

3A, 36V, Step-Down Converter



General Description

The FP6150B is a buck regulator with a built in internal power MOSFET. It achieves 3A continuous output current over a wide input supply range with excellent load and line regulation. Current mode operation provides fast transient response and eases loop stabilization. A wide switching frequency range allows efficiency and external component size to be optimized. The device includes under voltage lockout and thermal shutdown protection. The regulator only consumes 10 μ A supply current in shutdown mode. The FP6150B requires a minimum number of readily available external components to complete a 3A buck regulator solution.

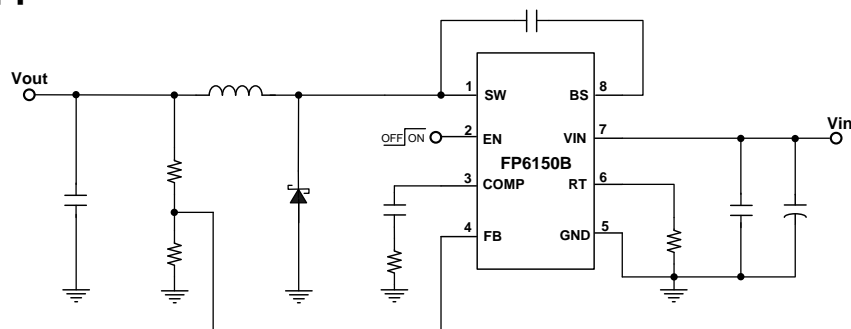
Features

- Operating Input Range up to 36V
- 3A Output Current
- Built-in Soft-Start
- 0.12 Ω Internal Power MOSFET Switch
- Up to 90% Efficiency
- 10 μ A Shutdown Mode Current
- Adjustable Switching Frequency using external Resistance setting (200KHz~2MHz)
- Thermal Shutdown
- Cycle-by-Cycle Over Current Protection
- Output Over Voltage Protection
- Under Voltage Lockout
- Internal soft-start: 2ms
- Available SOP8 With Exposed PAD

Applications

- Automotive Distributed Power Systems
- Battery Charger
- Pre-Regulator for Linear Regulators

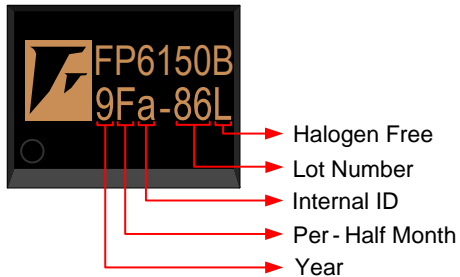
Typical Application Circuit



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Marking Information

SOP-8L (EP)



Halogen Free: Halogen free product indicator

Internal ID: Tracking Code

Per-Half Month: Production period indicator in half month time unit

For Example :

- A → First Half Month of January
- B → Second Half Month of January
- C → First Half Month of February
- D → Second Half Month of February

Year: Production year's last digit

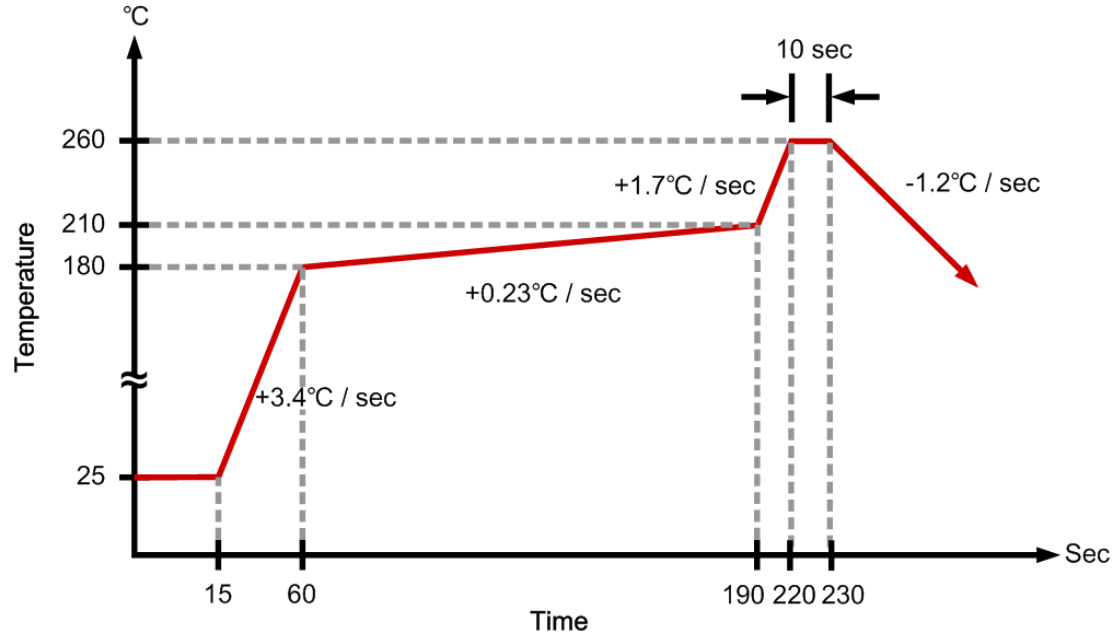
Ordering Information

Part Number	Operating Temperature	Package	MOQ	Description
FP6150BXR-G1	-40°C ~ +85°C	SOP-8L(EP)	3000EA	Tape & Reel

Absolute Maximum Ratings

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	V_{IN}		-0.3		42	V
Supply Voltage	V_{sw}		-0.3		$V_{IN} + 0.3$	V
Bootstrap Voltage	V_{BS}		$V_{sw} - 0.3$		$V_{sw} + 6$	V
Enable Voltage	V_{EN}		-0.3		V_{IN}	V
All Other Pins			-0.3		6	V
Junction Temperature	T_J				+150	°C
Storage Temperature	T_S		-65		+150	°C
Thermal Resistance	θ_{JA}	SOP-8L(EP)			60	°C / W
	θ_{JC}	SOP-8L(EP)			10	°C / W
Operating Temperature			-40		+85	°C
Lead Temperature (soldering, 10 sec)					+260	°C

Suggested IR Re-flow Soldering Curve



Recommended Operating Conditions

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Supply Voltage	V_{IN}		4.5		36	V
Operating Temperature		Ambient Temperature	-40		85	°C

DC Electrical Characteristics ($V_{IN}=12V$, $T_A=25^{\circ}C$, unless otherwise noted)

Parameter	Symbol	Test Conditions	Min.	Typ.	Max.	Unit
Standby Current	I_{SB}	$V_{EN}=2V$, $V_{FB}=1.0V$		0.6	1.0	mA
Shutdown Supply Current	I_{ST}	$V_{EN}=0$		10	20	μA
Feedback Voltage	V_{FB}	$9V < V_{IN} < 40V$	0.788	0.808	0.828	V
Feedback Current	I_{FB}	$V_{FB}=0.8V$		1		nA
Switch ON Resistance	R_{ON}			120		m Ω
Switch Leakage Current	I_{IL}	$V_{EN}=0$, $V_{SW}=0V$		0	10	μA
Error Amplifier Transconductance	G_{EA}	$I_{comp}=\pm 3\mu A$		68		$\mu A / V$
Current Sensing Transconductance	G_{CS}			9		A / V
Current Limit	I_{CL}	$F_{OSC}=200KHZ$		4.5		A
Switching Frequency	F_{OSC}	$V_{FB}=0.6V$; $RT=200k$	400	500	600	KHz
Foldback Switching Frequency	F_{SC}	$V_{FB}=0V$; $RT=200k$	50	125	175	KHz
Minimum On Time	T_{ON}			100		ns
Minimum Off Time	T_{OFF}			200		ns
Under Voltage Lockout Threshold	V_{UVLO}	V_{EN} Rising	3.9	4.2	4.5	V
Under Voltage Lockout Threshold Hysteresis	V_{HYS}			800		mV
EN Input Low Voltage					0.4	V
EN Input High Voltage			1.2			V
EN Internal Pull Up Current	I_{EN}	$V_{EN}=2V$		-1		μA
Thermal Shutdown	T_{TS}			150		°C

Function Description

The FP6150B is a current-mode step-down DC / DC converter that provides excellent transient response with external compensation components. It regulates input voltages from 4.5V to 36V down to an output voltage as low as 0.808V with maximum 3A load current. And a high-efficiency design with excellent AC and DC performance. The output voltage is measured at FB through a resistive voltage divider and amplified by the internal error amplifier. The output current of the transconductance error amplifier is presented at COMP where a network compensates the regulation control system. The voltage at COMP is compared to the switch current measured internally to control the output voltage. The converter uses internal n-channel MOSFET switches to step-down the input voltage to the regulated output voltage. Since the MOSFET requires a gate voltage greater than the input voltage, a boost capacitor connected between SW and BS drives the gate. The capacitor is charged from the internal regulator when the SW pin is low.

Output Voltage (V_{OUT})

The output voltage is set using a resistive voltage divider from the output voltage to FB. The voltage divider divides the output voltage down by the ratio:

$$V_{FB} = V_{OUT} \times \frac{R_4}{R_2 + R_4}$$

Thus the output voltage is:

$$V_{OUT} = V_{FB} \times \frac{R_2 + R_4}{R_4}$$

Resistor Selection for Common Output Voltages

Vout	R2 (KΩ)	R4 (KΩ)
1.8V	33 (1%)	27 (1%)
2.5V	51 (1%)	24 (1%)
3.3V	43 (1%)	14 (1%)
5V	62 (1%)	12 (1%)
12V	220 (1%)	16 (1%)

Oscillator

The oscillator frequency (200KHz~2MHz) can be set by an external resistor. The value of R_T can be calculated from:

$$\text{Frequency(kHz)} = \frac{10^5}{R_T(\text{k}\Omega)}$$

Enable Mode / Shutdown Mode

The FP6150B has a dedicated enable control pin, EN. By pulling it high or low, that can be enabled and disabled. Tie EN to VIN through a 100K Ω resistor for automatic start up. To disable the part, EN must be pulled low for at least 5 μ s. When floating, EN is pulled up to about 2.0V by an internal 1 μ A current source so it is enabled.

Boost High-Side Gate Drive (BST)

Since the MOSFET requires a gate voltage greater than the input voltage, user should connect a flying bootstrap capacitor between SW and BS pin to provide the gate-drive voltage to the high-side n-channel MOSFET switch. The capacitor is charged by the internally regulator periodically when SW pin is pulled to ground. During startup, an internal low-side switch pulls SW to ground and charges the BST capacitor to internally regulator output voltage. Once the BST capacitor is charged, the internal low-side switch is turned off and the BST capacitor provides the necessary enhancement voltage to turn on the high-side switch.

Over Current Protection

Over-current limiting is implemented by sensing the drain-to-source voltage across the high-side MOSFET. The drain to source voltage is then compared to a voltage level representing the over-current threshold limit. If the drain-to-source voltage exceeds the over-current threshold limit, the over-current indicator is set true. Once over-current indicator is set true, over-current limiting is triggered. The high-side MOSFET is turned off for the rest of the cycle. The output voltage will start to drop if the output is dead-short to ground, suddenly. Once the FB is lower than 0.3V, the switching frequency of FP6150B is folded back to around 1/4 Fosc.

Over Voltage Protection

The FP6150B is with an output voltage protection circuit to minimize output voltage overshoot when fast unload transients or fast supply transients or recovering from overloaded conditions, especially in application design with high inductance and low output capacitance. If the FB pin voltage is rising over 108% of reference voltage ($V_{FB}=0.808V$), the high side MOS is turned-off immediately. When the FB pin voltage drops below 104% of reference voltage, the high side MOS goes to normal operation.

Although there is an output overvoltage protection, the overshooting voltage would still be seen in designs with improper inductance (L) and output capacitance (Cout) due to the energy stored in inductor transfer to output capacitor.

For example with $V_{out}=5V$, the output protection voltage $V_{OVP}=5.4V$, the output overshoot voltage $V_{overshoot}$ would be around 7.35V during a fast load transient current (i) from 5A to 1mA with $L=22\mu H$ and $C_{out}=22\mu F$. But with the same fast load transient, the output overshoot voltage would be down to around 5.62V with $L=10\mu H$ and $C_{out}=100\mu F$. The value of output overshoot voltage $V_{overshoot}$ can be calculated from:

$$V_{overshoot} = \sqrt{\frac{L}{C_{out}} i^2 + V_{ovp}^2}$$

Thermal Shutdown Protection

The FP6150B features integrated thermal shutdown protection. When the IC junction temperature exceeds $+150^{\circ}C$, thermal shutdown protection will be triggered. The internal power MOSFET is then turned off to limit the device power dissipation (P_D). Once thermal shutdown occurs, this device can go back to normal operation until the junction temperature drops below $+130^{\circ}C$ approximately.

Application Information

Input Capacitor Selection

The input current to the step-down converter is discontinuous, therefore a capacitor is required to supply the AC current to the step-down converter while maintaining the DC input voltage. Use low ESR capacitors for the best performance. Ceramic capacitors are preferred, but tantalum or low-ESR electrolytic capacitors may also suffice.

The input capacitor can be electrolytic, tantalum or ceramic. When electrolytic or tantalum capacitors are used, a small, high quality 0.1 μ F ceramic capacitor should be placed beside the IC as possible.

When using ceramic capacitors, make sure that they have enough capacitance to provide sufficient charge to prevent excessive voltage ripple at converter input. The input voltage ripple can be estimated by

$$C_{IN} = \frac{I_o}{f \times \Delta V_{IN}} \times D(1-D)$$

Inductor Selection

The inductor is required to supply constant current to the output load while being driven by the switched input voltage. A larger value inductor will result in less ripple current that will result in lower output ripple voltage. However, the larger value inductor will have a larger physical size, higher series resistance, and/or lower saturation current. A good rule for determining the inductance to use is to allow the peak-to-peak ripple current in the inductor to be approximately 30% of the maximum switch current. Also, make sure that the peak inductor current is below the maximum switch current limit. The inductance value can be calculated by

$$L = \frac{V_o + V_D}{I_o \gamma f} \times (1-D)$$

Where r is the ripple current ratio

$$\text{RMS current in inductor } I_{L_{rms}} = I_o \sqrt{1 + \frac{\gamma^2}{12}}$$

Output Capacitor Selection

The output capacitor is required to maintain the DC output voltage. Ceramic, tantalum, or low ESR electrolytic capacitors are recommended. Low ESR capacitors are preferred to keep the output voltage ripple low. The output voltage ripple can be estimated by:

$$\Delta V_{OUT} = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{f \times L \times V_{IN}} \times \left(\text{ESR} + \frac{1}{8 \times f \times C_{OUT}} \right)$$

In the case of ceramic capacitors, the output ripple is dominated by the capacitance value because of its low ESR. In the case of tantalum or electrolytic capacitors, the capacitor high ESR dominates the output ripple. Followings are equations for determining appropriate capacitor parameters.

I . Ceramic capacitors: choose capacitance value

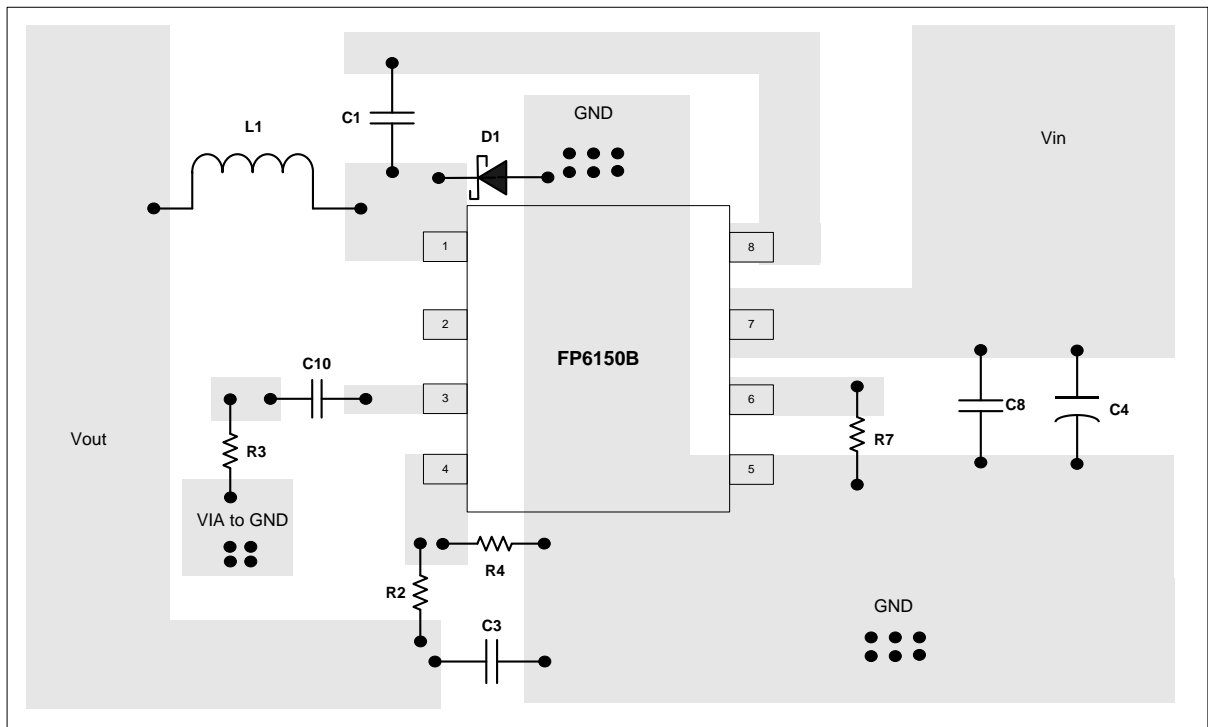
$$C_{OUT} = \frac{V_{OUT}}{8 \times f^2 \times L \times \Delta V_{OUT}} \times \left(1 - \frac{V_{OUT}}{V_{IN}} \right)$$

II . Tantalum or electrolytic capacitors: choose capacitor with ESR value

$$ESR = \frac{\Delta V_{OUT} \times f \times L \times V_{IN}}{V_{OUT} \times (V_{IN} - V_{OUT})}$$

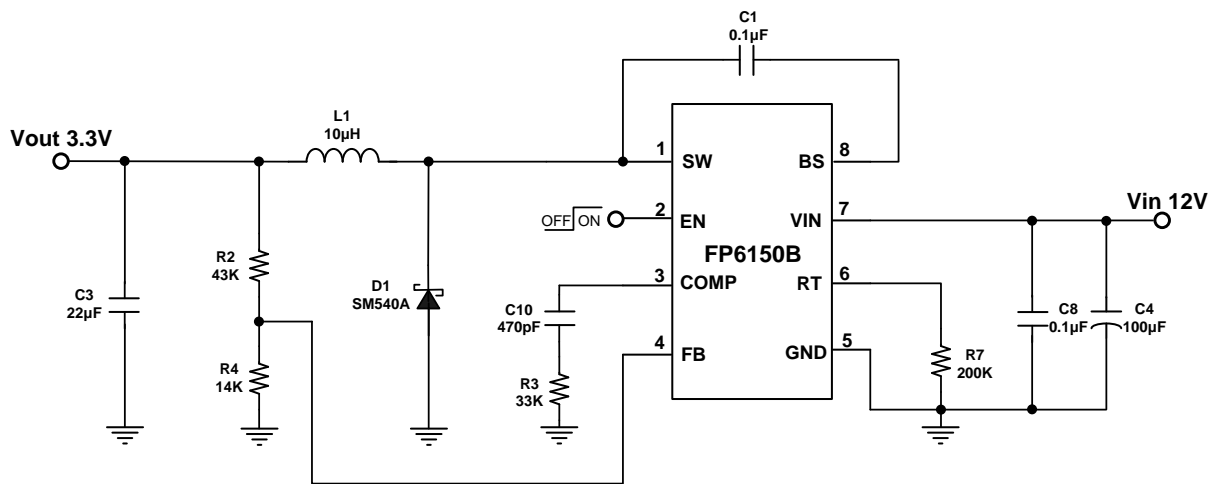
Layout Considerations

1. The power traces, consisting of the GND, SW and V_{IN} traces, should be kept short, direct and wide.
2. Place C_{IN} near IN pin as closely as possible to maintain input voltage steady and filter out the pulsing input current.
3. The resistive divider R_2 and R_4 must be connected directly to FB pin as closely as possible.
4. FB is a sensitive node. Please keep it away from switching node SW. A good approach is to route the feedback trace on another layer and have a ground plane between the top and feedback trace routing layer. This reduces EMI radiation on to the DC-DC converter's own voltage feedback trace.



Suggested Layout

Typical Application

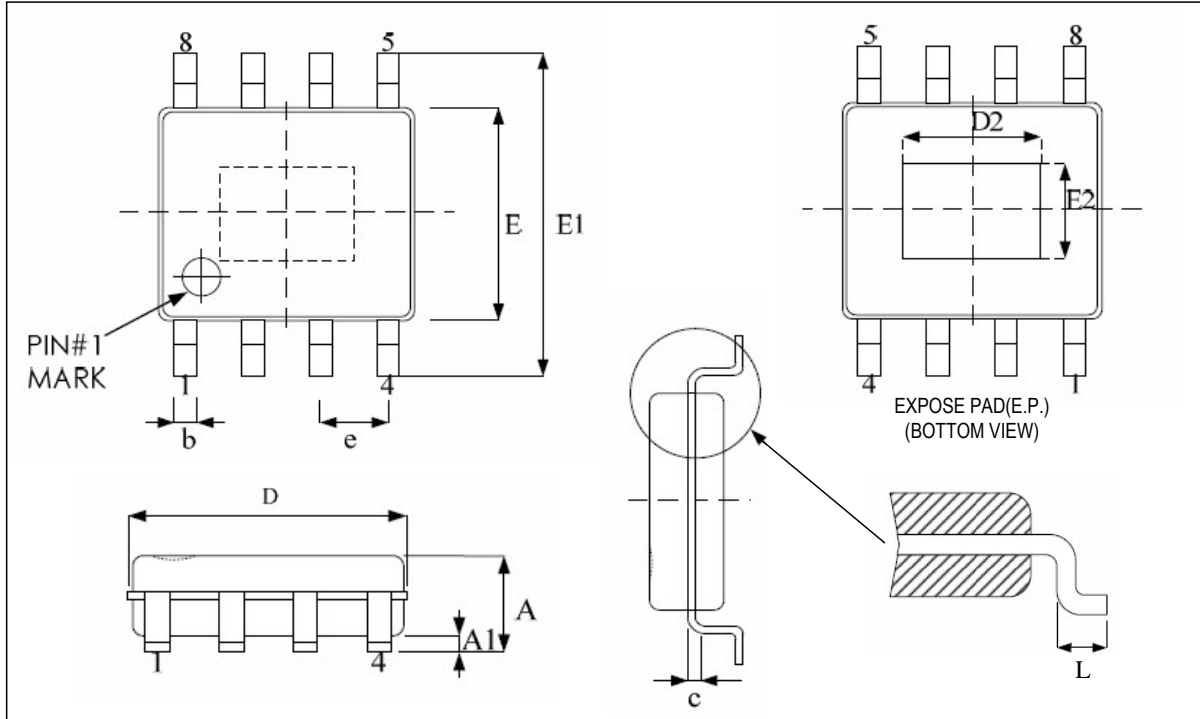


Note:

Output voltage must be lower than input voltage 2V.

Package Outline

SOP-8L (EP)


UNIT: mm

Symbols	Min. (mm)	Max. (mm)
A	1.35	1.75
A1	0.00	0.25
b	0.31	0.51
c	0.10	0.25
D	4.80	5.00
E	3.81	4.00
E1	5.79	6.20
e	1.27 BSC	
L	0.40	1.27

Exposed PAD Dimensions:

Symbols	Min. (mm)	Max. (mm)
D2	2.84	3.30
E2	2.06	2.41