Six-input Type Single Chip Inverter IC

Application Guide

【Rev 2】

Applicable models

| AC 200V system | ECN30620 | ECN30622 |

Hitachi Power Semiconductor Device, Ltd.
1. Outline
1.1 System Configuration

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

![Single-chip inverter IC](image)

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

(a) SOP26  (b) DIP26  (c) DIP26N

![Package](image)

**FIGURE 1.1.1.2 Package**

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

![System Configuration](image)

**FIGURE 1.1.2.1 Example of System Configuration**
1.2 Block Diagram of Inverter IC

Fig. 1.2.1 shows the block diagram of the 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.
   - If the maximum ratings are exceeded even momentarily there is a possibility of degradation or destruction. The maximum ratings should never be exceeded under any conditions of use.

(2) Electrical Characteristics
   - It specifies electrical characteristics of IC and describes minimum, typical, 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) Pin Assignments and Pin Definitions
   - It describes pin assignments, pin names and pin definitions.

(6) Inspection
   - It describes inspection conditions.

(7) Important Notice Precautions
   - It describes notes of the static electricity, the maximum rating, handling and so on.

(8) Appendix and Reference Data
   - It describes SOA, deratings and package dimensions and so on.
### 3. Specifications

#### 3.1 IC Types

Table 3.1.1 shows the maximum ratings, package type, and mounting method of each type of the IC.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Maximum ratings</th>
<th>Package type</th>
<th>Mounting method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ECN30620F</td>
<td>Output device breakdown voltage : 600V</td>
<td>SOP26</td>
<td>Surface mount</td>
</tr>
<tr>
<td>2</td>
<td>ECN30620P</td>
<td>Output current (Pulse) : 2A</td>
<td>DIP26</td>
<td>Pin insertion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Output current (DC) : 1A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>ECN30620PN</td>
<td></td>
<td>DIP26N</td>
<td>Pin insertion</td>
</tr>
<tr>
<td>4</td>
<td>ECN30622F</td>
<td>Output device breakdown voltage : 600V</td>
<td>SOP26</td>
<td>Surface mount</td>
</tr>
<tr>
<td>5</td>
<td>ECN30622P</td>
<td>Output current (Pulse) : 3A</td>
<td>DIP26</td>
<td>Pin insertion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Output current (DC) : 2A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>ECN30622PN</td>
<td></td>
<td>DIP26N</td>
<td>Pin insertion</td>
</tr>
</tbody>
</table>
3.2 Pin Locations

Table 3.2.1 shows pin locations.

**TABLE 3.2.1 Pin Locations**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Pin name</th>
<th>Description</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CL</td>
<td>For the charge pump circuit</td>
<td>Note 1</td>
</tr>
<tr>
<td>2</td>
<td>CD</td>
<td>For the charge pump circuit</td>
<td>Note 1</td>
</tr>
<tr>
<td>3</td>
<td>C+</td>
<td>For the charge pump circuit</td>
<td>Note 1</td>
</tr>
<tr>
<td>4</td>
<td>VS</td>
<td>High voltage power supply</td>
<td>Note 1</td>
</tr>
<tr>
<td>5</td>
<td>MW</td>
<td>W-phase output</td>
<td>Note 1</td>
</tr>
<tr>
<td>6</td>
<td>MV</td>
<td>V-phase output</td>
<td>Note 1</td>
</tr>
<tr>
<td>7</td>
<td>MU</td>
<td>U-phase output</td>
<td>Note 1</td>
</tr>
<tr>
<td>8</td>
<td>GHW</td>
<td>Emitter of W-phase bottom arm IGBT and anode of W-phase bottom arm FWD</td>
<td>Note 1</td>
</tr>
<tr>
<td>9</td>
<td>GHV</td>
<td>Emitter of V-phase bottom arm IGBT and anode of V-phase bottom arm FWD</td>
<td>Note 1</td>
</tr>
<tr>
<td>10</td>
<td>GHU</td>
<td>Emitter of U-phase bottom arm IGBT and anode of U-phase bottom arm FWD</td>
<td>Note 1</td>
</tr>
<tr>
<td>11</td>
<td>RS</td>
<td>Input for current limit and over-current protection</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>UB</td>
<td>Input control signal for U-phase bottom arm</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>VB</td>
<td>Input control signal for V-phase bottom arm</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>WB</td>
<td>Input control signal for W-phase bottom arm</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>UT</td>
<td>Input control signal for U-phase top arm</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>VT</td>
<td>Input control signal for V-phase top arm</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>WT</td>
<td>Input control signal for W-phase top arm</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>FU</td>
<td>U-phase back EMF signal output</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>FV</td>
<td>V-phase back EMF signal output</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>FW</td>
<td>W-phase back EMF signal output</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>F</td>
<td>Fault signal output or setting over-current protection reset time</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>CBL</td>
<td>VBL power supply output (5V)</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>CBH</td>
<td>VBH power supply output (7.5V)</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>OC</td>
<td>Setting for current limit function (enable/disable) and over-current protection reset method</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>VCC</td>
<td>15V power supply</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>GL</td>
<td>Ground</td>
<td></td>
</tr>
</tbody>
</table>

Note 1: High voltage pin. The voltage between CD and CL and between C+ and VS are low. Therefore, the distances between these pins are the same as that between the low voltage pins.

Note 2: The tab potential is the same as that of the GL pin.
### 3.3 Pin Function

#### TABLE 3.3.1 Pin Function (1/3)

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

![Figure 3.3.1 Equivalent Circuit around UT, VT, WT, UB, VB, WB Pins](chart.png)
### TABLE 3.3.1 Pin Function (2/3)

<table>
<thead>
<tr>
<th>No.</th>
<th>Pin name</th>
<th>Items</th>
<th>Functions and cautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>8</td>
<td>RS</td>
<td>Input pin for over current detection</td>
<td>• Monitors the voltage of the Rs shunt resistor and detects its over current.</td>
<td>3.5.1 (2) Setting method for current limit and over-current protection</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 3.3.2 Equivalent Circuit around RS Pin](image)

<table>
<thead>
<tr>
<th>No.</th>
<th>Pin name</th>
<th>Items</th>
<th>Functions and cautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>C+</td>
<td>Top arm drive circuit power pin</td>
<td>• Powers the drive circuit for the top arm. • Connect capacitors between C+ and VS and between CD and CL.</td>
<td>3.5.2 Charge pump circuit</td>
<td>High voltage pin</td>
</tr>
</tbody>
</table>

![Figure 3.3.3 Equivalent Circuit around C+, CL, CD Pins](image)

<table>
<thead>
<tr>
<th>No.</th>
<th>Pin name</th>
<th>Items</th>
<th>Functions and cautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>FU, FV, FW</td>
<td>Output pin for back EMF signal</td>
<td>• NMOS open drain output pin. Pull up to CBL or 5V through the external resistor RF* (10kΩ±5% recommended). • Outputs back EMF information of each phase when input signals to the control input pins of each arm are all &quot;L&quot; (UT, VT, WT, UB, VB, WB = L). • Outputs &quot;H&quot; independently when each voltage at the MU, MV and MW pins is VIHE or more. Outputs &quot;L&quot; independently when each voltage at the MU, MV and MW pins is VILE or less.</td>
<td>3.5.5 Back EMF detection circuit</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 3.3.4 Equivalent Circuit around FU, FV, FW Pins](image)
### TABLE 3.3.1 Pin Function (3/3)

<table>
<thead>
<tr>
<th>No.</th>
<th>Pin name</th>
<th>Items</th>
<th>Functions and cautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 11  | OC       | Selection pin for current limit (enable/disable) and reset method for over-current protection | · Selects to enable or disable the current limit and selects reset method for the over-current protection by connecting to one of the GL, CBH and VCC pins.  
· For setting method, see Section 3.5.1 (c) OC Setting Method. | · 3.5.1  
(2) Setting method for current limit and over-current protection |         |

**FIGURE 3.3.5 Equivalent Circuit around OC Pin**

<table>
<thead>
<tr>
<th>No.</th>
<th>Pin name</th>
<th>Items</th>
<th>Functions and cautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 12  | F        | Fault signal output or setting of over-current protection reset time | · NMOS open drain output pin  
· The NMOS turns on only when the over-current protection operates, and in other cases, the NMOS is off.  
· Pull up to the CBL pin or 5V through an external resistor RF. When the OC pin is connected to the GL or CBH pin, recommended RF resistance is 10kΩ±5%. Moreover, to remove switching noise, connect the capacitor CF (0.01μF±10% recommended) between the F pin and GND.  
· When the OC pin is connected to the VCC (15V) pin, recovery time from the over-current protection (Trs) is determined from the external resistance RF and the capacitor CF. When RF=820kΩ and CF=1000pF, the over-current protection recovery time (Trs) is about 1ms. | · 3.5.1  
(2) Setting method for current limit and over-current protection |         |

**FIGURE 3.3.6 Equivalent Circuit around F Pin**
3.4 Markings
The resin surface of the IC is marked by laser.

FIGURE 3.4.1 SOP26 Marking Specifications

FIGURE 3.4.2 DIP26 Marking Specifications

FIGURE 3.4.3 DIP26N Marking Specifications

Mark No. (1) to (7): Model name
Mark No. (8) to (12): Lot number

The lot number consists of the followings.

No. (8): Last one-digit of the year of assembly
No. (9): Month of assembly:
    January: A,  February: B,  March: C,  April: D,  May: E,  June: K,
No. (10) to (12): 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 Precautions for Use

3.5.1 Protection Functions

(1) VCC (15V) low-voltage detection

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

If the detection for VCC (15V) low-voltage operates during motor rotation, Vs power supply voltage may rise due to regenerative electric power. The voltage at the VS pin must not exceed the maximum rating. Particular attention is needed when the capacity between the VS and GND is small, making the voltage more likely to rise.

(2) Setting method for current limit and over-current protection

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

![FIGURE 3.5.1.1 Timing Chart for VCC (15V) Low-voltage Detection (LVSD Operation)]

![FIGURE 3.5.1.2 Example of Current Path of Enabled Current Limit and Over-current Protection]

![FIGURE 3.5.1.3 Example of Reflux Current]
(a) Current Limit Function
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 IGBTs of the top arms are all turned off. When each of the input UT, VT, and WT is "L", this limit operation is individually reset in each phase. Fig. 3.5.1.5 shows a timing chart. In this function, "L" is not outputted to the F pin.

(b) Over-current Protection
When the voltage at the RS pin exceeds the Vref2 (typ. 1.0V) of the internal detection circuit, the IGBTs of the top and bottom arms are all turned off and the F pin output is "L". When this function is not used, connect the F pin to the VCC pin. After the over-current protection operates, by resetting the IC, it returns to a state in which the IGBTs of the top and bottom arms all operate depending on input signals. The reset method is described in Section 3.5.1 (c) OC Setting Method. The IC may turn to a state in which the over-current protection operates immediately after the VCC (15V) power-on. In this case, reset the IC as described in Section 3.5.1 (c) OC Setting Method. Figs. 3.5.1.5, 3.5.1.6, and 3.5.1.7 show timing charts.

(c) OC Setting Method
The settings of the OC pin depend on whether to use the current limit function or not the current limit function and how to reset the over-current protection operation. Connect the OC pin to one of the GL, CBH and VCC (15V) pins based on your preference. Table 3.5.1 shows a setting method of the OC pin. Figs. 3.5.1.5, 3.5.1.6, and 3.5.1.7 show timing charts of the protection function in each setting.

<table>
<thead>
<tr>
<th>Connected pin</th>
<th>Current Limit Function</th>
<th>Method for resetting over-current protection operation</th>
<th>Timing chart</th>
</tr>
</thead>
<tbody>
<tr>
<td>GL</td>
<td>Enable</td>
<td>Holding all inputs “L”</td>
<td>Fig. 3.5.1.5</td>
</tr>
<tr>
<td>CBH</td>
<td>Disable</td>
<td>(Reset after holding &quot;L&quot; for more than the Fault reset input time (Tfirs))</td>
<td>Fig. 3.5.1.6</td>
</tr>
<tr>
<td>VCC (15V)</td>
<td>Disable</td>
<td>Automatically</td>
<td>Fig. 3.5.1.7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Reset after the recovery time (Trs) passes)</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 3.5.1.5 Timing Chart in Case of OC Connected to GL

FIGURE 3.5.1.6 Timing Chart in Case of OC Connected to CBH

FIGURE 3.5.1.7 Timing Chart in Case of OC Connected to VCC (15V)
(d) How to set current values of current limit and over-current protection

The current value of current limit operation $IO_1$ is calculated as follows:

$$IO_1 = \frac{V_{ref1}}{R_s}$$

$V_{ref1}$: Reference voltage for current limitation

$Rs$ : Value of shunt resistor

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

$$IO_2 = \frac{V_{ref2}}{R_s}$$

$V_{ref2}$: Reference voltage for over-current protection

$Rs$ : Value of shunt resistor

In setting current values, you should allow for $V_{ref1}$ and $V_{ref2}$ variances, $Rs$ variance, and the delay ($T_{ref1}$, $T_{ref2}$) between the time the operating condition of the current limit or the over-current protection is satisfied and the time the IGBTs are turned off. Users are requested to observe the output currents (the coil currents of the motor) of the IC and confirm a design margin. Set the shunt resistance so that voltages of the GHU, GHV, and GHW pins are within the specified GH voltage ($V_{gh}$) range in the product specification.

(e) Wiring precautions

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

(3) Over Temperature Protection

When IC temperature exceeds the operating temperature of over temperature protection ($T_{SDON}=$typ.160°C), the IGBTs of the top and bottom arms are all turned off regardless of the input signal. When IC temperature goes down a hysteresis width ($T_{SDHYS}$) from the operating temperature of over temperature protection ($T_{SDON}$), the IC returns to a state in which the IGBTs operate depending on input signals. "L" is not outputted to the F pin in this function operation.

![FIGURE 3.5.1.8 Timing Chart for Over Temperature Protection Operation](image)

(4) Short-circuit Protection

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

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

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

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

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

![Charge Pump Circuit Diagram](image)

3.5.3 Power Supply Sequence

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

(1) Power-on sequence
(2) Power-off sequence
(3) Power-off and reset operation in instantaneous power failure occurrence

3.5.4 VBH Power Supply and VBL Power Supply

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

This circuit constitutes a feedback circuit. To prevent oscillation, connect capacitors CH0 and CL0 to the CBH and CBL pins respectively. The recommended capacity for the CH0 and CL0 are 1.0μF±10%.

The larger the capacities, the more stable the VBH and VBL power supplies. However, setting the capacity figure to an excessive level is not recommended. As a guide, it should be 2μF to 3μF or less.

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

![VBH and VBL Power Supplies Diagram](image)
3.5.5 Back EMF Detection Circuit

When an external force is rotating the motor (free-running) while the inverter stops operating, the back EMF signals are outputted as information on the rotor position. The U-phase back EMF signal, V-phase back EMF signal and W-phase back EMF signal are outputted from the FU, FV and FW pins respectively. Fig. 3.5.5.1 shows a timing chart. A condition to output the back EMF signals is satisfied when the UT, VT, WT, UB, VB and WB pin inputs are all “L”. In the other conditions, you must not use the signals from the FU, FV and FW pins as the information on the rotor position. When motor speed is decreased and the back EMF goes down below the detection level (VILE), the FU, FV and FW pin outputs are “L”. In using this signal, consider motor variance and detection level variance.

![Timing Chart for Motor Output (MU, MV, MW) and FU, FV, FW Pin Signal Output](image)

### FIGURE 3.5.5.1 Timing Chart for Motor Output (MU, MV, MW) and FU, FV, FW Pin Signal Output

3.5.6 Internal Filter Circuit

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

![Internal Filter Circuit Operation](image)

### FIGURE 3.5.6.1 Internal Filter Circuit Operation

3.5.7 Derating

How much to derate a unit from the maximum rating is an important issue to consider for a reliable design. Items to be considered in the system design stage 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 3.5.7.1 specifies the derating standards 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 control within the standard, use other means as necessary, such as selecting a device having higher maximum ratings. Please consult our sales representative in advance.

### TABLE 3.5.7.1 Derating Design Standards

<table>
<thead>
<tr>
<th>Item</th>
<th>Type</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction temperature Tj</td>
<td>110°C maximum</td>
<td>ECN30620F/ECN30620P/ECN30620PN</td>
</tr>
<tr>
<td>Vs power supply voltage</td>
<td>450V maximum</td>
<td>ECN30622F/ECN30622P/ECN30622PN</td>
</tr>
<tr>
<td>Output peak current</td>
<td>0.7A maximum</td>
<td>1.4A maximum</td>
</tr>
</tbody>
</table>
3.6 Handling

3.6.1 Mounting

(1) Insulation between pins

High voltages are applied between the pin numbers specified below. Please apply coating resin or molding treatment as necessary.
- Between pin numbers: 2-3, 4-5, 5-6, 6-7, 7-8

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

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

The tab and the GL pin of the IC are connected in the frame. Set the tab potential to open or the same as that of the GL pin. Each tab of the DIP26 and DIP26N is placed on the top surface of the IC. If the insulation between the tab and the cabinet is insufficient, the IC will not be able to withstand an isolation withstand voltage test in which a high voltage is applied between the external cabinet and the GND. Please insert an insulation sheet or something similar between the IC tab and the external cabinet. The tab of the SOP26 is placed on the bottom surface of the IC (side of the PCB). The wiring lines except the GND on the PCB should not bring into contact with the tab with or without coatings such as a solder resist. In particular, ensure a sufficient distance between the high voltage wiring lines and the tab.

(3) Soldering conditions (For ECN30620F and ECN30622F)

These ICs are lead-free (Pb-free). The recommended reflow soldering condition is shown in Fig. 3.6.1.

![Figure 3.6.1 Recommended Conditions for Infrared Reflow or Air Reflow](image)

(4) Soldering conditions (For ECN30620P, ECN30620PN, ECN30622P and ECN30622PN)

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.

(5) Solder joint reliability

Reliability of solder joints is influenced by soldering conditions, PCB material and foot patterns. Perform adequate evaluations on thermal cycle tests, heat shock tests, and other tests after mounting the IC on a PCB. Special care should be taken if the SOP26 is mounted on a high thermal expansion PCB (such as CEM-3) because the solder joint life could be shortened.
3.6.2 Precautions for mounting heat sink

To radiate heat of the IC, attaching a heat sink to the tab side is effective. When attaching a heat sink, notice the following points.

(1) Heat sink

Inappropriate heat sinks will hinder heat radiation. In addition, adding unnecessary stress will cause characteristic degradation or resin cracks.

Observe the following points regarding heat sinks:

(a) To avoid a heat sink causing convex or concave warping, keep the warp and twisting between screw holes less than 0.05 mm (Fig. 3.6.2.1).

(b) For aluminum, copper, and iron boards, make sure there is no press tension, and always bevel the screw holes.

(c) A contact surface with the IC must be ground flat. (Average surface roughness Ra shall be 3.2 to 6.3 μm.)

(d) Prevent and remove any shaved particles between the IC tab and the heat sink.

(e) Make sure the screw hole gaps match those of the IC (typ.29.5mm). If they are too wide or too narrow, resin cracks may occur.

![FIGURE 3.6.2.1 Heat Sink Warping](image1)

(2) Screws

The screws that attach the heat sink to the device are generally classified into small screws and tapping screws. Observe the following precautions when using these types of screws:

(a) Use small bind and truss screws that have heads which meet JIS-B1101 standards.

(b) Avoid using countersink screws, which add abnormal stress to devices (Fig. 3.6.2.2).

(c) The use of tapping screws increases tightening torque. Therefore, there is a possibility that desired contact resistance cannot be obtained. When using tapping screws, prevent tightening torque from becoming too large. For tightening torque, see Section 3.6.2 (3).

(d) Use tapping screws that are thinner than the IC attachment hole diameter. If thicker screws are used, tapping the IC attachment holes or heat sinks can promote failures.

![FIGURE 3.6.2.2 Classification of Recommended Screws and Those That Must Not Be Used](image2)
(3) Tightening torque
Insufficient tightening torque invites an increase in heat resistance, and excessive torque invites such failures as warping of the device, die destruction, and connector lead breakage. Please use the tightening torque value 0.39 to 0.59N·m (4 to 6 kg·cm). (Attached screw: M3)

Tightening sequence is shown as Fig 3.6.2.3.

(a) Tightening sequence
   - Temporary tightening: 1 -> 2
   - Final tightening: 1 -> 2

Torque for temporary tightening should be 20 - 30 % of maximum torque.

(b) Flat washer should be put in.
   IC might get crack without the washer.

FIGURE 3.6.2.3 Typical Tightening Sequence

(4) Silicone grease
A thin layer of silicon grease is generally applied evenly over the contact surface between the IC and the heat sink to maximize heat conduction. Avoid high-viscosity or non-homogeneous greases because forces that develop as the package is tightened to the heat sink may cause package cracking. Avoid application of excessive amounts of grease for the same reason.

Example of silicone grease is shown in Table 3.6.2.1. We recommend the silicone grease shown below or comparable one.

<table>
<thead>
<tr>
<th>No.</th>
<th>Product name</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>G-747</td>
<td>Shin-Etsu Chemical Co., Ltd</td>
</tr>
</tbody>
</table>
4. Recommended Circuit

4.1 Standard External Parts

TABLE 4.1.1 shows recommended external parts.

<table>
<thead>
<tr>
<th>TABLE 4.1.1 Standard External Parts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parts</strong></td>
</tr>
<tr>
<td>CH0, CL0</td>
</tr>
<tr>
<td>C1, C2</td>
</tr>
<tr>
<td>Rs</td>
</tr>
<tr>
<td>RFU, RFV, RFW</td>
</tr>
<tr>
<td>CF</td>
</tr>
<tr>
<td>RF</td>
</tr>
<tr>
<td>CF</td>
</tr>
<tr>
<td>RF</td>
</tr>
</tbody>
</table>

Note 1. Caution in selecting parts of charge pump circuit

When capacity of a capacitor is small, the voltage between the C+ pin and the VS pin drops because of the internal dissipation current from the C+ pin of the IC.

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

The voltage impressed to the capacitor is VCC in operation. Therefore, the withstand voltage of the capacitors must be the VCC voltage or more. When using external parts whose values are different from the standard values, pay close attention.
Note 2. Caution in setting Rs resistor
The current values of current limit and over-current protection are set using Rs resistance value.
The current value of current limit operation IO_1 can be calculated as follows.
\[ IO_1 = \frac{V_{\text{ref1}}}{Rs} \]
Vref1: Reference voltage for current limitation
Rs : Value of shunt resistor

The current value of over-current protection operation IO_2 can be calculated as follows.
\[ IO_2 = \frac{V_{\text{ref2}}}{Rs} \]
Vref2: Reference voltage for over-current protection
Rs : Value of shunt resistor

Determine the shunt resistance Rs with reference to the above and the Production Specification.
Make the wiring between the shunt resistor Rs and the RS pin and between the RS pin and the GH* pins as short as possible.
The RS pin is connected to built-in CR filters. The CR filter for the current limit circuit has a time constant of 1.2 μs. The CR filter for the over-current protection circuit has a time constant of 0.6 μs.
It is effective to add the CR filter externally if the current limit function or the over-current protection operates erroneously because of the effect of a noise and the like. However, note that adding the external CR filter increases the delay between the time the operating condition of the current limit or the over-current protection is satisfied and the time the IGBTs are turned off. It is recommended that a time constant of the externally added CR filter is 0.5 μs or less.

4.2 Other External Parts
It is recommended to mount the parts shown in Table 4.1.2 to stabilize the power supply and protect the IC from voltage surge.
Adjust the settings of parts in accordance with the usage conditions. Moreover, mount each of the parts close to the pins of the IC to achieve the effect of the voltage surge absorption.

<table>
<thead>
<tr>
<th>No.</th>
<th>Parts</th>
<th>Purpose</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cvcc1</td>
<td>for VCC. High frequency noise suppressing</td>
<td>Ceramic capacitor with good frequency response etc. About 1μF</td>
</tr>
<tr>
<td>2</td>
<td>Cvcc2</td>
<td>for VCC. VCC power supply smoothing</td>
<td>Electrolytic capacitor etc. About 1μF</td>
</tr>
<tr>
<td>3</td>
<td>ZDvcc</td>
<td>for VCC. Over voltage suppressing</td>
<td>Zener diode with good frequency response</td>
</tr>
<tr>
<td>4</td>
<td>Cvs1</td>
<td>for VS. High frequency noise suppressing</td>
<td>Ceramic capacitor with good frequency response etc. About 33nF/630V</td>
</tr>
<tr>
<td>5</td>
<td>Cvs2</td>
<td>for VS. Vs power supply smoothing</td>
<td>Electrolytic capacitor etc. About 1μF/630V</td>
</tr>
<tr>
<td>6</td>
<td>ZDvs</td>
<td>for VS. Over voltage suppressing</td>
<td>Zener diode with good frequency response</td>
</tr>
</tbody>
</table>
5. Failure Examples (Assumptions)

5.1 IC Destruction by an External Surge Inputted to VS and VCC (15V) Lines (Case 1)

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

5.2 IC Destruction by an External Surge Inputted to VS and VCC (15V) Lines (Case 2)

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

![FIGURE 5.2.1 Example of Surge Waveforms for Different Bypass Capacitor Capacities](image)

5.3 IC Destruction by an External Surge Inputted to VS and VCC (15V) Lines (Case 3)

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

![FIGURE 5.3.1 Example of Surge Waveform for Different Bypass Capacitor Locations on the Board](image)
5.4 IC Destruction by an External Surge Inputted to VCC (15V) Line

- **Cause**: Pulsed noise of a voltage that is lower than the LVSD level (LVSDON) enters the VCC (15V) line. In this case, the IC repeats split-second LVSD operation. Then, the IC will have the possibility of causing the overheating destruction.

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

- **Countermeasure**:
  ① Remove the noise that enters the motor VCC line by reviewing the power supply circuit (inductance of power cable, noise filter circuit or the like).
  ② Connect a capacitor having sufficient capacity at a short distance between the VCC pin and GL pin of the IC.

[![Diagram](VCC voltage level: VCC) (Noise pulse width: TL) (Detection voltage of LVSD)](VCC=15V VCCL=10V TL= about 2μs)

**FIGURE 5.4.1 Example of Pulsed Noise on VCC at IC Destruction**

5.5 IC Destruction by VCC (15V) Line Noise

- **Cause**: Surge voltage that exceeded the maximum rating for the IC enters the VCC (15V) pin.

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

- **Countermeasure**:
  ① Mount a bypass capacitor C1 close to the pin of the IC. For maximum effectiveness, use a capacitor that has excellent frequency characteristics, such as a ceramic capacitor. As a guide, capacitors of around 1μF are recommended.
  ② It is more effective to mount a surge suppression device such as bypass capacitor C2 close to the connector of a motor control circuit board as shown in Fig. 5.5.1.

[![Diagram](Motor power supply cable VCC (15V))](Motor control circuit board connector) (IC VCC pin) (Bypass capacitor) (PCB)

**FIGURE 5.5.1 Example of Mounted Surge Suppression Devices**
5.6 IC Destruction by Noise at Vs Power Supply Power-on

- **Cause**: Surge voltage that exceeded the maximum rating for the IC enters the VS pin because the voltage rises suddenly when the Vs power supply is powered on.
- **Phenomenon**: The motor does not rotate because the over-voltage destroys the IC.
- **Countermeasure**: Mount a power supply smoothing capacitor close to the VS pin of the IC. An electrolytic capacitor is generally used as a power supply smoothing capacitor.

![Diagram of IC Destruction by Noise at Vs Power Supply Power-on](image)

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

5.7 IC Destruction by Inspection Machine Relay Noise

- **Cause**: A mechanical relay for on-off control of the electric connection between the IC and an inspection machine generates a surge that enters the IC.
- **Phenomenon**: The motor does not rotate because the over-voltage destroys the IC.
- **Countermeasure**: Use a mercury relay, etc. Confirm a surge generated when the relay is on-off is less than the maximum rated value.

![Surge Waveform When Mechanical Relay is Used](image)

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

5.8 Motor Failure (Missing Phase Output)

- **Cause**: The motor with missing phase has been out on the market.
- **Phenomenon**: The motor might start depending on the rotor position when starting even if the motor has missing phase output. Therefore, the missing phase output of motor cannot be detected by the motor rotation test.
- **Countermeasure**: Monitor the motor current or oscillation in order to detect the missing phase output of motor.

![Example of Motor Current Waveform in Phase Missing Condition](image)

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

6.1 Countermeasure against Electrical Static Discharge (ESD)

Customers are advised to follow the procedures below to protect semiconductor devices from Electrical Static Discharge (ESD).

- The material of the container or any other device used to carry semiconductor devices should be free from ESD, which can be caused by vibration during transportation. Use of electrically conductive containers is recommended as an effective countermeasure.
- Everything that touches semiconductor devices, such as the work platform, machine, measuring equipment, and test equipment, should be grounded.
- Workers should be high-impedance grounded (around 100kΩ to 1MΩ) while working with the semiconductor, to avoid damaging the inverter IC by ESD.
- Friction with other materials, such as high polymers, should be avoided.
- When a PCB with a mounted inverter IC is carried, ensure that electric potential is kept on the same level by the short-circuit terminals and that vibration or friction does not occur.
- The humidity at assembly line to mount the inverter IC on circuit boards should be kept around 45 to 75 percents using humidifiers or the like. If the humidity cannot be controlled sufficiently, it is effective to use neutralization apparatuses such as ionizers.

6.2 Storage Conditions (For ECN30620F, ECN30622F)

The following conditions are applied to ECN30620F and ECN30622F.

1. Before opening the moisture prevention bag (aluminum laminate bag)
   - Temperature: 5 to 35℃
   - Humidity: 85%RH or lower
   - Period: less than 2 years

2. After opening the moisture prevention bag (aluminum laminate bag)
   - Temperature: 5℃ to 30℃
   - Humidity: 70%RH or lower
   - Period: less than 1 week (from opening the bag to reflow soldering)

3. Temporal storage after opening the moisture prevention bag
   - When ICs are stored temporarily after opening the bag they should be returned into the bag with desiccant within 10 minutes. Then, the open side of the bag should be folded under twice, and closed with adhesive tape. And it should be kept in the following conditions.
     - Temperature: 5℃ to 35℃
     - Humidity: 85%RH or lower
     - Period: less than 1 month

※ When the period of (1) to (3) is expected to expire, it is recommended to store the IC in a drying furnace (30%RH or lower) at ordinary temperature.

4. Baking process
   - When the period of (1) to (3) has expired, the IC should be baked in accordance with the following conditions. (However, when the IC is stored in a drying furnace (30%RH or lower) at ordinary temperature, there is no need to bake.)
   - Do not bake the tape and the reel of the taping package because they are not heat resistant.
   - Transfer the IC to a heat resistant container prior to baking.
     - Temperature: 125±5℃
     - Period: 16 to 24 hours
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