Description
The FP6791 is a CMOS step-up switching controller incorporates a reference voltage circuit, an oscillator, an error amplifier, a PWM controller, an under voltage lockout circuit (UVLO) and a timer latch short-circuit protection circuit.

The switching frequency can be controlled by the resistor connected to the ROSC pin and the maximum duty ratio can be controlled by the resistor connected to the RDUTY pin.

In addition, the FP6791 provides adjustable short-circuit protection delay time with an external capacitor connected to the CSP pin. If the maximum duty condition continues because of short-circuiting, the capacitor externally connected to the CSP pin is charged, and oscillation stops after a specific time. This condition is cleared by re-application of power. This controller IC allows various settings and employs a small package, making it very easy to use.

Features
- Programmed Switching Frequency
- Programmed Maximum Duty Ratio
- Reference Voltage: 1.0V ±1.5%
- UVLO (Under-Voltage Lockout) Function:
  - Detection Voltage 2.2V
  - Hysteresis Width 0.3V
- Timer Latch Short-Circuit Protection Circuit: Delay Time Set by an External Capacitor.
- Internal Soft-Start Function
- External Compensation Network
- Small Package: 8-pin TSSOP
- RoHS Compliant

Applications
- LCD Panel
- Portable Equipments

Pin Assignment
TS Package (TSSOP-8)

![Pin Assignment Diagram]

Figure 1. Pin Assignment of FP6791

Ordering Information
FP6791
TR: Tape / Reel
P: Green
G: Green
Package Type
TS: TSSOP-8
Typical Application Circuit

Figure 2. Typical Application Circuit of FP6791

External Parts List:

<table>
<thead>
<tr>
<th>Element Name</th>
<th>Symbol</th>
<th>Application1: (V_{in}=5V, V_{out}=12V,) Frequency~700kHz</th>
<th>Application2: (V_{in}=3.3V, V_{out}=10.5V,) Frequency~1.1MHz</th>
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<tbody>
<tr>
<td>Inductor</td>
<td>L1</td>
<td>4.7μH, TDK</td>
<td>10μH, TDK</td>
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<tr>
<td>Diode</td>
<td>D1</td>
<td>Schottky Diode</td>
<td>Schottky Diode</td>
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<tr>
<td>Output Capacitor</td>
<td>C_{OUT}</td>
<td>40μF</td>
<td>10μF</td>
</tr>
<tr>
<td>Transistor</td>
<td>M1</td>
<td>Power MOS</td>
<td>Power MOS</td>
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<tr>
<td>Oscillation Frequency Setting Resistor</td>
<td>R_{OSC}</td>
<td>180kΩ±1% resistor</td>
<td>120kΩ±1% resistor</td>
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<tr>
<td>Maximum Duty Ratio Setting Resistor</td>
<td>R_{DUTY}</td>
<td>220kΩ±1% resistor</td>
<td>110kΩ±1% resistor</td>
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<td>Short-Circuit Protection Delay Setting Capacitor</td>
<td>C_{DP}</td>
<td>0.1μF ceramic capacitor</td>
<td>0.1μF ceramic capacitor</td>
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<tr>
<td>Output Voltage Setting Resistor1</td>
<td>R_{FB1}</td>
<td>8.2kΩ±1% resistor</td>
<td>6.8kΩ±1% resistor</td>
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<td>Output Voltage Setting Resistor2</td>
<td>R_{FB2}</td>
<td>750Ω±1% resistor</td>
<td>715Ω±1% resistor</td>
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<tr>
<td>FB Pin Capacitor</td>
<td>C_{FB}</td>
<td>2.2nF ceramic capacitor</td>
<td>1nF ceramic capacitor</td>
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<tr>
<td>Phase Compensation Resistor</td>
<td>RZ</td>
<td>56kΩ±1% resistor</td>
<td>100kΩ±1% resistor</td>
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<td>Phase Compensation Capacitor</td>
<td>CZ</td>
<td>10μF ceramic capacitor</td>
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<tr>
<td>Input Capacitor</td>
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<td>10μF ceramic capacitor</td>
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Functional Pin Description

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Function</th>
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<tbody>
<tr>
<td>CC</td>
<td>Error amplifier circuit output and phase compensation pin</td>
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<tr>
<td>FB</td>
<td>Output voltage feedback pin</td>
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<tr>
<td>CSP</td>
<td>Short-circuit protection delay time setting pin</td>
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<tr>
<td>VIN</td>
<td>Power supply input pin</td>
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<tr>
<td>EXT</td>
<td>External transistor connection pin</td>
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<td>VSS</td>
<td>GND pin</td>
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<td>ROSC</td>
<td>Oscillation frequency setting resistor connection pin</td>
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<td>RDUTY</td>
<td>Maximum duty setting resistor connection pin</td>
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Block Diagram

![Figure 3. Block Diagram of FP6791](image-url)
Absolute Maximum Ratings

- Supply Voltage (VIN) -0.3V to +6.5V
- FB pin voltage (VFB) -0.3V to +6.5V
- EXT pin voltage (VEXT) -0.3V to +6.5V
- CSP pin voltage (VCSP) -0.3V to +6.5V
- CC pin voltage (VCC) -0.3V to +6.5V
- CC pin current (ICC) ±10mA
- ROSC pin voltage (VROSC) -0.3V to +6.5V
- ROSC pin current (IROSC) ±10mA
- RDUTY pin voltage (VRDUTY) -0.3V to +6.5V
- RDUTY pin current (IRDUTY) ±10mA
- Storage temperature (TSTG) -40 to +125 ℃
- Power dissipation (TA=+25°C), TSSOP-8 +560mW
- Package Thermal Resistance, TSSOP-8 (θJA) 180°C/W
- Junction Temperature +150°C
- Storage Temperature Range -65°C to +150°C
- Lead Temperature (Soldering, 10s) +260°C

Note1: Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device.

Recommended Operating Conditions

- Supply Voltage (VIN) +2.6V to +6V
- Operation Temperature Range (TOPR) -40°C to +85°C
**Electrical Characteristics**

*V<sub>IN</sub>+5V, T<sub>A</sub>=25ºC, unless otherwise specified.*

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Conditions</th>
<th>Min</th>
<th>Typ</th>
<th>Max</th>
<th>Unit</th>
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<td>Current Consumption (V&lt;sub&gt;IN&lt;/sub&gt;=3.3V)</td>
<td>I&lt;sub&gt;INT&lt;/sub&gt;</td>
<td>Fosc = 1.1MHz : V&lt;sub&gt;FB&lt;/sub&gt; = 0.95V</td>
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<td>700</td>
<td>900</td>
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<td>EXT Pin Output Current (V&lt;sub&gt;IN&lt;/sub&gt;=3.3V)</td>
<td>I&lt;sub&gt;EXT&lt;/sub&gt;</td>
<td>V&lt;sub&gt;EXT&lt;/sub&gt;=V&lt;sub&gt;IN&lt;/sub&gt; - 0.4V</td>
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<td>Oscillation Frequency</td>
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<td>R&lt;sub&gt;OSC&lt;/sub&gt;=120kΩ (Note3)</td>
<td>1.02</td>
<td>1.133</td>
<td>1.246</td>
<td>MHz</td>
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<tr>
<td>Oscillation Frequency Temperature Coefficient (Note5)</td>
<td>∆F&lt;sub&gt;OSC&lt;/sub&gt;/∆T&lt;sub&gt;a&lt;/sub&gt;</td>
<td>T&lt;sub&gt;a&lt;/sub&gt; = -40 ºC to +85 ºC</td>
<td>Fosc = 1.1MHz</td>
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<td>ppm/ºC</td>
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<td>Short-circuit protection delay time</td>
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<td>C&lt;sub&gt;SP&lt;/sub&gt;=0.1μF</td>
<td>33</td>
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<td>ms</td>
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<td>uA</td>
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<td>V&lt;sub&gt;FB&lt;/sub&gt;=0V</td>
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<td></td>
<td>uA</td>
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<td>Timer Latch Reset Voltage</td>
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<td>0.7</td>
<td>1</td>
<td>1.3</td>
<td>V</td>
</tr>
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</table>

**Note2:** Specifications are production tested at T<sub>a</sub>=25ºC. Specifications over the -40ºC to 85ºC operating temperature range are guaranteed by design.

**Note3:** The recommend R<sub>OSC</sub> value for setting oscillation frequency is ranging from 100kΩ to 300kΩ (F<sub>OSC</sub> = 500kHz to 1.3MHz). The oscillation frequency is in the range of typical values when an ideal R<sub>OSC</sub> is connected, so the fluctuation of the IC (±10%) must be considered.

**Note4:** The recommended R<sub>DUTY</sub>/R<sub>OSC</sub> ratio for setting the maximum duty is ranging from 0.5 to 3.2 (Max. Duty = 55% to 88.5%). The maximum duty is in the range of typical value when an ideal R<sub>DUTY</sub> is connected, so the fluctuation of the IC (±5%) must be considered.

**Note5:** Guarantee by design.
Typical Performance Curves

Figure 4. Efficiency vs. Output Current

Figure 5. Output Voltage vs. Output Current

Figure 6. Frequency vs. Input Voltage

Figure 7. Frequency vs. Junction Temperature

Figure 8. UVLO Low Level vs. Junction Temperature

Figure 9. UVLO High Level vs. Junction Temperature
Typical Performance Curves (Continued)

**Figure 10.** $V_{FB}$ vs. Junction Temperature

**Figure 11.** Load transient Response

**Figure 12.** Load transient Response

**Figure 13.** Load transient Response
Typical Performance Curves (Continued)

Figure 14. Light Load Start-up Waveform

Figure 15. Heavy Load Start-up Waveform
Applications Information

PWM Voltage Mode Converter

The FP6791 is a CMOS step-up converter using a pulse width modulation method (PWM). The maximum duty ratio of FP6791 can be controlled by the resistor connected to the RDUTY pin. The converter can operate in both discontinuous conduction mode (DCM) and continuous conduction mode (CCM). The FP6791 operation can be best understood by referring to the block diagram in Figure 3. The error amplifier monitors the output voltage via the feedback resistor divider by comparing the feedback voltage with the reference voltage. When the feedback voltage is lower than the reference voltage, the error amplifier output will increase. The error amplifier output is then compared with the oscillator ramp voltage at the PWM controller. When the error amplifier output voltage is higher than ramp, the EXT pin turned on the external transistor, the output voltage will increase, and vice versa. As the feedback voltage is higher than the reference voltage, the error amplifier output will decrease. When the error amplifier output voltage is lower than ramp, the EXT pin turned off the external transistor, the output voltage will decrease.

Soft Start

The FP6791 includes internal 20mS (Typ.) soft start function. The soft start function can minimize the inrush current. When power on, a constant current charges an internal capacitor. When power off, the internal capacitor will be discharge for next soft start time.

Output Voltage Setting

With the FP6791, the output voltage can be set value by external divider network. An external resistor divider is required to divide the output voltage down to the nominal reference voltage. As shown in Figure 2, the resistor divider output feeds to the FB pin, which connects to the inverting input of the error amplifier. The non-inverting input of the error amplifier is connected to a 1V (Typ.) reference voltage. The following equation can be used to calculate the $R_{FB1}$ and $R_{FB2}$ value.

$$V_{OUT} = \left(1 + \frac{R_{FB1}}{R_{FB2}}\right) \times V_{FB}$$

Under Voltage Lockout

The under voltage lockout (UVLO) comparator has two voltage references, the start and stop thresholds. During power up, the UVLO comparator stop EXT pin switching and the external FET is held in the off status until the VIN reaches UVLO detection voltage. During VIN power down, the UVLO comparator allows the EXT pin switching until the UVLO stop threshold is reached. The UVLO function can prevent the IC form malfunction due to a transient status when power is applied or a momentary drop of the power supply voltage.

Short Circuit Protection

The short circuit protection function stops switching when output voltage drop due to output short circuiting. The capacitor that connected to the CSP pin is used to set delay time of short circuit protection. If the maximum duty condition continues because of short circuit, the capacitor externally connected to the CSP pin is charged, and EXT pin stops switching after CSP pin voltage rises above the reference voltage. Than FP6791 latches off until input voltage is re-started.

Compensation

The compensation circuit is designed to guarantee stability over the full input/output voltage and full output load range. The compensation circuit can prevent excessive output ripple and unstable operation from deteriorating the efficiency. The compensation is implemented by connecting $R_z$ and $C_z$ series network between VSS pin and CC pin. $R_z$ set the high frequency gain for a high speed transient response. $C_z$ set the pole and zero of the error amplifier and keeps the system stable. Adjust $R_z$ and $C_z$, taking into consideration conditions such as the inductor, output, and load current, so that optimum transient characteristics can be obtained.
Oscillation Frequency Setting

The oscillation of FP6791 can be set in a range of 500kHz to 1.3MHz (R_{OSC}=100kΩ to 300kΩ) using external resistor that connect to ROSC pin. Select the resistor by Figure 16.

![Figure 16. Rosc vs. Frequency](image)

Maximum Duty Ratio Setting

The maximum duty of FP6791 can be set in a range of 55% to 88.5% by an external resistor that connects to RDUTY pin. The ratio of R_{DUTY}/R_{OSC} must ranging from 0.5 to 3.2 and R_{OSC} conform to range between 100kΩ to 300kΩ. Select the resistor by referring to Figure 17.

![Figure 17. R_{DUTY}/R_{OSC} vs. Max. Duty](image)

Inductor selection

The inductor selection depends on the switching frequency and current ripple by the following formula:

\[
L \geq \frac{V_{IN}}{f_{OSC} \times \Delta I_L} \left( 1 - \frac{V_{IN}}{V_{OUT}} \right)
\]

Where \( f_{OSC} \) is switching frequency of the FP6791

*The switching frequency of the FP6791 ranges between 500kHz and 1.3MHz. The switching frequency can be set value by external resistor.

Although small physical size and high efficiency are major concerns, the inductor should have low core losses and series resistance (DCR, copper wire resistance). The minimum inductor value, peak current rating and series resistance will affect the converter efficiency, maximum output load capability, transient response time and output voltage ripple. The inductor selection depends on input voltage, output voltage and maximum output current. Very high inductor minimize the current ripple and therefore reduce the peak current, which decreases core losses in the inductor and conduct losses in the entire power path. However, large inductor values also require more energy storage and more turns of wire. The size of inductor will become bigger and increase conduct losses. Low inductor values decrease the size but increase the current ripple and the peak current. Choosing the inductor values based on the application. In addition, it is important to ensure the inductor saturation current exceeds the peak value of inductor current in application to prevent core saturation. Calculating the ripple current at operation point and the peak current required for the inductor:

\[
\Delta I_L = \frac{V_{IN(MIN)} \times (V_{OUT} - V_{IN(MIN)})}{L \times V_{OUT} \times f_{OSC}}
\]

\[
I_{L(MAX)} = I_{IN(DC,MAX)} + \frac{\Delta I_L}{2}
\]

\[
I_{L(MAX)} = I_{IN(DC,MAX)} + \frac{V_{IN}}{2 \times f_{OSC} \times L} \left( 1 - \frac{V_{IN(MIN)}}{V_{OUT}} \right)
\]

\[
I_{L(MAX)} = I_{OUT(MAX)} \times \frac{V_{OUT}}{\eta \times V_{IN(MIN)}} + \frac{V_{IN}}{2 \times f_{OSC} \times L} \left( 1 - \frac{V_{IN(MIN)}}{V_{OUT}} \right)
\]
Applications Information (Continued)

Where $\eta$=expected efficiency at that operating point. The value can be taken from an appropriate curve in the typical operating characteristics. $\Delta I_L$=inductor ripple current, $I_{L(MAX)}$=inductor peak current. In addition, the following equation used here assumes a constant $K$, which is the ratio of the inductor peak-to-peak AC current to average DC inductor current. A good compromise between the size of the inductor versus loss and output ripple is to choose a K 0.3 to 0.5. The peak inductor current is then given by:

$$\Delta I_L = \frac{I_{OUT(MAX)} \times V_{OUT}}{\eta \times V_{IN(MIN)}} \left(1 + \frac{K}{2}\right)$$

Where $K$=ratio of the inductor peak-to-peak AC current to average DC inductor current, $\Delta I_L$=inductor ripple current.

The inductor value is then given by:

$$L = \frac{V_{IN(MIN)}^2 \times \eta \times D}{K \times f_{OSC} \times V_{OUT} \times I_{OUT(MAX)}}$$

Where

$D$=Duty cycle $= \frac{V_{IN(MIN)} - (V_F + V_{OUT})}{V_{IN(MAX)} \times R_{ds(on)}} - (V_F + V_{OUT})$

$V_F$=Catch diode forward drop

$f$=Switching frequency

The inductor’s saturation current rating should exceed $I_{L(MAX)}$ and the inductor DC current rating should exceed $I_{L(DC,MAX)}$.

Rectifier diode selection

The diode is the largest source of loss in DC-DC converters. A high speed diode is necessary due to the high switching frequency. The Schottky diodes are recommended because of their fast recovery time and low forward drop voltage for better efficiency. The forward droop voltage of the Schottky diode will result in the conduction losses in the diode, and the diode capacitance will cause the switching losses. Therefore, it is necessary to consider both forward voltage drop and diode capacitance for diode selection. In addition, the reverse voltage rating of this diode should 1.3 times of the maximum output voltage. The rectifier diode must meet the output and peak inductor current requirement.

Output Capacitor Selection

The capacitor on the output side ($C_{OUT}$) is used for sustaining the output voltage when the external MOSFET or diode is switched on and smoothing the ripple voltage. Select an appropriate capacitance value based on the load condition. For lower output voltage ripple, the low ESR ceramic capacitor is recommended. The output voltage ripple consists of two components. One is the pulsating output ripple current through ESR, and the other is the capacitive ripple caused by charging and discharging.

$$\Delta V_O = V_{RIPPLE_ESR} + V_{RIPPLE_C}$$

$$\equiv \Delta I_L \times R_{ESR} \times \frac{\Delta I_L}{C_{OUT}} \left(\frac{V_{OUT} - V_{IN}}{V_{OUT} \times f_{OSC}}\right)$$

Where $\Delta V_O$=output voltage ripple, $\Delta I_L$=inductor ripple current, $I_{L(MAX)}$=inductor peak current.

The optimal capacitor differs depending on the inductor value, wiring, and application (output load), so select the capacitor after performing sufficient evaluation under the actual usage condition.

Input Capacitor Selection

The capacitor on input side ($C_{IN}$) can stabilize the input voltage and minimize peak current ripple form the power source for better efficiency. The value of the capacitor depends on the impedance of the input source used. For better input bypassing, low ESR ceramic capacitor is recommended for better performance.

External Switch Transistor

An enhancement N-channel MOSFET or a bipolar NPN transistor can be used as the external switch transistor. For high efficiency, using a MOSFET with a low $R_{DS-ON}$ and small input capacitance is ideal. It is a more efficient switch than a bipolar NPN transistor. The $R_{DS-ON}$ and input capacitance generally share a trade-off relationship. The $R_{DS-ON}$ is efficient in a range in which the output current is relatively great during low frequency switching, and the input capacitance is efficient in a range in which the output current is middling during high frequency switching.
Applications Information (Continued)

Select a MOSFET whose $R_{DS-ON}$ and input capacitance are optimal depending on the usage conditions. The input voltage is supplied for the gate voltage of the MOSFET, so select a MOSFET with a gate withstanding voltage that is equal to maximum usage value of the input voltage or higher and drain withstanding voltage that is equal to the output voltage and diode voltage or higher. An enhancement N-channel MOSFET can be selected by the following guidelines:

1. Low $R_{DS-ON}$.
2. Low gate threshold voltage.
3. Rated continuous drain current should be larger than the peak inductor current.
4. Low gate capacitance.

If a MOSFET with a threshold is near the UVLO detection voltage is used, a large current may flow, stopping the output voltage from rising and possibly generating heat in the worst case. Select a MOSFET with a threshold that is sufficiently lower than the UVLO detection voltage value.

Feed-forward Capacitor Selection

The feed-forward capacitor ($C_F$) is used to improve the performance of internally compensated DC-DC converter. To optimize transient response, a feed-forward capacitor value is chosen such that the gain and phase of the feedback increases the bandwidth of the converter, while still maintaining an acceptable phase margin. In general, capacitor causes the loop gain to crossover too high in frequency and the feed-forward capacitor phase contribution is insufficient, resulting in unacceptable phase margin or instability. The following process outlines a step by step procedure for optimizing the feed-forward capacitor:

1. Determine the crossover frequency of converter.
2. Once the crossover frequency is known, the equation allows calculation of feed-forward capacitor value which prompts a good compromise between bandwidth improvement and acceptable phase margin.

The feed-forward capacitor selection by the following formula:

$$C_F = \frac{1}{2\pi f_{crossover}} \times \frac{1}{R_{FB1}} \times \left( \frac{1}{R_{FB1}} + \frac{1}{R_{FB2}} \right)$$

Layout Recommendation

For high frequency switching power supplies, the device’s performance including efficiency, output noise, transient response and control loop stability is dramatically affected by PCB layout.

There are some general guidelines for layout:

1. Place the external power components (the input capacitors, output capacitors, inductor and diode, etc.) in close proximity to the device. Traces to these components should be kept as short and wide as possible to minimize parasitic inductance and resistance.
2. Place output capacitor next to the Schottky diode as possible.
3. Place input capacitor close to the VIN pin.
4. The input and output capacitor’s ground should be wide and short enough to connect to a ground plane.
5. The feedback network should sense the output voltage directly form the point of load, and be as far away form noisy loop as possible.
6. The compensation circuit should be kept away form the power loops and should be shielded with a ground trace to prevent noise coupling.
7. Place the resistor close to RDUTY and ROSC pin.
Outline Information

TSSOP-8 Package (Unit: mm)

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<th>SYMBOLS</th>
<th>UNIT</th>
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<th>MAX</th>
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Note: Followed from JEDEC MO-153-F.