



# MAX15005A Evaluation Kit

Evaluates: MAX15005A

## General Description

The MAX15005A evaluation kit (EV kit) is a fully assembled and tested PCB that contains an 11W flyback DC-DC converter for vacuum-fluorescent displays (VFDs) in automotive applications. The circuit uses a MAX15005A high-performance, current-mode pulse-width modulation (PWM) controller in a 16-pin TSSOP package. The EV kit circuit is configured for output voltages of 3V, 60V, and 110V, and provides up to 650mA, 12mA, and 55mA of current from the respective output. Additionally, a 5V low-dropout (LDO) voltage regulator output is provided that can source up to 15mA. Power for the EV kit circuit is provided from a 6.5V to 16V DC source. The MAX15005A EV kit input circuit can sustain a 40V transient.

High efficiency of up to 71% is achieved using a single-transistor flyback DC-DC converter topology. Low cost is achieved through the use of direct secondary-side regulation that does not require optical couplers. Input undervoltage lockout (UVLO), output overvoltage protection (OVP), and soft-start provide for a robust 11W power supply.

Operation at 100kHz minimizes the size of the transformer and passive components.

**Warning:** The MAX15005A 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

- ◆ 6.5V to 16V DC Input Range
- ◆ Outputs
  - 3V Provides Up to 650mA (VFD Filament)
  - 60V Provides Up to 12mA (VFD Grid)
  - 110V Provides Up to 55mA (VFD Anode)
- ◆ Output Voltage Accuracy
  - 110V (Anode) =  $\pm 3\%$  (Regulated Output)
  - 60V (Grid) =  $\pm 5\%$  (Proportional Loading)
  - 3V (Filament) =  $\pm 10\%$  (Proportional Loading)
- ◆ 71% Efficiency at 16V Input and Full Load
- ◆ 5V LDO Output Provides Up to 15mA
- ◆ Hiccup Current-Limit and Overtemperature Shutdown
- ◆ 100kHz Switching Frequency
- ◆ Capacitor Adjustable Soft-Start
- ◆ High-Accuracy Undervoltage Lockout (UVLO)
- ◆ Output Overvoltage Protection (OVP)
- ◆ Capable of Synchronizing to an External Clock
- ◆ Low-Cost, Robust Flyback Design
- ◆ Fully Assembled and Tested

## Ordering Information

PART	TYPE
MAX15005AEVKIT+	EV Kit

+Denotes lead-free and RoHS-compliant.

## Component List

DESIGNATION	QTY	DESCRIPTION
C1	1	330 $\mu$ F, 50V electrolytic capacitor (12.5mm x 13.5mm) Panasonic EEVFK1H331Q
C2	1	0.1 $\mu$ F $\pm 10\%$ , 50V X7R ceramic capacitor (0603) Murata GRM188R71H104K
C3, C10	2	1 $\mu$ F $\pm 10\%$ , 16V X7R ceramic capacitors (0805) Murata GRM21BR71C105K

DESIGNATION	QTY	DESCRIPTION
C4	1	100pF $\pm 2\%$ , 50V COG ceramic capacitor (0603) Murata GRM1885C1H101G
C5	1	1000pF $\pm 5\%$ , 50V COG ceramic capacitor (0603) Murata GRM1885C1H102J
C6	1	4700pF $\pm 10\%$ , 50V X7R ceramic capacitor (0603) Murata GMR188R71H472K



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## Component List (continued)

DESIGNATION	QTY	DESCRIPTION
C7	1	47pF $\pm 5\%$ , 50V C0G ceramic capacitor (0603) Murata GRM1885C1H470J
C8	1	0.68 $\mu$ F $\pm 10\%$ , 16V X7R ceramic capacitor (0805) Murata GRM219R71C684K
C9	1	560pF $\pm 5\%$ , 50V C0G ceramic capacitor (0603) Murata GRM1885C1H561J
C11	1	2200pF $\pm 10\%$ , 100V X7R ceramic capacitor (0603) Murata GRM188R72A222K
C12, C14	2	100pF $\pm 10\%$ , 63V C0G ceramic capacitors (1206) TKD C3216C0G2J101K
C13	1	10 $\mu$ F, 200V electrolytic capacitor (10mm x 10.5mm) SANYO 200CE10FS
C15	1	22 $\mu$ F, 80V electrolytic capacitor (8mm x 10.2mm) Panasonic EEEFK1K220P
C16	1	330 $\mu$ F, 6.3V electrolytic capacitor (8mm x 10.5mm) SANYO 6CE330EX
C17	1	2.2 $\mu$ F $\pm 20\%$ , 10V X5R ceramic capacitor (0603) AVX 0603ZD225MAT
C18	1	4700pF $\pm 10\%$ , 100V X7R ceramic capacitor (0805) Murata GRM219R72A472K
D1	1	100V, 1A super-fast diode (SMA) Diodes Inc. ES1B-13-F
D2	1	600V, 1A super-fast diode (SMB) Diodes Inc. MURS160-F
D3	1	400V, 1A super-fast diode (SMA) Diodes Inc. MURS140-13-F

DESIGNATION	QTY	DESCRIPTION
D4	1	40V, 3A Schottky diode (SMA) Diodes Inc. B340A-13-F
D5	1	8.2V, 350mW $\pm 5\%$ Zener diode (SOT23) Central Semiconductor CMPZ5237B
JU1, JU2	2	2-pin headers
JU3	1	3-pin header
N1	1	80V, 1.4A n-channel MOSFET (8-pin SO) Vishay Si4896DY-T1-E3
R1	1	11.5k $\Omega$ $\pm 1\%$ resistor (0603)
R2	1	560 $\Omega$ $\pm 5\%$ resistor (1210)
R3	1	51 $\Omega$ $\pm 5\%$ resistor (0805)
R4	1	402k $\Omega$ $\pm 1\%$ resistor (0603)
R5	1	1k $\Omega$ $\pm 5\%$ resistor (0603)
R6	1	0.070 $\Omega$ $\pm 1\%$ power resistor (2010) IRC LRC-LR2010LF-01-R070-F
R7	1	510 $\Omega$ $\pm 5\%$ resistor (1206)
R8	1	100k $\Omega$ $\pm 5\%$ resistor (1206)
R9	1	220 $\Omega$ $\pm 5\%$ resistor (1206)
R10	1	36k $\Omega$ $\pm 5\%$ resistor (1206)
R11	1	1.33M $\Omega$ $\pm 1\%$ resistor (0603)
R12	1	12.1k $\Omega$ $\pm 1\%$ resistor (0603)
R13	1	118k $\Omega$ $\pm 1\%$ resistor (0603)
R14	1	1.33k $\Omega$ $\pm 1\%$ resistor (0603)
R15	1	100 $\Omega$ $\pm 5\%$ resistor (0805)
R16	1	10 $\Omega$ $\pm 5\%$ resistor (1210)
R17	1	187k $\Omega$ $\pm 1\%$ resistor (0603)
R18	1	47.5k $\Omega$ $\pm 1\%$ resistor (0603)
R19	1	10k $\Omega$ $\pm 5\%$ resistor (0805)
R20	1	232k $\Omega$ $\pm 1\%$ resistor (0603)
T1	1	15 $\mu$ H, 10W, 1:3.438:2.813:0.188 turn, 100kHz transformer (10-pin gull wing) Coiltronics CTX03-17677-R
U1	1	MAX15005AAUE+ (16-pin TSSOP-EP)
—	2	Shunts (JU1, JU2, JU3)
—	1	PCB: MAX15005A Evaluation Kit+

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## Component Suppliers

SUPPLIER	PHONE	WEBSITE
AVX Corp.	843-946-0238	www.avxcorp.com
Central Semiconductor	631-435-1110	www.centralsemi.com
Cooper Electronic Tech./Coiltronics	561-752-5000	www.cooperet.com
Diodes Inc.	805-446-4800	www.diodes.com
IRC	361-992-7900	www.irctt.com
Murata Mfg. Co., Ltd.	770-436-1300	www.murata.com
Panasonic Corp.	714-373-7366	www.panasonic.com
SANYO Corp.	619-661-6322	www.sanyodevice.com
Vishay	402-563-6866	www.vishay.com

**Note:** Indicate that you are using the MAX15005A when contacting these component suppliers.

## Quick Start

### Required Equipment

Before beginning, the following equipment is needed:

- One 6.5V to 16V power supply capable of providing up to 3A
- Three voltmeters

### Procedure (Outputs)

The MAX15005A EV kit is fully assembled and tested. Follow the steps below to verify board operation.

**Caution: Do not turn on the power supply until all connections are completed.**

- 1) Connect a voltmeter to the FILAMENT+ and FILAMENT- pads.
- 2) Connect the second voltmeter to the V\_GRID and PGND pads.
- 3) Connect the third voltmeter to the V\_ANODE and PGND pads.
- 4) Verify that a shunt is installed across the pins of jumpers JU1 (ON/OFF) and JU2 (SYNC).
- 5) Verify that a shunt is installed across pins 2-3 of jumper JU3 (OVP).
- 6) Connect the power supply's positive terminal to the VIN pad. Connect the power supply's ground to the PGND pad.
- 7) Turn on the power supply above 7V and verify the following voltmeters readings:
  - FILAMENT = 3V
  - V\_GRID = 60V
  - V\_ANODE = 110V

The maximum current for each output should be limited

to less than 650mA, 12mA, and 55mA for each respective output detailed above in step 7.

## Detailed Description

The MAX15005A EV kit is an 11W flyback DC-DC converter that provides output voltages of 3V at up to 650mA, 60V at up to 12mA, and 110V at up to 55mA. The MAX15005A flyback power supply is designed to provide power to automotive VFDs. The circuit can be powered from a 6.5V to 16V DC source, which provides 3A to the EV kit.

The flyback DC-DC converter achieves up to 71% efficiency and the single-transistor topology provides for a lower-cost design. The MAX15005A EV kit provides cycle-by-cycle primary-side current-limit protection. Current-sense resistor R6 senses the current through the transformer's (T1) primary winding, switching transistor (N1), and turns off the transistor when the trip level of 0.3V is reached. The MAX15005A EV kit features a resistor/capacitor/diode (RCD) snubber network (R2, C11, and D1) to minimize leakage energy ringing and clamp the voltage at the drain of MOSFET N1 during switching.

Secondary-side regulation through feedback resistors R13 and R14 provide  $\pm 3\%$  regulation for the 110V output (V\_Anode). Resistors R8, R10, and R15 preload the respective output and assist with overall regulation at minimum loading. UVLO provides controlled turn-on and shutdown during brownouts, power-up, or power-down. The UVLO setting can be changed by replacing resistor R18.

The MAX15005A analog soft-start allows the output voltage to slowly ramp up in a controlled manner within 56ms and is set by capacitor C8. The OVP is provided by independently sensing the 110V output (V\_Anode) through resistors R11 and R12.

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The MAX15005A controller switches at a fixed 100kHz frequency and is set by resistor/capacitor network R1 and C5. The switching duty cycle is varied to control energy transfer to the outputs. The maximum duty cycle is 50% for the EV kit's discontinuous current-mode flyback design.

## Shutdown Mode (Jumper- or Remote-Control Method)

The MAX15005A EV kit features a jumper (JU1) that can be used to shut down the flyback DC-DC converter. An alternate shutdown method (remote control) can be done with a user-supplied relay contact connected to pin 2 of jumper JU1 of the EV kit. Table 1 shows jumper options.

Table 1. Jumper JU1 Shutdown Mode

SHUNT POSITION	ON/OFF PIN	MAX15005A EV KIT OUTPUT
Installed	UVLO resistors R17 and R18 determine startup voltage	MAX15005A enabled
Not installed	Pulled low to PGND through resistor R18	Shutdown mode
Not installed	Relay contacts connected between JU1 pin 2	Remote mode

## SYNC Mode

The MAX15005A can be synchronized to an external TTL/CMOS square-wave clock source. The 2-pin jumper (JU2) selects the SYNC mode of operation or 100kHz internal frequency for the MAX15005A. Table 2 shows jumper options.

The TTL/CMOS square-wave clock source (from 105kHz to 130kHz) must provide the following signal qualities:

- Output voltage:
  - Logic-low = 0 to 0.8V
  - Logic-high = 2V to 5.5V
- Output frequency = 105kHz to 130kHz
- Minimum positive-pulse width = 50ns
- Connect the external square-wave clock to the SYNC and PGND pads. Refer to the MAX15005A data sheet for more information on the SYNC pin.

Table 2. Jumper JU2 SYNC Mode Functions

SHUNT POSITION	SYNC PIN	MAX15005A OPERATING MODE
Installed	Connected to SGND	Internal clock mode (100kHz set by R1 and C5)
Not installed	Connected to an external TTL/CMOS square-wave clock source at the SYNC and SGND pads	Synchronization mode (synchronized to an external clock frequency)

## Evaluating Other Current Limits, Input UVLO, and Output OVP Shutdown

### Current Limiting

The EV kit features current limiting for the transformer's primary current. The MAX15005A IC turns off switching MOSFET N1 when the voltage at the MAX15005A CS pin reaches 0.3V. Current-sense resistor R6 (0.07Ω) limits the transformer peak primary current to 4.2A (0.3V / 0.07Ω = 4.2A). To evaluate a lower current limit, current-sense resistor R6 must be replaced with a different surface-mount resistor (2010 size), as determined by the following equation:

$$R6 = (0.300V / I_{PRIMARY})$$

where  $I_{PRIMARY}$  is the transformer's maximum peak primary current.

### Input UVLO (ON/OFF)

The MAX15005A EV kit features a brownout and input-supply startup UVLO circuit that prevents operation below the programmed input-supply-start voltage. Resistors R17 and R18 set the input UVLO threshold of the EV kit. To change the input UVLO voltage, replace resistor R17 (or R18) with another surface-mount resistor (0603 size). Using the desired startup voltage, resistor R17 is then found by the following equation:

$$R17 = \left( \frac{V_{INSTARTUP}}{1.230V} - 1 \right) \times R18$$

where  $V_{INSTARTUP}$  is the desired startup voltage that the EV kit starts at, and resistor R18 is typically in the 50kΩ range (47.5kΩ default). Refer to the *Startup Operation/UVLO/ON/OFF* section of the MAX15005A data sheet for additional information on the ON/OFF pin of the MAX15005A IC.

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## Output OVP Shutdown

The MAX15005A EV kit features an OVP circuit that prevents operation above the programmed V\_ANODE output supply voltage (136V default). Jumper JU3 configures the circuit for output OVP protection when the shunt is placed across pins 2-3. Resistors R11 and R12 set the OVI threshold of the OVP circuit for the MAX15005A IC. To evaluate other OVP voltages, replace resistor R11 with another surface-mount resistor (0603 size). Using the desired OVP voltage, resistor R11 is then found by the following equation:

$$R11 = \left( \frac{(OVP)}{1.228V} - 1 \right) \times R12$$

where OVP is the desired voltage that the circuit shutdown is at and resistor R12 is typically in the 10kΩ range (12.1kΩ default). See Table 3 for configuring jumper JU3 for output OVP protection.

## Input OVP Shutdown (Load Dump Protection)

The MAX15005A EV kit OVP circuit can be reconfigured to provide load dump protection for VIN when it rises above the programmed VIN supply voltage (24.7V default). Jumper JU3 configures the circuit for input OVP protection when the shunt is placed across pins 1-2. Resistors R12 and R20 set the OVI threshold of the

OVP circuit for the MAX15005A IC. To evaluate other OVP voltages, replace resistor R20 with another surface-mount resistor (0603 size). Using the desired OVP voltage, resistor R20 is then found by the following equation:

$$R20 = \left( \frac{(OVP)}{1.228V} - 1 \right) \times R12$$

where OVP is the desired voltage that the circuit shutdown is at and resistor R12 is typically in the 10kΩ range (12.1kΩ default). See Table 3 for configuring jumper JU3 for input OVP protection.

**Table 3. Jumper JU3 OVP Shutdown**

SHUNT POSITION	OVI PIN	OVP OPERATION
1-2	Sense VIN input	Input overvoltage protection (load dump)
2-3*)	Sense V_ANODE output	Output overvoltage protection
Not installed	No sensing	OVP disabled

\*Default position.

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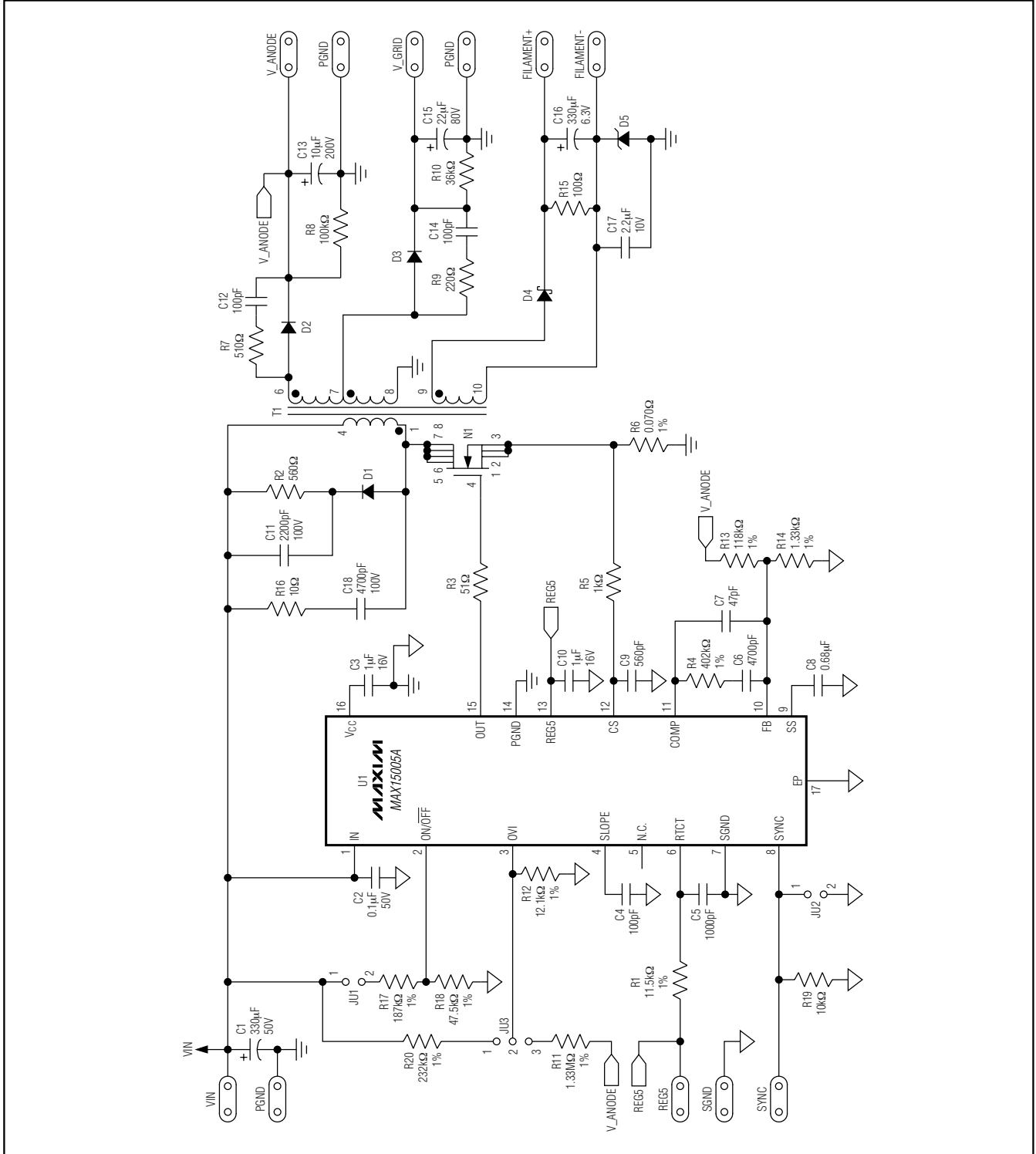


Figure 1. MAX15005A EV Kit Schematic

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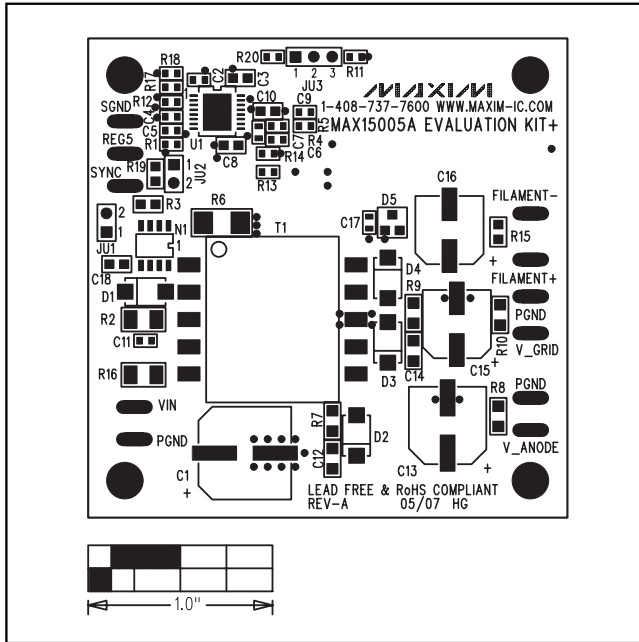


Figure 2. MAX15005A EV Kit Component Placement Guide—Component Side

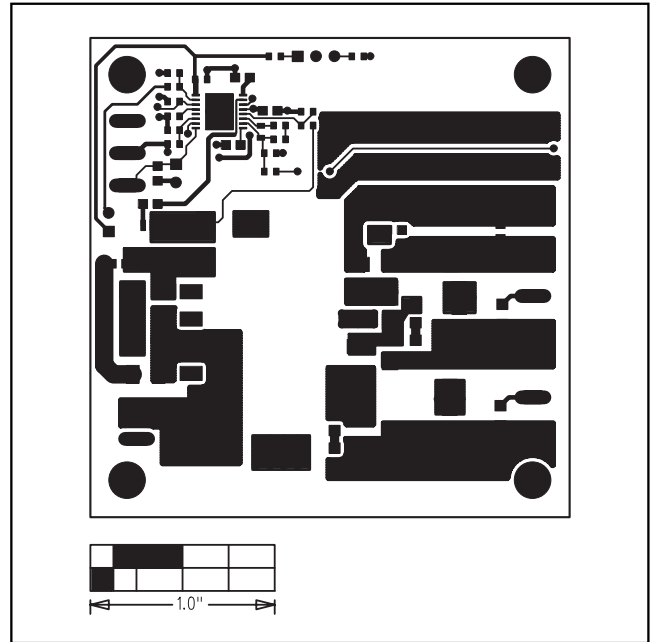


Figure 3. MAX15005A EV Kit PCB Layout—Component Side

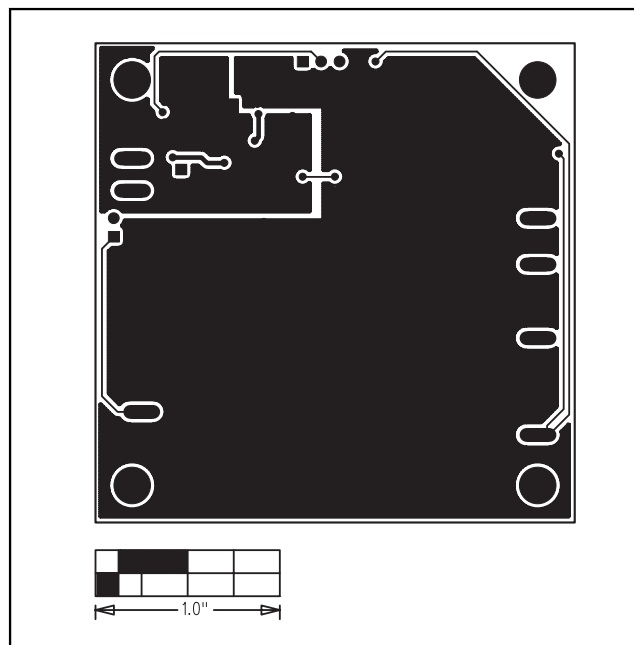


Figure 4. MAX15005A EV Kit PCB Layout—Solder Side

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