3 Phase Brushless DC Motor Control IC

■FEATURES

- Supply Voltage \( V_{CC} = 6.3 \text{ to } 36V \)
- Low Quiescent Current \( I_{CC} = 2.9mA \text{ typ.} \ (V_{CC} = 12V) \)
- PWM Control
- Forward / Reverse Function
- FG Output
  (Selectable from 2 types of cycles)
- Lock Protection
  (Selectable from Auto Release method or Latching method)
- Over Current Detection
- Thermal Shutdown
- Under Voltage Lockout
- Operating Temperature \( T_{op} = -40 \text{ to } +125°C \)
- Package EQFN24-LE

■GENERAL DESCRIPTION

The NJW4315 is a 3 phase brushless DC motor pre-driver with 120° commutation.

The NJW4315 generates 3 phase sequence based on external hall signal input and drives power elements.

It features wide operating voltage range from 6.3V to 36V, small package and wide temperature range.

Therefore, it is suitable for various fan motors and electric circuit built-in small DC motors.

■APPLICATION

FAN Motors
Electric circuit built-in small DC motors

■TYPICAL APPLICATION

![Diagram of NJW4315](image-url)
## PIN CONFIGURATION

### <Top View>

<table>
<thead>
<tr>
<th>PIN NO.</th>
<th>SYMBOL</th>
<th>I/O</th>
<th>DESCRIPTION</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H1-</td>
<td>I</td>
<td>Hall Input Pin H1-</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>H2+</td>
<td>I</td>
<td>Hall Input Pin H2+</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>H2-</td>
<td>I</td>
<td>Hall Input Pin H2-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>H3+</td>
<td>I</td>
<td>Hall Input Pin H3+</td>
<td>-</td>
</tr>
<tr>
<td>5</td>
<td>H3-</td>
<td>I</td>
<td>Hall Input Pin H3-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>FR</td>
<td>I</td>
<td>Direction Setting Pin</td>
<td>L=Forward Rotation H or OPEN=Reverse Rotation</td>
</tr>
<tr>
<td>7</td>
<td>VERR</td>
<td>I</td>
<td>Speed Control Pin</td>
<td>Combine with the OSC pin to set the PWM duty. At not using, connect to pull-up.</td>
</tr>
<tr>
<td>8</td>
<td>OSC</td>
<td>-</td>
<td>PWM Frequency Setting Pin</td>
<td>Connect a capacitor between GND for setting PWM frequency.</td>
</tr>
<tr>
<td>9</td>
<td>CT</td>
<td>-</td>
<td>Lock Protection Setting Pin</td>
<td>Connect a capacitor between GND for setting time of lock protection.</td>
</tr>
<tr>
<td>10</td>
<td>GND</td>
<td>-</td>
<td>Ground Pin</td>
<td>Connect to GND.</td>
</tr>
<tr>
<td>11</td>
<td>FG</td>
<td>O</td>
<td>FG Output Pin</td>
<td>Rotation signal output</td>
</tr>
<tr>
<td>12</td>
<td>ILIMIT</td>
<td>I</td>
<td>Over Current Detection Pin</td>
<td>Connect a detection resistor to the motor output element side to detect the motor current. At not using, connect to Ground.</td>
</tr>
<tr>
<td>13</td>
<td>WL</td>
<td>O</td>
<td>WL Output Pin</td>
<td>W Phase Output for Low Side</td>
</tr>
<tr>
<td>14</td>
<td>VL</td>
<td>O</td>
<td>VL Output Pin</td>
<td>V Phase Output for Low Side</td>
</tr>
<tr>
<td>15</td>
<td>UL</td>
<td>O</td>
<td>UL Output Pin</td>
<td>U Phase Output for Low Side</td>
</tr>
<tr>
<td>16, 21</td>
<td>NC</td>
<td>-</td>
<td>Non Connection</td>
<td>Not Internally Connected.</td>
</tr>
<tr>
<td>17</td>
<td>WH</td>
<td>O</td>
<td>WH Output Pin</td>
<td>W Phase Output for High Side</td>
</tr>
<tr>
<td>18</td>
<td>VH</td>
<td>O</td>
<td>VH Output Pin</td>
<td>V Phase Output for High Side</td>
</tr>
<tr>
<td>19</td>
<td>UH</td>
<td>O</td>
<td>UH Output Pin</td>
<td>U Phase Output for High Side</td>
</tr>
<tr>
<td>20</td>
<td>VCC</td>
<td>-</td>
<td>Power Supply Pin</td>
<td>-</td>
</tr>
<tr>
<td>22</td>
<td>FGSEL</td>
<td>I</td>
<td>FG Output Cycle Select Pin</td>
<td>L=synthesized with three hall signals H or OPEN=synchronized with H1</td>
</tr>
<tr>
<td>23</td>
<td>LDSEL</td>
<td>I</td>
<td>Lock Protection Method Select Pin</td>
<td>L=Auto Release Method H or OPEN= Latching Method</td>
</tr>
<tr>
<td>24</td>
<td>H1+</td>
<td>I</td>
<td>Hall Input Pin H1+</td>
<td>-</td>
</tr>
</tbody>
</table>

### <Bottom View>

- Exposed PAD - Exposed PAD | It must be set to open or connected to GND.
NJW4315-T1

PRODUCT NAME INFORMATION

NJW4315 MLE - T1 (TE1)

Part Number Package Grade Taping Form

ORDERING INFORMATION

<table>
<thead>
<tr>
<th>PRODUCT NAME</th>
<th>PACKAGE OUTLINE</th>
<th>RoHS</th>
<th>HALOGEN-FREE</th>
<th>TERMINAL FINISH</th>
<th>MARKING</th>
<th>WEIGHT (mg)</th>
<th>MOQ (pcs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NJW4315MLE-T1(TE1)</td>
<td>EQFN24-LE</td>
<td>yes</td>
<td>yes</td>
<td>Sn2Bi</td>
<td>4315T1</td>
<td>31</td>
<td>1000</td>
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</tbody>
</table>

ABSOLUTE MAXIMUM RATINGS

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>RATINGS</th>
<th>UNIT</th>
<th>NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>VCC</td>
<td>40</td>
<td>V</td>
<td>VCC Pin</td>
</tr>
<tr>
<td>H Side Output Pin Voltage</td>
<td>VOH</td>
<td>40</td>
<td>V</td>
<td>UH, VH, WH Pin</td>
</tr>
<tr>
<td>FG Pin Voltage</td>
<td>VF</td>
<td>7</td>
<td>V</td>
<td>FG Pin</td>
</tr>
<tr>
<td>Hall Input Pin Voltage</td>
<td>VHI</td>
<td>7</td>
<td>V</td>
<td>H1+, H1-, H2+, H2-, H3+, H3- Pin</td>
</tr>
<tr>
<td>Logic Input Pin Voltage</td>
<td>VIN</td>
<td>7</td>
<td>V</td>
<td>FR, FGSEL, LDSEL Pin</td>
</tr>
<tr>
<td>ILIMIT Pin Voltage</td>
<td>VIM</td>
<td>3.5</td>
<td>V</td>
<td>ILIMIT Pin</td>
</tr>
<tr>
<td>VERR Pin Voltage</td>
<td>VERR</td>
<td>7</td>
<td>V</td>
<td>VERR Pin</td>
</tr>
<tr>
<td>H Side Output Current</td>
<td>IOH</td>
<td>150</td>
<td>mA</td>
<td>UH, VH, WH Pin</td>
</tr>
<tr>
<td>L Side Output Current</td>
<td>IOL</td>
<td>150</td>
<td>mA</td>
<td>UL, VL, WL Pin</td>
</tr>
<tr>
<td>FG Output Current</td>
<td>IF</td>
<td>15</td>
<td>mA</td>
<td>FG Pin</td>
</tr>
<tr>
<td>Power Dissipation (Ta=25°C)</td>
<td>PD</td>
<td>910(1)</td>
<td>mW</td>
<td></td>
</tr>
<tr>
<td>EQFN24-LE</td>
<td>2100(2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>Tj</td>
<td>-40 to +150</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>ToPr</td>
<td>-40 to +125</td>
<td>°C</td>
<td></td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>Tstg</td>
<td>-50 to +150</td>
<td>°C</td>
<td></td>
</tr>
</tbody>
</table>

(1): Mounted on glass epoxy board. (101.5×114.5×1.6mm: based on EIA/JEDEC standard, 2Layers FR-4, with Exposed Pad)
(2): Mounted on glass epoxy board. (101.5×114.5×1.6mm: based on EIA/JEDEC standard, 4Layers FR-4, with Exposed Pad)
(For 4Layers: Applying 99.5×99.5mm inner Cu area and thermal via holes to a board based on JEDEC standard JESD51-5)

RECOMMENDED OPERATING CONDITIONS

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>RATINGS</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>VCC</td>
<td>6.3 to 36</td>
<td>V</td>
</tr>
</tbody>
</table>
# PIN OPERATING CONDITION

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITION</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall Input Pin (H1+, H1-, H2+, H2-, H3+, H3-)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hall Input Sensitivity</td>
<td>$\Delta V_{MH}$</td>
<td>Peak to peak</td>
<td>0.08</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Hall Input Voltage Range</td>
<td>$V_{ICM,H}$</td>
<td>$V_{ICM,H}&lt;2.0V$</td>
<td>0</td>
<td>-</td>
<td>3.0</td>
<td>V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Logic Input Pin (FR, FGSEL, LDSEL)</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>H Level Input Voltage 1</td>
<td>$V_{HIN1}$</td>
<td>FR, FGSEL Pin</td>
<td>2.0</td>
<td>-</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>H Level Input Voltage 2</td>
<td>$V_{HIN2}$</td>
<td>LDSEL Pin</td>
<td>2.4</td>
<td>-</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>L Level Input Voltage</td>
<td>$V_{LIN}$</td>
<td></td>
<td>0</td>
<td>-</td>
<td>0.8</td>
<td>V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VERR Pin</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Voltage Range</td>
<td>$V_{ICM,VERR}$</td>
<td></td>
<td>0</td>
<td>-</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>PWM Input Frequency</td>
<td>$f_{PWM,VERR}$</td>
<td></td>
<td>-</td>
<td>-</td>
<td>150</td>
<td>kHz</td>
</tr>
</tbody>
</table>

# ELECTRICAL CHARACTERISTICS

(Unless otherwise noted, $V_{CC}=24V$, $Ta=25^\circ C$)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITION</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GENERAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiescent Current 1</td>
<td>$I_{CC1}$</td>
<td>$V_{CC}=12V$</td>
<td>2.4</td>
<td>2.9</td>
<td>3.8</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{CC}=12V$, $Ta=-40^\circ C$ to 125$^\circ C$</td>
<td>2.2</td>
<td>-</td>
<td>4.1</td>
<td>mA</td>
</tr>
<tr>
<td>Quiescent Current 2</td>
<td>$I_{CC2}$</td>
<td>$Ta=-40^\circ C$ to 125$^\circ C$</td>
<td>2.7</td>
<td>3.2</td>
<td>4.1</td>
<td>mA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>THERMAL SHUTDOWN BLOCK</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>TSD Operating Temperature</td>
<td>$T_{TSD1}$</td>
<td></td>
<td>-</td>
<td>180</td>
<td>-</td>
<td>°C</td>
</tr>
<tr>
<td>TSD Recovery Temperature</td>
<td>$T_{TSD2}$</td>
<td></td>
<td>-</td>
<td>130</td>
<td>-</td>
<td>°C</td>
</tr>
<tr>
<td>TSD Hysteresis Temperature</td>
<td>$\Delta T_{TSD}$</td>
<td></td>
<td>-</td>
<td>50</td>
<td>-</td>
<td>°C</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UNDER VOLTAGE LOCK OUT BLOCK</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>UVLO Detection Voltage</td>
<td>$V_{DUMO}$</td>
<td>$V_{CC}$ Decreasing</td>
<td>4.8</td>
<td>5.4</td>
<td>6.0</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{CC}$ Decreasing, $Ta=-40^\circ C$ to 125$^\circ C$</td>
<td>4.7</td>
<td>-</td>
<td>6.1</td>
<td>V</td>
</tr>
<tr>
<td>UVLO Recovery Voltage</td>
<td>$V_{RUMO}$</td>
<td>$V_{CC}$ Increasing</td>
<td>4.9</td>
<td>5.5</td>
<td>6.1</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{CC}$ Increasing, $Ta=-40^\circ C$ to 125$^\circ C$</td>
<td>4.8</td>
<td>-</td>
<td>6.2</td>
<td>V</td>
</tr>
<tr>
<td>UVLO Hysteresis Voltage Width</td>
<td>$\Delta V_{UMO}$</td>
<td></td>
<td>-</td>
<td>0.1</td>
<td>-</td>
<td>V</td>
</tr>
</tbody>
</table>
## ELECTRICAL CHARACTERISTICS

(Unless otherwise noted, $V_{CC}=24V$, $Ta=25^\circ C$)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITION</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>LOCK PROTECTION BLOCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lock Protection ON Time</td>
<td>$t_{ON}$</td>
<td>$C_{CT}=0.47\mu F$</td>
<td>-</td>
<td>0.25</td>
<td>-</td>
<td>s</td>
</tr>
<tr>
<td>H Level Voltage</td>
<td>$V_{HCT}$</td>
<td>$Ta=-40^\circ C$ to $125^\circ C$</td>
<td>2.8</td>
<td>3.0</td>
<td>3.2</td>
<td>V</td>
</tr>
<tr>
<td>L Level Voltage</td>
<td>$V_{LCT}$</td>
<td>$Ta=-40^\circ C$ to $125^\circ C$</td>
<td>0.8</td>
<td>1.0</td>
<td>1.2</td>
<td>V</td>
</tr>
<tr>
<td>Lock Charge Current</td>
<td>$I_{CHGCT}$</td>
<td>$V_{CT}=0V$ to $2.0V$</td>
<td>5.0</td>
<td>6.5</td>
<td>8.5</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td>$V_{CT}=0V$ to $2.0V$, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>4.0</td>
<td></td>
<td>10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lock Discharge Current</td>
<td>$I_{DCHGCT}$</td>
<td>$V_{CT}=3.5V$ to $2.0V$</td>
<td>0.3</td>
<td>0.65</td>
<td>0.9</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td>$V_{CT}=3.5V$ to $2.0V$, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>0.3</td>
<td></td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lock Charge Discharge Current Ratio</td>
<td>$I_{CHGCT}/I_{DCHGCT}$</td>
<td></td>
<td></td>
<td>10</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>HALL AMP BLOCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hysteresis Voltage Width</td>
<td>$\Delta V_{HYSH}$</td>
<td>$Ta=-40^\circ C$ to $125^\circ C$</td>
<td>10</td>
<td>30</td>
<td>50</td>
<td>$mV$</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>$I_{BH}$</td>
<td>Per 1 Input</td>
<td>-</td>
<td></td>
<td>60</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Per 1 Input, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>-</td>
<td></td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>HIGH SIDE OUTPUT BLOCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Side Output Voltage</td>
<td>$V_{OHL}$</td>
<td>$I_{OH(SINK)}=50mA$</td>
<td>-</td>
<td>0.4</td>
<td>1.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{OH(SINK)}=50mA$, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>-</td>
<td>-</td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>High Side Leak Current</td>
<td>$I_{OHLEAK}$</td>
<td>$V_{OH}=36V$</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{OH}=36V$, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>LOW SIDE OUTPUT BLOCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Side Output H Voltage 1</td>
<td>$V_{OLH1}$</td>
<td>$V_{CC}=12V$, $I_{OL(SOURCE)}=50mA$</td>
<td>8.0</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{CC}=12V$, $I_{OL(SOURCE)}=50mA$, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>8.0</td>
<td></td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Low Side Output H Voltage 2</td>
<td>$V_{OLH2}$</td>
<td>$I_{OL(SOURCE)}=50mA$</td>
<td>8.0</td>
<td>10.0</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{OL(SOURCE)}=50mA$, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>8.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Side Output L Voltage</td>
<td>$V_{OLL}$</td>
<td>$I_{OL(SINK)}=50mA$</td>
<td>-</td>
<td>0.3</td>
<td>1.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$I_{OL(SINK)}=50mA$, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>-</td>
<td></td>
<td>1.6</td>
<td></td>
</tr>
<tr>
<td>Low Side Clamp Voltage</td>
<td>$V_{OLCL}$</td>
<td>$V_{CC}=36V$, $I_{OL(SOURCE)}=0.1mA$</td>
<td>-</td>
<td></td>
<td>16.0</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{CC}=36V$, $I_{OL(SOURCE)}=0.1mA$, $Ta=-40^\circ C$ to $125^\circ C$</td>
<td>-</td>
<td></td>
<td>16.0</td>
<td></td>
</tr>
</tbody>
</table>
### ELECTRICAL CHARACTERISTICS
(Unless otherwise noted, $V_{CC}=24V$, $T_a=25^\circ C$)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>TEST CONDITION</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>FG OUTPUT BLOCK</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Output Voltage</td>
<td>$V_{FG}$</td>
<td>$I_{FG}=10mA$</td>
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<td>0.2</td>
<td>0.6</td>
<td>V</td>
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<tr>
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<td>$I_{FG}=10mA$, $T_a=40^\circ C$ to $125^\circ C$</td>
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<td>-</td>
<td>0.6</td>
<td>V</td>
</tr>
<tr>
<td>Leak Current</td>
<td>$I_{FGLEAK}$</td>
<td>$V_{FG}=5V$</td>
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<td>-</td>
<td>1</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{FG}=5V$, $T_a=40^\circ C$ to $125^\circ C$</td>
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<td>-</td>
<td>1</td>
<td>$\mu A$</td>
</tr>
<tr>
<td>OVER CURRENT DETECTION BLOCK</td>
<td></td>
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</tr>
<tr>
<td>Detection Voltage</td>
<td>$V_{DETLIM}$</td>
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<td>0.25</td>
<td>0.28</td>
<td>0.31</td>
<td>V</td>
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<td></td>
<td>$T_a=40^\circ C$ to $125^\circ C$</td>
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<tr>
<td>Input Bias Current</td>
<td>$I_{BLIM}$</td>
<td>$V_{DETLIM}=0V$</td>
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<td>1</td>
<td>2</td>
<td>$\mu A$</td>
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<tr>
<td></td>
<td></td>
<td>$T_a=40^\circ C$ to $125^\circ C$</td>
<td></td>
<td></td>
<td></td>
<td>$\mu A$</td>
</tr>
<tr>
<td>ERROR AMP BLOCK</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>PWM0% Detection Voltage</td>
<td>$V_{PWM1ERR}$</td>
<td>$\text{Output ON Duty}=0%$</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$\text{Output ON Duty}=0%$, $T_a=40^\circ C$ to $125^\circ C$</td>
<td>-</td>
<td>-</td>
<td>0.6</td>
<td>V</td>
</tr>
<tr>
<td>PWM100% Detection Voltage</td>
<td>$V_{PWM2ERR}$</td>
<td>$\text{Output ON Duty}=100%$</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
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<td></td>
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<td>$\text{Output ON Duty}=100%$, $T_a=40^\circ C$ to $125^\circ C$</td>
<td>3.5</td>
<td>-</td>
<td>-</td>
<td>V</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>$I_{BERR}$</td>
<td>$V_{PWM1ERR}=0V$</td>
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<td>1</td>
<td>2</td>
<td>$\mu A$</td>
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<tr>
<td></td>
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<td>$V_{PWM2ERR}=0V$, $T_a=40^\circ C$ to $125^\circ C$</td>
<td>-</td>
<td>-</td>
<td>5</td>
<td>$\mu A$</td>
</tr>
<tr>
<td>OSCILLATOR BLOCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Saw Wave Peak Voltage</td>
<td>$V_{POSC}$</td>
<td></td>
<td>2.7</td>
<td>3.0</td>
<td>3.3</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_a=40^\circ C$ to $125^\circ C$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saw Wave Bottom Voltage</td>
<td>$V_{BOSC}$</td>
<td></td>
<td>0.8</td>
<td>1.0</td>
<td>1.2</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$T_a=40^\circ C$ to $125^\circ C$</td>
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<td></td>
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<tr>
<td>OSC Charge Current</td>
<td>$I_{CHGOSC}$</td>
<td></td>
<td>50</td>
<td>80</td>
<td>120</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{OSC}=0V$ to $2.0V$</td>
<td></td>
<td></td>
<td></td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{OSC}=0V$ to $2.0V$, $T_a=40^\circ C$ to $125^\circ C$</td>
<td>40</td>
<td>-</td>
<td>130</td>
<td>$\mu A$</td>
</tr>
<tr>
<td>OSC Discharge Current</td>
<td>$I_{DCHGOSC}$</td>
<td></td>
<td>0.6</td>
<td>1.3</td>
<td>2.0</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{OSC}=3.5V$ to $2.0V$</td>
<td></td>
<td></td>
<td></td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_{OSC}=3.5V$ to $2.0V$, $T_a=40^\circ C$ to $125^\circ C$</td>
<td>0.5</td>
<td>-</td>
<td>2.1</td>
<td>mA</td>
</tr>
<tr>
<td>Oscillation Frequency</td>
<td>$f_{OSC}$</td>
<td>$C_{OSC}=1000pF$</td>
<td>-</td>
<td>35</td>
<td>50</td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$C_{OSC}=1000pF$, $T_a=40^\circ C$ to $125^\circ C$</td>
<td>-</td>
<td>-</td>
<td>55</td>
<td>kHz</td>
</tr>
<tr>
<td>LOGIC INPUT BLOCK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>H Level Input Current</td>
<td>$I_{HN}$</td>
<td>Per 1 Input</td>
<td>-10</td>
<td>-</td>
<td>10</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Per 1 Input, $T_a=40^\circ C$ to $125^\circ C$</td>
<td>-10</td>
<td>-</td>
<td>10</td>
<td>$\mu A$</td>
</tr>
<tr>
<td>L Level Input Current</td>
<td>$I_{LN}$</td>
<td>$V_N=0V$, Per 1 Input</td>
<td>30</td>
<td>50</td>
<td>100</td>
<td>$\mu A$</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$V_N=0V$, Per 1 Input, $T_a=40^\circ C$ to $125^\circ C$</td>
<td>30</td>
<td>-</td>
<td>100</td>
<td>$\mu A$</td>
</tr>
<tr>
<td>Pull Up Resistance</td>
<td>$R_N$</td>
<td></td>
<td>-</td>
<td>100</td>
<td>-</td>
<td>k$\Omega$</td>
</tr>
</tbody>
</table>
APPLICATION NOTE / GLOSSARY

- Pin and Circuit Operation Definition

**<Hall Input Voltage Range>**

- **$V_{IH}$**: 3.0V
- **$V_{ICM}$**: 2.0V
- **$V_{IH}$**: 0V

**<Hall Input Hysteresis Voltage width>**

- **$V_{IH}$**: 3.0V
- **$V_{ICM}$**: 2.0V
- **$\Delta V_{HYS}$**: Logic Inversion

**<FR, FGSEL Pin>**

- **$V_{IN}$**: 5.5V
- **H Level Input Voltage 1**: 2.0V
- **Undefined**: 0.8V
- **L Level Input Voltage**: 0V

**<LDSEL Pin>**

- **$V_{IN}$**: 5.5V
- **H Level Input Voltage 2**: 2.4V
- **Undefined**: 0.8V
- **L Level Input Voltage**: 0V

**<OSC Pin>**

- **$V_{OSC}$**: $f_{OSC}=1/(t_{CHGOSC} + t_{DCHGOSC})$
- **$V_{POS}$**:
- **$V_{BOS}$**:

- **$t_{CHGOSC}$**:
- **$t_{DCHGOSC}$**:

**<VERR Pin>**

- **$V_{VERR}$**: Full Speed (PWM=100% Duty)
- **$V_{PWM2VERR}$**:
- **$V_{POS}$**:
- **$V_{BOS}$**: PWM Duty Variable Range
- **$V_{PWM1VERR}$**: Stop (PWM=0% Duty)
<ILIMIT Pin>

Local OSC

\[ f_{OSCLO}=18\text{kHz typ. fixed} \]

\[ V_{UL}, V_{VL}, V_{WL} \]

Active L L L Active

Status

Normal ILIMIT Operation Normal

<CT Pin>

Hall Signal Input Timing

Motor Rotate Motor Lock

<Thermal Shutdown>

TSD Recovery Temperature (Normal Operation)

Hysteresis Temperature

TSD Operating Temperature (Output OFF)

-40°C \( T_{SD2} \)

150°C \( T_{SD1} \)

\( T_{j} \)

<Under Voltage Lockout>

\[ V_{CC} \]

36.0V

Recommended Operating Range

6.3V

UVLO Recovery Voltage (Normal Operation)

\( V_{RUVLO} \)

\( \Delta V_{UVLO} \): UVLO Hysteresis Voltage Width

\( V_{DUVLO} \)

UVLO Detection Voltage (Output Stop)

0V
## Truth Table

(H1>H1-, H2>H2-, H3>H3- = "H", Don't care = "X")

<table>
<thead>
<tr>
<th>No.</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>FR</th>
<th>TSD</th>
<th>LV/LD</th>
<th>LMT</th>
<th>VERR</th>
<th>OSC</th>
<th>CT</th>
<th>UH</th>
<th>VH</th>
<th>WH</th>
<th>UL</th>
<th>VL</th>
<th>FGS</th>
<th>FGSEL=L</th>
<th>FGSEL=H</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>H/L</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>Forward (PWM)</td>
</tr>
<tr>
<td>2</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>OFF</td>
<td>OFF</td>
<td>H/L</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>Forward (PAM)</td>
</tr>
<tr>
<td>3</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>OFF</td>
<td>X</td>
<td>X</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>Forward (Output Off Period)</td>
</tr>
<tr>
<td>4</td>
<td>L</td>
<td>H</td>
<td>H</td>
<td>L</td>
<td>OFF</td>
<td>OFF</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>L</td>
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<td>L</td>
<td>L</td>
<td>Forward (Output Off Period)</td>
</tr>
<tr>
<td>5</td>
<td>L</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>OFF</td>
<td>OFF</td>
<td>L</td>
<td>H</td>
<td>L</td>
<td>X</td>
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<td>Forward (Output Off Period)</td>
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<td>ON</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H/Z</td>
<td>H/Z</td>
<td>L</td>
<td>Forward (PWM)</td>
</tr>
<tr>
<td>7</td>
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<td>L</td>
<td>L</td>
<td>ON</td>
<td>X</td>
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<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>L</td>
<td>L</td>
<td>L</td>
<td>H/Z</td>
<td>H/Z</td>
<td>L</td>
<td>Forward (PWM)</td>
</tr>
</tbody>
</table>

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Ver.1.1

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Timing Chart
1. Forward

- VCC
- H1
- H2
- H3
- FR
- L
- VERR
- OSC
- CT
- ILIMIT
- 0V
- FG (FGSEL=L)
- UH
- VH
- WH
- UL
- VL
- WL

STATUS Forward
2. Forward with PWM

- Forward Duty=100%
- Forward Duty=50%
- Forward Duty=0%
3. Switch from forward rotation to reverse rotation

**Diagram showing the transition between forward and reverse rotation.**

- **VCC**
- **H1**
- **H2**
- **H3**
- **FR**
- **VERR**
- **OSC**
- **CT**
- **ILIMIT**
- **FG (FGSEL=L)**
- **UH**
- **VH**
- **WH**
- **UL**
- **VL**
- **WL**
- **Local OSC**

**Status**

- **Forward**
- **Brake**
- **Reverse**

**Brake Dead Time**
4. Lock Protection (When select to auto release method: LDSEL=L)

- VCC
- H1
- H2
- H3
- FR
- VERR
- OSC
- CT
- ILIMIT
- FG (FGSEL=L)
- UH
- VH
- WH
- UL
- VL
- WL

Status:
- Motor: Forward Rotation
- Output OFF
- Forward Rotation

Lock
Lock Release
5. Lock Protection (When select to latching method: LDSEL=H)
6. Under Voltage Lockout

**24V**

- **V_DUVLO**
- **V_RUVLO**

**5V**

- **V_{CC} ≤ 3.0V typ. → Indefinite**

**FG (FGSEL=L)**

- **V_{CC} ≤ 3.0V typ. → Indefinite**

**STATUS**

- Forward
- UVLO Operation
- Forward
7. Thermal Shutdown

TSD Operation

24V

Tj < T_{SD1}

Tj > T_{SD1}

Tj < T_{SD2}

VCC

H1

H2

H3

FR

5V

VERR

OSC

CT

ILIMIT

3.3V

FG (FGSEL=L)

UH

VH

WH

UL

VL

WL

STATUS

Forward

TSD Operation

Forward
FUNCTION DESCRIPTION

1. Hall Input (H1+, H1-, H2+, H2-, H3+, H3- Pin)
   1-1: When using Hall Element
   These are hall signal input pins. These are connected to input differential amplifiers (hall amplifiers) internally.
   The internal circuit detects the voltage level like following that H+ > H- is “H” and H+ < H- is “L”.
   The hall amplifiers have the input hysteresis voltage range of 60mV (max).
   Therefore, it should be input the amplitude larger than 100mVp-p with considering the margin.
   Moreover, the hall signal peak value should be less than \( V_{ICMH} \) and the hall signal center voltage should be less than \( V_{IHB} \).
   Some noise might overlap to the hall signal based on the GND level fluctuations by phase current or the unbalance of output signal path, etc.
   If the malfunction of the output chattering etc. occurs, it should be connected between the positive pins and the negative pins with filter capacitors in range of 1nF to 100nF.

   1-2: When using Hall IC
   Although NJW 4315 is a product adapted to the Hall Element, the Hall IC can also be used.
   However, it is necessary to match the output amplitude of the Hall IC to the input voltage range of the IC.

   e.g.) Application circuit at using Hall IC

   ![Application Circuit Diagram]
2. Output Block (UL, VL, WL / UH, VH, WH Pin)

2-1: Low Side Output UL, VL, WL Pin (120° Commutation Output and ON/OFF Output)
These pins are composed of totem poles and can directly drive the gate of the low-side Nch.FETs of 3-phase motor.
These output the phase switching signal generated from the hall input.
In addition, the PWM function, the lock protection and the over current detection are controlled by these low side outputs.
These have built-in voltage clamp circuit to prevent overvoltage to the gate of Nch.FETs.
Transient current and ringing during switching can be reduced by inserting output series resistors externally.
It is recommended that the gate output series resistors (R_{UL}, R_{VL}, R_{WL}) are connected in the range of 100 to 1000Ω.

2-2: High Side Output UH, VH, WH Pin (120° Commutation Output)
These pins are composed of open-drain output and can drive the gate of the high-side Pch.FETs of 3-phase motor.
These output the phase switching signal generated from the hall input.
These are required the pull-up resistors (R_{UH1}, R_{VH1}, R_{WH1}), so that optimal gate-source voltage is applied to Pch.FET.
It is recommended that the gate output series resistance (R_{UH2}, R_{VH2}, R_{WH2}) are connected in the range of 100 to 1000Ω.

3. Forward / Reverse Function (FR Pin)
The phase excitation sequence based on the direction of motor rotation can be changed by FR pin.
FR=L : Forward Rotation
FR=H or Open : Reverse Rotation
Further, the FR pin has pull-up resistor internally.
The sequence at FR switching is as shown below, and it is controlled by internal Local OSC timing and CT pin charge time.
After FR switching,
During the next Local OSC one cycle : Dead Time
\[ \downarrow \]
CT pin charge time (up to V_{HCT}) : Brake
\[ \downarrow \]
Until the next Local OSC one cycle completion : Dead Time
\[ \downarrow \]
The motor output is based on the truth table after FR switching

When changing the direction of rotation, it is necessary to adjust the timing so that the phase excitation sequence is changed after the motor stops.
Therefore, it should be switched the FR after stopping the motor rotation once, or reserved a Brake Time until motor stops with adjust the capacitor of the CT pin.
4. FG Output Function (FG, FGSEL Pin)

4-1 : FG Pin

FG pin outputs the signal as a pulse with a cycle proportional to motor rotation.
The output pattern can be selected from two kinds of cycles according to the setting of the FGSEL pin.
Refer to the following truth table for two kinds of cycles.
FG pin is an open-drain output with an absolute maximum rating of 7 V, so it should be connected to the power supply up to 5V with a pull-up resistor (R_{\text{FG}}).

<FG Output Frequency>
The hall input block and the FG output block have filter circuits in order to prevent malfunction such as chattering.
Therefore, if the hall input pulse width is less than the appropriate value, the FG output may not be able to obtain an appropriate output frequency by causing pulse skipping.

The guideline for the appropriate value of the Hall input pulse width is as follows.

- When select to the FG output synthesized with three hall signals : hall input pulse width ≥450µs
- When select to the FG output synchronized with H1 : hall input pulse width ≥125µs

Especially, if the above problem occurs due to the high hall input frequency, select to the H1 synchronous output pattern and secure enough hall input pulse width.

4-2 : FGSEL Pin
Select the output cycle of the FG pin.

- FGSEL=L : the FG output synthesized with three hall signals
- FGSEL=H or Open : the FG output synchronized with H1

Further, the FGSEL pin has pull-up resistor internally.

<FG Truth Table>

<table>
<thead>
<tr>
<th></th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>FGSEL=L</th>
<th>FGSEL=H</th>
</tr>
</thead>
<tbody>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
<td>L</td>
<td>Hi-Z</td>
<td>Hi-Z</td>
</tr>
<tr>
<td>H</td>
<td>H</td>
<td>L</td>
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<table>
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<tr>
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<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>FGSEL=L</th>
<th>FGSEL=H</th>
</tr>
</thead>
<tbody>
<tr>
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</tr>
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<td>L</td>
<td>L</td>
<td>H</td>
<td>Hi-Z</td>
<td>Hi-Z</td>
</tr>
</tbody>
</table>

● Forward Rotation (FR=L)

● Reverse Rotation (FR=H)
5. PWM Function (VERR, OSC Pin)

The PWM function compares the VERR pin voltage with the OSC pin voltage, and the low side output turns ON when $V_{\text{VERR}} > V_{\text{OSC}}$.

There are two ways to use PWM function as follows.

5-1 : PWM Control according to DC Voltage Input

The PWM output is generated inside the IC according to the DC voltage input level to the VERR pin.

The OSC pin connects to the capacitor $C_{\text{OSC}}$.

The saw wave voltage $V_{\text{OSC}}$ is generated by the internal oscillator circuit.

Also, if the speed command is directly supplied PWM signal, input after converting it into a DC signal by configuring two RC filters externally.

This compares $V_{\text{OSC}}$ and $V_{\text{VERR}}$ with the comparator inside the IC and performs PWM operation in which the low side output turns ON when $V_{\text{VERR}} > V_{\text{OSC}}$.

When the voltage higher than the saw wave peak voltage $V_{\text{POS}}$ is input to the VERR pin, the output becomes duty 100%.

When the voltage lower than the saw wave bottom voltage $V_{\text{BO}}$ is input to the VERR pin, the output turns OFF (duty 0%).

The PWM frequency is the same as the oscillation frequency $f_{\text{OSC}}$ of the saw wave generated by charging / discharging the capacitor $C_{\text{OSC}}$.

The $f_{\text{OSC}}$ is determined by $C_{\text{OSC}}$, $V_{\text{POS}}$, $V_{\text{BO}}$, $I_{\text{CHGOSC}}$, and $I_{\text{DCHGOSC}}$.

It is possible to approximate from the relation of $I_{\text{CHGOSC}} << I_{\text{DCHGOSC}}$ by the following formula.

The $C_{\text{OSC}}$ recommended value is from 330pF to 2200pF.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Calculation Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSC Frequency</td>
<td>$f_{\text{OSC}}$</td>
<td>$f_{\text{OSC}} [\text{Hz}] \approx 35 \times 10^6 / C_{\text{OSC}} [\text{pF}]$</td>
</tr>
</tbody>
</table>
5-2 : Direct PWM Input Control

The PWM output follows the duty of the input signal to the VERR pin without generating the PWM output inside the IC.

The OSC pin should be fixed to a center voltage between the saw wave peak voltage $V_{POS}$ (3V typ.) and the saw wave bottom voltage $V_{BOS}$ (1V typ.) in order to forcibly stop the internal oscillator circuit.

The logic signal with PWM duty controlled from the outside should be input to the VERR pin.

e.g.) When setting $V_{OSC}=2.2$ V

Connect the OSC pin to 1.8kΩ when the pull up voltage is 5V and 6.2kΩ when the pull up voltage is 12V.

The external PWM signal with $V_{VERR}=0$-5V should be input to the VERR pin.

However, there is possibility that the external MOSFET cannot be driven sufficiently if the PWM signal is high frequency or small ON duty.

In this case, consider usage conditions in consideration of the external MOSFET characteristics.
6. Lock Protection (CT, LDSEL Pin)

The lock protection detects the hall signal period and restricts energization to the motor winding when the motor locks.

The various time constants of lock protection can be set with capacitor (C_CT) connected to CT pin. Even when lock protection is not required, connect a capacitor of 0.1μF to 10μF in the recommended capacitance range to the CT pin.

Moreover, if the motor startup is slow or the motor is used low speed, the hall signal input cycle becomes long, so even if the motor is rotating, it may be misdetected as a locked state.

If there is a possibility of misdetection of the locked state, adjust the capacitor and secure enough time constants.

The CT pin repeats rapid discharge (220μs typ.) and charge to the capacitor every time the hall signal is switched. When the CT pin voltage (V_CT) becomes higher than V_HCT due to the flow of the lock charge current (I_CHGCT), it shifts to the lock protection status and the low side outputs (UL, VL, WL) are all L level.

The time until shift to this lock protection status is defined as lock protection ON time (t_ON).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Calculation Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lock Protection ON Time</td>
<td>t_ON</td>
<td>( t_{ON} = \frac{V_{HCT} \times C_{CT}}{I_{CHGCT}} = 0.46 \times 10^6 \times C_{CT} )</td>
</tr>
</tbody>
</table>

An operation after shift to the lock protection status can be selected from the following two methods depending on the LDSEL pin setting.

However, the LDSEL pin setting should be fixed.

LDSEL=L : Auto release method
LDSEL=H or Open : Latching method

Further, the LDSEL pin has pull-up resistor internally.
6-1: Auto Release Method (LDSEL=L)

When it is shifted to the lock protection status, the capacitor (C_{CT}) of the CT pin is discharged by the lock discharge current (I_{DCHGCT}).

When the CT pin voltage (V_{CT}) becomes lower than V_{HCT}, the lock protection status is released.

The time until release this lock protection status is defined as lock protection OFF time (t_{OFF}).

After the lock protection state is released, shift to normal operation, and the CT pin is charged again by the lock charge current (I_{CHGCT}).

If the CT pin voltage (V_{CT}) becomes higher than V_{HCT} again, it shifts to the lock protection operation again.

The time until shift to this lock protection status after the second time is defined as lock protection auto release ON time (t_{ONAR}).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Calculation Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lock Protection Auto Release ON Time</td>
<td>t_{ONAR}</td>
<td>t_{ONAR} = (V_{HCT}-V_{LCT}) x C_{CT} / I_{DCHGCT} = 0.307 x 10^6 x C_{CT}</td>
</tr>
<tr>
<td>Lock Protection OFF Time</td>
<td>t_{OFF}</td>
<td>t_{OFF} = (V_{HCT}-V_{LCT}) x C_{CT} / I_{DCHGCT} = 3.07 x 10^6 x C_{CT}</td>
</tr>
</tbody>
</table>

<At low speed rotation>

![Diagram of Motor Status and Output Status at low speed rotation]

<At high speed rotation>

![Diagram of Motor Status and Output Status at high speed rotation]
6-2: Latching Method (LDSEL=H)
When it is shifted to lock protection status, it latches this status. Further, the CT pin repeats charge/discharge during the latch state of lock protection too, but it does not affect the operation. In order to release the latched status, it is possible to force reset by the power (VCC) restart or switching logic of the LDSEL pin.

<At low speed rotation>

<At high speed rotation>
7. Over Current Detection (ILIMIT Pin)

The overcurrent detection value (I\textsubscript{LIMIT}) to the motor winding can be set arbitrarily by the current detection resistor (R\textsubscript{LIMIT}). It is possible to detect the over current of all phase due to bundle the source current of the external low side MOSFETs to the current detection resistor R\textsubscript{LIMIT}.

When the ILIMIT pin voltage becomes higher than over current detection voltage V\textsubscript{DETLIM} (0.28V typ.), the low side outputs (UL, VL, WL) are all L level.

The ILIMIT pin performs pulse-by-pulse output with the internal Local OSC (f\textsubscript{OSCLO}=18kHz typ.) as the trigger while the overcurrent is detected.

The calculation formula is as follows.

\[
I_{LIMIT} = \frac{V_{DETLIM}}{R_{LIMIT}}
\]

The ILIMIT pin is frequently generated short surge pulses about several 100ns caused by the parasitic capacitance of the external FETs.

If these pulses are entered to the ILIMIT pin, there is possible that the over current detection circuit malfunctions, so it becomes low speed rotation or torque reduction of the motor.

The influence of such surge pulses can be avoided due to add the RC low pass filter to the ILIMIT pin.

If the pulse voltage generated in R\textsubscript{LIMIT} is VI and the pulse width is t, the condition of RC value is as follows.

\[
R_{LPF} \times C_{LPF} > \frac{-t}{\ln(1 - \frac{V_{DETLIM}}{V_I})}
\]

e.g.) When V\textsubscript{DETLIM}=0.22[V] (min. value and 0.03V as margin), V_I=1[V], t=1[\mu s]

\[R_{LPF} \times C_{LPF} > 4.02 \times 10^6 \quad \rightarrow \quad \text{It is available to compose in a combination such as } R_{LPF}=4.3\Omega, C_{LPF}=1000pF.\]
Typical Application

- FG OUT
- VCC
- R люд
- VREF
- UVLO
- H1+
- H1-
- H2+
- H2-
- H3+
- H3-
- FGSEL
- OSC
- VERR
- LDSEL
- GND
- CT
- C
- 3 Phase Motor
- 18kHz Fixed
- PWM Logic
- Lock
- Detector
- FR
- Dead
- Time
- TSD
- Predriver & Clamp
- Lowpass Filter
- ILIMIT
- R
- VUH
- VUH1
- VUH2
- WH
- WH1
- WH2
- UL
- UL1
- UL2
- VL
- VL1
- VL2
- WL
- WL1
- WL2
- VCC
- V
- D
- S
- N
- H
- +
- V
- Limit
- VREF
- V
- VCC
TYPICAL CHARACTERISTICS

- **I\(_{\text{CC}}\) vs. V\(_{\text{CC}}\)**
  - [Graph showing I\(_{\text{CC}}\) vs. V\(_{\text{CC}}\) for different temperatures.]

- **I\(_{\text{CC}}\) vs. T\(_{\text{j}}\)**
  - [Graph showing I\(_{\text{CC}}\) vs. T\(_{\text{j}}\) for different V\(_{\text{CC}}\) values.]

- **V\(_{\text{DUVLO}}\), V\(_{\text{RUVLO}}\) vs. T\(_{\text{j}}\)**
  - [Graph showing V\(_{\text{DUVLO}}\) and V\(_{\text{RUVLO}}\) vs. T\(_{\text{j}}\).]

- **\(\Delta V_{\text{HYSH}}\) vs. T\(_{\text{j}}\)**
  - [Graph showing \(\Delta V_{\text{HYSH}}\) vs. T\(_{\text{j}}\) for V\(_{\text{CC}}\) = 24V.]

- **f\(_{\text{OSCLO}}\) vs. T\(_{\text{j}}\)**
  - [Graph showing f\(_{\text{OSCLO}}\) vs. T\(_{\text{j}}\) for V\(_{\text{CC}}\) = 24V.]

- **R\(_{\text{IN}}\) vs. T\(_{\text{j}}\)**
  - [Graph showing R\(_{\text{IN}}\) vs. T\(_{\text{j}}\) for V\(_{\text{CC}}\) = 24V.]
**TYPICAL CHARACTERISTICS**

- **$V_{HCT}$ vs. $T_j$**
  
  - $V_{HCT}$ vs. $T_j$ ($V_{CC}=24V$)
  
- **$V_{LCT}$ vs. $T_j$**
  
  - $V_{LCT}$ vs. $T_j$ ($V_{CC}=24V$)
  
- **$I_{CHGCT}$ vs. $T_j$**
  
  - $I_{CHGCT}$ vs. $T_j$ ($V_{CC}=24V, V_{CT}=0V \rightarrow 2V$)
  
- **$I_{DCHGCT}$ vs. $T_j$**
  
  - $I_{DCHGCT}$ vs. $T_j$ ($V_{CC}=24V, V_{CT}=3.5V \rightarrow 2V$)
  
- **$I_{CHGCT}/I_{DCHGCT}$ vs. $T_j$**
  
  - $I_{CHGCT}/I_{DCHGCT}$ vs. $T_j$ ($V_{CC}=24V$)
  
- **$V_{DETLIM}$ vs. $T_j$**
  
  - $V_{DETLIM}$ vs. $T_j$ ($V_{CC}=24V$)
TYPICAL CHARACTERISTICS

- $V_{POS} vs. T_j$ ($V_{CC}=24V$)
- $V_{BOSC} vs. T_j$ ($V_{CC}=24V$)
- $I_{CHGOSC} vs. T_j$ ($V_{CC}=24V, V_{BOSC}=0V \rightarrow 2.0V$)
- $I_{DCHGOSC} vs. T_j$ ($V_{CC}=24V, V_{BOSC}=3.5V \rightarrow 2.0V$)
- $f_{OSC} vs. T_j$ ($V_{CC}=24V, C_{osc}=1000pF$)
- $V_{FG} vs. T_j$ ($V_{CC}=24V, I_{FG}=10mA$)
■ TYPICAL CHARACTERISTICS

- $V_{OHL}$ vs. $I_{OH(BLINK)}$  
  ($V_{CC}=24V, Ta=25^\circ C$)

- $V_{OHL}$ vs. $Tj$  
  ($V_{CC}=24V$)

- $I_{OHLEAK}$ vs. $Tj$  
  ($V_{CC}=24V, V_{OH}=36V$)

- $V_{OLH1}$ vs. $I_{OL(SOUR)}$  
  ($Ta=25^\circ C$)

- $V_{OLH2}$ vs. $I_{OL(SOUR)}$  
  ($Tj=25^\circ C$)

- $V_{OLH1}$ vs. $Tj$  
  ($V_{CC}=12V$)

- $V_{OLH2}$ vs. $Tj$  
  ($V_{CC}=24V$)
TYPICAL CHARACTERISTICS

$V_{OL}$ vs. $I_{OL(SINK)}$ ($V_{CC}=24V$, $T_a=25^\circ C$)

$V_{OL}$ vs. $T_j$ ($V_{CC}=24V$)

$V_{OLCL}$ vs. $T_j$ ($V_{CC}=36V$, $I_{OL(SOURCE)}=0.1mA$)
**Packing Spec**

**Taping Dimensions**

![Diagram of taping dimensions]

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>DIMENSION</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.35±0.05</td>
<td>BOTTOM DIMENSION</td>
</tr>
<tr>
<td>B</td>
<td>4.35±0.05</td>
<td>BOTTOM DIMENSION</td>
</tr>
<tr>
<td>D0</td>
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<td></td>
</tr>
<tr>
<td>D1</td>
<td>1.0±0.1</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>1.7±0.1</td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>0.5±0.05</td>
<td></td>
</tr>
<tr>
<td>W1</td>
<td>9.5</td>
<td>THICKNESS 0.1max</td>
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</tbody>
</table>

**Reel Dimensions**

![Diagram of reel dimensions]

<table>
<thead>
<tr>
<th>SYMBOL</th>
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<tbody>
<tr>
<td>A</td>
<td>φ 180.3</td>
</tr>
<tr>
<td>B</td>
<td>φ 60.4</td>
</tr>
<tr>
<td>C</td>
<td>φ 13±0.2</td>
</tr>
<tr>
<td>D</td>
<td>φ 21±0.8</td>
</tr>
<tr>
<td>E</td>
<td>2±0.5</td>
</tr>
<tr>
<td>W</td>
<td>13 1/2</td>
</tr>
<tr>
<td>W1</td>
<td>1.2</td>
</tr>
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</table>

**Taping State**

![Diagram of taping state]

**Packing State**

![Diagram of packing state]
**RECOMMENDED MOUNTING METHOD**

INFRARED REFLOW SOLDERING METHOD

*Recommended reflow soldering procedure*

The temperature indicates at the surface of mold package.
<table>
<thead>
<tr>
<th>Date</th>
<th>Revision</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td>09.May.2019</td>
<td>Ver.1.1</td>
<td>FUNCTION DESCRIPTION - 4. FG Output Function</td>
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<tr>
<td></td>
<td></td>
<td>Added &lt;FG Output Frequency&gt;</td>
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</tbody>
</table>
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