Qg – Gate charge:

Q_g is the gate charge required to charge the input capacitance such that to raise the gate voltage from a specified minimum to maximum value.

Cres – Reverse transfer capacitance:

The reverse transfer capacitance is defined as the capacitance between the collector and the gate terminals. This capacitance is sometimes referred to as “*Miller*” capacitance. This capacitance is effectively in parallel with the input capacitance and hence has influence on the rise time of the collector current.

LM – Module inductance – per switch:

This is inductance of the IGBT switch measured between collector-emitter terminals.

RINT – Internal transistor resistance – per switch:

This internal resistance of the IGBT switch is measured between collector-emitter terminals but excludes the resistance of the bond wires and the chip. The collector-emitter voltage measured at the busbar level is given by the Eqn.5.

$$V_{CE\ (busbar)} = V_{CE(Sat)} + R_{INT} \times I_C \qquad (5)$$

SCData – Short circuit current, I_{SC}:

This describes the typical short circuit current of the IGBT switch under the given conditions. When the IGBT is switched on into a hard short circuit it reaches a maximum current which is a function of gate driver characteristics, the IGBT trans-conductance (g_m) and the junction temperature. This peak is measured under the conditions of $T_j = 150$ $C, V_{CC} = 2500V, t_p \leq$

$10\mu s, V_{GE} = 15V$.

Dynamic Characteristics:

T_{case} = 25°C unless stated otherwise

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Units
$t_{d(off)}$	Turn-off delay time	I_C = 1500A V_{GE} = ±15V V_{CE} = 1800V $R_{g(ON)}$ = 1.65Ω $R_{g(OFF)}$ = 1.5Ω C_{GE} = 330nF L_S ~ 150nH		2700		ns
t_f	Fall time			520		ns
E_{OFF}	Turn-off energy loss			2900		mJ
$t_{d(on)}$	Turn-on delay time			1000		ns
t_r	Rise time			400		ns
E_{ON}	Turn-on energy loss			1900		mJ
Q_{rr}	Diode reverse recovery charge	I_F = 1500A V_{CE} = 1800V dI_F/dt = 4000A/μs		850		μC
I_{rr}	Diode reverse recovery current			920		A
E_{rec}	Diode reverse recovery energy			1000		mJ

T_{case} = 125°C unless stated otherwise

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Units
$t_{d(off)}$	Turn-off delay time	I_C = 1500A V_{GE} = ±15V V_{CE} = 1800V $R_{g(ON)}$ = 1.65Ω $R_{g(OFF)}$ = 1.5Ω C_{GE} = 330nF L_S ~ 150nH		2750		ns
t_f	Fall time			570		ns
E_{OFF}	Turn-off energy loss			3250		mJ
$t_{d(on)}$	Turn-on delay time			1020		ns
t_r	Rise time			420		ns
E_{ON}	Turn-on energy loss			2500		mJ
Q_{rr}	Diode reverse recovery charge	I_F = 1500A V_{CE} = 1800V dI_F/dt = 4000A/μs		1400		μC
I_{rr}	Diode reverse recovery current			1160		A
E_{rec}	Diode reverse recovery energy			1700		mJ

T_{case} = 150°C unless stated otherwise

Symbol	Parameter	Test Conditions	Min	Typ.	Max	Units
$t_{d(off)}$	Turn-off delay time	I_C = 1500A V_{GE} = ±15V V_{CE} = 1800V $R_{g(ON)}$ = 1.65Ω $R_{g(OFF)}$ = 1.5Ω C_{GE} = 330nF L_S ~ 150nH		2800		ns
t_f	Fall time			550		ns
E_{OFF}	Turn-off energy loss			3450		mJ
$t_{d(on)}$	Turn-on delay time			1030		ns
t_r	Rise time			430		ns
E_{ON}	Turn-on energy loss			2750		mJ
Q_{rr}	Diode reverse recovery charge	I_F = 1500A V_{CE} = 1800V dI_F/dt = 4000A/μs		1600		μC
I_{rr}	Diode reverse recovery current			1200		A
E_{rec}	Diode reverse recovery energy			1950		mJ

Table 4: Dynamic electrical characteristics

The dynamic characteristics given in the Dynex IGBT module datasheets are based on an inductive switching using a clamped inductive load as encountered in many applications. The basic test circuit is shown in Fig. III. The switching parameters definition may vary from other manufacturers and this should be taken into consideration when benchmarking modules from different suppliers.

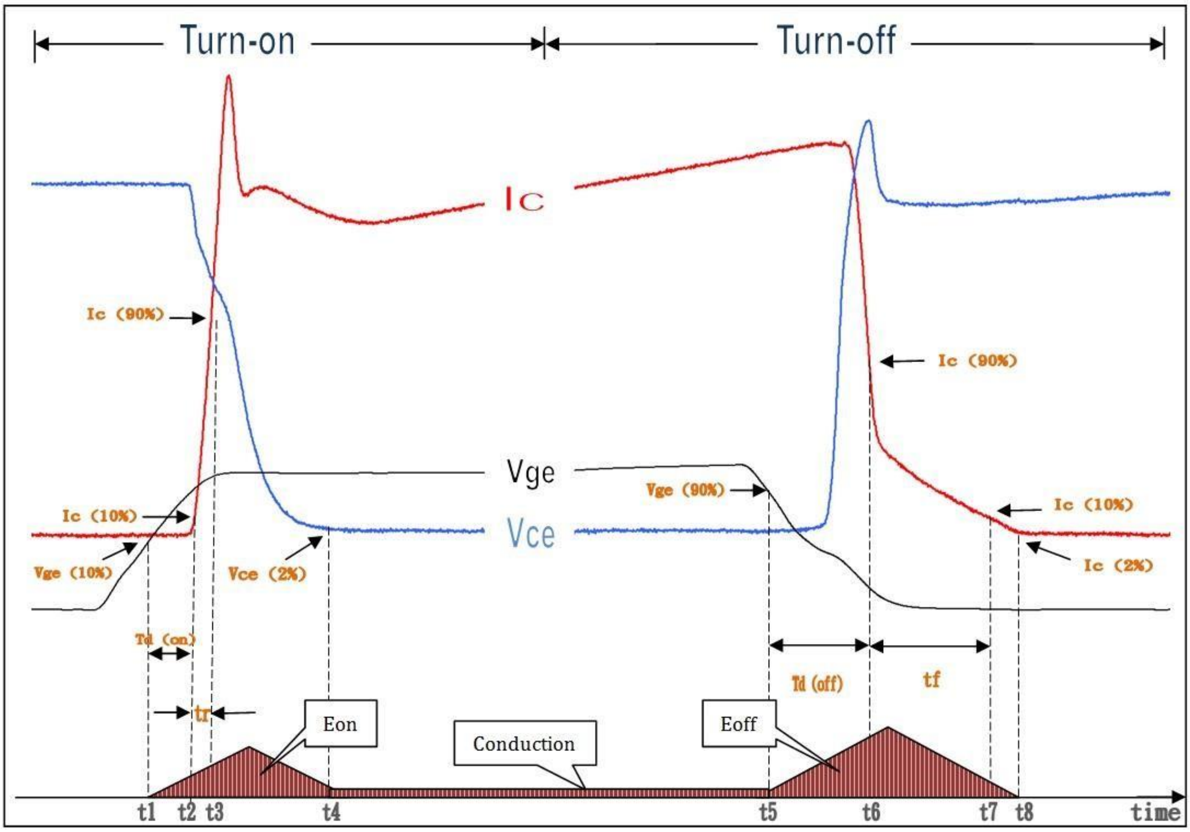


Figure I: Timing diagram and energy losses

td(on) - Turn-on delay time:

The turn-on delay time $t_{d(on)}$is defined as the time for V_G to reach 10% of its final value to the time when the collector current $I_c$has reached 10% of its final value.$t_{d(on)} = t2 - t1.$

(See Fig. I)

tr – Rise time:

The rise time t_r is defined as the time taken for the collector current to increase from 10% to

90% of its final value. t_r is influenced by the IGBT gate characteristics.$t_r = t3 - t2.$ (See

Fig. I)

EON - Turn-on energy loss:

The turn-on energy loss per pulse $E_{ON}$is defined as per Fig. I, from$t1 - t4$. This loss is the integration of the collector-emitter voltage and the collector current as expressed by Eqn.6.

$$E_{ON} = \int_{t_1}^{t_4} \left(I_C(t) \times V_{CE}(t) \right) dt \quad (6)$$

td(off) - Turn-off delay time:

$t_{d(off)}$ is defined as the time interval from $V_{GE} = 90\%$ of its initial value to $I_C = 90\%$ of its initial value, prior to turn-off transition. $t_{d(off)} = t6 - t5$. (See Fig. I)

tf – Fall time:

The fall time of collector current tf is defined as the time interval between $I_C = 90\%$ to 10% of initial value. $t_r = t7 - t6$. (See Fig. I)

EOFF - Turn-off energy loss:

The turn-off energy loss per pulse E_{OFF} is defined as per Fig. I, from $t5 - t8$. This loss is the integration of the collector-emitter voltage and the collector current as expressed by Eqn.7.

$$E_{OFF} = \int_{t_5}^{t_8} \left(I_C(t) \times V_{CE}(t) \right) dt \quad (7)$$

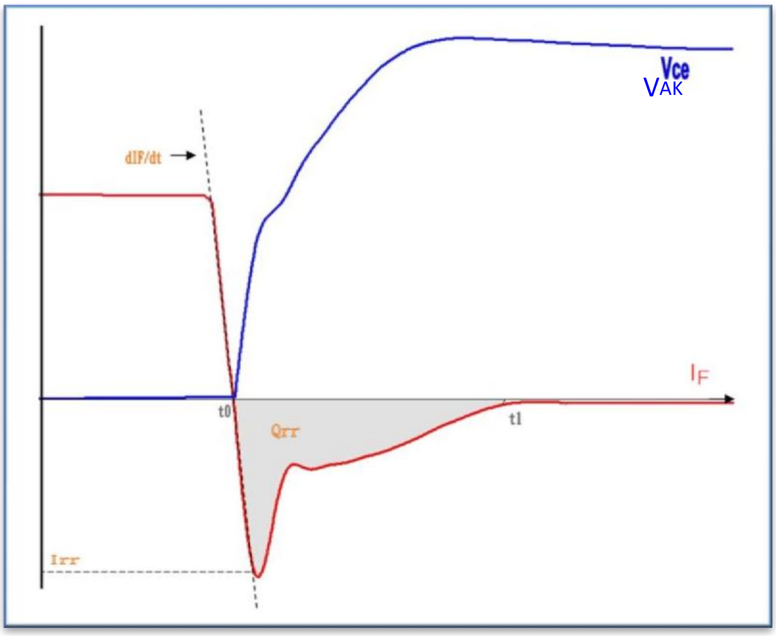


Figure II: Diode timing diagram

Qrr – Diode reverse recovery charge:

Diode reverse recovery charge is specified under the conditions of diode forward current (I_F),the applied reverse voltage $(V_{CE})$and the rate of fall of diode current (dI_F/dt).The total

reverse recovery charge is obtained by the integral of the reverse recovery current, thus

$$Q_{rr} = \int_{t_0}^{t_1} \left(I_R(t) \right) dt \qquad (8)$$

For the measurement purpose the actual integration time is defined in the Fig. II.

Irr – Diode reverse recovery current:
This is the peak reverse recovery current in the diode. This is defined under the conditions ofI_F, V_{CE} and dI_F/dt.

Erec – Diode reverse recovery energy:
The diode reverse recovery energy is defined by the Eqn.9. For the purpose of measurement the integration time is defined in the Fig. II.

$$E_{rec} = \int_{t_o}^{t_1} \left(I_R(t) \times V_R(t) \right) dt \qquad (9)$$

Basic Test Circuit and Switching Definitions:
Fig. III shows the schematic of the circuit used to test the IGBTs for inductive switching. Switching is accomplished using a double pulse method. The first pulse switches the IGBT on and establishes current in the load inductance. At the end of this pulse, the DUT is turned off and the current is transferred to the free-wheel diode. The second pulse turns the DUT on again and free-wheel diode recovers and the IGBT is turned off at the end of this pulse. The timings of these pulses are adjusted to give the required collector current amplitude. The associated switching wave forms are given in Fig. I. This figure also gives definitions used by Dynex for the switching characteristics.

CURVES:

Output Characteristics:
Output Characteristics depict the saturation characteristics of the IGBT where collector current is plotted against collector-emitter saturation voltage with case temperature and gateemitter voltage as parameters as shown in Fig. 3 and Fig. 4.

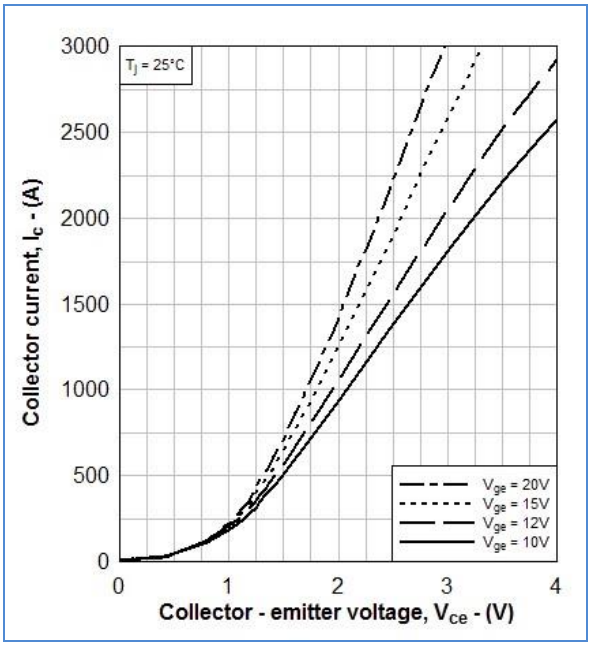


Figure 3: Typical output characteristics Tj @ 25°C

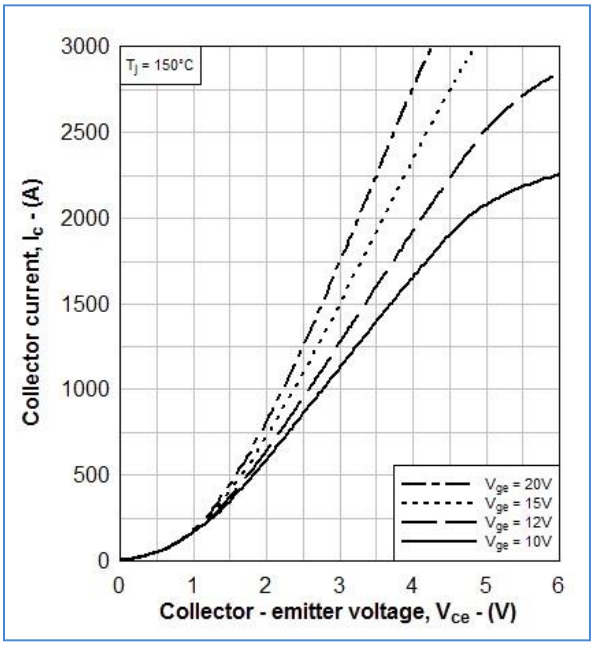


Figure 4: Typical output characteristics Tj @ 150°C

This is one of the key parameters of the IGBT and it is used to calculate on-state power loss in the IGBT. The average conduction power loss $\mathrm{P}_{\mathrm{avg(cond)}}$ in the IGBT is given by:

$$P_{avg(cond)} = I_C \times V_{CE(sat)} \times \delta \qquad (10)$$

Where δ is the duty cycle.

Switching Energies:

The switching energies i.e. the turn-on energy (E_{ON}), the turn-off energy (E_{OFF}) in the IGBT and the reverse recovery energy in the diode (E_{rec}) are functions of collector current, collector voltage, gate resistance and junction temperature. These relationships are graphically represented by curves of:

i) E_{ON}, E_{OFF} and E_{rec} Vs collector current see Fig. 5 and
ii) E_{ON}, E_{OFF} and E_{rec} Vs gate resistance Fig. 6.

These switching losses are measured under inductive switching conditions. Both E_{ON} and E_{OFF} increase with increase in collector current and case temperature. The gate resistance has a marked influence on Eon. The reason for this is by increasing the gate resistance the rate of rise of collector current decreases. The collector - emitter voltage also falls gradually hence giving rise to increased losses. In order to estimate average power losses due switching energy, read off appropriate E_{ON} and E_{OFF} for specified operating conditions then the average switching power dissipation is given by:

$$P_{avg(switching)} = (E_{ON} + E_{OFF}) \times f_r \qquad (11)$$

Where f_r is the repetition frequency. Switching losses are a function of operating frequency and at higher frequencies these losses become dominant over the conduction losses.

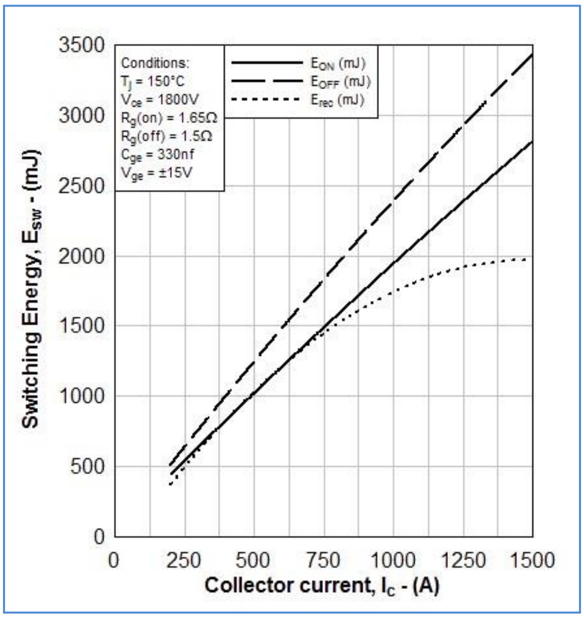


Figure 5: Typical switching energy VS collector current

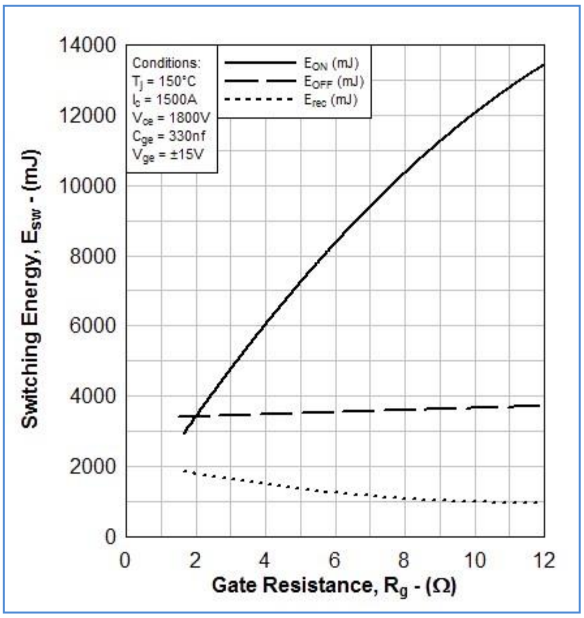
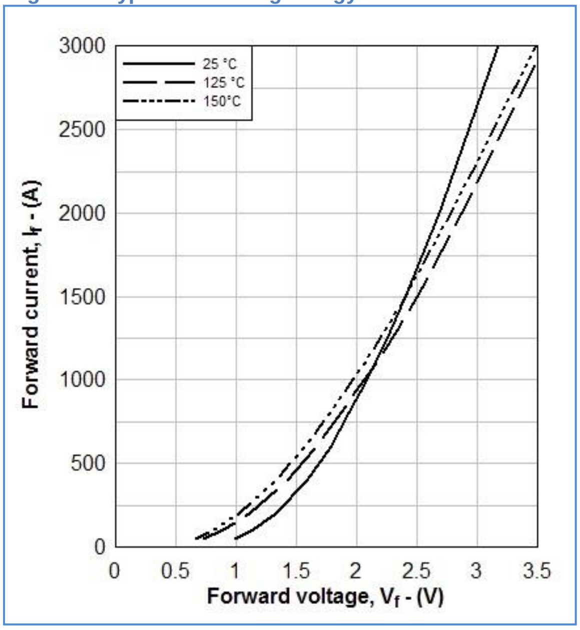


Figure 6: Typical switching energy VS gate resistance



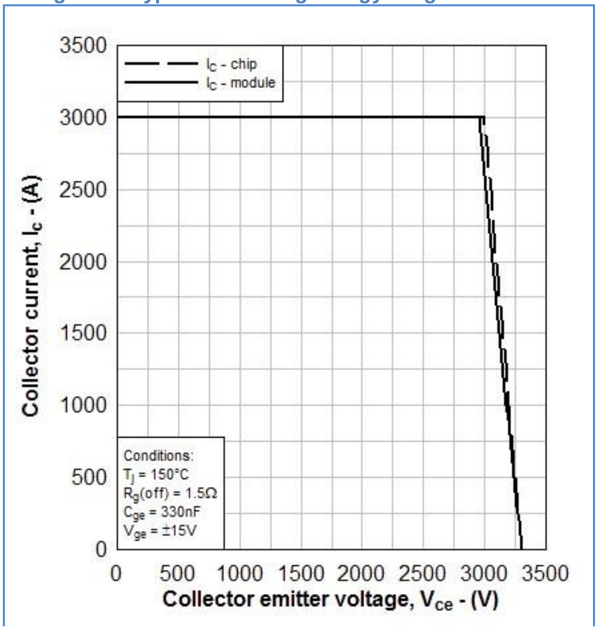


Figure 7: Diode typical forward characteristics

Figure 8: Reverse bias safe operating area

Diode forward characteristic:

Fig. 7 shows typical diode forward characteristics with junction temperature at 25°C, 125°C and 150°C.

Reverse bias safe operating area (RBSOA):

The safe operating area SOA of an IGBT is the area bounded by a curve of collector current vs collector-emitter voltage. The curve gives the limits of current and voltage related to the total power dissipation of the device. If the operating conditions of the device are within this area, then the device will function safely provided $T_{j\ max}$ is not exceeded. The reverse bias safe operating area (RBSOA) curve is the locus of points defining the maximum permissible simultaneous occurrence of collector current and collector-emitter voltage during the turn-off phase, (see Fig. 8). The curve exhibits three limiting boundaries; maximum collector current (the flat portion of the curve), the maximum power (sloping line) and maximum voltage (vertical line). The user should observe that the RBSOA curve is constructed for a given set of conditions and so it is useful for comparison between different devices.

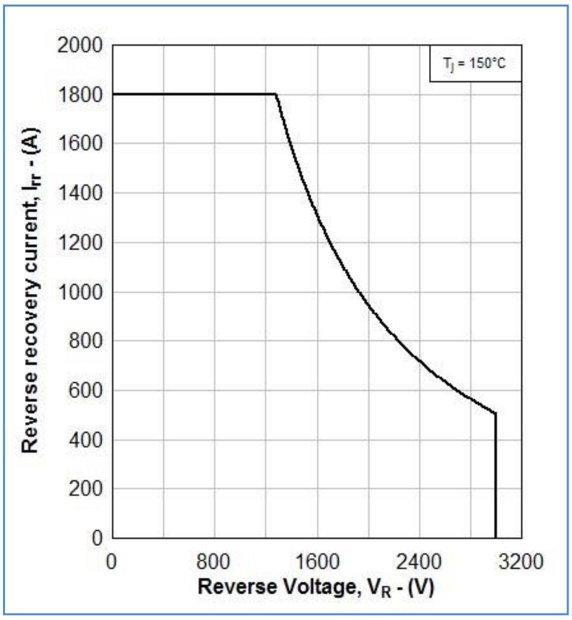


Figure 9: Diode reverse bias safe operating area

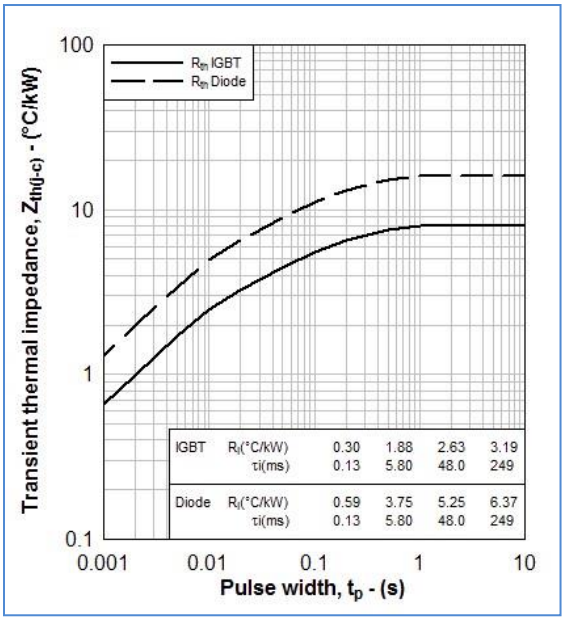


Figure 10: Transient thermal impedance

Diode RBSOA:

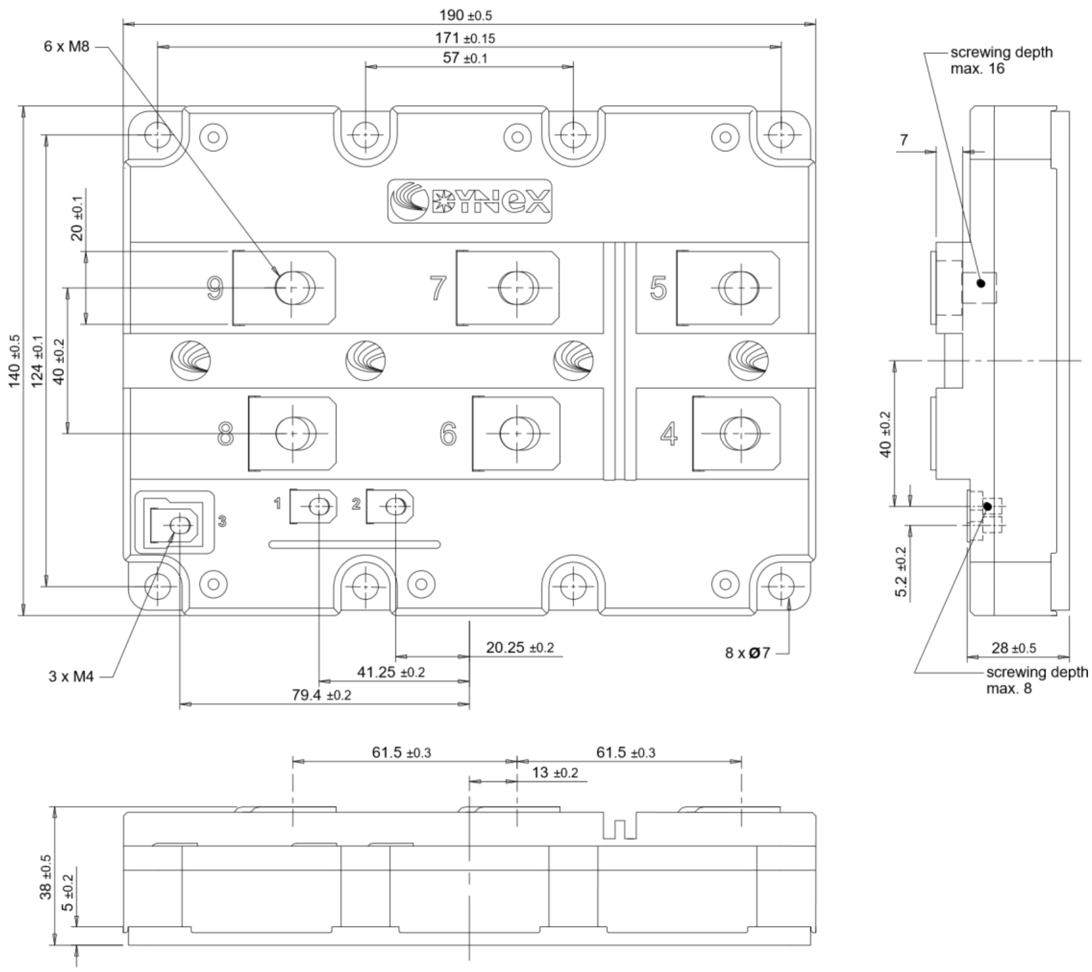
Fig. 9 shows diode reverse bias safe operating area. This is the plot of the instantaneous reverse recovery current against reverse recovery voltage. The maximum limit of reverse recovery current is set by the recommended gate resistor specified in the datasheet. The maximum limit of reverse recovery voltage is set by the diode reverse blocking voltage rating. The user should verify that during the commutation of diode current to the IGBT, the reverse recovery current and the voltage should stay within the RBSOA of the diode for the complete process. Also the maximum junction temperature of the FWD should not exceed 150°C and the maximum switching dI/dt controlled by the gate conditions of the IGBT should not be allowed to be exceeded.

Transient Thermal Impedance Curves:
This curve shows how the junction-case thermal resistance of the device varies with time, as measured from the start of power dissipation. Fig. 10 shows the curves for the IGBT and diode. Also the analytical function for these curves modelled by the sum of four exponential terms is specified by the Eqn. 12.

$$Z_{th(j-c)}(t) = \sum_{i=1}^{4} R_i \times \left(1 - e^{\frac{-t}{\tau_i}}\right) \qquad (12)$$

The coefficients of the curve fit Ri and τi are given in a table embedded in the figure. The analytical function is especially suitable for calculations performed on the computer.

Package Outline Details:
This gives the drawing of the package outline with dimensions (in mm, unless otherwise stated), Fig. 11. Any additional information can be obtained by contacting Dynex Customer Service Centres.



Nominal Weight: 1400g Module Outline Type Code: E

Figure 11: Module outline drawing

Dynamic Test Circuit:

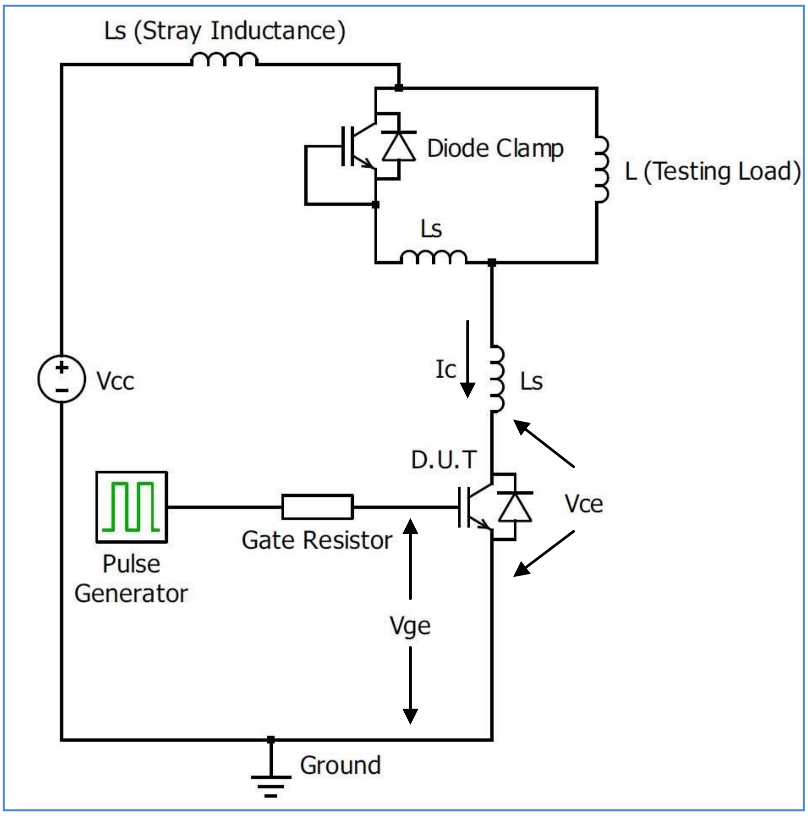


Figure III: Dynamic Test Circuit

$Where\ ;$

$resistance \quad Rg = Gate$

$inductance \quad LS = Stray$

$inductance \quad L = Load$

$to\ Emitter\ voltage \quad VGE = Gate$

$to\ Emitter\ voltage \quad VCE = Collector$

$Voltage \quad VCC = DC$

$current \quad I_C = Collector$

Short circuit waveform:

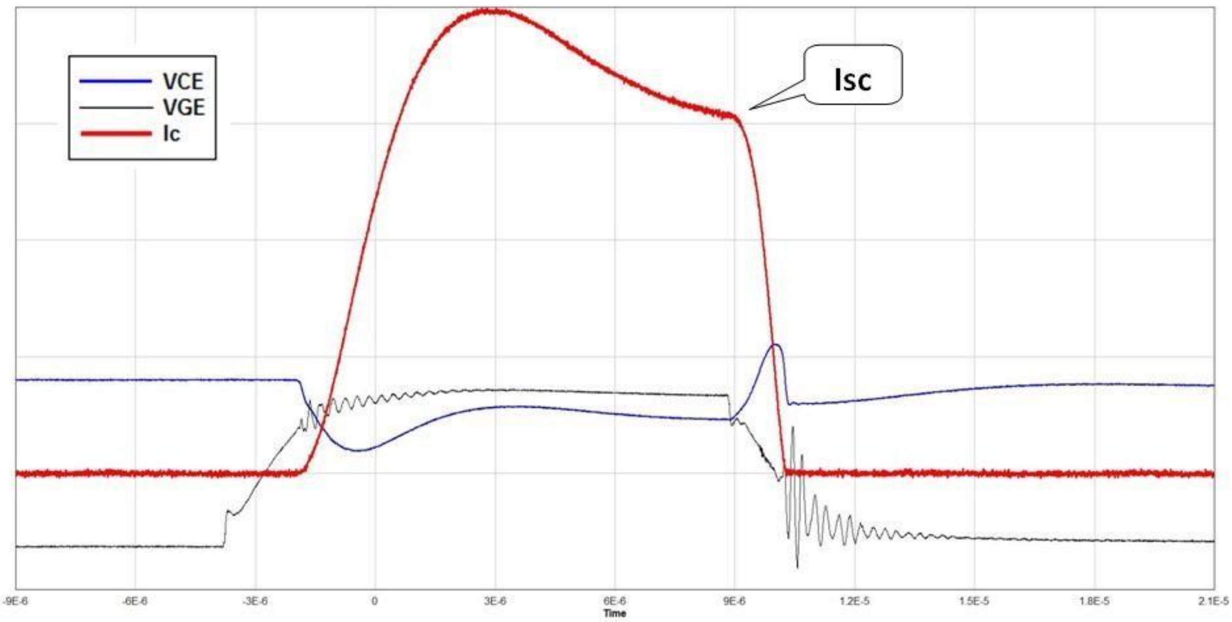


Figure IV: Short Circuit Current ISC

IMPORTANT INFORMATION:

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.**

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