19-2986; Rev 0; 9/03

MAXIM

MAX5051 Evaluation Kit

General Description

The MAX5051 evaluation kit (EV kit) is a fully assembled and tested circuit board that contains a high-efficiency, 50W, isolated, synchronously rectified forward converter in the industry-standard 1/8th brick pinout. The circuit is configured for a +3.3V output voltage and provides up to 15A of output current. The circuit can be powered from either a +36V to +72V or -36V to -72V DC source used in the telecom/datacom markets (48V modules), industrial environments, or in automotive 42V power systems.

Up to 91% high efficiency is achieved at 10A using a clamped, two-transistor power topology on the primary side and synchronous rectifiers on the secondary side. Part of the efficiency improvement is due to the recovery of stored leakage and magnetizing inductance energy at the primary side. On the secondary side, high efficiency is achieved through synchronous rectification. Up to 500V galvanic isolation is achieved by optocouplers and a planar surface-mount transformer.

Operation at 250kHz allows the use of small magnetics and output capacitors. The EV kit provides cycle-by cycle current-limit protection. Integrating fault protection provides additional steady-state fault protection that reduces average dissipated power during continuous short-circuit conditions. The MAX5051 also has a programmable undervoltage lockout (UVLO).

Warning: *The MAX5051 EV kit is designed to operate with high voltages. Dangerous voltages are present on this EV kit and on equipment connected to it. Users who power up this EV kit or power the sources connected to it must be careful to follow safety procedures appropriate to working with high-voltage electrical equipment.*

Under severe fault or failure conditions, this EV kit may dissipate large amounts of power, which could result in the mechanical ejection of a component or of component debris at high velocity. Operate this EV kit with care to avoid possible personal injury.

Features

- ♦ 50W, High-Efficiency, Isolated Forward Converter
- ♦ Synchronous Rectified
- ♦ ±36V to ±72V Input Range
- ♦ +3.3V Output at 15A
- ♦ V_{OUT} Regulation Better than 0.5% Over Line and Load
- ♦ 91% Efficiency at 3.3V/10A Output
- ♦ Cycle-by-Cycle Current-Limit Protection
- ♦ Programmable Integrating Fault Protection
- ♦ 1/8th Brick Module Pinout
- ♦ 250kHz Switching Frequency
- ♦ Soft-Start
- ♦ Remote Output Voltage Sense
- ♦ Output Voltage Trim Pin
- ♦ Fully Assembled and Tested

Ordering Information

PART	TEMP RANGE	IC PACKAGE
MAX5051EVKIT	0°C to +50°C*	28 TSSOP

*With 100LFM airflow.

Component List

DESIGNATION	QTY	DESCRIPTION
C1	1	100pF ±2%, 50V C0G ceramic capacitor (0603) Murata GRM1885C1H101GA01D
C2	1	390pF ±5%, 50V C0G ceramic capacitor (0603) Taiyo Yuden UMK107CH391JZ
C3	1	4.7µF ±10%, 10V X5R ceramic capacitor (0805) TDK C2012X5R1A475K
C4	1	4.7µF ±10%, 6.3V X5R ceramic capacitor (0805) TDK C2012X5R0J475K
C5	1	4700pF ±10%, 50V X7R ceramic capacitor (0603) TDK C1608X7R1H472K

Evaluates: MAX5051

Component List (continued)

DESIGNATION	QTY	DESCRIPTION
C6	1	0.1µF ±10%, 250V X7R ceramic capacitor (1206) TDK C3216X7R2E104K
C7, C36	2	0.22µF ±10%, 10V X7R ceramic capacitors (0603) TDK C1608X7R1C224K
C8	1	4.7µF ±10%, 16V X7R ceramic capacitor (1206) TDK C3216X7R1C475K
C9	1	1µF ±10%, 16V X7R ceramic capacitor (0805) Taiyo Yuden EMK212BJ105KG
C10, C11	2	0.47µF ±10%, 100V X7R ceramic capacitors (1206) TDK C3216X7R2A474K
C12	1	1µF ±20%, 100V X7R ceramic capacitor (1210) TDK C3225X7R2A105M or AVX12101C105KAT9A
C13, C14, C15	3	270µF, 4V aluminum organic capacitors (X) Kemet A700X277M004AT
C16	1	3.3µF ±10%, 6.3V X5R ceramic capacitor (0805) Taiyo Yuden JMK212BJ335KG
C17	1	0.33µF ±10%, 10V X5R ceramic capacitor (0603) TDK C1608X5R1A334K
C18, C24	2	1000pF ±5%, 50V C0G ceramic capacitors (0603) TDK C1608C0G1H102J
C19, C33	2	1µF ±10%, 10V X5R ceramic capacitors (0603) TDK C1608X5R1A105K
C20	1	220pF ±10%, 50V C0G ceramic capacitor (0603) TDK C1608C0G1H221K
C21	1	4.7µF, 80V electrolytic capacitor (D) Cornell Dubilier AFK475M80D16B

DESIGNATION	QTY	DESCRIPTION
C22	1	2200pF ±10%, 2kV X7R ceramic capacitor (1812) TDK C4532X7R3D222K
C23	1	1000pF, 250V X7R ceramic capacitor (0603) Murata GRM188R72E102KW07
C25	1	0.047µF ±10%, 100V X7R ceramic capacitor (0805) TDK C2012X7R2A473K
C26, C29, C30, C31	4	0.1µF ±10%, 16V X7R ceramic capacitors (0603) TDK C1608X7R1C104K
C27	1	0.15µF ±10%, 16V X7R ceramic capacitor (0603) Taiyo Yuden EMK107BJ154KA
C28	1	0.047µF ±10%, 25V X7R ceramic capacitor (0603) TDK C1608X7R1E473K
C32, C35	2	1µF ±10%, 25V X7R ceramic capacitors (0805) TDK C2012X7R1E105K
C34	1	330pF ±5%, 250V C0G ceramic capacitor (0603) TDK C1608C0G2E331J
D1	1	150mA, 100V Schottky diode (SOD-123) Diodes Incorporated BAT46W
D2, D3	2	2A, 100V Schottky diodes (SMB) Diodes Incorporated B2100
D4, D7	2	3A, 20V Schottky diodes (SMA) Diodes Incorporated B320A
D5, D6, D8	3	250mA, 100V fast-switching diodes (SOD-323) Diodes Incorporated 1N4448HWS
L1	1	2.4µH, 20A inductor Payton Planar Magnetics Ltd. 50661 or Pulse Engineering PA1494-242 or Coilcraft A9860-B*

Component List (continued)

DESIGNATION	QTY	DESCRIPTION
N1, N2	2	100V, 7.3A N-channel MOSFETs (8-pin SO) IR IRF7495 or Vishay Siliconix Si4486EY
N3, N4	2	20V, 20A N-channel MOSFETs (8-pin SO) IR IRF7832 or Vishay Siliconix Si4864DY
N5	1	170mA, 100V N-channel MOSFET (SOT23) Fairchild BSS123
R1	1	11.5kΩ ±1% resistor (0603)
R2	1	2.55kΩ ±1% resistor (0603)
R3	1	2.2kΩ ±5% resistor (0603)
R4	1	1MΩ ±1% resistor (0603)
R5	1	38.3kΩ ±1% resistor (0603)
R6	1	1MΩ ±1% resistor (0805)
R7, R20	2	0Ω ±5% resistors (0603)
R8, R9	2	8.2Ω ±5% resistors (0603)
R10	1	20Ω ±5% resistor (1206)
R11	1	360Ω ±5% resistor (0603)
R12	1	100kΩ ±1% resistor (0603)
R13	1	47Ω ±5% resistor (1206)
R14	1	270Ω ±5% resistor (0603)
R15	1	31.6kΩ ±1% resistor (0603)
R16	1	10.5kΩ ±1% resistor (0603)
R17	1	0.027Ω ±1%, 0.5W resistor (1206) IRC LR1206-01-R027-F
R18	1	4.7Ω ±5% resistor (1206)
R19	1	475Ω ±1% resistor (0805)
R21	1	24.9kΩ ±1% resistor (0805)
R22	1	15kΩ ±5% resistor (1206)

DESIGNATION	QTY	DESCRIPTION
R23, R24	2	10Ω ±5% resistors (0805)
R25	1	100kΩ ±5% resistor (0805)
R26	1	560Ω ±5% resistor (0805)
R27	1	10Ω ±5% resistor (0603)
R28	1	2kΩ ±5% resistor (0805)
R29	1	1Ω ±5% resistor (0603)
T1	1	Planar transformer Pulse Engineering PA0370 or Payton Planar Magnetics Ltd. 50659*
U1	1	MAX5051AUI (28-pin TSSOP)
U2	1	High-speed, high-voltage photocoupler (ultra small flat lead) CEL/NEC PS2913-1-F3-M
U3	1	0.6V ±0.5% shunt regulator (5-pin SOT23) Maxim MAX8515AEZK-T
U4, U7	2	7.6A MOSFET drivers (6-pin SOT23) Maxim MAX5048AAUT-T
U5	1	65V high-voltage linear regulator (8-pin SO) Maxim MAX5023MASA
U6	1	10Mbps photocoupler (5-pin SOP) CEL/NEC PS9715-F3
+VIN, -VIN, ON/OFF, SENSE(+), SENSE(-), TRIM	6	0.040in PC pins
VOUT, SGND	2	0.062in PC pins
None	1	MAX5051 PC board

**Modifications to the PC board traces are required to evaluate this component.*

Quick Start

Required Equipment

- ±36V to ±72V power supply capable of providing up to 3A
- Voltmeter
- A fan to provide at least 100LFM airflow for extended operation at 15A
- 100µF, 100V bulk storage capacitor to be connected to the input terminals of the EV kit

The MAX5051 EV kit is fully assembled and tested. Follow these steps to verify board operation. **Do not turn on the power supply until all connections are completed.**

Forward DC-DC Converter No-Load Output

1) Connect a jumper wire from the VOUT terminal to the SENSE(+) terminal.
2) Connect a jumper wire from the SGND terminal to the SENSE(-) terminal.
3) Connect a voltmeter to the SENSE(+) and SENSE(-) terminals to measure the output voltage.

4) Connect a 100µF, 100V bulk storage capacitor to the top of the $+V_{IN}$ and $-V_{IN}$ pins.
5) Connect the positive terminal of a 36V to 72V power supply to the +VIN terminal. Connect the power supply's ground to the -VIN terminal.
6) Turn on the power supply above 36V and verify that the voltmeter reads +3.3V.

Detailed Description

The MAX5051 EV kit is a 50W isolated forward converter that provides +3.3V at up to 15A output. The circuit can be powered from a ±36V to ±72V DC source. **The user should supply an additional 100µF bulk storage capacitor between the input terminals (+VIN, -VIN).** This capacitor should be rated for 100V and be able to carry 1.5A of ripple current. Lower ripple-current-rated capacitors should be fine for short-term operation.

The 50W forward converter achieves high efficiency by using a clamped two-transistor power topology at the input power stage. The PC board footprint is minimized by using two external surface-mount, 8-pin SO N-channel, 100V-rated MOSFETs. Cycle-by-cycle current limiting protects the converter against short circuits at the output. For a continuous short circuit at the output, the MAX5051's fault integration feature provides hiccup fault protection, thus greatly minimizing destructive temperature rise. Current-sense resistor R17 senses the current through the primary of transformer T1 and turns off both external transistors N1 and N2 when the trip level of 154mV (typ) is reached. The programmable integrating fault protection allows transient overload conditions to be ignored and is configured by resistor R4 and capacitor C7.

The planar surface-mount transformer features a bias winding that (along with diode D5, current-limiting resistor R18, and reservoir capacitor C21) power the MAX5051 once the input voltage is stable. Upon initial input voltage application, bootstrap resistor R22 and capacitor C21 enable the MAX5051 to start up within approximately 70ms. No reset windings are required on the transformer with a clamped two-transistor power topology simplifying transformer design and maximizing the available copper window in the transformer. When both external primary-side transistors turn off, Schottky diodes D2 and D3 recover the magnetic energy stored in the core and feed it back to the input supply. The transformer provides galvanic isolation up to 500V.

On the transformer's secondary side, a 0.6V shunt regulator (MAX8515, U3) along with feedback resistors R1 and R2 provide voltage feedback to the primary side through optocoupler U2. Remote output voltage sensing is provided by the SENSE(+) and SENSE(-) pins for accurate output voltage regulation across the load. The MAX5051 receives the voltage feedback signal on the primary side from biasing resistors R15, R16, and compensation resistor-capacitor network R11/C17 and C24 connected to optocoupler U2.

Optocoupler U6 receives the MAX5051 synchronous rectifier drive signal from the primary side and provides the MAX5048 secondary-side high-speed MOSFET drivers, U4 and U7, with a galvanically isolated signal. MOSFET N4 forms a synchronous rectifier for freewheeling-diode D4 and MOSFET N3 forms the synchronous rectifier for rectifier-diode D7. Voltage regulation for U4, U6, and U7 is provided by a MAX5023 linear regulator on the secondary side.

The MAX5051 controller switches at 250kHz frequency set by resistor R21 and capacitor C1. The duty cycle is varied to control energy transfer to the output. The maximum duty cycle is 50% for the EV kit's forward converter design.

The MAX5051 features output-voltage soft-start, thus eliminating any output-voltage overshoots. Soft-start allows the output voltage to slowly ramp up in a controlled manner within approximately 3ms. Capacitor C5 sets the soft-start time.

The brownout UVLO threshold voltage is set by resistors R5 and R6. This prevents the power supply from operating below the programmed input supply voltage.

The four-layer PC board layout and component placement have been designed to have an industry-standard 1/8th brick pinout. The actual PC board dimensions (58.42mm x 41.65mm) of the power-supply board are somewhat larger than that of 1/8th brick power supplies.

Evaluating Other Output Voltages, Current Limits, Soft-Starts, and UVLOs

VOUT Output Voltage

The MAX5051 EV kit's output (VOUT) is set to +3.3V by feedback resistors (R1, R2). To generate output voltages other than +3.3V (from +2.6V to +4.0V, limited by the output-capacitor voltage rating), select different voltage-divider resistors (R1, R2). Resistor R1 is typically chosen to be less than 25kΩ. Using the desired output voltage, resistor R2 is then found by the following equation:

$$R2 = \frac{R1}{\left((VOUT/V_{REF}) - 1\right)}$$

where V_{REF} = 0.6V

The maximum output current should be limited to less than 15A. The usable output voltage range for the EV kit is +2.6V to +4.0V. Additionally, U3, U2, and resistor R19 limit the minimum output voltage (VOUT) to +2.6V.

Current Limiting

The EV kit features cycle-by-cycle current limiting of the transformer primary current. The MAX5051 turns off both external switching transistors (N1, N2) when the voltage at the CS pin of the MAX5051 reaches 154mV (typ). Current-sense resistor R17 (= 0.027Ω) limits the peak primary current to approximately 5.7A (154mV/0.027Ω ≈ 5.7A). This limits short-circuit current on the secondary output (VOUT) to 20.3A peak typically. Under short-circuit conditions, the average output current is only 473mA typically due to hiccup-mode fault protection. To evaluate lower current limits, current-sense resistor R17 must be replaced with a different value surface-mount resistor (1206 size) as determined by the following equation:

$$R17 = \frac{V_{SENSE}}{\left((N_S / N_P) \times (1.2 \times I_{OUTMAX})\right)}$$

where V_{SENSE} = 0.154V, N_S = 2, N_P = 8 and I_{OUTMAX} = maximum DC output current (15A or less). Note that some fine tuning may be required when selecting the current-limit resistor. There are errors introduced as a result of the presence of the transformer and output inductor ripple current.

Soft-Start

The MAX5051 EV kit limits the output voltage rate of rise with a soft-start feature. Capacitor C5 sets the ramp time to 91ms. To evaluate other soft-start ramp times, replace capacitor C5 with another surface-mount capacitor (0603 size) as determined by the following equation:

$$C5 = \frac{(65\mu A \times softstart\_time)}{1.24V}$$

where softstart_time is the desired soft-start time in seconds.

Undervoltage Lockout (UVLO)

The MAX5051 EV kit features a UVLO circuit that prevents operation below the programmed input supply start voltage. Resistors R5 and R6 set the input voltage brownout UVLO of the EV kit. To evaluate other input UVLO voltages, replace resistor R6 with another surface-mount resistor (0805 size). Using the desired startup voltage, resistor R6 is then found by using the following equation:

$$R6 = \left(\frac{(VIN_{STARTUP} - 1.24V)}{1.24V}\right) \times R5$$

where $VIN_{STARTUP}$ is the desired startup voltage at which the EV kit starts and resistor R5 is typically 38.3kΩ.

Component Suppliers

SUPPLIER	PHONE	FAX	WEBSITE
AVX	843-946-0238	843-626-3123	www.avxcorp.com
CEL/NEC; California Eastern Laboratories	800-997-5227	408-588-2213	www.cel.com
Coilcraft	847-639-6400	847-639-1469	www.coilcraft.com
Cornell Dubilier	508-996-8564	508-336-3830	www.cornell-dubilier.com
Diodes Inc	805-446-4800	805-446-4850	www.diodes.com
Fairchild	888-522-5372	Local representative only	www.fairchildsemi.com
International Rectifier	310-322-3331	310-726-8721	www.irf.com
IRC	361-992-7900	361-992-3377	www.irctt.com
Kemet	864-963-6300	864-963-6322	www.kemet.com
Murata	770-436-1300	770-436-3030	www.murata.com
Payton Planar Magnetics Ltd.	561-969-9585	561-989-9587	www.paytongroup.com
Pulse Engineering	858-674-8100	858-674-8262	www.pulseeng.com
Taiyo Yuden	800-348-2496	847-925-0899	www.t-yuden.com
TDK	847-803-6100	847-390-4405	www.component.tdk.com
Vishay	—	—	www.vishay.com

Synchronous Rectified Forward DC-to-DC Converter Waveforms

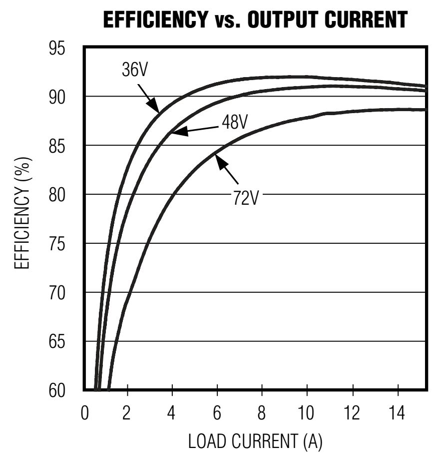

Figure 1. Efficiency vs. Output Current

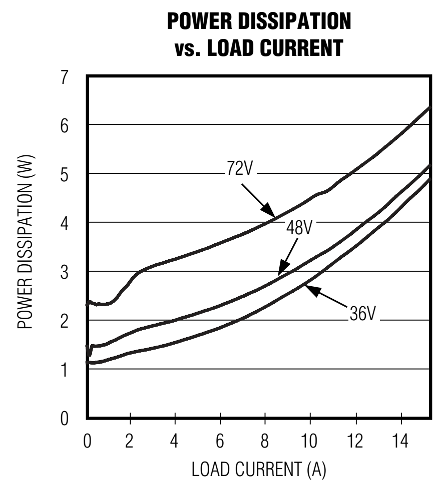

Figure 2. Power Dissipation vs. Load Current

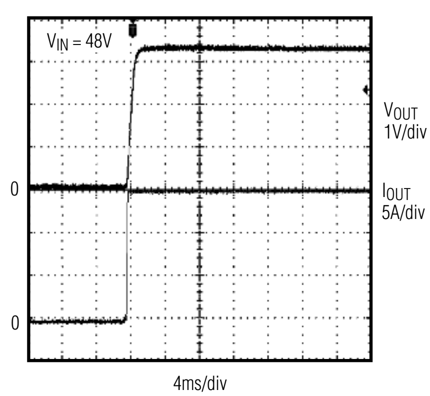

Figure 3. Turn-On Transient at Full Load (Resistive Load)

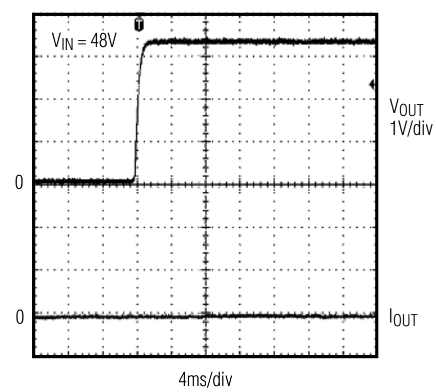

Figure 4. Turn-On Transient at Zero Load

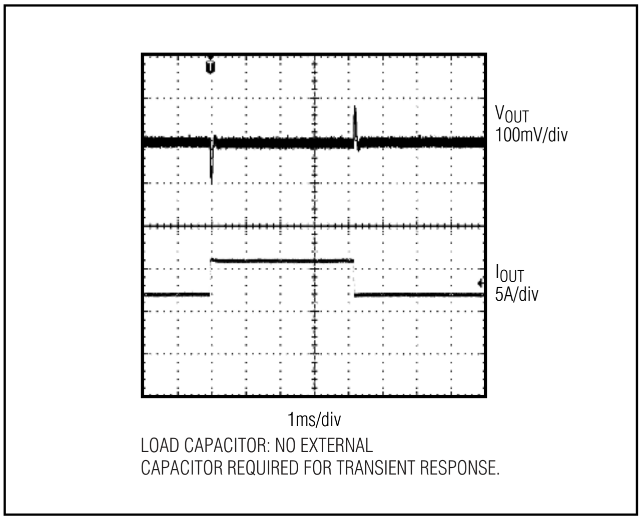

Figure 5. Output Voltage Response to Step Change in Load Current (50%-75%-50% of I_{OUT} (max), di/dt = 5A/ms, 7.5A to 11.25A to 7.5A)

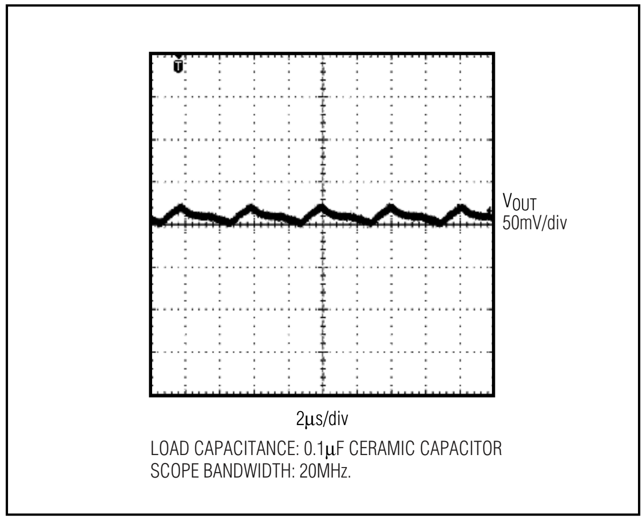

Figure 6. Output Voltage Ripple at Nominal Input Voltage and Rated Load Current

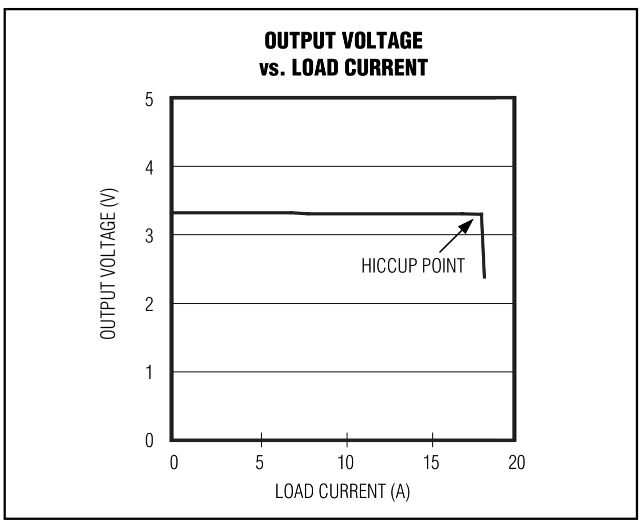

*Figure 7. Output Voltage vs. Load Current Showing Typical Limit Curves and Converter Shutdown Points (**Note:** Hiccup Current Limiting Provides Current Foldback Mechanism that Helps to Minimize Power-Supply Power Dissipation During Fault Conditions)*

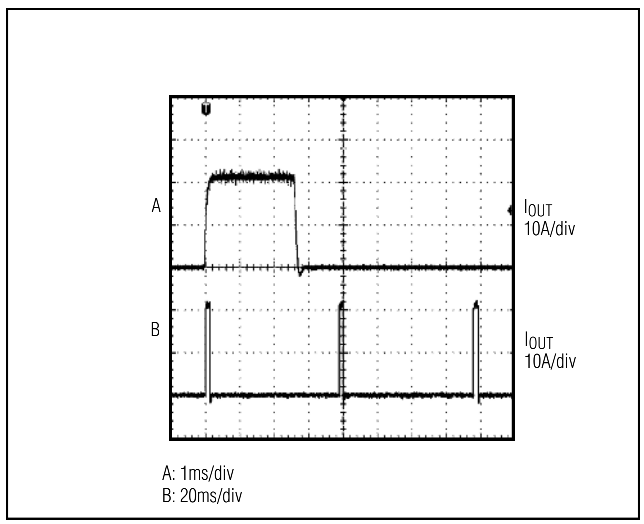

Figure 8. Load Current (10A/div) as a Function of Time when Converter Attempts to Turn On into a 0.050Ω Short Circuit (Also Acts as Current-Sense Resistor)

MAX5051 Evaluation Kit

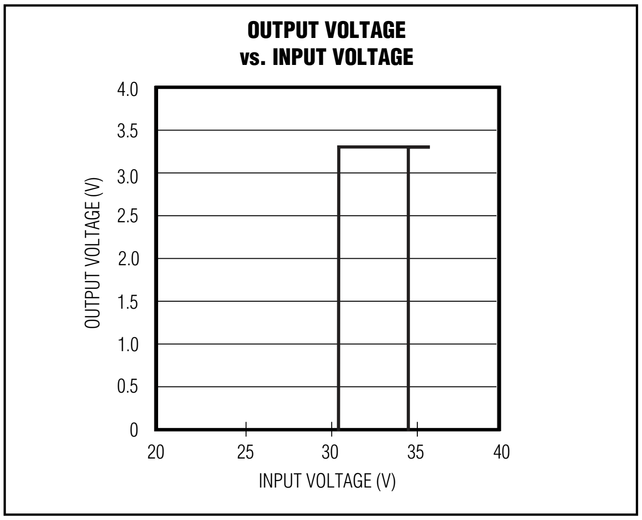

Figure 9. Output Voltage vs. Input Voltage (Point Device Comes Out of Programmed UVLO and Goes Into UVLO)

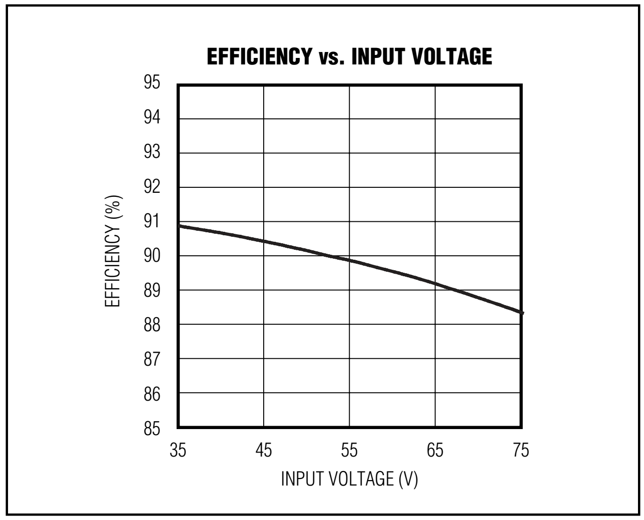

Figure 10. Efficiency vs. Input Voltage, I_{OUT} = 15A

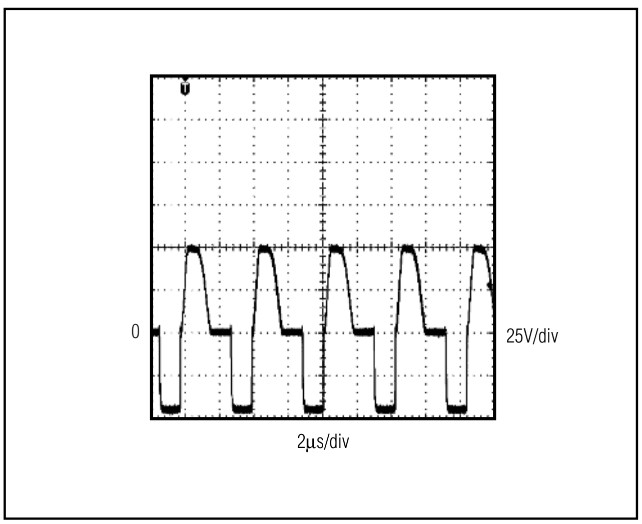

Figure 11. Waveform Across Primary-Side Transformer (T1), Input = 48V

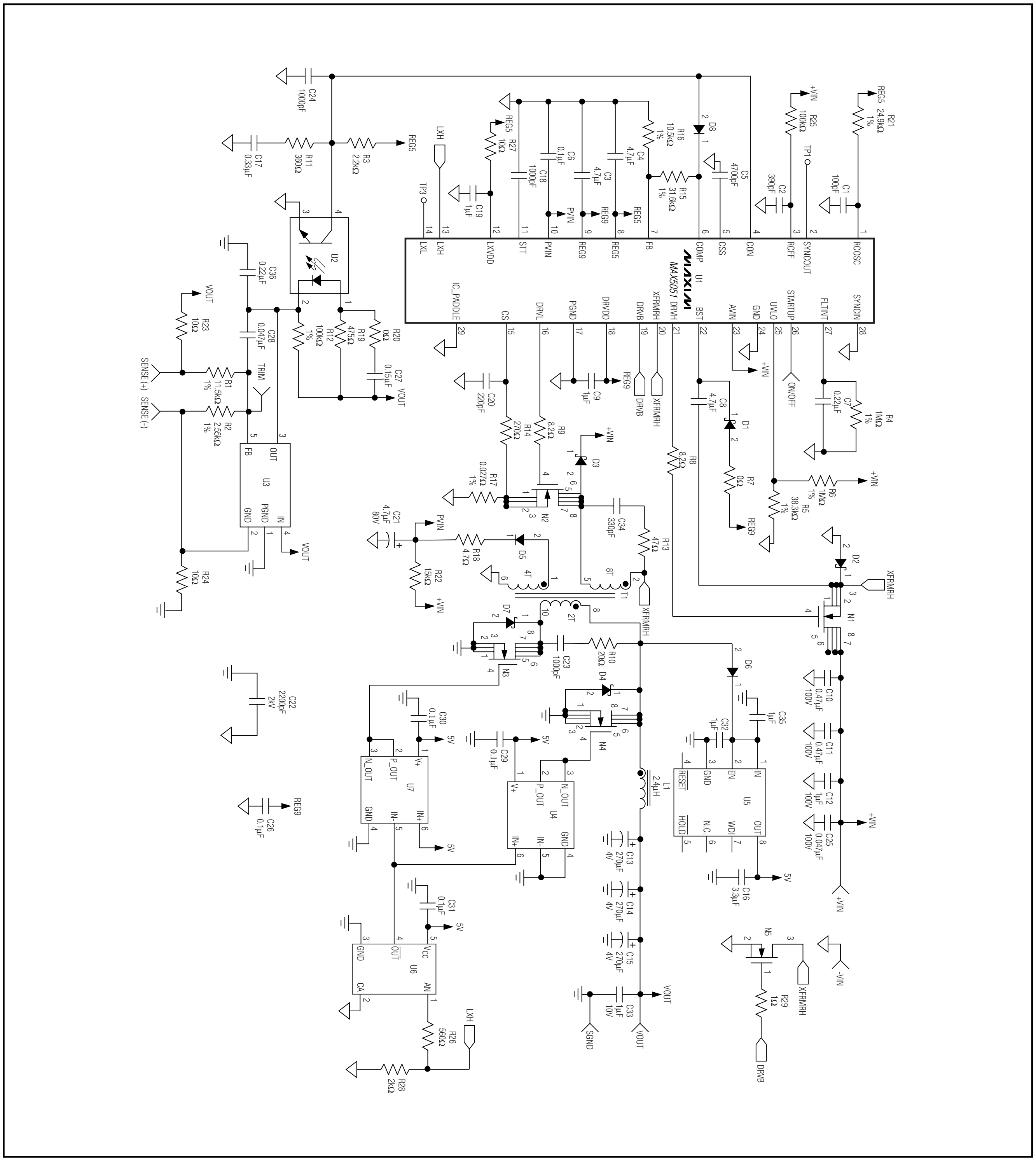

Figure 12. MAX5051 EV Kit Schematic

MAX5051 Evaluation Kit

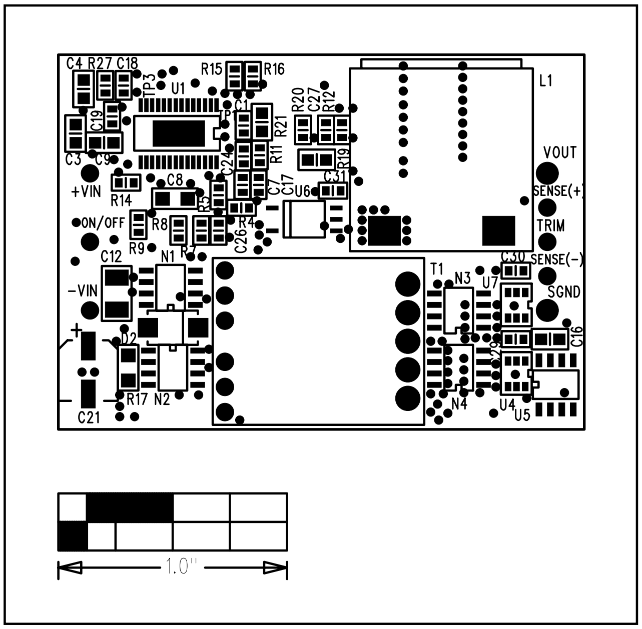

Figure 13. MAX5051 EV Kit Component Placement Guide—Component Side

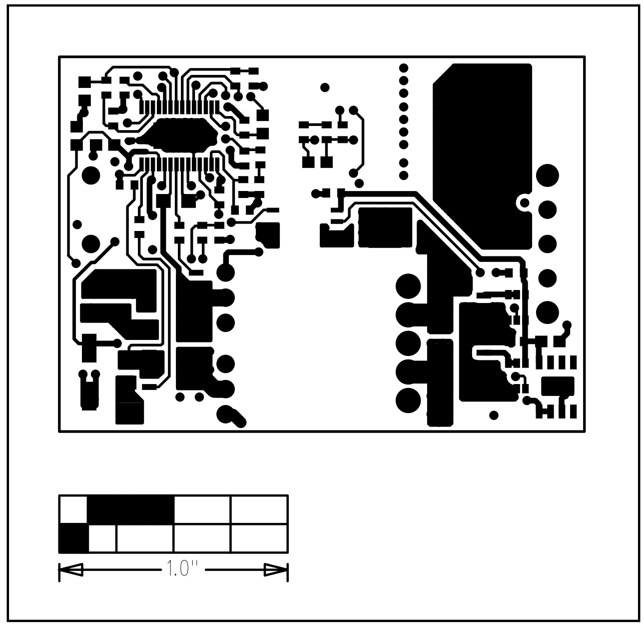

Figure 14. MAX5051 EV Kit PC Board Layout—Component Side

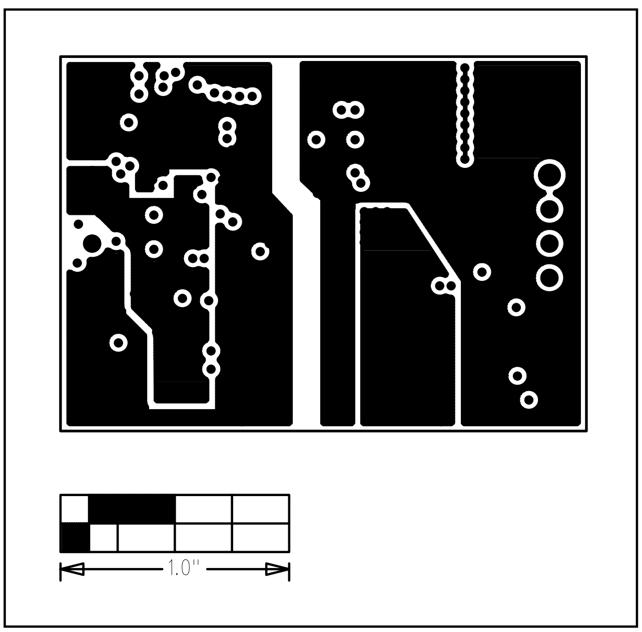

Figure 15. MAX5051 EV Kit PC Board Layout—Inner Layer, GND Plane

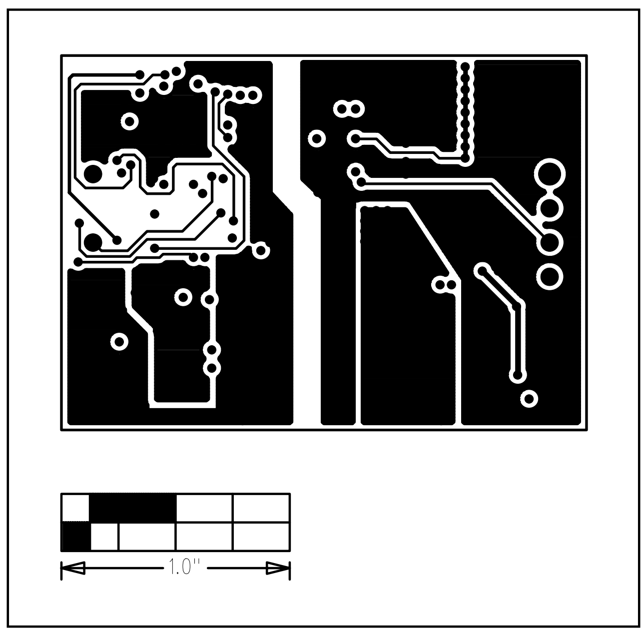

Figure 16. MAX5051 EV Kit PC Board Layout—Inner Layer, V_{CC} Plane

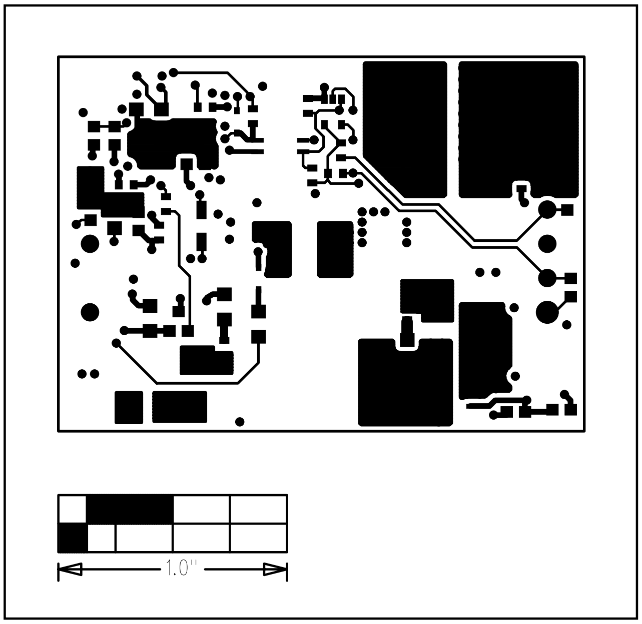

Figure 17. MAX5051 EV Kit PC Board Layout—Solder Side

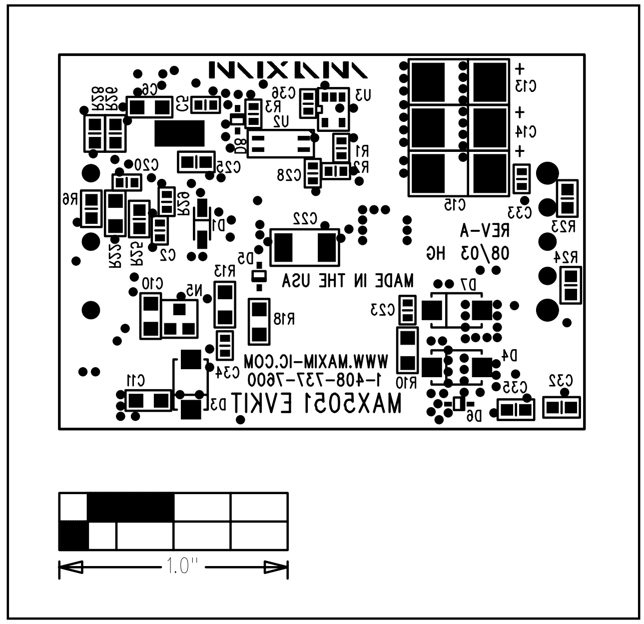

Figure 18. MAX5051 EV Kit Component Placement Guide—Solder Side