

# STK541UC62K-E

## Intelligent Power Module (IPM) 600 V, 10 A



ON Semiconductor®

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### 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

### Certification

- UL1557 (File Number : E339285)

### Specifications

#### Absolute Maximum Ratings at Tc = 25°C

| Parameter                       | Symbol             | Conditions                                                          | Ratings                 | Unit |
|---------------------------------|--------------------|---------------------------------------------------------------------|-------------------------|------|
| Supply voltage                  | V <sub>CC</sub>    | P to N, surge < 500 V *1                                            | 450                     | V    |
| Collector-emitter voltage       | V <sub>CE</sub>    | P to U, V, W or U, V, W to N                                        | 600                     | V    |
| Output current                  | I <sub>o</sub>     | 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             | I <sub>op</sub>    | P, N, U, V, W terminal current for a Pulse width of 1 ms.           | ±20                     | A    |
| Pre-driver voltage              | VD1, 2, 3, 4       | VB1 to U, VB2 to V, VB3 to W, V <sub>DD</sub> to V <sub>SS</sub> *2 | 20                      | V    |
| Input signal voltage            | V <sub>IN</sub>    | HIN1, 2, 3, LIN1, 2, 3                                              | -0.3 to 7               | V    |
| FLTEN terminal voltage          | V <sub>FLTEN</sub> | FLTEN terminal                                                      | -0.3 to V <sub>DD</sub> | V    |
| Maximum power dissipation       | P <sub>d</sub>     | IGBT per channel                                                    | 22                      | W    |
| Junction temperature            | T <sub>j</sub>     | IGBT, FRD                                                           | 150                     | °C   |
| Storage temperature             | T <sub>stg</sub>   |                                                                     | -40 to +125             | °C   |
| Operating substrate temperature | T <sub>c</sub>     | IPM case temperature                                                | -40 to +100             | °C   |
| Tightening torque               |                    | Case mounting screws *3                                             | 0.9                     | Nm   |
| Isolation voltage               | V <sub>is</sub>    | 50 Hz sine wave AC 1 minute *4                                      | 2000                    | VRMS |

Reference voltage is “V<sub>SS</sub>” 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 to U, VD2 = VB2 to V, VD3 = VB3 to W, VD4 = V<sub>DD</sub> to V<sub>SS</sub>

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

\*4 : Test conditions : AC 2500 V, 1 s.

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.

### ORDERING INFORMATION

See detailed ordering and shipping information on page 14 of this data sheet.

# STK541UC62K-E

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

| Parameter                                                       | Symbol                                   | Conditions                                                                                                                            |                        | Test circuit | min           | typ  | max  | Unit |
|-----------------------------------------------------------------|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|------------------------|--------------|---------------|------|------|------|
| Power output section                                            |                                          |                                                                                                                                       |                        |              |               |      |      |      |
| Collector-emitter cut-off current                               | I <sub>CE</sub>                          | V <sub>CE</sub> = 600 V                                                                                                               |                        | Fig.1        | —             | —    | 0.1  | mA   |
| Bootstrap diode reverse current                                 | I <sub>R(BD)</sub>                       | V <sub>R(BD)</sub>                                                                                                                    |                        |              | —             | —    | 0.1  | mA   |
| Collector to emitter saturation voltage                         | V <sub>CE(sat)</sub>                     | I <sub>c</sub> = 10 A                                                                                                                 | Upper side             | Fig.2        | —             | 1.4  | 2.3  | V    |
|                                                                 |                                          |                                                                                                                                       | T <sub>j</sub> = 25°C  |              | Lower side *1 | —    | 1.7  |      |
|                                                                 |                                          | I <sub>c</sub> = 5 A                                                                                                                  | Upper side             |              | —             | 1.3  | —    |      |
|                                                                 |                                          |                                                                                                                                       | T <sub>j</sub> = 100°C |              | Lower side *1 | —    | 1.6  |      |
| Diode forward voltage                                           | V <sub>F</sub>                           | I <sub>F</sub> = 10 A                                                                                                                 | Upper side             | Fig.3        | —             | 1.3  | 2.2  | V    |
|                                                                 |                                          |                                                                                                                                       | T <sub>j</sub> = 25°C  |              | Lower side *1 | —    | 1.6  |      |
|                                                                 |                                          | I <sub>F</sub> = 5 A                                                                                                                  | Upper side             |              | —             | 1.2  | —    |      |
|                                                                 |                                          |                                                                                                                                       | T <sub>j</sub> = 100°C |              | Lower side *1 | —    | 1.5  |      |
| Junction to case thermal resistance                             | θ <sub>j-c(T)</sub>                      | IGBT                                                                                                                                  |                        |              | —             | —    | 5.5  | °C/W |
|                                                                 | θ <sub>j-c(D)</sub>                      | FRD                                                                                                                                   |                        |              | —             | —    | 6.5  |      |
| Control (Pre-driver) section                                    |                                          |                                                                                                                                       |                        |              |               |      |      |      |
| Pre-driver current consumption                                  | I <sub>D</sub>                           | V <sub>D1, 2, 3</sub> = 15 V                                                                                                          |                        | Fig.4        | —             | 0.08 | 0.4  | mA   |
|                                                                 |                                          | V <sub>D4</sub> = 15 V                                                                                                                |                        |              | —             | 1.6  | 4.0  |      |
| High level Input voltage                                        | V <sub>in H</sub>                        | H <sub>IN1</sub> , H <sub>IN2</sub> , H <sub>IN3</sub> ,<br>L <sub>IN1</sub> , L <sub>IN2</sub> , L <sub>IN3</sub> to V <sub>SS</sub> |                        |              | 2.5           | —    | —    | V    |
| Low level Input voltage                                         | V <sub>in L</sub>                        |                                                                                                                                       |                        |              | —             | —    | 0.8  | V    |
| Input threshold voltage hysteresis *1                           | V <sub>inH(hys)</sub>                    |                                                                                                                                       |                        |              | 0.5           | 0.8  | —    | V    |
| Logic 0 input leakage current                                   | I <sub>IN+</sub>                         | V <sub>IN</sub> = +3.3 V                                                                                                              |                        |              | 76            | 118  | 160  | μA   |
| Logic 1 input leakage current                                   | I <sub>IN-</sub>                         | V <sub>IN</sub> = 0 V                                                                                                                 |                        |              | 97            | 150  | 203  | μA   |
| FLTEN terminal input electric current                           | I <sub>oSD</sub>                         | FAULT : ON/VFLTEN = 0.1 V                                                                                                             |                        |              | —             | 2    | —    | mA   |
| FAULT clearance delay time                                      | FLTCLR                                   | Fault output latch time                                                                                                               |                        |              | 6             | 9    | 12   | ms   |
| FLTEN Threshold                                                 | V <sub>EN+</sub>                         | Enable                                                                                                                                |                        |              | 2.5           | —    | —    | V    |
|                                                                 | V <sub>EN-</sub>                         | Disable                                                                                                                               |                        |              | —             | —    | 0.8  |      |
| V <sub>CC</sub> and V <sub>S</sub> undervoltage upper threshold | V <sub>CCUV+</sub><br>V <sub>SUV+</sub>  |                                                                                                                                       |                        |              | 10.5          | 11.1 | 11.7 | V    |
| V <sub>CC</sub> and V <sub>S</sub> undervoltage lower threshold | V <sub>CCUV-</sub><br>V <sub>SUV-</sub>  |                                                                                                                                       |                        |              | 10.3          | 10.9 | 11.5 | V    |
| V <sub>CC</sub> and V <sub>S</sub> undervoltage hysteresis      | V <sub>CCUVH</sub><br>V <sub>SUVH-</sub> |                                                                                                                                       |                        |              | 0.14          | 0.2  | —    | A    |
| Over current protection level                                   | ISD                                      | PW = 100 μs                                                                                                                           |                        | Fig.5        | 10            | —    | 17   | A    |
| Output level for current monitor                                | ISO                                      | I <sub>o</sub> = 10 A                                                                                                                 |                        |              | 0.30          | 0.33 | 0.36 | V    |

Reference voltage is "V<sub>SS</sub>" terminal voltage unless otherwise specified.

\*1 : The lower side's V<sub>CE(sat)</sub> and V<sub>F</sub> include a loss by the shunt resistance

## Electrical Characteristics at Tc = 25°C, VD1, VD2, VD3, VD4 = 15 V, V<sub>CC</sub> = 300 V, L = 3.9 mH

| Parameter                         | Symbol           | Conditions                                                                                     | Test circuit | min         | typ | max | Unit |
|-----------------------------------|------------------|------------------------------------------------------------------------------------------------|--------------|-------------|-----|-----|------|
| <b>Switching Character</b>        |                  |                                                                                                |              |             |     |     |      |
| Switching time                    | t <sub>ON</sub>  | I <sub>o</sub> = 10 A                                                                          | Fig.6        | 0.2         | 0.4 | 1.1 | μs   |
|                                   | t <sub>OFF</sub> | Inductive load                                                                                 |              | —           | 0.5 | 1.2 |      |
| Turn-on switching loss            | E <sub>on</sub>  | I <sub>c</sub> = 5 A, P = 300 V,<br>V <sub>DD</sub> = 15 V, L = 3.9 mH                         | Fig.6        | —           | 200 | —   | μJ   |
| Turn-off switching loss           | E <sub>off</sub> | T <sub>c</sub> = 25°C                                                                          |              | —           | 130 | —   | μJ   |
| Total switching loss              | E <sub>tot</sub> |                                                                                                |              | —           | 330 | —   | μJ   |
| Turn-on switching loss            | E <sub>on</sub>  | I <sub>c</sub> = 5 A, P = 300 V,<br>V <sub>DD</sub> = 15 V, L = 3.9 mH                         | Fig.6        | —           | 240 | —   | μJ   |
| Turn-off switching loss           | E <sub>off</sub> | T <sub>c</sub> = 100°C                                                                         |              | —           | 160 | —   | μJ   |
| Total switching loss              | E <sub>tot</sub> |                                                                                                |              | —           | 400 | —   | μJ   |
| Diode reverse recovery energy     | E <sub>rec</sub> | I <sub>F</sub> = 5 A, P = 400 V, V <sub>DD</sub> = 15 V,<br>L = 0.5 mH, T <sub>c</sub> = 100°C |              | —           | 17  | —   | μJ   |
| Diode reverse recovery time       | T <sub>rr</sub>  |                                                                                                |              | —           | 62  | —   | ns   |
| Reverse bias safe operating area  | RBSOA            | I <sub>o</sub> = 20 A, V <sub>CE</sub> = 450 V                                                 |              | Full square |     |     |      |
| Short circuit safe operating area | SCSOA            | V <sub>CE</sub> = 400 V, T <sub>c</sub> = 100°C                                                |              | 4           | —   | —   | μs   |

Reference voltage is "V<sub>SS</sub>" terminal voltage unless otherwise specified.

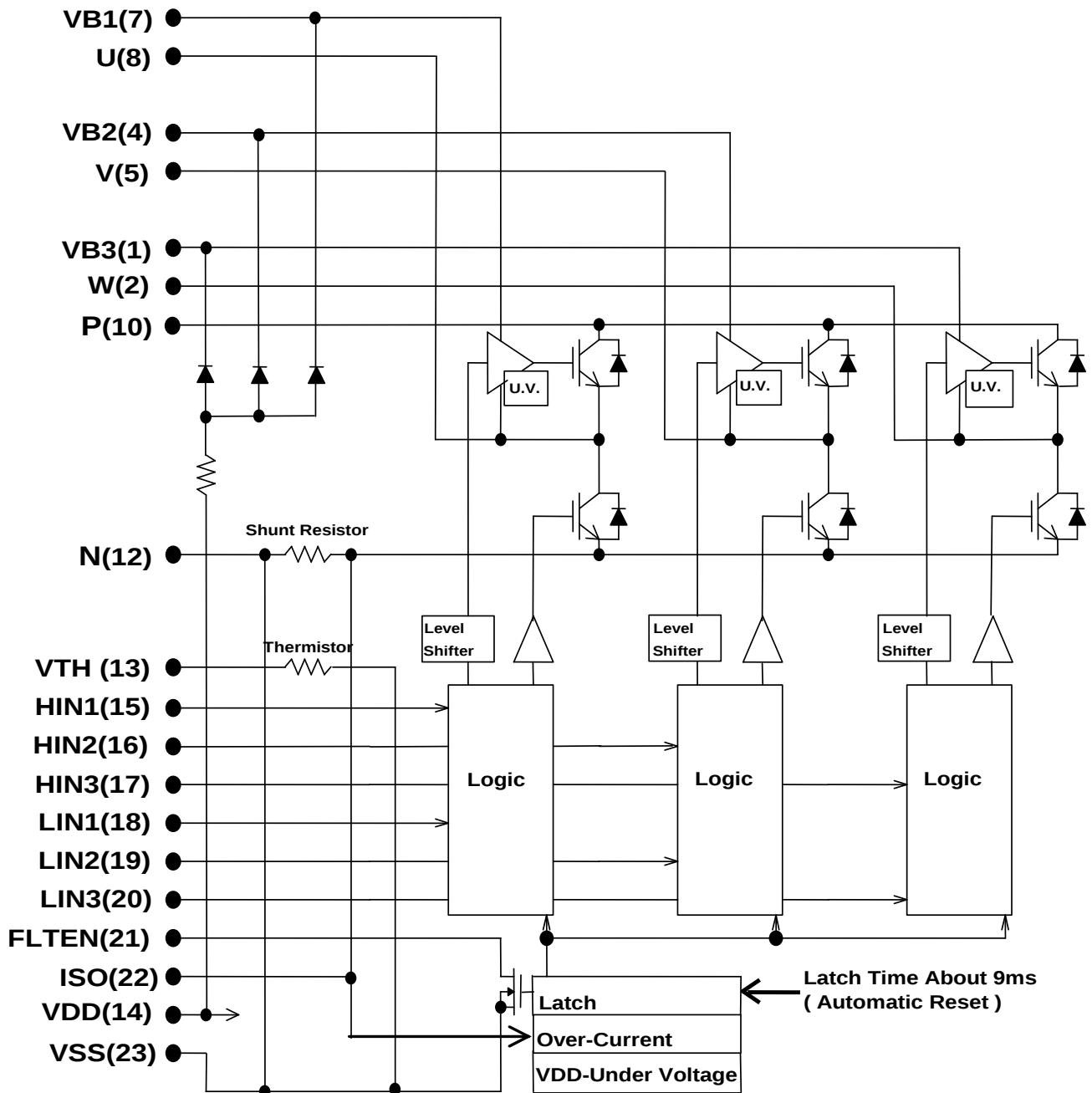
Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

### Notes :

- The pre-drive power supply low voltage protection has approximately 0.2 V of hysteresis and operates 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 'high'.  
Lower side : The gate is turned off and will automatically reset when recovering to normal voltage. It does not depend on input signal voltage.
- The pre-drive low voltage protection is the feature to protect devices when the pre-driver supply voltage falls due to an operating malfunction.

# STK541UC62K-E

## Equivalent Block Diagram



## STK541UC62K-E

### 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   | –      | Witout Pin                                          |
| 4   | VB2    | High Side Floating Supply voltage 2                 |
| 5   | V,VS2  | Output 2 - High Side Floating Supply Offset Voltage |
| 6   | –      | Witout Pin                                          |
| 7   | VB1    | High Side Floating Supply voltage 1                 |
| 8   | U,VS1  | Output 1 - High Side Floating Supply Offset Voltage |
| 9   | –      | Witout Pin                                          |
| 10  | P      | Positive Bus Input Voltage                          |
| 11  | –      | Witout Pin                                          |
| 12  | N      | Negative Bus Input Voltage                          |
| 13  | VTH    | Temperature Feedback                                |
| 14  | VDD    | +15 V 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                                |

# STK541UC62K-E

## Test Circuit

The tested phase U+ shows the upper side of the U phase and U- shows the lower side of the U phase.

### ■ $I_{CE}$ / $I_R(BD)$

|   | 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    |

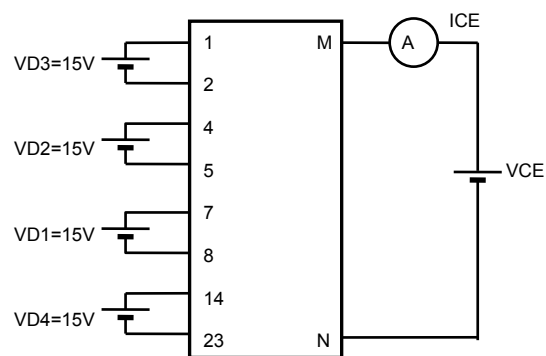


Fig.1

### ■ $V_{CE(sat)}$ (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 |

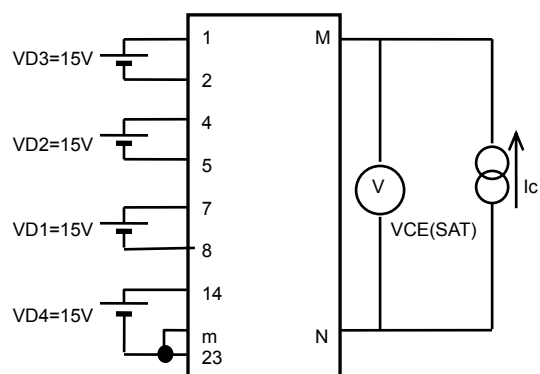


Fig.2

### ■ $V_F$ (test by pulse)

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

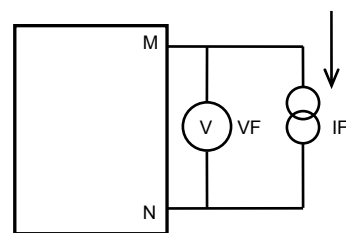


Fig.3

### ■ $I_D$

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

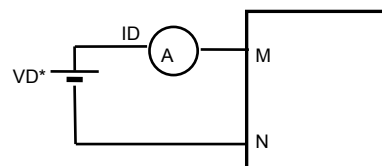


Fig.4

■ ISD

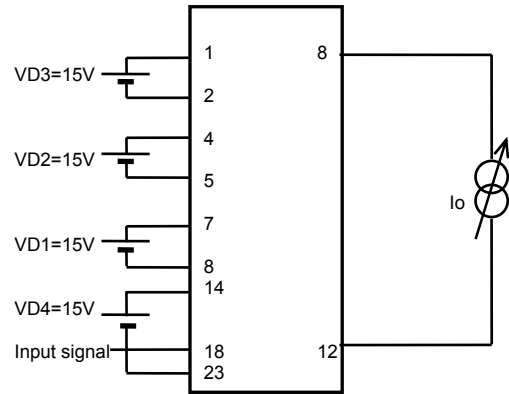
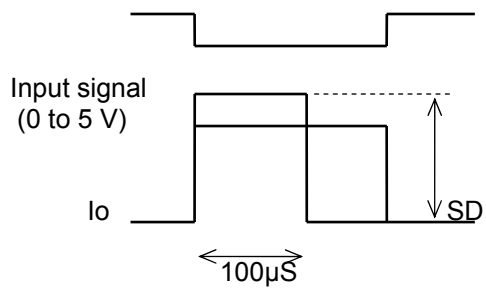


Fig.5

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

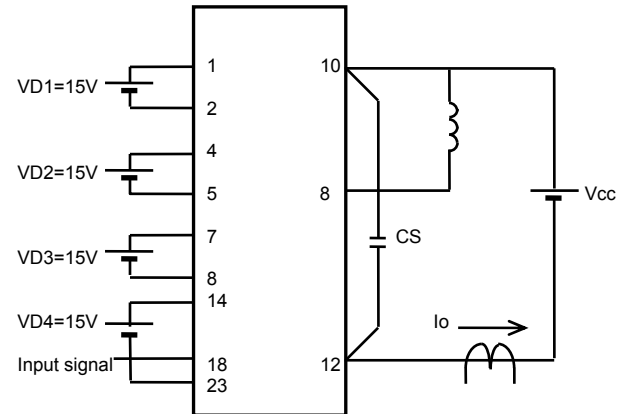
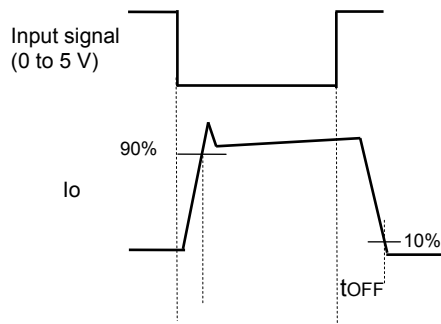


Fig.6

Input / Output Timing Diagram

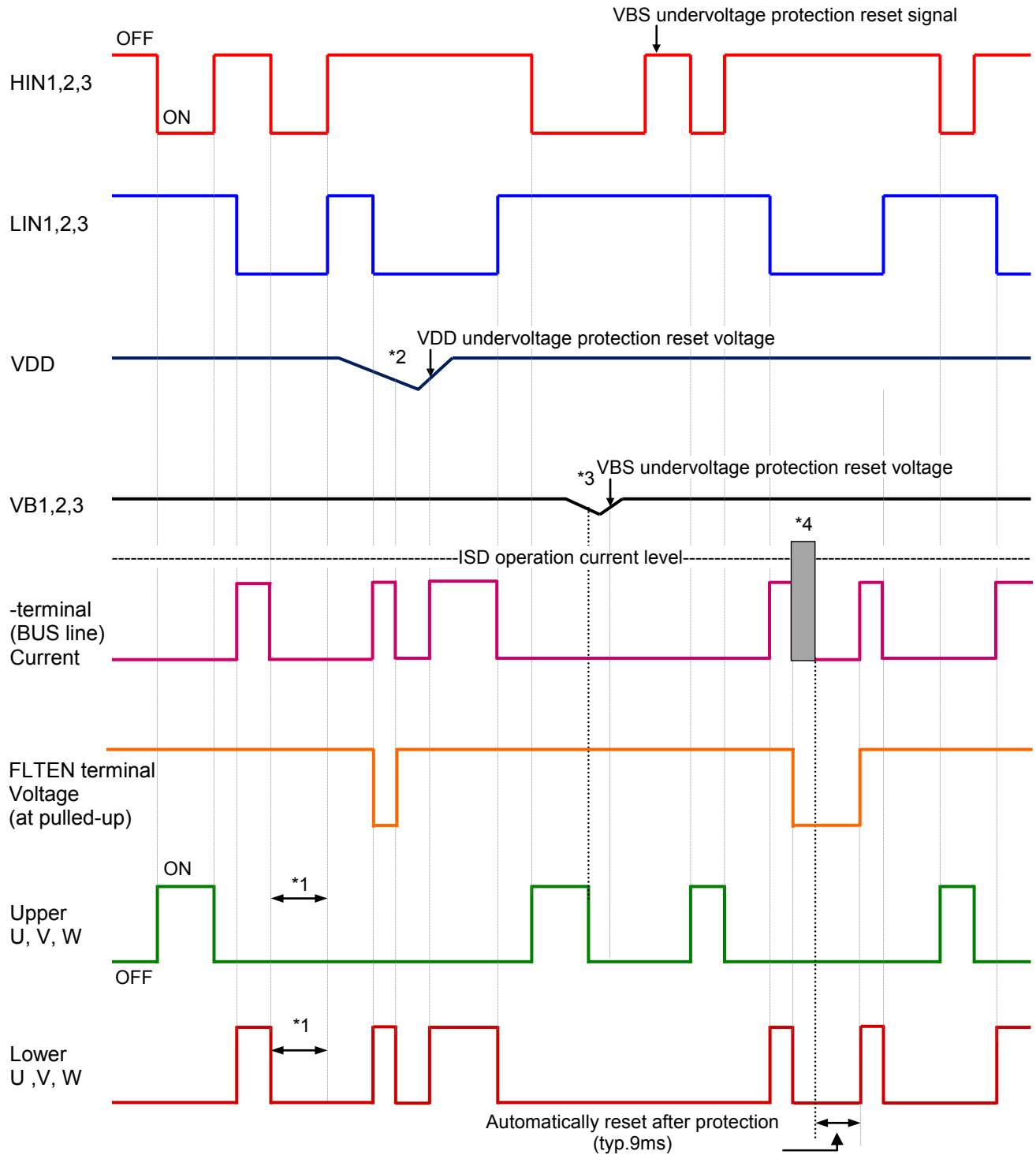


Fig.7

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

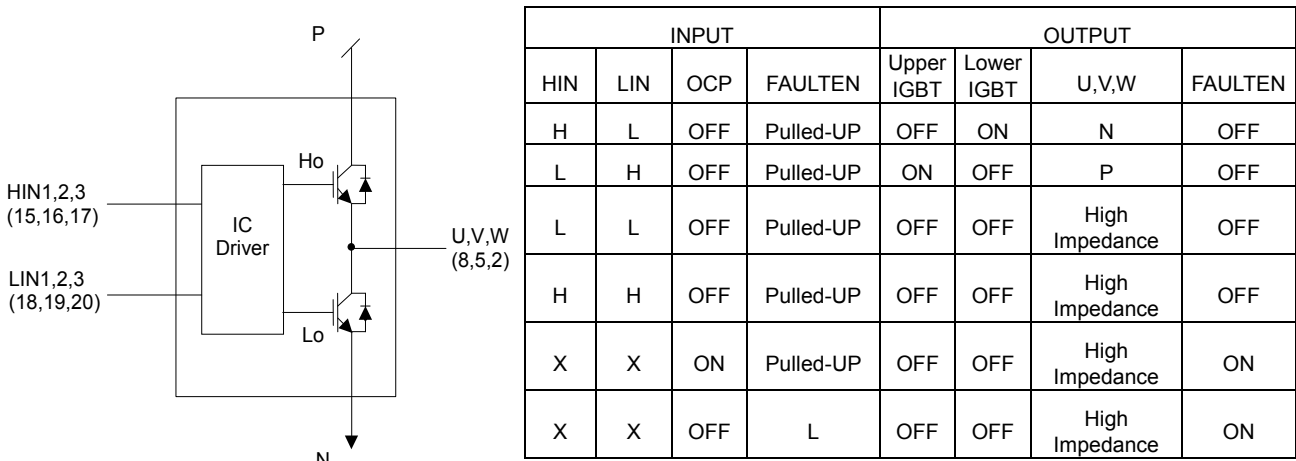


Fig. 8

# STK541UC62K-E

## Sample Application Circuit

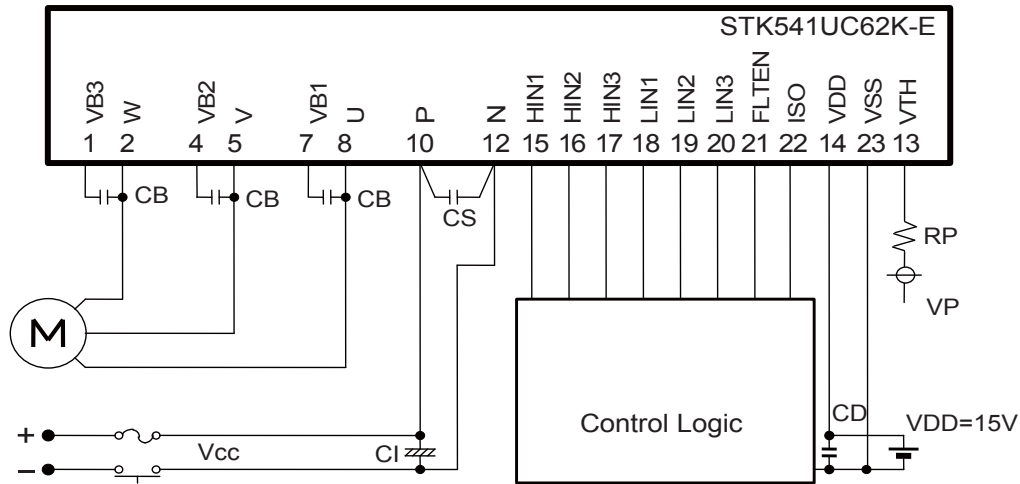


Fig. 9

## Recommended Operating Conditions

| Item                        | Symbol               | Conditions                            | min  | typ | max  | Unit |
|-----------------------------|----------------------|---------------------------------------|------|-----|------|------|
| Supply voltage              | V <sub>CC</sub>      | 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 <sub>DD</sub> to V <sub>SS</sub> *1 | 13.5 | 15  | 16.5 |      |
| ON-state input voltage      | V <sub>IN(ON)</sub>  | HIN1, HIN2, HIN3,                     | 0    | —   | 0.3  | V    |
| OFF-state input voltage     | V <sub>IN(OFF)</sub> | LIN1, LIN2, LIN3                      | 3.0  | —   | 5.0  |      |
| PWM frequency               | f <sub>PWM</sub>     | —                                     | 1    | —   | 20   | kHz  |
| Dead time                   | DT                   | Turn-off to turn-on                   | 2    | —   | —    | μs   |
| Allowable input pulse width | P <sub>WIN</sub>     | ON and OFF                            | 1    | —   | —    | μs   |
| Tightening torque           | —                    | *M3' type screw                       | 0.6  | —   | 0.9  | Nm   |

\*1 Pre-drive power supply (VD4 = 15 ±1.5 V) must have the capacity of I<sub>o</sub> = 20 mA (DC), 0.5 A (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 47 μF, however this value needs to be verified prior to production. If selecting the capacitance more than 47 μF (±20%), connect a resistor (about 20 Ω) 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 wiring 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 10 μF.
3. "ISO" (pin22) is terminal for current monitor. When the pull-down resistor is used, please select it more than 5.6 kΩ
4. "FLTEN" (pin21) is open DRAIN output terminal (Active Low). Pull up resistor is recommended more than 5.6 kΩ.
5. Inside the IPM, a thermistor used as the temperature monitor for internal substrate 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<sub>SS</sub>" 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<sub>SS</sub>" terminal are connected in IPM).
8. When input pulse width is less than 1.0 μs, 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                                | $R_{25}$  | $T_c = 25^{\circ}\text{C}$  | 99   | 100  | 101  | k $\Omega$         |
| Resistance                                | $R_{100}$ | $T_c = 100^{\circ}\text{C}$ | 5.12 | 5.38 | 5.66 | k $\Omega$         |
| B-Constant (25 to 50 $^{\circ}\text{C}$ ) | B         |                             | 4165 | 4250 | 4335 | K                  |
| Temperature Range                         |           |                             | -40  | -    | +125 | $^{\circ}\text{C}$ |

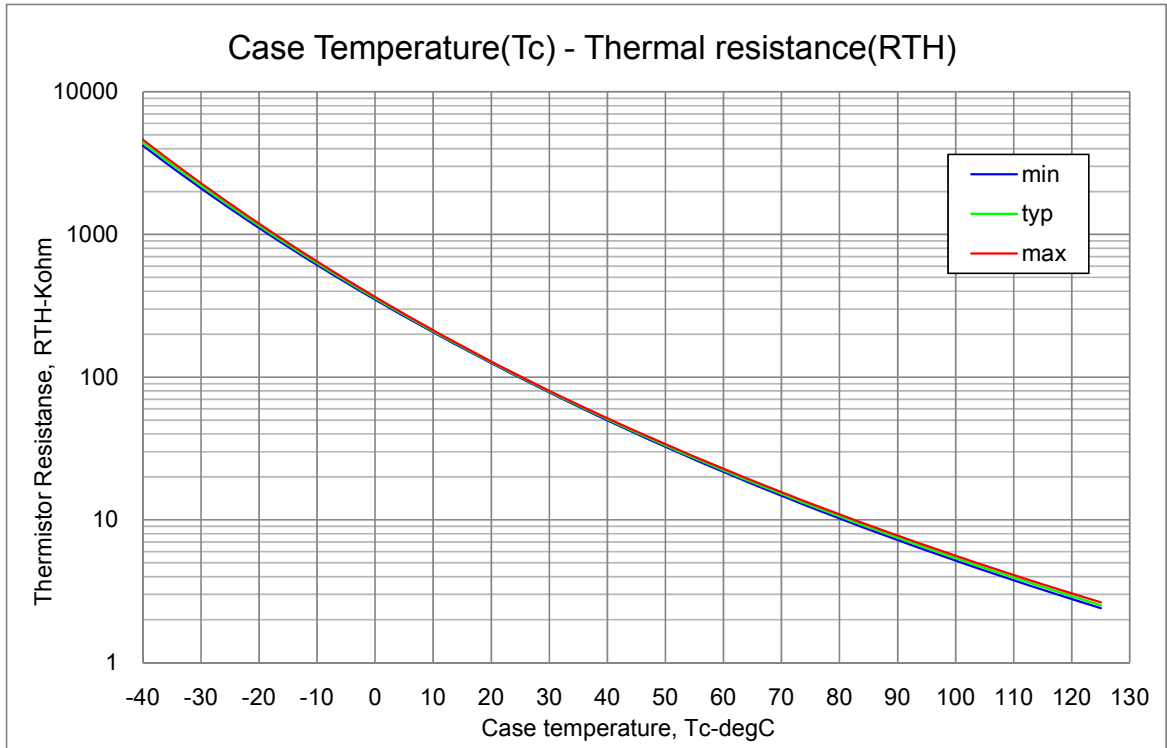


Fig.10 Variation of thermistor resistance with temperature

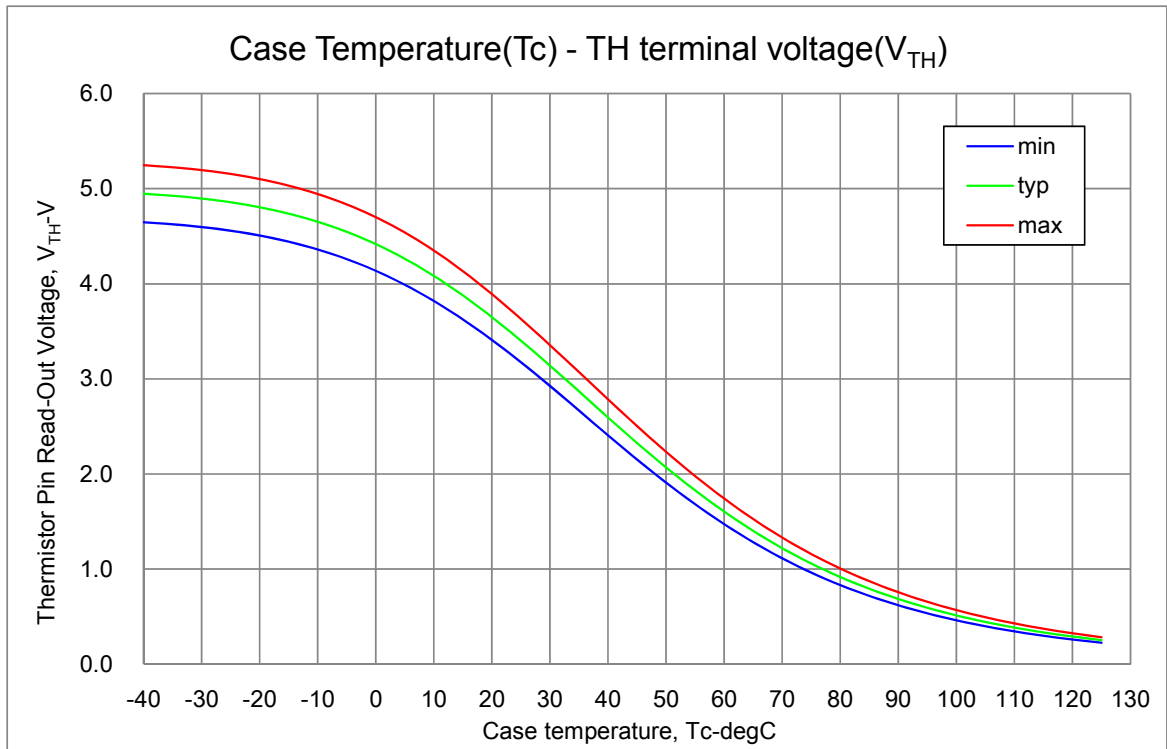


Fig.11 Variation of thermistor terminal voltage with temperature  
(47 k $\Omega$  pull-up resistor, 5 V)

The characteristic of PWM switching frequency

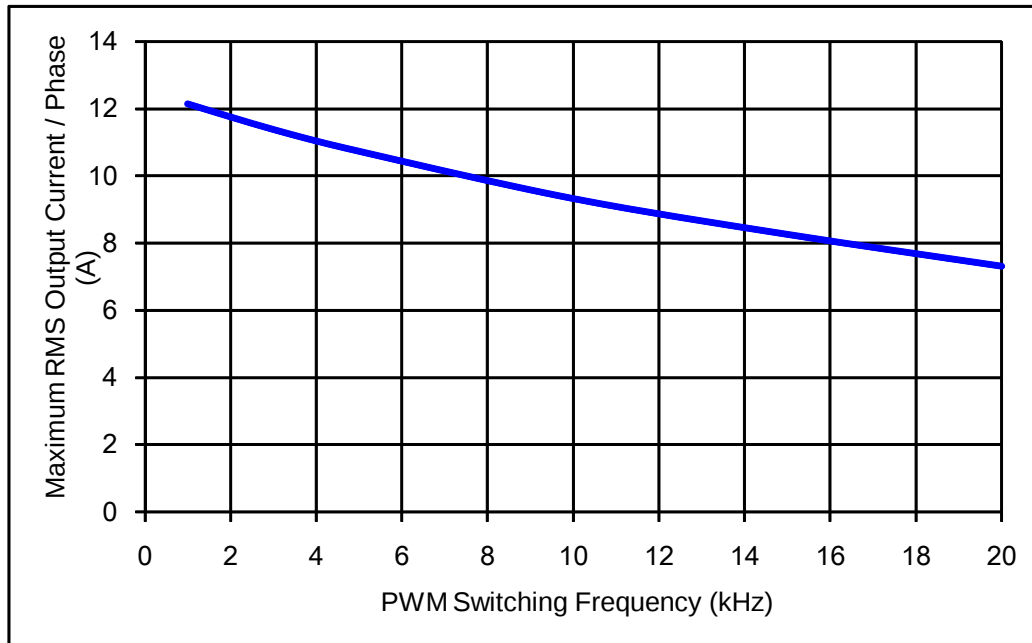


Fig. 12 Maximum sinusoidal phase current as function of switching frequency  
at  $T_c = 100^\circ\text{C}$ ,  $V_{CC} = 400\text{ V}$

## 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 15 V            | 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 15 V to UVLO | TONMAX | –     | s    |

### Capacitance calculation formula

Thus, the following formula are true

$$VBS \times CB - QG - IDMAX \times TONMAX = UVLO \times CB$$

therefore,

$$CB = (QG + IDMAX \times TONMAX) / (VBS - UVLO)$$

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 47 μF, however, this value needs to be verified prior to production.

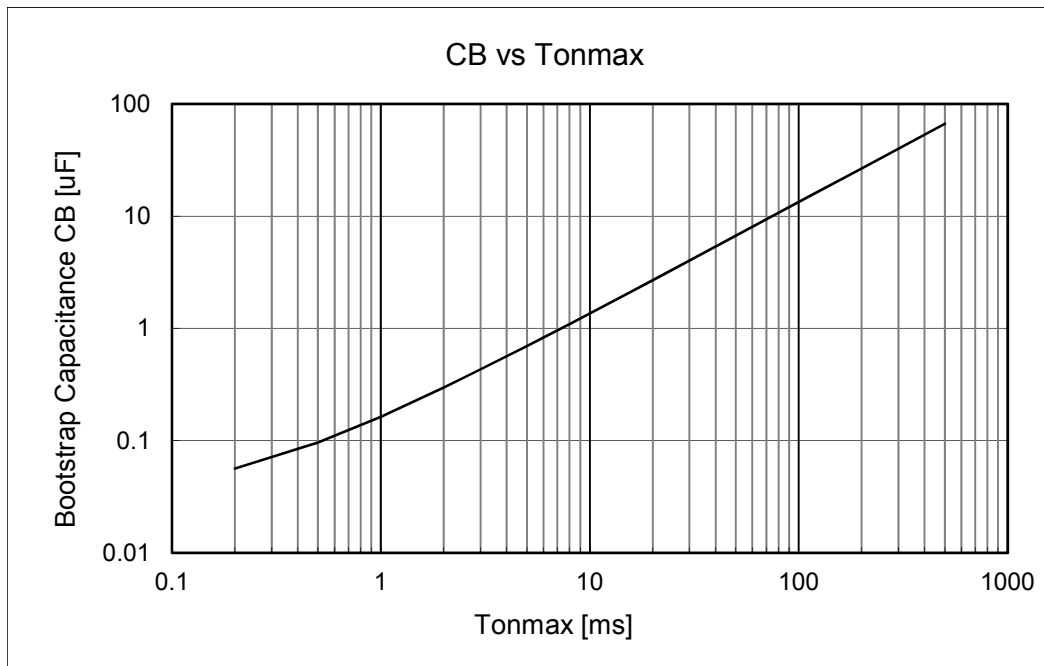


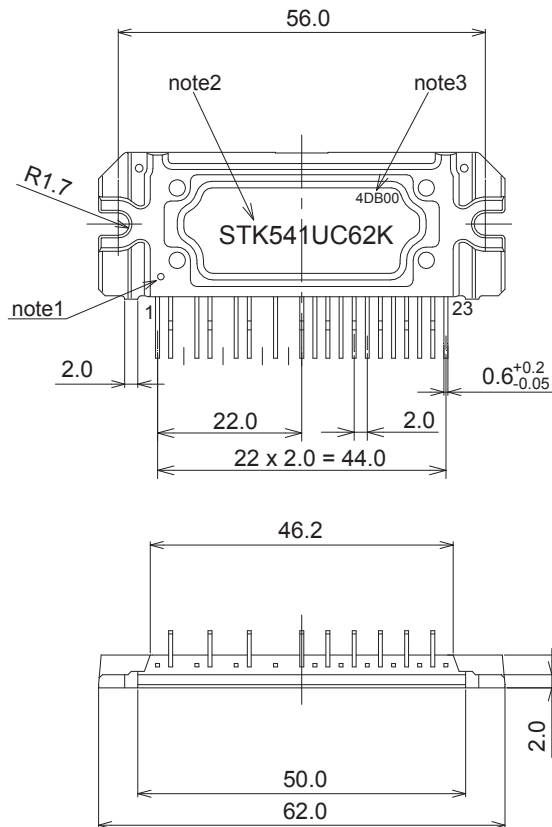
Fig. 15 Tonmax - CB characteristic

# STK541UC62K-E

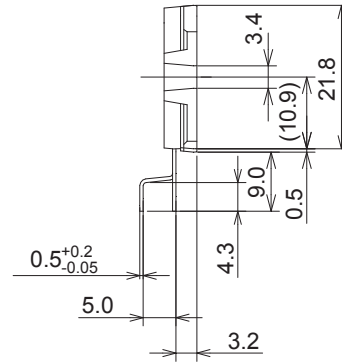
## PACKAGE DIMENSIONS

unit : mm

The tolerances of length are  $\pm 0.5$  mm 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 IPM.
- note3 : This indicates the date code.  
The form of a character in this drawing differs from that of IPM.

## STK541UC62K-E

### ORDERING INFORMATION

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

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