# LTC1434 Low Noise Current Mode Step-down DC/DC Converter

## DESCRIPTION

This demonstration circuit is a step-down (buck) regulator using the LTC®1434. Exclusive use of surface mount components results in a highly efficient application in a small board space. The output voltages are selectable via a programmable pin for 3.3V and 5V without additional components. The board can also be set up to meet any output voltage requirement through an additional resistive divider. This demo board highlights the capabilities of the LTC1434, which uses a current mode PWM architecture to switch two internal P-channel power MOSFETs. This results in a power supply that has low ripple and fast transient response. The LTC1434 also features Linear Technology's Adaptive Power™ output stage to provide excellent efficiency at both low and high load currents without sacrificing constant-frequency operation. In dropout, the internal P-channel MOSFETs are turned on continuously (100% duty cycle) providing low dropout operation with $V_{OUT}$ at $V_{IN}$. The part can also be shut down, in which case it draws about 15µA, making it ideal for current-sensitive applications. An onboard low-battery detector allows the user to monitor the input supply through an external resistive divider. This divided voltage is compared with an internal 1.19V reference voltage. The LTC1434 also allows the user to synchronize the device with an external clock through its internal PLL. **Gerber files for this circuit board are available. Call the LTC factory.**

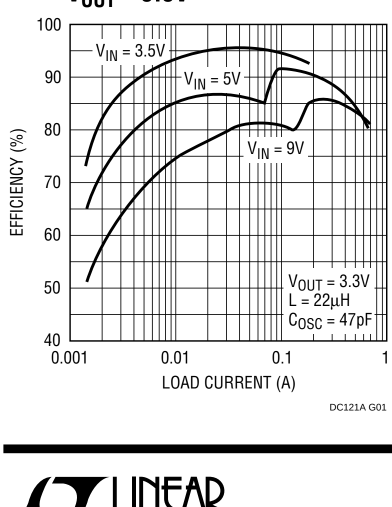


## PERFORMANCE SUMMARY

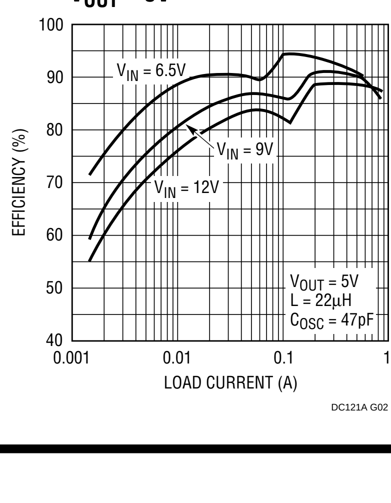
| SYMBOL | PARAMETER | CONDITIONS | JUMPER POSITION | VALUE |
|---|---|---|---|---|
| $V_{IN}$ | Input Working Voltage Range | | All | 3.5V to 12.5V |
| $V_{OUT}$ | Output Voltage | | Left<br>Right<br>Remove | 5V ±0.12V<br>3.3V ±0.08V<br>1.19V ±0.012V |
| $I_Q$ | Typical Supply Current | $V_{IN}$ = 12.5V, LBI = 6V, $I_{OUT}$ = 0mA<br>RUN/SS = 0V, LBI = 6V, $I_{OUT}$ = 0mA<br>RUN/SS = 0V, LBI = 0V, $I_{OUT}$ = 0mA | All<br>All<br>All | 470µA<br>35µA<br>15µA |

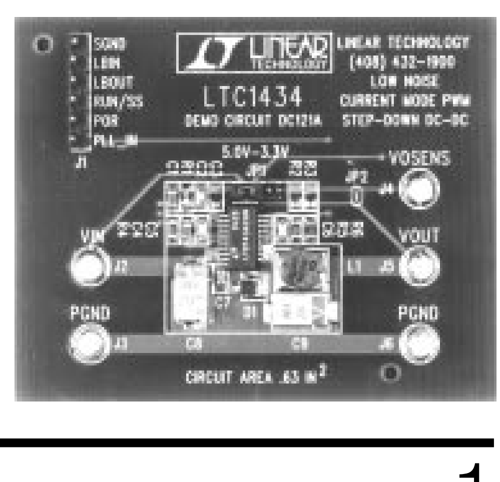
## TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO

**Efficiency vs Load Current**
**$V_{OUT}$ = 3.3V**




**Efficiency vs Load Current**
**$V_{OUT}$ = 5V**

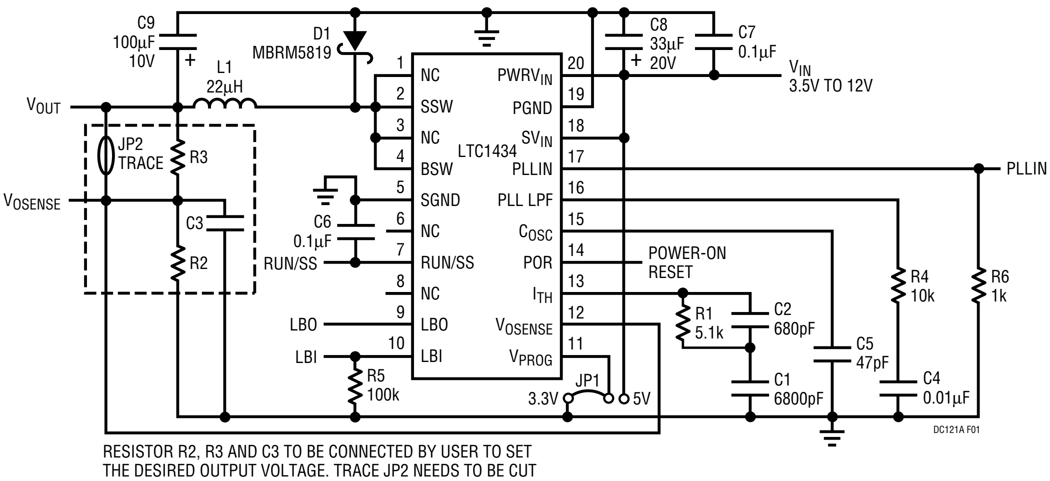


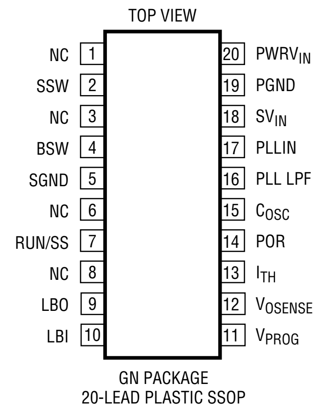



## PERFORMANCE SUMMARY

| SYMBOL | PARAMETER | CONDITIONS | JUMPER POSITION | VALUE |
|---|---|---|---|---|
| $I_{OUT}$ | Minimum Output Current | $V_{IN}$ = 6.5V, $V_{OUT}$ = 5V<br>$V_{IN}$ = 5V, $V_{OUT}$ = 3.3V | Left<br>Right | 400mA<br>400mA |
| $V_{RIPPLE}$ | Typical Output Ripple | $I_{OUT}$ = 400mA, $V_{IN}$ = 12.5V | All | $30mV_{P-P}$ |
| $\Delta V_{OUT}$ | Typical Load Regulation | 0mA < $I_{OUT}$ < 0.4A, $V_{IN}$ = 12.5V | All | 0.5% |
| $V_{LBTP}$ | Low-Battery Trip Point | | All | 1.19 ±0.1V |

## PACKAGE AND SCHEMATIC DIAGRAMS




**LTC1434GN**

**Figure 1. Demo Board Schematic**

## PARTS LIST

| REFERENCE DESIGNATOR | QUANTITY | PART NUMBER | DESCRIPTION | VENDOR | TELEPHONE |
|---|---|---|---|---|---|
| C1 | 1 | 08055C682MAT1A | 6800pF 50V 20% X7R Capacitor | AVX | (803) 946-0362 |
| C2 | 1 | 08055A681KAT1A | 680pF 50V 10% NPO Capacitor | AVX | (803) 946-0362 |
| C4 | 1 | 08055C103MAT1A | 0.01µF 50V 20% X7R Capacitor | AVX | (803) 946-0362 |
| C5 | 1 | 08055A470JAT1A | 47pF 50V 5% NPO Capacitor | AVX | (803) 946-0362 |
| C6, C7 | 2 | 08055C104MAT1A | 0.1µF 50V 20% X7R Capacitor | AVX | (803) 946-0362 |
| C8 | 1 | TPSD336M020R0200 | 33µF 20V 20% Tantalum Capacitor | AVX | (207) 282-5111 |
| C9 | 1 | TPSD107M010R0080 | 100µF 10V 20% Tantalum Capacitor | AVX | (207) 282-5111 |
| D1 | 1 | MBRM5819T3 | 40V 1A Schottky Diode | Motorola | (602) 244-3576 |
| JP1 | 1 | 2802S-03G2 | 0.079"cc 3-Pin Jumper | COMM CON | (818) 301-4200 |
| J1 | 1 | 3801S-06G1 | 6-Pin 1 Row 0.100cc Header Connector | COMM CON | (818) 301-4200 |
| J2 to J6 | 5 | 1502-2 | 0.09" Turret Connector | Keystone | (718) 956-8900 |
| L1 | 1 | CD54-220 | 22µH Inductor | Sumida | (847) 956-0666 |
| R1 | 1 | CR21-512J-T | 5.1k 5% 0.1W Chip Resistor | AVX | (803) 946-0524 |
| R4 | 1 | CR21-103J-T | 10k 5% 0.1W Chip Resistor | AVX | (803) 946-0524 |
| R5 | 1 | CR21-104J-T | 100k 5% 0.1W Chip Resistor | AVX | (803) 946-0524 |
| R6 | 1 | CR21-102J-T | 1k 5% 0.1W Chip Resistor | AVX | (803) 946-0524 |
| U1 | 1 | LTC1434GN | 20-Pin Narrow SSOP IC | LTC | (408) 432-1900 |

## QUICK START GUIDE

Demonstration board DC121 is easy to set up for evaluation of the LTC1434. Please follow the procedure below for proper operation.

- Move jumper JP1 to the left for 5V output or to the right for 3.3V output. For other output voltages, remove the jumper, connect the appropriate resistive divider and cut trace JP2 on the board. For higher noise immunity, connect a 100pF capacitor (C3) across the lower leg of the resistive divider.
- For synchronized operation, connect the clock signal between the PLLIN and ground pins. A 1k resistor is connected between this pin and ground. Do not apply more than 6V to this pin.
- The LBO pin is a current sinking pin. When the LBI pin goes below 1.19V the LBO pin will sink 1.6mA of current.
- The LBI 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). A 100k resistor is connected between this pin and ground.
- For POR evaluation, connect a resistor from this pin to a supply. Do not exceed 12V on the supply.
- Connect the input power supply to the $V_{IN}$ and GND terminals.
- Connect the load between the $V_{OUT}$ and GND terminals. Refer to Figure 4 for proper measurement equipment setup.
- To put this part in shutdown, connect the RUN/SS pin to ground. For further reduction in shutdown current, connect the LBI pin to ground.

## OPERATION

The circuit shown in Figure 1 operates from input voltages of 3.5V to 12.5V. The output can be easily set for 3.3V or 5V by moving the jumper JP1. For other output voltages, the jumper should be removed and a trace should be cut. In addition, a resistive divider and a decoupling capacitor should be connected on the provided pads. The frequency of operation for the LTC1434 is set at 210kHz.

This demonstration unit is intended for the evaluation of the LTC1434 switching regulator IC and was not designed for any other purposes.

### OPERATION

The LTC1434 uses the constant-frequency, pulse-width modulated current mode architecture shown in Figure 2. Current mode operation provides the well known advantages of clean start-up and excellent line and load regulation.

To obtain high efficiency and constant frequency at low load current, the LTC1434 uses the new Adaptive Power output stage. At low load current, gate-charge losses dominate. To reduce these losses, only the internal small P-channel MOSFET is used. At higher load current, both the small and large internal MOSFETs are turned on, because losses due to the drops across the FETs are more significant than gate-charge losses. This is the principle behind Adaptive Power mode operation. On the efficiency plot, the transition point where the large FET is used is represented by a small kink.

The LTC1434 operates as follows: the internal P-channel power MOSFETs are turned on each cycle when the oscillator sets the latch (FF3), and turned off when the current comparator ($I_{COMP}$) resets it. The peak inductor current at which the $I_{COMP}$ resets the latch is controlled by the voltage on the $I_{TH}$ pin, which is the output of the error amplifier (GM). Pins $V_{PROG}$ and $V_{OSENSE}$ allow GM to receive an output feedback voltage ($V_{FB}$) from either the internal or external resistive divider. When the load current increases, it causes a slight decrease in $V_{FB}$ relative to the 1.19V reference, which in turn causes the $I_{TH}$ voltage to increase until the average inductor current matches the new load current.

### 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 10), which is compared with a 1.19V reference voltage. On the demo board, a 100k resistor is connected as the lower leg of the

## OPERATION

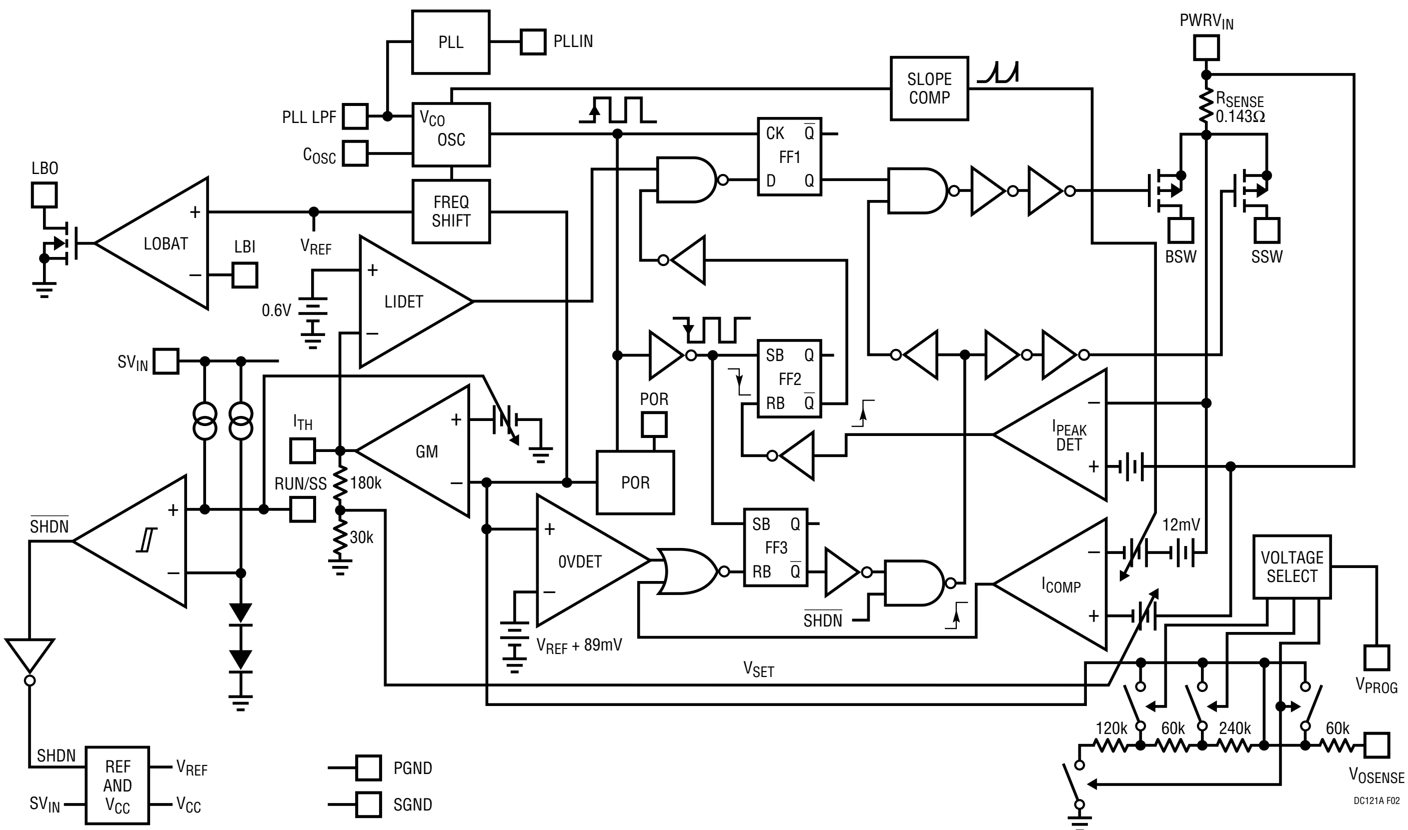



**Figure 2. LTC1434 Block Diagram**

divider. Because the current going into pin 10 is negligible, the following expression can be used for setting the trip limit:

$$V_{LBTRIP} = 1.19\left(1 + \frac{R_{TRIP}}{100{,}000}\right)$$

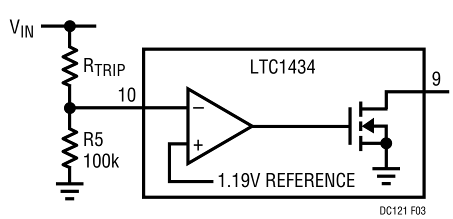



**Figure 3. Low-Battery Comparator**

### POWER-ON RESET FUNCTION

The power-on reset function serves to indicate whether the switching regulator output voltage is close to regulation. An external pull-up resistor is required on the POR pin (pin 14). When the power is first applied or when coming out of shutdown, the POR output is pulled to ground. When the output voltage rises above 5% below the regulated output value, an internal counter starts. After counting $2^{16}$ (65,536) clock cycles, the POR's pull-down device turns off.

The POR output will go low whenever the output voltage drops below 7.5% of its regulated value for longer than approximately 30μs, signaling an out-of-regulation condition.

### FREQUENCY SYNCHRONIZATION

The LTC1434 has an internal voltage controlled oscillator and phase detector comprising a phase locked loop. The demo board circuit is set up with the PLLIN connected to ground through a 1k resistor. In the absence of any external signal on PLLIN, the phase locked loop will try to lock on to DC (0Hz) but because there is a minimum lock-on range from the center frequency, the switching regulator operates at its minimum frequency (210kHz for this demo board). The maximum synchronizable frequency is 390kHz. This translates to a ±30% synchronizable range from the center frequency.

# 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 LTC1434's control loop looks for the information to keep the output voltage constant. This information occurs between pin 12 and pin 5 of the LTC1434. 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.

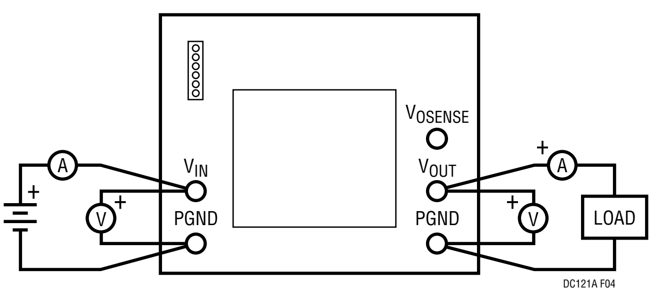



**Figure 4. Correct Measurement Setup**

## 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.

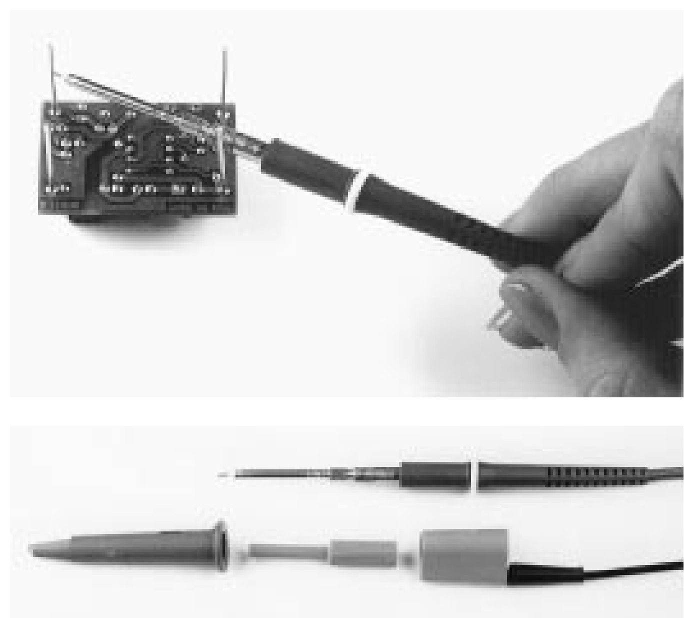


**Figure 5. Scope Probe and Typical Measurement Setup**

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 the LTC1434 demonstration board can cause errors in the measurement. This noise (especially spikes) can propagate through the bench supply and appear on the ground of the demonstration unit. If this is a problem, a battery can be used to power the unit for ripple tests.

## OPERATION

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 this 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 $(\Delta I_{LOAD})(ESR)$, where ESR is the effective series resistance of $C_{OUT}$. $\Delta I_{LOAD}$ 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 $25(C_{LOAD})$. Thus, a 10µF capacitor would require a 250µs rise time, limiting the charging current to about 200mA.

### 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 LTC1434 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) C8 and C9 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 (especially 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 overstressed. 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 are 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.

#### Inductor

To most engineers, inductors are the least familiar components in a switching power supply. This is unfortunate because the most flexible component in the system is the

## OPERATION

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 LTC1434 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 Sumida, there are a wide variety of inductors available from other manufacturers. A Dale LPT4545 series inductor can be used for this demo board as can Coilcraft's DO3316 series and Coiltronic's CTX series. However, recharacterizing the circuit for efficiency is necessary if any of the alternate inductors are used in place of the one supplied.

There are many inductors that will work in this circuit. Each inductor design will have a different physical size, different loss characteristics and 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 the 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 that will meet your needs is on the shelf.

### 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 for 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 LTC1434 circuits will be well served by a MBRM5819 or MBRS130LT3 Schottky diode.

### Component Manufacturers

Besides those components that are use on the demonstration board, other components may also be used. Tables 1 and 2 are a partial list of the manufacturers whose components can be used for the switching regulators. Using components other than the ones on the demonstration board requires recharacterizing the circuit for efficiency.

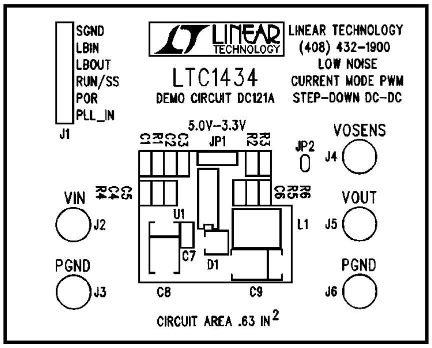
**Table 1. Inductor Manufacturers**

| MANUFACTURER | PART NUMBERS |
|---|---|
| Coilcraft<br>1102 Silver Lake Road<br>Cary, Illinois 60013<br>(Phone) 847-639-6400<br>(Fax) 847-639-1469 | D03316 Series |
| Coiltronics International<br>6000 Park of Commerce Blvd<br>Boca Raton, FL 33487<br>(Phone) 407-241-7876<br>(Fax) 407-241-9339 | Econo-Pac<br>Octa-Pac |
| Dale Electronics Inc<br>E. Highway 50<br>P.O Box 180<br>Yankton, SD 57078-0180<br>(Phone) 605-665-9301<br>(Fax) 605-665-1627 | LPT4545 |
| Sumida Electric Co Ltd.<br>5999 New Wilke Rd, Suite #110<br>Rolling Meadows, IL 60008<br>(Phone) 847-956-0666<br>(Fax) 847-956-0702 | CLS62 Series<br>CD 54 Series<br>CDR74B Series |

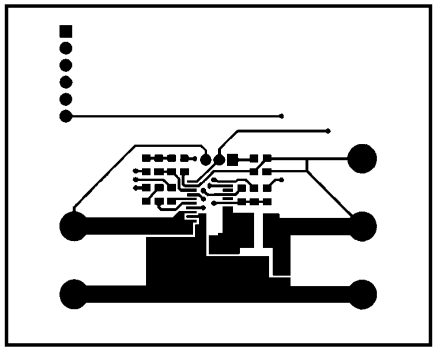
**Table 2. Capacitor Manufacturers**

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

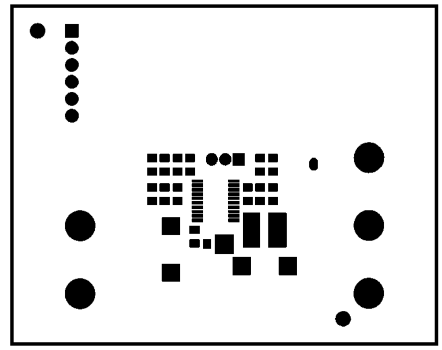
## PCB LAYOUT AND FILM



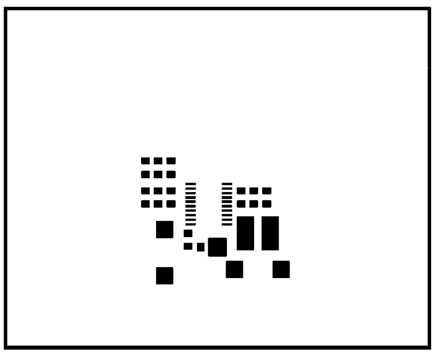

**Component Side Silkscreen**



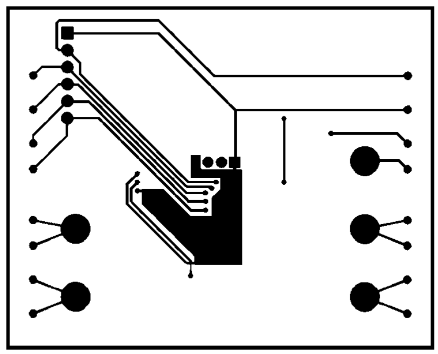
**Component Side**



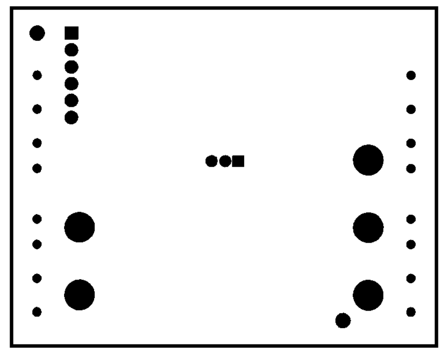
**Component Side Solder Mask**



**Pastemask**

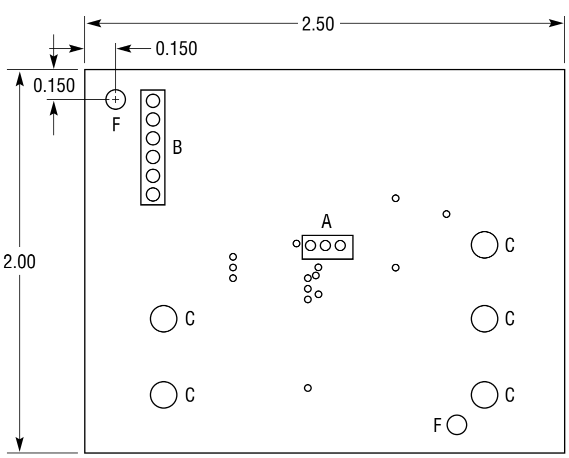


**Solder Side**



**Solder Side Solder Mask**

## PC FAB DRAWING




NOTES:
1. ALL DIMENSIONS ARE IN INCHES ±0.003
2. FINISHED MATERIAL IS FR4, 0.062 THICK, 2 OZ COPPER, 2-LAYERS
3. FINISHED HOLE SIZES ARE +0.003/–0, HOLE F NONPLATED 2 PLACES
5. SOLDER MASK BOTH SIDES USING GREEN SR1020 OR EQUIVALENT
6. SILKSCREEN WHITE NONCONDUCTIVE INK COMPONENT SIDE

| SYMBOL | DIAMETER | NUMBER OF HOLES |
|---|---|---|
| NONE | 0.010 | 14 |
| A | 0.031 | 3 |
| B | 0.040 | 6 |
| C | 0.095 | 5 |
| F | 0.070 | 2 |
| | TOTAL HOLES | 30 |

DC121 • PC DWG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