# Six-input Type Single Chip Inverter IC

## Application Note

## 【Rev. 1】

**Models**

| | |
|---|---|
| **200V AC system** | **ECN30632** |

Hitachi Power Semiconductor Device, Ltd.
Design Development Division

— Contents —

# 1. Outline

## 1.1 System Configuration

### 1.1.1 Single Chip Inverter ICs

Hitachi single chip inverter ICs are monolithic ICs integrating various constituent devices and circuits required for inverter control on a single chip by using SOI technology. They are for driving motors, suited for variable speed control of three-phase induction motors and brushless DC motors. The advantage of downsizing by the use of a single chip structure can be used to reduce the control board in size, which can be incorporated in a motor.

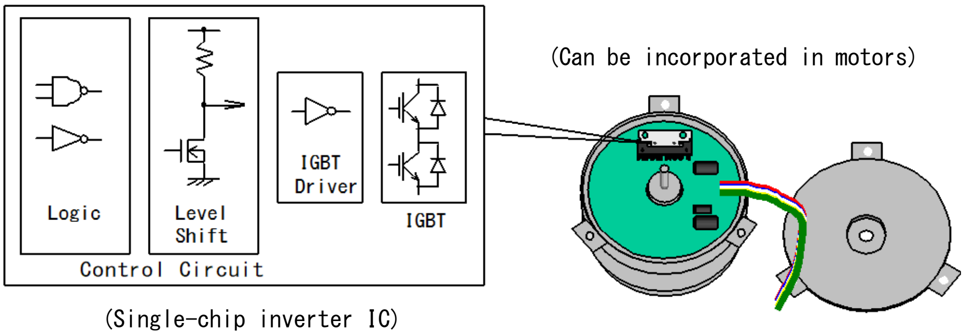


**FIGURE 1.1.1.1 Image of Motor with Built-in Control Board**

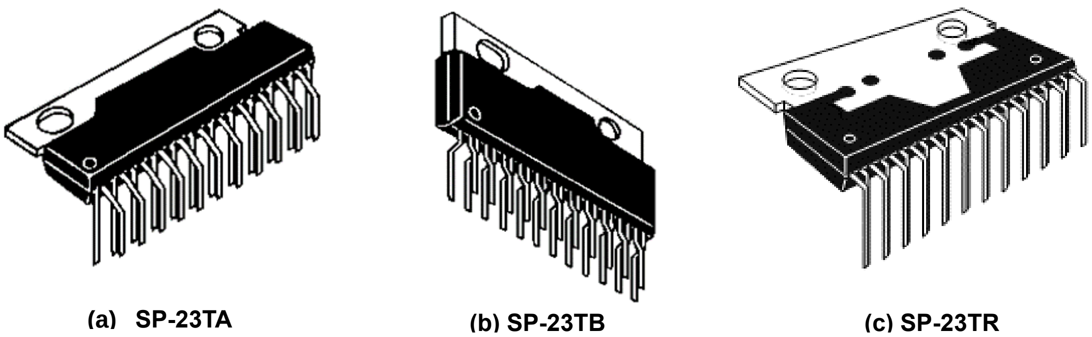


**FIGURE 1.1.1.2 Types and Packages of IC**

### 1.1.2 Composition of Inverter IC

An inverter is a device that converts DC currents into AC. It can be used to drive motors for efficient variable-speed control. Figure 1.1.2.1 shows the basic configuration of an inverter IC. To drive the three-phase motor with an inverter, six IGBTs and free wheel diodes are used as output stages. The IC consists of an IGBT driving power circuit, level shift circuit, a logic circuit and other components. Hitachi Inverter ICs can directly receive high voltage supplied from rectifying commercial AC power, because they have high dielectric strength. This obviates the need of a step-down circuit, thus inhibiting efficiency cuts induced by voltage conversion.

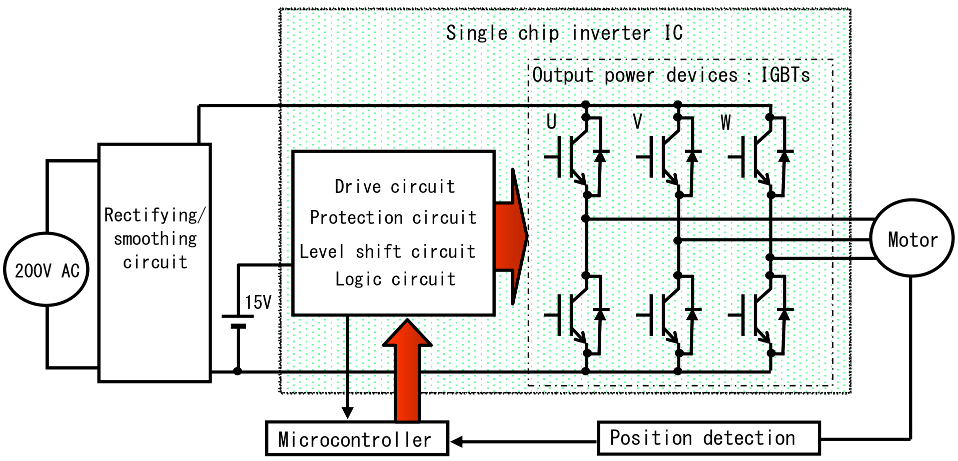


**FIGURE 1.1.2.1 Example of Basic Configuration of an Inverter IC**

1.2 Block Diagram of Inverter IC

Figure 1.2.1 shows a block diagram of the inverter IC.

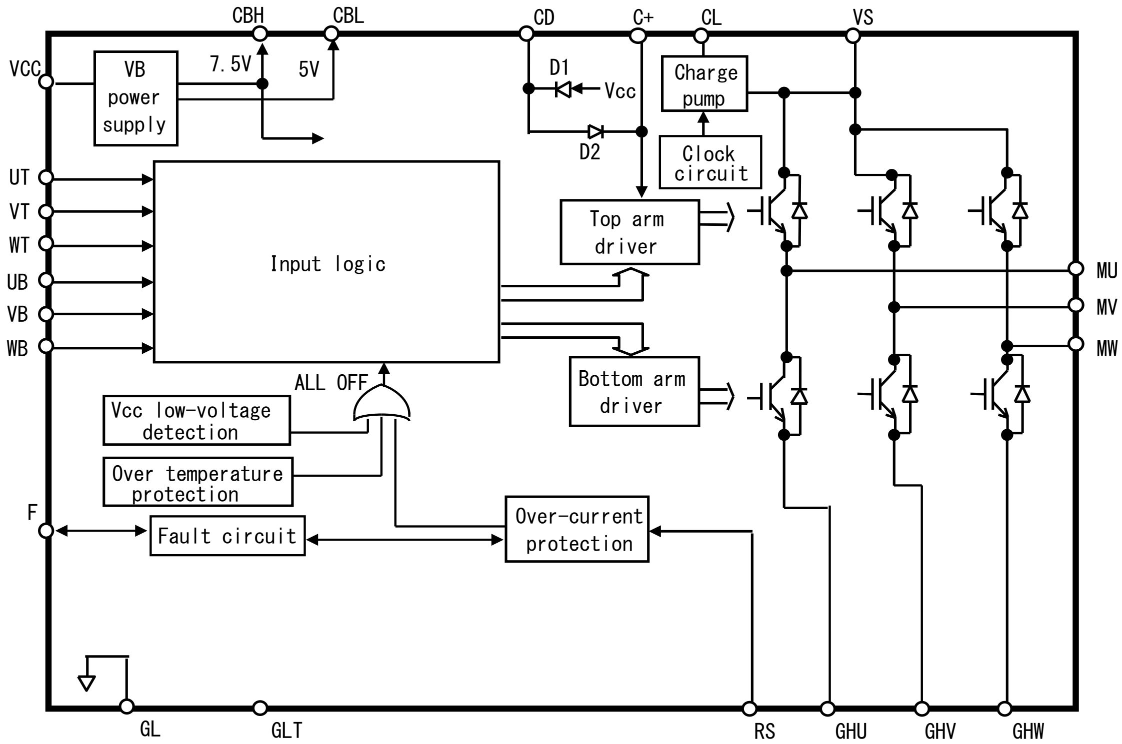


**FIGURE 1.2.1 Block Diagram of Inverter IC**

## 2. Content of Specifications

The following items have been described in the specifications.

(1) Maximum ratings

・It describes direct conditions (electric, thermal use conditions) leading to IC destruction and so on. And the safety operating range with operating conditions is shown by minimum or maximum value.

・In a case the specified values shown in each item are exceeded, products may be damaged or destroyed even for a moment. These specified values should never be exceeded under any operating conditions.

(2) Electrical characteristics

・It provides for electric characteristics of the IC, and describes minimum, standard, and maximum.

(3) Function and operation

・It describes Truth Table, Timing Chart, Protection Function and so on.

(4) Standard application

・It describes circuit examples and external parts to operate IC.

(5) SOA and deratings

・It describes Safe Operation Area (SOA), deratings, and so on.

(6) Pin assignments and pin definitions

・It describes pin assignments, pin names and pin definitions.

(7) Inspection

・It describes inspection conditions.

(8) Important notice, precautions

・It describes notes of the static electricity, the maximum rating, handling and so on.

(9) Appendix and reference data

・It describes packaging and dimensions.

## 3. Specifications

3.1 IC Types

Table 3.1.1 shows ratings, package types, and mounting types of the ICs.

**TABLE 3.1.1 IC and Package Types**

| No. | Type | Maximum ratings | Package type | Mounting type |
|---|---|---|---|---|
| 1 | ECN30632SP | Output device withstand voltage：600V<br>Output current (Pulse)：3A<br>Output current (DC)：2A | SP-23TA | Pin insertion type |
| 2 | ECN30632SPV | | SP-23TB | Pin insertion type |
| 3 | ECN30632SPR | | SP-23TR | Pin insertion type |

3.2 Pin Locations

Table 3.2.1 shows pin locations.

**TABLE 3.2.1 Pin Locations**

| Pin No. | Symbol | Pin functions | Remarks |
|---|---|---|---|
| 1 | GLT | To be set to ground potential | Note 2, Note 3 |
| 2 | MW | W-phase output | Note 1 |
| 3 | VS | High voltage power supply | Note 1 |
| 4 | C+ | For the charge pump circuit | Note 1 |
| 5 | CD | For the charge pump circuit | Note 1 |
| 6 | CL | For the charge pump circuit | Note 1 |
| 7 | GL | Ground | Note 2 |
| 8 | VCC | 15V power supply | |
| 9 | CBH | VBH power supply output (7.5V) | |
| 10 | CBL | VBL power supply output (5V) | |
| 11 | F | Fault signal output or setting over-current protection reset time | |
| 12 | WT | Input control signal for W-phase top arm | |
| 13 | VT | Input control signal for V-phase top arm | |
| 14 | UT | Input control signal for U-phase top arm | |
| 15 | WB | Input control signal for W-phase bottom arm | |
| 16 | VB | Input control signal for V-phase bottom arm | |
| 17 | UB | Input control signal for U-phase bottom arm | |
| 18 | RS | Input for over-current protection | |
| 19 | GHU | Emitter of U-phase bottom arm IGBT and anode of U-phase bottom arm FWD | |
| 20 | GHV | Emitter of V-phase bottom arm IGBT and anode of V-phase bottom arm FWD | |
| 21 | GHW | Emitter of W-phase bottom arm IGBT and anode of W-phase bottom arm FWD | |
| 22 | MU | U phase output | Note 1 |
| 23 | MV | V phase output | Note 1 |

Note 1: High voltage pin. The voltage between CD and CL and the voltage between C+ and VS are low.

Note 2: Connect GLT to GL externally.

Note 3: The potential of tab (IC heat sink) is the same as that of the GLT pin. Set the tab potential to open or the same as that of GL pin.

## 3.3 Functions of Pins

**TABLE 3.3.1 List of Pins and Functions (1/3)**

| No. | Pin | Items | Functions and Precautions | Related items | Remarks |
|---|---|---|---|---|---|
| 1 | VCC | Control power supply pin | ・Powers the drive circuits for the top and bottom arms, the charge pump circuit, the built-in VB supply circuit, and others.<br>・Determine the capacity of the power supply for Vcc (15V), allowing for a margin determined by adding the standby current ICC and the current taken out of the CBL and CBH pins. | ・3.5.1<br>(1) Vcc (15V) low-voltage detection<br>・5.1 to 5.5<br>Inverter IC destruction by external surge or line noise | |
| 2 | VS | IGBT power pin | ・Connected to the collector of the IGBTs of the top arms. | ・5.1 to 5.3, 5.6<br>Inverter IC destruction by external surge or noise | High voltage pin |
| 3 | CBL<br>CBH | Output pin for built-in power supply | ・Outputs a voltage generated in the built-in VBL and VBH power supplies (VBL=5.0V, VBH=7.5V (typ.)).<br>When the total current of these built-in power supplies is 50mA or less, they can be used together.<br>・VB supply powers the IC internal circuits (input buffer, over-current protection and others) and can be used as a power supply for external circuits such as MCU, position sensor signals and so on.<br>・Connect oscillation prevention capacitors CL0 and CH0 to the CBL and CBH pins respectively. A capacitor capacity of 1.0μF ±10% is recommended. | ・3.5.4 VBH power supply, VBL power supply | |
| 4 | GL | Control GND pin | ・It is the ground pin for the Vcc (15V) and VB power lines. | — | |
| 5 | GHU<br>GHV<br>GHW | IGBT emitter pin | ・The GHU, GHV and GHW pins are connected to the emitters of the U-phase, V-phase and W-phase bottom arm IGBTs respectively.<br>・The current in each phase can be detected by connecting a shunt resistor between these pins (GHU, GHV, GHW) and the GL pin.<br>・DC current can be detected by connecting the GHU, GHV and GHW pins all together and connecting a shunt resistor (Rs) between the RS pin and the GL pin. | ・3.5.1<br>(2) Setting method for over-current protection | |
| 6 | MU<br>MV<br>MW | Inverter output pin | ・These are outputs of a three-phase bridge consisting of six IGBTs and free wheel diodes. | | High voltage pin |
| 7 | UT<br>VT<br>WT<br>UB<br>VB<br>WB | Control input pin of each arm | ・Inputs control signals of each phase.<br>・When inputting “H”, the IGBTs turn on.<br>When inputting “L”, the IGBTs turn off.<br>・U, V and W stand for each phase. T and B stand for top arm and bottom arm respectively.<br>・If the switching noise is monitored, mount a capacitor.<br>・The maximum rating of input voltage is VBH+0.5V. | | |

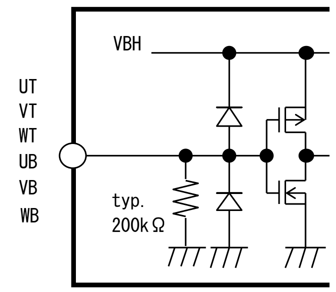


**FIGURE 3.3.1 Equivalent Circuit around UT, VT, WT, UB, VB, WB Pins**

**TABLE 3.3.1 List of Pins and Functions (2/3)**

<table>
<tr><th>No.</th><th>Pin</th><th>Items</th><th>Functions and Precautions</th><th>Related items</th><th>Remarks</th></tr>
<tr><td rowspan="2">8</td><td rowspan="2">RS</td><td>Input pin for over current detection</td><td>・Monitors the voltage of the Rs shunt resistor and detects over current status.</td><td>・3.5.1<br>(2) Setting method for over-current protection</td><td rowspan="2"></td></tr>
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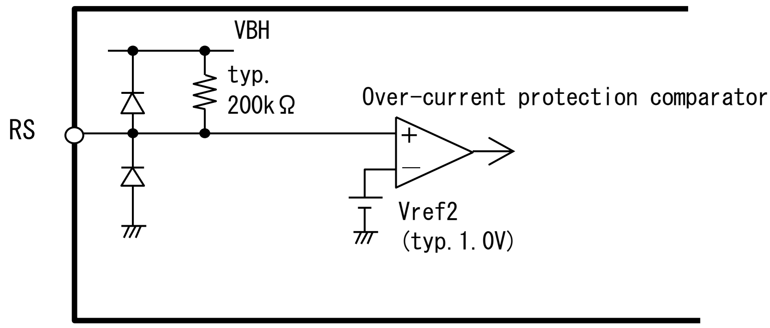


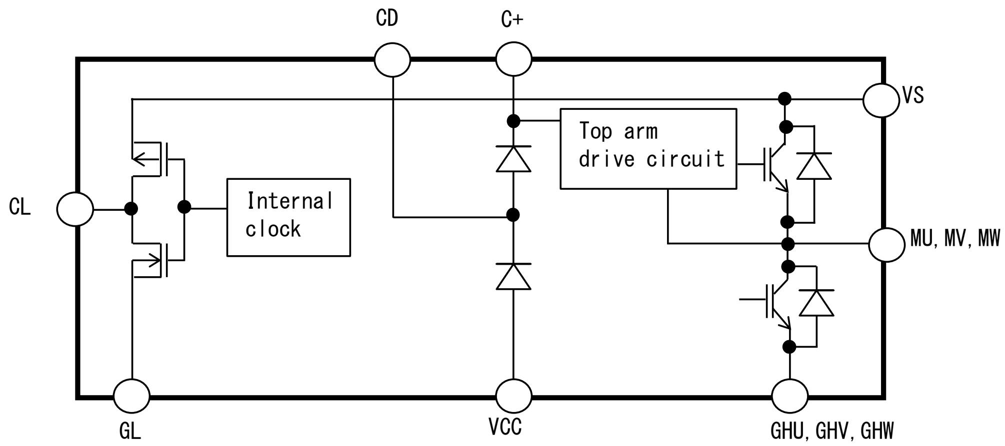

**FIGURE 3.3.2 Equivalent Circuit around RS Pin**
</td></tr>
<tr><td rowspan="2">9</td><td rowspan="2">C+<br>CL<br>CD</td><td>Top arm drive circuit power pin<br><br>Charge pump circuit pin</td><td>・Powers the drive circuit for the top arm.<br>・Connect a capacitor between C+ and VS, CD and CL, respectively.</td><td>・3.5.2<br>Charge pump circuit</td><td rowspan="2">High voltage pin</td></tr>
<tr><td colspan="3">



**FIGURE 3.3.3 Equivalent Circuit around C+, CL, CD Pins**
</td></tr>
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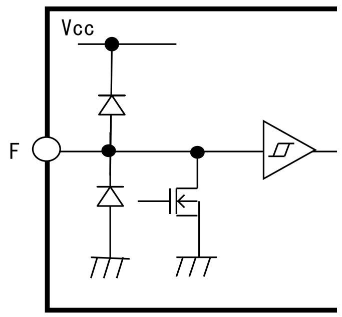
**TABLE 3.3.1 List of Pins and Functions (3/3)**

| No. | Pin | Items | Functions and Precautions | Related items | Remarks |
|---|---|---|---|---|---|
| 10 | F | Fault signal output or setting of over-current protection reset time | ・NMOS open drain output pin<br>・The NMOS turns on only when the over-current protection operates, and in other cases, the NMOS is off.<br>・Pull up to the CBL pin or 5V through an external resistor RF. The recommended RF resistance is 10kΩ±5%. Moreover, to remove switching noise, connect the capacitor CF (0.01μF±10% recommended) between the F pin and GND. | ・3.5.1<br>(2) Setting method for over-current protection | |
| | | <br><br>**FIGURE 3.3.4 Equivalent Circuit around F Pin** | | | |

3.4 Markings

The resin surface of the IC is marked by laser.

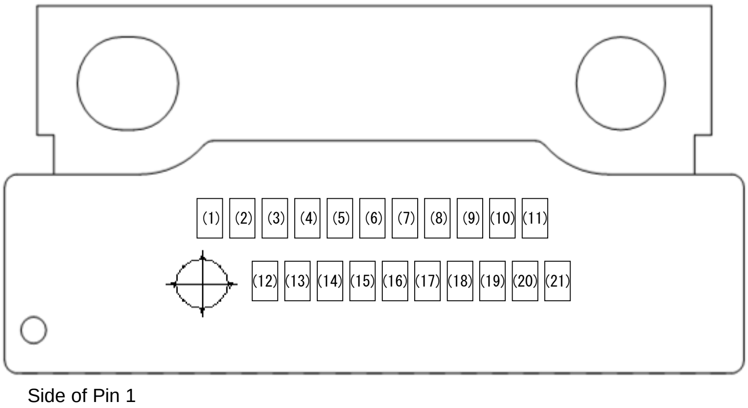



**FIGURE 3.4.1 SP-23TA, SP-23TB Marking Specifications**

Mark No. (1) to (11): Model name
Mark No. (12) to (16): Country (JAPAN)
Mark No. (17) to (21): Lot number

The lot number consists of the followings.

No. (17) : Last one-digit of the year of assembly
No. (18) : Month of assembly:
January: A, February: B, March: C April: D, May: E, June: K,
July: L, August: M, September: N, October: X, November: Y, December: Z
No. (19) to (21): Quality control number
Represented with letters from “A” to “Z” except “I” and ”O”, numbers from “0” to “9”, or blank.

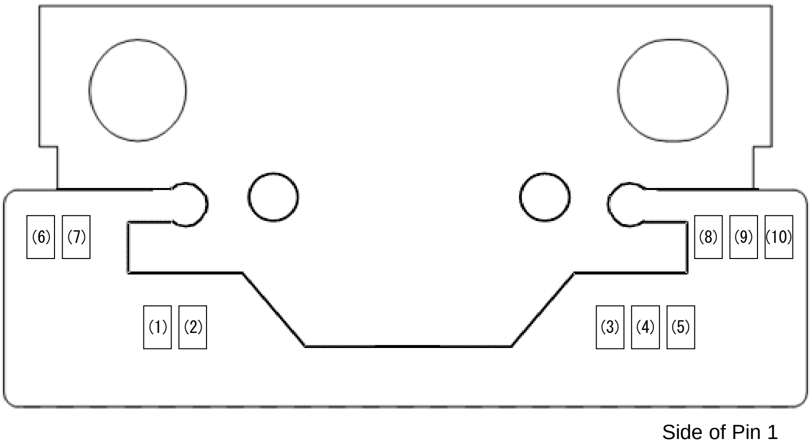



**FIGURE 3.4.2 SP-23TR Marking Specifications**

Mark No. (1) to (5): Numbers of model name
(e.g.) In the case of ECN30632SPR, shown as “30632”.
Mark No. (6) to (10): Lot number

The lot number consists of the followings.

No. (6): Last one-digit of the year of assembly
No. (7): Month of assembly:
January: A, February: B, March: C April: D, May: E, June: K,
July: L, August: M, September: N, October: X, November: Y, December: Z
No. (8) to (10): Quality control number
Represented with letters from “A” to “Z” except “I” and ”O”, numbers from “0” to “9”, or blank.

## 3.5 Functions and Operational Precautions

### 3.5.1 Protection Function

#### (1) Vcc (15V) low-voltage detection

Hitachi Power Semiconductor Device calls the Vcc (15V) low-voltage detection “LVSD”. When the Vcc (15V) voltage drops below the LVSD operating voltage (LVSDON), all IGBTs (top and bottom arms) are all turned off regardless of the input signals. This function has hysteresis. When the Vcc (15V) voltage goes up again, the system returns to a state in which the output IGBTs operate depending on the input signals, at a level equal to or exceeding the LVSD recovery voltage (LVSDOFF). “L” is not outputted to the F pin in this function operation.

If the Vcc (15V) low-voltage detection operates during motor rotation, Vs voltage may rise due to regenerative electric power to the Vs power supply. The Vs voltage must not exceed the maximum rating. Particular attention is needed when the capacitance of a capacitor between the VS and GND is small, because it makes the voltage more likely to rise.

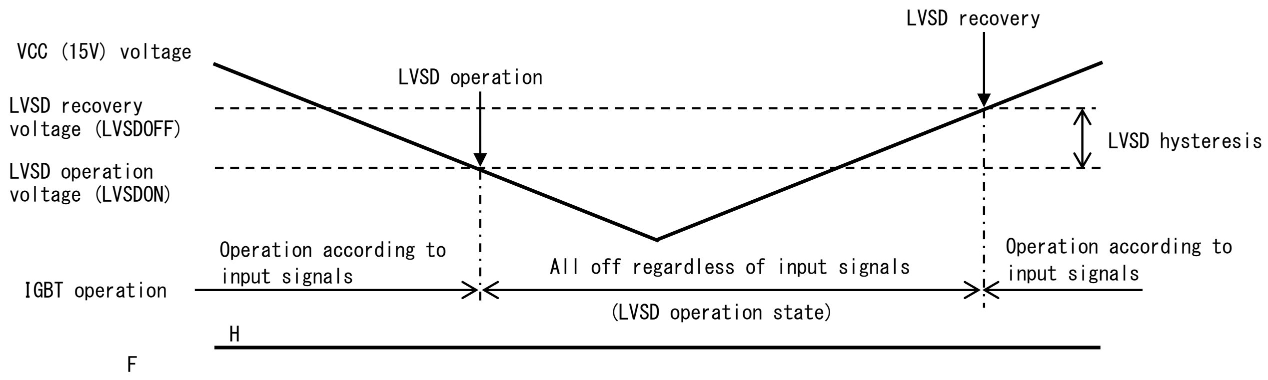



**FIGURE 3.5.1.1 Timing Chart for Vcc (15V) Low-voltage Detection (LVSD Operation)**

#### (2) Setting method for over-current protection

Fig. 3.5.1.2 shows an example of the current flowing through the shunt resistor when these functions are enabled. These functions are not effective for currents that do not flow forward (direction to the GL pin) through the shunt resistor, such as reflux current and power regenerative current (see Figs. 3.5.1.3 and 3.5.1.4).

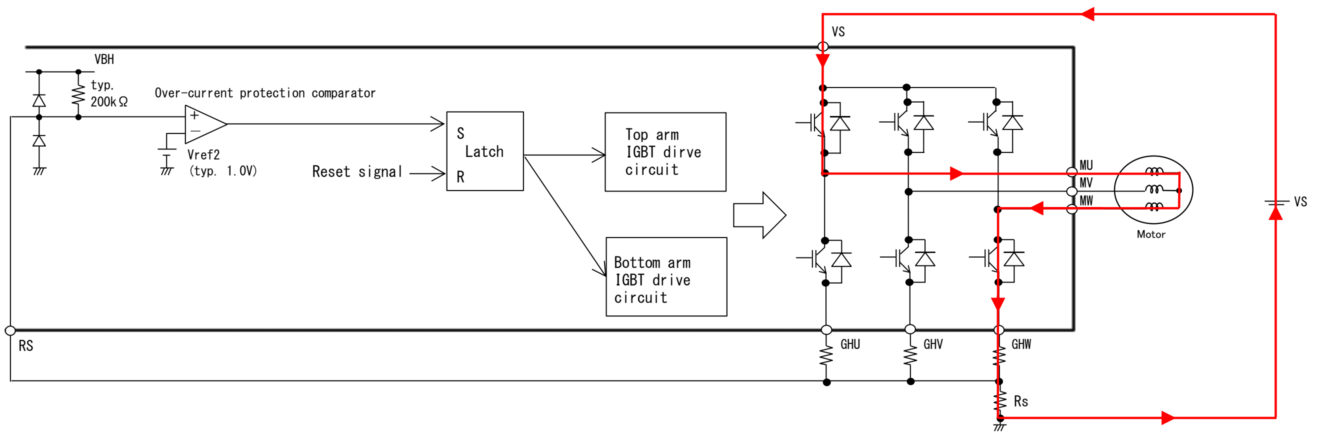



**FIGURE 3.5.1.2 Example of Current Path of Enabled Over-current Protection**

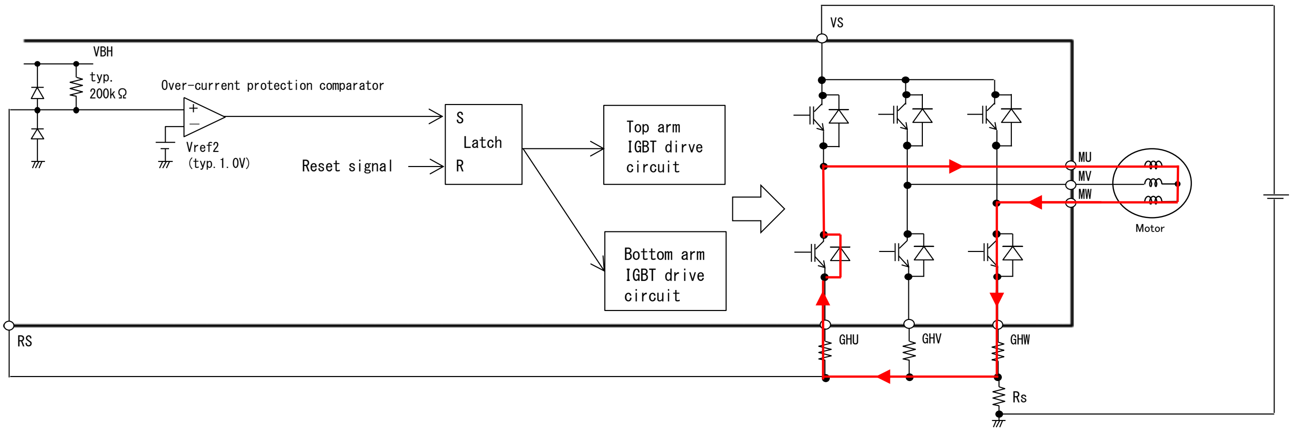



**FIGURE 3.5.1.3 Example of Reflux Current**

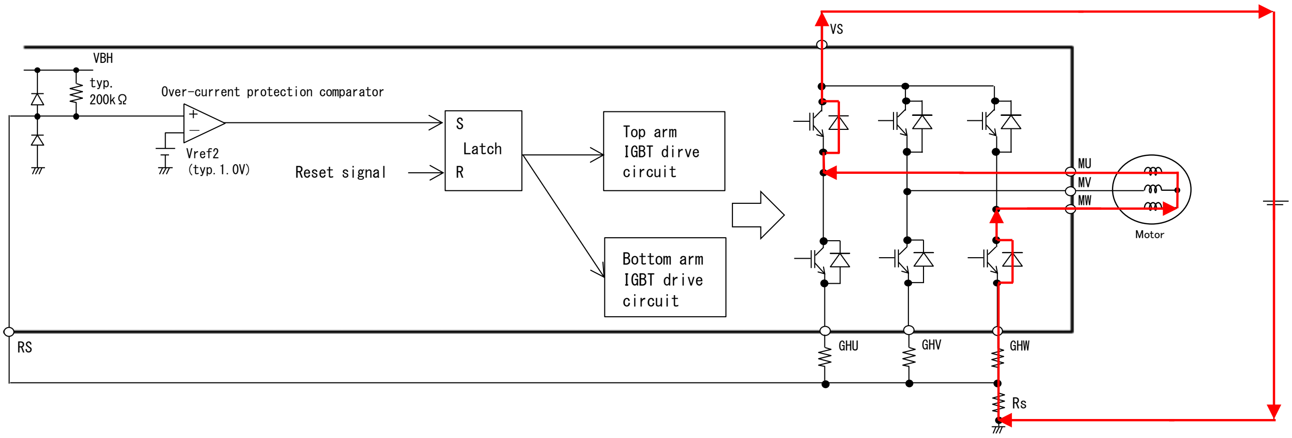



**FIGURE 3.5.1.4 Example of Power Regenerative Current**

(a) Over-current Protection

When the voltage at the RS pin exceeds the over-current protection reference voltage (Vref2, typ. 1.0V), the F output is "L" and the top and bottom arm IGBTs are all turned off. To reset this all off state, hold the inputs all "L" for more than the Fault reset input time (Tflrs).

When this function is not used, connect the F pin to the VCC pin.

Fig. 3.5.1.5 shows the timing chart of the over-current protection operation.

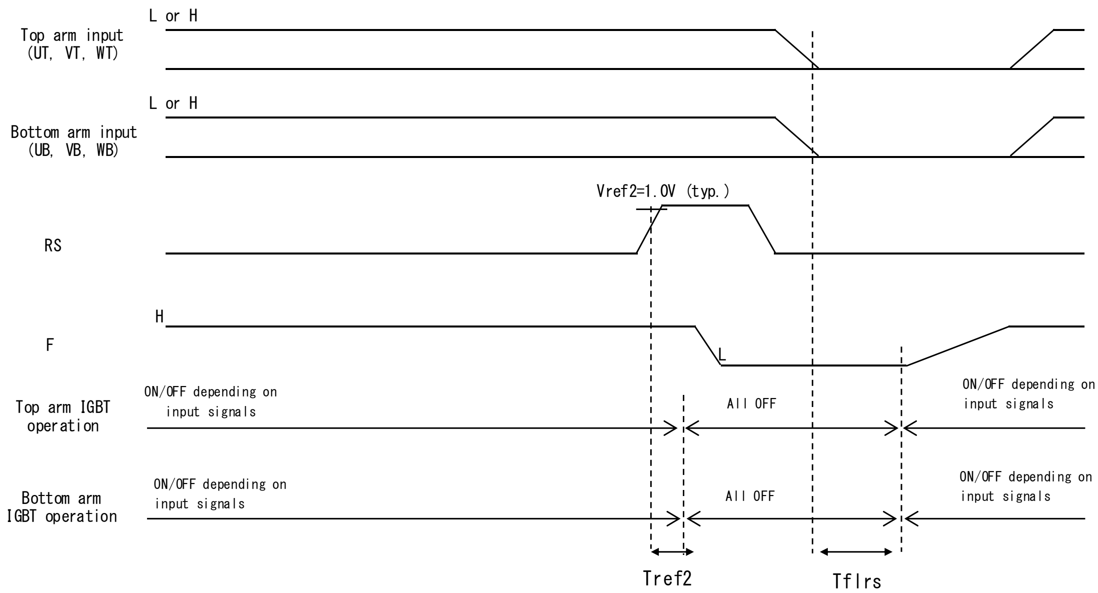



**FIGURE 3.5.1.5 Timing Chart for Over-current Protection**

(b) How to set current values of over-current protection

The current value of over-current protection operation IO_2 is calculated as follows:

IO_2=Vref2/Rs

Vref2: Reference voltage for over-current protection
Rs : Resistance of shunt resistor

In setting current values, allow for Vref2 variances, Rs variance, and the delay time (Tref2) between the time the operating condition of the over-current protection is satisfied and the time the IGBTs are turned off. Observe the output currents of the IC (the coil currents of the motor) and confirm a design margin. Set the shunt resistance so that voltages of the GHU, GHV, and GHW pins are within the specified GH voltage (Vgh) range in the Product Specification.

Moreover, if you are going to add CR filter to RS pin in order to remove the influence of noise, etc., CR filter increases the delay time until the operating condition of the over-current protection is satisfied. You should allow for the margin of this delay time that gets longer and short-circuit tolerance. A time constant of the added CR filter should be 0.5μs or less.

(c) Wiring precautions

Make the wiring of the shunt resistor Rs as short as possible. The GHU, GHV and GHW are connected to the IGBT emitters. If the wiring has a high resistance or inductance component the emitter potential of the IGBT changes, which can result in IGBT malfunction.

(3) Over Temperature Protection

When the IC temperature reaches or exceeds the operating temperature of over temperature protection (TSDON=typ.160℃), the IGBTs of the top and bottom arms are all turned off regardless of the input signals. When the IC temperature goes down a hysteresis width (TSDHYS) from the operating temperature of over temperature protection (TSDON), the IC returns to a state in which the IGBTs operate according to input signals. “L” is not outputted to the F pin in this function operation.

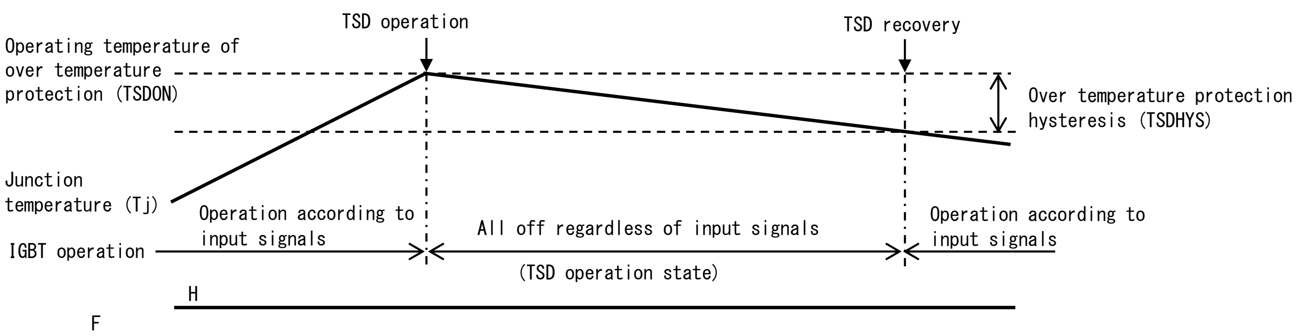



**FIGURE 3.5.1.8 Timing Chart for Over Temperature Protection Operation**

(4) Short-circuit Protection

If output of the inverter is short-circuited (load short-circuit, earth fault, and short-circuit between the top and bottom arms), there is a possibility that the IC will be destroyed. The over-current protection prevents damage to the IC due to load short-circuit and short-circuit between the top and bottom arms. However, in the case of earth fault whose current does not flow through the shunt resistor, the over-current protection does not operate because the IC cannot detect over-current. Thus, be sure to protect the device using external circuits of the IC in order to prevent damage caused when the IC cannot detect over-current such as an earth fault. Two or more occurrences of short-circuits can lead to the IC damage or failure because of local heat generated in the IGBTs. Proper precautions should be taken to prevent the over-current protection from operating repeatedly more than once caused by short-circuit.

3.5.2 Charge Pump Circuit

Fig. 3.5.2.1 shows a block diagram of the charge pump circuit. When 15V is inputted to the VCC pin, SW1 and SW2 alternately turn on and off.

① When SW1 is off and SW2 is on, the CL pin has a potential of 0V. Through passage (a), the capacitor C1 is charged.

② When SW1 is turned on and SW2 is turned off, the potential of the CL pin rises to the Vs level. Through passage (b), the charge of the capacitor C1 is pumped up to the capacitor C2.

These operations ① and ② are repeated with the frequency of the internal clock, and the charge is given to the capacitor C2.

The capacitor C2 constitutes a power supply for the drive circuit for the top arm.

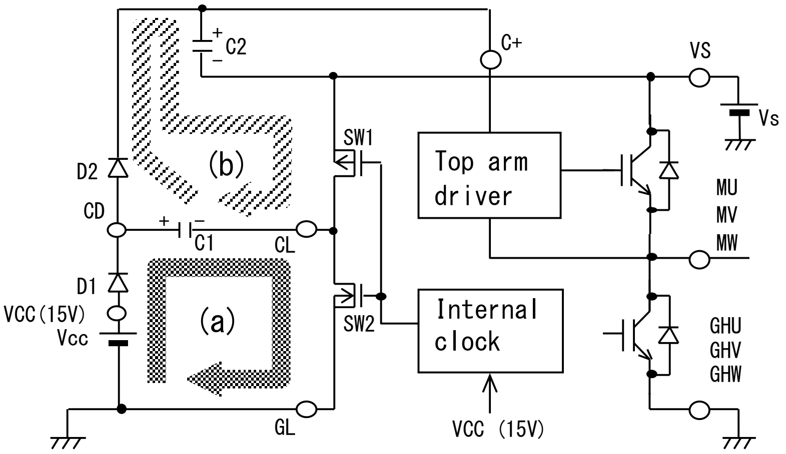



**FIGURE 3.5.2.1 Charge Pump Circuit**

3.5.3 Power On/Off Sequence

Sequence free in followings (1), (2), and (3).

(1) Power-on sequence

(2) Power-off sequence

(3) Power-off and reset operation in instantaneous power failure occurrence

3.5.4 VBH Power Supply and VBL Power Supply

The VBH and VBL power supplies are generated from Vcc (15V) power supply and outputted from the CBH and CBL pins. The VBH power is supplied to the IC internal circuits such as the over-current protection circuit. Fig. 3.5.4.1 shows an equivalent circuit. This circuit constitutes a feedback circuit.

To prevent oscillation, connect capacitors CH0 and CL0 to the CBH and CBL pins respectively. The recommended capacitance for the CH0 and CL0 are 1.0μF±10%.

The larger the CH0 and CL0 capacity, the more stable the VBH and VBL power supplies. However, excessive capacitance is not recommended. As a guide, it should be 2μF to 3μF or less.

The CBH and CBL pins can be simultaneously used. However, a total current of the IBH and IBL must be less than 50mA.

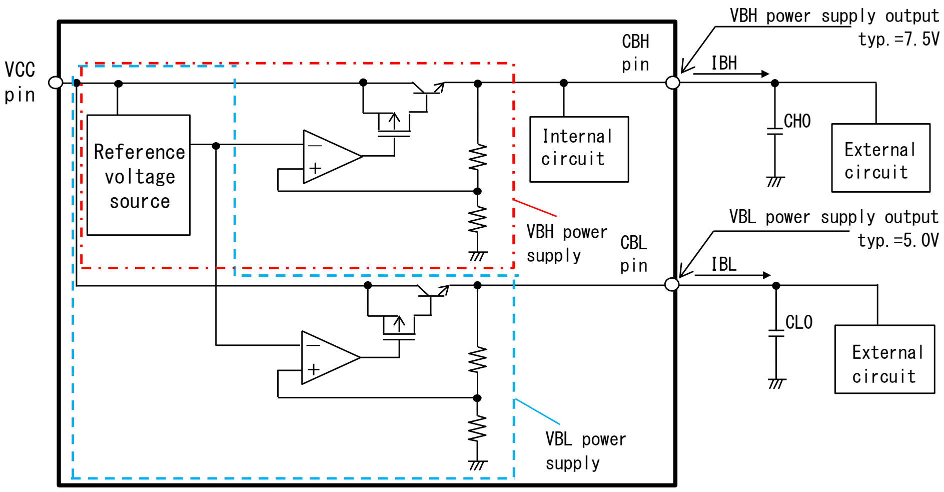



**FIGURE 3.5.4.1 Equivalent Circuit for VBH and VBL Power Supplies**

### 3.5.5 Internal Filter Circuit

Internal filter circuits are located before the top and bottom arm drivers. The filter circuits remove signals and switching noise with widths less than about 0.5μs inputted to the input pins (UT, VT, WT, UB, VB, WB).

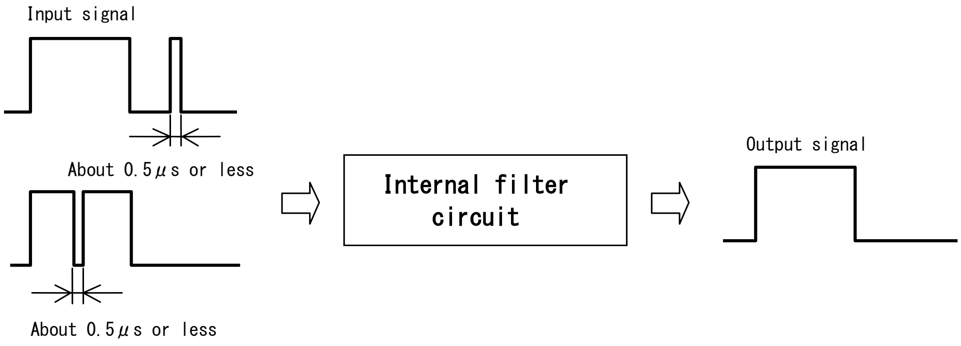



**FIGURE 3.5.5.1 Internal Filter Circuit Operation**

### 3.5.6 Derating

How much to derate a unit from the maximum rating is an important issue to consider for a reliable design. Items to be considered in the stage of system design include the derating of voltage, current, power, load, and electric stresses, along with the derating of temperature, humidity, other environmental conditions, vibration, impact, and other mechanical stresses.

Table 3.5.6.1 specifies the standard examples of derating to be considered when creating a reliable design. To consider these derating items in the equipment design stage is desirable for achieving reliability. If any item is difficult to be controlled within the standard, another means will be necessary, such as selecting a device having higher maximum ratings. Please consult our sales representative in advance.

**TABLE 3.5.6.1 Typical Derating Design Standards**

| | |
|---|---|
| Junction temperature Tj | 110℃ maximum |
| Vs power supply voltage | 450V maximum |
| Output peak current | 1.4A maximum |

## 3.6 Handling

### 3.6.1 Mounting

(1) Insulation between pins

High voltages are applied between the pin numbers specified below. Please apply coating resin or molding treatment as necessary.

・Between pin numbers: 1-2, 2-3, 4-5, 6-7, 21-22, 22-23

(2) Connection of tabs

The tab and the GLT pin of the IC are connected in the frame. Regarding the tab, take note of the following points.

(a) SP-23TA

The tab potential of this IC is same as that of the GLT pin. Please make sure to connect the GLT pin to GL pin externally. Therefore, the tab has the same potential as the GL pin. Never leave the GLT pin unconnected.

The tab is placed on the IC lower surface (on PCB side). Wiring lines other than GND on the PCB must not touch the tab even if a coating such as solder resist is applied. Please secure sufficient insulation distance particularly between high voltage wiring lines and the tab.

(b) SP-23TB, SP-23TR

The tab potential of this IC is same as that of the GLT pin. Please make sure to connect the GLT pin to GL pin externally. Therefore, the tab has the same potential as the GL pin. Never leave the GLT pin unconnected.

If a heat sink is attached to the tab by screwing, leave the heat sink unconnected or set the heat sink potential to the same as that of the GL pin and GLT pin. If a heat sink is not attached to the tab and it is required to insulate between the IC tab and the housing, please insert an insulation sheet or something similar between them. If the insulation between the tab and the housing is insufficient, the IC will not be able to withstand an isolation withstand voltage test in which a high voltage is applied between the housing and the GND.

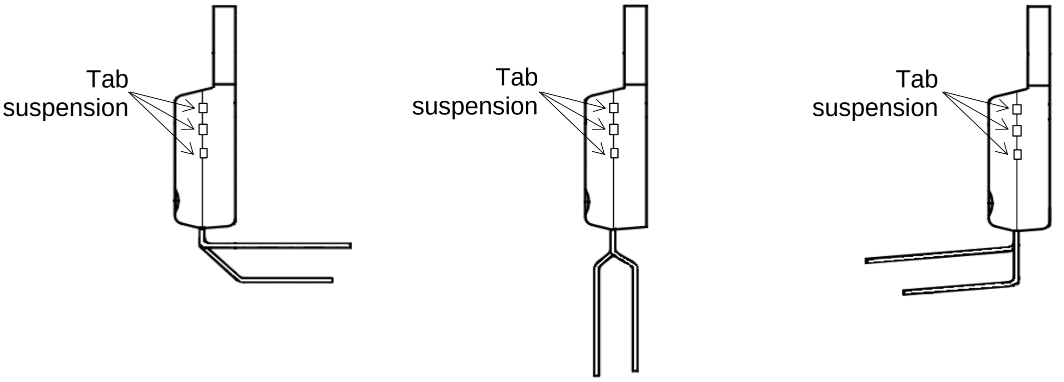
(3) Lead pin reliability

When using the IC with the heat sink attached, the lead pin can be destroyed by vibration or impact depending on use conditions because a load is applied to the lead pin. Please sufficiently assess the IC by a vibration test after mounting the IC. In particular, please note that space between the IC body (resin part) and PCB increases a load.

(4) Tab suspension

Figure 3.6.1.1 shows a side view of the IC.

There are parts called “tab suspension” on both side surfaces of the IC. When the wire or/and parts are laid out close to the tab suspensions, insulate them with coating, mold, or other treatment.




(a) SP-23TA (b) SP-23TB (c) SP-23TR

**FIGURE 3.6.1.1 Side Views of IC**

(5) Coating resin

The influence of coating resin on semiconductor devices (thermal stress, mechanical stress and other stress) depends on PCB size, mounted parts, etc. to be used. When selecting a coating resin, consult with your PCB manufacturer and resin manufacturer.

(6) Soldering conditions

The peak temperature of flow soldering※ must be 260°C or less, and the dip time must be within 10 seconds. High stress by mounting, such as long time thermal stress by preheating, mechanical stress, etc., can lead to degradation or destruction. Make sure that your mounting method does not cause problem as a system.

※ Flow soldering: Only pins enter a solder bath, while the resin or tab does not.

(7) Solder joint reliability

Reliability of solder joints is influenced by soldering conditions, PCB material, etc. Perform adequate evaluations on thermal cycle tests, heat shock tests, and other tests after mounting the IC on a PCB.

## 4. Recommended Circuit

4.1 Standard External Parts

TABLE 4.1.1 shows recommended external parts.

**TABLE 4.1.1 Standard External Parts**

| Parts | Standard value | Usage | Remarks |
|---|---|---|---|
| CH0, CL0 | 1.0μF±10%, 25V | Smooths the internal power supply (VB) | |
| C1, C2 | 0.22μF±10%, 25V | For charge pump | For precautions, see Note 1. |
| Rs | Differs depending on systems. For setting method, see Note 2. | Sets over-current protection | For setting method, see Note 2. |
| CF | 0.01μF±10%, 25V | Removes output noise of Fault signal | |
| RF | 10kΩ±10% | For pull up | |

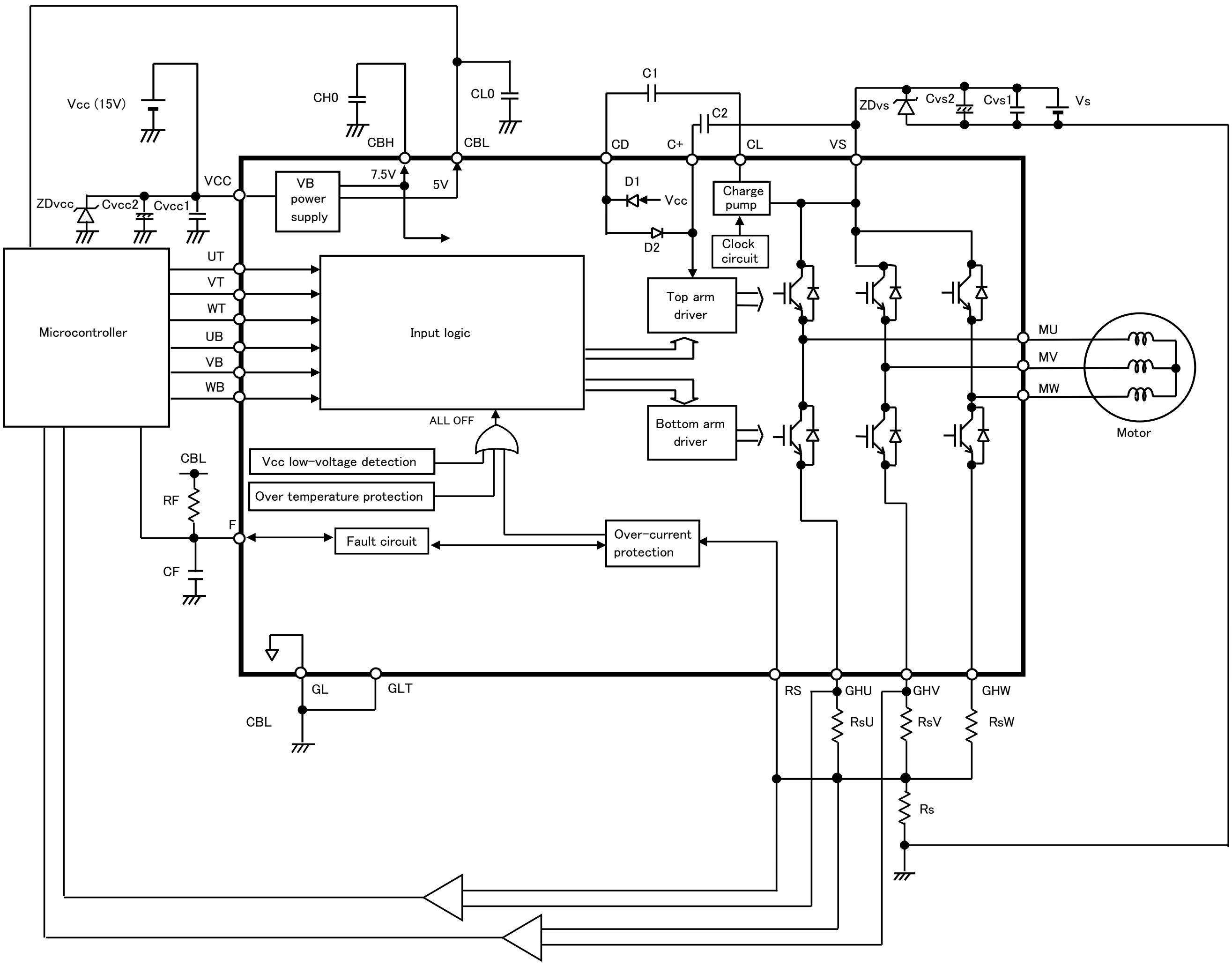



**FIGURE 4.1.1 Block Diagram and External Parts of IC**

Note 1. Attention of parts settings of charge pump circuit

When capacity of a capacitor is small, the voltage between the C+ pin and the VS pin drops because of the internal dissipation current from the C+ pin of the IC. When the voltage between the C+ pin and the VS pin drops, the gate voltage of the top arm IGBTs also drops. The drop of the gate voltage could cause a rise of Tj because of ON-resistance increase of the top arm IGBTs and could cause a decrease in saturation current of the top arm IGBTs. That could lead to degradation or destruction of the IC. Caution is therefore needed when deciding capacity of a capacitor.

The voltage between the C+ pin and the VS pin and the voltage between the CD pin and the CL pin must not be less than 8V.

The voltage impressed to the capacitor is almost the same as Vcc in operation. Therefore, the withstand voltage of the capacitor requires more than the Vcc voltage. Pay close attention when using parts other than those shown in Table 4.1.1.

Note 2. Caution in setting Rs resistor

The current value of over-current protection operation IO_2 can be calculated as follows.

IO_2=Vref2/Rs

Vref2: Reference voltage for over-current protection
Rs : Resistance of shunt resistor

Determine the shunt resistance Rs with reference to the above and the Product Specification.
Make the wiring between the shunt resistor Rs and the RS pin and between the RS pin and the GH∗ pins as short as possible.

The RS pin is connected to built-in CR filters. The CR filter for the over-current protection circuit has a time constant of 0.6 μs.

It is effective to add the CR filter externally if the over-current protection operates erroneously because of the effect of a noise and the like. However, note that adding the external CR filter increases the delay between the time the operating condition of the over-current protection is satisfied and the time the IGBTs are turned off. It is recommended that a time constant of the externally added CR filter is 0.5 μs or less.

## 4.2 Other External Parts

It is recommended to mount the parts shown in Table 4.2.1 to stabilize the power supply and protect the IC from voltage surge.

Adjust the settings of parts in accordance with the usage conditions. Moreover, mount each of the parts close to the pins of the IC to achieve the effect of the voltage surge absorption.

**TABLE 4.2.1 Other External Parts**

| No. | Parts | Purpose | Remarks |
|---|---|---|---|
| 1 | Cvcc1 | for VCC. To suppress high frequency noise | Ceramic capacitor with good frequency response, etc. About 1μF |
| 2 | Cvcc2 | for VCC. To smooth Vcc power supply | Electrolytic capacitor, etc. About 1μF |
| 3 | ZDvcc | for VCC. To suppress over voltage | Zener diode with good frequency response |
| 4 | Cvs1 | for VS. To suppress high frequency noise | Ceramic capacitor with good frequency response, etc. About 33nF/630V |
| 5 | Cvs2 | for VS. To smooth Vs power supply | Electrolytic capacitor, etc. About 1μF/630V |
| 6 | ZDvs | for VS. To suppress over voltage | Zener diode with good frequency response |

**5. Failure Examples (Assumptions)**

5.1 Inverter IC Destruction by an External Surge Inputted to Vs and Vcc (15V) Lines (Case 1)

- Cause : An external surge enters the IC on the Vs and Vcc (15V) lines of the motor. Because the Zener voltage of the surge suppressor diode was higher than the maximum rating voltage of the IC, it does not protect the IC.
- Phenomenon : The motor does not rotate because the over-voltage destroys the IC.
- Countermeasure: Use a surge suppressor diode with Zener voltage, which is lower than the maximum rating voltage of the IC. The larger the rating capacity of the Zener diode, the more effectively the surge suppressor works.

5.2 Inverter IC Destruction by an External Surge Inputted to Vs and Vcc (15V) Lines (Case 2)

- Cause : An external surge enters the IC on the Vs and Vcc (15V) lines of the motor. Because the capacitance of the bypass capacitor for surge suppression was small, the surge could not be sufficiently suppressed.
- Phenomenon : The motor does not rotate due to the over-voltage destruction of the IC.
- Countermeasure : Use the bypass capacitor for surge suppression; its capacity should be enough to suppress surges.

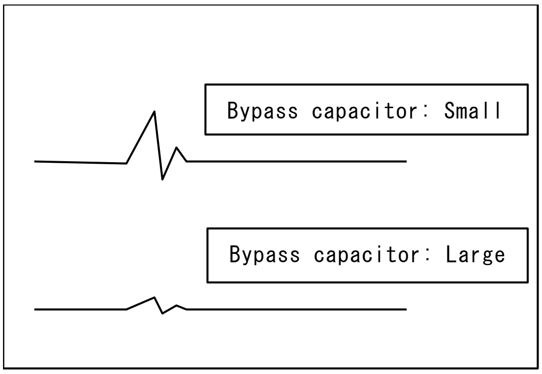



**FIGURE 5.2.1 Example of Surge Waveforms for Different Bypass Capacitor Capacities**

5.3 Inverter IC Destruction by an External Surge Inputted to Vs and Vcc (15V) Lines (Case 3)

- Cause : An external surge enters the IC on the Vs and Vcc (15V) lines of the motor. Because the external parts for surge suppression were positioned far from the IC on the board, the surge could not be sufficiently suppressed.
- Phenomenon : The motor does not rotate due to the over-voltage destruction of the IC.
- Countermeasure : The bypass capacitor and Zener diode for surge suppression should be mounted close to the IC.

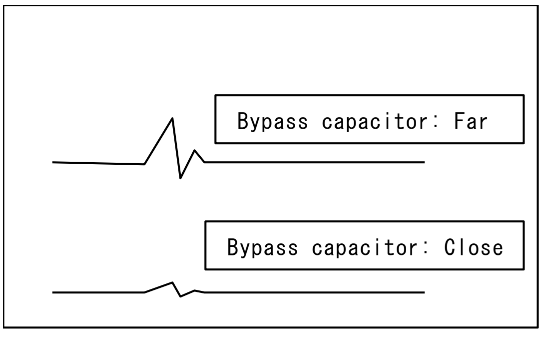



**FIGURE 5.3.1 Example of Surge Waveform for Different Bypass Capacitor Locations on the Board**

5.4 Inverter IC Destruction by an External Surge Inputted to Vcc (15V) Line

・Cause : Pulsed noise of a voltage that is lower than the LVSD level (LVSDON) enters the Vcc (15V) line. In this case, the IC repeats split-second LVSD operation. Then the IC has the possibility of overheat breakage.

・Phenomenon : The motor does not rotate due to the destruction of the IC.

・Countermeasure:

① Remove the noise that enters the motor Vcc line by reviewing the power supply circuit (inductance of power cable, noise filter circuit or the like).

② Connect a capacitor having sufficient capacitance close to the VCC pin and GL pin of the IC to absorb noise.

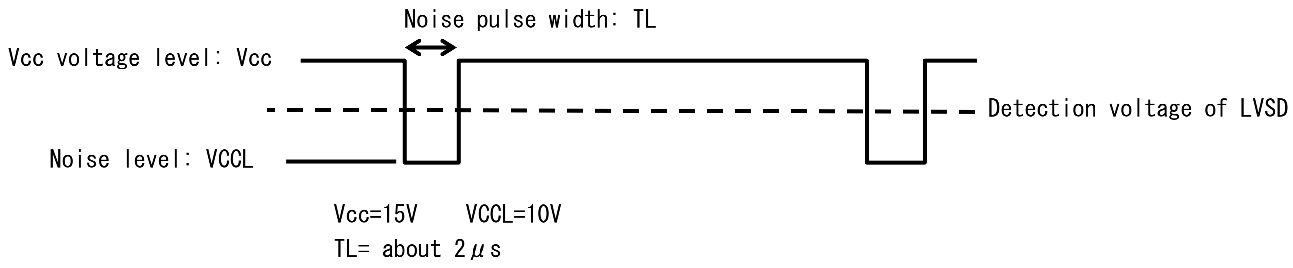



**FIGURE 5.4.1 Example of Pulsed Noise on Vcc Line**

5.5 Inverter IC Destruction by Vcc (15V) Line Noise

・Cause : Surge voltage that exceeds the maximum rating for the IC enters the VCC (15V) pin.

・Phenomenon : The motor does not rotate due to the over-voltage destruction of the IC.

・Countermeasure:

① Mount a bypass capacitor C1 near the pin of the IC. Use a capacitor that has excellent frequency characteristics, such as a ceramic capacitor. As a guide, a capacitor of around 1μF is recommended.

② It is more effective to mount a surge suppression device, such as bypass capacitor C2 shown in Fig. 5.5.1, close to the connector of a motor control circuit board.

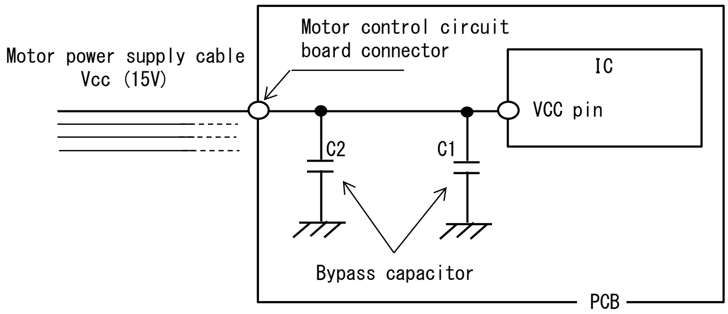



**FIGURE 5.5.1 Example of Mounted Surge Suppression Devices**

5.6 Inverter IC Destruction by Noise at Vs Power Supply Power-on

・Cause : Surge voltage that exceeds the maximum rating for the IC enters the VS pin because the voltage rises suddenly when the Vs power supply is powered on.

・Phenomenon : The motor does not rotate due to the over-voltage destruction of the IC.

・Countermeasure : Mount a power supply smoothing capacitor near the VS pin of the IC. An electrolytic capacitor is generally used as a power supply smoothing capacitor.

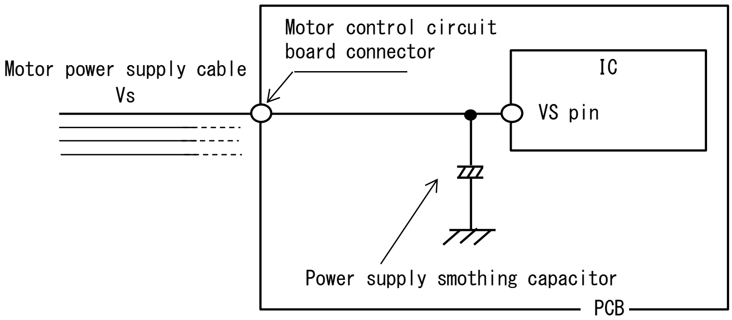



**FIGURE 5.6.1 Example of Mounted Power Supply Smoothing Capacitor**

5.7 Inverter IC Destruction by Inspection Machine Relay Noise

・Cause : A mechanical relay for on-off control of the electric connection between the IC and an inspection machine generates a surge that enters the IC.

・Phenomenon : The motor does not rotate because the over-voltage destruction of the IC.

・Countermeasure : Use a mercury relay, etc. Confirm a surge generated when the relay is on-off is less than the maximum rated value.

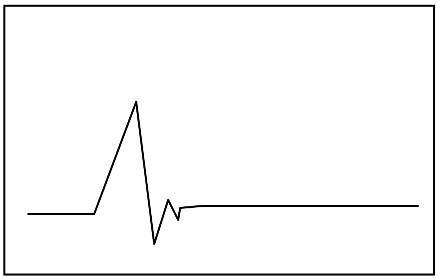


**FIGURE 5.7.1 Example of Surge Waveform When Mechanical Relay is Used**

5.8 Motor Failure (Missing Phase Output)

・Cause : The motor with missing phase has been out on the market.

・Phenomenon : The motor might start depending on the rotor position when starting even if the motor has missing phase output. Therefore, the missing phase output of motor cannot be detected by the motor rotation test.

・Countermeasure: Monitor the motor current or oscillation in order to detect the missing phase output of motor.

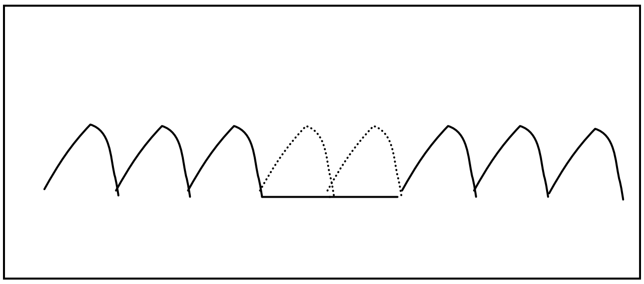


**FIGURE 5.8.1 Example of Motor Current Waveform in Phase Missing Condition**

## 6. Precautions for Use

6.1 Countermeasures against Electrostatic Discharge (ESD)

(a) Customers need to take precautions to protect ICs from electrostatic discharge (ESD). The material of the container or any other device used to carry ICs should be free from ESD, which can be caused by vibration during transportation. Use of electrically conductive containers is recommended as an effective countermeasure.

(b) Everything that touches ICs, such as the work platform, machine, measuring equipment, and test equipment, should be grounded.

(c) Workers should be high-impedance grounded (100kΩ to 1MΩ) while working with ICs, to avoid damaging the ICs by ESD.

(d) Friction with other materials, such as high polymers, should be avoided.

(e) When carrying a PCB with a mounted IC, ensure that the electric potential is maintained at a constant level using the short-circuit terminals and that there is no vibration or friction.

(f) The humidity at an assembly line where ICs are mounted on circuit boards should be kept around 45 to 75 percent using humidifiers or such. If the humidity cannot be controlled effectively, using ionized air blowers (ionizers) is effective.

6.2 Maximum Ratings

Regardless of changes in external conditions during use of IC (the product of Hitachi Power Semiconductor Device, hereinafter called “HPSD’s IC”), the “maximum ratings” should never be exceeded when designing electronic circuits that employ HPSD’s IC. If maximum ratings are exceeded, HPSD’s IC may be damaged or destroyed. In no event shall Hitachi Power Semiconductor Device (hereinafter called “HPSD”) be liable for any failure in HPSD’s IC or any secondary damage resulting from use at a value exceeding the maximum ratings.

6.3 Derating Design

Continuous high-load operation (high temperatures, high voltages, large currents) should be avoided and derating design should be applied, even within the ranges of the maximum ratings, to ensure reliability.

6.4 Safe Design

The HPSD’s IC may fail due to accidents or unexpected surge voltages. Accordingly, adopt safe design features, such as redundancy and measures to prevent misuse, in order to avoid extensive damage in the event of a failure.

6.5 Application

If HPSD’s IC is applied to the following uses where high reliability is required, obtain the document of permission from HPSD in advance.

・Automobile, Train, Vessel, etc.

Do not apply HPSD’s IC to the following uses where extremely high reliability is required.

・Nuclear power control system, Aerospace instrument, Life-support-related medical equipment, etc.

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