LTC1265 High Efficiency Step-Down DC/DC Converter

DESCRIPTION

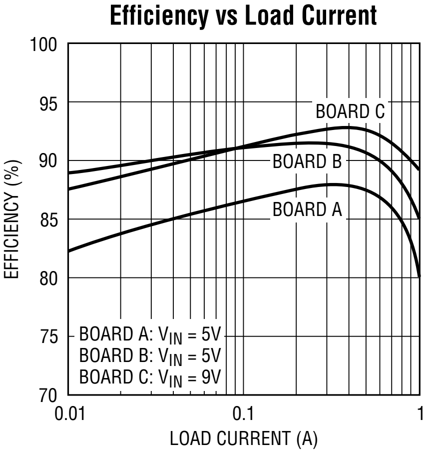
This demonstration circuit is a step-down (buck) regulator using the LTC®1265/LTC1265-3.3/LTC1265-5. Exclusive use of surface mount components results in a highly efficient application in a small board space. This demo board highlights the capabilities of the LTC1265 which uses a current mode, constant 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 load currents the LTC1265 automatically switches to Burst Mode™ operation to reduce switching losses and maintain high operating efficiencies. In dropout, the internal P-channel MOSFET is turned on continuously (100% duty cycle) providing low dropout operation with $V_{OUT} \cong V_{IN}$. The part can also be shut down, drawing less than 15μA, making this part ideal for current sensitive applications. An on-board low-battery detector allows the user to monitor the input supply through an external resistive divider. This divided voltage is compared with an internal 1.25V reference voltage. **Gerber files for this circuit board are available. Call the LTC factory.**

PERFORMANCE SUMMARY

SYMBOL	PARAMETER	CONDITIONS	BOARD SUFFIX	VALUE
V_{IN}	Input Voltage Range		A & B C	3.5V to 12.5V 5.0V to 12.5V
V_{OUT}	Output Voltage	LTC1265 LTC1265-3.3 LTC1265-5	A B C	2.5V ±0.06V 3.3V ±0.10V 5.0V ±0.2V
I_Q	Typical Supply Current	I_{OUT} = 0mA at 12.5V Input In Shutdown at 12.5V Input	ALL ALL	160μA 15μA
I_{OUT}	Maximum Output Current		ALL	1.0A
V_{RIPPLE}	Typical Output Ripple	Burst Mode Operation, I_{OUT} = 100mA Continuous Mode Operation, I_{OUT} = 1A	ALL ALL	$70mV_{P-P}$ $30mV_{P-P}$

TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO

Efficiency vs Load Current



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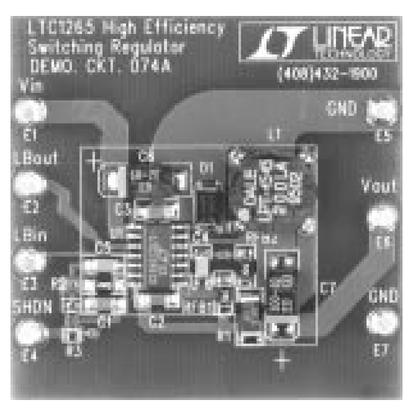
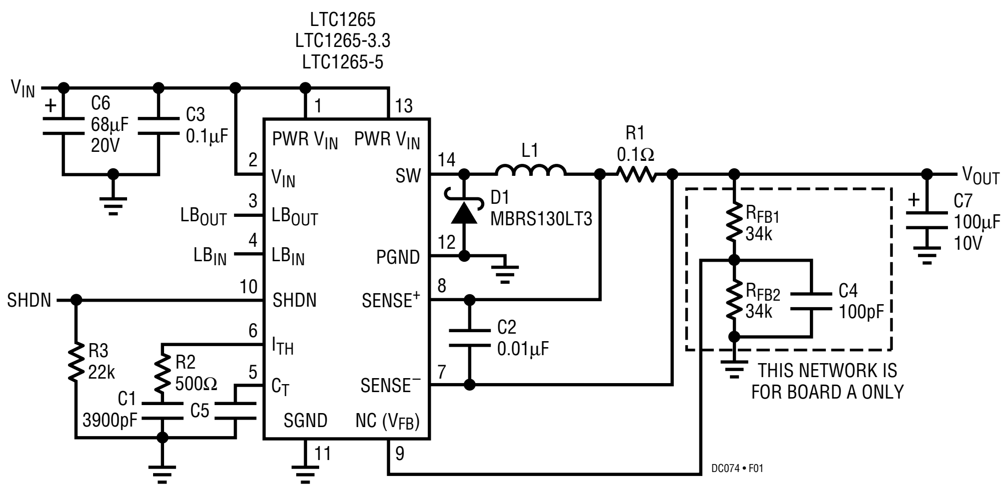
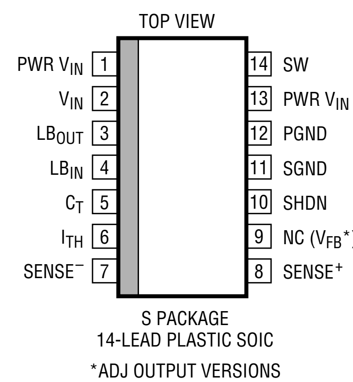


PERFORMANCE SUMMARY

SYMBOL	PARAMETER	CONDITIONS	BOARD SUFFIX	VALUE
ΔV_{OUT}	Typical Load Regulation	0mA < I_{OUT} < 1A, V_{IN} = 10V	A	30mV
		0mA < I_{OUT} < 1A, V_{IN} = 10V	B	50mV
		0mA < I_{OUT} < 1A, V_{IN} = 10V	C	70mV
V_{IH}	Shutdown Pin High	Minimum Voltage at Pin 10 for Device to Be in Shutdown	ALL	1.2V
V_{IL}	Shutdown Pin Low	Maximum Voltage at Pin 10 for Device to Be in Active	ALL	0.6V
I_Q	Low-Battery Trip Point		ALL	1.25 ±0.1V

PACKAGE AND SCHEMATIC DIAGRAMS





LTC1265CS
LTC1265CS-3.3
LTC1265CS-5

Figure 1.

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
C1	1	VJ1206A392KXAT	Cap, Mono Chip, 3900pF, 50V, 10%	Vitramon	(203) 268-6261
C2	1	VJ1206U103MXAT	Cap, Mono Chip, 0.01µF, 25V, 10%	Vitramon	
C3	1	VJ1206U104MXXAT	Cap, Mono Chip, 0.1µF, 25V, 10%	Vitramon	
C4	1	VJ1206A101KXAT	Cap, Mono Chip, 100pF, 50V, 10%	Vitramon	
C5	1	VJ1206A181JXAT VJ1206A151JXAT	Cap, Mono Chip, 180pF, 50V, 5%: Board A Cap, Mono Chip, 150pF, 50V, 5% : Board B & C	Vitramon	
C6	1	593D686X0020E2W	Tantalum Cap, 68µF, 20V, 20%	Sprague	(207) 324-4140
C7	1	593D107X0010D2W	Tantalum Cap, 100µF, 10V, 20%	Sprague	
D1	1	MBRS130LT3	Schottky Diode	Motorola	(602) 244-3558
L1	1	LPT4545-200 LPT4545-330	Inductor, 20µH : Board A & B Inductor, 33µH : Board C	Dale	(605) 665-9301

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
R1	1	WSL2010-0.1	0.1Ω 1% 0.5W Resistor	Dale	(605) 665-9301
R2	1	CRCW1206499J	499Ω 5% Chip Resistor	Dale	
R3	1	CRCW1206223J	22k 5% Chip Resistor	Dale	
RFB1, RFB2	1	CRCW1206343J	34k 5% Chip Resistor: Board A	Dale	
U1	1	LTC1265CS LTC1265CS-3.3 LTC1265CS-5	Board A IC Board B IC Board C IC	LTC	(408) 432-1900

QUICK START GUIDE

This demonstration board is easy to set up to evaluate the performance of the LTC1265. Please follow the procedure outline below for proper operation.

- Connect the input power supply to the V_{IN} and GND terminals.
- The LB_{OUT} pin is a current sinking pin. When the LB_{IN} pin goes below 1.25V the LB_{OUT} pin will sink 1mA of current.
- The LB_{IN} pin is the low battery detector input pin. Normally, its input comes from the input voltage through a resistive divider network (see LOW BATTERY DETECTOR).
- Connect the load between the V_{OUT} and GND terminals.
- Refer to Figure 4 for proper arrangement of measurement equipment setup
- The SHDN pin is pulled down to ground by R3. To put the part in shutdown, connect a voltage greater than 1.2V to this pin.

OPERATION

The circuit shown in Figure 1 operates from input voltages of 3.5V to 12.5V. For Board A, the output voltage is set to 2.5V by the resistive dividers, RFB1 and RFB2. For Board A and Board B, the circuit is optimized at input voltage of 5V while Board C is optimized at a 9V input voltage. For all boards, the LTC1265 is operating at a frequency of 200kHz when at their respective optimized input voltage and the LTC1265 is operating in continuous mode.

This demonstration unit is intended for the evaluation of the LTC1265 switching regulator IC and was not designed for any other purposes.

OPERATION

The LTC1265 switching regulator uses the constant off-time, current mode architecture shown in Figure 2. Current mode operation was judged to be mandatory for its well-known advantages of clean start-up, accurate current limit and excellent line and load regulation. The constant off-time adds to this list simplicity (neither an oscillator nor ramp compensation are required), inherent 100% duty cycle in dropout, and constant inductor ripple current.

Because the off-time is constant, the operating frequency changes with input voltage. For example, in an LTC1265-3.3 application the frequency will double when V_{IN} is increased from 4.7V to 8V with V_{OUT} at 3.3V. To maximize the efficiency over a wide current range, loss reducing circuit techniques must be carefully applied. Because of the MOSFET gate charge, switching the gate from V_{IN} to ground ends up as additional input current from V_{IN}, decreasing efficiency. At low output currents this loss term dominates. This is the principal reason that the LTC1265 changes to Burst Mode operation as the output current drops.

OPERATION

The continuous mode operation is as follows: the internal P-channel MOSFET switch is turned on at the end of the off-time and turned off when the inductor current has ramped up to the current comparator threshold. During the off-time the catch diode D1 turns on. At the end of the constant off-time, the P-channel MOSFET is again turned on and the cycle repeats.

LTC1265 Burst Mode is automatically invoked when the current required by the load is less than the minimum current supplied by the continuous operation. During Burst Mode operation the output voltage is regulated via a hysteretic comparator which, when tripped, shuts down the MOSFET driver and much of the control circuitry to conserve DC supply current. From the time the comparator trips until the lower comparator threshold is reached, the load current is completely supplied by a charge stored in the output capacitor. When the output capacitor discharges to the lower threshold, the main loop again briefly turns on at a low current level to recharge the capacitor. This cycle repeats at a progressively slower rate as the output current is reduced.

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 4) which is compared with a 1.25V reference voltage. With the current going into pin 4 being negligible, the following expression is used for setting the trip limit:

$$V_{LB\_TRIP} = 1.25\left(1 + \frac{R4}{R3}\right)$$

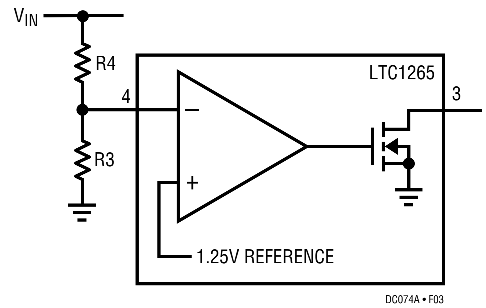


Figure 3. Low-Battery Comparator

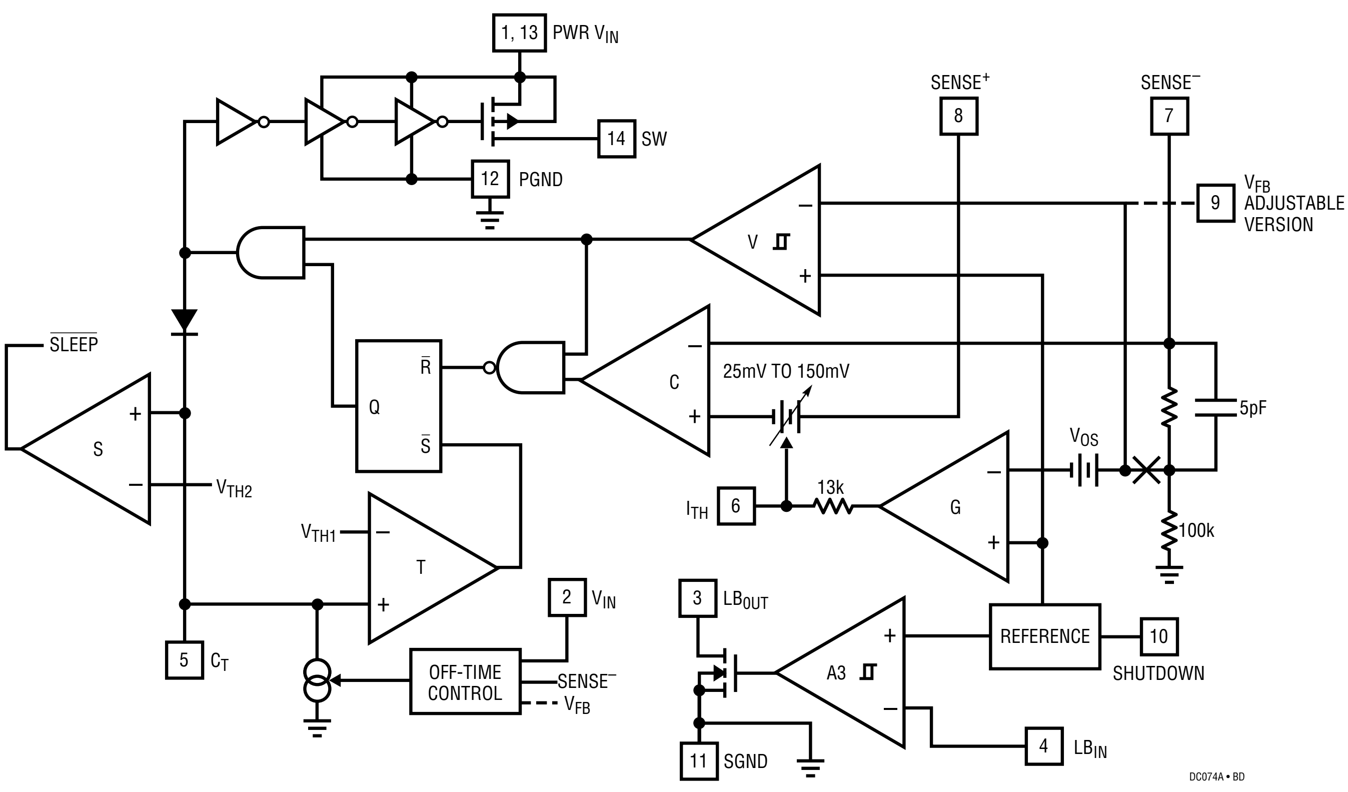


Figure 2. LTC1265 Block Diagram

OPERATION

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 LTC1265's control loop looks for the information to keep the output voltage constant. This information occurs between Pin 7 and Pin 11 of the LTC1265. 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 4 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.

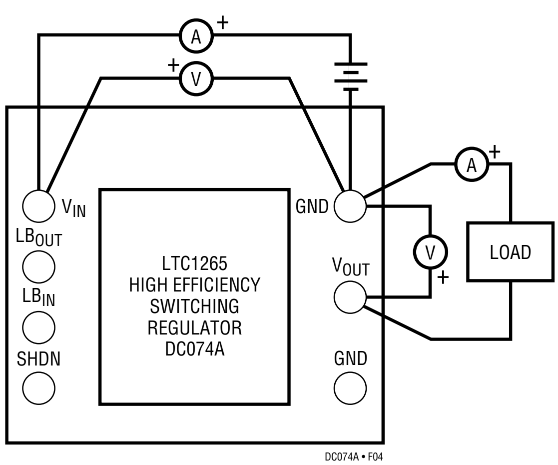


Figure 4. Proper Measurement Setup

RIPPLE MEASUREMENT

For the purpose of measuring output ripple it is best to measure directly across the output terminals.

As in the regulation tests the supply must be fed from a regulated DC source so that ripple on the input to the circuit under test does not add to the output ripple, causing errors in the measurement.

The technique used to measure the ripple is also important. Here is a list of things to do and not to do when using a scope probe:

1. DO NOT USE THE GROUND LEADS/CLIPS THAT ARE ATTACHED TO THE SCOPE PROBE!
2. DO ATTACH THE SHIELD OF THE PROBE BODY TO THE NEGATIVE SIDE OF THE OUTPUT CAPACITOR! DO NOT USE WIRE!
3. DO PUT THE TIP OF THE SCOPE PROBE DIRECTLY ON THE POSITIVE TERMINAL OF THE OUTPUT CAPACITOR.
4. DO NOT USE A PROBE WHOSE BODY IS NOT COMPLETELY SHIELDED.

Any unshielded lead, such as a ground lead on a scope probe, acts as an antenna for the switching noise in the supply. Therefore any use of a ground lead will invalidate the measurement.

Be extremely careful to ensure that other sources of noise do not invalidate the measurement. Noise from the 60Hz power line that feeds the bench power supply powering

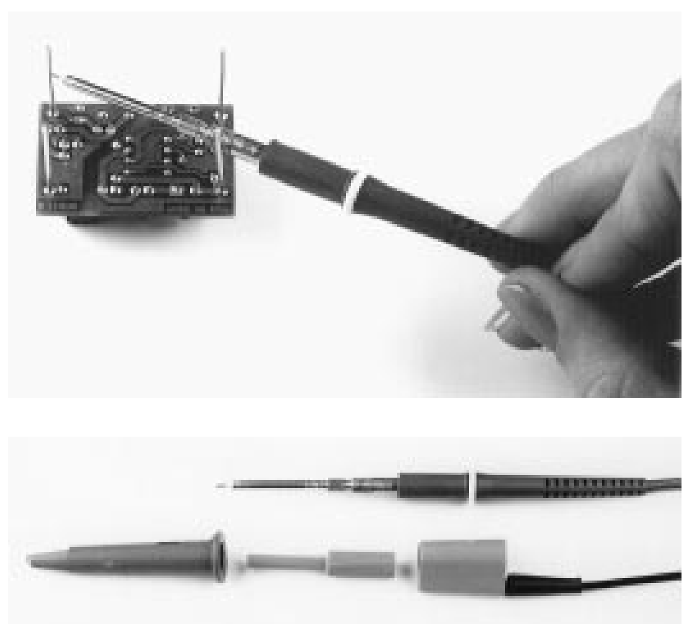


Figure 5. Scope Probe and Typical Measurement Setup

the LTC1265 demonstration board can cause errors in the measurement. This noise (especially spikes) can propagate through the bench supply and appear on the ground

OPERATION

of the demonstration unit. If this is a problem, a battery can be used to power the unit for ripple tests.

Also be wary of ground loops. The input DC supply should float and the only ground should be that of the scope probe. Never float the oscilloscope as it may present a safety hazard.

An alternate technique is to take a 50Ω or 75Ω piece of coax and solder the leads directly to the output capacitor. Keep the shield over the center conductor for as great a distance as possible. The center conductor can pick up stray radiation when it is not shielded, so minimize the length of exposed center conductor. The other end of the coax should have a BNC connector for attaching to the oscilloscope.

CHECKING TRANSIENT RESPONSE

Switching regulators take several cycles to respond to a step in DC (resistive) load current. When a load step occurs, V_{OUT} shifts by an amount equal to $\Delta I_{LOAD} \times ESR$, where ESR is the effective series resistance of C_{OUT}. ΔI_{LOAD} also begins to charge or discharge C_{OUT} until the regulator loop adapts to the current change and returns V_{OUT} to its steady-state value. During this recovery time V_{OUT} can be monitored for overshoot or ringing which would indicate a stability problem. The external components shown in the Figure 1 circuit will prove adequate for most applications.

A second, more severe transient is caused by switching in loads with large (>1μF) supply bypass capacitors. The discharged bypass capacitors are effectively put in parallel with C_{OUT}, causing a rapid drop in V_{OUT}. No regulator can deliver enough current to prevent this problem if the load switch resistance is low and it is driven quickly. The only solution is to limit the rise time of the switch drive so that the load rise time is limited to approximately $25 \times C_{LOAD}$. Thus a 10μF capacitor would require a 250μs rise time, limiting the charging current to about 200mA.

COMPONENTS

Components selection can be very critical in switching power supply applications. This section discusses some of the guidelines with selecting the different components. The LTC1265 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) C6 and C7 are all specially developed low ESR, high ripple-current tantalum capacitors specifically designed for use in switching power supplies. ESR or Equivalent Series Resistance is the parasitic series resistance in the capacitor. Very often this resistance is the limiting element in reducing ripple at the output or input of the supply. Standard wet electrolytics may cause the feedback loop to be unstable (this means your power supply becomes an oscillator). They may also cause poor transient response or have a limited operating life. Standard parts normally do not have an ESR specification at high frequencies (100kHz) so, although you may find a part that works to your satisfaction in a prototype, **the same part may not work consistently in production**. Furthermore, surface mount versions of wet electrolytics are not space efficient, and they may have high ESR and limited lifetimes.

Normal tantalums are not recommended for use in these applications (most notably the low cost ones) as they do not have the ability to take the large peak currents that are required for the application. Tantalums have a failure mechanism whereby they become a low value resistance or short. Wet electrolytics rarely short; they usually fail by going high impedance if over-stressed. Very few tantalum manufacturers have the ability to make capacitors for power applications.

There are some tantalums, such as those used in this design, that are specifically designed for switching power supplies. They are much smaller than wet electrolytic capacitors and are surface mountable but they do cost more.

One other choice that fits between wet electrolytics and tantalums is organic semiconductor type capacitors (OS-CON) that are specifically made for power supply applications. They are very low ESR and are ≈1/2 the size of an equivalent wet electrolytic.

OPERATION

Inductor

To most engineers, inductors are the least familiar component in a switching power supply. This is unfortunate because the most flexible component in the system is the inductor. The size, shape, efficiency, form factor and cost are variables that can be traded off against one another. The only fixed requirement of the inductor used with the LTC1265 is that it must be able to support the output DC current and still maintain its inductance value.

Although the inductor used in the demo board is from Dale, there are a wide variety of inductors available from other manufacturers. Sumida's CDR 74B, CD75, CDR105B and CDR125 series are suitable for this demo board. In addition, Coilcraft's DO3316 series and Coiltronics CTX series are also suitable in this demo board. However, re-characterizing the circuit for efficiency is necessary if any of the alternate inductors are used in place of the existing one.

There are many inductors that will work in this circuit. Each inductor design will have a different physical size, different loss characteristics as well as different stray field patterns. All of these items must be considered to optimize a design.

Because of the aforementioned variations in design and cost of inductor, we suggest you contact some of the inductor manufacturers in Table 1 and discuss your needs with them. Very often, a standard low cost solution which will meet your needs is on the shelf.

Sense Resistor

The current sense resistor specified in the component list is manufactured by Dale. Alternate resistor sources include International Resistive Company and the SL, SP series by KRL/Bantry.

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. A fast switching diode must also be used to optimize efficiency. Schottky diodes are a good choice for low forward drop and fast switching times. Most LTC1265 circuits will be well served by a MBRS130LT3 Schottky diode.

Component Manufacturers

Besides those 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 re-characterizing the circuit for efficiency.

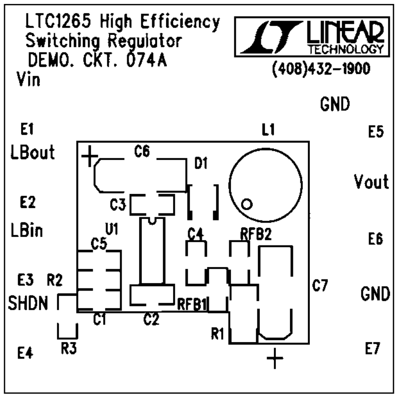
Table 1. Inductor Manufacturer

MANUFACTURER	PART NUMBERS
Coilcraft 1102 Silver Lake Road Cary, Illinois (Phone) 708-639-6400 (Fax) 708-639-1469	D03316 Series
Coiltronics International 6000 Park of Commerce Blvd. Boca Raton, FL 33487 (Phone) 407-241-7876 (Fax) 407-241-9339	Econo-Pac Octa-Pac
Dale Electronics Inc. E. Highway 50 P.O. Box 180 Yankton, SD 57078-0180 (Phone) 605-665-9301 (Fax) 605-665-1627	LPT4545
Sumida Electric Co. Ltd. 5999 New Wilke Rd., Suite #110 Rolling Meadows, IL 60008 (Phone) 708-956-0666 (Fax) 708-956-0702	CD 74B Series CD 75 Series CDR105B

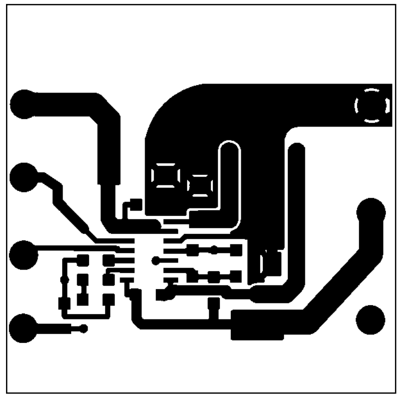
Table 2. Capacitor Manufacturers

MANUFACTURER	PART NUMBERS
AVX Corporation P.O. Box 887 Myrtle Beach, S.C. 29578 (Phone) 803-448-9411 (Fax) 803-448-1943	TPS Series
Sanyo Video Components 2001 Sanyo Avenue San Diego, CA 92071 (Phone) 619-661-6322 (Fax) 619-661-1055	OS-CON Series
Sprague 678 Main Street Sanford, ME 04073 (Phone) 207-324-4140 (Fax) 207-324-7223	593D Series

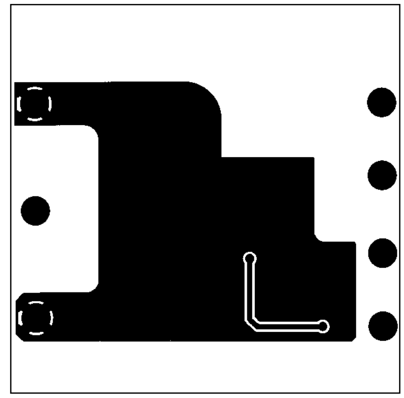
PCB LAYOUT AND FILM



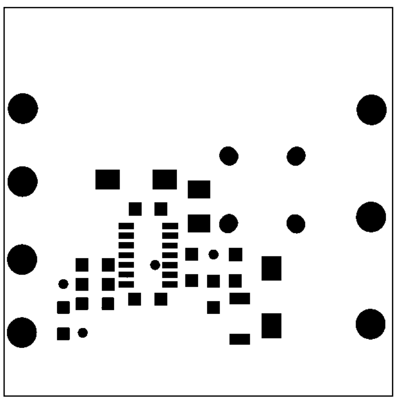
Component Side Silkscreen



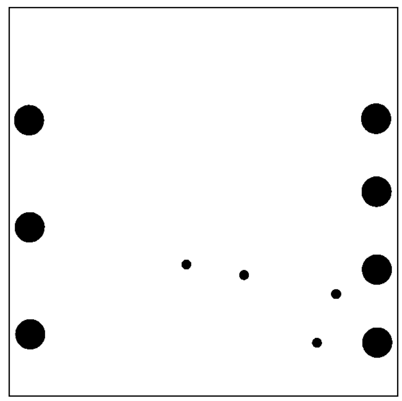
Component Side



Solder Side

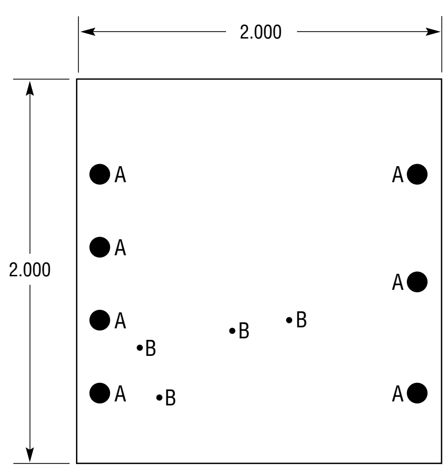


Component Side Solder Mask



Solder Side Solder Mask

PC FAB DRAWING



SYMBOL	DIAMETER	NUMBER OF HOLES
A	0.094	7
B	0.018	4
	TOTAL HOLES	11

DC074A • PCB01

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