Electrical Characteristics at Tc = 25°C, VD1, VD2, VD3, VD4=15V

Parameter	Symbol	Conditions		Test circuit	Ratings Min.	Ratings Typ.	Ratings Max.	Unit
Power output section								
Collector to emitter cut-off current	I_{CE}	V_{CE}=600V		Fig.1	-	-	100	μA
Bootstrap diode reverse current	IR(BD)	VR(BD)=600V		Fig.1	-	-	100	μA
Collector to emitter saturation voltage	V_{CE}(sat)	Ic=30A	Upper side	Fig.2	-	1.7	2.5	V
			Lower side		-	2.2	3.1	V
		Ic=15A, Tj=100°C	Upper side		-	1.4	-	V
			Lower side		-	1.7	-	V
Diode forward voltage	VF	IF=30A	Upper side	Fig.3	-	1.8	2.7	V
			Lower side		-	2.3	3.1	V
		IF=15A, Tj=100°C	Upper side		-	1.45	-	V
			Lower side		-	1.7	-	V
Junction to case thermal resistance	θj-c(T)	IGBT		-	-	1.8	-	°C/W
	θj-c(D)	FWD		-	-	2.3	-	°C/W
Control (Pre-driver) section								
Pre-drive power supply consumption current	ID	VD1, 2, 3=15V		Fig.4	-	0.05	0.4	mA
		VD4=15V			-	1.0	4.0	mA
High level input voltage	Vin H	HIN1, HIN2, HIN3, LIN1, LIN2, LIN3 to V_{SS}		-	2.5	-	-	V
Low level input voltage	Vin L			-	-	-	0.8	V
Logic 1 input leakage current	I_{IN+}	VIN=+3.3V		-	-	100	195	μA
Logic 0 input leakage current	I_{IN-}	VIN=0V		-	-	-	1	μA
Bootstrap limiting resistor	RBoot			-	-	39	-	Ω
Gate resistor	Rb			-	-	30	-	Ω
	Rg			-	-	47	-	Ω
Protection section								
Over-current protection current	ISD	PW=100μs,RSD=0Ω		Fig.5	37	-	49	A
Over-current protection noise filter time constant	ISDNF			-	-	2.0	-	us
V_{dd} and V_{Bx} supply undervoltage positive going input threshold	V_{ddUV+} V_{BxUV+}			-	10.6	11.1	11.6	V
V_{dd} and V_{Bx} supply undervoltage negative going input threshold	V_{ddUV-} V_{BxUV-}			-	10.4	10.9	11.4	V
V_{dd} and V_{Bx} supply undervoltage $I_{lockout}$ hysteresis	V_{ddUVH} V_{BxUVH}			-	-	0.2	-	V
FAULT terminal sink current	IOSD	VFAULT=0.1V		-	1	1.5	-	mA
FAULT clearance delay time	FLTCLR	From time fault condition clear		-	1.3	1.65	2.5	ms
Switching character								
Switching time	tON	Io=30A, Inductive load		Fig.6	-	0.8	1.5	μs
	tOFF				-	1.0	2.0	μs
Turn-on switching loss	Eon	Io=30A, V_{CC}=300V, VD=15V, L=690μH			-	1070	-	μJ
Turn-off switching loss	Eoff				-	890	-	μJ
Total switching loss	Etot				-	1960	-	μJ
Turn-on switching loss	Eon	Io=15A, V_{CC}=300V, VD=15V, L=690μH, Tc=100°C			-	590	-	μJ
Turn-off switching loss	Eoff				-	590	-	μJ
Total switching loss	Etot				-	1180	-	μJ
Diode reverse recovery energy	Erec	Io=15A, V_{CC}=300V, VD=15V, L=690μH, Tc=100°C		-	-	95	-	μJ
Diode reverse recovery time	Trr				-	145	-	ns
Reverse bias safe operating area	RBSOA	Io = 49A, V_{CE}=450V		-	Full square			
Short circuit safe operating area	SCSOA	V_{CE}=400V, Tc=100°C		-	4	-	-	μs
Electric current output signal level	ISO	Io=30A		-	0.384	0.405	0.427	V

Reference voltage is V_{SS} terminal voltage unless otherwise specified.

*1: The lower side's V_{CE}(sat) and VF include a loss by the shunt resistance.

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.

Notes

1. When the internal protection circuit operates, a Fault signal is turned ON (When the Fault terminal is low level, Fault signal is ON state : output form is open DRAIN) but the Fault signal does not latch.After protection operation ends,it returns automatically within about 18ms to 80ms and resumes operation beginning condition. So, after Fault signal detection, set all input signals to OFF (Low) at once.However, the operation of pre-drive power supply low voltage protection (UVLO:with hysteresis about 0.2V) is as follows.

   Upper side:
   The gate is turned off and will return to regular operation when recovering to the normal voltage, but the latch will continue till the input signal will turn ‘low’.

   Lower side:
   The gate is turned off and will automatically reset when recovering to normal voltage. It does not depend on input signal voltage.

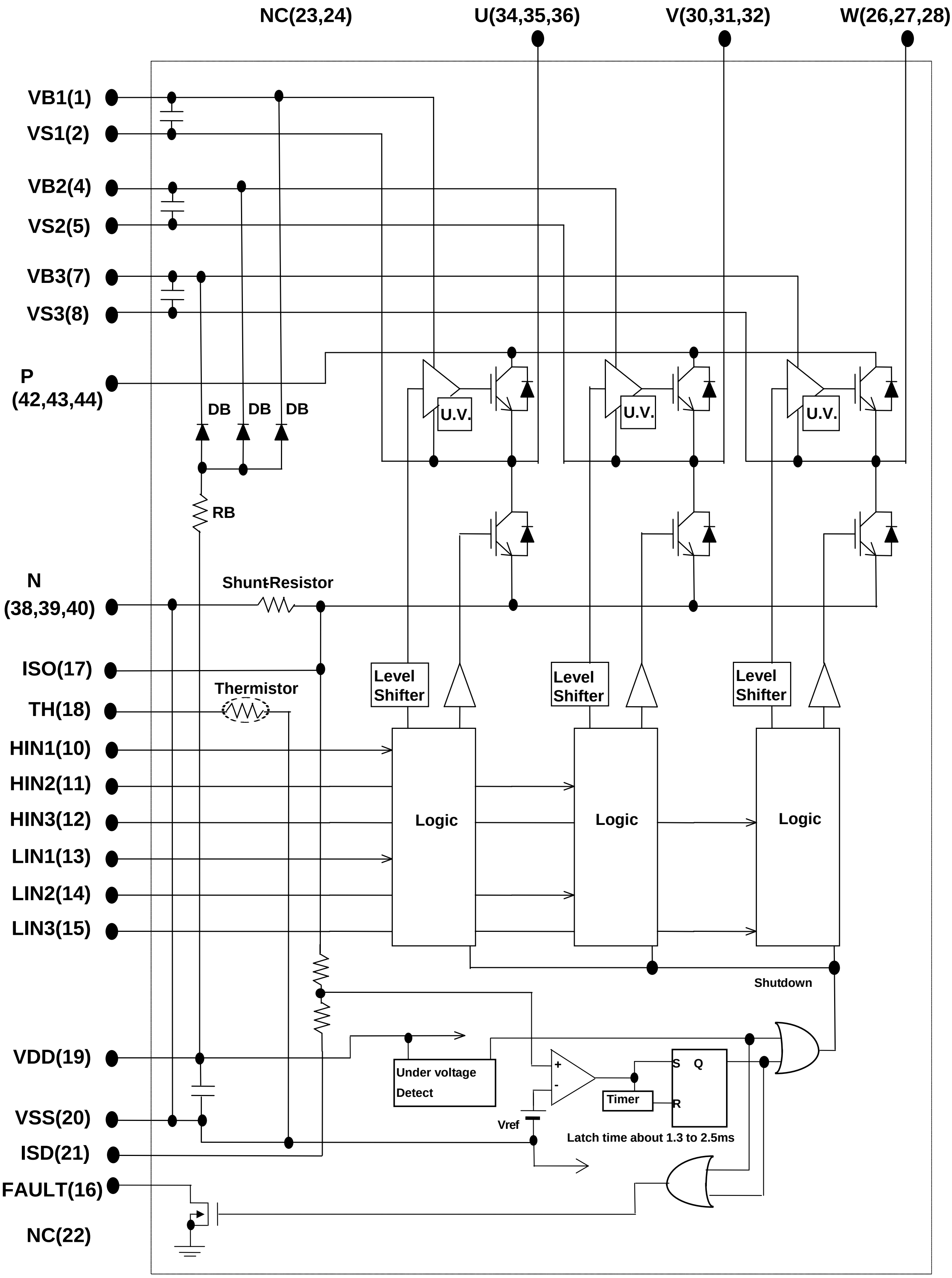
2. When assembling the IPM on the heat sink with M4 type screw, tightening torque range is 0.79 Nm to 1.17 Nm.

3. The pre-drive low voltage protection is the feature to protect devices when the pre-driver supply voltage falls due to an operating malfunction.

Pin Assignment

Pin No.	Name	Description	Pin No.	Name	Description
1	VB1	High side floating supply voltage 1	44	P	Positive bus input voltage
2	VS1	High side floating supply offset voltage	43	P	Positive bus input voltage
3	-	Without pin	42	P	Positive bus input voltage
4	VB2	High side floating supply voltage 2	41	-	Without pin
5	VS2	High side floating supply offset voltage	40	N	Negative bus input voltage
6	-	Without pin	39	N	Negative bus input voltage
7	VB3	High side floating supply voltage 3	38	N	Negative bus input voltage
8	VS3	High side floating supply offset voltage	37	-	Without pin
9	-	Without pin	36	U	U-phase output
10	HIN1	Logic input high side driver-Phase1	35	U	U-phase output
11	HIN2	Logic input high side driver-Phase2	34	U	U-phase output
12	HIN3	Logic input high side driver-Phase3	33	-	Without pin
13	LIN1	Logic input low side driver-Phase1	32	V	V-phase output
14	LIN2	Logic input low side driver-Phase2	31	V	V-phase output
15	LIN3	Logic input low side driver-Phase3	30	V	V-phase output
16	FAULT	Fault out (open drain)	29	-	Without pin
17	ISO	Current monitor pin	28	W	W-phase output
18	TH	Thermistor out	27	W	W-phase output
19	VDD	+15V main supply	26	W	W-phase output
20	VSS	Negative main supply	25	-	Without pin
21	ISD	Over-current protection level setting pin	24	NC	-
22	NC	-	23	NC	-

Block Diagram



Test Circuit

(The tested phase: U+ shows the upper side of the U phase and U– shows the lower side of the U phase.)

■ ICE / IR(BD)

	U+	V+	W+	U-	V-	W-
M	42	42	42	34	30	26
N	34	30	26	38	38	38

	U(BD)	V(BD)	W(BD)
M	1	4	7
N	20	20	20

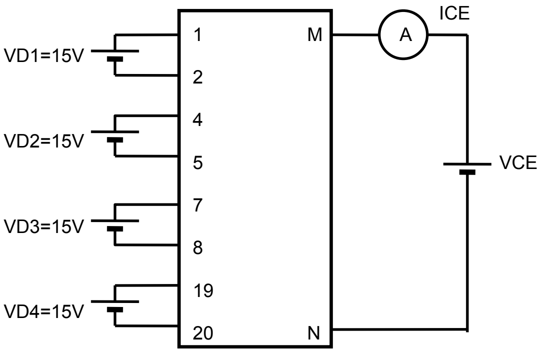


Fig.1

■ VCE(SAT) (Test by pulse)

	U+	V+	W+	U-	V-	W-
M	42	42	42	34	30	26
N	34	30	26	17	19	21
m	10	11	12	13	14	15

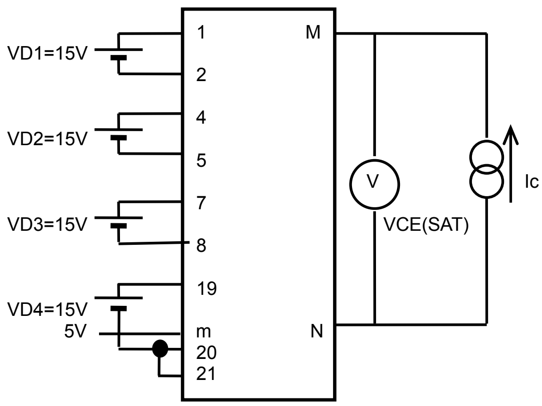


Fig.2

■ VF (Test by pulse)

	U+	V+	W+	U-	V-	W-
M	42	42	42	34	30	26
N	34	30	26	38	38	38

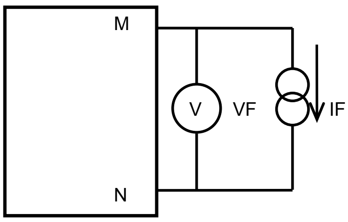


Fig.3

■ ID

	VD1	VD2	VD3	VD4
M	1	4	7	19
N	2	5	8	20

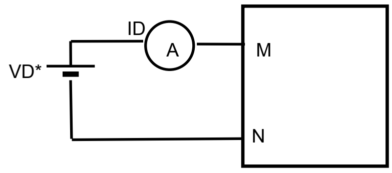
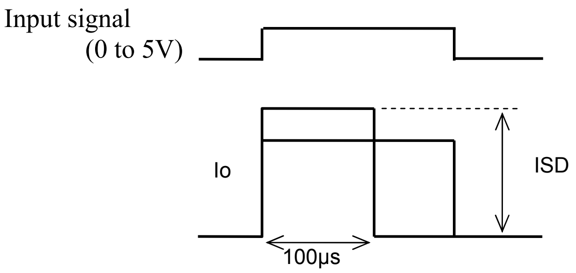


Fig.4

■ **ISD**



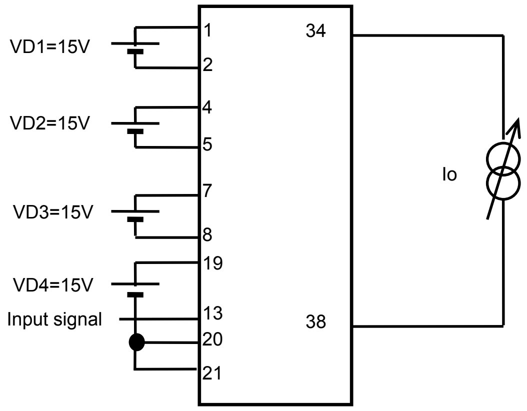
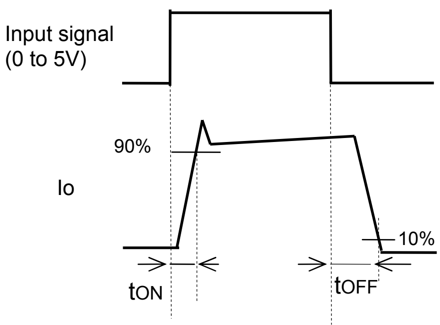


Fig.5

■ **Switching time (The circuit is a representative example of the lower side U phase.)**



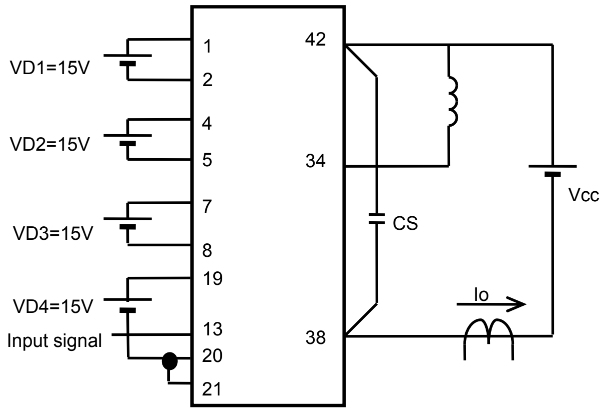
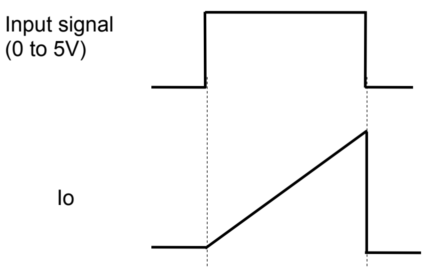


Fig.6

■ **RB-SOA (The circuit is a representative example of the lower side U phase.)**



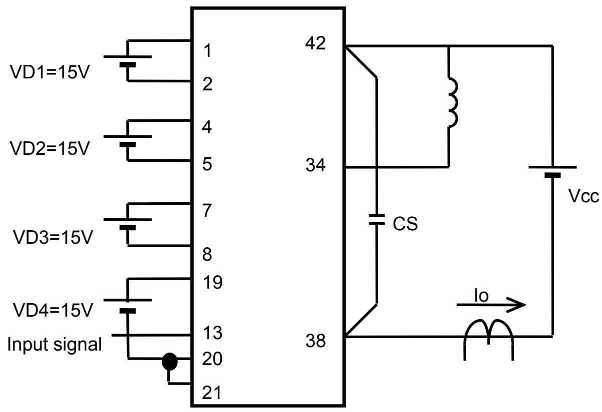


Fig.7

Logic Timing Chart

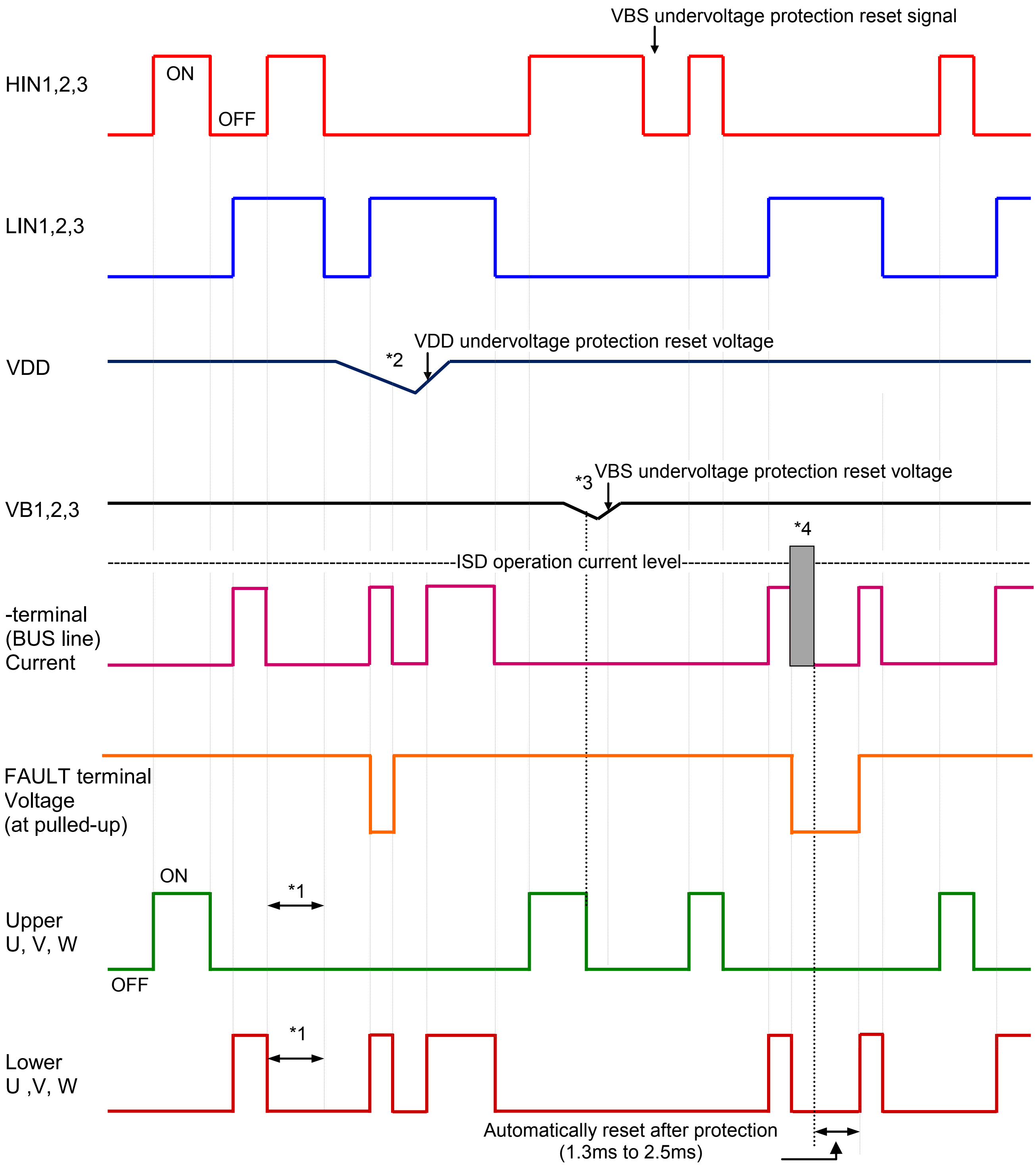


Fig. 8

Notes

*1 : Diagram shows the prevention of shoot-through via control logic. More dead time to account for switching delay needs to be added externally.

*2 : When V_{DD} decreases all gate output signals will go low and cut off all of 6 IGBT outputs. part. When V_{DD} rises the operation will resume immediately.

*3 : When the upper side gate voltage at VB1, VB2 and VB3 drops only, the corresponding upper side output is turned off. The outputs return to normal operation immediately after the upper side gat voltage rises.

*4 : In case of over current detection, all IGBT's are turned off and the FAULT output is asserted. Normal operation resumes in 1.3 to 2.5ms after the over current condition is removed.

Logic level table

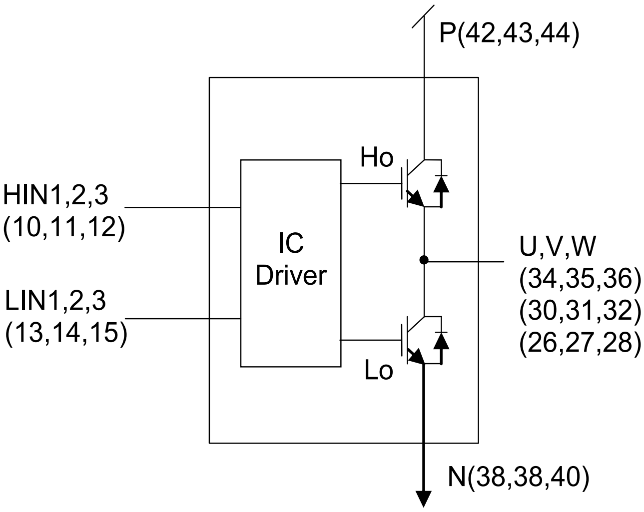


Fig.9

INPUT			OUTPUT			
HIN	LIN	OCP	Ho	Lo	U,V,W	FAULT
H	L	OFF	H	L	P	OFF
L	H	OFF	L	H	N	OFF
L	L	OFF	L	L	High Impedance	OFF
H	H	OFF	L	L	High Impedance	OFF
X	X	ON	L	L	High Impedance	ON

Application Circuit Example

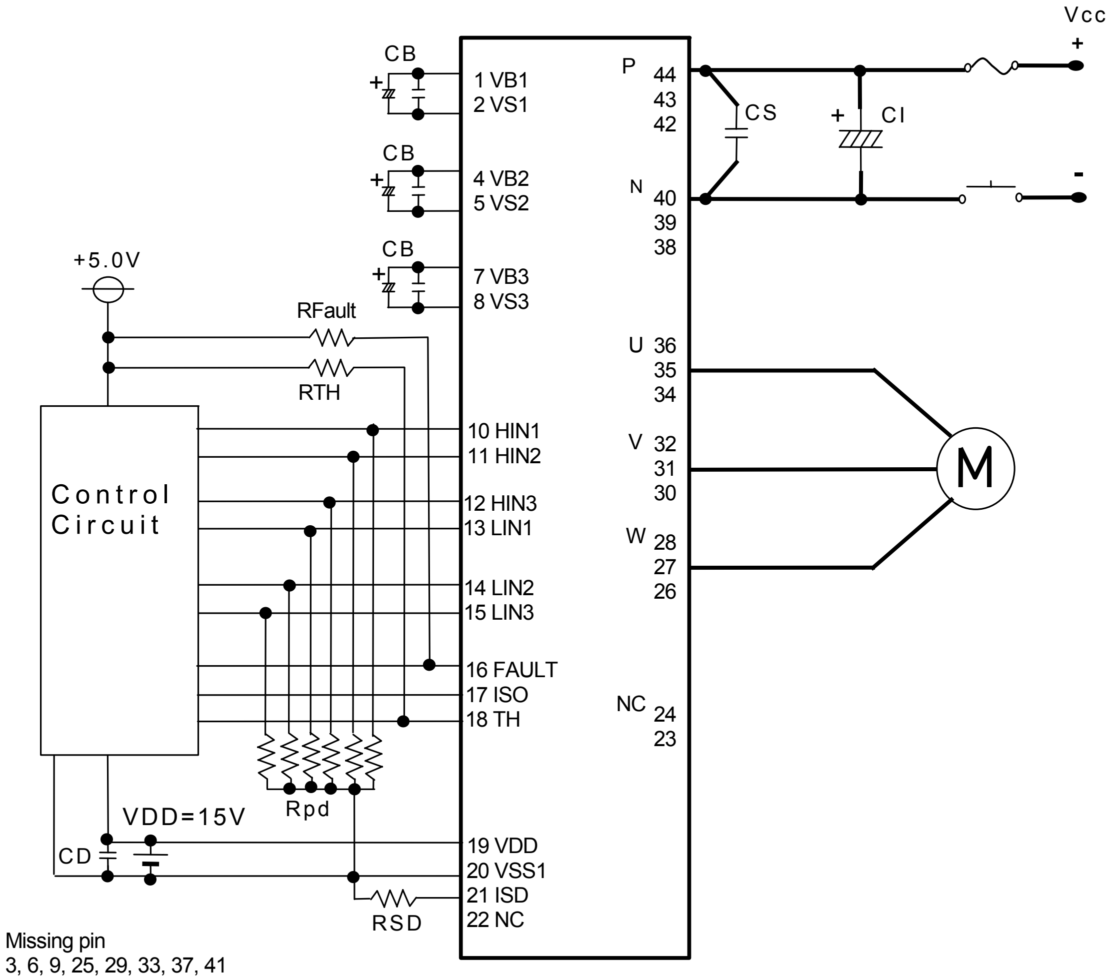


Fig.10

Recommended Operating Conditions at Tc = 25°C

Parameter	Symbol	Conditions	Ratings			Unit
			Min	Typ	Max	
Supply voltage	V_{CC}	P to N	0	280	450	V
Pre-driver supply voltage	VD1,2,3	VB1 to VS1, VB2 to VS2, VB3 to VS3	12.5	15	17.5	V
	VD4	V_{DD} to V_{SS} *1	13.5	15	16.5	
Input ON voltage	VIN(ON)	HIN1,HIN2,HIN3, LIN1,LIN2,LIN3	3.0	-	5.0	V
Input OFF voltage	VIN(OFF)		0	-	0.8	
PWM frequency	fPWM		1	-	20	kHz
Dead time	DT	Turn-off to turn-on (external)	2	-	-	μs
Allowable input pulse width	PWIN	ON pulse width/OFF pulse width	1	-	-	μs
Tightening torque	MT	'M4' type screw	0.79	-	1.17	Nm

*1 Pre-driver power supply (VD4=15±1.5V) must have the capacity of Io=20mA (DC), 0.5A (Peak).

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

Usage Precautions

1. This IPM includes bootstrap diode and resistors. Therefore, by adding a capacitor "CB", a high side drive voltage is generated; each phase requires an individual bootstrap capacitor. The recommended value of CB is in the range of 1 to 47μF, however this value needs to be verified prior to production. If selecting the capacitance more than 47μF (±20%), connect a resistor (about 20Ω) in series between each 3-phase upper side power supply terminals (VB1,2,3) and each bootstrap capacitor. When not using the bootstrap circuit, each upper side pre-drive power supply requires an external independent power supply.

2. It is essential that wirning length between terminals in the snubber circuit be kept as short as possible to reduce the effect of surge voltages. Recommended value of "CS" is in the range of 0.1 to 10μF.

3. "ISO" (pin17) is terminal for current monitor.

4. "FAULT" (pin16) is open DRAIN output terminal. (Active Low). Pull up resistor is recommended more than 5.6kΩ.

5. Inside the IPM, a thermistor used as the temperature monitor for internal subatrate is connected between V_{SS} terminal and TH terminal, therefore, an external pull up resistor connected between the TH terminal and an external power supply should be used. The temperature monitor example application is as follows, please refer the Fig.11, and Fig.12 below.

6. The pull down resistor of 33kΩ is provided internally at the signal input terminals. An external resistor of 2.2k to 3.3kΩ should be added to reduce the influence of external wiring noise.

7. The over-current protection feature is not intended to protect in exceptional fault condition. An external fuse is recommended for safety.

8. When "N" and "V_{SS}" terminal are short-circuited on the outside, level that over-current protection (ISD) might be changed from designed value as IPM. Please check it in your set ("N" terminal and "V_{SS}" terminal are connected in IPM).

9. The over-current protection function operates normally when an external resistor RSD is connected between ISD and V_{SS} terminals. Be sure to connect this resistor. The level of the overcurrent protection can be changed according to the RSD value.

10. When input pulse width is less than 1.0μs, an output may not react to the pulse. (Both ON signal and OFF signal)

This data shows the example of the application circuit, does not guarantee a design as the mass production set.

The characteristic of thermistor

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Resistance	R_{25}	Tc=25°C	97	100	103	kΩ
Resistance	R_{100}	Tc=100°C	4.93	5.38	5.88	kΩ
B-Constant(25-50°C)	B		4165	4250	4335	K
Temperature Range			–40		+125	°C

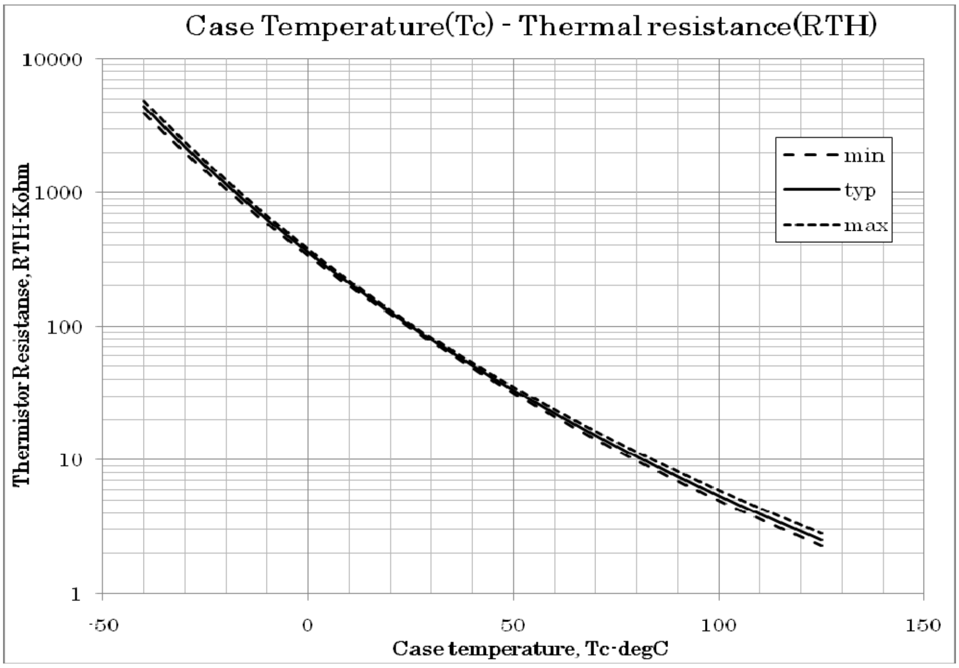


Fig.11 Variation of thermistor resistance with temperature

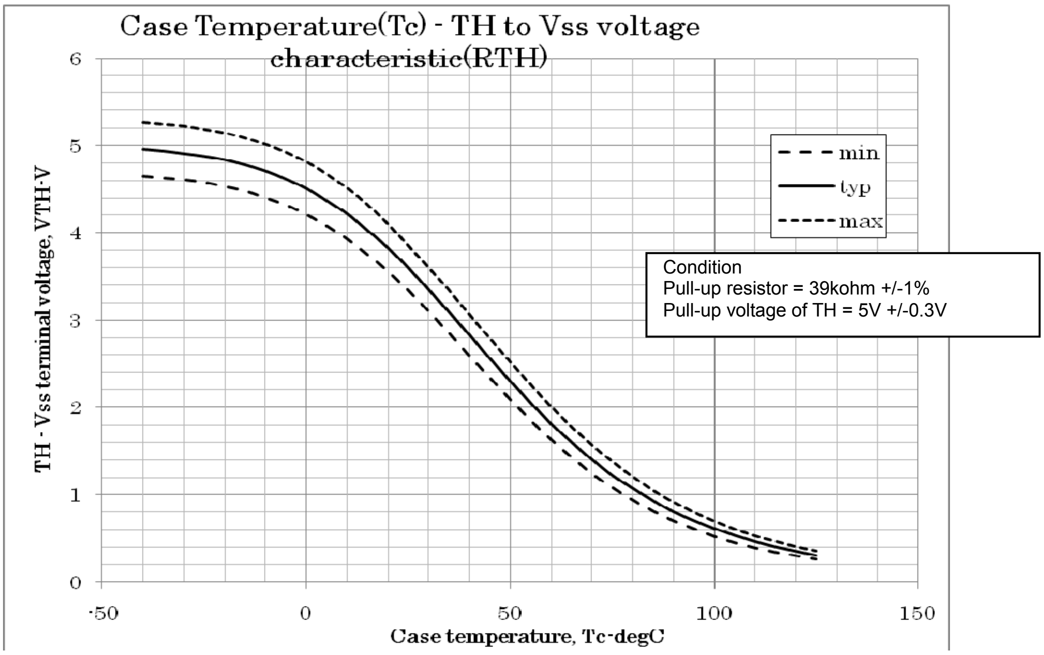


Fig.12 Variation of temperature sense voltage with thermistor temperature

Maximum Phase current

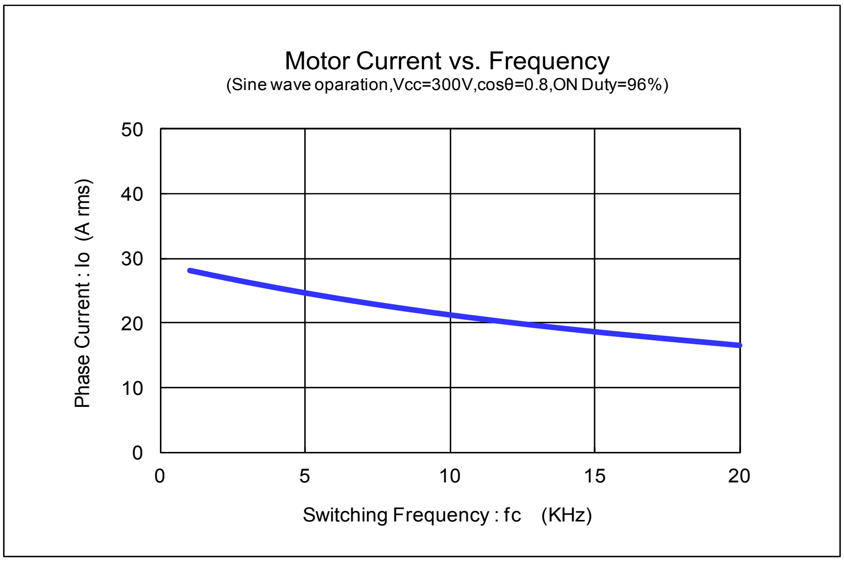
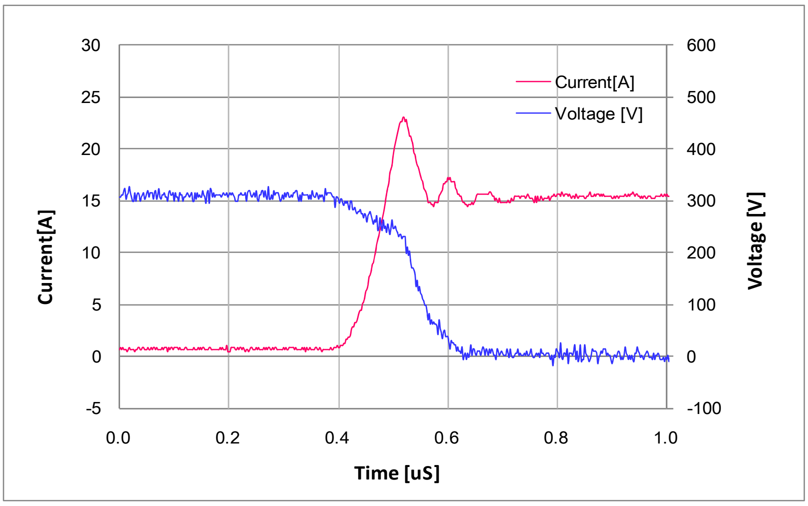


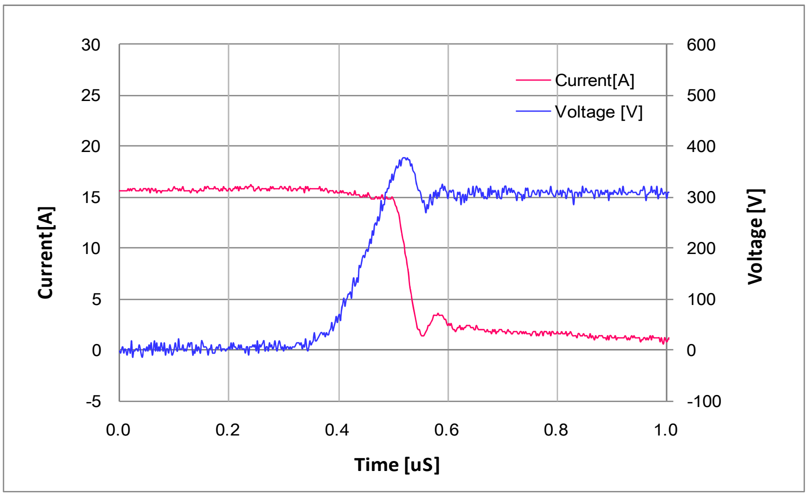
Fig.13 Maximum sinusoidal phase current as function of switching frequency at Tc=100°C, V_{CC}=300V

Switching waveform



Turn on

Fig. 14 IGBT Turn-on. Typical turn-on waveform at Tc=100°C, V_{CC}=300V, Ic=15A



Turn off

Fig. 15 IGBT Turn-off. Typical turn-off waveform Tc=100°C, V_{CC}=300V, Ic=15A

CB capacitor value calculation for bootstrap circuit

Calculate condition

Item	Symbol	Value	Unit
Upper side power supply	VBS	15	V
Total gate charge of output power IGBT at 15V.	Qg	0.266	μC
Upper side power supply low voltage protection.	UVLO	12	V
Upper side power dissipation.	IDmax	400	μA
ON time required for CB voltage to fall from 15V to UVLO	Ton-max	-	s

Capacitance calculation formula

CB must not be discharged below to the upper limit of the UVLO - the maximum allowable on-time (Ton-max) of the upper side is calculated as follows:

VBS × CB – Qg – IDmax × Ton-max = UVLO × CB
CB = (Qg + IDmax × Ton-max) / (VD – UVLO)

The relationship between Ton-max and CB becomes as follows. CB is recommended to be approximately 3 times the value calculated above. The recommended value of CB is in the range of 1 to 47μF, however, the value needs to be verified prior to production.

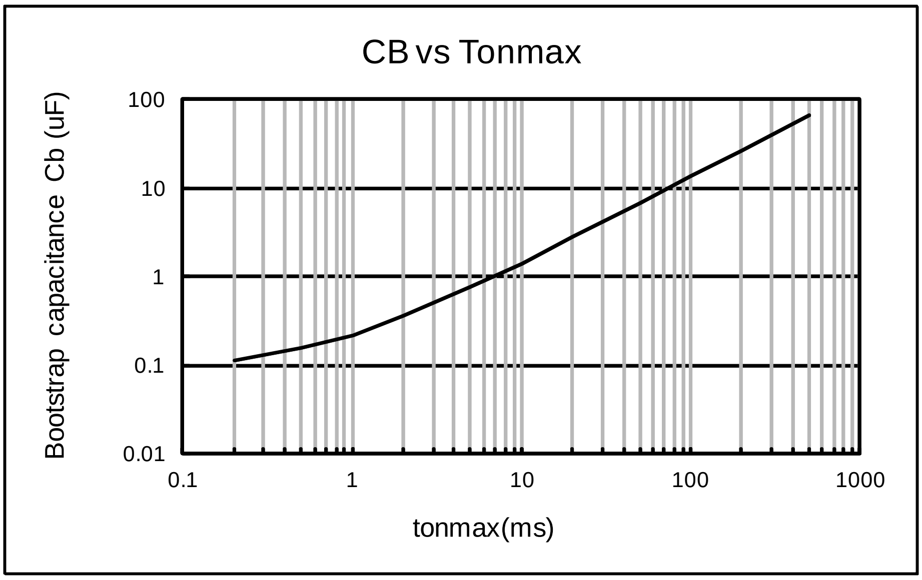


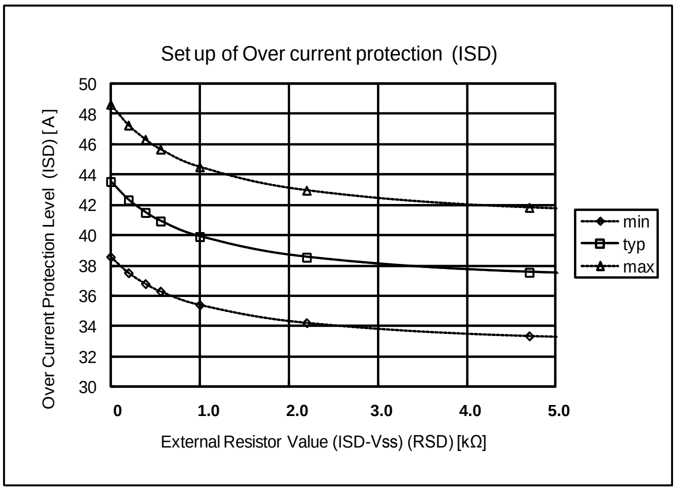
Fig.16 Ton-max vs CB characteristic

ISD terminal

The over-current protection function operates normally when an external resistor RSD is connected between ISD and VSS terminals. Be sure to connect this resistor.
The OCP trip level is programmed within the default or lower levels by an external resistor (RSD) between the ISD and VSD pins. When the default level is used both terminals must be shorted e.g. by a 0Ω resistor.

RSD values and resulting ISD curve

External Resistance (RSD) [kΩ]	Over Current Protection (ISD) [A]		
	min	typ	max
0.0	38.6	43.6	48.6
0.2	37.5	42.3	47.3
0.39	36.8	41.5	46.3
0.56	36.3	40.9	45.7
1.0	35.4	39.9	44.5
2.2	34.2	38.6	43.0
4.7	33.4	37.6	41.9
10.0	32.8	37.0	41.2
Open	32.3	36.3	40.4

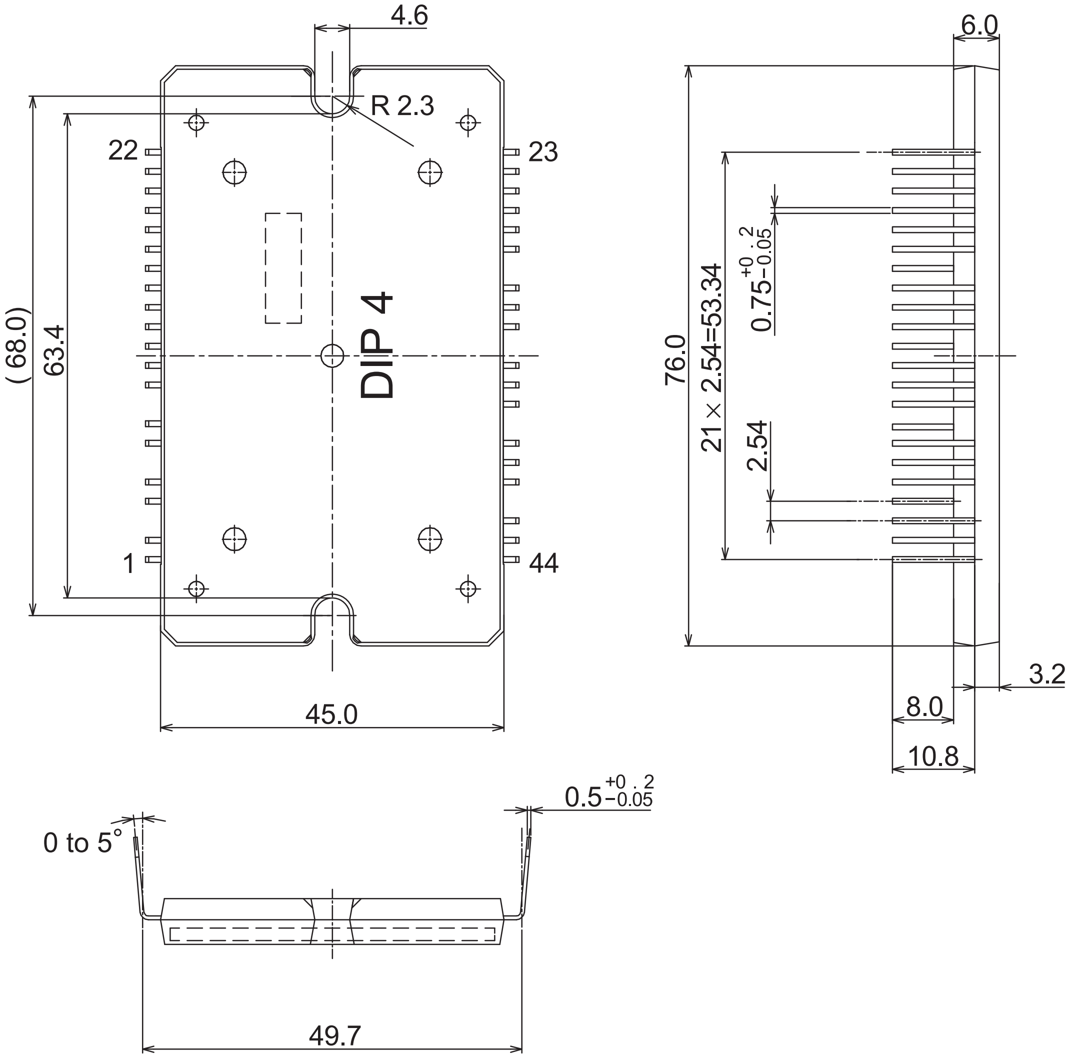


Package Dimensions

unit : mm

HYBRID INTEGRATED MODULE
CASE MODAW
ISSUE O

Missing Pin : 3, 6, 9, 29, 33, 37, 41



ORDERING INFORMATION

Device	Package	Shipping (Qty / Packing)
STK5F1U3C3D-E	MODAW, 610AC-DIP4-UL (Pb-Free)	6 / Tube