Auto SPM® Series Automotive 3-Phase IGBT Smart Power Module

FAM65V05DF1

General Description

FAM65V05DF1 is an advanced Auto SPM module providing a fully−featured high−performance auxiliary inverter output stage for hybrid and electric vehicles. These modules integrate optimized gate drive of the built−in IGBTs to minimize EMI and losses, while also providing various protection features, in a compact 12 cm^2 footprint.

Features

- Automotive SPM in 27 Pin DIP Package
- 650 V/50 A 3−phase IGBT Module with Low Loss IGBTs and Soft Recovery Diodes Optimized for Motor Control Applications
- Integrated Gate Drivers with Internal VS connection, Under Voltage lockout, Over−current shutdown, Temperature Sensing Unit and Fault reporting
- Electrically Isolated AlN Substrate with Low $R\theta jc$
- Module Serialization for Full Traceability
- UL Certified No. E209204 (UL 1557)
- Pb−Free, Halid Free and RoHS Compliant
- AEC & AQG324 Qualified and PPAP Capable

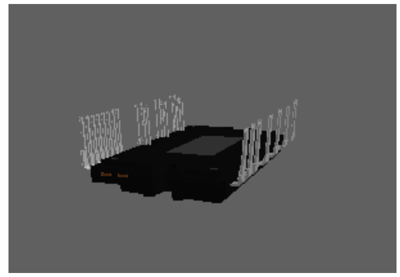
Applications and Benefits

Automotive high voltage auxiliary motors such as air conditioning compressor and oil pump.

- Compact Design
- Simplified PCB Layout and Low EMI
- Simplified Assembly
- High Reliability

Related Resources

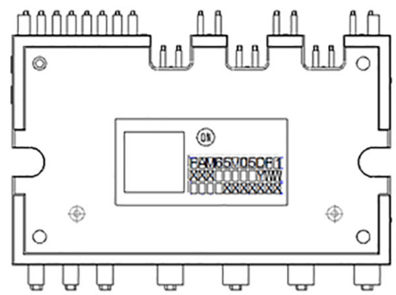
- AN−8422 – 650 V Auto SPM Series; Automotive 3−Phase IGBT Smart Power Module User’s Guide



3D Package Drawing
(Click to Activate 3D Content)

ASPM27−CCA
CASE MODCB

MARKING DIAGRAM



ON	= **onsemi** Logo
FAM65V05DF1	= Specific Device Code
XXX	= Lot Number
Y	= Year
WW	= Work Week
0000001	= Serial Number

ORDERING INFORMATION

See detailed ordering and shipping information on page 7 of this data sheet.

May, 2024 − Rev. 3
Publication Order Number:
FAM65V05DF1/D

PIN CONFIGURATION

TOP VIEW

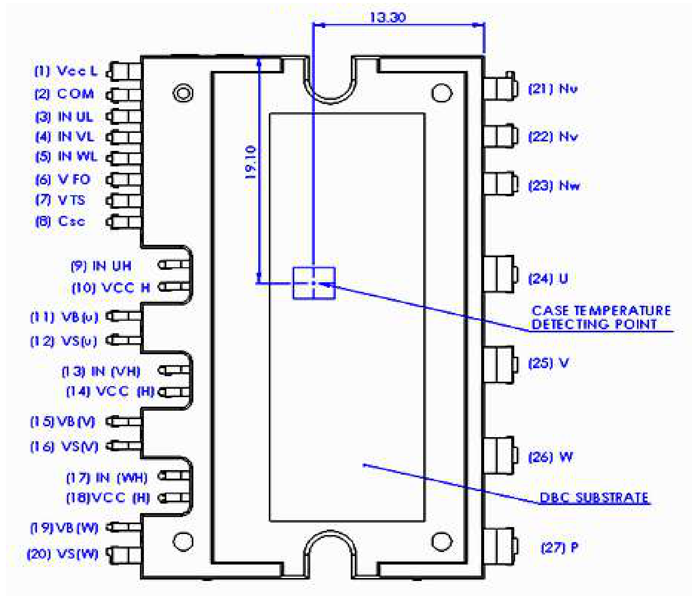


Figure 1. Pin Configuration

PIN DESCRIPTION

Pin Number	Name	Description
1	VCC (L)	Low−side Common Bias Voltage for IC and IGBTs Driving
2	COM	Common Supply Ground
3	IN (UL)	Signal Input for Low−side U Phase
4	IN (VL)	Signal Input for Low−side V Phase
5	IN (WL)	Signal Input for Low−side W Phase
6	VFO	Fault Output
7	VTS	Output for LVIC temperature sense
8	CSC	Capacitor (Low−pass Filter) for Short−Current Detection Input
9	IN (UH)	Signal Input for High−side U Phase
10	VCC (H)	High−side Common Bias Voltage for IC and IGBTs Driving
11	VB (U)	High−side Bias Voltage for U Phase IGBT Driving
12	VS (U)	High−side Bias Voltage Ground for U Phase IGBT Driving
13	IN (VH)	Signal Input for High−side V Phase
14	VCC (H)	High−side Common Bias Voltage for IC and IGBTs Driving
15	VB (V)	High−side Bias Voltage for V Phase IGBT Driving
16	VS (V)	High−side Bias Voltage Ground for V Phase IGBT Driving
17	IN (WH)	Signal Input for High−side W Phase
18	VCC (H)	High−side Common Bias Voltage for IC and IGBTs Driving
19	VB (W)	High−side Bias Voltage for W Phase IGBT Driving
20	VS (W)	High−side Bias Voltage Ground for W Phase IGBT Driving
21	NU	Negative DC–Link Input for U Phase
22	NV	Negative DC–Link Input for V Phase

PIN DESCRIPTION (continued)

Pin Number	Name	Description
23	NW	Negative DC–Link Input for W Phase
24	U	Output for U Phase
25	V	Output for V Phase
26	W	Output for W Phase
27	P	Positive DC–Link Input

INTERNAL EQUIVALENT CIRCUIT AND INPUT/OUTPUT PINS

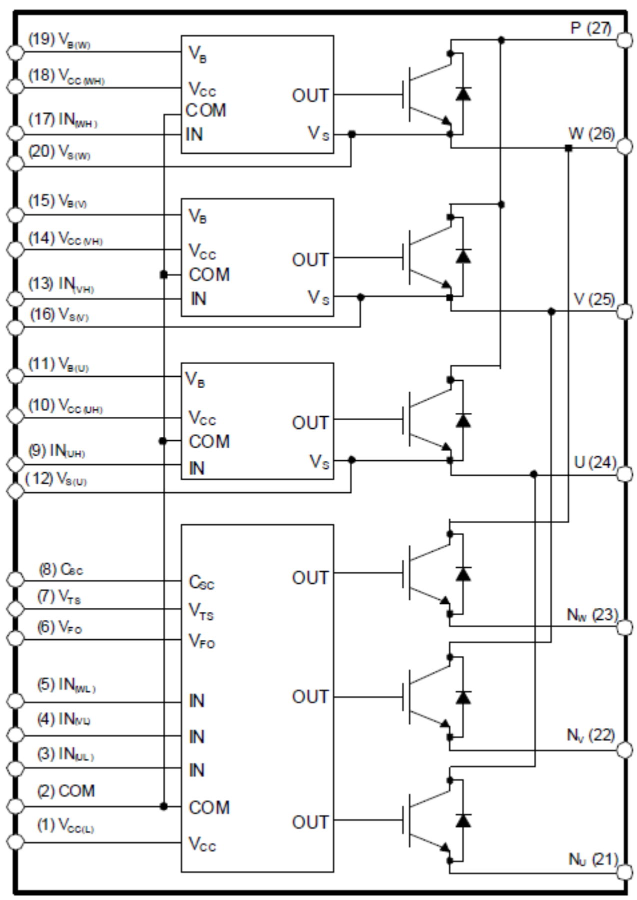


Figure 2. Schematic

GATE DRIVERS BLOCK DIAGRAM

High Side Gate Driver (x3 Single Channel)

- Control circuit under−voltage (UV) protection
- 3.3 V/5 V CMOS/LSTTL compatible, Schmitt trigger input

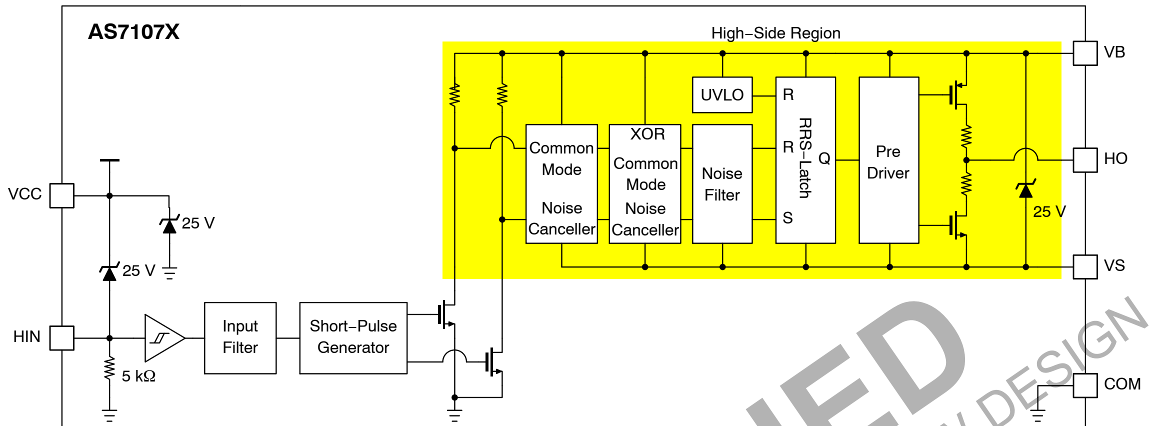


Figure 3. High Side Gate Drivers (Block Diagram)

Low Side Gate Driver (x1 Monolithic Three−Channel)

- Control circuit under−voltage (UV) protection
- Short circuit protection (SC)
- Temperature sensing unit
- Fault Output
- 3.3 V/5 V CMOS/LSTTL compatible, Schmitt trigger input

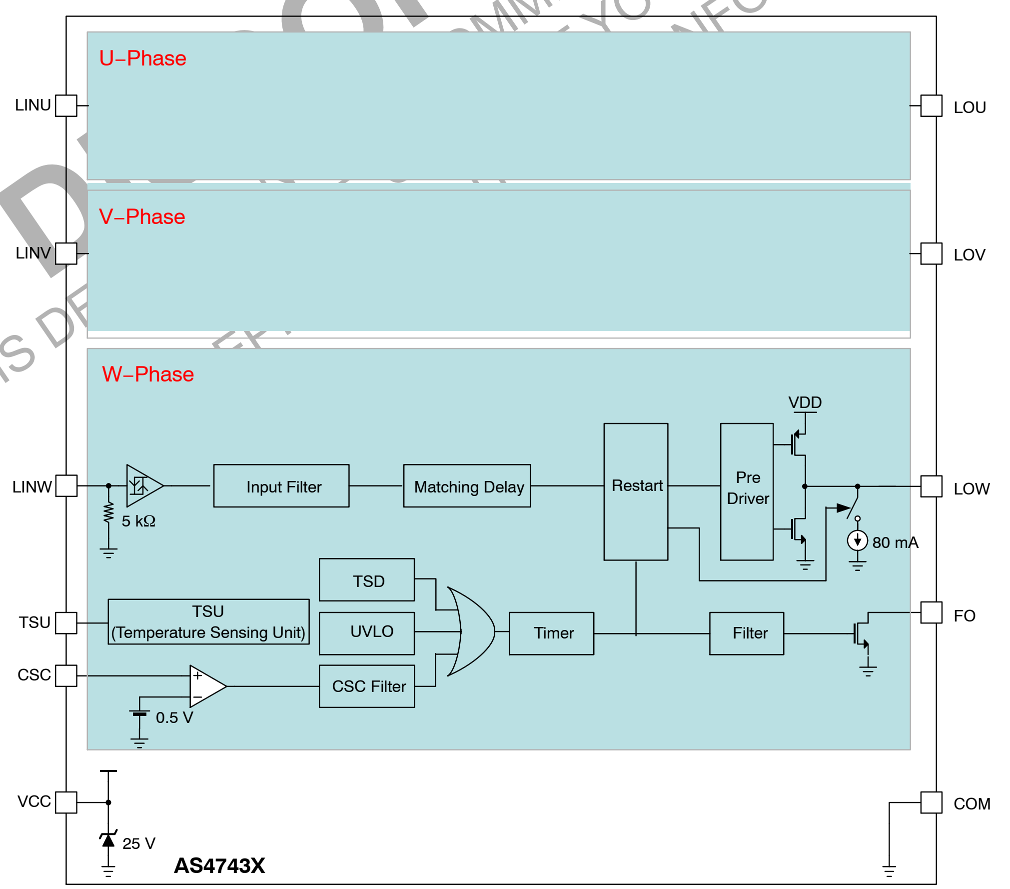


Figure 4. Low Side Gate Drivers (Block Diagram)

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

Symbol	Parameter	Conditions	Rating	Unit
INVERTER PART				
V_{PN}	Supply Voltage	Applied between P− N_U, N_V, N_W	500	V
$V_{PN(Surge)}$	Supply Voltage (Surge)	Applied between P− N_U, N_V, N_W dI/dt ≤ 3 A/ns	575	V
V_{CES}	Collector−Emitter Voltage at the IGBT/Diode	T_J = 25°C	650	V
$\pm I_C$	IGBT Continuous Collector Current	T_C = 100°C, T_{Jmax} = 175°C (Note 1)	50	A
$\pm I_{CP}$	IGBT Peak Collector Pulse Current	T_C = 100°C, T_{Jmax} = 175°C, V_{CC} = V_{BS} = 15 V, less than 1 ms (Note 6)	150	A
P_C	Collector Dissipation	T_C = 25°C per IGBT	333	W
T_J	Junction Temperature	IGBT/Diode	−40 ~ +175	°C
		Driver IC	−40 ~ +150	°C
CONTROL PART				
V_{CC}	Control Supply Voltage	Applied between $V_{CC(H)}$, $V_{CC(L)}$ − COM	20	V
V_{BS}	High−side Control Bias Voltage	Applied between $V_{B(U)}$ − $V_{S(U)}$, $V_{B(V)}$ − $V_{S(V)}$, $V_{B(W)}$ − $V_{S(W)}$	20	V
V_{IN}	Input Signal Voltage	Applied between $IN_{(UH)}$, $IN_{(VH)}$, $IN_{(WH)}$, $IN_{(UL)}$, $IN_{(VL)}$, $IN_{(WL)}$ − COM	−0.3 ~ V_{CC} + 0.3	V
V_{FO}	Fault Output Supply Voltage	Applied between V_{FO} − COM	−0.3 ~ V_{CC} + 0.3	V
I_{FO}	Fault Output Current	Sink Current at V_{FO} Pin	5	mA
V_{SC}	Current Sensing Input Voltage	Applied between C_{SC} − COM	−0.3 ~ V_{CC} + 0.3	V
V_{TS}	Temperature Sense Unit		−0.3 ~ 2/3 × V_{CC}	V
TOTAL SYSTEM				
T_{STG}	Storage Temperature		−40 ~ 125	°C
V_{ISO}	Isolation Voltage	60 Hz, Sinusoidal, AC 1 minute, Connection Pins to heat sink plate	2500	V_{rms}
T_{LEAD}	Max Lead Temperature at the Base of the Package During pcb Assembly	No remelt of internal solder joints	200	°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.

PACKAGE CHARACTERISTICS

Symbol	Parameter	Conditions	Typ	Max	Unit
$R_{th(j-c)Q}$	Junction to Case Thermal Resistance (Note 2)	Inverter IGBT part (per IGBT)	−	0.45	°C/W
$R_{th(j-c)F}$		Inverter FWD part (per DIODE)	−	0.85	°C/W
L_σ	Package Stray Inductance	P to N_U, N_V, N_W (Note 3)	24	−	nH

1. Current limited by package terminal, defined by design.
2. Case temperature measured below the package at the chip center, compliant with MIL STD 883−1012.1 (single chip heating), DBC discoloration allowed, please refer to application note AN−9190 *(Impact of DBC Oxidation on SPM Module Performance).*
3. Stray inductance per phase measured per IEC 60747−15.

ELECTRICAL CHARACTERISTICS

Symbol		Parameter	Test Conditions	Min	Typ	Max	Unit
INVERTER PART (T_J as specified)							
$V_{CE(SAT)}$		Collector-Emitter Leakage Current	$V_{CC} = V_{BS} = 15$ V, $V_{IN} = 5$ V $I_C = 50$ A, $T_J = 25°C$	–	1.65	–	V
			$V_{CC} = V_{BS} = 15$ V, $V_{IN} = 5$ V $I_C = 50$ A, $T_J = 125°C$	–	1.9	2.4	V
V_F		FWD Forward Voltage	$V_{IN} = 0$ V, $I_F = 30$ A, $T_J = 25°C$	–	2.1	–	V
			$V_{IN} = 0$ V, $I_F = 30$ A, $T_J = 125°C$	–	1.9	2.5	V
HS	t_{ON}	High Side Switching Times	$V_{PN} = 300$ V, $V_{CC} = V_{BS} = 15$ V $I_C = 50$ A $V_{IN} = 0$ V ↔ 5 V, Ls = 55 nH, Inductive Load $T_J = 25°C$ (Notes 4, 5)	–	0.73	–	μs
	$t_{C(ON)}$			–	0.12	–	
	t_{OFF}			–	0.80	–	
	$t_{C(OFF)}$			–	0.14	–	
	t_{rr}			–	0.10	–	
	t_{ON}	High Side Switching Times	$V_{PN} = 300$ V, $V_{CC} = V_{BS} = 15$ V $I_C = 50$ A $V_{IN} = 0$ V ↔ 5 V, Ls = 55 nH, Inductive Load $T_J = 125°C$ (Notes 4, 5)	–	0.70	–	μs
	$t_{C(ON)}$			–	0.15	–	
	t_{OFF}			–	0.87	–	
	$t_{C(OFF)}$			–	0.19	–	
	trr			–	0.20	–	
LS	t_{ON}	Low Side Switching Times	$V_{PN} = 300$ V, $V_{CC} = V_{BS} = 15$ V $I_C = 50$ A $V_{IN} = 0$ V ↔ 5 V, Ls = 55 nH, Inductive Load $T_J = 25°C$ (Notes 4, 5)	–	0.68	–	μs
	$t_{C(ON)}$			–	0.20	–	
	t_{OFF}			–	0.86	–	
	$t_{C(OFF)}$			–	0.19	–	
	t_{rr}			–	0.14	–	
	t_{ON}	Low Side Switching Times	$V_{PN} = 300$ V, $V_{CC} = V_{BS} = 15$ V $I_C = 50$ A $V_{IN} = 0$ V ↔ 5 V, Ls = 55 nH, Inductive Load $T_J = 125°C$ (Notes 4, 5)	–	0.64	–	μs
	$t_{C(ON)}$			–	0.24	–	
	t_{OFF}			–	0.88	–	
	$t_{C(OFF)}$			–	0.23	–	
	trr			–	0.20	–	
SCWT		Short Circuit Withstand Time (Note 6)	$V_{CC} = V_{BS} = 15$ V, $V_{PN} = 450$ V, $T_J = 25°C$, Non−repetitive	–	5	–	μs
I_{CES}		Collector−Emitter Leakage Current for IGBT and Diode in Parallel	$T_J = 25°C$, $V_{CE} = 650$ V	–	3	–	μA
			$T_J = 125°C$, $V_{CE} = 650$ V	–	150	1500	μA

ELECTRICAL CHARACTERISTICS (continued)

Symbol	Parameter	Test Conditions		Min	Typ	Max	Unit
CONTROL PART (T_J = −40°C to 150°C, unless otherwise specified, typical values specified at T_J = 125°C)							
I_{QCCL}	Quiescent V_{CC} Supply Current	V_{CC} = 15 V, $IN_{(UL, VL, WL)}$ = 0 V	$V_{CC(L)}$ − COM	–	–	5	mA
I_{QCCH}		V_{CC} = 15 V, $IN_{(UH, VH, WH)}$ = 0 V	$V_{CC(H)}$ − COM	–	–	150	μA
I_{PCCH}	Operating V_{CC} Supply Current	$V_{CC(UH, VH, WH)}$ = 15 V f_{PWM} = 20 kHz Duty = 50%, applied to one PWM signal input for high−side	$V_{CC(UH)}$ − COM $V_{CC(VH)}$ − COM $V_{CC(WH)}$ − COM	–	–	0.30	mA
I_{QCCL}		$V_{CC(UH, VH, WH)}$ = 15 V f_{PWM} = 20 kHz Duty = 50%, applied to one PWM signal input for low−side	$V_{CC(L)}$ − COM	–	–	8.5	mA
I_{QBS}	Quiescent V_{BS} Supply Current	V_{BS} = 15 V, $IN_{(UH, VH, WH)}$ = 0 V	$V_{B(U)} - V_{S(U)}$ $V_{B(V)} - V_{S(V)}$ $V_{B(W)} - V_{S(W)}$	–	–	150	μA
I_{PBS}	Operating V_{BS} Supply Current	$V_{CC} = V_{BC}$ = 15 V $IN_{(UH, VH, WH)}$ = 0 V	$V_{B(U)} - V_{S(U)}$ $V_{B(V)} - V_{S(V)}$ $V_{B(W)} - V_{S(W)}$	–	–	4.5	mA
V_{FOH}	Fault Output Voltage	V_{SC} = 0 V, V_{FO} Circuit: 4.7 kΩ to 5 V Pull−up		4.5	–	–	V
V_{FOL}		V_{SC} = 1 V, V_{FO} Circuit: 4.7 kΩ to 5 V Pull−up		–	–	0.5	V
$V_{SC(ref)}$	Short−Circuit Trip Level	V_{CC} = 15 V (Note 7)	C_{SC}−COM	0.45	0.52	0.59	V
UV_{CCD}	Supply Circuit Under−Voltage Protection	Detection Level, T_J = 125°C		10.6	–	13.2	V
UV_{CCR}		Reset Level, T_J = 125°C		11.0	–	13.8	V
UV_{BSD}		Detection Level, T_J = 125°C		10.5	–	13	V
UV_{BSR}		Reset Level, T_J = 125°C		10.8	–	13.3	V
t_{FOD}	Fault−out Pulse Width			–	60	–	μs
V_{TS}	LVIC Temperature Sensing Voltage Output	$V_{CC(L)}$ = 15 V, T_{LVIC} =125°C (Note 8)		–	2.4	–	V
$V_{IN(ON)}$	ON Threshold Voltage	Applied between $IN_{(UH)}$, $IN_{(VH)}$, $IN_{(WH)}$, $IN_{(UL)}$, $IN_{(VL)}$, $IN_{(WL)}$ − COM		–	2.6	3.1	V
$V_{IN(OFF)}$	OFF Threshold Voltage			0.9	1.2	–	V

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.

4. t_{ON} and t_{OFF} include the propagation delay time of the internal drive IC. $t_{C(ON)}$ and $t_{C(OFF)}$ are the switching times of IGBT itself under the given gate driving condition internally. Refer to Figure 6 for detailed information.
5. Stray inductance Ls is sum of stray inductance of module & setup.
6. Verified by design and bench−testing only.
7. Short−circuit current protection is functional only for low side.
8. T_{LVIC} is the junction temperature of the LVIC itself.

PACKAGE MARKING AND ORDERING INFORMATION

Part Number	Top Marking	Package	Shipping
FAM65V05DF1	FAM65V05DF1	ASPM27−CCA	10 Units/Tube

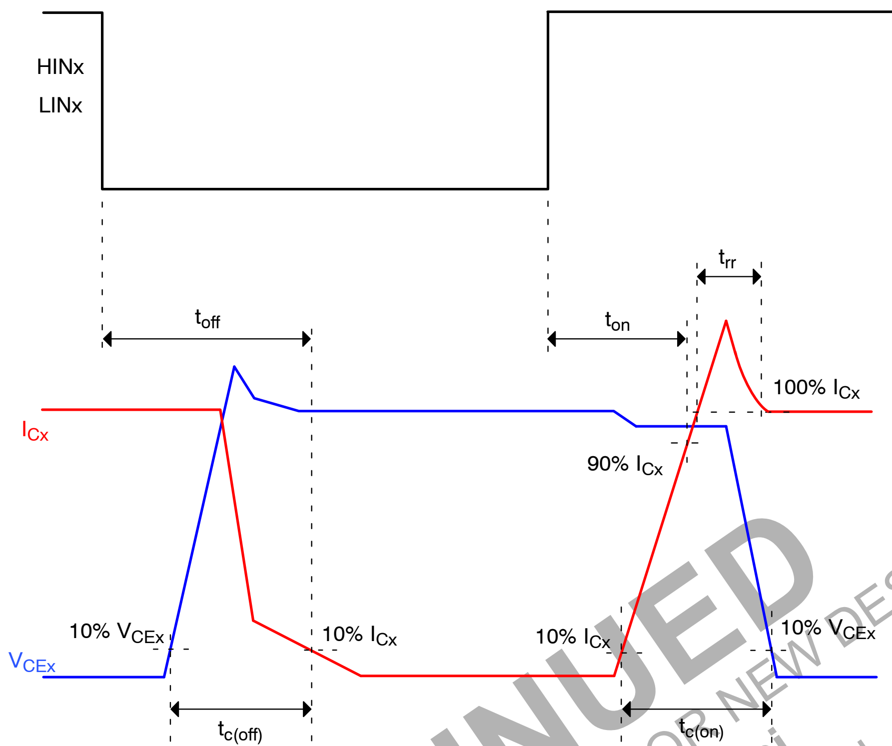


Figure 5. Switching Time Definition

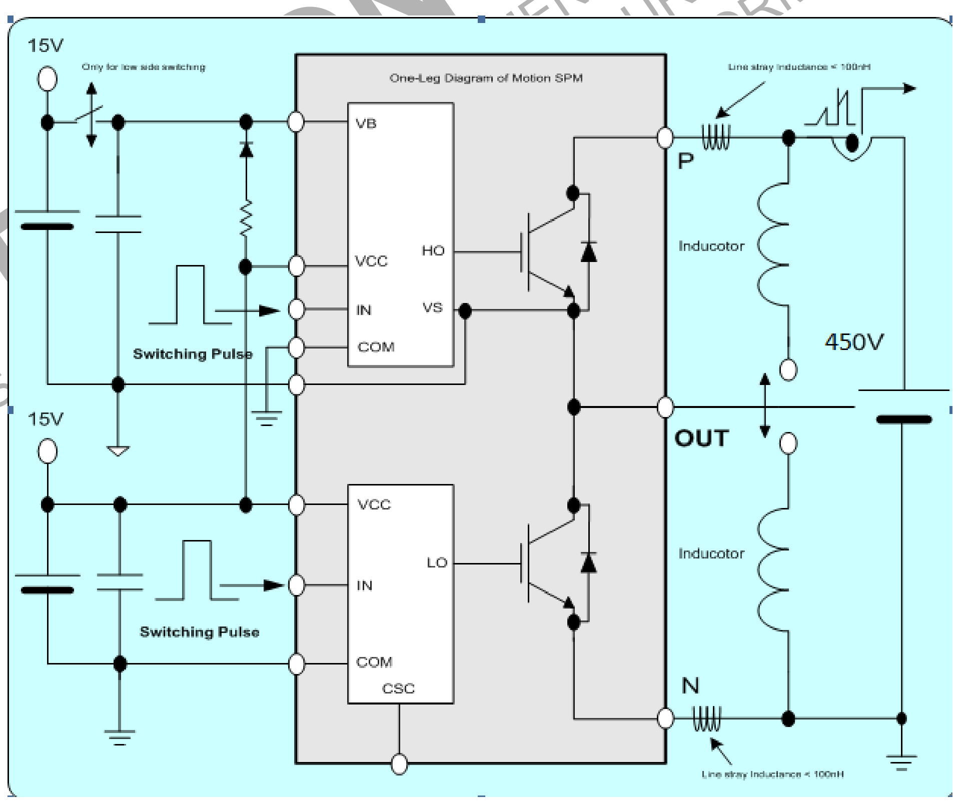


Figure 6. Switching Evaluation Circuit

RECOMMENDED OPERATING CONDITIONS

Symbol	Parameter	Conditions	Min	Max	Max	Unit
V_{PN}	Supply Voltage	Applied between P – N_U, N_V, N_W	–	450	500	V
V_{CC}	Control Supply Voltage	Applied between $V_{CC(H)}$, $V_{CC(L)}$ – COM	13.5	15	16.5	V
V_{BS}	High−side Bias Voltage	Applied between $V_{B(U)} - V_{S(U)}$, $V_{B(V)} - V_{S(V)}$, $V_{B(W)} - V_{S(W)}$	13.3	15	18.5	V
dV_{CC}/dt, dV_{BS}/dt	Control Supply Variation		−1	–	1	V/μs
t_{dead}	Blanking Time for Preventing Arm−short	For Each Input Signal	1.0	–	–	μs
f_{PWM}	PWM Input Signal	T_C = 125°C	–	–	20	kHz
V_{SEN}	Voltage for Current Sensing	Applied between N_U, N_V, N_W – COM (Including surge voltage)	−4	–	4	V
T_J	Junction Temperature		−40	–	150	°C

MECHANICAL CHARACTERISTICS AND RATINGS

Parameter	Conditions	Conditions	Limits			Unit
			Min	Typ	Max	
Mounting Torque	Mounting Screw: – M3	Recommended 0.62 N·m	0.52	0.62	0.80	N·m
Device Flatness			–	–	+150	μm
Weight			–	15	–	g

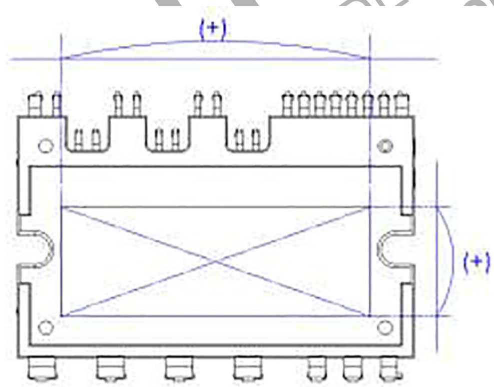


Figure 7. Flatness Measurement Position

TYPICAL INVERTER CHARACTERISTICS

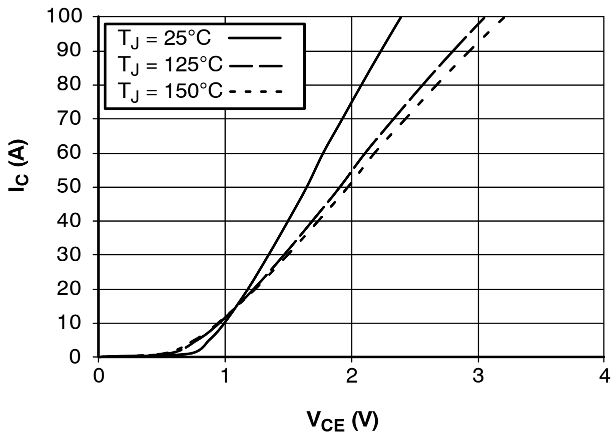


Figure 8. Output Characteristics IGBT Inverter (Typical)
$V_{CC} = V_{BS} = 15$ V, $V_{IN} = 5$ V

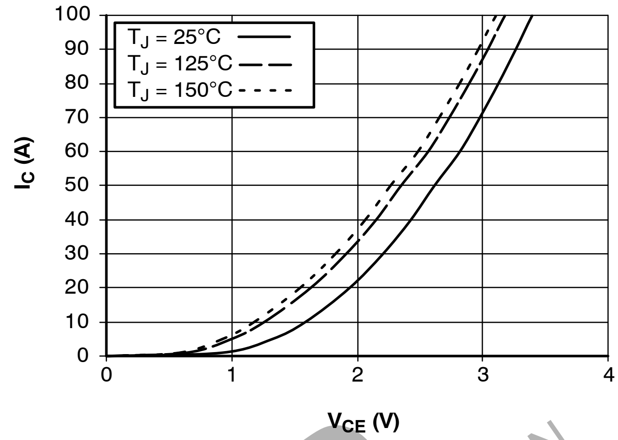


Figure 9. Forward Characteristics DIODE Inverter (Typical)
$V_{IN} = 0$ V

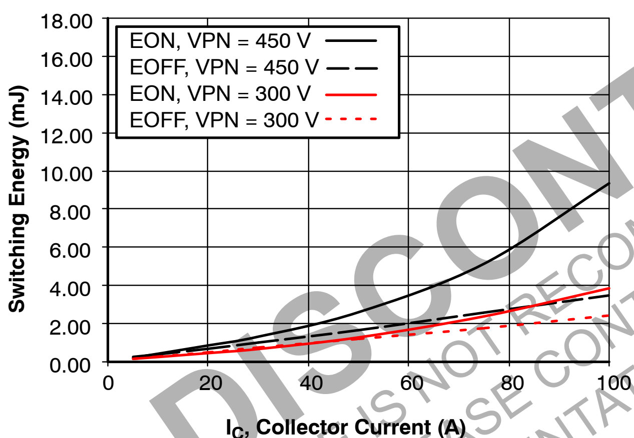


Figure 10. Switching Losses IGBT Inverter High−Side (Typical) versus Collector Current
$V_{CC} = V_{BS} = 15$ V
$V_{IN} = 0$ V ↔ 5 V, Ls = 55 nH, Inductive Load, $T_J = 125$°C

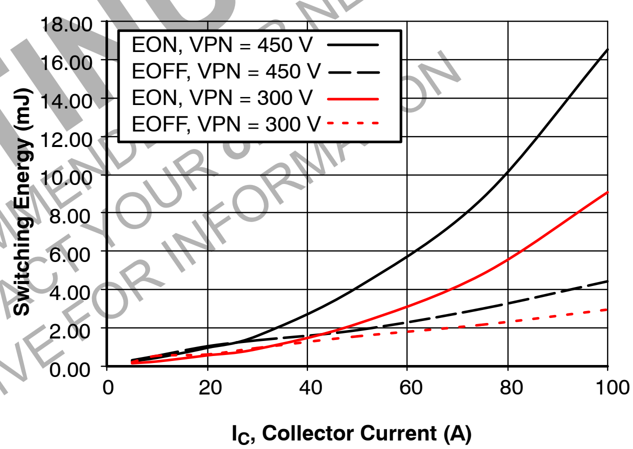


Figure 11. Switching Losses IGBT Inverter Low−Side (Typical) versus Collector Current
$V_{CC} = V_{BS} = 15$ V
$V_{IN} = 0$ V ↔ 5 V, Ls = 55 nH, Inductive Load, $T_J = 125$°C

TYPICAL INVERTER CHARACTERISTICS (continued)

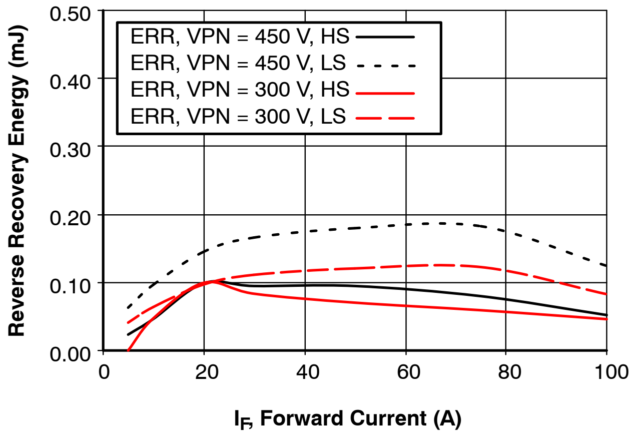


Figure 12. Reverse Recovery Energy DIODE Inverter (Typical) versus Forward Current

$V_{CC} = V_{BS} = 15$ V

$V_{IN} = 0$ V ↔ 5 V, Ls = 55 nH, Inductive Load, $T_J = 125°C$

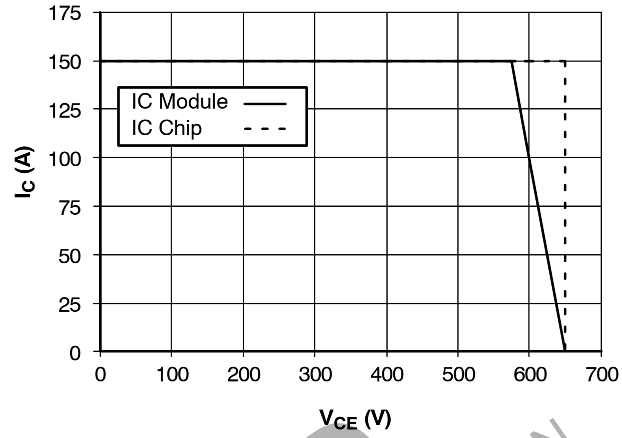


Figure 13. Reverse Bias Safe Operating Area IGBT (RBSOA) Inverter

$V_{CC} = V_{BS} = 15$ V, Tj = 150°C

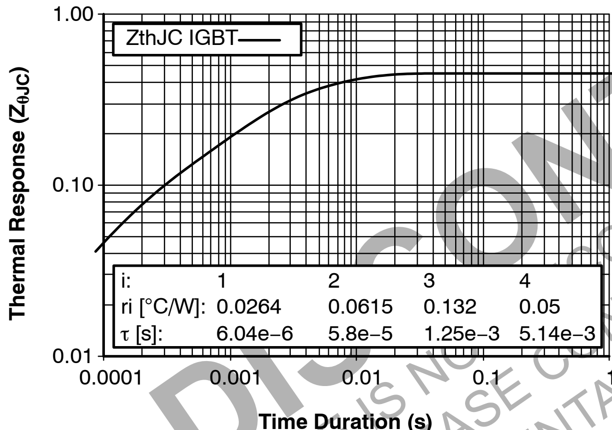


Figure 14. Transient Thermal Impedance IGBT Inverter

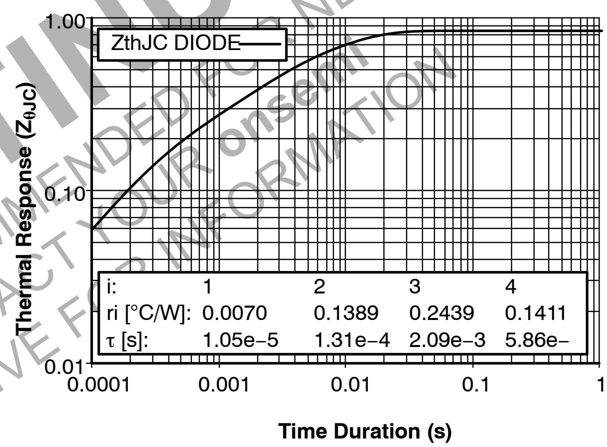


Figure 15. Transient Thermal Impedance DIODE Inverter

TYPICAL CONTROLLER CHARACTERISTICS

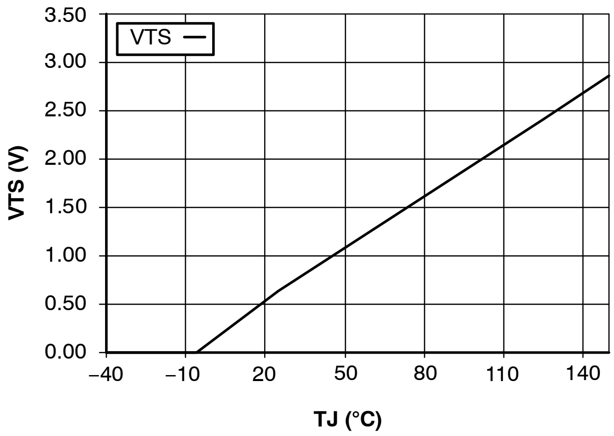


Figure 16. Temperature Profile of V_{TS} (Typical)

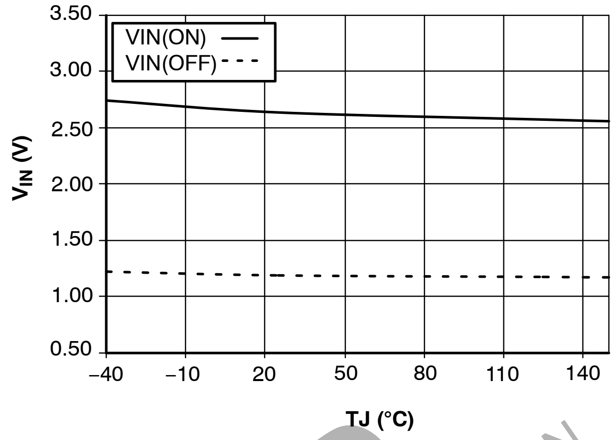


Figure 17. Threshold Voltage versus Temperature

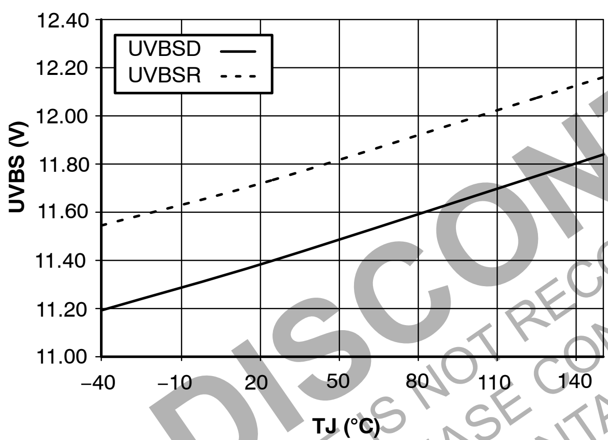


Figure 18. Supply Under−Voltage Protection High−Side (Typical)

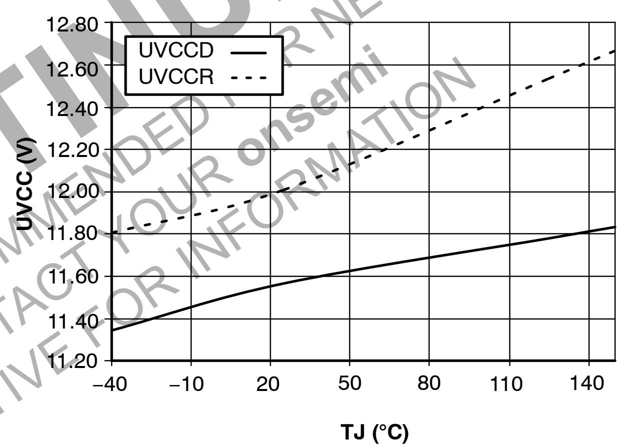
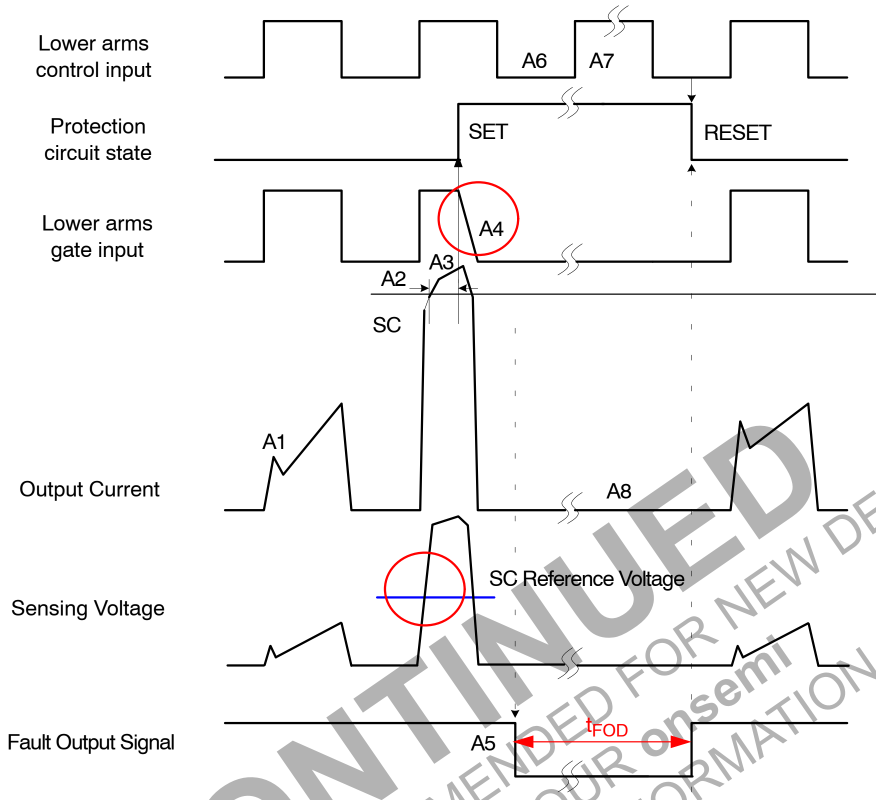


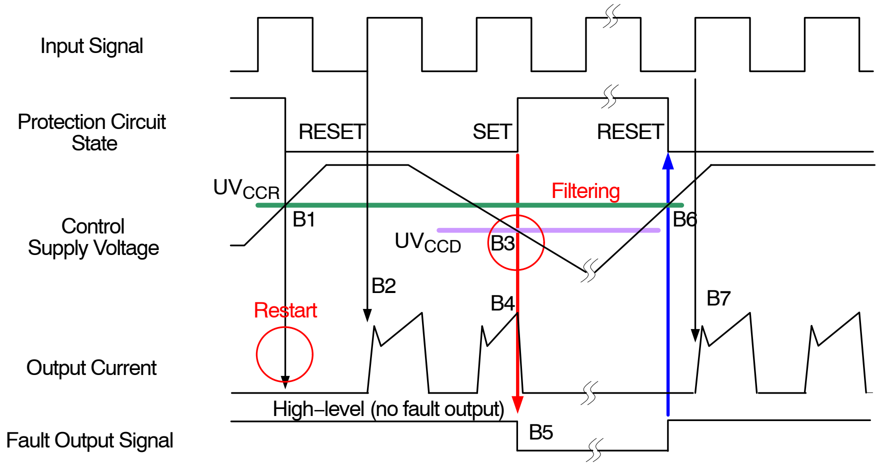
Figure 19. Supply Under−Voltage Protection Low−Side (Typical)

TIMING CHART PROTECTIVE FUNCTION



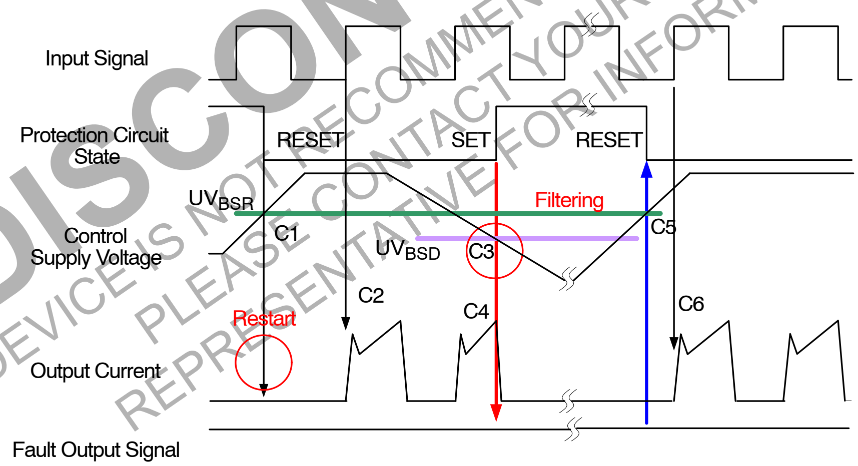
Step	Description
A1	Normal operation. IGBT on and carrying current
A2	Short−circuit current threshold reached
A3	Protection function triggered
A4	IGBT turns off with soft turn−off
A5	Fault output activated (initial delay 2 μs, t_{FOD} min. 50 μs)
A6	IGBT “LO” input
A7	IGBT “HI” input is ignored
A8	Current stays at zero during fault state

Figure 20. Short−Circuit Current Protection



Step	Description
B1	Control supply voltage rises above reset voltage UV_{CCR}
B2	Normal operation. IGBT on and carrying current
B3	Control supply voltage falls below detection voltage UV_{CCD}
B4	Filtered supply voltage falls below UV_{CCD} and IGBT turns off
B5	Fault output activated (initial delay 2 μs, t_{FOD} min. 50ms)
B6	Control supply voltage rises above reset voltage UV_{CCR}
B7	IGBT “HI” input is followed after fault output duration and supply voltage rise

Figure 21. Under−Voltage Protection (Low−side)



Step	Description
C1	Control supply voltage rises above reset voltage UV_{CCR}
C2	Normal operation. IGBT on and carrying current
C3	Control supply voltage falls below detection voltage UV_{CCD}
C4	Filtered supply voltage falls below UVCCD and IGBT turns off
C5	Control supply voltage rises above reset voltage UV_{CCR}
C6	IGBT “HI” input is followed after supply voltage rise

Figure 22. Under−Voltage Protection (High−side)

27LD MODULE PDD STD
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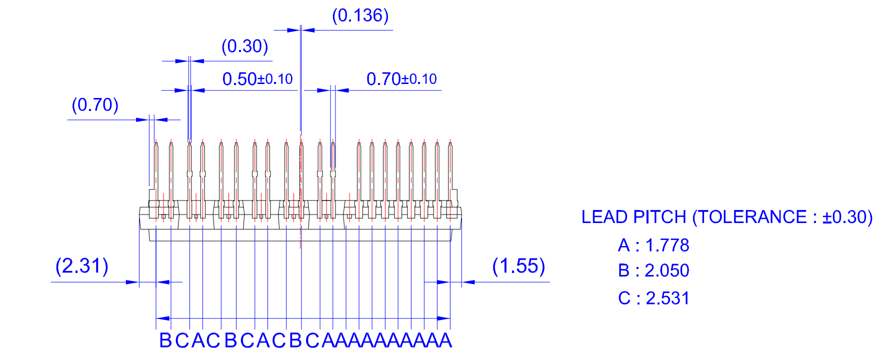

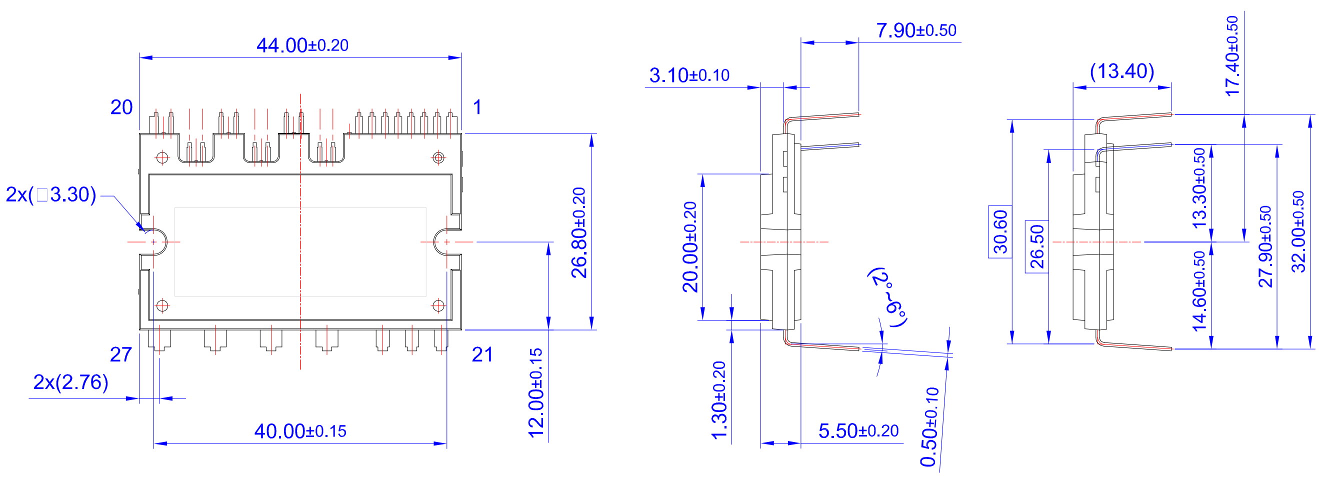

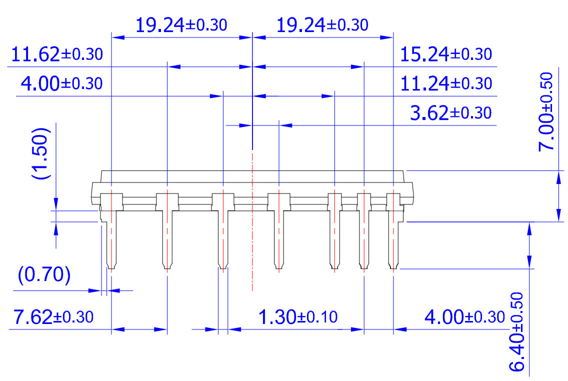

NOTES: UNLESS OTHERWISE SPECIFIED
A) THIS PACKAGE DOES NOT COMPLY TO ANY CURRENT PACKAGING STANDARD
B) ALL DIMENSIONS ARE IN MILLIMETERS.
C) DIMENSIONS ARE EXCLUSIVE OF BURRS, MOLD FLASH, AND TIE BAR EXTRUSIONS.
D) ( ) IS REFERENCE

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