OUTLINE

The R1221N Series are CMOS-based PWM step-down DC/DC Converter controllers embedded with a voltage detector, with low supply current.

Each step-down DC/DC converter in these ICs consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a soft-start circuit, a protection circuit, a PWM/VFM alternative circuit, a chip enable circuit, and resistors for voltage detection. A low ripple, high efficiency step-down DC/DC converter can be composed of this IC with only four external components, or a power-transistor, an inductor, a diode and a capacitor.

The output voltage of DC/DC converter can be supervised by the built-in voltage detector.

With a PWM/VFM alternative circuit, when the load current is small, the operation turns into the VFM oscillator from PWM oscillator automatically, therefore the efficiency at small load current is improved.

And the PWM/VFM alternative circuit is an option, in terms of C version and D version, the circuit is not included.

If the term of maximum duty cycle keeps on a certain time, the embedded protection circuit works. There are two types of protection function. One is latch-type protection circuit, and it works to latch an external Power MOS FET with keeping it disable. To release the condition of protection, after disable this IC with a chip enable circuit, enable it again, or restart this IC with power-on. The other is Reset-type protection circuit, and it works to restart the operation with soft-start and repeat this operation until maximum duty cycle condition is released. Either of these protection circuits can be designated by users' request.

FEATURES

- Wide Range of Input Voltage.............................. 2.3V to 13.2V
- Built-in Soft-start Function and two choices of Protection Function (Latch-type or Reset-type)
- Two choices of Oscillator Frequency .................. 300kHz, 500kHz
- High Efficiency............................................. Typ. 90%
- Standby Current............................................. Typ. 9μA
- Setting Output Voltage.................................. Stepwise setting with a step of 0.1V in the range of 1.5V to 5.0V
- High Accuracy Output Voltage.......................... ±2.0%
- Setting Detector Threshold Voltage...................... Stepwise setting with a step of 0.1V in the range of 1.2V to 4.5V
- High Accuracy Detector Threshold Voltage............ ±2.0%
- Low Temperature-Drift Coefficient of Output Voltage.... Typ. ±100ppm/°C

APPLICATIONS

- Power source for hand-held communication equipment, cameras, video instruments such as VCRs, camcorders.
- Power source for battery-powered equipment.
- Power source for household electrical appliances.
### BLOCK DIAGRAM

The block diagram illustrates the internal components of the R1221N Series IC, including the VIN and VOUT interfaces, PWM/VFM CONTROL, Soft Start Chip Enable, Oscillator (OSC), and Reference Voltage (Vref) blocks. The diagram also shows the protection features and connections to GND and EXT.

### SELECTION GUIDE

In the R1221N Series, the output voltage, the detector threshold, the oscillator frequency, the optional function, and the taping type for the ICs can be selected at the user’s request.

The selection can be made by designating the part number as shown below:

R1221Nxxxx-TR

![Diagram Image]

<table>
<thead>
<tr>
<th>Code</th>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>Setting Output Voltage ($V_{OUT}$): &lt;br&gt;Stepwise setting with a step of 0.1V in the range of 1.5V to 5.0V is possible.</td>
</tr>
<tr>
<td>b</td>
<td>Setting Detector Threshold ($V_{DET}$) &lt;br&gt;Stepwise setting with a step of 0.1V in the range of 1.2V to 4.5V is possible. &lt;br&gt;A: 3.0V</td>
</tr>
<tr>
<td>c</td>
<td>Designation of Oscillator Frequency and Optional Function &lt;br&gt;A: 300kHz, with a PWM/VFM alternative circuit, Latch-type protection &lt;br&gt;B: 500kHz, with a PWM/VFM alternative circuit, Latch-type protection &lt;br&gt;C: 300kHz, without a PWM/VFM alternative circuit, Latch-type protection &lt;br&gt;D: 500kHz, without a PWM/VFM alternative circuit, Latch-type protection &lt;br&gt;E: 300kHz, with a PWM/VFM alternative circuit, Reset-type protection &lt;br&gt;F: 500kHz, with a PWM/VFM alternative circuit, Reset-type protection &lt;br&gt;G: 300kHz, without a PWM/VFM alternative circuit, Reset-type protection &lt;br&gt;H: 500kHz, without a PWM/VFM alternative circuit, Reset-type protection</td>
</tr>
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</table>

Discontinued

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PIN CONFIGURATION

PIN DESCRIPTION

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>EXT</td>
<td>External Transistor Drive Pin (Output Type : CMOS)</td>
</tr>
<tr>
<td>2</td>
<td>VDOUT</td>
<td>Voltage Detector Output Pin (Output Type : Nch Open Drain)</td>
</tr>
<tr>
<td>3</td>
<td>VIN</td>
<td>Power Supply Pin</td>
</tr>
<tr>
<td>4</td>
<td>CE</td>
<td>Chip Enable Pin</td>
</tr>
<tr>
<td>5</td>
<td>GND</td>
<td>Ground Pin</td>
</tr>
<tr>
<td>6</td>
<td>VOUT</td>
<td>Pin for Monitoring Output Voltage</td>
</tr>
</tbody>
</table>

ABSOLUTE MAXIMUM RATING

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Rating</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VN</td>
<td>Vsupply Voltage</td>
<td>15</td>
<td>V</td>
</tr>
<tr>
<td>VEXT</td>
<td>EXT Pin Output Voltage</td>
<td>-0.3–VN+0.3</td>
<td>V</td>
</tr>
<tr>
<td>VCE</td>
<td>CE Pin Input Voltage</td>
<td>-0.3–VN+0.3</td>
<td>V</td>
</tr>
<tr>
<td>VDOUT</td>
<td>VDOUT Pin Output Voltage</td>
<td>-0.3–15</td>
<td>V</td>
</tr>
<tr>
<td>VOUT</td>
<td>VOUT Pin Input Voltage</td>
<td>-0.3–VN+0.3</td>
<td>V</td>
</tr>
<tr>
<td>IEXT</td>
<td>EXT Pin Inductor Drive Output Current</td>
<td>±25</td>
<td>mA</td>
</tr>
<tr>
<td>PD</td>
<td>Power Dissipation</td>
<td>250</td>
<td>mW</td>
</tr>
<tr>
<td>Topt</td>
<td>Operating Temperature Range</td>
<td>-40–+85</td>
<td>°C</td>
</tr>
<tr>
<td>Tstg</td>
<td>Storage Temperature Range</td>
<td>-55–+125</td>
<td>°C</td>
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</tbody>
</table>
## ELECTRICAL CHARACTERISTICS

- **R1221Nx xxA (C.E.G)** Output Voltage : $V_o$, Detector Threshold : $V_e$ (Topt=25°C)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Note*</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN}$</td>
<td>Operating Input Voltage</td>
<td>2.3</td>
<td>13.2</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{OUT}$</td>
<td>Step-down Output Voltage $V_{SC}=V_C+1.2V, I_{OUT}=-10mA$ $V_{OUT}$</td>
<td>0.98</td>
<td>$V_o$</td>
<td>1.02</td>
<td>A</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V_{OUT}/\Delta T$</td>
<td>Step-down Output Voltage Temperature Coefficient $-40°C\leq T\leq 85°C$</td>
<td>$\pm 100$</td>
<td>ppm/°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$f_{osc}$</td>
<td>Oscillator Frequency $V_{SC}=V_C+1.2V, I_{OUT}=-100mA$</td>
<td>240</td>
<td>300</td>
<td>360</td>
<td>A</td>
<td>kHz</td>
</tr>
<tr>
<td>$\Delta f_{osc}/\Delta T$</td>
<td>Frequency Temperature Coefficient $-40°C\leq T\leq 85°C$</td>
<td>$\pm 0.3$</td>
<td>%/°C</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{S}H$</td>
<td>Supply Current</td>
<td>$V_{SC}=13.2V, V_C=13.2V, V_{OUT}=13.2V$</td>
<td>100</td>
<td>160</td>
<td>B</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{S}B$</td>
<td>Standby Current</td>
<td>$V_{SC}=13.2V, V_C=0V, V_{OUT}=0V$</td>
<td>0.0</td>
<td>0.5</td>
<td>C</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{EXT}$</td>
<td>EXT “H” Output Current</td>
<td>$V_{SC}=8V, V_{EXT}=7.9V, V_{OUT}=8V, V_C=8V$</td>
<td>$\leq 10$</td>
<td>$\leq 6$</td>
<td>D</td>
<td>mA</td>
</tr>
<tr>
<td>$I_{EXT}$</td>
<td>EXT “L” Output Current</td>
<td>$V_{SC}=8V, V_{EXT}=0.1V, V_{OUT}=0V, V_C=0V$</td>
<td>10</td>
<td>20</td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>$I_{CEH}$</td>
<td>CE “H” Input Current</td>
<td>$V_{SC}=13.2V, V_C=13.2V, V_{OUT}=13.2V$</td>
<td>0.0</td>
<td>0.5</td>
<td>E</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{CEL}$</td>
<td>CE “L” Input Current</td>
<td>$V_{SC}=13.2V, V_C=0V, V_{OUT}=13.2V$</td>
<td>-0.5</td>
<td>0.0</td>
<td>E</td>
<td>μA</td>
</tr>
<tr>
<td>$V_{CEH}$</td>
<td>CE “H” Input Voltage</td>
<td>$V_{SC}=8V, V_C=0V→1.5V$</td>
<td>0.8</td>
<td>1.2</td>
<td>F</td>
<td>V</td>
</tr>
<tr>
<td>$V_{CEL}$</td>
<td>CE “L” Input Voltage</td>
<td>$V_{SC}=8V, V_C=1.5V→0V$</td>
<td>0.3</td>
<td>0.8</td>
<td>F</td>
<td>V</td>
</tr>
<tr>
<td>$Maxdt$</td>
<td>Oscillator Maximum Duty Cycle</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>$V_{FMd}$t</td>
<td>VFM Duty Cycle</td>
<td>Applied to B and F versions only</td>
<td>25</td>
<td></td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>$T_{start}$</td>
<td>Delay Time by Soft-Start function</td>
<td>$V_{SC}=V_C+1.2V, V_{CE}=0V→V_C+1.2V$ Specified at 80% of rising edge</td>
<td>5</td>
<td>10</td>
<td>16</td>
<td>F</td>
</tr>
<tr>
<td>$T_{prot}$</td>
<td>Delay Time for protection circuit</td>
<td>$V_{SC}=V_C+1.2V, V_{CE}=0V→1.2V→0V$</td>
<td>1</td>
<td>3</td>
<td>5</td>
<td>G</td>
</tr>
<tr>
<td>$I_{VOLK}$</td>
<td>VOUT Output Leakage Current</td>
<td>$V_{SC}=V_{OUT}=V_{CE}=V_{OUT}=8V$</td>
<td>0.0</td>
<td>0.5</td>
<td>I</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{VOL}$</td>
<td>VOUT “L” Output Current</td>
<td>$V_{SC}=V_{OUT}=2.3V, V_C=0V, V_{OUT}=0.1V$</td>
<td>0.5</td>
<td>1.0</td>
<td>I</td>
<td>mA</td>
</tr>
<tr>
<td>$-V_{DET}$</td>
<td>Detector Threshold</td>
<td>$V_{SC}=6V, V_C=6V, V_{OUT}=0V→V_{OUT}1.2V→0V$ Specified at 80% of rising edge</td>
<td>0.98</td>
<td>$V_o$</td>
<td>1.02</td>
<td>J</td>
</tr>
<tr>
<td>$t_{VOL}$</td>
<td>Output Delay Time for Released Voltage</td>
<td>$V_{SC}=6V, V_C=6V, V_{OUT}=0V→V_{OUT}1.2V$ Specified at 80% of rising edge</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>J</td>
</tr>
<tr>
<td>$V_{HY}$</td>
<td>Detector Threshold Hysteresis</td>
<td>$V_{SC}=6V, V_C=6V, V_{OUT}=0V→V_{OUT}1.2V$ Specified at 80% of rising edge</td>
<td>0.01</td>
<td>$V_o$</td>
<td>0.03</td>
<td>J</td>
</tr>
<tr>
<td>$\Delta V_{DET}/\Delta T$</td>
<td>Detector Threshold Temperature Coefficient $-40°C\leq T\leq 85°C$</td>
<td>$\pm 100$</td>
<td>ppm/°C</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Refer to Test Circuits
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Note*</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>V_{IN}</td>
<td>Operating Input Voltage</td>
<td></td>
<td>2.3</td>
<td></td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>V_{OUT}</td>
<td>Step-down Output Voltage</td>
<td>V_{IN}=V_{CE}=V_{O}=1.2V, I_{OUT}=-10mA</td>
<td></td>
<td>V_{O}</td>
<td>1.02</td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>ΔV_{DC} / ΔT</td>
<td>Step-down Output Voltage Temperature Coefficient</td>
<td>-40°C≤T_{概述}≤85°C</td>
<td>±100</td>
<td></td>
<td></td>
<td>ppm/°C</td>
<td></td>
</tr>
<tr>
<td>f_{osc}</td>
<td>Oscillator Frequency</td>
<td>V_{IN}=V_{CE}=V_{O}+1.2V, I_{OUT}=-100mA</td>
<td>400</td>
<td>500</td>
<td>600</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td>Δf_{osc} / ΔT</td>
<td>Frequency Temperature Coefficient</td>
<td>-40°C≤T_{概述}≤85°C</td>
<td>±0.3</td>
<td></td>
<td></td>
<td>%/°C</td>
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<tr>
<td>I_{DD1}</td>
<td>Supply Current I</td>
<td>V_{IN}=13.2V, V_{CE}=13.2V, V_{O}=13.2V</td>
<td>140</td>
<td>200</td>
<td></td>
<td></td>
<td>μA</td>
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<tr>
<td>I_{Stb}</td>
<td>Standby Current</td>
<td>V_{IN}=13.2V, V_{CE}=0V, V_{O}=0V</td>
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<td>0.5</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>I_{EXT}</td>
<td>EXT “H” Output Current</td>
<td>V_{IN}=8V, V_{OUT}=7.9V, V_{CE}=8V</td>
<td>-10</td>
<td>-6</td>
<td></td>
<td></td>
<td>mA</td>
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<tr>
<td>I_{EXL}</td>
<td>EXT “L” Output Current</td>
<td>V_{IN}=8V, V_{OUT}=0.1V, V_{CE}=0V</td>
<td>10</td>
<td>20</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>I_{CEH}</td>
<td>CE “H” Input Current</td>
<td>V_{IN}=13.2V, V_{CE}=13.2V, V_{O}=13.2V</td>
<td>0.0</td>
<td>0.5</td>
<td></td>
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<td>μA</td>
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<tr>
<td>I_{CEL}</td>
<td>CE “L” Input Current</td>
<td>V_{IN}=13.2V, V_{CE}=0V, V_{O}=13.2V</td>
<td>-0.5</td>
<td>0.0</td>
<td></td>
<td></td>
<td>μA</td>
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<tr>
<td>V_{CEH}</td>
<td>CE “H” Output Voltage</td>
<td>V_{IN}=8V, V_{CE}=0V→1.5V</td>
<td>0.8</td>
<td>1.2</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>V_{CEL}</td>
<td>CE “L” Input Voltage</td>
<td>V_{IN}=8V, V_{CE}=1.5V→0V</td>
<td>0.3</td>
<td>0.8</td>
<td></td>
<td></td>
<td>V</td>
</tr>
<tr>
<td>Maxdty</td>
<td>Oscillator Maximum Duty Cycle</td>
<td>Applied to B and F versions only</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
<td>%</td>
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<tr>
<td>VFMdty</td>
<td>VFM Duty Cycle</td>
<td>Applied to B and F versions only</td>
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<td></td>
<td>%</td>
</tr>
<tr>
<td>T_{start}</td>
<td>Delay Time by Soft-Start function</td>
<td>V_{IN}=V_{CE}=0V→V_{O}=1.2V Specified at 80% of rising edge</td>
<td>3</td>
<td>6</td>
<td>10</td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>T_{prot}</td>
<td>Delay Time for protection circuit</td>
<td>V_{IN}=V_{CE}=0V→V_{O}=1.2V Specified at 80% of rising edge</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td></td>
<td>ms</td>
</tr>
<tr>
<td>I_{VOUT}</td>
<td>V_{OUT} Output Leakage Current</td>
<td>V_{IN}=V_{OUT}=V_{CE}=V_{O}=8V Specified at 80% of rising edge</td>
<td>0.0</td>
<td>0.5</td>
<td></td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>I_{VCE}</td>
<td>V_{CE} Output Leakage Current</td>
<td>V_{IN}=V_{OUT}=2.3V, V_{CE}=0V Specified at 80% of rising edge</td>
<td>0.5</td>
<td>1.0</td>
<td></td>
<td></td>
<td>mA</td>
</tr>
<tr>
<td>I_{DET}</td>
<td>Detector Threshold</td>
<td>V_{IN}=6V, V_{CE}=6V, V_{O}=1.2V→0V Specified at 80% of rising edge</td>
<td>0.98</td>
<td>V_{O}</td>
<td>1.02</td>
<td></td>
<td>J</td>
</tr>
<tr>
<td>V_{TV}</td>
<td>Output Delay Time for Released Voltage</td>
<td>V_{IN}=6V, V_{CE}=6V, V_{O}=0V→V_{O}=1.2V Specified at 80% of rising edge</td>
<td>1.5</td>
<td>3.5</td>
<td>6.0</td>
<td></td>
<td>ms</td>
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<tr>
<td>V_{HT}</td>
<td>Detector Threshold Hysteresis</td>
<td>V_{IN}=6V, V_{CE}=6V, V_{O}=0V→V_{O}=1.2V Specified at 80% of rising edge</td>
<td>0.01</td>
<td>V_{O}</td>
<td>0.03</td>
<td></td>
<td>J</td>
</tr>
<tr>
<td>ΔV_{TV} / ΔT</td>
<td>Detector Threshold Temperature Coefficient</td>
<td>-40°C≤T_{概述}≤85°C</td>
<td>±100</td>
<td></td>
<td></td>
<td>ppm/°C</td>
<td></td>
</tr>
</tbody>
</table>

Note: Refer to Test Circuits
**TEST CIRCUITS**

**A)**

```
VIN  
3 1 6  
4 2 5  
OSCILLOSCOPE
```

**B)**

```
VIN  
3 1 6  
4 2 5  
```

**C)**

```
VIN  
3 1 6  
4 2 5  
```

**D)**

```
VIN  
3 1 6  
4 2 5  
```

**E)**

```
VIN  
3 1 6  
4 2 5  
```

**F)**

```
VIN  
3 1 6  
4 2 5  
```

**G)**

```
VIN  
3 1 6  
4 2 5  
```

**H)**

```
VIN  
3 1 6  
4 2 5  
```

**I)**

```
VIN  
3 1 6  
4 2 5  
```

**J)**

```
VIN  
3 1 6  
4 2 5  
```

---

Inductor \( L : 27 \mu \text{H (Sumida Electronic, CD104)} \)
Diode SD \( : \text{RB-491D (Rohm, Schottky type)} \)
Capacitor \( C_1 : 47 \mu \text{F (Tantalum type)} \)
\( C_{10} : 22 \mu \text{F (Tantalum type)} \)
Power MOS PMOS \( : \text{HAT1020R (Hitachi)} \)
Resistor \( R : 100 \Omega \)
TYPICAL APPLICATIONS AND APPLICATION HINTS

PMOS: HAT102R0 (Hitachi), Si3443DV (Siliconix)
SD1 : RB491D (Rohm)
Cin  : 10μF (Tantalum Type)
L    : CD105 (Sumida, 27μH)
Cout : 47μF (Tantalum Type)
R1   : 100kΩ
When you use these ICs, consider the following issues:

- As shown in the block diagram, a parasitic diode is formed in each terminal, each of these diodes is not formed for load current, therefore do not use it in such a way. When you control the CE pin by another power supply, do not make its “H” level more than the voltage level of VCC pin.
- Detector threshold hysteresis is set at 3 percent of detector threshold voltage. (Min. 1 percent, Max. 5 percent)
- Setting detector threshold voltage range depends on Output voltage of DC/DC converter.
- Release Voltage from Reset condition must not be more than Output voltage of DC/DC converter.
- When the R1221Nxxxx is on stand-by mode, the output voltage of VOUT is GND level, therefore if the pull-up resistor for VOUT pin is pulled up another power supply, a certain amount of current is loading through the resistor.
- The operation of latch-type protection circuit is as follows;
  - When the maximum duty cycle continues longer than the delay time for protection circuit, (Refer to the Electrical Characteristics) the protection circuit works to shut-down the external Power MOS with its latching operation. Therefore when an input/output voltage difference is small, the protection circuit may work even at small load current.
  - To release the protection state, after disable this IC with a chip enable circuit, enable it again, or restart this IC with power-on. However, in the case of restarting this IC with power-on, after the power supply is turned off, if a certain amount of charge remains in Cso, or some voltage is forced to VCC from Cso, this IC might not be restarted even after power-on.
  - If rising transition speed of supply voltage is too slow, or the time which is required for VCC voltage to reach the output voltage of DC/DC converter is longer than soft-starting time plus delay time for protection circuit, protection circuit works before VCC voltage reaches Output Voltage of DC/DC converter. To avoid this condition, make this IC disable (CE = “L”) first, then force VCC voltage, and after VCC voltage becomes equal or more than VOUT, make this IC enable (CE = “H”).
- Set external components as close as possible to the IC and minimize the connection between the components and the IC. In particular, a capacitor should be connected to VOUT pin with the minimum connection. And make sufficient grounding and reinforce supplying. A large switching current flows through the connection of power supply, an inductor and the connection of VOUT. If the impedance of power supply line is high, the voltage level of power supply of the IC fluctuates with the switching current. This may cause unstable operation of the IC.
- Use capacitors with a capacity of 22μF or more for VOUT Pin, and with good high frequency characteristics such as tantalum capacitors. We recommend you to use capacitors with an allowable voltage which is at least twice as much as setting output voltage. This is because there may be a case where a spike-shaped high voltage is generated by an inductor when an external transistor is on and off.
- Choose an inductor that has sufficiently small DC resistance and large allowable current and is hard to reach magnetic saturation. And if the value of inductance of an inductor is extremely small, the IX may exceed the absolute maximum rating at the maximum loading.
- Use an inductor with appropriate inductance.
- Use a diode of a Schottky type with high switching speed, and also pay attention to its current capacity.
- Do not use this IC under the condition at VCC voltage less than minimum operating voltage.
The performance of power source circuits using these ICs extremely depends upon the peripheral circuits. Pay attention in the selection of the peripheral circuits. In particular, design the peripheral circuits in a way that the values such as voltage, current, and power of each component, PCB patterns and the IC do not exceed their respected rated values.

**OPERATION of Step-down DC/DC Converter and Output Current**

The step-down DC/DC converter charges energy in the inductor when Lx transistor is ON, and discharges the energy from the inductor when Lx transistor is OFF and controls with less energy loss, so that a lower output voltage than the input voltage is obtained. The operation will be explained with reference to the following diagrams:

- **Discontinuous Conduction Mode and Continuous Conduction Mode**

  The maximum value (ILmax) and the minimum value (ILmin) of the current which flows through the inductor are the same as those when LxTr is ON and when it is OFF.

  The difference between ILmax and ILmin, which is represented by ΔI:

  \[ ΔI = ILmax - ILmin = V_{OUT} \times \text{ton} / L = (V_{IN} - V_{OUT}) \times \text{ton} / L \]

  Equation 1
wherein $T = 1/f_{osc} = \text{ton} + \text{toff}$

$$\text{duty} (\%) = \frac{\text{ton}}{T} \times 100 = \frac{\text{ton} \times f_{osc} \times 100}{\text{toff}}$$

In Equation 1, $V_{\text{OUT}} \times \text{ton}/L$ and $(V_{\text{IN}} - V_{\text{OUT}}) \times \text{ton}/L$ respectively show the change of the current at ON, and the change of the current at OFF.

When the output current ($I_{\text{OUT}}$) is relatively small, $\text{ton} < \text{toff}$ as illustrated in the above diagram. In this case, the energy is charged in the inductor during the time period of ton and is discharged in its entirety during the time period of toff, therefore $I_{\text{Lmin}}$ becomes to zero ($I_{\text{Lmin}} = 0$). When $I_{\text{OUT}}$ is gradually increased, eventually, $\text{ton}$ becomes to toff ($\text{ton} = \text{toff}$), and when $I_{\text{OUT}}$ is further increased, $I_{\text{Lmin}}$ becomes larger than zero ($I_{\text{Lmin}} > 0$). The former mode is referred to as the discontinuous mode and the latter mode is referred to as continuous mode.

In the continuous mode, when Equation 1 is solved for $\text{ton}$ and assumed that the solution is $t_{\text{on}}$:

$$t_{\text{on}} = \frac{V_{\text{OUT}}}{V_{\text{IN}}} \frac{\text{ton}}{L} \frac{1}{f_{osc}} \frac{100}{100} \text{ from Equation 2}$$

When $\text{ton} < t_{\text{on}}$, the mode is the discontinuous mode, and when $\text{ton} = t_{\text{on}}$, the mode is the continuous mode.

**Output Current and Selection of External Components**

When $L_{\text{XTr}}$ is ON:

(Wherein, Ripple Current P-P value is described as $I_{\text{p-p}}, \text{ON}$ resistance of $L_{\text{XTr}}$ is described as $R_{\text{p}}$ the direct current resistance of the inductor is described as $R_{\text{L}}$)

$$V_{\text{IN}} = V_{\text{OUT}} + (R_{\text{p}} + R_{\text{L}}) \times I_{\text{OUT}} + L \times \text{ton} \frac{1}{L} \frac{1}{f_{osc}} \frac{100}{100} \text{ from Equation 3}$$

When $L_{\text{XTr}}$ is OFF:

$$L \times \text{toff} \frac{1}{L} \frac{1}{f_{osc}} \frac{100}{100} \text{ from Equation 4}$$

Put Equation 4 to Equation 3 and solve for ON duty, $\text{ton}/(\text{toff} + \text{ton}) = D_{\text{ON}}$,

$$D_{\text{ON}} = (V_{\text{OUT}} + V_{\text{p}} + R_{\text{L}} \times I_{\text{OUT}}) \frac{1}{V_{\text{IN}} + V_{\text{p}} + R_{\text{L}} \times I_{\text{OUT}}} \text{ from Equation 5}$$

Ripple Current is as follows:

$$I_{\text{p-p}} = (V_{\text{IN}} - V_{\text{OUT}} + R_{\text{L}} \times I_{\text{OUT}}) \frac{1}{L} \text{ from Equation 6}$$

wherein, peak current that flows through $L$, $L_{\text{XTr}}$, and $SD$ is as follows:

$$I_{\text{Lmax}} = I_{\text{OUT}} + I_{\text{p-p}}/2 \text{ from Equation 7}$$
Consider ILmax, condition of input and output and select external components.

★ The above explanation is directed to the calculation in an ideal case in continuous mode.

**External Components**

1. **Inductor**
   - Select an inductor that peak current does not exceed ILmax. If larger current than allowable current flows, magnetic saturation occurs and make transform efficiency worse.
   - When the load current is same, the smaller value of L is used, the larger the ripple current is.
   - Provided that the allowable current is large in that case and DC current is small, therefore, for large output current, efficiency is better than using an inductor with a large value of L and vice versa.

2. **Diode**
   - Use a diode with low Vs (Schottky type is recommended) and high switching speed.
   - Reverse voltage rating should be more than Vs and current rating should be equal or more than ILmax.

3. **Capacitor**
   - As for C(t), use a capacitor with low ESR (Equivalent Series Resistance) and a capacity of at least 10μF for stable operation. C(t) can reduce ripple of Output Voltage, therefore 47 to 100μF tantalum type is recommended.

4. **Lx Transistor**
   - Pch Power MOS FET is required for this IC.
   - Its breakdown voltage between gate and source should be a few volt higher than the input voltage.
   - In the case of the input voltage is low, to turn on MOS FET completely, select a MOS FET with low threshold voltage.
   - If a large load current is necessary for your application and important, choose a MOS FET with low ON resistance for good efficiency.
   - If a small load current is mainly necessary for your application, choose a MOS FET with low gate capacity for good efficiency.
   - Maximum continuous drain current of MOS FET should be larger than peak current, ILmax.
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current

2) Efficiency vs. Output Current

Discontinued
3) Ripple Voltage vs. Output Current

- **R1221N50xB (VIN=12V)**
- **R1221N50xC (VIN=6.0V)**
- **R1221N50xA (VIN=4.5V, VIN=8V)**

Discontinued
4) Oscillator Frequency vs. Input Voltage

5) Output Voltage vs. Input Voltage
6) Output Voltage vs. Temperature

7) Detector Threshold vs. Temperature
8) Oscillator Frequency vs. Temperature

R1221N33AB (VD=3.0V)  

Temperature Topt (°C)

Oscillator Frequency fosc (kHz)

L=27µH  
VIN=4.5V

R1221N25xA

L=27µH
VIN=3.7V

9) Supply Current vs. Temperature

R1221N33AH

Supply Current1 (µA)

VIN=15V  
VIN=13.2V  
VIN=8V

R1221N33AG

Supply Current (µA)

VIN=15V  
VIN=13.2V  
VIN=8V

Discontinued
10) Soft-start Time vs. Temperature

- **R1221N33AB**
  - $L=27\mu H$
  - $V_{IN}=4.5V$

- **R1221N25xA**
  - $L=27\mu H$
  - $V_{IN}=3.7V$

11) Delay Time for Latch-type Protection vs. Temperature

- **R1221N33AB**
  - $V_{IN}=4.5V$

- **R1221N25xA**
  - $V_{IN}=3.7V$

12) Delay Time for Reset-type Protection vs. Temperature

- **R1221N33AH**
  - $V_{IN}=4.5V$

- **R1221N33AG**
  - $V_{IN}=4.5V$

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Discontinued
13) VD Output Delay Time vs. Temperature
R1221N33AB \[V_{IN}=8.0V\]

14) EXT'H' Output Current vs. Temperature
R1221N33AB

15) EXT 'L' Output Current vs. Temperature
R1221N33AB

Discontinued
16) VD \text{out} \text{ 'L' Output Current vs. Temperature}

Temperature Topt (°C)

\begin{align*}
-50 & \quad 0 & \quad 50 & \quad 100 \\
0.0 & \quad 0.2 & \quad 0.4 & \quad 0.6 & \quad 0.8 & \quad 1.0 & \quad 1.2 & \quad 1.4 & \quad 1.6 \\
\text{VDLC (mA)}
\end{align*}

17) Load Transient Response

VIN=5V
L=27µH

Output Current I_{\text{OUT}} (mA)

Time (sec)

Output Voltage V_{\text{OUT}} (V)
R1221N

**18) Turn-on Waveform**

R1221N33AC

VIN=5V
L=27µH

Output Voltage V

Output Current I

Time (sec)

R1221N33AC

VIN=5V
L=27µH

Output Voltage V

Output Current I

Time (sec)

R1221N33AD

VIN=5V
L=27µH

Output Voltage V

Output Current I

Time (sec)

R1221N33AD

VIN=5V
L=27µH

Output Voltage V

Output Current I

Time (sec)

Discontinued
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