Three-input Type Single Chip Inverter IC

Application Note

【Rev 1】

Applicable to

AC 100V system	**ECN33101**
AC 200V system	**ECN33202** **ECN33201**

Hitachi Power Semiconductor Device, Ltd.

－Contents－

1. Outline

1.1 System Configuration

1.1.1 Single Chip Inverter IC

Hitachi single chip inverter IC is the monolithic IC integrating various devices and circuits, needed for inverter control, onto a single chip by using DI technology. This IC is for motor drive and suitable for variable speed control of three-phase induction motors and DC brushless motors. The advantage of miniaturization by a single chip structure makes possible a motor with a built-in control board.

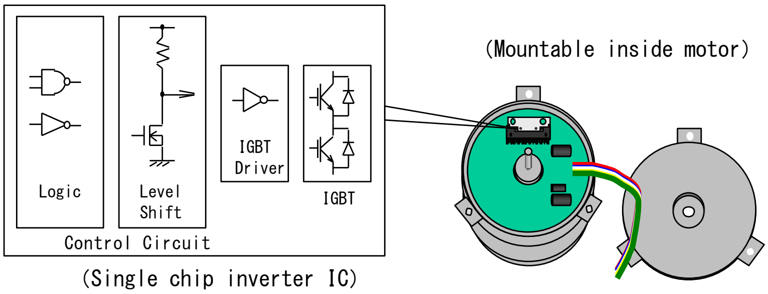


FIGURE 1.1.1.1 Image of Motor with Built-in Control Board

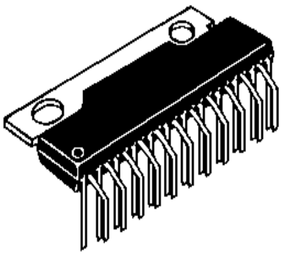


FIGURE 1.1.1.2 Package (Package Type: SP-23TA)

1.1.2 System Configuration

An inverter is equipment that converts direct current (DC) to alternating current (AC) and makes possible efficient variable speed control of a motor. Fig. 1.1.2.1 shows the basic configuration of the inverter IC. The inverter IC consists of IGBT drive circuits, level-shift circuits, logic circuits, six free-wheeling diodes and six IGBTs for inverter drive of a three-phase motor. Hitachi inverter IC can directly receive high-voltage rectified from commercial AC power supply due to high-voltage specification. Therefore, a step-down circuit is unnecessary, and the efficiency reduction caused by voltage conversion is suppressed.

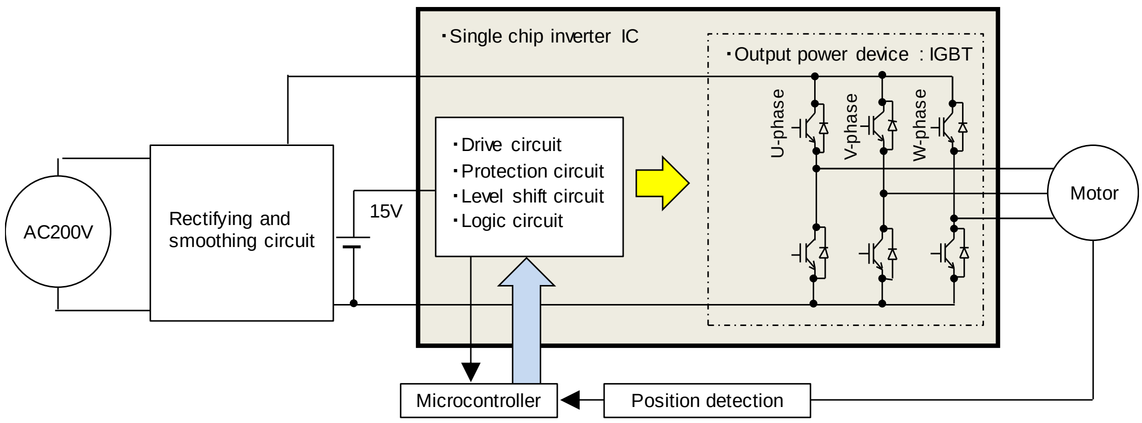
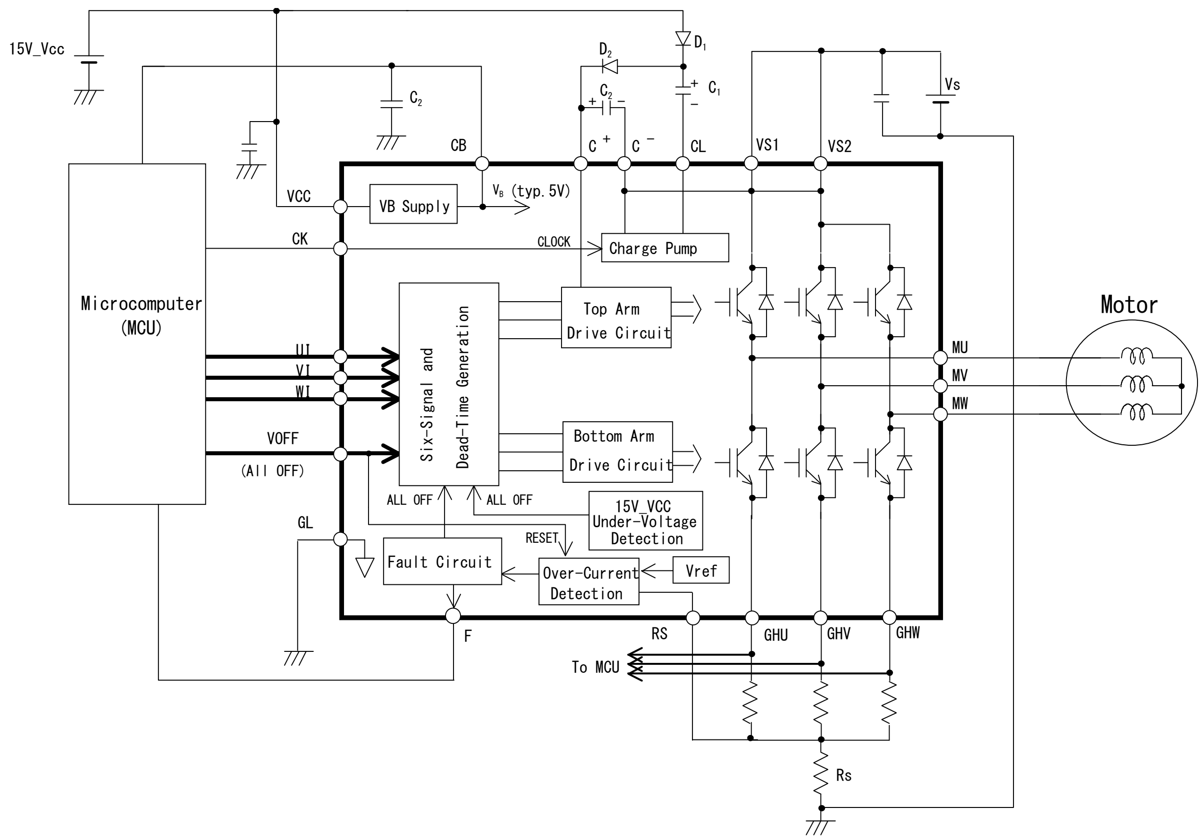


FIGURE 1.1.2.1 Example of Basic System Configuration

1.2 Inverter IC Block Diagram

Fig. 1.2.1 shows the block diagram of the inverter IC.



*1 The inverter IC is shown inside the bold line.

FIGURE 1.2.1 Inverter IC Block Diagram

2. Specifications

2.1 Pin Locations

Table 2.1.1 shows pin locations.

Table 2.1.1 Pin Locations

Pin	Symbol	Definition	Remarks
1	MV	V phase output	Note 1
2	VS2	Power supply for top arm IGBTs of V and W phases	Note 1, Note 2
3	GHW	Emitter of W phase bottom arm IGBT and anode of W phase bottom arm FWD (Connect over-current protection resistance.)	
4	MW	W phase output	Note 1
5	VCC	15V control power supply	
6	GL	Control system GND	
7	C+	For the charge pump circuit, power supply for top arm drive circuits	Note 1
8	C-	For the charge pump circuit	Note 1, Note 2
9	CL	For the charge pump circuit	Note 1
10	CB	5V power supply output	
11	RS	RS voltage input for over-current protection	
12	CK	Clock input	
13	VOFF	All off input	
14	F	Fault signal output	
15	—	Feedback signal output for kit product (ECN39*** series) Open the pin.	
16	UI	Input control signal for U phase	
17	VI	Input control signal for V phase	
18	WI	Input control signal for W phase	
19	NC	No connection	Note 3
20	MU	U phase output	Note 1
21	VS1	Power supply for top arm IGBT of U phase	Note 1, Note 2
22	GHU	Emitter of U phase bottom arm IGBT and anode of U phase bottom arm FWD (Connect over-current protection resistance.)	
23	GHV	Emitter of V phase bottom arm IGBT and anode of V phase bottom arm FWD (Connect over-current protection resistance.)	

Note 1: High voltage pin.

Note 2: The VS1, VS2 and C− pins are connected within the inverter IC but VS1 and VS2 must also be connected by external wiring because of current capacity.

Note 3: Not connected to the internal chip.

2.2 Pin Function

Table 2.2.1 Pin Function (1/3)

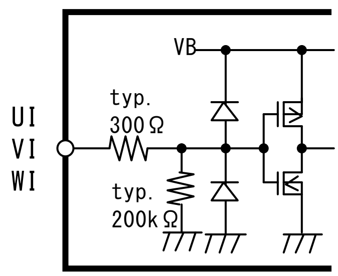
No.	Pin Signs	Items	Functions and cautions	Related items	Remarks
1	VCC	Control power supply pin	・Powers the drive circuits for the top and bottom arms, the charge pump circuit, the built-in VB supply circuit, and others. ・Determine the capacity of the power supply for 15V_VCC, allowing a margin determined by adding the standby current ICC and the current taken out of the CB pin.	・2.3.1 (1) 15V_VCC under-voltage Detection ・4.1 to 4.5 Inverter IC destruction by external surge or line noise.	
2	VS1 VS2	IGBT power pin	・Connected to the collector of the top arm IGBTs. ・Connect VS1 and VS2 close to the inverter IC pins. If either pin is open, the inverter IC may be destroyed.	・4.1 to 4.3, 4.6 Inverter IC destruction by external surge	High voltage pin
3	CB	Output pin of the built-in VB supply	・Outputs a voltage (typ. 5.0V) generated in the built-in VB power supply. ・Provides power from the VB power supply to the internal circuit of the inverter IC (input buffer, over-current protection, etc). Can be used as a power supply for MCU, position sensor signals, etc. ・Connect a capacitor C0 to prevent oscillation to the CB pin. A capacitor capacity of 1.0μF ±20% is recommended.	・2.3.4 VB power supply	
4	GL	Control GND pin	・The GND pin for the 15V_VCC and VB power lines.	−	
5	GHU GHV GHW	IGBT emitter pin	・GHU is connected to the emitter of the U-phase bottom arm IGBT. GHV is connected to the emitter of the V-phase bottom arm IGBT. GHW is connected to the emitter of the W-phase bottom arm IGBT. ・Connected to a shunt resistance Rs, to detect over-current and monitor phase current.	・2.3.1 (2) Over-current protection	
6	MU MV MW	Inverter output pin	・The output of a three-phase bridge consisting of six IGBTs and six FWDs.		High voltage pin
7	UI VI WI	Control input pin of each arm	・Inputs control signals of each phase. ・When "H" is input, the top arm IGBTs turn on. When inputting "L", the bottom arm IGBTs turn on. ・If the switching noise is monitored, mount a capacitor. ・The maximum rating is VB+0.5V.	Product Specification ・3.2 Input pins	
		 **FIGURE 2.2.1 UI, VI, WI Equivalent Circuit**			

Table 2.2.1 Pin Function (2/3)

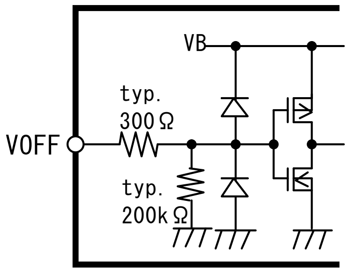
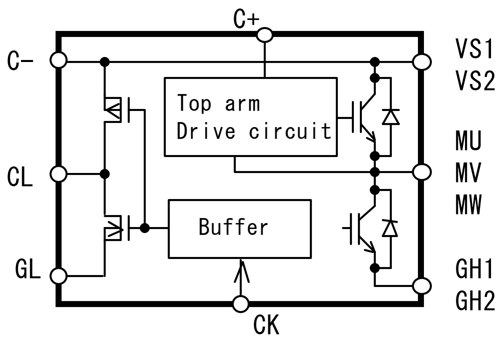
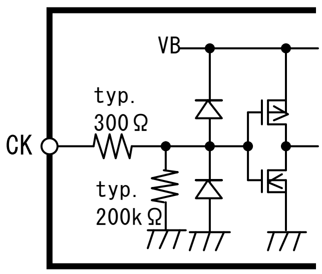
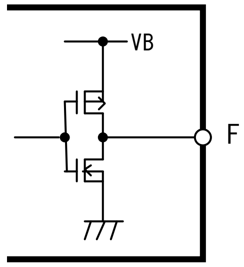
No.	Pin Signs	Items	Functions and cautions	Related items	Remarks
8	VOFF	All off input	・When "H" is input, IGBTs are turned on/off depending on control input for each arm. ・When "L" is input, IGBTs are all turned off.	Product Specification ・2.4.6 Input Signals at Standby condition ・3.2 Input pins	
		 FIGURE 2.2.2 VOFF Equivalent Circuit			
9	C+ C- CL	Top arm drive circuit power pin Charge pump circuit pin	・Powers the drive circuit for the top arm. ・Connect external components (capacitors and diodes).	・2.3.2 Charge pump circuit	High voltage pin
		 FIGURE 2.2.3 C+, C-, CL Equivalent Circuit			
10	CK	Clock input pin for charge pump	・Inputs clock signal for the charge pump circuit.	・2.3.2 Charge pump circuit Product Specification ・2.4.6 Input Signals at Standby condition ・3.2 Input pins	
		 FIGURE 2.2.4 CK Equivalent Circuit			

Table 2.2.1 Inverter IC Pins and Their Functions (3/3)

<table>
<tr><th>No.</th><th>Pin Signs</th><th>Items</th><th>Functions and cautions</th><th>Related items</th><th>Remarks</th></tr>
<tr><td rowspan="2">11</td><td rowspan="2">F</td><td>Fault signal output pin</td><td>・When the over-current protection is operating, F pin output is “L”.
・F pin outputs “H” in the steady state.</td><td>・2.3.1
(2) Over-current protection</td><td rowspan="2"></td></tr>
<tr><td colspan="3">
FIGURE 2.2.5 F Equivalent Circuit</td></tr>
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2.3 Functions and Precautions for Use

2.3.1 Protection Function

(1) 15V_VCC under-voltage detection

When the 15V_VCC voltage goes below the LVSD operating voltage (LVSDON), the output IGBTs of the top and bottom arms are all turned off regardless of the input signal.

This function has hysteresis (Vrh). When the 15V_VCC voltage goes up again, the system returns to a state in which the ouput IGBT operates according to the input signal, at a level equal to or exceeding the LVSD recovery voltage (LVSDOFF).

If the detection for 15V_VCC under-voltage operates during motor rotation, VS voltage may rise due to regenerative electric power. VS voltage must not exceed the maximum rating. Particular attention is needed when the capacity between the VS and GND is small, making the voltage more likely to rise.

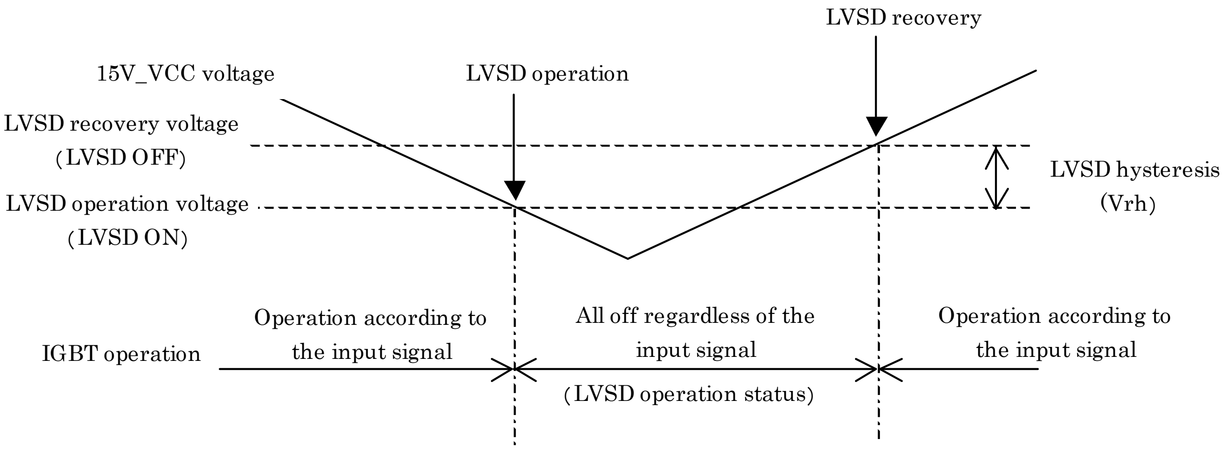

FIGURE 2.3.1.1 Time Chart for Detection of 15V_VCC Under Voltage (LVSD Operation)

(2) Over-current protection

(a) Over-current protection operation

The inverter IC monitors the current through the shunt resistance Rs. When the voltage at the RS pin exceeds the Vref (Vref is typically 0.5V) of the internal detection circuit, all IGBTs are turned off and the F pin outputs “L”. Input “L” at VOFF pin to reset this all off state. The F pin outputs “H” by inputting “L” after a lapse of fault reset delay time (tflrs). Lengthen the period of VOFF “L” for the fault reset delay time or more.

Input “H” at VOFF pin to restart.

Just after the 15V_VCC is input, the over-current protection may operate. In this case, reset the all off state.

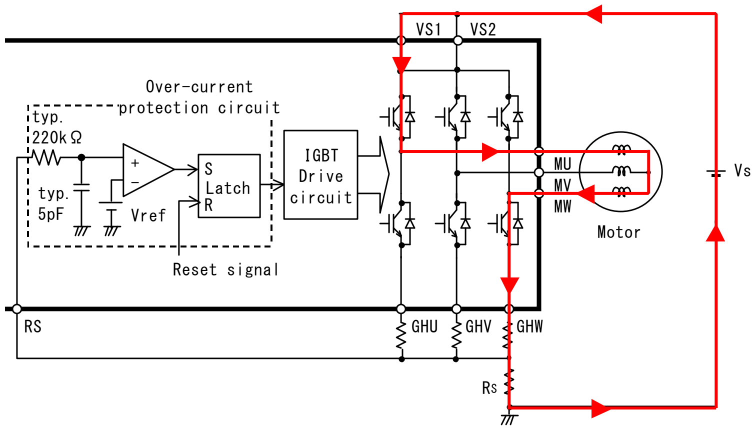

FIGURE 2.3.1.2 Example of Current through the Shunt Resistance

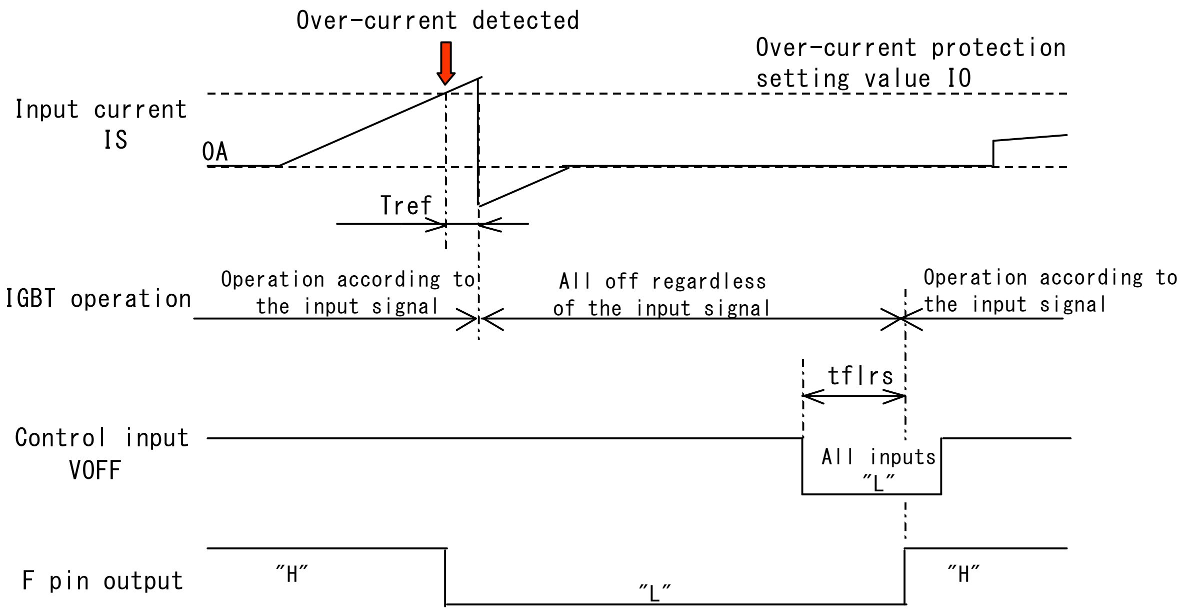

FIGURE 2.3.1.3 Time Chart of Over-current Protection

(b) How to set up over-current protection level

The over-current protection setting I0 is calculated as follows;

I0 = Vref / Rs

Where

Vref : Reference voltage for current protection

Rs : Shunt resistance

In setting a over-current protection level, you should allow for Vref variance, Rs variance, and the delay between the time the over-current protection is detected and the time the IGBT is turned off. In practice, check the output currents of the inverter IC (motor phase currents).

Set the shunt resistance so that voltages of GHU, GHV, and GHW pins are within the specified GH voltage (Vgh) range in the product specification.

This function is not effective for currents that do not flow forward through Rs, such as reflux current and power regenerative current (see Fig. 2.3.1.4 and 2.3.1.5).

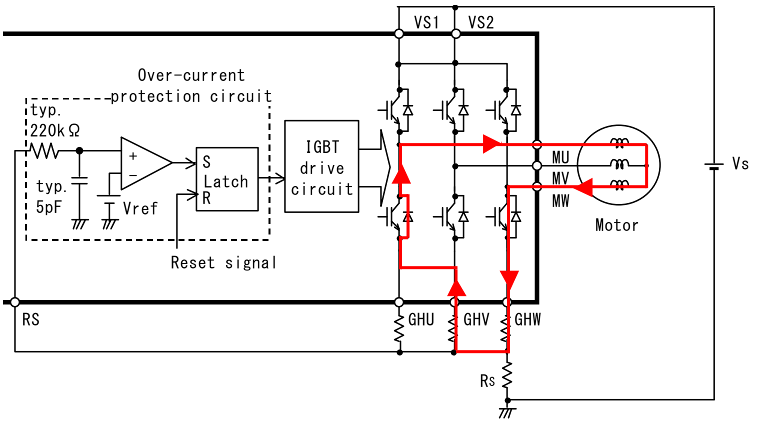

FIGURE 2.3.1.4 Example of Reflex Current

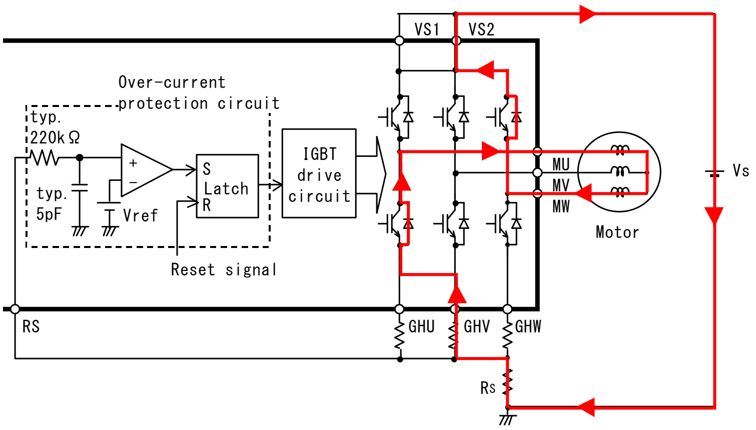

FIGURE 2.3.1.5 Example of Power Regenerative Current

(c) Wiring precautions

Make the wiring of the shunt resistance 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) Short-circuit protection

If output is short-circuited (load short-circuit, earth fault, and short-circuit between the top and bottom arms), there is a possibility that the inverter IC will be destroyed. Thus, be sure to protect the device externally.

2.3.2 Charge Pump Circuit

2.3.2.1 Operation of Charge Pump Circuit

Fig. 2.3.2.1.1 shows the block diagram of the charge pump circuit. SW1 and SW2 alternately turn on and off, in synchronization with the clock inputted into the CK pin.

When SW1 is off and SW2 is on, the CL pin has a potential of 0V. Through passage ①, the capacitor C1 is charged. Next, SW1 is turned on and SW2 is turned off, and the potential of the CL pin rises to the VS level. Through passage ②, the charge of the capacitor C1 is pumped up to the capacitor C2.

This operation is 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.

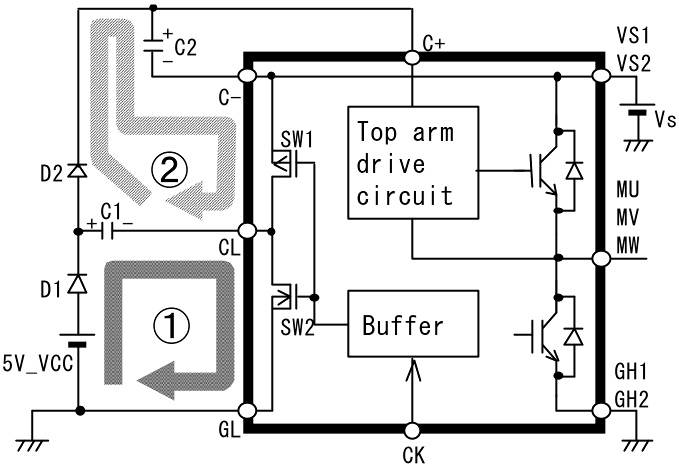

FIGURE 2.3.2.1.1 Charge Pump Circuit

2.3.2.2 Part Setting of the Charge Pump Circuit

(1) Recommended external parts

・Table 2.3.2.2.1 shows recommended external parts.

Table 2.3.2.2.1 Recommended External Parts

Type	Parts	Standard values	Remarks
ECN33101	C1, C2	1.0µF±20%	Voltage stress: 15V_VCC
	D1, D2	400V, 1.0A trr≦100ns	
ECN33201	C1, C2	1.0µF±20%	Voltage stress: 15V_VCC
ECN33202	D1, D2	600V, 1.0A trr≦100ns	

(2) Caution

When using external parts whose values are different from the standard values, pay close attention to the followings:

(a) When the voltage (Vcp) between C+ and C− drops, the gate voltage of the top arm IGBTs also drops, and then the loss of the inverter IC increases. Vcp must not become Vcp<10V.

(b) Capacitor

・When capacity is small, Vcp drops due to the internal dissipation current from the C+ pin of the inverter IC.

・The voltage impressed to the capacitor is 15V_VCC in operation. Therefore, the withstand voltage of the capacitors must be more than the 15V_VCC voltage.

(D) Diode

・Forward voltage (VF) as small as possible is recommended, because Vcp drops when VF is large.

・Reverse recovery time (trr) as short as possible is recommended, because when trr is long the reverse recovery charge (Qrr) increases during charge pump operation and then, Vcp drops.

・The withstand voltage of the diodes must be more than the VS voltage because the CL voltage changes from about 0V to VS.

・The rush current flows to diodes D1 and D2 by charging capacitors C1 and C2 when the 15V_VCC power supply is turned on at VS=0V. Select the rating current of the diode with consideration of this current.

2.3.2.3 Clock Signal Setting

Input the clock signal specified as follows into CK pin.

- H level = VB, L level = 0V, Duty = 50%
- Frequency : min. = 12kHz, max. = 22kHz

2.3.3 Power Supply Sequence

Follow the power supply sequence below.

- At the time of power on ; Power on VCC→ Power on VS→ Input clock to CK pin→ Input "H" at VOFF pin
- At the time of power off ; Input "L" at VOFF pin→ Stop inputting clock to CK pin→ Power off VS→Power off VCC

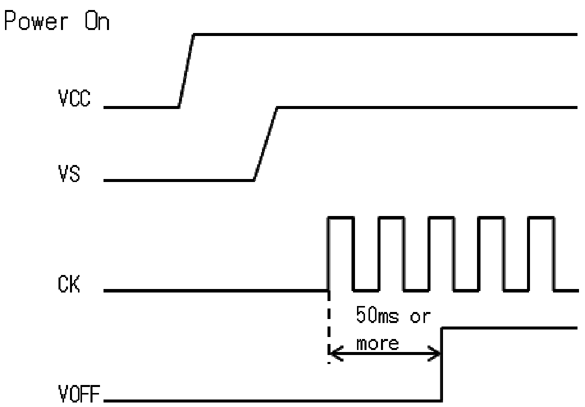

FIGURE 2.3.3.1
Power Supply Sequence at Time of Power On

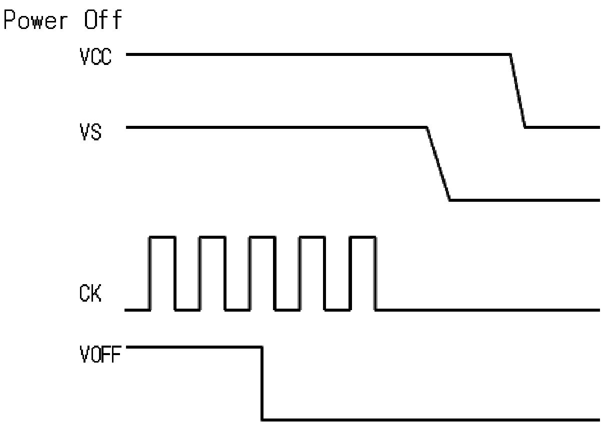

FIGURE 2.3.3.2
Power Supply Sequence at Time of Power Off

2.3.4 VB Power Supply

The VB power supply (VB = typ. 5.0V) to be output to the CB pin is generated at 15V_VCC power supply. The VB power is supplied to the internal circuits of the inverter IC such as the over-current protection circuit.

The VB power supply circuit constitutes a feedback circuit (see Fig. 2.3.4.1). To prevent oscillation, connect a capacitor C0 to the CB pin.

The recommended capacity for the C0 is 1.0μF±20%.

The larger the C0 capacity, the more stable the VB power supply. However, setting the capacity figure to an excessive level is not recommended. As a guide, it should be 2μF to 3μF or less.

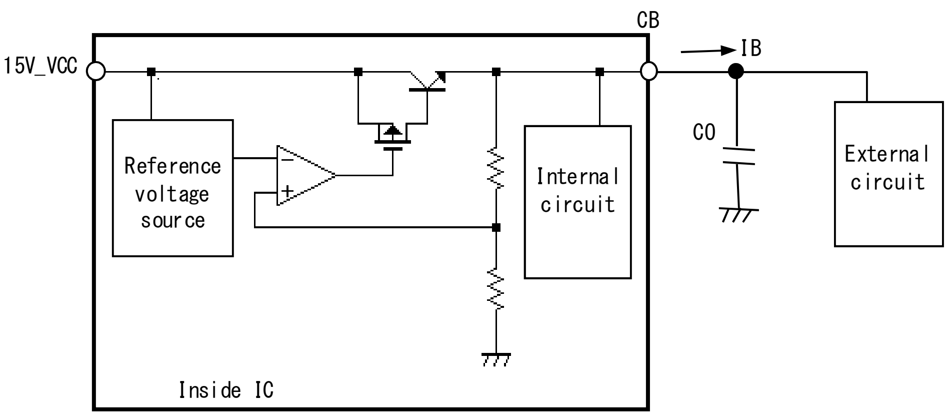

FIGURE 2.3.4.1 Equivalent Circuit for the VB Power Supply

2.4 Handling

2.4.1 Mounting

(1) Insulation between pins

High voltages are applied between the pin numbers specified below. Hitachi advises the application of coating resin or molding treatment.

Between pin numbers: 1 - 2, 2 - 3, 3 - 4, 4 - 5, 6 - 7, 8 - 9, 9 - 10, 18 - 20, 20 - 21, 21 - 22

Coating resin comes in various types. It is unclear as to how much thermal and mechanical stress is placed on semiconductor devices by board shape factors such as size and thickness, and the effects of other components. When selecting a coating resin, consult with your manufacturer.

(2) Connection of tab (radiator panel of inverter IC)

Fig. 2.4.1.1 presents a cross section of the inverter IC. The tab and the GL pin of the inverter IC are connected with high impedance (Rp = several hundreds kΩ to several MΩ).

Open the tab or set it to the same potential of the GL pin.

If the tab is mounted on the external cabinet of the motor for heat radiation purposes, the inverter IC will not be able to withstand an isolation withstand voltage test in which a high voltage is applied between the external cabinet and the GND. Insert a mylar sheet or something similar between the inverter IC tab and the external cabinet.

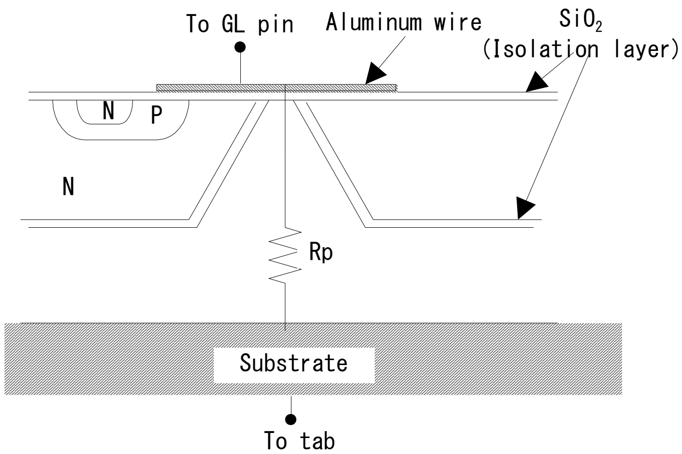

FIGURE 2.4.1.1 Cross Section of Inverter IC

(3) Soldering conditions

The peak temperature of flow soldering must be less than 260°C, and the dip time must be less than 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.

2.5 Markings

The resin surface of the IC is marked by laser.

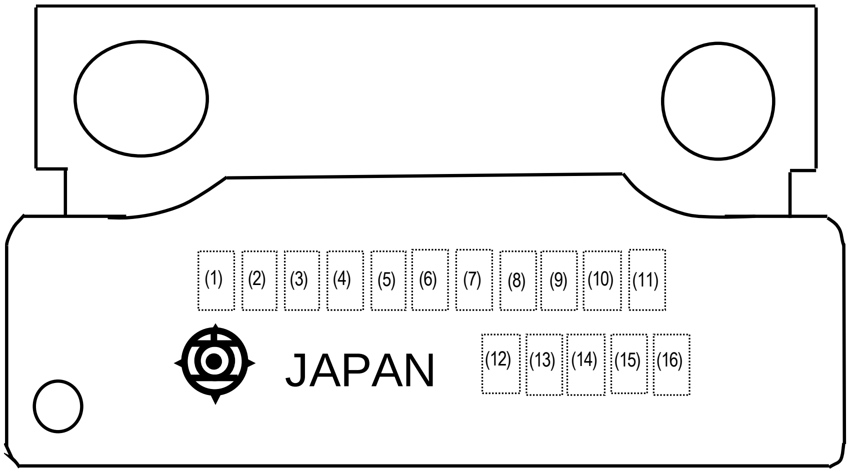

FIGURE 2.5.1 SP-23TA, SP-23TB Marking Specifications

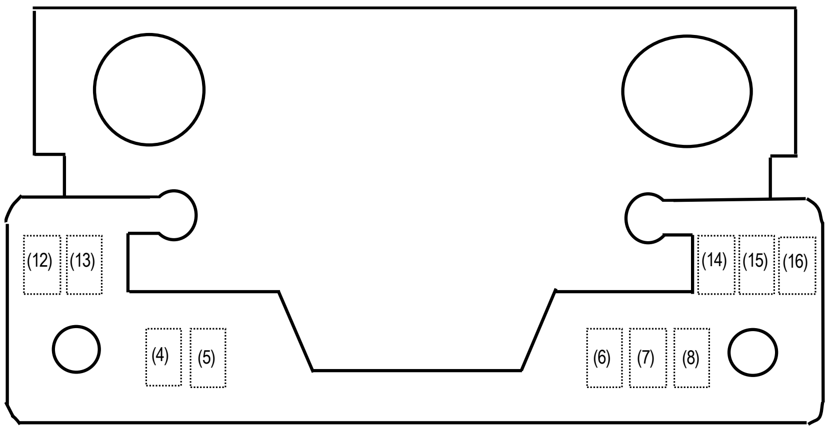

FIGURE 2.5.2 SP-23TR Marking Specifications

Mark No. (1) to (11): Model name

Mark No. (12) to (16): Lot number

No. (12) : Last one-digit of the year of assembly

No. (13) : 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. (14) to (16) : Quality control number

Represented with letters from “A” to “Z” except “I” and ”O”, numbers from “1” to “9”, or blank.

3. Recommended Circuit

3.1 Standard External Parts

Fig. 3.1.1 shows an example of recommended circuits. This is just an indicator. Select peripheral parts considering redundancy in design.

Select parts based on specific user situations. To absorb voltage surges, mount each part close to the inverter IC pins. Make the shunt resistance Rs wiring as short as possible.

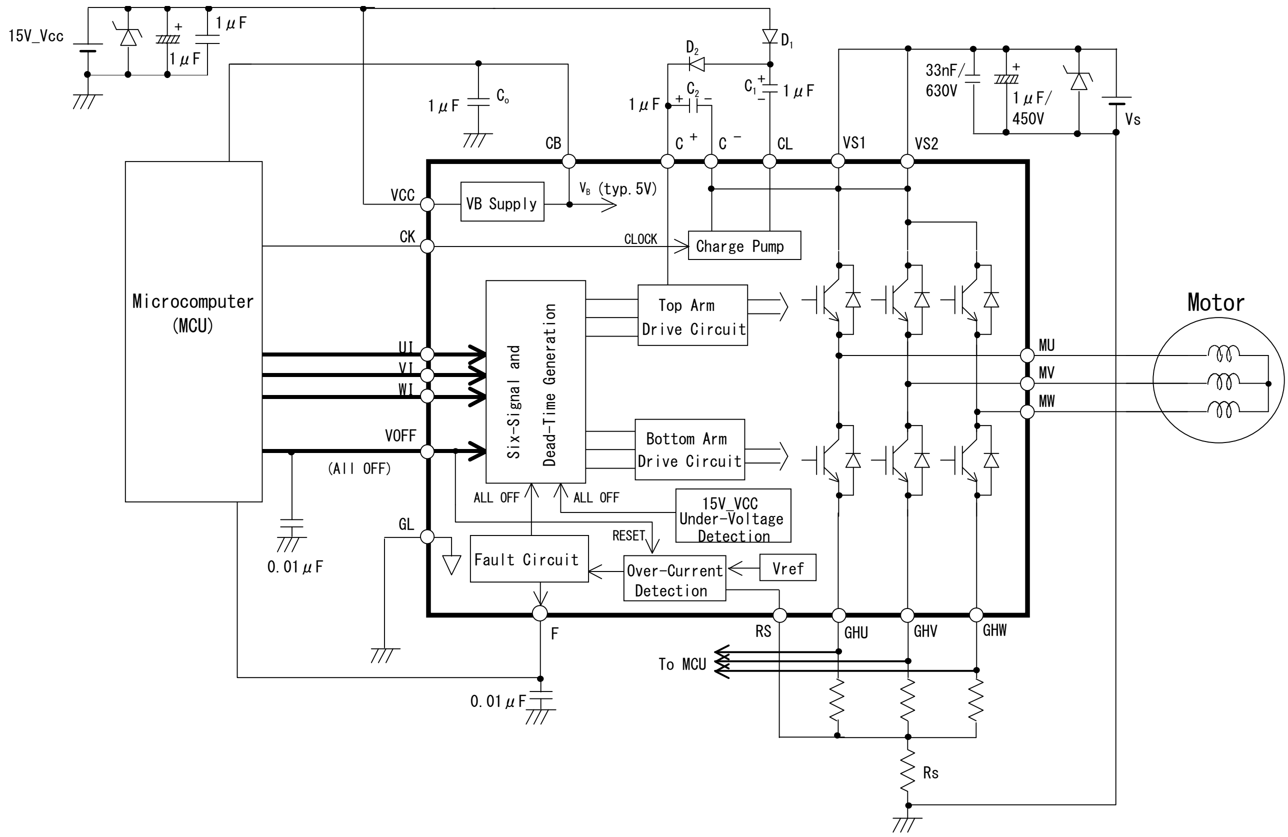

FIGURE 3.1.1 Example of Recommended Circuit

4. Failure Examples (Assumptions)

4.1 Inverter IC Destruction by an External Surge Inputted to VS and VCC Lines (Case 1)

- Cause : An external surge entered the inverter IC on the VS and VCC lines. Because the Zener voltage of the surge suppressor diode was higher than the maximum rating voltage of the inverter IC, it did not protect the inverter IC.
- Phenomenon : The motor does not rotate due to the over-voltage destruction of the inverter IC.
- Countermeasure : Use a surge suppressor diode with Zener voltage, which is lower than the maximum rating voltage of the inverter IC. The larger the rating capacity of the Zener diode, the more effectively the surge suppressor works.

4.2 Inverter IC Destruction by an External Surge Inputted to VS and VCC Lines (Case 2)

- Cause : An external surge entered the inverter IC on the VS and VCC lines. Because the capacity 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 inverter IC.
- Countermeasure : Use the bypass capacitor for surge suppression; its capacity should be enough to suppress surges.

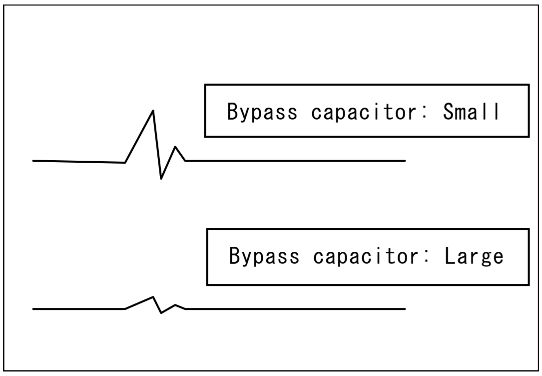

FIGURE 4.2.1 Example of Surge Waveforms for Different Bypass Capacitor Capacities

4.3 Inverter IC Destruction by an External Surge Inputted to VS and VCC Lines (Case 3)

- Cause : An external surge entered the inverter IC on the VS and VCC lines. Because the external parts for surge suppression was badly positioned on the motor populated board, the surge could not be sufficiently suppressed.
- Phenomenon : The motor does not rotate due to the over-voltage destruction of the inverter IC.
- Countermeasure : The bypass capacitor and Zener diode for surge suppression should be mounted close to the inverter IC.

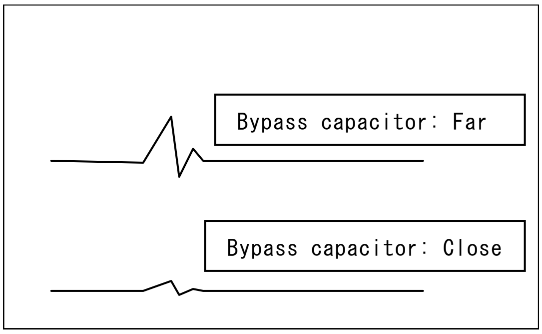

FIGURE 4.3.1 Example of Surge Waveform for Different Bypass Capacitor Locations on the Board

4.4 Inverter IC Destruction by an External Surge Inputted to VCC Line

- Cause : Pulse-shape noise whose voltage was lower than the low voltage detection level (LVSD level) entered the VCC line.
  In such case, the inverter IC repeated momentary LVSD operation. That could cause destruction because of overheating.
- Phenomenon : The motor does not rotate due to the destruction of the inverter IC.
- Countermeasure: ① Exclude the noise superimposed on the motor VCC line by reviewing the power supply circuit (power supply cable, noise filter circuit or the like)
  ② Connect a capacitor having a sufficient capacitance close to VCC and GL pins of the inverter IC.

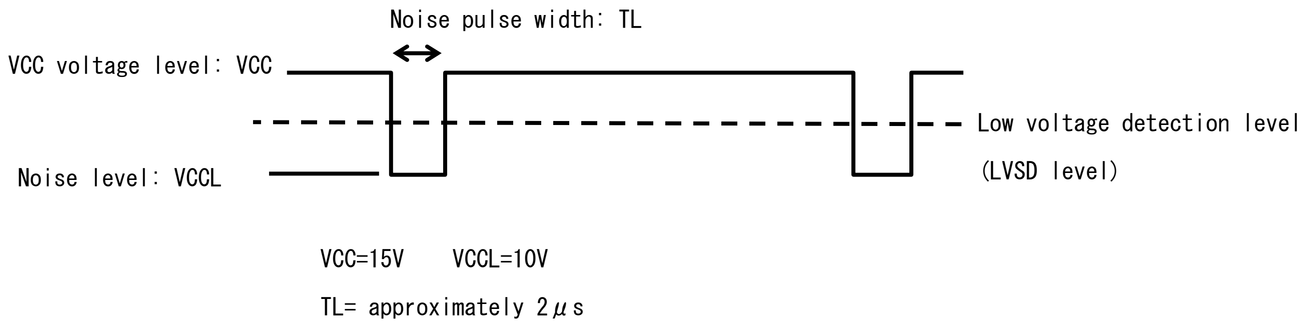

FIGURE 4.4.1 Example of VCC Noise Waveform

4.5 Inverter IC Destruction by VCC Line noise

- Cause : Surge voltage that exceeded the maximum rating for the inverter IC entered the VCC pin.
- Phenomenon : The motor does not rotate because the over-voltage destroys the inverter IC.
- Countermeasure:
  ① Mount a bypass capacitor C1 near the pin of the inverter IC. For maximum effectiveness, use a capacitor that has excellent frequency characteristics, such as a ceramic capacitor. As a guide, capacitors of around 1μF are recommended (the larger the capacity, the more effective the device is).
  ② It is more effective to mount a surge suppression device, such as bypass capacitor C2 shown in Fig. 4.5.1, close to the connector of a motor populated board.

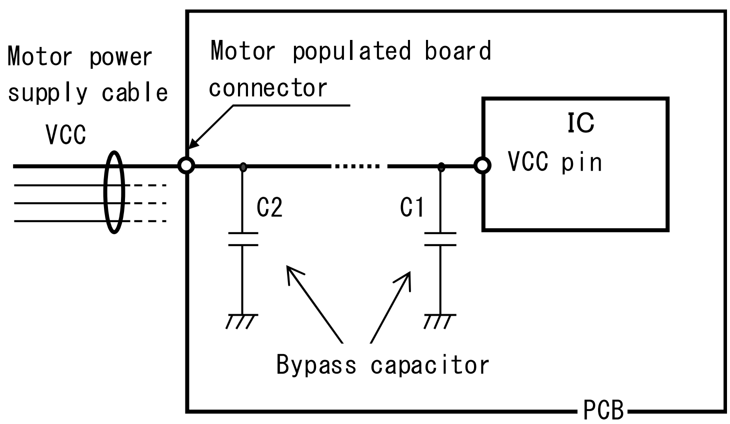

FIGURE 4.5.1 Example of Mounted Surge Suppression Devices

4.6 Inverter IC Destruction by Noise When Vs Power Supply is Powered ON

・Cause : Surge voltage that exceeded the maximum rating for the inverter IC entered the VS pin when the Vs power supply was powered ON.

・Phenomenon : The motor does not rotate because the over-voltage destroys the inverter IC.

・Countermeasure: Mount a power supply smoothing capacitor near the VS pin of the inverter IC. It is common to use an electrolytic capacitor as a power supply smoothing capacitor.

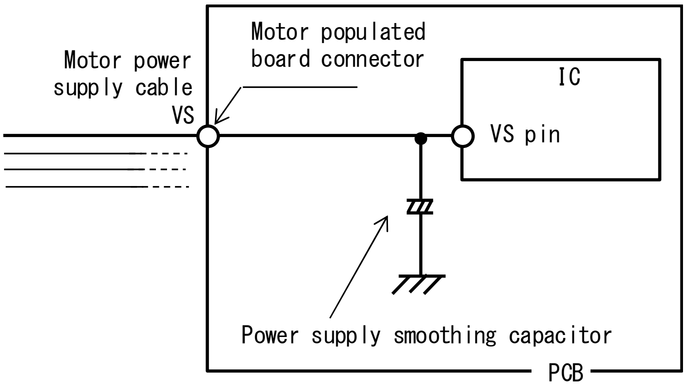

FIGURE 4.6.1 Example of Mounted Power Supply Smoothing Capacitor

4.7 Inverter IC Destruction by Inspection Machine Relay Noise

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

・Phenomenon : The motor does not rotate because the over-voltage destroys the inverter IC.

・Countermeasure : Use a wet relay (mercury relay, etc). Confirm a surge is not generated when the relay is on-off.

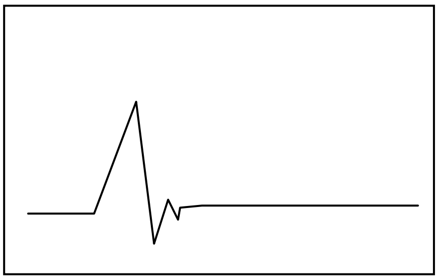

FIGURE 4.7.1 Example of Surge Waveform When Using Mechanical Relay

4.8 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.

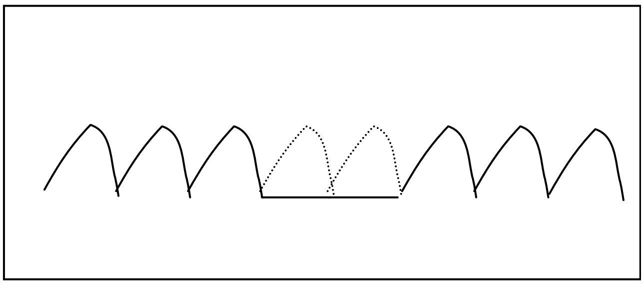

FIGURE 4.8.1 Example of Motor Current Waveform in Phase Missing Condition

5. Precautions for Use

5.1 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.

5.2 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.

5.3 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.

5.4 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.

5.5 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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