19-4781; Rev 0; 5/00

MAX1710 Evaluation Kit

General Description

The MAX1710 evaluation kit (EV kit) demonstrates the data sheet's standard 7A notebook CPU application circuit (see MAX1710/MAX1711 data sheet). This DC-DC converter steps down high-voltage batteries and/or AC adapters, generating a precision, low-voltage CPU core V_{CC} rail.

The circuit was designed for a 7V to 24V battery range, but accommodates from 4.5V to 24V. Some parameters, such as load-transient response and maximum thermal load capability, may be degraded by going outside the 7V to 24V range. The continuous output current rating, based on worst-case MOSFET $R_{DS(ON)}$, heat sinking, and other thermal stress issues, is 5.5A at T_A = +70°C.

This EV kit is a fully assembled and tested circuit board. It also allows the evaluation of the MAX1711.

Ordering Information

PART	TEMP. RANGE	IC PACKAGE
MAX1710EVKIT	0°C to +70°C	24 QSOP

NOTE: *To evaluate the MAX1711, request a MAX1711EEG free sample with the MAX1710 EV Kit.*

Features

- ♦ **High Speed, Accuracy, and Efficiency**
- ♦ **Fast-Response QUICK-PWM™ Architecture**
- ♦ **7V to 24V Input Voltage Range**
- ♦ **1.25V to 2V Output Voltage Range**
- ♦ **7A Peak Load-Current Capability (5.5A Continuous)**
- ♦ **93% Efficient (V_{OUT} = 2V, V_{BATT} = 7V, I_{LOAD} = 4A)**
- ♦ **300kHz Switching Frequency**
- ♦ **No Current-Sense Resistor**
- ♦ **Remote GND and V_{OUT} Sensing**
- ♦ **Power-Good Output**
- ♦ **24-Pin QSOP Package**
- ♦ **Low-Profile Components**
- ♦ **Fully Assembled and Tested**

Component List

DESIGNATION	QTY	DESCRIPTION
C1–C4	4	4.7µF, 25V ceramic capacitors Taiyo Yuden TMK325BJ475K
C1–C4 (ALTERNATE)	4	10µF, 25V ceramic capacitors Tokin C34Y5U1E106Z or United Chemi Con/Marcon THCR50E1E106ZT
C5, C6, C7	3	470µF, 6.3V, 30mΩ low-ESR tantalum capacitors Kemet T510X477M006AS
C8	1	10µF, 6.3V ceramic capacitor Taiyo Yuden JMK325BJ106MN or TDK C3225X5R1A106M
C9	1	0.1µF ceramic capacitor
C11, C12	2	0.22µF ceramic capacitors
C14	1	470pF ceramic capacitor
C15	1	1µF ceramic capacitor
C16, C17, C18	0	Not installed
D1	1	2A Schottky diode SGS-Thomson STPS2L25U or Nihon EC31QS03L
D2	1	100mA Schottky diode Central Semiconductor CMPSH-3 Hitachi HRB0103A
D3	1	1A Schottky diode Motorola MBRS130LT3, Nihon EC10QS03, or International Rectifier 10BQ040 Hitachi HRF22
D4	1	200mV switching diode Central Semiconductor CMPD2838
L1	1	2µH power inductor Panasonic ETQP6F2R0HFA, Coiltronics UP4B-2R2, or Coilcraft DO5022P-222HC
N1	1	N-channel MOSFET International Rectifier IRF7807, Fairchild FDS6612A, or Siliconix Si4416DY
N2	1	N-channel MOSFET International Rectifier IRF7805,or Fairchild FDS6670A, or NEC uPA1706, or Hitachi HAT2040R
R1	1	20Ω ±5% resistor

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Component List (continued)

DESIGNATION	QTY	DESCRIPTION
R2, R3, R9	3	1MΩ ±5% resistors
R4	1	100kΩ, ±5% resistor
R6	0	Not installed
R7	1	3Ω, ±5% resistor
R10, R12	1	1kΩ, ±5% resistor
U1	1	MAX1710EEG (24-QSOP)
JU1, JU2	2	2-pin headers
None	1	Shunt (JU1)
SW1	1	DIP-8 dip switch Digi-Key CT2084-ND
SW2	1	Momentary switch, normally open Digi-Key P8006/7S
J1	1	Scope-probe connector Berg Electronics 33JR135-1
None	1	MAX1710 PC board
None	1	MAX1710/MAX1711 data sheet

Component Suppliers

SUPPLIER	PHONE	FAX
Central Semiconductor	516-435-1110	516-435-1824
Coilcraft	708-639-6400	708-639-1469
Coiltronics	561-241-7876	561-241-9339
Dale-Vishay	402-564-3131	402-563-6418
Fairchild	408-721-2181	408-721-1635
Hitachi	888-777-0384	650-244-7947
International Rectifier	310-322-3331	310-322-3332
IRC	512-992-7900	512-992-3377
Kemet	408-986-0424	408-986-1442
Motorola	602-303-5454	602-994-6430
NEC	408-588-6000	408-588-6130
Nihon	847-843-7500	847-843-2798
Panasonic	714-373-7939	714-373-7183
Sanyo	619-661-6835	619-661-1055
SGS-Thomson	617-259-0300	617-259-9442
Siliconix	408-988-8000	408-970-3950
Sumida	708-956-0666	708-956-0702
Taiyo Yuden	408-573-4150	408-573-4159
TDK	847-390-4373	847-390-4428
Tokin	408-432-8020	408-434-0375

Equipment Needed

- 7V to 24V, >20W power supply, battery, or notebook AC adapter
- DC bias power supply, 5V at 100mA
- Dummy load capable of sinking 7A
- Digital multimeter (DMM)
- 100MHz dual-trace oscilloscope

Quick Start

1) Ensure that the circuit is connected correctly to the supplies and dummy load prior to applying any power.
2) Ensure that the shunt is connected at JU1 ($\overline{SHDN}$ = V_{CC}).
3) Turn on battery power prior to +5V bias power; otherwise, the output UVLO timer will time out and the fault latch will be set, disabling the regulator until +5V power is cycled or shutdown is toggled.
4) Observe the output with the DMM and/or oscilloscope. Look at the LX switching-node and MOSFET gate-drive signals while varying the load current.
5) Don't change the DAC code without cycling +5V bias power; otherwise, the output voltage ramp will probably bump into the over- or undervoltage protection thresholds and latch the circuit off. If this happens, just cycle power or **press the RESET button**.
6) Set switch SW1 per Table 1 to get the desired output voltage.

Detailed Description

This 7A buck-regulator design is optimized for a 300kHz frequency and output voltage settings around 1.6V. At lower output voltages, transient response is degraded slightly and efficiency worsens. At higher output voltages (approaching 2V), output ripple and reflected input ripple increase.

The PC board layout deliberately includes long output power and ground buses in order to facilitate evaluation of the remote sense circuitry and to provide plenty of experimentation space for soldering in different types of output filter capacitors. These buses are also useful for introducing the small amounts of parasitic trace resistance necessary when using capacitors having high-frequency ESR zeros (see the *All-Ceramic-Capacitor Application* section in MAX1710/MAX1711 data sheet). Position the experimental ceramic capacitors at different places along the length of the buses to see the effect of different amounts of ESR.

Table 1. MAX1710/1711 Output Voltage Adjustment Settings

D3	D2	D1	D0	OUTPUT VOLTAGE (V)
0	0	0	0	2.00
0	0	0	1	1.95
0	0	1	0	1.90
0	0	1	1	1.85
0	1	0	0	1.80
0	1	0	1	1.75
0	1	1	0	1.70
0	1	1	1	1.65
1	0	0	0	1.60
1	0	0	1	1.55
1	0	1	0	1.50
1	0	1	1	1.45
1	1	0	0	1.40
1	1	0	1	1.35
1	1	1	0	1.30
1	1	1	1	1.25

Setting the Output Voltage

Select the output voltage using the D0–D3 pins. The MAX1710/MAX1711 uses an internal DAC as a feedback resistor voltage-divider. The output voltage can be digitally set from 1.25V to 2V, in 50mV increments, using the D0–D3 inputs. Switch SW1 sets the desired output voltage (Table 1).

Load-Transient Measurement

One interesting experiment is to subject the output to large, fast load transients and observe the output with an oscilloscope. This necessitates careful instrumentation of the output, using the supplied scope-probe jack. Accurate measurement of output ripple and load-transient response invariably requires that ground clip leads be completely avoided and that the probe hat be removed to expose the GND shield, so the probe can be plugged directly into the jack. Otherwise, EMI and noise pickup will corrupt the waveforms.

Most benchtop electronic loads intended for power-supply testing lack the ability to subject the DC-DC converter to ultra-fast load transients. Emulating the supply current Δi/Δt at the CPU VCORE pins requires at least 10A/µs load transients. One easy method for generating such an abusive load transient is to solder a MOSFET, such as an MTD3055 or 12N05, directly across the scope-probe jack then drive its gate with a strong pulse generator at a low duty cycle (10%) to minimize heat stress in the MOSFET. Vary the high-level output voltage of the pulse generator to vary the load current.

To determine the load current, you might expect to insert a meter in the load path, but this method is prohibited here by the need for low resistance and inductance in the path of the dummy-load MOSFET. There are two easy alternative methods to determine how much load current a particular pulse-generator amplitude is causing. The first and best is to observe the inductor current with a calibrated AC current probe, such as a Tektronix AM503. In the buck topology, the load current is equal to the average value of the inductor current. The second method is to first put on a static dummy load and measure the battery current. Then, connect the MOSFET dummy load at 100% duty momentarily, and adjust the DC gate-drive signal amplitude until the battery current rises to the appropriate level (the MOSFET load must be well heatsinked for this to work without causing smoke and flames).

Efficiency Measurements

Testing the power conversion efficiency P_{OUT}/P_{IN} fairly and accurately requires more careful instrumentation than might be expected. One common error is to use inaccurate DMMs. Another is to use only one DMM, and move it from one spot to another to measure the various input/output voltages and currents. This second error usually results in changing the exact conditions applied to the circuit due to series resistance in the ammeters. It's best to get four 3-1/2 digit or better DMMs that have been recently calibrated, and monitor V_{BATT}, V_{OUT}, I_{BATT}, and I_{LOAD} simultaneously, using separate test leads directly connected to the input and output PC board terminals. Note that it's inaccurate to test efficiency at the remote V_{OUT} and ground terminals, as this incorporates the parasitic resistance of the PC board output and ground buses in the measurement (a significant power loss).

Remember to include the power consumed by the +5V bias supply when making efficiency calculations:

$$\text{Efficiency} = \frac{V_{OUT} \times I_{LOAD}}{(V_{BATT} \times I_{BATT}) + (5V \times I_{BIAS})}$$

The choice of MOSFET has a large impact on efficiency performance. The International Rectifier MOSFETs used were of leading-edge performance for the 7A application at the time this kit was designed. However, the pace of MOSFET improvement is rapid, so the latest offerings should be evaluated.

Jumper and Switch Settings

Table 2. Jumper JU1 Functions (Shutdown Mode)

SHUNT LOCATION	$\overline{\text{SHDN}}$ PIN	MAX1710 OUTPUT
On	Connected to V_{CC}	MAX1710 enabled
Off	Connected to GND	Shutdown mode, $V_{OUT} = 0$

Table 3. Jumper JU2 Functions (Low-Noise Mode)

SHUNT LOCATION	$\overline{\text{SKIP}}$ PIN	OPERATIONAL MODE
On	Connected to V_{CC}	Low-noise mode, forced fixed-frequency PWM operation.
Off	Connected to GND	Normal operation, allows automatic PWM/PFM switchover for pulse skipping at light load, resulting in highest efficiency.

Table 4. Jumpers JU3/JU4/JU5 Functions (Switching-Frequency Selection)

JUMPER	SHUNT LOCATION	TON PIN	FREQUENCY (kHz)
JU3 JU4 and JU5	On Off	Connected to V_{CC}	200
JU4 JU3 and JU5	On Off	Connected to REF	400
JU5 JU3 and JU4	On Off	Connected to GND	550
JU3, JU4, JU5	Off	Floating	300

IMPORTANT: *Don't change the operating frequency without first re-calculating component values, because the frequency has a significant effect on the peak current-limit level, MOSFET heating, PFM/PWM switchover point, output noise, efficiency, and other critical parameters.*

Table 5. Jumper JU6 Functions (Fixed/Adj. Current-Limit Selection)

SHUNT LOCATION	ILIM PIN	CURRENT-LIMIT THRESHOLD
On	Connected to V_{CC}	100mV (default)
Off	Connected to GND via external resistor R6. Refer to the ILIM line in the *Pin Description* (MAX1710/MAX1711 data sheet) for information on selecting R6.	Adjustable between 50mV and 200mV

Table 6. Jumpers JU7/JU10 Functions (GNDS Integrator Disable Selection)

JUMPER	SHUNT LOCATION	GND PIN	GROUND REMOTE-SENSE
JU7 JU10	On Off	Connected to V_{CC}	Disables the GNDS integrator
JU7 JU10	Off On	Connected to GND directly at the load	GNDS internally connects to the integrator that fine-tunes the ground offset voltage.

Table 7. Jumpers JU8/JU9 Functions (FBS and FB Integrator Disable Selection)

JUMPER	SHUNT LOCATION	FBS PIN	GROUND REMOTE-SENSE
JU8 JU9	On Off	Connected to V_{CC}	Disables the FBS and the main FB-REF integrators
JU8 JU9	Off On	Connected to V_{OUT} directly at the load	FBS internally connects to the integrator that fine-tunes the DC output voltage.

Table 8. Jumper JU11 Functions (Overvoltage Protection Disable)

SHUNT LOCATION	$\overline{\text{OVP}}$ PIN	OVERVOLTAGE PROTECTION
On	Connected to V_{CC}	OVP disabled
Off	Connected to GND	Normal operation, OVP is enabled.

Table 9. Troubleshooting Guide

SYMPTOM	POSSIBLE PROBLEM	SOLUTION
Circuit won't start when power is applied.	Power-supply sequencing: +5V bias supply was applied first.	Press the RESET button.
Circuit won't start when RESET is pressed, +5V bias supply cycled.	Output overvoltage due to shorted high-side MOSFET.	Replace the MOSFET.
	Output overvoltage due to load recovery overshoot	Reduce the inductor value, raise the switching frequency, or add more output capacitance.
	Overload condition	Remove the excessive load or raise the ILIM threshold by changing R_{LIM} (R6).
	Transient overload condition	Add more low-ESR output capacitors.
	Broken connection, bad MOSFET, or other catastrophic problem.	Troubleshoot the power stage. Are the DH and DL gate-drive signals present? Is the 2V V_{REF} present? Exercising $\overline{\text{OVP}}$ mode and then $\overline{\text{SKIP}}$ no-fault mode can help you decipher the nature of the problem (see MAX1710/MAX1711 data sheet *Pin Description*).
On-time pulses are erratic or have unexpected changes in period.	VBATT power source has poor impedance characteristic.	Add a bulk electrolytic bypass capacitor across the benchtop power supply, or substitute a real battery.
	Noise is being injected into FB.	Add an RC filter on FB (1kΩ and 100pF suggested) at R11 and C18.
Circuit latches off when DAC code is changed.	FB is crossing the +12.5% OVP threshold or the -70% UVLO threshold due to fast DAC response.	This is a normal operating condition. If desired, disable the OVP fault circuit via the $\overline{\text{OVP}}$ input (JU11) or raise the OVP threshold to >2V by substituting a MAX1711 for the MAX1710.
Load-transient waveform shows excess ringing **OR** LX switching waveform exhibits double-pulsing (pulses separated only by a 500ns min off-time).	Instability due to low-ESR ceramic placed across fast feedback path (FB-GND).	Add parasitic PC board trace resistance between the LX-FB connection and the ceramic capacitor. **OR** Substitute a different capacitor type (OS-CON, tantalum, aluminum electrolytic work well).
Excessive EMI, poor efficiency at high input voltages.	Gate-drain capacitance of N2 is causing shoot-through cross-conduction.	Observe the gate-source voltage of N2 during the low-to-high LX node transition (this requires careful instrumentation). Is the gate voltage being pulled above 1.5V, causing N2 to turn on? Use a smaller low-side MOSFET or add a higher-value BST resistor (R7).
Poor efficiency at high input voltages, N1 gets hot.	N1 has excessive gate capacitance.	Use a smaller high-side MOSFET or add more heatsinking.

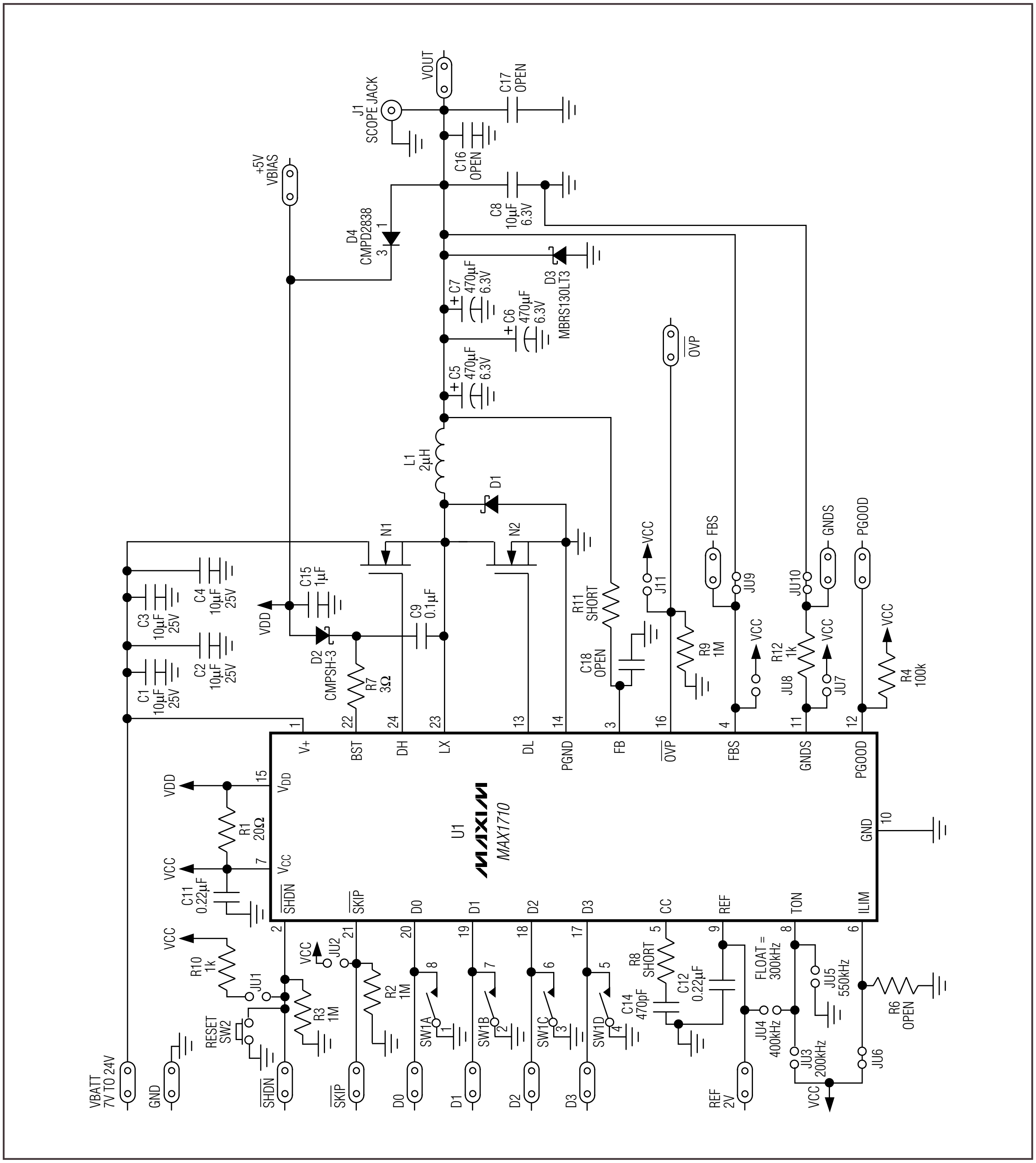

Figure 1. MAX1710 EV Kit Schematic

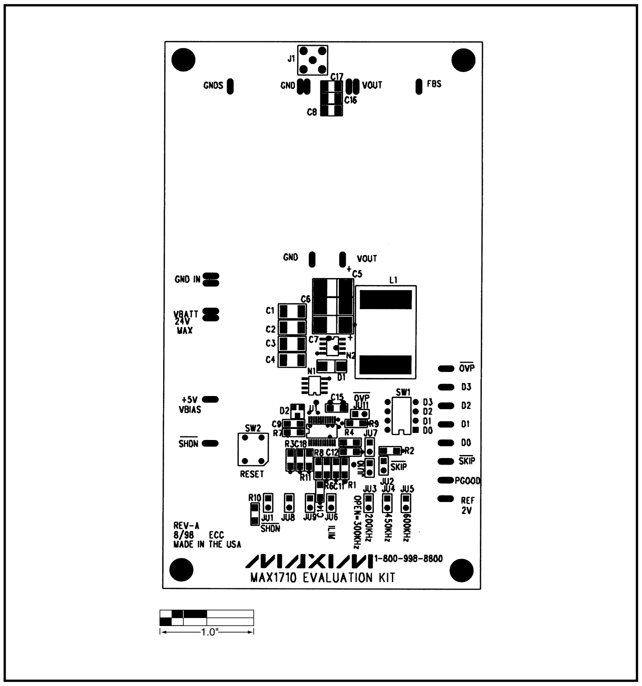

Figure 2. Component Placement Guide —Component Side

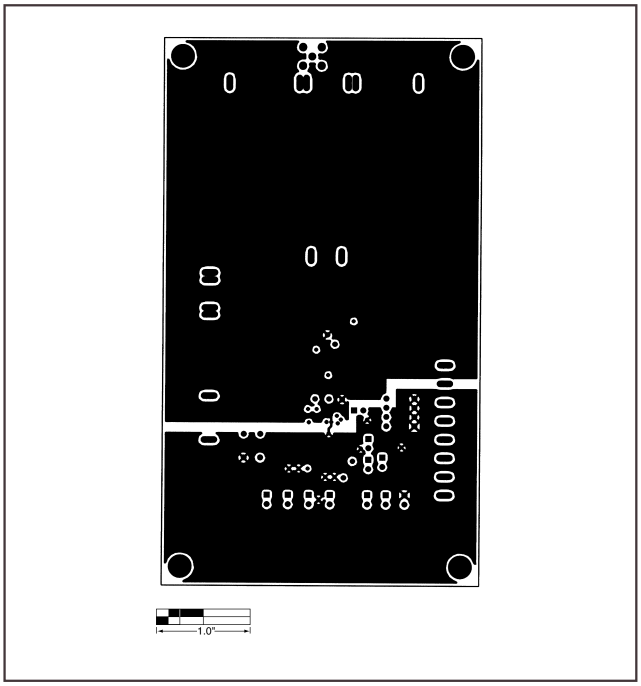

Figure 3. PC Board Layout—Internal GND Plane Layer 2

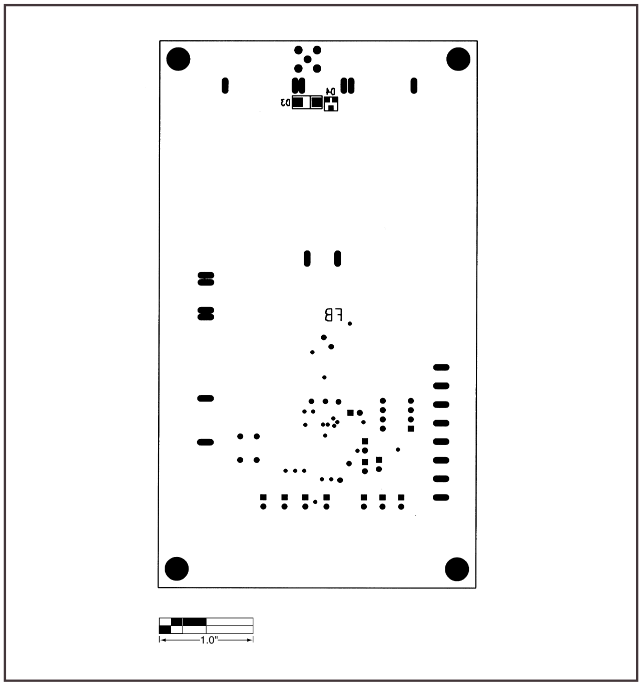

Figure 4. Component Placement Guide—Solder Side

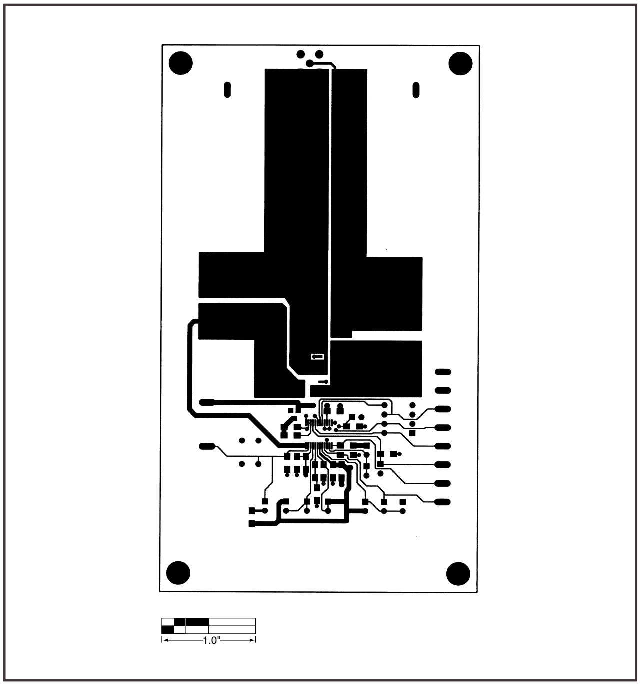

Figure 5. PC Board Layout—Component Side

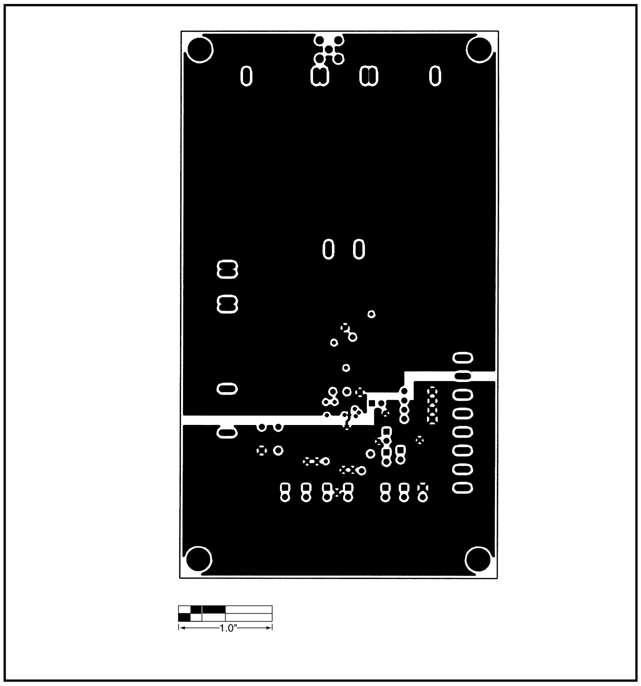

Figure 6. PC Board Layout—Internal GND Plane Layer 3

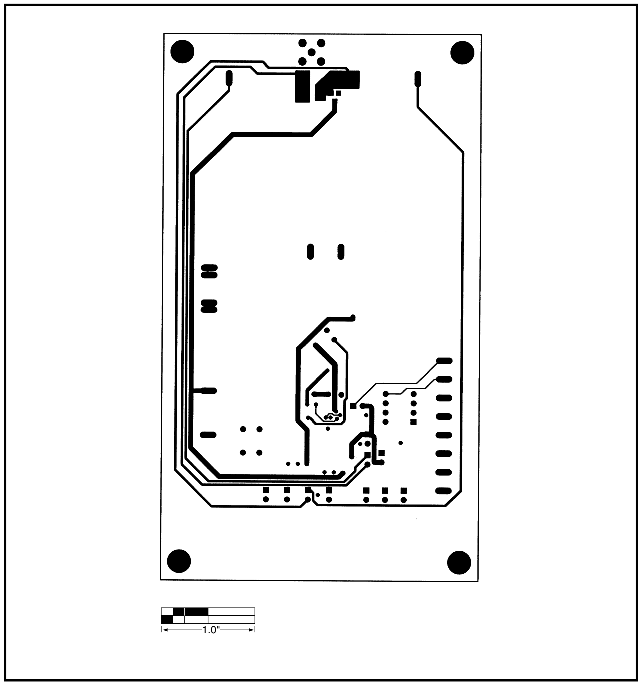

Figure 7. PC Board Layout—Solder Side