1MHz 2.5A Current-Mode Step-Up DC/DC Converter

Description

The FP67380 is a current-mode, pulse-width modulation, step-up DC/DC converter. The built-in high voltage N-channel MOSFET allows FP67380 for step-up applications with up to 24V output voltage, as well as for Single Ended Primary Inductance Converter (SEPIC).

The high switching frequency (1MHz) allows the use of small external components. The soft-start function is programmable with an external capacitor, which sets the input current ramp rate.

The FP67380 is available in space-saving TDFN-6 (2mm×2mm) package.

Features

- Fixed Frequency 1MHz Current-Mode PWM Operation
- Adjustable Output Voltage up to 24V
- Automatically Switch to PSM Mode for Improving Efficiency at Light Load
- 3V to 24V Input Range
- Maximum 1μA Shutdown Current
- Programmable Soft-start / Internal Soft-start
- Meet SMD Ceramic Inductor application
- Space-Saving TDFN-6 (2mm×2mm) Package
- RoHS Compliant

Applications

- LCD Displays
- Portable Applications
- Handheld Devices

Pin Assignments

WD Package: TDFN-6 (2mm×2mm)

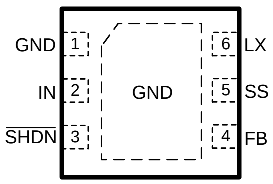
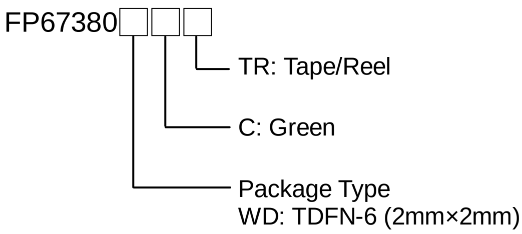


Figure 1. Pin Assignment of FP67380

Ordering Information



TDFN-6 (2mmx2mm) Marking

Part Number	Product Code
FP67380WDCTR	**FM3**

Typical Application Circuit

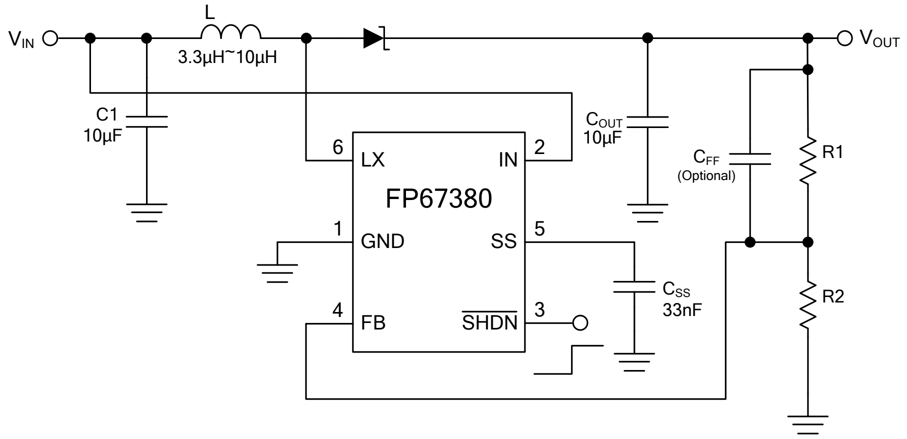


Figure 2. Typical Application Circuit

Functional Pin Description

Pin Name	Pin No.	Pin Function
GND	1	Ground.
IN	2	Internal Bias Voltage Input. Connect IN to the input voltage source. Bypass IN to GND with a 10μF or greater capacitor as close to IN as possible.
$\overline{SHDN}$	3	Shutdown Input. Drive $\overline{SHDN}$ low to turn off the converter. To automatically start the converter, connect $\overline{SHDN}$ to IN. Do not leave $\overline{SHDN}$ unconnected
FB	4	Feedback Pin. Connect a resistive voltage-divider from the output to FB to set the output voltage.
SS	5	Soft-start Input. Connect a soft-start capacitor from SS to GND to soft-start the converter. Leave SS open to inform internal soft-start function.
LX	6	Switch Node Pin. Connect LX to the inductor and output rectifier. Connect components as close to LX as possible.

Block Diagram

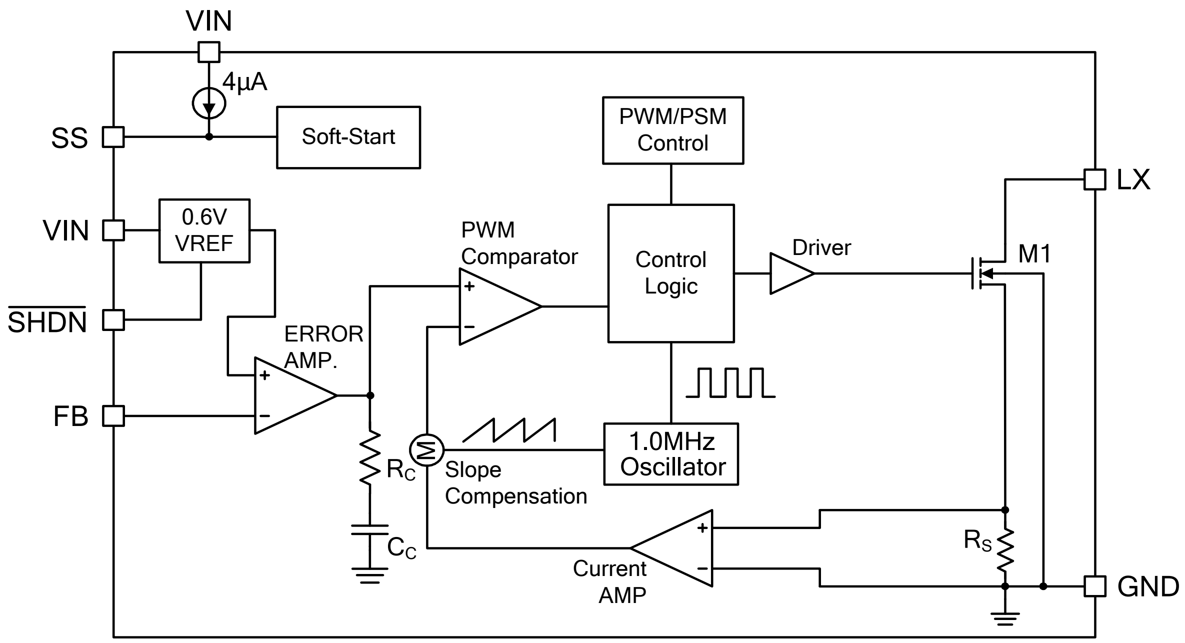


Figure 3. Block Diagram

Absolute Maximum Ratings (Note 1)

- LX , Vin to GND -- +26V
- All Other Pins to GND --- +6V
- LX Voltage V_{LX} (15ns) -- -6V to V_{IN}+6V
- Power Dissipation @T_A=25°C, (P_D)

  TDFN-6 (2mm×2mm)-- 1.25W
- Package Thermal Resistance, (θ_{JA})

  TDFN-6 (2mm×2mm)-- 80°C/W
- Package Thermal Resistance, (θ_{JC})

  TDFN-6 (2mm×2mm)-- 56°C/W
- Junction Temperature (T_J) -- +150℃
- Storage Temperature Range (T_S) -- -65℃ to +150℃
- Lead Temperature (Soldering, 10 sec.) (T_{LEAD}) -- +260℃

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

Recommended Operating Conditions

- Input Voltage (V_{IN}) -- +3V to +24V
- Operating Junction Temperature Range (T_{OP}) -- -40℃ to +85℃

Electrical Characteristics

(V_{IN}=5V, T_A=25 ºC, unless otherwise specified.)

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input Supply Range	V_{IN}		3		24	V
Output Voltage Adjustable Range	V_{OUT}				24	V
Quiescent Current	I_{IN}	V_{FB}=0.7V, not switching		250	400	μA
		V_{FB}=0.6V, switching		1		mA
Shutdown Supply Current	I_{SD}	$V_{\overline{SHDN}}$=0V		0.1	1	μA
Under Voltage Lockout	V_{UVLO}				2.9	V
Under Voltage Lockout Hysteresis	ΔV_{UVLO}			0.2		V
Thermal Shutdown (Note 2)	T_{SD}			150		°C
Thermal Shutdown Hysteresis				30		°C
Error Amplifier						
Feedback Regulation Set Point	V_{FB}		0.588	0.6	0.612	V
FB Input Bias Current	I_{FB}	V_{FB}=0.6V		21	80	nA
Line Regulation		3V<VIN<24V		0.05	1	%/V
Oscillator						
Frequency	f_{OSC}		800	1000	1200	KHz
Maximum Duty Cycle	DC	FB=GND	90	95		%
Power Switch						
On Resistance	$R_{DS(ON)}$	Guaranteed By Design		0.2		Ω
Switch Current Limit	I_{LIM}			2.5		A
Leakage Current	$I_{LX(OFF)}$	V_{LX}=25V, T_A=+25°C		0.1	1	μA
Soft-Start						
Charge Current	I_{SS}		2	4	7	μA
Soft-start time	t_{SS}	SS Pin Voltage=1V, C_{SS}=10nF		2		ms
Internal Soft-start time	t_{SS}	C_{SS}=NC		1		ms
Control Input						
Input Low Voltage	V_{IL}	$V_{\overline{SHDN}}$, V_{IN}=2.5V to 6V			0.3	V
Input High Voltage	V_{IH}	$V_{\overline{SHDN}}$, V_{IN}=2.5V to 6V	1.0			V
$\overline{SHDN}$ Input Current	$I_{\overline{SHDN}}$	$V_{\overline{SHDN}}$=5V		0.1	1	μA

Note 2: The specification is guaranteed by design, not production test.

Typical Performance Curves

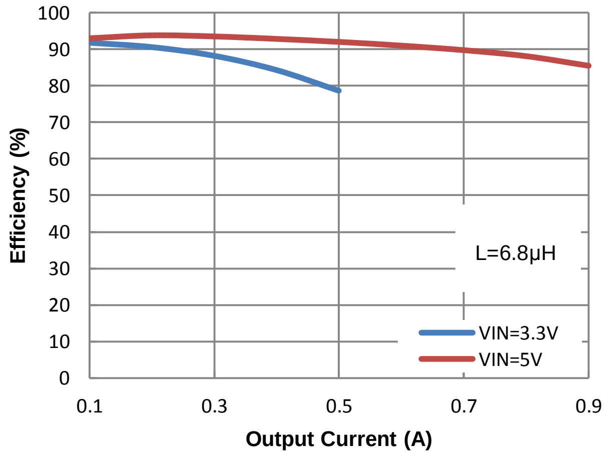


Figure 4. Efficiency vs. Output Current (VOUT=12V)

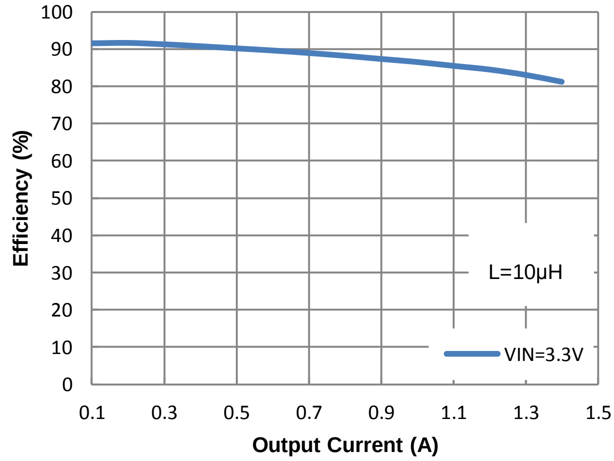


Figure 5. Efficiency vs. Output Current (VOUT=5V)

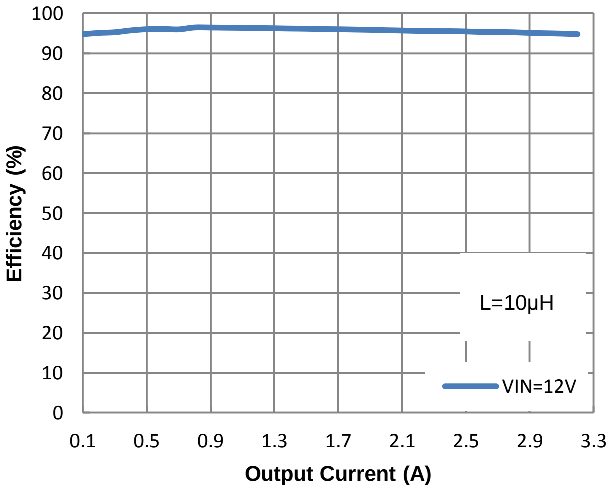


Figure 6. Efficiency vs. Output Current (VOUT=13V)

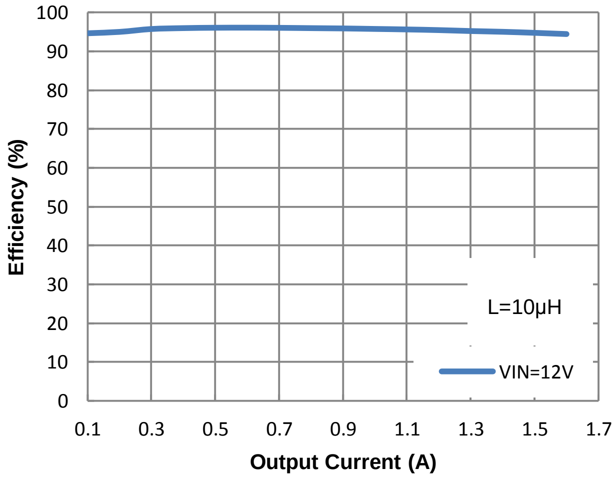


Figure 7. Efficiency vs. Output Current (VOUT=18V)

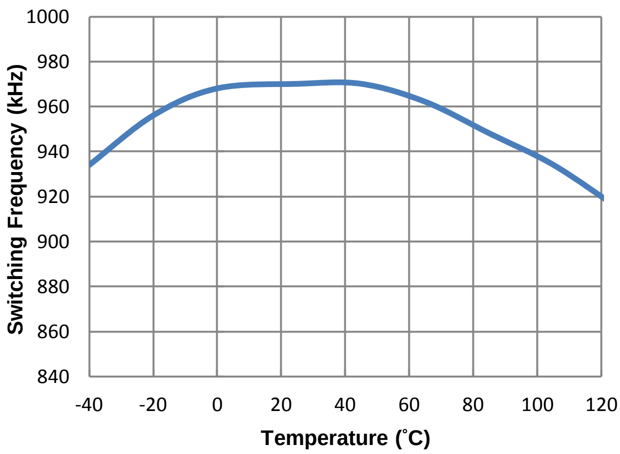


Figure 8. Switching Frequency vs. Temperature

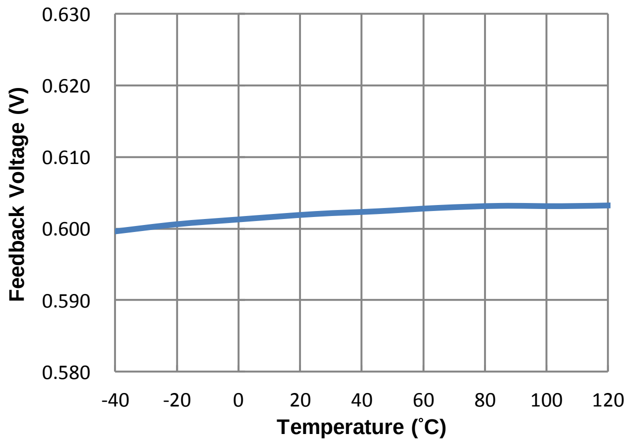
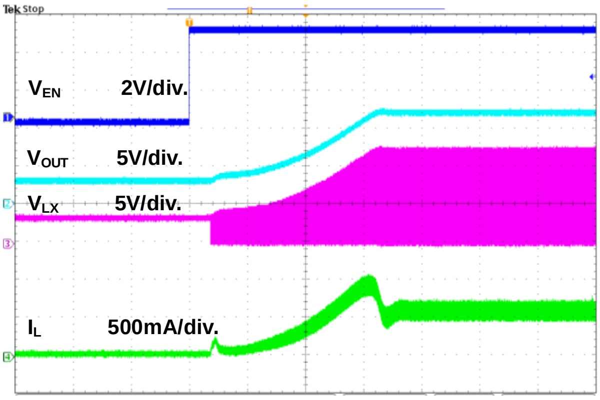


Figure 9. Feedback Voltage vs. Temperature

Typical Performance Curves (Continued)

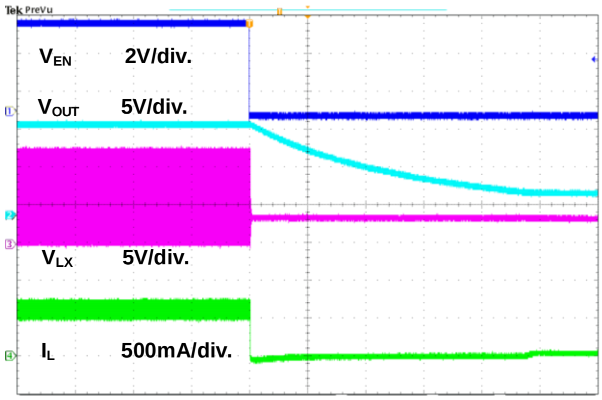
V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=140mA



400μs/div.

Figure 10. Power On Through EN Waveform

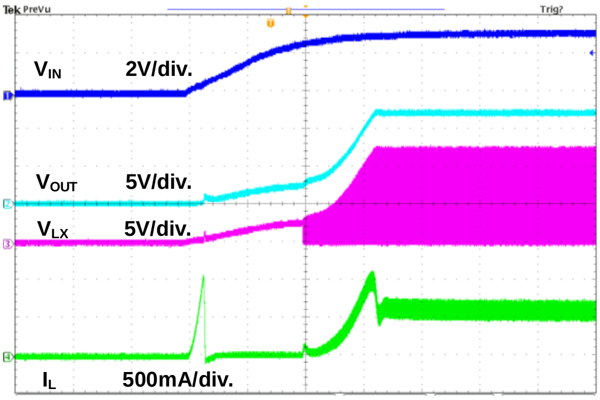
V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=140mA



200μs/div.

Figure 11. Power Off Through EN Waveform

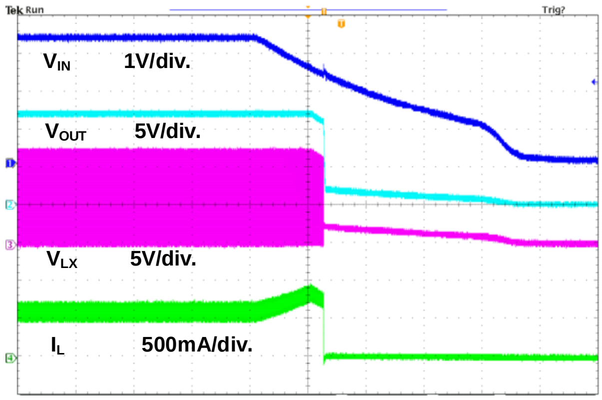
V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=140mA



1ms/div.

Figure 12. Power On Through VIN Waveform

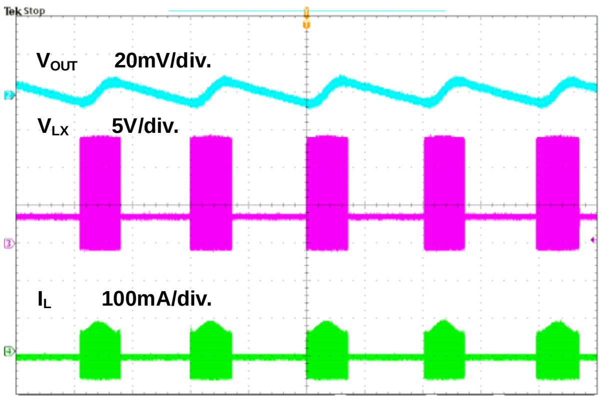
V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=140mA



40ms/div.

Figure 13. Power Off Through VIN Waveform

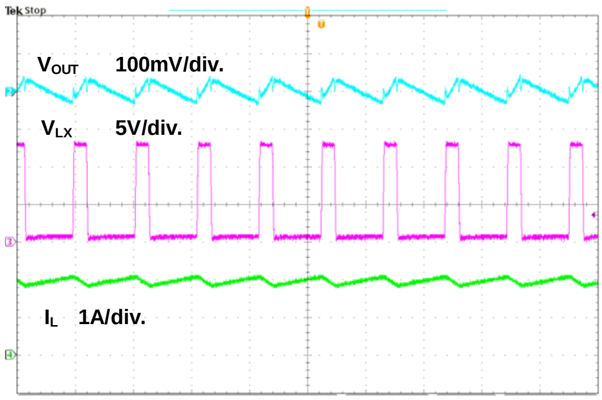
V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=0mA



4ms/div.

Figure 14. Switching Waveform

V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=420mA



1μs/div.

Figure 15. Switching Waveform

Typical Performance Curves (Continued)

V_{IN}=12V, V_{OUT}=18V, I_{OUT}=0mA

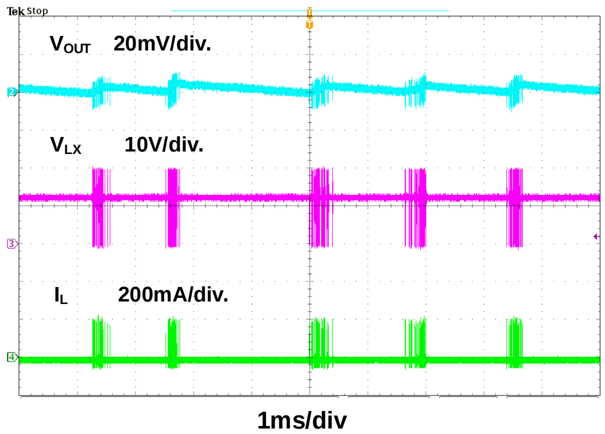


Figure 16. Switching Waveform

V_{IN}=12V, V_{OUT}=18V, I_{OUT}=1400mA

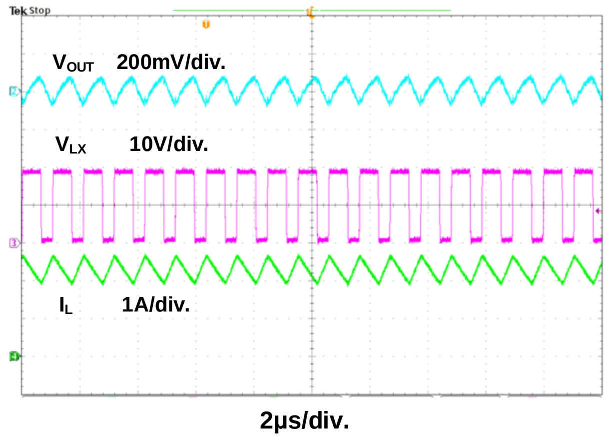


Figure 17. Switching Waveform

V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=50mA→200mA

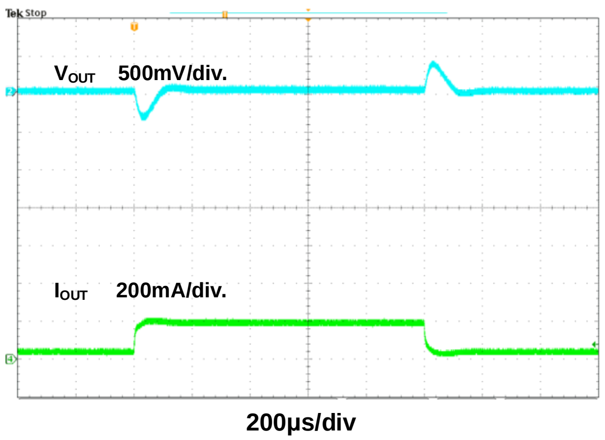


Figure 18. Load Transient Response

V_{IN}=3.3V, V_{OUT}=12V, I_{OUT}=200mA→400mA

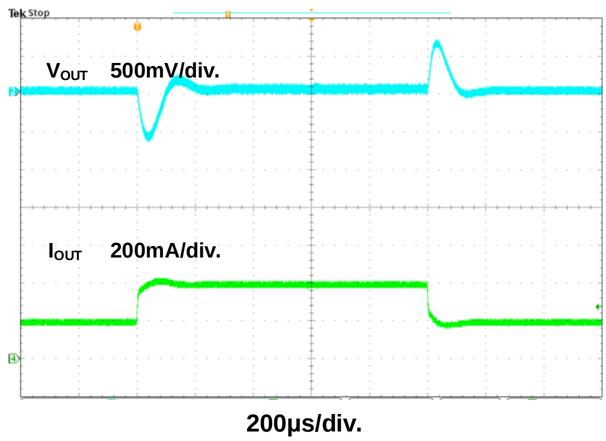


Figure 19. Load Transient Response

V_{IN}=12V, V_{OUT}=18V, I_{OUT}=100mA→800mA, PSM→PWM

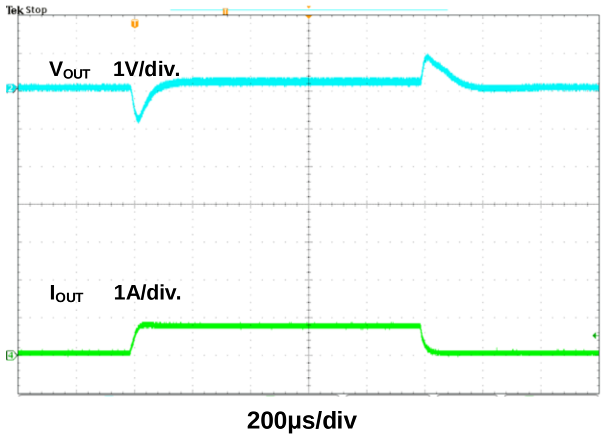


Figure 20. Load Transient Response

V_{IN}=12V, V_{OUT}=18V, I_{OUT}=800mA→1600mA

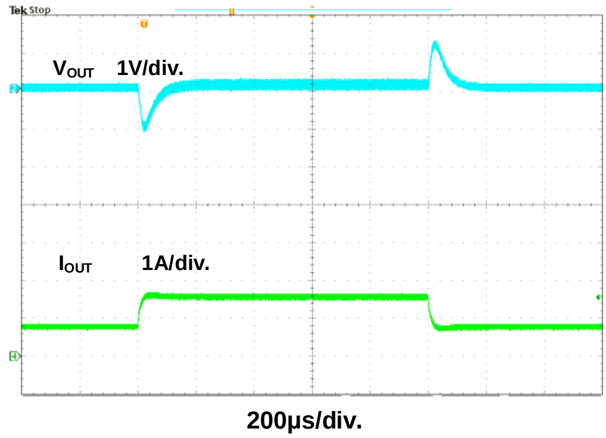


Figure 21. Load Transient Response

Function Information

Controller Circuit

The device is based on a current-mode control topology and uses a constant frequency pulse-width modulator to regulate the output voltage. The controller limits the current through the power switch on a pulse by pulse basis. The current sensing circuit is integrated in the device; therefore, no additional components are required. Due to the nature of the boost converter topology used here, the peak switch current is the same as the peak inductor current, which will be limited by the integrated current limiting circuits under normal operating conditions.

PSM Mode

The FP67380 is designed for high efficiency over wide output current range. Even at light load, the efficiency stays high because the switching losses of the converter are minimized by effectively reducing the switching frequency. The controller will enter a power saving mode if certain conditions are met. In this mode, the controller only switches on the transistor if the output voltage trips below a set threshold voltage. It ramps up the output voltage with one or several pulses, and goes again into PSM mode once the output voltage exceeds a set threshold voltage.

Device Enable

The device will be shut down when EN is set to GND. In this mode, the regulator stops switching, all internal control circuitry including the low-battery comparator will be switched off. This also means that the output voltage may drop below the input voltage during shutdown.

The device is put into operation when EN is set high. During start-up of the converter, the duty cycle is limited in order to avoid high peak currents drawn from the battery. The limit is set internally by the current limit circuit.

Current Limit Protection

The FP67380 provides cycle-by-cycle over-current protection. Current limit is accomplished by sensing voltage drop across the drain to source of power switch. If the current sense amplifier output voltage is larger than current-limited threshold level (Typ. 2.5A), it will immediately turn off power MOS.

Thermal Protection

Thermal protection limits total power dissipation in the FP67380. When the junction temperature exceeds Tj=150°C, the thermal sensor signals the shutdown logic and turns off most of the internal circuitry. The thermal sensor will turn internal circuitry on again after the IC's junction temperature drops 30°C.

Open-Circuit Protection

In the cases of output open circuit, when the R1 are disconnected from the circuit, the feedback voltage will be zero. The FP67380 will then switch at a high duty cycle resulting in a high output voltage, which may cause the LX pin voltage to exceed its maximum 24V rating. A zener diode can be used at the output to limit the voltage on the LX pin (Figure 22). The zener voltage should be larger than the maximum voltage of the V_{OUT}. The current rating of the zener should be larger than 0.1mA.

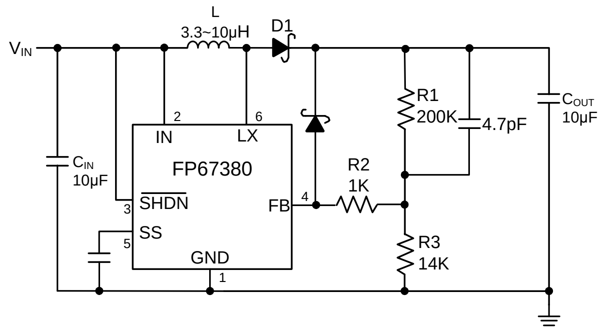


Figure 22. With Open-Circuit Protection

Application Information

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:

$$\Delta I_L=\frac{(V_{OUT}-V_{IN})}{L\times f_S}\left(\frac{V_{IN}}{V_{OUT}}\right)$$

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%~40% of the maximum load current is also acceptable. Then the inductor ripple current can be calculated with the following equation:

$$\Delta I_L=0.3\times I_{OUT(MAX)}\times\frac{V_{OUT}}{V_{IN}}$$

The inductor value can be calculated as:

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

A 3.3μH to 10μH inductor is recommended for general use. The value of inductor depends on the operating frequency. Higher frequency allows smaller inductor and capacitor but increasing internal switching loss. There are two inductor parameters should be considered, current rating and DCR. The DCR of inductor affects the efficiency of the converter. The inductor with lowest DCR is chosen for highest efficiency.

The inductor should be rated for the maximum output current ($I_{O(MAX)}$) plus the inductor ripple current (ΔI_L) to avoid saturation. The maximum inductor current ($I_{L(MAX)}$) is given by:

$$I_{L(MAX)}=I_{O(max)}\times\frac{V_{OUT}}{V_{IN}}+\frac{\Delta I_L}{2}$$

Adjustable Output Voltage

The output voltage V_{OUT} is set using a resistive divider from the output to FB. The FB pin regulated voltage is 0.6V. Thus the output voltage is:

$$V_{OUT}=0.6\times\left(1+\frac{R1}{R2}\right)$$

Capacitor Selection

The input capacitor can reduce peak current and noise at power source. It should be 10μF at least and be increased for better input voltage filtering. Select the input capacitor to meet the input ripple current and voltage rating.

When selecting an output capacitor, consider the output ripple voltage and the ripple current. The ESR of capacitor is a major factor to the output ripple. For best performance, a low ESR output capacitor is required. The ripple voltage is given by:

$$\Delta V_O=ESR\times\Delta I_L$$

The minimum output capacitor can be calculated with the following equation:

$$C_{OUT(min)}=\frac{I_{OUT(max)}\times(V_{OUT}-V_{IN})}{V_{OUT}\times f_S\times\Delta V_O}$$

The small size of ceramic capacitors makes them ideal for FP67380 applications.

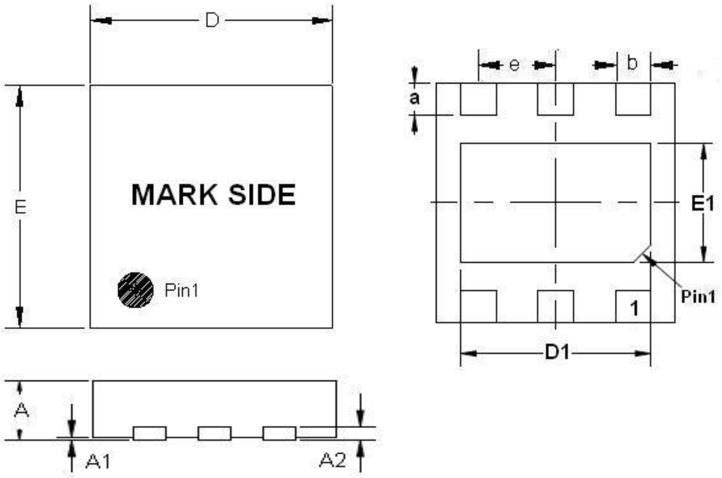
X5R and X7R types are recommended because they retain their capacitance over wider voltage and temperature ranges than other types such as Y5V or Z5U. A 10μF input capacitor and a 10μF output capacitor are sufficient for most FP67380 applications.

Diode Selection

Schottky diodes, with their low forward voltage drop and fast reverse recovery, are the ideal choices for FP67380 applications. The forward voltage drop of a Schottky diode represents the conduction losses in the diode, while the diode capacitance (C_T or C_D) represents the switching losses. For diode selection, both forward voltage drop and diode capacitance need to be considered. Schottky diodes with higher current ratings usually have lower forward voltage drop and larger diode capacitance, which can cause significant switching losses at the 1MHz switching frequency of the FP67380. A Schottky diode rated at 3A is sufficient for most FP67380 applications.

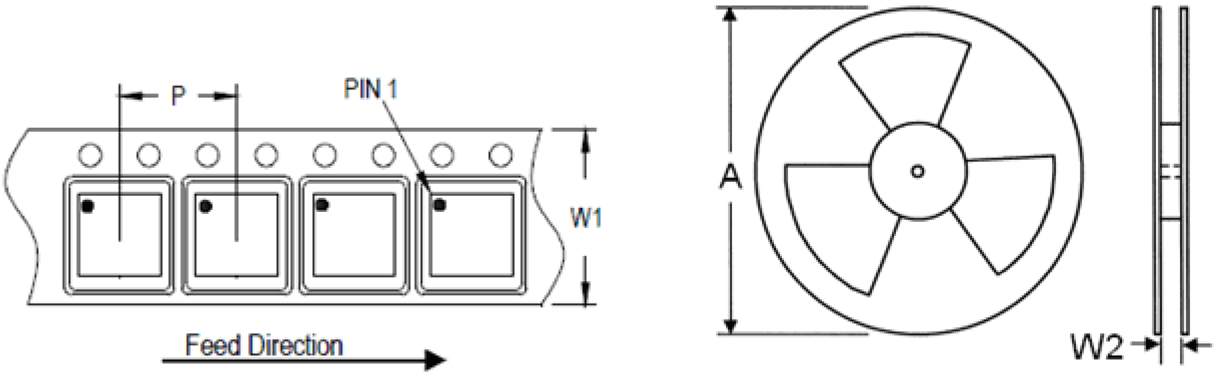
Outline Information

TDFN-6 2mm×2mm (pitch 0.65 mm) 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

Life Support Policy
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