LTC1772 Constant Frequency Current Mode Step-Down DC/DC Converter

DESCRIPTION

Demo board DC270 is a step-down (buck) regulator using the LTC1772. The exclusive use of surface mount components results in a highly efficient application in a very small board space. It is ideal for cell phones and other portable electronics operating from one or two Li-Ion cells or three to six NiCd cells. DC270 is capable of providing 1A at an output voltage of 2.5V with an input supply of 4.2V. This demo board highlights the capabilities of the LTC1772, which uses a current mode PWM architecture to drive an external P-channel power MOSFET. The result is a high performance power supply that has low output voltage ripple. Constant operating frequency makes the LTC1772 attractive for noise-sensitive applications. In addition, high efficiency over a wide load current range makes the LTC1772 ideal for battery-powered applications. In dropout, the external P-channel MOSFET is turned on continuously (100% duty cycle), providing low dropout operation with $V_{OUT} \cong V_{IN}$. To further enhance efficiency at low load currents, the LTC1772 is configured for Burst Mode™ operation. The LTC1772 is capable of operating down to approximately 2.2V input voltage before the undervoltage lockout feature is activated. **Gerber files for this circuit board are available. Call the LTC factory**.

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Burst Mode is a trademark of Linear Technology Corporation.

PERFORMANCE SUMMARY

SYMBOL	PARAMETER		CONDITIONS	VALUE
V_{IN}	Input Working Voltage Range		V_{OUT} = 2.5V	2.5V to 9.8V
V_{OUT}	Output Voltage		I_{OUT} = 1A	2.5V ± 0.0625V
V_{FB}	Feedback Voltage			0.8V ± 0.02V
I_Q	Typical Supply Current	Normal Mode	V_{IN} = 4.2V, I_{OUT} = 0mA	220µA
		Shutdown	V_{IN} = 4.2V, $V_{ITH/RUN}$ = 0V	7µA

TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO
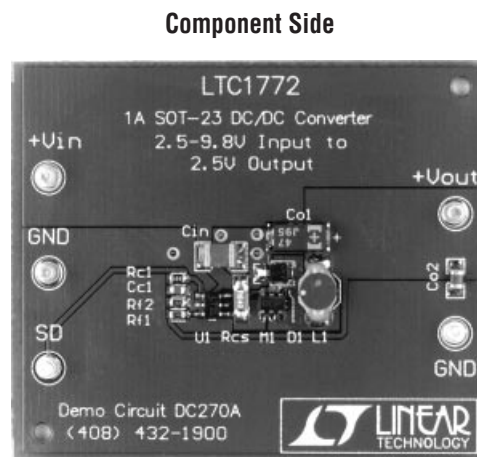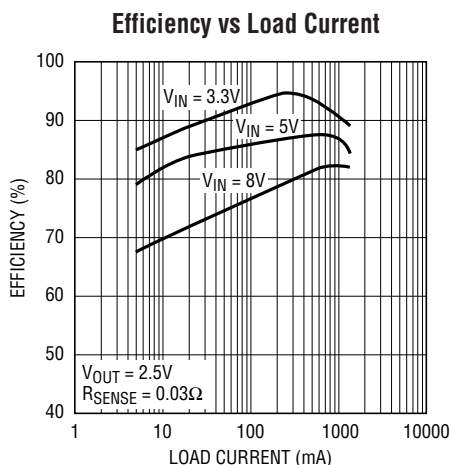
Efficiency vs Load Current

Component Side

PERFORMANCE SUMMARY

SYMBOL	PARAMETER	CONDITIONS	VALUE
I_{OUT}	Maximum Output Current	V_{IN} = 4.2V, V_{OUT} = 2.5V	1A (Min)
ΔV_{OUT}	Typical Load Regulation	0mA ≤ I_{OUT} ≤ 1A, V_{IN} = 8.5V	−1%
V_{RIPPLE}	Typical Output Ripple in Burst Mode Operation	I_{OUT} = 100mA, V_{IN} = 4.2V	120mV$_{P-P}$

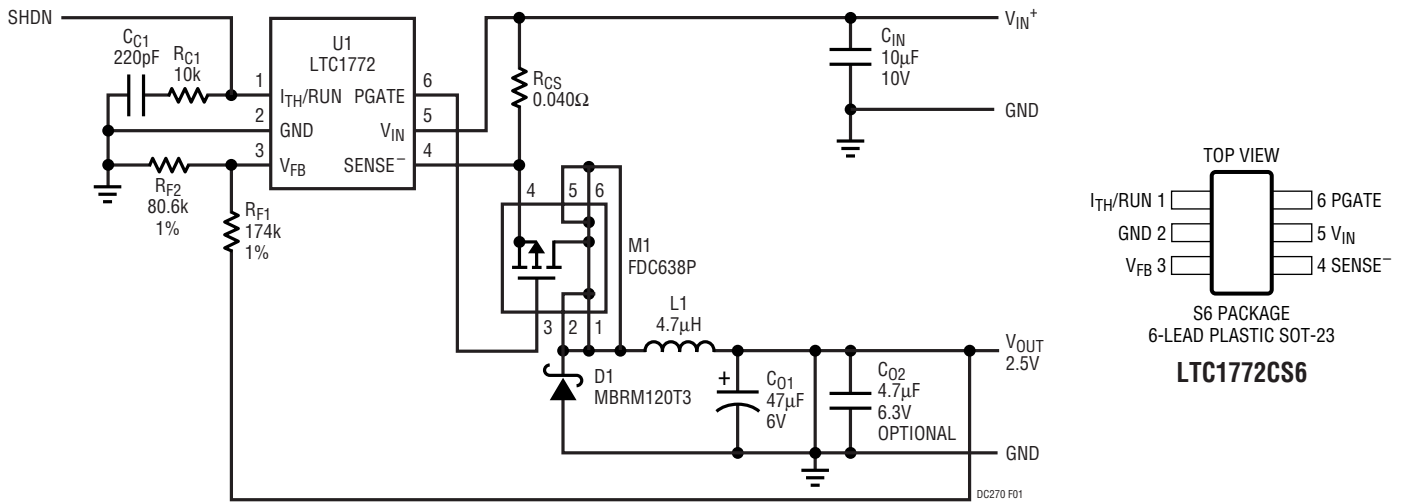# PACKAGE AND SCHEMATIC DIAGRAMS

Figure 1. LTC1772 Constant Frequency, Current Mode, Step-Down DC/DC Converter Schematic

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
C_{O1}	1	6TPA47M	47µF 6V POSCAP Capacitor	Sanyo	(619) 661-6835
C_{O2} (Optional)	1	JMK212BJ475MG	4.7µF 6.3V Capacitor	Taiyo Yuden	(408) 573-4150
C_{IN}	1	LMK325BJ106K-T	10µF 10V Capacitor	Taiyo Yuden	(408) 573-4150
C_{C1}	1	06035A221KAT	220pF 10% NPO Capacitor	AVX	(843) 946-0362
D1	1	MBRM120T3	Schottky Diode	ON Semiconductor	(602) 244-6600
L1	1	DO1608C-472	4.7µH Inductor	Coilcraft	(847) 639-6400
M1	1	FDC638P	MOSFET	Fairchild	(408) 822-2126
R_{CS}	1	LR1206-01-R040F	0.040Ω 1% 0.25W 1206 Resistor	IRC	(361) 992-7900
R_{C1}	1	CR16-103JM	10k 5% 1/8W 0603 Resistor	TAD	(800) 508-1521
R_{F1}	1	CR16-1743FM	174k 1% 0.1W 0603 Resistor	TAD	(800) 508-1521
R_{F2}	1	CR16-8062FM	80.6k 1% 0.1W 0603 Resistor	TAD	(800) 508-1521
U1	1	LTC1772CS6	6-Pin SOT-23 IC	LTC	(408) 432-1900

QUICK START GUIDE

This demonstration board is easy to set up to evaluate the performance of the LTC1772. Please follow the procedure outlined below for proper operation.

1. Connect the input power supply to the V_{IN} and GND terminals.

2. Connect the load between the V_{OUT} and GND terminals. Refer to Figure 4 for proper measurement equipment setup.

3. To shut down the circuit, connect the I_{TH}/RUN pin to ground.

OPERATION

The circuit shown in Figure 1 operates from an input voltage between 2.5V and 9.8V. The output voltage of 2.5V is fixed. For other output voltages, resistor R_{F1} must be replaced (see Output Voltage Setup).

This demonstration circuit has been optimized for efficiency and physical footprint. For other requirements, please contact the factory. This demonstration circuit is intended for the evaluation of the LTC1772 switching regulator IC and was not designed for any other purpose.

OPERATION

The LTC1772 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.

The LTC1772 is designed to operate down to approximately 2.2V input voltage, making it suitable for applications that are powered either by a low input supply or a single lithium-ion battery. The external MOSFET can limit the minimum input voltage; therefore, be careful when specifying the MOSFET.

To prevent damage to a lithium-ion battery by deep discharge, an undervoltage lockout circuit is incorporated into the LTC1772. When the input supply drops to approximately 2.2V, all circuitry except the undervoltage detector block is turned off.

The LTC1772 operates as follows: the external P-channel power MOSFET is turned on at the beginning of each cycle when the oscillator sets the latch (RS1) and is turned off when the current comparator (ICOMP) resets the latch. The peak inductor current at which ICOMP resets the RS latch is controlled by the voltage on the I_{TH}/RUN pin, which is the output of the error amplifier, EAMP. An external resistive divider connected between V_{OUT} and ground allows the EAMP to receive an output feedback voltage, V_{FB}. When the load current increases, it causes a slight decrease in V_{FB} relative to the 0.8V reference, which, in turn, causes the I_{TH}/RUN voltage to increase until the average inductor current matches the new load current.

The main control loop is shut down by pulling the I_{TH}/RUN pin low. Releasing I_{TH}/RUN allows an internal 0.5μA current source to charge the external compensation network. When the I_{TH}/RUN pin reaches 0.4V, the main control loop is enabled with the I_{TH}/RUN voltage, and then pulled up to its zero-current level of approximately 0.7V. As the external compensation network continues to charge, the corresponding output current trip level follows, allowing normal operation.

Comparator OVP guards against transient overshoots >7.5% of the target output voltage by turning off the P-channel power MOSFET and keeping it off until the fault is removed.
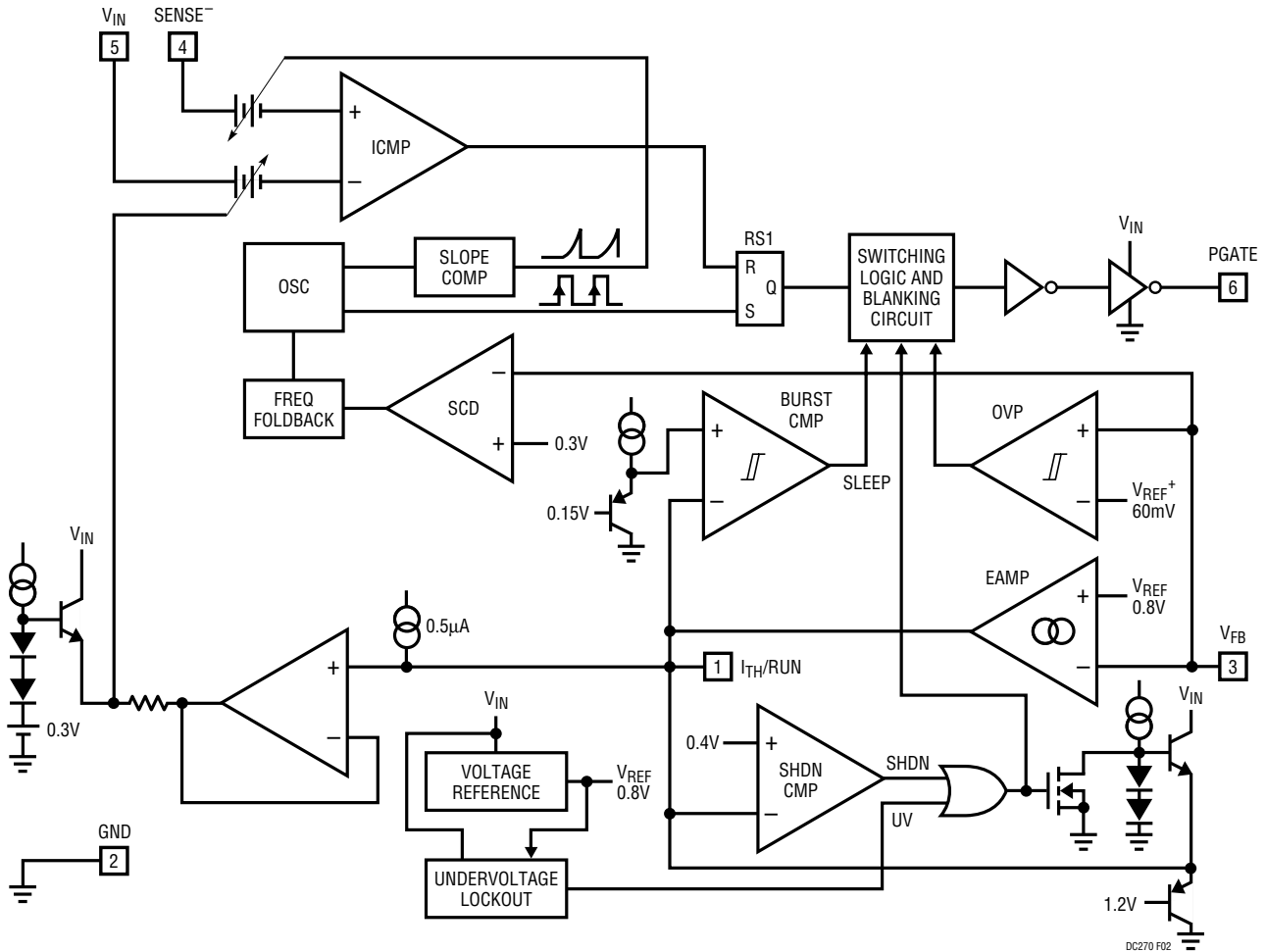
OPERATION

Figure 2. LTC1772 Block Diagram

Burst Mode Operation

The LTC1772 enters Burst Mode operation at low load currents. In this mode, the peak current of the inductor is set as if $V_{ITH}/RUN = 1V$ (at low duty cycles), even though the voltage at the I_{TH}/RUN pin is at a lower value. If the inductor's average current is greater than the load requirement, the voltage at the I_{TH}/RUN pin will drop. When the I_{TH}/RUN voltage goes below 0.85V, the sleep signal goes high, turning off the external MOSFET. The sleep signal goes low when the I_{TH}/RUN voltage goes above 0.925V and the LTC1772 resumes normal operation. The next oscillator cycle will turn the external MOSFET on and the switching cycle repeats.

Undervoltage Lockout

To prevent deep discharge of a lithium-ion battery when it is near its end of charge, an undervoltage lockout circuit is incorporated into the LTC1772. When the input supply voltage drops below approximately 2.2V, the UV lockout feature turns off the P-channel MOSFET and all circuitry except the undervoltage block, which draws only several microamperes.

OPERATION

Short-Circuit Protection

When the output is shorted to ground, the frequency of the oscillator is reduced to about 90kHz. This low frequency allows the inductor current to safely discharge, thereby preventing current runaway. The oscillator's frequency will gradually increase to its designed rate when the feedback voltage again approaches 0.8V.

Output Voltage Setup

In this demonstration circuit, the output voltage is set for 2.5V. Output voltages other than 2.5V can be obtained by removing component R_{F1} = 174k and replacing it with a resistor of the value:

$$R_{F1} = 80.6k\left(\frac{V_{OUT}}{0.8} - 1\right)$$

Note that output voltages below 0.8V are not possible with this topology.

Higher output voltages may require a substitute output capacitor, since the installed output capacitor is rated for 6V.
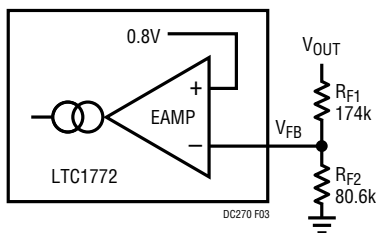
HOW TO MEASURE VOLTAGE REGULATION

When measuring voltage regulation, all measurements must be taken at the point of regulation. This point is where the LTC1772 control loop looks for the information to keep the output voltage constant. This information appears between Pin 3 and Pin 2 of the LTC1772. For output voltages above 0.8V, the voltage at Pin 3 can be adjusted by the resistor divider network. These points correspond to the output terminals of the demonstration board. Test leads should be attached to these terminals and the load should be attached as close to these terminals as possible. This applies to line regulation (input-to-output voltage regulation) as well as load regulation tests. In performing line regulation tests, always look at the input voltage across the input terminals. Refer to Figure 4 for proper monitoring equipment configuration.

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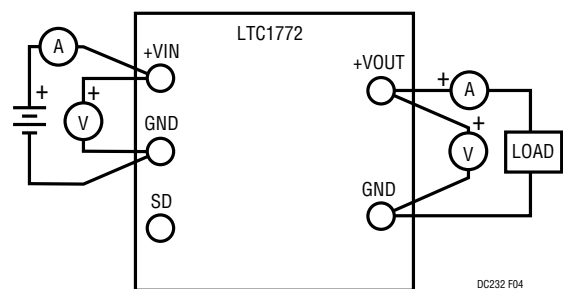

Figure 3. Output Voltage Setting

Figure 4. Correct Measurement Setup

OPERATION

CHECKING TRANSIENT RESPONSE

Switching regulators take several cycles to respond to a step in DC 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}. 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 Figure 1 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 LTC1772 data sheet details more specific selection criteria for most of the external components surrounding the IC. 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) C_{IN} and C_{O1} are low ESR, high ripple-current capacitors. ESR (or 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. The capacitors used in this circuit are specifically designed for switching power supplies.

One other choice of capacitors is organic semiconductor types (OS-CON) that are specifically made for power supply applications. They have very low ESR and are ~1/2 the size of equivalent wet electrolytics.

Power MOSFET

Since the LTC1772 is designed for operation down to approximately 2.2V, a sublogic threshold MOSFET ($R_{DS(ON)}$ guaranteed at V_{GS} = 2.5V) is required for applications that work close to this voltage. When these MOSFETs are used, make sure that the input supply to the LTC1772 is less than the absolute maximum V_{GS} ratings, typically 8V.

Inductor

Although the inductor used in the demo board is from Coilcraft, a wide variety of inductors are available from other manufacturers. Many inductors will work in this circuit; the only fixed requirement is that the inductor be able to support the output DC current and still maintain its inductance value. Each inductor design will have a different physical size, different loss characteristics and different stray field patterns. Therefore, the circuit must be recharacterized for efficiency if any of the alternate inductors are used in place of the existing one.

Because of the aforementioned variations in design and cost of the inductor, we suggest you contact some of the inductor manufacturers in Table 1 to discuss your needs. Often, a standard, low cost solution that will meet your needs is available.

OPERATION

Sense Resistor

The current sense resistor specified in the component list is manufactured by International Resistive Company. Alternate resistors can be obtained from Dale.

Schottky Diode

The catch diode D1 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 high speed switching diode optimizes efficiency. Schottky diodes are a good choice for low forward drop and fast switching times.

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 can be used for the switching regulator. Using components other than the ones on the demonstration board requires recharacterizing the circuit for performance.

Table 1. Inductor Manufacturers

| MANUFACTURER	PART NUMBERS
Coilcraft 1102 Silver Lake Road, Cary, IL 60013 (847) 639-6400, FAX: (847) 639-1469	D01608 Series
Coiltronics International 6000 Park of Commerce Blvd., Boca Raton, FL 33487 (561) 241-7876, FAX: (561) 241-9339	Econo-Pac Octa-Pac
API Delevan 270 Quaker Road, East Aurora, NY 14052 (716) 652-3600, FAX: (716) 652-4814	4501 Series
Sumida Electric Co. Ltd. 5999 New Wilke Rd., Suite 110, Rolling Meadows, IL 60008 (847) 956-0667, FAX: (847) 956-0702	CD 43 Series CDH 53 Series CDRH62B
Murata Electronics 1900 W. College Ave., State College, PA 16801-2799 (814) 237-1431, FAX: (814) 238-0490	LQN6C Series

Table 2. Capacitor Manufacturers

| MANUFACTURER	PART NUMBERS
AVX Corporation P.O. Box 867, Myrtle Beach, SC 29578 (843) 946-0362, FAX: (843) 448-1943	TPS Series
Sanyo Video Components 2001 Sanyo Avenue, San Diego, CA 92173 (619) 661-6835, FAX: (619) 661-1055	OS-CON Series POSCAP Series
Sprague 678 Main Street, Sanford, ME 04073 (207) 324-4140, FAX: (207) 324-7223	593D Series
Murata Electronics 1900 W. College Ave., State College, PA 16801-2799 (814) 237-1431, FAX: (814) 238-0490	GRM 200 Series

PCB LAYOUT AND FILM
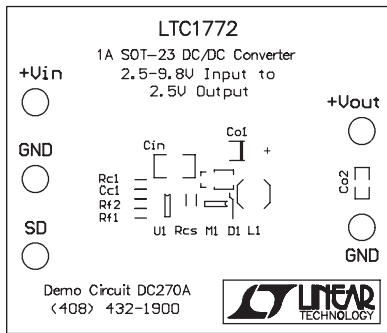
Component Side Silkscreen
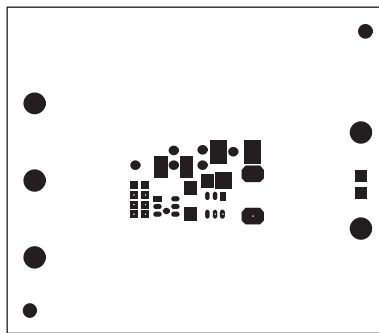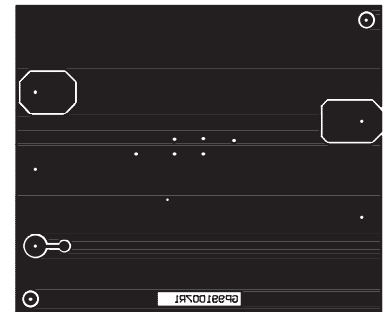

Component Side Solder Mask
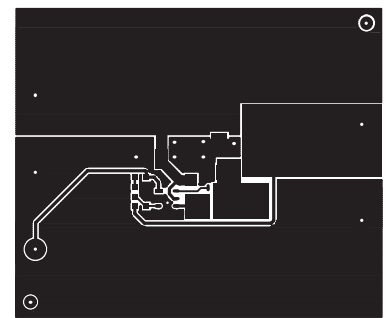
Top Layer
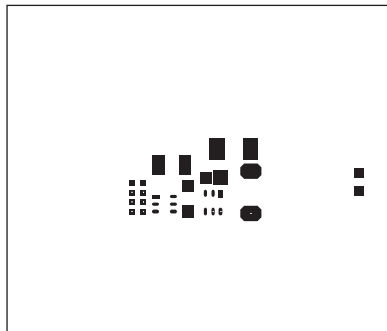
Component Side Paste
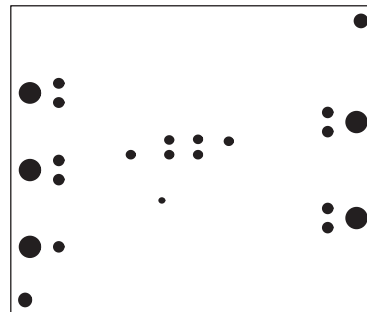
Solder Side Solder Mask

Solder Side

PC FAB DRAWING
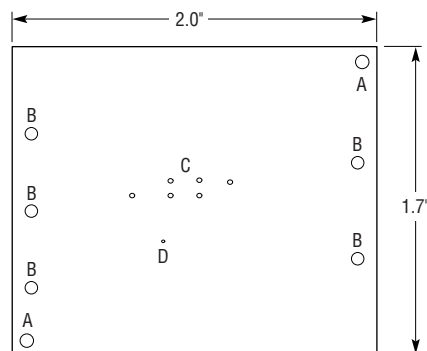
SYMBOL	DIAMETER	NUMBER OF HOLES
A	0.070	2
B	0.065	5
C	0.025	6
D	0.015	1
TOTAL HOLES		14

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