

High Efficiency 1.5MHz 1.2A Synchronous Step Down LED Driver

Description

The FP6395 is a high efficiency, high frequency synchronous DC-DC step-down LED driver. The 100% duty cycle feature provides low dropout operation, extending battery life in portable systems.

The internal synchronous switch increases efficiency and eliminates the need for external Schottky diode. At shutdown mode, the input supply current is less than 1 μ A.

The FP6395 fault protection includes over current protection, short circuit protection, UVLO, input over voltage protection and thermal shutdown.

The FP6395 is offered in TDFN-6 (1.6mm $\times$ 1.6mm) TDFN-6 (2mm $\times$ 2mm) and SOT-23-5 Packages.

Features

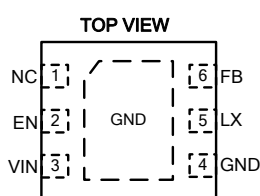
- 2.5V~5.7V Input Voltage Range
- 0.2V Reference Voltage
- 1.2A Output Current
- Low $R_{DS(ON)}$ for Internal Switch (Top/Bottom): 340m Ω /210m Ω
- 1.5MHz Switching Frequency
- Internal Compensation Function
- 1kHz $\pm$ 10% PWM Dimming Control
- 100% Dropout Operation
- Input Over Voltage Protection
- Over Current Protection
- Over Temperature Protection with Auto Recovery
- RoHS Compliant and Halogen Free
- TSCA (USA) Compliant

Applications

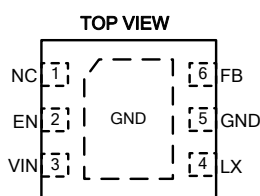
- NB Camera
- 3AA or 4AA Batteries Powered Flashlight
- 1 Cell Li-Ion Battery Powered Flashlight

Pin Assignments

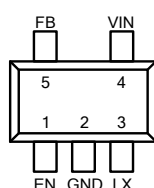
D2 Package: TDFN-6 (1.6mm $\times$ 1.6mm)



D7 Package: TDFN-6 (2mm $\times$ 2mm)



S5 Package: SOT-23-5



Ordering Information

FP6395	Package Type
	D2: TDFN-6 (1.6mm $\times$ 1.6mm)
	D7: TDFN-6 (2mm $\times$ 2mm)
	S5: SOT-23-5

TDFN-6 Marking

Part Number	Product Code
FP6395D2	A
FP6395D7	FZ2

SOT-23-5 Marking

Part Number	Product Code
FP6395S5	GE7

Figure 1. Pin Assignment of FP6395

Typical Application Circuit

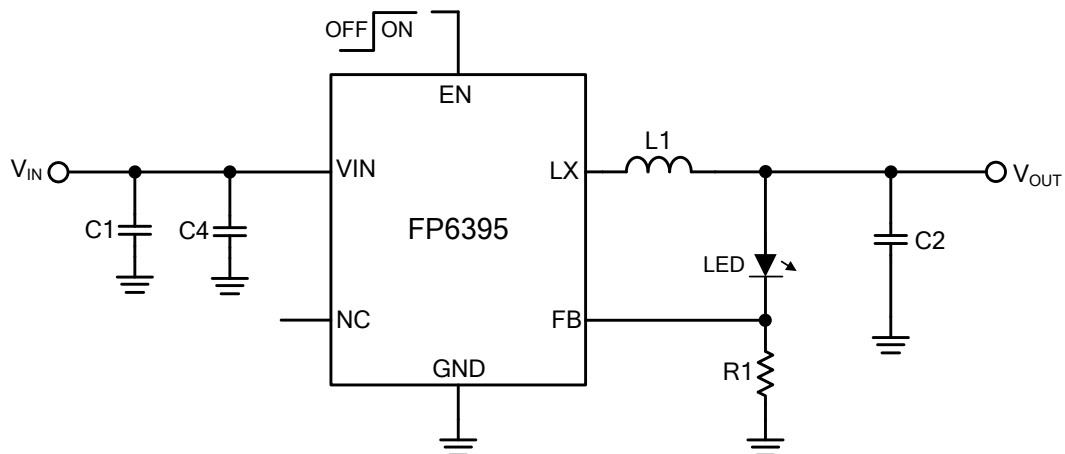


Figure 2. Schematic Diagram

VIN=5V, the recommended BOM list is as below.

C1	C4	L1	C2
4.7 μ F MLCC	0.1 μ F MLCC	2.2 μ H	10 μ F MLCC

Table 1. Recommended Component Values

Functional Pin Description

Pin Name	D2 Package Pin No.	D7 Package Pin No.	S5 Package Pin No.	Pin Function
NC	1	1	-	No Connection.
EN	2	2	1	Enable control pin. Pull high to turn the IC on, and pull low to disable the IC. Don't leave this pin floating.
VIN	3	3	4	Power supply input pin. Placed input capacitors as close as possible from VIN to GND to avoid noise influence.
GND	4	5	2	Ground pin. Connect GND to exposed pad.
LX	5	4	3	Power switching node. Connect an external inductor to this switching node.
FB	6	6	5	Voltage feedback input pin. Connect FB and V_{OUT} with a resistive voltage divider. This IC senses feedback voltage via FB and regulates it at 0.2V.

Block Diagram

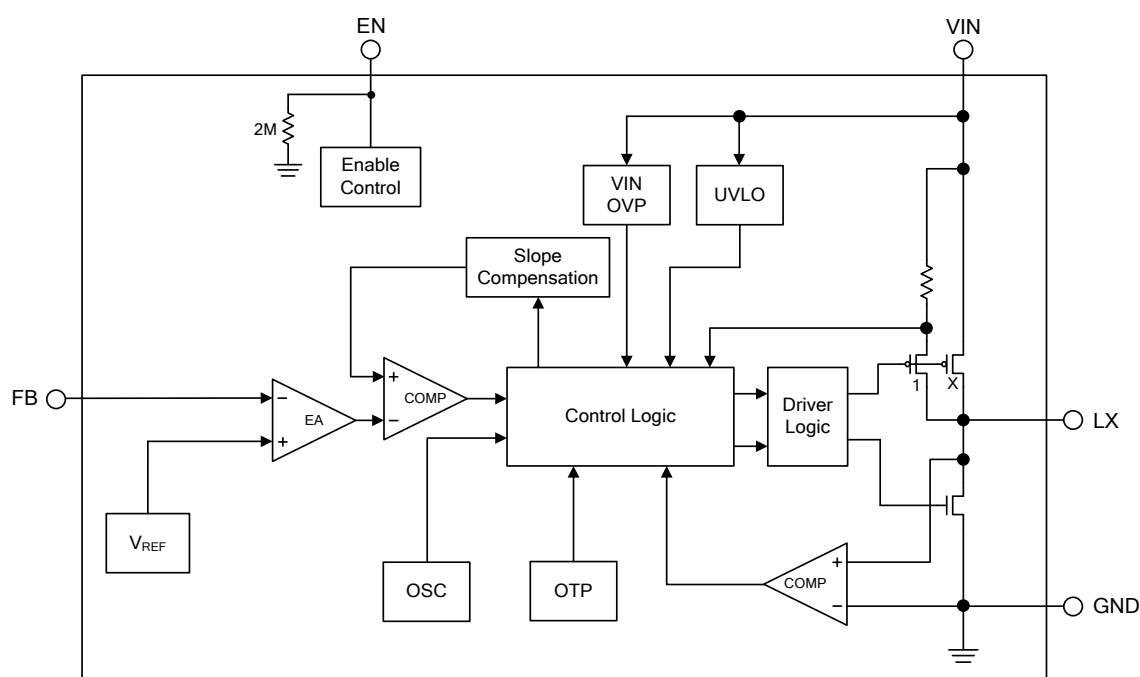


Figure 3. Block Diagram of FP6395

Absolute Maximum Ratings ^(Note 1)

- VIN to GND ----- -0.3V to +6.5V
- LX to GND ----- -0.3V to (VIN +0.3V)
- EN, FB to GND ----- -0.3V to VIN
- Package Thermal Resistance, (θ_{JA}) ^(Note 2)
 - TDFN-6 (1.6mm×1.6mm) ----- 160°C/W
 - TDFN-6 (2mm×2mm) ----- 136°C/W
 - SOT-23-5 ----- 250°C/W
- Package Thermal Resistance, (θ_{JC}) ^(Note 2)
 - TDFN-6 (1.6mm×1.6mm) ----- 62°C/W
 - TDFN-6 (2mm×2mm) ----- 56°C/W
 - SOT-23-5 ----- 130°C/W
- Maximum Junction Temperature (T_J) ----- +150°C
- Lead Temperature (Soldering, 10sec.) ----- +260°C
- Storage Temperature (T_S) ----- -65°C to +150°C

Note 1: Stresses beyond this listed under "Absolute Maximum Ratings" may cause permanent damage to the device.

Note 2: θ_{JA} is measured at 25°C ambient with the component mounted on a high effective thermal conductivity 4-layer board of JEDEC-51-7. θ_{JC} is measured at the exposed pad. The thermal resistance greatly varies with layout, copper thickness, number of layers and PCB size.

Recommended Operating Conditions

- Supply Voltage (V_{IN}) ----- +2.5V to +5.7V
- Operation Temperature Range (T_{OPR}) ----- -40°C to +85°C

Electrical Characteristics

($V_{IN}=5V$, $V_{OUT}=2.5V$, $T_A=25^{\circ}C$, unless otherwise specified.)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input Supply Voltage	V_{IN}		2.5		5.7	V
Input Over Voltage Protection	$V_{IN\ OVP}$			6.3		V
Shutdown Current	I_{SHDN}	EN=0V		0.1	1	μA
Quiescent Current	I_q	$V_{FB}=0.65V$, $I_{OUT}=0A$		30	50	μA
Reference Voltage	V_{REF}		0.194	0.2	0.206	V
FB Input Leakage Current	I_{FB}	$V_{FB}=V_{IN}$		0.01	1	μA
P-Channel MOSFET On-Resistance ^(Note 3)	$R_{DS(ON)}$			340		m Ω
N-Channel MOSFET On-Resistance ^(Note 3)	$R_{DS(ON)}$			210		m Ω
P-Channel Current Limit ^(Note 3)	I_{LIM}			1.5		A
EN High-Level Input Voltage	$V_{EN(H)}$		1.5			V
EN Low-Level Input Voltage	$V_{EN(L)}$				0.4	V
EN Input Current	I_{EN}			2.5		μA
Under Voltage Lockout Voltage	UVLO			2.4		V
UVLO Hysteresis	V_{HYS}			0.3		V
Oscillation Frequency	F_{OSC}	$I_{OUT}=200mA$	1.2	1.5	1.8	MHz
Minimum On Time				50		ns
Maximum Duty Cycle			100			%
LX Discharge Resistance				100		Ω
Thermal Shutdown Temperature ^(Note 3)	T_{SD}			150		$^{\circ}C$

Note 3: Guarantee by design.

Typical Performance Curves

$V_{IN}=5V$, $I_{LED}=300mA$, $C1=4.7\mu F$, $C2=10\mu F$, $L1=2.2\mu H$, $T_A=+25^\circ C$, unless otherwise noted.

$V_{FB}=0.65V$, $I_O=0A$

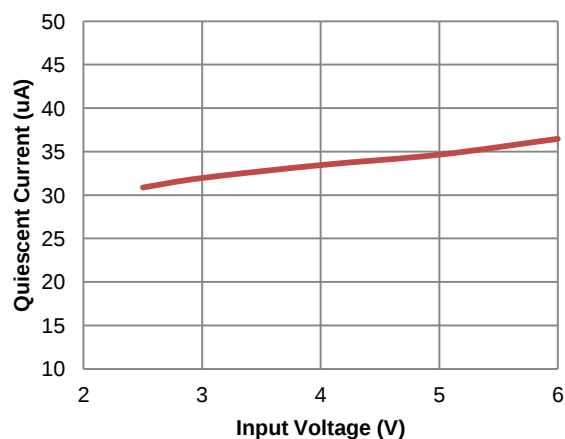


Figure 4. Quiescent Current vs. Input voltage

$V_{EN}=0V$

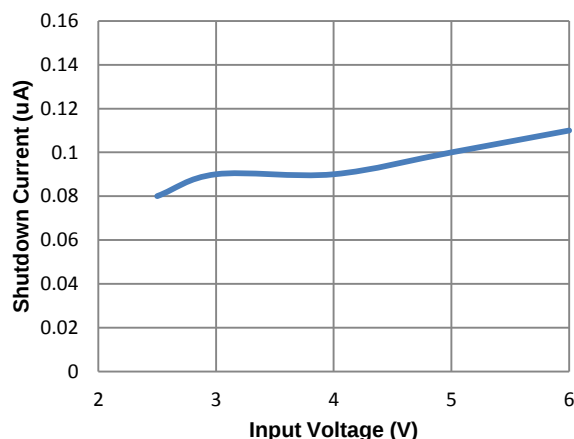


Figure 5. Shutdown Current vs. Input Voltage

$V_{EN}=0V$

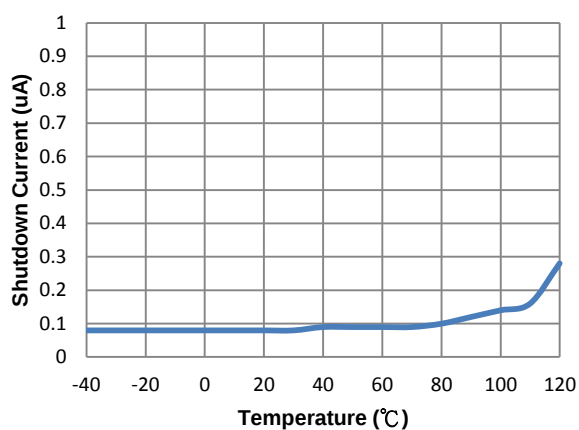


Figure 6. Shutdown Current vs. Temperature

1LED, $V_F=3.3V$, $I_{LED}=300mA$

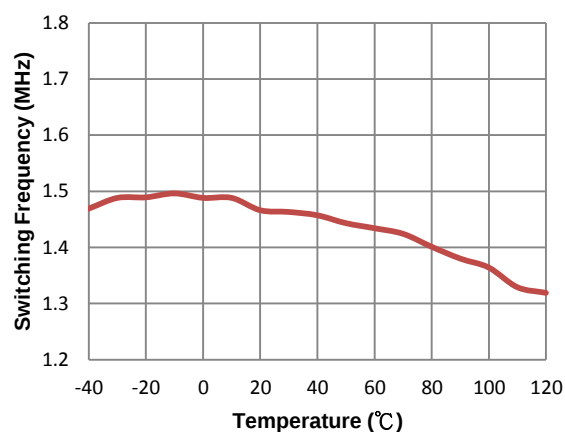


Figure 7. Switching Frequency vs. Temperature

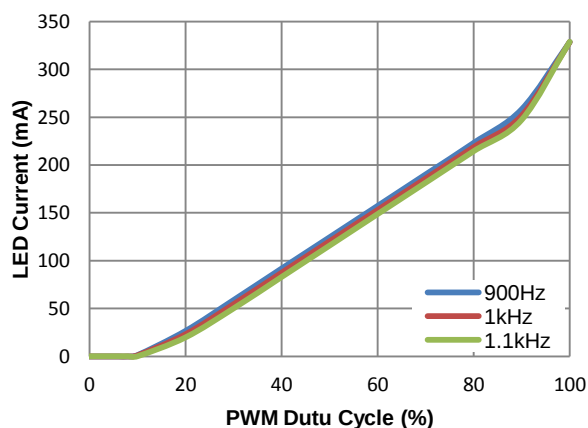


Figure 8. LED Current vs. PWM Duty Cycle

$V_{OUT}=3.3V$

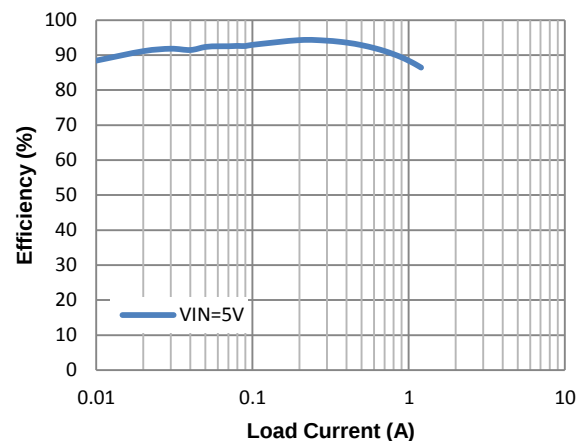


Figure 9. Efficiency vs. Load Current

Typical Performance Curves (Continued)

$V_{IN}=5V$, $I_{LED}=300mA$, $C1=4.7\mu F$, $C2=10\mu F$, $L1=2.2\mu H$, $T_A=+25^{\circ}C$, unless otherwise noted.

1LED, $V_F=3.3V$, $I_{LED}=300mA$

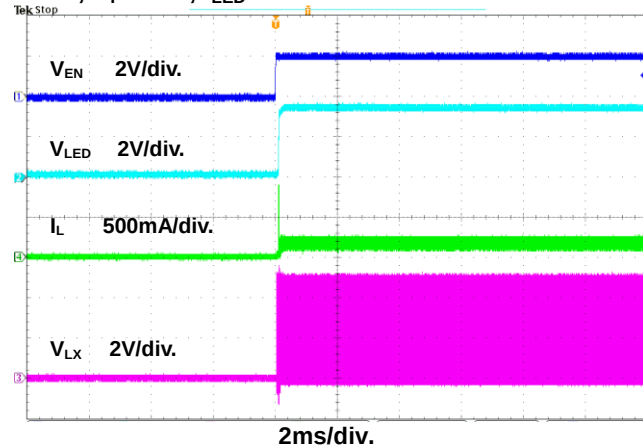


Figure 10. Power On Through Enable Control Waveform

1LED, $V_F=3.3V$, $I_{LED}=300mA$

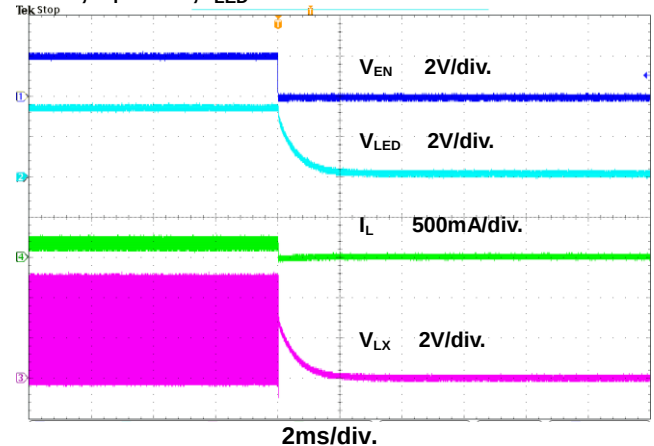


Figure 11. Power Off Through Enable Control Waveform

1LED, $V_F=3.3V$, $I_{LED}=300mA$

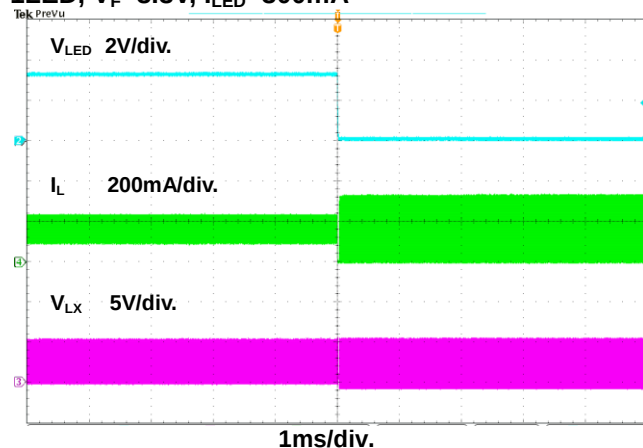


Figure 12. Short LED Waveform

1LED, $V_F=3.3V$, $I_{LED}=300mA$

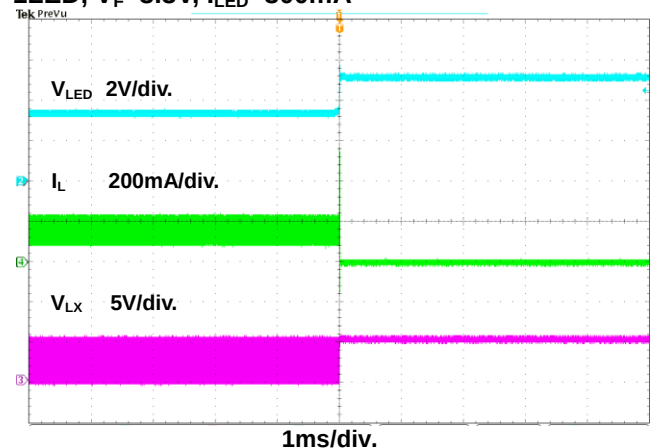


Figure 13. Open LED Waveform

1LED, $V_F=3.3V$, $I_{LED}=300mA$

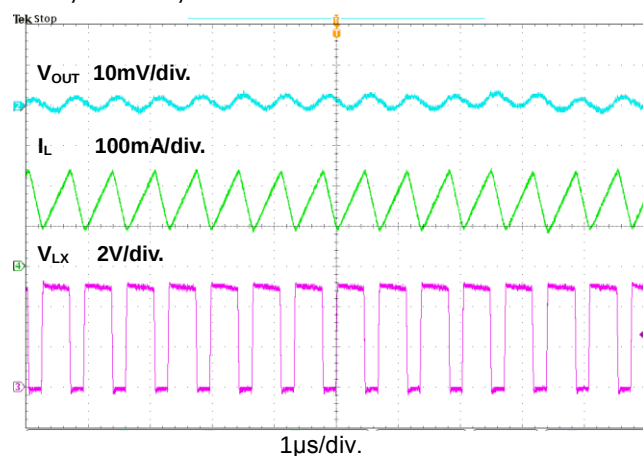


Figure 14. Steady State Waveform

Function Description

The FP6395 is a high efficiency, internal compensation and constant frequency current mode step-down synchronous LED driver. It has integrated high-side (340mΩ, typ.) and low-side (210mΩ, typ.) power switches, and provides 1.2A continuous load current. It regulates input voltage from 2.5V to 5.7V, and down to an output voltage as low as 0.2V.

Enable

The FP6395 EN pin provides digital control to turn on/off the regulator. When the voltage of EN exceeds the threshold voltage, the regulator will start the soft start function. If the EN pin voltage is below the shutdown threshold voltage, the regulator will turn into the shutdown mode and the shutdown current will be smaller than 1μA. For auto start-up operation, connect EN to VIN.

It also includes a PWM dimming input that can accept an external control signal with a duty ratio of 5% to 100% and PWM dimming frequency is from 900Hz to 1.1kHz.

Under Voltage Lockout

When the FP6395 is power on, the internal circuits will be held inactive until V_{IN} voltage exceeds the UVLO threshold voltage. And the regulator will be disabled when V_{IN} is below the UVLO threshold voltage. The hysteresis of the UVLO comparator is 200mV (typ).

Input Over Voltage Protection

The FP6395 supports input over voltage protection. When input voltage exceeds the input over Voltage threshold, the regulator will be shutdown unless the input over voltage is removed.

Over Current Protection

The FP6395 over current protection function is implemented by using cycle-by-cycle current limit architecture. The inductor current is monitored by measuring the high-side MOSFET series sense resistor voltage. When the load current increases, the inductor current will also increase. When the peak inductor current reaches the current limit threshold, the output voltage will start to drop. When the over current condition is removed, the output voltage will return to the regulated value.

Short Circuit Protection

The FP6395 provides short circuit protection function to prevent the device damaged from short condition. When the short condition occurs and the feedback voltage drops lower than 40% of the regulation level, the oscillator frequency will be reduced to prevent the inductor current increasing beyond the current limit. In the meantime, the current limit will also be reduced to lower the short current. Once the short condition is removed, the frequency and current limit will return to normal.

Over Temperature Protection

The FP6395 incorporates an over temperature protection circuit to protect itself from overheating. When the junction temperature exceeds the thermal shutdown threshold temperature, the regulator will be shutdown. And the hysteresis of the over temperature protection is 30°C (typ).

Application Information

Setting LED Current

The FB pin regulated voltage is 200mV. Thus the LED current is:

$$R_{SEN} = \frac{200mV}{I_{LED}}$$

Input Capacitor Selection

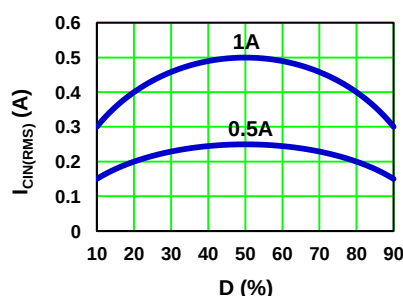
The use of the input capacitor is filtering the input voltage ripple and the MOSFETS switching spike voltage. Because the input current to the step-down converter is discontinuous, the input capacitor is required to supply the current to the converter to keep the DC input voltage. The capacitor voltage rating should be 1.25 to 1.5 times greater than the maximum input voltage. The input capacitor ripple current RMS value is calculated as:

$$I_{CIN(RMS)} = I_{OUT} \times \sqrt{D \times (1-D)}$$

$$D = \frac{V_{OUT}}{V_{IN}}$$

Where D is the duty cycle of the power MOSFET.

This function reaches the maximum value at D=0.5 and the equivalent RMS current is equal to $I_{OUT}/2$. The following diagram is the graphical representation of above equation.



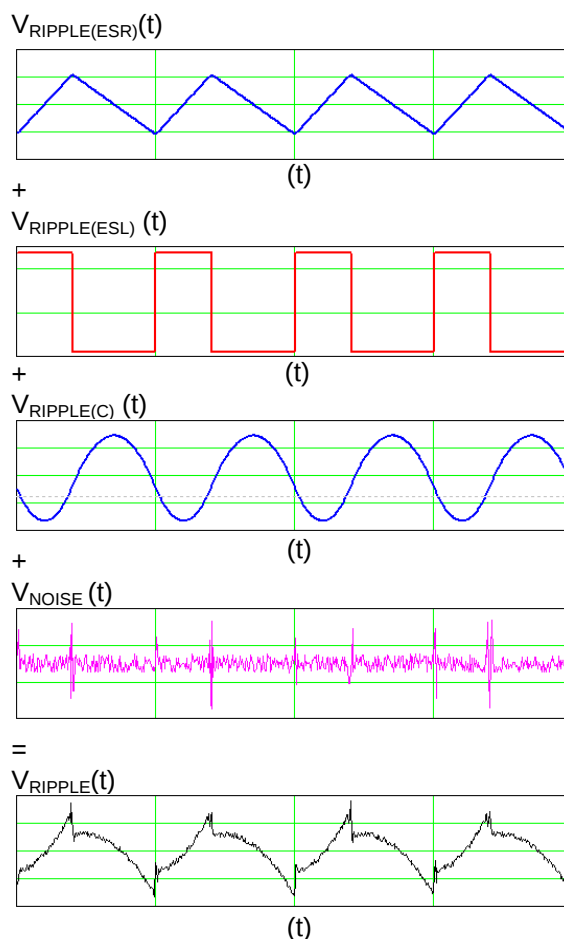
A low ESR capacitor is required to keep the noise minimum. Ceramic capacitors are better, but tantalum or low ESR electrolytic capacitors may also suffice.

Output Capacitor Selection

The output capacitor is used to keep the DC output voltage and supply the load transient current. When operating in constant current mode, the output ripple is determined by four components:

$$V_{RIPPLE}(t) = V_{RIPPLE(C)}(t) + V_{RIPPLE(ESR)}(t) + V_{RIPPLE(ESL)}(t) + V_{NOISE}(t)$$

The following figures show the form of the ripple contributions.



Application Information (Continued)

$$V_{\text{RIPPLE(ESR)}} = \frac{V_{\text{OUT}}}{F_{\text{OSC}} \times L} \times \left(1 - \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right) \times \text{ESR}$$

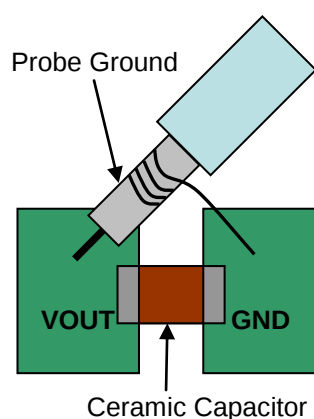
$$V_{\text{RIPPLE(ESL)}} = \frac{\text{ESL}}{L} \times V_{\text{IN}}$$

$$V_{\text{RIPPLE(C)}} = \frac{V_{\text{OUT}}}{8 \times F_{\text{OSC}}^2 \times L \times C_{\text{OUT}}} \times \left(1 - \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right)$$

Where F_{OSC} is the switching frequency, L is the inductance value, V_{IN} is the input voltage, ESR is the equivalent series resistance value of the output capacitor, ESL is the equivalent series inductance value of the output capacitor and the C_{OUT} is the output capacitor.

Low ESR capacitors are preferred to use. Ceramic, tantalum or low ESR electrolytic capacitors can be used depending on the output ripple requirements. When using the ceramic capacitors, the ESL component is usually negligible.

It is important to use the proper method to eliminate high frequency noise when measuring the output ripple. The figure shows how to locate the probe across the capacitor when measuring output ripple. Remove the scope probe plastic jacket in order to expose the ground at the tip of the probe. It gives a very short connection from the probe ground to the capacitor and eliminates noise.



Inductor Selection

The output inductor is used for storing energy and filtering output ripple current. But the trade-off condition often happens between maximum energy storage and the physical size of the inductor. The first consideration for selecting the output inductor is to make sure that the inductance is large enough to keep the converter in the continuous current mode.

That will lower ripple current and result in lower output ripple voltage. The ΔI_L is inductor peak-to-peak ripple current:

$$\Delta I_L = \frac{V_{\text{OUT}}}{F_{\text{OSC}} \times L} \times \left(1 - \frac{V_{\text{OUT}}}{V_{\text{IN}}}\right)$$

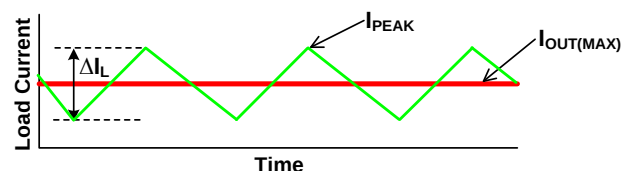
A good compromise value between size and efficiency is to set the peak-to-peak inductor ripple current ΔI_L equal to 30% of the maximum load current. But setting the peak-to-peak inductor ripple current ΔI_L between 20%~50% of the maximum load current is also acceptable. Then the inductance can be calculated with the following equation:

$$\Delta I_L = 0.3 \times I_{\text{OUT(MAX)}}$$

$$L = \frac{(V_{\text{IN}} - V_{\text{OUT}}) \times V_{\text{OUT}}}{V_{\text{IN}} \times F_{\text{OSC}} \times \Delta I_L}$$

To guarantee sufficient output current, peak inductor current must be lower than the FP6395 high-side MOSFET current limit. The peak inductor current is shown as below:

$$I_{\text{PEAK}} = I_{\text{OUT(MAX)}} + \frac{\Delta I_L}{2}$$



Application Information (Continued)

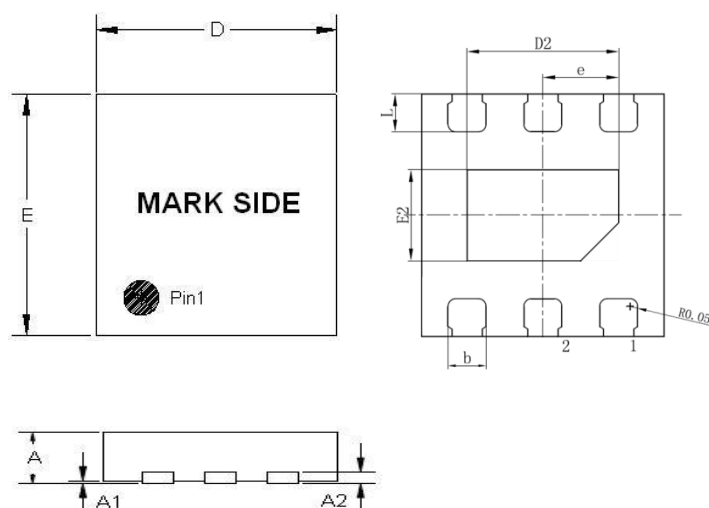
PCB Layout Recommendation

The device's performance and stability are dramatically affected by PCB layout. It is recommended to follow these general guidelines shown as below:

1. Place the input capacitors and output capacitors as close to the device as possible. The traces which connect to these capacitors should be as short and wide as possible to minimize parasitic inductance and resistance.
2. Place feedback resistors close to the FB pin.
3. Keep the sensitive signal (FB) away from the switching signal (LX).
4. Multi-layer PCB design is recommended.

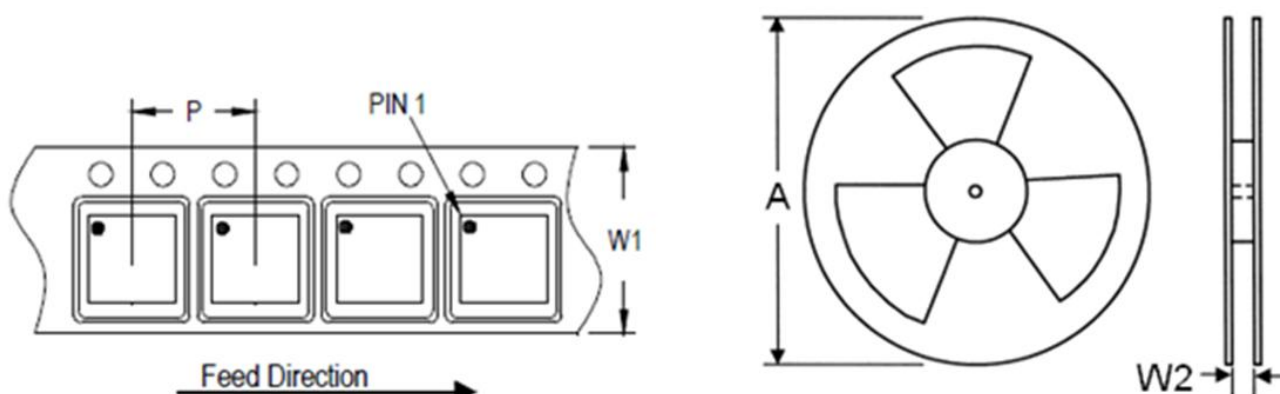
Outline Information

TDFN-6 1.6mm×1.6mm Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.70	0.80
A1	0.00	0.05
A2	0.18	0.25
D	1.55	1.65
E	1.55	1.65
L	0.18	0.30
b	0.18	0.30
e	0.45	0.55
D2	0.95	1.05
E2	0.55	0.65

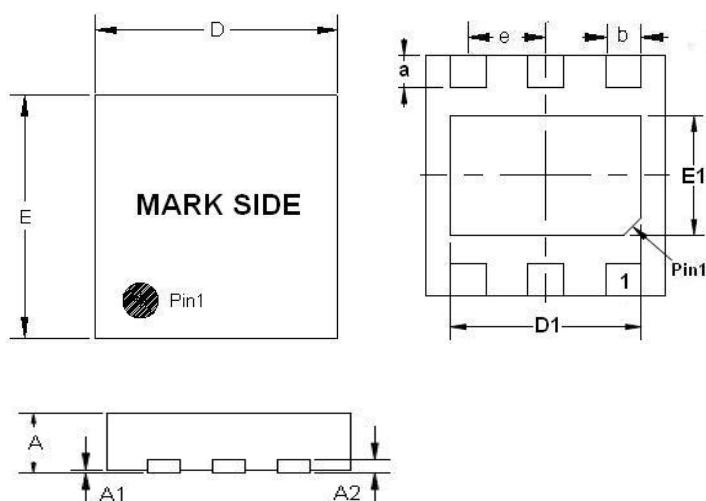
Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
12	4	7	180	8.4	400~1000	3,000

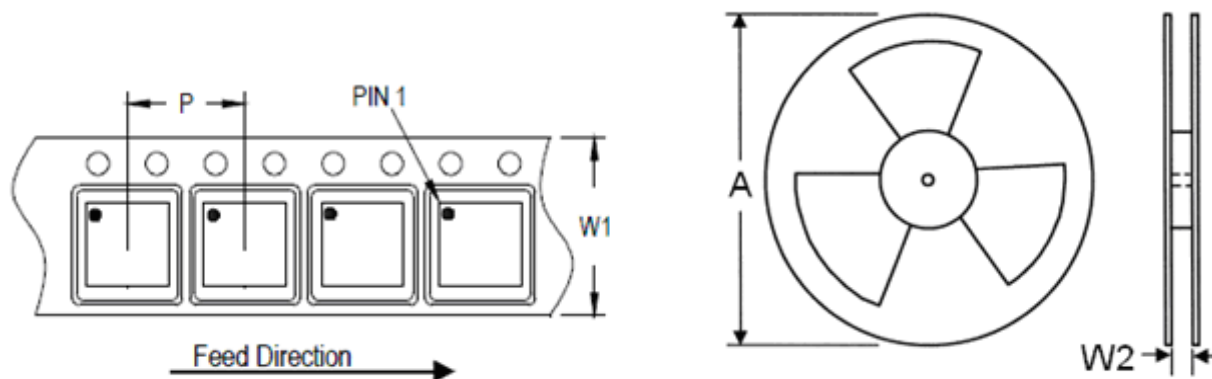
Outline Information (Continued)

TDFN-6 2mm×2mm Package (Unit: mm)



SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.70	0.80
A1	0.00	0.05
A2	0.19	0.22
D	1.95	2.05
E	1.95	2.05
a	0.20	0.40
b	0.25	0.35
e	0.60	0.70
D1	1.15	1.65
E1	0.55	1.05

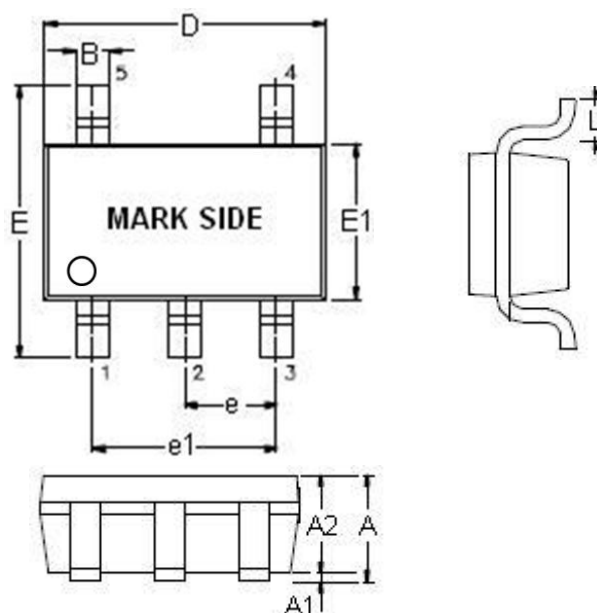
Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
8	4	7	180	8.4	400~1000	3,000

Outline Information (Continued)

SOT-23-5 Package (Unit: mm)

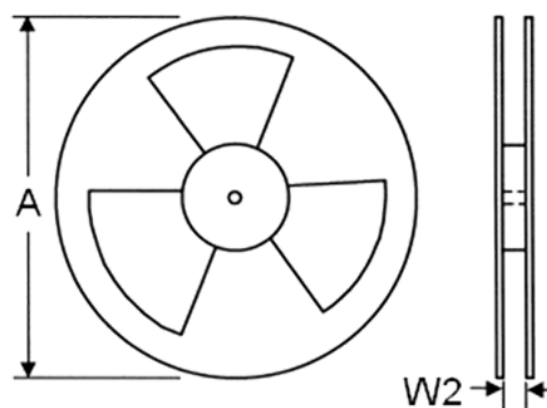
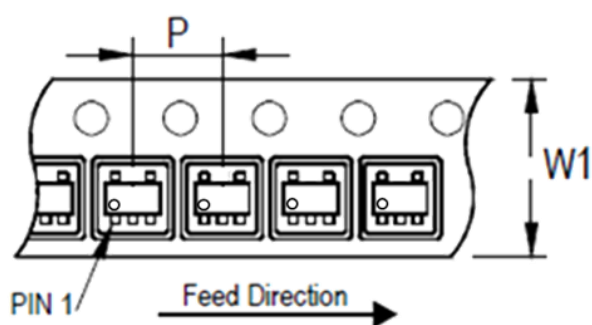


SYMBOLS UNIT	DIMENSION IN MILLIMETER	
	MIN	MAX
A	0.90	1.45
A1	0.00	0.15
A2	0.90	1.30
B	0.30	0.50
D	2.80	3.00
E	2.60	3.00
E1	1.50	1.70
e	0.90	1.00
e1	1.80	2.00
L	0.30	0.60

Note 4: Followed From JEDEC MO-178-C.

Note 5: Body dimensions do not include mold flash or protrusion. Mold flash and protrusion shall not exceed 0.3mm.

Carrier Dimensions



Tape Size (W1) mm	Pocket Pitch (P) mm	Reel Size (A)		Reel Width (W2) mm	Empty Cavity Length mm	Units per Reel
		in	mm			
8	4	7	180	8.4	300~1000	3,000

Life Support Policy

Fitipower's products are not authorized for use as critical components in life support devices or other medical systems.