

## 3A High Performance Step-Up DC/DC Converter

### General Description

The PT Í FÎ F includes a high performance step-up DC/DC converter that provides a regulated supply voltage for active-matrix thin-film transistor (TFT) liquid-crystal displays (LCDs).

The Boost Converter incorporates current mode, fixed-frequency, pulse-width modulation (PWM) circuitry with a built-in N-Channel power MOSFET to achieve high efficiency and fast transient response.

The HM5161 is available in a WDFN -10L 3x3 package.

### Ordering Information

HM5161 □ □

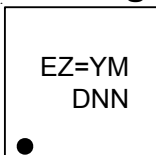
- Package Type  
QW : WDFN-10L 3x3 (W-Type)
- Lead Plating System  
G : Green (Halogen Free and Pb Free)

Note :

Richtek products are :

- ▶ RoHS compliant and compatible with the current requirements of IPC/JEDEC J-STD-020.
- ▶ Suitable for use in SnPb or Pb-free soldering processes.

### Marking Information



EZ= : Product Code  
YMDNN : Date Code

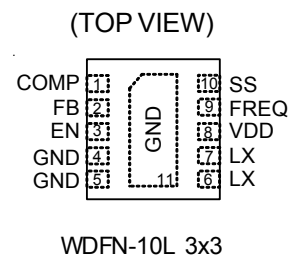
### Features

- High Efficiency Up to 90%
- Adjustable Output Voltage :  $V_{DD}$  to 24V
- Wide Input Supply Voltage : 2.6V to 5.5V
- Input Under Voltage Lockout
- Pin-Programmable Switching Frequency 640kHz/1.2MHz
- Programmable Soft-Start
- Small 10-Lead WDFN Package
- RoHS Compliant and Halogen Free

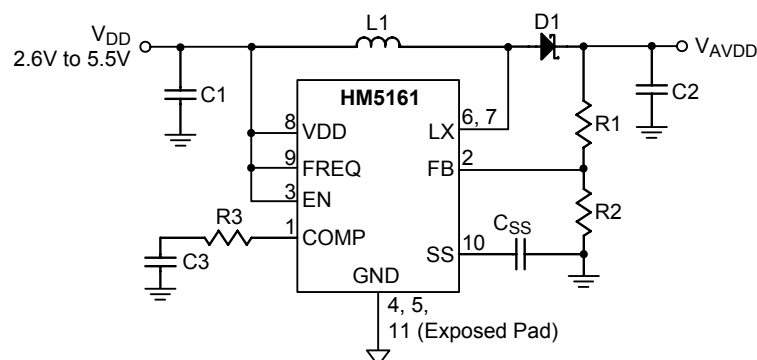
### Applications

- Notebook Computer Displays
- LCD Monitor Panels
- LCD TV Panels

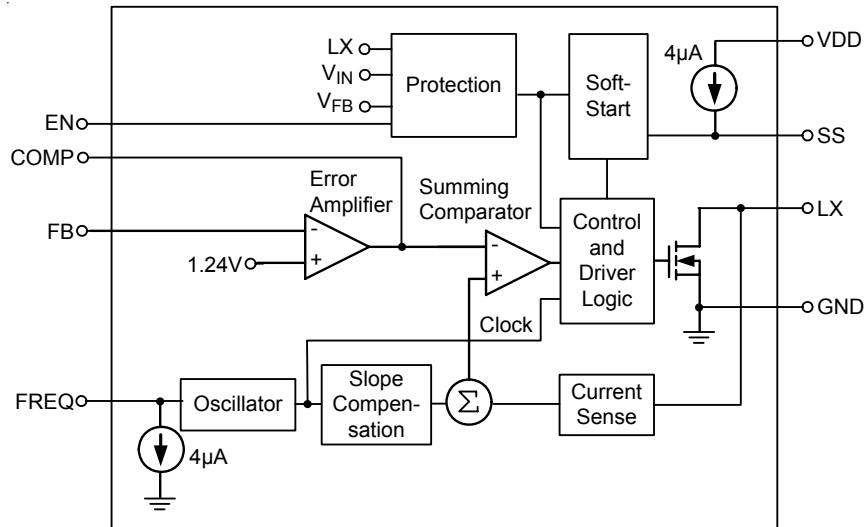
### Pin Configurations



### Typical Application Circuit



## Function Block Diagram



## Functional Pin Description

Pin No.	Pin Name	Pin Function
1	COMP	Compensation Pin for Error Amplifier. Connect a series RC from COMP to ground.
2	FB	Feedback. The feedback regulation voltage is 1.24V nominal. Connect an external resistive voltage-divider between the step-up regulator's output ( $V_{AVDD}$ ) and GND, with the center tap connected to FB. Place the divider close to the IC and minimize the trace area to reduce noise coupling.
3	EN	Enable Control Input. Drive EN low to turn off the Boost Converter.
4, 5 11 (Exposed Pad)	GND	Ground. The exposed pad must be soldered to a large PCB and connected to GND for maximum power dissipation.
6, 7	LX	Switch. LX is the drain of the internal MOSFET. Connect the inductor/rectifier diode junction to LX and minimize the trace area for lower EMI.
8	VDD	Supply Pin. Bypass $V_{DD}$ with a minimum $1\mu\text{F}$ ceramic capacitor directly to GND.
9	FREQ	Frequency-Select Input. When FREQ is low, the oscillator frequency will be set to 640kHz. When FREQ is high, the frequency will be set to 1.2MHz. This input has a $6\mu\text{A}$ pull-down current.
10	SS	Soft-Start Control. Connect a soft-start capacitor ( $C_{SS}$ ) to this pin. A $4\mu\text{A}$ constant current charges the soft-start capacitor. When EN connected to GND, the soft-start capacitor is discharged. When EN connected to $V_{DD}$ high, the soft-start capacitor is charged to $V_{DD}$ . Leave floating for not using soft-start.

## Absolute Maximum Ratings (Note 1)

• LX to GND	-----	-0.3V to 26V
• Other Pins to GND	-----	-0.3V to 6V
• Power Dissipation, $P_D$ @ $T_A = 25^\circ\text{C}$		
WDFN-10L 3x3	-----	1.667W
• Package Thermal Resistance (Note 2)		
WDFN-10L 3x3, $\theta_{JA}$	-----	60°C/W
WDFN-10L 3x3, $\theta_{JC}$	-----	8.2°C/W
• Lead Temperature (Soldering, 10 sec.)	-----	260°C
• Junction Temperature	-----	150°C
• Storage Temperature Range	-----	-65°C to 150°C
• ESD Susceptibility (Note 3)		
HBM (Human Body Model)	-----	2kV
MM (Machine Model)	-----	200V

## Recommended Operating Conditions (Note 4)

• Supply Input Voltage, $V_{DD}$	-----	2.6V to 5.5V
• Junction Temperature Range	-----	-40°C to 125°C
• Ambient Temperature Range	-----	-40°C to 85°C

## Electrical Characteristics

( $V_{DD} = 3.3\text{V}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
<b>Supply Current</b>						
Input Voltage Range	$V_{DD}$	$V_{AVDD} < 18\text{V}$	2.6	--	5.5	V
		$18\text{V} < V_{AVDD} < 24\text{V}$	4	--	5.5	
Output Voltage Range	$V_{AVDD}$		$V_{DD}$	--	24	V
Under-Voltage Lockout Threshold	$V_{UVLO}$	$V_{DD}$ Rising	--	2.4	--	V
		Hysteresis	--	50	--	mV
Quiescent Current	$I_Q$	$V_{FB} = 1.3\text{V}$ , LX Not Switching	--	0.5	--	mA
		$V_{FB} = 1\text{V}$ , LX Switching	--	4	--	
Shutdown Current	$I_{SHDN}$	EN = GND	--	0.1	10	$\mu\text{A}$
<b>Oscillator</b>						
Oscillator Frequency	$f_{OSC}$	FREQ = GND	500	640	750	kHz
		FREQ = $V_{IN}$	1000	1240	1500	
Maximum Duty Cycle			--	90	--	%
<b>Error Amplifier</b>						
Feedback Regulation Voltage	$V_{FB}$		1.22	1.24	1.26	V
Feedback Input Bias Current	$I_{FB}$		--	125	250	nA

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Feedback Line Regulation			--	0.05	0.2	%/V
Transconductance	gm	$\Delta I = \pm 2.5\mu A$ at COMP = 1V	--	135	--	$\mu A/V$
Voltage Gain	Av	FB to COMP	--	700	--	V/V
<b>N- MOSFET</b>						
Current Limit	I <sub>LIM</sub>		3	3.8	5	A
On-Resistance	R <sub>DS(ON)</sub>		--	125	250	m $\Omega$
Leakage Current	I <sub>LEAK</sub>	V <sub>LX</sub> = 24V	--	30	45	$\mu A$
Current-Sense Transresistance	R <sub>CS</sub>		--	0.25	--	V/A
<b>Soft-Start</b>						
Charge Current	I <sub>SS</sub>		--	4	--	$\mu A$
<b>Control Inputs</b>						
EN, FREQ Input Low Voltage	V <sub>IL</sub>		--	--	0.3 x V <sub>DD</sub>	V
EN, FREQ Input High Voltage	V <sub>IH</sub>		0.7 x V <sub>DD</sub>	--	--	V
EN, FREQ Input Hysteresis			--	0.1 x V <sub>DD</sub>	--	V
FREQ Pull-down Current			--	6	--	$\mu A$
EN Input Current	I <sub>EN</sub>	EN = GND	--	0.001	1	$\mu A$

**Note 1.** Stresses beyond those listed "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 in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

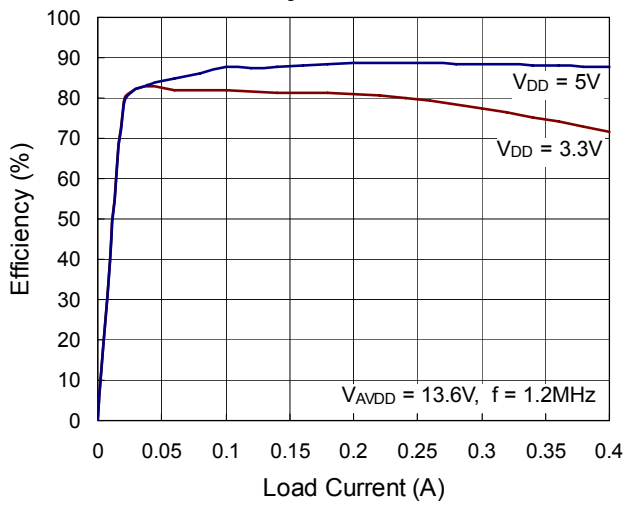
**Note 2.**  $\theta_{JA}$  is measured at T<sub>A</sub> = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7.  $\theta_{JC}$  is measured at the exposed pad of the package.

**Note 3.** Devices are ESD sensitive. Handling precaution is recommended.

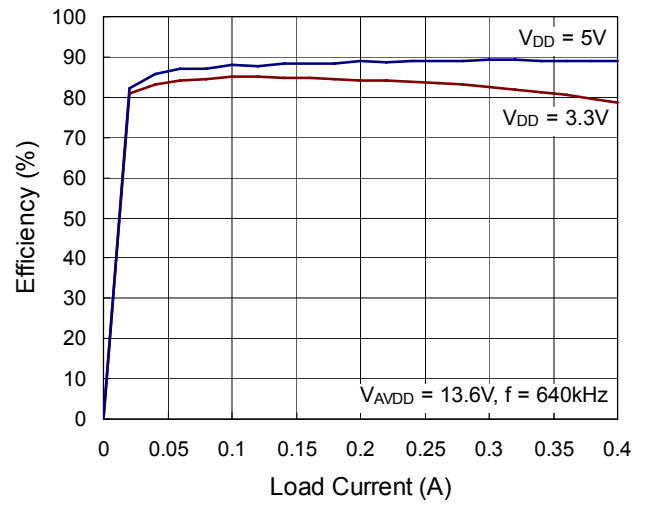
**Note 4.** The device is not guaranteed to function outside its operating conditions.

## Typical Operating Characteristics

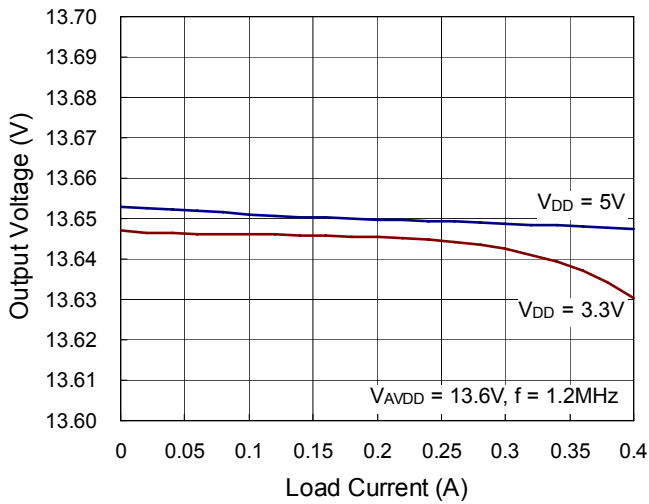
**Efficiency vs. Load Current**



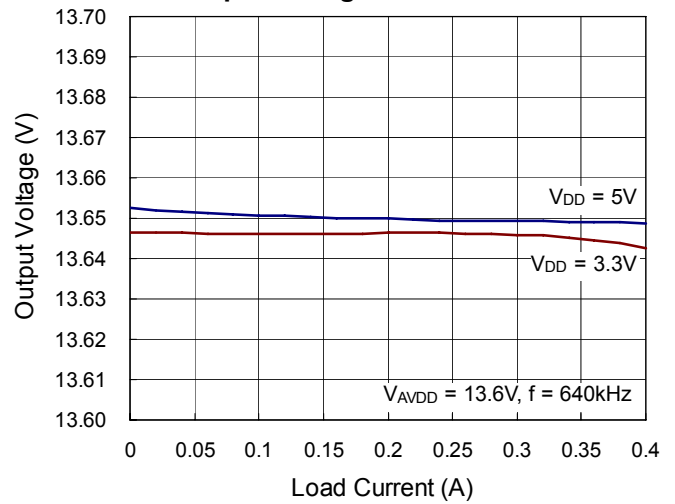
**Efficiency vs. Load Current**



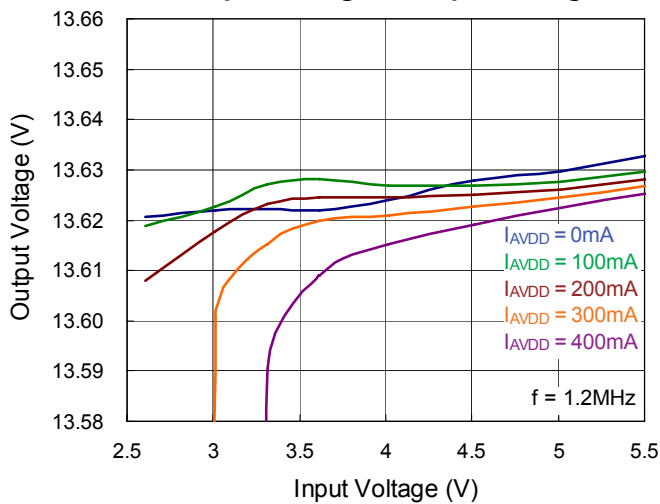
**Output Voltage vs. Load Current**



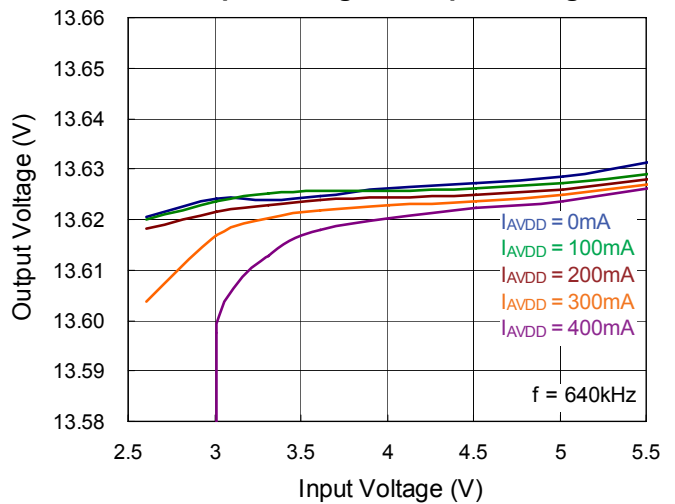
**Output Voltage vs. Load Current**



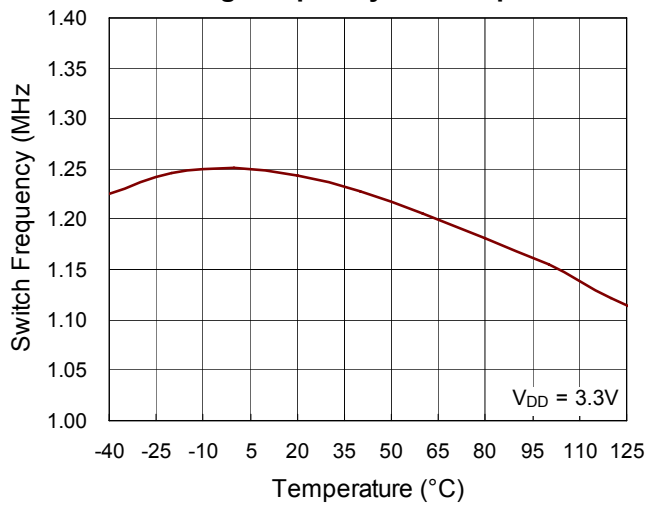
**Output Voltage vs. Input Voltage**



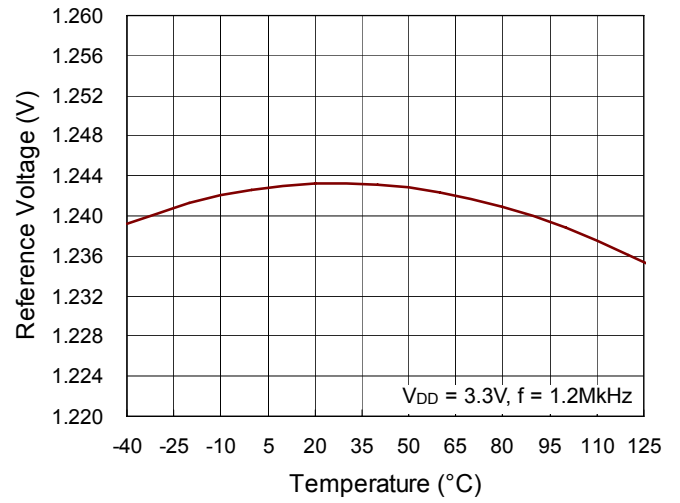
**Output Voltage vs. Input Voltage**



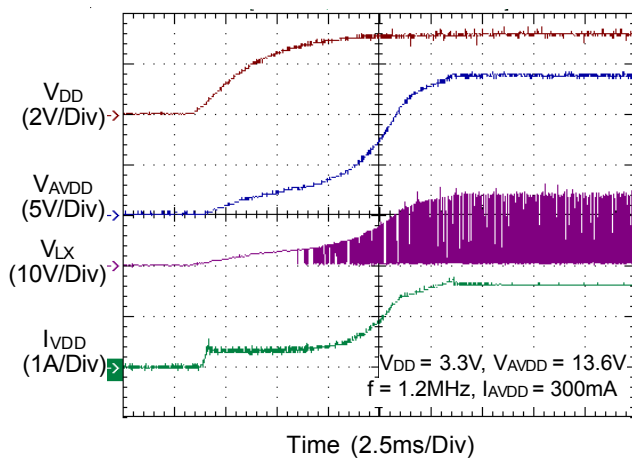
**Switching Frequency vs. Temperature**



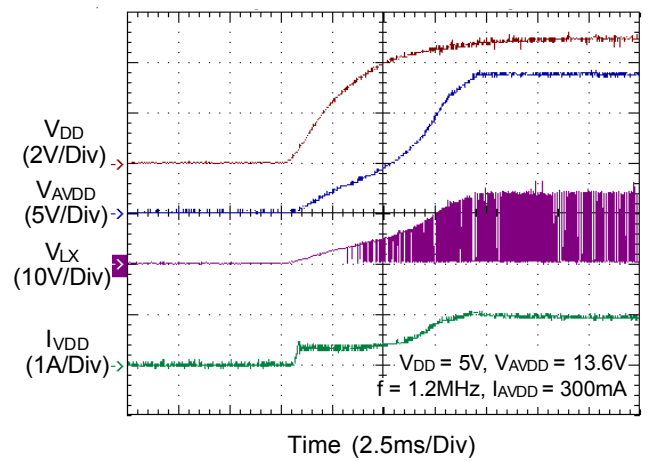
**Reference Voltage vs. Temperature**



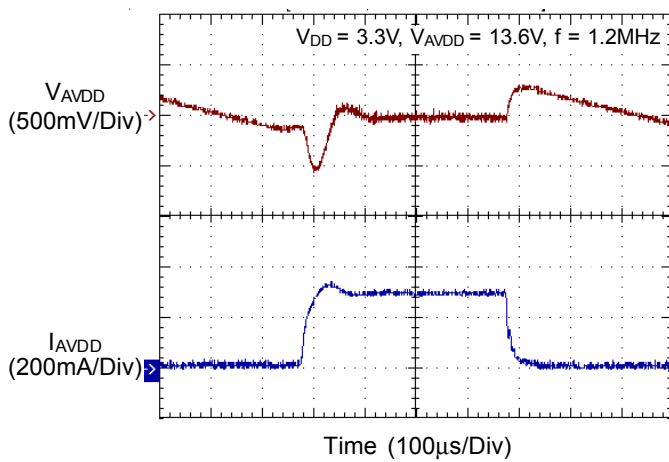
**Start Up**



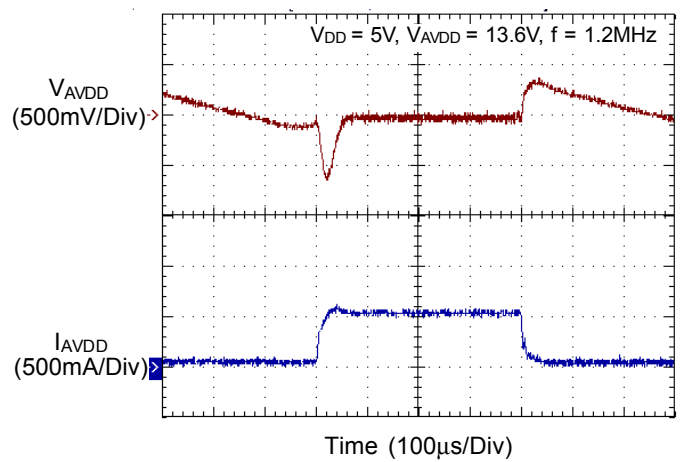
**Start Up**



**Load Transient Response**



**Load Transient Response**



## Application Information

The HM5161 contains a high performance boost regulator to generate voltage for the panel source driver ICs. The following content contains the detailed description and the information of component selection.

### Boost Regulator

The boost regulator is a high efficiency current-mode PWM architecture with 640K / 1.2MHz operation frequency. It performs fast transient responses to generate source driver supplies for TFT LCD display. The high operation frequency allows smaller components used to minimize the thickness of the LCD panel. The output voltage setting can be achieved by setting the resistive voltage-divider sensing at FB pin. The error amplifier varies the COMP voltage by sensing the FB pin to regulate the output voltage. For better stability, the slope compensation signal summed with the current-sense signal will be compared with the COMP voltage to determine the current trip point and duty cycle.

### Soft-Start

The HM5161 provides soft-start function to minimize the inrush current. When power on, an internal constant current charges an external capacitor. The rising voltage rate on the COMP pin is limited during the charging period and the inductor peak current will also be limited at the same time. When power off, the external capacitor will be discharged for next soft start time.

The soft-start function is implemented by the external capacitor with a 4μA constant current charging to the soft-start capacitor. Therefore, the capacitor should be large enough for output voltage regulation. Typical value for soft-start capacitor range is 33nF. The available soft-start capacitor range is from 10nF to 100nF.

### Output Voltage Setting

The regulated output voltage is shown as following equation :

$$V_{AVDD} = 1.24V \times \left(1 + \frac{R_1}{R_2}\right)$$

The recommended value for R2 should be up to 10kΩ without some sacrificing. To place the resistor divider as close as possible to the chip can reduce noise sensitivity.

### Loop Compensation

The voltage feedback loop can be compensated with an external compensation network consisted of R<sub>COMP</sub> and C<sub>COMP</sub>. Choose R<sub>COMP</sub> to set high frequency integrator gain for fast transient response and C<sub>COMP</sub> to set the integrator zero to maintain loop stability. For typical application V<sub>DD</sub> = 3.3V , V<sub>AVDD</sub> = 13.6V , C4 = 4.7μF x 3 , L = 3.6μH, the recommended value for compensation is as below : R<sub>COMP</sub> = 56kΩ, C<sub>COMP</sub> = 330pF.

### Over Current Protection

The HM5161 boost converter has over-current protection to limit peak inductor current. It prevents large current from damaging the inductor and diode. During the ON-time, once the inductor current exceeds the current limit, the internal LX switch turns off immediately and shortens the duty cycle. Therefore, the output voltage drops if the over-current condition occurs. The current limit there should be also affected by the input voltage, duty cycle and inductor value.

### Over Temperature Protection

The HM5161 boost converter has thermal protection function to prevent the chip from overheating. When the junction temperature exceeds 155°C, it will shut down the device. Once the device cools down by approximately 30°C, it will start to operate normally. For continuous operation, do not operate over the maximum junction temperature rating 125°C.

### Inductor Selection

The inductance depends on the maximum input current. The inductor current ripple is 20% to 40% of maximum input current that is a general rule. Assume, choose 40% as the criterion then

$$I_{VDD(MAX)} = \frac{V_{AVDD} \times I_{AVDD(MAX)}}{\eta \times V_{DD}}$$

$$I_{RIPPLE} = 0.4 \times I_{VDD(MAX)}$$

Where η is the efficiency, I<sub>IN(MAX)</sub> is the maximum input current, I<sub>RIPPLE</sub> is the inductor current ripple. Besides, the input peak current is maximum input current plus half of inductor current ripple.

$$I_{PEAK} = 1.2 \times I_{VDD(MAX)}$$

Note that the saturated current of inductor must be greater than  $I_{PEAK}$ . The inductance can be eventually determined as follow equation :

$$L = \frac{\eta \times (V_{DD})^2 \times (V_{AVDD} - V_{DD})}{0.4 \times (V_{AVDD})^2 \times I_{AVDD(MAX)} \times f_{OSC}}$$

Where  $f_{OSC}$  is the switching frequency. To consider the system performance, a shielded inductor is preferred to avoid EMI issue.

### Diode Selection

Schottky diode is a good choice for an asynchronous Boost converter due to the small forward voltage. However, power dissipation, reverse voltage rating and pulsating peak current are the important parameters for Schottky diode selection. It is recommended to choose a suitable diode whose reverse voltage rating is greater than the maximum output voltage.

### Capacitor Selection

Output ripple voltage is an important index for estimating the performance. This portion consists of two parts, one is the product of input current and ESR of output capacitor, another part is formed by charging and discharging process of output capacitor. Refer to Figure 1, evaluate  $\Delta V_{OUT1}$  by ideal energy equalization. According to the definition of Q, the Q value can be calculated as following equation :

$$Q = \frac{1}{2} \times \left[ \left( I_{IN} + \frac{1}{2} \Delta I_L - I_{OUT} \right) + \left( I_{IN} - \frac{1}{2} \Delta I_L - I_{OUT} \right) \right] \times \frac{V_{IN}}{V_{OUT}} \times \frac{1}{f_{SW}} = C_{OUT} \times \Delta V_{OUT1}$$

where  $f_{SW}$  is the switching frequency, and  $\Delta I_L$  is the inductor ripple current. Move  $C_{OUT}$  to the left side to estimate the value of  $\Delta V_{OUT1}$  as the following equation :

$$\Delta V_{OUT1} = \frac{D \times I_{OUT}}{\eta \times C_{OUT} \times f_{SW}}$$

Finally, by taking ESR into consideration, the overall output ripple voltage can be determined as the following equation :

$$\Delta V_{OUT} = I_{IN} \times ESR + \frac{D \times I_{OUT}}{\eta \times C_{OUT} \times f_{SW}}$$

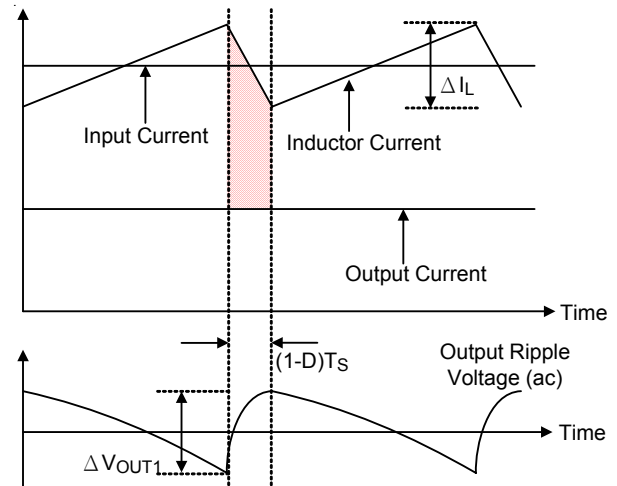


Figure 1. The Output Ripple Voltage without the Contribution of ESR

### Input Capacitor Selection

Low ESR ceramic capacitors are recommended for input capacitor applications. Low ESR will effectively reduce the input voltage ripple caused by switching operation. A 10 $\mu$ F is sufficient for most applications. Nevertheless, this value can be decreased for lower output current requirement. Another consideration is the voltage rating of the input capacitor must be greater than the maximum input voltage.

### Thermal Considerations

For continuous operation, do not exceed absolute maximum operation junction temperature. The maximum power dissipation depends on the thermal resistance of IC package, PCB layout, the rate of surroundings airflow and temperature difference between junction to ambient. The maximum power dissipation can be calculated by following formula :

$$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$$

Where  $T_{J(MAX)}$  is the maximum operation junction temperature 125°C,  $T_A$  is the ambient temperature and the  $\theta_{JA}$  is the junction to ambient thermal resistance.

For recommended operating conditions specification, where  $T_{J(MAX)}$  is the maximum junction temperature of the die (125°C) and  $T_A$  is the maximum ambient temperature. The junction to ambient thermal resistance  $\theta_{JA}$  is layout



dependent. For WDFN-10L 3x3 packages, the thermal resistance  $\theta_{JA}$  is 60°C/W on the standard JEDEC 51-7 four layers thermal test board. The maximum power dissipation at  $T_A = 25^\circ\text{C}$  can be calculated by following formula :

$$P_{D(\text{MAX})} = (125^\circ\text{C} - 25^\circ\text{C}) / (60^\circ\text{C/W}) = 1.667\text{W for WDFN-10L 3x3 package}$$

The maximum power dissipation depends on operating ambient temperature for fixed  $T_{J(\text{MAX})}$  and thermal resistance  $\theta_{JA}$ . The Figure 2 of derating curves allows the designer to see the effect of rising ambient temperature on the maximum power allowed.

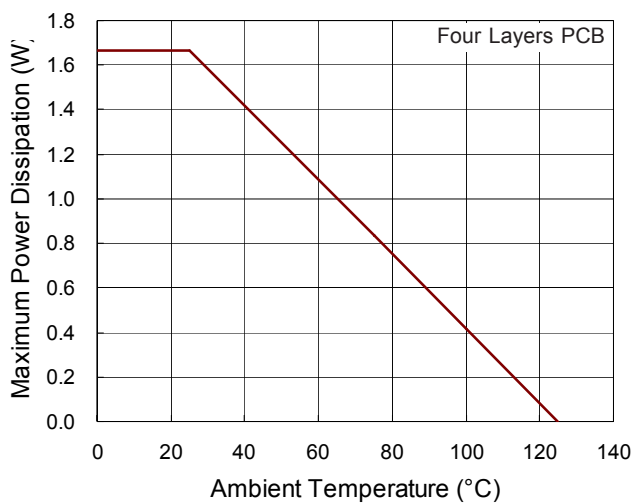


Figure 2. Derating Curve of Maximum Power Dissipation

### Layout Considerations

For high frequency switching power supplies, the PCB layout is important to get good regulation, high efficiency and stability. The following descriptions are the guidelines for better PCB layout.

- ▶ For good regulation, place the power components as close as possible. The traces should be wide and short enough especially for the high-current output loop.
- ▶ The feedback voltage-divider resistors must be near the feedback pin. The divider center trace must be shorter and the trace must be kept away from any switching nodes.
- ▶ The compensation circuit should be kept away from the power loops and be shielded with a ground trace to prevent any noise coupling.
- ▶ Minimize the size of the LX node and keep it wide and shorter. Keep the LX node away from the FB.
- ▶ The exposed pad of the chip should be connected to a strong ground plane for maximum thermal consideration.

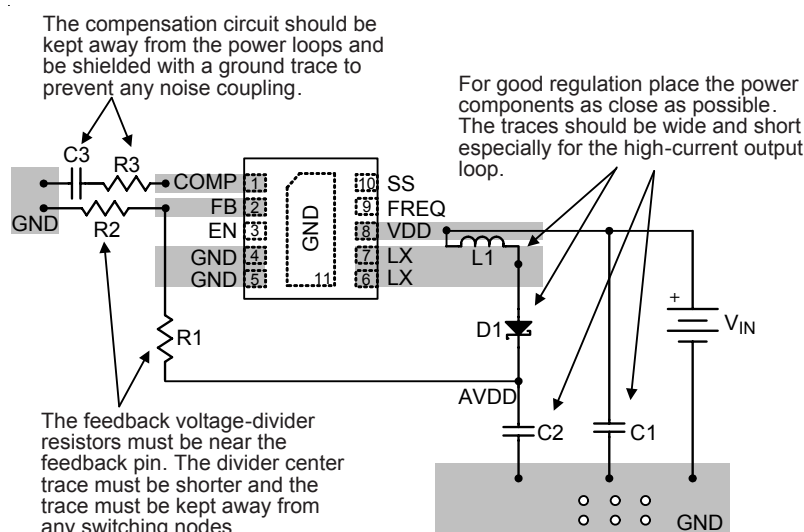
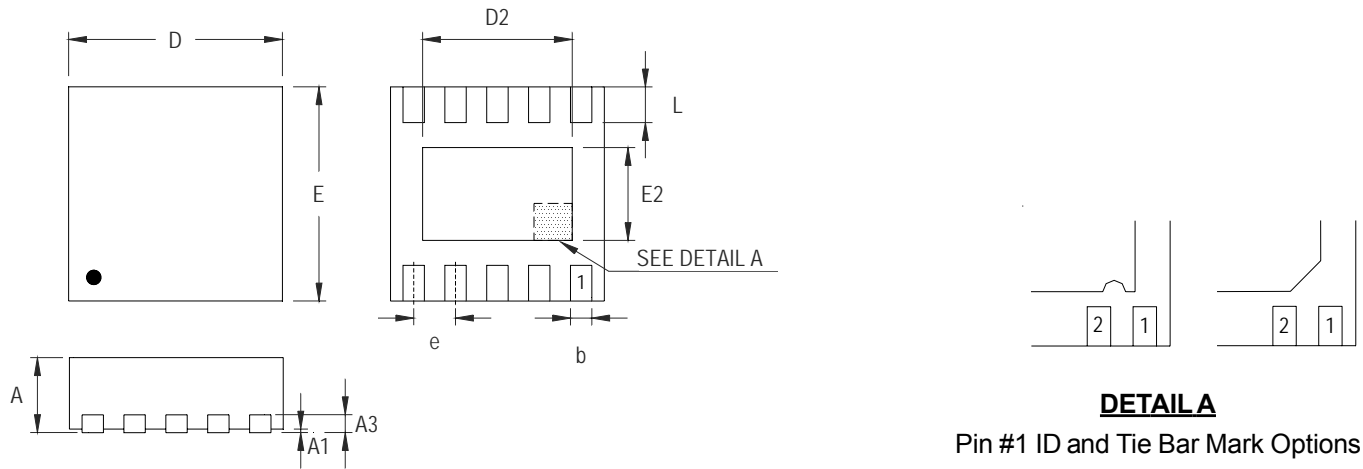


Figure 3. PCB Layout Guide

## Outline Dimension



Note : The configuration of the Pin #1 identifier is optional, but must be located within the zone indicated.

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.175	0.250	0.007	0.010
b	0.180	0.300	0.007	0.012
D	2.950	3.050	0.116	0.120
D2	2.300	2.650	0.091	0.104
E	2.950	3.050	0.116	0.120
E2	1.500	1.750	0.059	0.069
e	0.500		0.020	
L	0.350	0.450	0.014	0.018

**W-Type 10L DFN 3x3 Package**

