VSP Input Type Single Chip Inverter IC

Application Note

【Rev 1】

Models

100V AC system	ECN30114
200V AC system	ECN30214

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. They are for driving motors, suited for variable speed control of 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.
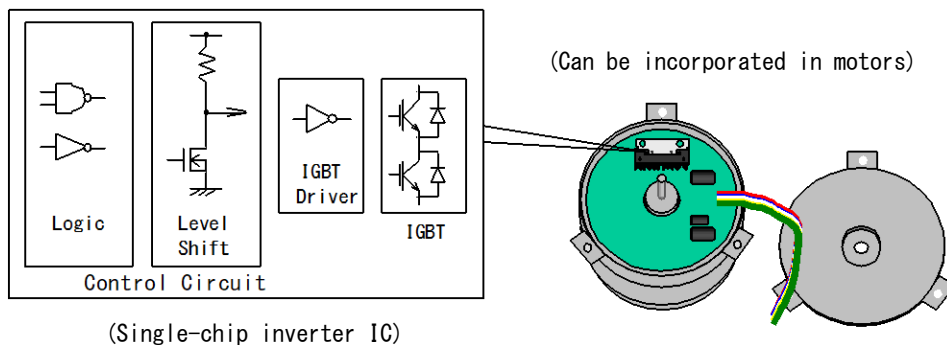
FIGURE 1.1.1.1 Image of Motor with Built-in Control Board

(a) SP-23TA   (b) SP-23TB   (c) SP-23TR
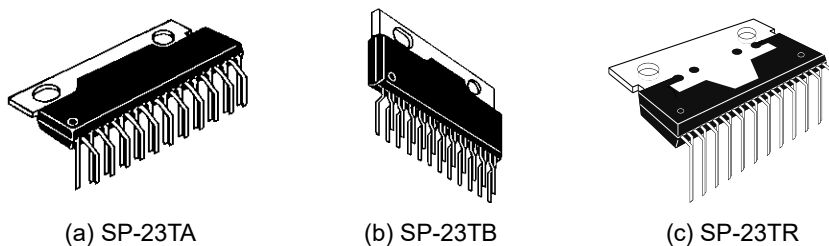
FIGURE 1.1.1.2 Types and Packages of IC

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.
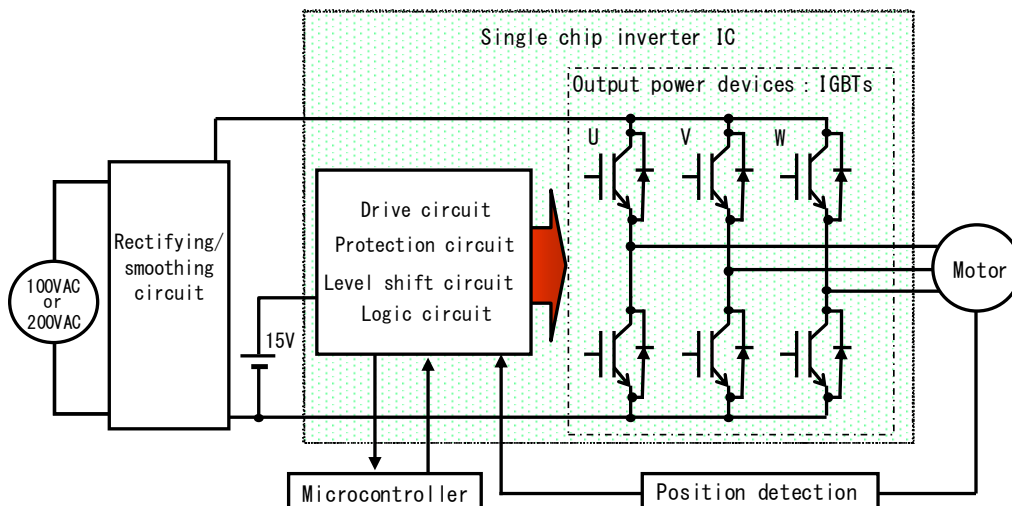
FUGURE 1.1.2.1 Example of Basic Configuration of an Inverter IC

1.2 Block Diagram of Inverter IC

Figure 1.2.1 shows a block diagram of the ECN30114 and ECN30214.
・Hall elements applicable
・Built-in charge pump diodes
・Built-in FG (Frequency Generator) circuits for monitoring motor speed, three pulses per cycle
・Various protection functions
(Current limit function, Vcc low-voltage detection function, over temperature protection function)

※ Inside of bold line shows the inverter IC (ECN30114, ECN30214)

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.
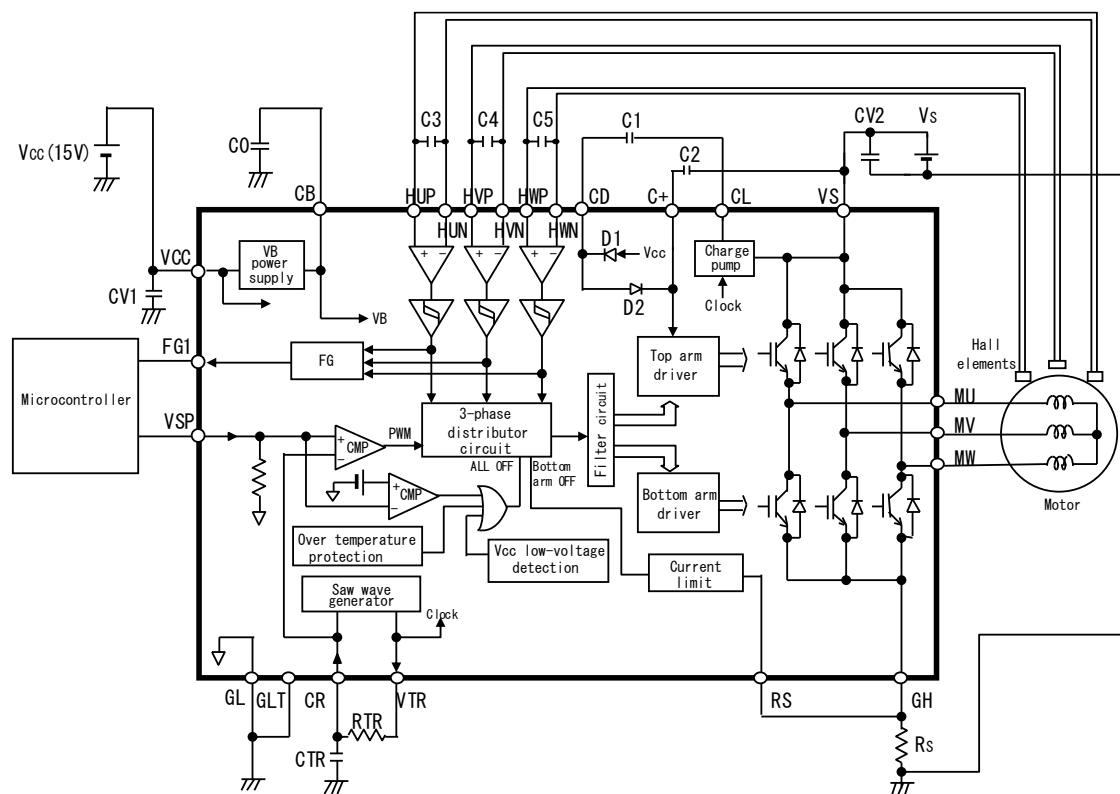   ・In a case the specified values shown in each item are exceeded, products may be damaged or destroyed even for a moment. These specified values should never be exceeded under any operating conditions.
   (2) Electrical characteristics
      ・It provides for electric characteristics of the IC, and describes 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	ECN30114SP	Output device withstand voltage：250V Output current (Pulse)：1.4A Output current (DC)：1.0A	SP-23TA	Pin insertion type
2	ECN30114SPV		SP-23TB	Pin insertion type
3	ECN30114SPR		SP-23TR	Pin insertion type
4	ECN30214SP	Output device withstand voltage：600V Output current (Pulse)：1.5A Output current (DC)：0.7A	SP-23TA	Pin insertion type
5	ECN30214SPV		SP-23TB	Pin insertion type
6	ECN30214SPR		SP-23TR	Pin insertion type

3.2 Pin Locations

Table 3.2.1 shows pin locations.

TABLE 3.2.1 Pin Location

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	VSP	Analog speed command signal input	
10	CB	VB power supply output	
11	CR	Connect a resistor and a capacitor to set the PWM frequency	
12	VTR	Connect a resistor to set the PWM frequency	
13	HWP	W phase Hall signal plus input	
14	HWN	W phase Hall signal minus input	
15	HVP	V phase Hall signal plus input	
16	HVN	V phase Hall signal minus input	
17	HUP	U phase Hall signal plus input	
18	HUN	U phase Hall signal minus input	
19	FG1	Output for motor rotational speed monitor	
20	RS	Input for current limit	
21	GH	Emitters of bottom arm IGBTs and anodes of bottom arm FWDs (Connected to a shunt resistor)	
22	MU	U phase output	Note 1
23	MV	V phase output	Note 1

Note1: High voltage pin. The voltage between CD and CL and the voltage between C+ and VS are low.

Note2: Connect GLT to GL externally.

Note3: The potential of tab (IC heat sink) is the same as that of the GLT pin. Please make sure to connect the GLT pin to the
   GL pin.

3.3 Functions of Pins

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

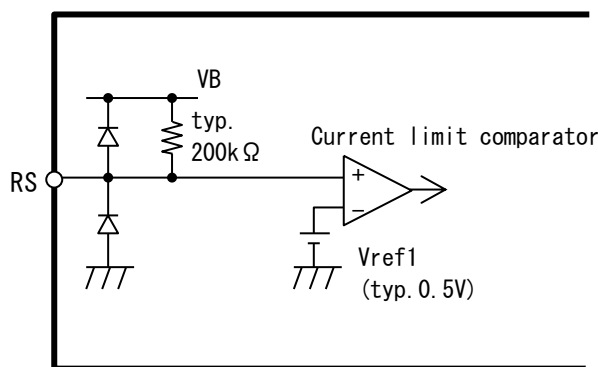| No.	Pin	Items	Functions and Precautions	Related items	Remarks
1	VCC	Analog / Logic power supply	・Powers the drive circuits for the top and bottom arms, the charge pump circuit, the built-in VB supply circuit, and others. ・Determine the capacity of the power supply for Vcc (15V) allowing for a margin by adding the standby current ICC and the current taken out of CB.	・3.5.1 (1) Vcc low-voltage detection ・3.5.3 Power on/off sequence ・4.3 to 4.8 Inverter IC destruction by surge or noise	
2	VS	IGBT power pin	・Connected to the collector of the top arm IGBT.	・3.5.3 Power on/off sequence ・4.3 to 4.6 Inverter IC destruction by surge	High voltage pin
3	CB	VB power supply output	・Outputs a voltage (typ. 7.5V) generated in the built-in VB power supply. ・VB supply powers the IC internal circuits (3-phase distributor circuit and others) ・Connect an oscillation prevention capacitor C0 (1.0μF±10% recommended) to the CB pin.	・3.5.4 VB power supply	
4	GL	Analog / Logic ground	・It is the ground pin for Vcc (15V) and VB power lines.	—	
5	GLT	Ground setting pin	・Connected to tab (IC heat sink). ・Make sure to connect to GL pin externally.	—	
6	GH	IGBT emitter pin	・The GH pin is connected to the emitters of U, V and W-phase bottom arm IGBTs. ・The GH pin is connected to a shunt resistor Rs to perform current limit. ・Make the wiring of the shunt resistor Rs as short as possible. If the wiring has high resistance or inductance, the emitter potential of the IGBT changes, perhaps resulting in the IGBT malfunctioning.	・3.5.1 (2) Current limit	
7	MU MV MW	Inverter output pin	・These are outputs of a three-phase bridge consisting of six IGBTs and free wheel diodes.	—	High voltage pin
8	RS	For current limit	・Monitors the voltage of the Rs shunt resistor using the RS pin and detects over current status.	・3.5.1 (2) Current limit	

FIGURE 3.3.1 Equivalent Circuit around RS Pin

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

No.	Pin	Items	Functions and Precautions	Related items	Remarks
9	HUP HUN HVP HVN HWP HWN	Hall signal input	・The potential difference between HUP and HUN, HVP and HVN, HWP and HWN decides internal logic. ・The maximum input voltage is VB+0.5V. ・If the IC malfunctions due to a noise, install a capacitor. The influence of noise can be found out by monitoring FG1 signal.	・Product Specification Truth table Timing chart	

FIGURE 3.3.2 Equivalent Circuit around Hall Signal Pins

No.	Pin	Items	Functions and Precautions	Related items	Remarks
10	C+ CL CD	Top arm drive circuit power pin, Charge pump circuit pin	・Powers the drive circuit for the top arm. ・Connect a capacitor between C+ and VS, CD and CL.	・3.5.2 Charge pump circuit	High voltage pin

FIGURE 3.3.3 Equivalent Circuit around C+, CL, CD Pins

No.	Pin	Items	Functions and Precautions	Related items	Remarks
11	FG1	Output for motor rotational speed monitor	・Output pulses in synchronization with the input signals of the HUP, HUN, HVP, HVN, HWP and HWN. ・Motor rotation speed can be monitored by measuring the frequency of output pulse. ・FG1 output pulse is three pulses per cycle.	・4.2 Electrical destruction of FG1 pin caused by external surge ・Product Specification Truth table Timing chart	

FIGURE 3.3.4 Equivalent Circuit around FG1 Pin

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

No.	Pin	Items	Functions and Precautions	Related items	Remarks

12	VSP	Analog speed command signal input	· Input a speed command signal to generate a PWM signal.
			· If a noise is detected, install a resistor and/or capacitor.
				· 3.5.3
				  Power on/off sequence
				· 3.5.5
				  PWM operation
				· 3.5.6
				  All IGBT shutoff function
				· 4.1
				  Electrical destruction of VSP pin caused by external surge	

			 FIGURE 3.3.5 Equivalent Circuit around VSP Pin		

13	CR
	VTR
		PWM frequency setting pin	· Externally connected resistor and capacitor are used to determine the PWM frequency (internal clock).
			· The PWM frequency is approximated by the following equation.
			  $f_{PWM} \fallingdotseq 0.494 / (C \times R)$ (Hz)
				· 3.5.5
				  PWM operation	

			 FIGURE 3.3.6 Equivalent Circuit around CR, VTR Pins		

3.4 Markings

The resin surface of the IC is marked by laser.
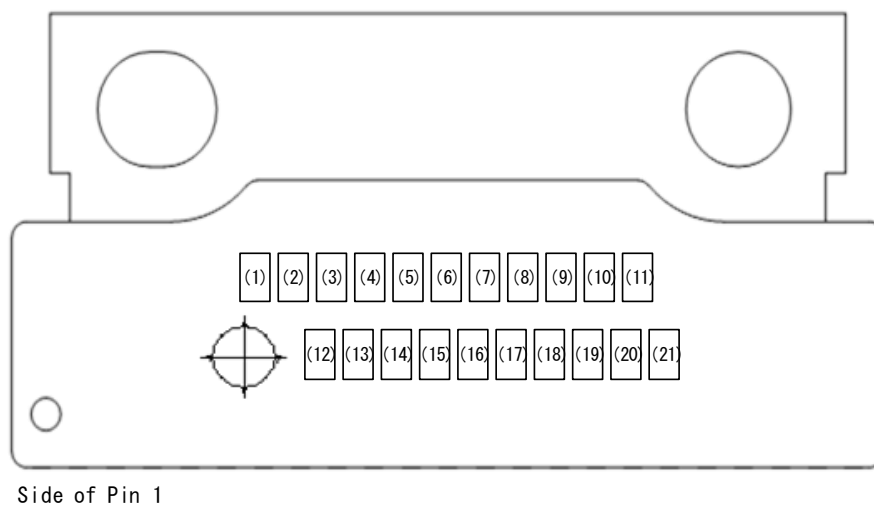

Side of Pin 1

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.
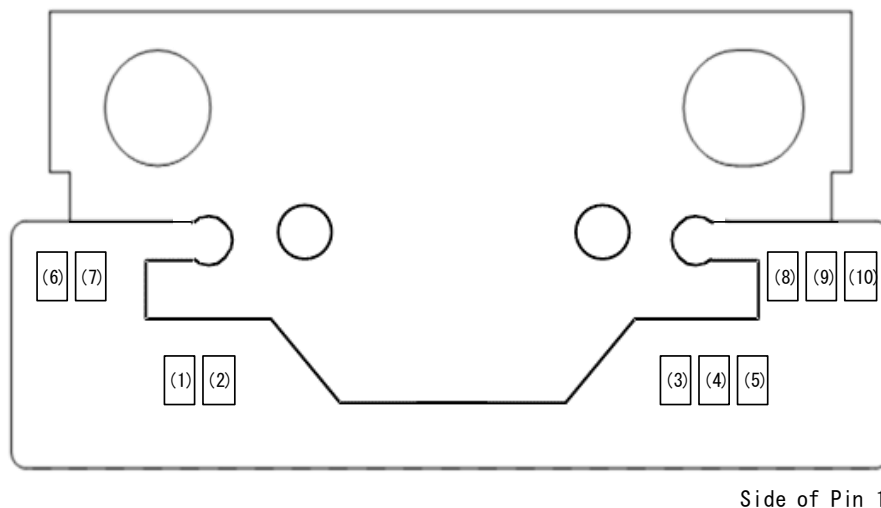
Side of Pin 1

FIGURE 3.4.2 SP-23TR Marking Specifications

Mark No. (1) to (5) : Numbers of model name

   (e.g.) The mark numbers of ECN30114SPR is represented as "30114".

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 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 turned off regardless of the input signals. This function has hysteresis. When the Vcc voltage goes up again, the system returns to a state in which the ouput IGBTs operate depending on the input signals, at a level equal to or exceeding the LVSD recovery voltage (LVSDOFF).

When the IGBTs of the top and bottom arms are all turned off by operation of this function or other function during motor driving, the power supply voltage may rise as a result of a regenerative current flow. The power supply voltage must not exceed the maximum rating.
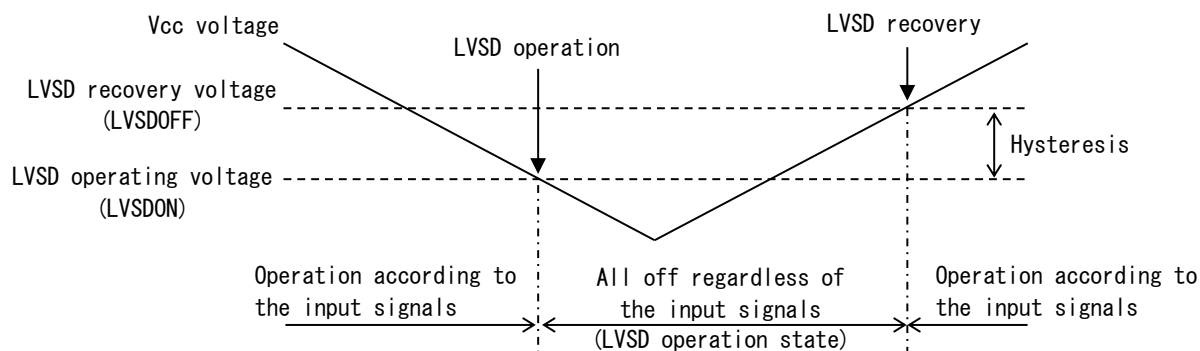

FIGURE 3.5.1.1 Timing Chart for Vcc Low-voltage Detection (LVSD Operation)

(2) Current limit

(a) Operation

The IC detects the current using the voltage at the RS pin. When the voltage at the RS pin exceeds the Vref1 (typ. 0.5V) of the internal detection circuit, the bottom arm IGBTs are all turned off. Reset after current limit operation is performed in each cycle of the internal clock signal (VTR pin voltage).
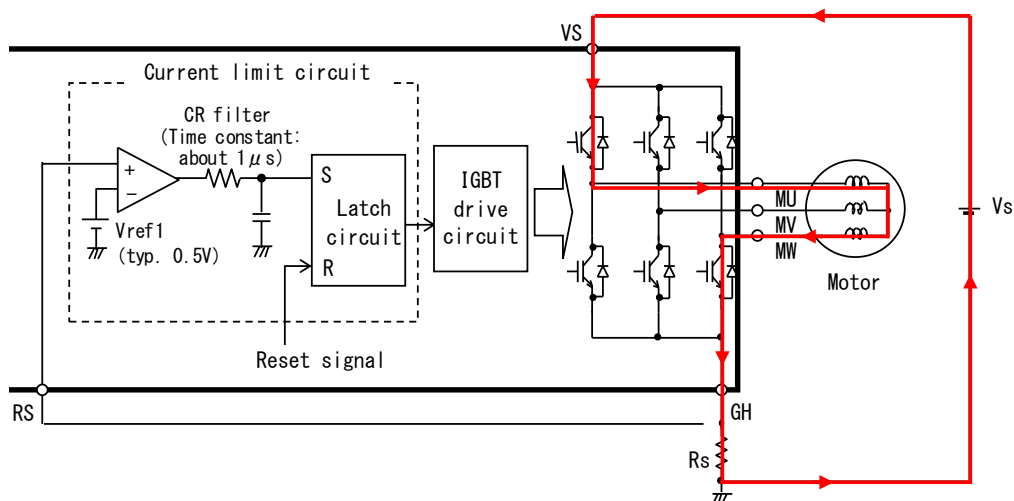

FIGURE 3.5.1.2 Equivalent Circuit of Current Limit Circuit and Example of Current of Shunt Resistor
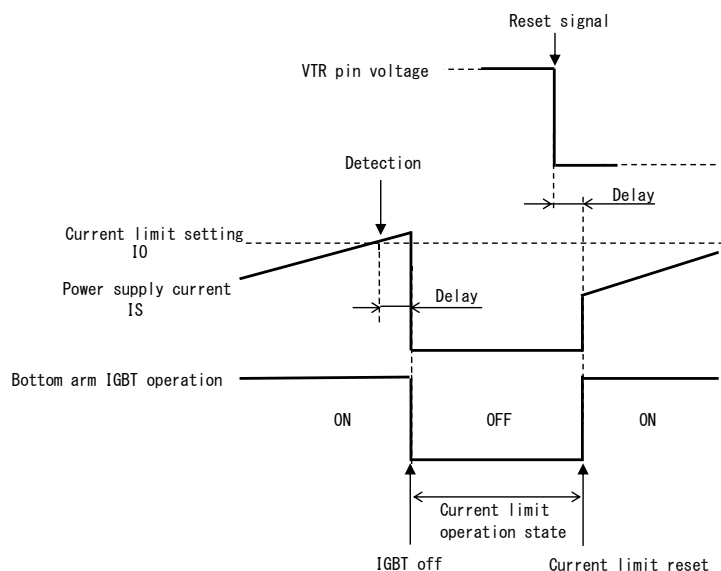
FIGURE 3.5.1.3 Timing Chart for Current Limit

(b) How to set up

The current limit setting IO is calculated as follows;

$$IO = Vref1 / Rs$$

Where

Vref1: Reference voltage for current limit

Rs : Resistance of shunt resistor

In setting a current limit, allow for Vref1 variance, Rs resistance variance, and the delay time from current limit detection to IGBT turn-off. Observe the output currents of the IC (the coil currents of the motor) and confirm a design margin.

This function is 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. 3.5.1.4 and 3.5.1.5).
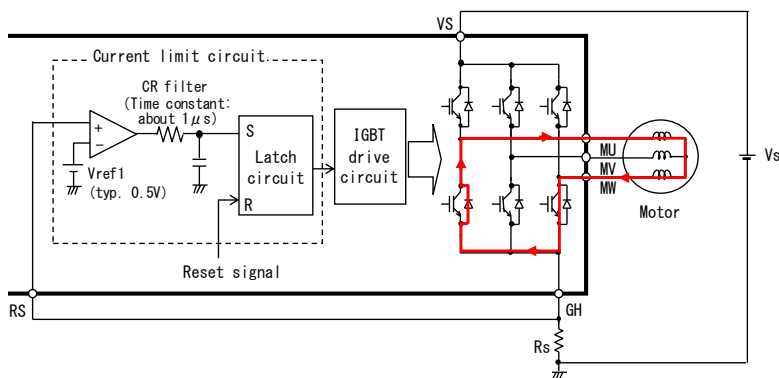

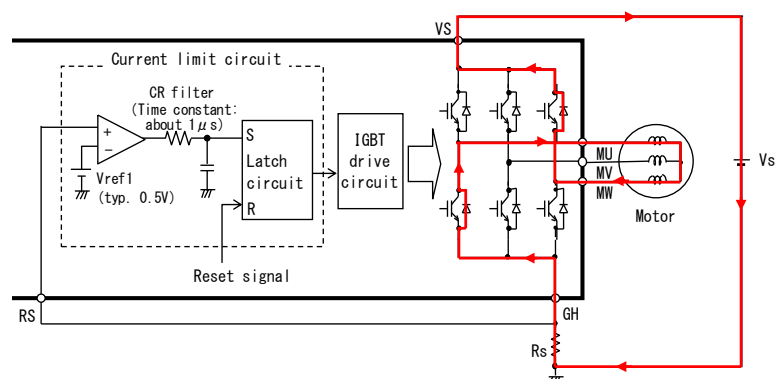**FIGURE 3.5.1.4 Example of Reflux Current**

FIGURE 3.5.1.5 Example of Power Regenerative Current

(3) Over temperature protection

Figure 3.5.1.6 shows a timing chart for the over temperature protection operation.

Hitachi Power Semiconductor Device calls the over temperature protection "TSD". When the IC temperature reaches or exceeds the operating temperature of over temperature protection (TSDON = typ. 170℃), the IGBTs of the top and bottom arms are all turned off regardless of the input signals. When the IC temperature goes down to the recovery temperature of the over temperature protection (TSDOFF = typ. 145℃), the IC returns to a state in which the IGBTs operate according to input signals.
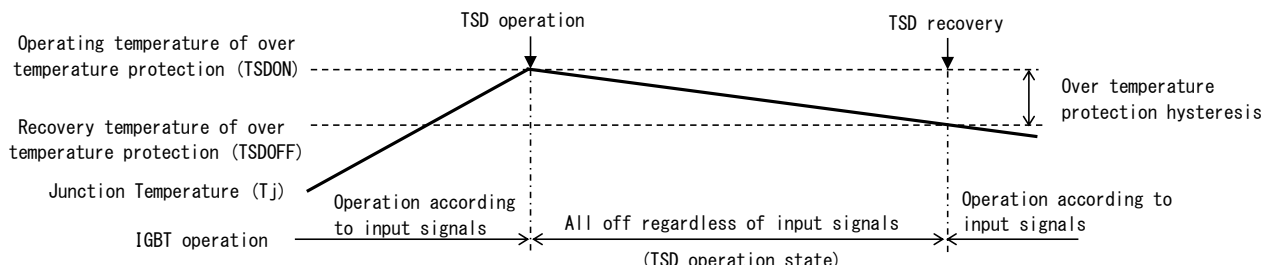
FIGURE 3.5.1.6 Timing Chart for Over Temperature Protection Operation

3.5.2 Charge Pump Circuit

3.5.2.1 Operation of Charge Pump Circuit

Figure 3.5.2.1.1 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), 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 capacitor C1 is pumped up to capacitor C2.

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

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

FIGURE 3.5.2.1.1 Charge Pump Circuit

3.5.3 Power On/Off Sequence

(1) ECN30114
  Current of the IGBT is not saturated regardless of the power on/off sequence of the Vcc power supply, Vs power supply, and Vsp voltage.

(2) ECN30214
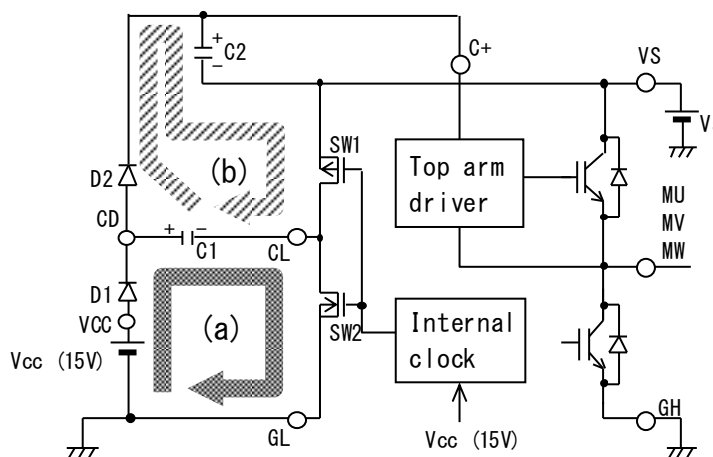 When the output pin current is 1A or less, current of the IGBT is not saturated regardless of the power on/off sequence of the Vcc power supply, Vs power supply, and Vsp voltage.
  When the output pin current is no less than 1A, the following sequences are recommended.

  ■ At power-on : Vcc on → Vs on → Vsp on
  ■ At power-off : Vsp off → Vs off → Vcc off

  If any sequence is involved other than those specified above, please refer to Tables 3.5.3.1 and 3.5.3.2.
  When the sequence is No. 4 or No. 6 in Table 3.5.3.1 or No. 4 or No. 6 in Table 3.5.3.2, see the section of "Power On/Off Sequence and Current Derating for Vcc" of the Product Specification.

TABLE 3.5.3.1 Power On Sequence

No	①	→ ②	→ ③	Permit or Inhibit
1	Vcc	Vs	Vsp	Permit
2	Vcc	Vsp	Vs	Permit
3	Vs	Vcc	Vsp	Permit
4	Vs	Vsp	Vcc	Inhibit
5	Vsp	Vcc	Vs	Permit
6	Vsp	Vs	Vcc	Inhibit

TABLE 3.5.3.2 Power Off Sequence

No	①	→ ②	→ ③	Permit or Inhibit
1	Vsp	Vs	Vcc	Permit
2	Vs	Vsp	Vcc	Permit
3	Vsp	Vcc	Vs	Permit
4	Vcc	Vsp	Vs	Inhibit
5	Vs	Vcc	Vsp	Permit
6	Vcc	Vs	Vsp	Inhibit

3.5.4 VB Power Supply

  The VB voltage (typ. 7.5V) is generated from the Vcc (15V) power supply and outputted from the CB pin.
  Figure 3.5.4.1 shows an equivalent circuit. This circuit constitutes a feedback circuit.
  To prevent oscillation, connect a capacitor C0 to the CB pin. The recommended capacitance for the C0 is 1.0µF±10%.
  The larger the C0 capacity, the more stable the VB power supply. However, excessive capacitance is not recommended.
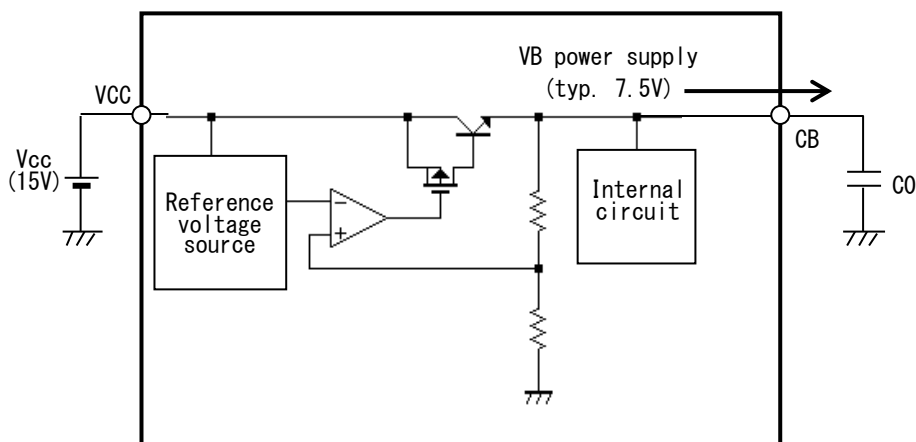 As a guide, it should be 2µF to 3µF or less.

FIGURE 3.5.4.1 Equivalent Circuit for VB Power Supply

3.5.5 PWM Operation

PWM signals are generated by comparing the VSP input voltage and internal triangular signal (CR pin voltage).
Figure 3.5.5.1 shows the relation between the PWM duty and VSP input voltage. The PWM duty indicates the duty of the IGBT gate drive signals. The voltages at the output pins (MU, MV, MW) may differ from those shown in Figure 3.5.5.1 depending on use conditions.
PWM switching is conducted by the bottom arms. Figure 3.5.5.2 shows the timing chart of PWM operation.
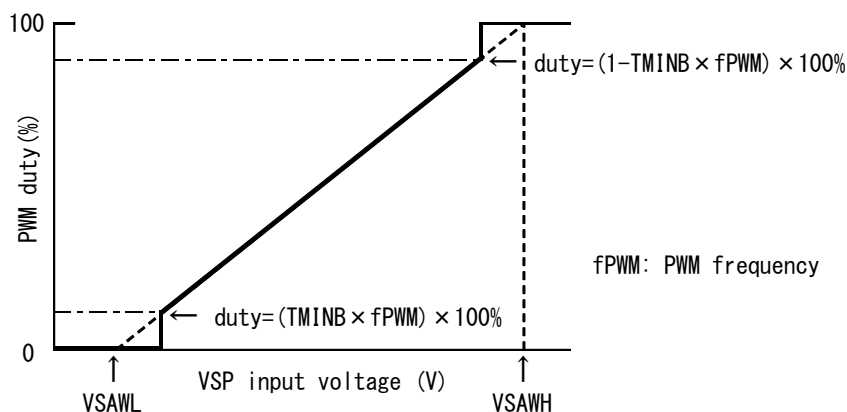

FIGURE 3.5.5.1 Relation between VSP Input Voltage and PWM Duty
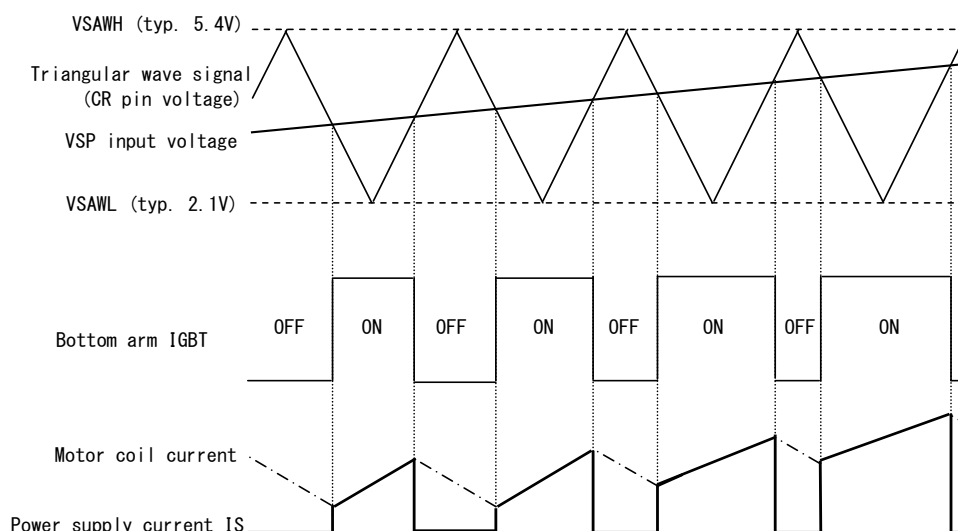
FIGURE 3.5.5.2 Timing Chart of PWM Operation

3.5.6 All IGBT Shutoff Function

When the input voltage at the VSP pin drops below VSAWL (typ. 2.1V), the IC stops the motor drive. When the input voltage at the VSP pin drops further from VSAWL and becomes below Voff (typ. 1.23V), the IGBTs (top and bottom arms) are all shut off to reduce current consumption within the IC. The state of the output IGBTs with regard to the VSP input voltage is shown in Table 3.5.6.1.

TABLE 3.5.6.1 State of Output IGBTs with Regard to VSP Input Voltage

VSP input voltage	Motor drive state	Top arm IGBTs	Bottom arm IGBTs
0V≦VSP＜Voff	Stop	All off	All off
Voff≦VSP＜VSAWL		Based on Hall signal inputs	All off
VSAWL≦VSP	Drive	Based on Hall signal inputs	Based on Hall signal inputs

3.5.7 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.
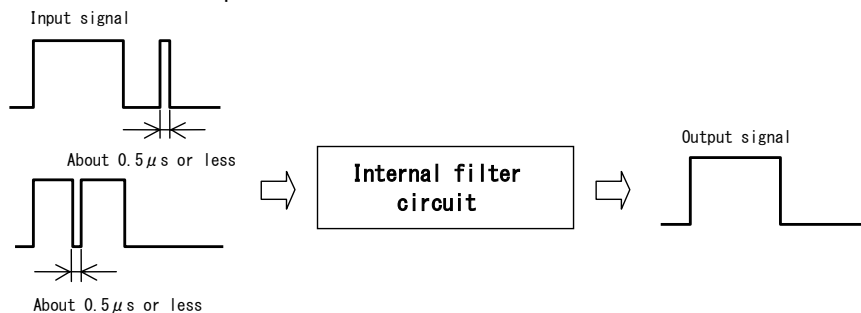

FIGURE 3.5.7.1 Operation of Internal Filter Circuit

### 3.5.8 Calculation of Power Consumption

(1) Power consumption

This IC applies the 120-degree energization method. Here are simple formulae for calculating of power consumption. As for the constants required for calculation, contact our sales representative.

Total IC power consumption ; $P=Pigbt+Pfwd+Psw+Pr+Pis+Picc$ (W)

① Steady-state power dissipation of IGBTs
  $Pigbt=Iave \times VONT+Iave \times VONB \times D$ (W)
② Steady-state power dissipation of Free Wheeling Diodes (FWDs)
  $Pfwd=Iave \times VFDT \times (1-D)$ (W)
③ Switching power dissipation of IGBTs
  $Psw=(Eon+Eoff) \times fPWM$ (W)
④ Recovery power dissipation of FWDs
  $Pr=1/4 \times (IrrT \times Vs \times trrT \times fPWM)$ (W)
⑤ Power consumption in high voltage circuit
  $Pis=Vs \times IS$ (W)
⑥ Power consumption in control circuit
  $Picc=Vcc \times ICC$ (W)

Iave	; Average output current (see Fig. 3.5.8.1)	(A)
VONT	; Drop in the output voltage of the top arm IGBT @I=Iave	(V)
VONB	; Drop in the output voltage of the bottom arm IGBT @I=Iave	(V)
D	; PWM duty	
VFDT	; Forward voltage drop in the FWD of the top arm @I=Iave	(V)
Eon	; Switching loss when the IGBT is turned on @I=Iave	(J/pulse)
Eoff	; Switching loss when the IGBT is turned off @I=Iave	(J/pulse)
fPWM	; PWM frequency	(Hz)
IrrT	; Recovery current of the FWD of the top arm	(A)
trrT	; Reverse recovery time of the FWD of the top arm	(s)
Vs	; Vs power voltage	(V)
Vcc	; Vcc power voltage	(V)
IS	; Current consumption of the high-voltage circuit	(A)
ICC	; Current consumption of the control circuit	(A)

(Note) FWD: Free Wheeling Diode
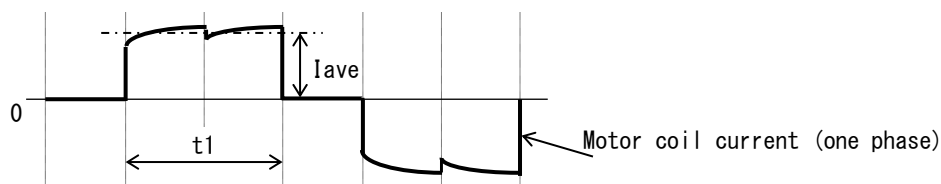
Iave: average motor coil current during the period t1

FIGURE 3.5.8.1 Current Waveform of the Motor Coil (120-degree Energization)

(2) Calculation of junction temperature

A junction temperature can be calculated by the following equation after measuring the temperature of the IC case.

$$T_j = T_c + R_{jc} \times P$$

T_j : Junction temperature (℃)

T_c : IC case temperature (℃) (actual measurement)

R_{jc} : Thermal resistance of between junction and IC case (℃/W)

P : Total IC power consumption (W)

・Measuring method of Tc

A thermo-couple is set on the tab of IC to measure the IC case temperature Tc.

After starting to apply a current, wait until the temperature becomes saturated (temperature stops rising). Use a value measured after temperature saturation. The tab is connected to the GLT pin as described in Section 3.6.1 (2). Therefore, be careful not to get an electric shock when the potential at the GLT pin is floating with respect to earth ground.

3.5.9 Derating

・How much to derate a unit from the maximum rating is an important issue to consider 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 3.5.9.1 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 3.5.9.1 Typical Derating Design Standards

Item	Derating Design Standard (example)	
Junction temperature Tj	110℃ maximum	
Vs power supply voltage	ECN30114	210V maximum
	ECN30214	450V maximum

3.5.10 External Parts

Table 3.5.10.1 shows recommended external parts.

TABLE 3.5.10.1 External Parts

Part	Typical value	Usage	Remarks
C0	1.0μF±10%, 25V	Smooths the internal power supply (VB)	
CV1	1.0μF±10%, 25V	Smooths the Vcc power supply	Note 1
CV2	33nF±10%, 400V (ECN30114) 33nF±10%, 630V (ECN30214)	Smooths the Vs power supply	Note 2
C1, C2	0.22μF±10%, 25V	For charge pump	Note 7
C3, C4, C5	1000pF±10%, 25V	Eliminates Hall signal noise	Note 3
Rs	1Ω±1%, 1W	Sets current limit	Note 4, Note 6
CTR	2200pF±5%, 25V	Sets PWM frequency	Note 5
RTR	11kΩ±5%		

Note 1. As necessary, increase the capacitance and add a zener diode in consideration of noise immunity. Mount each of the parts close to the pins of the IC.

Note 2. As necessary, increase the capacitance and add a zener diode (5W as a guide) in consideration of noise immunity. Mount each of the parts close to the pins of the IC.

Note 3. Adjust the capacitance in accordance with the usage conditions.

Note 4. The current limit set value can be calculated as follows. $I = Vref1 / Rs$ (A)
Determine the shunt resistance Rs with reference to the above and Section 4 in the Product Specification.

Note 5. The PWM frequency is approximated by the following equation: $fPWM \fallingdotseq 0.494 / (CTR \times RTR)$ (Hz)
Please set the maximum frequency of PWM is 20kHz as a guide. When the PWM frequency is set a high frequency, the switching loss is increased. And it increases the temperature of IC. Please confirm the IC temperature with an actual set, and use it in the range of derating.

Note 6. Please shorten the wiring between the resistor Rs and the RS pin, and the wiring between the resistor Rs and the GH pin as much as possible.

Note 7. Attention of parts settings of charge pump circuit
The following attention is necessary when using parts other than those shown in Table 3.5.10.1.
・When the voltage (Vcp) between C+ and VS is dropped, the gate voltage of top arm IGBTs is dropped. And then the loss of IC increases. The Vcp must not become Vcp<10V.
・Capacitor： The Vcp is dropped by the internal current dissipation from C+ terminal of IC, when capacity is small. 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.
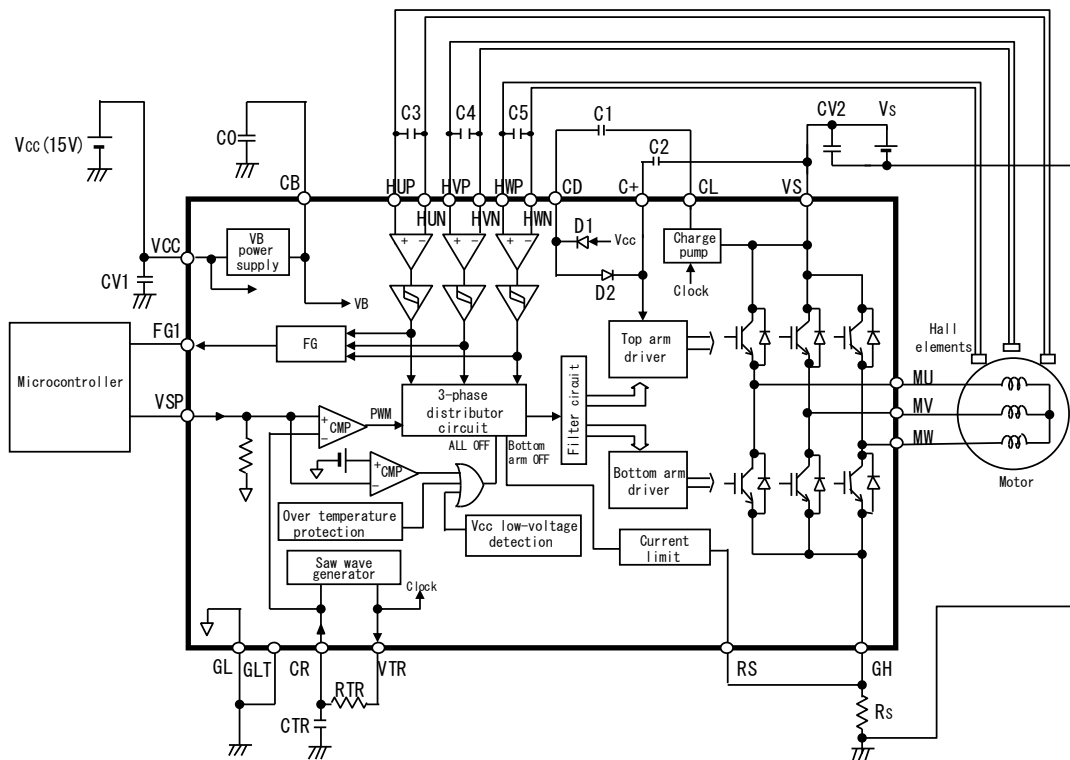

FIGURE 3.5.10.1 Block Diagram and External Parts of IC

3.6 Handling Instruction

3.6.1 Mounting

(1) Insulation between pins
Apply resin coating to the pins that high voltage is impressed to or encapsulate the PCB by resin molding.

(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.
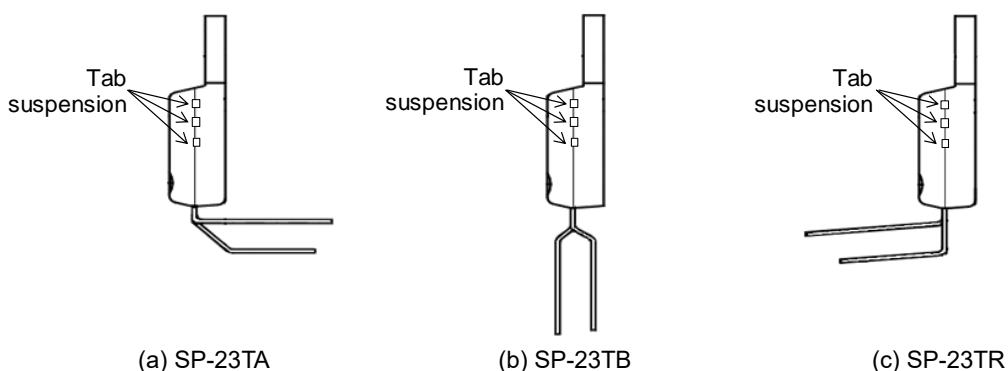

(a) SP-23TA   (b) SP-23TB   (c) SP-23TR

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. Failure Examples (Assumptions)

4.1 Electrical Destruction of VSP Pin Caused by External Surge

・Cause　　　　　 : An external surge enters the IC on the Vsp line of the motor.
・Phenomenon　　 : The Vsp signal is not transmitted into the IC, and the motor does not rotate.
・Countermeasure : Insert series resistance so that the external surge does not directly enter the IC. If a capacitor is also
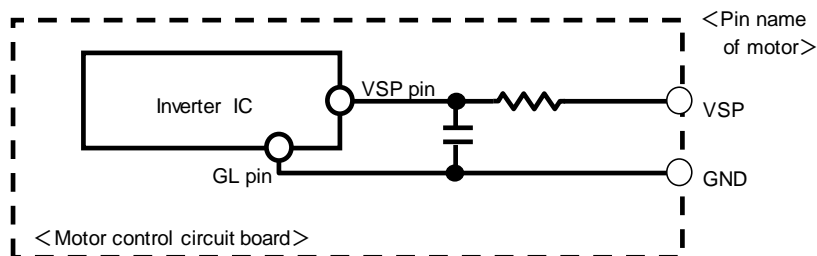　　　　　　　　　　 added, it becomes more effective.

FIGURE 4.1.1 Example of Configuration for External Parts of VSP

4.2 Electrical Destruction of FG1 Pin Caused by External Surge

・Cause　　　　　 : An external surge directly enters the IC on the FG line of the motor.
・Phenomenon　　 : The FG signal of the IC is not outputted.
・Countermeasure : Use the buffer circuit using the transistor on the motor control circuit board so that the external surge
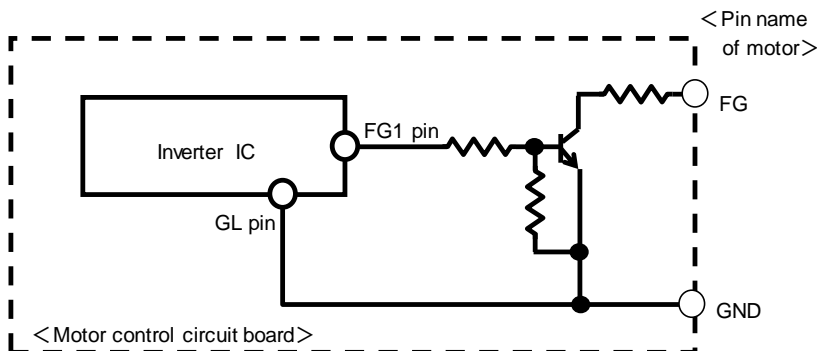　　　　　　　　　　 does not directly enter the IC.

FIGURE 4.2.1 Example of Configuration for External Parts of FG1

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

・Cause　　　　　 : An external surge enters the IC on the Vs and Vcc 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.
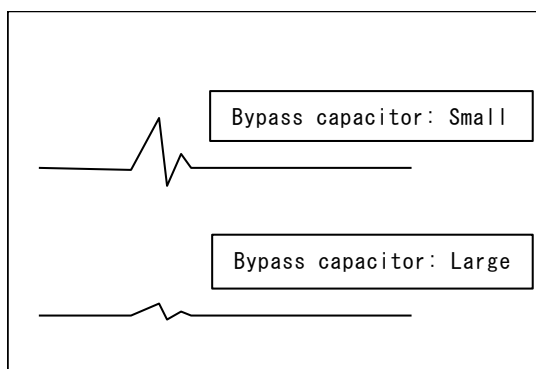・Countermeasure : Use the bypass capacitor for surge suppression; its capacity should be enough to suppress surges.

FIGURE 4.3.1 Example of Surge Waveforms for Different Bypass Capacitors

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

・Cause : An external surge enters the IC on the Vs and Vcc lines of the motor. Because the external parts for surge suppression were positioned far from the IC on the circuit board, the surge could not be sufficiently suppressed.

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

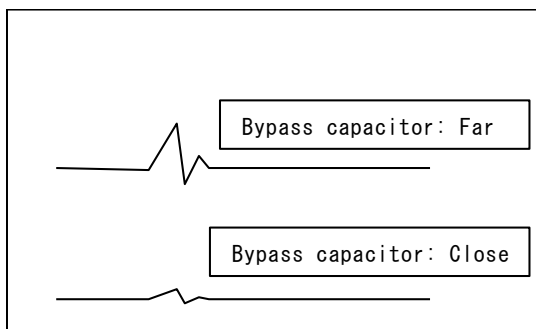・Countermeasure : The bypass capacitor and Zener diode for surge suppression should be mounted close to the IC.

FIGURE 4.4.1 Example of Surge Waveform for Different Bypass Capacitor Locations on Board

4.5 Inverter IC Destruction by External Surge Inputted to Vs and Vcc (15V) Line (Case 3)

・Cause : When a power supply line is in an open state due to the connector contact failure of Vs or Vcc (15V) line or the like, the supply power is turned on. Then, when the power supply line goes into a closed state, a surge occurs and enters the IC.

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

・Countermeasure: The Zener diode for surge suppression should be mounted close to the IC.

4.6 Inverter IC Destruction by External Surge Inputted to Vs and Vcc (15V) Line (Case 4)

・Cause : An external surge enters the IC on the Vs and Vcc lines of the motor. Because the Zener voltage of the surge suppressor diode is higher than the maximum rating voltage of the IC, it does not protect the IC.

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

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

・Cause : Pulsed noise of a voltage that is lower than the operating voltage of the Vcc low-voltage detection (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:①Remove the noise that enters the motor Vcc line by reviewing the power supply circuit (inductance of power cable or the like).

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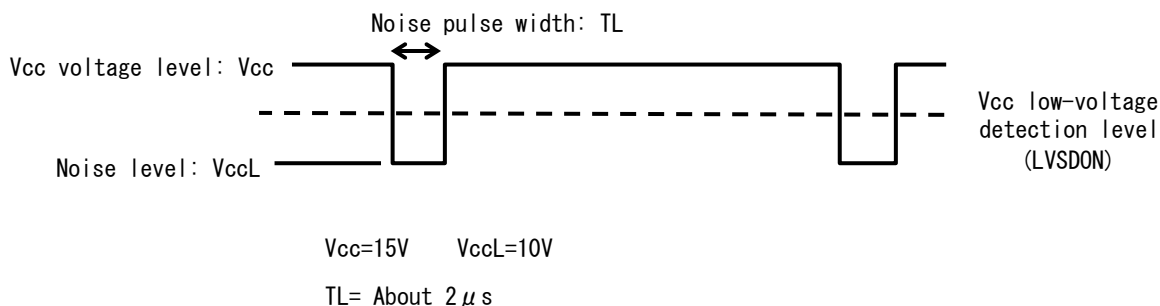

Vcc=15V   VccL=10V

TL= About 2μs

FIGURE 4.7.1 Example of Pulsed Noise on Vcc Line

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

・Cause   : Surge voltage that exceeds the maximum rating for the IC enters the VCC 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.
　　②It is more effective to mount a surge suppression device, such as bypass capacitor C2 shown in Fig. 4.8.1, close to the connector of a motor control circuit board.
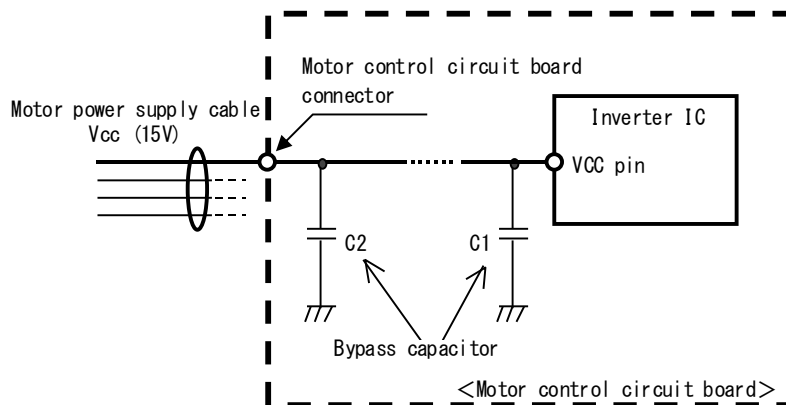
FIGURE 4.8.1 Example of Mounted Surge Suppression Devices

4.9 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 due to the over-voltage destruction of the IC.
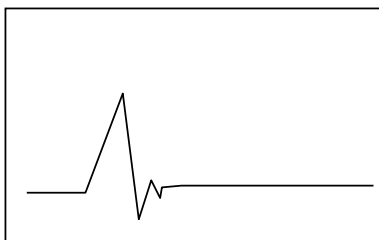・Countermeasure : Use a mercury relay, etc. Confirm a surge is not generated when the relay is on-off.

FIGURE 4.9.1 Example of Surge Waveform When Mechanical Relay is Used

4.10 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.
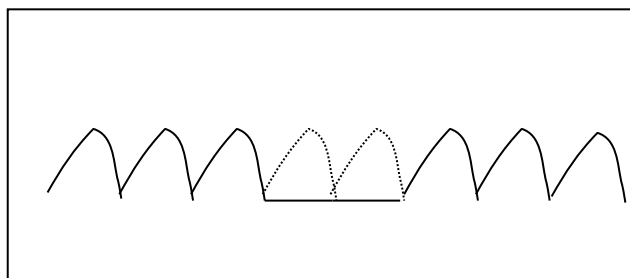・Countermeasure: Monitor the motor current or torque pulsations in order to detect the missing phase output of motor.

FIGURE 4.10.1 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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