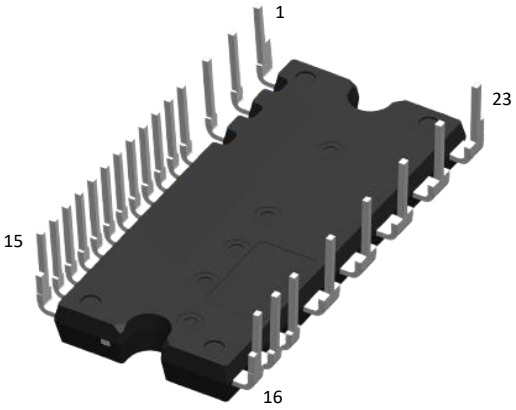
AIP5D05V060Q6(S/U)

Dual-In-Line Package Intelligent Power Module

External View



Size: 33.4 x 15 x 3.6 mm

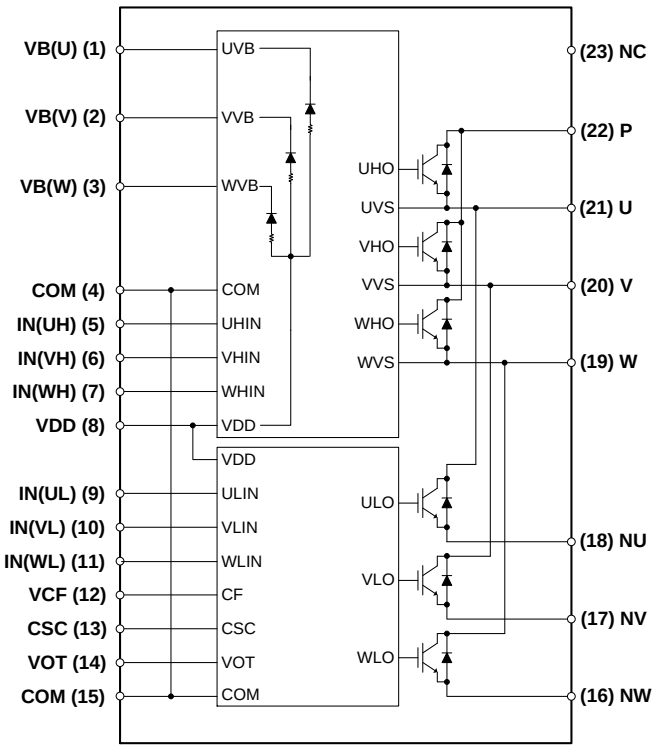
Features

- 600V-5A with rugged IGBT and low Qrr fast recovery diode
- 3 phase Inverter module including HVIC drivers
- Built-in bootstrap diodes with current-limiting resistor
- Control supply under-voltage lockout protection (UVLO)
- Temperature monitoring (VOT) and optional over-temperature protection (OT)
- Short-circuit current protection (CSC)
- Fault signaling (VCF): Corresponding to SC, UV and OT fault (The fault output duration time can be controlled)
- Enable MCU to shut down all low-side IGBTs
- Input interface: 3.3V and 5V line, Schmitt trigger receiver circuit (Active high)
- Isolation rating of 2000Vrms/min

Applications

- AC 100-240Vrms class low power motor drives
- Refrigerator, Dishwasher, Fan Motor and Washing Machine

Internal Equivalent Circuit / Pin Configuration



Ordering Information

Part Number	Package	Description	Pin Length Description
AIP5D05V060Q6	-40°C to 150°C	IPM-5	Normal
AIP5D05V060Q6S	-40°C to 150°C	IPM-5A	Short
AIP5D05V060Q6U	-40°C to 150°C	IPM-5C	Ultra-short

AOS Green Products use reduced levels of Halogens, and are also RoHS compliant.
Please visit https://aosmd.com/sites/default/files/media/AOSGreenPolicy.pdf for additional information.

Pin Description

Pin Number	Pin Name	Pin Function
1	VB(U)	High-side bias voltage for U-phase IGBT driving
2	VB(V)	High-side bias voltage for V-phase IGBT driving
3	VB(W)	High-side bias voltage for W-phase IGBT driving
4	COM	Common supply ground
5	IN(UH)	Signal input for high-side U-phase
6	IN(VH)	Signal input for high-side V-phase
7	IN(WH)	Signal input for high-side W-phase
8	VDD	Control supply voltage
9	IN(UL)	Signal input for low-side U-phase
10	IN(VL)	Signal input for low-side V-phase
11	IN(WL)	Signal input for low-side W-phase
12	VCF	Controllable fault output
13	CSC	Short-circuit current detection Input
14	VOT	Voltage output of LVIC temperature
15	COM	Common supply ground
16	NW	Negative dc-link input for W-phase
17	NV	Negative dc-link input for V-phase
18	NU	Negative dc-link input for U-phase
19	W	Output for W-phase
20	V	Output for V-phase
21	U	Output for U-phase
22	P	DC-link positive input
23	NC	No connection

Absolute Maximum Ratings

T_J = 25°C, unless otherwise specified.

Symbol	Parameter	Conditions	Ratings	Units
Inverter				
V_{PN}	Supply voltage	Applied between P-Nx, x=U, V, W	450	V
$V_{PN(surge)}$	Supply voltage (surge)	Applied between P-Nx	500	V
V_{CES}	Collector-emitter voltage	T_J=25°C	600	V
I_C	IGBT collector current (continuous)	T_C=25°C, T_J<150°C	5	A
		T_C=100°C, T_J<150°C	3	A
$\pm I_{PK}$	IGBT collector current (pulsed)	T_C=25°C, less than 1ms pulse width	10	A
P_C	Maximum power dissipation	T_C=25°C, per chip	18.9	W
T_J	Operating junction temperature		-40 to 150	°C
Control (Protection)				
V_{DD}	Control supply voltage	Applied between VDD-COM	-0.3 ~ 20	V
V_{BS}	High-side control supply voltage	Applied between VB(x)-x	-0.3 ~ 20	V
V_{IN}	IN input voltage	Applied between IN(xH), IN(xL)-COM	-0.3 ~ V_{DD}+0.5	V
V_{CF}	Fault output supply voltage	Applied between VCF-COM	-0.3 ~ 5.5	V
I_{CF}	Fault output current	Sink current at VCF terminal	1	mA
V_{CSC}	Current sensing input voltage	Applied between CSC-COM	-0.3 ~ 5.5	V
V_{OT}	Temperature output	Applied between VOT-COM	-0.3 ~ 5.5	V
Total System				
$V_{PN(PROT)}$	Self-protection supply voltage limit (Short-circuit protection capability)	V_{DD}=13.5-16.5V, Inverter part Non-repetitive, less than 2µs	400	V
T_C	Module case operation temperature	Measurement point of T_C is provided in Figure 1	-40 to 125	°C
T_{STG}	Storage temperature		-40 to 150	°C
V_{ISO}	Isolation voltage	60Hz, sinusoidal, AC 1min, between connected all pins and heat sink plate	2000	V_{rms}

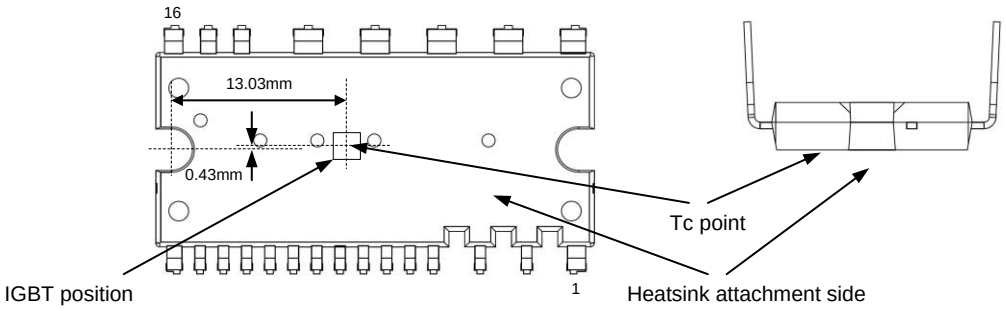


Figure 1. Tc Measurement Point

Thermal Resistance

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Units
$R_{th(j-c)Q}$	Junction to case thermal resistance (Note 1)	Single IGBT	-	-	6.6	K/W
$R_{th(j-c)F}$		Single Diode	-	-	8.5	K/W

Note:

1. For the measurement point of case temperature (T_C), please refer to Figure 1.

Electrical Characteristics

V_{DD}=15V, V_{BS}=15V and T_J=25°C, unless otherwise specified.

Symbol	Parameter	Conditions		Min.	Typ.	Max.	Units
Inverter							
$V_{CE(SAT)}$	Collector-emitter saturation voltage	V_{IN}=5V	I_C=2.5A, T_J=25°C	-	1.45	1.85	V
			I_C=2.5A, T_J=125°C	-	1.65	-	V
V_F	FWD forward voltage	V_{IN}=0V	I_F=2.5A, T_J=25°C	-	1.45	1.90	V
t_{OFF}	Switching time	V_{PN}=300V, I_C=2.5A, T_J=25°C, V_{IN}=0V ↔ 5V, Inductive load (high-side)		-	1.01	-	µs
t_f				-	0.07	-	µs
t_{ON}				-	0.82	-	µs
t_r				-	0.03	-	µs
t_{rr}				-	0.10	-	µs
I_{CES}	Collector-emitter leakage current	V_{IN}=0V, V_{CE}=600V	T_J=25°C	-	-	1	mA
			T_J=125°C	-	-	10	mA
Control (Protection)							
I_{QDD}	Quiescent VDD supply current	$V_{IN(xL)}$=$V_{IN(xH)}$=0V, VDD-COM		-	-	1.5	mA
		$V_{IN(xL)}$=5V, $V_{IN(xH)}$=0V, VDD-COM		-	-	2.6	mA
I_{QBS}	Quiescent VBS supply current	$V_{IN(xL)}$=$V_{IN(xH)}$=0V, VB(x)-x		-	-	0.1	mA
		$V_{IN(xL)}$=0V, $V_{IN(xH)}$=5V, VB(x)-x		-	-	1.0	mA
UV_{DDT}	VDD supply under-voltage protection	Trip level		10.3	11.4	12.5	V
UV_{DDR}		Reset level		10.8	11.9	13.0	V
UV_{BST}	VBS supply under-voltage protection	Trip level		9.0	10.0	11.0	V
UV_{BSR}		Reset level		10.0	11.0	12.0	V
I_{IN}	Input bias current	V_{IN}=5V		-	0.72	-	mA
$V_{IN,TH(ON)}$	ON threshold voltage	IN(xH), IN(xL)-COM		-	2.3	2.6	V
$V_{IN,TH(OFF)}$	OFF threshold voltage			0.8	1.2	-	V
$V_{CSC(REF)}$	Short-circuit trip level	CSC-COM (Note 2)		0.455	0.480	0.505	V
V_{OT}	Temperature output	Pull-down R=10kΩ (Note 3)	LVIC T_J=95°C	2.72	2.85	2.97	V
			LVIC T_J=25°C	0.77	1.00	1.25	V
T_{OT}	Over-temperature protection (Note 4)	Trip level		115	130	145	°C
$T_{OT(HYS)}$		Reset hysteresis		-	30	-	°C
V_{CFH}	Fault output voltage	V_{CSC}=0V, VCF with 10kΩ and 5V pull-up		4.9	-	-	V
V_{CFL}		V_{CSC}=1V, VCF with 10kΩ and 5V pull-up		-	-	0.5	V
V_{CF+}	CF positive going threshold			-	1.9	2.2	V
V_{CF-}	CF negative going threshold			0.8	1.1	-	V
t_{FO}	Fault output pulse width	Pull-up resistor only (Note 5)		20	-	-	µs
Bootstrap Diode							
$V_{F(BSD)}$	Bootstrap diode forward voltage	I_F=10mA including voltage drop by limiting resistor and bootstrap diode		-	2.5	-	V
R_{BSD}	Bootstrap diode equivalent resistance			-	250	-	Ω

Notes:

2. Short-circuit protection works only for low side IGBTs.
3. When temperature exceeds the protective level that the user defined, the controller (MCU) should stop the IPM. Temperature of LVIC vs. V_{OT} output characteristics is described in Figure 2.
4. When the LVIC temperature exceeds OT Trip temperature level (T_{OT}), OT protection is triggered and fault outputs.
5. Fault signal (V_{CF}) outputs when SC, UV or OT protection is triggered. Its duration time can be controlled by using the capacitor (see Figure 4). It is noted that VCF output has min. 20µs of t_{FO} pulse width when SC protection works.

Recommended Operation Conditions

Symbol	Parameter	Conditions	Min.	Typ.	Max	Units
V_{PN}	Supply voltage	Applied between P-Nx	0	300	450	V
V_{DD}	Control supply voltage	Applied between VDD-COM	13.5	15.0	16.5	V
V_{BS}	High-side bias voltage	Applied between VB(x)-x	13.5	15.0	18.5	V
dV_{DD}/dt, dV_{BS}/dt	Control supply voltage variation		-1	-	1	V/µs
t_{DEAD}	Dead time	For each input signal	1.0	-	-	µs
f_{PWM}	PWM input frequency	-40°C < T_J < 150°C	-	-	20	kHz
$PW_{IN(ON)}$	Minimum input pulse width	(Note 6)	0.7	-	-	µs
$PW_{IN(OFF)}$			0.7	-	-	µs
COM	COM variation	Between COM-Nx (including surge)	-5.0	-	5.0	V

Note:

6. IPM may not respond if the input pulse width is less than $PW_{IN(ON)}$, $PW_{IN(OFF)}$.

VOT: Temperature Monitoring

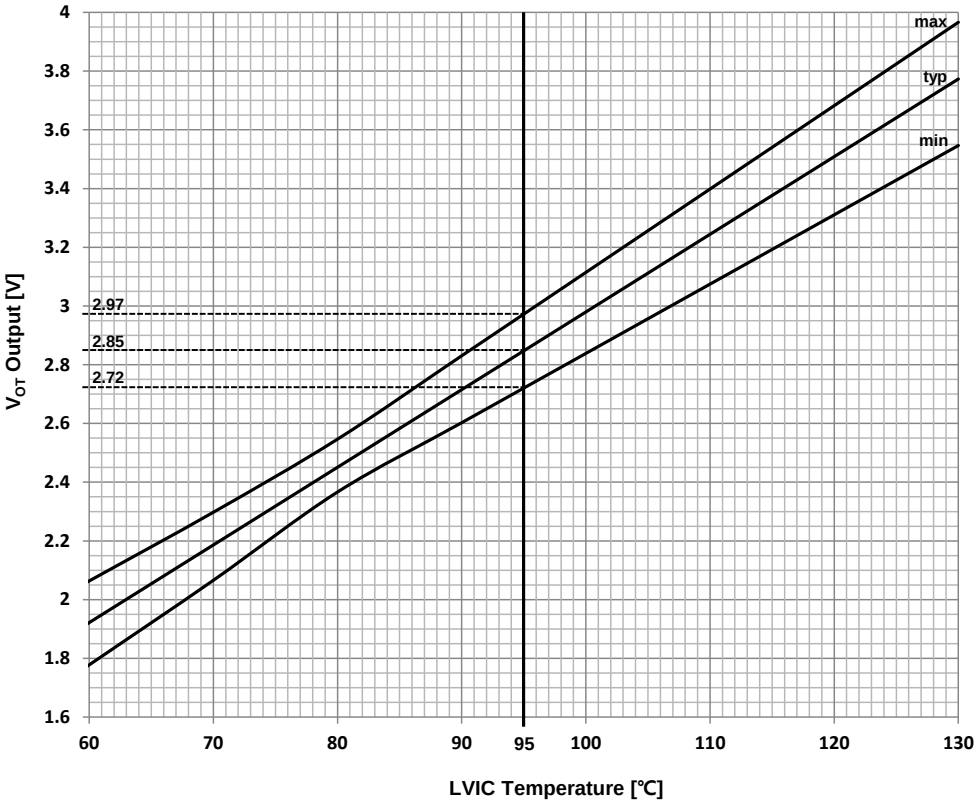


Figure 2. Temperature of LVIC vs. VOT Output Characteristics

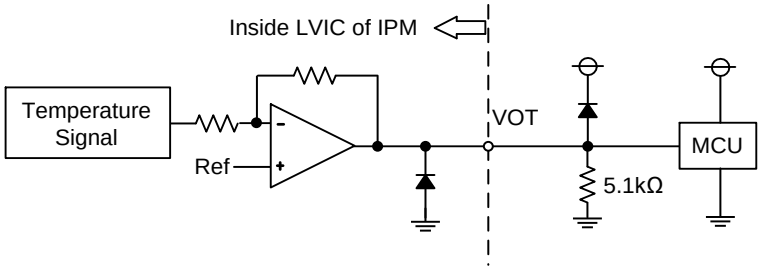


Figure 3. VOT Output Circuit

VOT configuration	Internal OT	Monitoring VOT
Adding pull-down resistor	Disable	Enable
No pull-down resistor	Enable	Enable

(1) VOT generates the analog voltage that is converted from temperature detected in LVIC.

(2) VOT signal is generated regardless of pull-down resistor (recommended 5.1kΩ) as shown in Figure 3. Note OT function is disabled by the pull-down resistor connection as described in table above.

(3) The output voltage of VOT can reach up to 5V. Therefore, when connecting VOT to MCU powered with 3.3V, VOT output could exceed MCU supply voltage as temperature rises excessively. To prevent VOT exceeding MCU supply voltage, it is recommended to add a clamp diode between control supply of the controller and VOT output for preventing over voltage destruction.

(4) In case not to use VOT, leave VOT output with non-connection.

VCF: Controllable Fault Output

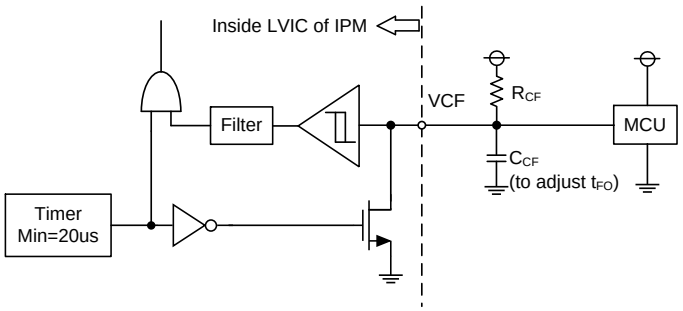


Figure 4. VCF Circuit

(1) VCF provides controllable fault output signal duration time and enables MCU to shut down all low-side IGBTs.

(2) When VCF is in the high state, the IPM operates normally, whereas VCF is in a low state, the low-side IGBTs are turned off until VCF recovers to the high state.

(3) VCF pin provides fixed or adjustable pulse width of fault output signal. Using pull-up resistor only (R_{CF}=10kΩ) generates t_{FO} of minimum 20usec. If the external capacitor C_{CF} (1nF) is connected with R_{CF} (1MΩ) as shown in Figure 4, t_{FO} is adjusted as the following equation;

$$t_{FO} = -(R_{CF} \cdot C_{CF}) \cdot ln\left(1 - \frac{V_{CF+}}{5V}\right) + 20usec$$
$$\approx 0.48(R_{CF} \cdot C_{CF}) + 20usec$$

for example, using R_{CF}=1MΩ and C_{CF}=1nF, t_{FO}≈500us.

Short-Circuit (SC) Protection and Timing Chart

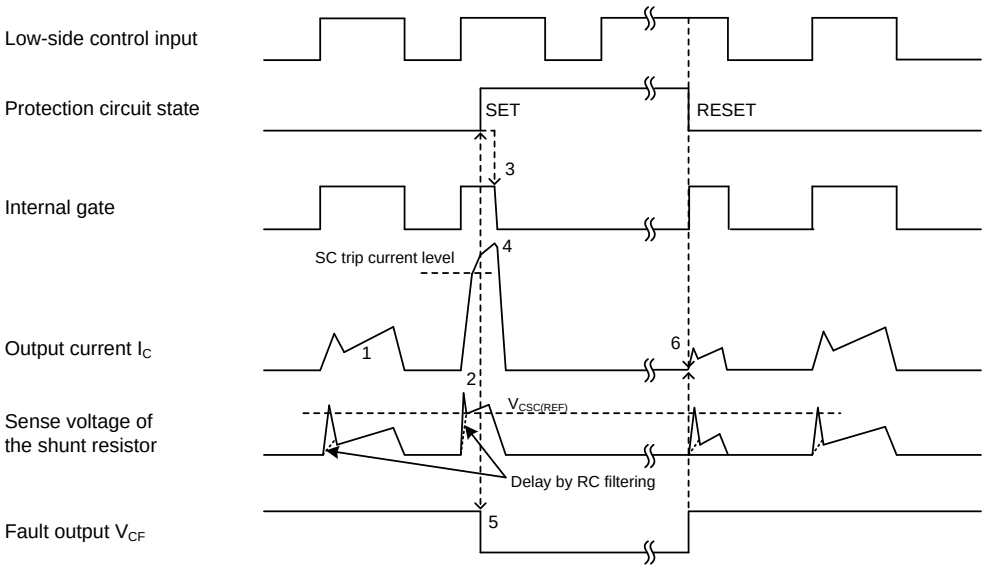


Figure 5. Short-Circuit Protection

(Low-side Operation Only with External Shunt Resistor and RC Filter)

(1) Normal operation: IGBT turns on and output current.

(2) Short-circuit current is detected when sensed I_C is exceeds $V_{CSC(REF)}$.

(3) All low-side IGBTs gate are turned off.

(4) Accordingly, the all IGBTs are turned off.

(5) Fault signal outputs. VCF duration time (t_{FO}) is minimum 20μs.

(6) Fault output finishes. Normal operation starts according to the input signal.

VDD Under-voltage Lock-out (UVLO) Protection and Timing Chart

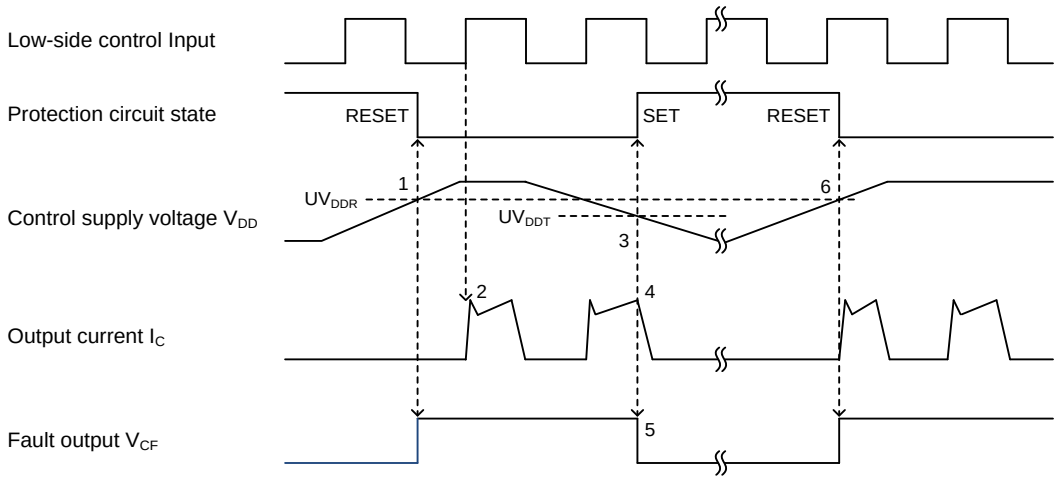


Figure 6. Under-Voltage Protection (Low-side, V_{DD})

(1) Supply voltage V_{DD} becomes higher than under-voltage reset level (UV_{DDR}), and IGBTs are turned on by the next ON signal.
(2) Normal operation: IGBTs turn-on and output current.
(3) V_{DD} level drops to under-voltage trip level (UV_{DDT}).
(4) All IGBTs are turned off regardless of control input condition.
(5) VCF output is generated, and V_{CF} stays low as long as V_{DD} is below UV_{DDR}.
(6) V_{DD} level reaches UV_{DDR}. Normal operation starts according to the input signal.

VBS Under-voltage Lock-out (UVLO) Protection and Timing Chart

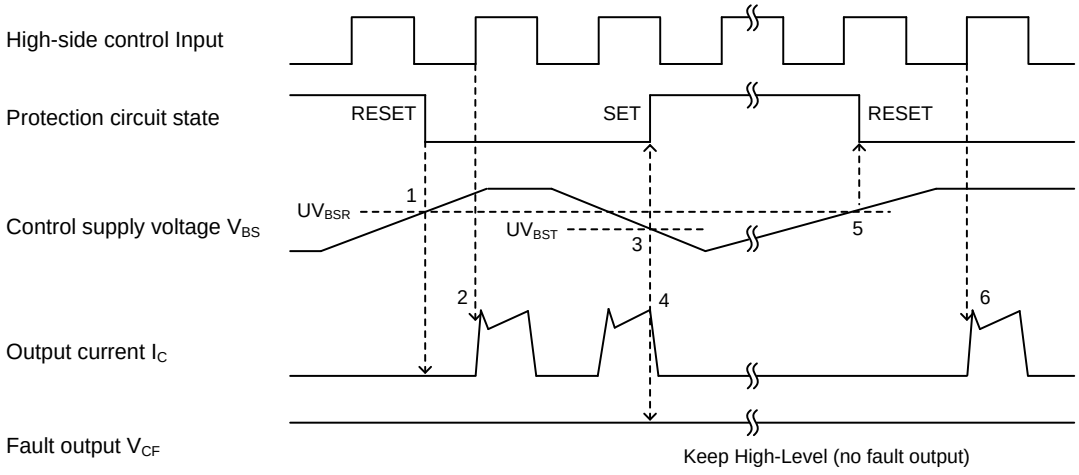


Figure 7. Under-Voltage Protection (High-side, V_{BS})

(1) Control supply voltage V_{BS} rises. After the voltage reaches under-voltage reset level (UV_{BSR}), IGBTs are turned on by the next ON signal.
(2) Normal operation: IGBTs turn on and output current.
(3) V_{BS} level drops to under-voltage trip level (UV_{BST}).
(4) All high-side IGBTs are turned off regardless of control input condition.
(5) V_{BS} level reaches UV_{BSR}.
(6) Normal operation starts according to the input signal.

Over Temperature (OT) Protection and Timing Chart

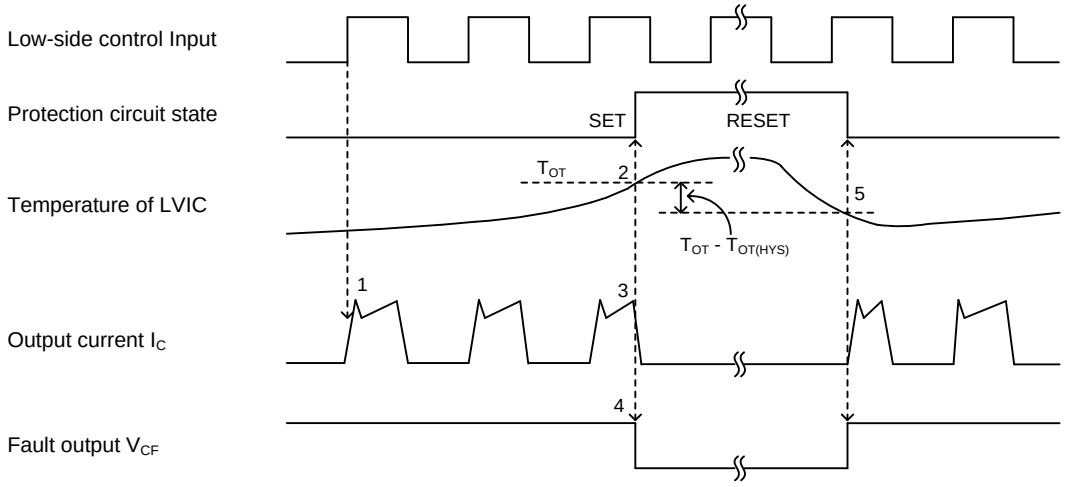
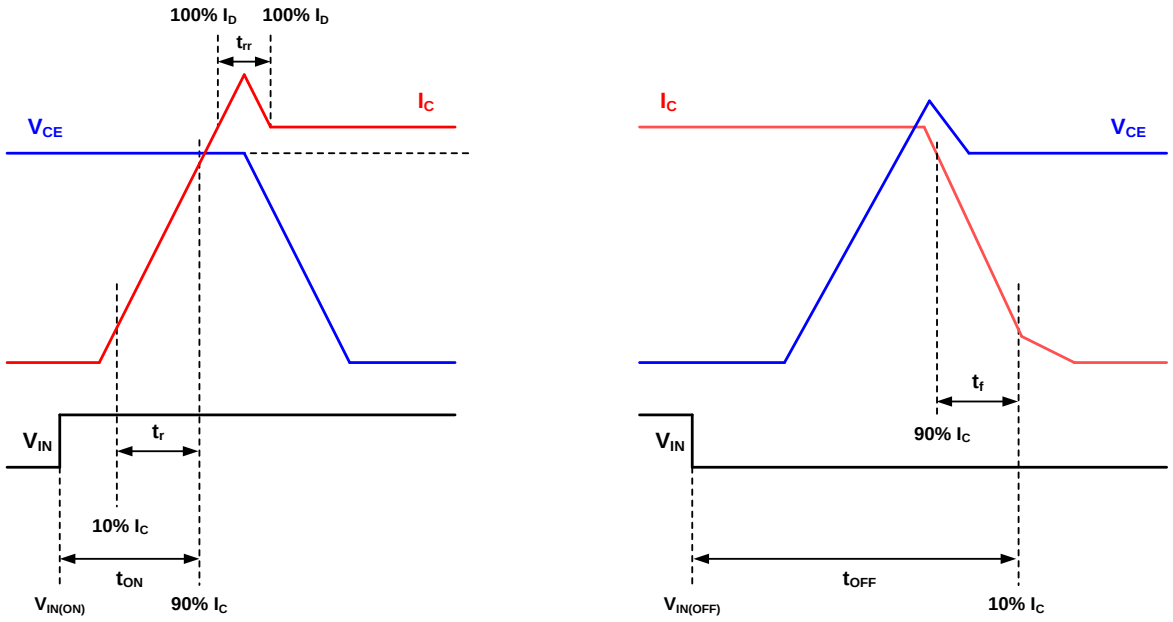


Figure 8. Over-Temperature Protection (Detecting LVIC Temperature)

(1) Normal operation: IGBTs turn on and output current.
(2) LVIC temperature exceeds over-temperature trip level (T_{OT}).
(3) All low-side IGBTs are turned off regardless of control input condition.
(4) VCF output is generated, and F_O stays low as long as LVIC temperature is over T_{OT}.
(5) LVIC temperature drops to over-temperature reset level (T_{OT} - $T_{OT(HYS)}$). Normal operation starts according to the input signal.

Switching Time Definitions

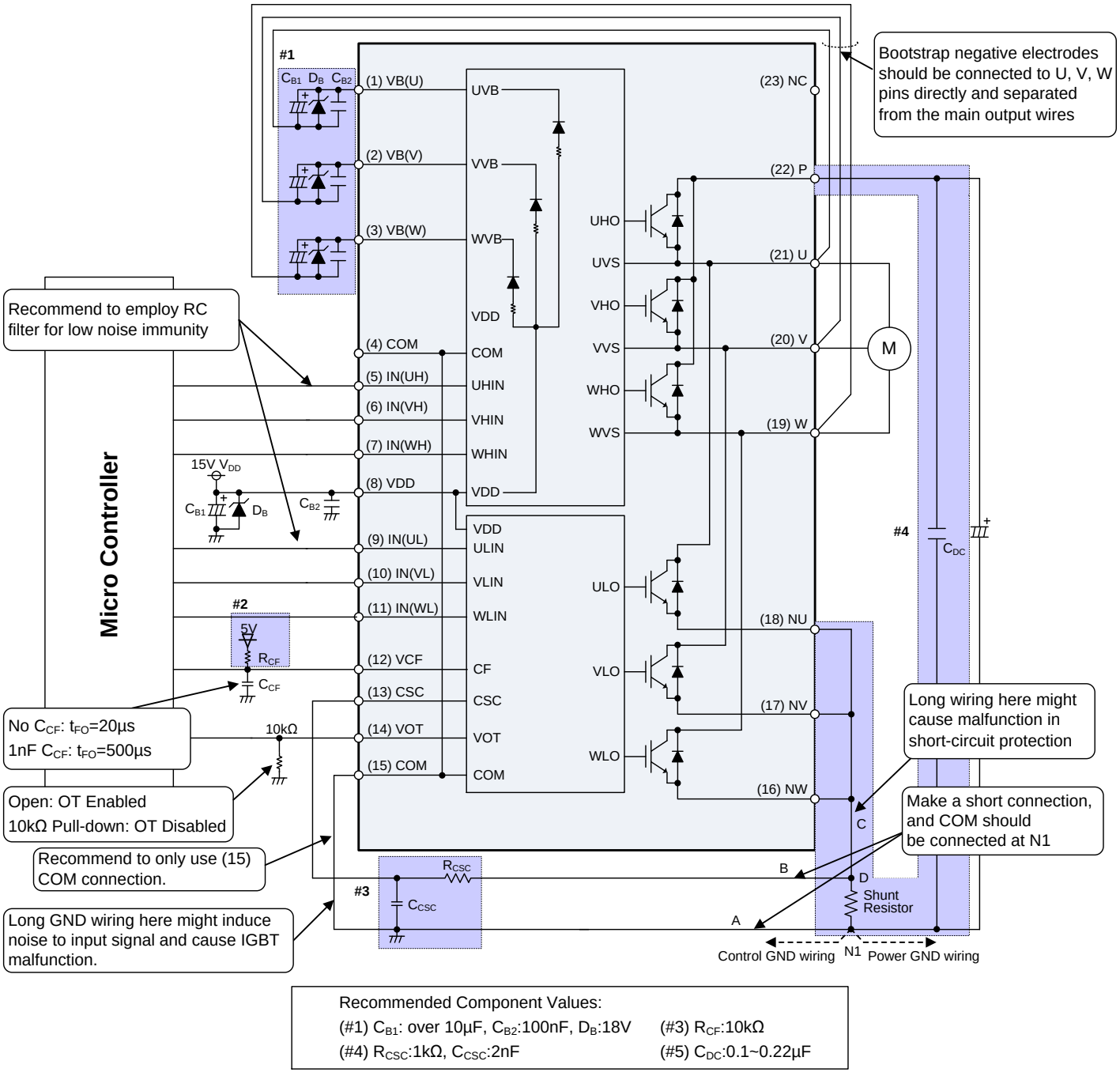


(a) Turn-on Waveform

(b) Turn-off Waveform

Figure 9. Switching Time Definitions

Example of Application Circuit



Recommended Component Values:

(#1) C_{B1}: over 10µF, C_{B2}:100nF, D_B:18V (#3) R_{CF}:10kΩ

(#4) R_{CSC}:1kΩ, C_{CSC}:2nF (#5) C_{DC}:0.1~0.22µF

(1) GND pattern: The star ground design is recommended. GND pattern should be separated at the one point of the shunt resistors. PCB patterns of A, B and C needs to be as short as possible to prevent the noise-caused malfunction.

(2) Bootstrap capacitors: It is recommended that all capacitors are mounted as close to VB of the IPM as possible and make return path of U, V and W as short as possible. In addition, it is recommended to use C_{B1} and C_{B2} with good temperature and frequency characteristics.

(3) A zener diode D_B (18V/1W) is recommended between each pair of control supply pins to avoid damage by external surge.

(4) Snubber capacitor: Prevention of surge destruction can further be improved by placing the bus capacitor C_{DC} as close to pin P and N1 as possible.

(5) CSC circuit: Switching noise filter of R_{CSC} and C_{CSC} of should be placed as close to CSC pin and COM(15) pin as possible to

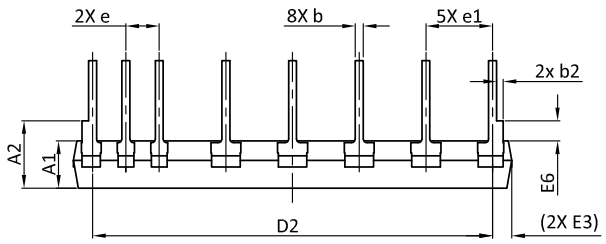
prevent protection function errors. It is recommended to use R_{CSC} and C_{CSC} with low tolerance and temperature-compensated type. Time constant of the filter can be determined considering switching frequency, which is selected within typically 2µs in general motor drives.

(6) Input circuit: The R_{IN} and C_{IN} filter circuit is recommended to place as close to IPM as possible to reduce input signal noise by switching operation. Typically, they are recommended 100Ω and 1nF, respectively.

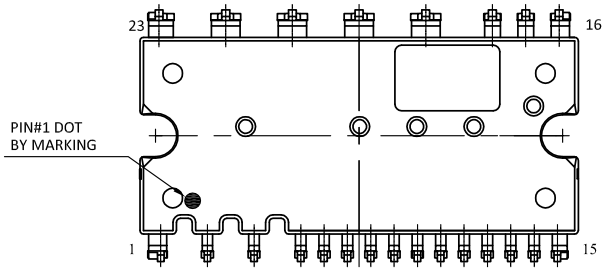
(7) VCF circuit: VCF should be pulled up to the positive side of the 5V or 3.3V supply voltage with a proper resistor R_{CF}. The recommended value is 10kΩ for the pull-up resistor. To adjust t_{FO}, please refer to Figure 4.

(8) COM pin: It is recommended to only use COM (15) pin and leave pin (4) as no connection.

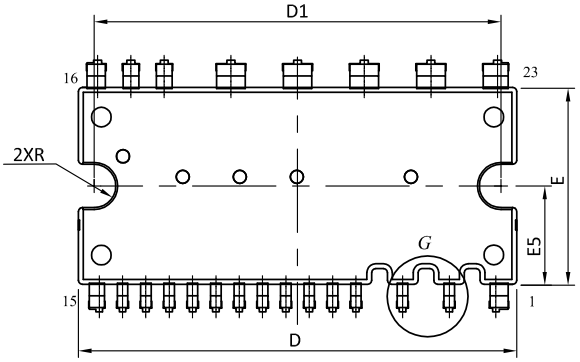
Package Dimensions, IPM-5



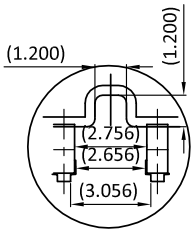
SIDE VIEW

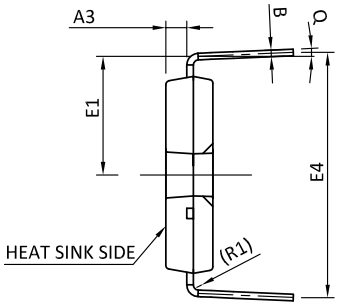


BOTTOM VIEW

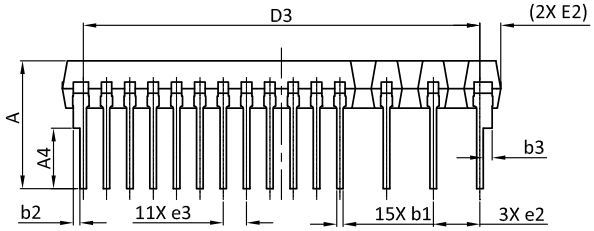


TOP VIEW



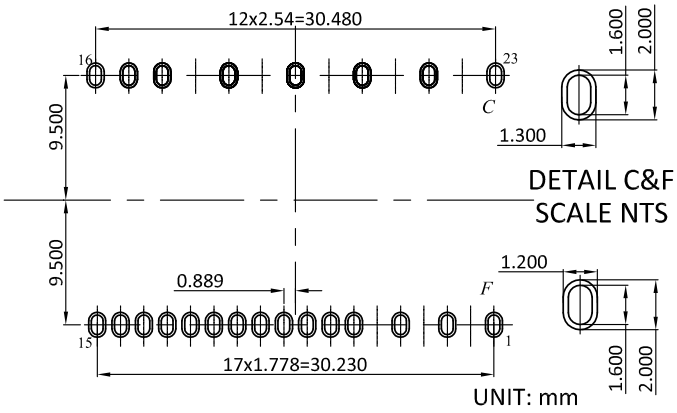


SIDE VIEW



SIDE VIEW

LAND PATTERN RECOMMENDATIONS

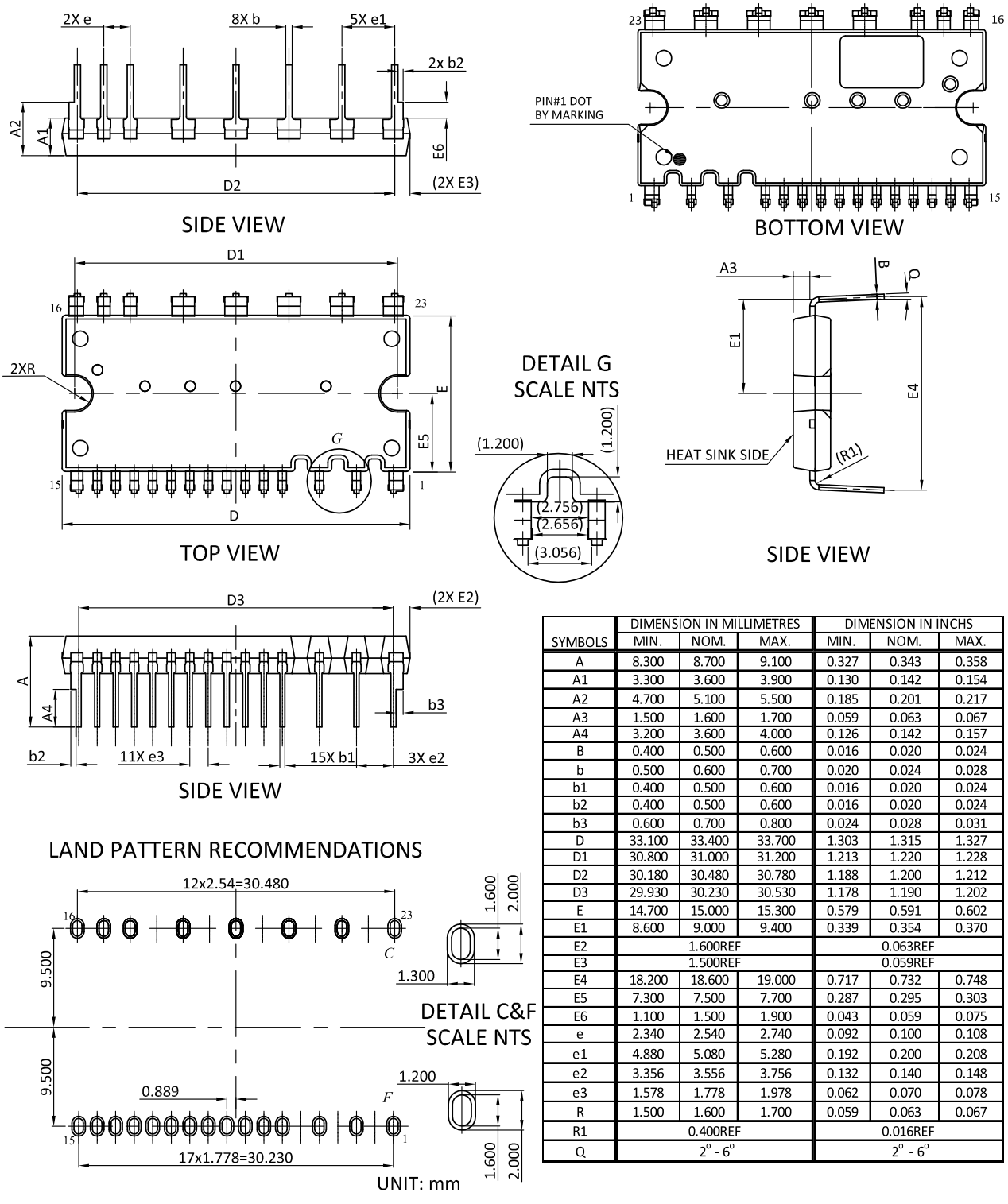


UNIT: mm

SYMBOLS	DIMENSION IN MILLIMETRES			DIMENSION IN INCHS		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	9.300	9.700	10.100	0.366	0.382	0.398
A1	3.300	3.600	3.900	0.130	0.142	0.154
A2	4.700	5.100	5.500	0.185	0.201	0.217
A3	1.500	1.600	1.700	0.059	0.063	0.067
A4	4.200	4.600	5.000	0.165	0.181	0.197
B	0.400	0.500	0.600	0.016	0.020	0.024
b	0.500	0.600	0.700	0.020	0.024	0.028
b1	0.400	0.500	0.600	0.016	0.020	0.024
b2	0.400	0.500	0.600	0.016	0.020	0.024
b3	0.600	0.700	0.800	0.024	0.028	0.031
D	33.100	33.400	33.700	1.303	1.315	1.327
D1	30.800	31.000	31.200	1.213	1.220	1.228
D2	30.180	30.480	30.780	1.188	1.200	1.212
D3	29.930	30.230	30.530	1.178	1.190	1.202
E	14.700	15.000	15.300	0.579	0.591	0.602
E1	8.600	9.000	9.400	0.339	0.354	0.370
E2	1.600REF			0.063REF		
E3	1.500REF			0.059REF		
E4	18.300	18.700	19.100	0.720	0.736	0.752
E5	7.300	7.500	7.700	0.287	0.295	0.303
E6	1.100	1.500	1.900	0.043	0.059	0.075
e	2.340	2.540	2.740	0.092	0.100	0.108
e1	4.880	5.080	5.280	0.192	0.200	0.208
e2	3.356	3.556	3.756	0.132	0.140	0.148
e3	1.578	1.778	1.978	0.062	0.070	0.078
R	1.500	1.600	1.700	0.059	0.063	0.067
R1	0.400REF			0.016REF		
Q	2° - 6°			2° - 6°		

NOTES
1. PACKAGE BODY SIZES EXCLUDE MOLD FLASH AND GATE BURRS, MOLD FLASH SHOULD BE LESS THAN 6 MIL.
2. TOLERANCE 0.100 MILLIMETERS UNLESS OTHERWISE SPECIFIED.
3. CONTROLLING DIMENSION IS MILLIMETER, CONVERTED INCH DIMENSIONS ARE NOT NECESSARILY EXACT.
4. ( ) IS REFERENCE.

Package Dimensions, IPM-5A



SYMBOLS	DIMENSION IN MILLIMETRES			DIMENSION IN INCHS		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	8.300	8.700	9.100	0.327	0.343	0.358
A1	3.300	3.600	3.900	0.130	0.142	0.154
A2	4.700	5.100	5.500	0.185	0.201	0.217
A3	1.500	1.600	1.700	0.059	0.063	0.067
A4	3.200	3.600	4.000	0.126	0.142	0.157
B	0.400	0.500	0.600	0.016	0.020	0.024
b	0.500	0.600	0.700	0.020	0.024	0.028
b1	0.400	0.500	0.600	0.016	0.020	0.024
b2	0.400	0.500	0.600	0.016	0.020	0.024
b3	0.600	0.700	0.800	0.024	0.028	0.031
D	33.100	33.400	33.700	1.303	1.315	1.327
D1	30.800	31.000	31.200	1.213	1.220	1.228
D2	30.180	30.480	30.780	1.188	1.200	1.212
D3	29.930	30.230	30.530	1.178	1.190	1.202
E	14.700	15.000	15.300	0.579	0.591	0.602
E1	8.600	9.000	9.400	0.339	0.354	0.370
E2		1.600REF			0.063REF	
E3		1.500REF			0.059REF	
E4	18.200	18.600	19.000	0.717	0.732	0.748
E5	7.300	7.500	7.700	0.287	0.295	0.303
E6	1.100	1.500	1.900	0.043	0.059	0.075
e	2.340	2.540	2.740	0.092	0.100	0.108
e1	4.880	5.080	5.280	0.192	0.200	0.208
e2	3.356	3.556	3.756	0.132	0.140	0.148
e3	1.578	1.778	1.978	0.062	0.070	0.078
R	1.500	1.600	1.700	0.059	0.063	0.067
R1		0.400REF			0.016REF	
Q		2° - 6°			2° - 6°	

NOTES
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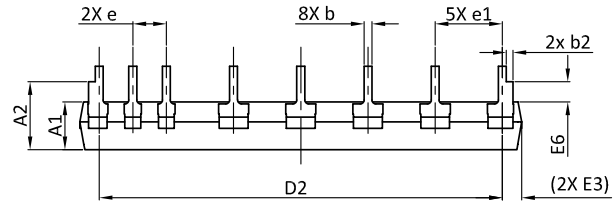
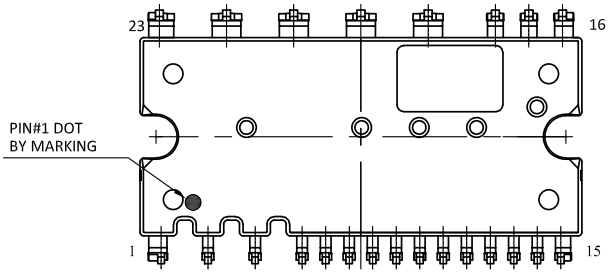
4. ( ) IS REFERENCE.

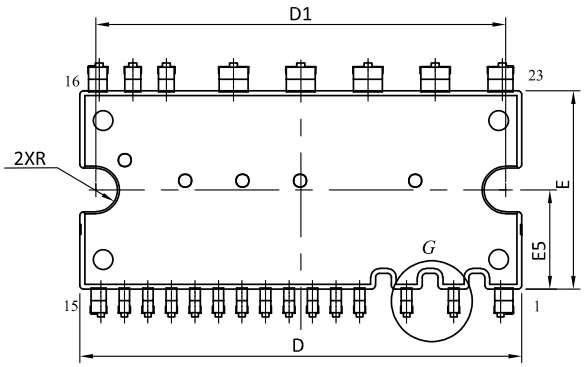
Package Dimensions, IPM-5C



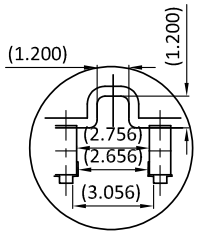
SIDE VIEW

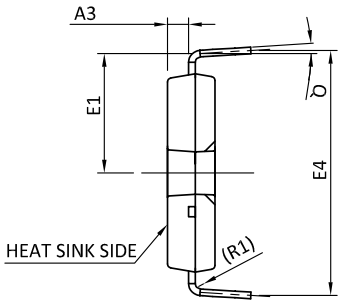


BOTTOM VIEW

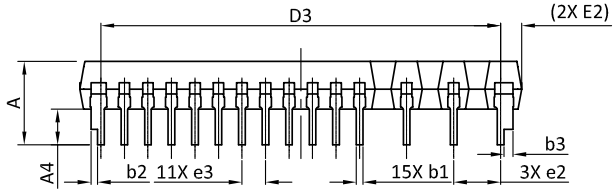


TOP VIEW



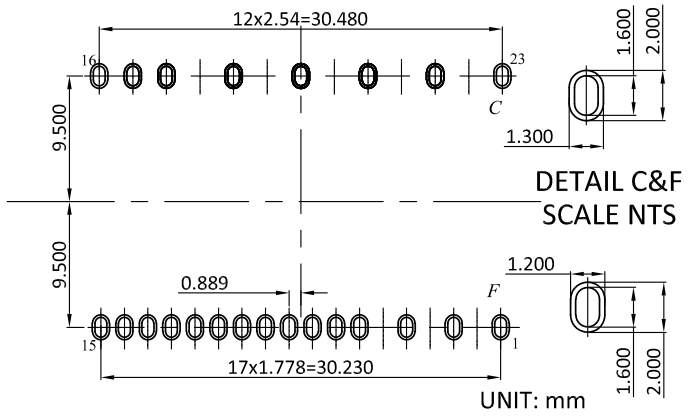


SIDE VIEW



SIDE VIEW

LAND PATTERN RECOMMENDATIONS



UNIT: mm

SYMBOLS	DIMENSION IN MILLIMETRES			DIMENSION IN INCHS		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	5.900	6.300	6.700	0.232	0.248	0.264
A1	3.400	3.600	3.800	0.134	0.142	0.150
A2	4.700	5.100	5.500	0.185	0.201	0.217
A3	1.500	1.600	1.700	0.059	0.063	0.067
A4	2.500	2.700	2.900	0.098	0.106	0.114
B	0.400	0.500	0.600	0.016	0.020	0.024
b	0.500	0.600	0.700	0.020	0.024	0.028
b1	0.400	0.500	0.600	0.016	0.020	0.024
b2	0.400	0.500	0.600	0.016	0.020	0.024
b3	0.600	0.700	0.800	0.024	0.028	0.031
D	33.100	33.400	33.700	1.303	1.315	1.327
D1	30.800	31.000	31.200	1.213	1.220	1.228
D2	30.180	30.480	30.780	1.188	1.200	1.212
D3	29.930	30.230	30.530	1.178	1.190	1.202
E	14.700	15.000	15.300	0.579	0.591	0.602
E1	8.600	9.000	9.400	0.339	0.354	0.370
E2	1.600REF			0.063REF		
E3	1.500REF			0.059REF		
E4	18.120	18.520	18.920	0.713	0.729	0.745
E5	7.300	7.500	7.700	0.287	0.295	0.303
E6	1.100	1.500	1.900	0.043	0.059	0.075
e	2.340	2.540	2.740	0.092	0.100	0.108
e1	4.880	5.080	5.280	0.192	0.200	0.208
e2	3.356	3.556	3.756	0.132	0.140	0.148
e3	1.578	1.778	1.978	0.062	0.070	0.078
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R1	0.400REF			0.016REF		
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2. A critical component in any component of a life support, device, or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.