

LTC1474/LTC1475

10 μ A I_Q, High Efficiency, Step-Down DC/DC Converter

DESCRIPTION

This demonstration circuit is a step-down (buck) regulator using the LTC[®]1474/LTC1475. The exclusive use of surface mount components and the LTC1474/LTC1475 in the tiny MSOP package results in a highly efficient application in a small board space. This demo board highlights the capabilities of the LTC1474/LTC1475, which use a current mode, constant off-time architecture to switch an internal P-channel power MOSFET. This results in a power supply that has low ripple and fast transient response. At low output currents the LTC1474/LTC1475 automatically switch to Burst Mode™ operation to maintain high operating efficiencies and minimize supply current. At no load, only

10 μ A (typical) is required to regulate the output. The parts can be shut down to further reduce the supply current to 6 μ A (typical). In dropout, the internal P-channel MOSFET is turned on continuously (100% duty cycle), providing low dropout operation with $V_{OUT} \cong V_{IN}$. An onboard low-battery detector allows the user to monitor the input supply through an external resistive divider. This board is intended for applications such as cellular phones, GSM systems, 4mA to 20mA current-loop pirate supplies or any portable battery-powered application. **Gerber files for this circuit board are available. Call the LTC factory.**

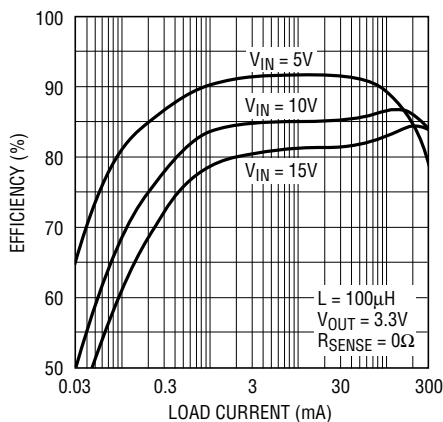
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PERFORMANCE SUMMARY

SYMBOL	PARAMETER	CONDITIONS	BOARD SUFFIX	VALUE
V _{IN}	Input Voltage Range	V _{OUT} = 3.3V V _{OUT} = 5V	A, B, D, E C, F	3.3V to 18V 5V to 18V
V _{OUT}	Output Voltage	LTC1474/LTC1475 LTC1474-3.3/LTC1475-3.3 LTC1474-5/LTC1475-5	A, D B, E C, F	3.3V \pm 0.10V 3.3V \pm 0.10V 5V \pm 0.15V
I _{OUT}	Maximum Output Current	R _{SENSE} = 0 Ω R _{SENSE} = 0.25 Ω	ALL ALL	300mA 150mA
I _Q	Typical Supply Current	V _{IN} = 10V, I _{LOAD} = 0 V _{IN} = 10V, I _{LOAD} = 0	A, B, C D, E, F	10 μ A 15 μ A

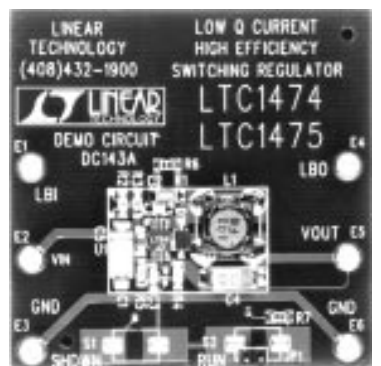
TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO

Board A, B, D, E Efficiency



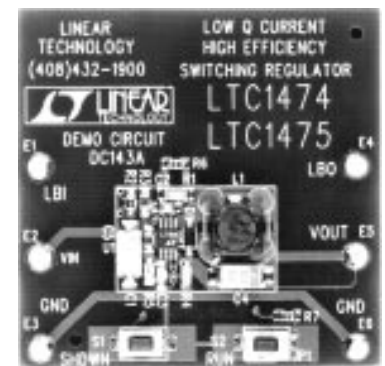
DM143 TPC

Demo Board A



DM143 DB A

Demo Board D



DM143 DB D

PERFORMANCE SUMMARY

SYMBOL	PARAMETER	CONDITIONS	BOARD SUFFIX	VALUE
V_{RIPPLE}	Typical Output Ripple	$I_{OUT} = 100mA$	All	50mV
ΔV_{OUT}	Typical Line Regulation	$4V < V_{IN} < 18V, R_{SENSE} = 0\Omega, I_{LOAD} = 100mA$	A, D	35mV
		$4V < V_{IN} < 18V, R_{SENSE} = 0.25\Omega, I_{LOAD} = 100mA$		25mV
		$4V < V_{IN} < 18V, R_{SENSE} = 0\Omega, I_{LOAD} = 100mA$	B, E	20mV
		$4V < V_{IN} < 18V, R_{SENSE} = 0.25\Omega, I_{LOAD} = 100mA$		10mV
	Typical Load Regulation	$0 < I_{LOAD} < 300mA, R_{SENSE} = 0\Omega, V_{IN} = 10V$	C, F	20mV
		$0 < I_{LOAD} < 150mA, R_{SENSE} = 0.25\Omega, V_{IN} = 10V$		10mV
V_{LBI}	Low-Battery Trip Threshold		All	1.23V

PACKAGE A D SCHEMATIC DIAGRAMS

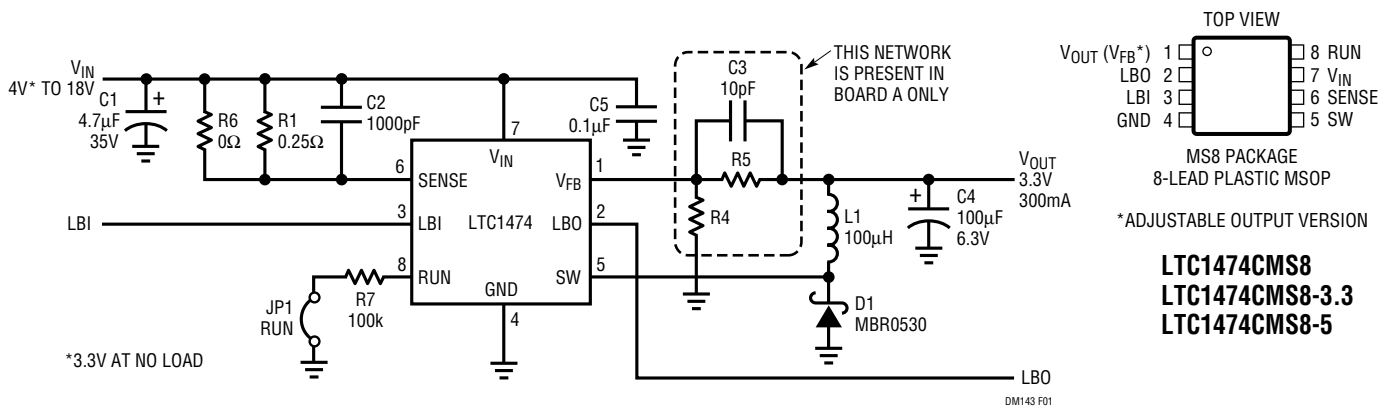


Figure 1. LTC1474 Demo Board Schematic

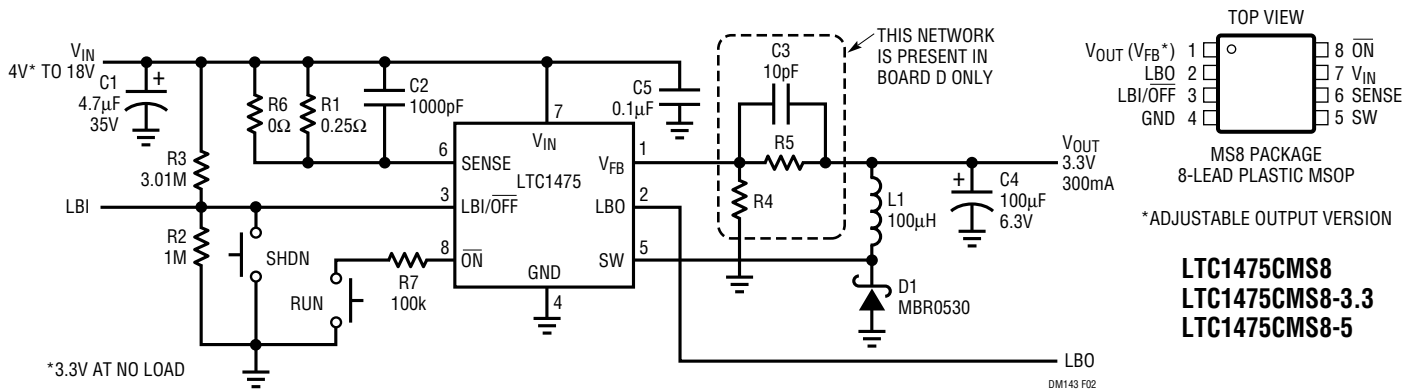


Figure 2. LTC1475 Demo Board Schematic

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
C1	1	TPSC475M035	4.7µF 35V 20% Tantalum Capacitor	AVX	(207) 282-5111
C2	1	080553102KAT2A	1000pF 25V 10% X7R Capacitor	AVX	(803) 946-0362
C3	1	08055310KAT1A	10pF 25V 10% NPO Capacitor (Boards B, C, E, F Only)	AVX	(803) 946-0362
C4	1	TPSC107M006R0150 TPSC336M010R0375	100µF 6.3V 20% Tantalum Capacitor (Boards A, B, D, E) 33µF 6.3V 20% Tantalum Capacitor (Boards C, F)	AVX	(207) 282-5111
C5	1	08053E104ZAT1A	0.1µF 25V +80% to -20% Y5V Capacitor	AVX	(803) 946-0362
D1	1	MBR0530	0.5A 30V Schottky Diode	Motorola	(602) 244-3576
E1 to E6	6	2501-02	Terminal Turret	Mill Max	(516) 922-6000
JP1	1	2802S-02-G2	Connector Pin Header (Boards A, B, C)	Comm Con	(818) 301-4200
L1	1	CDRH73-101	100µH Inductor	Sumida	(847) 956-0666
R1	1	LR1206 01 R250 F0	0.25Ω 0.25W 1% Resistor	IRC	(512) 992-7900
R2	1	CR21-105J-T	1M 0.1W 5% Resistor (Boards D, E, F Only)	AVX	(803) 946-0524
R3	1	CR21-225J-T	2.2M 0.1W 5% Resistor (Boards D, E, F Only)	AVX	(803) 946-0524
R4	1	WCR0805-1474-F-P-LT	1.47M 0.1W 1% Resistor (Boards B, C, E, F Only)	IRC	(512) 992-7900
R5	1	CJ21-000J-T WCR0805-2494-F-P-LT	0805 Shunt Resistor (Boards B, C, E, F) 2.49M 0.1W 1% Resistor (Boards A, D)	AVX IRC	(803) 946-0524 (512) 992-7900
R6	1	CJ21-000J-T	0805 Shunt Resistor	AVX	(803) 946-0524
R7	1	CR21-104J-T	100k 0.1W 5% Resistor	AVX	(803) 946-0524
S1, S2	2	EVQ PJS05K	Momentary Switch (Boards D, E, F)	Panasonic	(201) 392-4511
U1	1	LTC1474CMS8 LTC1474CMS8-3.3 LTC1474CMS8-5 LTC1475CMS8 LTC1475CMS8-3.3 LTC1475CMS8-5	8-Pin MSOP IC, LTC1474 (Board A) 8-Pin MSOP IC, LTC1474-3.3 (Board B) 8-Pin MSOP IC, LTC1474-5 (Board C) 8-Pin MSOP IC, LTC1475 (Board D) 8-Pin MSOP IC, LTC1475-3.3 (Board E) 8-Pin MSOP IC, LTC1475-5 (Board F)	LTC	(408) 432-1900

Table 1. Demo Board Version Cross Reference

BOARD SUFFIX	PART NUMBER	OUTPUT VOLTAGE	ON/OFF CONTROL
A	LTC1474	3.3V (Adjustable)	Jumper
B	LTC1474-3.3	3.3V	Jumper
C	LTC1474-5	5V	Jumper
D	LTC1475	3.3V (Adjustable)	Pushbutton
E	LTC1475-3.3	3.3V	Pushbutton
F	LTC1475-5	5V	Pushbutton

QUICK START GUIDE

Demonstration Board DC143 is easy to set up for evaluation of the LTC1474/LTC1475. Please follow the procedure below for proper operation:

- Connect the input power supply to the V_{IN} and GND terminals.
- The LBO pin is a current sinking pin. When the LBI pin goes below 1.23V, the LBO pin will sink 0.7mA of current.
- The LBI pin is the low-battery detector input pin. Normally, its input comes from the input voltage through a resistor network (the resistor divider is present only on boards D, E and F).
- Connect the load between the V_{OUT} and GND terminals. Refer to Figure 6 for proper measurement equipment setup.
- For board A, B or C, open jumper JP1 to turn on or short the jumper to shut down. For Board C, D or E, momentarily depress the RUN push-button to turn on or momentarily depress the SHDN push-button to shut down.

OPERATION

The circuits shown in Figures 1 and 2 operate from input voltages of 3.3V to 18V. The six different versions of the demo board provide 3.3V or 5V, as specified in Table 1. For output voltages other than 3.3V or 5V, use Board A or D and change the resistive divider R4/R5 to the appropriate ratio. For output voltages lower than 3V, input voltages as low as 3V can be used. The demo boards provide two on/off options—by opening or shorting jumper JP1 (Boards A, B and C) or push-button (Boards D, E and F).

Operation

The LTC1474/LTC1475 use a current mode, constant off-time architecture shown in Figure 3. Current mode operation provides the well known advantages of clean start-up and excellent line and load regulation. Constant off-time adds to this list simplicity (neither an oscillator nor ramp compensation is required) and inherent 100% duty cycle in dropout.

The LTC1474/LTC1475 use Burst Mode operation to keep the output capacitor charged to the proper output voltage while minimizing quiescent current. Burst Mode operation works by using short burst cycles to keep the output capacitor charged, followed by a “sleep” mode where the load current is supplied by the output capacitor and the LTC1474/LTC1475 draw only 9 μ A of supply current. Because of Burst Mode operation and the constant off-time, the frequency changes with input voltage and

load. During sleep mode, the low quiescent current is achieved by turning on only the voltage comparator and voltage reference, which are needed to monitor the output voltage, and the low-battery comparator. The low quiescent current and variable frequency minimize losses that would normally dominate at light loads (DC supply current losses and switching losses due to the MOSFET switch gate charge). This results in the high efficiencies down to extremely light loads and the ultralow supply current required to maintain the output voltage at no load.

The LTC1474/LTC1475 also provide user-programmable peak inductor current: the user can set the peak current to any value between 10mA and 400mA with the appropriate sense resistor. At the beginning of the burst cycle, the internal P-channel MOSFET switch is turned on, causing the inductor current to begin to increase. This current flows through both an internal and an optional external sense resistor. The internal current comparator monitors the voltage drop across the sense resistors and, when the voltage reaches 100mV, the current comparator trips and turns the switch off, causing the inductor current to decrease. At the end of the 4.75 μ s off-time, the switch either turns back on or stays off (sleep mode), depending on the status of the voltage comparator. Without an external sense resistor (Pins 6 and 7 shorted), the peak current defaults to the 400mA max due to the internal sense resistor.

OPERATION

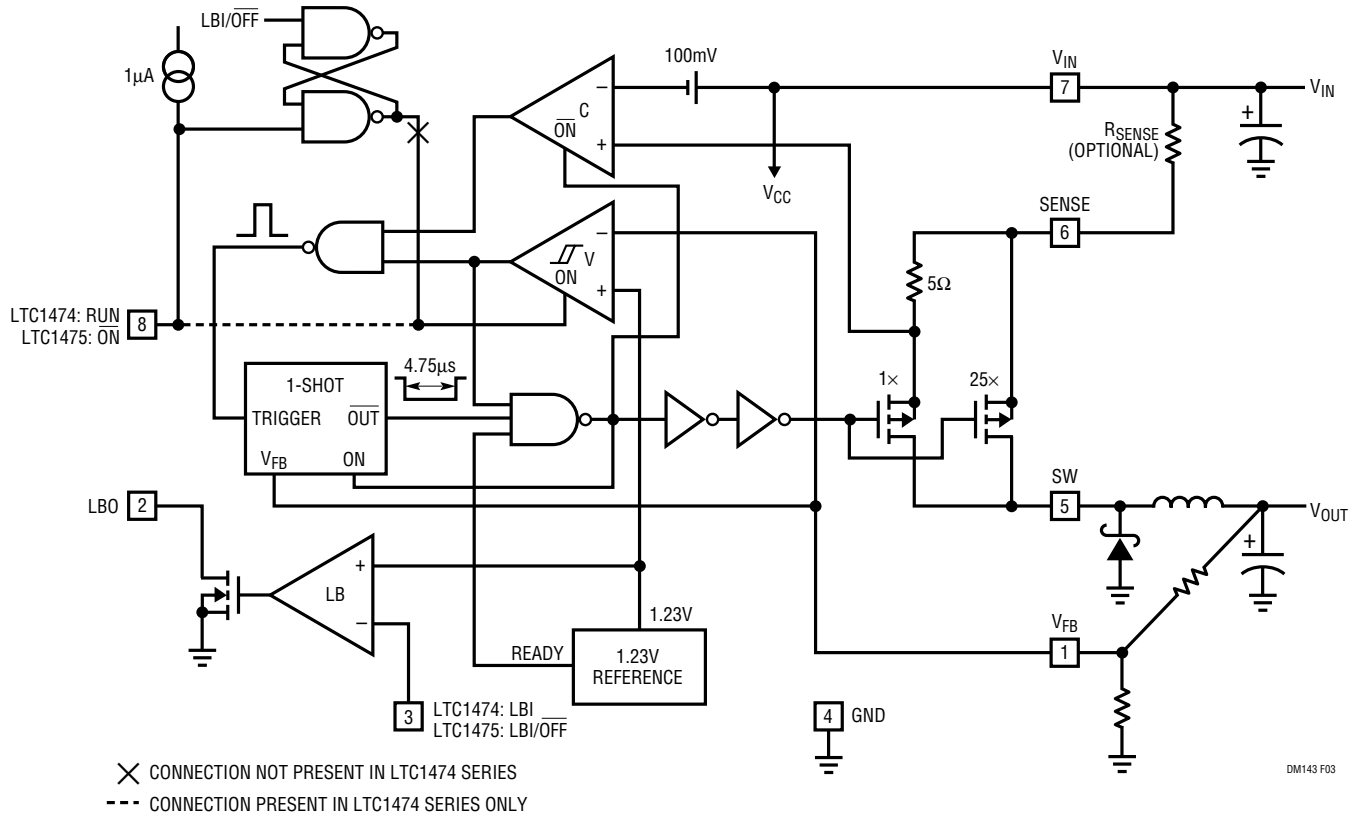


Figure 3. LTC1474/LTC1475 Block Diagram

The demo board includes two sense resistors; 0.25Ω R1 is shorted out with a 0Ω resistor (R6) to easily demonstrate peak current programming. With the short in place (R_{SENSE} = 0Ω), the peak current is the maximum 400mA providing a maximum load of 300mA. With the short removed (R_{SENSE} = 0.25Ω), the peak current is reduced to 200mA and the maximum load is 150mA.

Low-Battery Detector

The low-battery indicator senses the input voltage through an external resistive divider. This divided voltage connects to the (–) input of a voltage comparator (Pin 3), which is compared with a 1.23V reference voltage. Because the current going into Pin 3 is negligible, the following expression is used for setting the trip point:

$$V_{LBTRIP} = 1.23(1 + R3/R2)$$

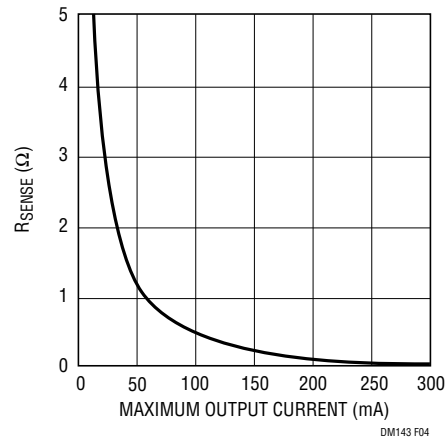


Figure 4. R_{SENSE} Selection

OPERATION

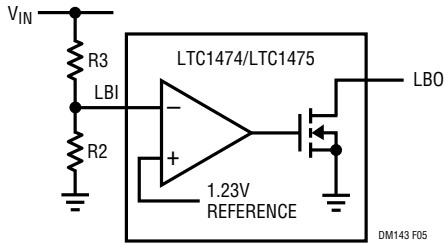


Figure 5. Low-Battery Comparator

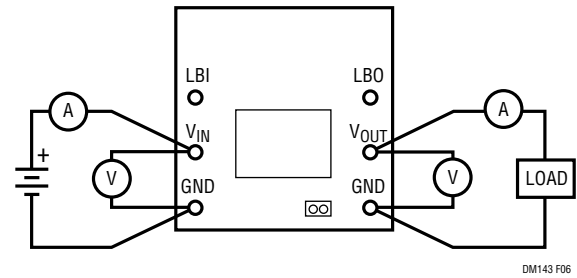


Figure 6. Correct Measurement Setup

HOW TO MEASURE VOLTAGE REGULATION

When trying to measure voltage regulation, remember that all measurements must be taken at the point of regulation. This point is where the LTC1474/LTC1475's control loop looks for the information to keep the output voltage constant. This information occurs between Pins 1 and 4 of the LTC1474/LTC1475. These points correspond to the output terminals of the demonstration board. Test leads should be attached to these terminals. Measurements should not be taken at the end of test leads at the load. Refer to Figure 6 for proper monitoring equipment configuration. This applies to line regulation (input-to-output voltage regulation) as well as load regulation tests. In doing line regulation tests, always look at the input voltage across the input terminals.

For the purposes of these tests, the demonstration circuit should be fed from a regulated DC bench supply so additional variation on the DC input does not add an error to the regulation measurements.

For measurement of no-load supply current and measurement of efficiency at loads below 1mA, *the input impedance of the voltmeters may have a significant effect on measurements.* For example, in the case of voltmeters with 10MΩ impedance, the no-load supply current at $V_{IN} = 15V$ will increase from 10.5μA with no meters connected to 12μA with meters connected to both the input and output. Likewise, with $V_{IN} = 15V$ and $I_{LOAD} = 100\mu A$, the efficiency decreases from 59% to 56.8% when the voltmeters are connected. Therefore, for the most accurate measurements at light loads, first record the voltmeter readings, then disconnect the voltmeters before making the input supply current measurement.

COMPONENTS

Component selection can be very critical in switching power supply applications. This section discusses some of the guidelines for selecting the different components. The LTC1474/LTC1475 data sheet details more specific selection criteria for most of the external components surrounding the IC. Be sure to refer to the data sheet if changes to this demo circuit are anticipated.

Capacitors

The most common component uncertainty with switching power supplies involves capacitors. In this circuit (refer to Figure 1) C1 and C4 are low ESR, high ripple current tantalum capacitors specifically designed and developed for use in switching power supplies. ESR (equivalent series resistance) is the parasitic series resistance in the capacitor. Often, this resistance is the limiting element in reducing ripple at the output or input of the supply.

Other choices are organic semiconductor type capacitors (OS-CON) that are specifically made for power supply applications. For lower current applications (<50mA) ceramic capacitors, available as large as 10μF, provide the smallest size and lowest ESR.

Normal tantalums are not recommended for use in these applications (especially the low cost ones), as they do not have the ability to take the large peak currents that are required for the application. Standard wet electrolytics also may not meet requirements, due to their high ESR, limited operating life and larger size.

OPERATION

Inductor

Many off-the-shelf surface mount inductors are available that work well in LTC1474/LTC1475 applications. The inductor used in this demo board is from Sumida, but there is a wide variety of inductors available from other manufacturers, such as the Dale LPT4545 series, Coilcraft DO1608 and DO3316 series and Coiltronics CTX series. The inductors vary in size, shape, cost, current rating and loss characteristics. The only fixed requirement of the inductor is that it must be able to support the output DC current and still maintain its inductance value. The other variables need to be traded off against the requirements for area, efficiency and cost in choosing the optimal inductor.

Sense Resistor

The demo board is provided with a 0.25Ω current sense resistor—a special, low valued, current shunt resistor made by IRC. However, in most cases the least expensive solution is obtained by paralleling standard resistors (available in values ≥1Ω) instead of using this special low valued resistor. Although a single resistor could be used with the desired value, these low valued resistor types are much more expensive and are currently not available in case sizes smaller than 1206. Three or four 0603 size standard resistors require about the same area as one 1206 size low valued resistor and are available at a fraction of the cost.

Schottky Diode

The catch diode carries load current during the off-time. The average diode current is therefore dependent on the P-channel switch duty cycle. At high input voltages the diode conducts most of the time. As V_{IN} approaches V_{OUT} the diode conducts only a small fraction of the time. The most stressful condition for the diode is when the output is short-circuited. Under this condition, the diode must safely handle I_{PEAK} at close to 100% duty cycle.

To maximize both low and high current efficiency, a fast switching diode with low forward drop and low reverse leakage should be used. *Low reverse leakage current is critical to maximize low current efficiency, since the leakage can potentially approach the magnitude of the LTC1474/LTC1475 supply current.* Low forward drop is critical for high current efficiency, since loss is proportional to forward drop. These are conflicting parameters, but a good compromise is the MBR0530 0.5A Schottky diode specified in the schematic. Using a diode with slightly lower forward drop, for example the MBRS130, increases the efficiency by 1.3%, but also increases the no-load supply current from 10μA to 16μA.

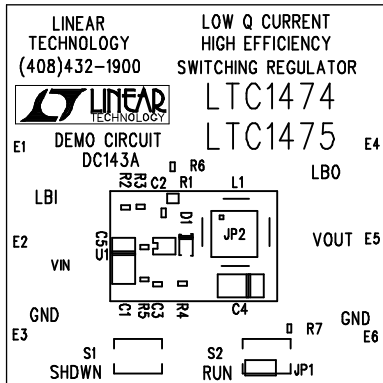
Component Manufacturers

Beside the components that are used on the demonstration board, other components may also be used. Below is a partial list of the manufacturers whose components you can use for the switching regulator. Using components other than the ones on the demonstration board requires recharacterizing the circuit for efficiency.

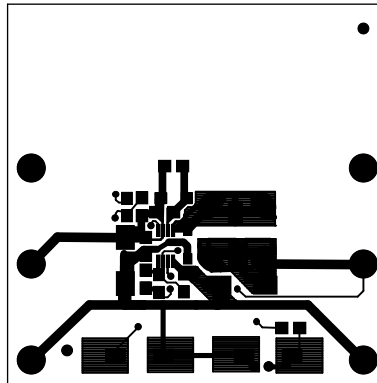
MANUFACTURER	COMPONENT	PART NUMBERS	TELEPHONE	FAX
Coilcraft	Inductors	DO1608, DO3316 Series	(847) 639-6400	(847) 639-1469
Coiltronics International	Inductors	Econo-Pac, Octa-Pac	(561) 241-7876	(561) 241-9339
Dale Electronics	Inductors	LPT4545	(605) 665-9301	(605) 665-1627
Sumida Electric Co. Ltd	Inductors	CD54, CDRH74B Series	(847) 956-0666	(847) 956-0702
AVX Corporation	Capacitors	TPS/TAJ Series, AA Series	(803) 448-9411	(803) 448-1943
Sanyo Video Components	Capacitors	OS-CON Series	(619) 661-6835	(619) 661-1055
Sprague	Capacitors	593D Series	(207) 324-4140	(207) 324-7223
Marcon	Capacitors	THC Series	(847) 696-2000	(847) 518-9985

DEMO MANUAL DC143

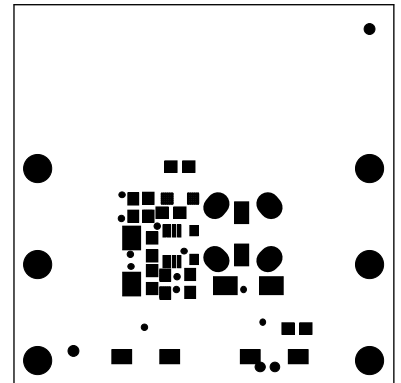
PCB LAYOUT AND FILM



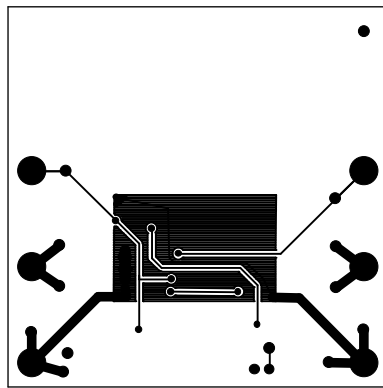
Component Side Silkscreen



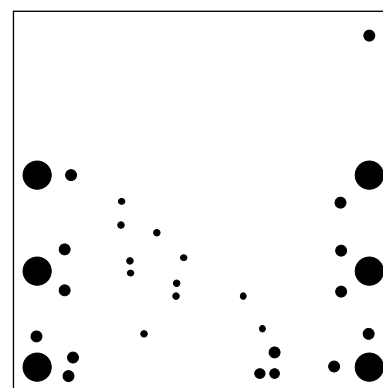
Component Side



Component Side Solder Mask

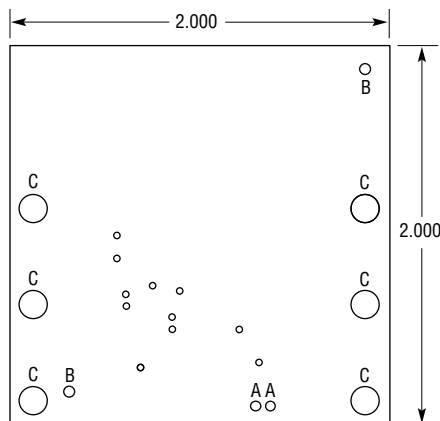


Solder Side



Solder Side Solder Mask

PC FAB DRAWING



SYMBOL	DIAMETER (INCH)	NUMBER OF HOLES	PLATED
UNMARKED	0.015	11	YES
A	0.030	2	YES
B	0.070	2	NO
C	0.094	6	YES
TOTAL HOLES		21	

NOTES:

1. MATERIAL IS FR4, 0.062" THICK WITH 2 OZ COPPER
2. PCB WILL BE DOUBLE-SIDED WITH PLATED THROUGH HOLES
3. PLATED THROUGH HOLE — WALL THICKNESS MIN 0.0014" (1 oz)
4. SOLDER MASK BOTH SIDES
5. SILKSCREEN COMPONENT SIDE
6. ALL HOLE SIZES AFTER PLATING +0.003/-0