R1211x SERIES

PWM Step-up DC/DC Controller for Automotive Applications

OUTLINE

The R1211x Series are CMOS-based PWM step-up DC/DC converter controllers with low supply current. Each of the R1211x Series consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a reference current unit, a protection circuit, and an under voltage lockout (UVLO) circuit. A low ripple, high efficiency step-up DC/DC converter can be composed of this IC with some external components, or an inductor, a diode, a power MOSFET, divider resistors, and capacitors. Phase compensation has been made internally in this device, and it has stand-by mode. Max duty cycle is internally fixed typically at 90%.

Soft start function is built-in, and Soft-starting time is set typically at 9ms (B, 700kHz version) or 10.5ms (D, 300kHz version). As for the protection circuit, after the soft-starting time, if the maximum duty cycle is continued for a certain period, the R1211x Series latch the external driver with its off state, or Latch-type protection circuit works.

The delay time for latch the state can be set with an external capacitor. To release the protection circuit, restart with power-on (Voltage supplier is equal or less than UVLO detector threshold level), or once after making the circuit be stand-by with chip enable pin and enable the circuit again.

FEATURES

- Input Voltage Range (Maximum Rating).........2.5V to 6.0V (6.5 V)
- Built-in Latch-type Protection Circuit..............Protection Delay Time can be set with an external capacitor
- Oscillator Frequency (PWM control).............300kHz, 700kHz
- Maximum Duty Cycle ..................................Typ. 90%
- Standby Current .......................................Typ. 0μA
- Feedback Voltage .......................................1.0V
- Feedback Voltage Accuracy.........................±1.5%
- UVLO Threshold level.................................Typ. 2.2V (Hysteresis Typ. 0.13V)
- Feedback Voltage Temperature Coefficient......Typ. ±150ppm/°C
- Package ..................................................SOT-23-6W

APPLICATIONS

- Power source for accessories such as car audios, car navigation systems, and ETC systems
**SELECTION GUIDE**

In the R1211x Series, the oscillator frequency, the optional function, and the package type for the ICs can be selected at the user’s request.

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Package</th>
<th>Quantity per Reel</th>
<th>Pb Free</th>
<th>Halogen Free</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1211N002$-TR-#E</td>
<td>SOT-23-6W</td>
<td>3,000 pcs</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

$ : Designation of Oscillator Frequency and Optional Function
(B) 700kHz, with CE pin (Internal Phase Compensation Type, with Stand-by)
(D) 300kHz, with CE pin (Internal Phase Compensation Type, with Stand-by)

# : Specify Automotive Class Code

<table>
<thead>
<tr>
<th></th>
<th>Operating Temperature Range</th>
<th>Guaranteed Specs Temperature Range</th>
<th>Screening</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-40°C to 85°C</td>
<td>25°C</td>
<td>High Temperature</td>
</tr>
</tbody>
</table>
## PIN CONFIGURATIONS

### SOT-23-6W

<table>
<thead>
<tr>
<th>Pin No</th>
<th>Symbol</th>
<th>Pin Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>DELAY</td>
<td>Pin for External Capacitor (for Setting Output Delay Time of Protection)</td>
</tr>
<tr>
<td>2</td>
<td>CE</td>
<td>Chip Enable Pin (&quot;H&quot; Active)</td>
</tr>
<tr>
<td>3</td>
<td>V&lt;sub&gt;FB&lt;/sub&gt;</td>
<td>Feedback Pin for monitoring Output Voltage</td>
</tr>
<tr>
<td>4</td>
<td>V&lt;sub&gt;In&lt;/sub&gt;</td>
<td>Power Supply Pin</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>Ground Pin</td>
</tr>
<tr>
<td>6</td>
<td>EXT</td>
<td>External FET Drive Pin (CMOS Output)</td>
</tr>
</tbody>
</table>
ABSOLUTE MAXIMUM RATINGS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Rating</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN</td>
<td>V_IN Pin Voltage</td>
<td>6.5</td>
<td>V</td>
</tr>
<tr>
<td>VEXT</td>
<td>EXT Pin Output Voltage</td>
<td>−0.3 ~ VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VDELAY</td>
<td>DELAY Pin Voltage</td>
<td>−0.3 ~ VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VCE</td>
<td>CE Pin Input Voltage</td>
<td>−0.3 ~ VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VFB</td>
<td>V_FB Pin Voltage</td>
<td>−0.3 ~ VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>IEXT</td>
<td>EXT Pin Inductor Drive Output Current</td>
<td>±50</td>
<td>mA</td>
</tr>
<tr>
<td>Pd</td>
<td>Power Dissipation (SOT-23-6W)*1</td>
<td>430</td>
<td>mW</td>
</tr>
<tr>
<td>Tj</td>
<td>Junction Temperature</td>
<td>−40 ~ 125</td>
<td>°C</td>
</tr>
<tr>
<td>Tstg</td>
<td>Storage Temperature Range</td>
<td>−55 ~ 125</td>
<td>°C</td>
</tr>
</tbody>
</table>

*1 Refer to PACKAGE INFORMATION for detailed information.

ABSOLUTE MAXIMUM RATINGS

Electronic and mechanical stress momentarily exceeded absolute maximum ratings may cause the permanent damages and may degrade the life time and safety for both device and system using the device in the field. The functional operation at or over these absolute maximum ratings is not assured.

RECOMMENDED OPERATING RATINGS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Rating</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN</td>
<td>Input Voltage</td>
<td>2.5 to 6.0</td>
<td>V</td>
</tr>
<tr>
<td>Ta</td>
<td>Operating Temperature Range</td>
<td>−40 to 85</td>
<td>°C</td>
</tr>
</tbody>
</table>

RECOMMENDED OPERATING RATINGS

All of electronic equipment should be designed that the mounted semiconductor devices operate within the recommended operating ratings. The semiconductor devices cannot operate normally over the recommended operating ratings, even if when they are used over such ratings by momentary electronic noise or surge. And the semiconductor devices may receive serious damage when they continue to operate over the recommended operating ratings.
### ELECTRICAL CHARACTERISTICS

**R1211x002B**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V&lt;sub&gt;FB&lt;/sub&gt;</td>
<td>Feedback Voltage</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=3.3V</td>
<td>0.985</td>
<td>1.000</td>
<td>1.015</td>
<td>V</td>
</tr>
<tr>
<td>I&lt;sub&gt;FB&lt;/sub&gt;</td>
<td>VFB Input Current</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=6V, V&lt;sub&gt;FB&lt;/sub&gt;=0V or 6V</td>
<td>−0.1</td>
<td>0.1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>f&lt;sub&gt;OSC&lt;/sub&gt;</td>
<td>Oscillator Frequency</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=3.3V, V&lt;sub&gt;DLY&lt;/sub&gt;=V&lt;sub&gt;FB&lt;/sub&gt;=0V</td>
<td>595</td>
<td>700</td>
<td>805</td>
<td>kHz</td>
</tr>
<tr>
<td>Δf&lt;sub&gt;OSC&lt;/sub&gt;/ΔTa</td>
<td>Oscillator Frequency Temperature Coefficient</td>
<td>−40°C ≤ Ta ≤ 85°C</td>
<td>±1.4</td>
<td></td>
<td></td>
<td>kHz/°C</td>
</tr>
<tr>
<td>I&lt;sub&gt;DD1&lt;/sub&gt;</td>
<td>Supply Current 1</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=6V, V&lt;sub&gt;DLY&lt;/sub&gt;=V&lt;sub&gt;FB&lt;/sub&gt;=0V, EXT at no load</td>
<td>600</td>
<td>900</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>maxdty</td>
<td>Maximum Duty Cycle</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=3.3V, EXT &quot;H&quot; side</td>
<td>82</td>
<td>90</td>
<td>94</td>
<td>%</td>
</tr>
<tr>
<td>R&lt;sub&gt;EXTH&lt;/sub&gt;</td>
<td>EXT &quot;H&quot; ON Resistance</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=3.3V, I&lt;sub&gt;EXT&lt;/sub&gt;=20mA</td>
<td>5</td>
<td>10</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>R&lt;sub&gt;EXTL&lt;/sub&gt;</td>
<td>EXT &quot;L&quot; ON Resistance</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=3.3V, I&lt;sub&gt;EXT&lt;/sub&gt;=20mA</td>
<td>3</td>
<td>6</td>
<td></td>
<td>Ω</td>
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<tr>
<td>I&lt;sub&gt;DLY1&lt;/sub&gt;</td>
<td>Delay Pin Charge Current</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=3.3V, V&lt;sub&gt;DLY&lt;/sub&gt;=V&lt;sub&gt;FB&lt;/sub&gt;=0V</td>
<td>2.5</td>
<td>5.0</td>
<td>7.5</td>
<td>μA</td>
</tr>
<tr>
<td>I&lt;sub&gt;DLY2&lt;/sub&gt;</td>
<td>Delay Pin Discharge Current</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=V&lt;sub&gt;FB&lt;/sub&gt;=2.5V, V&lt;sub&gt;DLY&lt;/sub&gt;=0.1V</td>
<td>2.5</td>
<td>5.5</td>
<td>9.0</td>
<td>mA</td>
</tr>
<tr>
<td>V&lt;sub&gt;DLY&lt;/sub&gt;</td>
<td>Delay Pin Detector Threshold</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=3.3V, V&lt;sub&gt;FB&lt;/sub&gt;=0V, V&lt;sub&gt;DLY&lt;/sub&gt;=0V→2V</td>
<td>0.95</td>
<td>1.00</td>
<td>1.05</td>
<td>V</td>
</tr>
<tr>
<td>T&lt;sub&gt;START&lt;/sub&gt;</td>
<td>Soft-start Time</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=3.3V</td>
<td>4.5</td>
<td>9.0</td>
<td>13.5</td>
<td>ms</td>
</tr>
<tr>
<td>V&lt;sub&gt;UVLO&lt;/sub&gt;</td>
<td>UVLO Detector Threshold</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=2.5V→2V, V&lt;sub&gt;DLY&lt;/sub&gt;=V&lt;sub&gt;FB&lt;/sub&gt;=0V</td>
<td>2.1</td>
<td>2.2</td>
<td>2.3</td>
<td>V</td>
</tr>
<tr>
<td>V&lt;sub&gt;HYS&lt;/sub&gt;</td>
<td>UVLO Detector Hysteresis</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=2V→2.5V, V&lt;sub&gt;DLY&lt;/sub&gt;=V&lt;sub&gt;FB&lt;/sub&gt;=0V</td>
<td>0.08</td>
<td>0.13</td>
<td>0.18</td>
<td>V</td>
</tr>
<tr>
<td>V&lt;sub&gt;UVLOL&lt;/sub&gt;</td>
<td>UVLO Minimum Operating Voltage</td>
<td></td>
<td>1.15</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>I&lt;sub&gt;STB&lt;/sub&gt;</td>
<td>Standby Current</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=6V, V&lt;sub&gt;CE&lt;/sub&gt;=0V</td>
<td>0</td>
<td>1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>I&lt;sub&gt;CEH&lt;/sub&gt;</td>
<td>CE &quot;H&quot; Input Current</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=6V, V&lt;sub&gt;CE&lt;/sub&gt;=6V</td>
<td>−0.5</td>
<td>0.5</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>I&lt;sub&gt;CEL&lt;/sub&gt;</td>
<td>CE &quot;L&quot; Input Current</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=6V, V&lt;sub&gt;CE&lt;/sub&gt;=0V</td>
<td>−0.5</td>
<td>0.5</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>V&lt;sub&gt;CEH&lt;/sub&gt;</td>
<td>CE &quot;H&quot; Input Voltage</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=6V, V&lt;sub&gt;CE&lt;/sub&gt;=0V→6V</td>
<td>1.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>V&lt;sub&gt;CEL&lt;/sub&gt;</td>
<td>CE &quot;L&quot; Input Voltage</td>
<td>V&lt;sub&gt;IN&lt;/sub&gt;=2.5V, V&lt;sub&gt;CE&lt;/sub&gt;=2V→0V</td>
<td>0.3</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Symbol</td>
<td>Item</td>
<td>Conditions</td>
<td>Min.</td>
<td>Typ.</td>
<td>Max.</td>
<td>Unit</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------------------------------</td>
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<td>--------</td>
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</tr>
<tr>
<td>$V_{FB}$</td>
<td>$V_{FB}$ Voltage Tolerance</td>
<td>$V_{IN}=3.3\text{V}$</td>
<td>0.985</td>
<td>1.000</td>
<td>1.015</td>
<td>V</td>
</tr>
<tr>
<td>$I_{FB}$</td>
<td>$V_{FB}$ Input Current</td>
<td>$V_{IN}=6\text{V}, V_{FB}=0\text{V}$ or 6V</td>
<td>−0.1</td>
<td>0.1</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>$f_{OSC}$</td>
<td>Oscillator Frequency</td>
<td>$V_{IN}=3.3\text{V}, V_{DLY}=V_{FB}=0\text{V}$</td>
<td>240</td>
<td>300</td>
<td>360</td>
<td>kHz</td>
</tr>
<tr>
<td>$\Delta f_{OSC}/\Delta T_a$</td>
<td>Oscillator Frequency Temperature Coefficient</td>
<td>$-40^\circ\text{C} \leq T_a \leq 85^\circ\text{C}$</td>
<td>±0.6</td>
<td></td>
<td></td>
<td>kHz/°C</td>
</tr>
<tr>
<td>$I_{DD1}$</td>
<td>Supply Current 1</td>
<td>$V_{IN}=6\text{V}, V_{DLY}=V_{FB}=0\text{V}$, EXT at no load</td>
<td>300</td>
<td>500</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>maxdty</td>
<td>Maximum Duty Cycle</td>
<td>$V_{IN}=3.3\text{V}$, EXT &quot;H&quot; side</td>
<td>82</td>
<td>90</td>
<td>94</td>
<td>%</td>
</tr>
<tr>
<td>$R_{EXTH}$</td>
<td>EXT &quot;H&quot; ON Resistance</td>
<td>$V_{IN}=3.3\text{V}$, I_{EXT}=−20mA</td>
<td>5</td>
<td>10</td>
<td></td>
<td>Ω</td>
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<tr>
<td>$R_{EXTL}$</td>
<td>EXT &quot;L&quot; ON Resistance</td>
<td>$V_{IN}=3.3\text{V}$, I_{EXT}=20mA</td>
<td>3</td>
<td>6</td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>$I_{DLY1}$</td>
<td>Delay Pin Charge Current</td>
<td>$V_{IN}=3.3\text{V}, V_{DLY}=V_{FB}=0\text{V}$</td>
<td>2.0</td>
<td>4.5</td>
<td>7.0</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{DLY2}$</td>
<td>Delay Pin Discharge Current</td>
<td>$V_{IN}=V_{FB}=2.5\text{V}, V_{DLY}=0.1\text{V}$</td>
<td>2.5</td>
<td>5.5</td>
<td>9.0</td>
<td>mA</td>
</tr>
<tr>
<td>$V_{DLY}$</td>
<td>Delay Pin Detector Threshold</td>
<td>$V_{IN}=3.3\text{V}, V_{FB}=0\text{V}$, $V_{DLY}=0\text{V}$→2V</td>
<td>0.95</td>
<td>1.00</td>
<td>1.05</td>
<td>V</td>
</tr>
<tr>
<td>$T_{START}$</td>
<td>Soft-start Time</td>
<td>$V_{IN}=3.3\text{V}$</td>
<td>5.0</td>
<td>10.5</td>
<td>16.0</td>
<td>ms</td>
</tr>
<tr>
<td>$V_{UVLO}$</td>
<td>UVLO Detector Threshold</td>
<td>$V_{IN}=2.5\text{V}$→2V, $V_{DLY}=V_{FB}=0\text{V}$</td>
<td>2.1</td>
<td>2.2</td>
<td>2.3</td>
<td>V</td>
</tr>
<tr>
<td>$V_{HYS}$</td>
<td>UVLO Detector Hysteresis</td>
<td>$V_{IN}=2\text{V}$→2.5V, $V_{DLY}=V_{FB}=0\text{V}$</td>
<td>0.08</td>
<td>0.13</td>
<td>0.18</td>
<td>V</td>
</tr>
<tr>
<td>$V_{UVLOL}$</td>
<td>UVLO Minimum Operating Voltage</td>
<td></td>
<td>1.15</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$I_{STB}$</td>
<td>Standby Current</td>
<td>$V_{IN}=6\text{V}, V_{CE}=0\text{V}$</td>
<td>0</td>
<td>1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$I_{CEH}$</td>
<td>CE &quot;H&quot; Input Current</td>
<td>$V_{IN}=6\text{V}, V_{CE}=6\text{V}$</td>
<td>−0.5</td>
<td>0.5</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$I_{CEL}$</td>
<td>CE &quot;L&quot; Input Current</td>
<td>$V_{IN}=6\text{V}, V_{CE}=0\text{V}$</td>
<td>−0.5</td>
<td>0.5</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$V_{CEH}$</td>
<td>CE &quot;H&quot; Input Voltage</td>
<td>$V_{IN}=6\text{V}, V_{CE}=0\text{V}$→6V</td>
<td>1.5</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>$V_{CEL}$</td>
<td>CE &quot;L&quot; Input Voltage</td>
<td>$V_{IN}=2.5\text{V}, V_{CE}=2\text{V}$→0V</td>
<td>0.3</td>
<td></td>
<td></td>
<td>V</td>
</tr>
</tbody>
</table>
TYPICAL APPLICATIONS

< R1211x002B/R1211x002D >

NMOS : IRF7601 (International Rectifier)
Inductor: LDR655312T-100  10μH (TDK) for R1211x002B
        : LDR655312T-220  22μH (TDK) for R1211x002D
Diode   : CRS02 (Toshiba)
C1 : 4.7μF (Ceramic)   R1 : Setting Output Voltage Resistor 1
C2 : 0.22μF (Ceramic)   R2 : Setting Output Voltage Resistor 2
C3 : 10μF (Ceramic)     R3 : 30kΩ
C4 : 680pF (Ceramic)

[Note]
These example circuits may be applied to the output voltage requirement is 15V or less. If the output voltage requirement is 15V or more, ratings of NMOS and diode as shown above is over the limit, therefore, choose other external components.
TECHNICAL NOTES

- Use a 1μF or more capacitance value of bypass capacitor between VIN pin and GND, C1 as shown in the typical applications above.

- In terms of the capacitor for setting delay time of the latch protection, C2 as shown in typical applications of the previous page, connect between Delay pin and GND pin of the IC with the minimum wiring distance.

- Connect a 1μF or more value of capacitor between VOUT and GND, C3 as shown in typical applications of the previous page. (Recommended value is from 10μF to 22μF.) If the operation of the composed DC/DC converter may be unstable, use a tantalum type capacitor instead of ceramic type.

- Connect a capacitor between VOUT and the dividing point, C4 as shown in typical applications of the previous page. The capacitance value of C4 depends on divider resistors for output voltage setting. Typical value is between 100pF and 1000pF.

- Output Voltage can be set with divider resistors for voltage setting, R1 and R2 as shown in typical applications of the previous page. Refer to the next formula.
  \[ \text{Output Voltage} = V_{FB} \times \frac{R1+R2}{R2} \]
  \( R1+R2=100k\Omega \) is recommended range of resistances.

- The operation of Latch protection circuit is as follows: When the IC detects maximum duty cycle, charge to an external capacitor, C2 of DELAY pin starts. And maximum duty cycle continues and the voltage of DELAY pin reaches delay voltage detector threshold, \( V_{DLY} \), outputs "L" to EXT pin and turns off the external power MOSFET.
  
  To release the latch protection operation, make the IC be standby mode with CE pin and make it active in terms of B/D version. Otherwise, restart with power on.

  The delay time of latch protection can be calculated with C2, \( V_{DLY} \), and Delay Pin Charge Current, \( I_{DLY1} \), as in the next formula.
  \[ t=C2\times\frac{V_{DLY}}{I_{DLY1}} \]
  Once after the maximum duty is detected and released before delay time, charge to the capacitor is halt and delay pin outputs "L".

- EXT pin outputs GND level at standby mode.

- In UVLO function, EXT pin outputs GND level when the input voltage becomes lower than or equal to UVLO detector threshold. However, UVLO does not operate if the input voltage is lower than or equal to the minimum operating voltage, and EXT pin might output indeterminately. Therefore, it requires considerable attention when CE input is active and the input voltage rises/falls gradually. In that case, be sure to use the FET with gate cut-off voltage that prevents FET turn on even if EXT pin outputs indeterminately. The recommended FETs are as follows.

  | CPH6443 (Sanyo) |
  | TPC6008-H (Toshiba) |

- Select the Power MOSFET, the diode, and the inductor within ratings (Voltage, Current, Power) of this IC. Choose the power MOSFET with low threshold voltage depending on Input Voltage to be able to turn on the FET completely. Choose the diode with low \( V_F \) such as Shottky type with low reverse current \( I_R \), and with fast switching speed. When an external transistor is switching, spike voltage may be generated caused by an inductor, therefore recommended voltage tolerance of capacitor connected to VOUT is three times of setting voltage or more.

  * The performance of power circuit with using this IC depends on external components. Choose the most suitable components for your application.
Output Current and Selection of External Components

**<Basic Circuit>**

- \(i_1\) CLL Tr
- \(V_{IN}\)
- \(I_{OUT}\)
- \(V_{OUT}\)
- \(i_2\)
- Inductor
- Diode
- GND
- CL

**<Circuit through L>**

**Discontinuous Mode**

- \(I_L\)
- \(I_{L\text{xmax}}\)
- \(I{L_{\text{xmin}}}\)
- \(T_{f}\)
- \(T_{on}\)
- \(T_{off}\)
- \(T = 1/f_{osc}\)

**Continuous Mode**

- \(I_L\)
- \(I_{L\text{xmax}}\)
- \(I_{\text{const}}\)
- \(T_{on}\)
- \(T_{off}\)
- \(T = 1/f_{osc}\)

There are two modes, or discontinuous mode and continuous mode for the PWM step-up switching regulator depending on the continuous characteristic of inductor current.

During on time of the transistor, when the voltage added on to the inductor is described as \(V_{IN}\), the current is \(V_{IN} \times t/L\). Therefore, the electric power, \(P_{ON}\), which is supplied with input side, can be described as in next formula.

\[
P_{ON} = \int_{0}^{T_{on}} V_{IN}^2 \times t/L \ dt \quad \text{Formula 1}
\]

With the step-up circuit, electric power is supplied from power source also during off time. In this case, input current is described as \((V_{OUT} - V_{IN}) \times t/L\), therefore electric power, \(P_{OFF}\) is described as in next formula.

\[
P_{OFF} = \int_{0}^{T_{off}} V_{IN} \times (V_{OUT} - V_{IN}) \times t/L \ dt \quad \text{Formula 2}
\]

In this formula, \(T_{f}\) means the time of which the energy saved in the inductance is being emitted. Thus average electric power, \(P_{AV}\) is described as in the next formula.

\[
P_{AV} = 1/(T_{on} + T_{off}) \times \left( \int_{0}^{T_{on}} V_{IN}^2 \times t/L \ dt + \int_{0}^{T_{off}} V_{IN} \times (V_{OUT} - V_{IN}) \times t/L \ dt \right) \quad \text{Formula 3}
\]

In PWM control, when \(T_{f} = T_{off}\) is true, the inductor current becomes continuous, then the operation of switching regulator becomes continuous mode.
In the continuous mode, the deviation of the current is equal between on time and off time.

\[ V_{IN} \times T_{ON}/L = (V_{OUT} - V_{IN}) \times T_{off}/L \]  \hspace{2cm} \text{Formula 4}

Further, the electric power, \( P_{AV} \) is equal to output electric power, \( V_{OUT} \times I_{OUT} \), thus,

\[ I_{OUT} = f_{OSC} \times V_{IN}^2 \times T_{ON}/(2 \times L \times (V_{OUT} - V_{IN})) = V_{IN}^2 \times T_{ON}/(2 \times L \times V_{OUT}) \]  \hspace{2cm} \text{Formula 5}

When \( I_{OUT} \) becomes more than formula 5, the current flows through the inductor, then the mode becomes continuous. The continuous current through the inductor is described as \( I_{\text{const}} \), then,

\[ I_{OUT} = f_{OSC} \times V_{IN}^2 \times T_{ON}/(2 \times L \times (V_{OUT} - V_{IN})) + V_{IN} \times I_{\text{const}}/V_{OUT} \]  \hspace{2cm} \text{Formula 6}

In this moment, the peak current, \( I_{Lx\text{max}} \) flowing through the inductor and the driver \( T_{r} \) is described as follows:

\[ I_{Lx\text{max}} = I_{\text{const}} + V_{IN} \times T_{ON}/L \]  \hspace{2cm} \text{Formula 7}

With the formula 4, 6, and \( I_{Lx\text{max}} \) is,

\[ I_{Lx\text{max}} = V_{OUT}/V_{IN} \times I_{OUT} + V_{IN} \times T_{ON}/(2 \times L) \]  \hspace{2cm} \text{Formula 8}

Therefore, peak current is more than \( I_{OUT} \). Considering the value of \( I_{Lx\text{max}} \), the condition of input and output, and external components should be selected.

In the formula 7, peak current \( I_{Lx\text{max}} \) at discontinuous mode can be calculated. Put \( I_{\text{const}}=0 \) in the formula.

The explanation above is based on the ideal calculation, and the loss caused by \( L_{x} \) switch and external components is not included. The actual maximum output current is between 50% and 80% of the calculation. Especially, when the \( L_{x} \) is large, or \( V_{IN} \) is low, the loss of \( V_{IN} \) is generated with the on resistance of the switch. As for \( V_{OUT} \), \( V_{f} \) (as much as 0.3V) of the diode should be considered.
TIMING CHART

• R1211x002B/R1211x002D

<Soft-start Operation>
Soft-start operation is starting from power-on as follows:

(Step1)
The voltage level of SS is rising gradually by constant current circuit of the IC and a capacitor. V_{REF} level which is input to OP AMP is also gradually rising. V_{OUT} is rising up to input voltage level just after the power-on, therefore, V_{FB} voltage is rising up to the setting voltage with input voltage and the ration of R1 and R2. AMPOUT is at "L", and switching does not start.

(Step2)
When the voltage level of SS becomes the setting voltage with the ration of R1 and R2 or more, switching operation starts. V_{REF} level gradually increases together with SS level. V_{OUT} is also rising with balancing V_{REF} and V_{FB}. Duty cycle depends on the lowest level among AMPOUT, SS, and DTC of the 4 input terminals in the PWM comparator.

(Step3)
When SS reaches 1V, soft-start operation finishes. V_{REF} becomes constant voltage (=1V). Then the switching operation becomes normal mode.
**<Latch Protection Operation>**

The operation of Latch protection circuit is as follows: When AMPOUT becomes "H" and the IC detects maximum duty cycle, charge to an external capacitor, C2 of DELAY pin starts. And maximum duty cycle continues and the voltage of DELAY pin reaches delay voltage detector threshold, $V_{DLY}$, outputs "L" to EXT pin and turns off the external power MOSFET.

To release the latch protection operation, make the IC be standby mode with CE pin and make it active. Otherwise, make supply voltage down to UVLO detector threshold or lower, and make it rise up to the normal input voltage.

During the soft-start time, if the duty cycle may be the maximum, protection circuit does not work and DELAY pin is fixed at GND level.

The delay time of latch protection can be calculated with C2, $V_{DLY}$, and Delay Pin Charge Current, $I_{DLY1}$, as in the next formula.

$$t = \frac{C2 \times V_{DLY}}{I_{DLY1}}$$

Once after the maximum duty is detected and released before delay time, charge to the capacitor is halt and delay pin outputs "L".
PACKAGE INFORMATION

POWER DISSIPATION (SOT-23-6W)

Power Dissipation ($P_D$) depends on conditions of mounting on board. This specification is based on the measurement at the condition below:

**Measurement Conditions**

<table>
<thead>
<tr>
<th></th>
<th>Standard Land Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Mounting on Board (Wind velocity=0m/s)</td>
</tr>
<tr>
<td>Board Material</td>
<td>Glass cloth epoxy plastic (Double sided)</td>
</tr>
<tr>
<td>Board Dimensions</td>
<td>40mm × 40mm × 1.6mm</td>
</tr>
<tr>
<td>Copper Ratio</td>
<td>Top side: Approx. 50%, Back side: Approx. 50%</td>
</tr>
<tr>
<td>Through-holes</td>
<td>$\phi$ 0.5mm × 44pcs</td>
</tr>
</tbody>
</table>

**Measurement Result** (Ta=25°C, Tjmax=125°C)

<table>
<thead>
<tr>
<th></th>
<th>Standard Test Land Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Dissipation</td>
<td>430mW</td>
</tr>
<tr>
<td>Thermal Resistance</td>
<td>$\theta_{JA} = (125-25{}^\circ\text{C})/0.43\text{W} = 233{}^\circ\text{C/W}$</td>
</tr>
</tbody>
</table>

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

**Measurement Board Pattern**

- IC Mount Area (Unit: mm)
PACKAGE DIMENSIONS (SOT-23-6W)

MARK SPECIFICATION (SOT-23-6W)

1 2: Product Code … Refer to MARK SPECIFICATION TABLE (SOT-23-6W)
3 4: Lot Number … Alphanumeric Serial Number

MARK SPECIFICATION TABLE (SOT-23-6W)

<table>
<thead>
<tr>
<th>Product Name</th>
<th>1 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1211N002B</td>
<td>L 1</td>
</tr>
<tr>
<td>R1211N002D</td>
<td>L 3</td>
</tr>
</tbody>
</table>
TEST CIRCUITS

- R1211x002B/R1211x002D

  - Oscillator Frequency, Maximum Duty Cycle, $V_{FB}$ Voltage Test

  - Consumption Current Test

  - EXT "H" ON Resistance

  - EXT "L" ON Resistance

  - DELAY Pin Charge Current

  - DELAY Pin Discharge Current

  - DELAY Pin Detector Threshold Voltage Test

- $V_{FB}$ Input Current

- Consumption Current Test

- EXT "H" ON Resistance

- DELAY Pin Charge Current

- DELAY Pin Discharge Current

- DELAY Pin Detector Threshold Voltage Test
**Standby Current Test**

![Standby Current Test Diagram]

**UVLO Detector Threshold/Hysteresis Range Test**

![UVLO Detector Threshold/Hysteresis Range Test Diagram]

**CE "L" Input Current/"H" Input Current Test**

![CE "L" Input Current/"H" Input Current Test Diagram]

**CE "L" Input Voltage/"H" Input Voltage Test**

![CE "L" Input Voltage/"H" Input Voltage Test Diagram]

**Soft-start Time Test**

![Soft-start Time Test Diagram]

**Components**

Inductor (L) : 22μH (TDK LDR655312T-220)
Diode (SD) : CRS02 (Toshiba)
Capacitors C1 : 680pF (Ceramic), C2: 22μF (Tantalum)+2.2μF (Ceramic), C3 : 68μF (Tantalum)+2.2μF (Ceramic), C5: 22μF (Tantalum)
NMOS Transistor : IRF7601 (International Rectifier)
Resistors : R1: 90kΩ, R2: 10kΩ, R3: 30kΩ
TYPICAL CHARACTERISTICS

Note: Typical Characteristics are intended to be used as reference data; they are not guaranteed.

1) Output Voltage vs. Output Current

<table>
<thead>
<tr>
<th>R1211x002B</th>
<th>R1211x002B</th>
</tr>
</thead>
<tbody>
<tr>
<td>L=10μH</td>
<td>L=10μH</td>
</tr>
<tr>
<td>VOUT=5V</td>
<td>VOUT=10V</td>
</tr>
<tr>
<td>VIN=2.5V</td>
<td>VIN=2.5V</td>
</tr>
<tr>
<td>VIN=3.3V</td>
<td>VIN=3.3V</td>
</tr>
<tr>
<td>VIN=5.0V</td>
<td>VIN=5.0V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R1211x002B</th>
<th>R1211x002D</th>
</tr>
</thead>
<tbody>
<tr>
<td>L=10μH</td>
<td>L=22μH</td>
</tr>
<tr>
<td>VOUT=15V</td>
<td>VOUT=5V</td>
</tr>
<tr>
<td>VIN=2.5V</td>
<td>VIN=2.5V</td>
</tr>
<tr>
<td>VIN=3.3V</td>
<td>VIN=3.3V</td>
</tr>
<tr>
<td>VIN=5.0V</td>
<td>VIN=5.0V</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>R1211x002D</th>
<th>R1211x002D</th>
</tr>
</thead>
<tbody>
<tr>
<td>L=22μH</td>
<td>L=22μH</td>
</tr>
<tr>
<td>VOUT=10V</td>
<td>VOUT=15V</td>
</tr>
<tr>
<td>VIN=2.5V</td>
<td>VIN=2.5V</td>
</tr>
<tr>
<td>VIN=3.3V</td>
<td>VIN=3.3V</td>
</tr>
<tr>
<td>VIN=5.0V</td>
<td>VIN=5.0V</td>
</tr>
</tbody>
</table>
2) Efficiency vs. Output Current

**R1211x002B**

- **L=10μH**
- **V_{OUT}=5V**

---

**R1211x002B**

- **L=10μH**
- **V_{OUT}=10V**

---

**R1211x002B**

- **L=10μH**
- **V_{OUT}=15V**

---

**R1211x002D**

- **L=22μH**
- **V_{OUT}=5V**

---

**R1211x002D**

- **L=22μH**
- **V_{OUT}=10V**

---

**R1211x002D**

- **L=22μH**
- **V_{OUT}=15V**
3) \( V_{FB} \) Voltage vs. Input Voltage (\( Ta=25°C \))

4) Oscillator Frequency vs. Input Voltage (\( Ta=25°C \))

5) Supply Current vs. Input Voltage (\( Ta=25°C \))
6) Maximum Duty Cycle vs. Input Voltage (Ta=25°C)

- **R1211x002B**

- **R1211x002D**

7) \( V_{FB} \) Voltage vs. Temperature

- **R1211x002x**

8) Oscillator Frequency vs. Temperature

- **R1211x002B**

- **R1211x002D**
9) Supply Current vs. Temperature

- **R1211x002B**
  - \( V_{IN} = 3.3V \)
  - Supply Current (\( \mu A \))
  - Temperature \( T_{opt} (°C) \)

- **R1211x002D**
  - \( V_{IN} = 3.3V \)
  - Supply Current (\( \mu A \))
  - Temperature \( T_{opt} (°C) \)

10) Maximum Duty Cycle vs. Temperature

- **R1211x002B**
  - \( V_{IN} = 3.3V \)
  - Maximum Duty Cycle (%)
  - Temperature \( T_{opt} (°C) \)

- **R1211x002D**
  - \( V_{IN} = 3.3V \)
  - Maximum Duty Cycle (%)
  - Temperature \( T_{opt} (°C) \)

11) EXT "H" On Resistance vs. Temperature

- **R1211x002x**
  - \( V_{IN} = 3.3V \)
  - EXT "H" ON Resistance (\( \Omega \))
  - Temperature \( T_{opt} (°C) \)

12) EXT "L" On Resistance vs. Temperature

- **R1211x002x**
  - \( V_{IN} = 3.3V \)
  - EXT "L" ON Resistance (\( \Omega \))
  - Temperature \( T_{opt} (°C) \)
13) Soft-start Time vs. Temperature

**R1211x002B**

![Graph showing Soft-start Time vs. Temperature for R1211x002B with VIN=3.3V]

**R1211x002D**

![Graph showing Soft-start Time vs. Temperature for R1211x002D with VIN=3.3V]

14) UVLO Detector Threshold vs. Temperature

**R1211x002x**

![Graph showing UVLO Detector Threshold vs. Temperature for R1211x002x with VIN=3.3V]

15) DELAY Pin Charge Current vs. Temperature

**R1211x002B**

![Graph showing DELAY Pin Charge Current vs. Temperature for R1211x002B with VIN=3.3V]

**R1211x002D**

![Graph showing DELAY Pin Charge Current vs. Temperature for R1211x002D with VIN=3.3V]
16) DELAY Pin Detector Threshold vs. Temperature

17) DELAY Pin Discharge Current vs. Temperature

18) CE "L" Input Voltage vs. Temperature

19) CE "H" Input Voltage vs. Temperature

20) Standby Current vs. Temperature
21) Load Transient Response

**R1211x002B**

L=10μH  
VIN=3.3V, C3=22μF  
VOUT=5V, IOUT=1-100mA

**R1211x002B**

L=10μH  
VIN=3.3V, C3=22μF  
VOUT=10V, IOUT=1-100mA

**R1211x002B**

L=10μH  
VIN=3.3V, C3=22μF  
VOUT=15V, IOUT=1-50mA
R1211x002D

L = 22μH
V_in = 3.3V, C3 = 22μF
V_out = 5V, I_out = 1-100mA

Time (5ms/div)

Output Voltage V_out (V)

Output Current I_out (mA)

R1211x002D

L = 22μH
V_in = 3.3V, C3 = 22μF
V_out = 10V, I_out = 1-100mA

Time (5ms/div)

Output Voltage V_out (V)

Output Current I_out (mA)

R1211x002D

L = 22μH
V_in = 3.3V, C3 = 22μF
V_out = 15V, I_out = 1-50mA

Time (5ms/div)

Output Voltage V_out (V)

Output Current I_out (mA)
22) Power-on Response

**R1211x002B**

- \( L = 10 \mu \text{H} \)
- \( V_{\text{IN}} = 3.3 \text{V}, \ I_{\text{OUT}} = 10 \text{mA} \)

- (c) \( V_{\text{OUT}} = 15 \text{V} \)
- (b) \( V_{\text{OUT}} = 10 \text{V} \)
- (a) \( V_{\text{OUT}} = 5 \text{V} \)

**R1211x002D**

- \( L = 22 \mu \text{H} \)
- \( V_{\text{IN}} = 3.3 \text{V}, \ I_{\text{OUT}} = 10 \text{mA} \)

- (c) \( V_{\text{OUT}} = 15 \text{V} \)
- (b) \( V_{\text{OUT}} = 10 \text{V} \)
- (a) \( V_{\text{OUT}} = 5 \text{V} \)

23) Turn-on speed with CE pin

**R1211x002B**

- \( L = 10 \mu \text{H} \)
- \( V_{\text{IN}} = 3.3 \text{V}, \ I_{\text{OUT}} = 10 \text{mA} \)

- (c) \( V_{\text{OUT}} = 15 \text{V} \)
- (b) \( V_{\text{OUT}} = 10 \text{V} \)
- (a) \( V_{\text{OUT}} = 5 \text{V} \)

**R1211x002D**

- \( L = 22 \mu \text{H} \)
- \( V_{\text{IN}} = 3.3 \text{V}, \ I_{\text{OUT}} = 10 \text{mA} \)

- (c) \( V_{\text{OUT}} = 15 \text{V} \)
- (b) \( V_{\text{OUT}} = 10 \text{V} \)
- (a) \( V_{\text{OUT}} = 5 \text{V} \)
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