Ordering number : EN*A2355

STK541UC62K-E

Advance Information

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Inverter IPM for 3-phase Motor Drive

Overview

This “Inverter IPM” is highly integrated device containing all High Voltage (HV) control from HV-DC to 3-phase outputs in a single SIP module (Single-In line Package). Output stage uses IGBT/FRD technology and implements Under Voltage Protection (UVP) and Over Current Protection (OCP) with a Fault Detection output flag. Internal Boost diodes are provided for high side gate boost drive.

Function

- Single control power supply due to Internal bootstrap circuit for high side pre-driver circuit
- All control input and status output are at low voltage levels directly compatible with microcontrollers
- Built-in cross conduction prevention
- Externally accessible embedded thermistor for substrate temperature measurement
- The level of the over-current protection current is adjustable with the external resistor, “RSD”

Certification

- UL1557 (File Number : E339285).

Specifications

Absolute Maximum Ratings at Tc = 25°C

Parameter	Symbol	Conditions	Ratings	Unit
Supply voltage	V_{CC}	P to N, surge<500V *1	450	V
Collector-emitter voltage	V_{CE}	P to U,V,W or U,V,W to N	600	V
Output current	Io	P, N, U,V,W terminal current	±10	A
		P, N, U,V,W terminal current at Tc=100°C	±5	A
Output peak current	Iop	P, N, U,V,W terminal current for a Pulse width of 1ms.	±20	A
Pre-driver 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	0 to 7	V
FLTEN terminal voltage	VFLTEN	FLTEN terminal	–0.3 to V_{DD}	V
Maximum power dissipation	Pd	IGBT per channel	22	W
Junction temperature	Tj	IGBT,FRD	150	°C
Storage temperature	Tstg		–40 to +125	°C
Operating substrate temperature	Tc	IPM case temperature	–40 to +100	°C
Tightening torque		Case mounting screws *3	0.9	Nm
Withstand voltage	Vis	50Hz sine wave AC 1 minute *4	2000	VRMS

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

*1: Surge voltage developed by the switching operation due to the wiring inductance between “P” and “N” terminal.

*2: Terminal voltage: VD1=VB1–U, VD2=VB2–V, VD3=VB3–W, VD4=V_{DD}–V_{SS}

*3: Flatness of the heat-sink should be 0.15mm and below.

*4: Test conditions : AC2500V, 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.

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 17 of this data sheet.

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

Parameter	Symbol	Conditions		Test circuit	min	typ	max	Unit
Power output section								
Collector-emitter cut-off current	ICE	VCE = 600V		Fig.1	-	-	0.1	mA
Bootstrap diode reverse current	IR(BD)	VR(BD)			-	-	0.1	mA
Collector to emitter saturation voltage	VCE(SAT)	Ic=10A Tj=25°C	Upper side	Fig.2	-	1.4	2.3	V
			Lower side *1		-	1.7	2.6	
		Ic=5A Tj=100°C	Upper side		-	1.3	-	
			Lower side *1		-	1.6	-	
Diode forward voltage	VF	IF=10A Tj=25°C	Upper side	Fig.3	-	1.3	2.2	V
			Lower side *1		-	1.6	2.5	
		IF=5A Tj=100°C	Upper side		-	1.2	-	
			Lower side *1		-	1.5	-	
Junction to case thermal resistance	θj-c(T)	IGBT			-	-	5.5	°C/W
	θj-c(D)	FRD			-	-	6.5	
Control (Pre-driver) section								
Pre-driver current consumption	ID	VD1, 2, 3=15V		Fig.4	-	0.08	0.4	mA
		VD4=15V			-	1.6	4.0	
High level Input voltage	Vin H	HIN1, HIN2, HIN3, LIN1, LIN2, LIN3 to VSS			-	-	0.8	V
Low level Input voltage	Vin L				2.5	-	-	V
Input threshold voltage hysteresis*1	Vinth(hys)				0.5	0.8	-	V
Logic 0 input leakage current	I_{IN+}	VIN=+3.3V			76	118	160	uA
Logic 1 input leakage current	I_{IN-}	VIN=0V			97	150	203	uA
FLTEN terminal input electric current	IoSD	FAULT : ON/VFLTEN=0.1V			-	2	-	mA
FAULT clearance delay time	FLTCLR	Fault output latch time			6	9	12	ms
V_{CC} and V_S undervoltage upper threshold	V_{CCUV+} V_{SUV+}				10.5	11.1	11.7	V
V_{CC} and V_S undervoltage lower threshold	V_{CCUV-} V_{SUV-}				10.3	10.9	11.5	V
V_{CC} and V_S undervoltage hysteresis	V_{CCUVH} V_{SUVH-}				0.14	0.2	-	A
Over current protection level	ISD	PW=100μs		Fig.5	10	-	17	A
Output level for current monitor	ISO	Io=10A			0.30	0.33	0.36	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.

Electrical Characteristics at Tc = 25°C, VD1, VD2, VD3, VD4 = 15V, V_{CC} = 300V, L = 3.9mH

Parameter	Symbol	Conditions	Test circuit	min	typ	max	Unit
Switching Character							
Switching time	tON	Io=10A Inductive load	Fig.6	0.2	0.4	1.1	μs
	tOFF			-	0.5	1.2	
Turn-on switching loss	Eon	Ic=5A, P=300V, V_{DD}=15V, L=3.9mH Tc=25°C	Fig.6	-	200	-	μJ
Turn-off switching loss	Eoff			-	130	-	μJ
Total switching loss	Etot			-	330	-	μJ
Turn-on switching loss	Eon	Ic=5A, P=300V, V_{DD}=15V, L=3.9mH Tc=100°C	Fig.6	-	240	-	μJ
Turn-off switching loss	Eoff			-	160	-	μJ
Total switching loss	Etot			-	400	-	μJ
Diode reverse recovery energy	Erec	I_F=5A, P=400V, V_{DD}=15V, L=0.5mH, Tc=100°C		-	17	-	μJ
Diode reverse recovery time	Trr			-	62	-	ns
Reverse bias safe operating area	RBSOA	Io=20A, V_{CE}=450V	Fig.7	Full square			
Short circuit safe operating area	SCSOA	V_{CE}=400V, Tc=100°C		4	-	-	μs
Allowable offset voltage slew rate	dv/dt	Between U, V, W to N		−50	-	50	V/ns

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

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 6ms to 12ms 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.

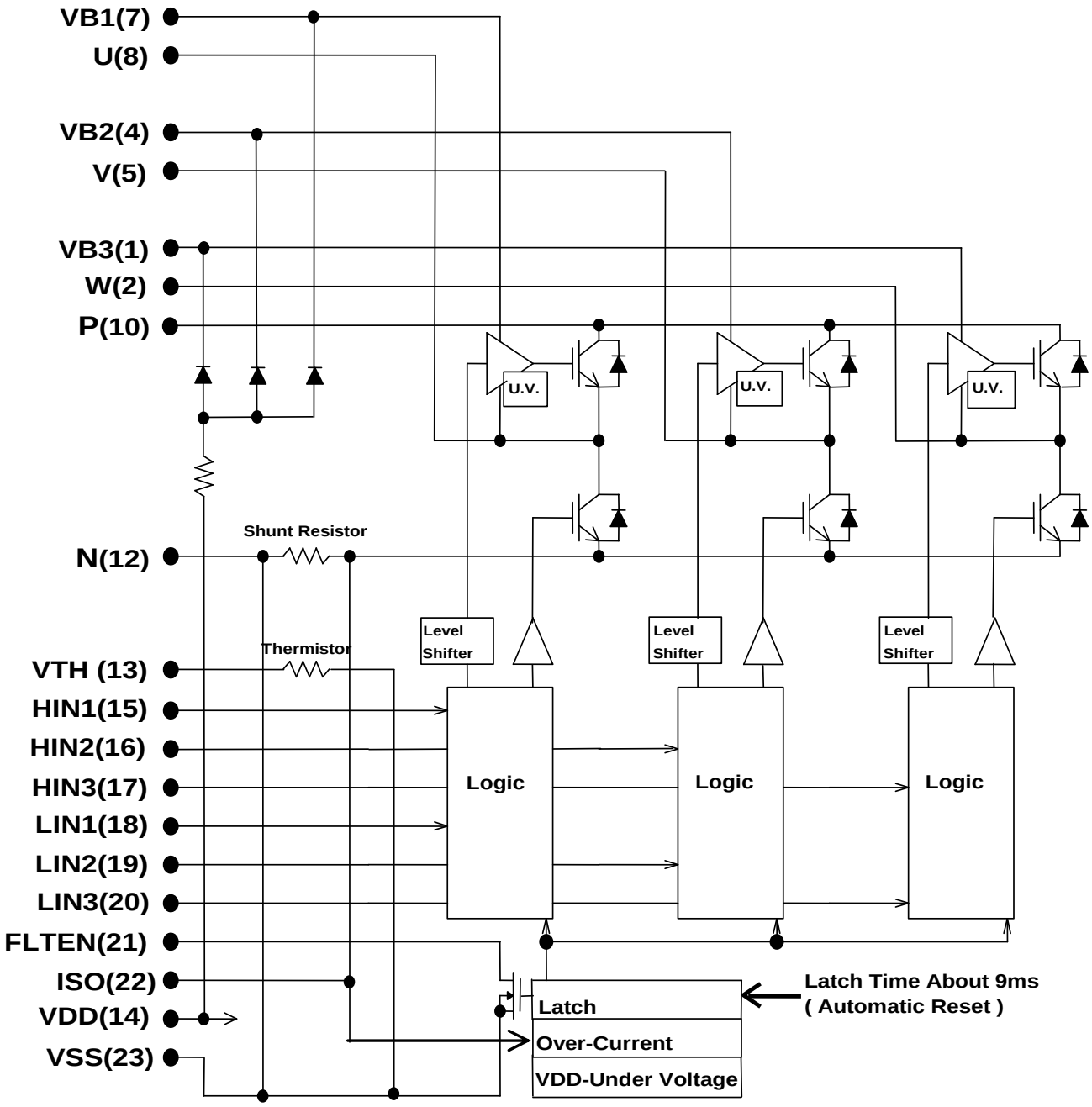
Upper side:
The gate is turned off and will return to regular operation when recovering to the normal voltage, but the latch will continue till the input signal will turn 'low'.

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 M3 type screw, tightening torque range is 0.6 Nm to 0.9 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.

Equivalent Block Diagram



Module Pin-Out Description

Pin	Name	Description
1	VB3	High Side Floating Supply Voltage 3
2	W, VS3	Output 3 - High Side Floating Supply Offset Voltage
3	NA	None
4	VB2	High Side Floating Supply voltage 2
5	V,VS2	Output 2 - High Side Floating Supply Offset Voltage
6	NA	None
7	VB1	High Side Floating Supply voltage 1
8	U,VS1	Output 1 - High Side Floating Supply Offset Voltage
9	NA	None
10	P	Positive Bus Input Voltage
11	NA	None
12	N	Negative Bus Input Voltage
13	VTH	Temperature Feedback
14	VDD	+15V Main Supply
15	HIN1	Logic Input High Side Gate Driver - Phase U
16	HIN2	Logic Input High Side Gate Driver - Phase V
17	HIN3	Logic Input High Side Gate Driver - Phase W
18	LIN1	Logic Input Low Side Gate Driver - Phase U
19	LIN2	Logic Input Low Side Gate Driver - Phase V
20	LIN3	Logic Input Low Side Gate Driver - Phase W
21	FLTEN	Fault output and Enable
22	ISO	Current monitor output
23	VSS	Negative Main Supply

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	10	10	10	8	5	2
N	8	5	2	12	12	12

	U(BD)	V(BD)	W(BD)
M	7	4	1
N	23	23	23

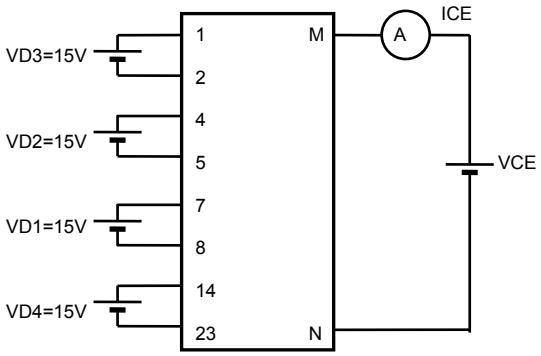


Fig.1

■VCE(SAT) (test by pulse)

	U+	V+	W+	U-	V-	W-
M	10	10	10	8	5	2
N	8	5	2	12	12	12
m	15	16	17	18	19	20

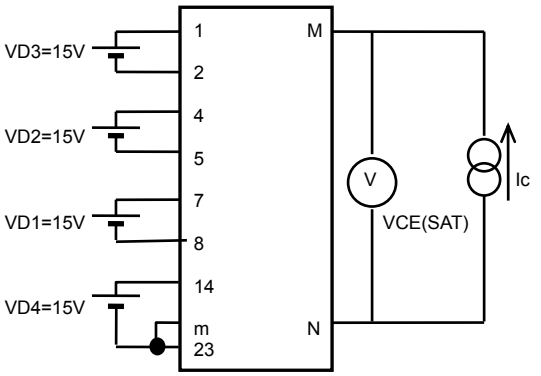


Fig.2

■VF (test by pulse)

	U+	V+	W+	U-	V-	W-
M	10	10	10	8	5	2
N	8	5	2	12	12	12

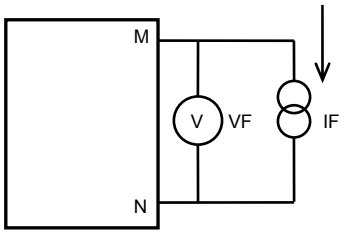


Fig.3

■ID

	VD1	VD2	VD3	VD4
M	7	4	1	14
N	8	5	2	23

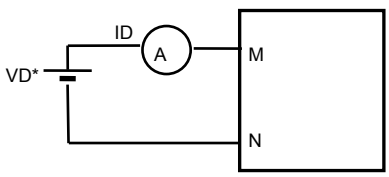


Fig.4

■ISD

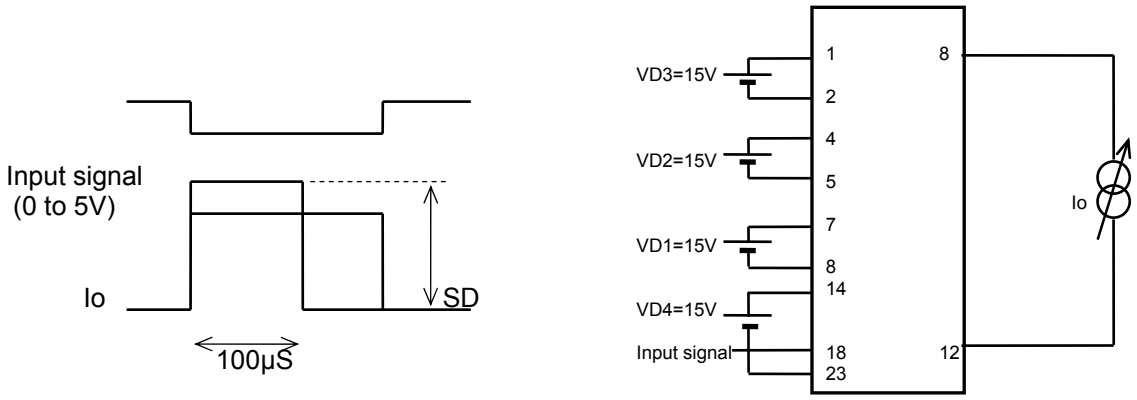


Fig.5

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

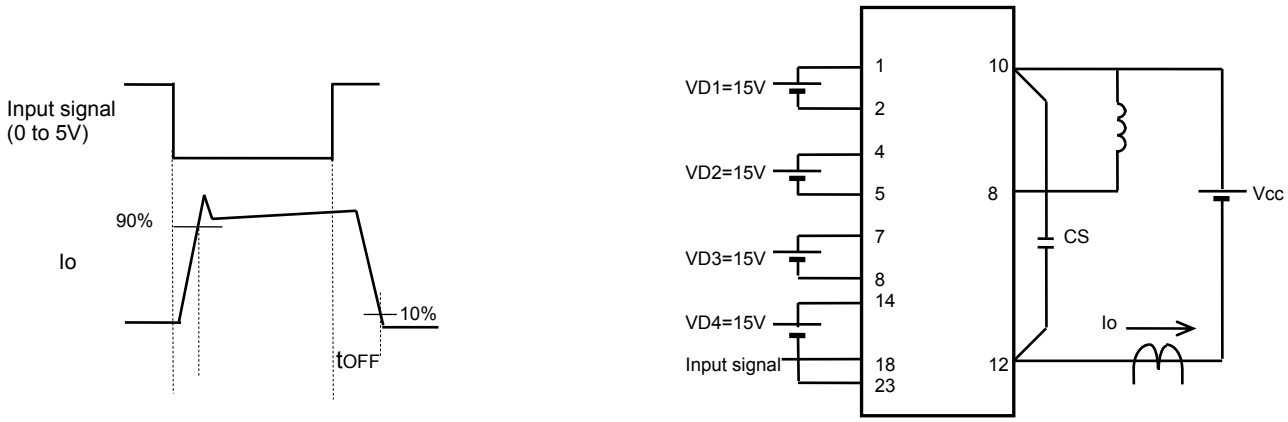


Fig.6

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

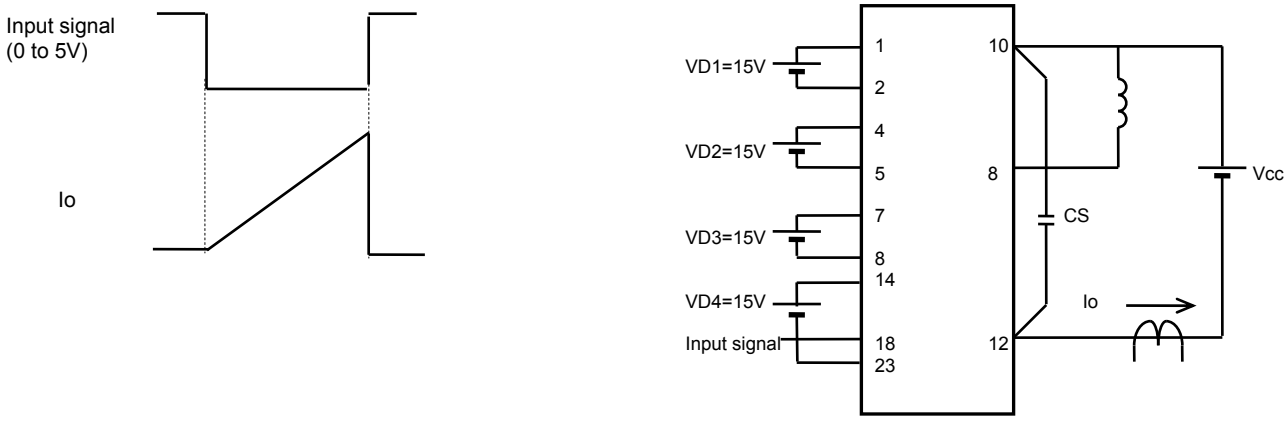


Fig.7

Input / Output Timing Diagram

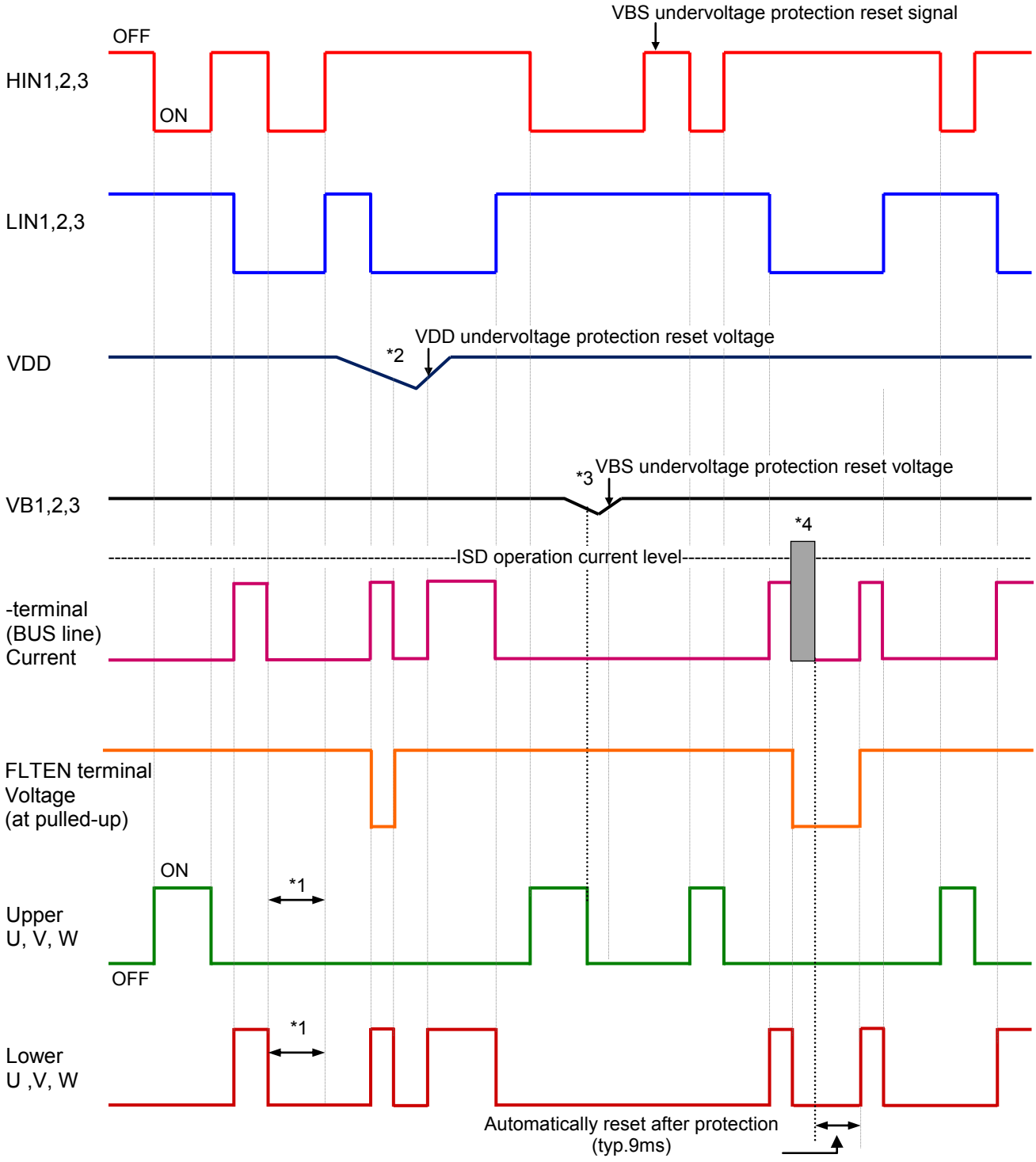


Fig.8

Notes

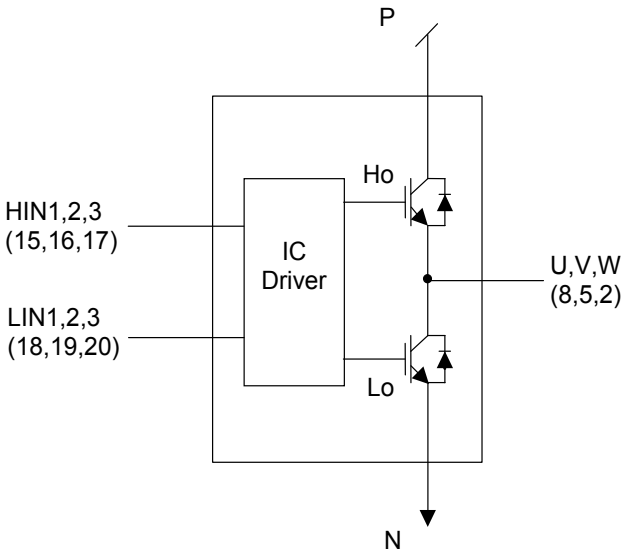
*1 : Diagram shows the prevention of shoot-through via control logic. More dead time to account for switching delay needs to be added externally.

*2 : When V_{DD} decreases all gate output signals will go low and cut off all of 6 IGBT outputs. 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 gate 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 6 to 12ms after the over current condition is removed.

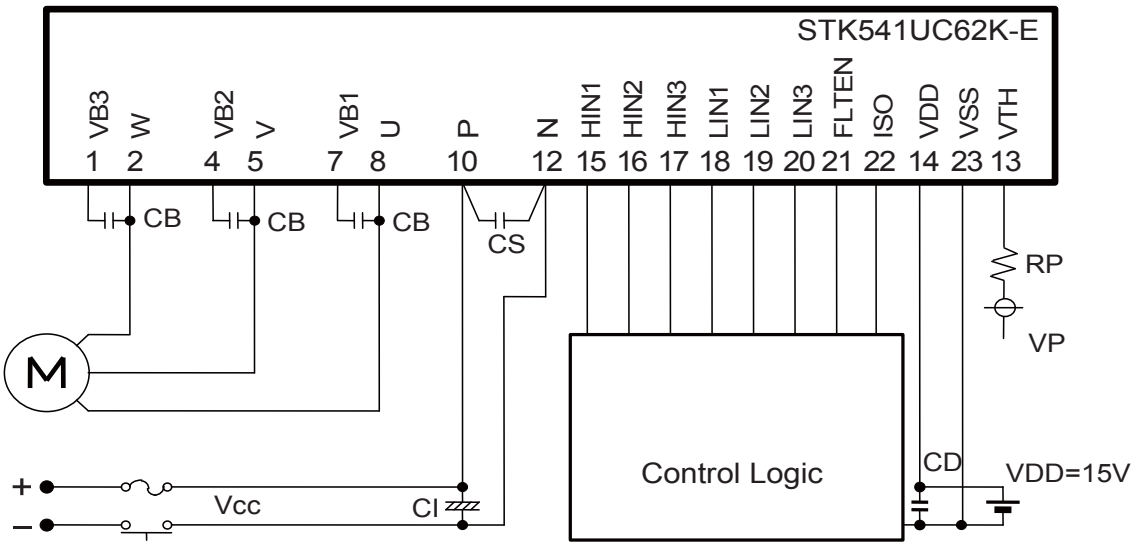
Logic level table



INPUT			OUTPUT			
HIN	LIN	OCP	Ho	Lo	U,V,W	FLTEN
H	L	OFF	L	H	N	OFF
L	H	OFF	H	L	P	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

Fig. 9

Sample Application Circuit



Recommended Operating Conditions at Tc = 25°C

Item	Symbol	Conditions	min	typ	max	Unit
Supply voltage	V_{CC}	P to N	0	280	450	V
Pre-driver supply voltage	VD1,2,3	VB1 to U, VB2 to V, VB3 to W	12.5	15	17.5	V
	VD4	V_{DD} to V_{SS} *1	13.5	15	16.5	
ON-state input voltage	VIN(ON)	HIN1, HIN2, HIN3, LIN1, LIN2, LIN3	0	-	0.3	V
OFF-state input voltage	VIN(OFF)		3.0	-	5.0	
PWM frequency	fPWM	-	1	-	20	kHz
Dead time	DT	Turn-off to turn-on	2	-	-	μs
Allowable input pulse width	PWIN	ON and OFF	1	-	-	μs
Tightening torque	-	'M3' type screw	0.6	-	0.9	Nm

*1 Pre-drive power supply (VD4=15±1.5V) must be 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 Precaution

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" (pin22) is terminal for current monitor. When the pull-down resistor is used, please select it more than 5.6kΩ
4. "FLTEN" (pin21) 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 VSS terminal and VTH 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.10 and below.
6. The over-current protection feature is not intended to protect in exceptional fault condition. An external fuse is recommended for safety.
7. 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).
8. 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	99	100	101	kΩ
Resistance	R_{100}	Tc=100°C	5.12	5.38	5.66	kΩ
B-Constant (25 to 50°C)	B		4165	4250	4335	K
Temperature Range			–40	-	+125	°C

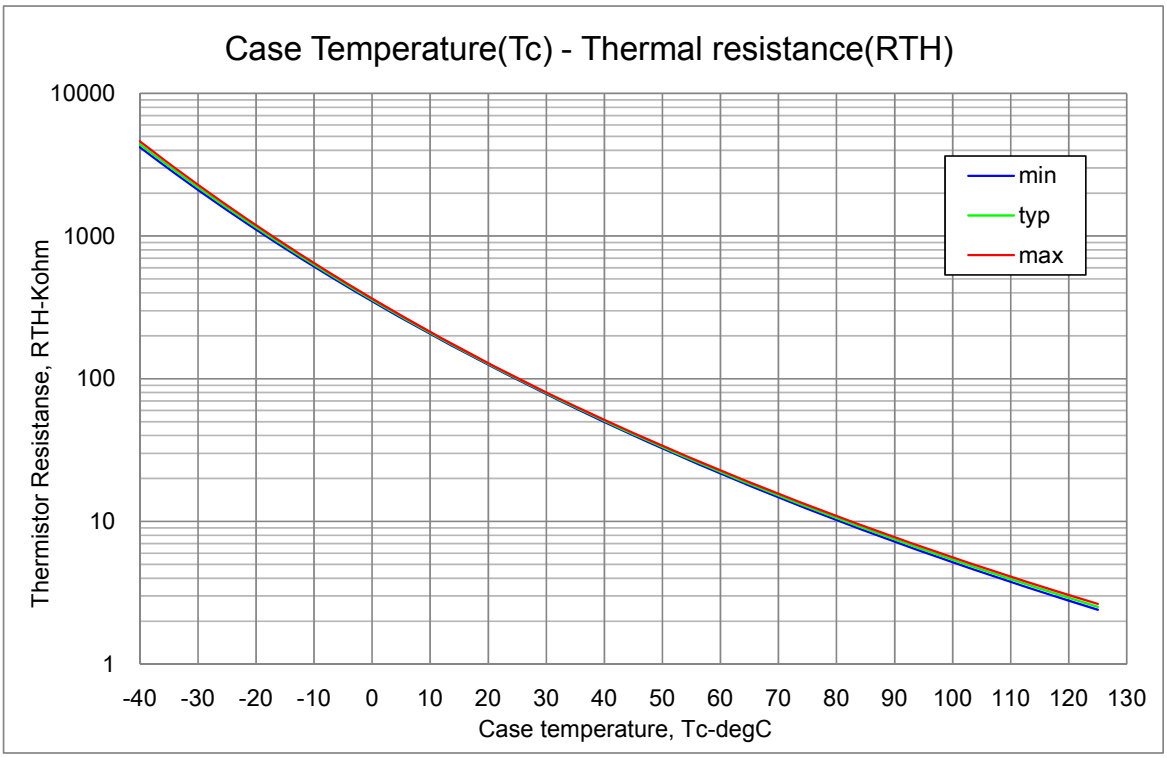


Fig.10 Variation of thermistor resistance with temperature

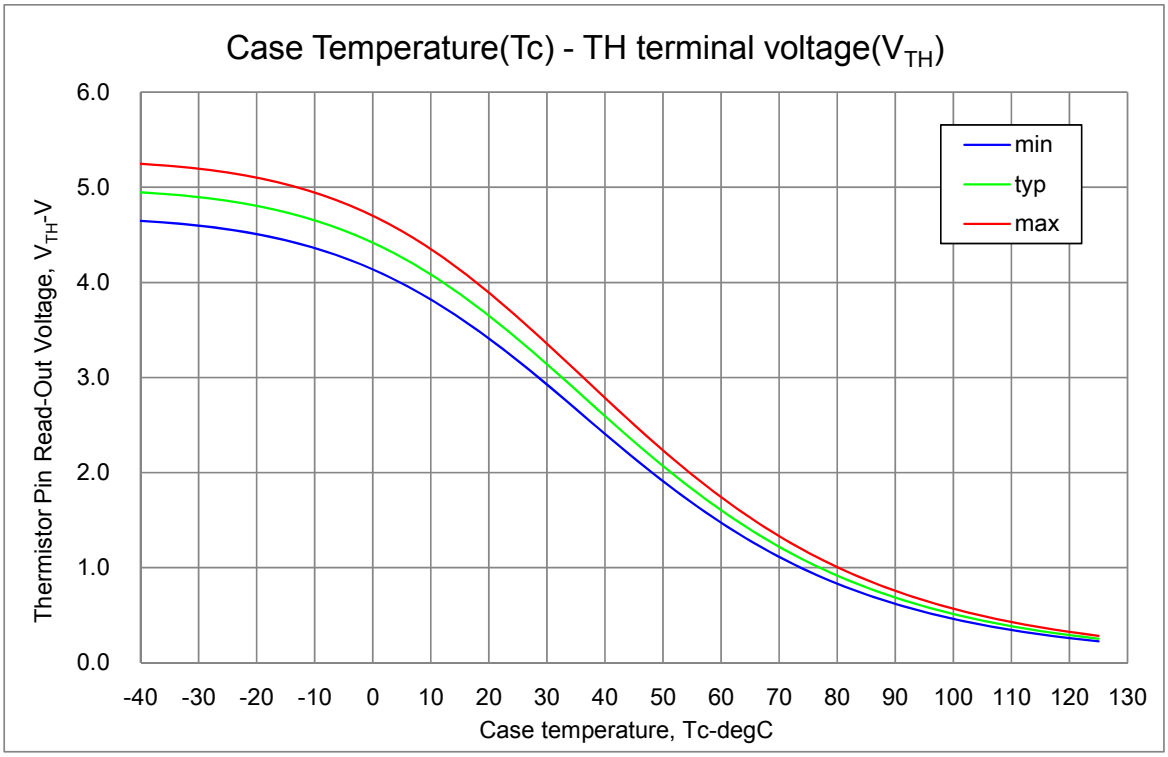


Fig.11 Variation of thermistor terminal voltage with temperature
(47kΩ pull-up resistor, 5V)

The characteristic of PWM switching frequency

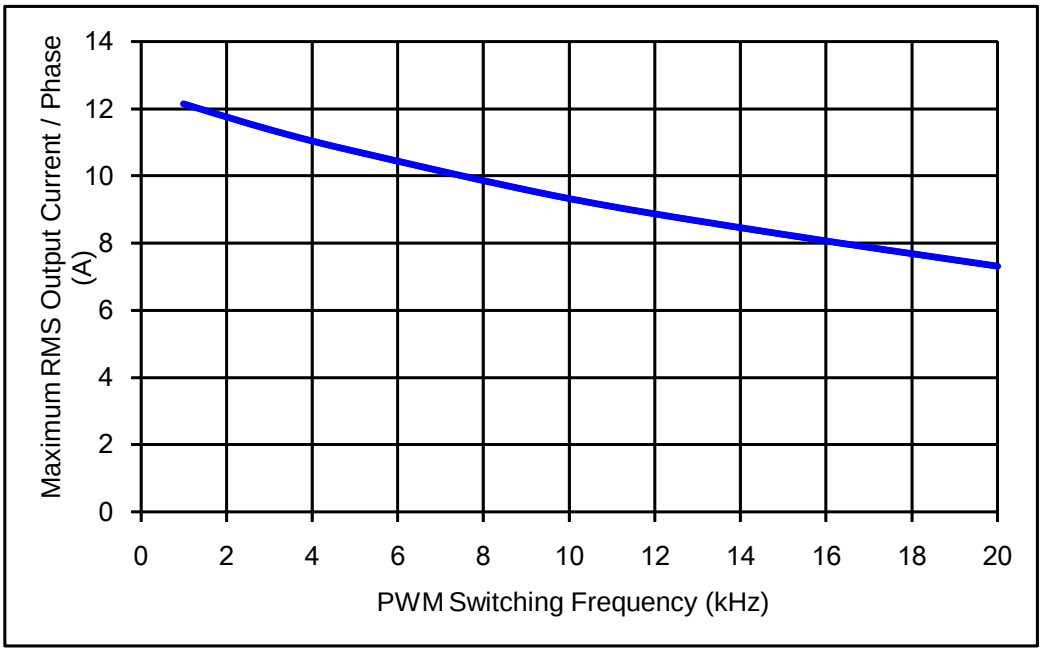


Fig. 12 Maximum sinusoidal phase current as function of switching frequency
at Tc=100℃, V_{CC}=400V

Switching waveform

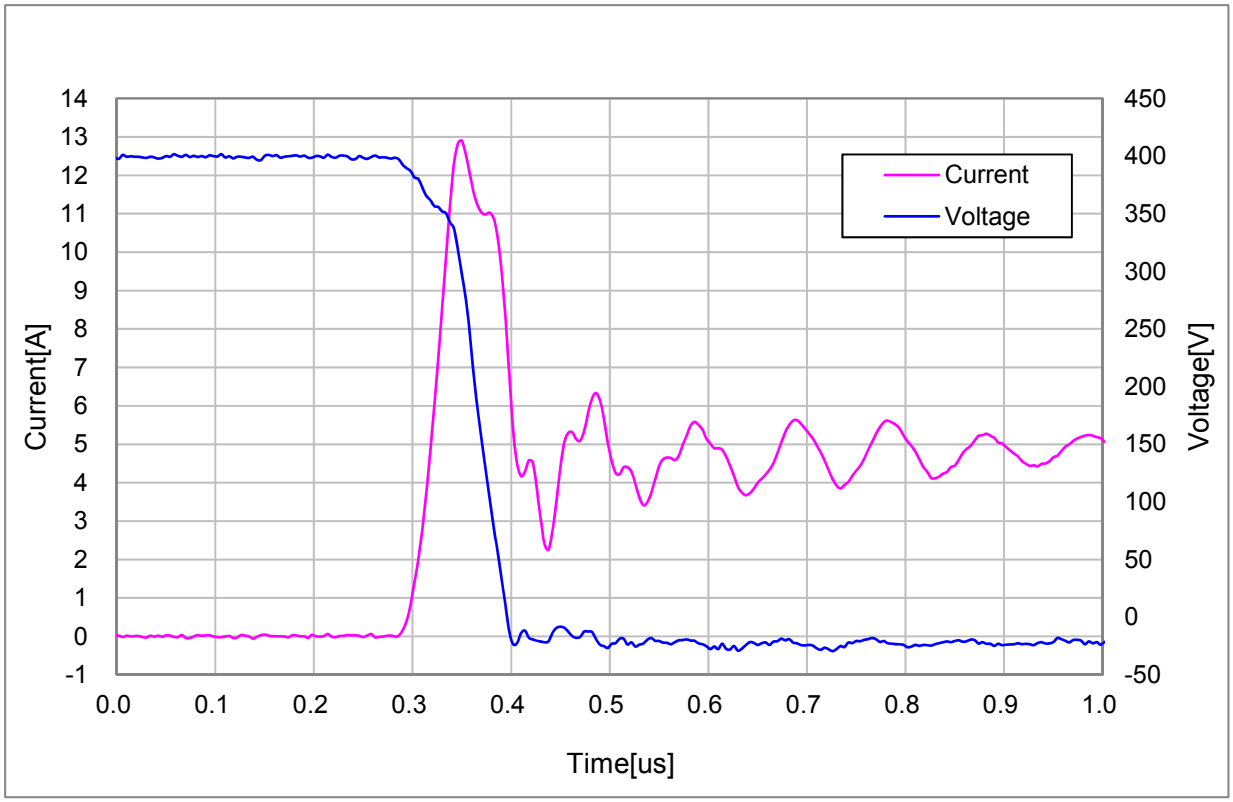


Fig. 13 IGBT Turn-on. Typical turn-on waveform at Tc=100°C, V_{CC}=400V

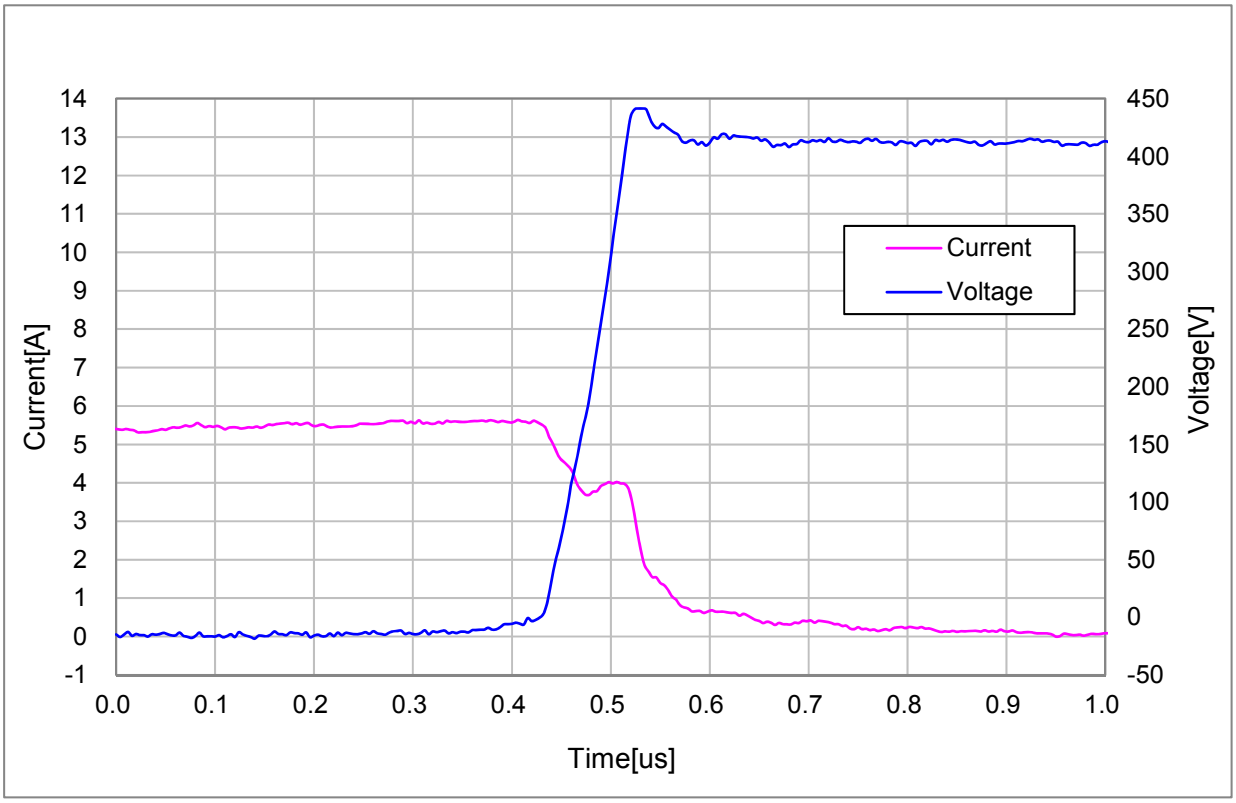


Fig. 14 IGBT Turn-off. Typical turn-off waveform at Tc=100°C, V_{CC}=400V

CB capacitor value calculation for bootstrap circuit

Calculate conditions

Parameter	Symbol	Value	Unit
Upper side power supply.	VBS	15	V
Total gate charge of output power IGBT at 15V.	QG	89	nC
Upper limit 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	TONMAX	-	s

Capacitance calculation formula

Thus, the following formula are true
VBS x CB - QG - IDMAX * TONMAX = UVLO * CB
therefore,
CB = (QG + IDMAX * TONMAX) / (VBS - UVLO)

The relationship between TONMAX 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, this value needs to be verified prior to production.

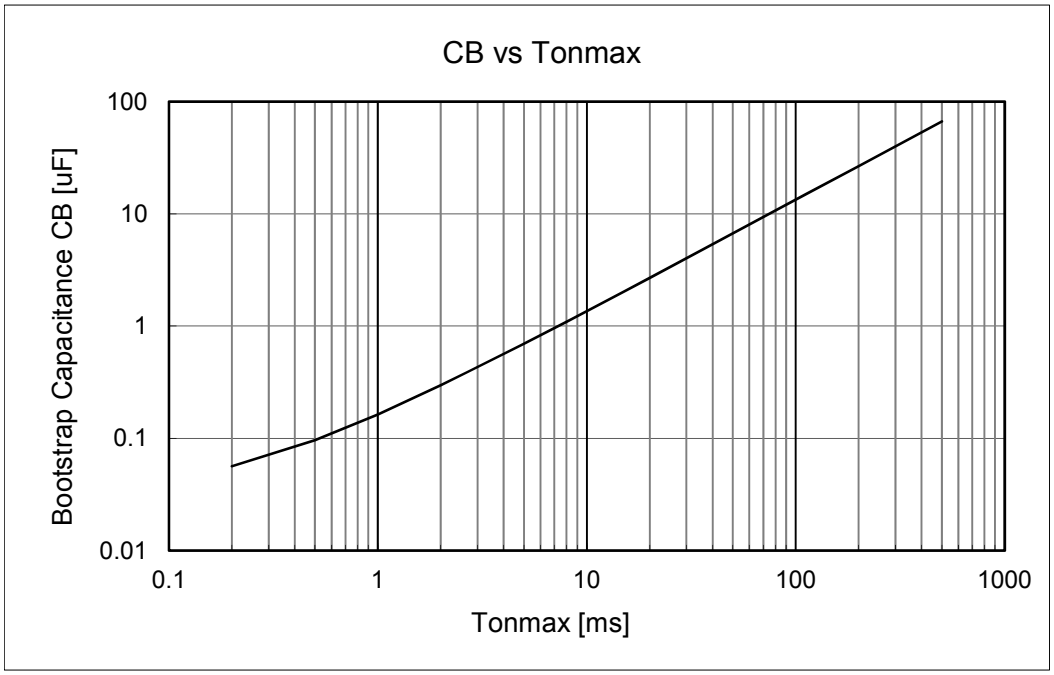


Fig. 15 Tonmax - CB characteristic

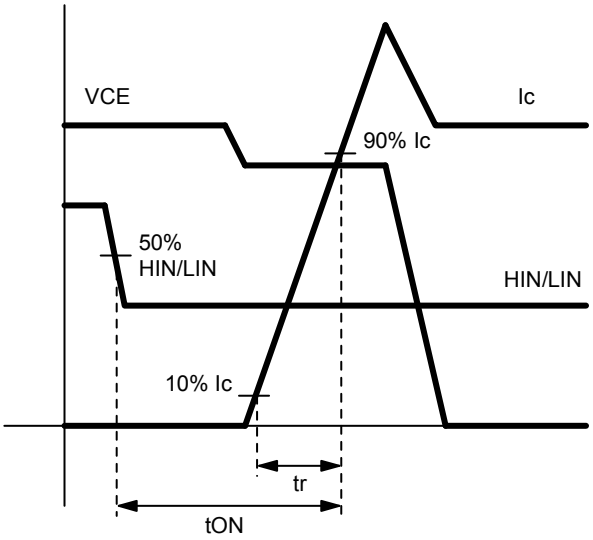


Fig. 16a Input to output propagation turn-on delay time

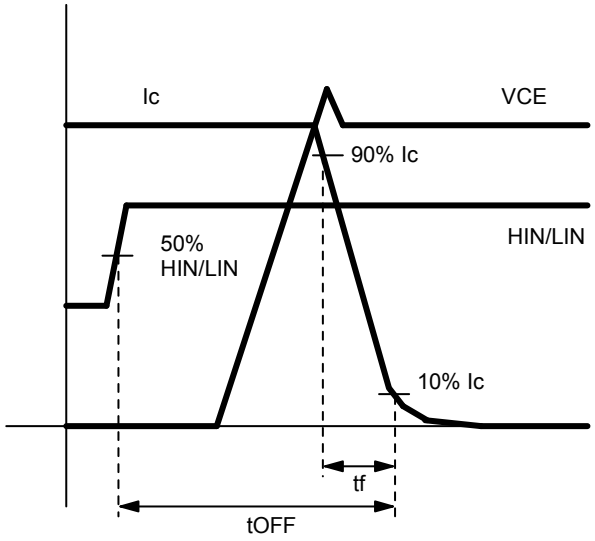


Fig. 16b Input to output propagation turn-off delay time

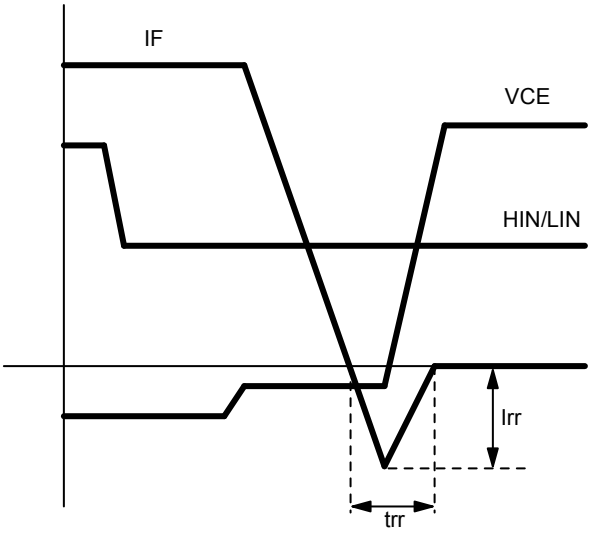
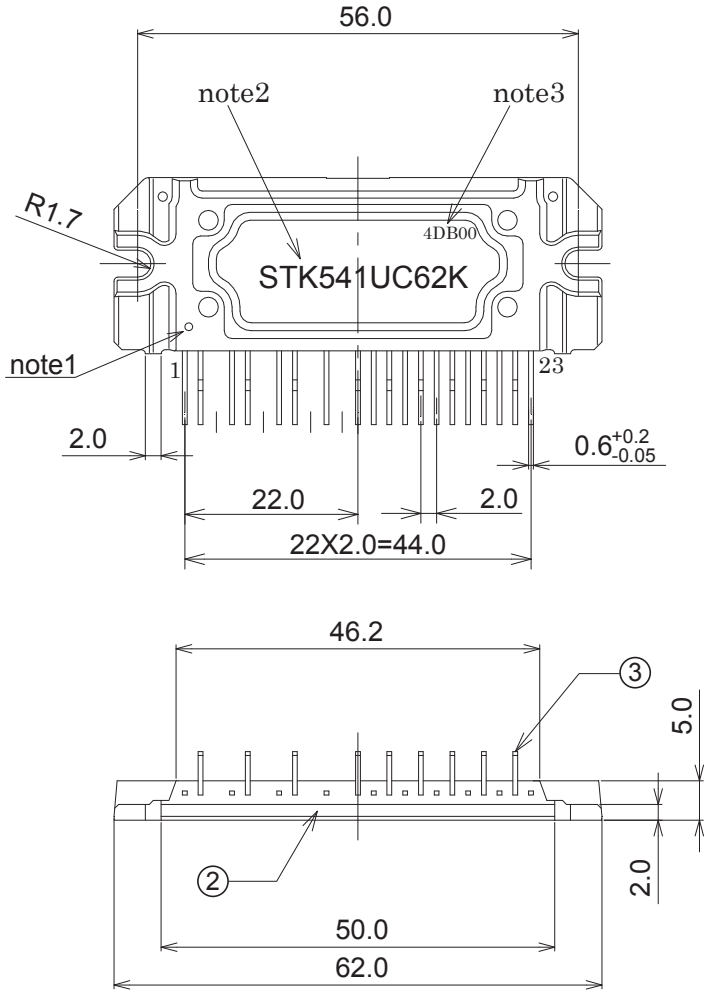


Fig. 16c Diode reverse recovery

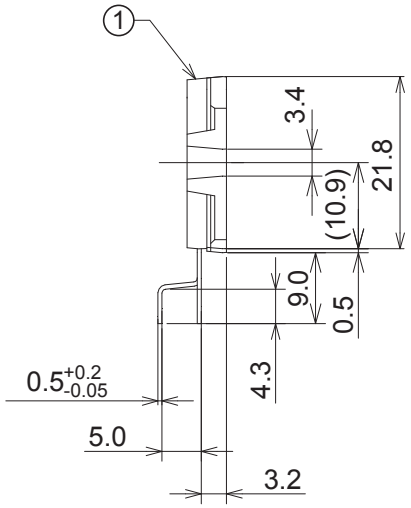
Package Dimensions

(unit : mm)

The tolerances of length are +/- 0.5mm unless otherwise specified.



missing pin ; 3, 6, 9, 11



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 date code. The form of a character in this drawing differs from that of HIC.

ORDERING INFORMATION

Device	Package	Shipping (Qty / Packing)
STK541UC62K-E	SIP23 56x21.8 (Pb-Free)	8 / Tube