The R1234D Series are CMOS-based PWM step-down DC/DC Converters with synchronous rectifier, low supply current. Each of these ICs consists of an oscillator, a PWM control circuit, a reference voltage unit, an error amplifier, a soft-start circuit, protection circuits, a protection against miss operation under low voltage (UVLO), PWM/VFM alternative circuit, a chip enable circuit, and a driver transistor. A low ripple, high efficiency step-down DC/DC converter can be easily composed of this IC with only a few kinds of external components, or an inductor and capacitors. (As for R1234D001C/D types, divider resistors are also necessary.) In terms of Output Voltage, it is fixed internally in the R1234Dxx1A/B types. While in the R1234D001C/D types, Output Voltage is adjustable with external divider resistors.

PWM/VFM alternative circuit is active with Mode Pin of the R1234D Series. Thus, when the load current is small, the operation can be switching into the VFM operation from PWM operation by the logic of MODE pin and the efficiency at small load current can be improved. As protection circuits, Current Limit circuit which limits peak current of Lx at each clock cycle, and Latch type protection circuit which works if the term of Over-current condition keeps on a certain time in PWM mode exist. Latch-type protection circuit works to latch an internal driver 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 or make the supply voltage at UVLO detector threshold level or lower than UVLO.

**FEATURES**

- Supply Current ............................................................. Typ. 230μA (R1234Dxx1A/C)
- Standby Current ............................................................. Typ. 0μA
- Input Voltage Range ....................................................... 2.4V to 5.5V (ABSOLUTE MAXIMUM : 6.5V)
- Output Voltage Range ....................................................... 2.2V to 3.3V (R1234Dxx1A/B)
- Oscillator Frequency ....................................................... Typ. 500kHz (R1234Dxx1A/C)
- Built-in Driver ON Resistance ........................................... Pch 0.4Ω, Nch 0.6Ω (VIN=3V)
- Control mode switch ....................................................... MODE pin=“L”: PWM
- Efficiency ................................................................. Typ. 90%
- Package ................................................................. SON-8
- Built-in Soft-start Function ............................................. Typ. 1.5ms
- Latch-type Protection Function ...................................... Typ. 1.5ms
- Built-in Current Limit Circuit

**APPLICATIONS**

- Power source for portable equipment.
SELECTION GUIDE

In the R1234D Series, the output voltage, the oscillator frequency, and the taping type for the ICs can be selected at the user's request.

The selection can be made with designating the part number as shown below;

\[ \text{R1234D}xx \overline{1x-xx-x} \rightarrow \text{Part Number} \]

+---+---+---+---+---+---+
| a | b | c | d | e | f |
+---+---+---+---+---+---+
| a | Designation of Package Type; D: SON-8 |
| b | Setting Output Voltage (V_{out}); Stepwise setting with a step of 0.1V in the range of 1.2V to 3.3V is possible for A/B version. "00" is for Output Voltage Adjustable C/D version (0.8V to ) |
| c | 1: fixed |
| d | Designation of Optional Function A: 500kHz, Fixed Output Voltage B: 800kHz, Fixed Output Voltage C: 500kHz, Adjustable Output Voltage D: 800kHz, Adjustable Output Voltage |
| e | Designation of Taping Type; (Refer to Taping Specification) "TR" is prescribed as a standard. |
| f | Designation of Composition of pin plating -F: Lead free plating |

Discontinued
PIN CONFIGURATION

• SON-8

Top View

Bottom View

PIN DESCRIPTION

<table>
<thead>
<tr>
<th>Pin No</th>
<th>Symbol</th>
<th>Pin Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>VIN</td>
<td>Voltage Supply Pin</td>
</tr>
<tr>
<td>2</td>
<td>PGND</td>
<td>Power Ground Pin</td>
</tr>
<tr>
<td>3</td>
<td>VDD</td>
<td>Voltage Supply Pin</td>
</tr>
<tr>
<td>4</td>
<td>CE</td>
<td>Chip Enable Pin (active with &quot;H&quot;)</td>
</tr>
<tr>
<td>5</td>
<td>VOUT/VFB</td>
<td>Output/Feedback Pin</td>
</tr>
<tr>
<td>6</td>
<td>MODE</td>
<td>Mode changer Pin (&quot;L&quot;=PWM, &quot;H&quot;=VFM)</td>
</tr>
<tr>
<td>7</td>
<td>AGND</td>
<td>Analogue Ground Pin</td>
</tr>
<tr>
<td>8</td>
<td>LX</td>
<td>Lx Pin (CMOS)</td>
</tr>
</tbody>
</table>

* Tab in the parts have GND level. (They are connected to the reverse side of this IC.) Do not connect to other wires or land patterns.

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>VIN Supply Voltage</td>
<td>6.5</td>
<td>V</td>
</tr>
<tr>
<td>VDD</td>
<td>VDD Pin Voltage</td>
<td>6.5</td>
<td>V</td>
</tr>
<tr>
<td>VLX</td>
<td>Lx Pin Voltage</td>
<td>−0.3 to VIN +0.3</td>
<td>V</td>
</tr>
<tr>
<td>VCE</td>
<td>CE Pin Input Voltage</td>
<td>−0.3 to VIN +0.3</td>
<td>V</td>
</tr>
<tr>
<td>VMODE</td>
<td>MODE Pin Input Voltage</td>
<td>−0.3 to VIN +0.3</td>
<td>V</td>
</tr>
<tr>
<td>VFB</td>
<td>VFB Pin Input Voltage</td>
<td>−0.3 to VIN +0.3</td>
<td>V</td>
</tr>
<tr>
<td>ILX</td>
<td>Lx Pin Output Current</td>
<td>−0.8</td>
<td>A</td>
</tr>
<tr>
<td>PD</td>
<td>Power Dissipation (SON-8)</td>
<td>480</td>
<td>mW</td>
</tr>
<tr>
<td>Topt</td>
<td>Operating Temperature Range</td>
<td>−40 to +85</td>
<td>°C</td>
</tr>
<tr>
<td>Tstg</td>
<td>Storage Temperature Range</td>
<td>−55 to +125</td>
<td>°C</td>
</tr>
</tbody>
</table>

* ) For Power Dissipation, please refer to PACKAGE INFORMATION to be described.
# ELECTRICAL CHARACTERISTICS

<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>VIN</td>
<td>Operating Input Voltage</td>
<td></td>
<td>2.4</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>VOUT</td>
<td>Step-down Output Voltage</td>
<td>$V_{IN}=V_{CE}=V_{SET}+1.5V$, $V_{MODE}=0V$, $I_{OUT}=10mA$</td>
<td>Typ.</td>
<td>$V_{SET}$</td>
<td>Typ.</td>
<td>$V$</td>
</tr>
<tr>
<td>$\Delta V_{OUT}/\Delta Topt$</td>
<td>Step-down Output Voltage Temperature Coefficient</td>
<td>$-40^\circ C \leq Topt \leq 85^\circ C$</td>
<td>±150</td>
<td>ppm/°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>fosc</td>
<td>Oscillator Frequency</td>
<td>$V_{IN}=V_{CE}=V_{SET}+1.5V$</td>
<td>425</td>
<td>500</td>
<td>575</td>
<td>kHz</td>
</tr>
<tr>
<td>IDD</td>
<td>Supply Current</td>
<td>$V_{IN}=V_{CE}=V_{SET}+1.5V$, $V_{OUT}=V_{MODE}=0V$</td>
<td>230</td>
<td>300</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>Istandby</td>
<td>Standby Current</td>
<td>$V_{IN}=5.5V$, $V_{CE}=V_{OUT}=0V$</td>
<td>0</td>
<td>5</td>
<td>μA</td>
<td></td>
</tr>
<tr>
<td>$R_{ONP}$</td>
<td>ON Resistance of Pch Transistor</td>
<td>$V_{IN}=5.0V$</td>
<td>0.2</td>
<td>0.4</td>
<td>0.9</td>
<td>Ω</td>
</tr>
<tr>
<td>$R_{ONN}$</td>
<td>ON Resistance of Nch Transistor</td>
<td>$V_{IN}=5.0V$</td>
<td>0.2</td>
<td>0.6</td>
<td>0.9</td>
<td>Ω</td>
</tr>
<tr>
<td>$I_{LXleak}$</td>
<td>LX Leakage Current</td>
<td>$V_{IN}=5.5V$, $V_{CE}=0V$, $V_{LX}=0V$ or 5.5V</td>
<td>$-5.0$</td>
<td>0.0</td>
<td>5.0</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{VOUTleak}$</td>
<td>VOUT Leakage Current</td>
<td>$V_{IN}=5.5V$, $V_{CE}=0V$, $V_{VX}=0V$ or 5.5V</td>
<td>$-0.1$</td>
<td>0.0</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>ICE</td>
<td>CE Input Current</td>
<td>$V_{IN}=5.5V$, $V_{MODE}=0V$, $V_{MODE}=5.5V$ or 0V</td>
<td>$-0.1$</td>
<td>0.0</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{MODE}$</td>
<td>MODE Pin Input Current</td>
<td>$V_{IN}=5.5V$, $V_{CE}=0V$, $V_{MODE}=5.5V$ or 0V</td>
<td>$-0.1$</td>
<td>0.0</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>VCEH</td>
<td>CE &quot;H&quot; Input Voltage</td>
<td>$V_{IN}=5.5V$, $V_{OUT}=0V$</td>
<td>1.5</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VCEL</td>
<td>CE &quot;L&quot; Input Voltage</td>
<td>$V_{IN}=2.4V$, $V_{OUT}=0V$</td>
<td>0.3</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{MODEH}$</td>
<td>MODE &quot;H&quot; Input Voltage</td>
<td>$V_{IN}=V_{CE}=5.5V$, $V_{OUT}=0V$</td>
<td>1.5</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$V_{MODEL}$</td>
<td>MODE &quot;L&quot; Input Voltage</td>
<td>$V_{IN}=V_{CE}=2.4V$, $V_{OUT}=0V$</td>
<td>0.3</td>
<td>V</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maxduty</td>
<td>Oscillator Maximum Duty Cycle</td>
<td>$V_{MODE}=0V$</td>
<td>100</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tstart</td>
<td>Delay Time by Soft-Start function</td>
<td>at no load, $V_{IN}=V_{CE}=V_{SET}+1.5V$</td>
<td>0.5</td>
<td>1.5</td>
<td>2.5</td>
<td>ms</td>
</tr>
<tr>
<td>$V_{LXlim}$</td>
<td>LX Limit Voltage</td>
<td>$V_{MODE}=V_{OUT}=0V$, $V_{IN}=3.0V$</td>
<td>$V_{IN}$</td>
<td>0.15</td>
<td>$V_{IN}$</td>
<td>−0.35</td>
</tr>
<tr>
<td>Tprot</td>
<td>Delay Time for protection circuit</td>
<td>$V_{IN}=V_{CE}=V_{SET}+1.5V$, $V_{MODE}=0V$</td>
<td>0.5</td>
<td>1.5</td>
<td>2.5</td>
<td>ms</td>
</tr>
<tr>
<td>$V_{UVLO1}$</td>
<td>UVLO Threshold Voltage</td>
<td>$V_{IN}=V_{CE}=2.5V$ to 1.5V, $V_{OUT}=0V$</td>
<td>1.8</td>
<td>2.1</td>
<td>2.2</td>
<td>V</td>
</tr>
<tr>
<td>$V_{UVLO2}$</td>
<td>UVLO Released Voltage</td>
<td>$V_{IN}=V_{CE}=1.5V$ to 2.5V, $V_{OUT}=0V$</td>
<td>1.9</td>
<td>2.2</td>
<td>2.3</td>
<td>V</td>
</tr>
<tr>
<td>VFMduty</td>
<td>VFM Duty Cycle</td>
<td>$V_{IN}=V_{CE}=V_{MODE}=2.4V$, $V_{OUT}=0V$</td>
<td>55</td>
<td>65</td>
<td>85</td>
<td>%</td>
</tr>
</tbody>
</table>

Discontinued
### Symbol | Item | Conditions | Min. | Typ. | Max. | Unit
--- | --- | --- | --- | --- | --- | ---
\( V_{IN} \) | Operating Input Voltage | | 2.4 | 5.5 | | V
\( V_{OUT} \) | Step-down Output Voltage | \( V_{IN}=V_{CE}=V_{SET}+1.5V, \) \( V_{MODE}=0V, \) \( I_{OUT}=10mA \) | Typ. \( \times 0.98 \) | \( V_{SET} \) | Typ. \( \times 1.02 \) | V
\( \Delta V_{OUT}/\Delta T_{opt} \) | Step-down Output Voltage Temperature Coefficient | \( -40^\circ C \leq T_{opt} \leq 85^\circ C \) | ±150 | | | ppm/°C
\( f_{osc} \) | Oscillator Frequency | \( V_{IN}=V_{CE}=V_{SET}+1.5V \) | 680 | 800 | 920 | kHz
\( I_{DD} \) | Supply Current | \( V_{IN}=V_{CE}=V_{SET}+1.5V, \) \( V_{OUT}=V_{MODE}=0V \) | 250 | 450 | | μA
\( I_{standby} \) | Standby Current | \( V_{IN}=5.5V, \) \( V_{CE}=V_{OUT}=0V \) | 0 | 5 | | μA
\( R_{ONP} \) | ON Resistance of Pch Transistor | \( V_{IN}=5.0V \) | 0.2 | 0.4 | 0.9 | Ω
\( R_{ONN} \) | ON Resistance of Nch Transistor | \( V_{IN}=5.0V \) | 0.2 | 0.6 | 0.9 | Ω
\( I_{LXleak} \) | Lx Leakage Current | \( V_{IN}=5.5V, \) \( V_{CE}=0V, \) \( V_{LX}=0V \) or 5.5V | -5.0 | 0.0 | 5.0 | μA
\( I_{VOUTleak} \) | VOUT Leakage Current | \( V_{IN}=5.5V, \) \( V_{CE}=0V, \) \( V_{OUT}=0V \) | -0.1 | 0.0 | 0.1 | μA
\( I_{ICE} \) | CE Input Current | \( V_{IN}=5.5V, \) \( V_{MODE}=0V, \) \( V_{CE}=5.5V \) or 0V | -0.1 | 0.0 | 0.1 | μA
\( I_{MODE} \) | MODE Pin Input Current | \( V_{IN}=5.5V, \) \( V_{CE}=0V, \) \( V_{MODE}=5.5V \) or 0V | -0.1 | 0.0 | 0.1 | μA
\( V_{CEH} \) | CE "H" Input Voltage | \( V_{IN}=5.5V, \) \( V_{OUT}=0V \) | 1.5 | | | V
\( V_{CEL} \) | CE "L" Input Voltage | \( V_{IN}=2.4V, \) \( V_{OUT}=0V \) | 0.3 | | | V
\( V_{MODEH} \) | MODE "H" Input Voltage | \( V_{IN}=V_{CE}=5.5V, \) \( V_{OUT}=0V \) | 1.5 | | | V
\( V_{MODEL} \) | MODE "L" Input Voltage | \( V_{IN}=V_{CE}=2.4V, \) \( V_{OUT}=0V \) | 0.3 | | | V
Maxduty | Oscillator Maximum Duty Cycle | \( V_{MODE}=0V \) | 100 | | | %
tstart | Delay Time by Soft-Start function | at no load, \( V_{IN}=V_{CE}=V_{SET}+1.5V \) | 0.5 | 1.5 | 2.5 | ms
\( V_{LXlim} \) | Lx Limit Voltage | \( V_{MODE}=V_{OUT}=0V, \) \( V_{IN}=V_{CE}=3.0V \) | \( V_{IN} \) \( -0.15 \) | \( V_{IN} \) \( -0.35 \) | \( V_{IN} \) \( -0.65 \) | V
Tprot | Delay Time for protection circuit | \( V_{IN}=V_{CE}=V_{SET}+1.5V, \) \( V_{MODE}=0V \) | 0.5 | 1.5 | 2.5 | ms
\( V_{UVLO1} \) | UVLO Threshold Voltage | \( V_{IN}=V_{CE}=2.5V \rightarrow 1.5V, \) \( V_{OUT}=0V \) | 1.8 | 2.1 | 2.2 | V
\( V_{UVLO2} \) | UVLO Released Voltage | \( V_{IN}=V_{CE}=1.5V \rightarrow 2.5V, \) \( V_{OUT}=0V \) | 1.9 | 2.2 | 2.3 | V
VFMDuty | VFM Duty Cycle | \( V_{IN}=V_{CE}=V_{MODE}=2.4V, \) \( V_{OUT}=0V \) | 55 | 65 | 85 | %
<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>$V_{IN}$</td>
<td>Operating Input Voltage</td>
<td></td>
<td>2.7</td>
<td>5.5</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{FB}$</td>
<td>Feedback Voltage</td>
<td>$V_{IN}=V_{CE}=V_{SET}+1.5V$, $V_{MODE}=0V$, $I_{OUT}=10mA$</td>
<td>0.776</td>
<td>0.800</td>
<td>0.824</td>
<td>V</td>
</tr>
<tr>
<td>$\Delta V_{FB}/\Delta T_{opt}$</td>
<td>Feedback Voltage Temperature Coefficient</td>
<td>$-40^\circ C \leq T_{opt} \leq 85^\circ C$</td>
<td>300</td>
<td></td>
<td>ppm/°C</td>
<td></td>
</tr>
<tr>
<td>$f_{osc}$</td>
<td>Oscillator Frequency</td>
<td>$V_{IN}=V_{CE}=V_{SET}+1.5V$</td>
<td>425</td>
<td>500</td>
<td>575</td>
<td>kHz</td>
</tr>
<tr>
<td>$I_{DD}$</td>
<td>Supply Current</td>
<td>$V_{IN}=V_{CE}=V_{SET}+1.5V$, $V_{FB}=V_{MODE}=0V$</td>
<td>230</td>
<td>300</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$I_{standby}$</td>
<td>Standby Current</td>
<td>$V_{IN}=5.5V$, $V_{CE}=V_{FB}=0V$</td>
<td>0</td>
<td>5</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$R_{ONP}$</td>
<td>ON Resistance of Pch Transistor</td>
<td>$V_{IN}=5.0V$</td>
<td>0.2</td>
<td>0.4</td>
<td>0.9</td>
<td>Ω</td>
</tr>
<tr>
<td>$R_{ONN}$</td>
<td>ON Resistance of Nch Transistor</td>
<td>$V_{IN}=5.0V$</td>
<td>0.2</td>
<td>0.6</td>
<td>0.9</td>
<td>Ω</td>
</tr>
<tr>
<td>$I_{LXleak}$</td>
<td>LX Leakage Current</td>
<td>$V_{IN}=5.5V$, $V_{CE}=0V$, $V_{LX}=0V$ or $5.5V$</td>
<td>−5.0</td>
<td>0.0</td>
<td>5.0</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{VFBleak}$</td>
<td>VFB Leakage Current</td>
<td>$V_{IN}=5.5V$, $V_{CE}=0V$, $V_{FB}=0V$ or $5.5V$</td>
<td>−0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{CE}$</td>
<td>CE Input Current</td>
<td>$V_{IN}=5.5V$, $V_{MODE}=0V$, $V_{CE}=5.5V$ or $0V$</td>
<td>−0.1</td>
<td>0.0</td>
<td>0.1</td>
<td>μA</td>
</tr>
<tr>
<td>$I_{MODE}$</td>
<td>MODE Pin Input Current</td>
<td>$V_{IN}=5.5V$, $V_{CE}=0V$, $V_{MODE}=5.5V$ or $0V$</td>
<td>−0.1</td>
<td>0.1</td>
<td></td>
<td>μA</td>
</tr>
<tr>
<td>$V_{CEH}$</td>
<td>CE &quot;H&quot; Input Voltage</td>
<td>$V_{IN}=5.5V$, $V_{FB}=0V$</td>
<td>1.5</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{CEL}$</td>
<td>CE &quot;L&quot; Input Voltage</td>
<td>$V_{IN}=2.4V$, $V_{FB}=0V$</td>
<td>0.3</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{MODEH}$</td>
<td>MODE &quot;H&quot; Input Voltage</td>
<td>$V_{IN}=V_{CE}=5.5V$, $V_{FB}=0V$</td>
<td>1.5</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>$V_{MODEL}$</td>
<td>MODE &quot;L&quot; Input Voltage</td>
<td>$V_{IN}=V_{CE}=2.4V$, $V_{FB}=0V$</td>
<td>0.3</td>
<td></td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Maxduty</td>
<td>Oscillator Maximum Duty Cycle</td>
<td>$V_{MODE}=0V$</td>
<td>100</td>
<td></td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>$t_{start}$</td>
<td>LX Limit Voltage</td>
<td>at no load, $V_{IN}=V_{CE}=V_{SET}+1.5V$</td>
<td>0.5</td>
<td>1.5</td>
<td>2.5</td>
<td>ms</td>
</tr>
<tr>
<td>$V_{LXlim}$</td>
<td>Delay Time by Soft-Start function</td>
<td>$V_{MODE}=V_{FB}=0V$, $V_{IN}=V_{CE}=3.0V$</td>
<td>$V_{IN}$</td>
<td>$V_{IN}$</td>
<td>$V_{IN}$</td>
<td>V</td>
</tr>
<tr>
<td>Tprot</td>
<td>Delay Time for protection circuit</td>
<td>$V_{IN}=V_{CE}=3.6V$, $V_{MODE}=0V$</td>
<td>0.5</td>
<td>1.5</td>
<td>2.5</td>
<td>ms</td>
</tr>
<tr>
<td>$V_{UVLO1}$</td>
<td>UVLO Threshold Voltage</td>
<td>$V_{IN}=V_{CE}=2.5V$ to $1.5V$, $V_{MODE}=0V$</td>
<td>1.95</td>
<td>2.20</td>
<td>2.45</td>
<td>V</td>
</tr>
<tr>
<td>$V_{UVLO2}$</td>
<td>UVLO Released Voltage</td>
<td>$V_{IN}=V_{CE}=1.5V$ to $2.7V$, $V_{FB}=0V$</td>
<td>2.20</td>
<td>2.40</td>
<td>2.65</td>
<td>V</td>
</tr>
<tr>
<td>VFMDuty</td>
<td>VFM Duty Cycle</td>
<td>$V_{IN}=V_{CE}=V_{MODE}=2.4V$, $V_{FB}=0V$</td>
<td>55</td>
<td>65</td>
<td>85</td>
<td>%</td>
</tr>
</tbody>
</table>
### R1234DxxxD

**Symbol** | **Item** | **Conditions** | **Min.** | **Typ.** | **Max.** | **Unit**
--- | --- | --- | --- | --- | --- | ---
\(V_{IN}\) | Operating Input Voltage | | 2.7 | 5.5 | | V
\(V_{FB}\) | Feedback Voltage | \(V_{IN}=V_{CE}=V_{SET}+1.5V, V_{MODE}=0V, I_{OUT}=10mA\) | 0.776 | 0.800 | 0.824 | V
\(\Delta V_{FB}/\Delta T_{opt}\) | Feedback Voltage Temperature Coefficient | \(-40^\circ C \leq T_{opt} \leq 85^\circ C\) | ±300 | | | ppm/°C
\(I_{OOD}\) | Supply Current | \(V_{IN}=V_{CE}=V_{SET}+1.5V, V_{FB}=V_{MODE}=0V\) | 250 | 400 | | μA
\(I_{standby}\) | Standby Current | \(V_{IN}=5.5V, V_{CE}=V_{FB}=0V\) | 0 | 5 | | μA
\(R_{ONP}\) | ON Resistance of Pch Transistor | \(V_{IN}=5.0V\) | 0.2 | 0.4 | 0.9 | Ω
\(R_{ONN}\) | ON Resistance of Nch Transistor | \(V_{IN}=5.0V\) | 0.2 | 0.6 | 0.9 | Ω
\(I_{LXleak}\) | LX Leakage Current | \(V_{IN}=5.5V, V_{CE}=0V, V_{LX}=0V \text{ or } 5.5V\) | −5.0 | 0.0 | 5.0 | μA
\(I_{VFBleak}\) | VFB Leakage Current | \(V_{IN}=5.5V, V_{CE}=0V, V_{FB}=0V \text{ or } 5.5V\) | −0.1 | 0.0 | 0.1 | μA
\(I_{CE}\) | CE Input Current | \(V_{IN}=5.5V, V_{MODE}=0V, V_{CE}=5.5V \text{ or } 0V\) | −0.1 | 0.0 | 0.1 | μA
\(I_{MODE}\) | MODE Pin Input Current | \(V_{IN}=5.5V, V_{CE}=0V, V_{MODE}=5.5V \text{ or } 0V\) | −0.1 | 0.1 | | μA
\(V_{CEH}\) | CE "H" Input Voltage | \(V_{IN}=5.5V, V_{FB}=0V\) | 1.5 | | | V
\(V_{CEL}\) | CE "L" Input Voltage | \(V_{IN}=2.4V, V_{FB}=0V\) | 0.3 | | | V
\(V_{MODEH}\) | MODE "H" Input Voltage | \(V_{IN}=V_{CE}=5.5V, V_{FB}=0V\) | 1.5 | | | V
\(V_{MODEL}\) | MODE "L" Input Voltage | \(V_{IN}=V_{CE}=2.4V, V_{FB}=0V\) | 0.3 | | | V
\(Maxduty\) | Oscillator Maximum Duty Cycle | \(V_{MODE}=0V\) | 100 | | | %
\(t_{start}\) | LX Limit Voltage | at no load, \(V_{IN}=V_{CE}=V_{SET}+1.5V\) | 0.5 | 1.5 | 2.5 | ms
\(V_{LXlim}\) | Delay Time by Soft-Start function | \(V_{MODE}=V_{FB}=0V, V_{IN}=V_{CE}=3.0V\) | \(V_{IN}=-0.15\) | \(V_{IN}=-0.35\) | \(V_{IN}=-0.65\) | V
\(T_{prot}\) | Delay Time for protection circuit | \(V_{IN}=V_{CE}=3.6V, V_{MODE}=0V\) | 0.5 | 1.5 | 2.5 | ms
\(V_{UVLO1}\) | UVLO Threshold Voltage | \(V_{IN}=V_{CE}=2.5V \rightarrow 1.5V, V_{MODE}=0V\) | 1.95 | 2.20 | 2.45 | V
\(V_{UVLO2}\) | UVLO Released Voltage | \(V_{IN}=V_{CE}=1.5V \rightarrow 2.7V, V_{FB}=0V\) | 2.20 | 2.40 | 2.65 | V
\(VFMduty\) | VFM Duty Cycle | \(V_{IN}=V_{CE}=V_{MODE}=2.4V, V_{FB}=0V\) | 55 | 65 | 85 | %
TEST CIRCUITS

Discontinued

Test Circuit for Input Current and Leakage Current

Test Circuit for Input Voltage and UVLO voltage

Test Circuit for Output Voltage, Oscillator Frequency, Soft-Starting Time

Test Circuit for Supply Current and Standby Current

Test Circuit for ON resistance of Lx, Limit Voltage, Delay Time of Protection Circuit

The bypass capacitor between power supply and GND is a ceramic capacitor 10μF.
**TYPICAL APPLICATION AND TECHNICAL NOTES**

1) Fixed Output Voltage Type

- **C\textsubscript{IN}** 10\(\mu\)F C3216JB0J106M (TDK)
- **C\textsubscript{OUT}** 10\(\mu\)F ECSTOJX106R (Panasonic)
- **L** 10\(\mu\)H LQH3C100K54 (Murata)

2) Adjustable Output Voltage Type

- **C\textsubscript{IN}** 10\(\mu\)F C3216JB0J106M (TDK)
- **C\textsubscript{OUT}** 10\(\mu\)F ECSTOJX106R (Panasonic)
- **L** 10\(\mu\)H LQH3C100K54 (Murata)

VFM mode may work with a parasitic diode, but we recommend that VFM mode used with an external diode in between LX and GND. As for PWM mode, an external diode is not necessary.

As for how to choose C\textsubscript{b}, R\textsubscript{b}, R\textsubscript{1}, and R\textsubscript{2} values, refer to the technical notes.
When you use these ICs, consider the following issues;

- Input same voltage into the power supply pins, \( V_{IN} \) and \( V_{DD} \). Set the same level as AGND and PGND.
- When you control the CE pin and MODE pin by another power supply, do not make its "H" level more than the voltage level of \( V_{IN}/V_{DD} \). pin.
- Set external components such as an inductor, \( C_{IN} \), \( C_{OUT} \) as close as possible to the IC, in particular, minimize the wiring to \( V_{IN} \) pin and PGND pin.
- At stand by mode, (CE="L"), the \( L_X \) output is Hi-Z, or both P-channel transistor and N-channel transistor of \( L_X \) pin turn off.
- Use an external capacitor \( C_{OUT} \) with a capacity of 10\( \mu \)F or more, and with good high frequency characteristics such as tantalum capacitors.
- At VFM mode, (MODE="H"), Latch protection circuit does not operate.
- If the mode is switched over into PWM mode from VFM mode during the operation, change the mode at light load current. If the load current us large, output voltage may decline.
- Reinforce the \( V_{IN} \), PGND, and \( V_{OUT} \) lines sufficiently. Large switching current may flow in these lines. If the impedance of \( V_{IN} \) and PGND lines is too large, the internal voltage level in this IC may shift caused by the switching current, and the operation might be unstable.

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:

- Step 1: P-channel Tr. turns on and current $I_L$ ($=i_1$) flows, and energy is charged into CL. At this moment, IL increases from $I_{L_{min}}$ ($=0$) to reach $I_{L_{max}}$ in proportion to the on-time period ($t_{on}$) of P-channel Tr.
- Step 2: When P-channel Tr. turns off, Synchronous rectifier N-channel Tr. turns on in order that L maintains IL at $I_{L_{max}}$, and current $I_L$ ($=i_2$) flows.
- Step 3: IL ($=i_2$) decreases gradually and reaches $I_L=I_{L_{min}}=0$ after a time period of $t_{open}$, and N-channel Tr. Turns off. Provided that in the continuous mode, next cycle starts before IL becomes to 0 because $t_{off}$ time is not enough. In this case, IL value increases from this $I_{L_{min}}$ ($>-0$).

In the case of PWM control system, the output voltage is maintained by controlling the on-time period ($t_{on}$), with the oscillator frequency ($f_{osc}$) being maintained constant.

**Discontinuous Conduction Mode and Continuous Conduction Mode**

The maximum value ($I_{L_{max}}$) and the minimum value ($I_{L_{min}}$) of the current flowing through the inductor are the same as those when P-channel Tr. turns on and off.

The difference between $I_{L_{max}}$ and $I_{L_{min}}$, which is represented by $\Delta I$;

$$\Delta I = I_{L_{max}} - I_{L_{min}} = V_{OUT} \times t_{open}/L = (V_{IN} - V_{OUT}) \times t_{on}/L$$

Where, $t = 1/f_{osc} = t_{on} + t_{off}$

- duty (%) = $t_{on}/t \times 100 = t_{on} \times f_{osc} \times 100$
- $t_{open} \leq t_{off}$

In Equation 1, $V_{OUT} \times t_{open}/L$ and $(V_{IN} - V_{OUT}) \times t_{on}/L$ are respectively shown the change of the current at ON, and the change of the current at OFF.

When the output current ($I_{out}$) is relatively small, $t_{open} < t_{off}$ as illustrated in the above diagram. In this case, the energy is charged in the inductor during the time period of $t_{on}$ and is discharged in its entirely during the time period of $t_{off}$, therefore $I_{L_{min}}$ becomes to zero ($I_{L_{min}}=0$). When $I_{out}$ is gradually increased, eventually, $t_{open}$ becomes to $t_{off}$ ($t_{open}=t_{off}$), and when $I_{out}$ is further increased, $I_{L_{min}}$ becomes larger than zero ($I_{L_{min}}>0$). 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 ton and assumed that the solution is tonc:

\[ \text{tonc} = t \times \frac{V_{\text{OUT}}}{V_{\text{IN}}} \] ................................. Equation 2

When ton<tonc, the mode is the discontinuous mode, and when ton=tonc, the mode is the continuous mode.

**OUTPUT CURRENT AND SELECTION OF EXTERNAL COMPONENTS**

When P-channel Tr. of LX is ON:

(Wherein, Ripple Current P-P value is described as IRP, ON resistance of P-channel Tr. and N-channel Tr. of LX are respectively described as RONP and RONN, and the DC resistor of the inductor is described as RL.)

\[ V_{\text{IN}} = V_{\text{OUT}} + (R_{\text{ONP}} + RL) \times I_{\text{OUT}} + L \times \frac{IRP}{ton} \] ................................. Equation 3

When P-channel Tr. of LX is "OFF"(N-channel Tr. is "ON"):

\[ L \times \frac{IRP}{toff} = V_{F} + V_{\text{OUT}} + R_{\text{ONN}} \times I_{\text{OUT}} \] ................................. Equation 4

Put Equation 4 to Equation 3 and solve for ON duty of P-channel transistor, Don=

\[ DON = \frac{(V_{\text{OUT}} - R_{\text{ONN}} \times I_{\text{OUT}} + RL \times I_{\text{OUT}})(V_{\text{IN}} + R_{\text{ONN}} \times I_{\text{OUT}} - R_{\text{ONP}} \times I_{\text{OUT}})}{L \times irp/ton / fosc/L} \] ................................. Equation 5

Ripple Current is as follows;

\[ IRP = (V_{\text{IN}} - V_{\text{OUT}} - R_{\text{ONP}} \times I_{\text{OUT}} - RL \times I_{\text{OUT}}) \times Don/fosc/L \] ................................. Equation 6

wherein, peak current that flows through L, and LX Tr. is as follows;

\[ IL_{\text{max}} = I_{\text{OUT}} + IRP/2 \] ................................. 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.
How to Adjust Output Voltage and about Phase Compensation

As for Adjustable Output type, feedback pin (VFB) voltage is controlled to maintain 0.8V.

Output Voltage, \( V_{OUT} \) is as following equation;

\[
V_{OUT} = \frac{V_{FB}(R1+R2)}{R2}
\]

Thus, with changing the value of R1 and R2, output voltage can be set in the specified range.

In the DC/DC converter, with the load current and external components such as L and C, phase might be behind 180 degree. In this case, the phase margin of the system will be less and stability will be worse. To prevent this, phase margin should be secured with proceeding the phase. A pole is formed with external components L and COUT.

\[
f_{pole} \approx \frac{1}{2\pi \sqrt{L_{OUT}}}
\]

A zero (signal back to zero) is formed with R1 and Cb.

\[
\approx f_{zero} \sim \frac{1}{2\pi \times R1 \times Cb}
\]

First, choose the appropriate value of R1, R2 and Cb.

Set R1+R2 value 100k\( \Omega \) or less.

For example, if L=10\( \mu \)H, COUT=10\( \mu \)F, the cut off frequency of the pole is approximately 16kHz. To make the cut off frequency of the zero higher than 16kHz, set R1=42k\( \Omega \) and Cb=100pF. If \( V_{OUT} \) is set at 1.5V, R2=48k\( \Omega \) is appropriate.

If a ceramic capacitor is desirable as COUT in your application, nonetheless of the usage of both the fixed output voltage type and adjustable output type, add 0.2\( \Omega \) or more resistance to compensate the ESR. Further, if a ceramic capacitor is desirable to use as COUT without adding another resister to compensate the ESR, phase should be back drastically. To make it, R2 value should be smaller compared to R1. As a result, the set output voltage may be large. For example, to make \( V_{OUT} \)=1.5V, constants are R1=42k\( \Omega \), R2=48k\( \Omega \), and Cb=100pF. If the ceramic capacitor is used, under the heavy load condition, oscillation may be result. On the other hand, if R2 = 12k\( \Omega \) and \( V_{OUT} \)=3.6V, phase back becomes also large, and even if the device is used with a heavy load, the operation will be stable.

Rb is effective for reducing the noise on VFB. However, it is not always necessary. If it is necessary, use a resistance as much as 30k\( \Omega \) as Rb.
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 makes transform efficiency be worse.
   Supposed that the load current is at the 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. Capacitor
   As for CIN, use a capacitor with low ESR (Equivalent Series Resistance) Ceramic type of a capacity at least 10μF for stable operation.
   COUT can reduce ripple of Output Voltage, therefore as much as 10μF ceramic type is recommended.

3. Diode
   If VFM mode is chosen at light load, use a Schottky diode with small VF. A diode with small VF makes the efficiency of the circuit improved. Small reverse direction current, IR is an important factor, however, VF has more important priority than IR.

TIMING CHART

The timing chart as shown above describes the waveforms starting from the IC is enabled with CE and latched with protection. During the soft-start time, until the level is rising up to the internal soft-start set voltage, the duty cycle of LX is gradually wider and wider to prevent the over-shoot of the voltage. During the term, the output of amplifier is "H". After the output voltage reaches the set output voltage, they are balanced well. Herein, if the output pin would be short circuit, the output of amplifier would become "H" again, and the condition would continue for 2.0ms (Typ.), latch circuit would work and the output of LX would be latched with "OFF". (Output = "High-Z")

If the output short is released before the latch circuit works (within 2ms after output shorted), the output of amplifier is balanced in the stable state again.

Once the IC is latched, to release the protection, input "L" with CE pin, or make the supply voltage at UVLO level or less.
TYPICAL CHARACTERISTICS

1) Output Voltage vs. Output Current

![R1234D181A Output Voltage vs. Output Current](image)

![R1234D181B Output Voltage vs. Output Current](image)

2) Efficiency vs. Output Current

![R1234D181A Efficiency vs. Output Current](image)

![R1234D181B Efficiency vs. Output Current](image)

3) Output Waveform (COUT=10μF, tantalum, PWM)

![R1234D181A Output Waveform](image)

![R1234D181B Output Waveform](image)

Discontinued
4) Load Transient Response (VIN=5.0V, PWM)

**R1234D181A**

**Output Current** 0mA → 100mA

**Output Voltage**

**R1234D181B**

**Output Current** 0mA → 100mA

**Output Voltage**

---

**R1234D181A**

**Output Current** 0mA → 200mA

**Output Voltage**

**R1234D181B**

**Output Current** 0mA → 200mA

**Output Voltage**
R1234D

Discontinued

R1234D181A

R1234D181B

Output Voltage $V_{out}(V)$

Output Current $I_{out}(mA)$

Time $t$ ($\mu s$)

Output Voltage $V_{out}(V)$

Output Current $I_{out}(mA)$

Time $t$ ($\mu s$)

Output Voltage $V_{out}(V)$

Output Current $I_{out}(mA)$

Time $t$ ($\mu s$)

Output Voltage $V_{out}(V)$

Output Current $I_{out}(mA)$

Time $t$ ($\mu s$)

Output Voltage $V_{out}(V)$

Output Current $I_{out}(mA)$

Time $t$ ($\mu s$)

Output Voltage $V_{out}(V)$

Output Current $I_{out}(mA)$

Time $t$ ($\mu s$)
5) Turn on speed with CE pin

**R1234D181A**

**R1234D181B**

---

**Discontinued**
6) Output Ripple Voltage vs. Output Current

R1234D181B

C\text{OUT}=10\mu\text{F}, \text{Tantalum, ESR}=400\text{m}\Omega

[Graph showing output ripple voltage vs. output current for different input voltages (V\text{IN}=5.0V, 3.3V)]

7) Output Voltage vs. Temperature

R1234D181B

[Graph showing output voltage vs. temperature for different input voltages (I\text{OUT}=100mA)]

8) Output Voltage vs. Input Voltage

R1234D181B

[I\text{OUT}=20mA]

[Graph showing output voltage vs. input voltage for different frequencies (800kHz, 500kHz)]

9) Frequency vs. Temperature

[Graph showing frequency vs. temperature for different input voltages (V\text{IN}=5.0V, 3.3V)]

10) Supply Current vs. Temperature

[Graph showing supply current vs. temperature for different input voltages (V\text{IN}=5.5V, 3.3V)]

11) Soft-start Time vs. Temperature

R1234D181B

[V\text{IN}=3.3V]

[Graph showing soft-start time vs. temperature for different frequencies (800kHz, 500kHz)]
12) UVLO Threshold vs. Temperature

13) CE Input Voltage vs. Temperature

14) Mode Input Voltage vs. Temperature

15) Maximum Duty Cycle at VFM Mode vs. Temperature

16) Lx Transistor On Resistance vs. Temperature

17) Lx Limit Voltage vs. Temperature
18) Protection Delay Time vs. Temperature

![Protection Delay Time vs. Temperature Graph]

- Protection Delay Time $t_{prot}(ms)$
- Temperature $T_{opt}(°C)$

Discontinued
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