DEMO MANUAL DC233

SOT-23 SWITCHING REGULATORS

LT1611/LT1613
1.4MHz Switching Regulators in SOT-23

DESCRIPTION

The LT®1611 and LT1613 are 5-lead SOT-23, current mode DC/DC converters. Intended for small, low power applications, both operate from inputs as low as 1V and switch at 1.4MHz, allowing the use of tiny, low cost capacitors and inductors.

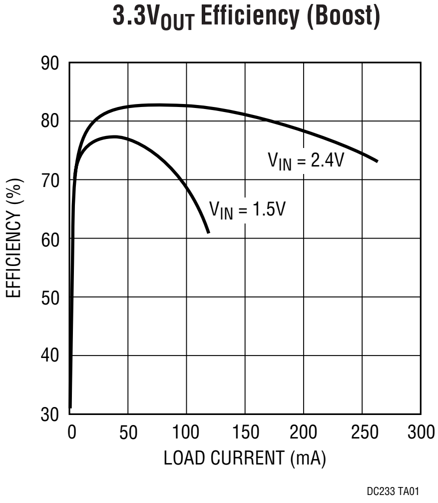
DC233 contains three switching regulator circuits. Two of these demonstrate the use of the LT1613CS5 in a simple boost regulator circuit and in an uncoupled SEPIC circuit. Both circuits produce 3.3V or 5V (jumper selected). The boost circuit produces 200mA in a typical application and occupies less than 0.2 square inches of circuit board area. The SEPIC circuit allows operation from input voltages either higher or lower than the output, making this circuit suitable for single Li-Ion cell to 3.3V conversion or four alkaline cells to 5V conversion. Typical output current for the SEPIC circuit is 120mA. The third circuit demonstrates the LT1611CS5 in a low noise inverting circuit. This circuit can convert 5V to –5V at 160mA.

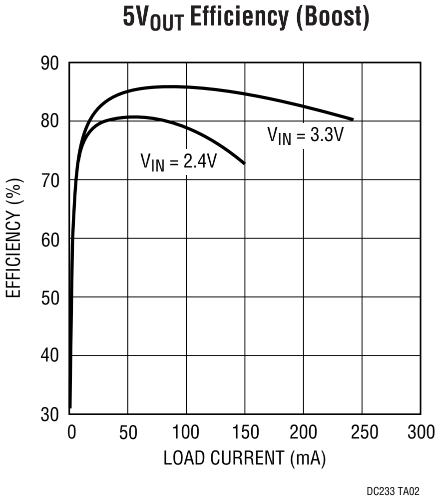
PERFORMANCE SUMMARY

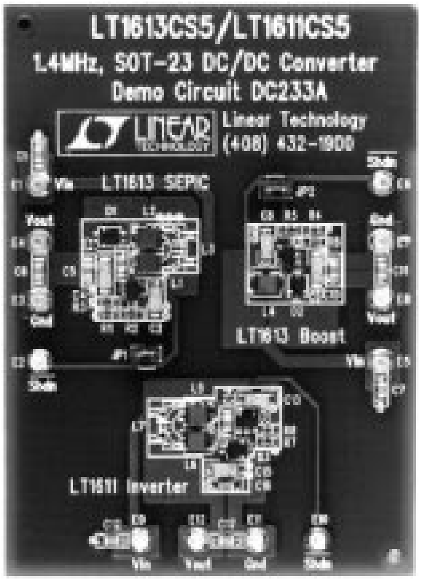
PARAMETER	CONDITIONS	VALUE
Boost		
Input Voltage (Note 1)	V_{OUT} = 3.3V V_{OUT} = 5V	1V to 3.6V 1V to 5.3V
Maximum Load Current (Min)	V_{OUT} = 3.3V, V_{IN} = 1.5V V_{OUT} = 5V, V_{IN} = 3V	115mA 190mA
Shutdown Current (Typ)	V_{IN} = 1.5V, $\overline{SHDN}$ = 0V	10µA

TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO

3.3V







DESCRIPTION

The LT1611 and LT1613 will find applications in battery-powered products, such as pagers, digital cameras, cellular phones, cordless phones and palmtop computers. The small circuit size and low component count make these parts suitable for use in PC cards, miniature disk drives and flash memory products, and for generating local logic supplies—for example, converting 3.3V to 5V. The LT1611 produces a very low noise negative output and is suitable for generating negative rails for op amp circuits and disk drives.

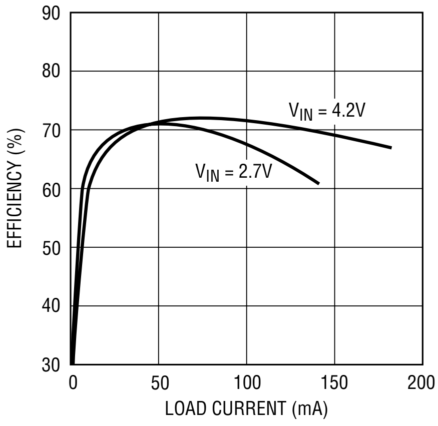
PERFORMANCE SUMMARY

PARAMETER	CONDITIONS	VALUE
SEPIC		
Input Voltage (Note 1)		1V to 6V
Maximum Load Current (Min)	V_{OUT} = 3.3V, V_{IN} = 3V V_{OUT} = 5V, V_{IN} = 5V	130mA 120mA
Shutdown Current (Typ)	V_{IN} = 3V, $\overline{SHDN}$ = 0V	0.5µA
Inverter		
Input Voltage (Note 1)		1V to 6V
Maximum Load Current (Min)	V_{OUT} = –5V, V_{IN} = 5V	165mA
Shutdown Current (Typ)	V_{IN} = 5V, $\overline{SHDN}$ = 0V	0.5µA

Note 1: This limit is based on the DC233 circuits. The LT1611 and LT1613 can operate from higher supply voltages.

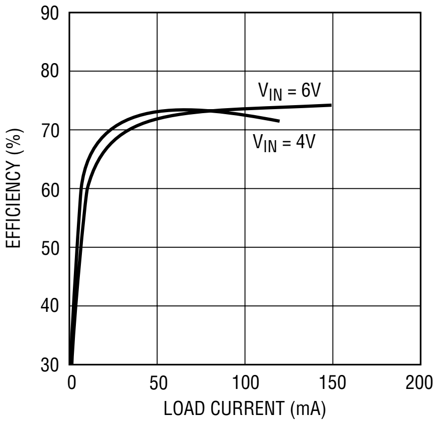
TYPICAL PERFORMANCE CHARACTERISTICS

3.3V_{OUT} Efficiency (SEPIC)



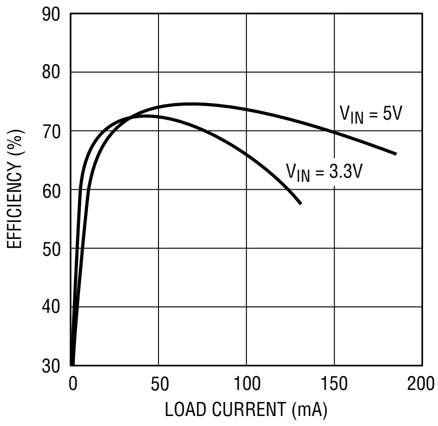
DC233 TA03

5V_{OUT} Efficiency (SEPIC)



DC233 TA04

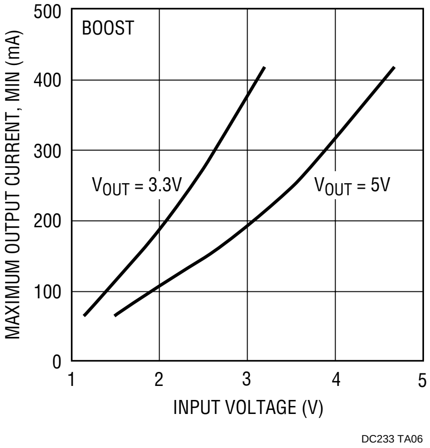
–5V_{OUT} Efficiency (Inverter)



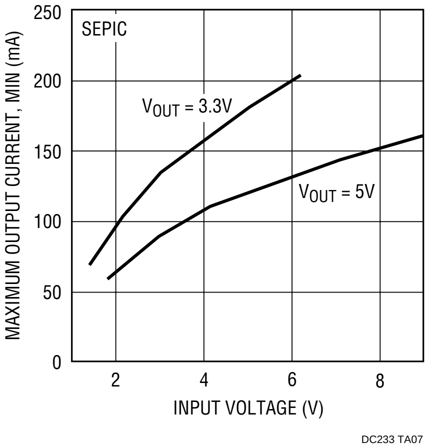
DC233 TA05

TYPICAL PERFORMANCE CHARACTERISTICS

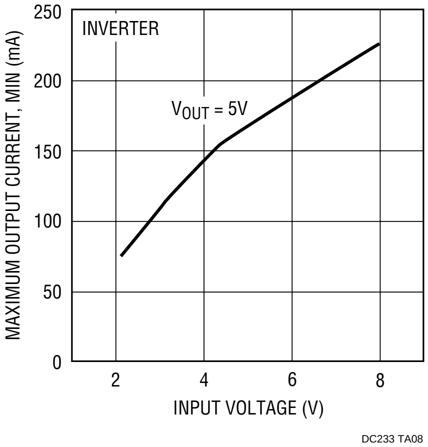
Max Load Current vs V_{IN} (Boost)



Max Load Current vs V_{IN} (SEPIC)

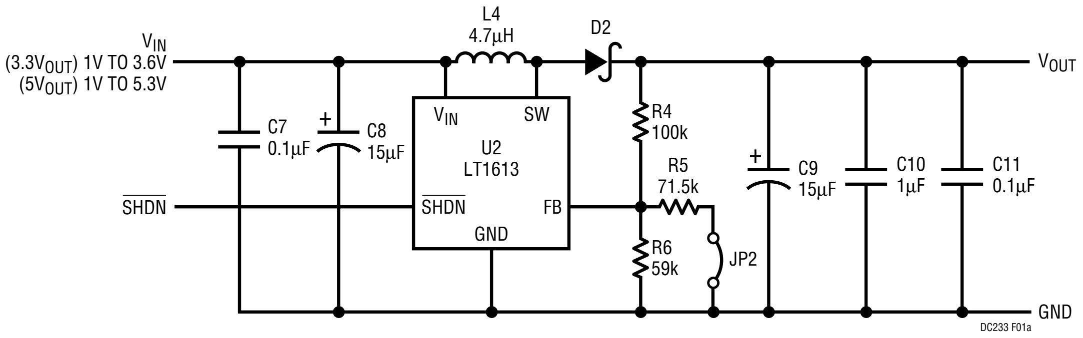


Max Load Current vs V_{IN} (Inverter)

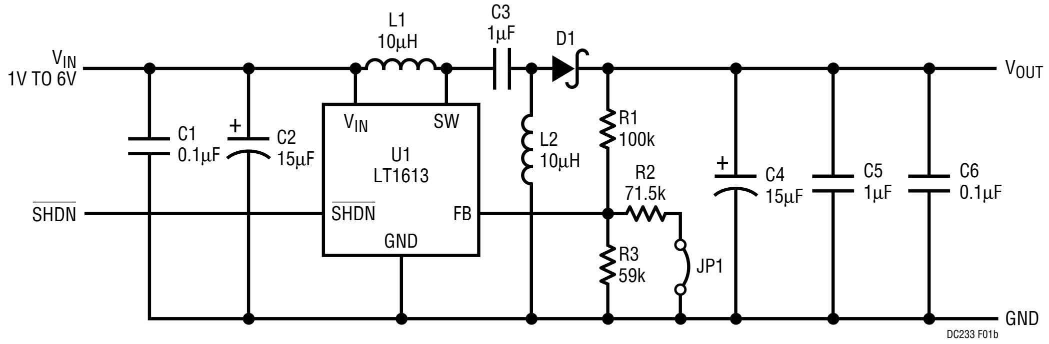


SCHEMATIC AND CONNECTION DIAGRAMS

Boost



SEPIC



Inverting

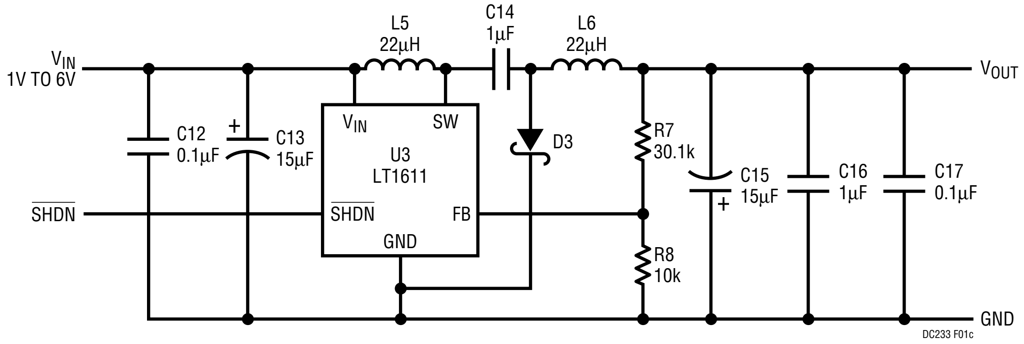
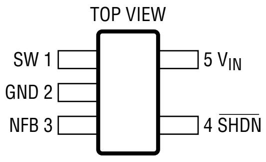
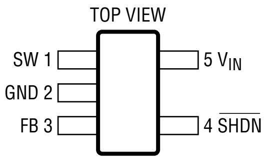


Figure 1. DC233 Schematics



S5 PACKAGE
5-LEAD PLASTIC SOT-23

LT1611CS5



S5 PACKAGE
5-LEAD PLASTIC SOT-23

LT1613CS5

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
Boost					
C7, C11	2	0805YC104MAT1A	0.1µF 16V X7R 0805 Capacitor	AVX	(843) 946-0362
C8, C9	2	TAJA156M010R	15µF 10V 20% Tantalum Capacitor	AVX	(207) 282-5111
C10	1	0805ZC105MAT1A	1µF 10V X7R 0805 Capacitor	AVX	(843) 946-0362
D2	1	MBR0520LT1	0.5A 20V SOD123 Schottky Diode	ON Semiconductor	(602) 244-6600
JP2	1	2802S-2-G1	2-Pin Header, 0.079 Center	Comm Con	(626) 301-4200
L4	1	LQH3C4R7M24	4.7µH Inductor	Murata	(770) 436-1300
R4	1	CR16-1003FM	100k 1/10W 1% 0603 Resistor	TAD	(800) 508-1521
R5	1	CR16-7152FM	71.5k 1/10W 1% 0603 Resistor	TAD	(800) 508-1521
R6	1	CR16-5902FM	59k 1/10W 1% 0603 Resistor	TAD	(800) 508-1521
U2	1	LT1613CS5	SOT-23 DC/DC Converter	LTC	(408) 432-1900
	1	CCIJ2MM-138G	Shunt, 0.079 Center	Comm Con	(626) 301-4200
SEPIC					
C1, C6	2	0805YC104MAT1A	0.1µF 16V X7R 0805 Capacitor	AVX	(843) 946-0362
C2, C4	2	TAJA156M010R	15µF 10V 20% Tantalum Capacitor	AVX	(207) 282-5111
C3, C5	2	0805ZC105MAT1A	1µF 10V X7R 0805 Capacitor	AVX	(843) 946-0362
D1	1	MBR0520LT1	0.5A 20V SOD123 Schottky Diode	ON Semiconductor	(602) 244-6600
JP1	1	2802S-2-G1	2-Pin Header, 0.079 Center	Comm Con	(626) 301-4200
L1, L2	2	LQH3C100K24	10µH Inductor	Murata	(770) 436-1300
R1	1	CR16-1003FM	100k 1/10W 1% 0603 Resistor	TAD	(800) 508-1521
R2	1	CR16-7152FM	71.5k 1/10W 1% 0603 Resistor	TAD	(800) 508-1521
R3	1	CR16-5902FM	59k 1/10W 1% 0603 Resistor	TAD	(800) 508-1521
U1	1	LT1613CS5	SOT-23 DC/DC Converter	LTC	(408) 432-1900
	1	CCIJ2MM-138G	Shunt, 0.079 Center	Comm Con	(626) 301-4200
Inverting					
C12, C17	2	0805YC104MAT1A	0.1µF 16V X7R 0805 Capacitor	AVX	(843) 946-0362
C13, C15	2	TAJA156M010R	15µF 10V 20% Tantalum Capacitor	AVX	(207) 282-5111
C14, C16	2	0805ZC105MAT1A	1µF 10V X7R 0805 Capacitor	AVX	(843) 946-0362
D3	1	MBR0520LT1	0.5A 20V SOD123 Schottky Diode	ON Semiconductor	(602) 244-6600
L5, L6	2	LQH3C220K34	22µH Inductor	Murata	(770) 436-1300
R7	1	CR16-3012FM	30.1k 1/10W 1% 0603 Resistor	TAD	(800) 508-1521
R8	1	CR16-1002FM	10k 1/10W 1% 0603 Resistor	TAD	(800) 508-1521
U3	1	LT1611CS5	SOT-23 DC/DC Converter	LTC	(408) 432-1900

QUICK START GUIDE

DC233 contains three switching regulator circuits. Two of these demonstrate the use of the LT1613CS5 in a simple boost regulator circuit and in an uncoupled SEPIC circuit. Both circuits produce 3.3V or 5V (jumper selected). The third circuit demonstrates the LT1611CS5 in a low noise inverting circuit, producing a –5V output. The three circuits are electrically isolated from each other, and have their own grounds. Each circuit has a similar set of inputs and outputs—this quick-start guide applies to all.

1. The output of the boost and SEPIC circuits can be set to either 3.3V or 5V. The board is shipped with a jumper in place that programs the output for 5V. Remove the jumper to program the circuit for 3.3V out.
2. Apply a voltage source to the input of the circuit between the V_{IN} and GND terminals. A benchtop supply with a 1A current limit is a good choice for this source. The circuit will operate from an input voltage between 1V and 6V. Do not apply more than 6V to the circuit. Note that the boost circuit will regulate the output only when the input voltage is less than the desired output voltage.
3. Attach a voltmeter or oscilloscope probe between the V_{OUT} and GND terminals of the circuit in order to monitor the output. To start the circuit, tie the $\overline{\text{SHDN}}$ terminal to the V_{IN} terminal. The LT1611/LT1613 will begin regulating the output voltage.
4. Attach a load to the output. The power capability of these circuits depends on the input voltage. A 100Ω one-half watt resistor soldered between the V_{OUT} and GND pins of the circuit is a good starting point, and will allow you to observe the operation of the circuit.
5. The circuit can be placed in shutdown mode by either floating the $\overline{\text{SHDN}}$ terminal or tying it to ground.
6. Proper hook-up is essential for accurate and meaningful evaluation of efficiency and regulation. Figure 2 shows the appropriate arrangement of the supply, load, ammeters and voltmeters.

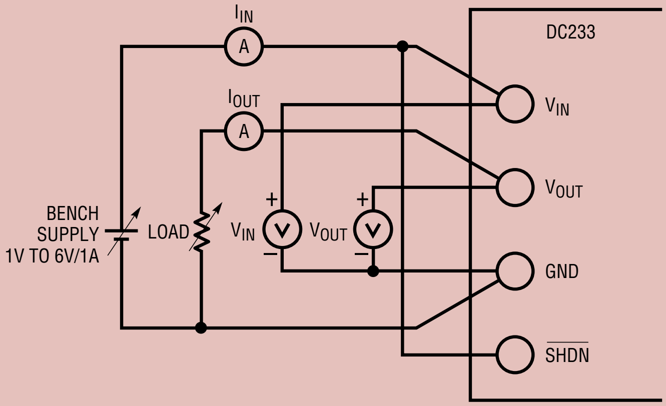


Figure 2. Proper Hook-Up for Evaluating the DC233

OPERATION

INTRODUCTION

DC233 contains three switching regulator circuits. Two of these demonstrate the use of the LT1613CS5 in a simple boost regulator circuit and in an uncoupled SEPIC[1] circuit. Both circuits produce 3.3V or 5V (jumper selected). The SEPIC circuit allows operation from input voltages either higher or lower than the output, making this circuit suitable for single Li-Ion cell to 3.3V conversion or four alkaline cells to 5V conversion. The third circuit demonstrates the LT1611CS5 in a low noise inverting circuit. This circuit can convert 5V to –5V at 160mA.

The three circuits on the DC233 are electrically isolated from each other and have their own grounds. Because the three circuits are functionally similar and have the same input and output connections (V_{IN}, V_{OUT}, GND and $\overline{SHDN}$), many of the comments that follow will apply to all three. Each circuit is described in more detail in its individual section.

This manual describes the operation of these demonstration circuits, their performance, and variations on the basic circuits. For a thorough discussion of the LT1611 and LT1613 and their applications, please consult the parts' data sheets.

Hook-Up and Initial Tests

DC233 contains fairly simple, low power switching regulators. However, some precautions are necessary in order to test the circuits safely. Proper hook-up and accurate measurements are necessary for meaningful evaluation of efficiency and line and load regulation. Refer to Figure 2 for proper connections.

The outputs of the boost and SEPIC circuits can be set to either 3.3V or 5V. The board is shipped with a jumper in place that programs the output for 5V. Remove the jumper to program the circuit for 3.3V out. The input can safely accept a voltage as high as 6V. A good starting point is to apply 2.5V between the V_{IN} and GND terminals of the DC233, using a benchtop supply with a 1A current limit. Because the $\overline{SHDN}$ pin has been left floating, the LT1611/LT1613 will default to its shutdown mode. Tie the $\overline{SHDN}$ terminal of the DC233 to the V_{IN} to start the regulator.

Apply a load between the V_{OUT} and GND terminals, using either a fixed resistor, a decade resistor box (provided it is rated for the power) or an active load. A simple initial load might be a one-half watt, 100Ω resistor. **Warning**: because the boost circuit contains a DC path between the input and output (through inductor L4 and diode D2), the circuit is not protected against a shorted output. It is recommended that preliminary testing of the circuit be performed using a current-limited supply on the input.

Figure 3 shows some of the boost circuit's operating waveforms. The scope photo shows the output voltage, the current through the internal power switch (the current into the SW pin) and the voltage on the SW pin of the LT1613. The SEPIC and inverting circuits display similar waveforms.

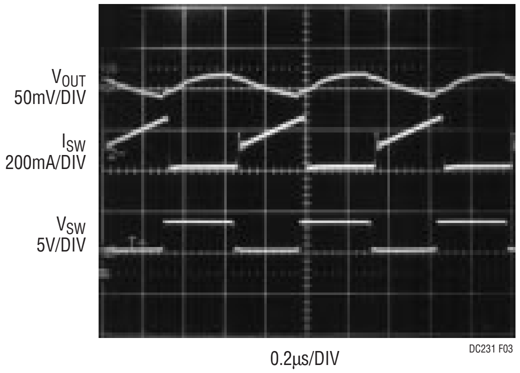


Figure 3. Operating Waveforms of the DC233 Boost Circuit (V_{IN} = 2V, V_{OUT} = 3.3V, I_{OUT} = 80mA)

PERFORMANCE

Efficiency

The efficiency of the DC233 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.

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[1] SEPIC is an acronym for "single-ended primary-inductance converter."

OPERATION

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 DC233 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 you must measure the input voltage while the ammeter is in the circuit—the input voltage will be lower than the voltage at the output of your benchtop supply.

Testing in Your System

You may want to paste this circuit into your system to test compatibility. This should be done with care, since long hook-up wires and ground loops can introduce noise sources and regulation problems that would not be present if the DC/DC converter were properly designed into your PCB.

Treat the DC233 as a 3-terminal device, with V_{IN}, V_{OUT} and GND terminals. Wire the DC233 to your circuit board with wires as short as practical, to points on the circuit board that are close to each other. Also, add high frequency bypass capacitors (0.1µF ceramics) from V_{IN} and V_{OUT} to ground on your circuit board.

If you are bringing power directly to the DC233, use two wires from the input source to the V_{IN} and GND terminals of the DC233. The output power should be applied to your system as described above and either the input supply or your circuit should be floating in order to avoid ground loops.

BOOST

The boost circuit is the simplest LT1613 circuit. It can be used to convert a low voltage to a higher output voltage, for example, converting 1- or 2-cell alkaline batteries to 3.3V or 5V or generating a local 5V logic supply from a 3.3V rail.

Input Range and Power Capability

The LT1613 will typically run from inputs down to 0.9V and is guaranteed to operate from inputs above 1V. The maximum allowable input voltage to this circuit is 6V, which is based on the voltage ratings of the input and output capacitors, C8 and C9. The boost circuit will allow the LT1613 to regulate the output only when the input voltage is less than the desired output voltage plus one diode drop. This means that the practical input range is 0.9V to 3.6V for a 3.3V output and 0.9V to 5.3V for a 5V output.

The power capability of the DC233 boost circuit is determined primarily by the input voltage and by the current limit of the LT1613's internal power switch and, to a lesser extent, by the value of the inductor L4. Therefore, the maximum load current that this circuit can supply depends on the input voltage. A graph of maximum load appears in the Typical Performance section of this manual. This curve is based on the minimum current limit specification in the LT1613 data sheet. A typical LT1613 will deliver more current. As load current is increased beyond this level, the output voltage will sag as the LT1613 reaches its current limit.

Be aware that L4 and D2 provide a direct path between the input and output, and that this circuit does not limit the output current. As an increasing load drags the output voltage below the input, a larger current will flow, limited only by the impedance of the power source, inductor L4 and diode D2.

OPERATION

Shutdown Mode

The $\overline{\text{SHDN}}$ pin of the LT1613 is tied directly to the $\overline{\text{SHDN}}$ terminal of the DC233 and has been left floating. In this condition, or with this pin grounded, the LT1613 is in its shutdown mode. In this state, the LT1613 will draw less than 1µA from the input. However, the inductor L4 and catch diode D2 provide a path from the input to the output and the feedback divider (R8, R10 and R11) may draw a few µA, depending on the input voltage. In addition, the load can draw power from the input while the LT1613 is shut down.

SEPIC

The LT1613 SEPIC circuit is slightly more complicated than the boost circuit, but it can regulate the output over a wider input voltage range. It might be used, for example, to convert a Li-Ion cell input (2.7V to 4.2V) to a 3.3V output.

Input Range and Power Capability

The LT1613 will typically run from inputs down to 0.9V, and is guaranteed to operate from inputs above 1V. The maximum allowable input voltage to this circuit is 6V, which is based on the voltage ratings of the input capacitor, C2. Unlike the boost circuit, the SEPIC can regulate the output voltage when the input voltage is higher.

As in the boost circuit, the power capability of the DC233 SEPIC circuit is determined primarily by the input voltage and by the current limit of the LT1613's internal power switch and, to a lesser extent, by the value of the inductors L1 and L2. Therefore, the maximum load current that this circuit can supply depends on the input voltage. A graph of maximum load appears in the Typical Performance section of this manual. This curve is based on the minimum current-limit specification in the LT1613 data sheet. A typical LT1613 will deliver more current. As load current is increased beyond this level, the output voltage will sag as the LT1613 reaches its current limit.

The SEPIC circuit can be implemented with either a pair of inductors or a 1:1 transformer. Figure 4 shows the transformer arrangement. The DC233 layout includes pads for installation of two types of 1:1 surface mount transformers from Sumida. The Sumida CLS62-100 is a 10µH inductor with two windings that can be used as a transformer. This coupled inductor reduces the ripple current in the LT1613, raising the output power capability of the circuit by 20%. There are also pads that accept the Sumida CLQ61B-8R2. Use this part to implement a low profile design. It can be mounted within a routed hole (not present on the DC233 circuit board), reducing the inductor height to less than 1.5mm above the top surface of the printed circuit board.

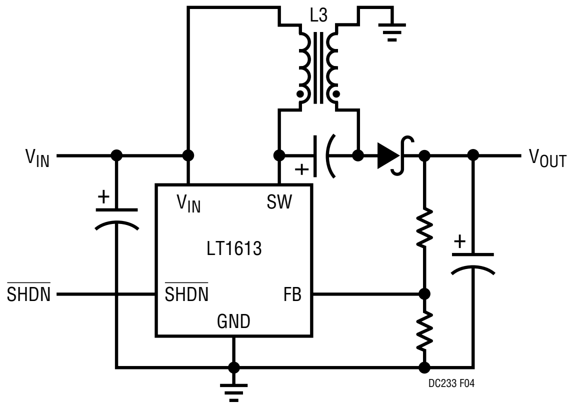


Figure 4. Transformer Arrangement for the SEPIC

Shutdown Mode

Float the $\overline{\text{SHDN}}$ terminal of the DC233 or tie it to ground to shut down the LT1613. The coupling capacitor C3 provides a DC block between the input and output of the SEPIC circuit. This provides an automatic disconnect function; when the LT1613 is placed in shutdown mode, the load cannot draw current from the input source. The shutdown current consumption is less than 1µA.

OPERATION

INVERTER

The LT1611 inverter uses a very low noise circuit topology. Both the input and output of this circuit are connected to inductors and AC current into the input and output capacitors is very low. This results in low voltage ripple at the input and output. This circuit provides lower noise and better regulation than switched capacitor inverters of equivalent power.

Input Range and Power Capability

The LT1611 will typically run from inputs down to 0.9V and is guaranteed to operate from inputs above 1V. The maximum allowable input voltage to this circuit is 6V, which is based on the voltage ratings of the input capacitor C13 and coupling capacitor C14. This inverting circuit can regulate a negative output voltage whose magnitude is either greater or less than the input voltage.

The power capability of the DC233 inverter is determined primarily by the input voltage and by the current limit of the LT1611's internal power switch and, to a lesser extent, by the value of the inductors L5 and L6. Therefore, the maximum load current that this circuit can supply depends on the input voltage. A graph of maximum load appears in the Typical Performance section of this manual. This curve is based on the minimum current limit specification in the LT1611 data sheet. A typical LT1611 will deliver more current. As load current is increased beyond this level, the output voltage will sag as the LT1611 reaches its current limit.

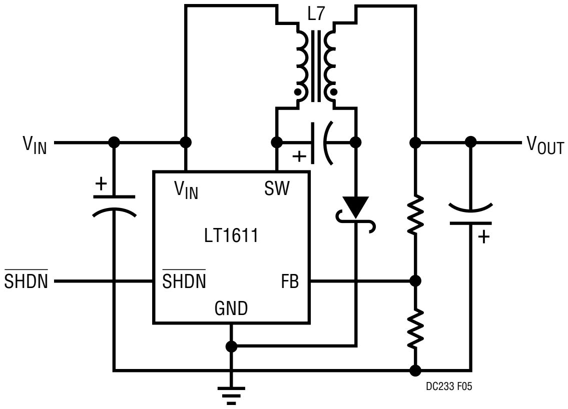


Figure 5. Transformer Arrangement for the Inverter

The inverter can be implemented with either a pair of inductors or with a 1:1 transformer. Figure 5 shows the transformer arrangement. The DC233 layout includes pads for installation of two types of 1:1 surface mount transformers from Sumida. The Sumida CLS62-100 is a 10µH inductor with two windings that can be used as a transformer. The Sumida CLS62-220 22µH inductor will increase power capability by ≈10% and decrease output ripple at the expense of slightly lower efficiency. There are also pads that accept the Sumida CLQ61B-8R2. Use this part to implement a low profile design. It can be mounted within a routed hole (not present on the DC233 circuit board), reducing the inductor height to less than 1.5mm above the top surface of the printed circuit board.

Shutdown Mode

Float the $\overline{\text{SHDN}}$ terminal of the DC233 or tie it to ground to shut down the LT1611. The coupling capacitor C14 provides a DC block between the input and output of the inverter. This provides an automatic disconnect function: when the LT1611 is placed in shutdown mode, the load cannot draw current from the input source. The shutdown current consumption is less than 1µA.

DESIGN ALTERNATIVES

Component Selection

The components used for the DC233 emphasize low cost and small size. Other component choices can provide improved performance. As described above, for example, replacing the inductors in the SEPIC and inverting circuits results in greater output current capability. This section will describe some other alternatives.

OPERATION

Diodes D1, D2 and D3 (Motorola MBR0520LT1) are one-half amp, 20V Schottky diodes. This is a good choice for nearly any LT1611/LT1613 application, unless the output voltage or the circuit topology requires a diode rated for higher reverse voltages. Motorola also offers 30V and 40V versions. Most one-half amp and one amp Schottky diodes are suitable; these are available from many manufacturers. If you use a silicon diode, it must be an ultrafast recovery type. Efficiency will be lower due to the silicon diode's higher forward voltage drop.

Inductors used with the LT1611 and LT1613 should be rated for approximately 0.5A. The value of the inductor should be matched to the power requirements and operating voltages of the application. In most cases a value of 4.7µH or 10µH is suitable. The Murata inductors used on the DC233 are small and inexpensive and are a good fit for the LT1611 and LT1613. Alternatives are the CD43 series from Sumida and the DO1608 series from Coilcraft. These inductors are slightly larger but will result in slightly higher circuit efficiency.

The voltage rating of the input capacitor limits the input voltage range of the circuits. The input range to the SEPIC and inverting circuit can be raised to 10V by replacing the input capacitor (C2 or C13) with a 16V capacitor and (in the case of the inverter) the coupling capacitor (C14) with a 16V part. Note that, in power supply applications, most tantalum capacitor manufacturers recommend using a capacitor with a voltage rating higher than the operating voltage.

The coupling capacitor in the SEPIC and inverting circuits (C3 or C14) should have a low ESR to ensure good efficiency and must have an adequate ripple current rating. It also must have a suitable voltage rating. In the case of the SEPIC circuit, it should be rated for the maximum input voltage or higher; in the inverter, its voltage rating must be higher than the sum of the magnitudes of the input and output voltages. If a coupled inductor is used, the value of this ceramic capacitor can be reduced to 0.22µF from the 1µF used here.

Lower Ripple

The quality of the output capacitor is the greatest determinant of the output voltage ripple. The output capacitor performs two major functions: it must have enough capacitance to satisfy the load under transient conditions and it must shunt the AC component of the current coming through the diode from the inductor. The ripple on the output results when this AC current passes through the finite impedance of the output capacitor. The capacitor should have low impedance at the 1.4MHz switching frequency of the LT1611/LT1613. At this frequency, the impedance is usually dominated by the capacitor's equivalent series resistance (ESR). Choosing a capacitor with lower ESR will result in lower output ripple.

The DC233 uses a combination of two capacitors to achieve these ends. The 15µF tantalum output capacitor (C4, C9 or C15) provides the bulk capacitance for good transient response. A 1µF ceramic capacitor (C5, C10 or C16) in parallel with the tantalum capacitor provides a low impedance bypass at the switching frequency. This results in low output ripple and helps to maintain good efficiency at high loads by eliminating AC losses in the main output capacitor.

This combination output capacitor provides good performance at low cost. Both capacitors are quite small. However, low ESR and the required bulk output capacitance can be obtained using a single larger output capacitor. Larger tantalum capacitors, newer capacitor technologies (for example the POSCAP from Sanyo and SPCAP from Panasonic) or large value ceramic capacitors will reduce the output ripple. Note, however, that the stability of the circuit depends on both the value of the output capacitor and its ESR. When using low value capacitors or capacitors with very low ESR, circuit stability should be evaluated carefully, as described below.

OPERATION

Loop Compensation

The LT1611 and LT1613 are current mode, PWM switching regulators. Each uses a linear control loop to regulate its output. This control loop is compensated internally, eliminating several external components. However, the stability of the control loop depends on the value of the output capacitor and its ESR. A tantalum capacitor's combination of capacitance and ESR will result in stable operation. As the amount of capacitance or ESR is decreased, the phase margin of the circuit will decrease and the transient response of the circuit may ring or the circuit may become unstable. After the power components (including the output capacitor) have been chosen, the circuit should be tested under transient loads for stable response. Linear Technology's Application Note 19 provides details of this method.

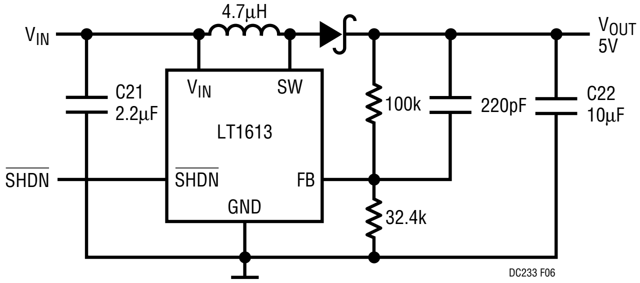
All-Ceramic Design

Large value ceramic capacitors that are suitable for use as the main output capacitor of an LT1611/LT1613 regulator are now available. These capacitors have very low ESR and therefore offer very low output ripple in a small package. However, you should approach their use with some caution.

Ceramic capacitors are manufactured using a number of dielectrics, each with different behavior across temperature and applied voltage. Y5V is a common dielectric type used for high value capacitors, but it can lose more than 80% of the original capacitance with applied voltage and extreme temperatures. The transient behavior and loop stability of the switching regulator depend on the value of the output capacitor, so you may not be able to afford this loss. Other dielectrics (X7R and X5R) result in more stable characteristics and are suitable for use as the output capacitor. The X7R type has better stability across temperature, whereas the X5R is less expensive and is available in higher values.

The second concern in using ceramic capacitors is that many switching regulators benefit from the ESR of the output capacitor because it introduces a zero in the regulator's loop gain. This zero may not be effective because the ceramic capacitor's ESR is very low. Most current mode switching regulators can be easily compensated without this zero. Any design should be tested for stability at the extremes of operating temperatures; this is particularly so of circuits that use ceramic output capacitors.

Figure 6 shows a boost design that uses ceramic capacitors at both the input and output, resulting in small circuit size and very low noise. A capacitor has been added in the feedback path for phase lead, compensating for the output capacitor's low ESR. Figure 7 compares the transient response and output ripple of the DC233 boost circuit with those for the all-ceramic design. The lower trace in each scope photo shows the load current stepping from 50mA to150mA. The upper trace shows the output as it responds to this load step. The output ripple for the DC233 boost circuit appears when the load current is high and is approximately $30mV_{P-P}$. The low ESR, 10µF ceramic capacitor results in output ripple under $5mV_{P-P}$.



C21: TAIYO YUDEN LMK212BJ225MF (0805 CASE SIZE)
C22: TAIYO YUDEN JMK316BJ106ML (1206 CASE SIZE)

Figure 6. This Boost Design Uses Ceramic Input and Output Capacitors for Small Circuit Size and Low Noise

OPERATION

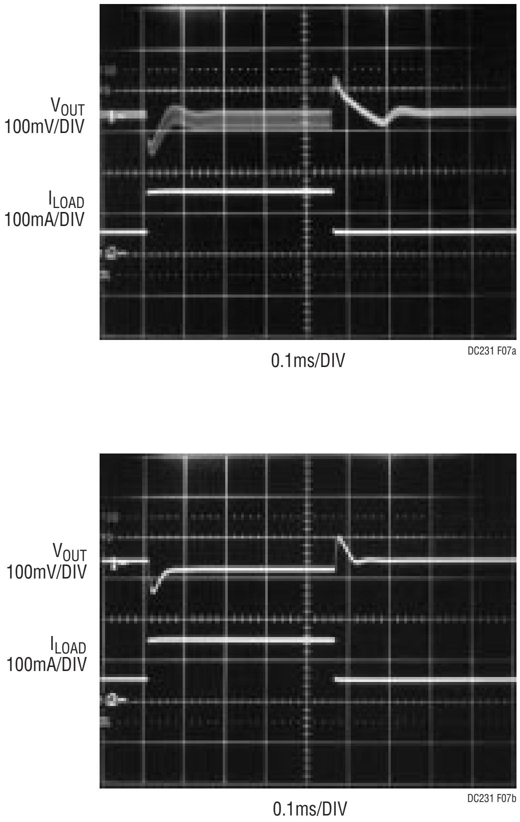
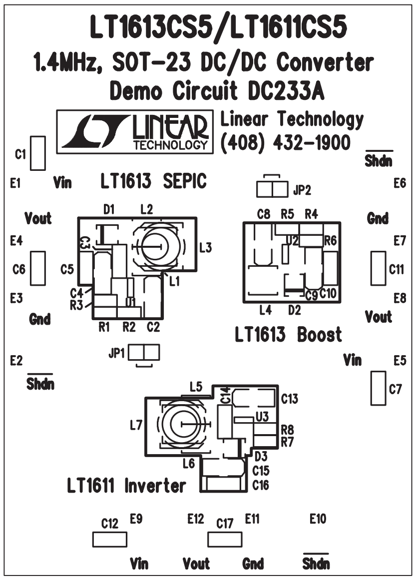
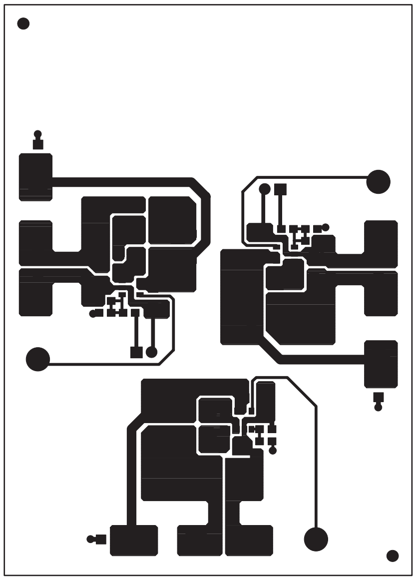


Figure 7. Transient Response of the DC233 Boost Circuit (Top Photo) and All Ceramic Design in Figure 6. (V_{IN} = 3V, V_{OUT} = 5V)

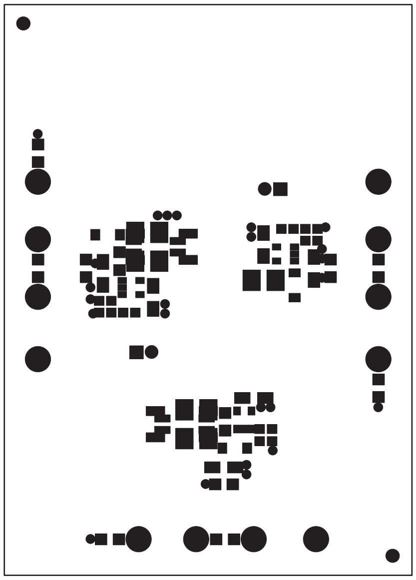
PCB LAYOUT AND FILM



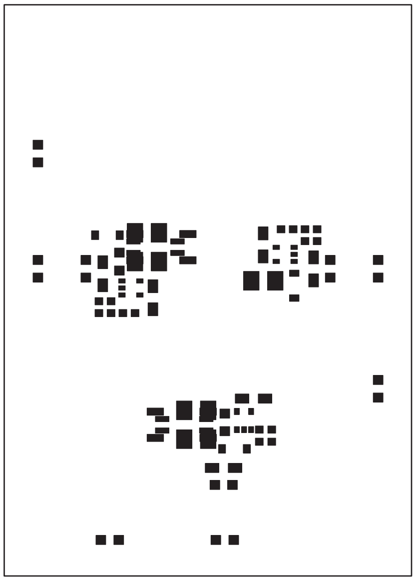
Component Side Silkscreen



Component Side

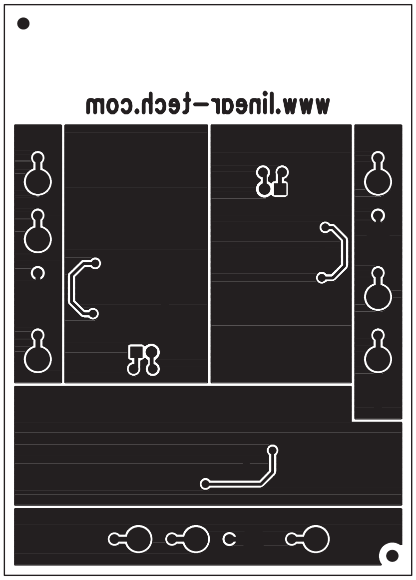


Component Side Solder Mask

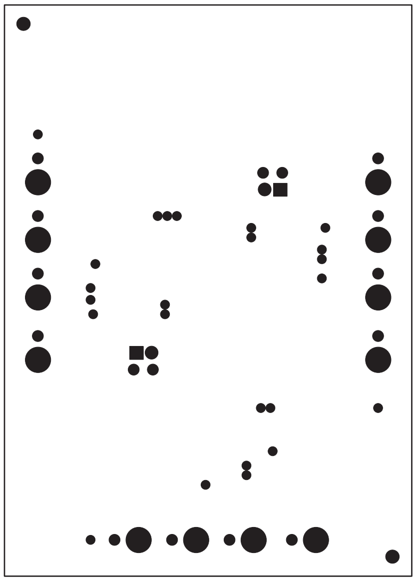


Component Side Paste Mask

PCB LAYOUT AND FILM

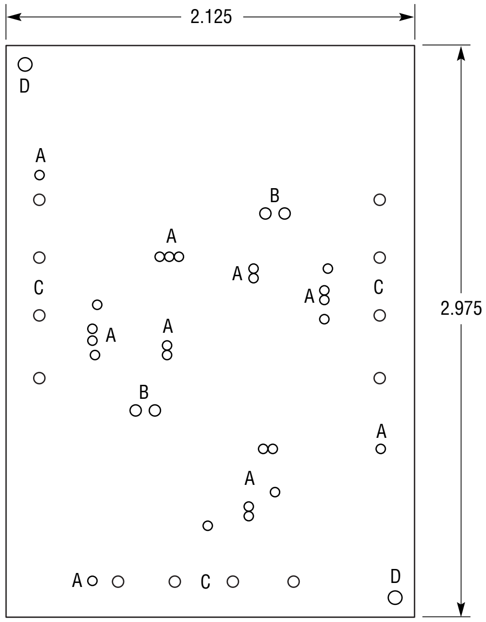


Solder Side



Solder Side Solder Mask

PC FAB DRAWING



NOTES: UNLESS OTHERWISE SPECIFIED
1. MATERIAL: FR4 OR EQUIVALENT EPOXY, 2 OZ COPPER CLAD, THICKNESS 0.062 ±0.006 TOTAL OF 2 LAYERS
2. FINISH: ALL PLATED HOLES 0.001 MIN/0.0015 MAX COPPER PLATE, ELECTRODEPOSITED TIN-LEAD COMPOSITION BEFORE REFLOW, SOLDER MASK OVER BARE COPPER (SMOBC)
3. SOLDER MASK: BOTH SIDES USING SR1020 OR EQUIVALENT
4. SILKSCREEN: USING WHITE NONCONDUCTIVE EPOXY INK
5. ALL DIMENSIONS IN INCHES

SYMBOL	**DIAMETER**	**NUMBER OF HOLES**
A	0.020	24
B	0.035	4
C	0.065	12
D	0.072	2
	TOTAL HOLES	42

233 FAB