Current Mode Control

Internal 1.8A MOSFET Switching Regulator IC for Buck Converter

**GENERAL DESCRIPTION**

The **NJW4155** is a buck converter with 40V/1.8A MOSFET. It corresponds to high oscillating frequency, and Low ESR Output Capacitor (MLCC) within wide input range from 4.5V to 40V.

Therefore, the **NJW4155** can realize downsizing of applications with a few external parts so that adopts current mode control.

Also, it has a soft start function, external clock synchronization, over current protection and thermal shutdown circuit.

It is suitable for supplying power to a Car Accessory, Office Automation Equipment, Industrial Instrument and so on.

**FEATURES**

- Current Mode Control
- External Clock Synchronization
- Wide Operating Voltage Range: 4.5V to 40V
- Switching Current: 2.7A min.
- PWM Control
- Built-in Compensation Circuit
- Correspond to Ceramic Capacitor (MLCC)
- Oscillating Frequency: 450kHz typ. (A, D ver.)
  300kHz typ. (B ver.)
- Soft Start Function: 4ms typ.
- UVLO (Under Voltage Lockout)
- Over Current Protection (Hiccup type)
- Thermal Shutdown Protection
- Power Good Function (NJW4155GM1 only)
- Standby Function
- Package Outline: NJW4155GM1 : HSOP8
  NJW4155DL3 : TO-252-5

**PACKAGE OUTLINE**

NJW4155GM1   NJW4155DL3
**PRODUCT CLASSIFICATION**

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Version</th>
<th>Oscillation Frequency</th>
<th>Power Good</th>
<th>Package</th>
<th>Operating Temperature Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>NJW4155GM1-A</td>
<td>A</td>
<td>450kHz typ.</td>
<td>✓</td>
<td>HSOP8</td>
<td>General Spec. Ta= -40°C to +125°C</td>
</tr>
<tr>
<td>NJW4155GM1-B</td>
<td>B</td>
<td>300kHz typ.</td>
<td>✓</td>
<td>HSOP8</td>
<td>General Spec. Ta= -40°C to +125°C</td>
</tr>
<tr>
<td>NJW4155DL3-B</td>
<td>B</td>
<td>300kHz typ.</td>
<td></td>
<td>TO-252-5</td>
<td>General Spec. Ta= -40°C to +125°C</td>
</tr>
<tr>
<td>NJW4155GM1-D</td>
<td>D</td>
<td>450kHz typ.</td>
<td>✓</td>
<td>HSOP8</td>
<td>General Spec. Ta= -40°C to +125°C</td>
</tr>
</tbody>
</table>

**PIN CONFIGURATION**

Exposed PAD on backside connect to GND

NJW4155GM1-A
NJW4155GM1-B

NJW4155GM1-D
NJW4155DL3-B

**PIN DESCRIPTIONS**

<table>
<thead>
<tr>
<th>PIN NAME</th>
<th>PIN NUMBER</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HSOP8</td>
<td>HSOP8</td>
</tr>
<tr>
<td>SW</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>GND</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>PG</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>IN-</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>EN/SYNC</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N.C.</td>
<td>–</td>
<td>7</td>
</tr>
<tr>
<td>V*</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Exposed PAD</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>
### Absolute Maximum Ratings (Ta=25°C)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>MAXIMUM RATINGS</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>V⁺</td>
<td>-0.3〜+45</td>
<td>V</td>
</tr>
<tr>
<td>V⁺ - SW pin Voltage</td>
<td>V⁺,SW</td>
<td>+45</td>
<td>V</td>
</tr>
<tr>
<td>EN/SYNC pin Voltage</td>
<td>VENS</td>
<td>-0.3〜+45</td>
<td>V</td>
</tr>
<tr>
<td>IN- pin Voltage</td>
<td>VIN-</td>
<td>-0.3〜+6</td>
<td>V</td>
</tr>
<tr>
<td>Power Good pin Voltage (*1)</td>
<td>VPN</td>
<td>-0.3〜+6</td>
<td>V</td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>P₀</td>
<td>790 (*2)</td>
<td>mW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2,500 (*3)</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>TO-252-5</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>1,190 (*4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3,125 (*5)</td>
<td></td>
</tr>
<tr>
<td>Junction Temperature Range</td>
<td>Tj</td>
<td>-40 to +150</td>
<td>°C</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>Topr</td>
<td>-40 to +125</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature Range</td>
<td>Tstg</td>
<td>-50 to +150</td>
<td>°C</td>
</tr>
</tbody>
</table>

(*1): Apply only the NJW4155GM1.

(*2): Mounted on glass epoxy board. (76.2×114.3×1.6mm: based on EIAJDEC standard, 2Layers)

(*3): Mounted on glass epoxy board. (76.2×114.3×1.6mm: based on EIAJDEC standard, 4Layers)

(For 4Layers: Applying 74.2×74.2mm inner Cu area and a thermal via hole to a board based on JEDEC standard JESD51-5)

(*4): Mounted on glass epoxy board. (76.2×114.3×1.6mm: based on EIAJDEC standard size, 2Layers, Cu area 100mm²)

### Recommended Operating Conditions

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>MIN.</th>
<th>TYP.</th>
<th>MAX.</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply Voltage</td>
<td>V⁺</td>
<td>4.5</td>
<td>–</td>
<td>40</td>
<td>V</td>
</tr>
<tr>
<td>Power Good pin Voltage (*5)</td>
<td>VPN</td>
<td>0</td>
<td>–</td>
<td>5.5</td>
<td>V</td>
</tr>
<tr>
<td>External Clock Input Range</td>
<td>fSYNC</td>
<td>440</td>
<td>–</td>
<td>600</td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>280</td>
<td>–</td>
<td>500</td>
<td></td>
</tr>
</tbody>
</table>

(*5): Apply only the NJW4155GM1.
### ELECTRICAL CHARACTERISTICS

(Unless otherwise noted, $V^+ = V_{\text{EN/SYNC}} = 12V$, $T_a = 25^\circ C$)

<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>Under Voltage Lockout Block</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON Threshold Voltage</td>
<td>$V_{T\text{ON}}$</td>
<td>$V^+ = L \rightarrow H$</td>
<td>4.2</td>
<td>4.4</td>
<td>4.5</td>
<td>V</td>
</tr>
<tr>
<td>OFF Threshold Voltage</td>
<td>$V_{T\text{OFF}}$</td>
<td>$V^+ = H \rightarrow L$</td>
<td>4.1</td>
<td>4.3</td>
<td>4.4</td>
<td>V</td>
</tr>
<tr>
<td>Hysteresis Voltage</td>
<td>$V_{\text{HYS}}$</td>
<td></td>
<td>70</td>
<td>90</td>
<td>–</td>
<td>mV</td>
</tr>
<tr>
<td>Soft Start Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soft Start Time</td>
<td>$T_{\text{SS}}$</td>
<td>$V_g=0.75V$</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>ms</td>
</tr>
<tr>
<td>Oscillator Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oscillation Frequency</td>
<td>$f_{\text{OSC}}$</td>
<td>A, D version, $V_{\text{IN}}=0.7V$</td>
<td>405</td>
<td>450</td>
<td>495</td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B version, $V_{\text{IN}}=0.7V$</td>
<td>270</td>
<td>300</td>
<td>330</td>
<td>kHz</td>
</tr>
<tr>
<td>Oscillation Frequency deviation (Supply voltage)</td>
<td>$f_{\text{DV}}$</td>
<td>$V^+ = 4.5V$ to $40V$</td>
<td>–</td>
<td>1</td>
<td>–</td>
<td>%</td>
</tr>
<tr>
<td>Oscillation Frequency deviation (Temperature)</td>
<td>$f_{\text{DT}}$</td>
<td>$T_a = -40^\circ C$ to $+85^\circ C$</td>
<td>–</td>
<td>5</td>
<td>–</td>
<td>%</td>
</tr>
<tr>
<td>Error Amplifier Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reference Voltage</td>
<td>$V_B$</td>
<td></td>
<td>-1.0%</td>
<td>0.8</td>
<td>+1.0%</td>
<td>V</td>
</tr>
<tr>
<td>Input Bias Current</td>
<td>$I_B$</td>
<td></td>
<td>-0.1</td>
<td>–</td>
<td>+0.1</td>
<td>$\mu A$</td>
</tr>
<tr>
<td>PWM Compare Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Duty Cycle</td>
<td>$M_{\text{AXDUTY}}$</td>
<td>$V_{\text{IN}}=0.7V$</td>
<td>92</td>
<td>95.5</td>
<td>–</td>
<td>%</td>
</tr>
<tr>
<td>Minimum ON Time1</td>
<td>$t_{\text{ON-min1}}$</td>
<td>A, D version</td>
<td>–</td>
<td>150</td>
<td>200</td>
<td>ns</td>
</tr>
<tr>
<td>(Use Built-in Oscillator)</td>
<td></td>
<td>B version</td>
<td>–</td>
<td>215</td>
<td>290</td>
<td>ns</td>
</tr>
<tr>
<td>Minimum ON Time2</td>
<td>$t_{\text{ON-min2}}$</td>
<td>A, D version, $f_{\text{SYNC}}=500kHz$</td>
<td>–</td>
<td>100</td>
<td>140</td>
<td>ns</td>
</tr>
<tr>
<td>(Use Ext CLK)</td>
<td></td>
<td>B version, $f_{\text{SYNC}}=400kHz$</td>
<td>–</td>
<td>145</td>
<td>200</td>
<td>ns</td>
</tr>
<tr>
<td>OCP Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COOL DOWN Time</td>
<td>$t_{\text{COOL}}$</td>
<td></td>
<td>–</td>
<td>75</td>
<td>–</td>
<td>ms</td>
</tr>
<tr>
<td>Output Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output ON Resistance</td>
<td>$R_{\text{ON}}$</td>
<td>$I_{\text{SW}}=1.5A$</td>
<td>–</td>
<td>0.2</td>
<td>0.4</td>
<td>$\Omega$</td>
</tr>
<tr>
<td>Switching Current Limit</td>
<td>$I_{\text{LIM}}$</td>
<td></td>
<td>2.7</td>
<td>3.4</td>
<td>4.0</td>
<td>$A$</td>
</tr>
<tr>
<td>SW Leak Current</td>
<td>$I_{\text{LEAK}}$</td>
<td>$V_{\text{ENSYNC}}=0V$, $V^+ = 45V$, $V_{\text{SW}}=0V$</td>
<td>–</td>
<td>–</td>
<td>3</td>
<td>$\mu A$</td>
</tr>
</tbody>
</table>
## ELECTRICAL CHARACTERISTICS

(Unless otherwise noted, $V^*=V_{EN/SYNC}=12V$, $T_a=25^\circ C$)

<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>Standby Control / Sync Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EN/SYNC pin High Threshold Voltage</td>
<td>$V_{THH_{EN/SYNC}}$</td>
<td>$V_{EN/SYNC}= L \rightarrow H$</td>
<td>1.6</td>
<td>–</td>
<td>$V^*$</td>
<td>$V$</td>
</tr>
<tr>
<td>EN/SYNC pin Low Threshold Voltage</td>
<td>$V_{THL_{EN/SYNC}}$</td>
<td>$V_{EN/SYNC}= H \rightarrow L$</td>
<td>0</td>
<td>–</td>
<td>0.5</td>
<td>$V$</td>
</tr>
<tr>
<td>Input Bias Current (EN/SYNC pin)</td>
<td>$I_{EN}$</td>
<td>$V_{EN/SYNC}=12V$</td>
<td>–</td>
<td>170</td>
<td>250</td>
<td>$\mu A$</td>
</tr>
</tbody>
</table>

| Power Good Block (*6) | | | | | | |
| High Level Detection Voltage | $V_{THH_{PG}}$ | Measured at IN- pin | 105  | 110 | 115  | % |
| Low Level Detection Voltage | $V_{THL_{PG}}$ | Measured at IN- pin | 85   | 90  | 95   | % |
| Hysterisis Region | $V_{HYS_{PG}}$ | – | 2  | – | % |
| Power Good ON Resistance | $R_{ON_{PG}}$ | $I_{PG}=10mA$ | – | 37 | 50 | $\Omega$ |
| Leak Current at OFF State | $I_{LEAK_{PG}}$ | $V_{PG}=6V$ | – | – | 0.1 | $\mu A$ |

| General Characteristics | | | | | | |
| Quiescent Current | $I_{OD}$ | A. D version, $R_L$=no load, $V_N=0.7V$ | – | 3.5 | 4.2 | mA |
| | | B version, $R_L$=no load, $V_N=0.7V$ | – | 3.0 | 3.6 | mA |
| Standby Current | $I_{DD_{,STB}}$ | $V_{EN/SYNC}=0V$ | – | – | 3  | $\mu A$ |

(*6): Apply only the NJW4155GM1.
## THERMAL CHARACTERISTICS

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>SYMBOL</th>
<th>VALUE</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Junction-to-ambient thermal resistance</td>
<td>$j_{ja}$</td>
<td>HSOP8 158 (*7) 50 (*8)</td>
<td>°C/W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TO-252-5 105 (*9) 40 (*8)</td>
<td></td>
</tr>
<tr>
<td>Junction-to-Top of package characterization parameter</td>
<td>$j_{jt}$</td>
<td>HSOP8 28 (*7) 12 (*8)</td>
<td>°C/W</td>
</tr>
<tr>
<td></td>
<td></td>
<td>TO-252-5 17 (*9) 12 (*8)</td>
<td></td>
</tr>
</tbody>
</table>

(*7): Mounted on glass epoxy board. (76.2×114.3×1.6mm: based on EIA/JDEC standard, 2Layers)
(*8): Mounted on glass epoxy board. (76.2×114.3×1.6mm: based on EIA/JDEC standard, 4Layers)
(For 4Layers: Applying 74.2×74.2mm inner Cu area and a thermal via hole to a board based on JEDEC standard JESD51-5)
(*9): Mounted on glass epoxy board. (76.2×114.3×1.6mm: based on EIA/JDEC standard size, 2Layers, Cu area 100mm²)

## POWER DISSIPATION vs. AMBIENT TEMPERATURE

New Japan Radio Co.,Ltd.

Ver.2020-03-17
TYPICAL APPLICATIONS

NJW4155

EN/SYNC
High: ON
Low: OFF
(Standby)

Power Good
(NJW4155GM1 only)

IN

GND

V^*

SW

NJW4155

PG

CIN1

CIN2

EN/SYNC

L

R1

R2

COUT

VOUT

VIN

VOUT

IN1

CIN2

R1

R2

COUT

Power Good
(NJW4155GM1 only)

High: ON
Low: OFF
(Standby)

High: ON
Low: OFF
(Standby)

High: ON
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(Standby)

High: ON
Low: OFF
(Standby)

High: ON
Low: OFF
(Standby)

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High: ON
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(Standby)

High: ON
Low: OFF
(Standby)

High: ON
Low: OFF
(Standby)

High: ON
Low: OFF
(Standby)
TYPICAL CHARACTERISTICS (A, B, D version)

Reference Voltage vs. Supply Voltage
(Ta=25°C)

Reference Voltage vs. Temperature
(V+=12V)

Switching Current Limit vs. Temperature
(V+=12V, 40V, 5V)

Output ON Resistance vs. Temperature
(I_{SW}=1.5A, V+=12V, 5V, 40V)
- TYPICAL CHARACTERISTICS (A, B, D version)

- Soft Start Time vs. Temperature

- Threshold Voltage vs. Temperature

- Under Voltage Lockout Voltage vs. Temperature

- Switching Leak Current vs. Temperature

- Standby Current vs. Temperature
TYPICAL CHARACTERISTICS (A, D version)

Oscillation Frequency vs. Supply Voltage
(A, D ver., V_{IN}=0.7V, Ta=25°C)

Quiescent Current vs. Supply Voltage
(A, D ver, R_{L}=no load, V_{IN}=0.7V, Ta=25°C)

Oscillation Frequency vs Temperature
(A, D ver., V^+=12V, V_{IN}=0.7V)

Maximum Duty Cycle vs. Temperature
(A, D ver., V^+=12V, V_{IN}=0.7V)

Minimum ON Time vs. Temperature
(A, D ver., V^+=12V)

Quiescent Current vs. Temperature
(A, D ver., R_{L}=no load, V_{IN}=0.7V)

V^+=12V
V^+=40V
V^+=4.5V

New Japan Radio Co., Ltd.
Ver.2020-03-17
TYPICAL CHARACTERISTICS (B version)

Oscillation Frequency vs. Supply Voltage (B ver., $V_{in}=0.7V$, $T_a=25^\circ C$)

Quiescent Current vs. Supply Voltage (B ver, $R_L$=no load, $V_{in}=0.7V$, $T_a=25^\circ C$)

Oscillation Frequency vs Temperature (B ver., $V^*=12V$, $V_{in}=0.7V$)

Maximum Duty Cycle vs. Temperature (B ver., $V^*=12V$, $V_{in}=0.7V$)

Minimum ON Time1 vs. Temperature (B ver., $V^*=12V$)

Quiescent Current vs. Temperature (B ver., $R_L$=no load, $V_{in}=0.7V$)

- New Japan Radio Co., Ltd.
- Ver.2020-03-17
Description of Block Features

1. Basic Functions / Features

● Error Amplifier Section (ER-AMP)
  0.8V±1% precise reference voltage is connected to the non-inverted input of this section.
  To set the output voltage, connects converter’s output to inverted input of this section (IN- pin). If requires output voltage over 0.8V, inserts resistor divider.
  Because the optimized compensation circuit is built-in, the application circuit can be composed of minimum external parts.

● PWM Comparator Section (PWM), Oscillation Circuit Section (OSC)
  The NJW4155 uses a constant frequency, current mode step down architecture. The oscillation frequency is 450kHz (typ.) at A, D version and 300kHz (typ.) at B version. The PWM signal is output by feedback of output voltage and slope compensation switching current at the PWM comparator block.
  The maximum duty ratio is 95.5% (typ.).

Table 1. Minimum ON time of NJW4155

<table>
<thead>
<tr>
<th></th>
<th>A, D version (f_{OSC} =450kHz)</th>
<th>B version (f_{OSC} =300kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use Built-in Oscillator</td>
<td>150ns typ.</td>
<td>215ns typ.</td>
</tr>
<tr>
<td>Use External Clock (f_{SYNC}=500kHz)</td>
<td>100ns typ.</td>
<td>145ns typ.</td>
</tr>
</tbody>
</table>

The buck converter of ON time is decided the following formula.

\[ t_{on} = \frac{V_{OUT}}{V_{IN} \times f_{OSC}} \text{ [s]} \]

\( V_{IN} \) shows input voltage and \( V_{OUT} \) shows output voltage.

When the ON time becomes below \( t_{on_{min}} \), in order to maintain output voltage at a stable state, change of duty or pulse skip operation may be performed.

● Power MOSFET (SW Output Section)
  The power is stored in the inductor by the switch operation of built-in power MOSFET. The output current is limited to 2.7A(min.) the overcurrent protection function. In case of step-down converter, the forward direction bias voltage is generated with inductance current that flows into the external regenerative diode when MOSFET is turned off.
  The SW pin allows voltage between the \( V^+ \) pin and the SW pin up to +45V. However, you should use an Schottky diode that has low saturation voltage.

● Power Supply, GND pin (\( V^+ \) and GND)
  In line with switching element drive, current flows into the IC according to frequency. If the power supply impedance provided to the power supply circuit is high, it will not be possible to take advantage of IC performance due to input voltage fluctuation. Therefore insert a bypass capacitor close to the \( V^+ \) pin – the GND pin connection in order to lower high frequency impedance.
Description of Block Features (Continued)

2. Additional and Protection Functions / Features

- Under Voltage Lockout (UVLO)

  The UVLO circuit operating is released above \( V^+ = 4.4 \text{V (typ.)} \) and IC operation starts. When power supply voltage is low, IC does not operate because the UVLO circuit operates. There is 90mV (typ.) width hysteresis voltage at rise and decay of power supply voltage. Hysteresis prevents the malfunction at the time of UVLO operating and releasing.

- Soft Start Function (Soft Start)

  The output voltage of the converter gradually rises to a set value by the soft start function. The soft start time is 4ms (typ.), It is defined with the time of the error amplifier reference voltage becoming from 0V to 0.75V. The soft start circuit operates after the release UVLO and/or recovery from thermal shutdown.

![Steady Operation](image)

Fig. 1. Startup Timing Chart
Description of Block Features (Continued)

Over Current Protection Circuit (OCP)

NJW4155 contains overcurrent protection circuit of hiccup architecture. The overcurrent protection circuit of hiccup architecture is able to decrease heat generation at the overload.

The NJW4155 output returns automatically along with release from the over current condition. At when the switching current becomes $I_{BL}$ or more, the overcurrent protection circuit is stopped the MOSFET output. The switching output holds low level down to next pulse output at OCP operating.

When the IN- pin voltage is 0.5V or lower(less), the switching operation stops after the overcurrent detection continued 128 pulses.

After NJW4155 switching operation was stopped, it restarts by soft start function after the cool down time of approx 75ms (typ.).

Thermal Shutdown Function (TSD)

When Junction temperature of the NJW4155 exceeds the 160°C*, internal thermal shutdown circuit function stops SW function. When junction temperature decreases to 145°C* or less, SW operation returns with soft start operation.

The purpose of this function is to prevent malfunctioning of IC at the high junction temperature. Therefore it is not something that urges positive use. You should make sure to operate within the junction temperature range rated (150°C). (* Design value)

Standby Function

The NJW4155 stops the operating and becomes standby status when the EN/SYNC pin becomes less than 0.5V. The EN/SYNC pin internally pulls down with 100kΩ, therefore the NJW4155 becomes standby mode when the EN/SYNC pin is OPEN. You should connect this pin to $V^*$ when you do not use standby function.

---

Fig. 2. Timing Chart at Over Current Detection

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Technical Information

NJW4155 Application Manual
Description of Block Features (Continued)

- External Clock Synchronization

By inputting a square wave to EN/SYNC pin, can be synchronized to an external frequency. You should fulfill the following specification about a square wave. (Table 2.)

Table 2. The input square wave to an EN/SYNC pin.

<table>
<thead>
<tr>
<th></th>
<th>A, D version (fOSC =450kHz)</th>
<th>B version (fOSC =300kHz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Frequency</td>
<td>440kHz to 600kHz</td>
<td>280kHz to 500kHz</td>
</tr>
<tr>
<td>Duty Cycle</td>
<td>25% to 75%</td>
<td>20% to 80%</td>
</tr>
<tr>
<td>Voltage magnitude</td>
<td>1.6V or more at High level</td>
<td>0.5V or less at Low level</td>
</tr>
</tbody>
</table>

The trigger of the switching operating at the external synchronized mode is detected to the rising edge of the input signal. At the time of switching operation from standby or asynchronous to synchronous operation, it has set a delay time approx 20μs to 30μs in order to prevent malfunctions. (Fig. 3.)

Power Good Function

It monitors the output status and outputs a signal from PG pin that internally connected to open drain MOSFET. The Power Good pin goes high impedance when the IN- pin voltage is stable around ±10%(typ.) of error amplifier reference voltage.

A low on the pin indicates that the IN- pin voltage is out of the setting voltage.

To prevent malfunction of the Power Good output, it has hysteresis 2%(typ.) and the delay time approx 20μs to 30μs against the IN- pin voltage changes.
Because large current flows to the inductor, you should select the inductor with the large current capacity not to saturate. Optimized inductor value is determined by the input voltage and output voltage.

The inductor setting example is shown in Table 3.

<table>
<thead>
<tr>
<th>Input Voltage $V_{\text{IN}}$</th>
<th>Output Voltage $V_{\text{OUT}}$</th>
<th>Inductor L $L$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Input Voltage $V_{\text{OUT}}$</td>
<td>A, D version ($f_{\text{OSC}}=450\text{kHz}$)</td>
</tr>
<tr>
<td>12V</td>
<td>3.3V</td>
<td>$\leq 27\mu\text{H}$</td>
</tr>
<tr>
<td></td>
<td>5.0V</td>
<td>$\leq 33\mu\text{H}$</td>
</tr>
<tr>
<td></td>
<td>8.0V</td>
<td>$\leq 33\mu\text{H}$</td>
</tr>
<tr>
<td>24V</td>
<td>3.3V</td>
<td>$\leq 39\mu\text{H}$</td>
</tr>
<tr>
<td></td>
<td>5.0V</td>
<td>$\leq 47\mu\text{H}$</td>
</tr>
<tr>
<td></td>
<td>8.0V</td>
<td>$\leq 47\mu\text{H}$</td>
</tr>
</tbody>
</table>

When increasing inductor value, it is necessary to increasing capacity of an output capacitor and to secure the stability of application. The minimum of inductor value is restricted from the following formula, when ON duty exceeds 50%.

- A, D version: $L \geq \frac{V_{\text{IN}} \times (2 \times D_{\text{cn}} - 1)}{1.11} [\mu\text{H}]$
- B version: $L \geq \frac{V_{\text{IN}} \times (2 \times D_{\text{cn}} - 1)}{0.74} [\mu\text{H}]$

Reducing L decreases the size of the inductor. However a peak current increases and adversely affects the efficiency. (Fig. 4.)

Moreover, you should be aware that the output current is limited because it becomes easy to operating to the overcurrent limit.

The peak current is decided the following formula.

$$\Delta L = \frac{(V_{\text{IN}} - V_{\text{OUT}}) \times V_{\text{OUT}}}{L \times V_{\text{IN}} \times f_{\text{OSC}}} [\text{A}]$$

$$I_{pk} = I_{\text{OUT}} + \frac{\Delta L}{2} [\text{A}]$$

Fig. 4. Inductor Current State Transition (Continuous Conduction Mode)
Application Information (Continued)

Input Capacitor

Transient current flows into the input section of a switching regulator responsive to frequency. If the power supply impedance provided to the power supply circuit is large, it will not be possible to take advantage of the NJW4155 performance due to input voltage fluctuation. Therefore insert an input capacitor as close to the MOSFET as possible. A ceramic capacitor is the optimal for input capacitor.

The effective input current can be expressed by the following formula.

\[ I_{\text{rms}} = \frac{V_{\text{out}} \times (V_{\text{in}} - V_{\text{out}})}{V_{\text{in}}} \ [\text{A}] \]

In the above formula, the maximum current is obtained when \( V_{\text{in}} = 2 \times V_{\text{out}} \), and the result in this case is \( I_{\text{rms}} = \frac{I_{\text{out}}(\text{MAX})}{2} \).

When selecting the input capacitor, carry out an evaluation based on the application, and use a capacitor that has adequate margin.

Output Capacitor

An output capacitor stores power from the inductor, and stabilizes voltage provided to the output. Because NJW4155 corresponds to the output capacitor of low ESR, the ceramic capacitor is the optimal for compensation. The output capacitor setting example is shown in Table 4.

Table 4. Output Capacitor Setting Example

<table>
<thead>
<tr>
<th>Input Voltage ( V_{\text{IN}} )</th>
<th>Output Voltage ( V_{\text{OUT}} )</th>
<th>Capacitor ( C_{\text{OUT}} )</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>A, D version</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12V, 24V</td>
<td>3.3V</td>
<td>( \geq 47 \mu F / 6.3V )</td>
<td>GRM31CB30J476KE18: Murata</td>
</tr>
<tr>
<td></td>
<td>5.0V</td>
<td>( \geq 22 \mu F / 6.3V )</td>
<td>GRM31CB30J226ME18: Murata</td>
</tr>
<tr>
<td></td>
<td>8.0V</td>
<td>( \geq 22 \mu F / 10V )</td>
<td>GRM31CR61A226ME19: Murata</td>
</tr>
<tr>
<td>B version</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12V, 24V</td>
<td>3.3V</td>
<td>( \geq 47 \mu F / 6.3V )</td>
<td>GRM31CB30J476KE18: Murata</td>
</tr>
<tr>
<td></td>
<td>5.0V</td>
<td>( \geq 47 \mu F / 6.3V )</td>
<td>GRM31CB30J226ME18: Murata</td>
</tr>
<tr>
<td></td>
<td>8.0V</td>
<td>( \geq 47 \mu F / 16V )</td>
<td>GRM32EB31C476KE15: Murata</td>
</tr>
</tbody>
</table>

The output capacitor uses capacity bigger than Table 4.

In addition, you should consider varied characteristics of capacitor (a frequency characteristic, a temperature characteristic, a DC bias characteristic and so on) and unevenness peculiar to a capacitor supplier enough. Therefore when selecting a capacitors, you should confirm the characteristics with supplier datasheets.

When selecting an output capacitor, you must consider Equivalent Series Resistance (ESR) characteristics, ripple current, and breakdown voltage.

The output ripple noise can be expressed by the following formula.

\[ V_{\text{ripple(p-p)}} = ESR \times \Delta I_L \ [V] \]

The effective ripple current that flows in a capacitor \( I_{\text{rms}} \) is obtained by the following equation.

\[ I_{\text{rms}} = \frac{\Delta I_L}{2\sqrt{3}} \ [\text{Arms}] \]
Application Information (Continued)

- **Catch Diode**

  When the switch element is in OFF cycle, power stored in the inductor flows via the catch diode to the output capacitor. Therefore during each cycle current flows to the diode in response to load current. Because diode's forward saturation voltage and current accumulation cause power loss, a Schottky Barrier Diode (SBD), which has a low forward saturation voltage, is ideal.

  An SBD also has a short reverse recovery time. If the reverse recovery time is long, through current flows when the switching transistor transitions from OFF cycle to ON cycle. This current may lower efficiency and affect such factors as noise generation.

- **Setting Output Voltage, Compensation Capacitor**

  The output voltage $V_{OUT}$ is determined by the relative resistances of $R_1$, $R_2$. The current that flows in $R_1$, $R_2$ must be a value that can ignore the bias current that flows in ER AMP:

  $$V_{OUT} = \left(\frac{R_2}{R_1} + 1\right) \times V_B \, [V]$$

  The zero points are formed with $R_2$ and $C_{FB}$, and it makes for the phase compensation of NJW4155. The zero point is shown the following formula.

  $$f_z = \frac{1}{2 \times \pi \times R_2 \times C_{FB}} \, [Hz]$$

  You should set the zero point as a guide from 50kHz to 70kHz.

  Output voltage setting resistor and compensation capacitor setting example is shown in Table 5.

Table 5. Output Voltage Setting Resistor and Compensation Capacitor Setting Example

<table>
<thead>
<tr>
<th>Input Voltage $V_N$</th>
<th>Output Voltage $V_{OUT}$</th>
<th>R1</th>
<th>R2</th>
<th>$C_{FB}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>12V, 24V</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.3V</td>
<td>4.7kΩ</td>
<td>15kΩ</td>
<td>180pF</td>
<td></td>
</tr>
<tr>
<td>5.0V</td>
<td>3.0kΩ</td>
<td>16kΩ</td>
<td>150pF</td>
<td></td>
</tr>
<tr>
<td>8.0V</td>
<td>2.2kΩ</td>
<td>20kΩ</td>
<td>120pF</td>
<td></td>
</tr>
</tbody>
</table>

(A version, B version and D version are common.)
Application Information (Continued)

- Board Layout

In the switching regulator application, because the current flow corresponds to the oscillation frequency, the substrate (PCB) layout becomes an important.

You should attempt the transition voltage decrease by making a current loop area minimize as much as possible. Therefore, you should make a current flowing line thick and short as much as possible. Fig.5. shows a current loop at step-down converter. Especially, should lay out high priority the loop of C_{IN}-SW-SBD that occurs rapid current change in the switching. It is effective in reducing noise spikes caused by parasitic inductance.

![Current Loop at Buck Converter](image)

Fig. 5. Current Loop at Buck Converter

Concerning the GND line, it is preferred to separate the power system and the signal system, and use single ground point.

The voltage sensing feedback line should be as far away as possible from the inductance. Because this line has high impedance, it is laid out to avoid the influence noise caused by flux leaked from the inductance.

Fig. 6. shows example of wiring at buck converter. Fig. 7 shows the PCB layout example.

![Board Layout at Buck Converter](image)

Fig. 6. Board Layout at Buck Converter
Application Information (Continued)

HSOP8 Package (A version and B version)

Connect Signal GND line and Power GND line on backside pattern

Fig. 7. Layout Example (upper view)
Calculation of Package Power

A lot of the power consumption of buck converter occurs from the internal switching element (Power MOSFET).

Power consumption of NJW4155 is roughly estimated as follows.

Input Power: \( P_{IN} = V_{IN} \times I_{IN} \) [W]

Output Power: \( P_{OUT} = V_{OUT} \times I_{OUT} \) [W]

Diode Loss: \( P_{DIODE} = V_{F} \times I_{L(avg)} \times \text{OFF duty} \) [W]

NJW4155 Power Consumption: \( P_{LOSS} = P_{IN} - P_{OUT} - P_{DIODE} \) [W]

Where:
- \( V_{IN} \): Input Voltage for Converter
- \( I_{IN} \): Input Current for Converter
- \( V_{OUT} \): Output Voltage of Converter
- \( I_{OUT} \): Output Current of Converter
- \( V_{F} \): Diode’s Forward Saturation Voltage
- \( I_{L(avg)} \): Inductor Average Current
- \( \text{OFF duty} \): Switch OFF Duty

Efficiency (\( \eta \)) is calculated as follows.

\[
\eta = \left( \frac{P_{OUT}}{P_{IN}} \right) \times 100 \% 
\]

You should consider temperature derating to the calculated power consumption: \( P_D \).

You should design power consumption in rated range referring to the power dissipation vs. ambient temperature characteristics.
Application Design Examples

- Buck Converter Application Circuit

IC: NJW4155GM1
Input Voltage: \( V_{IN} = 12V \)
Output Voltage: \( V_{OUT} = 5V \)
Output Current: \( I_{OUT} = 1.8A \)
Oscillation frequency:
  - A, D version: \( f_{osc} = 450kHz \)
  - B version: \( f_{osc} = 300kHz \)

The diagram illustrates the components and connections for the Buck Converter Application Circuit, including the IC, input and output voltages, and the operation of the EN/SYNC and Power Good signals.

<table>
<thead>
<tr>
<th>Reference</th>
<th>Qty.</th>
<th>Part Number</th>
<th>Description</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>IC</td>
<td>1</td>
<td>NJW4155GM1</td>
<td>Internal 1.8A MOSFET SW.REG. IC</td>
<td>New JRC</td>
</tr>
<tr>
<td>L</td>
<td>1</td>
<td>A, D ver.: CLF10040T-150M</td>
<td>Inductor 15μH, 3.2A</td>
<td>TDK</td>
</tr>
<tr>
<td></td>
<td></td>
<td>B ver.: CLF10040T-220M</td>
<td>Inductor 22μH, 2.7A</td>
<td>TDK</td>
</tr>
<tr>
<td>SBD</td>
<td>1</td>
<td>CMS16</td>
<td>Schottky Diode 40V, 3A</td>
<td>Toshiba</td>
</tr>
<tr>
<td>C_{IN1}</td>
<td>1</td>
<td>UMK325BJ106MM</td>
<td>Ceramic Capacitor 3225 10μF, 50V, X5R</td>
<td>Taiyo Yuden</td>
</tr>
<tr>
<td>C_{IN2}</td>
<td>1</td>
<td>Open</td>
<td>Optional</td>
<td>—</td>
</tr>
<tr>
<td>C_{OUT}</td>
<td>1</td>
<td>GRM32EB31C476KE15</td>
<td>Ceramic Capacitor 3225 47μF, 16V, B</td>
<td>Murata</td>
</tr>
<tr>
<td>C_{FB}</td>
<td>1</td>
<td>150pF</td>
<td>Ceramic Capacitor 1608 150pF, 50V, CH</td>
<td>Std.</td>
</tr>
<tr>
<td>R_{FB}</td>
<td>1</td>
<td>0Ω (Short)</td>
<td>Optional</td>
<td>—</td>
</tr>
<tr>
<td>R1</td>
<td>1</td>
<td>3kΩ</td>
<td>Resistor 1608 3kΩ, ±1%, 0.1W</td>
<td>Std.</td>
</tr>
<tr>
<td>R2</td>
<td>1</td>
<td>16kΩ</td>
<td>Resistor 1608 16kΩ, ±1%, 0.1W</td>
<td>Std.</td>
</tr>
</tbody>
</table>
NJW4155 Application Manual

Application Characteristics
- A, D version
- B version

Technical Information

![Efficiency vs. Output Current](V_{OUT}=5V, \text{Ta}=25^\circ\text{C})

- f=450kHz
- L=15\mu\text{H}
- V_{IN}=7V, 12V, 24V

![Output Voltage vs. Output Current](Ta=25^\circ\text{C})

- f=450kHz
- L=15\mu\text{H}
- V_{IN}=7V, 12V, 24V

![Efficiency vs. Output Current](V_{OUT}=5V, \text{Ta}=25^\circ\text{C})

- f=300kHz
- L=22\mu\text{H}
- V_{IN}=7V, 12V, 24V

![Output Voltage vs. Output Current](Ta=25^\circ\text{C})

- f=300kHz
- L=22\mu\text{H}
- V_{IN}=7V, 12V, 24V
[CAUTION]

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