MOSFET Drive Switching Regulator IC for Boost / Fly-back Converter

■ GENERAL DESCRIPTION

The NJW4140 is a MOSFET Drive switching regulator IC for Boost / Fly-back Converter that operates wide input range from 3V to 40V. It can provide large current application because of built-in highly effective Nch MOSFET drive circuit.

Built-in pulse-by-pulse current detecting type over current protection limits the output current at over load.

It is suitable for boost/fly-back application such as Car Accessory, Office Automation Equipment, Industrial Instrument and so on.

■ FEATURES

- Nch MOSFET Driving
- Wide Operating Voltage Range
- PWM Control
- Wide Oscillating Frequency
- Over Current Protection
- UVLO (Under Voltage Lockout)
- Standby Function
- Package Outline

Driving Voltage 5.3V (typ.)
3V to 40V
40kHz to 1MHz

■ PACKAGE OUTLINE

NJW4140R : MSOP8(VSP8)*
NJW4140M : DMP8

*MEET JEDEC MO-187-DA
PIN CONFIGURATION

NJW4140R
NJW4140M

PIN FUNCTION
1. V^*
2. EN
3. IN-
4. FB
5. CT
6. GND
7. SI
8. OUT

BLOCK DIAGRAM

EN
High: ON
Low: OFF
(Standby)

500kΩ

Soft Start

Vref

Low Frequency
Control

OSC

PWM Comparator

Error AMP

Driver

5V
Reg.

OUT

SI

V^*

ON/OFF

Enable Control

Pulse by Pulse

Vref

IN-

FB

CT

GND

NJW4140R
NJW4140M

New Japan Radio Co., Ltd.
Ver.2020-03-11
### 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>+45</td>
<td>V</td>
</tr>
<tr>
<td>OUT pin Voltage</td>
<td>V_{OUT}</td>
<td>-0.3 to +6 (*1)</td>
<td>V</td>
</tr>
<tr>
<td>SI pin Voltage</td>
<td>V_{SI}</td>
<td>-0.3 to +6</td>
<td>V</td>
</tr>
<tr>
<td>EN pin Voltage</td>
<td>V_{EN}</td>
<td>+45</td>
<td>V</td>
</tr>
<tr>
<td>IN pin Voltage</td>
<td>V_{IN}</td>
<td>+6</td>
<td>V</td>
</tr>
<tr>
<td>CT pin Voltage</td>
<td>V_{CT}</td>
<td>+6 (*1)</td>
<td>V</td>
</tr>
<tr>
<td>OUT pin Peak Current</td>
<td>I_{O_PEAK⁺}</td>
<td>200 (Source)</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>700 (Sink)</td>
<td></td>
</tr>
<tr>
<td>Power Dissipation</td>
<td>P_D</td>
<td>MSOP8(VSP8)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>DMP8</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>595 (*2)</td>
<td>mW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>530 (*2)</td>
<td></td>
</tr>
<tr>
<td>Junction Temperature</td>
<td>T_{j_max}</td>
<td>+150</td>
<td>°C</td>
</tr>
<tr>
<td>Storage Temperature</td>
<td>T_{stg}</td>
<td>-40 to +150</td>
<td>°C</td>
</tr>
</tbody>
</table>

(*1): When Supply voltage is less than +6V, the absolute maximum EN pin voltage is equal to the Supply voltage.

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

### 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>3</td>
<td>–</td>
<td>40</td>
<td>V</td>
</tr>
<tr>
<td>Timing Capacitor</td>
<td>C_T</td>
<td>120</td>
<td>–</td>
<td>3,900</td>
<td>pF</td>
</tr>
<tr>
<td>Oscillating Frequency</td>
<td>f_{OSC}</td>
<td>40</td>
<td>–</td>
<td>1,000</td>
<td>kHz</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>T_{opr}</td>
<td>-40</td>
<td>–</td>
<td>+85</td>
<td>°C</td>
</tr>
</tbody>
</table>
## ELECTRICAL CHARACTERISTICS

(Unless otherwise noted, \( V^* = V_{EN} = 12V, C_T = 470pF, T_a = 25^\circ C \))

<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>Oscillator Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oscillation Frequency 1</td>
<td>( f_{OSC1} )</td>
<td>( C_T = 470pF )</td>
<td>270</td>
<td>300</td>
<td>330</td>
<td>kHz</td>
</tr>
<tr>
<td>Oscillation Frequency 2</td>
<td>( f_{OSC2} )</td>
<td>( C_T = 680pF )</td>
<td>180</td>
<td>210</td>
<td>240</td>
<td>kHz</td>
</tr>
<tr>
<td>Charge Current</td>
<td>( I_{ch} )</td>
<td></td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>μA</td>
</tr>
<tr>
<td>Discharge Current</td>
<td>( I_{ds} )</td>
<td></td>
<td>150</td>
<td>200</td>
<td>250</td>
<td>μA</td>
</tr>
<tr>
<td>Voltage amplitude</td>
<td>( V_{OSC} )</td>
<td></td>
<td>–</td>
<td>0.7</td>
<td>–</td>
<td>V</td>
</tr>
<tr>
<td>Oscillation Frequency deviation (Supply voltage)</td>
<td>( f_{DV} )</td>
<td>( V^* = 3 \text{ to } 40V )</td>
<td>–</td>
<td>1</td>
<td>–</td>
<td>%</td>
</tr>
<tr>
<td>Oscillation Frequency deviation (Temperature)</td>
<td>( f_{DT} )</td>
<td>( T_a = -40 \text{ to } +85^\circ C )</td>
<td>–</td>
<td>6</td>
<td>–</td>
<td>%</td>
</tr>
<tr>
<td>Oscillation Frequency (Low Frequency Control)</td>
<td>( f_{OSC_LOW} )</td>
<td>( V_F = 0.3V, V_{FB} = 0.7V, C_T = 470pF )</td>
<td>90</td>
<td>105</td>
<td>120</td>
<td>kHz</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_{SS} )</td>
<td>( V_B = 0.75V )</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>ms</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>μA</td>
</tr>
<tr>
<td>Open Loop Gain</td>
<td>( A_V )</td>
<td></td>
<td>–</td>
<td>80</td>
<td>–</td>
<td>dB</td>
</tr>
<tr>
<td>Gain Bandwidth</td>
<td>( G_B )</td>
<td></td>
<td>–</td>
<td>3</td>
<td>–</td>
<td>MHz</td>
</tr>
<tr>
<td>Output Source Current</td>
<td>( I_{OM+} )</td>
<td>( V_{FB} = 1V, V_F = 0.7V )</td>
<td>50</td>
<td>100</td>
<td>150</td>
<td>μA</td>
</tr>
<tr>
<td>Output Sink Current</td>
<td>( I_{OM-} )</td>
<td>( V_{FB} = 1V, V_F = 0.9V )</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>mA</td>
</tr>
<tr>
<td>PWM Compare Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Input Threshold Voltage (FB pin)</td>
<td>( V_{T_0} )</td>
<td>Duty=0%, ( V_F = 0.6V )</td>
<td>0.32</td>
<td>0.4</td>
<td>0.54</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>( V_{T_50} )</td>
<td>Duty=50%, ( V_F = 0.6V )</td>
<td>0.63</td>
<td>0.7</td>
<td>0.77</td>
<td>V</td>
</tr>
<tr>
<td>Maximum Duty Cycle</td>
<td></td>
<td>( M_{AX_D_UTY} )</td>
<td>( V_{FB} = 1.2V )</td>
<td>85</td>
<td>90</td>
<td>95</td>
</tr>
<tr>
<td>Current Limit Detection Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current Limit Detection Voltage</td>
<td>( V_{IPK} )</td>
<td></td>
<td>115</td>
<td>140</td>
<td>165</td>
<td>mV</td>
</tr>
<tr>
<td>Delay Time</td>
<td>( T_{DELAY _U} )</td>
<td>( \Delta V_{SIP} = 300mV )</td>
<td>–</td>
<td>90</td>
<td>–</td>
<td>ns</td>
</tr>
<tr>
<td>Output Block</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output High Level ON Resistance</td>
<td>( R_{OH} )</td>
<td>( I_O = -50mA )</td>
<td>–</td>
<td>3</td>
<td>4.5</td>
<td>Ω</td>
</tr>
<tr>
<td>Output Low Level ON Resistance</td>
<td>( R_{OL} )</td>
<td>( I_O = +50mA )</td>
<td>–</td>
<td>2.5</td>
<td>3.5</td>
<td>Ω</td>
</tr>
<tr>
<td>Output Source Current</td>
<td>( I_{OH} )</td>
<td>OUT pin= 4.5V</td>
<td>45</td>
<td>65</td>
<td>85</td>
<td>mA</td>
</tr>
<tr>
<td>Output pin Limiting Voltage</td>
<td>( V_{OLIM} )</td>
<td></td>
<td>5</td>
<td>5.3</td>
<td>5.55</td>
<td>V</td>
</tr>
</tbody>
</table>
## ELECTRICAL CHARACTERISTICS

(Unless otherwise noted, \( V^+ = V_{EN} = 12V, C_T = 470pF, T_a = 25^\circ C \))

<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><strong>Under Voltage Lockout Block</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON Threshold Voltage</td>
<td>( V_{T,ON} )</td>
<td>( V^+ = L \rightarrow H )</td>
<td>2.65</td>
<td>2.8</td>
<td>2.95</td>
<td>V</td>
</tr>
<tr>
<td>OFF Threshold Voltage</td>
<td>( V_{T,OFF} )</td>
<td>( V^+ = H \rightarrow L )</td>
<td>2.4</td>
<td>2.55</td>
<td>2.7</td>
<td>V</td>
</tr>
<tr>
<td><strong>Enable Control Block</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ON Control Voltage</td>
<td>( V_{ON} )</td>
<td>( V_{EN} = L \rightarrow H )</td>
<td>1.7</td>
<td>–</td>
<td>–</td>
<td>V</td>
</tr>
<tr>
<td>OFF Control Voltage</td>
<td>( V_{OFF} )</td>
<td>( V_{EN} = H \rightarrow L )</td>
<td>0</td>
<td>–</td>
<td>0.9</td>
<td>V</td>
</tr>
<tr>
<td>Pull-down Resistance</td>
<td>( R_{PD} )</td>
<td>–</td>
<td>500</td>
<td>–</td>
<td>–</td>
<td>k( \Omega )</td>
</tr>
<tr>
<td><strong>General Characteristics</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quiescent Current</td>
<td>( I_{DD} )</td>
<td>( R_L = \text{no load, } V_N = V_{FB} = 0.7V )</td>
<td>–</td>
<td>1.4</td>
<td>1.7</td>
<td>mA</td>
</tr>
<tr>
<td>Standby Current</td>
<td>( I_{DD,STB} )</td>
<td>( V_{EN} = 0V )</td>
<td>–</td>
<td>2.5</td>
<td>6</td>
<td>( \mu A )</td>
</tr>
</tbody>
</table>

New Japan Radio Co., Ltd.
APPLICATION EXAMPLE

Non-isolated Boost Converter

Non-isolated Fly-back Converter
TYPICAL CHARACTERISTICS

Oscillation frequency vs. Timing Capacitor
(V = 12V, Ta = 25°C)

Maximum Duty Cycle vs. Oscillator Frequency
(V = 12V, VFB = 1.2V, Ta = 25°C)

Oscillation Frequency vs. Supply Voltage
(C = 470pF, Ta = 25°C)

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

Quiescent Current vs. Supply Voltage
(RL = no load, VFB = 0.7V, Ta = 25°C)

Error Amplifier Block
Voltage Gain, Phase vs. Frequency
(V = 12V, Gain = 40dB, Ta = 25°C)
**TYPICAL CHARACTERISTICS**

**Oscillation Frequency vs Temperature**

\[ (V^+ = 12\text{V}, C_T = 470\text{pF}) \]

**Reference Voltage vs. Temperature**

\[ (V^+ = 12\text{V}) \]

**Current Limit Detection Voltage vs. Temperature**

\[ (V^+ = 12\text{V}) \]

**OUT pin Limiting Voltage vs. Temperature**

\[ (V^+ = 12\text{V}) \]

**Output High Level ON Resistance vs. Temperature**

\[ (I_O = 50\text{mA}) \]

**Output Low Level ON Resistance vs. Temperature**

\[ (I_O = +50\text{mA}) \]

**Current Limit Detection Voltage**

\[ V_{\text{IPK}} \text{ (mV)} \]
TYPICAL CHARACTERISTICS

Under Voltage Lockout Voltage vs. Temperature

Enable Control ON/OFF Voltage vs. Temperature

Quiescent Current vs. Temperature

Standby Current vs. Temperature
### PIN DESCRIPTIONS

<table>
<thead>
<tr>
<th>PIN NUMBER</th>
<th>PIN NAME</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>V+</td>
<td>Power Supply pin</td>
</tr>
</tbody>
</table>
| 2          | EN       | Enable Control pin  
The ON/OFF pin internally pulls down with 500kΩ. Normal Operation at the time of High Level. Standby Mode at the time of Low Level or OPEN. |
| 3          | IN-      | Output Voltage Detecting pin  
Connects output voltage through the resistor divider tap to this pin in order to voltage of the IN- pin become 0.8V. |
| 4          | FB       | Feedback Setting pin  
The feedback resistor and capacitor are connected between the FB pin and the IN- pin. |
| 5          | CT       | Oscillating Frequency Setting pin by Timing Capacitor  
Oscillating Frequency should set between 40kHz and 1MHz. |
| 6          | GND      | GND pin |
| 7          | SI       | Current Sensing pin  
When difference voltage between the SI pin and the GND pin exceeds 140mV(typ.), over current protection operates. |
| 8          | OUT      | Output pin for Power MOSFET Driving  
The OUT pin Voltage is clamped with 5.3V(typ.) at the time of High level, in order to protect a gate of Nch MOSFET. |
Description of Block 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.

  This AMP section has high gain and external feedback pin (FB pin). It is easy to insert a feedback resistor and a capacitor between the FB pin and the IN- pin, making possible to set optimum loop compensation for each type of application.

- **Oscillation Circuit Section (OSC)**

  Oscillation frequency can be set by inserting capacitor between the CT pin and GND. Referring to the sample characteristics in "Timing Capacitor and Oscillation Frequency", set oscillation frequency between 40kHz and 1MHz.

  The triangular wave of the oscillating circuit is generated in the IC, having amplitude between 0.4V and 1.0V at $C_T=470\text{pF}\,(\text{ref.})$.

  If voltage of the IN- pin becomes less than 0.4V, the oscillation frequency decreases to one third (33%) and the energy consumption is suppressed.

- **PWM Comparator Section (PWM)**

  This section controls the switching duty ratio.

  PWM comparator receives the signal of the error amplifier and the triangular wave, and controls the duty ratio between 0% and 90%. The timing chart is shown in Fig.1.

```
<table>
<thead>
<tr>
<th>FB pin Voltage</th>
<th>OSC Waveform (IC internal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max Duty setting</td>
<td>V- (High)</td>
</tr>
</tbody>
</table>

Fig. 1. Timing Chart PWM Comparator and OUT pin
```
The output driver circuit is configured a totem pole type, it can efficiently drive a Nch MOSFET switching device. When the output is high level, the OUT pin voltage is clamped with 5.3V (typ.) by the internal regulator to protect gate of Nch MOSFET. (Ref. Fig.2. OUT pin)

![Driver Circuit and the OUT pin Voltage](image)

When supply voltage is decreasing, gate drive voltage output from the OUT pin is also decreasing. Although the OUT pin voltage is kept gate drive voltage by bypassing the internal regulator around supply voltage 5V. Fig.3. shows the example of the OUT pin voltage vs. supply voltage characteristic

The optimum drive ability of MOSFET depends on the oscillation frequency and the gate capacitance of MOSFET.

![OUT pin Voltage vs. Supply Voltage](image)
Description of Block Features (Continued)

- Power Supply, GND pin (V+, GND)

In line with MOSFET 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.

- Under Voltage Lockout Function (UVLO)

The UVLO circuit operating is released above V+=2.8V(typ.) and IC operation starts. When power supply voltage is low, IC does not operate because the UVLO circuit operates. There is 250mV width hysteresis voltage at rise and decay of power supply voltage. Hysteresis prevents the malfunction at the time of UVLO operating and releasing.

- Enable Function (Enable Control)

The NJW4140 stops the operating and becomes standby status when the EN pin becomes less than 0.9V. The EN pin internally pulls down with 500kΩ, therefore the NJW4140 becomes standby mode when the EN pin is OPEN. You should connect this pin to V+ when you do not use Enable function.

- 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. The operating frequency is controlled with a low frequency, approximately 33% of the set value by the timing resistor, until voltage of the IN- pin becomes approximately 0.4V.

![Startup Timing Chart](Image)
Description of Block Features (Continued)

- Over Current Protection Circuit

At when the potential difference between the V+ pin and the SI pin becomes 140mV or more, the over current protection circuit stops the switch output. The switching current is detected by inserted current sensing resistor (R_{SENSE}) between the SI pin and the GND pin. Fig.5. shows the timing chart of the over current protection detection.

The switching output holds low level until next pulse output at OCP operating. The NJW4140 output returns automatically along with release from the over current condition because the OCP is pulse-by-pulse type.

If voltage of the IN- pin becomes less than 0.4V, the oscillation frequency decreases to one third (33%) and the energy consumption is suppressed.

![Fig. 5. Timing Chart at Over Current Detection](image)

The current waveform contains high frequency superimposed noises due to the parasitic elements of MOSFET, the inductor and the others. Depending on the application, inserting RC low-pass filter between current sensing resistor (R_{SENSE}) and the SI pin to prevent the malfunction due to such noise. The time constant of RC low-pass filter should be equivalent to the spike width (T ≤ R × C) as a rough guide (Fig. 6).

![Fig. 6. Current Waveform and Filter Circuit](image)
**Application Information**

**Inductors**

- Large currents flow into inductor, therefore you must provide current capacity that does not saturate.
- Reducing L, the size of the inductor can be smaller. However, peak current increases and adversely affecting efficiency.
- On the other hand, increasing L, peak current can be reduced at switching time. Therefore conversion efficiency improves, and output ripple voltage reduces. Above a certain level, increasing inductance windings increases loss (copper loss) due to the resistor element.
- Ideally, the value of L is set so that inductance current is in continuous conduction mode. However, as the load current decreases, the current waveform changes from (1) CCM: Continuous Conduction Mode → (2) Critical Mode → (3) DCM: Discontinuous Conduction Mode (Fig. 7.).

In discontinuous mode, peak current increases with respect to output current, and conversion efficiency tends to decrease. Depending on the situation, increase L to widen the load current area to maintain continuous mode.

**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.
- When the switch element is in ON cycle, a reverse voltage flows to SBD. Therefore you should select a SBD that has reverse voltage rating greater than maximum output voltage. The power loss, which stored in output capacitor, will be increase due to increasing reverse current through SBD at high temperature. Therefore, there is cases preferring reverse current characteristics to forward current characteristic in order to improve efficiency.

**Switching Element**

- You should use a switching element (Nch MOSFET) that is specified for use as a switch. And select sufficiently low $R_{ON}$ MOSFET at less than $V_{GS}=5V$ because the NJW4140 OUT pin voltage is clamped 5.3 (typ.).
- However, when the supply voltage of the NJW4140 is low, the OUT pin voltage becomes low. You should select a suitable MOSFET according to the supply voltage specification. (Ref. Driver section)

Large gate capacitance is a source of decreased efficiency. That is charge and discharge from gate capacitance delays switching rise and fall time, generating switching loss.

The spike noise might occur at the time of charge/discharge of gate by the parasitic inductance element. You should insert resistance between the OUT pin and the gate and limit the current for gate protection when gate capacitance is small. However, it should be noted that the efficiency might decrease because the shape of waves may become duller when resistance is too large. The last fine-tuning should be done on the actual device and equipment.
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 NJW4140 performance due to input voltage fluctuation. Therefore insert an input capacitor as close to the MOSFET as possible.

Output Capacitor
An output capacitor stores power from the inductor, and stabilizes voltage provided to the output.
When selecting an output capacitor, you must consider Equivalent Series Resistance (ESR) characteristics, ripple current, and breakdown voltage.
Also, the ambient temperature affects capacitors, decreasing capacitance and increasing ESR (at low temperature), and decreasing lifetime (at high temperature). Concerning capacitor rating, it is advisable to allow sufficient margin.
Output capacitor ESR characteristics have a major influence on output ripple noise. A capacitor with low ESR can further reduce ripple voltage. Be sure to note the following points; when ceramic capacitor is used, the capacitance value decreases with DC voltage applied to the capacitor.
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. 8 shows a current loop at step-down 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. 9 shows example of wiring at boost converter. Fig. 10 shows the PCB layout example.

To avoid the influence of the voltage drop, the output voltage should be detected near the load.

Because IN- pin is high impedance, the voltage detection resistance: R1/R2 is put as much as possible near IC(N-).

Fig. 9. Board Layout at Boost Converter
Fig. 10  Layout Example (upper view)
Calculation of Package Power

You should consider derating power consumption under using high ambient temperature. Moreover, you should consider the power consumption that occurs in order to drive the switching element.

Supply Voltage: \( V^* \)

Quiescent Current: \( I_{DD} \)

Oscillation Frequency: \( f_{OSC} \)

ON time: \( t_{on} \)

Gate charge amount: \( Q_g \)

The gate of MOSFET has the character of high impedance. The power consumption increases by quickening the switching frequency due to charge and discharge the gate capacitance. Power consumption: \( P_D \) is calculated as follows.

\[
P_D = (V^* \times I_{DD}) + (V^* \times Q_g \times f_{OSC}) \ [W]
\]

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 (Fig. 11).

![Power Dissipation vs. Ambient Temperature Characteristics](image)

Mounted on glass epoxy board. (76.2×114.3×1.6mm:EIA/JDEC standard size, 2Layers)

Mounted on glass epoxy board. (76.2×114.3×1.6mm:EIA/JDEC standard size, 4Layers), internal Cu area: 74.2×74.2mm

Fig. 11. Power Dissipation vs. Ambient Temperature Characteristics
Application Design Examples

- Step-Up Application Circuit

**IC**: NJW4140R
- **Input Voltage**: $V_{IN}=9V$ to $15V$
- **Output Voltage**: $V_{OUT}=20V$
- **Output Current**: $I_{OUT}=1.5A$ (@$V_{IN}=12V$)
- **Oscillation frequency**: $f_{osc}=300kHz$

```
EN
High: ON
Low: OFF (Standby)
```

```
R1: 3.3kΩ
R2: 82kΩ
R3: 0Ω (Short)
R4: 330Ω
```

```
C1: 470pF
CT: 0.1µF/50V
CIN: 220µF/35V
COUT1: 0.1µF Ceramic Capacitor 1608 0.1µF, 50V, B Std.
COUT2: 0.1µF Ceramic Capacitor 1608 0.1µF, 50V, B Std.
CNF: 10,000pF Ceramic Capacitor 1608 0.1µF/50V
CFB: 820pF Ceramic Capacitor 1608 820pF, 50V, B Std.
CS1: 390pF Ceramic Capacitor 1608 390pF, 50V, B Std.
```

```
RSENSE: UR73D3ATTE39L0F Resistor 2512 39mΩ, ±1%, 1W KOA
```

```
V_{IN}=12V
```

```
V_{OUT}=20V
```

- **Reference Qty. Part Number Description Manufacturer**

<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>NJW4140R</td>
<td>MOSFET Drive Switching Regulator IC for Boost / Fly-back Converter IC</td>
<td>New JRC</td>
</tr>
<tr>
<td>Q1</td>
<td>1</td>
<td>TPCA8052-H</td>
<td>Nch MOSFET 40V, 20A</td>
<td>Toshiba</td>
</tr>
<tr>
<td>L1</td>
<td>1</td>
<td>CDRH127LDNP-220</td>
<td>Inductor 22µH, 4.7A</td>
<td>Sumida</td>
</tr>
<tr>
<td>SBD</td>
<td>1</td>
<td>DE5SC4M</td>
<td>Schottky Diode 40V, 5A</td>
<td>Shindengen</td>
</tr>
<tr>
<td>C_{IN1}</td>
<td>1</td>
<td>EEEFP1V221AP</td>
<td>Aluminum Electrolytic Capacitor 220µF, 35V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>C_{IN2}</td>
<td>1</td>
<td></td>
<td>Ceramic Capacitor 1608 0.1µF, 50V, B Std.</td>
<td></td>
</tr>
<tr>
<td>C_{OUT1}</td>
<td>2</td>
<td>EEEFP1V101AP</td>
<td>Aluminum Electrolytic Capacitor 100µF, 35V</td>
<td>Panasonic</td>
</tr>
<tr>
<td>C_{OUT2}</td>
<td>1</td>
<td></td>
<td>Ceramic Capacitor 1608 0.1µF, 50V, B Std.</td>
<td></td>
</tr>
<tr>
<td>C_{NF}</td>
<td>1</td>
<td></td>
<td>Ceramic Capacitor 1608 0.1µF, 50V, CH Std.</td>
<td></td>
</tr>
<tr>
<td>C_{FB}</td>
<td>1</td>
<td></td>
<td>Ceramic Capacitor 1608 820pF, 50V, B Std.</td>
<td></td>
</tr>
<tr>
<td>C_{S1}</td>
<td>1</td>
<td></td>
<td>Ceramic Capacitor 1608 390pF, 50V, B Std.</td>
<td></td>
</tr>
<tr>
<td>R1</td>
<td>1</td>
<td></td>
<td>Resistor 1608 3.3kΩ, ±1%, 0.1W</td>
<td>Std.</td>
</tr>
<tr>
<td>R2</td>
<td>1</td>
<td></td>
<td>Resistor 1608 82kΩ, ±1%, 0.1W</td>
<td>Std.</td>
</tr>
<tr>
<td>R_{NF}</td>
<td>1</td>
<td></td>
<td>Resistor 1608 13kΩ, ±1%, 0.1W</td>
<td>Std.</td>
</tr>
<tr>
<td>R_{FB}</td>
<td>1</td>
<td></td>
<td>Resistor 1608 20kΩ, ±1%, 0.1W</td>
<td>Std.</td>
</tr>
<tr>
<td>R_{SENSE}</td>
<td>1</td>
<td></td>
<td>Resistor 2512 39mΩ, ±1%, 1W</td>
<td>KOA</td>
</tr>
<tr>
<td>R3</td>
<td>1</td>
<td></td>
<td>Resistor 1608 0Ω (Short)</td>
<td>Std.</td>
</tr>
<tr>
<td>R_{S1}</td>
<td>1</td>
<td></td>
<td>Resistor 1608 330Ω, ±1%, 0.1W</td>
<td>Std.</td>
</tr>
</tbody>
</table>
Application Design Examples (Continued)

- Setting Oscillation Frequency
  
  From the Oscillation frequency vs. Timing Capacitor Characteristic, reads $C_T = 470 \, \mu F$, $t = 3.33 \, \mu s$ at $f_{osc} = 300 \, kHz$.

  Step-Up converter duty ratio is shown with the following equation.

  $$\text{Duty} = \left( 1 - \frac{V_{\text{IN}}}{V_{\text{OUT}}} \right) \times 100 = \left( 1 - \frac{12}{20} \right) \times 100 = 40 \, \%$$

  Therefore, $t_{\text{ON}} = 1.33 \, \mu s$, $t_{\text{OFF}} = 2.0 \, \mu s$

- Selecting Inductance
  
  The inductor's average current equals input current ($I_{\text{IN}}$). Estimated efficiency ($\eta$) is 93% and calculates input current as follows.

  $$I_{\text{IN}} = \frac{V_{\text{OUT}} \times I_{\text{OUT}}}{\eta \times V_{\text{IN}}} = \frac{20 \times 1.5}{0.93 \times 12} = 2.69 \, [A]$$

  $\Delta I_L$ is Inductance ripple current. When $\Delta I_L$ is 27% of input current:

  $$\Delta I_L = 0.27 \times I_{\text{IN}} = 0.27 \times 2.69 = 0.73 \, [A]$$

  This obtains inductance $L$.

  $$L = \frac{V_{\text{IN}}}{\Delta I_L} \times t_{\text{ON}} = \frac{12}{0.73} \times 1.33 \, \mu H = 22 \, [\mu H]$$

  Inductance $L$ is a theoretical value. The optimum value varies according such factors as application specifications and components. Fine-tuning should be done on the actual device.

  This obtains the peak current $I_{pk}$ at switching time.

  $$I_{pk} = I_{\text{IN}} + \frac{\Delta I_L}{2} = 2.69 + \frac{0.73}{2} = 3.06 \, [A]$$

  The current that flows into the inductance provides sufficient margin for peak current at switching time.

  In the application circuit, use $L = 22 \, \mu H$, $4.5 \, A$.

- Setting Over Current Detection
  
  In this application, current limitation value: $I_{\text{LIMIT}}$ is set to $I_{pk} = 3.5 \, A$.

  $$I_{\text{LIMIT}} = \frac{V_{\text{IN}}}{R_{\text{SC}}} = \frac{140 \, mV}{39 \, \Omega} = 3.59 \, [A]$$

  The limit value increases slightly according to response time from the overcurrent detection with the SI pin to the OUT pin stop.

  $$I_{\text{LIMIT DELAY}} = I_{\text{LIMIT}} + \frac{V_{\text{IN}}}{L} \times T_{\text{DELAY}} = 3.59 + \frac{12}{22 \, \mu} \times 90n = 3.64 \, [A]$$
Application Design Examples (Continued)

- Selecting the Input Capacitor
  The input capacitor corresponds to the input of the power supply. It is required to adequately reduce the impedance of the power supply. The input capacitor selection should be determined by the input ripple current and the maximum input voltage of the capacitor rather than its capacitance value.

  The effective input current can be expressed by the following formula.
  \[ I_{\text{RMS}_{\text{CN}}} = \frac{\Delta I_L}{2\sqrt{3}} = \frac{0.73}{2\sqrt{3}} = 0.21 \text{ [Arms]} \]

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

- Selecting the Output Capacitor
  The output capacitor is an important component that determines output ripple noise. Equivalent Series Resistance (ESR), ripple current, and capacitor breakdown voltage are important in determining the output capacitor.

  The output ripple noise can be expressed by the following formula.
  \[ V_{\text{ripple}} = \text{ESR} \times \left( I_L + \frac{\Delta I_L}{2} \right) = 40 \text{m} \times \left( 2.69 + \frac{0.73}{2} \right) = 122 \text{ [mV]} \]

  When selecting output capacitance, select a capacitor that allows for sufficient ripple current.
  The effective ripple current that flows in a capacitor \( I_{\text{RMS}_{\text{COUT}}} \) is obtained by the following equation.
  \[ I_{\text{RMS}_{\text{COUT}}} = I_{\text{OUT}} \times \sqrt{\frac{V_{\text{OUT}} - V_{\text{IN}}}{V_{\text{IN}}}} = 1.5 \times \sqrt{\frac{20 - 12}{12}} = 1.22 \text{ [Arms]} \]

  Consider sufficient margin, and use a capacitor that fulfills the above spec.
  In the application circuit, Aluminum Electrolytic Capacitor \( C_{\text{OUT}}=100 \mu\text{F}/35\text{V} \) are used by 2 parallel.

- Setting Output Voltage
  The output voltage \( V_{\text{OUT}} \) 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 Error AMP.
  \[ V_{\text{OUT}} = \left( \frac{R_2}{R_1 + 1} \right) \times V_B = \left( \frac{82k}{3.3k + 1} \right) \times 0.8 = 20.7 \text{ [V]} \]

  It is easy to make a feedback loop, because the error amplifier output connects to FB pin. DC gain affects voltage sensing of the error amplifier. If AC gain increases, it affects stability of regulator due to AC gain which contains switching noise, ripple noise and the others.
  Recommended way of feedback is high DC gain and low AC gain.
  In this application, a feedback resistor \( R_{\text{NF}}=13\text{k}\Omega \) and capacitor \( C_{\text{NF}}=10,000\text{pF} \) are connected in serial.

  However, if the AC gain is lowered too much, it happens slower transient response against fast load changes. The optimum value varies according such factors as application specifications and components. Fine-tuning should be done on the actual device.
Application Characteristics

Efficiency vs. Output Current
($V_{OUT}=20V$, $T_a=25^\circ C$)

Output Voltage vs Output Current
($T_a=25^\circ C$)
[CAUTION] The specifications on this databook are only given for information, without any guarantee as regards either mistakes or omissions. The application circuits in this databook are described only to show representative usages of the product and not intended for the guarantee or permission of any right including the industrial rights.