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Hitachi Single Chip Inverter IC Application Guide

(Applicable models)

	VSP-input type	6-input type
For ≅ AC115V	ECN30105 ECN30107	ECN30611
For ≅ AC230V	ECN30204 ECN30206 ECN30207	ECN30601 ECN30603 ECN30604

Development Department
Power Device Division
Hitachi, Ltd., Power Systems, Power & Industrial System Division

Precautions for Safe Use and Notices

If semiconductor devices are handled inappropriate manner, failures may result. For this reason, be sure to read this "Application Guide" before use.

⚠	This mark indicates an item about which caution is required.
⚠ CAUTION	This mark indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury and damage to property.

⚠ CAUTION

(1) Regardless of changes in external conditions during use "absolute maximum ratings" should never be exceed in designing electronic circuits that employ semiconductors. In the case of pulse use, furthermore,"safe operating area(SOA)"precautions should be observed.

(2) Semiconductor devices may experience failures due to accident or unexpected surge voltages. Accordingly, adopt safe design features, such as redundancy or prevention of erroneous action, to avoid extensive damage in the event of a failure.

(3) In cases where extremely high reliability is required (such as use in nuclear power control, aerospace and aviation, traffic equipment, life-support-related medical equipment, fuel control equipment and various kinds of safety equipment), safety should be ensured by using semiconductor devices that feature assured safety or by means of user's fail-safe precautions or other arrangement. Or consult Hitachi's sales department staff.

(If a semiconductor device fails, there may be cases in which the semiconductor device, wiring or wiring pattern will emit smoke or cause a fire or in which the semiconductor device will burst)

NOTICES

1. This Application Guide contains the specifications, characteristics(in figures and tables), dimensions and handling notes concerning power semiconductor products (hereinafter called "products") to aid in the selection of suitable products.
2. The specifications and dimensions, etc. stated in this Application Guide are subject to change without prior notice to improve products characteristics. Before ordering, purchasers are advised to contact Hitachi's sales department for the latest version of this Application Guide and specifications.
3. In no event shall Hitachi be liable for any damage that may result from an accident or any other cause during operation of the user's units according to this Application Guide. Hitachi assumes to responsibility for any intellectual property claims or any other problems that may result from applications of information, products or circuits described in this Application Guide.
4. In no event shall Hitachi be liable for any failure in a semiconductor device or any secondary damage resulting from use at a value exceeding the absolute maximum rating.
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6.
7. The products (technologies) described in this Application Guide are not to be provided to any party whose purpose in their application will hinder maintenance of international peace and safety nor are they to be applied to that purpose by their direct purchasers or any third party. When exporting these products (technologies), the necessary procedures are to be taken in accordance with related laws and regulations.

- Hitachi offers even better products by taking advantage of our long years of experiences in the market.
- Hitachi helps you save even more energy under our policy of "quality first."

Advanced
Hitachi Single-chip Inverter ICs

■■■ Much easy to use

It becomes easy to design the system power supply by the power supply up/down sequence free design of IC. [*1)].

■■■ Much reduce the effects on the environment

It conforms to lead (Pb) free phase category "Phase 3A" [*4)] of "electronic equipment" of JEITA [*3)] ETR-7021 (issue in June, 2004)".

■■■ Much strong noise-immunity

A built-in cancellation circuit designed to inhibit noises of no more than about 1 μs, reduces output malfunctions induced by noises in the input signal line [*2)].

*1) This applies to ECN30107s, ECN30611s, ECN30206s, ECN30207s, ECN30603s and ECN30604s.
*2) This applies to ECN30204s, ECN30206s, ECN30207s, ECN30601s, ECN30603s and ECN30604s
*3) JEITA: Japan Electronics and Information Technology Industries Association
*4) Phase 3A: The entire parts must be lead-free, include the internal connection and the part materials, that exclude exemption of EU RoHS [*5)] directive.
*5) EU RoHS: DIRECTIVE 2002/95/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment

≪Contents≫

1. Overview

1-1. Dielectric isolation (DI)

- **Hitachi Intelligent Power IC**
- **A logical device and a power-switching device can be integrated in a single chip.**
- **No mutual interference occurs, not only between devices but also between device and board.**

The Hitachi high-voltage monolithic IC is an intelligent power IC, developed based on a unique dielectric isolation technology (DI). It is structured that there be no latch-up between devices and between device and board, and that an IC can be made so a high-dielectric-strength, large-current output circuit is mixed with a logical circuit. The ICs can be made smaller than conventional discrete boards and hybrid ICs.

- **Latch-up-free IC offers wider range of applications.**

The Hitachi high-voltage monolithic IC developed with dielectric isolation technology are such that the devices are isolated with SiO_2 layers in between, unlike P-N junction isolation. In consequence, it can remain latched-up free even under high-temperature, large-current, high-noise, and other severe conditions. This technology also enables them to be extremely flexible in circuit designing and thus to meet more customer requirement.

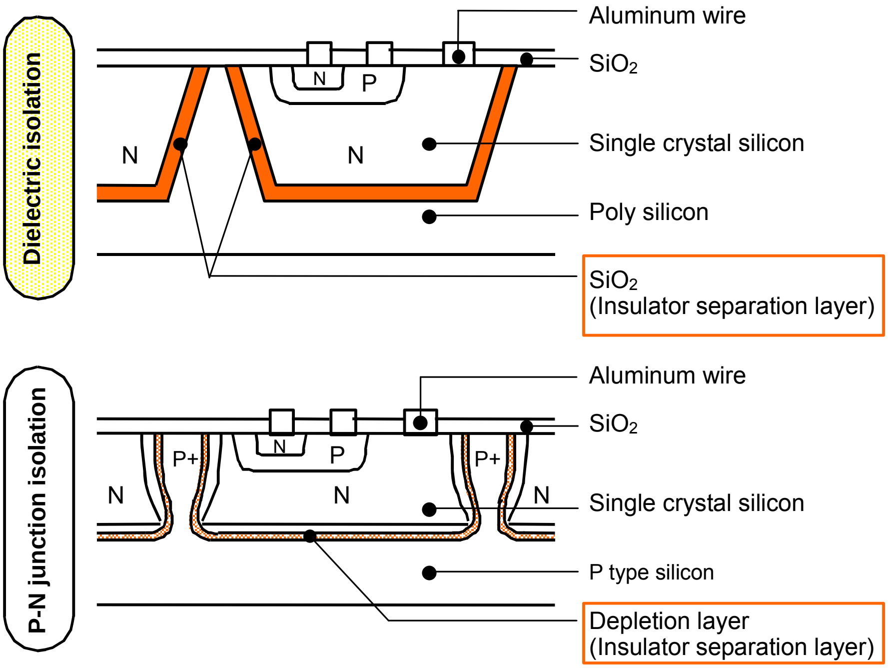


Fig. 1-1. Dielectric isolation and P-N junction isolation

1-2. 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 with dielectric isolation technology. They are for driving motors, best suited for controlling small three-phase 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 facilitates the incorporate of such ICs in motors.

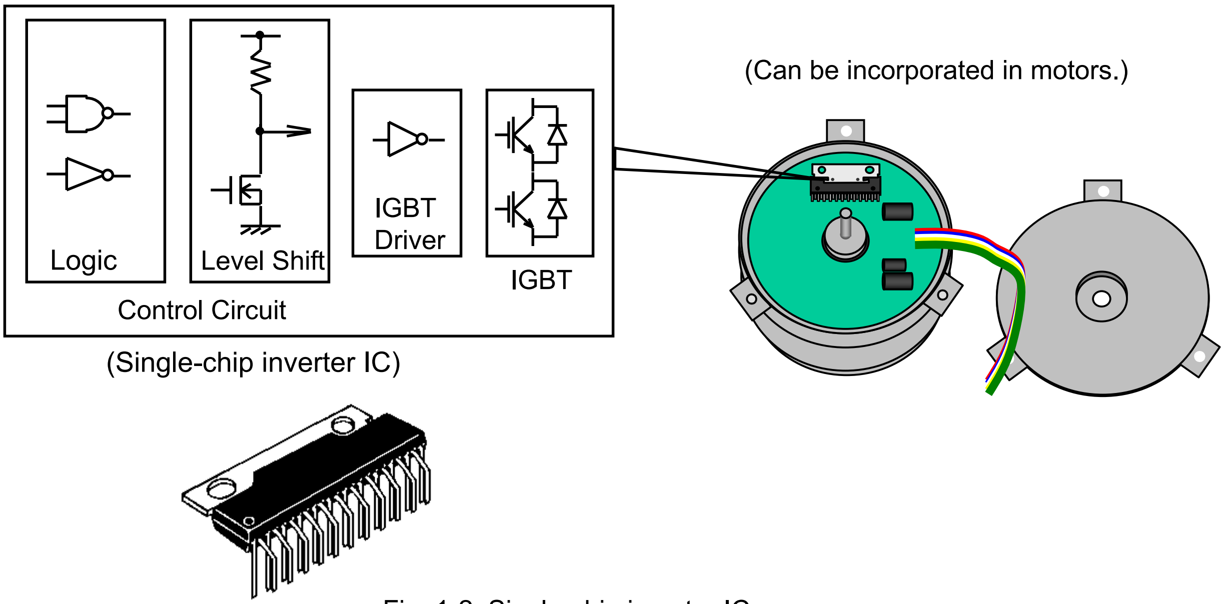


Fig. 1-2. Single-chip inverter IC

1-3. Composition of an 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. Fig. 1-3 shows the basic configuration of an inverter IC required for that purpose. 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 for IGBT control. 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.

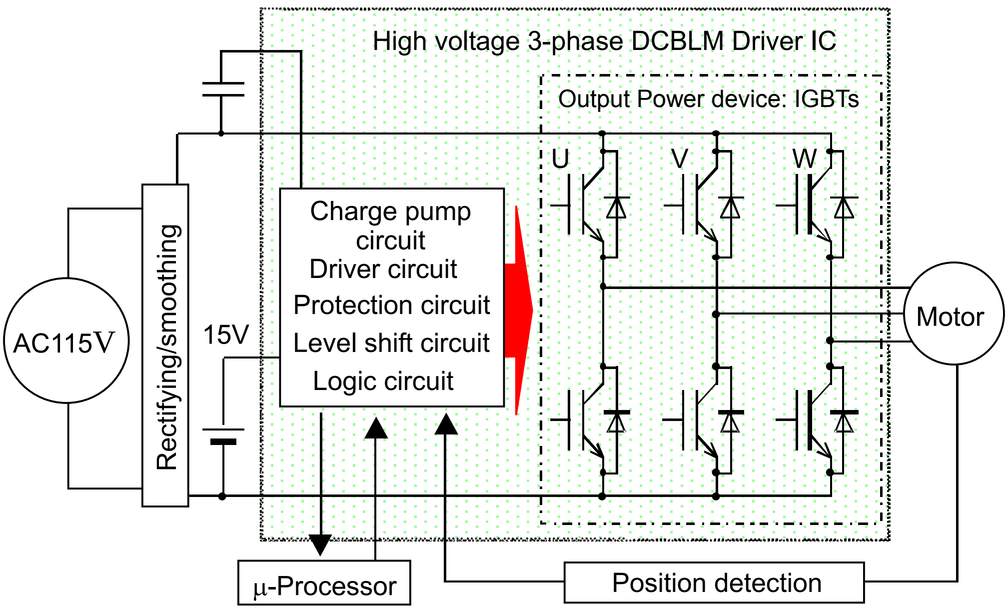


Fig.1-3. Basic configuration of an inverter IC

1-4. Motor drive system

Three-phase inverters generally fall into two categories according to the method of commutation of the six output-stage devices: 120-degree energization and 180-degree energization. The method of 120-degree energization is such that the device on the top arm and that on the bottom arm are controlled to set the energization period between phases to 120 degrees, thus transferring the current from phase U to V to W, thus driving the motor. Hitachi Single-chip Inverter ICs (VSP-input series) are based on 120-degree energization and receive position signals from hall ICs and VSP signals that constitute speed instructions, thus conducting PWM control by the chopping action of the lower arm. For uses of 180-degree energization, a six-input series are provided where six output stage devices can be controlled by each input signal.

1-5. Block Diagram of Inverter IC

Fig. 1-4 shows a block diagram of ECN30206 for receiving 230V AC, as an example of inverter IC. Its main function is to receive input signals from the three phases of hall ICs of the brushless DC motor, turns on and off the particular IGBTs with the three-phase distribution circuit, and to drive the motor. Other components include a charge pump circuit as a power self-supply circuit, a triangular wave oscillator and a comparator-based PWM generation circuit as rpm control circuits, an over current detection circuit which provides a current trip function at motor startup, and an under voltage detection circuit that detects power drops in the drive circuit and turns off the output.

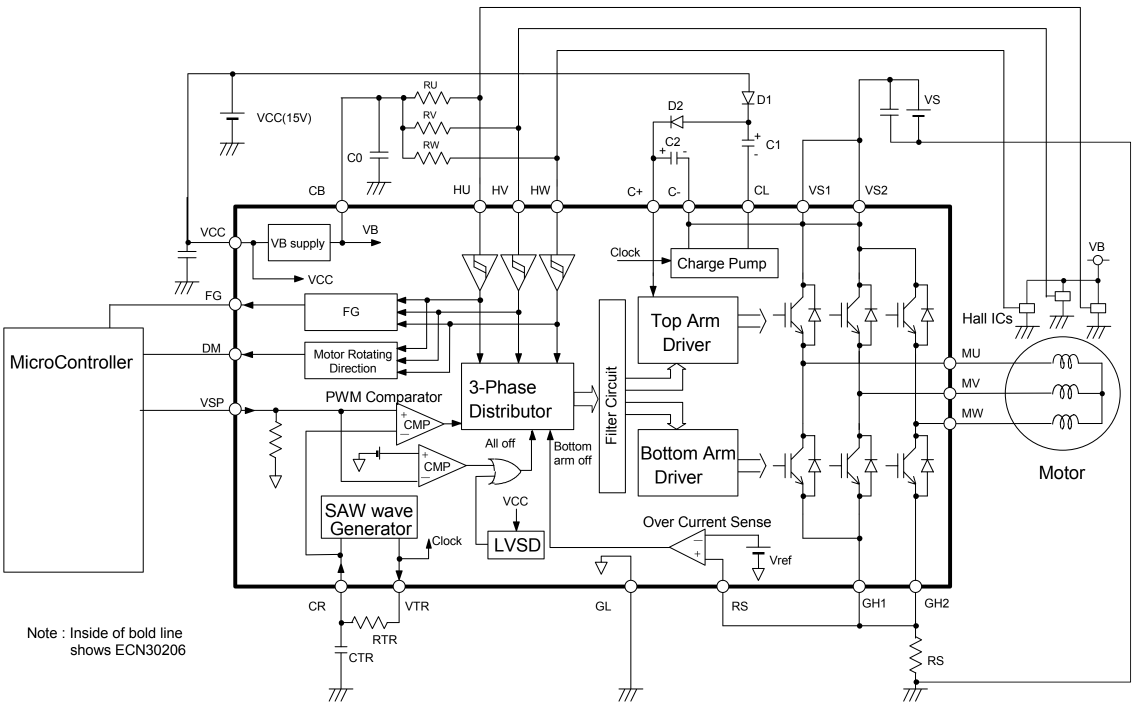


Fig.1-4. Block diagram of ECN30206

2. Content of specifications

The following items have been described in the specifications.

(1) Maximum Ratings

- It describes direct conditions(electric, thermal use conditions) of leading to IC destruction and so on. And the safety operating range with operating conditions is shown by minimum or maximum value.
- Each item is an independent item. Also, these items show the ratings value of not exceeding any use conditions. The maximum rating and other characteristics are mutually related, and not permitted at the same time.

(2) Electrical Characteristics

- It provides for an electric characteristic item that shows the function of IC, and describes minimum, standard, and maximum.

(3) Function and Operation

- It describes Truth Table, Time Chart, Protection Function and so on.

(4) Standard application

- It describes external parts to operate IC.

(5) Pin Assignments and Pin Definitions

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

(6) Important notice Precautions

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

(7) Appendix and Reference data

- It describes SOA and Deratings.

3. Package

3-1. Model name

ECN 30206 SP

- **SP** — Package type (SP, SPV, SPR)
- **30206** — Series name
- **ECN** — Hitachi High-voltage IC

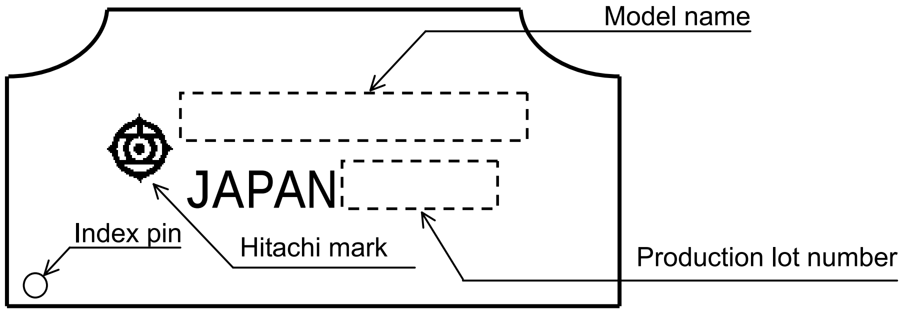
3-2. Production lot number

5 E 12 F

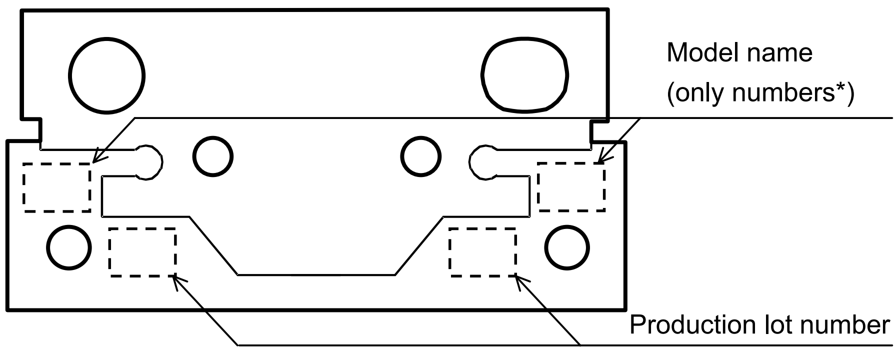
- **F** — Control number
  It shows by two digits or less (alphabetical character).
  Lead (Pb) Free: Last digit is Marked as “F”
- **12** — Quality control number.
  It shows by one digit or two digits. (Numerals from 1 to 9, alphabetical character (except O and I) or space is used.)
- **E** — Assembled month as shown in below
  January, A; February, B; March, C; April, D; May, E; June, K; July, L; August, M; September, N; October, X; November, Y; and December, Z
- **5** — Least significant digit of Assembled year (A.D.)

3-3. Marking

Package Type: SP, SPV



Package Type: SPR



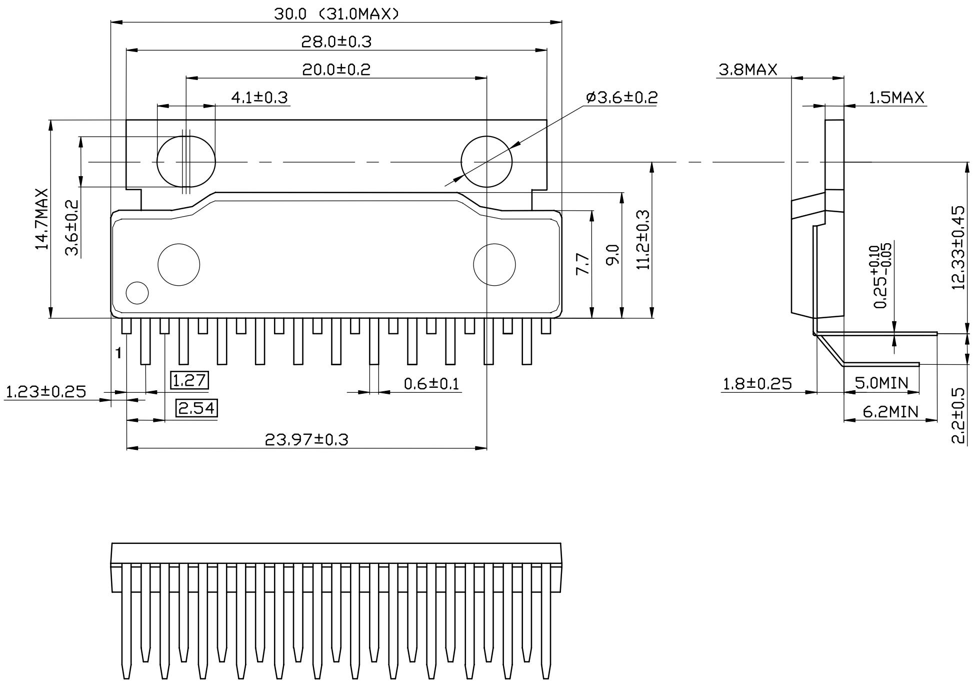
* e.g. ECN30206SPR is represented as “30206”.

Fig. 3-1. Marking diagram

3-4. Package Outline

Table 3-1(1). Package Dimensions (unit: mm)

<table>
<tr><th>Package Type</th><th>Package Dimensions</th></tr>
<tr><td>SP

(SP-23TA)</td><td>
</td></tr>
<tr><td>SPV

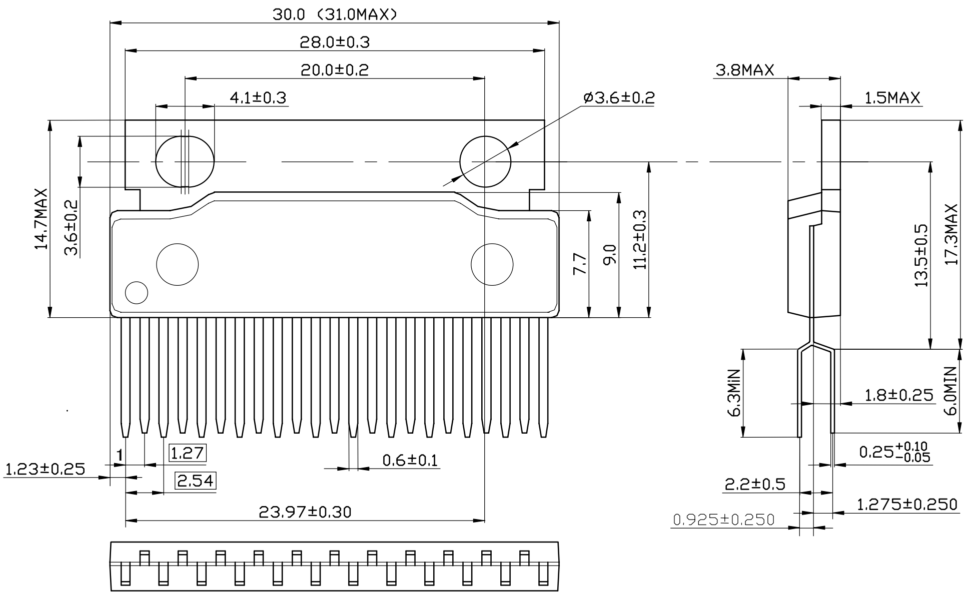
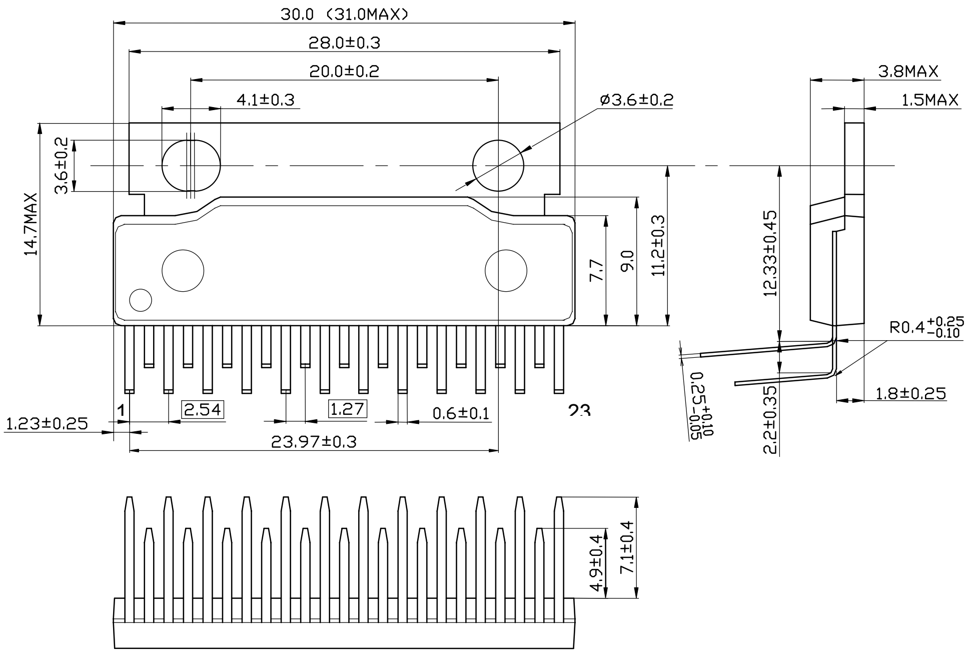
(SP-23TB)</td><td>
</td></tr>
</table>

Table 3-1(2). Package Dimensions (unit: mm)

<table>
<tr><th>Package Type</th><th>Package Dimensions</th></tr>
<tr><td>SPR

(SP-23TR)</td><td>
</td></tr>
</table>

4. Pins

4-1.Pin assignments

Table 4-1. Assignment table of pins

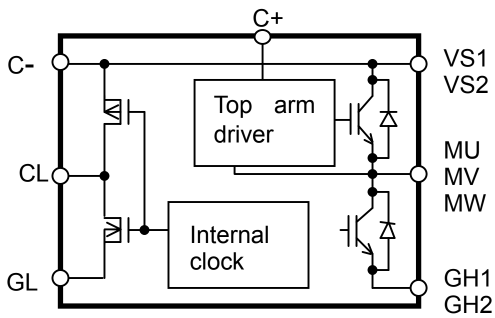
Applicable Model / Pin #	ECN30102 ECN30105 ECN30107 ECN30207	ECN30204 ECN30206	ECN30611 ECN30601 ECN30603 ECN30604
1	VS2	VS2	VS2
2	MW	MW	MW
3	NC note1	NC note1	NC note1
4	GH2	GH2	GH2
5	VCC	VCC	VCC
6	GL	GL	GL
7	C+	C+	C+
8	C-	C-	C-
9	CL	CL	CL
10	CB	CB	CB
11	CTR	CTR	CTR
12	VTR	VTR	VTR
13	VSP	VSP	WB
14	FG	FG	VB
15	NC note1	DM	UB
16	HW	HW	RS
17	HV	HV	WT
18	HU	HU	VT
19	RS	RS	UT
20	GH1	GH1	GH1
21	MU	MU	MU
22	VS1	VS1	VS1
23	MV	MV	MV

Note 1: NC represents an unconnected pin. It is not connected to an internal chip.

4-2.Functions of the pins

Table 4-2. List of pins and their functions (pins common to all models)

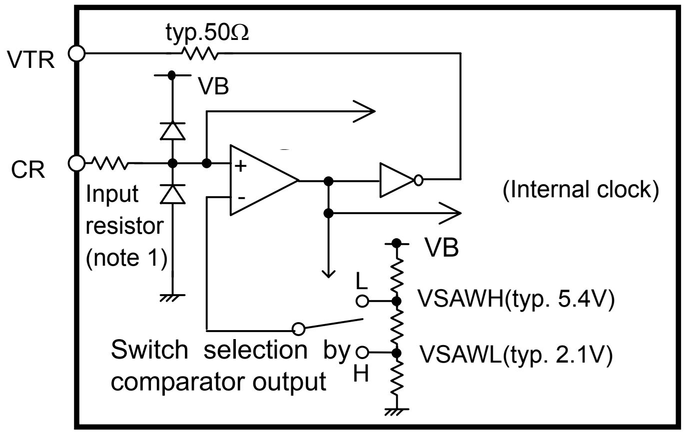
No.	Pin	Item	Functions and Precautions	Related items	Remarks
1	VCC	Control power supply pin	• Powers the drive circuits for the top and bottom arms, the charge pump circuit, the built-in VB supply circuit, and others. • Determine the capacity of the power supply for VCC allowing a margin by adding the standby current Icc and the current taken out of CB pin.	• 5-1. (1) VCC under voltage Detection • 5-3. Power supply sequence • 8-3 to 8-7 IC destruction by external surge or line noise	
2	VS1 VS2	IGBT power pin	• Connected to the collector of the top arm IGBT. • Connect pins VS1 and VS2 close to the IC pin. If either pin is open, the IC may get destroyed.	• 5-3. Power supply sequence • 8-3 to 8-5 IC destruction by external surge	High voltage pin
3	CB	Output pin of the build-in VB supply	• Outputs a voltage (typ 7.5V) generated in the build-in VB power supply. • Provides power from the VB power supply to the input, three-phase distribution, FG, internal clock, over current detection, and other circuits. • Connect a capacitor C0 to prevent oscillation to the CB pin. Capacitor with capacity of 0.22μF ±20% is recommended	• 5-4. VB power supply	
4	C+ C- CL	Top arm drive circuit power pin Charge pump circuit pin	• Powers the drive circuit for the top arm. • Connect external components (capacitor and diode).	• 5-2. Charge pump circuit	High voltage pin

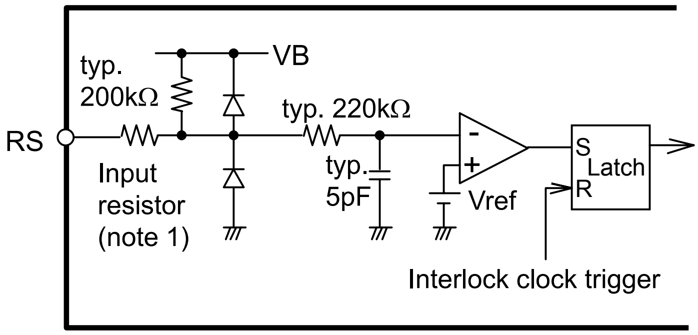


Equivalent Circuit

No.	Pin	Item	Functions and Precautions	Related items	Remarks
5	GL	Control ground pin	• It is the ground pin for VCC and VB power lines.	―――	
6	GH1 GH2	IGBT Emitter pin	• Connected to the emitter of the bottom arm IGBT. • Connected to a shunt resistor Rs to detect over currents. • Connect the GH1 and GH2 near the IC pin. If either pin is open, the IC may get destroyed.	• 5-1. (2) Current limitation	

Table 4-2. List of pins and their functions (pins common to all models) <Continued>

<table>
<tr><th>No.</th><th>Pin</th><th>Item</th><th>Functions and Precautions</th><th>Related items</th><th>Remarks</th></tr>
<tr><td rowspan="2">7</td><td rowspan="2">CR
VTR</td><td>PWM frequency setting pin
(VSP-input type)
Clock frequency setting pin
(6-input type)</td><td>• Externally connected resistors and capacitors are used to determine the frequency of the PWM (internal clock).
• Frequencies are roughly determined by the following equation:
$f \cong 0.494/(C \times R)$ (Hz)</td><td>• 5-5. (1) PWM operation</td><td></td></tr>
<tr><td colspan="3">

Equivalent Circuit</td><td>note 1) Input resistor value
• typ.300Ω
ECN30102
ECN30107
ECN30206
ECN30207
ECN30611
ECN30603
ECN30604
• typ.150Ω
ECN30105
ECN30204
ECN30601</td><td></td></tr>
<tr><td>8</td><td>MU
MV
MW</td><td>Inverter output pin</td><td>• It is an output of a three-phase bridge consisting of six IGBTs and free wheel diodes.</td><td></td><td>High-voltage pin</td></tr>
<tr><td rowspan="2">9</td><td rowspan="2">RS</td><td>Input pin for over current detection signals</td><td>• Monitors the voltage of the Rs shunt resistor and detects its over current status.</td><td>• 5-1. (2) Current limitation</td><td></td></tr>
<tr><td colspan="3">

Equivalent Circuit</td><td>note 1) Input resistor value
• typ.300Ω
ECN30102
ECN30107
ECN30206
ECN30207
ECN30611
ECN30603
ECN30604
• typ.150Ω
ECN30105
ECN30204
ECN30601</td><td></td></tr>
</table>

Table 4-3. List of pins and their functions (pin different according to model)

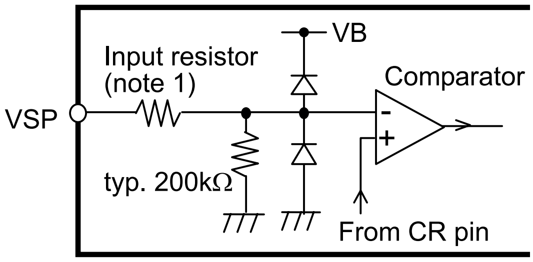
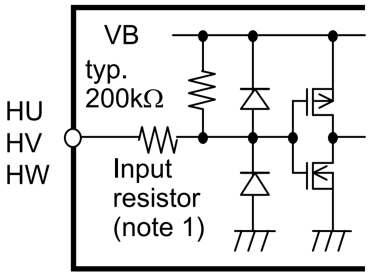
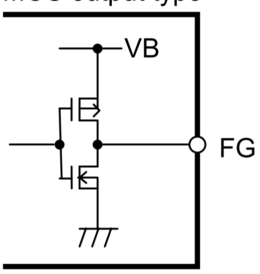
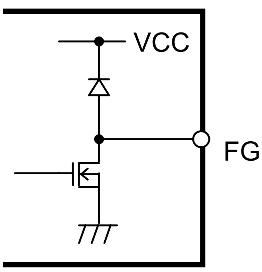
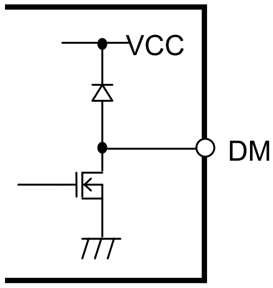
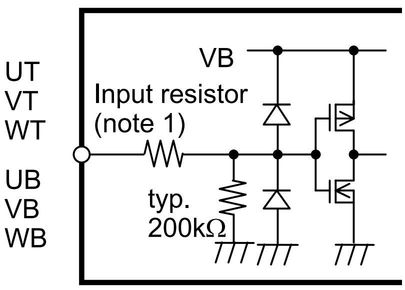
No.	Pin	Item	Applicable models	Functions and Precautions	Related items
	VSP	Speed instruction input pin	ECN30102 ECN30105 ECN30107 ECN30204 ECN30206 ECN30207	• Input a speed instruction signal to generate a PWM signal. • Entering an all-off operating voltage of the VSP terminal (typ. 1.23V) turns off all IGBTs. • If a noise is detected, install a resistor and/or capacitor.	•5-3. Power supply sequence •5-5. Operation of the output IGBT of the VSP input type •8-1. Electrical static destruction of VSP pin caused by external surge Data Sheet •4.2 Input terminals
				Equivalent Circuit	note 1) Input resistor value • typ. 300Ω ECN30102 ECN30107 ECN30206 ECN30207 • typ. 150Ω ECN30105 ECN30204
2	HU HV HW	Hall signal input pin	ECN30102 ECN30105 ECN30107 ECN30204 ECN30206 ECN30207	• Input a hall IC signal. Based on that signal, the system controls the phase switchover of the output IGBT. • If a noise is detected, install a capacitor. • The maximum input voltage is VB+0.5V. The output voltage of hall IC must not exceed the maximum input voltage.	Data Sheet •3.1. Truth table •4.2. Input Pins
				Equivalent Circuit	note 1) Input resistor value • typ. 300Ω ECN30102 ECN30107 ECN30206 ECN30207 • typ. 150Ω ECN30105 ECN30204
3	FG	Motor rotation speed monitoring pin	ECN30102 ECN30105 ECN30107	• Output pulses according to the input signals of the HU, HV and HW. • Motor rotation speed can be monitored by measuring the frequency of output pulse.	•8-2. Electrical static destruction of FG pin caused by external surge Data Sheet •3.2 Time chart
			ECN30204 ECN30206 ECN30207	• Output pulses according to the input signals of the HU, HV and HW. • Motor rotation speed can be monitored by measuring the frequency of output pulse. • Connect an external circuit such as a pull-up resistor of around 5kΩ to 10kΩ to VCC or CB pin.	
		CMOS output type  Equivalent Circuit	Applicable models ECN30102 ECN30105 ECN30107	Open drain output type  Equivalent Circuit	Applicable models ECN30204 ECN30206 ECN30207

Table 4-3. List of pins and their functions (pins common to all models) <Continued>

<table>
<tr><th>No.</th><th>Pin</th><th>Item</th><th>Applicable models</th><th>Functions and Precautions</th><th>Related items</th></tr>
<tr><td rowspan="2">4</td><td rowspan="2">DM</td><td rowspan="2">Direction of motor rotation detecting pin</td><td>ECN30204
ECN30206</td><td>• High or Low level output according to the input signal of the HU, HV and HW.
• Direction of motor rotation can be detected by measuring output voltage.
• Connect an external circuit such as a pull-up resistor of around 5kΩ to 10kΩ to VCC or CB pin.
• Direction of motor rotation relates to the DM output, as shown below ;
<table><tr><th>Direction of motor rotation</th><th>DM output</th></tr><tr><td>U --> V --> W</td><td>L</td></tr><tr><td>U --> W --> V</td><td>H</td></tr></table></td><td></td></tr>
<tr><td colspan="3">
Equivalent Circuit</td></tr>
<tr><td rowspan="2">5</td><td rowspan="2">UT
VT
WT
UB
VB
WB</td><td rowspan="2">Control input pin of each arm</td><td>ECN30611
ECN30601
ECN30603
ECN30604</td><td>• Input control signals of each arm.
• In each input, input the High level turns on the output IGBT. The UT, VT, and WT correspond to the top arm output IGBT.
• The UB, VB, and WB corrrespond to the bottom arm output IGBT.
• The input voltage is 5V CMOS or TTL logic level compatible.
• If a noise is detected, install a resistor and/or capacitor.
• The maximum input voltage is VB+0.5V.</td><td>•5-3. Power supply sequence
•5-7. Dead time

Data sheet
•4.2. Input Pins</td></tr>
<tr><td colspan="3">
Equivalent Circuit

note 1) Input resistor value
• typ. 300Ω
ECN30611
ECN30603
ECN30604
• typ. 150Ω
ECN30601</td></tr>
</table>

5. Functions and operational precautions

5-1. Protection function

(1) Detection of VCC under voltage (LVSD operation)

- When the 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 VCC voltage goes up again, the system goes back to a state where the ouput IGBT operates according to the input signal at a level equal to or exceeding the LVSD recovery voltage (LVSDOFF).

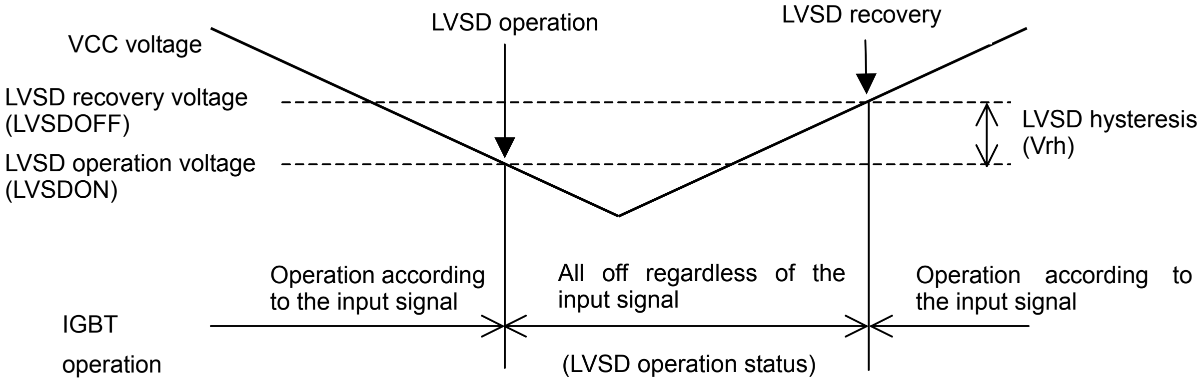


Fig. 5-1. Timing chart for detection of VCC under voltage (LVSD operation)

(2) Current limitation

(a) Operation description

- The system monitors the current flowing through the shunt resistance Rs at the RS pin (see Fig. 5-2). When the reference voltage for current limitation (Vref = typ. 0.5V) is exceeded, the IGBT of the bottom arm is turned off.
- Reset after current limitation is performed in each cycle of the internal clock signal (VTR pin voltage). (See Fig.5-3.)

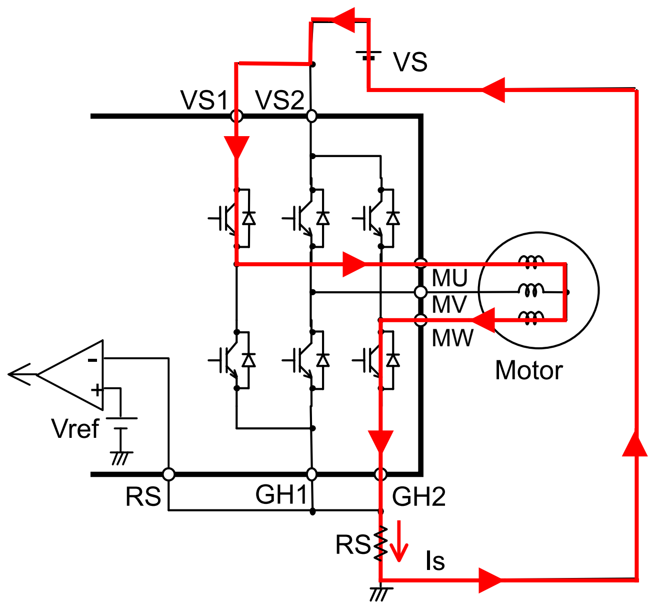


Fig. 5-2. Current of shunt resistance (typical)

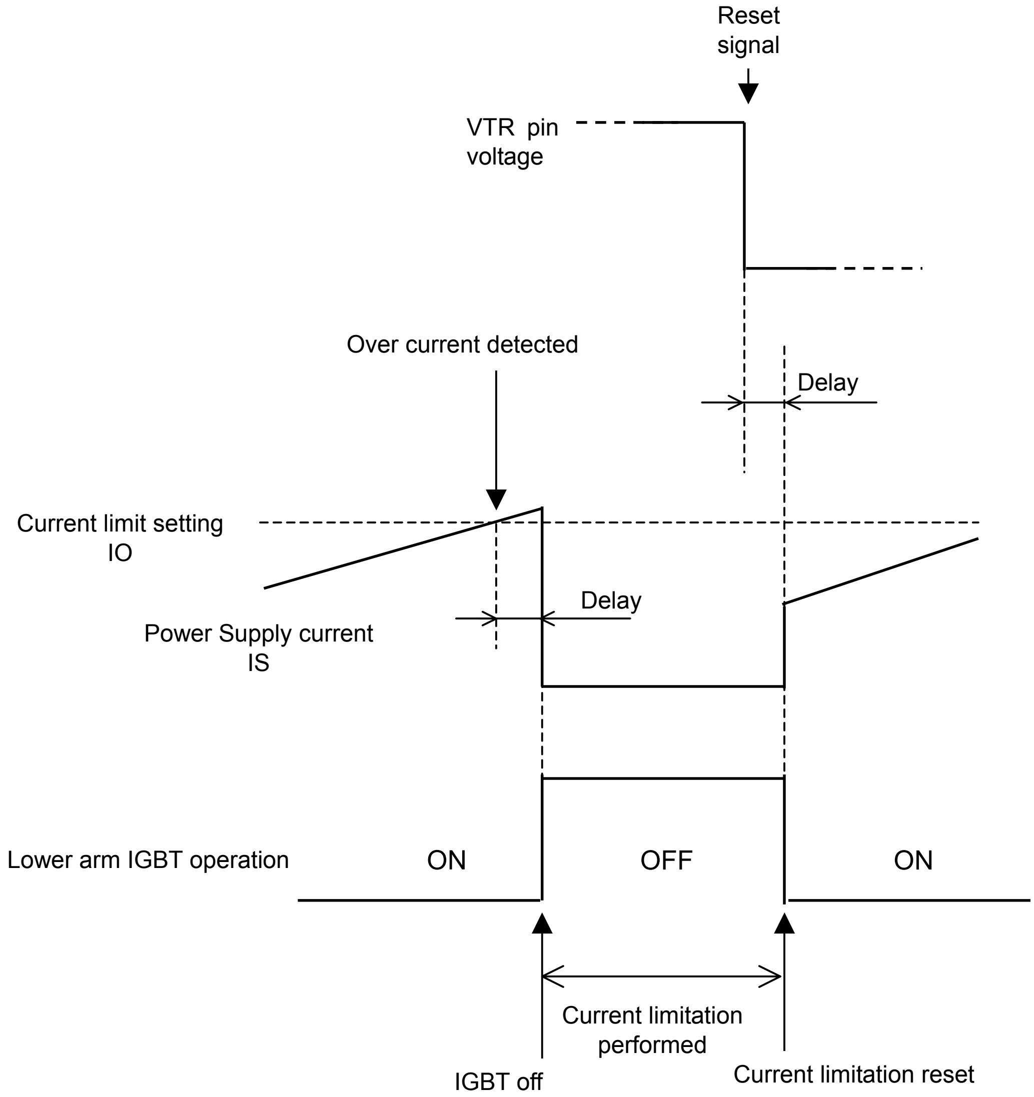


Fig. 5-3. Timing chart for current limitation

(b) How to set up

- The current limitation setting IO is calculated as follows ;

  IO = Vref / Rs

  where

  Vref: Standard voltage for current limitation

  Rs: Shunt resistor
- In setting a current limit, you should allow for Vref variance, Rs resistance variance, and the delay between the time the over current limitation is detected and the time the IGBT is turned off.
- This function is not effective for currents that do not flow forward through the shunt resistor, such as reflux current and power regenerative current (see Figs. 5-4 and 5-5). In practice, users are requested to observe and check the output currents (the coil currents of the motor) of the IC.

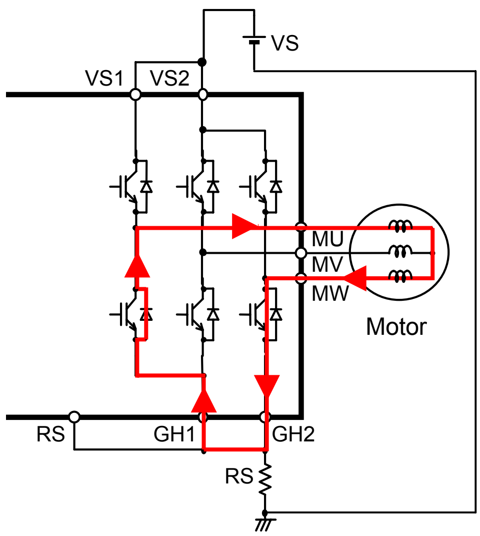


Fig. 5-4. Example to Reflux current

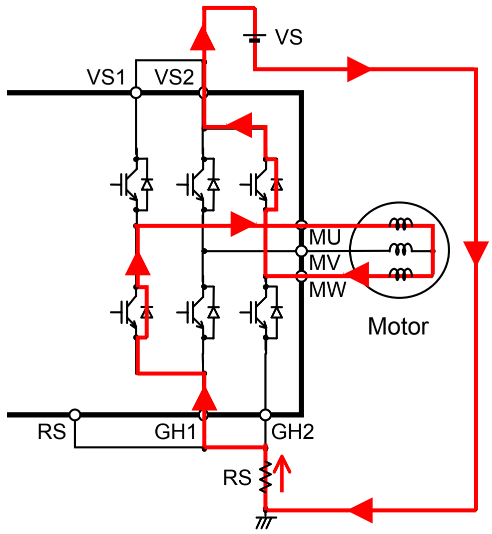
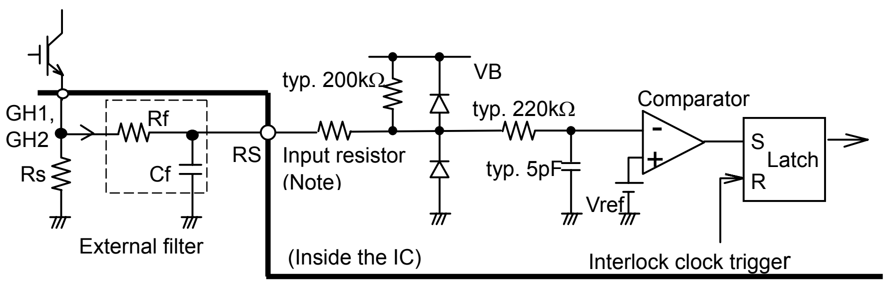


Fig. 5-5. Example to Power regenerative current

(c) Noises of the RS pin

- The RS pin contains a filter having a time constant of about 1μs.
- If the system malfunctions due to a noise, an effective solution is to add a filter externally. However, beware that the external filter increases the delay time before the IGBT turns off.



Note) See the section "RS" of Pin Name in Table 4.2 for the input resistor value.

Fig. 5-6. Example to add external filter

(d) Precautions on wiring

- Make the wiring of the shunt resistor Rs as short as possible. The GH1 and GH2 are connected to the IGBT emitter. If the wiring has a high resistance or inductance component, the emitter potential of the IGBT changes, perhaps resulting in the IGBT malfunctioning.
- Connect the GH1 and GH2 pins near the pin. If the resistance components of the wiring is poor balanced between the GH1 and GH2 pins and the shunt resistor Rs, the current limit levels in each phase may not be equal.

(e) Motor lock

- This IC does not contain a protection function against motor lock.
- If the motor locks, the phase where the output IGBT turns on is fixed, resulting in a constant current-limited state. This produces a major loss, which results in IC temperature increase and IC gets destroyed.

(3) Protection against short-circuit

- This IC does not contain a protection function against short-circuits (such as load short-circuit, earth fault, and short-circuit between the top and bottom arms).
- A short-circuit produces a large current exceeding the maximum rating in the IC. The IC may therefore get destroyed.

5-2. Charge pump circuit

(1) Description of operation

- Fig. 5-7 shows a block diagram of a charge pump circuit. The SW1 and SW2 repeat turning on and off alternatively, synchronously with the internal clock.
- When the SW1 is off and the SW2 is on, the CL pin has a potential of 0V. Through the passage (1), charge the capacitor C1.
- Next, the SW1 is turned on and the SW2 is turned off, and the CL pin rises in potential to the VS level. Through the 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.

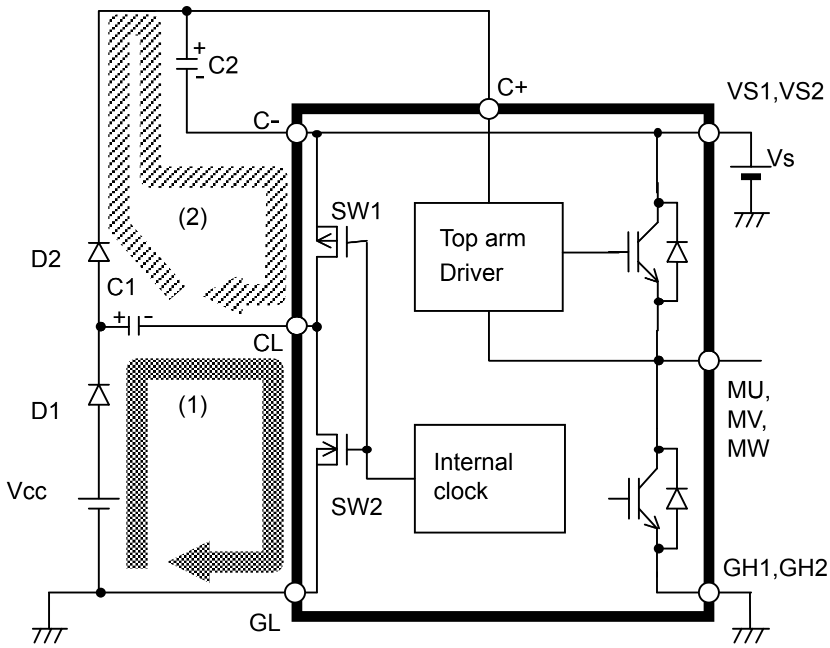


Fig. 5-7. Charge pump circuit

5-3. Power supply sequence

(1) Power supply sequence free type

- ECN30107, ECN30611, ECN30207, ECN30604, ECN30206 (below 1A), ECN30603 (below 1A)

(2) Power supply sequence setting type of the VSP-input type and 6-input type is described below.

- ECN30102, ECN30105, ECN30204 : Refer to (3) (a) VSP-input type
- ECN30601 : Refer to (3) (b) 6-input type

(3) How to set Power supply sequence

(a) VSP-input type

- Recommended sequences are as follows:
  ■ At power-up: VCC on --> VS on --> VSP on
  ■ At power-down: VSP off --> VS off --> VCC off
  If any sequence is involved other than those specified above, please refer to Tables 5-1 and 5-2.
- When the VSP is no higher than the VSAWL, the power sequence is free.
- As for the sequences No. 2 and 5 in Table 5-1, if the VS line gets noisy before the VS is powered up after the VCC and VSP are applied, the ON signal of the upper arm IGBT is reset and the motor may not start up. In such a case, first reduce the VSP to a level no higher than the all-off operating voltage (Voff), then apply it.
- In the case of No. 4 and 6 in Table 5-1 and No. 4 and 6 in Table 5-2, see "Current Derating for Power Sequence and Vcc Voltage" of the Product Specifications.

Table 5-1 Power up sequence (VSP-input type)

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 5-2 Power down sequence (VSP-input type)

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

(b) 6-input type

- Recommended sequences are as follows ;
  ■ At power-up: VCC on --> VS on --> "Control input" on
  ■ At power-down: "Control input" off --> VS off --> VCC off
  For any sequence other than those specified above, see Tables 5-3 and 5-4.
- The power sequence is free if the lower arm control inputs UB, VB, and WB are all low (L) and if the upper control inputs UT, VT, and WT are all low (L).
- In the sequences No. 2 and 5 in Table 5-3, after the VCC and "control input" are applied, when a noise enters the VS line before VS power-up, the ON signal of the top arm IGBT can be reset and the motor may not start up. In such a case, the control inputs (UT, VT, and WT) for the top arm should be set to low, then power the system up again.
- In the case of No. 4 and 6 in Table 5-3 and No. 4 and 6 in Table 5-4, see "Current Derating for power supply sequence and Vcc voltage" of the product specifications.

Table 5-3 Power up sequence (6-input type)

No.	(1)	(2)	(3)	Permit or Inhibit
1	VCC	VS	Control Input	Permit
2	VCC	Control Input	VS	Permit
3	VS	VCC	Control Input	Permit
4	VS	Control Input	VCC	Inhibit
5	Control Input	VCC	VS	Permit
6	Control Input	VS	VCC	Inhibit

Table 5-4 Power down sequence (6-input type)

No.	(1)	(2)	(3)	Permit or Inhibit
1	Control Input	VS	VCC	Permit
2	VS	Control Input	VCC	Permit
3	Control Input	VCC	VS	Permit
4	VCC	Control Input	VS	Inhibit
5	VS	VCC	Control Input	Permit
6	VCC	VS	Control Input	Inhibit

5-4. VB power supply

- The VB power (VB = typ. 7.5V) to be output to the CB pin is generated at the VCC power. The VB power is supplied to the IC internal circuits such as the triangular wave oscillation circuit, over current detection circuit and so on.
- The VB power circuit constitutes a feedback circuit (see Fig. 5-8). To prevent oscillation, connect a capacitor C0 to the CB pin.
- The recommended capacity for the C0 is 0.22μF ± 20%. If any value other than the recommended one is to be used, refer to the below precautions and determine a suitable capacity.

<Precautions>

- As shown in Fig. 5-9, the CB pin may be oscillated depending on the C0 capacity and the output current IB.
- The larger the C0 capacity is, the more stable the VB power supply is. It is recommended, however not to set the capacity figure to an excessive level. As a guide, it should be 2μ to 3μF or less in the non-oscillated region.

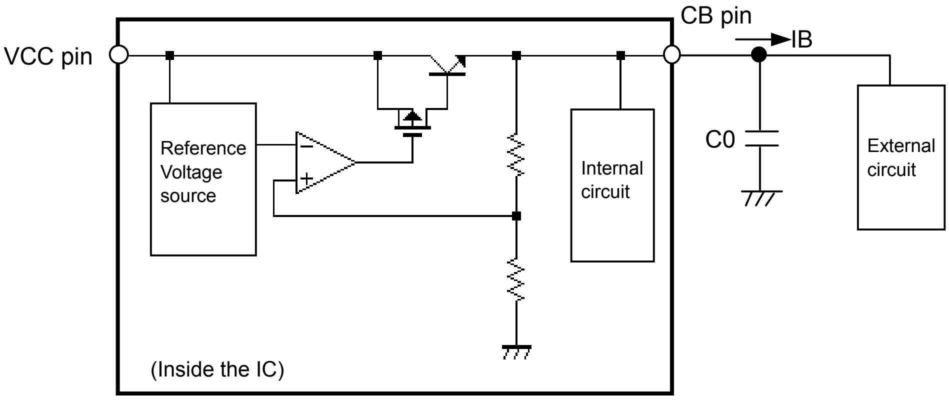


Fig. 5-8. Equivalent circuit for the VB power supply

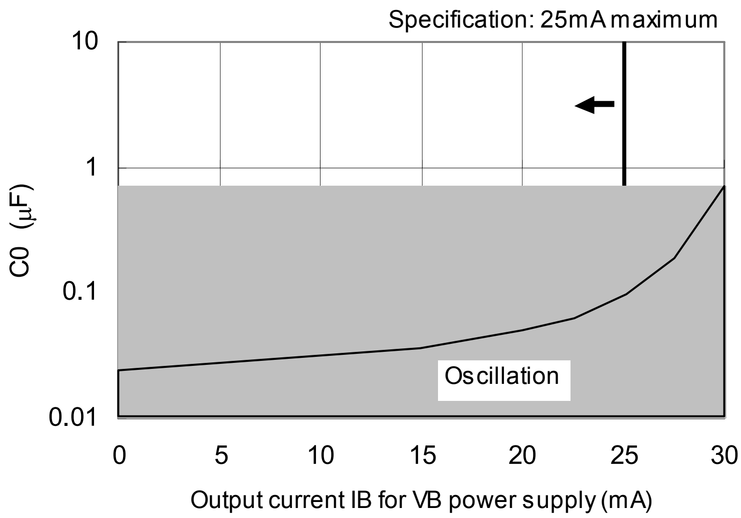


Fig.5-9. IB and C0 dependence of CB pin oscillation (reference data)

5-5. Operation of the output IGBTs of the VSP-input type

(Applicable models: ECN30102, ECN30105, ECN30107, ECN30204, ECN30206, ECN30207)

(1) PWM operation

- PWM signals are generated by comparing the VSP input voltage and triangular signal (CR pin voltage).
- Chopping with PWM is conducted by the lower arm. (See Fig.5-10.)
  VSP input voltage > triangular signal; the lower arm IGBT on
  VSP input voltage < triangular signal; lower arm IGBT off
- The PWM duty varies linearly between the bottom limit (VSAWL = typ. 2.1V) and the top limit (VSAWH = typ. 5.4V) of the triangular wave amplitude level. It becomes 0% at VSAWL, and 100% at VSAWH.

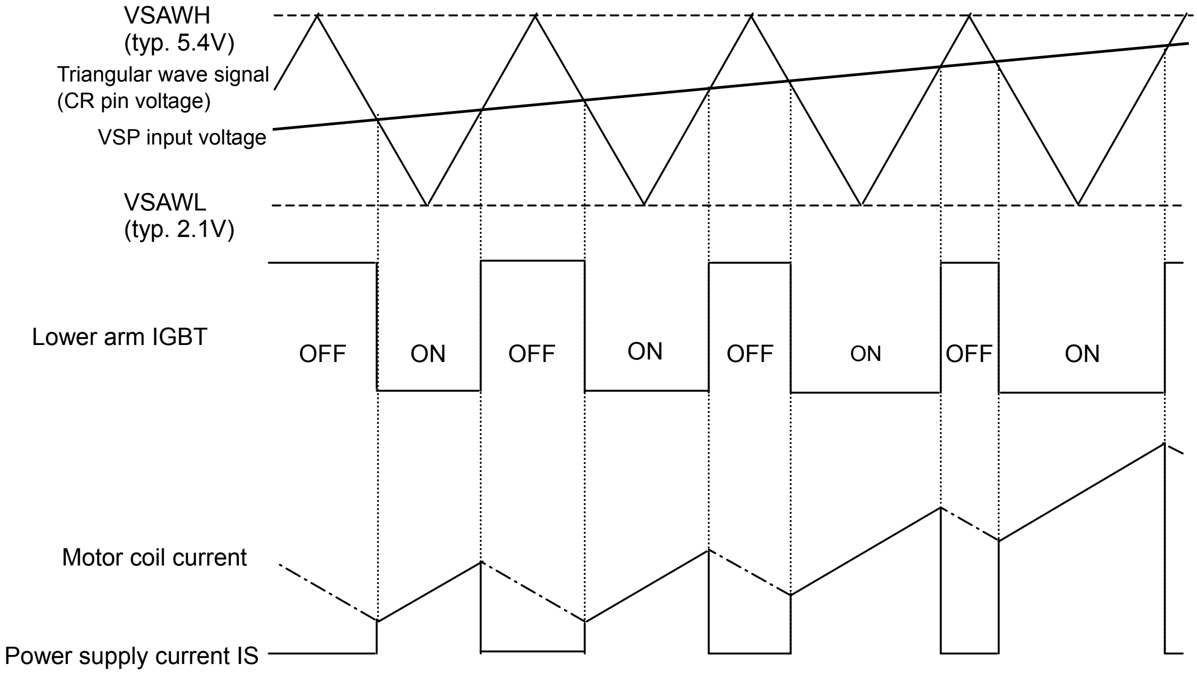


Fig. 5-10. Timing chart of PWM operation

(2) Output all-off function

(a) Function description

- When the input voltage of the VSP pin reaches or goes below the all-off operation voltage (Voff = typ 1.23V), this function turns off all the output IGBTs. The operation of the output IGBTs with regard to the VSP input voltage conforms to Table 5-5.

Table 5-5. Operation of the output IGBTs with regard to VSP input voltage

VSP input voltage	Top arm IGBT	Bottom arm IGBT
0V≦VSP＜Voff (typ. 1.23V)	All off	All off
Voff (typ. 1.23V) ≦VSP＜VSAWL (typ. 2.1V)	As per hall signal input	All off
VSAWL (typ. 2.1V) ≦VSP	As per hall signal input	As per hall signal input

(b) Precautions

- When the output all-off function is activated while the motor is rotating, a regenerative current is generated in the VS power supply, in some cases resulting in the VS power voltage rise. Keep the VS pin voltage equal to or below the maximum rating. Attention is particularly needed, when the capacity between the VS and GND is small, where the voltage is more likely to rise.

5-6.Internal Filter

(Applicable models: ECN30204, ECN30206, ECN30207, ECN30601, ECN30603, ECN30604)

- Internal Filter circuit is located before the Top and Bottom arm drivers (see Fig. 5-11.).
  This filter circuit removes the signal and the noise, that width is less than about 1μs (see Fig. 5-12.).
  Table 5-6. shows the effective pin of the internal filter circuit.
- The noise is coupled on Vcc line: The internal filter becomes effective, when the VCC level is dropped by the noise, that is lower than LVSDON voltage and that width is about 1μs or less.

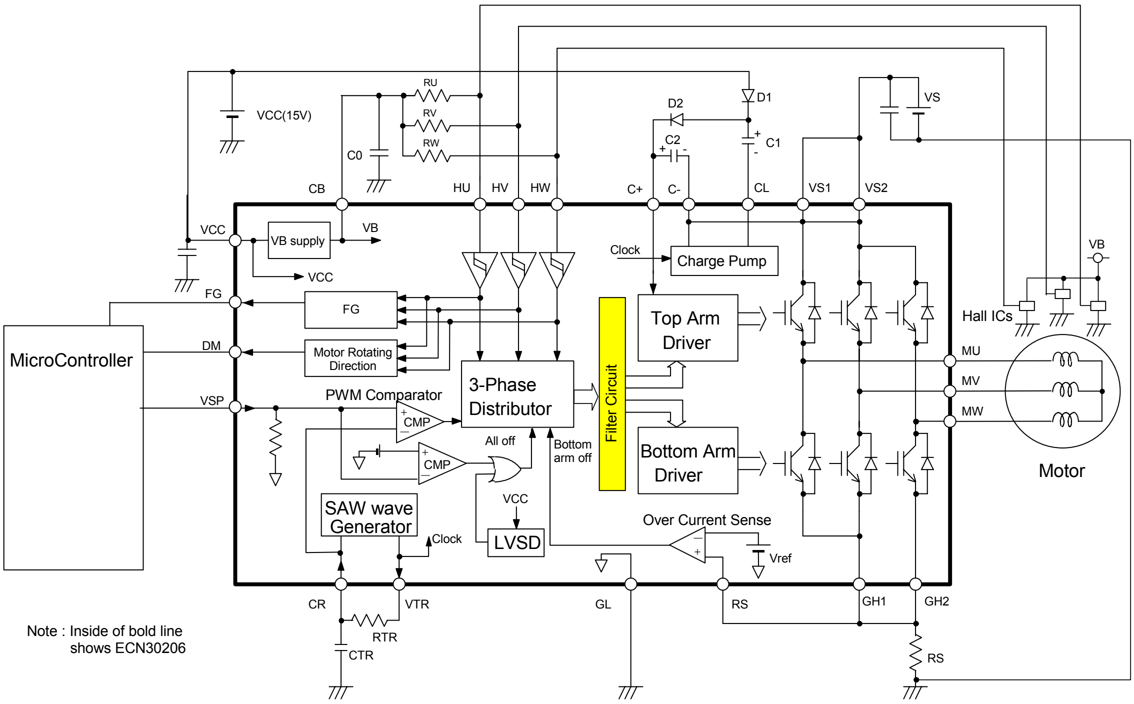


Fig.5-11. Block diagram of ECN30206

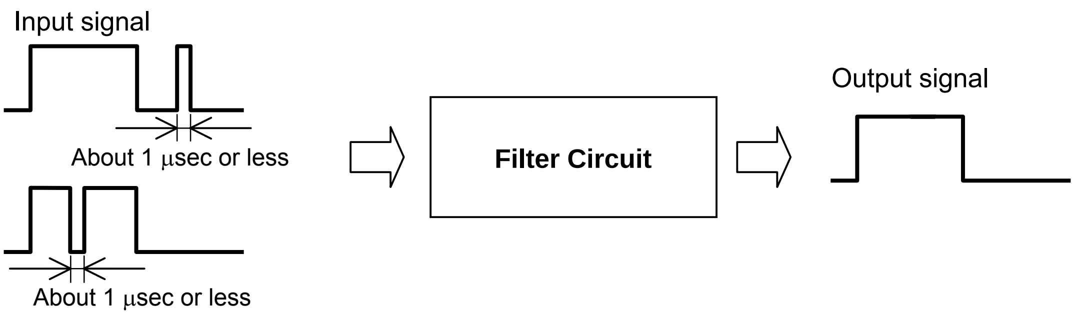


Fig. 5-12. Operation of Internal Filter circuit

Table 5-6 The effective pin of the internal filter circuit

Model	ECN30204 ECN30206 ECN30207	ECN30601 ECN30603 ECN30604
Effective Pin	VCC*	VCC*
	HU	UT
	HV	VT
	HW	WT
	VSP	UB
	CR	VB
	RS	WB
		RS

*) Effective only to the output signal of the LVSD Detection circuit.

5-7. Dead time

(Applicable model: ECN30611, ECN30601, ECN30603, ECN30604)

- Since this IC has an output of consisting of a totem pole of IGBTs, the IC may get destroyed when the top and bottom arm IGBTs of the same phase are turned on simultaneously. Therefore, allow for an internal delay of the IC and determine a dead time.
- Here is how the dead time (TDI) of the input pin in the IC relates to the dead time (TDO) of the output pin.
  TDO = TDI - TdOFF + TdON -------------------- (1)
  where
  TdON: Turn-on delay
  TdOFF: Turn-off delay
- To prevent the simultaneous turning-on of the top and bottom arms, the TDO should be set to more than zero.
  From Equation (1), TDI > TdOFF - TdON is the required setting condition of the dead time TDI. The worst case is when the TdOFF is maximum or TdON is minimum.
- The TdON and TdOFF have temperature-dependency (see Fig. 5-14 to Fig. 5-15). These should be considered as well.
- The above discussion does not allow for the effects of the populated board wiring and other elements. In practice, please monitor the power supply current and other factors, and check that the top and the bottom arm IGBTs of the same phase are not turned on simultaneously.

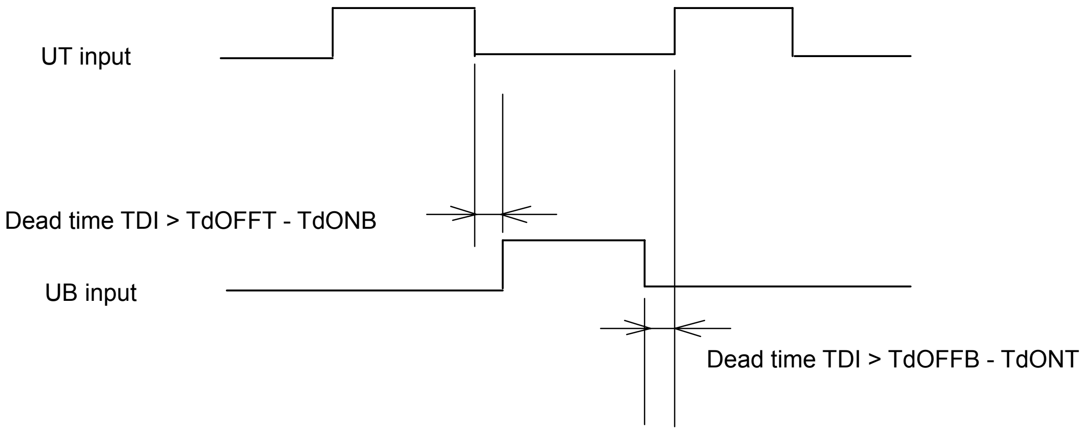


Fig. 5-13. Typical dead time settings

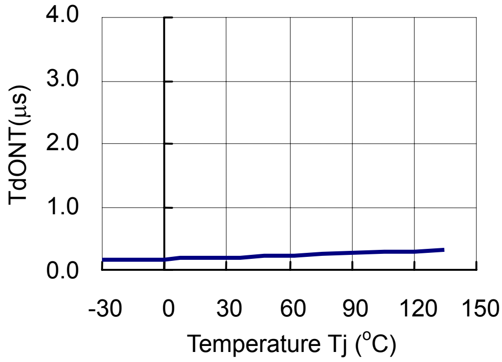
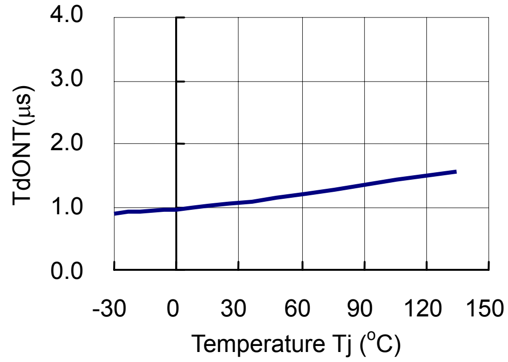
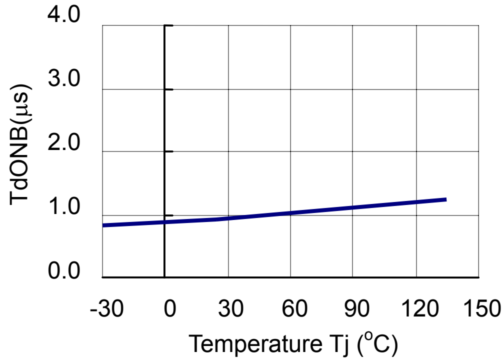
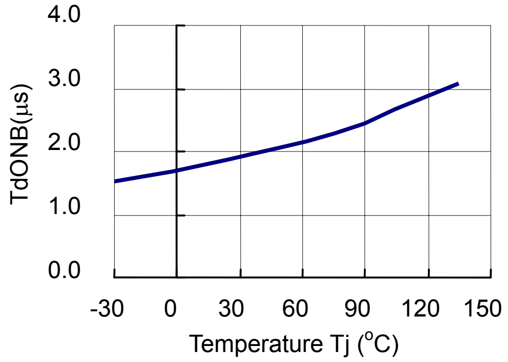
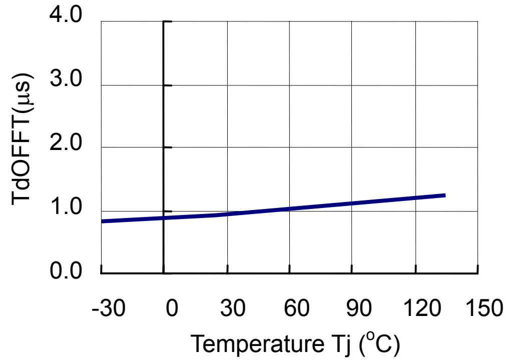
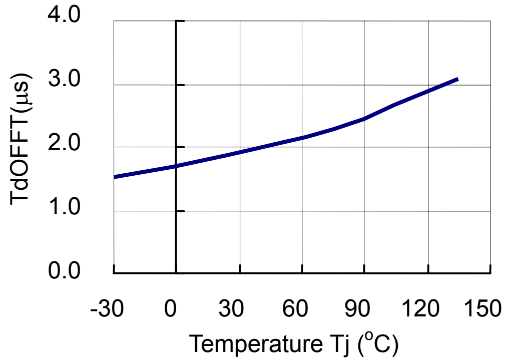
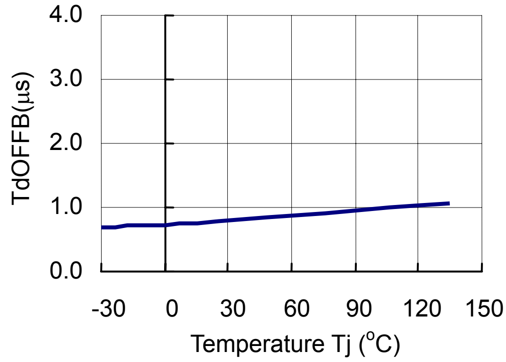
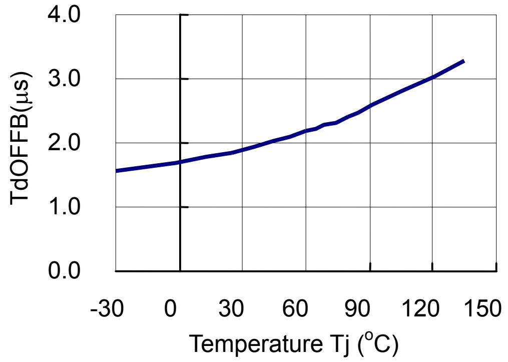
<table>
<tr><th></th><th>ECN306011</th><th>ECN30601</th></tr>
<tr><td>Turn on delay time (Top arm)</td><td></td><td></td></tr>
<tr><td>Turn on delay time (Bottom arm)</td><td></td><td></td></tr>
<tr><td>Turn off delay time (Top arm)</td><td></td><td></td></tr>
<tr><td>Turn off delay time (Bottom arm)</td><td></td><td></td></tr>
</table>

Fig. 5-14 Temperature-dependency of TdON and TdOFF (1)

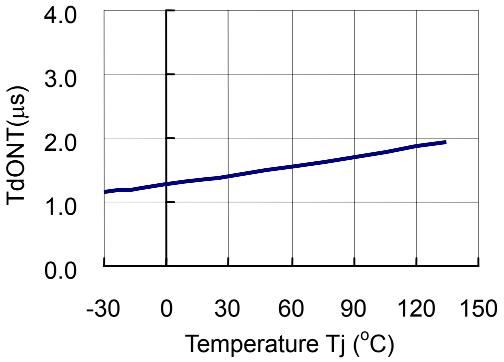
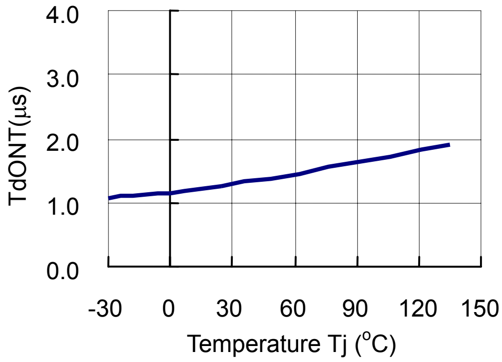
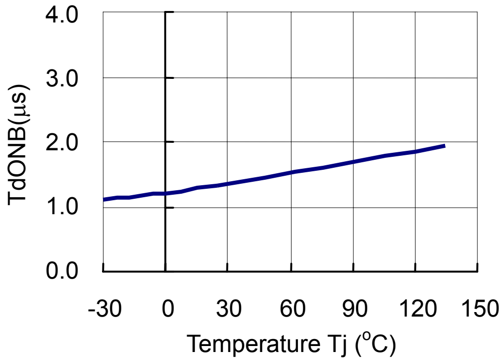
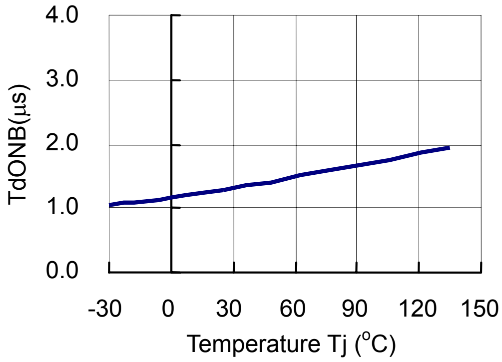
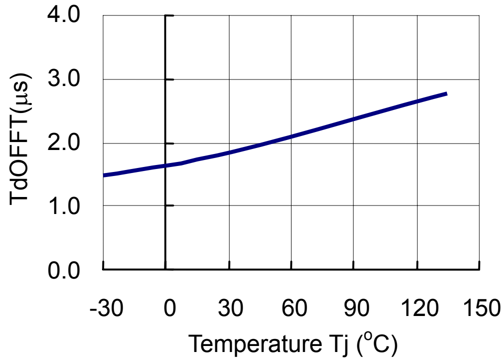
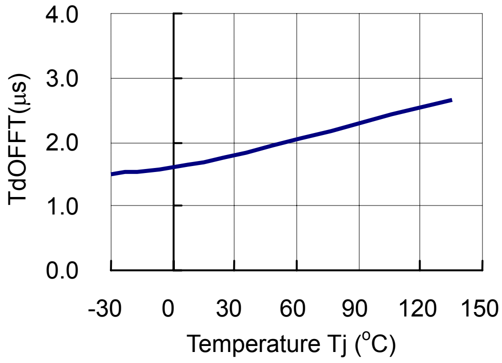
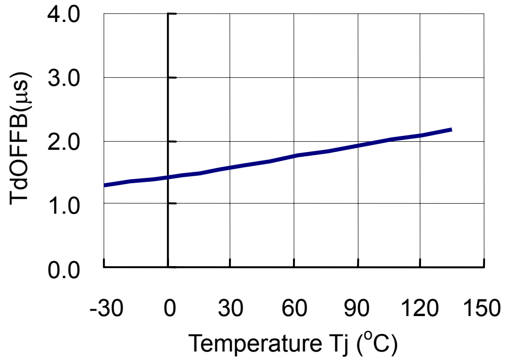
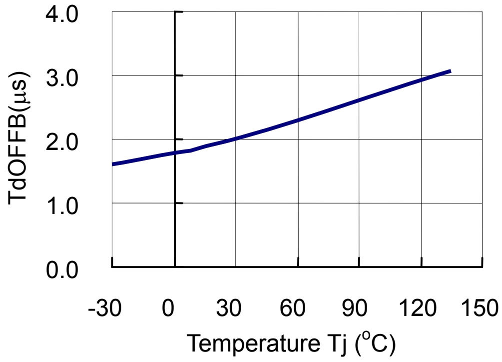
	ECN30603	ECN30604
Turn on delay time (Top arm)		
Turn on delay time (Bottom arm)		
Turn off delay time (Top arm)		
Turn off delay time (Bottom arm)		

Fig. 5-15 Temperature-dependency of TdON and TdOFF (2)

5-8. Calculation of power consumption

- Here are simple formulae for calculating of power consumption generated in the VSP-input type and the six-input type. As for the constant required for calculation, contact our sales representative.

(1) VSP-input type (Inverter controlled 120-degree commutation mode, bottom arm PWM chopping)
(Applicable models: ECN30102, ECN30105, ECN30107, ECN30204, ECN30206, ECN30207)

Total IC power consumption; $P = P_{IGBT} + P_{FWD} + P_{SW} + P_r + P_{IS} + P_{ICC}$ (W)

(1) Steady-state power dissipation of IGBTs
$P_{IGBT} = I_{AVE} \times VONT + I_{AVE} \times VONB \times D$ (W)

(2) Steady-state power dissipation of Free Wheeling Diodes (FWDs)
$P_{FWD} = I_{AVE} \times VFDT \times (1 - D)$ (W)

(3) Switching power dissipation of IGBTs
$P_{SW} = (E_{on} + E_{off}) \times f_{PWM}$ (W)

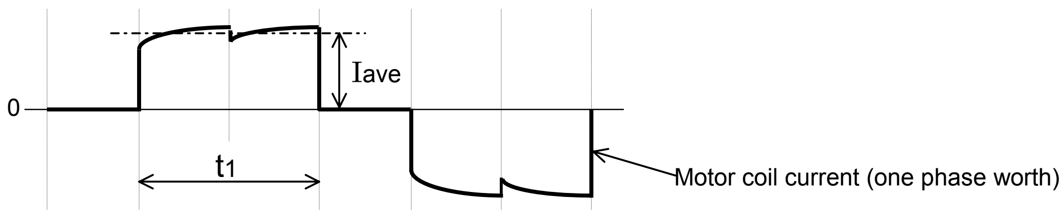
(4) Recovery power dissipation of FWDs
$P_r = 1/4 \times (IrrT \times VS \times trrT \times f_{PWM})$ (W)

(5) VS power supply consumption
$P_{IS} = VS \times IS$ (W)

(6) VCC power supply consumption
$P_{ICC} = VCC \times ICC$ (W)

I_{AVE}	; Average output current (see Fig. 5-16)	(A)
VONT	; Drop in the output voltage of the top arm IGBT @ $I = I_{AVE}$	(V)
VONB	; Drop in the output voltage of the bottom arm IGBT @ $I = I_{AVE}$	(V)
D	; PWM duty	
VFDT	; Forward voltage drop in the FWD of the upper arm @ $I = I_{AVE}$	(V)
E_{on}	; Switching loss when the IGBT is turned on @ $I = I_{AVE}$	(J/pulse)
Eoff	; Switching loss when the IGBT is turned off @ $I = I_{AVE}$	(J/pulse)
f_{PWM}	; 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	(sec)
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



Average output current Iave: average motor coil current during the period t1

Fig. 5-16. Current waveform of the motor coil (120-degree energization)

(2) Six-input type (inverter controlled 180^{o} sine wave commutation mode)
(Applicable model: ECN30611, ECN30601, ECN30603, ECN30604)

- The formula given below assumes the use of 180^{o} sine wave commutation mode (all arms PWM chopping).

Total IC power consumption; $P = P_{IGBT} + P_{FWD} + P_{SW} + P_r + P_{IS} + P_{ICC}$ (W)

(1) Steady-state power dissipation of IGBTs
$P_{IGBT} = I_P \times VONT_P \times (1/8 + D/3\pi \times \cos\theta) \times 3 + IP \times VONB_P \times (1/8 + D/3\pi \times \cos\theta) \times 3$ (W)
(2) Steady-state power dissipation of Free Wheeling Diodes (FWDs)
$P_{FWD} = I_P \times VFDT_P \times (1/8 - D/3\pi \times \cos\theta) \times 3 + I_P \times VFDB_P \times (1/8 - D/3\pi \times \cos\theta) \times 3$ (W)
(3) Switching power dissipation of IGBT
$P_{SW} = (E_{onP} + E_{offP}) \times f_{PWM}/\pi \times 6$ (W)
(4) Recovery power dissipation of FWDs
$P_r = 1/8 \times (IrrT \times VS \times trrT \times f_{PWM}) \times 3 + 1/8 \times (IrrB \times VS \times trrB \times f_{PWM}) \times 3$ (W)
(5) VS power supply consumption
$P_{IS} = VS \times IS$ (W)
(6) VCC power supply consumption
$P_{ICC} = VCC \times ICC$ (W)

I_P	; Peak current (see Fig.5-17)	(A)
$VONT_P$	; Drop in the output voltage of the top arm IGBT @ $I = I_P$	(V)
$VONB_P$	; Drop in the output voltage of the bottom arm IGBT @ $I = I_P$	(V)
$(1 + D \times \sin t)/2$	; PWM duty power factor during the time t	
$\cos\theta$	; Power factor	
$VFDT_P$	; Forward voltage drop in the FWD of the top arm @ $I = I_P$	(V)
$VFDB_P$	; Forward voltage drop in the FWD of the bottom arm @ $I = I_P$	(V)
E_{onP}	; Switching loss when the IGBT is turned on @ $I = I_P$	(J/pulse)
E_{offP}	; Switching loss when the IGBT is turned off @ $I = I_P$	(J/pulse)
f_{PWM}	; PWM frequency	(Hz)
IrrT	; Recovery current of the FWD of the top arm	(A)
IrrB	; Recovery current of the FWD of the bottom arm	(A)
trrT	; Reverse recovery time of the FWD of the top arm	(sec)
trrB	; Reverse recovery time of the FWD of the bottom arm	(sec)
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

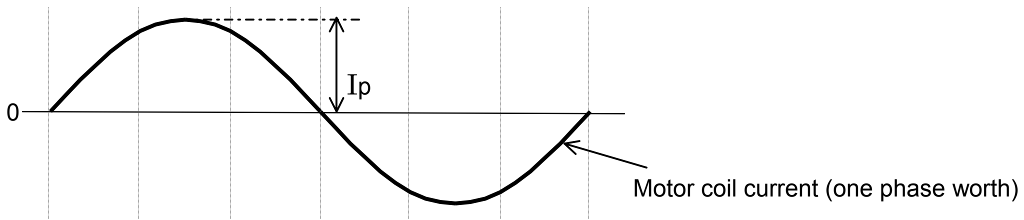


Fig.5-17. Current waveform of the motor coil (Inverter controlled 180^{o} sine wave commutation mode)

(3) Calculation of junction temperature

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

Tj = Tc + Rjc x P

Tj	: Junction Temperature	(^{o}C)	
Tc	: IC case(Tab) Temperature	(^{o}C)	(actual measurement)
Rjc	: Thermal resistance of between junction and IC case (Tab)		(^{o}C/W)
P	: Total IC power consumption	(W)	

- Measuring method of Tc
  The thermo-couple is set in the tab of IC (heat sink) and temperature Tc of the IC case is measured. The temperature of Tc has the time dependency, please measure the temperature after it is saturated.

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 and other environmental conditions and vibration, impact and other mechanical stresses.

■ Table 5-7 specifies the standard examples of derating to be considered a reliable designing. To consider these derating items in the stage of equipment design is desirable from the point of reliability securement. If any item is difficult to control 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 5-7. Typical derating design standards

Item	Typical derating standards (example)	
Junction temperature Tj	110^{o}C maximum	
VS power supply voltage	185V maximum	ECN30102, ECN30105 ECN30107, ECN30611
	450V maximum	ECN30204, ECN30206, ECN30207 ECN30601, ECN30603, ECN30604

5-10. External components

(1) Standard external components

Table 5-8. External components

Applicable models	Parts	Typical value	Usage	Remarks
Common	C0	0.22 μF +/-20%	Filters the internal power supply (VB)	Stress voltage is VB (=8.2V)
	Rs		Sets Over-Current limit	Please refer to the 4-1 (2) Note1
	CTR	1800 pF +/-5%	Sets PWM frequency	Stress voltage is VB (=8.2V) Note2
	RTR	22 kΩ +/-5%	Sets PWM frequency	Stress voltage is VB (=8.2V) Note2
	RU, RV, RW	5.6 kΩ +/-5%	Pull-up	
	C1, C2	1.0 μF +/-20%	For charge pump	Stress voltage is Vcc Note3
	Hall IC	Asahi Kasei EMD EW-632 or equivalent	For detecting the rotor position	For reference Note4
ECN30204, ECN30206, ECN30207, ECN30601, ECN30603, ECN30604	D1, D2	Hitachi DFG1C6 (Glass mold type) DFM1F6 (Resin mold type) or equivalent	For charge pump	600V, 1A, trr ≤ 100ns Note3
ECN30102, ECN30105 ECN30107, ECN30611	D1, D2	Hitachi DFG1C4 (Glass mold type) DFM1F4 (Resin mold type) or equivalent	For charge pump	400V, 1A, trr ≤ 100ns Note3

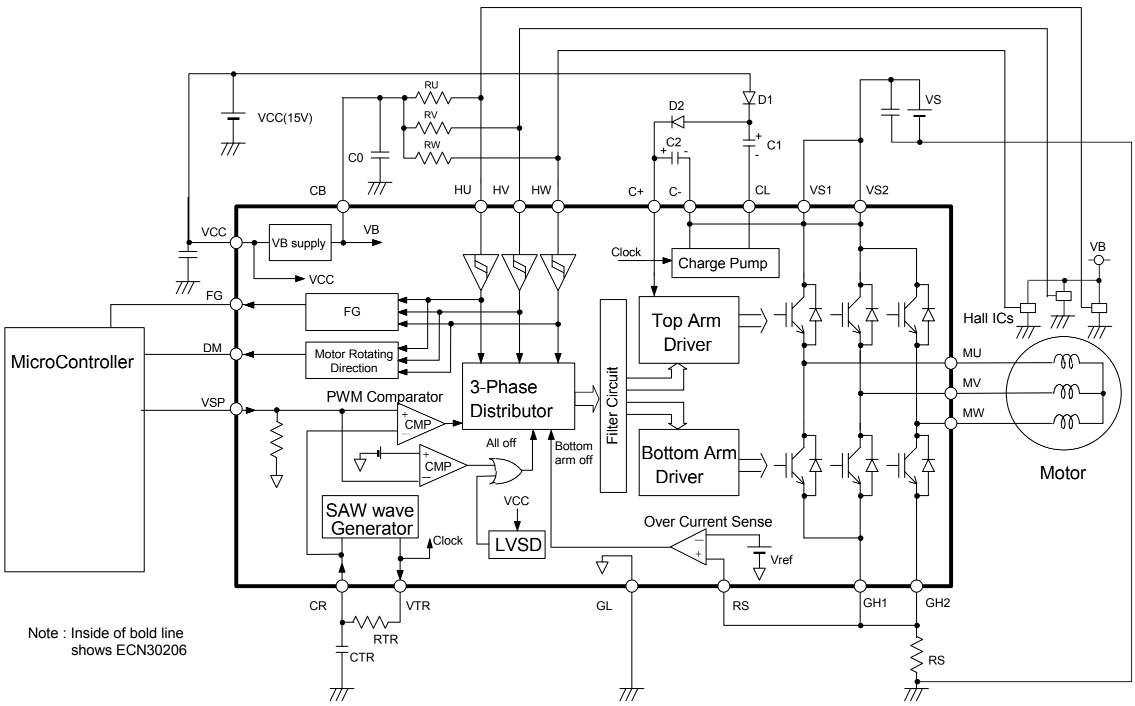


Fig.5-18. Block diagram of ECN30206

Table 5-8 and Fig. 5-18 are only for reference, select external components based on your system.

Note 1: Please shorten the wiring between the resistor Rs and the Rs pin, and the wiring between the resistor Rs and the GH1/GH2 pins as much as possible.

Note 2: The PWM frequency is approximated by the following equation:

PWM Frequency (in Hertz) $\cong$ 0.494 / (CTR x RTR)

Note: CTR is in Farads, RTR is in Ohms.

- Please set the maximum frequency of PWM is 20KHz or less.
- When the PWM frequency is set a high frequency, the switching loss is increased. And it produces an increase in temperature of IC.
- Please confirm the increased IC temperature with an actual set, and use it in the range of derating curve.

Note 3: Attention of part setting of charge pump circuit

The following attention is necessary when used excluding the standard part.

- When the voltage (Vcp) between C+ and C- is dropped, the gate voltage of top arm IGBTs is dropped. And then the loss of IC increases. Vcp must not become Vcp<10V.

■ Capacitor

- Vcp is dropped by the internal dissipation current from C+ terminal of IC, when capacity is small.
- The voltage impressed to the capacitor becomes VCC in operation. Therefore, the withstand voltage of the capacitor is necessary more than the VCC voltage.

■ Diode

- Forward voltage (VF) recommends the small one as much as possible. Because of, Vcp is dropped when VF is large.
- Reverse recovery time (trr) recommends the small one as much as possible. Because of, Reverse recovery charge (Qrr) becomes large at charge pump operation when trr is large. And then, VCP is drop.
- The withstand voltage of the diode is needed more than the VS voltage because CL is changed from about 0V to VS.
- The rush current flows to diode D1 and D2 by charging with capacitor C1 and C2 when the VCC power supply is turned on by VS=0V. Please select the ratings current of the diode in consideration of this current.

Note 4: When the VB supply is used for the power supply of Hall ICs, please select Hall IC in consideration of VB output current. The VB output current must be less than 25mA.

(2) Other external parts

- Parts of Table 5-9 are recommended to be arranged to protect stabilization and IC of the power supply from the voltage serge.
- Please adjust the part setting according to usage conditions. And also, please set up each part close to the terminal of IC to achieve the effect of the voltage serge absorption.

Table 5-9

Parts	Purpose	Remarks
Cvcc1	for High frequency noise suppressing	Ceramic capacitor with good frequency response etc.
Cvcc2	for Vcc power supply smoothing	Electrolytic capacitor etc.
ZDvcc	for Over voltage suppressing	Zener diode with good frequency response etc.
Cvs1	for High frequency noise suppressing	Ceramic capacitor with good frequency response etc.
Cvs2	for Vs power supply smoothing	Electrolytic capacitor etc.
ZDvs	for Over voltage suppressing	Zener diode with good frequency response etc.

6. Handling Instruction

6-1. Mounting

(1) Insulation between pins

- High voltages are applied between the pins of the numbers specified below. Hitachi advises to apply coating or molding treatment.

  1 - 2, 2 - 4, 6 - 7, 8 - 9, 9 - 10, 20 -21, 21- 22, 22 -23
- Coating resin comes in various types. There are some unclear points as to how much thermal and mechanical stresses are exercised on semiconductor devices by size, thickness, and other factors of board shape, and the effects of other components. In selecting coating resin, please consult with your manufacturer.

(2) Connection of tabs (radiator panels of the ICs)

- Fig. 6-1 is a cross section of the IC. The tab and the GL pin of the IC are connected with high impedance (Rp = hundreds of KΩ to several MΩ).
- Set the tab potential to open or GND.
- If the tab is mounted on the external cabinet of the motor for heat radiation purpose, the IC cannot withstand an isolation withstand voltage test where a high voltage is applied between the external cabinet and the ground. Please apply a mylar sheet or something similar between the IC tab and the external cabinet.

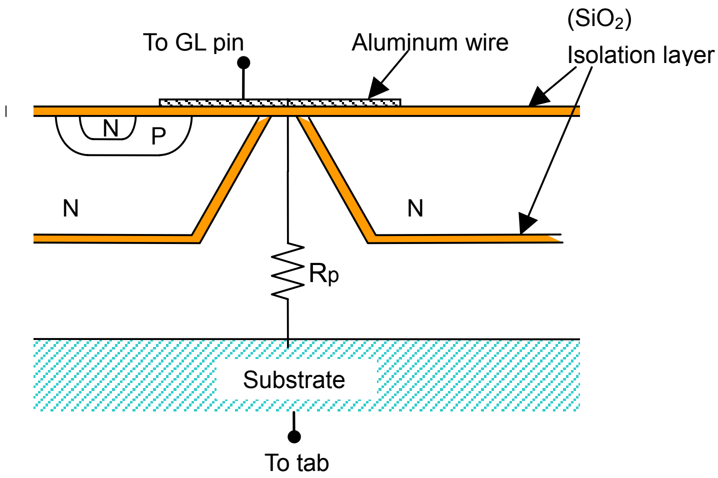


Fig. 6-1. Cross section of Hitachi HVIC

(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.

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

6-2. Antistatic measures

- Containers and jigs for transporting ICs should be designed not to get charged under vibration or other impact during transportation. One effective measure is to use a conductive container or aluminum foil.
- Ground all work benches, machines and devices, meters, and other units that may get in contact with the ICs.
- While handling an IC, ground your body with a high resistor (about 100kΩ to 1MΩ) to prevent breakdown due to static electricity that has charged your body and/or clothes.
- Do not produce any friction with other polymer compounds.
- To move any printed circuit board or other component equipped with an IC, make sure that no vibration or friction occurs and short-circuit the pins to keep the potential at the same level.
- Exercise control so that the humidity does not go too low.
- Take enough care in handling to prevent the breakdown of ICs due to static electricity.

7. Quality

7-1. Quality tests

- Table 7-1 shows the main quality tests performed by our company.

Table 7-1

No.	Test item	Test conditions
1	High temperature operation	VCC=VCCop, VS=Vsop, Tj=135°C, t=1000h
2	Motor rotation continuousness operation	VCC=VCCop, VS=Vsop, Tj=135°C, t=1000h
3	High temperature storage	Ta= 150°C, t=1000h
4	Low temperature storage	Ta= -40°C, t=1000h
5	Temperature cycle	-65°C to room temperature, 150°C, 100cycles (30min, 5min, 30min)

7-2.Quality Control Flow

Process Flow	Process Classinfication		Control Item	Control Method		Remarks
	No.	Process name		Contents	Sampling	
▽□ 1	1	Sillicon Wafer incoming inspection	Wefer receive insupection	Resistivity Thickness	Sampling	[Process symbols] ▽: Incoming □: Inspection ○: Processing or machining
○ 2	2	DI (dielectric isolation)	DI condition	Appearance Size	All	
○ 3	3	Photo lithography	Photo lithography condition	Pattern Form	Sampling	
○ 4	4	Diffusion	Diffusion condition	Resistivity Gate oxidation thickness	Sampling	
○ 5	5	Metal evaporation	Metal evaporation condition	Thickness Appearance	Sampling	
○ 6	6	Surface protection film deposition	Surface protection film deposition condition	Thickness Appearance	Sampling	
○ 7	7	Back grinding	Grinding condition	Wafer thickness Appearance	Sampling	
○ 8	8	Back metal evaporation	Metal evaporation condition	Thickness Appearance	Sampling	
□ 9	9	Wafer Probing	Electrical characteristic	Electrical characteristic	All	
▽□ 10	10	Assembling parts incoming inspection	Assembling parts receive inspection	Appearance Size	Sampling	
○ 11	11	Dicing	Dicing condition	Appearance	Sampling	
□ 12	12	Pellet appearance check	Appearance	Appearance	Sampling	
○ 13	13	Die bonding	Bonding condition	Appearance	Sampling	
○ 14	14	Joining	Joining condition	Appearance	Sampling	
○ 15	15	Wire bonding	Wire bonding condition	Appearance	Sampling	
○ 16	16	Molding	Molding condition	Appearance	Sampling	
○ 17	17	Lead plating	Lead plating condition	Appearance	Sampling	
○ 18	18	Marking Cutting bending	Marking condition Appearance	Appearance	Sampling	
□ 19	19	Assembly final appearance check	Appearance	Appearance	Sampling	
□ 20	20	Screening	Characteristic Appearance	Characteristic Appearance	All	
□ 21	21	Final check	Characteristic Appearance	Characteristic Appearance Size	Sampling	
□ 22	22	Store	Checking	Type The number Inventory code	Sampling	
□ 23	23	Shipping inspection	Checking	Type The number Inventory code	Sampling	
	24	Packing・Shipping	Shipping guide	-	-	

8. Inverter IC Handling Note

8-1. Electrical static destruction of VSP pin caused by external surge

Cause	The external surge on the VSP line of the motor was put into IC directly.
Phenomenon	The VSP signal is not transmitted in IC, and the motor doesn't rotate.
Countermeasure	The series resistance is inserted so that the external surge is not put into IC directly. In addition, if capacitor is added, it becomes more effective.

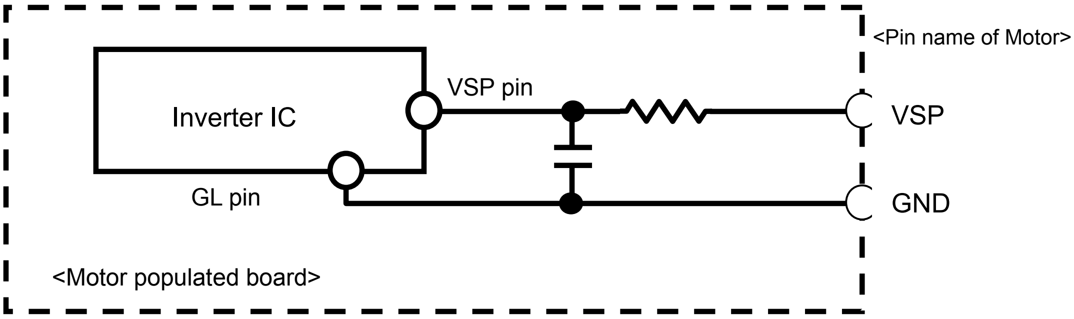


Fig. 8-1. Example to configuration for external parts of VSP

8-2. Electrical static destruction of FG pin caused by external surge

Cause	The external surge on the FG line of the motor was put into IC directly.
Phenomenon	The FG signal of the IC is not monitored.
Countermeasure	The buffer circuit using the transistor is used on the motor populated board so that the external surge is not put into IC directly.

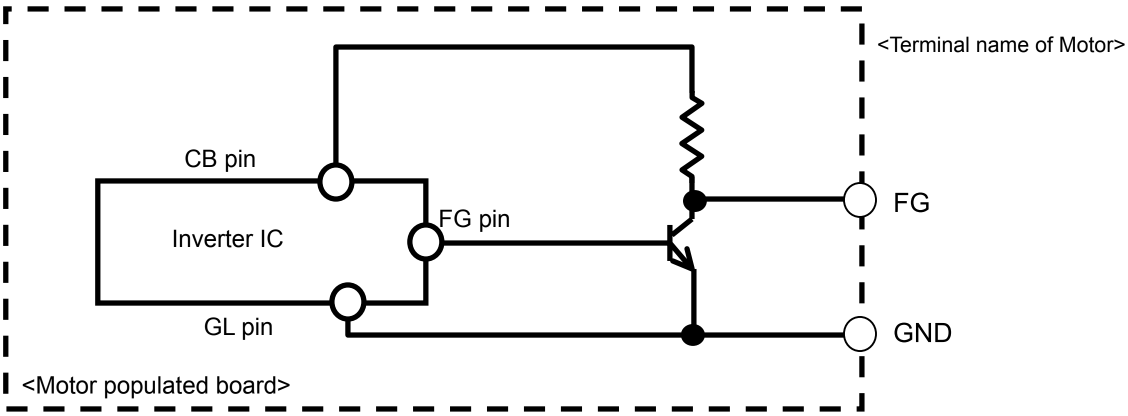


Fig. 8-2. Example to configuration for external parts of FG (CMOS output case)

8-3. IC destruction by external surge inputted to VS and VCC line (1)

Cause	The external surge on the VS and VCC line of the motor was put into IC. Because the Zener voltage of the surge suppressor diode was higher than the maximum rating voltage of IC, it did not protect IC.
Phenomenon	The motor doesn't rotate by the over voltage destruction of IC.
Countermeasure	Use the surge suppressor diode of the Zener voltage, which is lower than the maximum rating voltage of IC.

8-4. IC destruction by external surge inputted to VS and VCC line (2)

Cause	The external surge on the VS and VCC line of the motor was put into IC. Because the capacity of bypass capacitor for surge suppression was small, surge was not able to be suppressed enough.
Phenomenon	The motor doesn't rotate by the over voltage destruction of IC.
Countermeasure	Use the bypass capacitor for surge suppression, which capacity should be enough to suppress surge.

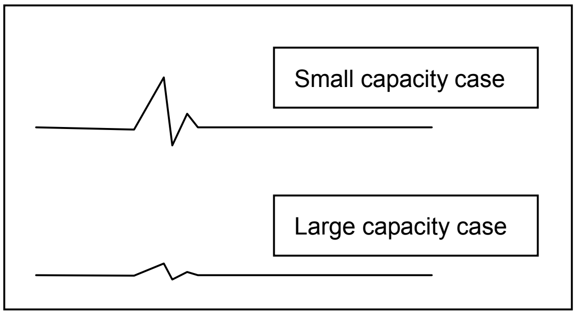


Fig. 8-3. Example to surge waveform by difference of capacity of bypass capacitor

8-5. IC destruction by external surge inputted to VS and VCC line (3)

Cause	The external surge on the VS and VCC line of the motor was put into IC. Because the position of external parts for surge suppression on the motor populated board was bad, surge was not able to be suppressed enough.
Phenomenon	The motor doesn't rotate by the over voltage destruction of IC.
Countermeasure	Bypass capacitor and Zener diode for surge suppression should be mounted close to IC.

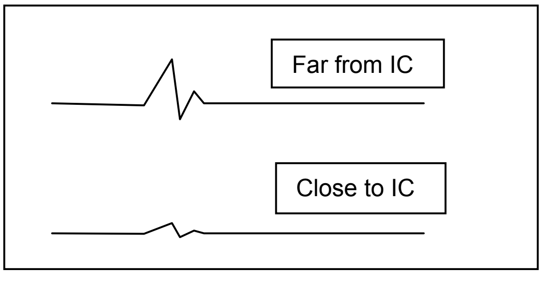


Fig. 8-4. Example to surge waveform by difference of the location on the board of bypass capacitor

8-6. IC destruction by line noise put into VCC (1)

Cause: Pulsed noise of a voltage that is lower than LVSD level was put into VCC line of IC. In this case, IC repeats split-second LVSD operation. Then, IC will have the possibility of causing the overheating destruction.

Phenomenon: The motor doesn't rotate by the overheating destruction of IC.

Countermeasure:
(1) The noise that is put into motor Vcc line is removed by reviewing the power supply circuit(inductance and so on of power cable).
(2) Suppress the noise by mounting the capacitor of enough capacity between Vcc and GND pin of IC. That capacitor should be mounted close to Vcc-GND pin of IC.

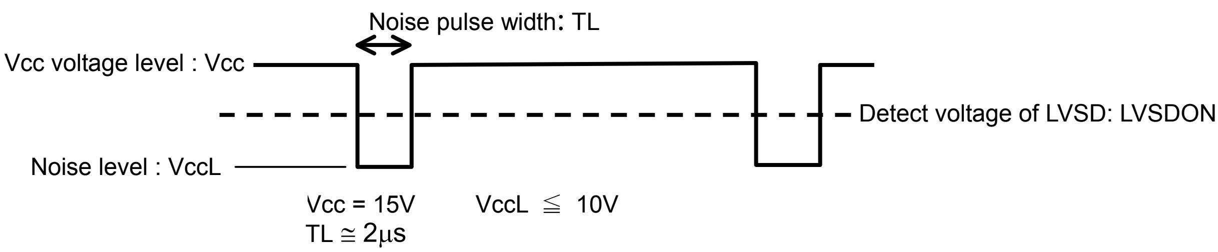


Fig. 8-5. Example to pulsed noise on Vcc at IC destruction

8-7. IC destruction by line noise put into VCC (2)

Cause: The surge voltage that exceeds the maximum ratings of IC that was put into VCC pin of IC.

Phenomenon: The motor doesn't rotate by the over voltage destruction of IC.

Countermeasure:
(1) Mount a bypass capacitor C1 close to pin of IC. It's effective to use a capacitor that has excellent frequency characteristics, such as a ceramic capacitor, as a bypass capacitor. As a guide, ones of around 1μF are recommended (The larger the capacity, the more effective it is.).
(2) It is more effective to mount a surge suppression device such as bypass capacitor C2 close to connector of motor populated board like figure 8-6.

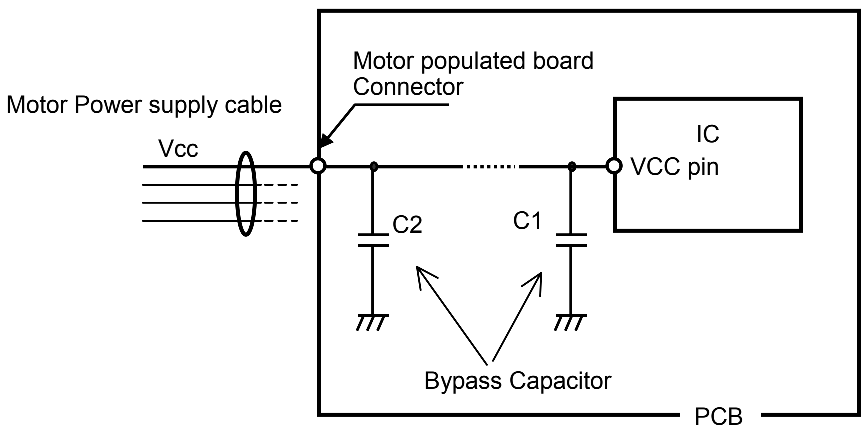


Fig. 8-6. Example to mount surge suppression devices

8-8. IC destruction by relay noise of inspection machine

Cause: A mechanical relay for On-off control of electric connection between IC and inspection machine was used. Surge was generated when it was on-off, and it was put into IC.

Phenomenon: The motor doesn't rotate by the over voltage destruction of IC.

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

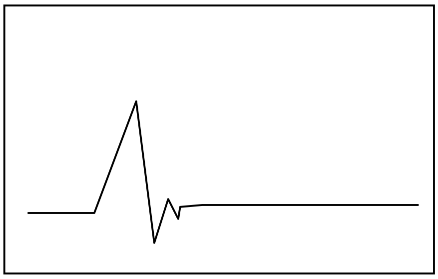


Fig. 8-7 Example to surge waveform when mechanical relay is used

8-9. Motor failure (missing phase output)

Cause: The motor has missing phase output that was shipped to the set maker.

Phenomenon: The motor might start depend on the position of the rotor 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 the torque pulsation in order to detect the missing phase output of motor.

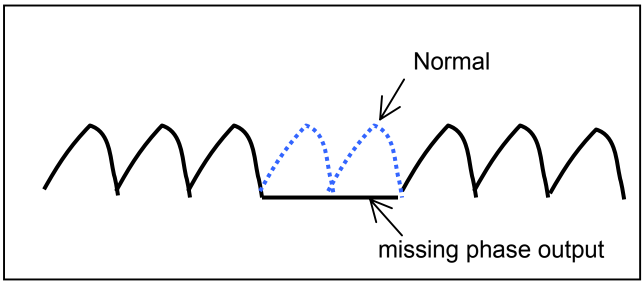


Fig. 8-8 Example to Motor current waveform of the motor that has missing phase output