TEXAS INSTRUMENTS

LMR61428

SIMPLE SWITCHER® 14Vout, 2.85A Step-Up Voltage Regulator in MSOP

Features

- 1.2V to 14V Input Voltage
- Adjustable Output Voltage up to 14V
- Switch current up to 2.85A
- Up to 2 MHz Switching Frequency
- Low shutdown Iq, <1µA
- Cycle by cycle current limitting
- MSOP-8 packaging (3.0 x 5.0 x 1.09mm)
- WEBENCH® enabled

Performance Benefits

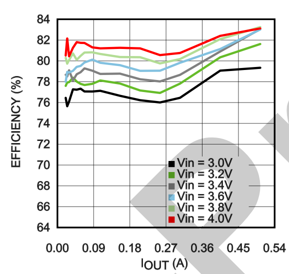
- Tight accuracy for powering digital ICs
- Extremely easy to use
- Tiny overall solution reduces system cost

Applications

- Boost/SEPIC conversions from 3.3V, 5V, and 12V
- Space constrained applications
- LCD displayed
- LED applications

System Performance

Efficiency vs Load Current V_{OUT} = 5V



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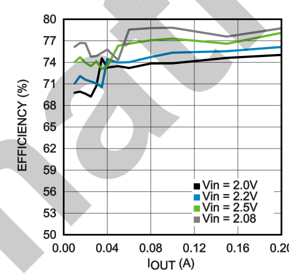
Efficiency vs Load Current V_{OUT} = 3.3V



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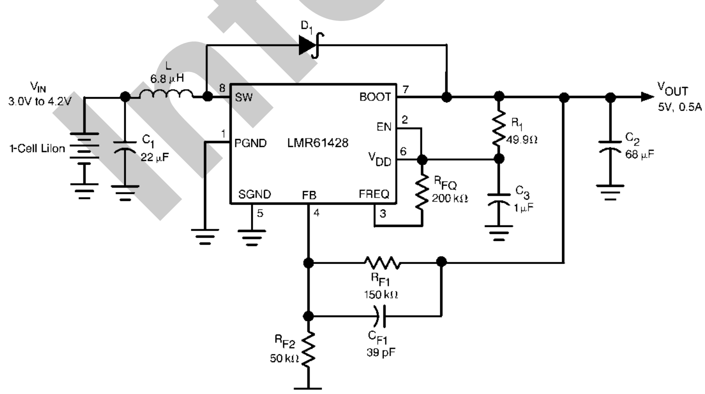
Typical Application Circuit



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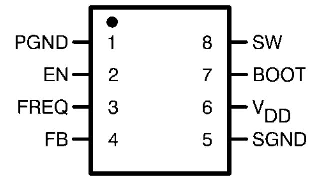
Connection Diagram

Mini SO-8 (MM) Package



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Top View

Ordering Information

Order Number	Package Type	Package Drawing	Package Marking	Supplied As
LMR61428XMMX	Mini SO-8	MUA08A	S06A	3000 Units on Tape and Reel
LMR61428XMM	Mini SO-8	MUA08A	S06A	1000 Units on Tape and Reel

Pin Description

Pin	Name	Function
1	PGND	Power Ground
2	EN	Active-Low Shutdown Input
3	FREQ	Frequency Adjust. An external resistor connected between this pin and Pin 6 (V_{DD}) sets the switching frequency of the LMR61428.
4	FB	Output Voltage Feedback
5	SGND	Signal Ground
6	V_{DD}	Power Supply for Internal Circuitry
7	BOOT	Bootstrap Supply for the Gate Drive of Internal MOSFET Power Switch
8	SW	Drain of the Internal MOSFET Power Switch

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Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.

SW Pin Voltage	−0.5 V to 14.5V
BOOT, V_{DD}, EN and FB Pins	−0.5V to 10V
FREQ Pin	100µA
θ_{JA} (Note 2)	240°C/W
T_{Jmax} (Note 2)	150°C
Storage Temperature Range	−65°C to +150°C
Lead Temp. (Soldering, 5 sec)	260°C
Power Dissipation (T_A=25°C) (Note 2)	500mW
ESD Rating (Note 3)	2kV

Operating Conditions (Note 1)

V_{DD} Pin	2.5V to 5V
FB, EN Pins	0 to V_{DD}
BOOT Pin	0 to 10V
Ambient Temperature (T_A)	−40°C to +85°C

Electrical Characteristics

Limits in standard typeface are for T_J = 25°C, and limits in **boldface** type apply over the full operating temperature range of −40°C to +85°C. Unless otherwise specified: V_{DD}= V_{OUT}= 3.3V.

Symbol	Parameter	Condition	Min	Typ	Max	Units
V_{IN_ST}	Minimum Start-Up Supply Voltage (Note 4)	I_{LOAD} = 0mA		1.1	**1.2**	V
V_{IN_OP}	Minimum Operating Supply Voltage (once started)	I_{LOAD} = 0mA		0.65		V
V_{FB}	FB Pin Voltage		**1.2028**	1.24	**1.2772**	V
V_{OUT_MAX}	Maximum Output Voltage			14		V
V_{HYST}	Hysteresis Voltage (Note 5)	At Feedback Pin		30	**45**	mV
η	Efficiency	V_{IN} = 3.6V;V_{OUT} = 5V;I_{LOAD} = 0.5A		87		%
		V_{IN} = 2.5V;V_{OUT} = 3.3V;I_{LOAD} = 0.2A		87		
D	Switch Duty Cycle		**60**	70	**80**	%
I_{DD}	Operating Quiescent Current (Note 6)	FB Pin > 1.3V; EN Pin at V_{DD}		80	**110**	µA
I_{SD}	Shutdown Quiescent Current (Note 7)	V_{DD}, BOOT and SW Pins at 5.0V; EN Pin <200mV		0.01	**2.5**	µA
I_{CL}	Switch Peak Current Limit			2.85		A
R_{DS_ON}	MOSFET Switch On Resistance			0.17		Ω
Enable Section						
V_{EN_LO}	EN Pin Voltage Low (Note 8)				**0.15V_{DD}**	V
V_{EN_HI}	EN Pin Voltage High (Note 8)		**0.7V_{DD}**			V

Note 1: Absolute maximum ratings indicate limits beyond which damage to the device may occur. Electrical specifications do not apply when operating the device outside of its rated operating conditions.

Note 2: The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{jmax} (maximum junction temperature), θ_{JA} (junction to ambient thermal resistance), and T_A (ambient temperature). The maximum allowable power dissipation at any temperature is $P_{dmax} = (T_{jmax} - T_A)/\theta_{JA}$ or the number given in the Absolute Maximum Ratings, whichever is lower.

Note 3: The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin. For Pin 8 (SW) the ESD rating is 1.5 kV.

Note 4: Output in regulation, $V_{OUT} = V_{OUT\ (NOMINAL)} \pm 5\%$

Note 5: This is the hysteresis value of the internal comparator used for the gated-oscillator control scheme.

Note 6: This is the current into the V_{DD} pin.

Note 7: This is the total current into pins V_{DD}, BOOT, SW and FREQ.

Note 8: When the EN pin is below V_{EN_LO}, the regulator is shut down; when it is above V_{EN_HI}, the regulator is operating.

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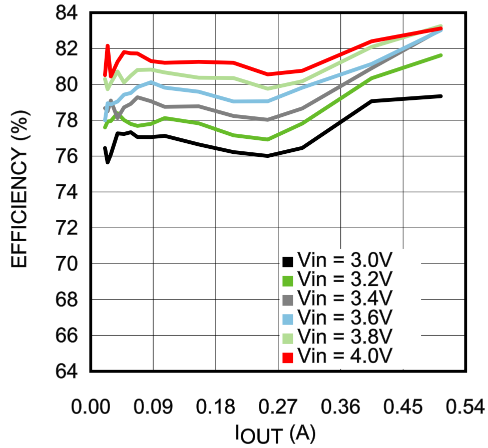
Typical Performance Characteristics

All curves taken at T_A = 25°C, unless specified otherwise.

Efficiency vs Load Current
V_{OUT} = 5.0V



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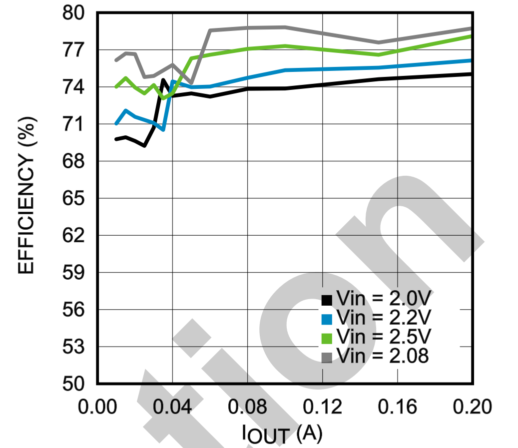
Efficiency vs Load Current
V_{OUT} = 3.3V



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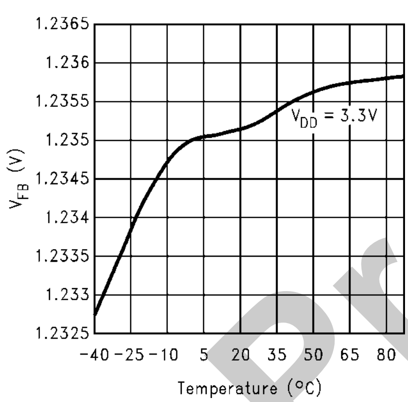
V_{FB} vs Temperature



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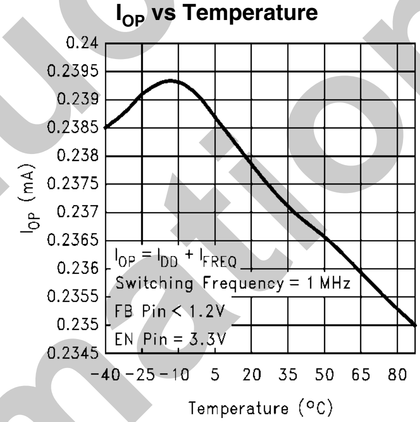
I_{OP} vs Temperature



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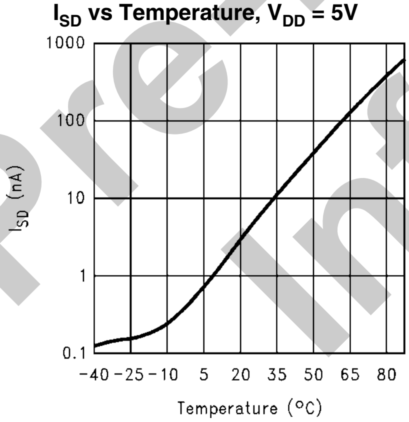
I_{SD} vs Temperature, V_{DD} = 5V



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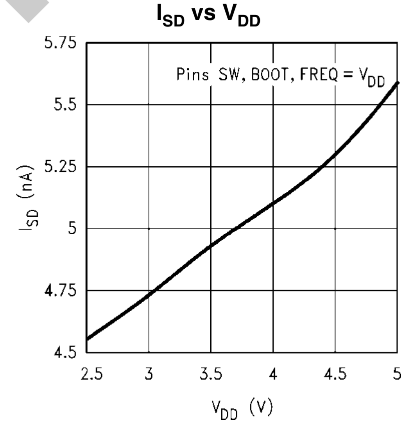
I_{SD} vs V_{DD}



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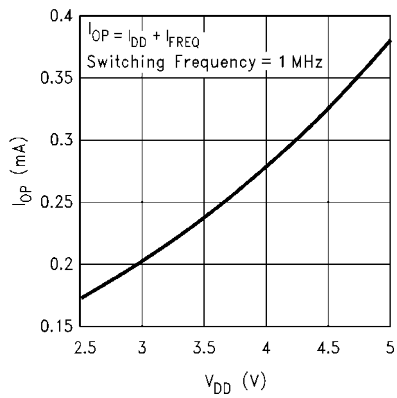
I_{OP} vs V_{DD}



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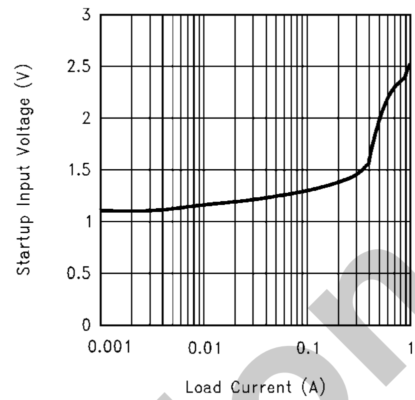
V_{IN_ST} vs Load Current V_{OUT} = 3.3V



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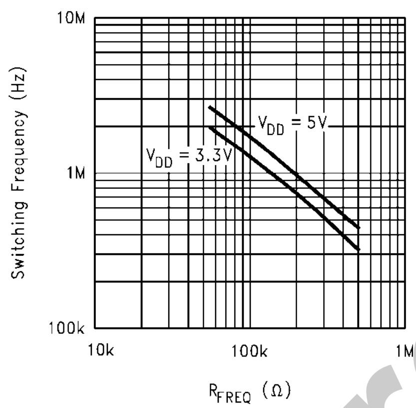
Switching Frequency vs R_{FQ}



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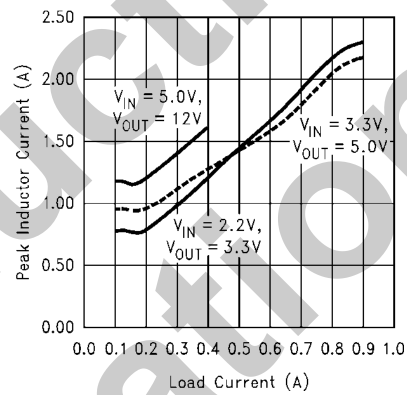
Peak Inductor Current vs Load Current



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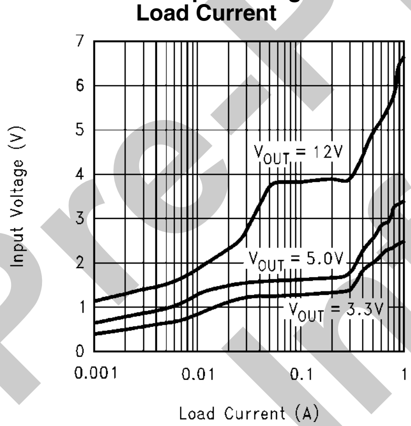
Minimum Input Voltage vs Load Current



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Simplified Block Diagram

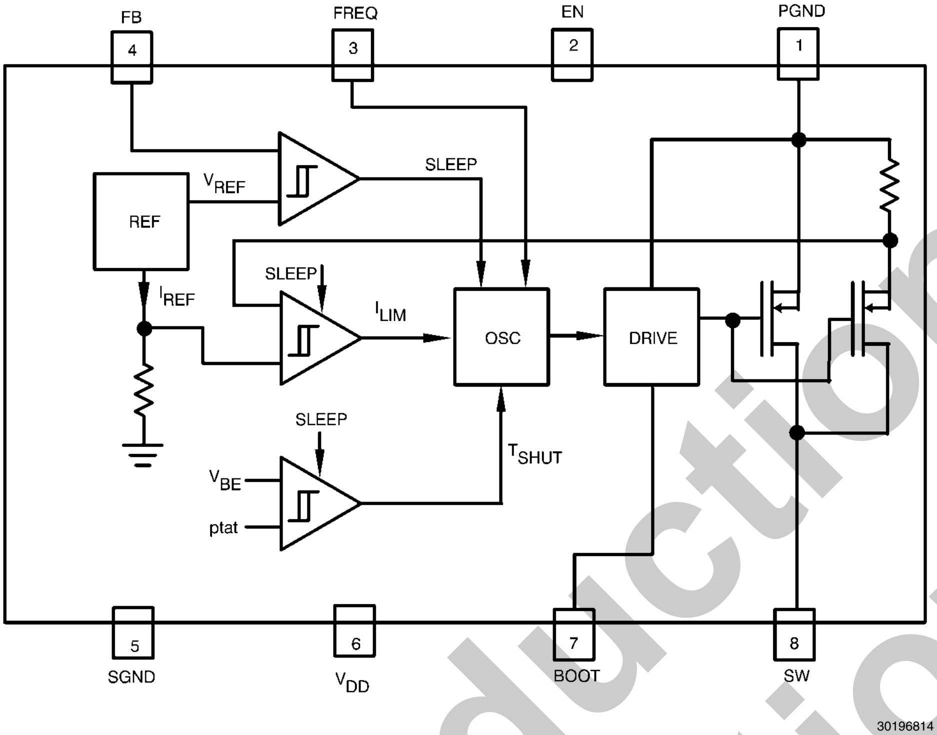

FIGURE 1. Block Diagram

Detailed Description

OPERATING PRINCIPLE

The LMR61428 is designed to provide step-up DC-DC voltage regulation in battery-powered and low-input voltage systems. It combines a step-up switching regulator, N-channel power MOSFET, built-in current limit, thermal limit, and voltage reference in a single 8-pin MSOP package. The switching DC-DC regulator boosts an input voltage between 1.2V and 14V to a regulated output voltage between 1.24V and 14V that is limited by a fixed maximum duty cylcle of 70%. The LMR61428 starts from a low 1.1V input and remains operational down to 0.65V.

This device is optimized for use in cellular phones and other applications requiring a small size, low profile, as well as low quiescent current for maximum battery life during stand-by and shutdown. A high-efficiency gated-oscillator topology offers an output of up to 1A.

Additional features include a built-in peak switch current limit, and thermal protection circuitry.

GATED OSCILLATOR CONTROL SCHEME

A unique gated oscillator control scheme enables the LMR61428 to have an ultra-low quiescent current and provides a high efficiency over a wide load range. The switching frequency of the internal oscillator is programmable using an external resistor and can be set between 300 kHz and 2 MHz.

This control scheme uses a hysteresis window to regulate the output voltage. When the output voltage is below the upper threshold of the window, the LMR61428 switches continuously with a fixed duty cycle of 70% at the switching frequency selected by the user. During the first part of each switching cycle, the internal N-channel MOSFET switch is turned on. This causes the current to ramp up in the inductor and store energy. During the second part of each switching cycle, the MOSFET is turned off. The voltage across the inductor reverses and forces current through the diode to the output filter capacitor and the load. Thus when the LMR61428 switches continuously, the output voltage starts to ramp up. When the output voltage hits the upper threshold of the window, the LMR61428 stops switching completely. This causes the output voltage to droop because the energy stored in the output capacitor is depleted by the load. When the output voltage hits the lower threshold of the hysteresis window, the LMR61428 starts switching continuously again causing the output voltage to ramp up towards the upper threshold. *Figure 2* shows the switch voltage and output voltage waveforms.

Because of this type of control scheme, the quiescent current is inherently very low. At light loads the gated oscillator control scheme offers a much higher efficiency compared to the conventional PWM control scheme.

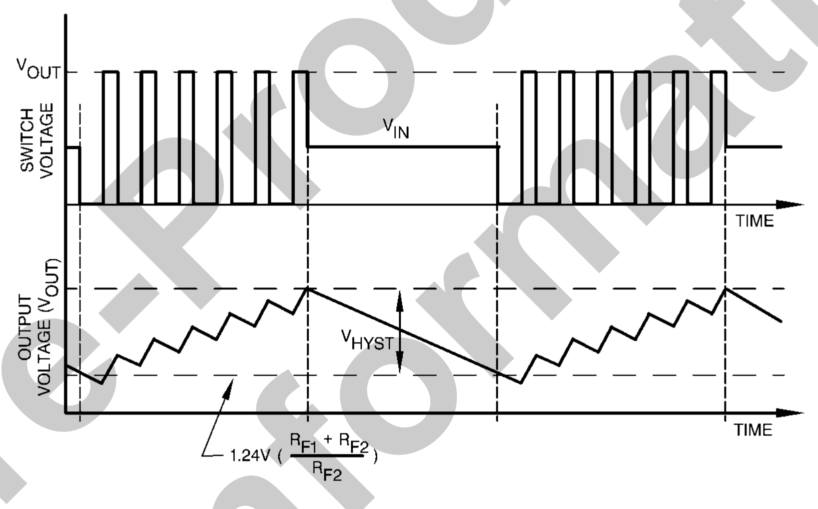

FIGURE 2. Typical Step-Up Regulator Waveforms

LOW VOLTAGE START-UP

The LMR61428 can start-up from input voltages as low as 1.1V. On start-up, the control circuitry switches the N-channel MOSFET continuously at 70% duty cycle until the output voltage reaches 2.5V. After this output voltage is reached, the normal step-up regulator feedback and gated oscillator control scheme take over. Once the device is in regulation it can operate down to a 0.65V input, since the internal power for the IC can be boot-strapped from the output using the V_{DD} pin.

SHUTDOWN

The LMR61428 features a shutdown mode that reduces the quiescent current to less than a guaranteed 2.5µA over temperature. This extends the life of the battery in battery powered applications. During shutdown, all feedback and control circuitry is turned off. The regulator's output voltage drops to one diode drop below the input voltage. Entry into the shutdown mode is controlled by the active-low logic input pin EN (Pin 2). When the logic input to this pin pulled below $0.15V_{DD}$, the device goes into shutdown mode. The logic input to this pin should be above $0.7V_{DD}$ for the device to work in normal step-up mode.

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OUTPUT VOLTAGE RIPPLE FREQUENCY

A major component of the output voltage ripple is due to the hysteresis used in the gated oscillator control scheme. The frequency of this voltage ripple is proportional to the load current. The frequency of this ripple does not necessitate the use of larger inductors and capacitors. The size of these components is determined by the switching frequency of the oscillator which can be set upto 2MHz using an external resistor.

INTERNAL CURRENT LIMIT AND THERMAL PROTECTION

An internal cycle-by-cycle current limit serves as a protection feature. This is set high enough (2.85A typical, approximately 4A maximum) so as not to come into effect during normal operating conditions. An internal thermal protection circuitry disables the MOSFET power switch when the junction temperature (T_J) exceeds about 160°C. The switch is re-enabled when T_J drops below approximately 135°C.

Design Procedure

SETTING THE OUTPUT VOLTAGE

The output voltage of the step-up regulator can be set between 1.24V and 14V. But because of the gated oscillator scheme, the maximum possible input to output boost ratio is fixed. For a boost regulator,

$$V_{OUT} / V_{IN} = 1 / [1–D]$$

The LMR61428 has a fixed duty cycle, D, of 70% typical. Therefore,

$$V_{OUT} / V_{IN} = 1 / 0.3$$

This sets the maximum possible boost ratio of V_{IN} to V_{OUT} to about 3 times. The user can now estimate what the minimum design inputs should be in order to achieve a desired output, or what the output would be when a certain minimum input is applied. E.g. If the desired V_{OUT} was 14V, then the least V_{IN} should be higher than V_{OUT} / 3. If the input voltage fell below this threshold, the output voltage would not be regulated because of the fixed duty cycle. If the minimum V_{IN} was guaranteed at 2V, the max possible V_{OUT} would be V_{IN} * 3.

The V_{OUT} is set by connecting a feedback resistive divider made of R_{F1} and R_{F2}. The feedback resistor values are selected as follows:

$$R_{F2} = R_{F1} /[(V_{OUT}/ 1.24) –1]$$

A value of 150kΩ is suggested for R_{F1}. Then, R_{F2} can be selected using the above equation. A 39pF capacitor (C_{ff}) connected across R_{F2} helps in feeding back most of the AC ripple at V_{OUT} to the FB pin. This helps reduce the peak-to-peak output voltage ripple as well as improve the efficiency of the step-up regulator, because a set hysteresis of 30mV at the FB pin is used for the gated oscillator control scheme.

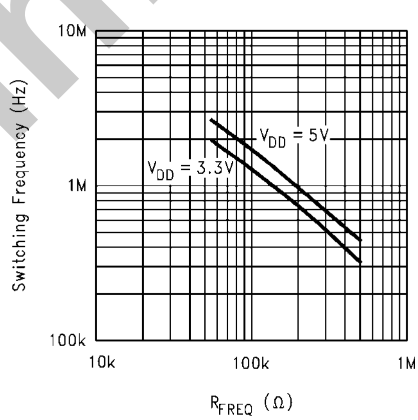
BOOTSTRAPPING

When the output voltage (V_{OUT}) is between 2.5V and 5.0V a bootstrapped operation is suggested. This is achieved by connecting the V_{DD} pin (Pin 6) to V_{OUT}. However if the V_{OUT} is outside this range, the V_{DD} pin should be connected to a voltage source whose range is between 2.5V and 5V. This can be the input voltage (V_{IN}), V_{OUT} stepped down using a linear regulator, or a different voltage source available in the system. This is referred to as non-bootstrapped operation. The maximum acceptable voltage at the BOOT pin (Pin 7) is 10V.

SETTING THE SWITCHING FREQUENCY

The switching frequency of the oscillator is selected by choosing an external resistor (R_{FQ}) connected between FREQ and V_{DD} pins. See the following graph for choosing the R_{FQ} value to achieve the desired switching frequency. A high switching frequency allows the use of very small surface mount inductors and capacitors and results in a very small solution size. A switching frequency between 300kHz and 2MHz is recommended.

Switching Frequency vs R_{FQ}



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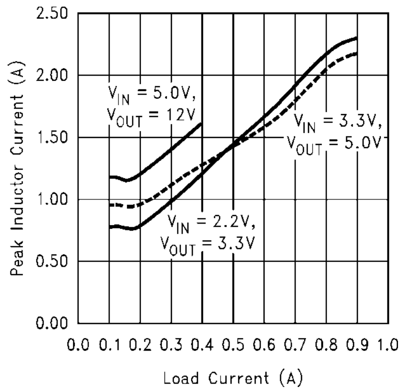
INDUCTOR SELECTION

The LMR61428's high switching frequency enables the use of a small surface mount inductor. A 6.8µH shielded inductor is suggested for a typical application. The inductor should have a saturation current rating higher than the peak current it will experience during circuit operation (see following graph). Less than 100mΩ ESR is suggested for high efficiency.

Peak Inductor Current vs Load Current



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Open-core inductors cause flux linkage with circuit components and interfere with the normal operation of the circuit. They should be avoided. For high efficiency, choose an inductor with a high frequency core material, such as ferrite, to reduce the core losses. To minimize radiated noise, use a toroid, pot core or shielded core inductor. The inductor should be connected to the SW pin as close to the IC as possible. See

OUTPUT DIODE SELECTION

A Schottky diode should be used for the output diode. The forward current rating of the diode should be higher than the load current, and the reverse voltage rating must be higher than the output voltage. Do not use ordinary rectifier diodes, since slow switching speeds and long recovery times cause the efficiency and the load regulation to suffer.

INPUT AND OUTPUT FILTER CAPACITORS SELECTION

While tantalum chip capacitors are recommended for the input and output filter capacitors, ceramic caps can also be used. A 22µF capacitor is suggested for the input filter capacitor. It should have a DC working voltage rating higher than the maximum input voltage. A 68µF tantalum capacitor is suggested for the output capacitor. The DC working voltage rating should be greater than the output voltage. Very high ESR values (>3Ω) should be avoided.

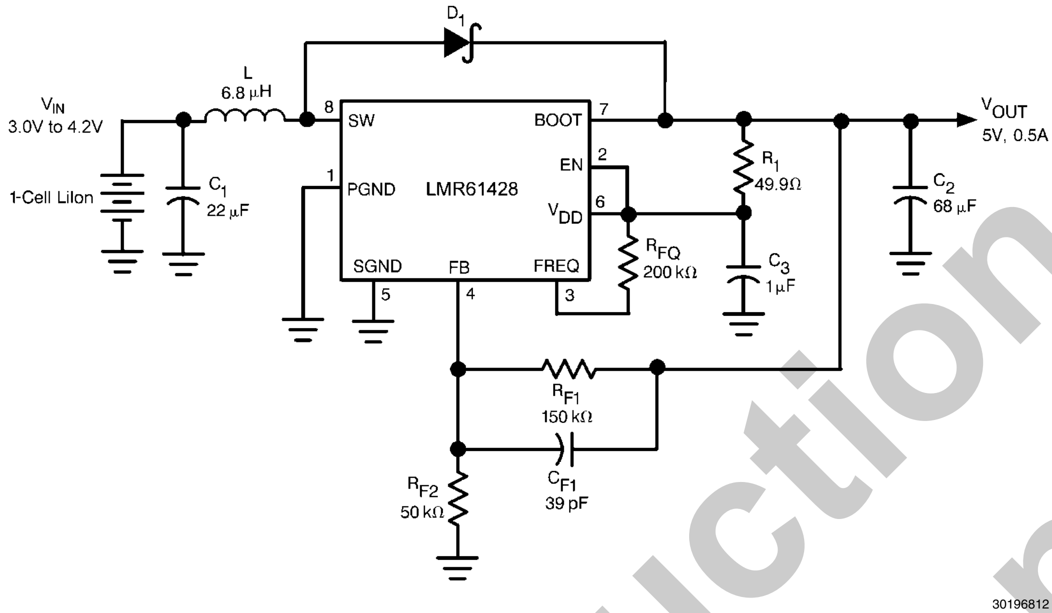
PC BOARD LAYOUT

High switching frequencies and high peak currents make a proper layout of the PC board an important part of design. Poor design can cause excessive EMI and ground-bounce, both of which can cause malfunction and loss of regulation by corrupting voltage feedback signal and injecting noise into the control section.

Power components - such as the inductor, input and output filter capacitors, and output diode - should be placed as close to the regulator IC as possible, and their traces should be kept short, direct and wide. The ground pins of the input and output filter capacitors and the PGND and SGND pins of LMR61428 should be connected using short, direct and wide traces. The voltage feedback network (R_{fbt}, R_{fbb}, and C_{ff}) should be kept very close to the FB pin. Noisy traces, such as from the SW pin, should be kept away from the FB and V_{DD} pins. The traces that run between V_{out} and the FB pin of the IC should be kept away from the inductor flux. Always provide sufficient copper area to dissipate the heat due to power loss in the circuitry and prevent the thermal protection circuitry in the IC from shutting the IC down. Additional ground planes as intermediate levels help with shielding and improve EMI mitigation.

Application examples

EXAMPLE 1. 5V/0.5A Step-Up Regulator



U1	Texas Instruments	LMR61428XMM
C1	Vishay/Sprague	595D226X06R3B2T, Tantalum
C2	Vishay/Sprague	595D686X0010C2T, Tantalum
D1	Motorola	MBRS140T3
L	Coilcraft	DT1608C-682

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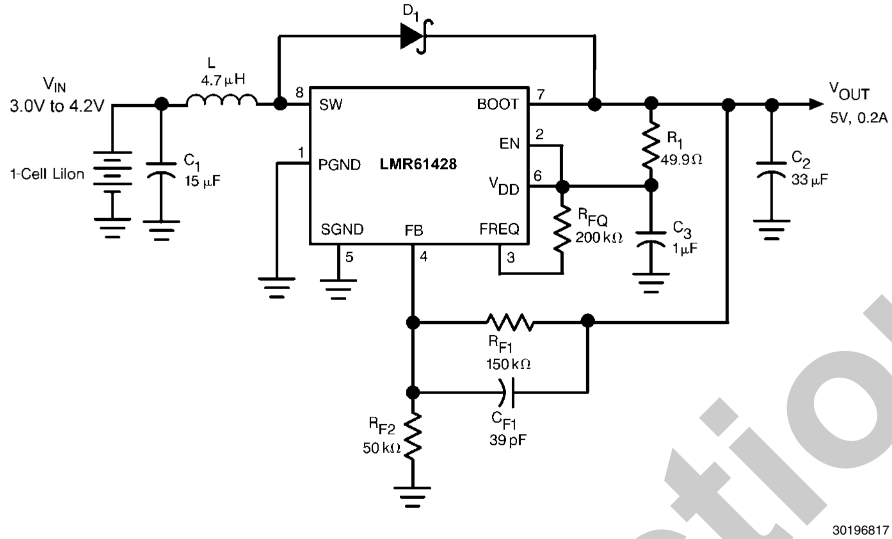
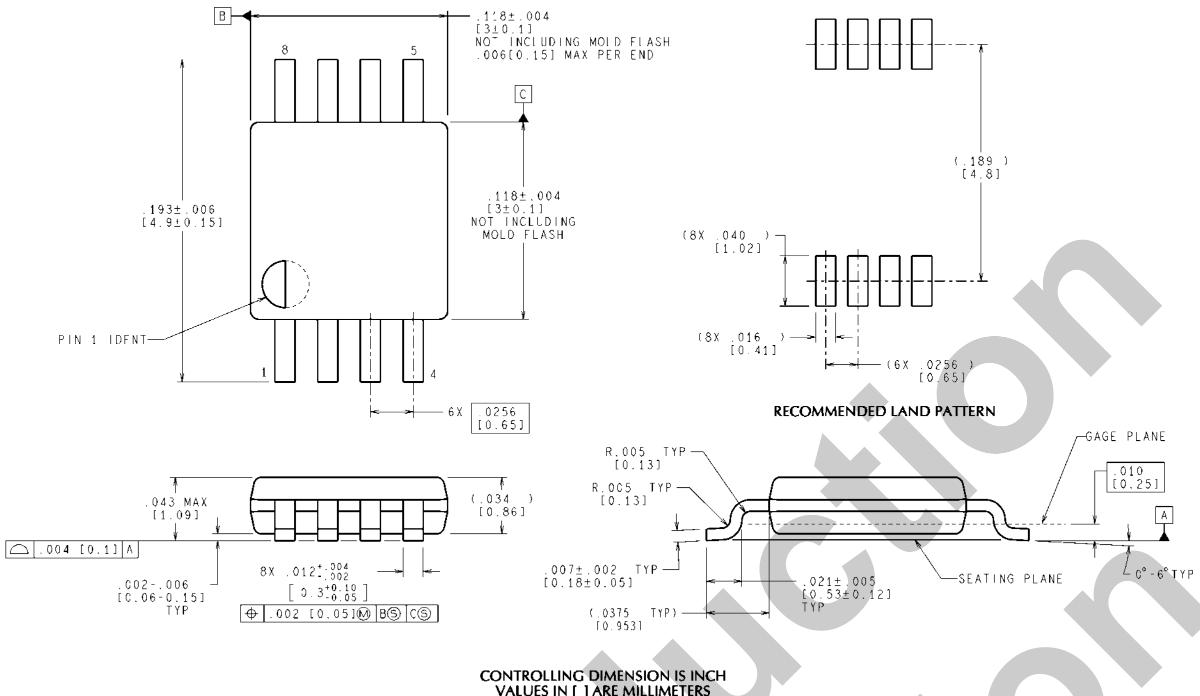
EXAMPLE 2. 2mm Tall 5V/0.2A Step-Up Regulator for Low Profile Applications



U1	Texas Instruments	LMR61428XMM
C1	Vishay/Sprague	592D156X06R3B2T, Tantalum
C2	Vishay/Sprague	592D336X06R3C2T, Tantalum
D1	Motorola	MBRS140T3
L	Vishay/Dale	ILS-3825-03

Physical Dimensions inches (millimeters) unless otherwise noted



MUA08A (Rev F)

8-Lead Mini SO-8 (MM)
Package Number MUA08AFor Order Numbers, refer to the table in the "Ordering Information" section of this document.

Notes

Notes

IMPORTANT NOTICE

Products		Applications	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
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Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Mobile Processors	www.ti.com/omap	TI E2E Community	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

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