

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

600 V

HGTG12N60A4D, HGTP12N60A4D, HGT1S12N60A4DS

The HGTG12N60A4D, HGTP12N60A4D and HGT1S12N60A4DS 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 TA49335. The diode used in anti-parallel is the development type TA49371.

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 TA49337.

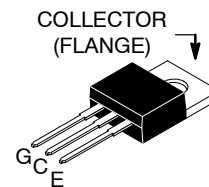
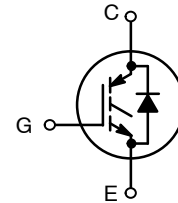
Features

- >100 kHz Operation 390 V, 12 A
- 200 kHz Operation 390 V, 9A
- 600 V Switching SOA Capability
- Typical Fall Time 70 ns at $T_J = 125^\circ\text{C}$
- Low Conduction Loss
- Temperature Compensating Saber™ Model
- Related Literature
 - ♦ TB334 "Guidelines for Soldering Surface Mount Components to PC Boards"
- These are Pb-Free Devices

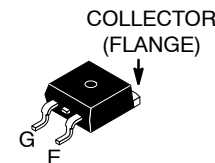


ON Semiconductor®

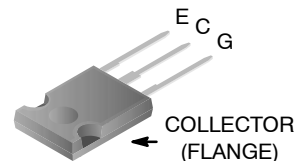
www.onsemi.com



TO-220-3LD
CASE 340AT
JEDEC ALTERNATE
VERSION

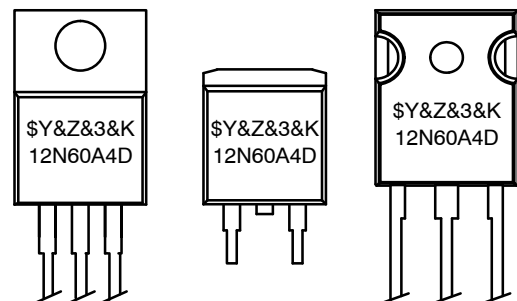


D²PAK-3
(TO-263, 3-LEAD)
CASE 418AJ
JEDEC STYLE



TO-247-3LD
SHORT LEAD
CASE 340CK
JEDEC STYLE

MARKING DIAGRAM



\$Y	= ON Semiconductor Logo
&Z	= Assembly Plant Code
&3	= Numeric Date Code
&K	= Lot Code
12N60A4D	= Specific Device Code

ORDERING INFORMATION

See detailed ordering and shipping information on page 8 of this data sheet.

HGTG12N60A4D, HGTP12N60A4D, HGT1S12N60A4DS

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

Parameter	Symbol	HGTG12N60A4D, HGTP12N60A4D, HGT1S12N60A4DS	Unit
Collector to Emitter Voltage	BV _{CES}	600	V
Collector Current Continuous At T _C = 25°C At T _C = 110°C	I _{C25} I _{C110}	54 23	A A
Collector Current Pulsed (Note 1)	I _{CM}	96	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 2	SSOA	60 A at 600 V	
Power Dissipation Total at T _C = 25°C	P _D	167	W
Power Dissipation Derating T _C > 25°C		1.33	W/°C
Operating and Storage Junction Temperature Range	T _J , T _{STG}	–55 to 150	°C
Maximum Temperature for Soldering Leads at 0.063 in (1.6 mm) from Case for 10 s Package Body for 10 s, see Tech Brief 334.	T _L T _{pkg}	300 260	°C °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. Pulse width limited by maximum junction temperature.

ELECTRICAL CHARACTERISTICS (T_J = 25°C unless otherwise specified)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
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 _J = 25°C	–	–	250 µA
			T _J = 125°C	–	–	2.0 mA
Collector to Emitter Saturation Voltage	V _{CE(SAT)}	I _C = 12 A, V _{GE} = 15 V	T _J = 25°C	–	2.0	2.7 V
			T _J = 125°C	–	1.6	2.0 V
Gate to Emitter Threshold Voltage	V _{GE(TH)}	I _C = 250 µA, V _{CE} = 600 V	–	5.6	–	V
Gate to Emitter Leakage Current	I _{GES}	V _{GE} = ±20 V	–	–	±250	nA
Switching SOA	SSOA	T _J = 150°C, R _G = 10 Ω, V _{GE} = 15 V, L = 100 µH, V _{CE} = 600 V	60	–	–	A
Gate to Emitter Plateau Voltage	V _{GEP}	I _C = 12 A, V _{CE} = 300 V	–	8	–	V
On-State Gate Charge	Q _{g(ON)}	I _C = 12 A, V _{CE} = 300 V	V _{GE} = 15 V	–	78	96 nC
			V _{GE} = 20 V	–	97	120 nC
Current Turn-On Delay Time	t _{d(ON)} I	IGBT and Diode at T _J = 25°C, I _{CE} = 12 A, V _{CE} = 390 V, V _{GE} = 15 V, R _G = 10 Ω, L = 500 µH, Test Circuit (Figure 24)	–	17	–	ns
Current Rise Time	t _{rl}		–	8	–	ns
Current Turn-Off Delay Time	t _{d(OFF)} I		–	96	–	ns
Current Fall Time	t _{fl}		–	18	–	ns
Turn-On Energy (Note 3)	E _{ON1}		–	55	–	µJ
Turn-On Energy (Note 3)	E _{ON2}		–	160	–	µJ
Turn-Off Energy (Note 2)	E _{OFF}		–	50	–	µJ
Current Turn-On Delay Time	t _{d(ON)} I	IGBT and Diode at T _J = 125°C, I _{CE} = 12 A, V _{CE} = 390 V, V _{GE} = 15 V, R _G = 10 Ω, L = 500 µH, Test Circuit (Figure 24)	–	17	–	ns
Current Rise Time	t _{rl}		–	16	–	ns
Current Turn-Off Delay Time	t _{d(OFF)} I		–	110	170	ns
Current Fall Time	t _{fl}		–	70	95	ns
Turn-On Energy (Note 3)	E _{ON1}		–	55	–	µJ
Turn-On Energy (Note 3)	E _{ON2}		–	250	350	µJ
Turn-Off Energy (Note 2)	E _{OFF}		–	175	285	µJ

HGTG12N60A4D, HGTP12N60A4D, HGT1S12N60A4DS

ELECTRICAL CHARACTERISTICS ($T_J = 25^\circ\text{C}$ unless otherwise specified) (continued)

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Diode Forward Voltage	V_{EC}	$I_{EC} = 12\text{ A}$	–	2.2	–	V
Diode Reverse Recovery Time	t_{rr}	$I_{EC} = 12\text{ A}, dI_{EC}/dt = 200\text{ A}/\mu\text{s}$	–	30	–	ns
		$I_{EC} = 1\text{ A}, dI_{EC}/dt = 200\text{ A}/\mu\text{s}$	–	18	–	ns
Thermal Resistance Junction To Case	$R_{\theta JC}$	IGBT	–	–	0.75	$^\circ\text{C}/\text{W}$
		Diode	–	–	2.0	$^\circ\text{C}/\text{W}$

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.

- 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 ($I_{CE} = 0\text{ A}$). 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.
- 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.

TYPICAL PERFORMANCE CURVES (unless otherwise specified)

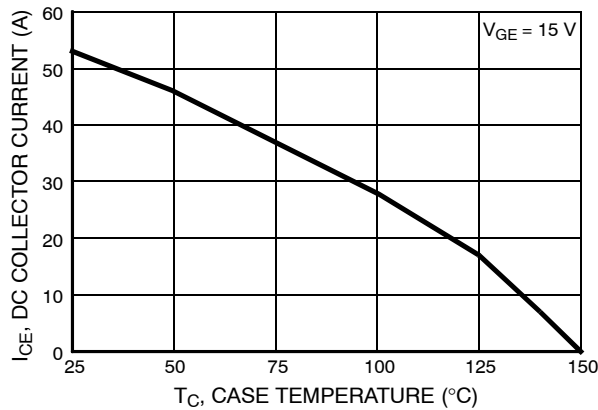


Figure 1. DC COLLECTOR CURRENT vs. CASE TEMPERATURE

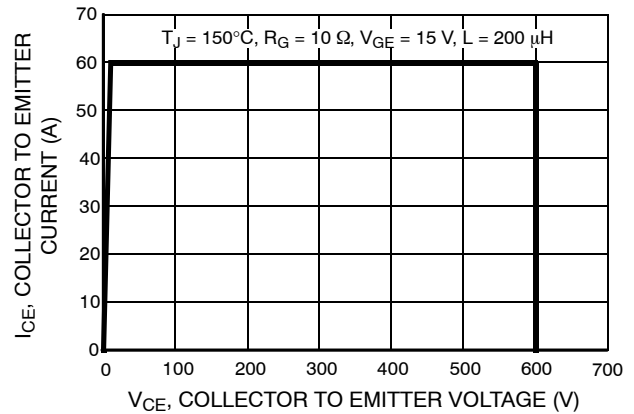


Figure 2. MINIMUM SWITCHING SAFE OPERATING AREA

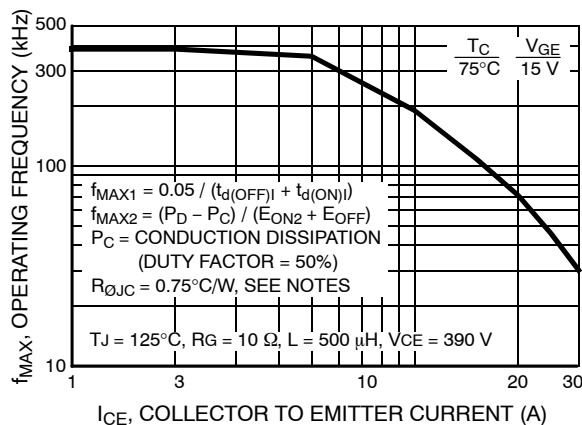


Figure 3. OPERATING FREQUENCY vs. COLLECTOR TO EMITTER CURRENT

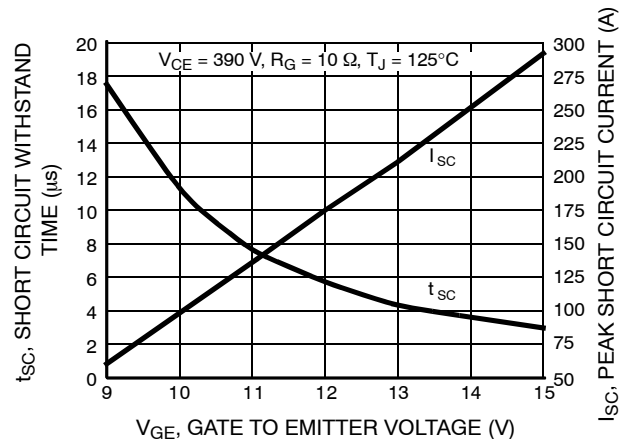


Figure 4. SHORT CIRCUIT WITHSTAND TIME

HGTG12N60A4D, HGTP12N60A4D, HGT1S12N60A4DS

TYPICAL PERFORMANCE CURVES (unless otherwise specified) (continued)

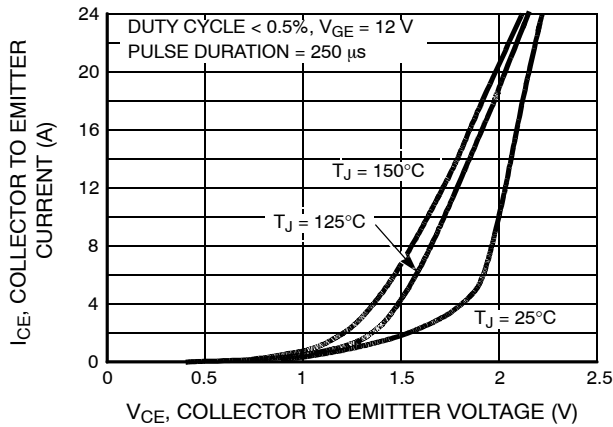


Figure 5. COLLECTOR TO EMITTER ON-STATE VOLTAGE

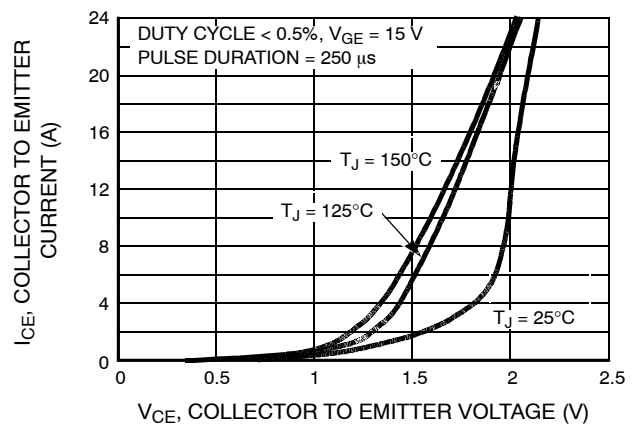


Figure 6. COLLECTOR TO EMITTER ON-STATE VOLTAGE

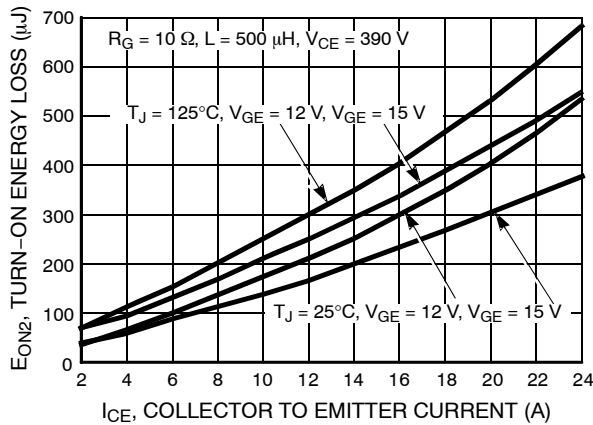


Figure 7. TURN-ON ENERGY LOSS vs. COLLECTOR TO EMITTER CURRENT

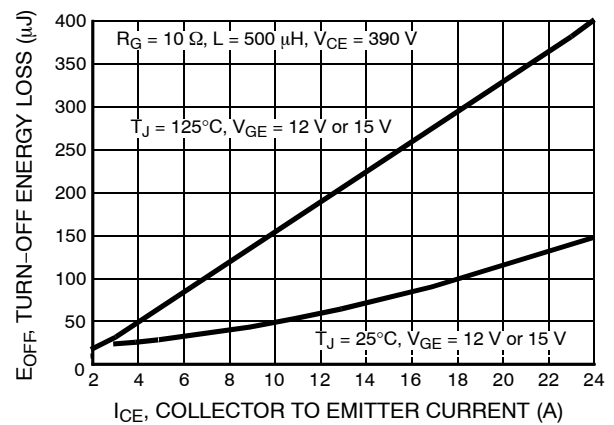


Figure 8. TURN-OFF ENERGY LOSS vs. COLLECTOR TO EMITTER CURRENT

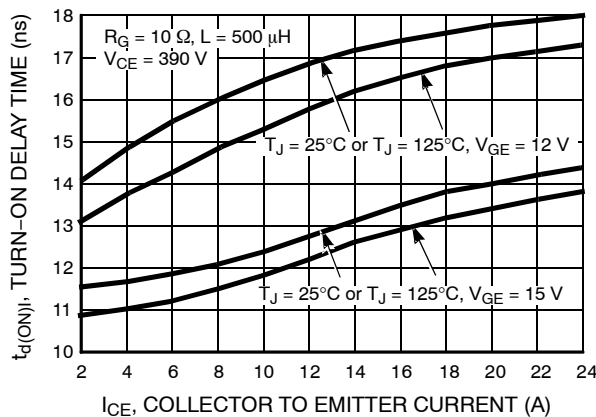


Figure 9. TURN-ON DELAY TIME vs. COLLECTOR TO EMITTER CURRENT

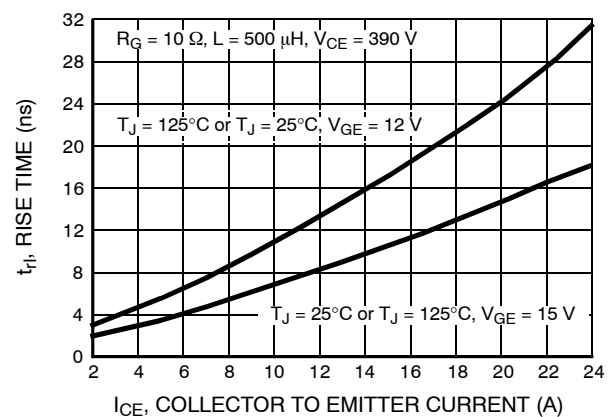


Figure 10. TURN-ON RISE TIME vs. COLLECTOR TO EMITTER CURRENT

HGTG12N60A4D, HGTP12N60A4D, HGT1S12N60A4DS

TYPICAL PERFORMANCE CURVES (unless otherwise specified) (continued)

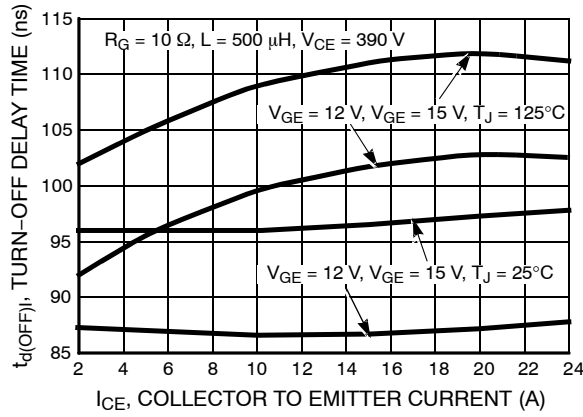


Figure 11. TURN-OFF DELAY TIME vs. COLLECTOR TO EMITTER CURRENT

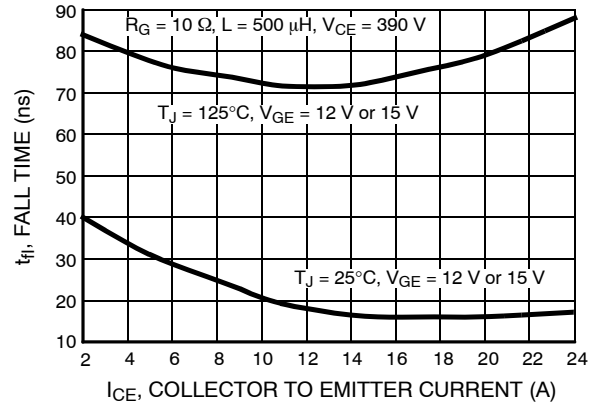


Figure 12. FALL TIME vs. COLLECTOR TO EMITTER CURRENT

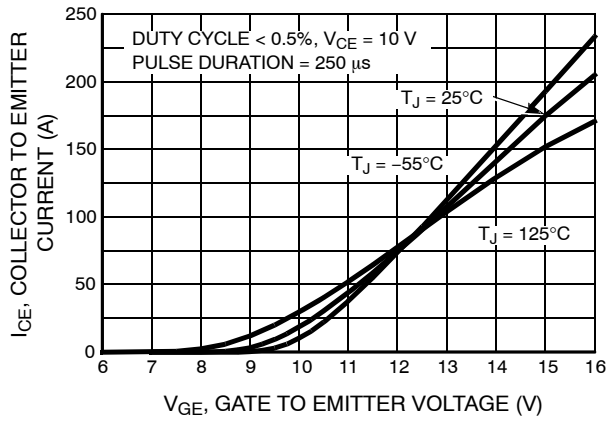


Figure 13. TRANSFER CHARACTERISTIC

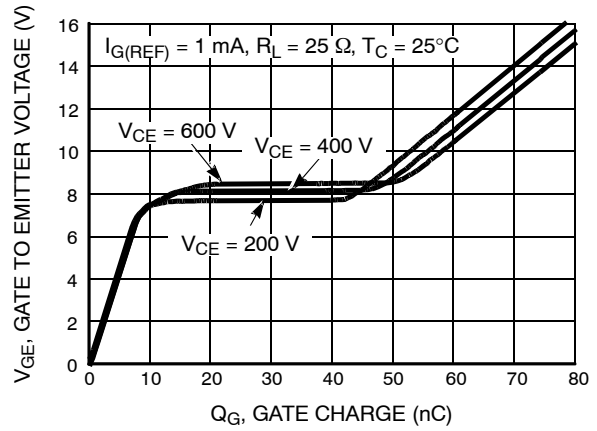


Figure 14. GATE CHARGE WAVEFORMS

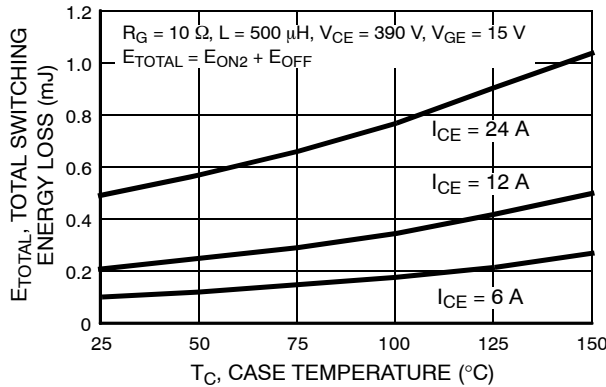


Figure 15. TOTAL SWITCHING LOSS vs. CASE TEMPERATURE

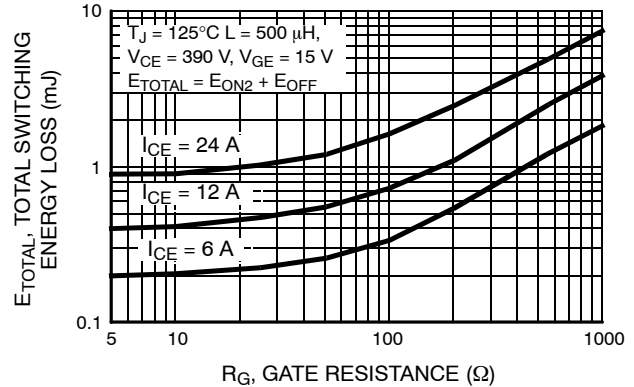


Figure 16. TOTAL SWITCHING LOSS vs. GATE RESISTANCE

HGTG12N60A4D, HGTP12N60A4D, HGT1S12N60A4DS

TYPICAL PERFORMANCE CURVES (unless otherwise specified) (continued)

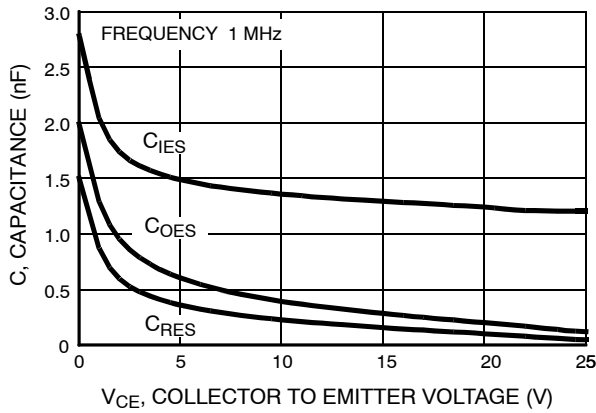


Figure 17. CAPACITANCE vs. COLLECTOR TO EMITTER VOLTAGE

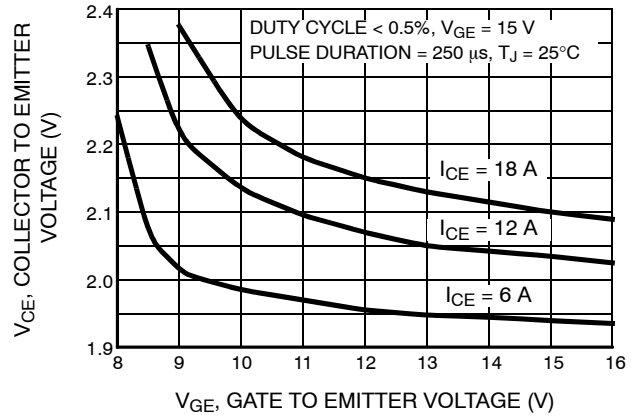


Figure 18. COLLECTOR TO EMITTER ON-STATE VOLTAGE vs. GATE TO EMITTER VOLTAGE

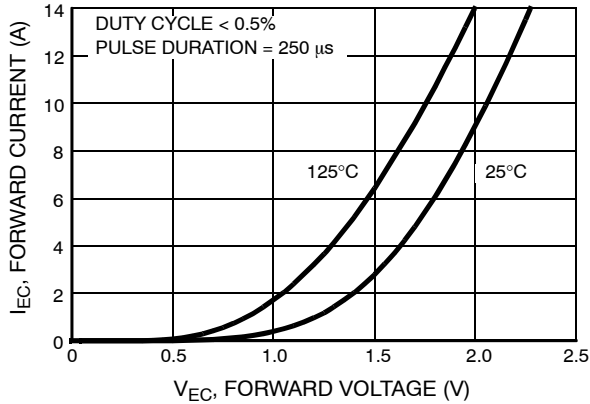


Figure 19. DIODE FORWARD CURRENT vs. FORWARD VOLTAGE DROP

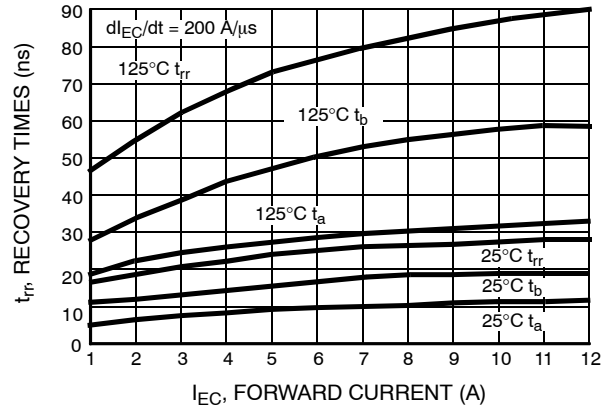


Figure 20. RECOVERY TIMES vs. FORWARD CURRENT

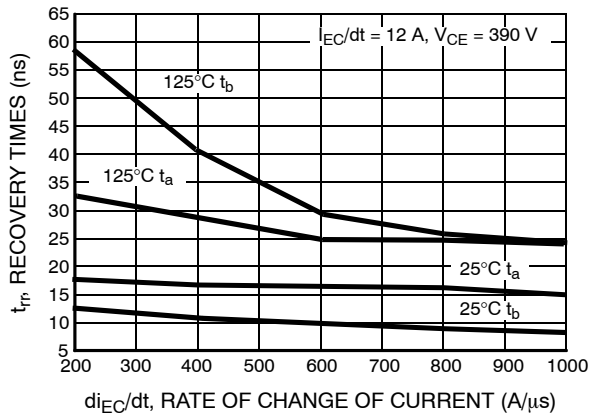


Figure 21. RECOVERY TIMES vs. RATE OF CHANGE OF CURRENT

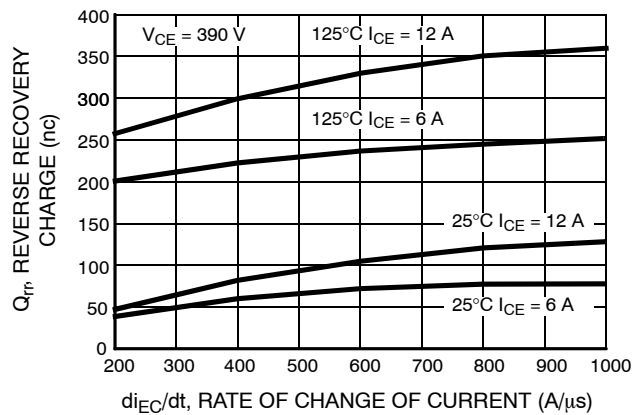


Figure 22. STORED CHARGE vs. RATE OF CHANGE OF CURRENT

HGTG12N60A4D, HGTP12N60A4D, HGT1S12N60A4DS

TYPICAL PERFORMANCE CURVES (unless otherwise specified) (continued)

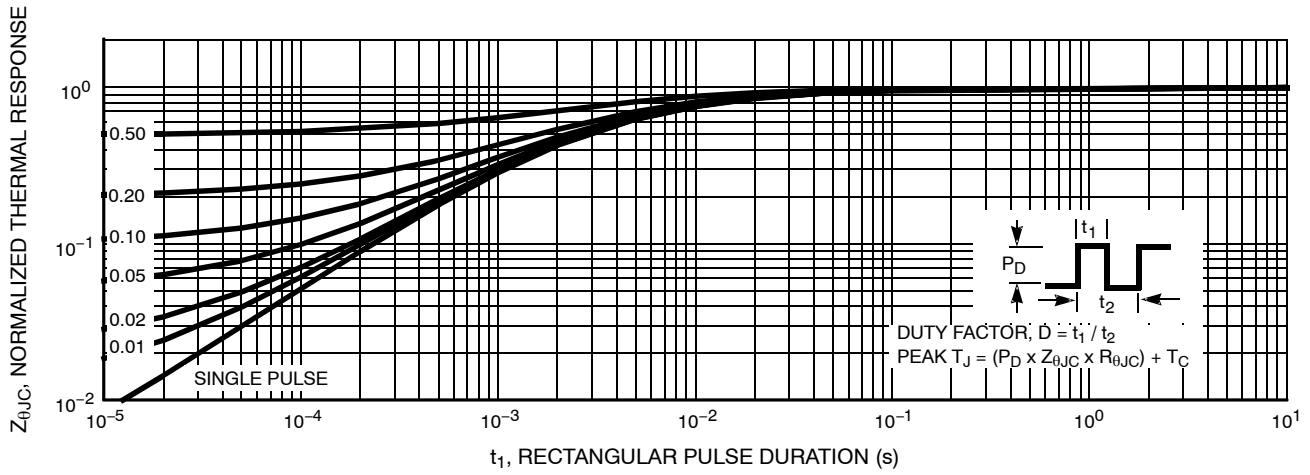


Figure 23. IGBT NORMALIZED TRANSIENT THERMAL RESPONSE, JUNCTION TO CASE

TEST CIRCUIT AND WAVEFORMS

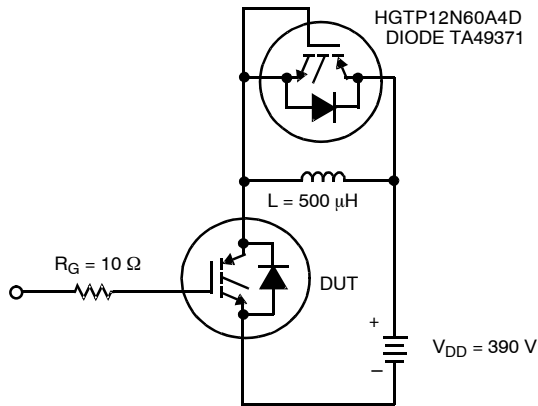


Figure 24. INDUCTIVE SWITCHING TEST CIRCUIT

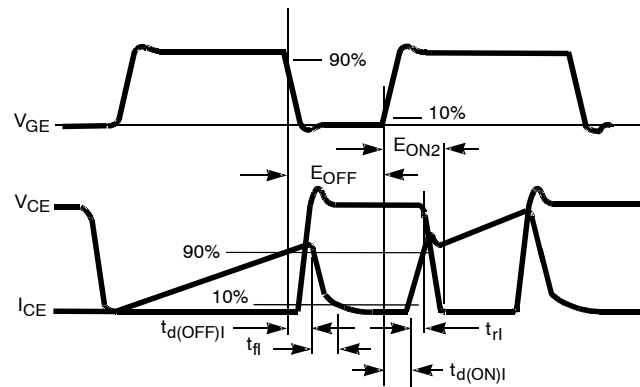


Figure 25. SWITCHING TEST WAVEFORMS

HANDLING PRECAUTIONS FOR IGBTs

Insulated Gate Bipolar Transistors are susceptible to gate–insulation damage by the electrostatic discharge of energy through the devices. When handling these devices, care should be exercised to assure that the static charge built in the handler’s body capacitance is not discharged through the device. With proper handling and application procedures, however, IGBTs are currently being extensively used in production by numerous equipment manufacturers in military, industrial and consumer applications, with virtually no damage problems due to electrostatic discharge. IGBTs can be handled safely if the following basic precautions are taken:

1. Prior to assembly into a circuit, all leads should be kept shorted together either by the use of metal shorting springs or by the insertion into conductive material such as “ECCOSORBD™ LD26” or equivalent.
2. When devices are removed by hand from their carriers, the hand being used should be grounded by any suitable means – for example, with a metallic wristband.
3. Tips of soldering irons should be grounded.
4. Devices should never be inserted into or removed from circuits with power on.
5. *Gate Voltage Rating* – Never exceed the gate–voltage rating of V_{GEM} . Exceeding the rated V_{GE} can result in permanent damage to the oxide layer in the gate region.
6. *Gate Termination* – The gates of these devices are essentially capacitors. Circuits that leave the gate open– circuited or floating should be avoided. These conditions can result in turn–on of the device due to voltage buildup on the input capacitor due to leakage currents or pickup.

7. *Gate Protection* – These devices do not have an internal monolithic Zener diode from gate to emitter. If gate protection is required an external Zener is recommended.

OPERATING FREQUENCY INFORMATION

Operating frequency information for a typical device (Figure 3) is presented as a guide for estimating device performance for a specific application. Other typical frequency vs collector current (I_{CE}) plots are possible using the information shown for a typical unit in Figures 5, 6, 7, 8, 9 and 11. The operating frequency plot (Figure 3) of a typical device shows f_{MAX1} or f_{MAX2} ; whichever is smaller at each point. The information is based on measurements of a typical device and is bounded by the maximum rated junction temperature.

f_{MAX1} is defined by $f_{MAX1} = 0.05 / (t_{d(OFF)I} + t_{d(ON)I})$. Deadtime (the denominator) has been arbitrarily held to 10% of the on–state time for a 50% duty factor. Other definitions are possible. $t_{d(OFF)I}$ and $t_{d(ON)I}$ are defined in Figure 25. Device turn–off delay can establish an additional frequency limiting condition for an application other than T_{JM} . $t_{d(OFF)I}$ is important when controlling output ripple under a lightly loaded condition.

f_{MAX2} is defined by $f_{MAX2} = (P_D - P_C) / (E_{OFF} + E_{ON2})$. The allowable dissipation (P_D) is defined by $P_D = (T_{JM} - T_C) / R_{\theta JC}$. The sum of device switching and conduction losses must not exceed P_D . A 50% duty factor was used (Figure 3) and the conduction losses (P_C) are approximated by $P_C = (V_{CE} \times I_{CE}) / 2$.

E_{ON2} and E_{OFF} are defined in the switching waveforms shown in Figure 25. E_{ON2} is the integral of the instantaneous power loss ($I_{CE} \times V_{CE}$) during turn–on and E_{OFF} is the integral of the instantaneous power loss ($I_{CE} \times V_{CE}$) during turn–off. All tail losses are included in the calculation for E_{OFF} ; i.e., the collector current equals zero ($I_{CE} = 0$).

ORDERING INFORMATION

Part Number	Package	Brand	Shipping†
HGTG12N60A4D	TO–247	12N60A4D	450 Units / Tube
HGTP12N60A4D	TO–220AB	12N60A4D	800 Units / Tube
HGT1S12N60A4DS	TO–263AB	12N60A4D	800 Units / Tube

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

NOTE: When ordering, use the entire part number. Add the suffix 9A to obtain the TO–263AB variant in tape and reel, e.g. HGT1S12N60A4DS9A.



TO-220-3LD
CASE 340AT
ISSUE B

DATE 08 AUG 2022

DIM	MILLIMETERS		
	MIN.	NOM.	MAX.
A	4.00	--	4.70
A1	SEE NOTE "F"		
A2	2.10	--	2.85
b	0.55	--	1.00
b2	1.10	--	1.62
b4	1.42	--	1.62
c	0.36	--	0.60
D	13.90	--	16.30
D1	8.13	--	9.40
D2	11.50	--	14.30
D3	15.42	--	16.51
E	9.65	--	10.67
E1	7.59	--	8.65
e	2.40	--	2.67
H1	6.06	--	6.69
L	12.70	--	14.04
L1	2.70	--	4.10
P	3.50	--	4.00
Q	2.50	--	3.40
z	2.13 REF		
z1	2.06 REF		
θ	3°	--	5°

IF PRESENT, SEE NOTE "D"

GENERIC
MARKING DIAGRAM*



XXXX = Specific Device Code
A = Assembly Location
Y = Year
WW = Work Week
ZZ = Assembly Lot Code

*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "▪", may or may not be present. Some products may not follow the Generic Marking.



NOTES:

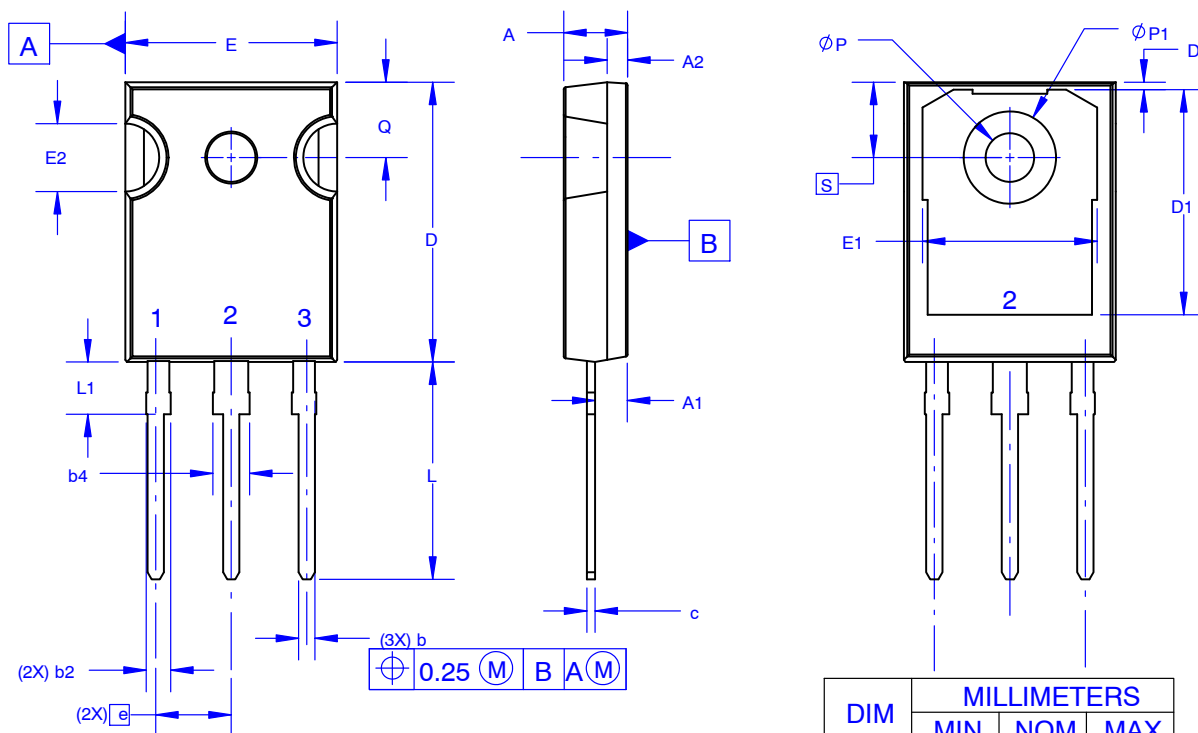
- A) REFERENCE JEDEC, TO-220, VARIATION AB
- B) ALL DIMENSIONS ARE IN MILLIMETERS.
- C) DIMENSIONS COMMON TO ALL PACKAGE SUPPLIERS EXCEPT WHERE NOTED [].
- D) LOCATION OF MOLDED FEATURE MAY VARY (LOWER LEFT CORNER, LOWER CENTER AND CENTER OF THE PACKAGE)
- E) DOES NOT COMPLY JEDEC STANDARD VALUE.
- F) "A1" DIMENSIONS AS BELOW:
SINGLE GAUGE = 0.51 - 0.61
DUAL GAUGE = 1.10 - 1.45
- G) PRESENCE IS SUPPLIER DEPENDENT
- H) SUPPLIER DEPENDENT MOLD LOCKING HOLES IN HEATSINK.

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DESCRIPTION:	TO-220-3LD	PAGE 1 OF 1

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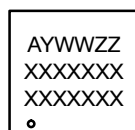
TO-247-3LD SHORT LEAD
CASE 340CK
ISSUE A

DATE 31 JAN 2019



NOTES: UNLESS OTHERWISE SPECIFIED.

- A. DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS.
B. ALL DIMENSIONS ARE IN MILLIMETERS.
C. DRAWING CONFORMS TO ASME Y14.5 - 2009.
D. DIMENSION A1 TO BE MEASURED IN THE REGION DEFINED BY L1.
E. LEAD FINISH IS UNCONTROLLED IN THE REGION DEFINED BY L1.

GENERIC
MARKING DIAGRAM*


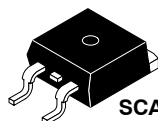
XXXX = Specific Device Code
A = Assembly Location
Y = Year
WW = Work Week
ZZ = Assembly Lot Code

*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "•", may or may not be present. Some products may not follow the Generic Marking.

DIM	MILLIMETERS		
	MIN	NOM	MAX
A	4.58	4.70	4.82
A1	2.20	2.40	2.60
A2	1.40	1.50	1.60
b	1.17	1.26	1.35
b2	1.53	1.65	1.77
b4	2.42	2.54	2.66
c	0.51	0.61	0.71
D	20.32	20.57	20.82
D1	13.08	~	~
D2	0.51	0.93	1.35
E	15.37	15.62	15.87
E1	12.81	~	~
E2	4.96	5.08	5.20
e	~	5.56	~
L	15.75	16.00	16.25
L1	3.69	3.81	3.93
ØP	3.51	3.58	3.65
ØP1	6.60	6.80	7.00
Q	5.34	5.46	5.58
S	5.34	5.46	5.58

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DESCRIPTION:	TO-247-3LD SHORT LEAD	PAGE 1 OF 1

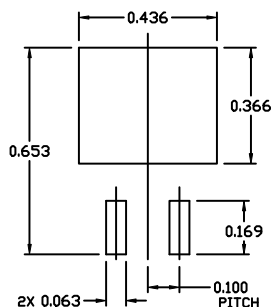
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SCALE 1:1

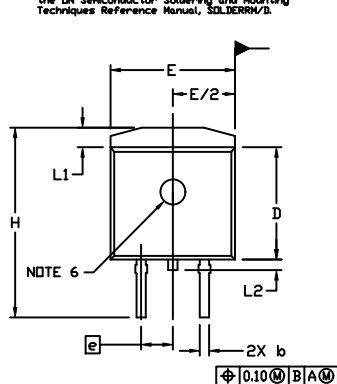
D²PAK-3 (TO-263, 3-LEAD)
CASE 418AJ
ISSUE F

DATE 11 MAR 2021



**RECOMMENDED
MOUNTING FOOTPRINT**

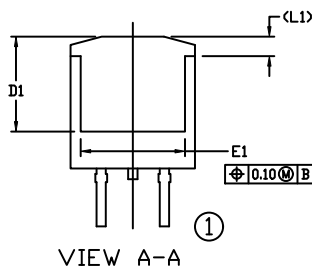
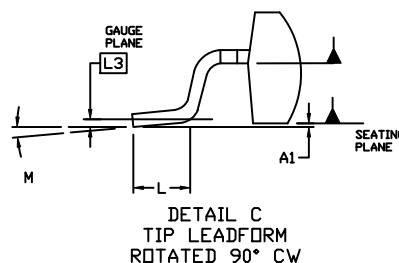
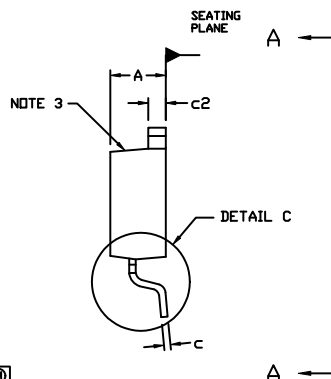
For additional information on our Pb-free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.



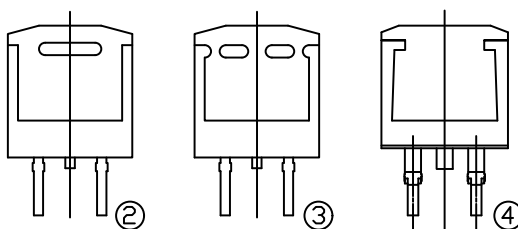
NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 2009.
2. CONTROLLING DIMENSION: INCHES
3. CHAMFER OPTIONAL.
4. DIMENSIONS D AND E DO NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.005 PER SIDE. THESE DIMENSIONS ARE MEASURED AT THE OUTERMOST EXTREMES OF THE PLASTIC BODY AT DATUM H.
5. THERMAL PAD CONTOUR IS OPTIONAL WITHIN DIMENSIONS E, L1, D1, AND E1.
6. OPTIONAL MOLD FEATURE.
7. ①, ② ... OPTIONAL CONSTRUCTION FEATURE CALL OUTS.

DIM	INCHES		MILLIMETERS	
	MIN.	MAX.	MIN.	MAX.
A	0.160	0.190	4.06	4.83
A1	0.000	0.010	0.00	0.25
b	0.020	0.039	0.51	0.99
c	0.012	0.029	0.30	0.74
c2	0.045	0.065	1.14	1.65
D	0.330	0.380	8.38	9.65
D1	0.260	---	6.60	---
E	0.380	0.420	9.65	10.67
E1	0.245	---	6.22	---
e	0.100 BSC	---	2.54 BSC	---
H	0.575	0.625	14.60	15.88
L	0.070	0.110	1.78	2.79
L1	---	0.066	---	1.68
L2	---	0.070	---	1.78
L3	0.010 BSC	---	0.25 BSC	---
M	0°	8°	0°	8°

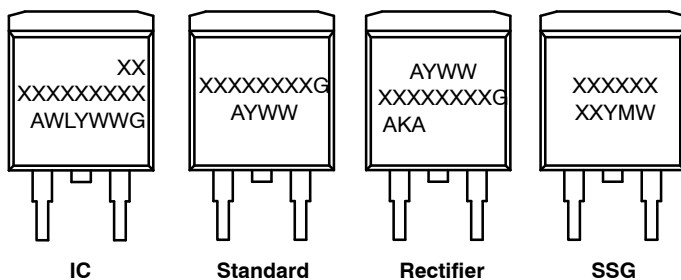


VIEW A-A



VIEW A-A
OPTIONAL CONSTRUCTIONS

GENERIC MARKING DIAGRAMS*



XXXXXX = Specific Device Code
A = Assembly Location
WL = Wafer Lot
Y = Year
WW = Work Week
W = Week Code (SSG)
M = Month Code (SSG)
G = Pb-Free Package
AKA = Polarity Indicator

*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "•", may or may not be present. Some products may not follow the Generic Marking.

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