Low Power DC/DC Boost Converter

UM1660 *SOT23-5*

General Description

The UM1660 is a high-frequency boost converter dedicated for small to medium LCD bias supply and white LED backlight supplies. The device is ideal to generate output voltages up to 28V from a single cell Li-Ion battery. The part can also be used to generate standard 3.3V/5V to 12V power conversions. The UM1660 operates with a switching frequency up to 1MHz. This allows the use of small external components using ceramic as well as tantalum output capacitors.
Together with the tiny SOT23 package, the UM1660 gives a very small overall solution size. The UM1660 has an internal 400mA switch current limit, offering lower output voltage ripple and allows the use of a smaller form factor inductor for lower power applications. The low quiescent current (typically 28μA) together with an optimized control scheme, allows device operation at very high efficiencies over the entire load current range.

Applications

- LCD Bias Supply
- White-LED Supply for LCD Backlights
- Digital Still Camera
- PDAs, Organizers and Handheld PCs
- Cellular Phones
- Internet Audio Player
- Standard 3.3V/5V to 12V Conversion

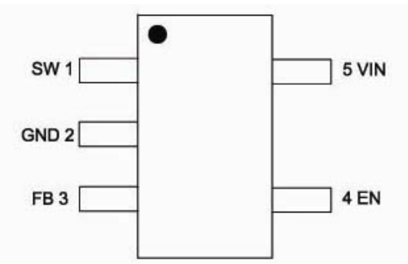
Features

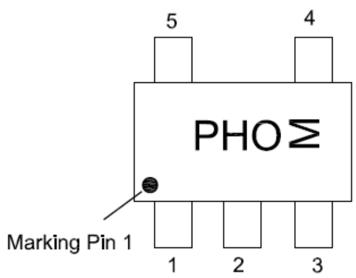
- 1.8V to 6.0V Input Voltage Range
- Adjustable Output Voltage Range up to 28V
- 400mA Internal Switch Current
- Up to 1MHz Switching Frequency
- 28μA Typical No Load Quiescent Current
- 1μA Typical Shutdown Current
- Internal Soft-Start
- Available in a Tiny SOT23-5 Package

Pin Configurations

Top View

Top View





M: Month Code
UM1660
SOT23-5

Ordering Information

Part Number	Packaging Type	Marking Code	Shipping Qty
UM1660	SOT23-5	PHO	3000pcs/7Inch Tape & Reel

Pin Description

Pin Number	Symbol	Function
1	SW	Connect the inductor and the Schottky diode to this pin. This is the switch pin and is connected to the drain of the internal power MOSFET.
2	GND	Ground
3	FB	This is the feedback pin of the device. Connect this pin to the external voltage divider to program the desired output voltage.
4	EN	This is the enable pin of the device. Pulling this pin to ground forces the device into shutdown mode reducing the supply current to less than 1μA. This pin should not be left floating and needs to be terminated.
5	VIN	Supply voltage pin

Absolute Maximum Ratings

Over operating free-air temperature (unless otherwise noted) (Note 1)

Symbol	Parameter	Value	Unit
V_{IN}	Supply Voltage on VIN (Note 2)	-0.3 to +7.0	V
$V_{FB,}$ V_{EN}	Voltages on FB, EN (Note 2)	-0.3 to V_{IN} +0.3	V
V_{SW}	Switch Voltage on SW (Note 2)	30	V
P_D	Continuous Power Dissipation at T_A = 25°C	357	mW
T_J	Operating Junction Temperature	-40 to +150	°C
T_{STG}	Storage Temperature Range	-65 to +150	°C
T_L	Maximum Lead Temperature for Soldering 10 seconds	+260	°C

Note 1: Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under recommended operating conditions is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Note 2: All voltage values are with respect to network ground terminal.

Recommended Operating Conditions

Symbol	Parameter	Min	Typ	Max	Unit
V_{IN}	Input Voltage Range	1.8		6.0	V
V_{OUT}	Output Voltage Range			28	V
L	Inductor (Note 3)	2.2	10		μH
f	Switching Frequency (Note 3)			1	MHz
C_{IN}	Input Capacitor (Note 3)		4.7		μF
C_{OUT}	Output Capacitor (Note 3)	1			μF
T_A	Operating Ambient Temperature	-40		85	°C
T_J	Operating Junction Temperature	-40		125	°C

Note 3: Refer to application section for further information.

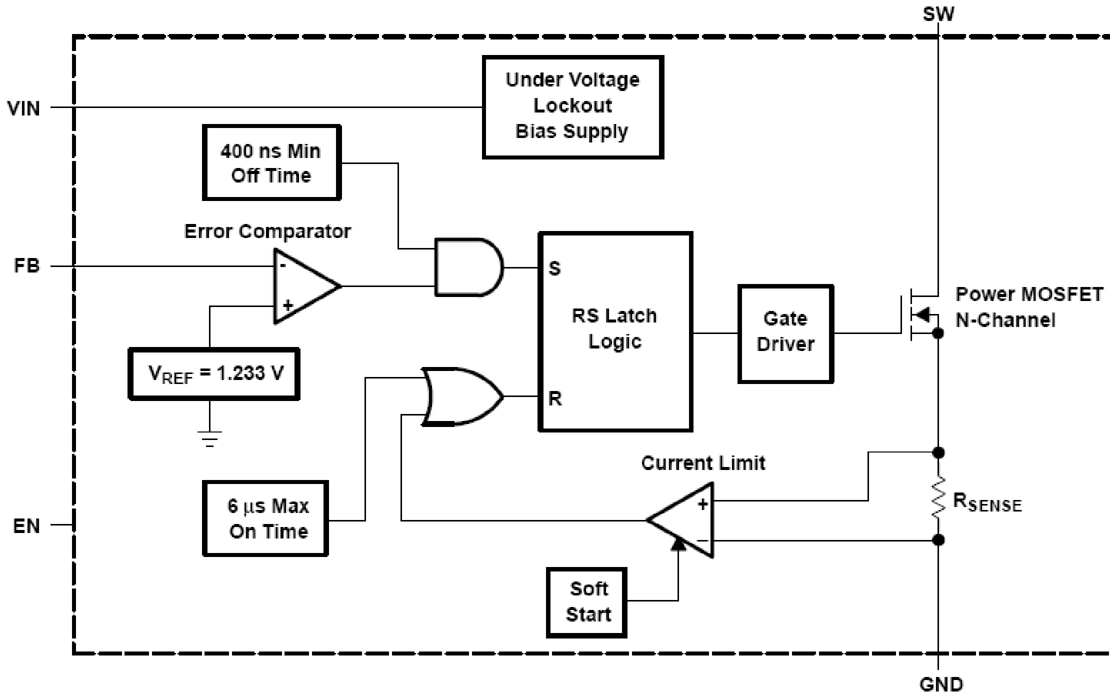
Electrical Characteristics

(V_{IN}= 2.4 V, EN = VIN, T_A = -40°C to 85°C, typical values are at T_A = 25°C, unless otherwise noted)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
SUPPLY CURRENT						
V_{IN}	Input Voltage Range		1.8		6.0	V
I_Q	Operating Quiescent Current	I_{OUT}=0mA, not switching V_{FB} = 1.3V		28	50	μA
I_{SD}	Shutdown Current	EN=GND		0.1	1	μA
V_{UVLO}	Under-voltage Lockout Threshold			1.5	1.7	V
ENABLE						
V_{IH}	EN High Level Input Voltage		1.3			V
V_{IL}	EN Low Level Input Voltage				0.4	V
I_L	EN Input Leakage Current	EN=GND or VIN		0.1	1	μA
POWER SWITCH AND CURRENT LIMIT						
V_{SW}	Maximum Switch Voltage				28	V
t_{ON}	Maximum On Time		4	6	7.5	μs
t_{OFF}	Minimum Off Time		250	400	550	ns
$R_{DS(ON)}$	MOSFET On Resistance	V_{IN} = 2.4V, I_{SW}=200mA		750	1200	mΩ
	MOSFET Leakage Current	V_{SW} =28V		1	10	μA
I_{LIM}	MOSFET Current Limit		350	400	450	mA
OUTPUT						
V_{OUT}	Adjustable Output Voltage Range		V_{IN}		28	V
V_{REF}	Internal Voltage Reference			1.233		V
I_{FB}	Feedback Input Bias Current	V_{FB} = 1.3V			1	μA
V_{FB}	Feedback Trip Point Voltage	1.8V $<$ V_{IN} $<$ 6.0V	1.208	1.233	1.258	V
	Line Regulation (Note 4)	1.8V $<$ V_{IN} $<$ 6.0V; V_{OUT} =18V; I_{LOAD}=10mA		0.05		%/V
	Load Regulation(Note 4)	V_{IN} = 2.4V; V_{OUT} =18V; 0mA $<$ I_{OUT} $<$ 30mA;		0.15		%/mA

Note 4: The line and load regulation depend on the external component selection. Refer to the application selection for further information.

Function Block Diagram



Operation

The UM1660 operates with an input voltage range of 1.8V to 6.0V and can generate output voltages up to 28V. The device operates in a pulse frequency modulation (PFM) scheme with constant peak current control. This control scheme maintains high efficiency over the entire load current range, and with a switching frequency up to 1MHz, the device enables the use of very small external components.

The converter monitors the output voltage, and as soon as the feedback voltage falls below the reference voltage of typically 1.233 V, the internal switch turns on and the current ramps up. The switch turns off as soon as the inductor current reaches the internally set peak current of typically 400mA. The second criteria that turns off the switch is the maximum on-time of 6µs (typical). This is just to limit the maximum on-time of the converter to cover for extreme conditions. As the switch is turned off the external Schottky diode is forward biased delivering the current to the output. The switch remains off for a minimum of 400 ns (typical), or until the feedback voltage drops below the reference voltage again. Using this PFM peak current control scheme the converter operates in discontinuous conduction mode (DCM) where the switching frequency depends on the output current, which results in very high efficiency over the entire load current range. This regulation scheme is inherently stable, allowing a wider selection range for the inductor and output capacitor.

Peak Current Control

The internal switch turns on until the inductor current reaches the typical dc current limit (I_{LIM}) of 400mA. Due to the internal propagation delay of typical 100 ns, the actual current exceeds the dc current limit threshold by a small amount. The typical peak current limit can be calculated as the following formula:

$$I_{peak(typ)} = I_{LIM} + \frac{Vin}{L} \times 100\ ns$$

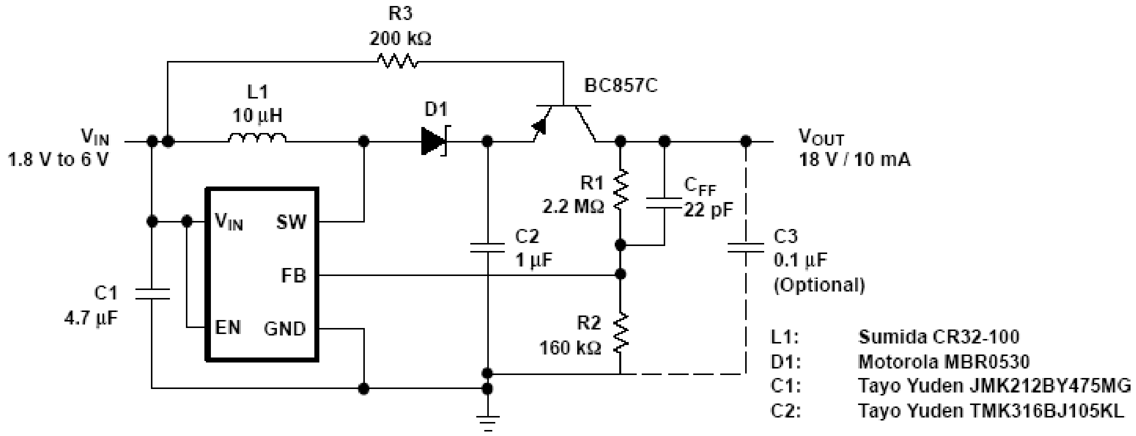
The higher the input voltage and the lower the inductor value, the greater the peak current. By selecting the L and V_{IN}, it is possible to tailor the design to the specific application current limit requirements. A lower current limit supports applications requiring lower output power and allows the use of an inductor with a lower current rating and a smaller form factor. A lower current limit usually has a lower output voltage ripple as well.

Soft-Start

All inductive step-up converters exhibit high inrush current during start-up if no special precaution is made. This can cause voltage drops at the input rail during start up and may result in an unwanted or early system shut down. The UM1660 limits this inrush current by increasing the current limit in two steps from $I_{LIM}/4$ for 256 cycles to $I_{LIM}/2$ for the next 256 cycles, and then full current limit.

Enable

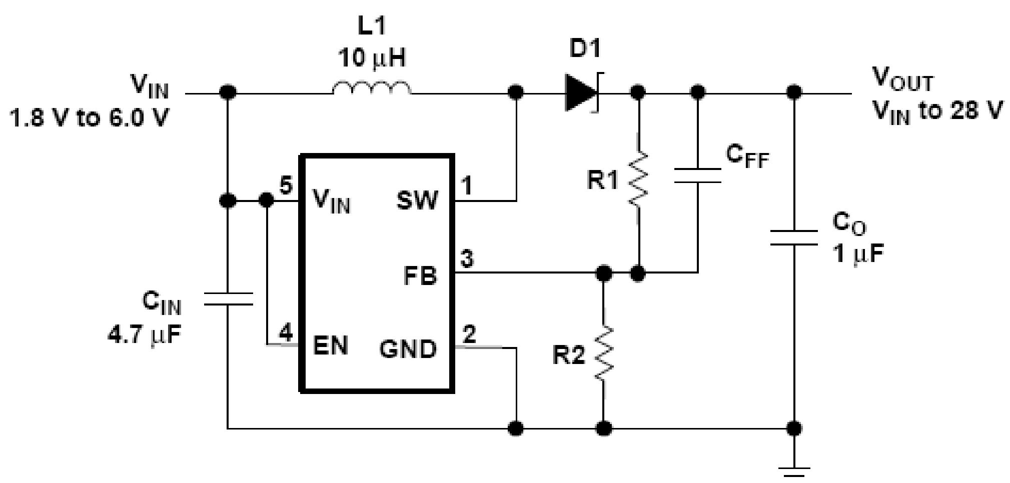
Pulling the enable pin (EN) to ground shuts down the device reducing the shutdown current to 1μA (typical). Since there is a conductive path from the input to the output through the inductor and Schottky diode, the output voltage is equal to the input voltage during shutdown. The enable pin needs to be terminated and should not be left floating. Using a small external transistor disconnects the input from the output during shutdown as shown in the Figure below.



Under-voltage Lockout

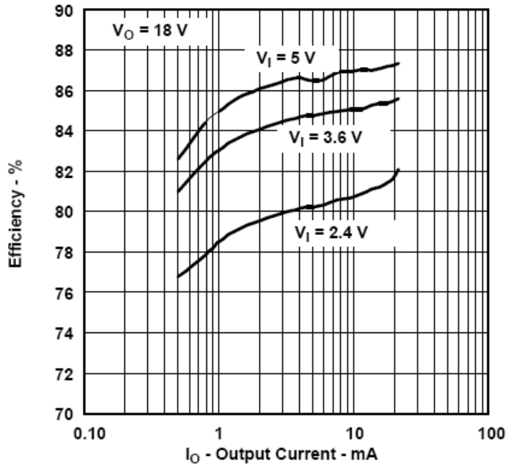
An under-voltage lockout prevents misoperation of the device at input voltages below typical 1.5 V. When the input voltage is below the under-voltage threshold the main switch is turned off.

Typical Application Circuit

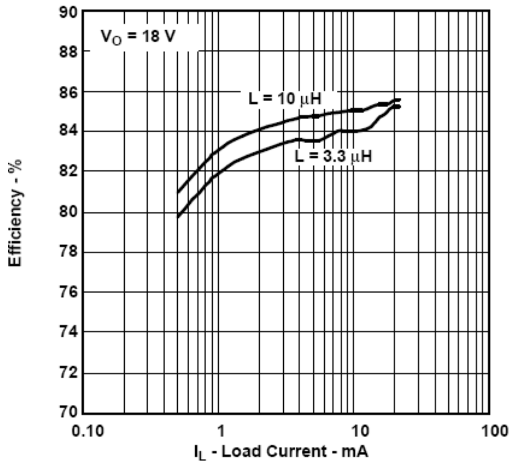


Typical Operating Characteristics

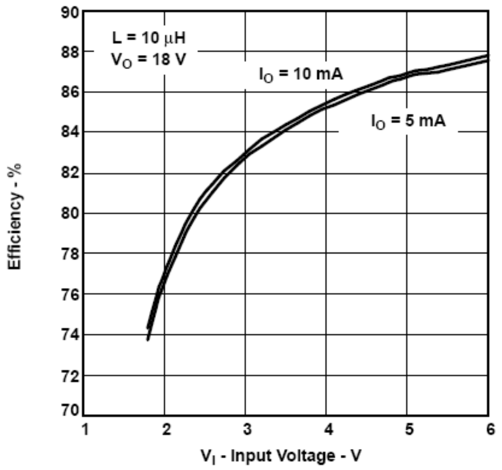
Efficiency vs Output Current



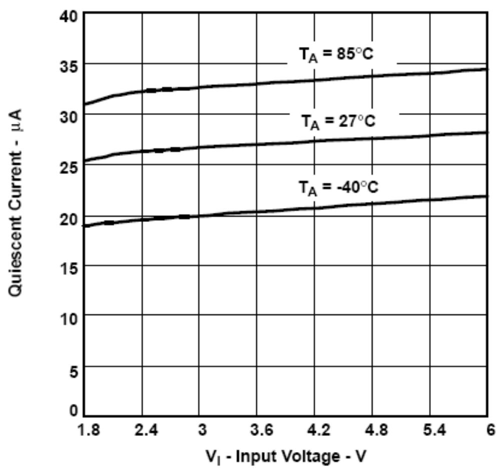
Efficiency vs Load Current



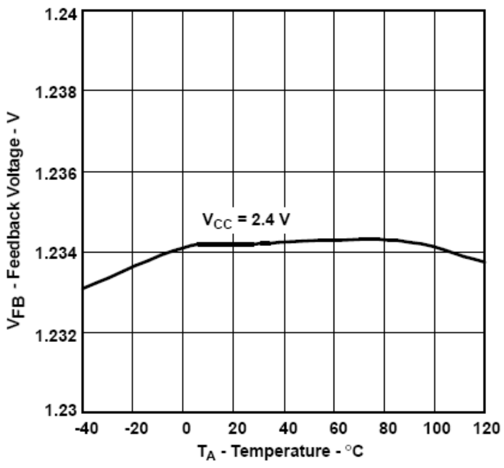
Efficiency vs Input Voltage



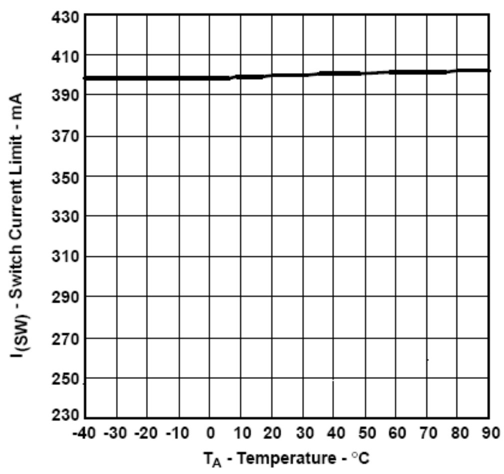
Quiescent Current vs Input Voltage



Feedback Voltage vs Temperature

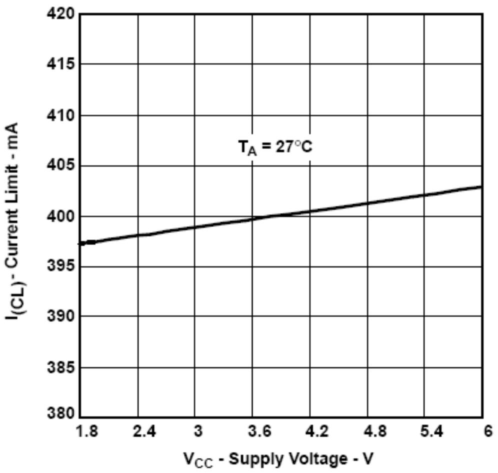


Switch Current Limit vs Temperature

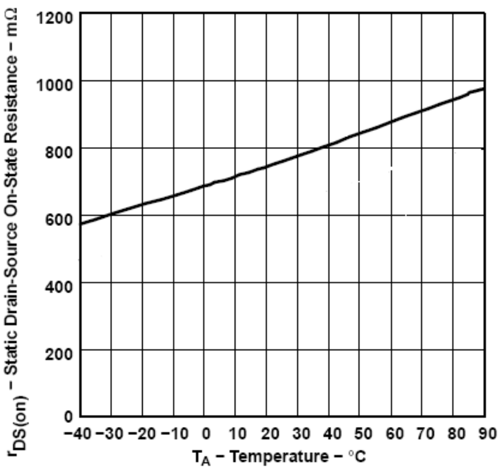


Typical Operating Characteristics

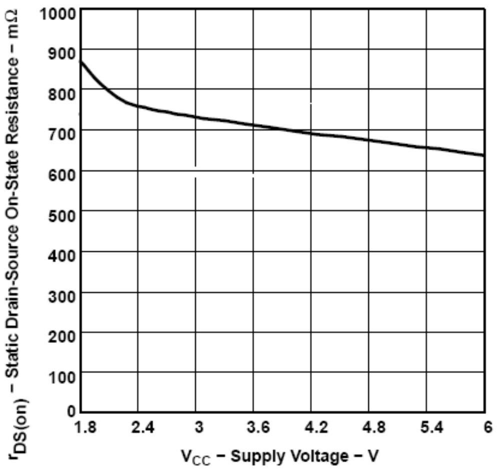
Current Limit vs Supply Voltage



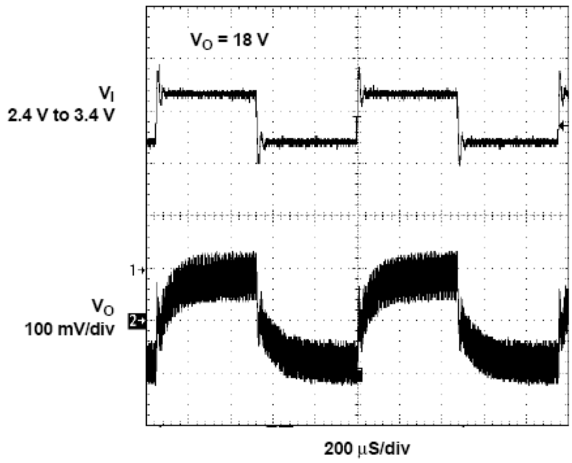
$R_{DS(ON)}$ vs Temperature



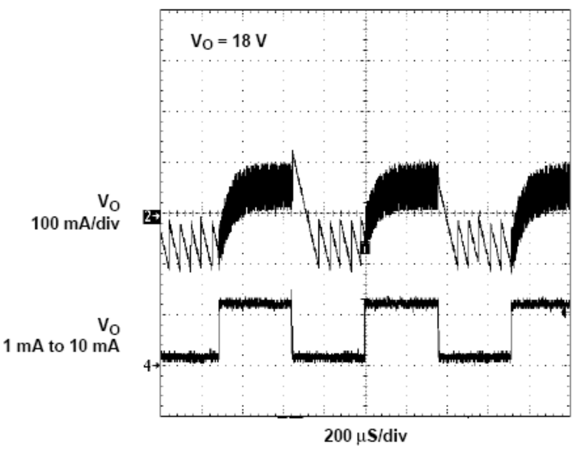
$R_{DS(ON)}$ vs Supply Voltage



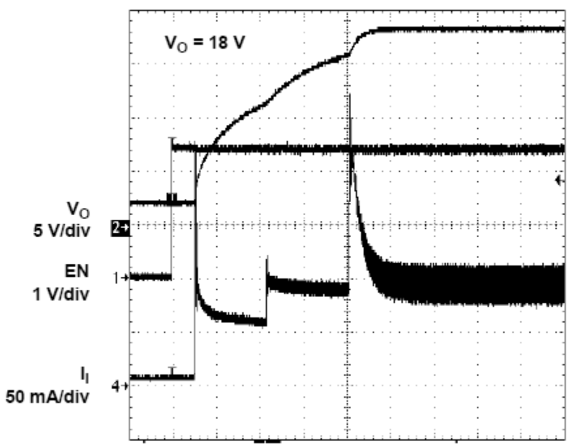
Line Transient Response



Load Transient Response



Start-up Behavior



Applications Information

Inductor Selection, Maximum Load Current

Since the PFM peak current control scheme is inherently stable, the inductor value does not affect the stability of the regulator. The selection of the inductor together with the nominal load current, input and output voltage of the application determines the switching frequency of the converter. Depending on the application, inductor values between 2.2µH up to 47µH are recommended. The maximum inductor value is determined by the maximum on time of the switch, typically 6µs. The peak current limit of 400mA (typically) should be reached within this 6µs period for proper operation.

The inductor value determines the maximum switching frequency of the converter. Therefore, select the inductor value that ensures the maximum switching frequency at the converter maximum load current is not exceeded. The maximum switching frequency is calculated by the following formula:

$$fS_{max} = \frac{Vin_{min} \times (Vout - Vin)}{I_P \times L \times Vout}$$

Where:

I_P = Peak current as described in the previous peak current control section

L = Selected inductor value

Vin_{min} = The highest switching frequency occurs at the minimum input voltage

If the selected inductor value does not exceed the maximum switching frequency of the converter, the next step is to calculate the switching frequency at the nominal load current using the following formula:

$$fS\left(I_{load}\right) = \frac{2 \times I_{load} \times (Vout - Vin + Vd)}{I_P^2 \times L}$$

Where:

I_P = Peak current as described in the previous peak current control section

L = Selected inductor value

Iload = Nominal load current

Vd = Rectifier diode forward voltage (typically 0.3V)

A smaller inductor value gives a higher converter switching frequency, but lowers the efficiency.

The inductor value has less effect on the maximum available load current and is only of secondary order. The best way to calculate the maximum available load current under certain operating conditions is to estimate the expected converter efficiency at the maximum load current. This number can be taken out of the efficiency graphs shown in page 6. The maximum load current can then be estimated as follows:

$$I_{load\,max} = \eta \frac{I_P^2 \times L \times fS_{max}}{2 \times (Vout - Vin)}$$

Where:

I_P = Peak current as described in the previous peak current control section

L = Selected inductor value

fS_{max} = Maximum switching frequency as calculated previously

η= Expected converter efficiency. Typically 70% to 85%

The maximum load current of the converter is the current at the operation point where the converter starts to enter the continuous conduction mode. Usually the converter should always operate in discontinuous conduction mode.

Last, the selected inductor should have a saturation current that meets the maximum peak current of the converter (as calculated in the peak current control section). Use the maximum value for I_{LIM} for this calculation.
Another important inductor parameter is the dc resistance. The lower the dc resistance, the higher the efficiency of the converter.

Setting the Output Voltage

The output voltage is calculated as:

$$V_{out} = 1.233\,V \times \left(1 + \frac{R1}{R2}\right)$$

For battery powered applications a high impedance voltage divider should be used with a typical value for R2 of 200kΩ and a maximum value for R1 of 2.2MΩ. Smaller values might be used to reduce the noise sensitivity of the feedback pin.
A feedforward capacitor across the upper feedback resistor R1 is required to provide sufficient overdrive for the error comparator. Without a feedforward capacitor, or one whose value is too small, the UM1660 shows double pulses or a pulse burst instead of single pulses at the switch node (SW), causing higher output voltage ripple. If this higher output voltage ripple is acceptable, the feedforward capacitor can be left out.
The lower the switching frequency of the converter, the larger the feedforward capacitor value required. A good starting point is to use a 10pF feedforward capacitor. As a first estimation, the required value for the feedforward capacitor at the operation point can also be calculated using the following formula:

$$C_{FF} = \frac{1}{2 \times \pi \times \frac{fS}{20} \times R1}$$

Where:
R1 = Upper resistor of voltage divider
fS = Switching frequency of the converter at the nominal load current (See previous section for calculating the switching frequency)
C_{FF} = Choose a value that comes closest to the result of the calculation
The larger the feedforward capacitor the worse the line regulation of the device. Therefore, when concern for line regulation is paramount, the selected feedforward capacitor should be as small as possible. See the next section for more information about line and load regulation.

Line and Load Regulation

The line regulation of the UM1660 depends on the voltage ripple on the feedback pin. Usually a 50mV peak-to-peak voltage ripple on the feedback pin FB gives good results.
Some applications require a very tight line regulation and can only allow a small change in output voltage over a certain input voltage range. If no feedforward capacitor C_{FF} is used across the upper resistor of the voltage feedback divider, the device has the best line regulation. Without the feedforward capacitor the output voltage ripple is higher because the UM1660 shows output voltage bursts instead of single pulses on the switch pin (SW), increasing the output voltage ripple. Increasing the output capacitor value reduces the output voltage ripple.
If a larger output capacitor value is not an option, a feedforward capacitor C_{FF} can be used as described in the previous section. The use of a feedforward capacitor increases the amount of voltage ripple present on the feedback pin (FB). The greater the voltage ripple on the feedback pin (50 mV), the worse the line regulation. There are two ways to improve the line regulation further:
1. Use a smaller inductor value to increase the switching frequency which will lower the output voltage ripple, as well as the voltage ripple on the feedback pin.
2. Add a small capacitor from the feedback pin (FB) to ground to reduce the voltage ripple on the feedback pin down to 50mV again. As a starting point, the same capacitor value as selected for

the feedforward capacitor C_{FF} can be used.

Output Capacitor Selection

For best output voltage filtering, a low ESR output capacitor is recommended. Ceramic capacitors have a low ESR value but tantalum capacitors can be used as well, depending on the application.
Assuming the converter does not show double pulses or pulse bursts on the switch node (SW), the output voltage ripple can be calculated as:

$$\Delta V_{out} = \frac{I_{out}}{C_{out}} \times \left(\frac{1}{fS(Iout)} - \frac{I_P \times L}{Vout + Vd - Vin} \right) + I_P \times ESR$$

Where:
I_P = Peak current as described in the previous peak current control section
L = Selected inductor value
Iout = Nominal load current
fS (Iout) = Switching frequency at the nominal load current as calculated previously
Vd = Rectifier diode forward voltage (typically 0.3V)
Cout = Selected output capacitor
ESR = Output capacitor ESR value

Input Capacitor Selection

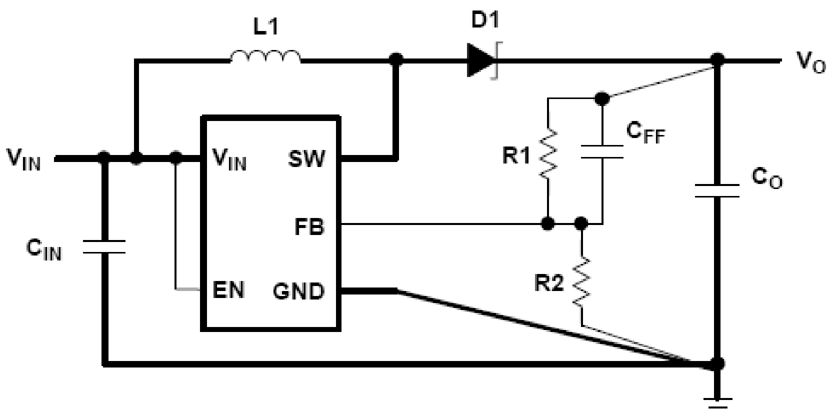
For good input voltage filtering, low ESR ceramic capacitors are recommended. A 4.7µF ceramic input capacitor is sufficient for most of the applications. For better input voltage filtering this value can be increased.

Diode Selection

To achieve high efficiency a Schottky diode should be used. The current rating of the diode should meet the peak current rating of the converter as it is calculated in the section peak current control. Use the maximum value for I_{LIM} for this calculation.

Lay out Considerations

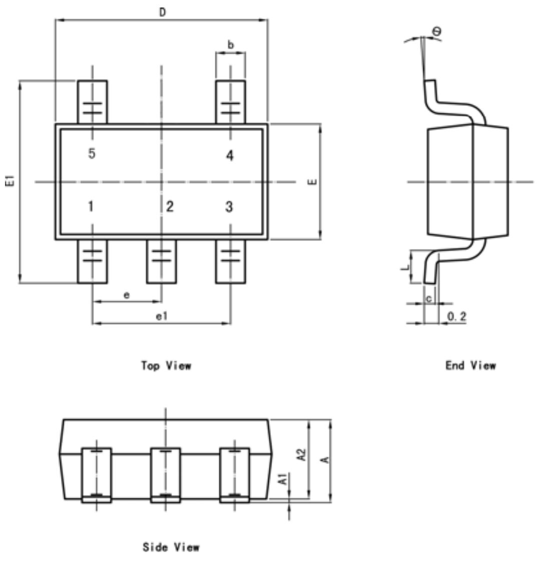
Typical for all switching power supplies, the layout is an important step in the design; especially at high peak currents and switching frequencies. If the layout is not carefully done, the regulator might show noise problems and duty cycle jitter.
The input capacitor should be placed as close as possible to the input pin for good input voltage filtering. The inductor and diode should be placed as close as possible to the switch pin to minimize the noise coupling into other circuits. Since the feedback pin and network is a high impedance circuit the feedback network should be routed away from the inductor. The feedback pin and feedback network should be shielded with a ground plane or trace to minimize noise coupling into this circuit.
Wide traces should be used for connections in bold as shown in the Figure below. A star ground connection or ground plane minimizes ground shifts and noise.



Package Information

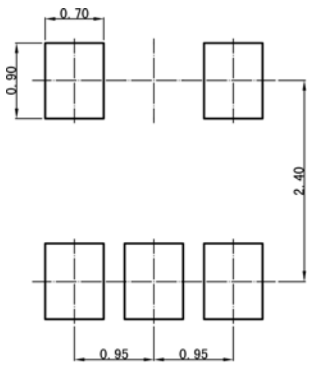
UM1660: SOT23-5

Outline Drawing



Symbol	DIMENSIONS			
	MILLIMETERS		INCHES	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950REF		0.037REF	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

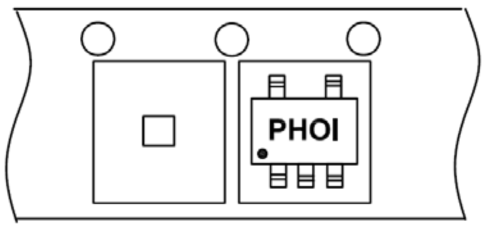
Land Pattern



NOTES:

1. Compound dimension: 2.92×1.60 ;
2. Unit: mm;
3. General tolerance ±0.05mm unless otherwise specified;
4. The layout is just for reference.

Tape and Reel Orientation



IMPORTANT NOTICE

Union Semiconductor, Inc

Add: 7F, No. 5, Bibo Road, Shanghai 201203

Tel: 021-51097928

Fax: 021-51026018

Website: www.union-ic.com