

LT1777 High Voltage, Low Noise Step-Down DC/DC Converter

DESCRIPTION

Demonstration Circuit DC242 is a high input voltage, low noise step-down (buck) regulator using the LT[®]1777 switching regulator IC. Typical applications are automotive cellular and GPS receivers, low noise telecom and industrial-instrument power supplies. This controller includes an onboard 700mA peak-current switch and is optimized for use with a high supply voltage. The input voltage can range from 7.4V to 48V. In order to achieve low noise, the LT1777 is equipped with di/dt limiting circuitry, which is programmed via a small external inductor in the power path. It also contains internal circuitry to limit the

dV/dt turn-on and turn-off ramp rates. By slowing down the sharp edges during turn-on and turn-off of the power switch, conducted and radiated EMI are significantly reduced. The output voltage is jumper selectable to either 3.3V or 5V. The LT1777 uses a 100kHz switching frequency and current mode control, which offers excellent dynamic input supply rejection and short-circuit protection. Additionally, the supply current can be shut down to less than 30μA in standby mode. **Gerber files for this circuit are available. Call the LTC factory.**

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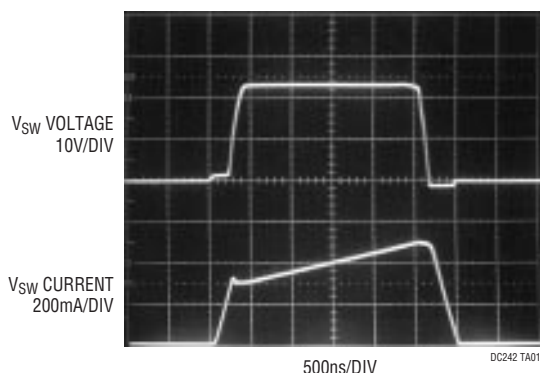
PERFORMANCE SUMMARY $T_A = 25^\circ\text{C}$

PARAMETER	CONDITIONS	VALUE
Input Voltage Range	$I_{OUT} = 0\text{mA to } 500\text{mA}$	7.4V to 48V
Output Voltage (Jumper Selectable)		3.3V, 5V
Maximum Output Load Current	$V_{IN} > 12\text{V}, V_{OUT} = 5\text{V}$	$I_O = 500\text{mA}^*$
Typical Output Ripple Voltage	$I_{OUT} = 500\text{mA}, V_{IN} = 24\text{V}$	17mV _{p-p}
Nominal Operating Frequency	$V_{IN} = 7.4\text{V to } 48\text{V}$	100kHz
I_Q , Supply Current in Shutdown		30μA

* $I_O = 450\text{mA}$ for $V_{IN} \leq 12\text{V}$ and $V_{OUT} = 5\text{V}$

TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO

V_{SW} Switching Waveforms



Component Side



SCHEMATIC AND PACKAGE DIAGRAMS

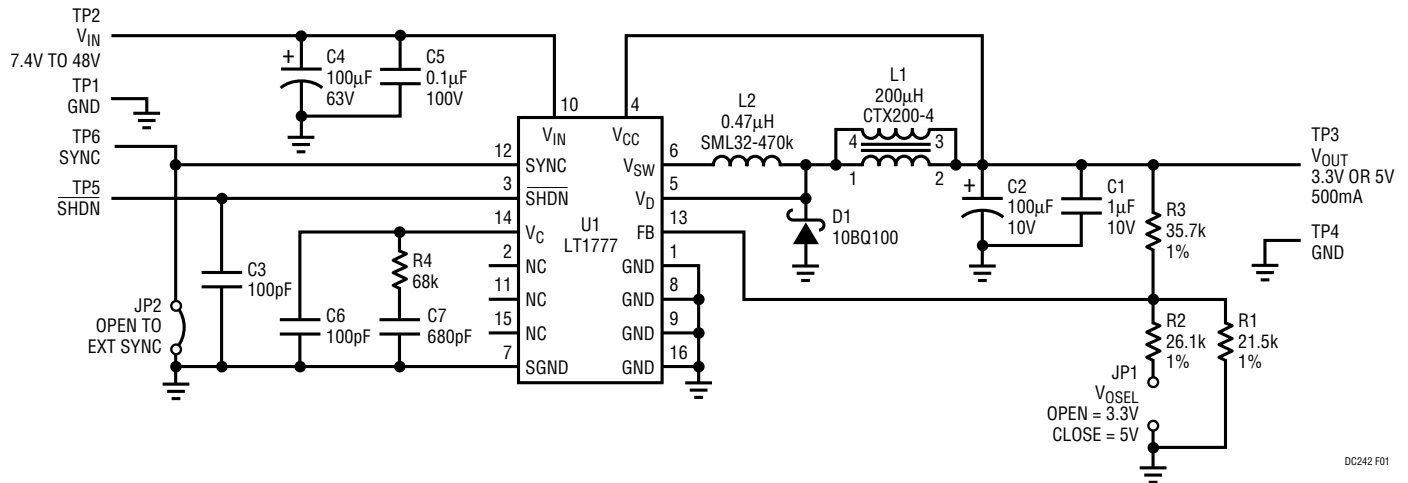
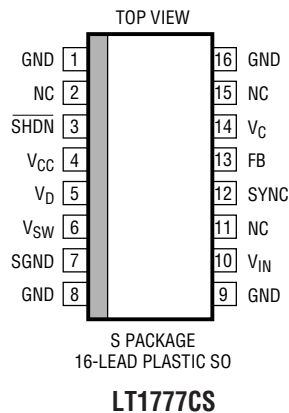


Figure 1. 100kHz Low Noise Step-Down Switching Regulator



PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
C1	1	0805ZC105MAT1A	1µF 10V 20% X7R Capacitor	AVX	(843) 946-0362
C2	1	TPSD107M010R0065	100µF 10V 20% Tantalum Capacitor	AVX	(207) 282-5111
C3, C6	2	06035A101JAT1A	100pF 50V 5% NPO Capacitor	AVX	(843) 946-0362
C4	1	63CV100BS	100µF 63V 20% Electrolytic Capacitor	Sanyo	(619) 661-6835
C5	1	12061C104MAT1A	0.1µF 100V 20% X7R Capacitor	AVX	(843) 946-0362
C7	1	06033A681JAT1A	680pF 25V 5% NPO Capacitor	AVX	(843) 946-0362
D1	1	10BQ100TR	100V 1A Schottky Diode	IR	(310) 322-3331
JP1, JP2	2	2802S-02G2	2mm 2-Pin Jumper	Comm Con	(626) 301-4200
JP1, JP2	2	CCIJ2mm-138-G	2mm 2-Pin Shunt	Comm Con	(626) 301-4200
L1	1	CTX200-4	200µH 0.6A SMT Inductor	Coiltronics	(561) 241-7876
L2	1	SML32-470K	470nH 450mA SMT Inductor	Gowanda	(716) 532-2234

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
L3	1	DT1608C-152	1.5 μ H Inductor (Alternate for L2)	Coilcraft	(847) 639-6400
R1	1	CR16-2152FM	21.5k 1/16W 1% Chip Resistor	Tad	(714) 255-9123
R2	1	CR16-2612FM	26.1k 1/16W 1% Chip Resistor	Tad	(714) 255-9123
R3	1	CR16-3572FM	35.7k 1/16W 1% Chip Resistor	Tad	(714) 255-9123
R4	1	CR16-683JM	68k 1/16W 5%	Tad	(714) 255-9123
TP1 to TP6	6	2501-2	0.090 Turret Testpoint	Mill-Max	(516) 922-6000
U1	1	LT1777CS	16-Lead SO DC/DC Controller IC	LTC	(408) 432-1900

QUICK START GUIDE

Refer to Figure 2 for proper measurement equipment set-up and follow the procedure outlined below:

1. Connect the input power supply to the V_{IN} and GND terminals. Input voltage is limited to between 7.4V and 48V.
2. Connect an ammeter in series with the input supply to measure input current.
3. Connect either power resistors or an electronic load to the V_{OUT} and GND terminals.
4. Connect an ammeter in series with the output load to measure output current.
5. The \overline{SHDN} pin should be left floating for normal operation or tied to GND for shutdown.
6. Leave jumper JP2 connected for switching the LT1777 at its nominal frequency of 100kHz.
7. Set the output voltage with jumper JP1, as shown in Table 1.
8. After all connections are made, turn on the input power and verify that the output voltage is correct.

Table 1

POSITION	OUTPUT VOLTAGE
Jumper JP1 Closed	5V
Jumper JP1 Open	3.3V

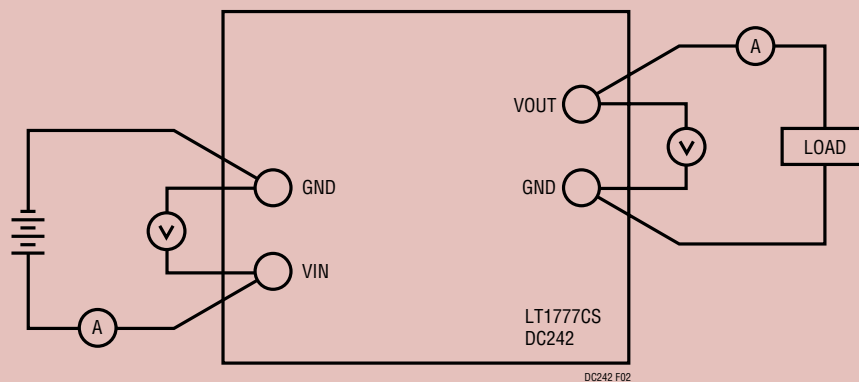


Figure 2. Proper Measurement Set-Up

OPERATION

Introduction

The schematic in Figure 1 highlights the capabilities of the LT1777. The application circuit is set up for an output voltage of either 3.3V or 5V, set by jumper JP1. The demo board comes equipped with input, output, GND, SYNC and SHDN terminals to make bench testing convenient.

Since the LT1777 allows such a wide input range, from 7.4V to 48V, the internal control circuitry draws power from the V_{CC} pin, which is normally connected to the output supply. During start-up, the LT1777 draws power from V_{IN} . However, after the switching supply output voltage reaches 2.9V, the LT1777 uses the output to supply its internal control circuitry, thereby reducing quiescent power by hundreds of milliwatts when operating at high input voltage. This helps maximize efficiency at high line voltages.

Theory of Operation

During normal operation, the internal power transistor is turned on during each cycle when the oscillator sets a latch and turned off when the main current comparator resets the latch. While the internal switch is off, Schottky diode (D1) carries the inductor current until it tries to reverse or until the beginning of the next cycle. The voltage on the V_C pin, which is the output of the error amplifier, controls the peak inductor current. The FB pin provides the error amplifier an output feedback voltage, V_{FB} , from an external resistor divider. When the load current increases, it causes a slight decrease in V_{FB} relative to the 1.24V reference, which, in turn, causes the voltage on the V_C pin to increase until the average inductor current matches the new load current.

Sense Inductor

The LT1777 uses an external sense inductor to program the di/dt limiting circuitry. The minimum useful inductance value for the sense inductor is 470nH, which produces a di/dt of approximately 2.2A/ μ s. Larger sense inductors yield lower current slew rates, resulting in reduced high frequency RFI emissions at the expense of slightly reduced efficiency. Refer to the “Selecting Sense

Inductor” section in the LT1777 data sheet for information on programming a different di/dt rate through the main power inductor.

SYNC Pin

This pin is used to synchronize the internal oscillator to an external clock with a frequency between 130kHz and 250kHz. If a switching frequency higher than nominal is desired, remove jumper JP2 and tie an external oscillator of the desired frequency between the SYNC terminal and the input GND terminal. The external oscillator can be a TTL compatible level or 3.3V, with a duty cycle between 10% and 90%. Refer to the “Selecting Main Inductor” section in the LT1777 data sheet for information on optimizing the inductor value for running at a higher frequency.

How to Measure Voltage Regulation and Efficiency

When trying to measure load regulation or efficiency, voltage measurements should be made directly across the V_{OUT} and GND terminals rather than at the end of test leads at the load. Similarly, input voltage should be measured directly at the V_{IN} and GND terminals of the DC242. Input and output current should be measured by placing an ammeter in series with the input supply and load. Figure 3 shows the typical efficiency curve for L2 (sense inductor) = 470nH, $V_{IN} = 12V$, $V_{OUT} = 5V$.

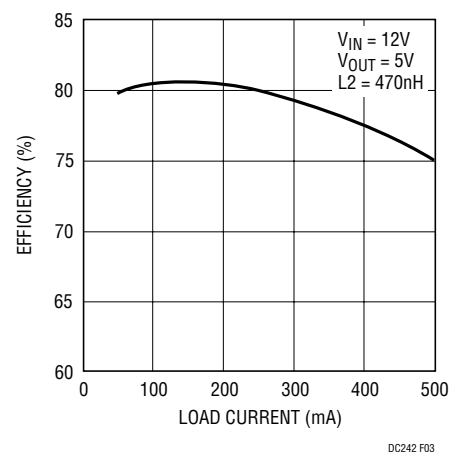


Figure 3. LT1777 Output Efficiency

OPERATION

How to Measure Output Voltage Ripple

In order to measure output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. A sturdy wire should be soldered on the output GND terminal. The other end of the wire is looped around the ground connection of the probe and should be kept as short as possible. The tip of the probe is touched directly to V_{OUT} (see Figure 4). Bandwidth is generally limited to 20MHz for ripple measurements. Also, if multiple pieces of line-powered test equipment are used, be sure to use isolation transformers on their power lines to prevent ground loops, which can cause erroneous results. Figure 5 shows the output voltage ripple with a steady state load of 500mA.

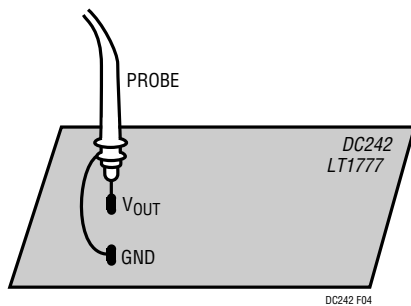


Figure 4. Measuring Output Voltage Ripple

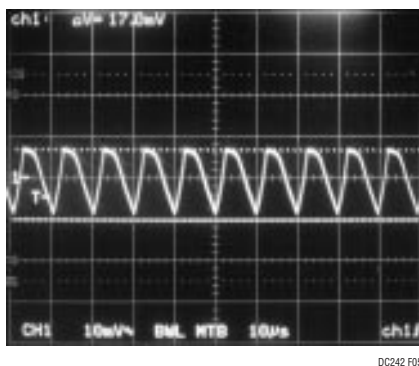


Figure 5. Output Voltage Ripple for the LT1777, $I_L = 500\text{mA}$

Heat Dissipation Issues

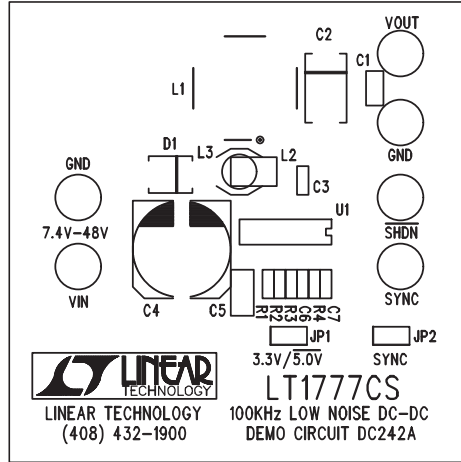
Since the LT1777 includes a 500mA onboard power switch, care must be taken not to exceed the maximum junction temperature for the part. A simple technique is to use the PC board as a heat sink. The four corner pins on the LT1777 IC are connected to the ground plane on both sides of the PC board. The two sides are connected through vias to better handle the power dissipation. If the LT1777 is placed on a multilayer board, it is desirable to have metal on the inner layers directly underneath the LT1777. This helps in spreading heat and improves the power dissipation capability of the PCB.

Layout Guidelines

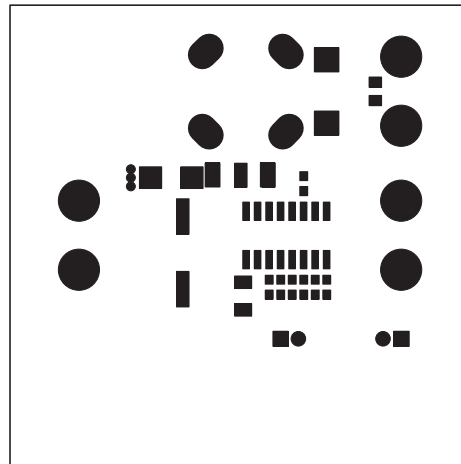
Since the LT1777 is a switching regulator, attention to proper layout is essential for good load regulation and to minimize radiated/conducted noise. Be sure to follow these layout guidelines:

1. The LT1777's V_{SW} pin, sense inductor L2 and Schottky diode D1 should be placed as close as possible to each other.
2. The anode of Schottky diode D1 should be tied directly to the ground plane.
3. Keep the trace from the FB pin to the junction of R3 and R2 short and use a long trace from the top of resistor R3 to the output terminal, rather than vice versa.
4. Output capacitor C2's grounds should be tied directly to the ground plane.
5. The ground of the feedback resistors and the loop compensation resistor/capacitor (connected to the V_C pin) should be referenced to the chip SGND pin, which, in turn, is directly tied to the ground plane.
6. C5 should be as close as possible to Pin 10.

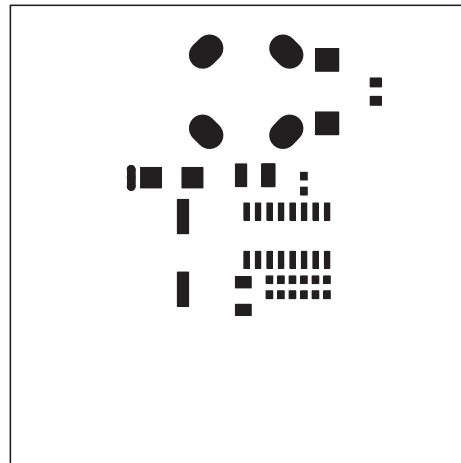
PCB LAYOUT AND FILM



Component Side Silkscreen

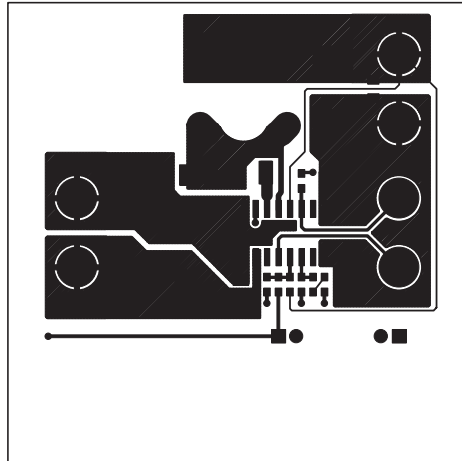


Component Side Solder Mask

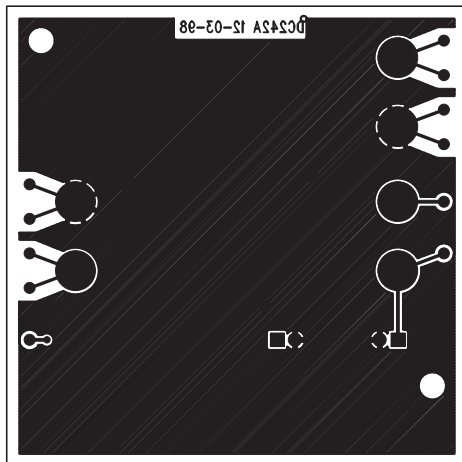


Component Side Paste Mask

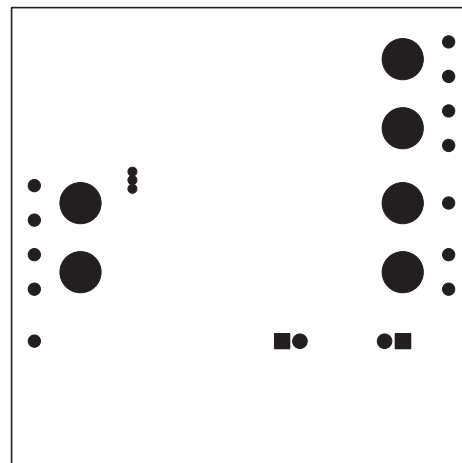
PCB LAYOUT AND FILM



Copper Layer 1 (Top)



Copper Layer 2

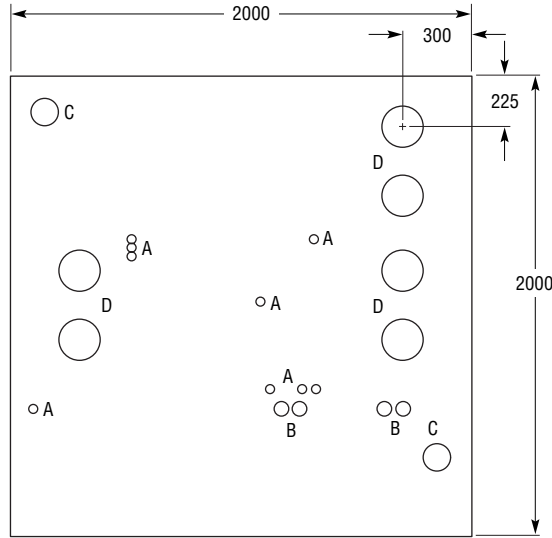


Solder Side Solder Mask

DEMO MANUAL DC242

DC/DC CONVERTER

PC FAB DRAWING



ALL DIMENSIONS ARE IN MILS

- NOTES: UNLESS OTHERWISE SPECIFIED
1. WORKMANSHIP SHALL BE IN ACCORDANCE WITH IPC-A-600E
 2. FINISHED MATERIAL IS FR4, 0.062 THICK 2 OZ COPPER, 2 LAYERS
PLATED HOLE WALL THICKNESS 0.001 MIN
 3. PROCESS AND PLATING: SMOBC, TIN-LEAD
 4. SOLDER MASK BOTH SIDES USING GLOSSY GREEN LPI
 5. SILKSCREEN WHITE NONCONDUCTIVE EPOXY INK COMPONENT SIDE

SYMBOL	DIAMETER	NUMBER OF HOLES
A	15	9
B	30	4
C	70	2
D	94	6
TOTAL HOLES		21