Ordering number : EN*A2240

STK57FU391A-E

Advance Information

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Thick-Film Hybrid IC

PFC converter + 3-phase Inverter Power H-IC for 3-phase Motor Drive

Overview

This "Inverter Power H-IC" includes the PFC, the output stage of a 3-phase inverter, pre-drive circuits, as well as protection circuits in one package.

Function

- Protective terminals including for over current protection each of Inverter part and PFC part are built in.
- Protective circuits including pre-drive low voltage protection is built in.
- Direct input of CMOS level control signals without an insulating circuit (photo coupler, etc) is possible. (Active High)
- Single power supply drive is possible by using a bootstrap circuit with a built-in IC.
- In Inverter part, built-in simultaneous upper/lower ON prevention circuit to prevent arm shorting through simultaneous ON input for the upper and lower side transistors.(Dead time is required for preventing shorting due to switching delay.)
- The emitter line of each lower phase transistor is outputting to the external terminal (3 terminals). Therefore, by connecting shunt resistor outside, it is possible to the control which detects 3-phase current.

Certification

- UL1557 (File Number: E339285)

Specifications

Absolute Maximum Ratings at Ta = 25°C

(1) PFC Part

Parameter	Symbol	Conditions	Ratings	Unit
IGBT part				
Collector to Emitter Voltage	VCE		600	V
Collector Current	IC		30	A
Collector Peak Current	ICpeak	PW=100usec.	40	A
Maximum loss	Pd		48	W
Junction-to-substrate thermal resistance	θj-c		2.6	°C/W
Diode part				
Repetitive Peak Reverse Voltage	VRM		600	V
Forward Current	IF		30	A
Maximum loss	Pd		31	W
Junction-to-substrate thermal resistance	θj-c		4.0	°C/W

This document contains information on a new product. Specifications and information herein are subject to change without notice.

ORDERING INFORMATION

See detailed ordering and shipping information on page 16 of this data sheet.

(2) Inverter Part

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	VCC	+ to U-(V-,W-), surge < 500V *1	450	V
Collector-emitter voltage	VCE	+ to U(V,W) or U(V,W) to U-(V-,W-)	600	V
Output current	IO	+,U-,V-,W-,U,V,W terminal current	±15	A
Output peak current	IOP	+,U-,V-,W-,U,V,W terminal current PW=100uSec	±30	A
Pre-driver supply voltage	VD1,2,3,4	VB1 to U,VB2 to V, VB3 to W, VDD to VSS *2	20	V
Input signal voltage	VIN	HIN1,2,3,LIN1,2,3,PFCIN terminal	0 to 15	V
FAULT terminal voltage	VFAULT	FAULT terminal	20	V
Maximum loss	Pd	Per 1 channel	31	W
Junction-to-substrate thermal resistance	θj-c(T)	IGBT	4	°C/W
	θj-c(D)	FWD	7.3	°C/W

In the case without the instruction, the voltage standard is – terminal=VSS terminal voltage.

*1 Surge voltage developed by the switching operation due to the wiring inductance between the + and –terminals.

*2 VD1= between VB1-U, VD2=VB2-V, VD3=VB3-W, VD4=VDD-VSS, terminal voltage.

(3) Total

Parameter	Symbol	Conditions	Ratings	Unit
Operating temperature	TC	H-IC case temperature	-20 to 100	°C
Junction temparature	Tj	IGBT,FRD junction temperature	150	°C
Storage temperature	Tstg		-40 to 125	°C
Tightening torque		A screw part at use M3 type screw *3	1.0	N·m
Withstand Voltage	Vis	50Hz sine wave AC 1 minute *4	2000	VRMS

*3 Flatness of the heat-sink should be lower than 0.2mm.

*4 The test condition is AC 2500 V, 1 second.

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

Electrical Characteristics at Tc = 25°C, VD = 15V

(1) PFC Part

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
IGBT part						
Collector-to-emitter cut-off current	ICE	VCE=600V	-	-	0.1	mA
Collector-to-emitter saturation voltage	VCEsat	IO=30A	-	1.7	2.3	V
FRD part						
Reverse Leakage Current	IR	VR=600V	-	-	0.1	mA
Forward Voltage Drop	VF	IF=30A	-	2.6	3.2	V
Other						
Switching time	tON	IO=30A, Inductive load	-	0.6	-	μs
	tOFF		-	0.8	-	μs

(2) Inverter Part

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Power output part						
Collector-to-emitter cut-off current	ICE	VCE=600V	-	-	0.1	mA
Boot-strap diode reverse current	IR(BD)	VR(BD)=600V	-	-	0.1	mA
Collector-to-emitter saturation voltage	VCEsat	IO=15A	-	1.8	2.4	V
Diode forward voltage	VF	IO=-15A	-	1.8	2.4	V
Other						
Switching time	tON	IO=15A, Inductive load	-	0.6	-	μs
	tOFF		-	1.0	-	μs

(3) Pre-driver Part

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Pre-drive power supply consumption electric current	ID	VD1,2,3=15V	-	0.08	0.4	mA
		VD4=15V	-	0.85	2.4	mA
Input ON voltage	Vin(on)	Voltage between the HIN1,2,3,LIN1,2,3,PFCIN and VSS	2.5	-	-	V
Input OFF voltage	Vin(off)	Voltage between the HIN1,2,3,LIN1,2,3,PFCIN and VSS	-	-	0.8	V

(4)Protection Part

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Pre-drive low voltage protection	UVLO		10		12	V
FLTEN terminal input electric current	IoSD	FAULT:ON / VFLTEN=0.1V		2		mA
FLTEN clearness delay time	FLTCLR	After each protection operation ending	1	2	3	Ms
ITRIP threshold voltage	VITRIP	Voltage between the ITRIP and VSS	0.44	-	0.54	V
PFCTRIP threshold voltage	VPFCTRIP	Voltage between the PFCTRIP and VSS	-0.37	-	-0.25	V
Resistance for substrate temperature monitors	Rt	Resistance between FLTEN(31) and VSS(35)	18.7	24.8	30.2	kΩ

In the case without the instruction, the voltage standard is VSS terminal voltage.

Notes

1. “Input ON voltage” indicates a value to turn on output stage IGBT.
   “Input OFF voltage” indicates a value to turn off output stage IGBT.
   At the time of output ON, set the input signal voltage Vin(on) Min. to 15V.
   At the time of output OFF, set the input signal voltage 0V to Vin(off) Max.

2. When the internal protection circuit operates, there is a Fault signal ON (When the Fault terminal is low level, Fault signal is ON state : output form is open DRAIN) but the Fault signal doesn't latch.
   After protection operation ends, it returns automatically within about 2ms (typ.) and resumes operation beginning condition. So, after Fault signal detection, set OFF (Low) to all input signals at once.

   However, the operation of pre-drive power supply low voltage protection (UVLO: it has a hysteresis about 0.2V is as follows.

   Upper side → There is no Fault signal output, but it does a corresponding gate signal OFF.
   Incidentally, it returns to the regular operation when recovering to the normal voltage, but the latch continues among input signal ON (High).
   Lower side → It outputs Fault signal with gate signal OFF.
   However, it is different from the protection operation of upper side, it is automatically resets and resumes operation beginning condition when recovering to normal voltage. (The protection operation doesn't latch by the input signal.)

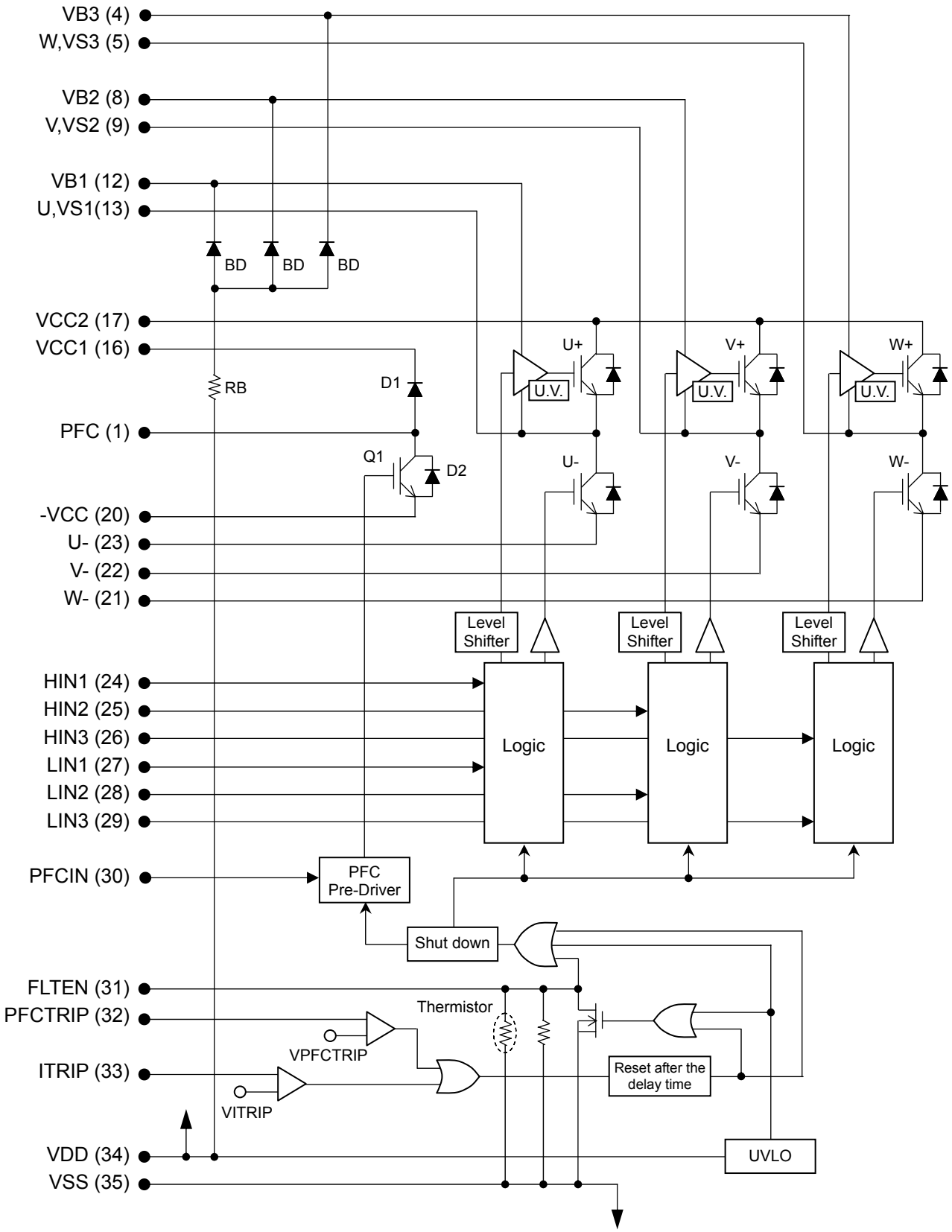
3. When assembling the hybrid IC on the heat sink with M3 type screw, tightening torque range is 0.8 to 1.0 N･m.

4. The pre-drive low voltage protection is the feature to protect a device when the pre-driver supply voltage declines with the operating malfunction. As for the pre-driver supply voltage decline in case of operation beginning, and so on, we request confirmation in the set.

Module Pin-Out Description

Pin	Name	Description
1	PFC	Input the Rectified AC Voltage
2	-	Without pin
3	-	Without pin
4	VB3	High Side Floating Supply Voltage 3
5	W,VS3	Output 3 – High Side Floating Supply Offset Voltage
6	-	Without pin
7	-	Without pin
8	VB2	High Side Floating Supply Voltage 2
9	V,VS2	Output 2 – High Side Floating Supply Offset Voltage
10	-	Without pin
11	-	Without pin
12	VB1	High Side Floating Supply Voltage 1
13	U,VS1	Output 1 – High Side Floating Supply Offset Voltage
14	-	Without pin
15	-	Without pin
16	VCC1	Positive PFC Output voltage
17	VCC2	Positive Bus Input Voltage
18	-	Without pin
19	-	Without pin
20	-VCC	Negative PFC Output Voltage
21	W-	Low Side Emitter Connection – Phase W
22	V-	Low Side Emitter Connection – Phase V
23	U-	Low Side Emitter Connection – Phase U
24	HIN1	Logic Input High Side Gate Driver – Phase U
25	HIN2	Logic Input High Side Gate Driver – Phase V
26	HIN3	Logic Input High Side Gate Driver – Phase W
27	LIN1	Logic Input Low Side Gate Driver – Phase U
28	LIN2	Logic Input Low Side Gate Driver – Phase V
29	LIN3	Logic Input Low Side Gate Driver – Phase W
30	PFCIN	Logic Input PFC Gate Driver
31	FLTEN	Enable input / Fault output / Thermistor
32	PFCTRIP	Current protection pin for PFC
33	ITRIP	Current protection pin for Inverter
34	VDD	+15V Main Supply
35	VSS	Negative Main Supply

Equivalent Block Diagram

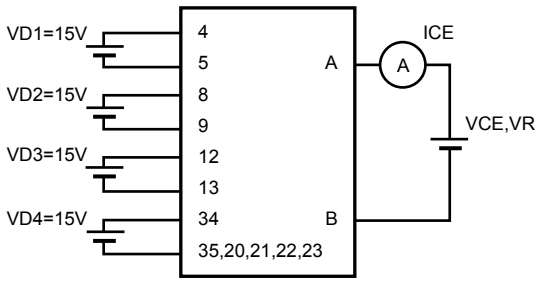


Test Circuit

■ ICES,IR(BD)

	U+	V+	W+	U-	V-	W-	Q1
A	17	17	17	13	9	5	1
B	13	9	5	23	22	21	20

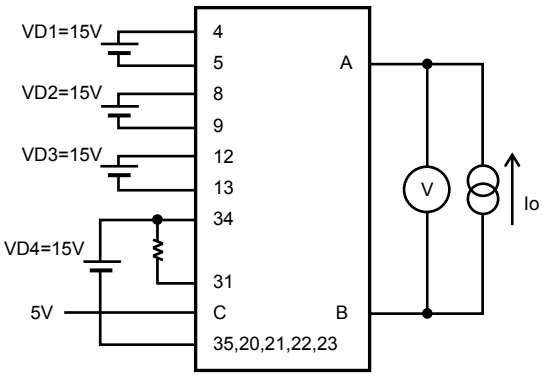
	U(BD)	V(BD)	W(BD)	D1
A	12	8	4	16
B	35	35	35	1



<Fig.1>

■ VCE(sat) (Test by pulse)

	U+	V+	W+	U-	V-	W-	Q1
A	17	17	17	13	9	5	1
B	13	9	5	23	22	21	20
C	24	25	26	27	28	29	30

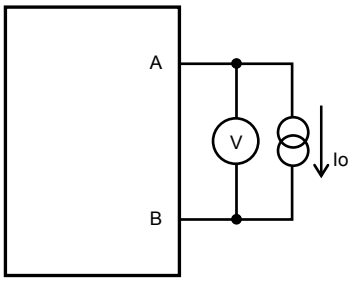


<Fig.2>

■ VF (Test by pulse)

	U+	V+	W+	U-	V-	W-
A	17	17	17	13	9	5
B	13	9	5	23	22	21

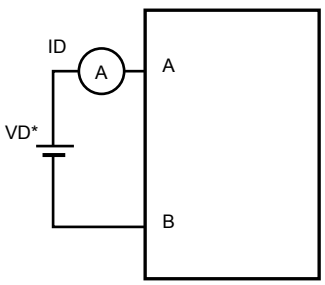
	U(BD)	V(BD)	W(BD)	D1	D2
A	12	8	4	16	1
B	34	34	34	1	20



<Fig.3>

■ ID

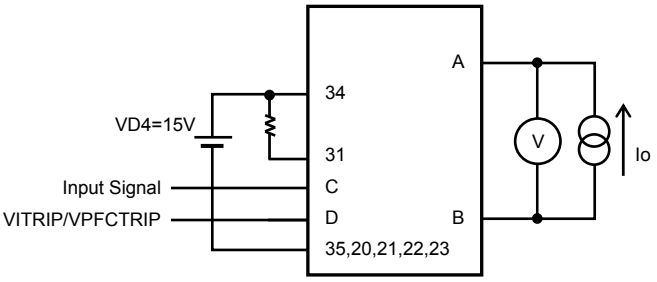
	VD1	VD2	VD3	VD4
A	12	8	4	34
B	13	9	5	35



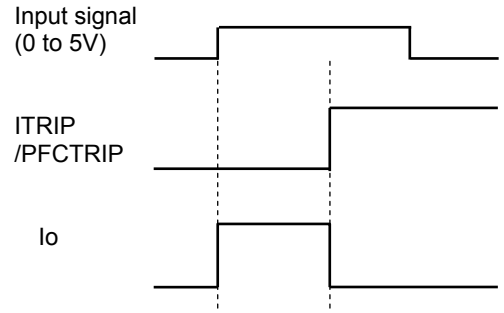
<Fig.4>

■ VITRIP, VPFCTRIP

	VITRIP(U-)	VPFCTRIP
A	13	1
B	23	20
C	27	30
D	33	32

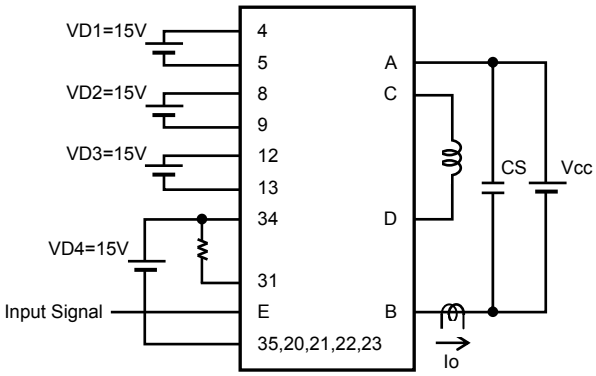


<Fig.5>

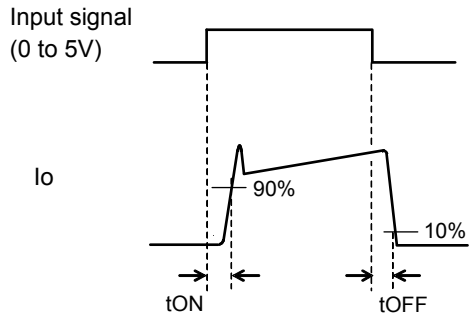


■ Switching time

	U+	V+	W+	U-	V-	W-	Q1
A	17	17	17	17	17	17	16
B	23	22	21	23	22	21	20
C	13	9	5	13	9	5	1
D	23	22	21	17	17	17	16
E	24	25	26	27	28	29	30

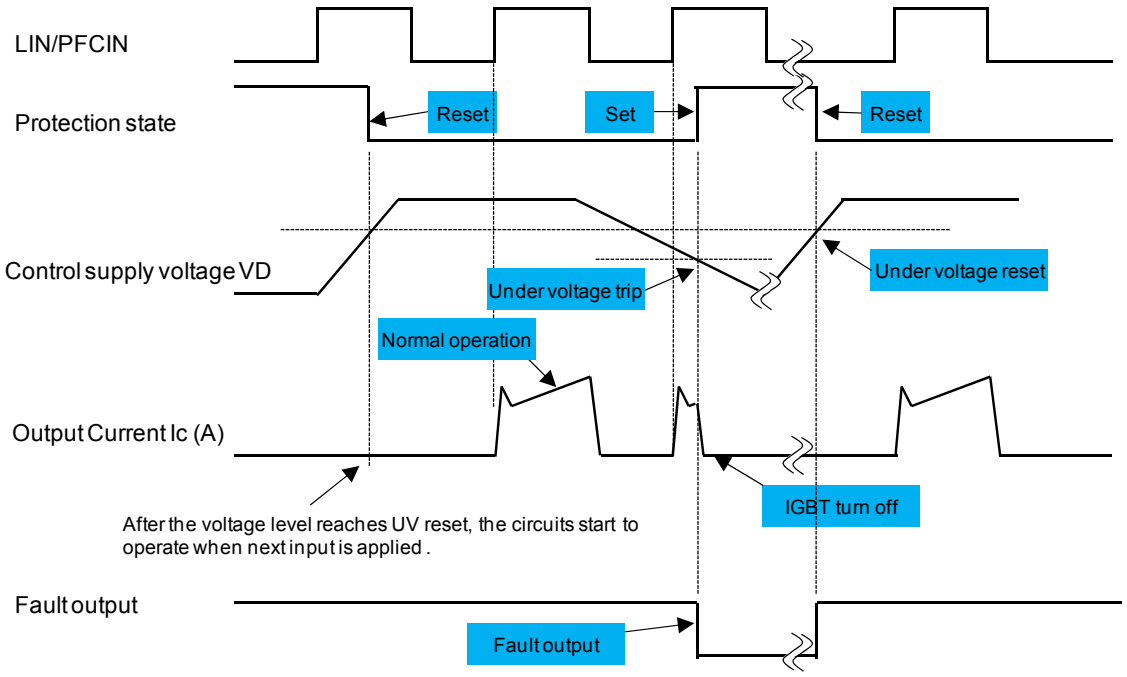


<Fig.6>



Input / Output Timing Chart

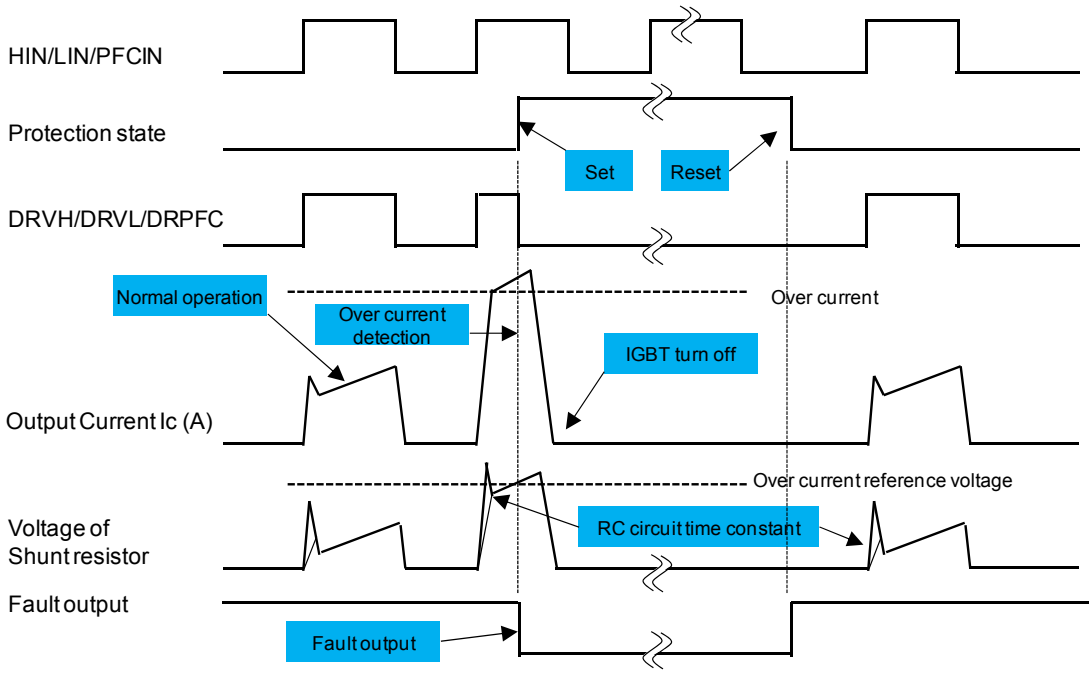
■ UVLO(under Voltage Lockout) protection



<Fig.7>

*1 : When VDD decreases all gate output signals will go low and cut off all 6 IGBT outputs. When VDD rises the operation will resume immediately.
*2 : When the upper side 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 gate voltage rises.

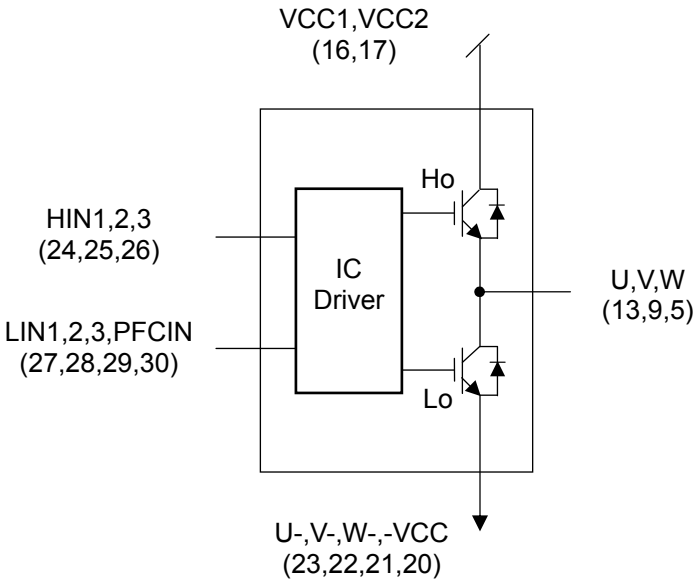
■ Over current protection (ITRIP/PFCTRIP).



<Fig.8>

*1 : When VITRIP exceeds threshold all IGBT's are turned off and normal operation resumes 2ms (typ) after over current condition is removed.

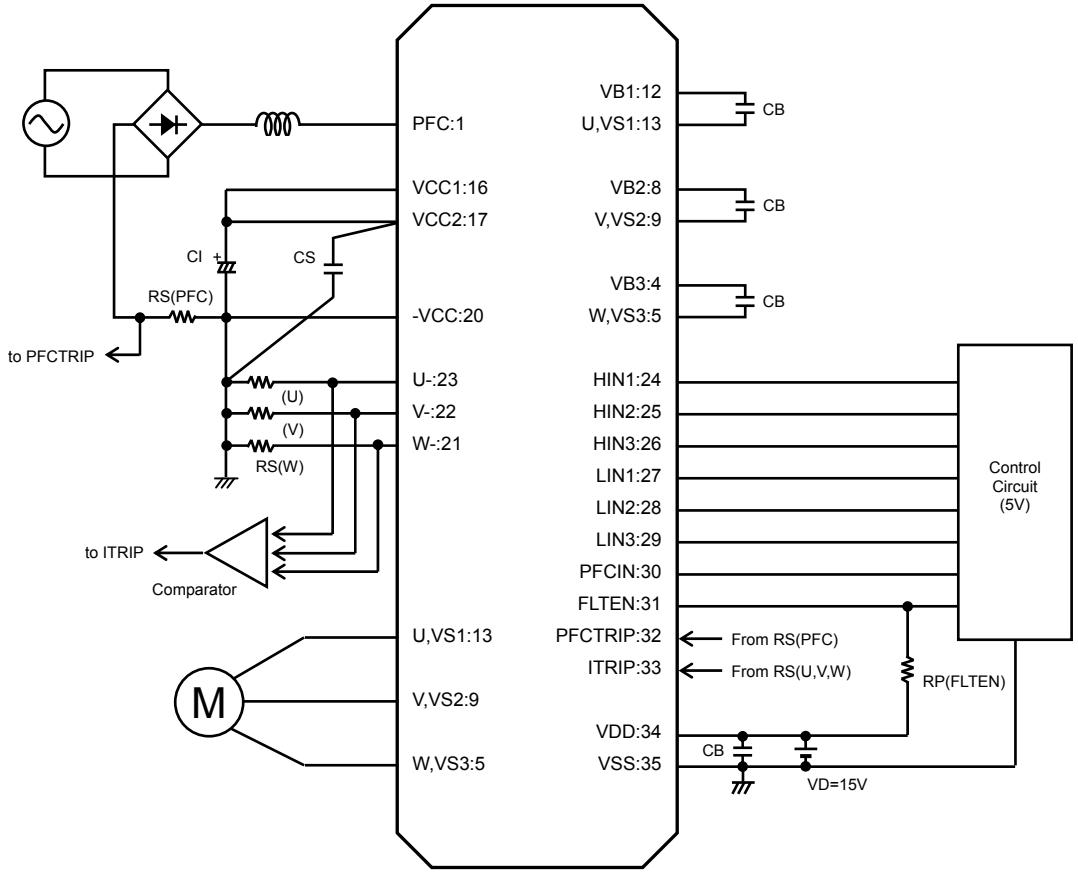
Logic level table



<Fig.9>

FLTEN	ITRIP, PFCTRIP	HIN1,2,3	LIN1,2,3,	PFCIN	U,V,W
1	0	1	0	X	Vbus
1	0	0	1	X	0
1	0	0	0	X	Off
1	0	1	1	X	Off
1	1	X	X	X	Off
0	X	X	X	X	Off

Equivalent Block Diagram



<Fig.10>

Recommended Operating Conditions at Ta = 25°C

Parameter	Symbol	Conditions	Ratings			Unit
			min	typ	max	
Supply voltage	VCC	+ to U-(V-,W-)	0	280	400	V
Pre-driver supply voltage	VD1,2,3	VB1 to U,VB2 to V,VB3 to W	12.5	15	17.5	V
	VD4	VDD to VSS	13.5	15	16.5	
Input ON voltage	VIN(ON)	HIN1,HIN2,HIN3,LIN1,LIN2,LIN3, PFCIN terminal	3.0	-	5.0	V
Input OFF voltage	VIN(OFF)		0	-	0.3	
PWM frequency(PFC part)	fPWMp		1	-	30	kHz
PWM frequency(Inverter part)	fPWMi		1	-	20	kHz
Dead time	DT	Upper/lower input signal downtime	1.5	-	-	μs
Operating temperature	TC	H-IC case temperature	-20	-	85	°C
Tightening torque	MT	'M3' type screw	0.8	-	1.0	N·m

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

Usage Precautions

1. This H-IC 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. The “FLTEN” terminal (pins 31) is open Drain (It is operating as “FAULT” when becoming Low).This terminal serves as the shut down function of the built-in pre-driver. Please make pulling up outside so that “FLTEN” terminal voltages become more than 3V. (When the terminal voltage is above 3V, normalcy works, and it is shut down when it is equal to or less than 0.8V). Moreover, thermistor built in between FLTEN(pins 31) and VSS(pins 35), so the substrate temperature can be monitored according to the voltage divided by the thermistor and the pull-up resistor. When the pull up voltage (VP) is at 5V, pull up resistor (RP) connects above 10kΩ, and in case of VP=15V, RP connects above 39kΩ. The substrate temperature detection by the thermistor is for the substrate temperature monitor in the state of regular operation and not for protection of HIC over-temperature. Moreover, it is not the one to momentary heating-up, and partial heating-up.

4. The pull-down resistor is connected with the inside of the signal input terminal, however please connect the pull-down resistor(about 2.2 to 3.3kΩ) outside to decrease the influence of the noise by wiring etc.

5. The over-current protection feature operates only when it is possible to do a circuit control normally. For safety, recommend installation a fuse, and so on in the “Vcc” line.

6. Because the H-IC can be destroyed when the motor connection terminal (pin No.5, 9 and 13) is opened while the motor is running, please be especially careful of the connection (soldering condition) of this terminal.

7. The “ITRIP” terminal (33pin) and the “PFCTRIP” terminal (32pin) are the input terminal of the built-in comparator. It can stop movement by inputting the voltage more than reference voltage. (At the time of movement, usually those terminals give it for the voltage less than reference voltage). Please use it as various protections such as the over-current protection (feedback from external shunt resistance). In addition, the protection movement is not done a latch of. After the protection movement end, It becomes the movement return state after 2ms (typ.). So, please do the protection movement detection of all input signals in OFF (LOW) promptly afterward.

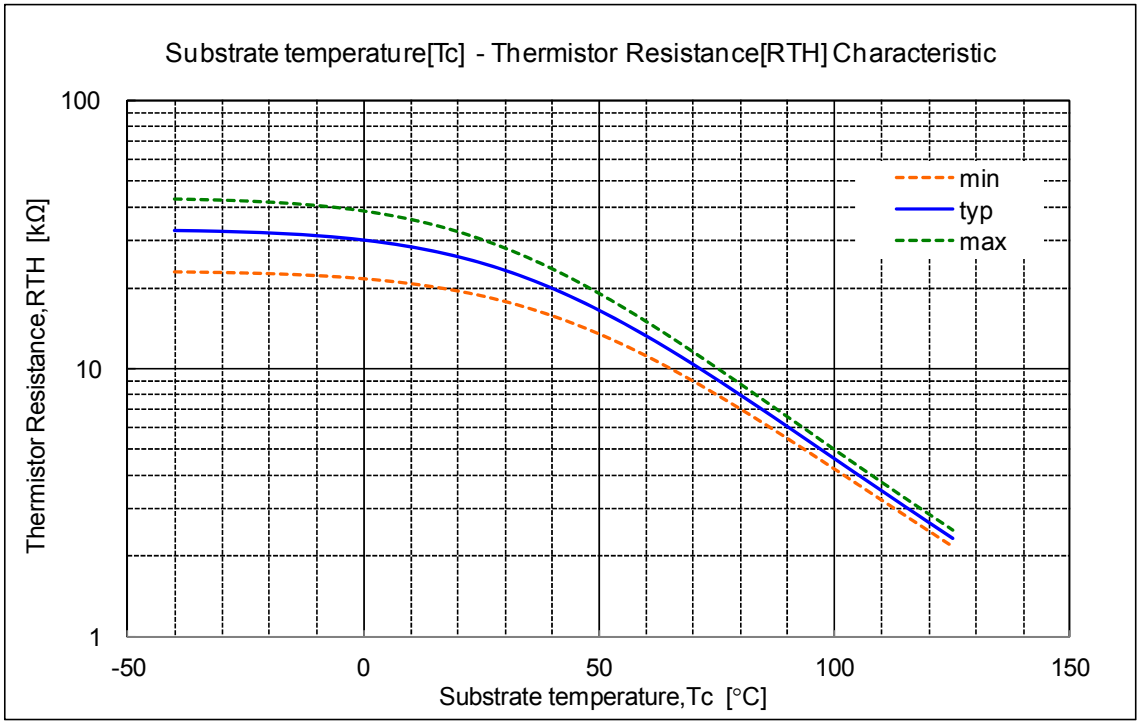
8. When input pulse width is less than 1.0us, an output may not react to the pulse. (Both ON signal and OFF signal)

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

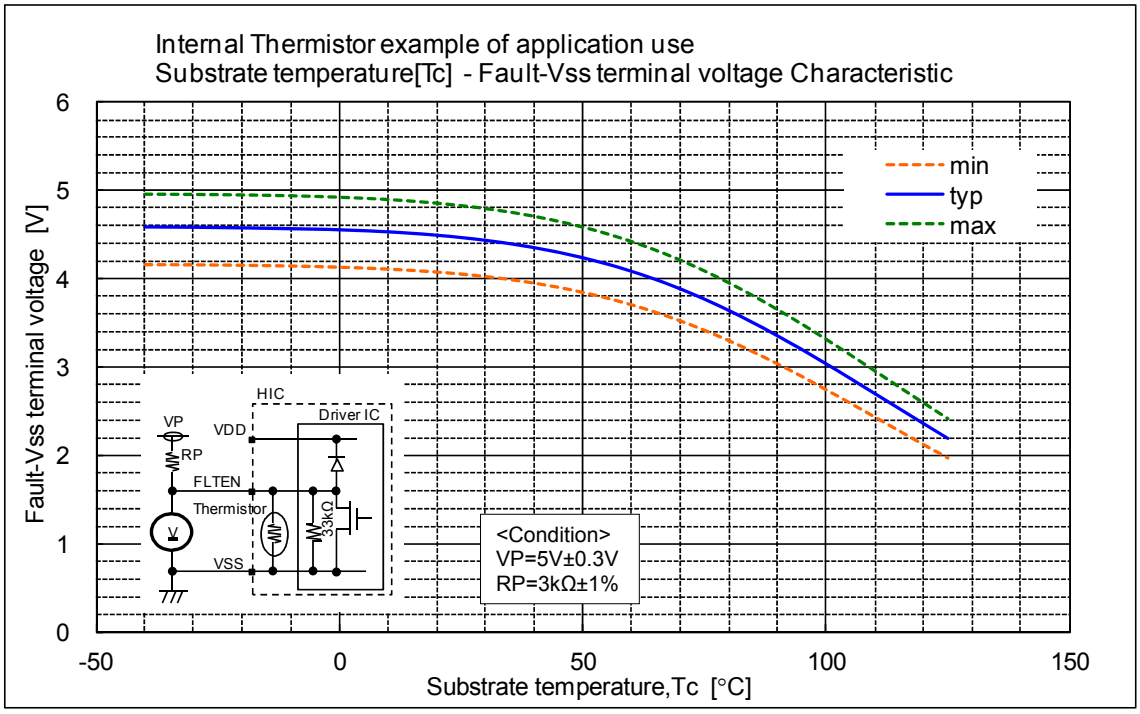
The characteristic of thermistor

Parameter	Symbol	Condition	Min	Typ.	Max	Unit
Resistance	R_{25}	T=25°C	18.7	24.8	30.2	kΩ
Resistance	R_{125}	T=125°C	2.18	2.34	2.49	kΩ
B-Constant(25-50°C)	B		4165	4250	4335	k
Temperature Range			-40		+125	°C

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



<Fig.11>



<Fig.12>

The characteristic of PWM switching frequency

Maximum sinusoidal phase current as function of switching frequency (VBUS=400V, Tc=100°C)

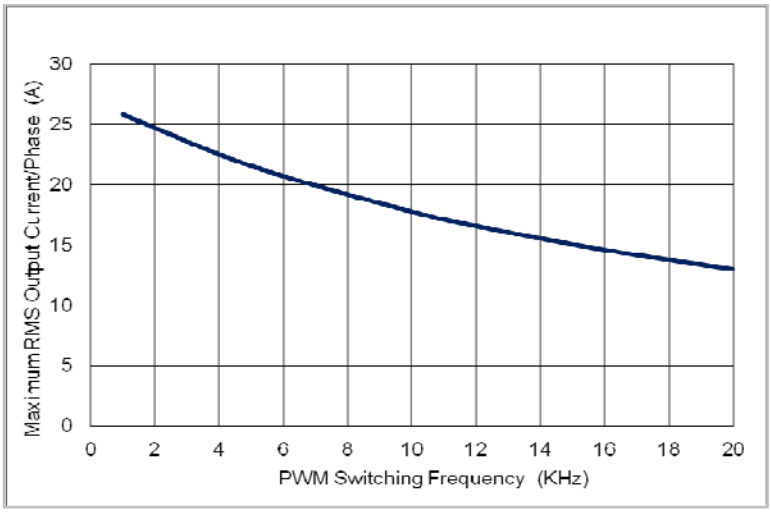


Fig.13

Switching waveform

IGBT Turn-on. Typical turn-on waveform atTc=100°C, Vcc=400V

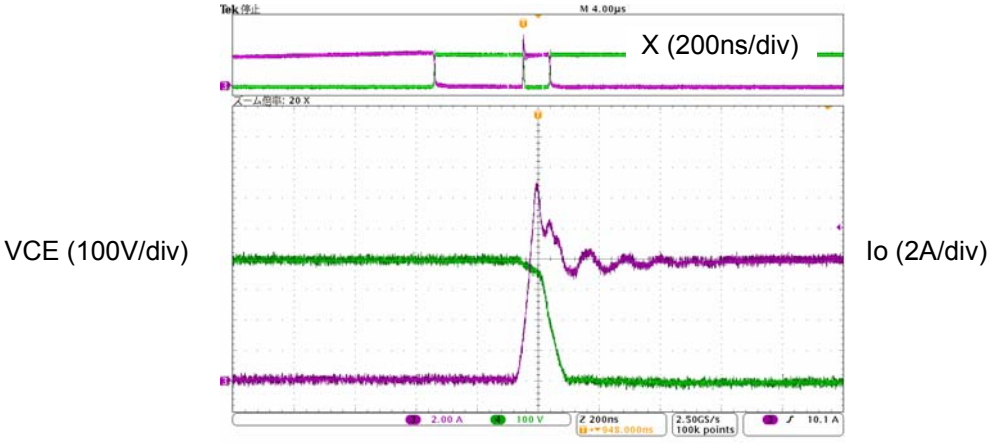


Fig.14

IGBT Turn-off. Typical turn-off waveform atTc=100°C, Vcc=400V

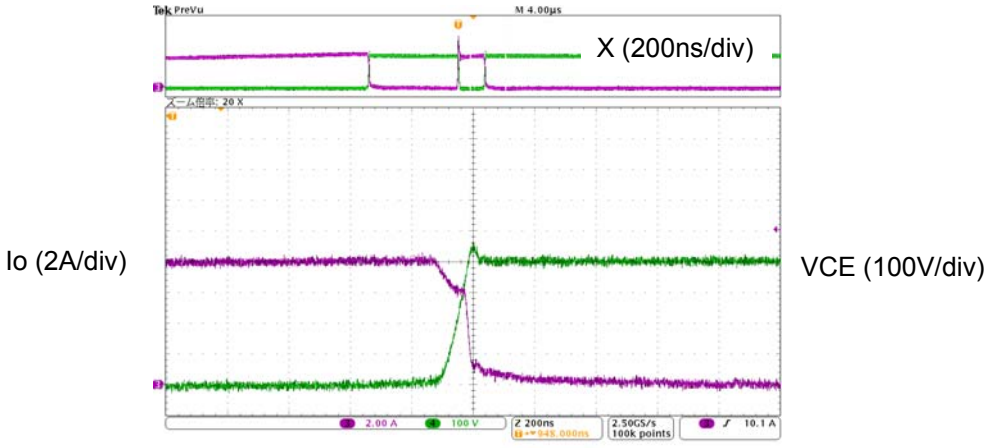


Fig.15

Cb capacitor value calculation for boot-strap circuit (Cb)

Calculate conditions

Parameter	Value
Upper side power supply.(VD)	15[V]
Total gate charge of output power IGBT at 15V.(Qg)	0.132[μC]
Upper side power supply low voltage protection.(UVLO)	12V
Upper side power dissipation.(Idmax)	400[uA]

Capacitance calculation formula

Tonmax is upper arm maximum on time' equal the time when the Cb voltage falls from 15V to the upper limit of 'Low voltage protection level.

“ton-maximum" of upper side is the time that Cb decreases 15V to the maximum low voltage protection of the upper side (12V).

Thus, the following formula ① is true.

VD x Cb – Qg – Idmax x tonmax = UVLO x Cb -------- *1

Cb = (Qg + Idma x tonmax) / (VD – UVLO) --------- *2

The relationship between tonmax and Cb becomes as follows.

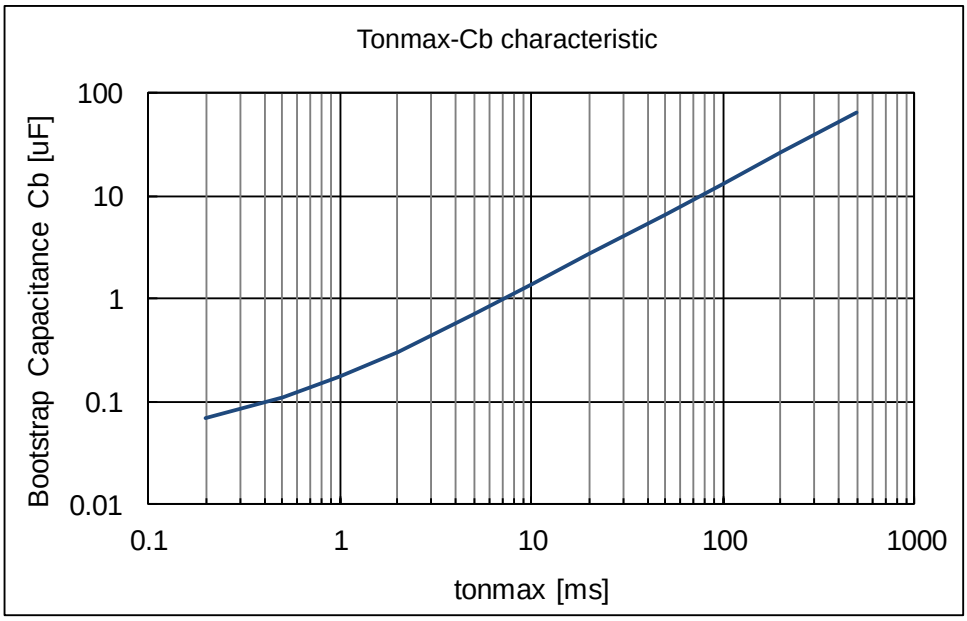
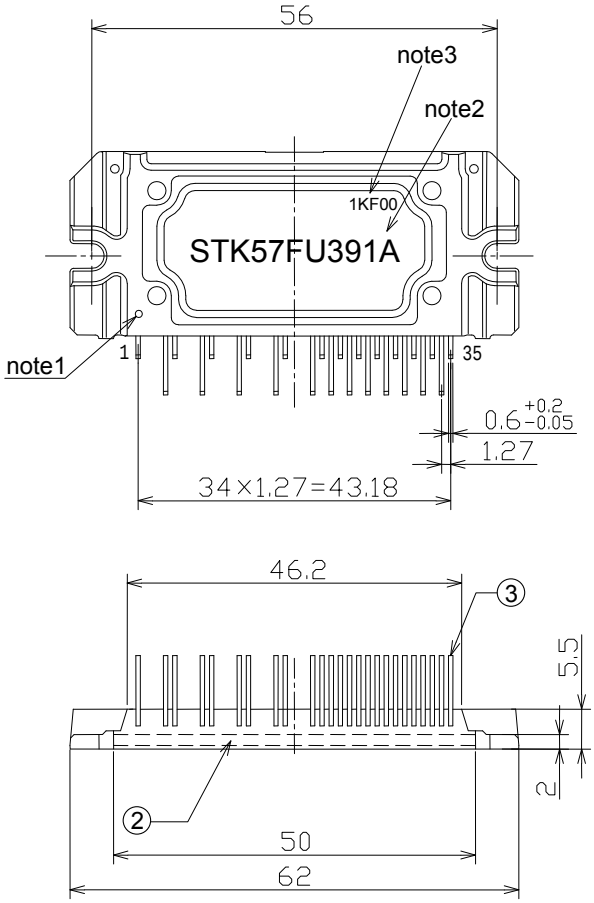


Fig.16

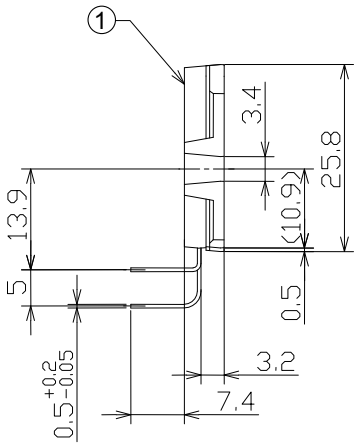
■ Recommended Cb is approximately 3 times of above calculated value.
Please make the decision by the evaluation with the set.

Package Dimensions

unit : mm



missing pin : 2,3,6,7,10,11,14,15,18,19



note1 : Mark for NO.1 pin identification.
note2 : The form of a character in this drawing differs from that of HIC.
note3 : This indicates the lot code. The form of a character in this drawing differs from that of HIC.

No.	Part Name	Material	Treatment
①	Case	EPOXY	
②	Substrate	IMST Substrate	
③	Lead Frame	Cu	Sn

ORDERING INFORMATION

Device	Package	Shipping (Qty / Packing)
STK57FU391A-E	SIP35 56x25.8 (Pb-Free)	8 / Fan-Fold