VSP-input Type Single Chip Inverter IC

Application Notes

【Rev 0】

Applicable models

<table>
<thead>
<tr>
<th>System</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC100V</td>
<td>ECN30110</td>
</tr>
<tr>
<td>AC200V</td>
<td>ECN30210</td>
</tr>
</tbody>
</table>

Hitachi Power Semiconductor Device, Ltd.
1. Outline

1.1 System Configuration

1.1.1 Single Chip Inverter ICs

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

![Image of Motor with Built-in Control Board](Can be incorporated in motors)

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

1.1.2 Composition of Inverter IC

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

![Diagram of Basic Configuration of an Inverter IC](Can be incorporated in motors)

**FIGURE 1.1.2.1 Example of Basic Configuration of an Inverter IC**
1.2 Block Diagram of Inverter IC

Figure 1.2.1 shows a block diagram of the ECN30110 and ECN30210.
- Hall elements applicable
- Built-in charge pump diodes
- Built-in FG (Frequency Generator) circuits for monitoring motor speed, three pulses and one pulse per cycle
- Various protection functions (current limit function, over-current protection function, Vcc low-voltage detection function, over temperature protection function, motor lock protection function)

※Inside of bold line shows the inverter IC (ECN30110, ECN30210)

FIGURE 1.2.1 Block Diagram of Inverter IC

2. Content of Specifications

The following items have been described in the specifications.

(1) Maximum ratings
- It describes direct conditions (electric, thermal use conditions) leading to IC destruction and so on. And the safety operating range with operating conditions is shown by minimum or maximum value.
- In a case the specified values shown in each item are exceeded, products may be damaged or destroyed even for a moment. These specified values should never be exceeded under any operating conditions.

(2) Electrical characteristics
- It provides for electric characteristics of the IC, and describes minimum, standard, and maximum.

(3) Function and operation
- It describes Truth Table, Timing Chart, Protection Function and so on.

(4) Standard application
- It describes circuit examples and external parts to operate IC.

(5) 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 ratings, package types, and mounting types of the ICs.

<table>
<thead>
<tr>
<th>No.</th>
<th>Type</th>
<th>Maximum ratings</th>
<th>Package type</th>
<th>Mounting type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>ECN30110F</td>
<td>Output device breakdown voltage: 250V</td>
<td>SOP26</td>
<td>Surface mount type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Output current (Pulse): 1.4A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Output current (DC): 1.0A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>ECN30110P</td>
<td></td>
<td>DIP26</td>
<td>Pin insertion type</td>
</tr>
<tr>
<td>3</td>
<td>ECN30210F</td>
<td>Output device breakdown voltage: 600V</td>
<td>SOP26</td>
<td>Surface mount type</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Output current (Pulse): 1.5A</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Output current (DC): 0.7A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>ECN30210P</td>
<td></td>
<td>DIP26</td>
<td>Pin insertion type</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 No.</th>
<th>Symbol</th>
<th>Pin functions</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>GH</td>
<td>Emitters of bottom arm IGBTs and anodes of bottom arm FWDs (Connected to a shunt resistor)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>RS</td>
<td>Input for current limit and over-current protection</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>FG2</td>
<td>Output for motor rotational speed monitor (one pulse / 360 electrical degrees)</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>FG1</td>
<td>Output for motor rotational speed monitor (three pulses / 360 electrical degrees)</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>HUN</td>
<td>U phase Hall signal minus input</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>HUP</td>
<td>U phase Hall signal plus input</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>HVN</td>
<td>V phase Hall signal minus input</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>HVP</td>
<td>V phase Hall signal plus input</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>HWN</td>
<td>W phase Hall signal minus input</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>HWP</td>
<td>W phase Hall signal plus input</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>CML</td>
<td>For motor lock protection</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>VTR</td>
<td>Connect a resistor to set the PWM frequency</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>CR</td>
<td>Connect a resistor and a capacitor to set the PWM frequency</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>HA</td>
<td>Output for Vcc standby function</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>CS</td>
<td>For over-current protection</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>CB</td>
<td>VB power supply output</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>VSP</td>
<td>Analog speed command signal input</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 those between low voltage pins.

Note 2: The voltage at exposed tap is the same as GL pin.
### 3.3 Functions of Pins

#### TABLE 3.3.1 List of Pins and Functions (1/4)

<table>
<thead>
<tr>
<th>No.</th>
<th>Pin</th>
<th>Items</th>
<th>Functions and Precautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 1   | VCC | Analog / Logic power supply | - Powers the drive circuits for the top and bottom arms, the charge pump circuit, the built-in VB supply circuit, and others.  
- Determine the capacity of the power supply for Vcc (15V) allowing for a margin by adding the standby current ICC and the current taken out of CB and HA pins. | 3.5.1 (1) Vcc low-voltage detection  
3.5.3 Power on/off sequence  
4.3 to 4.8 Inverter IC destruction by surge or noise | - |
| 2   | VS  | IGBT power pin | - Connected to the collector of the top arm IGBT. | 3.5.3 Power on/off sequence  
4.3 to 4.6 Inverter IC destruction by surge | High voltage pin |
| 3   | CB  | VB power supply output | - Outputs a voltage (typ. 7.5V) generated in the built-in VB power supply.  
- VB supply powers the IC internal circuits (input buffer, over current protection and others) and can be used as a power supply for external circuits such as Hall elements and so on.  
- Connect an oscillation prevention capacitor C0 (1.0μF±10% recommended) to the CB pin. | 3.5.4 VB power supply | |
| 4   | GL  | Analog / Logic ground | - It is the ground pin for Vcc (15V) and VB power lines. | - | - |
| 5   | GH  | IGBT emitter pin | - The GH pin is connected to the emitters of U, V and W-phase bottom arm IGBTs.  
- The GH pin is connected to a shunt resistor Rs to perform current limit and over-current protection.  
- Make the wiring of the shunt resistor Rs as short as possible.  
- If the wiring has high resistance or inductance, the emitter potential of the IGBT changes, perhaps resulting in the IGBT malfunctioning. | 3.5.1 (2) Current limit  
(3) Over-current protection | |
| 6   | MU  | Inverter output pin | - These are outputs of a three-phase bridge consisting of six IGBTs and free wheel diodes. | - | High voltage pin |
|     | MV  | | | | |
|     | MW  | | | | |
| 7   | RS  | For current limit and over-current protection | - Monitors the voltage of the Rs shunt resistor using the RS pin and detects over current status.  
- When the over-current protection is used, connect an external capacitor CF and an external resistor RF to the CS pin. When not used, connect the CS pin to the CB pin. | 3.5.1 (2) Current limit  
(3) Over-current protection | |

![FIGURE 3.3.1 Equivalent Circuit around RS, CS Pins]
### TABLE 3.3.1 List of Pins and Functions (2/4)

<table>
<thead>
<tr>
<th>No.</th>
<th>Pin</th>
<th>Items</th>
<th>Functions and Precautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
</table>
| 8   | HUP     | Hall signal input                    | • The potential difference between HUP and HUN, HVP and HVN, HWP and HWN decides internal logic.  
• The maximum input voltage is VB+0.5V.  
• If the IC malfunctions due to a noise, install a capacitor. The influence of noise can be found out by monitoring FG1 signal. |                                 | • Product Specification  
Truth table  
Timing chart | |
|     | HUN     |                                       |                                                                                        |                                 |                              |
|     | HVP     |                                       |                                                                                        |                                 |                              |
|     | HVN     |                                       |                                                                                        |                                 |                              |
|     | HWP     |                                       |                                                                                        |                                 |                              |
|     | HWN     |                                       |                                                                                        |                                 |                              |
| 9   | C+      | Top arm drive circuit power pin,     | • Powers the drive circuit for the top arm.  
• Connect a capacitor between C+ and VS, CD and CL. |olas.  
• 3.5.2 Charge pump circuit | High voltage pin |
|     | CL      | Charge pump circuit pin              |                                                                                        |                                 |                              |
|     | CD      |                                       |                                                                                        |                                 |                              |
| 10  | FG1     | Output for motor rotational speed    | • Output pulses in synchronization with the input signals of the HUP, HUN, HVP, HVN, HWP and HWN.  
• Motor rotation speed can be monitored by measuring the frequency of output pulse.  
• FG1 output pulse is three pulses per cycle.  
• FG2 output pulse is one pulse per cycle. |                                | • 4.2 Electrical destruction of FG1 and FG2 pins caused by external surge  
• Product Specification  
Truth table  
Timing chart |
|     | FG2     | monitor                              |                                                                                        |                                 |                              |
### TABLE 3.3.1 List of Pins and Functions (3/4)

<table>
<thead>
<tr>
<th>No.</th>
<th>Pin</th>
<th>Items</th>
<th>Functions and Precautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>VSP</td>
<td>Analog speed command signal input</td>
<td>• Input a speed command signal to generate a PWM signal.&lt;br&gt;• If a noise is detected, install a resistor and/or capacitor.</td>
<td>• 3.5.3 Power on/off sequence&lt;br&gt;• 3.5.5 PWM operation&lt;br&gt;• 3.5.6 All IGBT shutoff function&lt;br&gt;• 4.1 Electrical destruction of VSP pin caused by external surge</td>
<td></td>
</tr>
</tbody>
</table>

![FIGURE 3.3.5 Equivalent Circuit around VSP Pin](image1)

| 12  | CR  | PWM frequency setting pin | • Externally connected resistor and capacitor are used to determine the PWM frequency (internal clock).<br>• The PWM frequency is approximated by the following equation.<br>\( f \approx \frac{0.494}{C \times R} \) (Hz) | • 3.5.5 PWM operation | |

![FIGURE 3.3.6 Equivalent Circuit around CR, VTR Pins](image2)
<table>
<thead>
<tr>
<th>No.</th>
<th>Pin</th>
<th>Items</th>
<th>Functions and Precautions</th>
<th>Related items</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>CML</td>
<td>For motor lock protection function</td>
<td>• When the motor lock protection function is used, connect an external capacitor CM. When not used, connect this pin to the GL pin.</td>
<td>• 3.5.1 (4) Motor lock protection</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>HA</td>
<td>Output pin for Vcc standby function</td>
<td>• When the Vcc standby function is used, use this pin as a power supply for the Hall elements. When not used, connect this pin to the CB pin or do not connect anything to this pin.</td>
<td>• 3.5.7 Vcc standby function</td>
<td></td>
</tr>
</tbody>
</table>

**FIGURE 3.3.7 Equivalent Circuit around CML Pin**

**FIGURE 3.3.8 Equivalent Circuit around HA Pin**
3.4 Markings

The resin surface of the IC is marked by laser.

![Figure 3.4.1 SOP26 Marking Specifications](image1)

![Figure 3.4.2 DIP26 Marking Specifications](image2)

Mark No. (1) to (6): Model name
Mark No. (7) to (11): Lot number

The lot number consists of the followings.

No. (7): Last one-digit of the year of assembly
No. (8): Month of assembly:
January: A, February: B, March: C, April: D, May: E, June: K,
No. (9) to (11): Quality control number
Represented with letters from “A” to “Z” except “I” and “O”, numbers from “0” to “9”, or blank.
3.5 Functions and Operational Precautions

3.5.1 Protection Function

(1) Vcc low-voltage detection

Hitachi Power Semiconductor Device calls the Vcc (15V) low-voltage detection “LVSD”. When the Vcc (15V) voltage drops below the LVSD operating voltage (LVSDON), all IGBTs (top and bottom arms) are turned off regardless of the input signals. This function has hysteresis. When the Vcc voltage goes up again, the system returns to a state in which the output IGBTs operate depending on the input signals, at a level equal to or exceeding the LVSD recovery voltage (LVSDOFF).

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

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

(2) Current limit

(a) Operation

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

FIGURE 3.5.1.2 Equivalent Circuit of Current Limit Circuit and Example of Current of Shunt Resistor
(b) How to set up
The current limit setting IO is calculated as follows;
\[ IO = \frac{V_{ref1}}{R_s} \]

Where
- \( V_{ref1} \): Reference voltage for current limit
- \( R_s \): Resistance of shunt resistor

In setting a current limit, allow for \( V_{ref1} \) variance, \( R_s \) resistance variance, and the delay time from current limit detection to IGBT turn-off. Observe the output currents of the IC (the coil currents of the motor) and confirm a design margin. This function is not effective for currents that do not flow forward (direction to the GL pin) through the shunt resistor, such as reflux current and power regenerative current (see Figs. 3.5.1.4 and 3.5.1.5).
(3) Over-current protection

(a) Operation

Figure 3.5.1.6 shows an equivalent circuit of the over-current protection circuit. Figure 3.5.1.7 shows a timing chart for the over-current protection operation.

When the voltage at the RS pin exceeds the Vref2 (typ. 1.0V), the M1 is turned on, and the capacitor CF is discharged. When the voltage at the CS pin drops below the threshold voltage Vth1 of the Schmitt circuit, the IGBTs of the top and bottom arms are all turned off. When the IGBTs are turned off, and the voltage at the RS pin drops below the Vref2, the M1 is turned off, and the capacitor CF is charged through the resistor RF. When the the voltage at the CS pin exceeds the threshold voltage Vth2 of the Schmitt circuit, the IC returns to a state in which the IGBTs operate.

(b) Notice

Recommended constants of the external parts are CF=470pF and RF=2MΩ. If these constants are changed, the delay time may increase, or the heat generation may increase due to a reduction in recovery time. Mount the capacitor CF as close to the IC as possible so as not to be affected by noise. If the voltage at the CS pin is measured with a measuring instrument such as an oscilloscope (in evaluation, etc.) recovery voltage may change because of the influence of the current flowing through a measuring instrument. When the IGBTs of the top and bottom arms are all turned off by operation of this protection or other function during motor driving, the power supply voltage may rise as a result of a regenerative current flow. The power supply voltage must not exceed the maximum rating (ECN30110: 250V, ECN30210: 600V).

![FIGURE 3.5.1.6 Equivalent Circuit of Over-current Protection Circuit](image1)

![FIGURE 3.5.1.7 Timing Chart for Over-current Protection Operation](image2)
(4) Motor lock protection

(a) Operation

Figures 3.5.1.8 shows an equivalent circuit of the motor lock protection circuit. Figure 3.5.1.9 shows a timing chart of the motor lock protection function. The motor lock protection detects a lock state of the motor from a cycle of the FG1 signal.

- Period I: While the motor is rotating, the SW1 is turned on, and the CM is charged. The M1 is turned on, and the CM is discharged at the rising edge of the FG1. (These operations are repeated while the motor is rotating.)
- Period II: When the motor becomes in a lock state, and the voltage reaches the Vth2, the motor lock state is detected, and the IGBTs of the top and bottom arms are all turned off.
- Period III: When the motor lock state is detected, the SW1 is turned off, and the SW2 is turned on, and the CM is discharged. When the voltage goes down to the Vth1, the IC returns to a state in which the IGBTs operate.
- Period IV: The SW1 is turned on, and the SW2 is turned off, causing the CM to be charged. If the voltage goes up to the Vth2, the motor lock state is detected again. (In the motor lock state, the operations of the Periods III and IV are repeated.)
- Period V: When the motor becomes in the motor rotating state, the M1 is turned on at the rising edge of the FG1, and the CM is discharged.

Regarding information on using this function such as the method for setting the operation and recovery time, see Section 2.4.8 in the Product Specification.

(b) Notice

Mount the capacitor CM as close to the IC as possible so as not to be affected by noise. If the voltage at the CML pin is measured with a measuring instrument such as an oscilloscope, for example, in evaluation, operation and recovery time may change because of the influence of the current flowing through a measuring instrument.
(5) Over temperature protection

Figure 3.5.1.10 shows a timing chart for the over temperature protection operation. Hitachi Power Semiconductor Device calls the over temperature protection “TSD”. When the IC temperature reaches or exceeds the operating temperature of over temperature protection (TSDON = typ. 170°C), the IGBTs of the top and bottom arms are all turned off regardless of the input signals. When the IC temperature goes down to the recovery temperature of the over temperature protection (TSDOFF = typ. 145°C), the IC returns to a state in which the IGBTs operate according to input signals.

![FIGURE 3.5.1.10 Timing Chart for Over Temperature Protection Operation](image)

3.5.2 Charge Pump Circuit

3.5.2.1 Operation of Charge Pump Circuit

Figure 3.5.2.1.1 shows a block diagram of the charge pump circuit. When 15V is inputted to the VCC pin, SW1 and SW2 alternately turn on and off.

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

These operations 1 and 2 are repeated with the frequency of the internal clock, and the charge is given to capacitor C2. Capacitor C2 constitutes a power supply for the drive circuit for the top arm.

![FIGURE 3.5.2.1.1 Charge Pump Circuit](image)
3.5.3 Power On/Off Sequence

(1) ECN30110
Current of the IGBT is not saturated regardless of the power on/off sequence of the Vcc power supply, Vs power supply, and Vsp voltage. However, if the motor lock protection is enabled and Vs is powered on after the Vcc and Vsp power-on, the start-up may be delayed by the motor lock protection operation.

(2) ECN30210
When the output pin current is 1A or less, current of the IGBT is not saturated regardless of the power on/off sequence of the Vcc power supply, Vs power supply, and Vsp voltage. However, if the motor lock protection is enabled and Vs is powered on after the Vcc and Vsp power-on, the start-up may be delayed by the motor lock protection operation.

When the output pin current is no less than 1A, the following sequences are recommended.

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

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

<table>
<thead>
<tr>
<th>TABLE 3.5.3.1 Power On Sequence</th>
<th>TABLE 3.5.3.2 Power Off Sequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>①</td>
</tr>
<tr>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>1</td>
<td>Vcc</td>
</tr>
<tr>
<td>2</td>
<td>Vcc</td>
</tr>
<tr>
<td>3</td>
<td>Vs</td>
</tr>
<tr>
<td>4</td>
<td>Vs</td>
</tr>
<tr>
<td>5</td>
<td>Vsp</td>
</tr>
<tr>
<td>6</td>
<td>Vsp</td>
</tr>
</tbody>
</table>

3.5.4 VB Power Supply

The VB voltage (typ. 7.5V) is generated from the Vcc (15V) power supply and outputted from the CB pin. When the voltage at the VSP pin is higher than the all off operating voltage (typ. 1.23V), the VB voltage is also outputted from the HA pin through the internal device. The VB power is supplied to the IC internal circuits such as the over current protection circuit.

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

![Figure 3.5.4.1 Equivalent circuit for the VB power supply](image-url)
3.5.5 PWM Operation

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

PWM switching is conducted by the bottom arms. Figure 3.5.5.2 shows the timing chart of PWM operation.

![PWM Duty vs VSP Input Voltage](image)

**FIGURE 3.5.5.1 Relation between VSP Input Voltage and PWM Duty**

![Timing Chart of PWM Operation](image)

**FIGURE 3.5.5.2 Timing Chart of PWM Operation**

3.5.6 All IGBT Shutoff Function

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

<table>
<thead>
<tr>
<th>VSP input voltage</th>
<th>Motor drive state</th>
<th>Top arm IGBTs</th>
<th>Bottom arm IGBTs</th>
</tr>
</thead>
<tbody>
<tr>
<td>0V ≤ VSP &lt; Voff</td>
<td>Stop</td>
<td>All off</td>
<td>All off</td>
</tr>
<tr>
<td>Voff ≤ VSP &lt; VSAWL</td>
<td>Based on Hall signal inputs</td>
<td>All off</td>
<td></td>
</tr>
<tr>
<td>VSAWL ≤ VSP</td>
<td>Drive</td>
<td>Based on Hall signal inputs</td>
<td>Based on Hall signal inputs</td>
</tr>
</tbody>
</table>

**TABLE 3.5.6.1 State of Output IGBTs with Regard to VSP Input Voltage**
3.5.7 Vcc Standby Function

When the input voltage at the VSP pin is more than the all off operating voltage (typ. 1.23V), the internal element is turned on, and the current is applied from the HA pin to the Hall elements.

When the input voltage at the VSP pin is less than the all off operating voltage, the internal element is turned off, and the current to the Hall elements is shut off to reduce standby power consumption from Vcc power supply.

When the current to the Hall elements is shut off, the voltages at the Hall signal input pins (H+P, H+N) are all fixed at “L”. At this time, the FG1 and the FG2 output “L”. If there is need to confirm the motor rotating state through the FG1 or the FG2 output signal while the VSP input voltage is below the all off operating voltage, do not use this function (the HA pin).

Use the CB pin as the power supply for the Hall elements.

When this function is not used, open the HA pin or connect it to the CB pin.

FIGURE 3.5.7.1 Usage Example of Hall Elements and Internal Equivalent Circuit

3.5.8 Internal Filter Circuit

Internal filter circuits are located before the top and bottom arm drivers. The filter circuits remove signals and switching noise with widths less than about 0.5μs.

FIGURE 3.5.8.1 Operation of Internal Filter Circuit
3.5.9 Calculation of Power Consumption

(1) Power consumption

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

Total IC power consumption: \[ P = P_{\text{Iglt}} + P_{\text{Fwd}} + P_{\text{sw}} + P_{\text{pr}} + P_{\text{is}} + P_{\text{cc}} \] (W)

1. Steady-state power dissipation of IGBTs
   \[ P_{\text{Iglt}} = I_{\text{ave}} \times \text{VONT} + I_{\text{ave}} \times \text{VONB} \times D \] (W)

2. Steady-state power dissipation of Free Wheeling Diodes (FWDs)
   \[ P_{\text{Fwd}} = I_{\text{ave}} \times \text{VFDT} \times (1 - D) \] (W)

3. Switching power dissipation of IGBTs
   \[ P_{\text{sw}} = (E_{\text{on}} + E_{\text{off}}) \times f_{\text{PWM}} \] (W)

4. Recovery power dissipation of FWDs
   \[ P_{\text{pr}} = \frac{1}{4} \times (I_{\text{rT}} \times V_s \times t_{\text{rrT}} \times f_{\text{PWM}}) \] (W)

5. Power consumption in high voltage circuit
   \[ P_{\text{is}} = V_s \times I_s \] (W)

6. Power consumption in control circuit
   \[ P_{\text{cc}} = V_{\text{cc}} \times I_{\text{cc}} \] (W)

\( I_{\text{ave}} \): Average output current (see Fig. 3.5.9.1)

\( \text{VONT} \): Drop in the output voltage of the top arm IGBT @\( I = I_{\text{ave}} \)

\( \text{VONB} \): Drop in the output voltage of the bottom arm IGBT @\( I = I_{\text{ave}} \)

\( D \): PWM duty

\( \text{VFDT} \): Forward voltage drop in the FWD of the top arm @\( I = I_{\text{ave}} \)

\( E_{\text{on}} \): Switching loss when the IGBT is turned on @\( I = I_{\text{ave}} \)

\( E_{\text{off}} \): Switching loss when the IGBT is turned off @\( I = I_{\text{ave}} \)

\( f_{\text{PWM}} \): PWM frequency

\( I_{\text{rT}} \): Recovery current of the FWD of the top arm

\( t_{\text{rrT}} \): Reverse recovery time of the FWD of the top arm

\( V_s \): Vs power voltage

\( V_{\text{cc}} \): Vcc power voltage

\( I_s \): Current consumption of the high-voltage circuit

\( I_{\text{cc}} \): Current consumption of the control circuit

(Note) FWD: Free Wheeling Diode

FIGURE 3.5.9.1 Current Waveform of the Motor Coil (120-degree Energization)

\( I_{\text{ave}} \): average motor coil current during the period \( t_1 \)
(2) Calculation of junction temperature

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

\[ T_j = T_c + R_{jc} \times P \]

- \( T_j \): Junction temperature (°C)
- \( T_c \): IC case (tab) temperature (°C) (actual measurement)
- \( R_{jc} \): Thermal resistance of between junction and IC case (Tab) (°C/W)
- \( P \): Total IC power consumption (W)

- Measuring method of \( T_c \)
  The thermo-couple is set on the tab of IC, and temperature \( T_c \) of the IC case is measured.
  After starting to apply a current, wait until the temperature becomes saturated (temperature stops rising). Use a value measured after temperature saturation. The tab is connected to the GL pin as described in Section 3.6.1 (2). Therefore, be careful not to get an electric shock when the potential at the GL pin is floating with respect to earth ground.

3.5.10 Derating

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

- Table 3.5.10.1 specifies the standard examples of derating to be considered when creating a reliable design. To consider these derating items in the equipment design stage is desirable for achieving reliability. If any item is difficult to be controlled within the standard, another means will be necessary, such as selecting a device having higher maximum ratings. Please consult our sales representative in advance.

<table>
<thead>
<tr>
<th>Item</th>
<th>Derating Design Standard (example)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction temperature ( T_j )</td>
<td>110°C maximum</td>
</tr>
<tr>
<td>Vs power supply voltage</td>
<td>ECN30110  210V maximum</td>
</tr>
<tr>
<td></td>
<td>ECN30210  450V maximum</td>
</tr>
</tbody>
</table>
3.5.11 External Parts

Table 3.5.11.1 shows recommended external parts.

**TABLE 3.5.11.1 External Parts**

<table>
<thead>
<tr>
<th>Component</th>
<th>Typical value</th>
<th>Usage</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>C0</td>
<td>1.0μF±10%, 25V</td>
<td>Smooths the internal power supply (VB)</td>
<td></td>
</tr>
<tr>
<td>CV1</td>
<td>1.0μF±10%, 25V</td>
<td>Smooths the Vcc power supply</td>
<td>Note 1</td>
</tr>
<tr>
<td>CV2</td>
<td>33nF±10%, 400V (ECN30110) &lt;br&gt;33nF±10%, 630V (ECN30210)</td>
<td>Smooths the Vs power supply</td>
<td>Note 2</td>
</tr>
<tr>
<td>C1, C2</td>
<td>0.22μF±10%, 25V</td>
<td>For charge pump</td>
<td>Note 7</td>
</tr>
<tr>
<td>C3, C4, C5</td>
<td>1000pF±10%, 25V</td>
<td>Eliminates Hall signal noise</td>
<td>Note 3</td>
</tr>
<tr>
<td>Rs</td>
<td>1Ω±1%, 1W</td>
<td>Sets current limit</td>
<td>Note 4, Note 6</td>
</tr>
<tr>
<td>CTR</td>
<td>2200pF±5%, 25V</td>
<td>Sets PWM frequency</td>
<td>Note 5</td>
</tr>
<tr>
<td>RTR</td>
<td>11kΩ±5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CM</td>
<td>1.0μF±10%, 25V</td>
<td>For motor lock protection</td>
<td></td>
</tr>
<tr>
<td>CF</td>
<td>470pF±10%, 25V</td>
<td>For over-current protection</td>
<td></td>
</tr>
<tr>
<td>RF</td>
<td>2MΩ±10%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

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

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

Note 4. The current limit set value can be calculated as follows. $I = \frac{V_{ref1}}{R_s}$ (A)

Determine the shunt resistance $R_s$ with reference to the above and Appendix - Supplementary Data in the Product Specification.

Note 5. The PWM frequency is approximated by the following equation: $f_{PWM} \approx 0.494 / (CTR \times RTR)$ (Hz)

Please set the maximum frequency of PWM is 20kHz as a guide. When the PWM frequency is set a high frequency, the switching loss is increased. And it increases the temperature of IC. Please confirm the IC temperature with an actual set, and use it in the range of derating.

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

Note 7. Attention of parts settings of charge pump circuit

The following attention is necessary when using parts other than those shown in Table 3.5.11.1.

- When the voltage (Vcp) between C+ and VS is dropped, the gate voltage of top arm IGBTs is dropped. And then the loss of IC increases. The Vcp must not become Vcp<10V.
- Capacitor: The Vcp is dropped by the internal current dissipation from C+ terminal of IC, when capacity is small.

The voltage impressed to the capacitor becomes Vcc in operation. Therefore, the withstand voltage of the capacitor requires more than the Vcc voltage.
3.6 Handling Instruction

3.6.1 Mounting

(1) Insulation between pins
High voltages are applied between the pins of the numbers specified below. Please apply coating or molding treatment.
Pin No. 2 - 3, 4 - 5, 5 - 6, 6 - 7, 7 - 8

(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 GND. For DIP26, the tab is placed on the IC top surface. If insulation between the tab and the motor case is insufficient, the IC will not be able to withstand an isolation withstand voltage test. Please secure a space distance or insert an insulation sheet between the IC tab and the motor case.
For SOP26, the tab is placed on the IC bottom surface (PCB side). Wiring lines other than GND on the PCB must not touch the tab even if applying a coating such as solder resist in consideration of deviation of the IC mounting position. Please secure sufficient insulation distance particularly between high voltage wiring lines and the tab.

(3) Tab suspension
Figure 3.6.1.1 shows a side view of the IC.
There are parts called “tab suspension” on both side surfaces of the IC. These tab suspensions are connected to the same potential as the GL pin. When the high voltage wire or/and parts are laid out close to a tab suspension, insulation is required, with coating, mold, or other treatment.

![Tab suspension](a) SOP26  ![Tab suspension](b) DIP26
(4) Coating resin
The influence of coating resin on semiconductor devices (thermal stress, mechanical stress and other stress) depends on PCB size, mounted parts, etc. to be used. When selecting a coating resin, consult with your PCB manufacturer and resin manufacturer.

(5) Soldering conditions
(a) For DIP26
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.

(b) For SOP26
The recommended reflow soldering condition is shown in Fig. 3.6.1.2.

![FIGURE 3.6.1.2 Recommended Conditions for Infrared Reflow or Air Reflow](image)

(6) Solder joint reliability
Reliability of solder joints is influenced by soldering conditions, PCB material, foot patterns, etc. 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.
4. Failure Examples (Assumptions)

4.1 Electrical Destruction of VSP Pin Caused by External Surge
• Cause: An external surge enters the IC on the Vsp line of the motor.
• Phenomenon: The Vsp signal is not transmitted into the IC, and the motor does not rotate.
• Countermeasure: Insert series resistance so that the external surge does not directly enter the IC. If a capacitor is also added, it becomes more effective.

![FIGURE 4.1.1 Example of Configuration for External Parts of VSP](image)

4.2 Electrical Destruction of FG1 and FG2 Pins Caused by External Surge
• Cause: An external surge directly enters the IC on the FG line of the motor.
• Phenomenon: The FG signal of the IC is not outputted.
• Countermeasure: Use the buffer circuit using the transistor on the motor control circuit board so that the external surge does not directly enter the IC.

![FIGURE 4.2.1 Example of Configuration for External Parts of FG1, FG2](image)

4.3 Inverter IC Destruction by External Surge Inputted to Vs and Vcc (15V) Lines (Case 1)
• Cause: An external surge enters the IC on the Vs and Vcc lines of the motor. Because the capacitance of the bypass capacitor for surge suppression was small, the surge could not be sufficiently suppressed.
• Phenomenon: The motor does not rotate due to the over voltage destruction of the IC.
• Countermeasure: Use the bypass capacitor for surge suppression; its capacity should be enough to suppress surges.

![FIGURE 4.3.1 Example of Surge Waveforms for Different Bypass Capacitors](image)
4.4 Inverter IC Destruction by External Surge Inputted to Vs and Vcc (15V) Lines (Case 2)

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

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

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

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

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

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

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

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

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

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

- **Countermeasure**: Use a surge suppressor diode with Zener voltage, which is lower than the maximum rating voltage of the IC. The larger the rating capacity of the Zener diode, the more effectively the surge suppressor works.

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

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

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

- **Countermeasure**: ① Remove the noise that enters the motor Vcc line by reviewing the power supply circuit (inductance of power cable or the like). ② Connect a capacitor having sufficient capacitance close to the VCC pin and GL pin of the IC to absorb noise.

![FIGURE 4.4.1 Example of Surge Waveform for Different Bypass Capacitor Locations on Board](image)

![FIGURE 4.7.1 Example of Pulsed Noise on Vcc Line](image)
4.8 Inverter IC Destruction by Vcc (15V) Line Noise
- **Cause**: Surge voltage that exceeds the maximum rating for the IC enters the VCC pin.
- **Phenomenon**: The motor does not rotate due to the over-voltage destruction of the IC.
- **Countermeasure**:
  1. Mount a bypass capacitor C1 near the pin of the IC. Use a capacitor that has excellent frequency characteristics, such as a ceramic capacitor. As a guide, a capacitor of around 1μF is recommended.
  2. It is more effective to mount a surge suppression device, such as bypass capacitor C2 shown in Fig. 4.8.1, close to the connector of a motor control circuit board.

![FIGURE 4.8.1 Example of Mounted Surge Suppression Devices](image)

4.9 Inverter IC Destruction by Inspection Machine Relay Noise
- **Cause**: A mechanical relay for on-off control of the electric connection between the IC and an inspection machine generates a surge that enters the IC.
- **Phenomenon**: The motor does not rotate due to the over-voltage destruction of the IC.
- **Countermeasure**: Use a mercury relay, etc. Confirm a surge is not generated when the relay is on-off.

![FIGURE 4.9.1 Example of Surge Waveform When Mechanical Relay is Used](image)

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

![FIGURE 4.10.1 Example of Motor Current Waveform in Phase Missing Condition](image)
5. Precautions for use

5.1 Countermeasure against Electrical Static Discharge (ESD)
(a) Customers need to take precautions to protect ICs from electrostatic discharge (ESD). The material of the container or any other device used to carry ICs should be free from ESD, which can be caused by vibration during transportation. Use of electrically conductive containers is recommended as an effective countermeasure.
(b) Everything that touches ICs, such as the work platform, machine, measuring equipment, and test equipment, should be grounded.
(c) Workers should be high-impedance grounded (100kΩ to 1MΩ) while working with ICs, to avoid damaging the ICs by ESD.
(d) Friction with other materials, such as high polymers, should be avoided.
(e) When carrying a PCB with a mounted IC, ensure that the electric potential is maintained at a constant level using the short-circuit terminals and that there is no vibration or friction.
(f) The humidity at an assembly line where ICs are mounted on circuit boards should be kept around 45 to 75 percent using humidifiers or such. If the humidity cannot be controlled effectively, using ionized air blowers (ionizers) is effective.

5.2 Storage Conditions (For: ECN30110F, ECN30210F)
The following conditions are applied to ECN30110F and ECN30210F.
(1) Before opening the moisture prevention bag (aluminum laminate bag)
   Temperature: 5°C to 35°C
   Humidity: 85%RH or lower
   Period: less than 2 years

(2) After opening the moisture prevention bag (aluminum laminate bag)
   Temperature: 5°C to 30°C
   Humidity: 70%RH or lower
   Period: less than 1 week

(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°C to 35°C
   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 ECN30110F and ECN30210F in a drying furnace (30%RH or lower) at ordinary temperature.

(4) Baking process
   When the period of (1) to (3) has expired, the ECN30110F and ECN30210F should be baked in accordance with the following conditions. (However, when the ECN30110F and ECN30210F are 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 ECN30110F and ECN30210F to a heat resistant container prior to baking.
   Temperature: 125±5°C
   Period: 16 to 24 hours

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

5.4 Derating Design
Continuous high-load operation (high temperatures, high voltages, large currents) should be avoided and derating design should be applied, even within the ranges of the maximum ratings, to ensure reliability.
5.5 Safe Design
The HPSD’s IC may fail due to accidents or unexpected surge voltages. Accordingly, adopt safe design features, such as redundancy and measures to prevent misuse, in order to avoid extensive damage in the event of a failure.

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

- Automobile, Train, Vessel, etc.

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

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

6. Notes Regarding this Document

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