LT1616ES8
1.4MHz Step-Down Switching Regulator in SOT-23

DESCRIPTION

The LT®1616 is a current mode step-down switching regulator with an internal 600mA power switch in a SOT-23 package. It is used to convert an input voltage between 3.6V and 25V to a lower output voltage with output currents up to 400mA. Its high switching frequency (1.4MHz), small package, internal compensation and ceramic input and output capacitors result in a very small solution size.

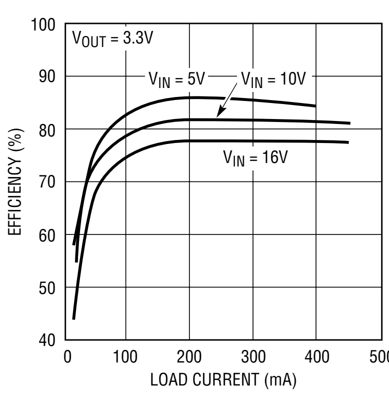
The DC310 demonstration circuit board contains two LT1616 circuits. The first accepts an input between 4.7V and 16V and produces a 400mA output at 3.3V. This circuit emphasizes small size and lower cost components. The second circuit accepts an input between 6.8V and 25V and produces 400mA at 5V. This circuit uses larger components to increase the input voltage range and to increase efficiency.

PERFORMANCE SUMMARY

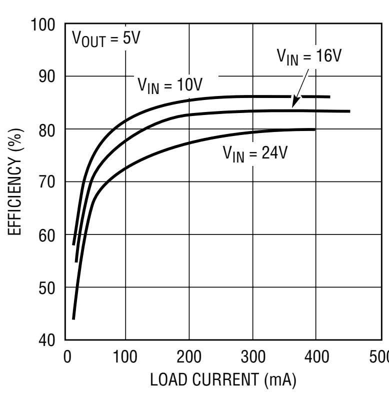
PARAMETER	CONDITIONS	VALUE
Circuit 1		
Output Voltage		3.3V
Input Voltage Range		4.5V to 16V
Output Current	V_{IN} > 4.7V	400mA
Circuit 2		
Output Voltage		5V
Input Voltage Range		6.5V to 25V
Output Current	V_{IN} > 6.8V	400mA

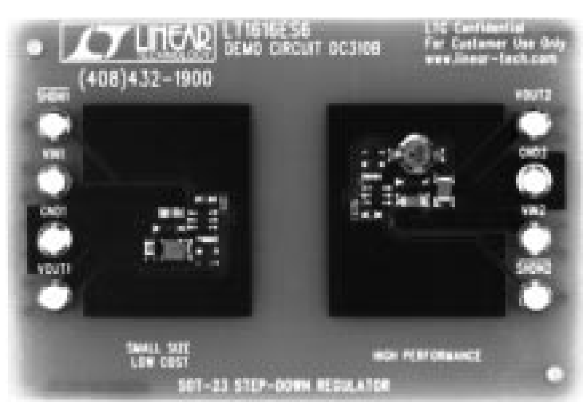
TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO

Efficiency Circuit 1



Efficiency Circuit 2



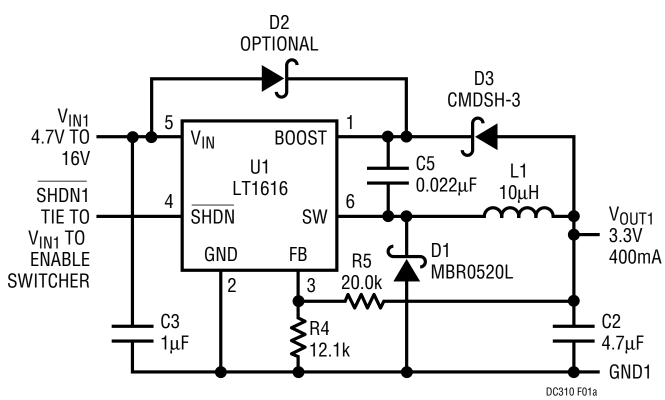


DESCRIPTION

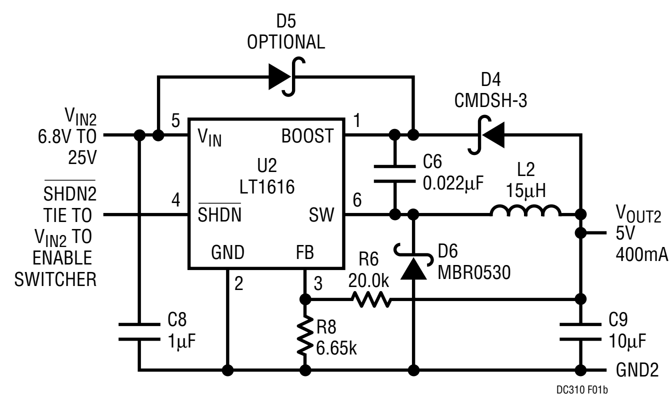
The LT1616's small size makes it suitable for use in a wide variety of systems. It can be used for regulating distributed supplies (for example, converting industrial power busses to 5V for data converter systems) and for generating local logic supplies from higher inputs (for example, converting 12V to 3.3V or 5V, or for converting either 12V or 5V to 3.3V or 2.5V for DSPs). The wide input range and micropower shutdown make the LT1616 attractive for battery-powered systems; it can operate from 4-cell alkaline batteries, 12V lead-acid batteries or the higher voltage batteries found in laptop computers. The LT1616 is an ideal replacement for TO-220 linear regulators that supply a few hundred milliamperes; the LT1616 solution is smaller than the TO-220 and doesn't require a heat sink. A common power source for small digital devices is the unregulated wall transformer; the LT1616 can handle the wide output voltage range of a wall transformer and regulate it to the desired low voltage.

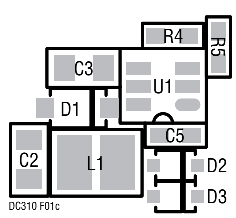
PACKAGE AND SCHEMATIC DIAGRAMS

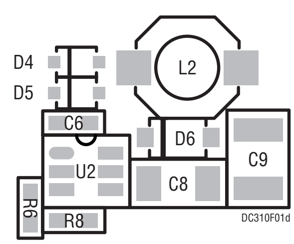
Circuit 1. Small Size/Low Cost

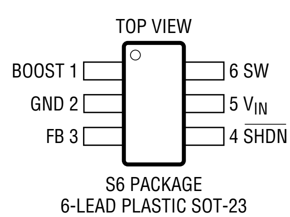


Circuit 2. High Performance









LT1616ES6

Figure 1. DC310 Schematics and Component Placement

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
Circuit 1—Low Cost					
C2	1	JMK212BJ475MG	4.7µF 6.3V X5R Capacitor	Taiyo-Yuden	(408) 573-4150
C3	1	EMK212BJ105MG	1µF 16V X5R Capacitor	Taiyo-Yuden	(408) 573-4150
C5	1	0603YC223KAT1A	0.022µF 16V 10% X7R Capacitor	AVX	(843) 946-0362
D1	1	MBR0520LT1	20V 0.5A Schottky Diode	ON Semiconductor	(602) 244-6600
D2	1	CMDSH-3TR (Omit)	Diode (Omit)	Central	(631) 435-1110
D3	1	CMDSH-3TR	30V 0.1A Schottky Diode	Central	(631) 435-1110
L1	1	LQH3C100K24	10µH 0.5A SMT Inductor	Murata	(770) 436-1300
R4	1	CR16-1212FM	12.1k 1/16W 1% Chip Resistor	AAC	(800) 508-1521
R5	1	CR16-2002FM	20k 1/16W 1% Chip Resistor	AAC	(714) 255-9186
TP1-TP4	4	2501-2	0.090 Turret Testpoint	Mill-Max	(516) 922-6000
U1	1	LT1616ES6	6-Lead SOT-23 Buck Converter IC	LTC	(408) 432-1900
Circuit 2—High Performance					
C6	1	0603YC223KAT1A	0.022µF 16V 10% X7R Capacitor	AVX	(843) 946-0362
C8	1	TMK316BJ105ML	1µF 25V X7R Capacitor	Taiyo-Yuden	(408) 573-4150
C9	1	JMK316BJ106ML	10µF 6.3V X5R Capacitor	Taiyo-Yuden	(408) 573-4150
D4	1	CMDSH-3TR	30V 0.1A Schottky Diode	Central	(631) 435-1110
D5	1	CMDSH-3TR (Omit)	Diode (Omit)	Central	(631) 435-1110
D6	1	MBR0530T1	30V 0.5A Schottky Diode	ON Semiconductor	(602) 244-6600
L2	1	A914BYW-150M	15µH 20% SMT Inductor	Toko	(847) 699-3425
R6	1	CR16-2002FM	20k 1/16W 1% Chip Resistor	AAC	(800) 508-1521
R8	1	CR16-6651FM	6.65k 1/16W 1% Chip Resistor	AAC	(714) 255-9186
TP5-TP8	4	2501-2	0.090 Turret Testpoint	Mill-Max	(516) 922-6000
U2	1	LT1616ES6	6-Lead SOT-23 Buck Converter IC	LTC	(408) 432-1900

QUICK START GUIDE

Demonstration Circuit DC310 contains two step-down switching regulator circuits. Circuit 1 produces 3.3V at 400mA from an input between 4.7V and 16V. Circuit 2 produces 5V at 400mA from an input between 6.8V and 25V. The two circuits are independent; their ground nodes are not connected. This quick start guide assumes that circuit 1 is under evaluation.

1. Connect a bench-top power supply (a 1A output is sufficient) between the V_{IN1} and GND1 turrets on the edge of the circuit board. Be careful not to exceed the maximum input voltage of 16V (25V for circuit 2).
2. Attach a load to the output of the circuit between V_{OUT1} and GND1. A 15Ω, 2W resistor is a simple load that will allow you to observe the switching waveforms and the output voltage ripple.
3. Tie $\overline{\text{SHDN1}}$ to GND1 to place the LT1616 in shutdown mode. Input current will fall to less than 1μA and the output voltage will fall to zero.
4. To enable the switching regulator, tie $\overline{\text{SHDN1}}$ to V_{IN1} or to any voltage between 1.8V and 25V (SHDN1 should not be left floating). The output will regulate to 3.3V (5V for circuit 2).
5. The switching waveform can be observed at the SW pin (Pin 6) of the LT1616.

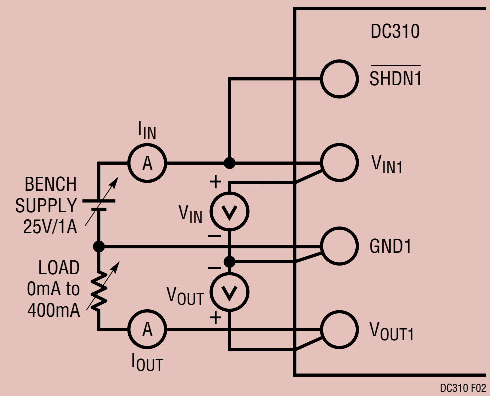


Figure 2. Proper Hook-Up for Evaluating the DC310

OPERATION

The LT1616 is a step-down switching regulator with an internal 600mA power switch. The LT1616 modulates this switch at 1.4MHz to generate a square wave at the SW pin. The inductor L1 (L2) averages this square wave to generate the output voltage at capacitor C2 (C9). See the LT1616 data sheet for details of the LT1616's control circuitry.

The simplest way to observe the operation of the LT1616 is to probe the SW pin. Use a high impedance (10×) oscilloscope probe with a short ground lead. The upper trace in Figure 3 shows the SW pin of circuit 1 as it delivers 300mA at 3.3V from an input of 10V. The SW pin is near 10V while the LT1616's internal switch is turned on. When the switch turns off, the SW pin is pulled low by the inductor current and is clamped near ground by diode D1. As the input voltage changes, the amplitude and the duty cycle of this waveform will change.

When the load current is low, the inductor current will become discontinuous and the SW pin will ring between switch cycles. As the load current decreases further, the LT1616 will begin to skip pulses, effectively operating at a lower frequency (see Figure 3).

Ripple at the output is under $10mV_{P-P}$. Again, care is required to properly probe the AC content of the output voltage. Remove the spring-loaded grabber and the ground

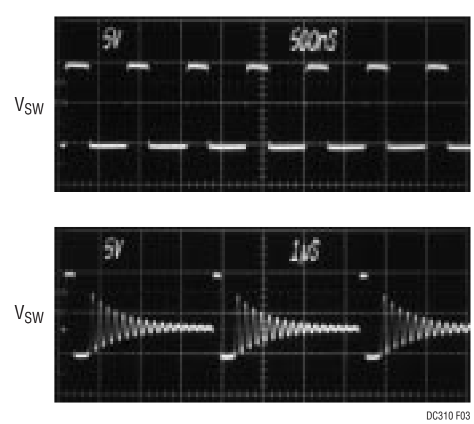


Figure 3. SW Pin Waveforms of Circuit 1 Operating from 10V. Top Photo, I_{OUT} = 300mA. Bottom Photo, I_{OUT} = 8mA

OPERATION

lead from the oscilloscope probe. Lean the exposed ground barrel of the probe against the GND1 turret and the probe tip against the V_{OUT1} turret. The output voltage of circuit 2 appears in Figure 4.

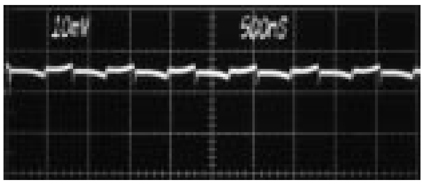


Figure 4. Output Ripple of Circuit 2, V_{IN} = 12V, I_{OUT} = 300mA

Both circuits use a 1µF input capacitor. This capacitor provides the AC current required by the buck regulator and bypasses the LT1616's internal circuitry. However, if the impedance of the input source is high (due to long wires, filter components or an ammeter) additional input capacitance may be necessary. High source impedance can result in oscillations below the switching frequency; this will be evident at the SW node of the LT1616. This is most likely to occur when the LT1616 is operating at high duty cycles (for example 5V in to 3.3V out) and high load currents. In such cases, increase the input capacitor to 2.2µF.

Efficiency

The efficiency of the DC310 circuits is plotted in the Typical Performance section of this manual. Efficiency measurements should be made with care as there are plenty of opportunities for errors to creep in.

The efficiency is defined as the power delivered to the load divided by the power drawn from the input supply. Normally, the average input voltage, input current, output voltage and output current are measured under steady-state conditions and the efficiency is calculated from these values. Each should be measured with the highest accuracy and precision possible.

Figure 2 shows connections for the proper measurement of efficiency and output regulation. The input and output voltages are measured at the DC310 terminals in order to avoid including voltage drops across ammeters and terminal connections. It is best to take all of these measurements at one time. Be aware that most digital multimeters drop significant voltage when they are used as ammeters, so the input voltage must be measured while the ammeter is in the circuit—the input voltage will be lower than the voltage at the output of the bench-top supply.

Component Selection and Circuit Modifications

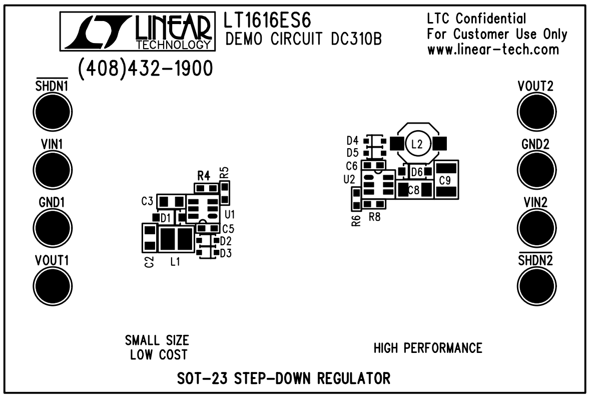
This demo manual does not contain complete design information for the LT1616. Please consult the LT1616 data sheet for a more extensive discussion of circuit design, component selection and printed circuit board layout. However, some comments on these two circuits may be helpful.

Circuit 1 emphasizes smaller, lower cost components. Limiting the maximum input voltage to 16V allows the use of a tiny 0805 sized 1µF 16V input capacitor. The catch diode (D1) sees a reverse bias equal to the input voltage, so a 20V version of the half-amp Schottky diode is adequate. The small inductor used here has sufficient inductance (10µH) and current capability (450mA) to deliver 400mA to the output. Finally, the value of the output capacitor (4.7µF) was chosen to fit into the 0805 case at a slight penalty in transient performance.

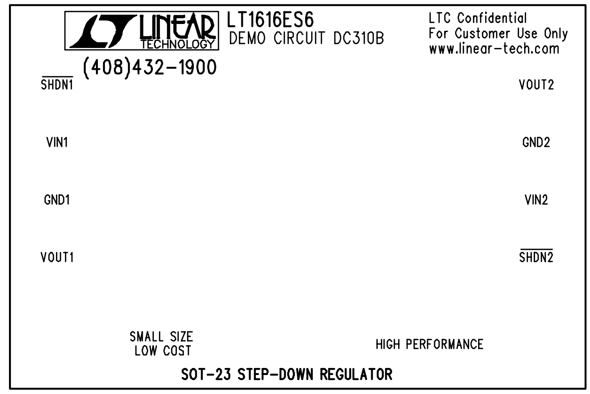
Circuit 2 emphasizes performance, using larger components to take advantage of the LT1616's 25V maximum input voltage. A larger case size is required for the 1µF input capacitor, and the catch diode (D6) is rated for 30V. With the output voltage increased to 5V, a larger value inductor is required to deliver 400mA and this larger inductance requires a physically larger inductor. The 15µH inductor used here is rated for 630mA, and its low resistance keeps the circuit efficiency high. The 10µF output capacitor results in slightly lower output ripple and slightly better transient performance compared with the 4.7µF capacitor used in circuit 1.

The output voltage is set by the feedback resistors. Before changing these resistors, read the section of the LT1616 data sheet that discusses limits on the BOOST pin circuitry. If the output voltage is less than 3V, the boost diode (D3 or D4) must be tied to the input source (instead of the output as is done here). DC310 has additional pads to do this; just move D3 or D4 to the unoccupied pads (D2, D5) next to the diode's current position.

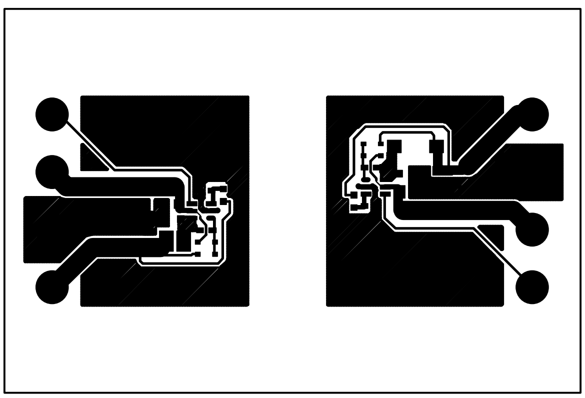
PCB LAYOUT AND FILM



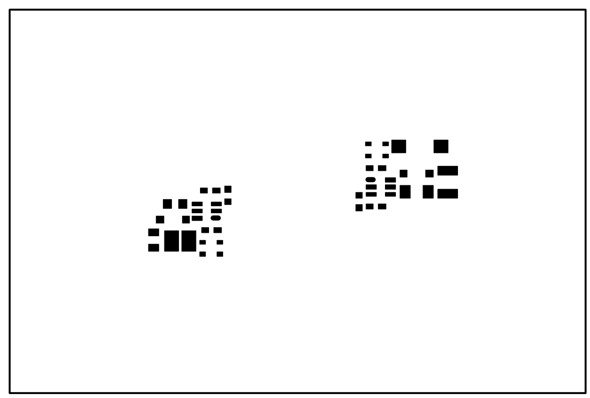
Component Locations



Component Side Silkscreen

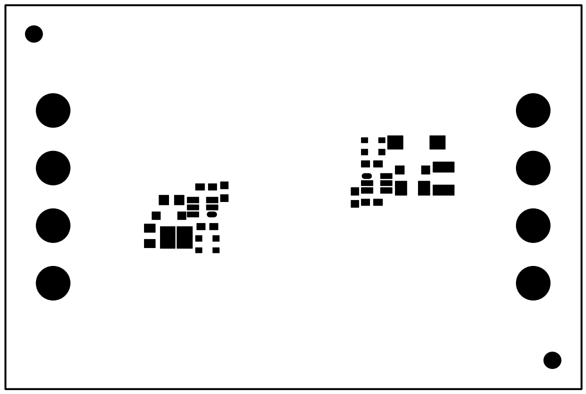


Component Side Copper

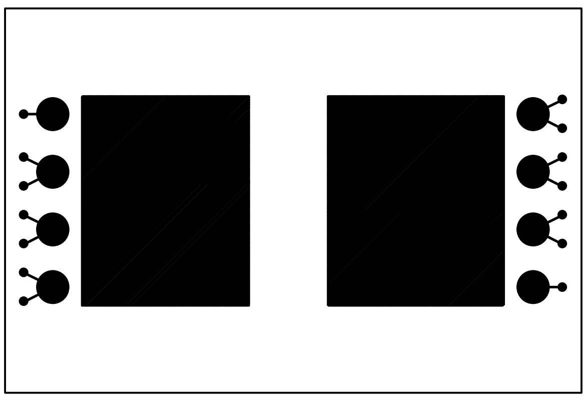


Component Side Pastemask

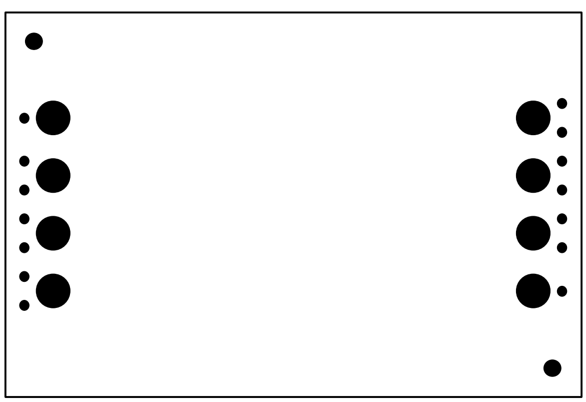
PCB LAYOUT AND FILM



Component Side Soldermask

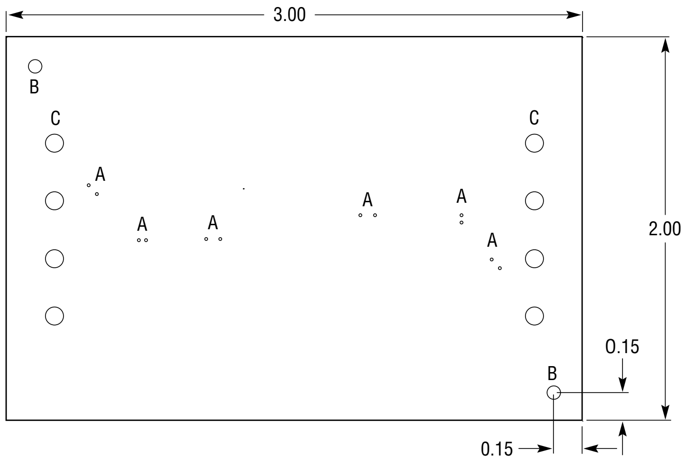


Solder Side Copper



Solder Side Soldermask

PC FAB DRAWING



SYMBOL	DIAMETER	NUMBER OF HOLES	PLATED
A	0.015	12	PLTD
B	0.070	2	NPLTD
C	0.094	8	PLTD
	TOTAL HOLES	22	

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