

Datasheet – MAP7160



600mA Step-Down Converter with Auto Fast Discharge Function

General Description

The MAP7160 is a 2MHz high efficiency step-down converter with input voltage of 2.7V to 5.5V. Output Voltage has as low as 0.6V. The MAP7160 has a high efficiency and Low ripple architecture.

The MAP7160 is programmable with external feedback resistors and it has a low 35uA no load quiescent current.

The MAP7160 operates as 2MHz switching frequency.

The MAP7160 is designed to maintain high efficiency at operating range. And The MAP7160 has an output auto discharge function. When Output voltage is disabled, it enables the device to quickly output discharge.

The MAP7160 is available in the Pb-free, 1.6mm x 1.6mm DFN 6P package and is rated over the -40°C to +85°C temperature range.

Features

- 2.7V to 5.5V input voltage range
- Output Ultra-Fast Discharger When Disable < 10ms
- Low Ripple at PWM Mode
- 35uA Quiescent Current at No Switching
- Up to 98% efficiency
- 600mA Max. Output Current
- 2MHz Switching Frequency
- 150us Soft Start
- Fast Load Transient
- Protection: OCP, OTP
- 100% Duty Cycle Low-Dropout Operation
- <1uA Shutdown Current
- Package: 1.6mm x 1.6mm, DFN package
- Temperature: -40°C to +85°C

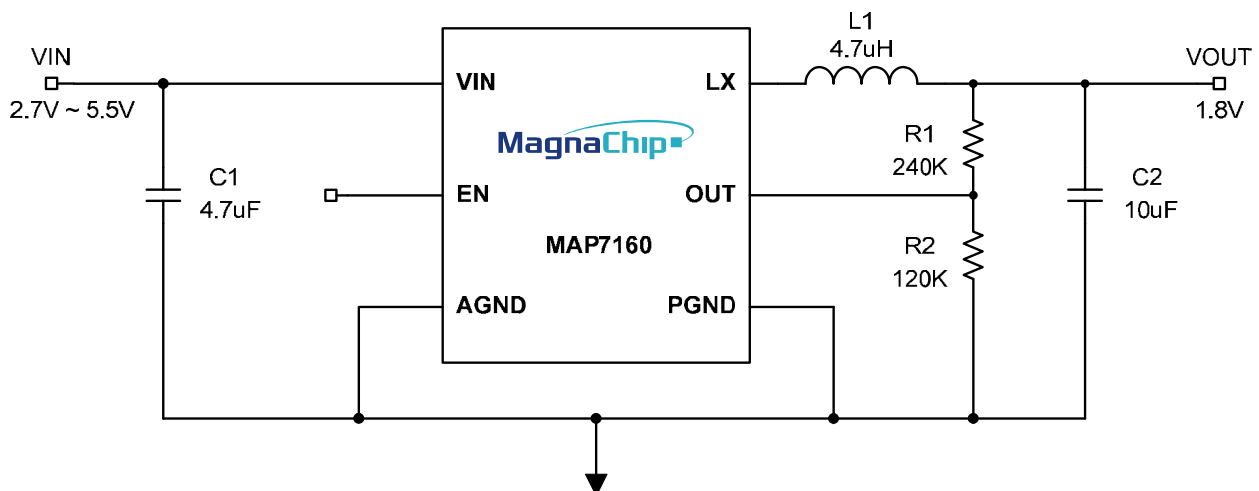
Applications

- Mobile Phones
- Digital Cameras
- PDAs and Handheld Computers
- USB Devices

Ordering Information

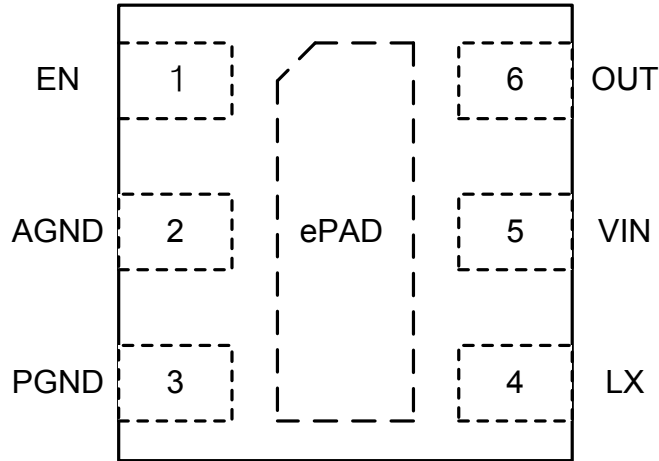
Part Number	Top Marking	Ambient Temperature Range	Package	RoHS Status
MAP7160 DFRH	MAP7160 YWLL	-40°C to +85°C	1.6mm x 1.6 mm, DFN 6P	Pb-free

Typical Application



Pin Configuration

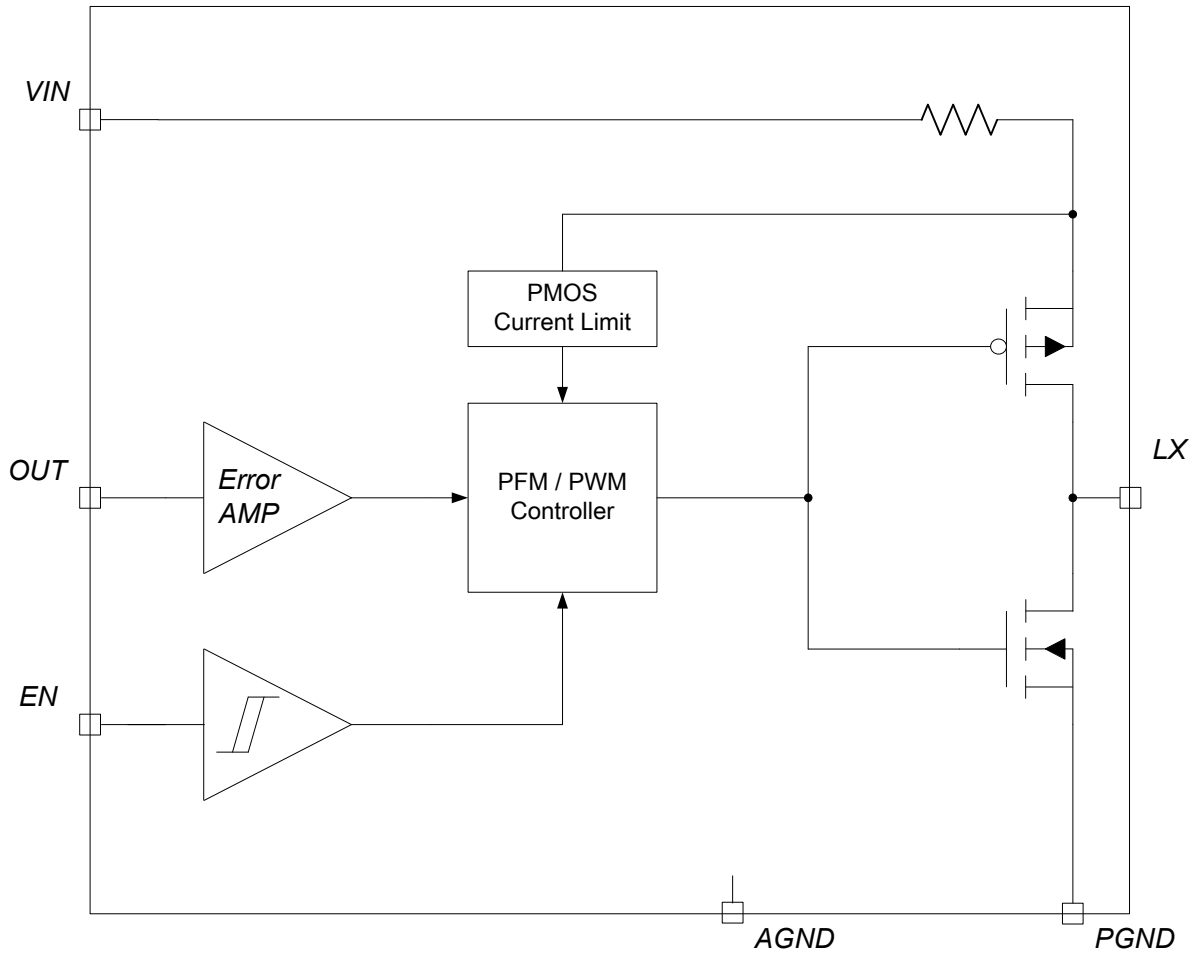
Top View



Pin Description

Pin No. (1.6mm x 1.6mm)	Name	Description
1	EN	Enable pin
2	AGND	Analog ground pin
3	PGND	Power ground pin.
4	LX	This is a switching node. connect the inductor to this pin.
5	VIN	Input supply voltage
6	OUT	Feedback input pin. This pin is connected converter output and external resistors for an adjusted output.
	Exposed PAD	Connected to GND

Functional Block Diagram



Absolute Maximum Ratings (Note 1)

Symbol	Parameter	Min	Max	Unit
V_{VIN}	Supply Voltage on V_{IN} pin	-0.3	6	V
V_{LX}	LX to GND	-0.3	$V_{IN} + 0.3$	V
V_{OUT}	OUT to GND	-0.3	$V_{IN} + 0.3$	V
V_{EN}	EN to GND	-0.3	$V_{IN} + 0.3$	V
T_S	Storage Temperature Range	-65	+150	°C
T_J	Junction Temperature Range	-40	+150	°C
θ_{JA}	Junction Thermal Resistance TSOT-23 8P		162	°C/W
P_D	Power Dissipation, @ $T_A=25^\circ\text{C}$		617	mW
$T_{PAD \& LEAD}$	Maximum Soldering Temperature(at pad & leads, 10 sec)		260	°C
ESD	HBM on All Pins (Note 2)	-2000	+2000	V
	MM on All Pins (Note 3)	-200	+200	

Note 1: Stresses beyond the above listed maximum ratings may damage the device permanently. Operating above the recommended conditions for extended time may stress the device and affect device reliability. Also the device may not operate normally above the recommended operating conditions. These are stress ratings only.

Note 2: ESD tested per JESD22A-114.

Note 3: ESD tested per JESD22A-115.

Recommended Operating Conditions (Note 1)

Parameter	Min	Max	Unit
V_{VIN} Supply Input Voltage	2.7	5.5	V
V_{OUT} Output voltage	0.6	$\leq V_{in}$	V
T_J Junction Temperature Range	-40	+125	°C
T_A Ambient Temperature Range (Note 2)	-40	+85	°C

Note 1: Normal operation of the device is not guaranteed if operating the device over outside range of recommended conditions.

Note 2: The ambient temperature may have to be de-rated if used in high power dissipation and poor thermal resistance conditions.

Electrical Characteristics

$V_{IN} = 3.6V$, $T_A = -40^{\circ}C$ to $85^{\circ}C$, unless otherwise noted. Typical values are at $T_A = +25^{\circ}C$

Parameter	Test Condition	Min	Typ.	Max	Unit		
Step-Down Converter							
V_{VIN}	Input Voltage Range	2.7		5.5	V		
V_{UVLO}	UVLO Threshold	V_{IN} Rising		2.7	V		
		Hysteresis		100	mV		
		V_{IN} Falling	1.8		V		
V_{VOUT}	Output Voltage Tolerance (Note2)	$I_{OUT} = 0mA$ to $600mA$, $V_{IN} = 2.7V$ to $5.5V$		-3.0	+3.0	%	
V_{VOUT}	Output Voltage Range (Note2)	0.6		V_{IN}	V		
I_Q	Quiescent Current	$I_{OUT} = 0mA$, $V_{FB} = 1V$, $V_{EN} > 2V$			35	50	μA
I_{SHDN}	Shutdown Current	EN = AGND = PGND				1.0	μA
I_{LIM}	P-Channel Current Limit	800					mA
$R_{DS(ON)H}$	High Side Switch On Resistance	$V_{IN} = 3.6V$, $I_{OUT} = 300mA$			0.35		Ω
$R_{DS(ON)L}$	Low Side Switch On Resistance	$V_{IN} = 3.6V$, $I_{OUT} = 300mA$			0.30		Ω
$V_{LINEREG}$	Line Regulation(Note2)	$V_{IN} = 2.7V$ to $5.5V$; $I_{OUT} = 600mA$			0.1		%/V
V_{VOUT}	Out Threshold Voltage Accuracy	0.6V Output, No Load; $T_A = 25^{\circ}C$		591	600	609	mV
I_{OUT}	Output Leakage Current	$V_{IN} = 5.5V$, $V_{OUT} = 0.6V$, $V_{EN} = 0V$				0.2	μA
T_S	Start-Up Time(Note2)	From Enable to Output Regulation			150		μs
F_{OSC}	Oscillator Frequency	$T_A = 25^{\circ}C$		1.3	2.0	2.7	MHz
T_{SD}	Over-Temperature Shutdown Threshold(Note2)				145		$^{\circ}C$
T_{HYS}	Over-Temperature Shutdown Hysteresis(Note2)				35		$^{\circ}C$
EN							
$V_{EN(L)}$	Enable Threshold Low				0.6		V
$V_{EN(H)}$	Enable Threshold High	1.4					V
$T_{DISCHARGE}$	Output Discharge Time	$V_{IN} = 3.0 - 5.5V$, $V_{EN} = V_{IN}$ to $0V$, $V_{OUT} = 3.0V$ to $0V$, $L = 4.7\mu H$, $C_{OUT} = 10\mu F$			4	10	ms

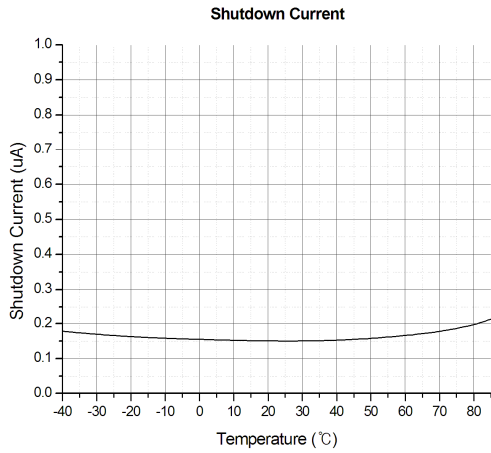
Note 1: Stress beyond the maximum ratings listed above may incur permanent damage to the device. Operating above the recommended conditions for extended time may stress the device and affect device reliability. Also the device may not operate normally above the recommended operating conditions. These are stress ratings only.

Note 2: Guaranteed by design; not test in production.

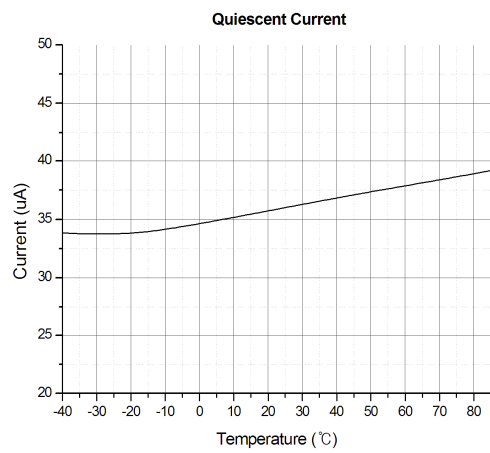
Typical Operating Characteristics

Unless otherwise noted, $V_{IN}=EN=3.6V$ and $T_A=25^\circ C$.

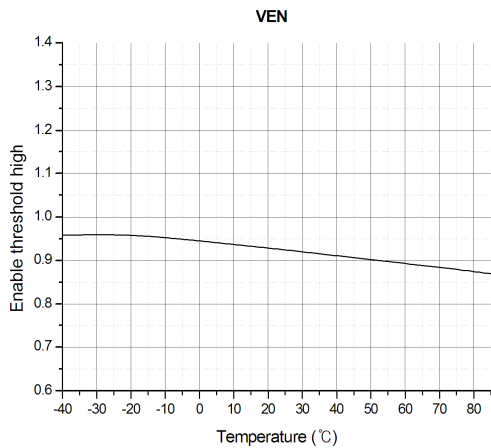
Shutdown Current vs Temperature



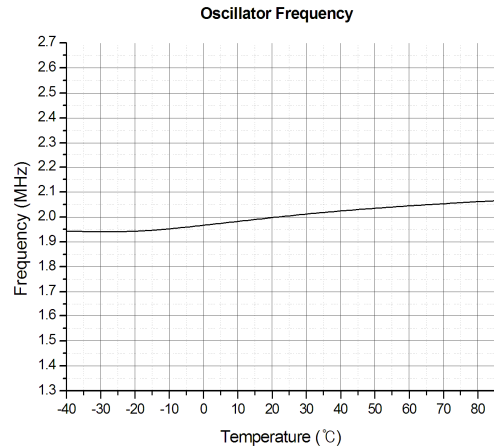
Quiescent Current vs Temperature



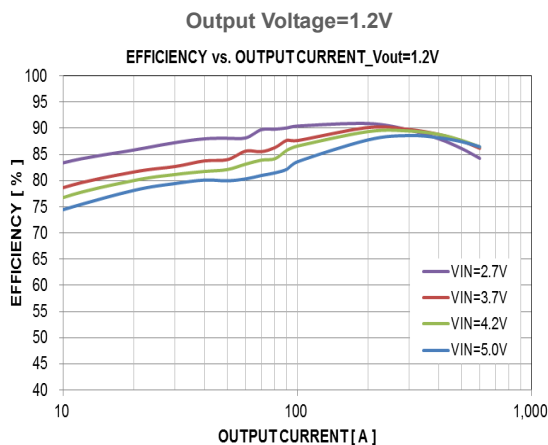
Enable threshold vs Temperature



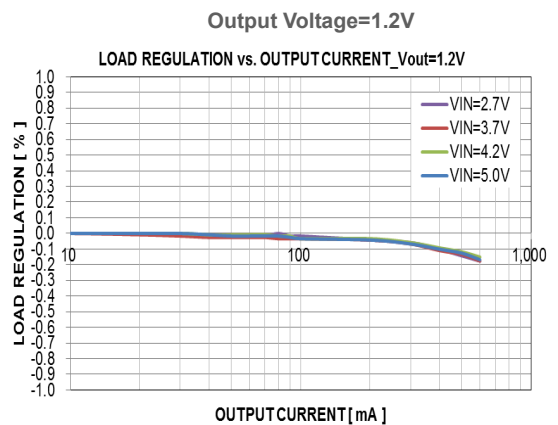
Oscillator Frequency vs Temperature



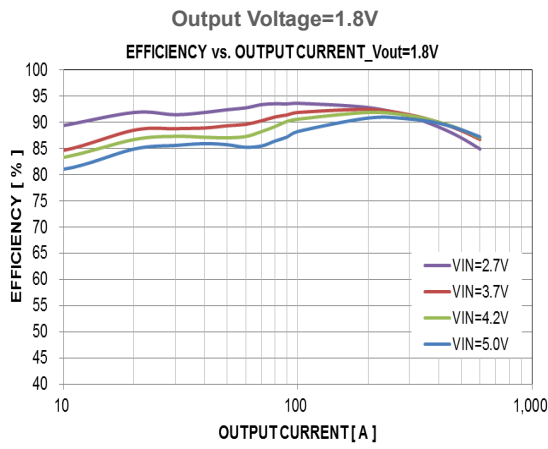
Efficiency vs Output Current



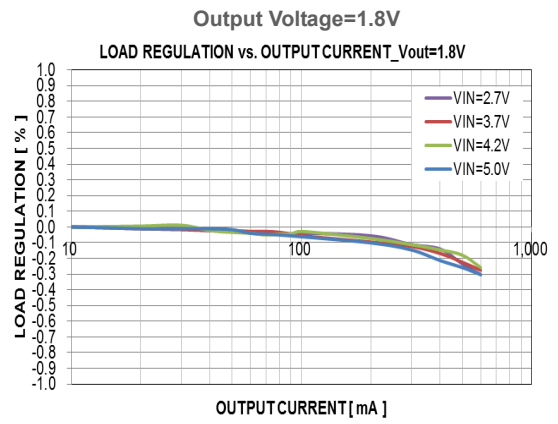
Load Regulation vs Output Current



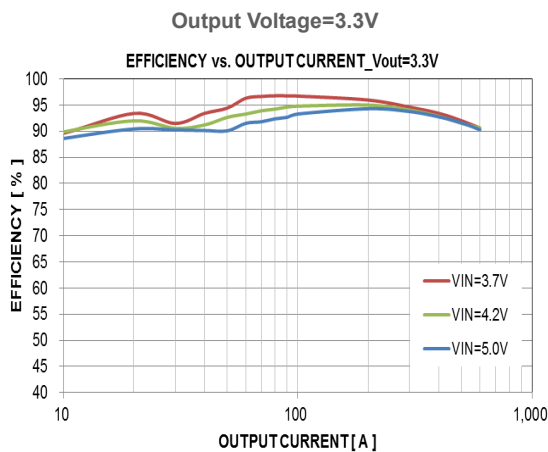
Efficiency vs Output Current



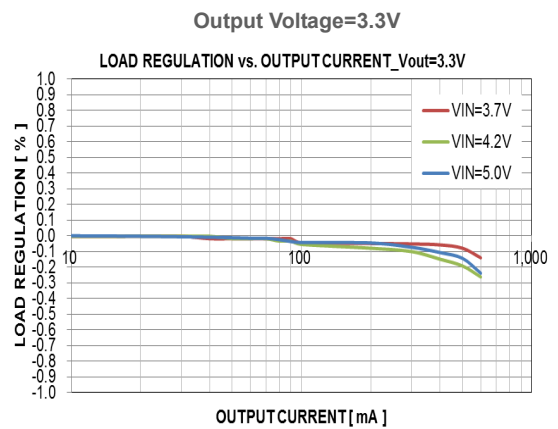
Load Regulation vs Output Current



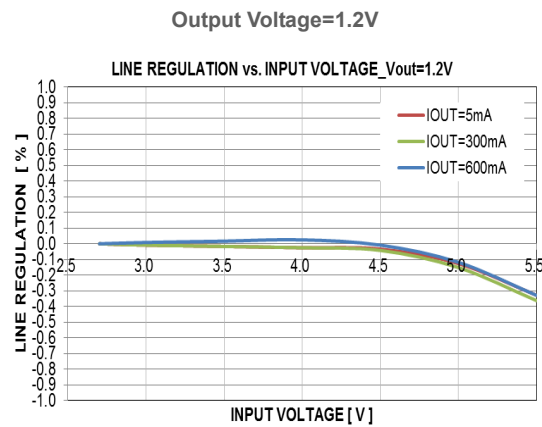
Efficiency vs Output Current



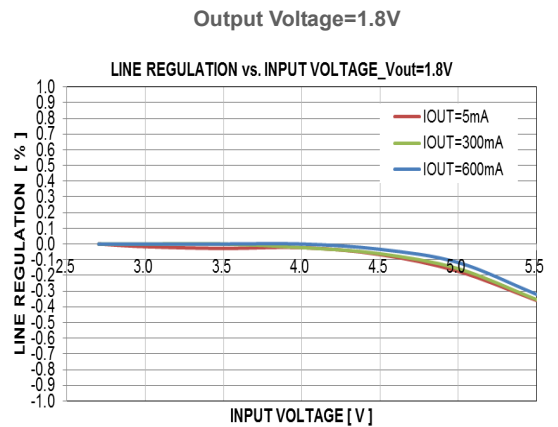
Load Regulation vs Output Current



Line Regulation vs Input Voltage

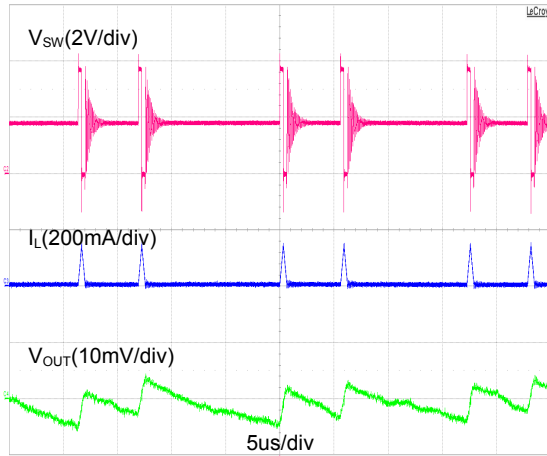


Line Regulation vs Input Voltage



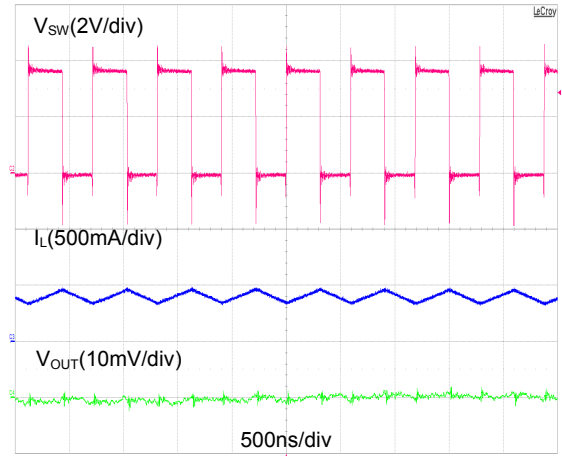
Output Voltage Ripple Waveforms

Vin=3.6V, Vout=1.8V, Iout=5mA



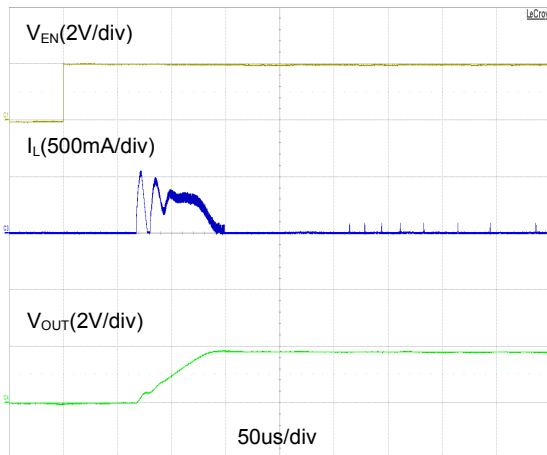
Output Voltage Ripple Waveforms

Vin=3.6V, Vout=1.8V, Iout=600mA



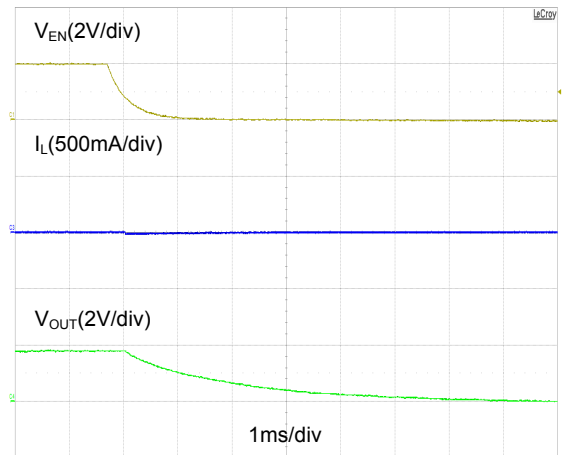
Start up Through Enable Waveforms

Vin=3.6V, Vout=1.8V, Iout=0mA



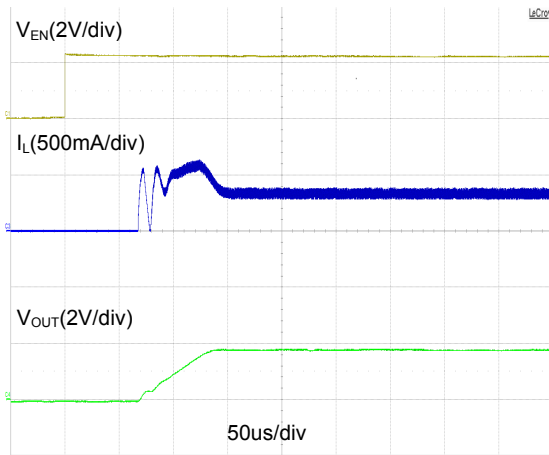
Shut down Through Enable Waveforms

Vin=3.6V, Vout=1.8V, Iout=0mA



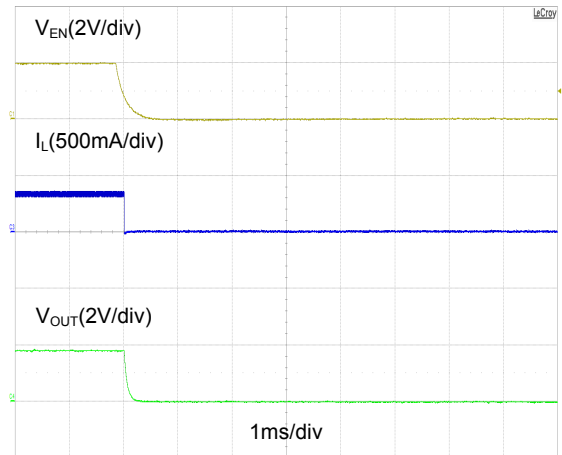
Start up Through Enable Waveforms

Vin=3.6V, Vout=1.8V, Iout=400mA



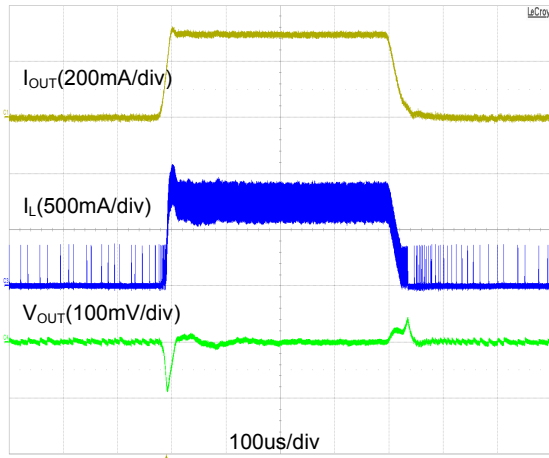
Shut down Through Enable Waveforms

Vin=3.6V, Vout=1.8V, Iout=400mA



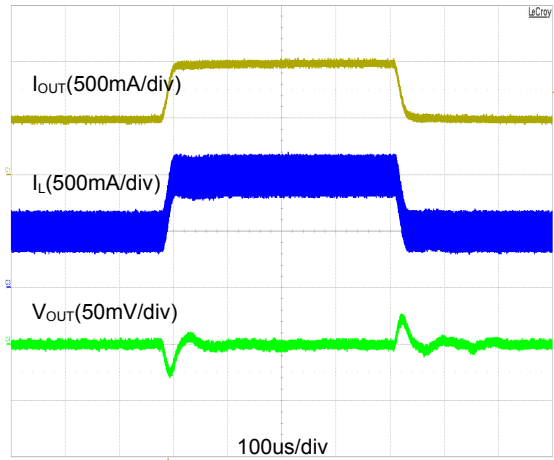
Load Transient Waveforms

Vin=3.6V, Vout=1.8V, Iout=0mA to 300mA



Load Transient Waveforms

Vin=3.6V, Vout=1.8V, Iout=200mA to 400mA



Operation Description

Device Information

The MAP7160 Switching is a 2MHz step-down converter with an input voltage range of 2.7V to 5.5V and output voltage as low as 0.6V. It is optimized to react quickly to a load variation.

The MAP7160 is synchronous Buck convertor, uses a peak current mode step-down architecture. Both the main P-MOS and synchronous N-MOS switches are internal. It has been designed with the goal of minimizing external component size and optimizing efficiency over the complete load range, and only a small L-C filter is required at the output. Typically, a 4.7 μ H inductor and a 10 μ F ceramic capacitor are recommended.

The MAP7160 works with two modes of operation; PWM/PFM depending on the current required. In PWM mode, the device can supply voltage with a tolerance of 3% and 95% efficiency or better. Light load currents cause the device to automatically switch into PFM mode for reduced current consumption and extended battery life. The MAP7160 can be programmed with external feedback to any voltage, ranging from 0.6V to the input voltage. An additional feed-forward capacitor can also be added to the external feedback to provide improved transient response. At dropout, the converter duty cycle increases to 100% and the output voltage tracks the input voltage minus the $R_{DS(ON)}$ drop of the high side P-MOS.

Additional the function includes soft-start, under voltage protection, over current protection, and thermal shutdown protection. As shown in typical application, only six external components are required. The part uses an internal reference voltage of 0.6V. It is recommended to keep the part in shutdown mode until the input voltage is 2.7 V or higher.

PFM Operating Mode

Under light load conditions, the MAP7160 enters in low current PFM mode operation to reduce power consumption. The output regulation is implemented by burst. If the output voltage drops below the threshold of PFM comparator, a new cycle will be initiated by the PFM comparator to turn on the P-MOS.

P-MOS remains ON during the minimum on time of the structure while N-MOS is in its current source mode. The peak inductor current depends upon the drop between input and output voltage. After a short dead time delay where P-MOS is switched OFF, N-MOS is turned in its ON state. The negative current detector will detect when the inductor current drops below zero and sends the signal to turn N-MOS to current source mode to prevent a too large deregulation of the output voltage. When the output voltage falls below the threshold of the PFM comparator, a new cycle starts immediately. P-MOS will be forced to end even if the inductor current is not reached peak inductor current.

PWM Operating Mode

The MAP7160 operation in PWM mode, regulation starts with an on state where a P-MOS switch is turn on and inductor current is ramped up until the off state begins. In the off state, the P-MOS switch is off and an N-MOS switch is turned on. The inductor current decreases to maintain an average value equal to the DC output load current.

The inductor current is continuously monitored. A current sense flags when the P-MOS switch current exceeds the current limit and the switcher is turned off to decrease the inductor current sense flags when the N-MOS switch current exceeds the current limit and redirects discharging current through the inductor back to the Input.

Soft Start

The MAP7160 uses soft-start (150us_Typ) to limit the inrush current when the device is initially enabled. Soft-start is implemented by gradually increasing the reference voltage until it reaches the full reference voltage. During startup, a pulsed current source charges the internal soft-start capacitor to provide gradually increasing reference voltage. When the voltage across the capacitor ramps up to the nominal reference voltage, the pulsed current source will be switched off and the reference voltage will switch to the regular reference voltage.

Output Auto Fast Discharge

When the MAP7160 is disabled ($V_{EN} = V_{IN}$ to 0V), the output is quickly discharged within 4ms.

Over Current Protection

For overload conditions, the peak input current is limited. To minimize power dissipation and stresses under current limit and short-circuit conditions, switching is terminated after entering current limit for a series of pulses. Switching is terminated for seven consecutive clock cycles after a current limit has been sensed for a series of four consecutive clock cycles.

Over Temperature Protection

Thermal protection completely disables switching when internal dissipation becomes excessive. The junction over-temperature threshold is 140°C with 15°C of hysteresis. Once an over-temperature or over-current fault conditions is removed, the output voltage automatically recovers.

Application Information

Typical Application Circuits

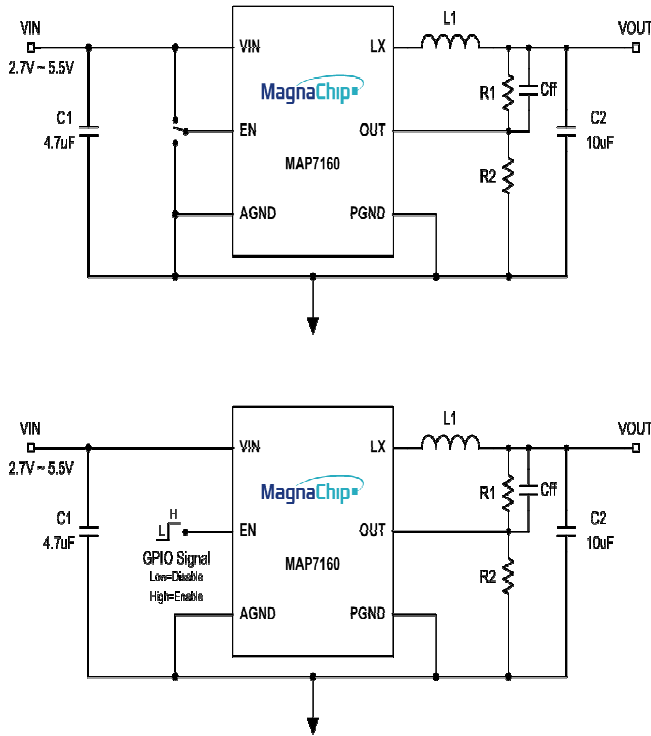


Table1. Recommended Component Values

V _{OUT} [V]	R1[KΩ]	R2[KΩ]	L[uH]	Cff[pF]
0.8V	60K	180K	1.5uH	22pF
1.0V	120K	180K	1.5uH	22pF
1.2V	180K	180K	2.2uH	22pF
1.5V	270K	180K	2.2uH	22pF
1.8V	240K	120K	4.7uH	22pF
2.5V	380K	120K	4.7uH	15pF
2.8V	275K	75K	4.7uH	15pF
3.3V	270K	60K	6.8uH	15pF

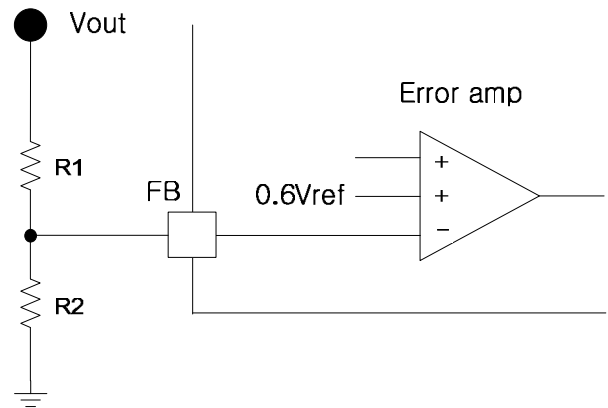
The basic MAP7160 application circuit is shown in Typical Application Circuit. External component selection is determined by the maximum load current and begins with the selection of the inductor value and operating frequency followed by C_{IN} and C_{OUT}.

Output Voltage Resistor Selection

Output voltage can be set by feeding back the output to the FB pin using a resistor divider network as shown

in Figure below. The resistor divider network includes R1 and R2. Usually, a design is started by picking a fixed R2 value and calculating the required R1 with the equation below:

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



Where is V_{REF} the internal reference voltage(0.6V Typ.) Some standard value of R1 and R2 for the most common output voltages are listed in Table 1.

The combination of R1 and R2 should be large enough to avoid drawing excessive current from the output, which will cause power loss. Since the switch duty cycle can be as high as 100 %, the maximum output voltage can be set as high as the input voltage minus the voltage drop on the upper PMOS and the inductor.

Input Filter Capacitor Selection

The input capacitor must be connected to the VIN pin and PGND pin of MAP7160 to maintain steady input voltage and filter out the pulsing input current. The voltage rating of input capacitor must be greater than maximum input voltage plus ripple voltage and use low ESR capacitors for the best performance.

The input ripple voltage can be approximated by equation below:

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

Since the input current is discontinuous in a buck converter, the current stress on the input capacitor is another concern when selecting the capacitor. For a buck circuit, the RMS value of input capacitor current can be calculated by:

$$I_{CIN_RMS} = I_{OUT} \times \sqrt{\left(1 - \frac{V_{OUT}}{V_{IN}}\right) \frac{V_{OUT}}{V_{IN}}} \dots\dots\dots (3)$$

This formula has a maximum at $V_{IN} = 2V_{OUT}$, where $I_{RMS} = I_{OUT}/2$. This simple worst-case condition is commonly used for design because even significant deviations do not offer much relief.

$$I_{CIN_RMS} \cong \frac{I_{OUT}}{2} \dots\dots\dots (4)$$

Choose a capacitor rated at a higher temperature than required. Several capacitors may also be paralleled to meet size or height requirements in the design.

For the input capacitor, a 4.7μF low ESR ceramic capacitor is recommended for the recommended capacitor. The selection of C_{OUT} is determined by the required ESR to minimize voltage ripple.

Output Filter Inductor Selection

The inductor is used to supply constant current to output when it is driven by a switching voltage. For given input and output voltage, inductance and switching frequency together decide the inductor ripple current, for most designs, the inductance value can be derived from the following equation:

$$L = \left(\frac{V_{OUT}}{f \times \Delta I_{L(max)}}\right) \times \left(1 - \frac{V_{OUT}}{V_{IN(max)}}\right) \dots\dots\dots (5)$$

$$\Delta I_L = \left(\frac{V_{OUT}}{f \times L}\right) \times \left(1 - \frac{V_{OUT}}{V_{IN}}\right) \dots\dots\dots (6)$$

The Peak inductor current is:

$$I_{Lpeak} = I_O + \frac{\Delta I_L}{2} \dots\dots\dots (7)$$

High inductance gives low inductor ripple current but requires larger size inductor to avoid saturation. Low ripple current reduces inductor core losses. It also reduces RMS current through inductor and switches, which results in less conduction loss. Usually, peak to peak ripple current on inductor is designed to be at least 20% to 40% of output current.

When selecting the inductor, make sure it is able to handle the peak current without saturation even at the highest operating temperature. The inductor is takes the highest current in the buck circuit. So the conduction losses on inductor need to be checked for

thermal and for highest efficiency, the inductor DC resistance should be lower value requirements.

Output Filter Capacitor Selection

The output capacitor is selected based on the DC output voltage rating, output ripple voltage specification and ripple current rating.

The selected output capacitor must have a higher rated voltage specification than the maximum desired output voltage including ripple. De-rating needs to be considered for long term reliability.

Output ripple voltage specification is another important factor for selecting the output capacitor. In a buck converter circuit, output ripple voltage is determined by inductor value, switching frequency, output capacitor value and ESR. It can be calculated by the equation below:

$$\Delta V_{OUT} = \Delta I_L \times \left(ESR_{COUT} + \frac{1}{8 \times f \times C_{OUT}}\right) \dots\dots (8)$$

Where, C_o is output capacitor value, and ESR C_o is the equivalent series resistance of the output capacitor.

When low ESR ceramic capacitor is used as output capacitor, the impedance of the capacitor at the switching frequency dominates. Output ripple is mainly caused by capacitor value and inductor ripple current. The output ripple voltage calculation can be simplified to:

$$\Delta V_{OUT} = \Delta I_L \times \frac{1}{8 \times f \times C_{OUT}} \dots\dots\dots (9)$$

If the impedance of ESR at switching frequency dominates, the output ripple voltage is mainly decided by capacitor ESR and inductor ripple current. The output ripple voltage calculation can be further simplified equation below:

$$\Delta V_{OUT} = \Delta I_L \times ESR_{COUT} \dots\dots\dots (10)$$

For lower output ripple voltage across the entire operating temperature range, X5R or X7R dielectric type of ceramic, or other low ESR tantalum are recommended to be used as output capacitors.

In a buck converter, output capacitor current is continuous. The RMS current of output capacitor is decided by the peak to peak inductor ripple current. It can be calculated by:

$$I_{COUT_RMS} = \frac{\Delta I_L}{\sqrt{12}} \dots\dots\dots (11)$$

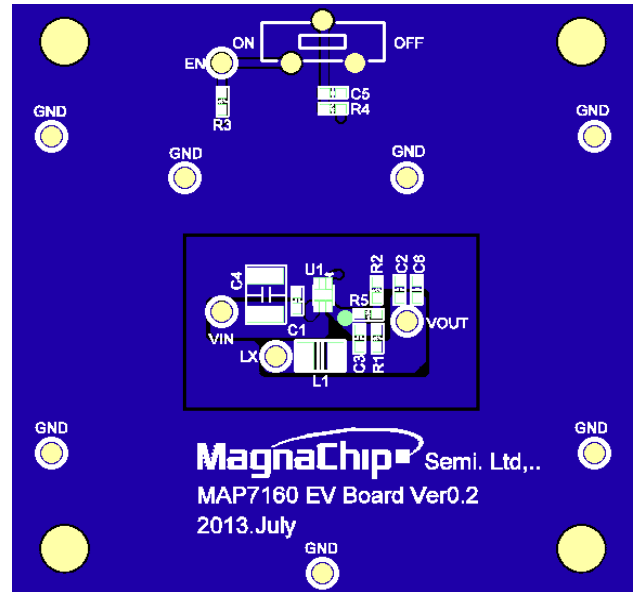
Usually, the ripple current rating of the output capacitor is a smaller issue because of the low current stress. When the buck inductor is selected to be very small and inductor ripple current is high, the output capacitor could be overstressed.

PCB Layout Guide

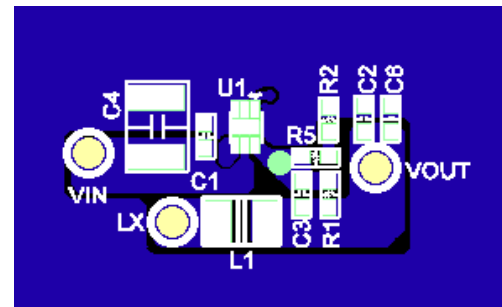
Careful PCB layout is critical to achieve clean and stable operation. It is highly recommended to duplicate the MAP7160 evaluation board layout for optimum performance. If deviation is necessary, follow these guidelines for good PCB layout:

- ✓ Make the power ground PGND connection shared between U1, CV_{IN} and CV_{OUT} compact. This minimizes the parasitic inductance of the switching loop paths.
- ✓ Place PGND on the top layer and connect it to the AGND ground plane next to Cout using several vias.
- ✓ Ensure that the routing loop, VIN PGND VOUT is the very shortest possible.
- ✓ Place the inductor away from the feedback pins to prevent unpredictable loop behavior.
- ✓ Use the application circuit layout from the datasheet whenever possible. Its performance has been verified.
- ✓ VIN and PGND must rout with the widest and shortest traces possible. It is acceptable for the traces connecting the inductor to be long rather than having long VIN or PGND traces. The SW node is a source of electrical switching noise. Do not route it near sensitive analog signals.
- ✓ Two small vias are used to connect the SW node to the inductor L1. Use solders filled vias if available.
- ✓ The expose pad and GND pin should be connected to a strong ground plane for heat sinking and noise protection.

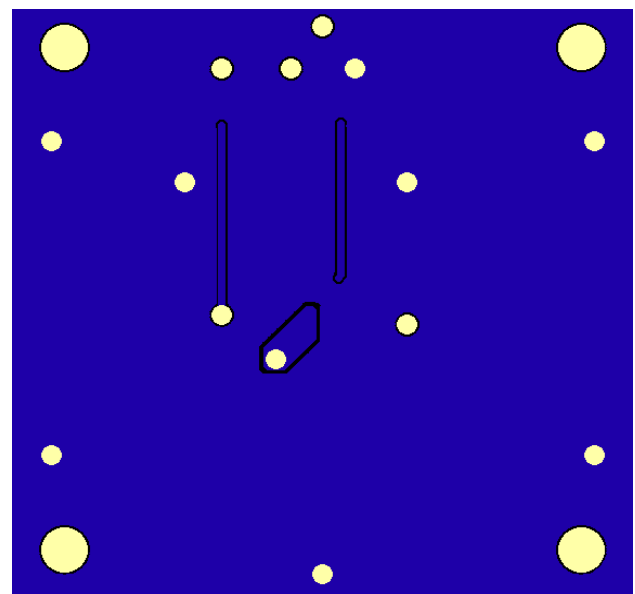
Top Side Layer



Top Side Layer Zoom

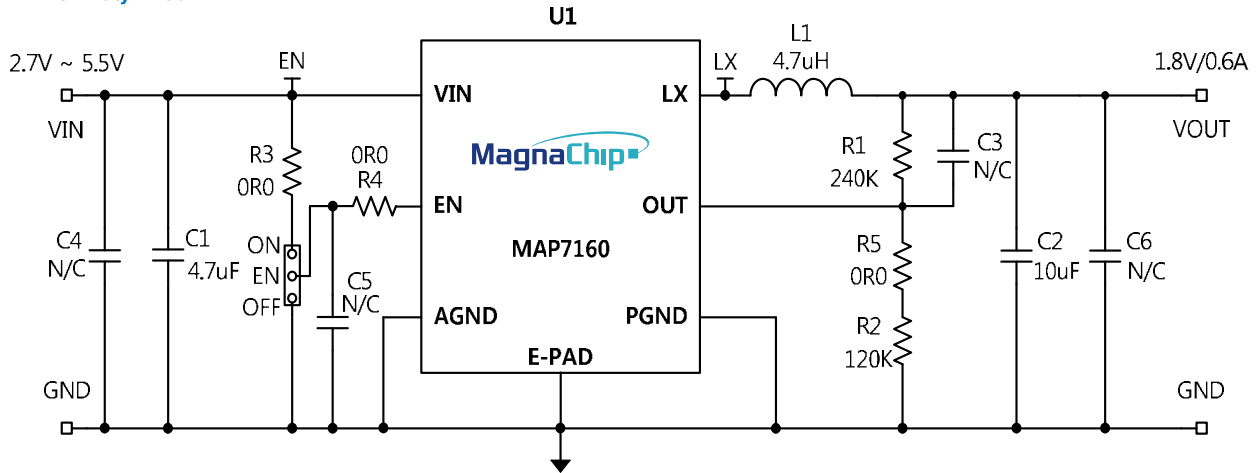


Bottom Side Layer



MAP7160 Evaluation Board Schematic

MAP7160 Evaluation Board Schematic
 Vin=EN=2.7~5.5V, Vout=1.8V/600mA
 Switching Frequency : 2MHz
 Max Duty = 100%

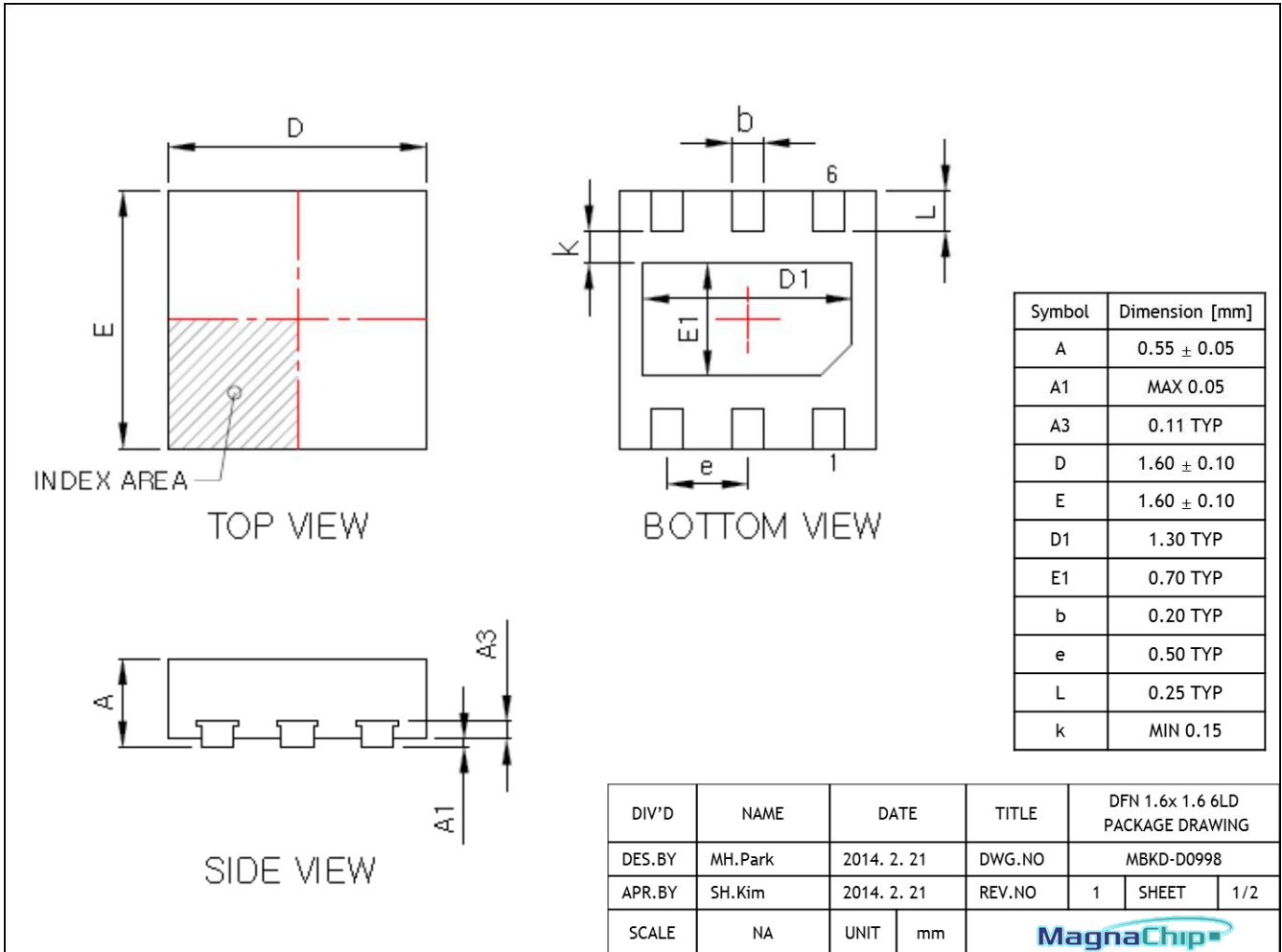


Bill of Material of MAP7160 Evaluation Board

Item	Part Number	Manufacturer	Description	Q'ty
U1	MAP7160	Magnachip Semiconductor	3A Synchronous Buck Converter	1
C1	CL10A475KQ8NNN	SAMSUNG	4.7uF/6.3V, MLCC, X5R, Size1608	1
C2	CL10A106KQ8NNN	SAMSUNG	10uF/6.3V, MLCC, X5R, Size1608	1
L1	EFE252012C	TOKO	4.7uH/1.5A, ±30%, Size2520	1
R1	RC1608F1203	SAMSUNG	240Kohm, 1%, Size1608	1
R2	RC1608F3002	SAMSUNG	120Kohm, 1%, Size1608	1
R3, R4	RC1608J0R0	SAMSUNG	0ohm, 10%, Size1608	2
EN	PH01(2.54)-3Pin	ELEPARTS	PH01(2.54)-SS40P-11.5MM	1

Physical Dimensions

- 1.6 X 1.6mm DFN 6P



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