**/VI/IXI/VI**

# MAX15000A Evaluation Kit

*Evaluates: MAX15000A*

## General Description

The MAX15000A evaluation kit (EV kit) is a fully assembled and tested circuit board that contains a 9W flyback DC-DC converter. The circuit is configured for +5V and +15V output voltages and provides up to 1.5A and 100mA of current at each respective output. Power for the circuit can be provided from either a +36V to +72V or a -36V to -72V DC source.

High efficiency up to 81% is achieved using a flyback DC-DC converter topology. The surface-mount transformer provides up to 1500V galvanic isolation for both outputs. Low cost is achieved through the use of primary-side regulation while undervoltage lockout (UVLO) and digital soft-start provide for a robust 9W isolated power supply.

Operation at 350kHz allows the use of small magnetics and output capacitors.

**Warning:** The MAX15000A 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 kit with care to avoid possible personal injury.

## Features

♦ **+36V to +72V or -36V to -72V DC Input Range**

♦ **Isolated Outputs**
    **VOUT1: +5V Provides Up to 1.5A**
    **VOUT2: +15V Provides Up to 100mA**

♦ **±5% (typ) Load Regulation for the +5V Output Set Point (150mA to 1.5A)**

♦ **81% Efficiency at 48V Input and Full Load**

♦ **Cycle-by-Cycle Current Limit**

♦ **350kHz Switching Frequency**

♦ **Digital Soft-Start**

♦ **High-Accuracy Undervoltage Lockout (UVLO)**

♦ **Undervoltage Lockout Open-Drain Flag Output**

♦ **Designed for 1500V Isolation with Primary-Side Regulation**

♦ **Low-Cost Flyback Design**

♦ **Fully Assembled and Tested**

## Ordering Information

| PART | TEMP RANGE | IC PACKAGE |
|------|-----------|------------|
| MAX15000AEVKIT | 0°C to +70°C | 10 µMAX® |

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## Component List

| DESIGNATION | QTY | DESCRIPTION |
|-------------|-----|-------------|
| C1, C2 | 2 | 1µF ±10%, 100V X7R ceramic capacitors (1812) TDK C4532X7R2A105K |
| C3 | 1 | 68µF, 6.3V electrolytic capacitor (V) Kemet A700V686M006ATE028 |
| C4 | 1 | 22µF ±20%, 6.3V X5R ceramic capacitor (1206) TDK C3216X5R0J226M |
| C5 | 1 | 47µF, 25V electrolytic capacitor (6.3mm x 5.8mm) Panasonic EEVFK1E470P |
| C6 | 1 | 0.0047µF ±10%, 250VAC X7R ceramic capacitor (1825) Murata GA355DR7GC472KY02L |

| DESIGNATION | QTY | DESCRIPTION |
|-------------|-----|-------------|
| C7, C11 | 2 | 0.22µF ±10%, 50V X7R ceramic capacitors (0805) Murata GRM21BR71H224KA01B |
| C8, C10, C19 | 0 | Not installed, ceramic capacitors (0603) |
| C9 | 1 | 100pF ±2%, 50V C0G ceramic capacitor (0603) Murata GRM1885C1H101G |
| C12 | 1 | 15µF ±10%, 35V tantalum capacitor (D) Kemet T491D156K035AS |
| C13 | 1 | 1µF ±10%, 16V X7R ceramic capacitor (0805) TDK C2012X7R1C105KT |

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## Component List (continued)

| DESIGNATION | QTY | DESCRIPTION |
|---|---|---|
| C14 | 1 | 3900pF ±10%, 50V X7R ceramic capacitor (0603) Murata GRM188R71H392K |
| C15 | 1 | 1µF ±10%, 25V X7R ceramic capacitor (0805) TDK C2012X7R1E105KT |
| C16 | 1 | 1µF ±10%, 50V X7R ceramic capacitor (1206) Murata GRM31MR71H105K |
| C17 | 0 | Not installed, ceramic capacitor (0805) |
| C18 | 1 | 0.1µF ±10%, 25V X7R ceramic capacitor (0603) Murata GRM188R71E104K |
| D1 | 1 | 40V, 10A Schottky diode (POWERMITE 3) Diodes Inc. SBM1040 |
| D2 | 1 | 200V, 1.5A super-fast diode (SMD) Vishay BYG20D |
| D3 | 0 | Not installed, 250V, 250mA high-voltage switching diode (SOD-123) Central Semiconductor CMHD2003 recommended |
| D4 | 1 | 5.6V, 0.5W zener diode (SOD-123) Diodes Inc. BZT52C5V6 |
| D5 | 1 | 18V, 0.5W zener diode (SOD-123) Diodes Inc. BZT52C18 |
| D6 | 1 | 75V, 250mA high-speed diode (SOT23) Central Semiconductor CMPD914 |
| D7 | 0 | Not installed, 14V, 250mW zener diode (SOD-323) Central Semiconductor CMDZ5244B recommended |

| DESIGNATION | QTY | DESCRIPTION |
|---|---|---|
| D8 | 1 | 40V, 0.5A Schottky diode (SOT23) Zetex ZHCS500 |
| JU1 | 1 | 2-pin header |
| L1 | 1 | 3A ferrite bead inductor (1806) Fair-Rite 2518066007Y3 |
| L2 | 1 | 100mA ferrite bead inductor (0805) Fair-Rite 2508051027Y0 |
| N1 | 1 | 200V, 1.2A n-channel MOSFET (SO-8) IR IRF7464 |
| R1 | 1 | 22.6kΩ ±1% resistor (0603) |
| R2 | 1 | 2.49kΩ ±1% resistor (0603) |
| R3 | 1 | 1.37MΩ ±1% resistor (0805) |
| R4 | 1 | 51.1kΩ ±1% resistor (0805) |
| R5 | 1 | 0.600Ω ±1% power resistor (1206) IRC LRC-LR1206-01-R600-F |
| R6 | 1 | 33kΩ ±5% resistor (1206) |
| R7, R12 | 2 | 1.2kΩ ±5% resistors (1206) |
| R8 | 0 | Not installed, resistor (1206) |
| R9 | 1 | 75kΩ ±1% resistor (0603) |
| R10 | 1 | 4.7Ω ±5% resistor (0805) |
| R11 | 1 | 100Ω ±5% resistor (0603) |
| R13 | 1 | 10kΩ ±5% resistor (0805) |
| R14 | 1 | 14.3kΩ ±1% resistor (0805) |
| R15 | 1 | 750Ω ±5% resistor (0603) |
| T1 | 1 | 28µH, 10W, 1:0.536:0.214:0.429 turn 350kHz transformer (10-pin gull wing) Coiltronics CTX03-17492-R |
| **U1** | **1** | **MAX15000AEUB+ (10-pin µMAX)** |
| — | 1 | Shunt, JU1 |
| — | 4 | Rubber bumpers |
| — | 1 | MAX15000A EV kit PC board |

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## Component Suppliers

| SUPPLIER | PHONE | WEBSITE |
|---|---|---|
| Central Semiconductor | 631-435-1110 | www.centralsemi.com |
| Cooper-Coiltronics | 561-752-5000 | www.cooperet.com |
| Dale-Vishay | 402-564-3131 | www.vishay.com |
| Diodes Inc. | 805-446-4800 | www.diodes.com |
| Fair-Rite Products | 845-895-2055 | www.fair-rite.com |
| International Rectifier | 310-322-3331 | www.irf.com |
| IRC | 361-992-7900 | www.irctt.com |
| Kemet | 864-963-6300 | www.kemet.com |
| Murata | 770-436-1300 | www.murata.com |
| Panasonic | 714-373-7366 | www.panasonic.com |
| TDK | 847-803-6100 | www.component.tdk.com |
| Vishay | 402-563-6325 | www.vishay.com |
| Zetex USA | 631-543-7100 | www.zetex.com |

**Note:** *Indicate that you are using the MAX15000A when contacting these component suppliers.*

## Quick Start

### Required Equipment
- 36V to 72V power supply capable of providing up to 1A
- Two voltmeters
- 22µF, 100V bulk storage capacitor to be connected to the input terminals of the EV kit

The MAX15000A 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.**

### Outputs
1) Connect a voltmeter to the VOUT1 SGND pads.

2) Connect a second voltmeter to the VOUT2 and SGND pads.

3) Connect a 750mA load to VOUT1 and a 50mA load to VOUT2.

4) Verify that a shunt is not installed across the pins of jumper JU1 ($\overline{\text{SHDN}}$).

5) Connect the power supply's positive terminal to the +VIN pad. Connect the power supply's ground to the -VIN pad.

6) Turn on the power supply above +36V and verify that the voltmeter at VOUT1 reads approximately +5V.

7) Verify that the voltmeter at VOUT2 reads approximately +15V.

The maximum current for each output should be limited to less than 1.5A for VOUT1 and 100mA for VOUT2.

For instructions on selecting the feedback resistors for other output voltages, see the *Evaluating Other Output Voltages, Current Limits, and Undervoltage Lockouts* section.

## Detailed Description

The MAX15000A EV kit is a 9W, isolated flyback DC-DC converter that provides a +5V output and a +15V output. The +5V output, $V_{OUT}1$, can provide up to 1.5A and the +15V output, $V_{OUT}2$, can provide up to 100mA. The circuit can be powered from a +36V to +72V or a -36V to -72V DC source. **The user must supply at least 22µF of bulk storage capacitance at the input terminals (+VIN, -VIN).** The capacitor should be rated for 100V and be able to carry approximately 200mA of ripple current.

The flyback DC-DC converter achieves up to 81% efficiency. The single-transistor topology and primary-side regulation provide for a low-cost design by eliminating

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the need for an optocoupler and shunt reference on the secondary side. The MAX15000A EV kit provides cycle-by-cycle, primary-side current-limit protection. Current-sense resistor, R5, senses the current through the transformer's (T1) primary winding, switching transistor (N1), and turns off the transistor when the trip level of 1V is reached. The surface-mount transformer provides galvanic isolation up to 1500V for both outputs. The MAX15000A EV kit features PC board pads for an RCD snubber network (R8, C10, D3) to minimize leakage energy ringing and clamp the voltage at the drain of MOSFET N1 during switching (with most MOSFETs this snubber circuit can be eliminated).

Primary-side regulation through feedback resistors R1 and R2, rectifier D6, and transformer T1 tertiary windings provide ±5% regulation for the 5V output set point. Resistors R7 and R12 are adjusted to preload the tertiary winding for the desired +5V ouput set point and regulation. UVLO provides controlled turn-on and shutdown during brownouts, powering up, or powering down. The UVLO settings can be changed by replacing resistor R3. Startup resistor R6 and reservoir capacitor C16 enable the MAX15000A to start up within approximately 37ms. The digital soft-start allows the output voltage to slowly ramp up in a controlled manner within 6ms.

The MAX15000A controller switches at a fixed 350kHz frequency and is set by resistor-capacitor networks R14, R15/C18, and C19. The switching duty cycle is varied to control energy transfer to the isolated outputs. The maximum duty cycle is 50% for the EV kit's discontinuous current-mode flyback design.

### Shutdown Mode (Jumper and Remote Control Methods)

The MAX15000A EV kit features two methods to shut down the flyback DC-DC converter. Jumper JU1 can be used to shut down the flyback DC-DC converter. An alternate method, remote control shutdown, can be done with a user-supplied open-collector/drain transistor or relay contact connected to the $\overline{SHDN}$ and -VIN pads of the EV kit. Table 1 lists the shutdown mode.

## Table 1. Jumper JU1 Shutdown Mode

| SHUNT LOCATION | MAX15000A UVLO/EN PIN | MAX15000A OUTPUT |
|---|---|---|
| Open | UVLO resistors R3 and R4 determine startup voltage | MAX15000A enabled |
| Installed | Pulled low to -VIN | Shutdown mode |

### Evaluating Other Output Voltages, Current Limits, and Undervoltage Lockouts

#### $V_{OUT}1$ and $V_{OUT}2$ Output Voltages

The MAX15000A EV kit's outputs $V_{OUT}1$ and $V_{OUT}2$ are set to +5V and +15V, respectively, by the transformer T1 tertiary windings, the transformer's respective secondary output windings, and the resistor-divider R1 and R2. To generate scaled output voltages other than +5V (+4.2V to +6.8V) and +15V (+12.3V to +20.2V), select different voltage-divider resistors (R1, R2). Resistor R2 is typically chosen to be less than 5kΩ. **When evaluating other output voltages, verify that the secondary outputs' components affected by increased voltage are rated for the appropriate voltage. Components C3, C4, C13, and D4 of VOUT1 and components C5, C15, and D5 should have their respective voltage rating evaluated.** Using the desired scaled output voltages, resistor R1 is then found by the following equation:

$$R1 = [[\{(V_{OUT}1 - V_{VD1}) \times N_T / N_1\} - V_{VD6}] / V_{FB} -1] \times R2$$

where $V_{OUT}1$ is the +5V output,

$N_T$ = 15 is the transformer's tertiary turns

$N_1$ = 6 is the transformer's secondary VOUT1, +5V output turns

$V_{FB}$ = 1.23V is the MAX15000A reference voltage

$V_{VD6}$ = 1.0V is the circuit's tertiary winding, high-speed diode D6 forward voltage drop

$V_{VD1}$ = 0.45V (typ) is the circuit's secondary-side Schottky diode D1 forward voltage drop at 1.5A

Both output voltages will be scaled up or down since the respective transformer's secondary output turns set the actual voltage. Additionally, the maximum current for each output should be limited to less than 1.5A for VOUT1 and 100mA for VOUT2.

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## Current Limiting

The EV kit features current limiting for the transformer's primary current. The MAX15000A IC turns off switching MOSFET N1 when the voltage at the MAX15000A CS pin reaches 1V. Current-sense resistor R5 (0.6$\Omega$) limits the transformer peak primary current to 1.67A (1V / 0.6$\Omega$ = 1.67A). This limits the average short-circuit current on the secondary outputs typically to 1.42A (average with $I_{OUT}2$ = 100mA) and 0.52A (average with $I_{OUT}1$ = 1.5A) for VOUT1 and VOUT2, respectively. To evaluate a lower current limit, current-sense resistor R5 must be replaced with a different surface-mount resistor (1206 size) as determined by the following equation.

When considering the transformer's primary input current:

$$R5 = (V_{SENSE} / I_{PRIMARY})$$

where $V_{SENSE}$ = 1V and $I_{PRIMARY}$ is the transformer's maximum primary current.

## Undervoltage Lockout (UVLO)

The MAX15000A EV kit features an accurate UVLO circuit that prevents operation below the programmed input-supply start voltage. Resistors R3 and R4 set the voltage at the MAX15000A's UVLO/EN pin that determines the UVLO wake-up and shutdown levels, 1.23V (typ) and 1.17V (typ), respectively. To evaluate other wake-up and shutdown levels, replace resistor R3 with another surface-mount resistor (0805 size). Refer to the *Undervoltage Lockout* section in the MAX15000/MAX15001 data sheet for instructions on selecting resistor R3 as determined by the following equation:

$$R3 = ((V_{IN} - V_{UVLO}) / V_{UVLO}) \times R4$$

where $V_{IN}$ is the 36V to 72V supply voltage applied between the +VIN and -VIN pads of the EV kit and $V_{UVLO}$ = 1.23V (typ).

## UVLO Flag (UFLG and FLG_PULL)

The MAX15000A EV kit features an open-drain UVLO flag output at the UFLG PC board pad. The UFLG signal can be used to indicate a UVLO condition has occurred. A voltage source of up to 25V can be connected to the PC board's FLG_PULL pad, which, along with resistor R13, pulls up the UFLG signal. Refer to the *UVLO Flag (UFLG)* section in the MAX15000/MAX15001 data sheet for instructions and additional information on using the UFLG pin of the MAX15000A.

# MAX15000A Evaluation Kit
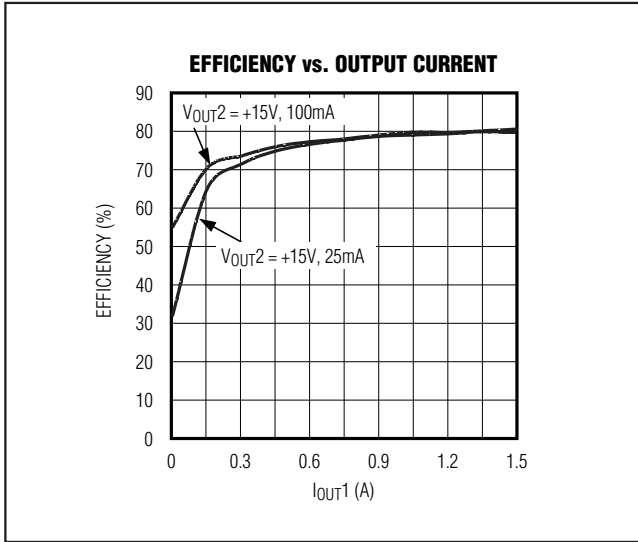
## Flyback Converter Waveforms

**EFFICIENCY vs. OUTPUT CURRENT**



Figure 1. Efficiency vs. Output Current $I_{OUT}1$ (+$V_{IN}$ = 48V)

**OUTPUT TURN-ON VOLTAGE TRANSIENT**



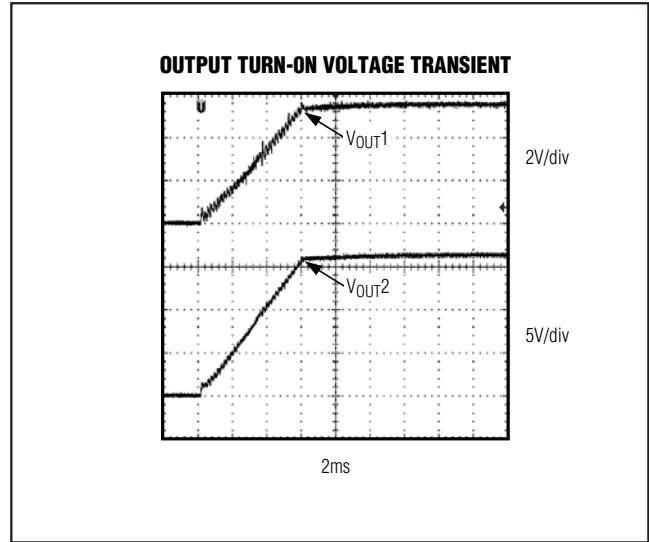Figure 2. Output Voltage Transient at Power-Up (+$V_{IN}$ = 48V, Channel 1 = $V_{OUT}1$ ($I_{OUT}1$ = 150mA), Channel 2 = $V_{OUT}2$ ($I_{OUT}2$ = 25mA))
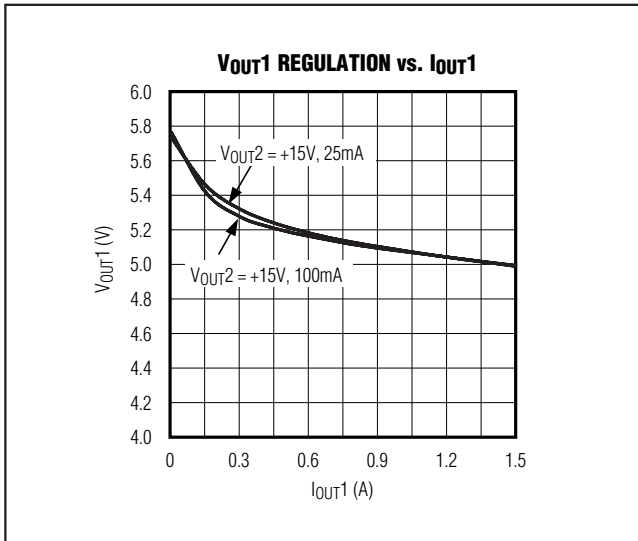
**$V_{OUT}1$ REGULATION vs. $I_{OUT}1$**



Figure 3. $V_{OUT}1$ (+5V) Output Voltage Regulation

**$V_{OUT}2$ REGULATION vs. $I_{OUT}2$**
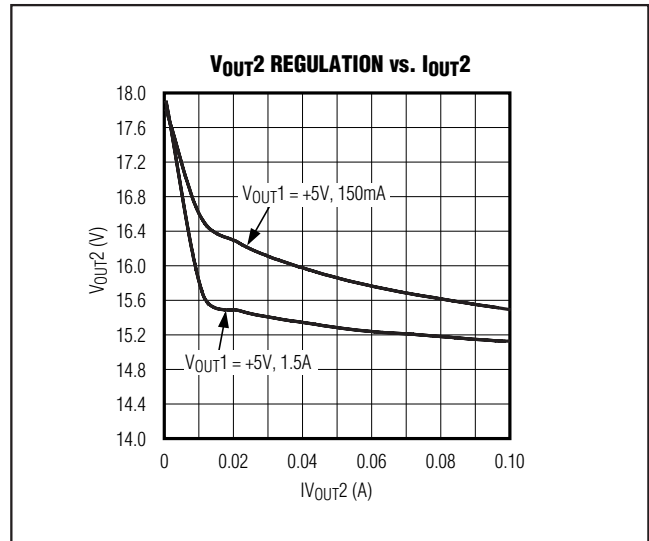


Figure 4. $V_{OUT}2$ (+15V) Output Voltage Regulation

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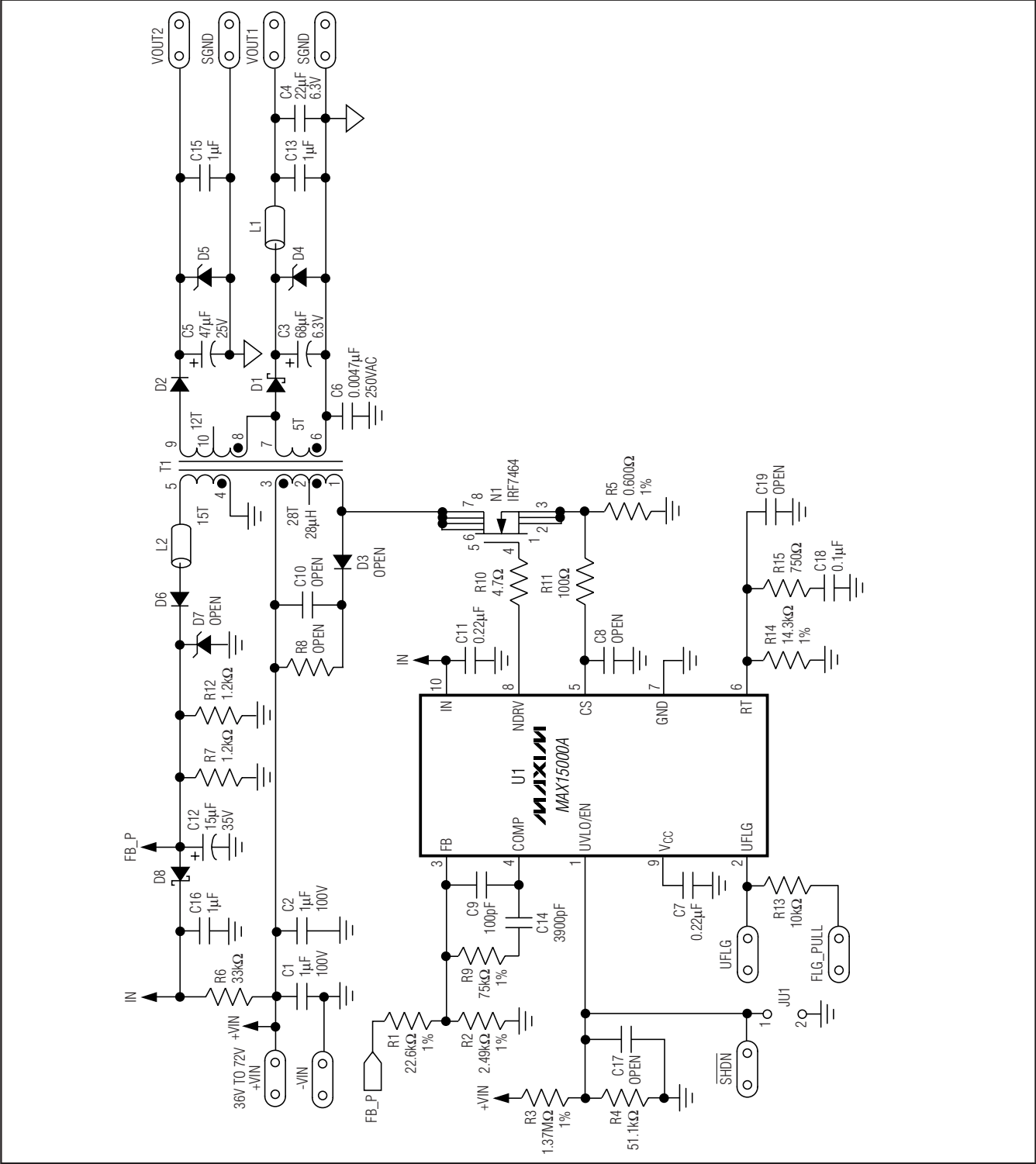
Figure 5. MAX15000A EV Kit Schematic

# MAX15000A Evaluation Kit
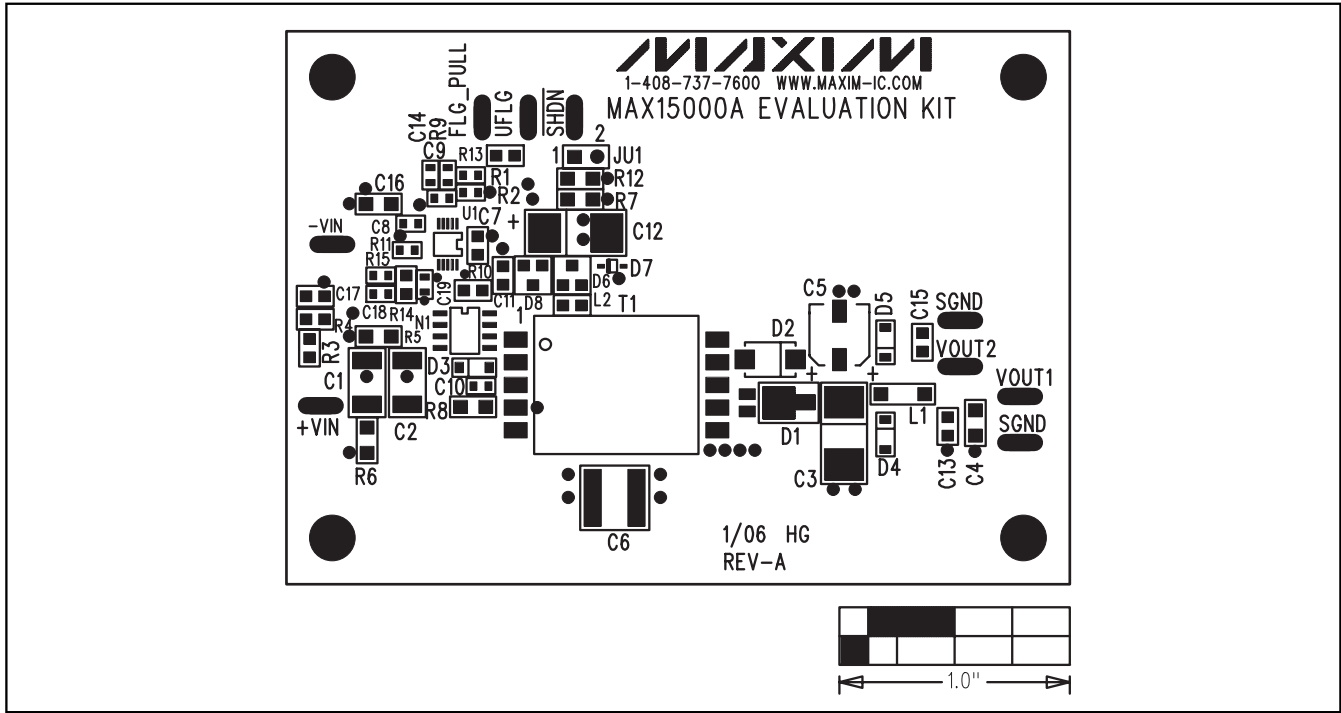
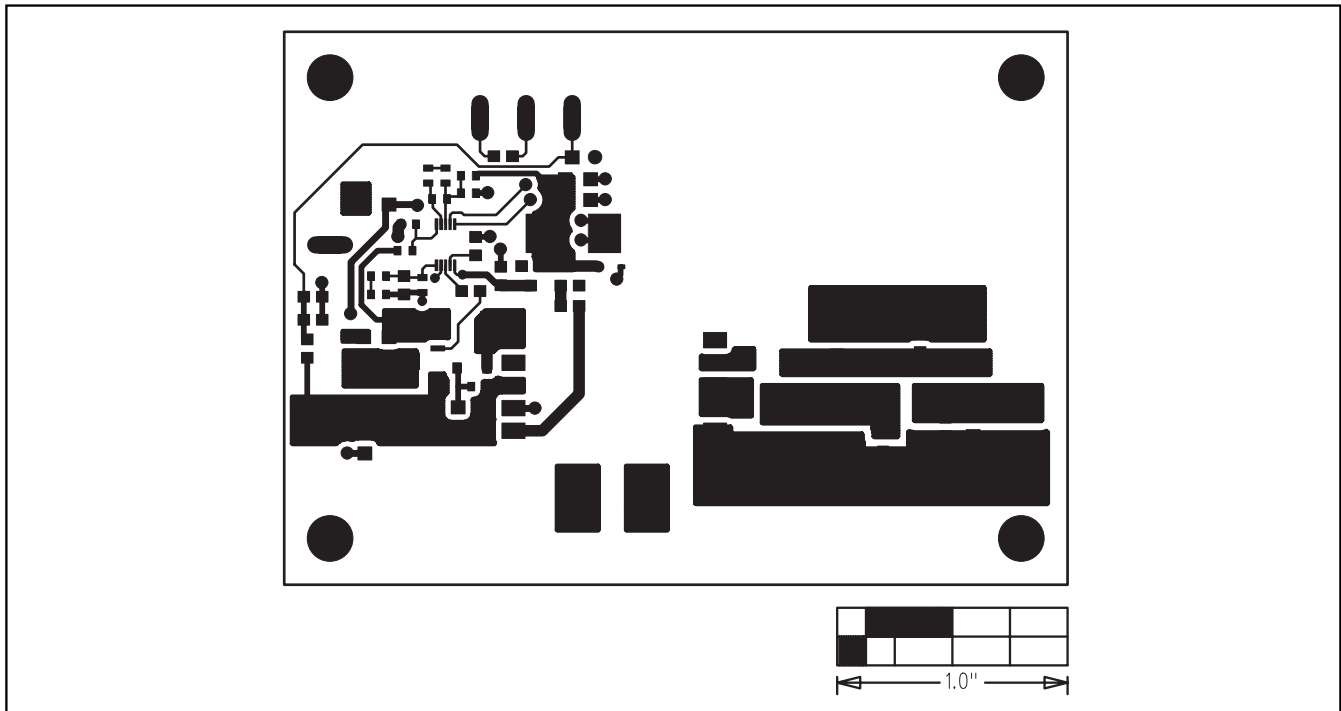Figure 6. MAX15000A EV Kit Component Placement Guide—Component Side



Figure 7. MAX15000A EV Kit PC Board Layout—Component Side
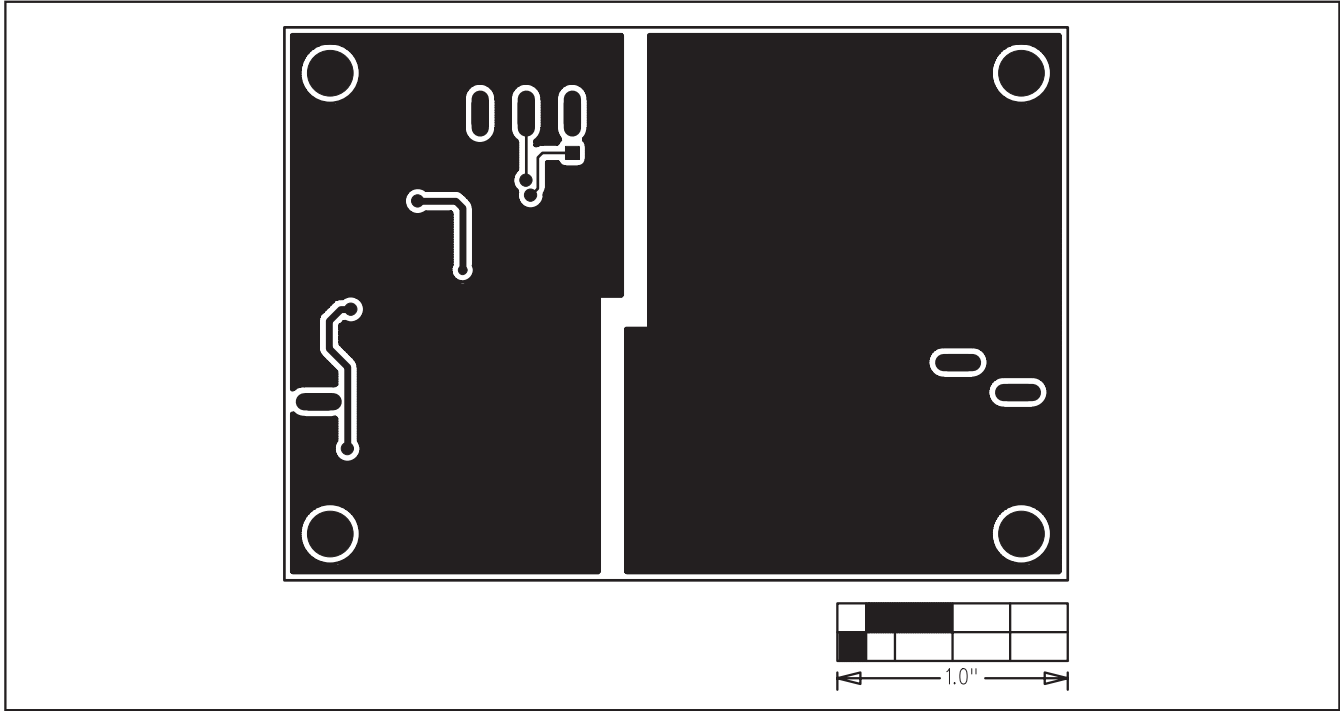
*Figure 8. MAX15000A EV Kit PC Board Layout—Solder Side*

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