19-5155; Rev 0; 2/10

MAX17409 Evaluation Kit

General Description

The MAX17409 evaluation kit (EV kit) demonstrates the high-power, dynamically adjustable, 1-phase application circuit for NVIDIA® graphics power supplies. This DC-DC converter is intended to either step down high-voltage batteries and/or the 5V system supply, generating a precision, low-voltage CPU core. The MAX17409 EV kit meets the NVIDIA transient voltage specification, power-good signaling, voltage-regulator thermal monitoring (VRHOT), and power-good output (PWRGD). The MAX17409 EV kit includes active voltage positioning with adjustable gain, reducing power dissipation and bulk output-capacitance requirements. An internal amplifier buffers the DAC and accurately controls the slew rate for all output-voltage transitions, including transitions between VID codes, startup, and shutdown. Precision slew-rate control provides just-in time arrival at the new DAC setting, minimizing surge currents to and from the battery.

The MAX17409 includes output undervoltage fault, overvoltage fault, and thermal overload protection. It also includes a voltage-regulator power-good (PWRGD) output.

This fully assembled and tested PCB provides a digitally adjustable 0.3375V to 1.1250V output voltage (6-bit on-board DAC) from a 7V to 24V battery-input range. It delivers up to 14A output current. The EV kit operates at 300kHz switching frequency and has superior line- and load-transient response.

Features

- **1-Phase, Fast-Response Quick-PWM™**
- **Active Voltage Positioning with Adjustable Gain—Independent DC and Transient Control**
- **High Speed, Accuracy, and Efficiency**
- **Low-Bulk Output-Capacitor Count**
- **7V to 24V Input-Voltage Range**
- **0.3375V to 1.1250V Output-Voltage Range (6-Bit DAC)**
- **14A Load-Current Capability**
- **300kHz Switching Frequency**
- **Power-Good (PWRGD) Indicator**
- **Thermal Fault (VRHOT) Output**
- **Output Overvoltage and Undervoltage Fault Protections**
- **28-Pin Thin QFN Package (4mm x 4mm)**
- **Fully Assembled and Tested**

Ordering Information

PART	TYPE
MAX17409EVKIT+	EV Kit

+Denotes lead(PB)-free and RoHS compliant.

Component List

DESIGNATION	QTY	DESCRIPTION
C1, C8	2	10µF ±20%, 25V X5R ceramic capacitors (1210) TDK C3225X7R1E106M AVX 12103D106M Taiyo Yuden TMK325BJ106MM
C2, C14	0	Not installed, ceramic capacitors (1210)
C3, C9, C31	3	0.1µF ±10%, 25V X7R ceramic capacitors (0603) Murata GRM188R71E104K TDK C1608X7R1E104K
C4	0	Not installed, ceramic capacitor (D case)
C5	1	470µF, 2V, 6mΩ low-ESR polymer capacitor (D case) SANYO 2TPF470M6 Panasonic EEF SX0D471XR
C6, C7	2	1µF ±10%, 10V X5R ceramic capacitors (0603) TDK C1608X7R1A105K Murata GRM188R61A105K
C10, C16, C18	0	Not installed, ceramic capacitors (0603)
C11, C12, C34	3	1000pF ±10%, 50V X7R ceramic capacitors (0603) TDK C1608X7R1H102K Murata GRM188R71H102K

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Quick-PWM is a trademark of Maxim Integrated Products, Inc.

MAX17409 Evaluation Kit

Component List (continued)

DESIGNATION	QTY	DESCRIPTION
C13	1	100pF ±10%, 50V C0G ceramic capacitor (0603) TDK C1608C0G1H101K Murata GRM1885C1H101J
C19–C30	12	10µF ±20%, 6.3V X5R ceramic capacitors (0805) TDK C2012X5R0J106M or Taiyo Yuden AMK212BJ106MG AVX 08056D106MAT
C33	1	0.22µF ±20%, 10V X7R ceramic capacitor (0603) Taiyo Yuden LMK107BJ224MA TDK C1608X7R1C224M AVX 06033D224KAT
D1	1	3A, 30V Schottky diode Nihon EC31QS03L Central Semi CMSH3-40M Lead Free
D2	1	LED, green clear SMD (0805)
IMON, PWRGD, SKIP, $\overline{\text{VRHOT}}$, VR_ON	5	Test points
L1	1	0.6µH, 16A, 2.30mΩ power inductor NEC TOKIN MPC0750LR60C TOKO FDU0650-R56M
N1	1	n-channel MOSFET (PowerPAK, 8 SO) Fairchild FDS6298 Vishay (Siliconix) SI4386DY
N2	0	Not installed, n-channel MOSFET (PowerPAK, 8 SO)
N3	1	n-channel MOSFET (PowerPAK, 8 SO) Fairchild FDS8670 Vishay (Siliconix) SI4336DY
N4	0	Not installed, n-channel MOSFET (DPAK)
R1	0	Not installed, 1W resistor—short (PC trace) (2512)

DESIGNATION	QTY	DESCRIPTION
R2, R34	2	10kΩ ±1% resistors (0603)
R3	1	200kΩ ±1% resistor (0603)
R4, R8, R20, R33, R37	0	Not installed, resistors (0603) R4, R20 are short (PC trace) and R8, R33, and R37 are open
R5	1	63.4kΩ ±1% resistor (0603)
R6	1	7.87kΩ ±1% resistor (0603)
R7	1	100kΩ ±5% NTC thermistor, ß = 4250 (0603) Murata NCP18WF104J03RB TDK NTCG163JF104J (0402)
R9	1	1kΩ ±5% resistor (0603)
R10, R16, R17	3	10Ω ±5% resistors (0603)
R11, R12, R19	3	0Ω resistors (0603)
R13	1	100Ω ±1% resistor (0603)
R14	0	Not installed, resistor (2512)
R18	1	51Ω ±5% resistor (0603)
R21–R29	9	100kΩ ±5% resistors (0603)
R30	1	1.3kΩ ±1% resistor (0603)
R31	1	2kΩ ±1% resistor (0603)
R32	1	10kΩ ±1% NTC thermistor, ß = 3380 (0603) Murata NCP18XH103F03RB TDK NTCG163JH103F
R36	1	6.81kΩ ±1% resistor (0603)
SW1	1	6-position low-profile DIP switch
SW2	1	2-position low-profile DIP switch
TP1, TP2, TP3, VID0–VID5, VID_VCC	0	Not installed, test points
U1	1	1-phase Quick PWM controller (28 TQFN-EP*) Maxim MAX17409GTI+
—	1	PCB: MAX17409 EVALUATION KIT+

**EP = Exposed pad.*

Component Suppliers

SUPPLIER	PHONE	WEBSITE
AVX Corporation	843-946-0238	www.avxcorp.com
Central Semiconductor Corp.	631-435-1110	www.centralsemi.com
Fairchild Semiconductor	888-522-5372	www.fairchildsemi.com
Murata Electronics North America, Inc.	770-436-1300	www.murata-northamerica.com
NEC TOKIN America, Inc.	408-324-1790	www.nec-tokinamerica.com
Nihon Inter Electronics Corp.	847-843-7500	www.niec.co.jp
Panasonic Corp.	800-344-2112	www.panasonic.com
SANYO Electric Co., Ltd.	619-661-6835	www.sanyodevice.com
Taiyo Yuden	800-348-2496	www.t-yuden.com
TDK Corp.	847-803-6100	www.component.tdk.com
TOKO America, Inc.	847-297-0070	www.tokoam.com
Vishay	402-563-6866	www.vishay.com

Note: *Indicate that you are using the MAX17409 when contacting these component suppliers.*

Quick Start

Recommended Equipment

- 7V to 24V, > 50W power supply, battery, or notebook AC adapter
- 5V at 1A DC bias power supply
- Dummy load capable of sinking 14A
- Digital multimeter (DMM)
- 100MHz dual-trace oscilloscope

Procedure

The MAX17409 EV kit is fully assembled and tesed. Follow the steps below to verify board operation. **Caution: Do not turn on the power supply until all connections are completed.**

1) Ensure that the circuit is connected correctly to the supplies and dummy load prior to applying any power.
2) Verify that all positions of SW2 are set to the on positions.

   The DAC code settings (D0–D5) are set by switch SW1. Set SW1 (1, 12), SW1 (3, 10) and SW1 (4, 9) to the on positions. The output voltage is set for 0.9000V.
3) Turn on the battery power before turning on the 5V bias power.
4) Observe the 0.9000V output voltage with the DMM and/or oscilloscope. Look at the LX switching-node and MOSFET gate-drive signals while varying the load current.

Detailed Description of Hardware

The MAX17409 14A, 1-phase buck-regulator design is optimized for a 300kHz switching frequency and output-voltage settings of approximately 0.9000V. At V_{OUT} = 0.9000V and V_{BATT} = 12V, the inductor ripple is approximately 30% (LIR = 0.3).

Setting the Output Voltage

The MAX17409 has an internal digital-to-analog converter (DAC) that programs the output voltage. The output voltage can be digitally set from 0.3375V to 1.1250V (see Table 1) using the D0–D5 pins. There are two ways to set the output voltage:

- **Drive the external VID0–VID5 inputs (all SW1 positions are off):** The output voltage is set by driving VID0–VID5 with open-drain drivers (pullup resistors are included on the board) or 3V/5V CMOS output logic levels.
- **Switch SW1:** When SW1 positions are off, the MAX17409's D0–D5 inputs are at logic 1 (connected to VDD). When SW1 positions are on, D0–D5 inputs are at logic 0 (connected to GND). The output voltage is changed during operation by activating SW1 on and off. As shipped, the EV kit is configured with SW1 positions set for 0.9000V output (see Table 1). Refer to the MAX17409 IC data sheet for more information.

Table 1. Output-Voltage VID DAC Codes Adjustment Settings

D5	D4	D3	D2	D1	D0	OUTPUT VOLTAGE (V)
1	0	0	0	0	0	1.1250
1	0	0	0	0	1	1.1125
1	0	0	0	1	0	1.1000
1	0	0	0	1	1	1.0875
1	0	0	1	0	0	1.0750
1	0	0	1	0	1	1.0675
1	0	0	1	1	0	1.0500
1	0	0	1	1	1	1.0375
1	0	1	0	0	0	1.0250
1	0	1	0	0	1	1.0125
1	0	1	0	1	0	1.0000
1	0	1	0	1	1	0.9875
1	0	1	1	0	0	0.9750
1	0	1	1	0	1	0.9625
1	0	1	1	1	0	0.9500
1	0	1	1	1	1	0.9375
1	1	0	0	0	0	0.9250
1	1	0	0	0	1	0.9125
1	**1**	**0**	**0**	**1**	**0**	**0.9000**
1	1	0	0	1	1	0.8875
1	1	0	1	0	0	0.8750
1	1	0	1	0	1	0.8625
1	1	0	1	1	0	0.8500
1	1	0	1	1	1	0.8375
1	1	1	0	0	0	0.8250
1	1	1	0	0	1	0.8125
1	1	1	0	1	0	0.8000
1	1	1	0	1	1	0.7875
1	1	1	1	0	0	0.7750
1	1	1	1	0	1	0.7625
1	1	1	1	1	0	0.7500
1	1	1	1	1	1	0.7375
0	0	0	0	0	0	0.7250
0	0	0	0	0	1	0.7125
0	0	0	0	1	0	0.7000
0	0	0	0	1	1	0.6875
0	0	0	1	0	0	0.6750
0	0	0	1	0	1	0.6625
0	0	0	1	1	0	0.6500
0	0	0	1	1	1	0.6275
0	0	1	0	0	0	0.6250
0	0	1	0	0	1	0.6125
0	0	1	0	1	0	0.6000
0	0	1	0	1	1	0.5875
0	0	1	1	0	0	0.5750
0	0	1	1	0	1	0.5625
0	0	1	1	1	0	0.5500
0	0	1	1	1	1	0.5275
0	1	0	0	0	0	0.5250
0	1	0	0	0	1	0.5125
0	1	0	0	1	0	0.5000
0	1	0	0	1	1	0.4875
0	1	0	1	0	0	0.4750
0	1	0	1	0	1	0.4625
0	1	0	1	1	0	0.4500
0	1	0	1	1	1	0.4275
0	1	1	0	0	0	0.4250
0	1	1	0	0	1	0.4125
0	1	1	0	1	0	0.4000
0	1	1	0	1	1	0.3875
0	1	1	1	0	0	0.3750
0	1	1	1	0	1	0.3625
0	1	1	1	1	0	0.3500
0	1	1	1	1	1	0.3375

Switch SW2 Settings

Switch SW2 controls the MAX17409 operating modes (see Table 2).

Dynamic Output-Voltage Transition Experiment

This MAX17409 EV kit is set to transition the output voltage at 12.5mV/µs.

During the voltage transition, watch the inductor current by looking at the current-sense inputs with a differential scope probe. Observe the low, well-controlled inductor current that accompanies the voltage transition. Slew-rate control during shutdown and startup results in well-controlled currents in to and out of the battery (input source).

There are two methods to create an output-voltage transition. Select D0–D5 (SW1). Then manually change the SW1 settings to a new VID code setting (see Table 1) or disable all SW1 settings and drive the VID0–VID5 PCB test points externally to the desired code settings.

Table 2. MAX17409 Operating Mode Truth Table

$\overline{SHDN}$ SW2 (1, 4)	SKIP SW2 (2, 3)	OPERATING MODE	DESCRIPTION
GND	X	Disabled	Low-Power Shutdown Mode. DL forced low and the controller is disabled. The supply current drops to 10µA (max).
Rising	X	Pulse-skipping 1.56mV/µs slew rate	Startup. When $\overline{SHDN}$ is pulled high, the MAX17409 begins the startup sequence. The controller enables the PWM controller and ramps the output voltage up to the boot voltage.
High	Low	Forced-PWM 12.5mV/µs slew rate	Full Power. The no-load output voltage is determined by the selected VID DAC code.
High	High	Pulse-skipping 12.5mV/µs slew rate	Skip Mode. The no-load output voltage is determined by the selected VID DAC code. When SKIP is pulled high, the MAX17409 immediately enters 1-phase pulse-skipping operation allowing automatic PWM/PFM switchover under light loads. The PWRGD upper threshold is blanked during the transition.
Falling	X	Forced-PWM 1.56mV/µs slew rate	Shutdown. When $\overline{SHDN}$ is pulled low, the MAX17409 immediately pulls PWRGD low, and the output voltage is ramped down to ground. Once the output reaches 0V, the controller enters the low-power shutdown state.
High	X	Disabled	Fault Mode. The fault latch has been set by the MAX17409 UVP or thermal shutdown protection, or by the OVP protection. The controller remains in fault mode until V_{CC} power is cycled or $\overline{SHDN}$ is toggled.

X = Don't care.

Load-Transient Experiment

One interesting experiment is to subject the output to large, fast-load transients and observe the output with an oscilloscope. Accurate measurement of output ripple and load-transient response invariably requires that ground clip leads be completely avoided, and that the probe be removed to expose the GND shield, so the probe is directly grounded with as short a wire as possible to the board. Otherwise, EMI and noise pickup corrupt the waveforms.

Most bench-top electronic loads intended for power-supply testing lack the ability to subject the DC-DC coverter to ultra-fast load transients. Emulating the supply current dI/dt at the VOUT pins requires at least 500A/µs load transients. One easy method for generating such an abusive-load transient is to install a power MOSFET at the N4 location and install resistor R14 between 5mΩ and 10mΩ to monitor the transient current. Then drive its gate (TP1) with a strong pulse generator at a low duty cycle (< 5%) 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. To determine how much load current a particular pulse-generator amplitude is causing, observe the current through inductor L1. In the buck topology, the load current is approximately equal to the average value of the inductor current.

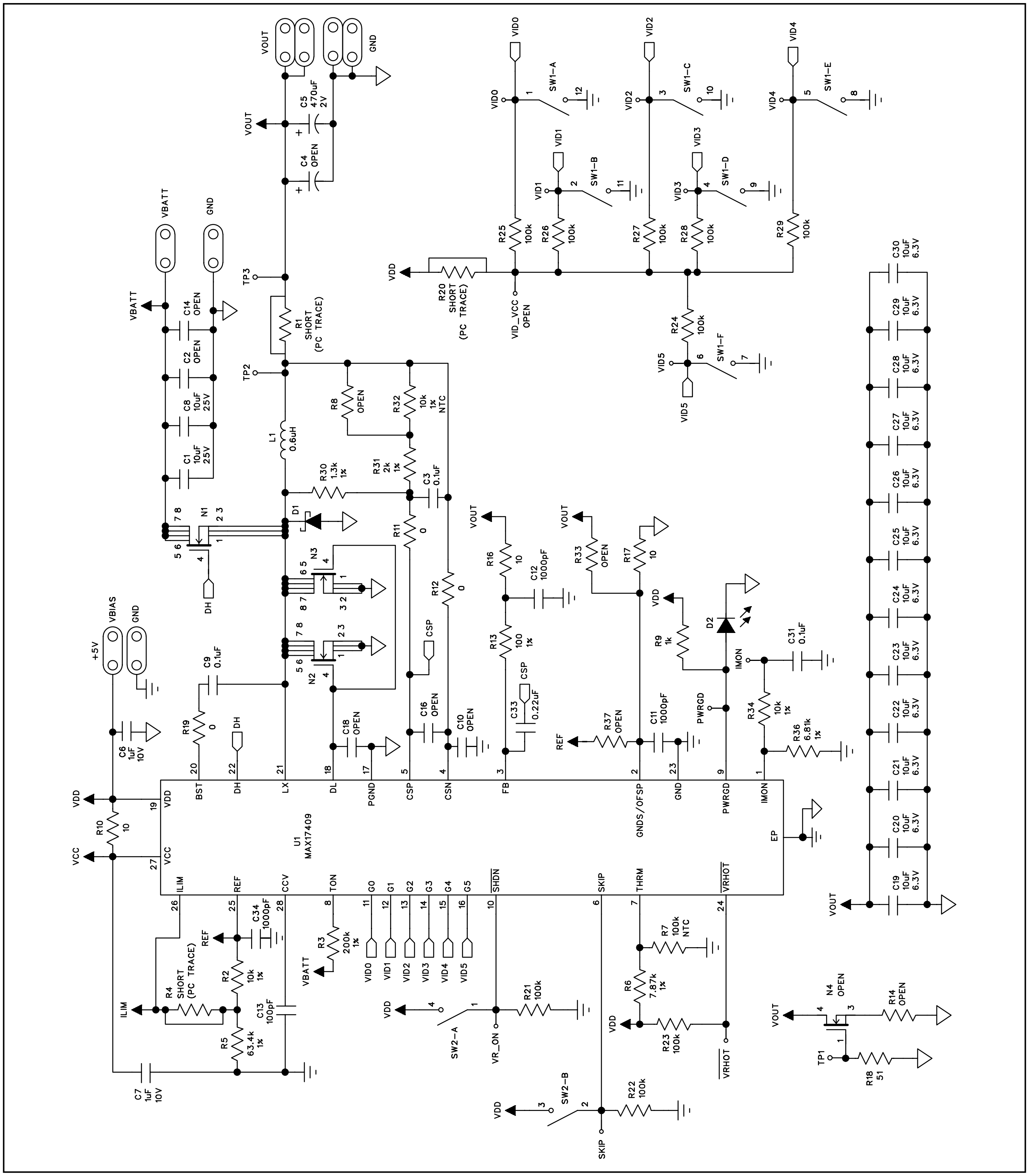

Figure 1. MAX17409 EV Kit Schematic

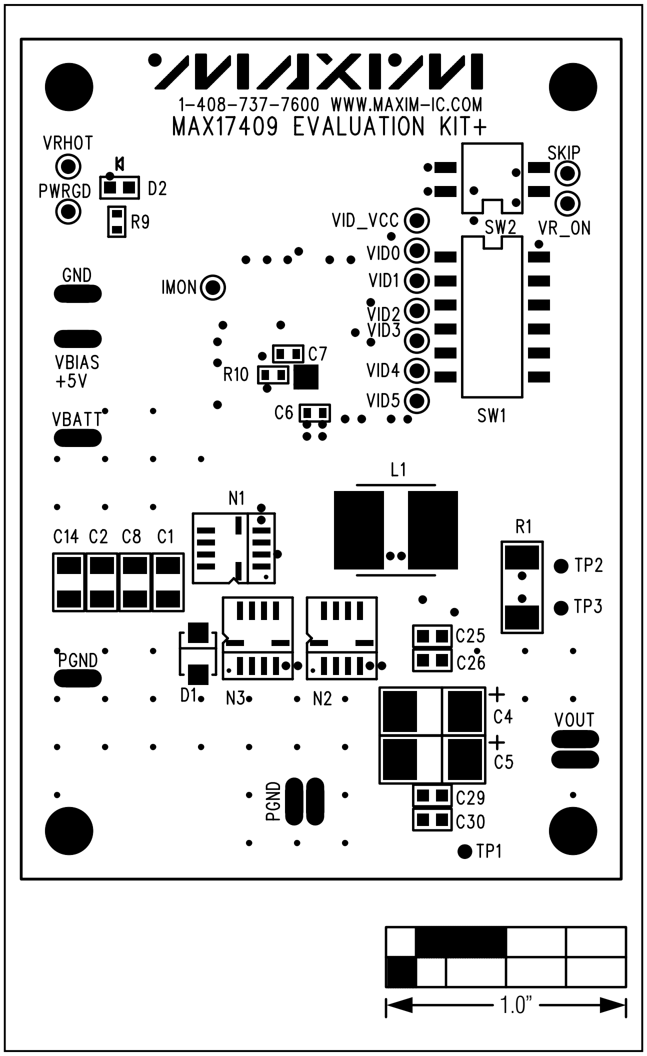

Figure 2. MAX17409 EV Kit Component Placement Guide—Component Side

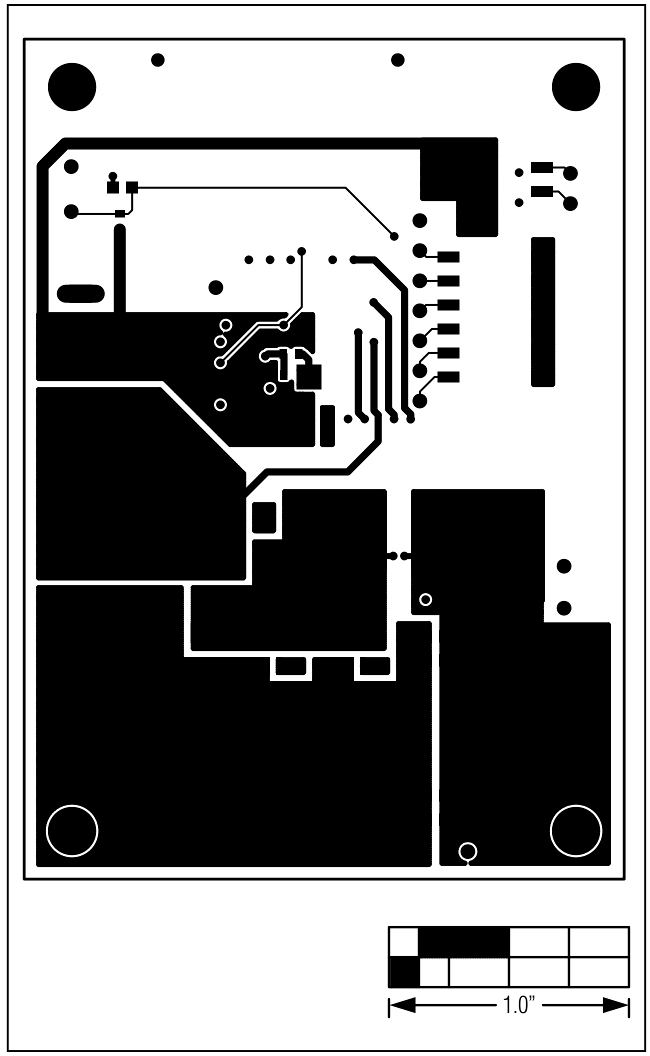

Figure 3. MAX17409 EV Kit PCB Layout—Component Side

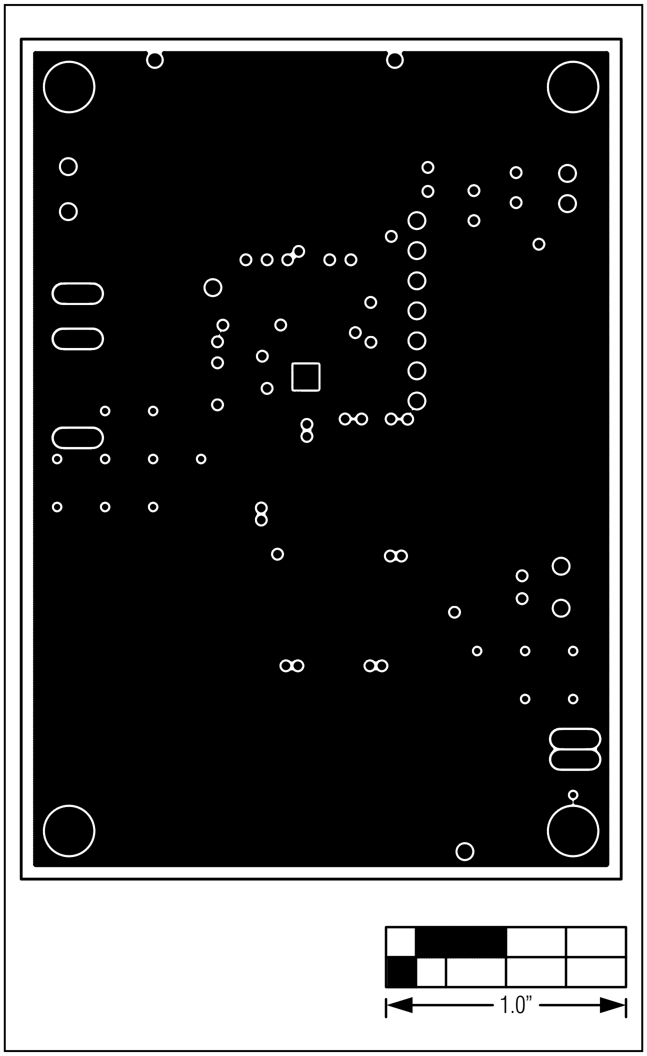

Figure 4. MAX17409 EV Kit PCB Layout—Internal Layer 2 (PGND Plane)

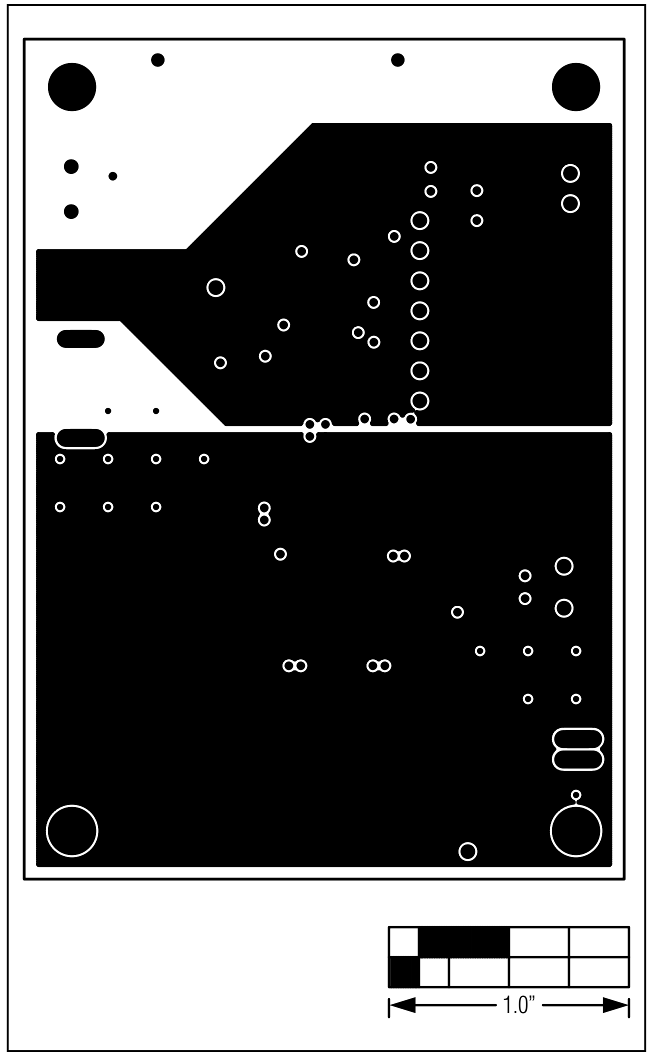

Figure 5. MAX17409 EV Kit PCB Layout—Internal Layer 3 (GND/PGND Layer)

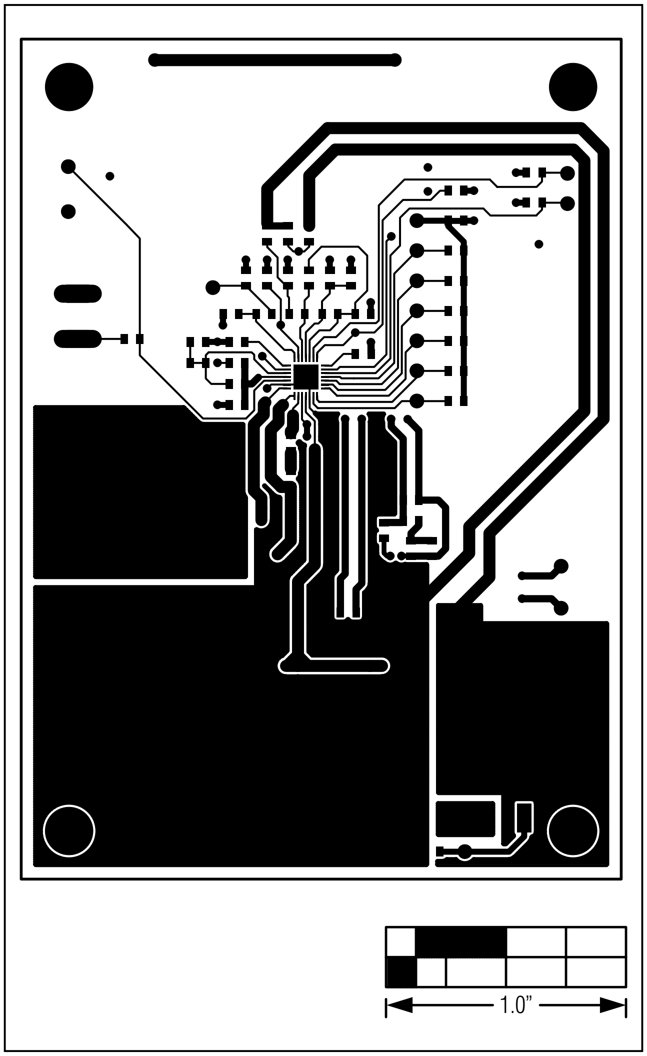

Figure 6. MAX17409 EV Kit PCB Layout—Solder Side

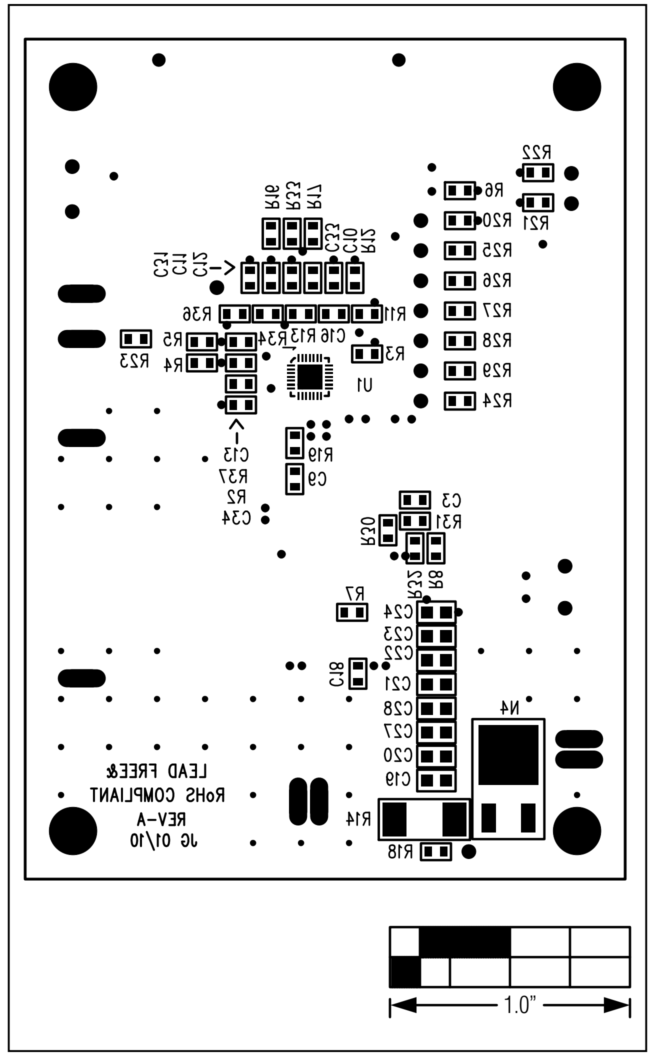

Figure 7. MAX17409 EV Kit Component Placement Guide—Solder Side