OUTLINE

The R1294L is the optimized DC/DC converter IC for TFT LCD displays. R1294L contains one PWM step-up DC/DC converter controller and two diode charge-pump controllers. The charge-pumps can control a boost output and a negative output and have the output voltage regulation function with external resistors. The power-on sequence can be made with setting the delay time with external capacitors for each charge-pump channel.

FEATURES

- **Input Voltage Range (Maximum Rating)**
  - R1294L101A: 2.0 V to 5.5 V (6.5 V)
  - R1294L102A: 2.5 V to 5.5 V (6.5 V)
  - R1294L103A: 3.3 V to 5.5 V (6.5 V)

- **Temperature Coefficient of VFB \( \Delta V_{FB}/\Delta T \)**
  - Typ. ±150 ppm/°C (−40°C ≤ Ta ≤ 95°C)

- **Temperature Coefficient of VREF \( \Delta V_{REF}/\Delta T \)**
  - Typ. 150 ppm/°C

- **Temperature Coefficient of CPPFB \( \Delta V_{PPFB}/\Delta T \)**
  - Typ. 150 ppm/°C (−40°C ≤ Ta ≤ 95°C, CPVCC = 9 V)

[Step-up DC/DC Controller]
- Built-in 2 A Nch-switch \( R_{ON} = 150 \, \text{m} \Omega \text{ Typ.} \)
- Overcurrent Protection
- Adjustable \( V_{OUT} \) up to 20 V with external resistors
- Adjustable Phase compensation with external components
- Maxduty adjustable with external resistors for DTC pin
- Soft-start time adjustable with external capacitor for SS pin
- Oscillator Frequency: Adjustable frequency with resistors (210 kHz to 1400 kHz)

[Charge-pump]
- Adjustable output voltage with external resistors
- Sequence function: Charge-pump turns on after the main step-up converter voltage outputs. The positive charge-pump and the negative charge-pump turn-on sequence control is adjustable by setting delay time for each channel
- Oscillator Frequency: 1/4 of the main step-up DC/DC converter oscillator frequency

[Controller]
- Under Voltage Lock-Out (UVLO: selectable detector threshold from 1.8 V/2.2 V/2.8 V)
- Reference Voltage (VREF: Typ.1.2 V)
- Short Protection with timer latch function (adjustable delay time with external capacitor)
- Shutdown all the outputs if at least one of three outputs is shorted to the GND.
- Stand-by function by CE pin
- Package: Thin 24-pin package QFN0404-24B
R1294L
No. EA-368-180323

APPLICATIONS

- Power source for hand-held equipment
- Power source for LCD and CCD

SELECTION GUIDE

The UVLO threshold voltage is user-selectable.

<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>R1294L10xA-E2</td>
<td>QFN0404-24B</td>
<td>1,000 pcs</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

x: Specify the UVLO threshold voltage

1: 1.8 V
2: 2.2 V
3: 2.8 V
R1294L Block Diagram
PIN DESCRIPTIONS

* The tab on the bottom of the package enhances thermal performance and is electrically connected to GND (substrate level). It is recommended that the tab be connected to the ground plane on the board, or otherwise be left floating.

---

<table>
<thead>
<tr>
<th>Pin No.</th>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PGND</td>
<td>Power GND Pin</td>
</tr>
<tr>
<td>2</td>
<td>PGND</td>
<td>Power GND Pin</td>
</tr>
<tr>
<td>3</td>
<td>AGND</td>
<td>Analog GND Pin</td>
</tr>
<tr>
<td>4</td>
<td>VIN</td>
<td>Power Input Pin</td>
</tr>
<tr>
<td>5</td>
<td>VREF</td>
<td>Reference Voltage Output Pin</td>
</tr>
<tr>
<td>6</td>
<td>CE</td>
<td>Chip Enable Pin</td>
</tr>
<tr>
<td>7</td>
<td>VFB</td>
<td>Step-up DC/DC Feedback Pin</td>
</tr>
<tr>
<td>8</td>
<td>SS</td>
<td>Step-up DC/DC Soft-start Pin</td>
</tr>
<tr>
<td>9</td>
<td>TST</td>
<td>TEST Pin</td>
</tr>
<tr>
<td>10</td>
<td>DTC</td>
<td>Step-up DC/DC Maxduty Setting Pin</td>
</tr>
<tr>
<td>11</td>
<td>DELAY</td>
<td>Short Protection Delay Setting Pin</td>
</tr>
<tr>
<td>12</td>
<td>AMPOUT</td>
<td>Amplifier Output Pin For Phase Compensation</td>
</tr>
<tr>
<td>13</td>
<td>RT</td>
<td>Oscillator Frequency Setting Pin</td>
</tr>
<tr>
<td>14</td>
<td>CPNDLY</td>
<td>Negative Charge-pump Delay Setting Pin</td>
</tr>
<tr>
<td>15</td>
<td>CPNFBD</td>
<td>Negative Charge-pump Feedback Pin</td>
</tr>
<tr>
<td>16</td>
<td>CPDPDLY</td>
<td>Positive Charge-pump Delay Setting Pin</td>
</tr>
<tr>
<td>17</td>
<td>CPFFBD</td>
<td>Positive Charge-pump Feedback Pin</td>
</tr>
<tr>
<td>18</td>
<td>CPGND</td>
<td>Charge-pump GND Pin</td>
</tr>
<tr>
<td>19</td>
<td>CPN</td>
<td>Negative Charge-pump Driver Output Pin</td>
</tr>
<tr>
<td>20</td>
<td>CPVCC</td>
<td>Power Pin for Charge-pump</td>
</tr>
<tr>
<td>21</td>
<td>CPP</td>
<td>Positive Charge-pump Driver Output Pin</td>
</tr>
<tr>
<td>22</td>
<td>CPPSW</td>
<td>Output Control Pin For Positive Charge-pump</td>
</tr>
<tr>
<td>23</td>
<td>LX</td>
<td>Step-up DC/DC Driver Output Pin</td>
</tr>
<tr>
<td>24</td>
<td>LX</td>
<td>Step-up DC/DC Driver Output Pin</td>
</tr>
</tbody>
</table>

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R1294L(QFN0404-24B) Pin Configuration
## ABSOLUTE MAXIMUM RATINGS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Ratings</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIN</td>
<td>VIN pin voltage</td>
<td>6.5</td>
<td>V</td>
</tr>
<tr>
<td>VDTC</td>
<td>DTC pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VFB</td>
<td>VFB pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VSS</td>
<td>SS pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VDELAY</td>
<td>DELAY pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VAMP</td>
<td>AMPOUT pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VLX</td>
<td>LX pin voltage</td>
<td>−0.3 to 24</td>
<td>V</td>
</tr>
<tr>
<td>ILX</td>
<td>LX pin current</td>
<td>Internally limited</td>
<td>A</td>
</tr>
<tr>
<td>VREF</td>
<td>VREF pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VCPVCC</td>
<td>CPVCC pin voltage</td>
<td>−0.3 to 24</td>
<td>V</td>
</tr>
<tr>
<td>VCE</td>
<td>CE pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VRT</td>
<td>RT pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VCPPDLY</td>
<td>CPPDLY pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VCPNDLY</td>
<td>CPNDLY pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VPPF</td>
<td>CPPFB pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VNFB</td>
<td>CPNFB pin voltage</td>
<td>−0.3 to VIN + 0.3</td>
<td>V</td>
</tr>
<tr>
<td>VCPP</td>
<td>CPP pin voltage</td>
<td>−0.3 to 24</td>
<td>V</td>
</tr>
<tr>
<td>VCPN</td>
<td>CPN pin voltage</td>
<td>−0.3 to 24</td>
<td>V</td>
</tr>
<tr>
<td>VPSW</td>
<td>CPPSW pin voltage</td>
<td>−0.3 to 24</td>
<td>V</td>
</tr>
<tr>
<td>IPSW</td>
<td>CPPSW pin current-A</td>
<td>20</td>
<td>mA</td>
</tr>
<tr>
<td>PD</td>
<td>Power dissipation (1) (QFN0404-24B, JEDEC STD. 51.7)</td>
<td>3400</td>
<td>mW</td>
</tr>
<tr>
<td>Tj</td>
<td>Junction Temperature</td>
<td>−40 to 125</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>

### ABSOLUTE MAXIMUM RATINGS

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

---

(1) Refer to **POWER DISSIPATION** in the APPENDIX for detailed information.
**RECOMMENDED OPERATING CONDITIONS**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Rating</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{IN}$</td>
<td>Input voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R1294L101A</td>
<td>2.0 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>R1294L102A</td>
<td>2.5 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>R1294L103A</td>
<td>3.3 to 5.5</td>
<td>V</td>
</tr>
<tr>
<td>CPVCC</td>
<td>CPVCC operating voltage</td>
<td>6 to 20</td>
<td>V</td>
</tr>
<tr>
<td>Ta</td>
<td>Operating temperature</td>
<td>−40 to 95</td>
<td>°C</td>
</tr>
</tbody>
</table>

**RECOMMENDED OPERATING CONDITIONS**

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

VIN is set as shown below for every version, unless otherwise noted.
R1294L101A: VIN = 2.5 V
R1294L102A: VIN = 2.5 V
R1294L103A: VIN = 3.5 V

The specifications surrounded by [ ] are guaranteed by design engineering at −40°C ≤ Ta ≤ 95°C.

### R1294L Electrical Characters

<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>I_{IN}</td>
<td>V_{IN} Supply Current</td>
<td>V_{IN} = 5.5 V, RT = 24 kΩ</td>
<td>3.5</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{UVLO1}</td>
<td>UVLO Detect Voltage</td>
<td>V_{IN} Falling</td>
<td>R1294L101A</td>
<td>1.7</td>
<td>1.8</td>
<td>1.9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R1294L102A</td>
<td>2.05</td>
<td>2.2</td>
<td>2.35</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R1294L103A</td>
<td>2.6</td>
<td>2.8</td>
<td>3.0</td>
</tr>
<tr>
<td>V_{UVLO2}</td>
<td>UVLO Release Voltage</td>
<td>V_{IN} Rising</td>
<td>R1294L101A</td>
<td>V_{UVLO1} +0.09</td>
<td>2.0</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R1294L102A</td>
<td>V_{UVLO1} +0.15</td>
<td>2.5</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R1294L103A</td>
<td>V_{UVLO1} +0.22</td>
<td>3.2</td>
<td>V</td>
</tr>
<tr>
<td>V_{FB}</td>
<td>V_{FB} Voltage</td>
<td></td>
<td></td>
<td>0.985</td>
<td>1.0</td>
<td>1.015</td>
</tr>
<tr>
<td>ΔV_{FB}/ΔT</td>
<td>V_{FB} Voltage Temperature Coefficient</td>
<td>−40°C ≤ Ta ≤ 95°C</td>
<td></td>
<td>±150</td>
<td>ppm/°C</td>
<td></td>
</tr>
<tr>
<td>V_{FBL}</td>
<td>V_{FB} Fault Voltage</td>
<td></td>
<td></td>
<td>V_{FB}×0.85</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>I_{FB}</td>
<td>V_{FB} Input Current</td>
<td>V_{IN} = 5.5 V, V_{FB} = 0 V or 5.5 V</td>
<td></td>
<td>−0.1</td>
<td>0.1</td>
<td>µA</td>
</tr>
<tr>
<td>V_{DTC0}</td>
<td>Duty = 0% DTC Voltage</td>
<td>RT = 24 kΩ</td>
<td>0.27</td>
<td>0.37</td>
<td>0.47</td>
<td>V</td>
</tr>
<tr>
<td>V_{DTC20}</td>
<td>Duty = 20% DTC Voltage</td>
<td>RT = 24 kΩ</td>
<td></td>
<td>0.49</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>V_{DTC80}</td>
<td>Duty = 80% DTC Voltage</td>
<td>RT = 24 kΩ</td>
<td></td>
<td>0.91</td>
<td>V</td>
<td></td>
</tr>
<tr>
<td>Maxduty</td>
<td>Maximum Duty Limit</td>
<td>RT = 24 kΩ, V_{DTC} = V_{IN}</td>
<td>86</td>
<td>91</td>
<td>96</td>
<td>%</td>
</tr>
<tr>
<td>I_{AMP}</td>
<td>AMP &quot;H&quot; Output Current</td>
<td>V_{FB} = 0.9 V</td>
<td>R1294L101A/102A</td>
<td>1.6</td>
<td>3.2</td>
<td>5.8</td>
</tr>
<tr>
<td>I_{AMPL}</td>
<td>AMP &quot;L&quot; Output Current</td>
<td>V_{FB} = 1.1 V</td>
<td>R1294L103A</td>
<td>4.7</td>
<td>14.5</td>
<td>mA</td>
</tr>
<tr>
<td>R_{ON}</td>
<td>Switch ON Resistance</td>
<td></td>
<td></td>
<td>150</td>
<td>mΩ</td>
<td></td>
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<tr>
<td>I_{LXOFF}</td>
<td>Leakage Current</td>
<td>V_{IN} = 5.5 V, V_{LX} = 20 V</td>
<td></td>
<td>5</td>
<td>µA</td>
<td></td>
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<tr>
<td>I_{LIMDC}</td>
<td>Switch Limit Current</td>
<td></td>
<td></td>
<td>2.0</td>
<td>A</td>
<td></td>
</tr>
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</table>
VIN is set as shown below for every version, unless otherwise noted.

R1294L101A: VIN = 2.5 V
R1294L102A: VIN = 2.5 V
R1294L103A: VIN = 3.5 V

The specifications surrounded by **are** guaranteed by design engineering at −40°C ≤ Ta ≤ 95°C.

### R1294L Electrical Characters (Continued)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Conditions</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>RT = 110 kΩ</td>
<td></td>
<td>175</td>
<td>210</td>
<td>245</td>
<td>kHz</td>
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<tr>
<td></td>
<td></td>
<td>RT = 24 kΩ</td>
<td></td>
<td>736</td>
<td>800</td>
<td>864</td>
<td>kHz</td>
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<tr>
<td></td>
<td></td>
<td>RT = 12 kΩ</td>
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<td>1300</td>
<td>1400</td>
<td>1500</td>
<td>kHz</td>
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<tr>
<td></td>
<td>VREF Voltage</td>
<td></td>
<td></td>
<td>1.182</td>
<td>1.2</td>
<td>1.218</td>
<td>V</td>
</tr>
<tr>
<td>ΔVREF/ΔT Voltage Temperature Coefficient</td>
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<td></td>
<td></td>
<td>150</td>
<td>ppm/C</td>
<td></td>
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<tr>
<td>IOUT VREF Current</td>
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<td>2.0</td>
<td>mA</td>
<td></td>
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<tr>
<td>ΔVREF/ΔVIN VREF Line Regulation</td>
<td>R1294L101A VIN = 2.0 to 5.5 V</td>
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<td>5</td>
<td>10</td>
<td>10</td>
<td>mV</td>
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<tr>
<td></td>
<td>R1294L102A VIN = 2.5 to 5.5 V</td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>R1294L103A VIN = 3.3 to 5.5 V</td>
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<tr>
<td>ΔVREF/ΔIOUT VREF Load Regulation</td>
<td>IOUT = 0.1 mA to 2.0 mA</td>
<td></td>
<td></td>
<td>6</td>
<td>20</td>
<td>20</td>
<td>mV</td>
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<tr>
<td>I_LIM Short Current Limit</td>
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<td></td>
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<td>15</td>
<td>mA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I_{CPVCC} CPVCC Supply Current</td>
<td>CPVCC = 9 V, RT = 24 kΩ</td>
<td></td>
<td></td>
<td>500</td>
<td>µA</td>
<td></td>
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<tr>
<td>I_SS Soft-Start Current</td>
<td>CPVCC = 9 V</td>
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<td></td>
<td>2.5</td>
<td>5.0</td>
<td>7.5</td>
<td>µA</td>
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<tr>
<td>t_{SS} CPP Soft-Start Time</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>4.0</td>
<td>ms</td>
<td></td>
<td></td>
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<tr>
<td>t_{NSS} CPN Soft-Start Time</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>4.0</td>
<td>ms</td>
<td></td>
<td></td>
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<tr>
<td>I_{PDLY} CPPDLY Charge Current</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>2.5</td>
<td>5.0</td>
<td>7.5</td>
<td>µA</td>
</tr>
<tr>
<td>I_{NDLY} CPNDLY Charge Current</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>2.5</td>
<td>5.0</td>
<td>7.5</td>
<td>µA</td>
</tr>
<tr>
<td>V_{PDLY} CPPDLY Detector Threshold</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>0.95</td>
<td>1.00</td>
<td>1.05</td>
<td>V</td>
</tr>
<tr>
<td>V_{NDLY} CPNDLY Detector Threshold</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>0.95</td>
<td>1.00</td>
<td>1.05</td>
<td>V</td>
</tr>
<tr>
<td>V_{PFBL} CPPFB Fault Voltage</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>1.475</td>
<td>1.500</td>
<td>1.525</td>
<td>V</td>
</tr>
<tr>
<td>ΔV_{PFBL} ΔT CPPFB Voltage Temperature Coefficient</td>
<td>CPVCC = 9 V</td>
<td>~40°C ≤ Ta ≤ 95°C</td>
<td></td>
<td>150</td>
<td>ppm/C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V_{PFBL} CPNFB Voltage</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>−0.03</td>
<td>0.00</td>
<td>0.03</td>
<td>V</td>
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<tr>
<td>V_{PFBL} CPPFB Fault Voltage</td>
<td>CPVCC = 9 V</td>
<td></td>
<td></td>
<td>VP_{FB}×0.85</td>
<td></td>
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<td>V</td>
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</table>
VIN is set as shown below for every version, unless otherwise noted.

- R1294L101A: VIN = 2.5 V
- R1294L102A: VIN = 2.5 V
- R1294L103A: VIN = 3.5 V

The specifications surrounded by [ ] are guaranteed by design engineering at $-40^\circ C \leq T_a \leq 95^\circ C$

### R1294L Electrical Characters (Continued) (Ta = 25°C)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Item</th>
<th>Conditions</th>
<th>Min.</th>
<th>Typ.</th>
<th>Max.</th>
<th>Unit</th>
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<tr>
<td>VNFBL</td>
<td>CPNFB Fault Voltage</td>
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<td>RCPPH</td>
<td>CPP &quot;H&quot; ON Resistance</td>
<td>CPVCC = 9 V</td>
<td>5</td>
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<tr>
<td>RCPPL</td>
<td>CPP &quot;L&quot; ON Resistance</td>
<td>CPVCC = 9 V</td>
<td>10</td>
<td></td>
<td></td>
<td>Ω</td>
</tr>
<tr>
<td>RCPNH</td>
<td>CPN &quot;H&quot; ON Resistance</td>
<td>CPVCC = 9 V</td>
<td>5</td>
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<td></td>
<td>Ω</td>
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<tr>
<td>RCPNL</td>
<td>CPN &quot;L&quot; ON Resistance</td>
<td>CPVCC = 9 V</td>
<td>10</td>
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<td>Ω</td>
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<td>fREQCP</td>
<td>Charge-pump Frequency</td>
<td>CPVCC = 9 V</td>
<td>fREQ/4 kHz</td>
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<td>IDELAY1</td>
<td>DELAY Charge Current</td>
<td>CPVCC = 9 V</td>
<td>2.5</td>
<td>5.0</td>
<td>7.5</td>
<td>µA</td>
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<tr>
<td>IDELAY2</td>
<td>DELAY Discharge Current</td>
<td>CPVCC = 9 V</td>
<td>200</td>
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<td>µA</td>
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<td>VDELAY</td>
<td>DELAY Detector Threshold</td>
<td>CPVCC = 9 V</td>
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<td>1.05</td>
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<tr>
<td>VPSW</td>
<td>CPSSW &quot;L&quot; Output Voltage</td>
<td>CPVCC = 9 V, I = 1 mA</td>
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<td></td>
<td>V</td>
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<td>Istandby1</td>
<td>Standby Current</td>
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<td>0.1</td>
<td>5</td>
<td></td>
<td>µA</td>
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<td>Istandby2</td>
<td>CPVCC Standby Current</td>
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<td>5</td>
<td></td>
<td>µA</td>
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<td>VCEL</td>
<td>CE &quot;L&quot; Input Voltage</td>
<td>R1294L101A VIN = 2.0 V</td>
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<td>V</td>
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<tr>
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<td>R1294L102A VIN = 2.5 V</td>
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<td></td>
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<td>V</td>
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<td>R1294L103A VIN = 3.3 V</td>
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<td>V</td>
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<tr>
<td>VCEH</td>
<td>CE &quot;H&quot; Input Voltage</td>
<td>VIN = 5.5 V</td>
<td></td>
<td></td>
<td>1.5</td>
<td>V</td>
</tr>
</tbody>
</table>
R1294L
No. EA-368-180323

THEORY OF OPERATION

Overcurrent Protection

R1294L monitors the Nch-switch current of the step-up DCDC converter and limits the current. If Nch-switch current reaches the current limit, the R1294L immediately turns off Nch-switch. Nch-switch turns on every internal cycle, and the R1294L monitors Nch-switch current and turns off Nch-switch if Nch-switch current reaches the current limit again. By repeating this operation, the R1294L protects itself from the overcurrent.

Under Voltage Lock Out (UVLO)

If Vin pin voltage becomes equal to or lower than UVLO detector threshold, the R1294L immediately disables all the switching outputs (Lx, CPP, and CPN) as well as discharges the external capacitors on DTC pin and SS pin down to 0 V immediately, and the system will be reset.

Operation and Output Current of Step-up DC/DC Converter

< Typical Circuit >

< Current through L >

Discontinuous Mode

Continuous Mode
In PWM step-up DC/DC converter, there are two modes; the discontinuous mode and the continuous mode. These two modes depend upon the continuous characteristic of the inductor current.

While PWM step-up DC/DC converter is turned on, the voltage into the inductance L will be $V_{IN}$, and the additional current ($i_1$) can be calculated by the next formula.

$$\Delta i_1 = \frac{V_{IN} \times ton}{L}$$

In the circuit of the step-up DC/DC converter, during the off time of the switching, the power is supplied. In this case, the decrease of input current ($i_2$) can be calculated by the next formula:

$$\Delta i_2 = \frac{(V_{OUT} - V_{IN}) \times T_f}{L}$$

In the PWM switching method, the current of inductor becomes continuous when it is $T_f = T_{off}$. The operating of DC/DC converter becomes continuous mode. In the continuous mode, the variance of the ratio of current is equal ($\Delta i_1 = \Delta i_2$), therefore the DUTY in the continuous mode is calculated by the next formula.

$$\text{duty} (\%) = \frac{ton}{ton + T_{off}} = \frac{(V_{OUT} - V_{IN})}{V_{OUT}}$$

If the input power and the output power are equal, the mode becomes continuous when the $I_{OUT}$ value is larger than the next formula.

$$V_{IN}^2 \times \frac{ton}{(2 \times L \times V_{OUT})}$$

The average of the inductor current when $T_f = T_{off}$ is calculated by the next formula.

$$i_1 \text{ (Ave.)} = \frac{V_{IN} \times ton}{(2 \times L)}$$

The peak current ($I_{Lxmax}$) of the inductor in the continuous mode can be calculated by the next formula:

$$I_{Lxmax} = \frac{I_{OUT} \times V_{OUT}}{V_{IN} + V_{IN} \times \frac{ton}{(2 \times L)}}$$

As stated above, the value of the peak current becomes larger than the $I_{OUT}$ value, therefore note that the $I_{Lxmax}$ to determine the I/O condition and the components around the I/O.

The actual maximum output current is 50 to 80% of the above-mentioned. Especially, in case that the IL is large, or $V_{IN}$ is low, the loss of $V_{IN}$ will be the amount of the ON resistance of the switch. As for the $V_{OUT}$, it is necessary to consider the $V_F$ of the diode (approximately 0.3 V).

Note: The above-mentioned explanation is based on the calculations of the ideal case. The external components or the loss of LX switching are not included.
The timing chart above describes from the power on to the $V_{OUT1}$, $V_{OUT2}$, and $V_{OUT3}$ turn on and until they are stable.

By releasing from the standby mode, $V_{OUT1}$ begins the soft-start, and the output voltage rises gradually. After preset soft-start time passes, and the $V_{OUT1}$ reaches the preset output voltage, the charge to capacitors set to CPPDLY pin and CPNDLY pin will start. CPPDLY pin and CPNDLY pin voltage reach respectively to the CPPDLY detector threshold ($V_{PDLY}$) and CPNDLY detector threshold ($V_{NDLY}$), then the soft-start of the charge-pump will begin. The delay time for soft-start of charge pump ($t_{PDLY}$, $t_{NDLY}$) can be set respectively.

When each delay time has passed, the soft-start of the charge-pump begins. $V_{OUT2}$ and $V_{OUT3}$ gradually turn on, and when the soft-start time ends, $V_{OUT2}$ and $V_{OUT3}$ reach the preset output voltage.
**VOUT1 Soft-start Operation**

The timing chart above describes from the CE signal turns on until the soft-start of VOUT1 ends.

**(STEP1)**
SS voltage gradually increases with the internal IC’s constant current and the external capacitor. During the soft-start time, the amplifier’s reference input to the OP AMP becomes an equal voltage as SS, and it gradually increases. Since VOUT reaches to the input voltage just after the power on, the VFB voltage rises at the specific voltage determined by the resistance ratio of the input voltage and the feedback part. However, the switching does not begin since AMPOUT is “L”.

**(STEP2)**
When the SS becomes the specified voltage determined with the resistance ratio of the input voltage and the feedback part, the switching begins. In this case, the amplifier reference rises as well as SS, therefore VOUT rises to balance the amplifier reference and VFB. The DUTY in this case is determined by the three inputs PWM comparator, among the AMPOUT and DTC, the lowest voltage is selected.

**(STEP3)**
When the SS becomes 1 V, the soft-start ends. After that, the amplifier reference becomes the constant voltage (≈ 1 V), and the operation changes to the normal switching. At this time, the voltage of the AMPOUT becomes constant. The AMPOUT value is determined by the I/O voltage and the output current.
During the soft-start period, the soft-start time needs to be set shorter than the timer latch delay time due to the charging of DELAY pin. When the preset soft-start time finishes, the charging of DELAY pin stops and discharges to the GND.
APPLICATION INFORMATION

TYPICAL APPLICATION

R1294L10xA  Typical Application 1
### Recommended External Components

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L</td>
<td>NR4018T100M (for 210 kHz) / NR4018T4R7M (for 700 kHz) / NR4018T2R2M (for 1.4 MHz), Taiyo Yuden / CLF7045T-100M-D (for 210 kHz) / CLF6045NIT-2R2N-D (for 1.4 MHz), TDK</td>
</tr>
<tr>
<td>D1</td>
<td>CRS10I30A, TOSHIBA / CRS10, TOSHIBA</td>
</tr>
<tr>
<td>D2-D7</td>
<td>1SS374, TOSHIBA</td>
</tr>
<tr>
<td>Tr1</td>
<td>2SA1586, TOSHIBA</td>
</tr>
</tbody>
</table>
Precautions for Selecting External Components

How to Set the Step-up Converter Output Voltage

\[ V_{OUT1} = V_{FB} \times \frac{(R1 + R2)}{R2} \]

How to Set the Step-up Charge-pump Output Voltage

\[ V_{OUT2} = V_{PFB} \times \frac{(R3 + R4)}{R4} \]

In the case of Typical Application 1, the maximum output voltage can be described as the following formula.

\[ V_{OUT2} \text{(Max.)} = CPVCC \times 2 - V_F \times 2 \]

Set C15, D6 and D7 of diodes, and C16 (refer to the Typical Application 2) if the output voltage needs more than the range above. In this case, the maximum output voltage can be described as the following formula.

\[ V_{OUT2} \text{(Max.)} = CPVCC \times 3 - V_F \times 4 \]

The maximum load current of the boost charge pump is determined by Cfly (C13, C15), the oscillator frequency of charge pump (fREQCP), and CPP "L" On Resistance (RCPPL) as described in the following formula.

\[ I_{OUT2} \text{(Max.)} = C_{fly} \times \left(1 - \exp \left(\frac{-1}{2 \times C_{fly} \times R_{CPPL} \times f_{REQCP}}\right)\right) \times (CPVCC \times 2 - V_{OUT2} - V_F \times 2) \times f_{REQCP} \]

How to Set the Inverting Charge-pump Output Voltage

\[ V_{OUT3} = V_{NFB} \times (V_{REF} - V_{NFB}) \times \frac{R5}{R6} \]

The minimum output voltage can be set by the following formula.

\[ V_{OUT3} \text{(Min.)} = - (CPVCC - V_F \times 2) \]

The maximum load current of inverting charge pump is determined by Cfly (C14), the oscillator frequency of charge pump (fREQCP), and CPN "L" ON Resistance (RCPNL) as described in the following formula.

\[ I_{OUT3} \text{(Max.)} = C_{fly} \times \left(1 - \exp \left(\frac{-1}{2 \times C_{fly} \times R_{CPNL} \times f_{REQCP}}\right)\right) \times (CPVCC + V_{OUT3} - V_F \times 2) \times f_{REQCP} \]
How to set the Step-up DC/DC Converter's Phase Compensation (Refer to Typical Application)

In the DC/DC converter, with the load current and the external components (L and C) the phase may be delayed by 180 degrees. Due to this, the phase margin of system is lost and stability would be worse. Thus, it is necessary to proceed the phase, and keep a certain phase margin.

The phase compensation and the system gain can be set with using the resistor, R7 and capacitors, C7 and C8. The position and the setting values shown in the Typical Application are one of the examples.

Select R7 and C7, so that the cut-off frequency of this Zero point may become approximately the cutoff frequency of pole made by the external components (L and C). The following formula shows the pole made by the external components (L and C) and the “Zero” point.

\[
F_{\text{pole}} \approx \frac{1}{2\pi \sqrt{L \times C_1}}
\]

\[
F_{\text{zero}} \approx \frac{1}{2\pi R_7 \times C_7}
\]

For example, when \( L = 4.7 \, \mu H \) and \( C_{\text{OUT}} (C_1) = 20 \, \mu F \), the cut-off frequency of the pole is approximately 16 kHz. Then set the cut-off frequency of the Zero point around 16 kHz to 1.6 kHz.

The gain can be set with the ratio of the resistance of R7 and combined resistance of R1 and R2 (\( RT: RT = R_1 \times R_2 / (R_1 + R_2) \)). If R7 is larger than the combined resistance (RT), the gain becomes high. If the gain is too high, the characteristics of response will be improved but the operating stability will be worse. Set R7 with an appropriate value.

Due to the R1 setting in the gain setting, another Zero point is set by R1 and C8.Set this cut-off frequency of Zero point at around the cut-off frequency by pole made by the external components (L and C). This Zero point is shown in the formula below.

\[
F_{\text{zero}} \approx \frac{1}{2\pi R_1 \times C_8}
\]

Noise Reduction of the Feedback Voltage (Refer to Typical Application)

When the system noise is large, the output noise may be on to the feedback loop, and the operation may become unstable. In this case, set the value of the resistance R1 to R6 low and make the noise into the feedback reduction. It is possible to reduce the noise to the \( V_{FB} \) pin by connecting the resistance in the range from 1 k\( \Omega \) to 5 k\( \Omega \) around as R8.

Input Voltage

The range of \( V_{IN} \) voltage must be between 2.0 V and 5.5 V. For CPVCC pin, it is possible to use input \( V_{\text{OUT1}} \) or input another voltage of 6 V to 20 V to CPVCC as a power supply. In that case, set a capacitor of 1.0 \( \mu F \) or more as C16 between GND and CPVCC pin.
How to Set the Oscillator Frequency

Set a resistor (R12) between GND and RT pin. The oscillator frequency of the step-up converter (fREQ) can be set according to the next formula. This value depends upon the resistance value.

\[ f_{\text{REQ}} = \frac{2.7 \times 10^{10}}{[0.8542 \times R12 \times (0.66 + \sqrt{0.66^2 + 12643 / R12})]} \]

Set the frequency between 210 kHz and 1400 kHz. The oscillator frequency of the charge-pump is one fourth of the oscillator frequency of the main step-up DC/DC converter.

How to Set the Soft-start of Step-up Converter (Refer to the Timing Chart)

The soft-start of the step-up converter operates when \( V_{\text{IN}} \) is equal to or more than the UVLO release voltage, or when CE signal is “H”. External capacitor of SS pin (C9) is charged with the soft-start charge current (I_{SS}). Then the voltage of SS pin is input to the error amplifier as the reference voltage. When the voltage of SS pin reaches to the reference voltage (Typ.1.0 V) in the normal state, the reference voltage of the error amplifier stabilized at 1.0 V, and it changes to the normal state. The soft-start of step-up converter time (t_{SS}) is set by the external capacitor (C9) for the SS pin in the next formula.

\[ t_{\text{SS}} = C9 \times \frac{V_{\text{FB}}}{I_{\text{SS}}} \]

How to Set the Start-up Sequence (Refer to the Timing Chart)

When the output voltage of step-up converter is up to 85% of a set value, and the soft-start is finished, the external capacitors (C10 and C11) of the CPPDLY pin and the CPNDLY pin are charged by the CPPDLY charge current (I_{POLY}) and the CPNDLY charge current (I_{NDLY}). When the voltage of the CPPDLY pin and the CPNDLY pin charged up to the CPPDLY detector threshold (V_{PDLY}) and the CPNDLY detector threshold (V_{NDLY}), then the soft-start of the positive charge-pump and the negative charge-pump is operated respectively. After the step-up converter is operated, the delay time (t_{POLY} and t_{NDLY}) until the soft-start of charge-pump is set by the external capacitors (C10 and C11) of the CPPDLY pin and the CPNDLY pin. The delay time is set by the following formula.

The delay time until the soft-start of positive charge-pump operates: \( t_{\text{POLY}} = C10 \times \frac{V_{\text{PDLY}}}{I_{\text{POLY}}} \)

The delay time until the soft-start of negative charge-pump operates: \( t_{\text{NDLY}} = C11 \times \frac{V_{\text{NDLY}}}{I_{\text{NDLY}}} \)

Thus, after the main step-up DC/DC converter starts operating, the positive charge-pump and the negative charge-pump can be operated by the arbitrary order.
Soft-start of the Charge-pump (Refer to Typical Application and Timing Chart)

When the soft-start of boost charge-pump operates, the output of CPPSW changes from “H” to “L”. Setting the PNP-Tr1 (Tr1) keeps VOUT2 = 0 V until the positive charge-pump is started. If it is not required to keep VOUT2 = 0 V, then PNP-Tr1 is unnecessary. In this case, VOUT2 outputs approximately the same voltage as VOUT1. Arrange the resistor (R11) between the CPPSW pin and the base of PNP-Tr1 (Tr1). The maximum current of Tr1 can be set by the R11 value. This value can be calculated in the next formula.

\[ I_{\text{max}} = h_{\text{FE}} \times (V_{\text{OUT1}} - V_{\text{BE}}) / R_{11} \]

[hFE is DC current gain of Tr1 and VBE is base emitter voltage of Tr1.]

Select the appropriate value for R11 since the efficiency gets worse if the value is too small (refer to the Short Current Protection section. PNP-Tr1 has some effect on the operation of the short-current protection).

When the positive charge-pump starts, the reference voltage of the error amplifier starts from 0 V, turns on to the reference voltage (= 1.5 V) and becomes stable. Thus, the output voltage of VOUT2 can turn on by set output voltage within the time period of soft-start time.

In the initial state before starting the positive charge-pump, CPP pin generates High- level output voltage from the voltage supplied of CPVCC pin. Minim voltage of VOUT2 may occur when the “High” output voltage of CPP pin turns on by a rising of CPVCC voltage. The rising voltage level is susceptible to the rising width of CPVCC-VIN under the normal condition), the capacitor C13 for CPP pin, and the capacitor C2 for VOUT2. Since estimated calculation is (CPVCC-VIN)×C13/(C2+C13), maximum voltage is about 0.79V for VIN=3.3V, CPVCC=12V, C13=0.1µF, and C2=1µF

Before the soft-start of the negative charge-pump starts, the reference voltage of the error amplifier rises to VREF voltage (= 1.2 V) and falls down to 0 V in the soft start time fixed internally by the soft-start operation. Thus, the output voltage of VOUT3 can turn on by set output volatge within the time period of soft-start time.

How to set the Short Current Protection and Timer Latch Delay Time

If any output among the step-up converter output, the positive charge-pump output or the negative charge-pump output falls, the R1294L detects the short circuit. If this short circuit condition stays for a certain time, the latch-type protection circuit shuts down all the switching outputs (Lx, CPP, CPN) and outputs “H” through the CPPSW pin. Even if the switching stopped, the current path from CPVCC to VOUT2 is remained. If PNP-Tr is set on the CPPSW pin, the current path to VOUT2 is cut off after shutdown.

The detect voltages of VFB, CPPFB and CPNFB are:
- 85% of predetermined VFB voltage for VFB
- 85% of predetermined CPPFB voltage for CPPFB
- + 0.15 V for CPNFB

The latch timer delay is set by an external capacitor (C12) of the DELAY pin. This delay time can be calculated by the next formula.

\[ t_{\text{DLY}} = C_{12} \times V_{\text{DLY}} / I_{\text{DLY}} \]

To release the latch state, set VIN voltage below UVLO detector threshold and restart, or Set the CE pin “L” once and change the CE pin to “H” level.
How to set the Maxduty Limit
The value of maxduty can be set by the input voltage to DTC pin. Set the voltage in which the $V_{REF}$ output divided with the resistors R9 and R10. If the voltage of DTC pin increases more than the limit value, the lower value between the set value and the internally fixed value is selected and in valid.

TEST Pin
In terms of TEST pin, connect the GND level or remain it open.
Other Notes

• Use a 1.0 μF or higher capacitor (C4) in between GND and V IN pin. Connect the capacitor as close as possible to the IC. If the noise level is large, use the 4.7 μF or higher capacitor is recommended.

• Use a 1.0 μF or higher capacitor (C1, C2, and C3) in between GND and each V OUT (VOUT1, VOUT2, and VOUT3). The recommended capacitance is C1 = 4.7 μF to 22 μF, C2 = C3 = 1 μF to 2.2 μF (refer to the Typical Application).

• Use a 0.1 μF to 1 μF or higher capacitance (C6) in between VREF and GND.

• To connect the GND of the capacitors (C9, C10, C11, and C12) for setting the delay time as short as possible to the GND of the IC.

• Selection of the diodes and inductors and capacitors should be considered. When Nch-switch turns on, the high voltage of spike by an inductor might be generated. Thus, using more than twice of the set output voltage for the voltage tolerance of the capacitor connecting to V OUT is recommended. The diode and inductors should not exceed the rated value of the voltage, the current and the power.

• Select the diode with low forward voltage such as a Schottky barrier diode. The small reverse current and the fast switching speed type is desirable. Especially, the characteristics of diode (D1) influence the efficiency and the stability of the system.
TYPICAL CHARACTERISTICS

Typical Characteristics are intended to be used as reference data, they are not guaranteed.

1) \( V_{OUT} \) (DCDC)

1-1) Output Voltage vs. Output Current

\[ f_{REQ} = 210 \text{kHz}, \, V_{OUT} = 8.0 \text{V} \]

\[ f_{REQ} = 1400 \text{kHz}, \, V_{OUT} = 8.0 \text{V} \]

\[ f_{REQ} = 700 \text{kHz}, \, V_{OUT} = 12.0 \text{V} \]

\[ f_{REQ} = 1400 \text{kHz}, \, V_{OUT} = 12.0 \text{V} \]
1-2) Efficiency vs. Output Current

1) Efficiency vs. Output Current

- For $f_{REQ} = 210\, \text{kHz}$, $V_{OUT} = 18.0\, \text{V}$
- For $f_{REQ} = 700\, \text{kHz}$, $V_{OUT} = 18.0\, \text{V}$
- For $f_{REQ} = 1400\, \text{kHz}$, $V_{OUT} = 18.0\, \text{V}$

- Efficiency [%] vs. $I_{OUT1}$ [mA]

2) Efficiency vs. Output Current

- For $f_{REQ} = 210\, \text{kHz}$, $V_{OUT} = 8.0\, \text{V}$
- For $f_{REQ} = 700\, \text{kHz}$, $V_{OUT} = 8.0\, \text{V}$

- Efficiency [%] vs. $I_{OUT1}$ [mA]
$f_{REQ} = 1400\text{kHz}, V_{OUT} = 8.0\text{V}$

$V_{IN} = 2.5\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 3.3\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 5.0\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 2.5\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 3.3\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 5.0\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 2.5\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 3.3\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 5.0\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 2.5\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 3.3\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 5.0\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 2.5\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 3.3\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 5.0\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 2.5\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 3.3\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 5.0\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 2.5\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 3.3\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 5.0\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 2.5\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 3.3\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]

$V_{IN} = 5.0\text{V}$, Efficiency [%] vs. $I_{OUT1}$ [mA]
2) $V_{OUT2}$ (Step-Up Charge-pump part)
2-1) Output Voltage vs. Output Current

- $f_{REQ} = 1400\text{kHz}, V_{OUT} = 18.0\text{V}$

- $f_{REQ} = 700\text{kHz}, CPVCC = 8.0\text{V}, V_{OUT} = 12.0\text{V}$

- $f_{REQ} = 700\text{kHz}, CPVCC = 8.0\text{V}, V_{OUT} = 16.0\text{V}$

- $f_{REQ} = 1400\text{kHz}, CPVCC = 8.0\text{V}, V_{OUT} = 12.0\text{V}$

- $f_{REQ} = 1400\text{kHz}, CPVCC = 8.0\text{V}, V_{OUT} = 16.0\text{V}$
3) $V_{OUT3}$ (Invert Charge-pump part)
3-1) Output Voltage vs. Output Current

- $f_{REQ} = 700\,\text{kHz}$, $CPVCC = 12.0\,\text{V}$, $V_{OUT} = 18.0\,\text{V}$
- $f_{REQ} = 1400\,\text{kHz}$, $CPVCC = 12.0\,\text{V}$, $V_{OUT} = 18.0\,\text{V}$
- $f_{REQ} = 700\,\text{kHz}$, $CPVCC = 12.0\,\text{V}$, $V_{OUT} = 24.0\,\text{V}$
- $f_{REQ} = 1400\,\text{kHz}$, $CPVCC = 12.0\,\text{V}$, $V_{OUT} = 24.0\,\text{V}$

- $f_{REQ} = 700\,\text{kHz}$, $CPVCC = 8.0\,\text{V}$, $V_{OUT} = -6.0\,\text{V}$
- $f_{REQ} = 1400\,\text{kHz}$, $CPVCC = 8.0\,\text{V}$, $V_{OUT} = -6.0\,\text{V}$
f_{REQ} = 700kHz, CPVCC=12.0V, V_{OUT}=-6.0V

f_{REQ} = 1400kHz, CPVCC=12.0V, V_{OUT}=-6.0V

4) VFB Voltage vs. Input Voltage

5) Oscillator Frequency vs. Input Voltage

Ta=25°C

f_{REQ} = 700kHz, Ta=25°C

f_{REQ} = 1400kHz, Ta=25°C
6) Supply Current vs. Input Voltage

\[ f_{\text{REQ}} = 210\,\text{kHz}, \quad T_a=25^\circ\text{C} \]

\[ V_{\text{IN}} (\text{V}) \]

\[ 0 \quad 200 \quad 400 \quad 600 \quad 800 \]

\[ 1 \quad 2 \quad 3 \quad 4 \quad 5 \]

\[ \text{Supply Current (uA)} \]

\[ f_{\text{REQ}} = 700\,\text{kHz}, \quad T_a=25^\circ\text{C} \]

\[ V_{\text{IN}} (\text{V}) \]

\[ 0 \quad 200 \quad 400 \quad 600 \quad 800 \]

\[ 1 \quad 2 \quad 3 \quad 4 \quad 5 \]

\[ \text{Supply Current (uA)} \]

7) Maxduty vs. Input Voltage

\[ f_{\text{REQ}} = 1400\,\text{kHz}, \quad T_a=25^\circ\text{C} \]

\[ V_{\text{IN}} (\text{V}) \]

\[ 0 \quad 200 \quad 400 \quad 600 \quad 800 \]

\[ 1 \quad 2 \quad 3 \quad 4 \quad 5 \]

\[ \text{Supply Current (uA)} \]

8) VIN Supply Current vs. Temperature

\[ V_{\text{IN}}=5.5\,\text{V}, \quad T_a=25^\circ\text{C} \]

\[ I_{\text{VIN}} (\text{mA}) \]

\[ 2 \quad 3 \quad 4 \quad 5 \]

\[ -40 \quad -15 \quad 10 \quad 35 \quad 60 \quad 85 \]

\[ T_a \,^\circ\text{C} \]

9) CP Supply Current vs. Temperature

\[ V_{\text{IN}}=5.5\,\text{V}, \quad \text{CPVCC}=9.0\,\text{V} \]

\[ I_{\text{CPC}} (\text{µA}) \]

\[ 0 \quad 200 \quad 400 \quad 600 \quad 800 \]

\[ -40 \quad -15 \quad 10 \quad 35 \quad 60 \quad 85 \]

\[ T_a \,^\circ\text{C} \]
10) UVLO Detect Voltage vs. Temperature

11) UVLO Release Voltage vs. Temperature
12) VFB Voltage vs. Temperature

13) Maxduty vs. Temperature

14) AMP"H"Output Current vs. Temperature

15) AMP"L"Output Current vs. Temperature

16) Switch ON Resistance vs. Temperature

17) Switch Leakage Current vs. Temperature
18) Switch Limit Current vs. Temperature

19) Oscillator Frequency vs. Temperature

20) VREF Voltage vs. Temperature

21) Terminal SS charge current vs. Temperature
22) CPP Soft-Start vs. Temperature

23) CPN Soft-Start vs. Temperature

24) CPPDLY Charge Current vs. Temperature

25) CPNDLY Charge Current vs. Temperature

26) CPPDLY Detector Threshold vs. Temperature

27) CPNDLY Detector Threshold vs. Temperature
28) CPPFB Voltage vs. Temperature

![CPPFB Voltage vs. Temperature Graph]

29) CPNFB Voltage vs. Temperature

![CPNFB Voltage vs. Temperature Graph]

30) CPP”H”ON Resistance vs. Temperature

![CPP”H”ON Resistance vs. Temperature Graph]

31) CPP”L”ON Resistance vs. Temperature

![CPP”L”ON Resistance vs. Temperature Graph]

32) CPN”H”ON Resistance vs. Temperature

![CPN”H”ON Resistance vs. Temperature Graph]

33) CPN”L”ON Resistance vs. Temperature

![CPN”L”ON Resistance vs. Temperature Graph]
34) Charge-pump Frequency vs. Temperature

35) DELAY Charge Current vs. Temperature

36) DELAY Discharge Current vs. Temperature

37) DELAY Detector Threshold vs. Temperature

38) CPPSW "L" Output Voltage vs. Temperature
39) Standby Current vs. Temperature

![Graph showing Standby Current vs. Temperature](image)

40) CE "L" Input Current vs. Temperature

![Graph showing CE "L" Input Current vs. Temperature](image)

41) CE "H" Input Current vs. Temperature

![Graph showing CE "H" Input Current vs. Temperature](image)
42) Road Transient Response

R1294L102A

$V_{IN}=3.3V$, $V_{OUT}=8V$, $I_{OUT}=1mA - 100mA$, $f_{REQ}=210kHz$

- **L** 10uH
- **C1** 20uF
- **R1** 70kΩ
- **R2** 10kΩ
- **C7** 4700pF
- **R7** 10kΩ
- **C8** 220pF
- **R8** 1kΩ

$V_{IN}=3.3V$, $V_{OUT}=12V$, $I_{OUT}=1mA - 100mA$, $f_{REQ}=210kHz$

- **L** 10uH
- **C1** 20uF
- **R1** 110kΩ
- **R2** 10kΩ
- **C7** 4700pF
- **R7** 10kΩ
- **C8** 220pF
- **R8** 1kΩ

$V_{IN}=3.3V$, $V_{OUT}=16V$, $I_{OUT}=1mA - 100mA$, $f_{REQ}=210kHz$

- **L** 10uH
- **C1** 20uF
- **R1** 150kΩ
- **R2** 10kΩ
- **C7** 4700pF
- **R7** 10kΩ
- **C8** 220pF
- **R8** 1kΩ
R1294L102A

$V_{in} = 3.3V$, $V_{out} = 8V$, $I_{out} = 1mA - 100mA$, $f_{req} = 800kHz$

$L$ | $4.7\mu H$
---|---
$C1$ | $20\mu F$
$R1$ | $70k\Omega$
$R2$ | $10k\Omega$
$C7$ | $4700pF$
$R7$ | $10k\Omega$
$C8$ | $100pF$
$R8$ | $1k\Omega$

---

$V_{in} = 3.3V$, $V_{out} = 12V$, $I_{out} = 1mA - 100mA$, $f_{req} = 800kHz$

$L$ | $4.7\mu H$
---|---
$C1$ | $10\mu F$
$R1$ | $110k\Omega$
$R2$ | $10k\Omega$
$C7$ | $4700pF$
$R7$ | $10k\Omega$
$C8$ | $100pF$
$R8$ | $1k\Omega$

---

$V_{in} = 3.3V$, $V_{out} = 16V$, $I_{out} = 1mA - 100mA$, $f_{req} = 800kHz$

$L$ | $4.7\mu H$
---|---
$C1$ | $10\mu F$
$R1$ | $150k\Omega$
$R2$ | $10k\Omega$
$C7$ | $4700pF$
$R7$ | $10k\Omega$
$C8$ | $100pF$
$R8$ | $1k\Omega$
R1294L102A
$V_{IN}=3.3\,V$, $V_{OUT}=8\,V$, $I_{OUT}=1\,mA$ - $100\,mA$, $f_{REQ}=1400\,kHz$

Time (ms)

$V_{IN}=3.3\,V$, $V_{OUT}=12\,V$, $I_{OUT}=1\,mA$ - $100\,mA$, $f_{REQ}=1400\,kHz$

Time (ms)

$V_{IN}=3.3\,V$, $V_{OUT}=16\,V$, $I_{OUT}=1\,mA$ - $100\,mA$, $f_{REQ}=1400\,kHz$

Time (ms)

<table>
<thead>
<tr>
<th>L</th>
<th>2.2uH</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>20uF</td>
</tr>
<tr>
<td>R1</td>
<td>70kΩ</td>
</tr>
<tr>
<td>R2</td>
<td>10kΩ</td>
</tr>
<tr>
<td>C7</td>
<td>2200pF</td>
</tr>
<tr>
<td>R7</td>
<td>10kΩ</td>
</tr>
<tr>
<td>C8</td>
<td>47pF</td>
</tr>
<tr>
<td>R8</td>
<td>1kΩ</td>
</tr>
</tbody>
</table>
43) CE Switch Response

R1294L102A

V_IN=3.3V
V_OUT1=8V/20mA, V_OUT2=12V/2mA, V_OUT3=-6V/2mA

R1294L102A

V_IN=3.3V
V_OUT1=12V/20mA, V_OUT2=18V/2mA, V_OUT3=-6V/2mA

R1294L102A

V_IN=3.3V
V_OUT1=18V/20mA, V_OUT2=24V/2mA, V_OUT3=-8V/2mA
The power dissipation of the package is dependent on PCB material, layout, and environmental conditions. The following measurement conditions are based on JEDEC STD. 51-7.

**Measurement Conditions**

<table>
<thead>
<tr>
<th>Item</th>
<th>Measurement Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environment</td>
<td>Mounting on Board (Wind Velocity = 0 m/s)</td>
</tr>
<tr>
<td>Board Material</td>
<td>Glass Cloth Epoxy Plastic (Four-Layer Board)</td>
</tr>
<tr>
<td>Board Dimensions</td>
<td>76.2 mm × 114.3 mm × 0.8 mm</td>
</tr>
<tr>
<td>Copper Ratio</td>
<td>Outer Layer (First Layer): Less than 95% of 50 mm Square</td>
</tr>
<tr>
<td></td>
<td>Inner Layers (Second and Third Layers): Approx. 100% of 50 mm Square</td>
</tr>
<tr>
<td></td>
<td>Outer Layer (Fourth Layer): Approx. 100% of 50 mm Square</td>
</tr>
<tr>
<td>Through-holes</td>
<td>φ 0.3 mm × 45 pcs</td>
</tr>
</tbody>
</table>

**Measurement Result**

<table>
<thead>
<tr>
<th>Item</th>
<th>Measurement Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Dissipation</td>
<td>3400 mW</td>
</tr>
<tr>
<td>Thermal Resistance (θja)</td>
<td>θja = 29°C/W</td>
</tr>
<tr>
<td>Thermal Characterization Parameter (ψjt)</td>
<td>ψjt = 10°C/W</td>
</tr>
</tbody>
</table>

θja: Junction-to-Ambient Thermal Resistance
ψjt: Junction-to-Top Thermal Characterization Parameter

![Power Dissipation vs. Ambient Temperature](image1.png)

![Measurement Board Pattern](image2.png)
* The tab on the bottom of the package enhances thermal performance and is electrically connected to GND (substrate level). The tab is recommended to connect to the ground plane on the board. Otherwise it may be left floating.

**HSOP-18 Package Dimensions**
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