Monolithic Power Systems

MP1556

1.7MHz, 600mA Synchronous Step-Down Converter

PRELIMINARY

General Description

The MP1556 is a 1.7MHz constant frequency, current mode, PWM step-down converter. The device integrates a main switch and a synchronous rectifier for high efficiency without an external Schottky diode. It is ideal for powering portable equipment that runs from a single cell Lithium-Ion (Li+) battery. The MP1556 can supply 600mA of load current from a 2.5V to 6V input voltage. The output voltage can be regulated as low as 0.6V. The MP1556 can also run at 100% duty cycle for low dropout applications.

The MP1556 is available in a low profile (1mm) 5 lead thin SOT package.

Ordering Information

Part Number*	Package	Temperature
MP1556DJ	TSOT23-5	-40°C to +85°C
EV0063	Evaluation Board	
* For Tape & Reel use suffix - Z (e.g. MP1556DJ-Z)		

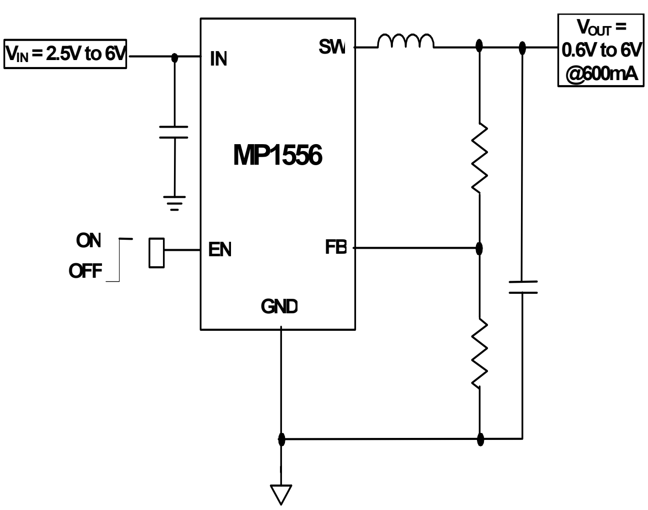
Features

- High Efficiency: Up to 95%
- 1.7MHz Constant Switching Frequency
- 600mA Available Load Current
- 2.5V to 6V Input Voltage Range
- Output Voltage as Low as 0.6V
- 100% Duty Cycle in Dropout
- Current Mode Control
- Short Circuit Protection
- Thermal Fault Protection
- <0.1μA Shutdown Current
- Space Saving 5LD Thin SOT23 Package

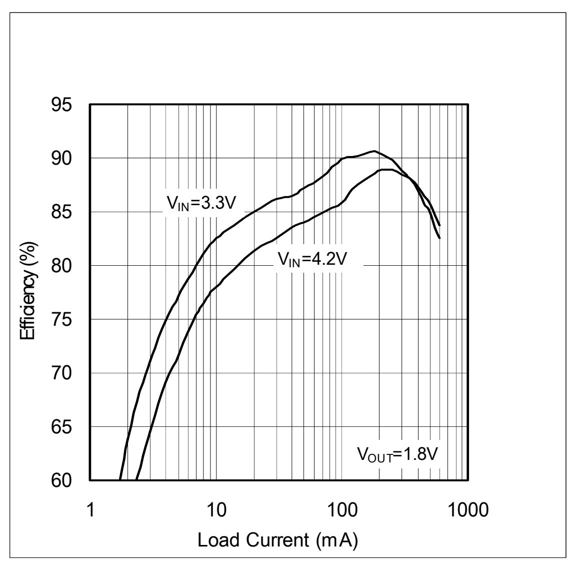
Applications

- Cellular and Smart Phones
- Microprocessors and DSP Core Supplies
- PDAs
- MP3 Players
- Digital Still and Video Cameras
- Portable Instruments

Typical Application Circuit



Efficiency vs. Load Current



Absolute Maximum Ratings (Note 1)

V_{IN} to GND	-0.3V to +6.5V
V_{SW} to GND	-0.3V to V_{IN}+0.3V
V_{FB}, V_{EN} to GND	-0.3V to +6.5V
SW Peak Current	1.4A
Junction Temperature	+150°C
Lead Temperature	+260°C
Storage Temperature	-65°C to +150°C

Recommended Operating Conditions (Note 2)

Supply Voltage V_{IN}	2.5V to 6V
Output Voltage V_{OUT}	0.6V to 6V
Operating Temperature	-40°C to +85°C

Package Thermal Characteristics (Note 3)

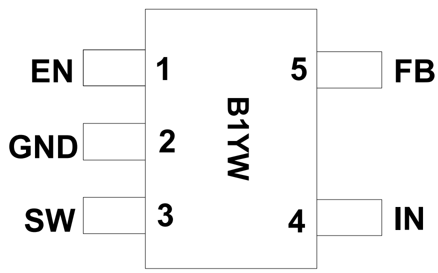
Thermal Resistance, θ_{JA} (TSOT23-5)	220°C/W

Electrical Characteristics (V_{IN}=V_{EN}=3.6V, T_A=+25°C unless otherwise specified, Note 4)

Parameters	Condition	Min	Typ	Max	Units
Supply Current	V_{EN}=V_{IN}, V_{FB}=0.65V		400	600	µA
Shutdown Current	V_{EN}=0V, V_{IN}=6V		0.01	1	µA
IN Undervoltage Lockout Threshold	Rising Edge	2.10	2.27	2.45	V
IN Undervoltage Lockout Hysteresis			55		mV
Output Line Regulation	V_{IN}=2.5V to 6V		0.03		%/V
Output Load Regulation	I_{LOAD}=50mA to 500mA		0.5		%
Regulated FB Voltage	T_A=+25°C -40°C≤T_A≤+85°C	0.588 0.582	0.600 0.600	0.612 0.618	V
FB Input Bias Current	V_{FB}=0.65V	-50	0.5	+50	nA
PFET On Resistance	I_{SW}=100mA		0.44		Ω
NFET On Resistance	I_{SW}=-100mA		0.29		Ω
SW Leakage Current	V_{EN}=0V, V_{IN}=6V V_{SW}=0V or 6V	-1		1	µA
PFET Current Limit	Duty Cycle=100%, Current Pulse Width<1ms	0.7	1.0	1.35	A
Oscillator Frequency		1.26	1.70	2.08	MHz
Thermal Shutdown Trip Threshold			145		°C
EN Trip Threshold	-40°C≤T_A≤+85°C	0.3	0.96	1.5	V
EN Input Current	V_{EN}=0V to 6V	-1		1	µA

Note 1. Exceeding these ratings may damage the device.
Note 2. Devices are not guaranteed to function outside of the operating range.
Note 3. Measured on approximately 1" square of 1 oz. copper.
Note 4. 100% production test at +25°C. Specifications over the temperature range are guaranteed by design and characterization.

Pin Configuration



TSOT23-5
Top View
Marking: B1YW

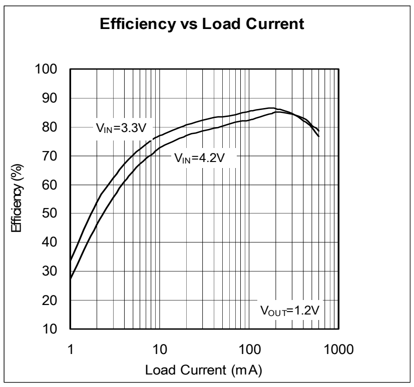
Table 1: Pin Designators

Name	Pin Number	Description
EN	1	Regulator Enable Control Input. Drive EN above 1.5V to turn on the MP1556. Drive EN below 0.3V to turn it off (shutdown current<0.1µA).
GND	2	Ground
SW	3	Power Switch Output. Inductor connection to drains of the internal PFET and NFET switches.
IN	4	Supply Input. Bypass to GND with a 2.2µF or greater ceramic capacitor.
FB	5	Feedback Input. Connect FB to the center point of the external resistor divider. The feedback threshold voltage is 0.6V.

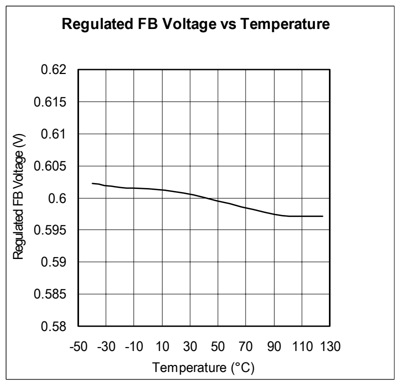
Typical Operating Characteristics

(Circuit of Figure 2. V_{IN}=3.3V, V_{OUT}=1.8V, L1=2.2µH, C1=4.7µF, C3=10µF, T_A=+25°C, unless otherwise noted.)

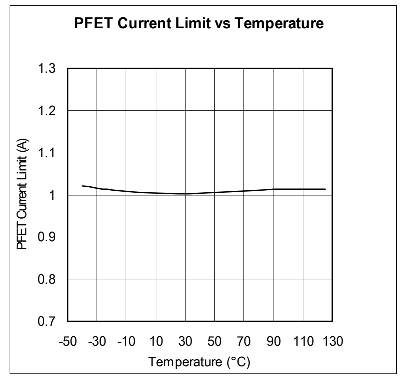
Efficiency vs. Load Current



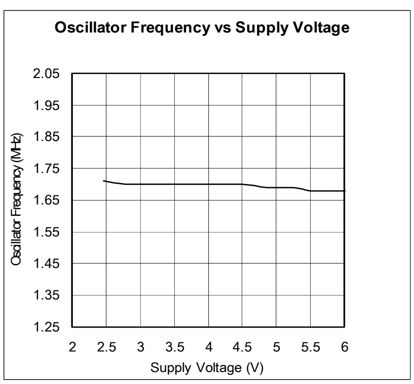
Regulated V_{FB} vs. Temp



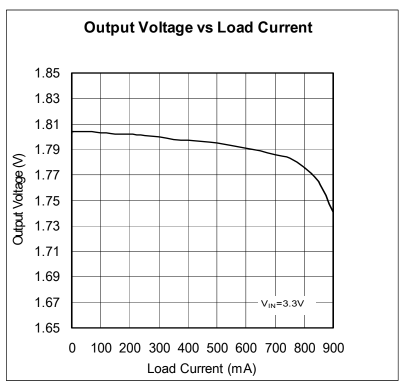
PFET Current Limit vs. Temp



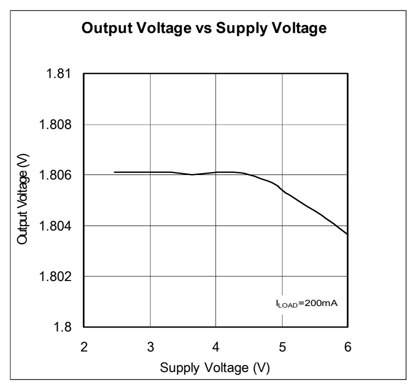
f_{OSC} vs. V_{IN}



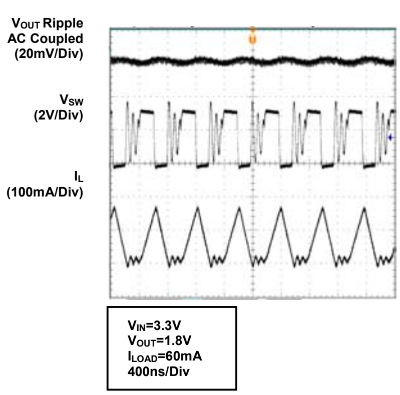
V_{OUT} vs. I_{LOAD}



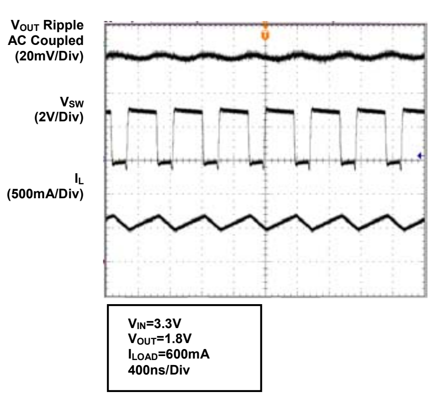
V_{OUT} vs. V_{IN}



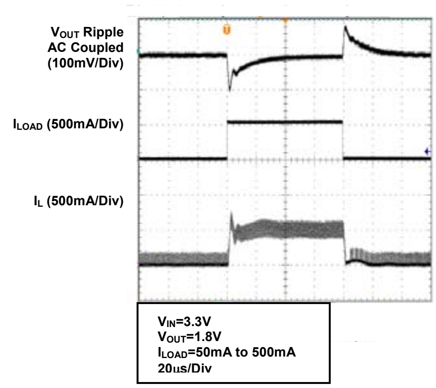
Light Load Operation



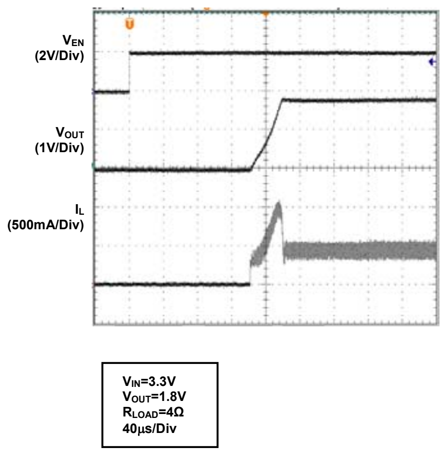
Heavy Load Operation



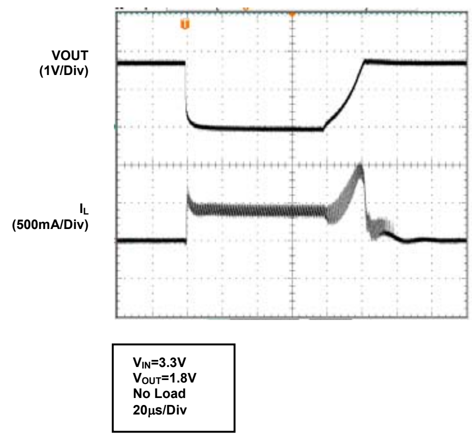
Load Transient



Startup from Shutdown



Short Circuit Recovery



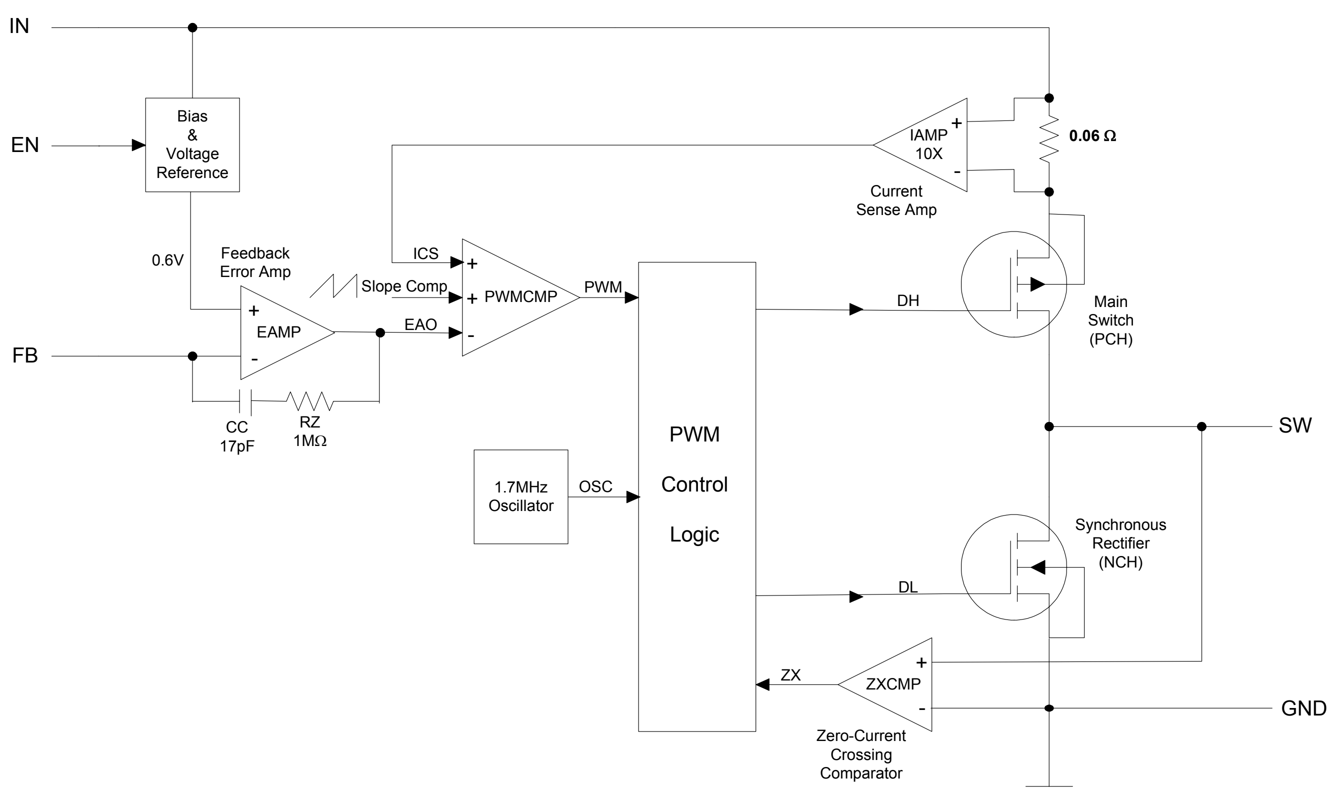


Figure 1: MP1556 Functional Block Diagram

Detailed Description

The MP1556 is a constant frequency current mode PWM step-down converter. The MP1556 is optimized for low voltage, Li-Ion battery powered applications where high efficiency and small size are critical. The MP1556 uses an external resistor divider to set the output voltage from 0.6V to 6V. The device integrates both a main switch and a synchronous rectifier, which provides high efficiency and eliminates an external Schottky diode. The MP1556 can achieve 100% duty cycle. The duty cycle D of a step-down converter is defined as:

$$D = T_{ON} \times f_{OSC} \times 100\% \approx \frac{V_{OUT}}{V_{IN}} \times 100\%$$

where T_{ON} is the main switch on time, and f_{OSC} is the oscillator frequency (1.7MHz).

Current Mode PWM Control

Slope compensated current mode PWM control provides stable switching and cycle-by-cycle current limit for superior load and line response and protection of the internal main switch and synchronous rectifier. The MP1556 switches at a constant frequency (1.7MHz) and regulates the output voltage. During each cycle the PWM comparator modulates the power transferred to the load by changing the inductor peak current based on the feedback error voltage. During normal operation, the main switch is turned on for a certain time to ramp the inductor current at each rising edge of the internal oscillator, and switched off when the peak inductor current is above the error voltage. When the main switch is off, the synchronous rectifier will be turned on immediately and stay on until either the next cycle starts or the inductor current drops to zero (see Figure 1). The device skips pulses to improve efficiency at light load.

Dropout Operation

The MP1556 allows the main switch to remain on for more than one switching cycle and increases the duty cycle while the input voltage is dropping close to the output voltage. When the duty cycle reaches 100%, the main switch is held on continuously to deliver current to the output up to the PFET current limit. The output voltage then is the input voltage minus the voltage drop across the main switch and the inductor.

Short Circuit Protection

The MP1556 has short circuit protection. When the output is shorted to ground, the oscillator frequency is reduced to prevent the inductor current from increasing beyond the PFET current limit. The PFET current limit is also reduced to lower the short circuit current. The frequency and current limit will return to the normal values once the short circuit condition is removed and the feedback voltage reaches 0.6V.

Maximum Load current

The MP1556 can operate down to 2.5V input voltage, however the maximum load current decreases at lower input due to large IR drop on the main switch and synchronous rectifier. The slope compensation signal reduces the peak inductor current as a function of the duty cycle to prevent sub-harmonic oscillations at duty cycles greater than 50%. Conversely the current limit increases as the duty cycle decreases.

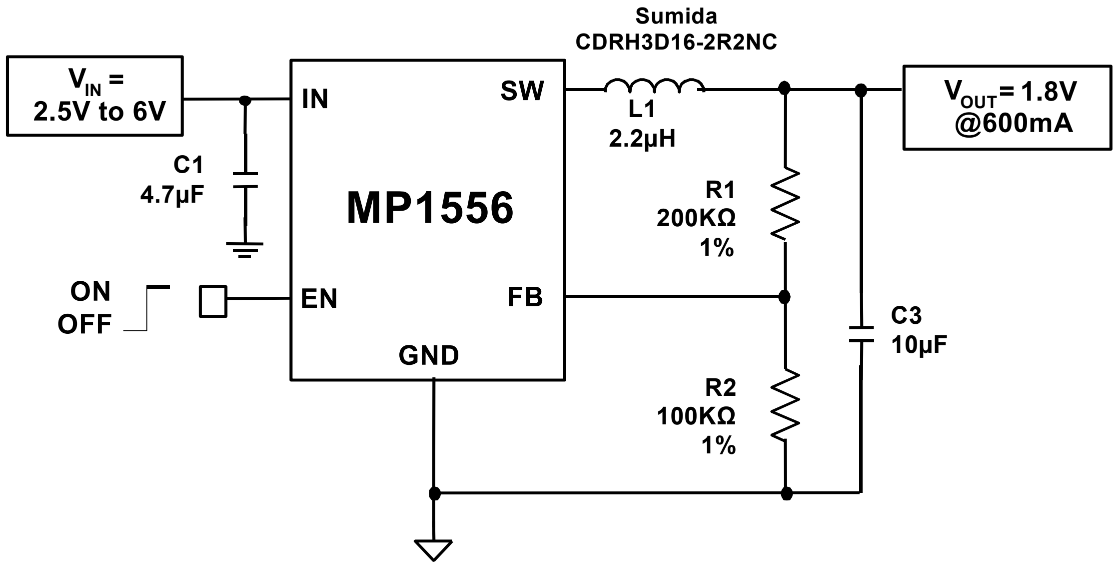


Figure 2: V_{IN}=2.5V to 6V, V_{OUT}=1.8V, I_{LOAD}=600mA Step-Down Circuit

Design Information

Output Voltage Setting

The external resistor divider sets the output voltage (see Figure 2). The feedback resistor R1 also sets the feedback loop bandwidth with the internal compensation capacitor (see Figure 1). Choose R1 around 200KΩ for optimal transient response. R2 is then given by:

$$R2 = \frac{R1}{\frac{V_{OUT}}{0.6V} - 1}$$

Table 2: Resistor Selection vs. Output Voltage Setting

V_{OUT}	R1	R2
1.2V	200KΩ (1%)	200KΩ (1%)
1.5V	200KΩ (1%)	133KΩ (1%)
1.8V	200KΩ (1%)	100KΩ (1%)
2.5V	200KΩ (1%)	63.4KΩ (1%)

Inductor Selection

A 1µH to 4.7µH inductor with DC current rating at least 20% higher than the maximum load current is recommended for most applications. For best efficiency, the inductor DC resistance shall be <200mΩ. See Table 3 for recommended inductors and manufacturers. For most designs, the inductance value can be derived from the following equation:

$$L = \frac{V_{OUT} \times (V_{IN} - V_{OUT})}{V_{IN} \times RI_L \times I_{LOAD(MAX)} \times f_{OSC}}$$

where RI_L is the percentage of the inductor ripple current. Choose RI_L between 20% and 40% of the maximum load current for the best performance.

The maximum inductor peak current is:

$$I_{L(MAX)} = (1 + \frac{RI_L}{2}) \times I_{LOAD(MAX)}$$

When the load current I_{LOAD} falls below $RI_L/2$, the inductor current becomes discontinuous.

Table 3: Suggested Surface Mount Inductors

Manufacturer	Part Number	Inductance (µH)	Max DCR (Ω)	Saturation Current (A)	Dimensions LxWxH (mm^3)
Coilcraft	LP1704-222M	2.2	0.07	1.7	6.5x5.3x2
Toko	D312C	2.2	0.14	1.0	3.6x3.6x1
Sumida	CDRH3D16	2.2	0.072	1.2	4x4x1.8
Taiyo Yuden	LBC2518	2.2	0.13	0.6	2.5x1.8x1.8

Input Capacitor Selection

The input capacitor reduces the surge current drawn from the input and switching noise from the device. The input capacitor impedance at the switching frequency shall be less than input source impedance to prevent high frequency switching current passing to the input. Ceramic capacitors with X5R or X7R dielectrics are highly recommended because of their low ESR and small temperature coefficients. For most applications, a 2.2µF capacitor is sufficient.

Output Capacitor Selection

The output capacitor keeps output voltage ripple small and ensures regulation loop stable. The output capacitor impedance ESR shall be low at the switching frequency. Ceramic capacitors with X5R or X7R dielectrics are recommended. The output ripple ΔV_{OUT} is approximately:

$$\Delta V_{OUT} \leq RI_L \times I_{LOAD(MAX)} \times \left[ESR + \frac{1}{8 \times f_{OSC} \times C3} \right]$$

PC Board Layout

The high current paths (GND, IN and SW) should be placed very close to the device with short, direct and wide traces. Input capacitor C1 needs to be as close as possible to the IN and GND pins. The external feedback resistors shall be placed next to the FB pin. Keep the switching node SW short and away from the feedback network. Figure 3 illustrates an example of PCB layout and signal routing.

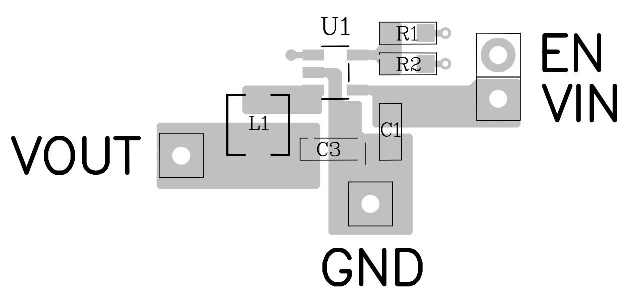


Figure 3: MP1556 Suggested Layout

Packaging

TSOT23-5