LTC1622 Low Input Voltage Current Mode Step-Down DC/DC Converter

DESCRIPTION

Demo board DC232 is a step-down (buck) regulator using the LTC1622. 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. DC232 is capable of providing 1.5A at an output voltage of 2.5V with an input supply of 4.2V. This demo board highlights the capabilities of the LTC1622, which uses a current mode PWM architecture to drive an external P-channel power MOSFET. The results are a high performance power supply that has low output voltage ripple. Constant operating frequency makes the LTC1622 attractive for noise-sensitive applications. In addition, high efficiency over wide load current range makes the LTC1622 ideal for battery-powered applications. In drop-out, 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 LTC1622 can be set up for Burst Mode™ operation or pulse skipping mode by either connecting the SYNC/MODE pin to V_{IN} or leaving it disconnected. The LTC1622 can also be synchronized to an external clock at frequencies of up to 750kHz. The LTC1622 is capable of operating down to a 2V input voltage before the undervoltage lockout feature is activated. Soft start is provided by an external capacitor, which can also be used to properly sequence supplies. **Gerber files for this circuit board are available. Call the LTC factory**.
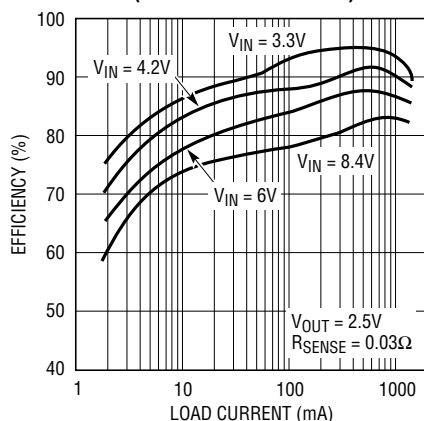
PERFORMANCE SUMMARY

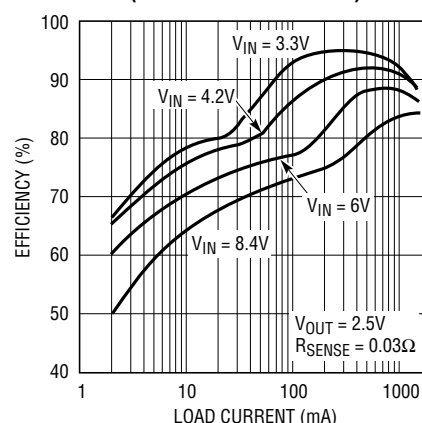| SYMBOL	PARAMETER		CONDITIONS	VALUE
V_{IN}	Input Working Voltage Range		V_{OUT} = 1.8V	2V to 8.5V
V_{OUT}	Output Voltage		I_{OUT} = 800mA	3.3V ± 0.033V
			I_{OUT} = 800mA	2.5V ± 0.025V
			I_{OUT} = 800mA	1.8V ± 0.018V
V_{FB}	Feedback Voltage			0.8V ± 0.04V
I_Q	Typical Supply Current	Normal Mode	V_{IN} = 4.2V, I_{OUT} = 0mA	400µA
		Shutdown	V_{IN} = 4.2V, $V_{RUN/SS}$ = 0V	15µA

TYPICAL PERFORMANCE CHARACTERISTICS AND BOARD PHOTO

Efficiency vs Load Current (Burst Mode Enabled)

Efficiency vs Load Current (Burst Mode Defeated)

Board Photo

PERFORMANCE SUMMARY

| SYMBOL	PARAMETER	CONDITIONS	VALUE
I_{OUT}	Maximum Output Current	$V_{IN} = 4.2V$, $V_{OUT} = 2.5V$	1.5A
ΔV_{OUT}	Typical Load Regulation	0mA < I_{OUT} < 1.5A, $V_{IN} = 8.5V$	−1%
V_{RIPPLE}	Typical Output Ripple	$I_{OUT} = 1.5A$, $V_{IN} = 4.2V$, Burst Mode Operation Defeated $I_{OUT} = 100mA$, $V_{IN} = 4.2V$, Burst Mode Operation Enabled	40mV$_{P-P}$ 120mV$_{P-P}$
f_{SYNC}	Maximum Synchronizable Frequency	$V_{OUT} = 2.5V$, $V_{IN} \leq 8.5V$ $V_{OUT} = 1.8V$, $V_{IN} \leq 7V$	750kHz 600kHz

PACKAGE AND SCHEMATIC DIAGRAMS
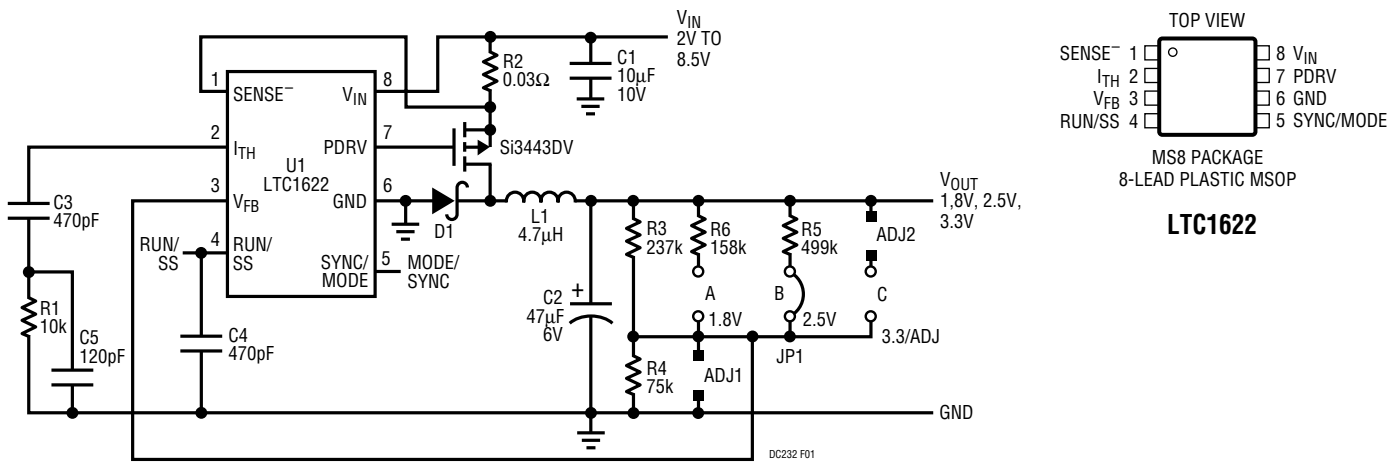
Figure 1. LTC1622 Low Input Voltage Current Mode Step-Down DC/DC Converter Schematic

PARTS LIST

REFERENCE DESIGNATOR	QUANTITY	PART NUMBER	DESCRIPTION	VENDOR	TELEPHONE
C1	1	LMK325BJ106K-T	10µF 10V Ceramic Capacitor	Taiyo Yuden	(408) 573-4150
C2	1	6TPA47M	47µF 6V POSCAP Capacitor	Sanyo	(619) 661-6835
C3, C4	1	06035A471KAT	470pF 50V 10% NPO Chip Capacitor	AVX	(843) 946-0362
C5	1	06035A121KAT	120pF 50V 10% NPO Chip Capacitor	AVX	(843) 946-0362
D1	1	IR10BQ015	Schottky Diode	International Rectifier	(310) 322-3331
J1 to J6	6	1502-2	0.09" Turret Connector	Keystone	(718) 956-8900
JP1	1	22025-6G2	0.079" cc 6-Pin Jumper	Comm Con	(626) 301-4200
L1	1	LQN6C-4R7	4.7µH Inductor	Murata	(814) 237-1431
M1	1	Si3443DV	Sublogic Threshold P-Channel MOSFET	Siliconix	(800) 554-5565
R1	1	CR16-103J	10k 5% 0.1W 0603 Resistor	TAD	(800) 508-1521
R2	1	LR1206-01-R030F	0.030Ω 1% 0.25W 1206 Resistor	IRC	(512) 992-7900
R3	1	CR16-2373FM	237k 1% 0.1W 0603 Resistor	TAD	(800) 508-1521
R4	1	CR16-7502FM	75k 1% 0.1W 0603 Resistor	TAD	(800) 508-1521
R5	1	CR16-4993FM	499k 1% 0.1W 0603 Resistor	TAD	(800) 508-1521
R6	1	CR16-1583FM	158k 1% 0.1W 0603 Resistor	TAD	(800) 508-1521
U1	1	LTC1622CMS8	8-Pin MSOP IC	LTC	(408) 432-1900

QUICK START GUIDE

This demonstration board is easy to set up to evaluate the performance of the LTC1622. Please follow the procedure outlined below for proper operation.

1. Move jumper JP1 to the appropriate position for the required output voltage. For voltages other than the preset value, make sure you install the calculated resistor at the pads provided (see Output Voltage Setup).

2. To shut down the circuit, connect the RUN/SS pin to ground.

3. For synchronized operation, connect the clock signal between the SYNC/MODE and ground pins. Do not apply more than the input voltage (V_{IN}) on this pin.

4. For Burst Mode operation at low load currents, float the SYNC/MODE pin or connect it to V_{IN}. Grounding or clocking this pin inhibits Burst Mode operation.

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

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

OPERATION

The circuit shown in Figure 1 operates from an input voltage between 2V and 8.5V. Output voltages of 1.8V, 2.5V and 3.3V can be easily set by moving jumper JP1 to the appropriate position. For other output voltages, a user-installable resistor must be connected to the pads provided (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 LTC1622 switching regulator IC and was not designed for any other purpose.

OPERATION

The LTC1622 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 LTC1622 is designed to operate down to a 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 the lithium-ion battery by deep discharge, an undervoltage lockout circuit is incorporated into the LTC1622. When the input supply drops to about

2V, all circuitry, except the undervoltage detector block, is turned off .

The LTC1622 operates as follows: the external P-channel power MOSFET is turned on at the beginning of each cycle when the oscillator sets the latch (R_{S1}), and is turned off when the current comparator (I_{COMP}) resets the latch. The peak inductor current at which the I_{COMP} resets the R_S latch is controlled by the voltage on the I_{TH} pin, which is the output of the error amplifier EA. An external resistive divider connected between V_{OUT} and ground allows EA 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} voltage to increase until the average inductor current matches the new load current.

The main control loop is shut down by tying the RUN/SS pin low. Releasing RUN/SS allows an internal 0.75µA current source to charge the soft start capacitor C4. When C4 reaches 0.7V, the main control loop is enabled, with the I_{TH} voltage clamped at approximately 5% of its maximum value. As C4 continues to charge, I_{TH} is gradually released, allowing normal operation to resume.

Comparator OV guards against output transients that are greater than 8% over the target output voltage by turning off the P-channel power MOSFET and keeping it off until the fault is removed.

OPERATION

Figure 2. LTC1622 Block Diagram

Burst Mode Operation

The LTC1622 can be enabled for Burst Mode operation at low load currents by connecting the SYNC/MODE pin to the input supply or allowing the pin to float. In this mode, the minimum peak current of the inductor is set to 0.036V/R_{SENSE} (at low duty cycle), even though the voltage at the I_{TH} pin would normally indicate a lower value. If the inductor's average current is greater than the load requirement, the voltage at the I_{TH} pin will drop as V_{OUT} increases. When the I_{TH} voltage goes below 0.12V, the sleep signal goes high, turning off the external MOSFET. The sleep signal goes low when the I_{TH} voltage goes above 0.22V and the LTC1622 resumes normal operation. The next oscillator cycle will turn the external MOSFET on and the switching cycle repeats.

Frequency Synchronization

The LTC1622 can be externally driven by a clock signal. For output voltages of 2.5V and 3.3V, this demo circuit can be synchronized to frequencies up to 750kHz. For an output voltage of 1.8V, it can be synchronized to frequencies of up to 600kHz. *Do not* synchronize the LTC1622 below its default operating frequency of 550kHz, as this may cause abnormal operation and an undesired frequency spectrum.

Synchronization is inhibited when the feedback voltage is below 0.3V. This is to prevent inductor current build-up under short-circuit conditions. Burst Mode operation is inhibited when the LTC1622 is driven by an external clock.

4

OPERATION

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 LTC1622. When the input supply voltage drops to 2V, all circuitry is turned off except the undervoltage block, which draws only several microamperes.

Short-Circuit Protection

When the output is shorted to ground, the frequency of the oscillator will be reduced to about 1/4.5 of its normal rate. This low frequency allows the inductor current to discharge, preventing runaway. The oscillator's frequency will gradually increase to its nominal rate when the feedback voltage increases above 0.65V. Note that synchronization is inhibited until the feedback voltage goes above 0.4V.

Output Voltage Setup

In this demonstration circuit, output voltages of 1.8V, 2.5V and 3.3V can be obtained by moving jumper JP1 to the appropriate position, as indicated on the demo board. In addition, provision has been made for the user to set the LTC1622 for other voltages by adding a resistor and moving the jumper to the ADJ position. To obtain voltages above 1.8V, move jumper JP1 to the A position and install the required resistance at the pads labelled ADJ1. The required resistance is given by:

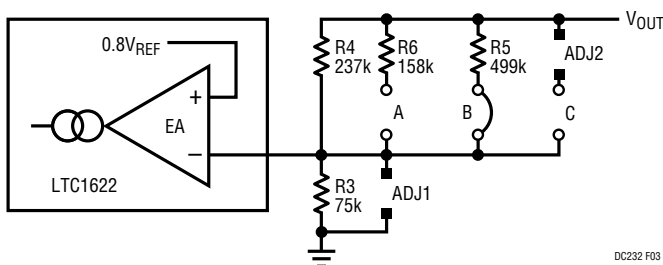$$R_{ADJ1}(k\Omega) = \frac{75.84}{V_{OUT} - 1.81}$$

Higher output voltages may require a substitute output capacitor since the installed output capacitor is rated at only 6V. Normally, we use a capacitor with a voltage rating of twice the output voltage. For output voltages below 1.8V, move the jumper JP1 to position C and install the required resistance at the pads labelled ADJ2. The required resistance is given by:

$$R_{ADJ2}(k\Omega) = \frac{17775(V_{OUT} - 0.8)}{249.6 - 75V_{OUT}}$$

HOW TO MEASURE VOLTAGE REGULATION

When measuring voltage regulation, all measurements must be taken at the point of regulation. This point is where the LTC1622 control loop looks for the information to keep the output voltage constant. This information occurs between Pin 3 and Pin 6 of the LTC1622. For output voltages other than 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.
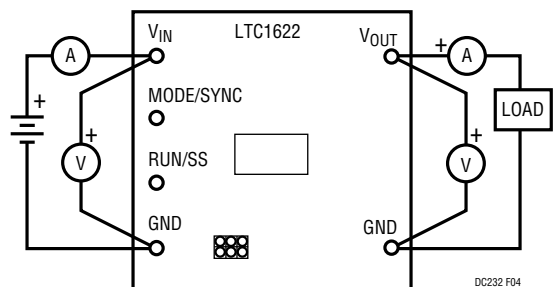

Figure 3. Output Voltage Setting

Figure 4. Correct Measurement Setup

OPERATION

CHECKING TRANSIENT RESPONSE

Switching regulators take several cycles to respond to a step in DC (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}. 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's 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 LTC1622 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) C1 and C2 are specially developed low ESR, high ripple-current capacitors specifically designed for use in switching power supplies. 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. 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 tantalum capacitors (especially low cost varieties) are not recommended for use in these applications, as they do not have the ability to handle 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 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 equivalent wet electrolytics.

Power MOSFET

Since the LTC1622 is designed for operation down to 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 LTC1622 is less than the absolute maximum V_{GS} ratings, typically 8V.

LINEAR
TECHNOLOGY

OPERATION

Inductor

Although the inductor used in the demo board is from Murata, a wide variety of inductors is 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 with them. Very often a standard low cost solution is on the shelf that will meet your needs.

Sense Resistor

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

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 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 efficiency.

Table 1. Inductor Manufacturers

| MANUFACTURER	PART NUMBERS
Coilcraft 1102 Silver Lake Road, Cary, IL 60013 (847) 639-6400, FAX: (847) 639-1469	D03316 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) 956-0666, FAX: (847) 956-0702	CD 43 Series CDH 53 Series CDRH62B

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
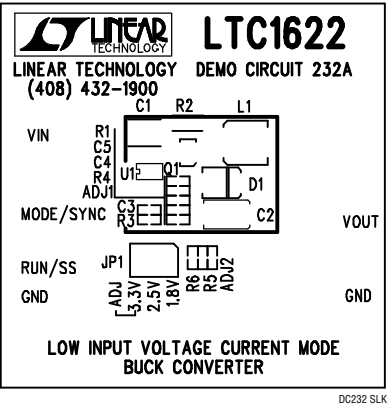
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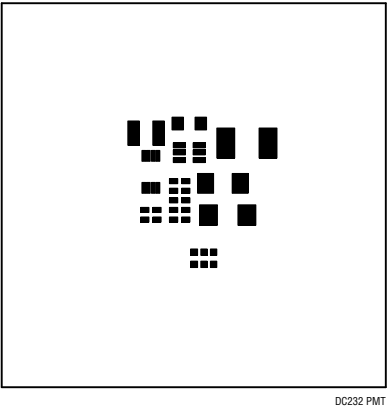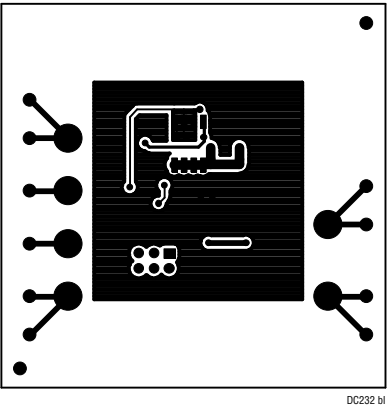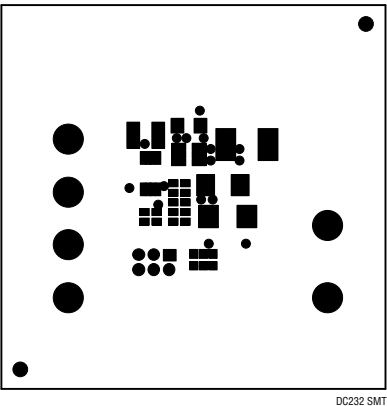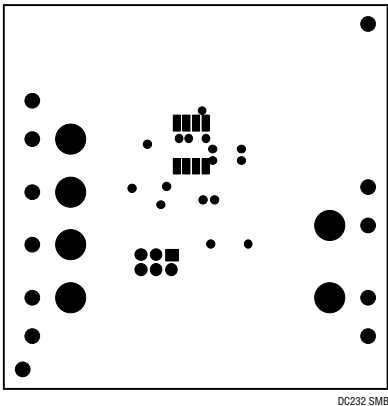
Component Side Solder Paste
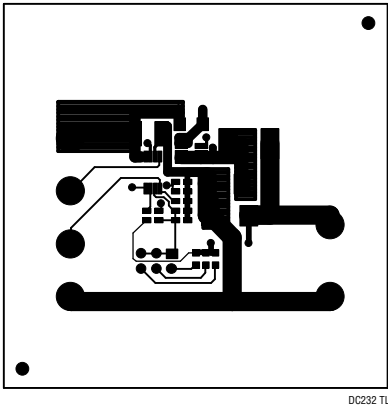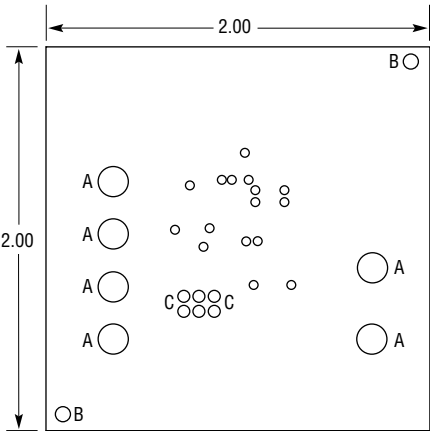
Top Layer

Bottom Layer

Component Side Solder Mask

Solder Side Solder Mask

PC FAB DRAWING

NOTES: UNLESS OTHERWISE SPECIFIED
1. MATERIAL: FR4 OR EQUIVALENT EPOXY, 2 OZ COPPER CLAD THICKNESS 0.062 ± 0.006 TOTAL OF TWO LAYERS
2. FINISH: ALL PLATED HOLES 0.001 MINIMUM/0.0015 MAXIMUM COPPER PLATE ELECTRODEPOSITED TIN-LEAD COMPOSITION BEFORE REFLOW, SOLDER MASK OVER BARE COPPER (SMOBC)
3. SOLDER MASK: BOTH SIDES USING LPI OR EQUIVALENT
4. SILKSCREEN: USING WHITE NONCONDUCTIVE EPOXY INK
5. UNUSED SMD COMPONENTS SHOULD BE FREE OF SOLDER
6. FILL UP ALL VIAS WITH SOLDER

HOLE CHART

SYMBOL	DIAMETER	NUMBER OF HOLES	PLATED
A	0.094	6	YES
B	0.07	2	NO
C	0.035	6	YES
NO SYMBOL	0.02	16	YES
TOTAL		30	

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1630 McCarthy Blvd., Milpitas, CA 95035-7417
(408)432-1900 • FAX: (408) 434-0507 • www.linear-tech.com

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- Поставка специализированных компонентов военного и аэрокосмического уровня качества (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Actel, Aeroflex, Peregrine, VPT, Syfer, Eurofarad, Texas Instruments, MS Kennedy, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

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