19-5750; Rev 0; 1/11

# MAX5977A Evaluation Kit

# Evaluates: MAX5977A/MAX5977B

## General Description

The MAX5977A EV kit is a hot-swap controller circuit board providing a controlled turn-on for high-power, high-capacitance loads, thus preventing glitches on the power-supply rail. The circuit uses a latching MAX5977A hot-swap controller IC in a 20-pin TQFN surface-mount package with an exposed pad. The EV kit operates from a 1V to 16V input source range connected at the VIN and GND connectors.

The IC controls two n-channel MOSFETs that deliver up to 40A of output current. The EV kit circuit ensures that the output voltage is stable and within the undervoltage (UV) and overvoltage (OV) thresholds. The circuit continually monitors load current to ensure that it does not exceed the circuit programmable fast and slow current-limit thresholds. The EV kit circuit provides a buffered output of the IC's current-sense amplifier and includes a precision current source providing a 2.5V output when enabling the IC's calibration-mode function.

The EV kit can also be used to evaluate the MAX5977B autoretry hot-swap controller after IC replacement of U1.

## Features

- **1V to 16V Input Range**
- **Demonstrates Latched-Fault Output**
- **Configurable Input Undervoltage (9V) and Overvoltage (15V) Thresholds**
- **Output Current Up to 40A**
- **Configurable Slow and Fast Current-Limit Thresholds**
- **Precision Current Monitoring**
- **Calibration Mode**
- **Selectable Digital Voltage Supply (VIO)**
- **$\overline{\text{FAULT}}$ and Power-Good LED Indicators**
- **Buffered Current-Sense Amplifier Output Drives External Circuitry**
- **Evaluates MAX5977A Latched-Off Version**
- **Evaluates MAX5977B Autoretry Version After IC Replacement**
- **Surface-Mount Components**
- **Proven PCB Layout**
- **Fully Assembled and Tested**

*Ordering Information appears at end of data sheet.*

## Component List

| DESIGNATION | QTY | DESCRIPTION |
|---|---|---|
| 2.5V_CAL, CALSENSE, $\overline{\text{FAULT}}$, FCOMP, GATE, IN, OV, PG, PWR, REG, SCOMP, SENSE, TP1, TP3, UV | 15 | Small red test points |
| C1, C8, C9, C13, C14, C16 | 6 | 0.1µF ±10%, 50V X5R ceramic capacitors (0603) Murata GRM188R61H104K |
| C2, C15 | 0 | Not installed, ceramic capacitors (0603) |

| DESIGNATION | QTY | DESCRIPTION |
|---|---|---|
| C3 | 1 | 1000pF ±5%, 50V X5R ceramic capacitor (0603) Murata GRM1885C1H102J |
| C4, C5, C10 | 3 | 1µF ±10%, 25V X5R ceramic capacitors (0603) Murata GRM188R61E105K |
| C6, C7 | 2 | 10µF ±10%, 25V X5R ceramic capacitors (1206) Murata GRM31CR61E106K |
| C11 | 1 | 10µF ±10%, 6.3V X5R ceramic capacitor (0805) Murata GRM21BR60J106K |
| C12 | 0 | Not installed, ceramic capacitor (0805) |

## Component List (continued)

| DESIGNATION | QTY | DESCRIPTION |
|---|---|---|
| D1 | 1 | 5A, 40V Schottky rectifier (SMC)<br>Diodes Inc. B540C |
| D2 | 1 | 3.9V zener diode (PowerDI®323)<br>Diodes Inc. PD3Z284C3V9-7 |
| D3 | 1 | 20V, 600W unidirectional TVS (SMB)<br>Diodes Inc. SMBJ18A<br>(Top Mark: LT) |
| D4 | 1 | Red LED (1206) |
| D5 | 1 | Green LED (1206) |
| GND (x2), VIN, VOUT | 4 | Screw terminals |
| JU1, JU3 | 2 | 3-pin headers |
| JU2 | 1 | 2-pin header |
| N1, N2 | 2 | 25V, 100A n-channel MOSFETs (LFPAK)<br>NXP Semi PSMN1R2-25YL |
| N3 | 1 | Single n-channel logic-level MOSFET (SOT23)<br>Central Semi 2N7002 |
| P1 | 1 | Single p-channel logic-level MOSFET (SOT23)<br>Fairchild Semi NDS0605 |
| Q1 | 1 | npn transistor (SOT523)<br>Fairchild MMBT2222ATCT<br>(Top Mark: A02), or<br>Diodes Inc. MMBT22AT-7-F<br>(Top Mark: IP_ _) |
| R1, R2 | 2 | 249Ω ±5% resistors (0805) |
| R3, R4, R24 | 0 | Not installed, resistors (0603) |
| R5, R14 | 2 | 100kΩ ±1% resistors (0603) |
| R6 | 1 | 453Ω ±1% resistor (0603) |
| R7 | 1 | 825Ω ±1% resistor (0603) |
| R8 | 1 | 0.5mΩ ±1%, 3W sense resistor (3921)<br>Vishay/Dale WSL3921L5000FEA |
| R9, R13 | 2 | 20.0kΩ ±1% resistors (0603) |
| R10 | 1 | 49.9Ω ±1% resistor (0603) |
| R11 | 1 | 4.12kΩ ±1% resistor (0603) |
| R12 | 1 | 4.99kΩ ±1% resistor (0603) |
| R15, R21, R22 | 3 | 100kΩ ±5% resistors (0603) |
| R16 | 1 | 7.15kΩ ±1% resistor (0603) |
| R17, R18 | 2 | 1Ω ±5% resistors (0603) |
| R19 | 1 | 10Ω ±5% resistor (0603) |
| R20 | 1 | 1kΩ ±1% resistor (0603) |
| R23 | 1 | 0Ω ±5% resistor (0603) |
| SW1, SW2 | 2 | 3-position, top-slide DIP switches |
| TP2, TP4–TP7 | 5 | Small black test points |
| U1 | 1 | Hot-swap controller (20 TQFN-EP)<br>Maxim MAX5977AETP+ |
| U2 | 1 | 2.5V voltage reference (6 SOT23)<br>Maxim MAX6033AAUT25#G16<br>(Top Mark: ABDF) |
| U3 | 1 | High-precision op amp (6 SOT23)<br>Maxim MAX4236EUT+<br>(Top Mark: AAUV) |
| U4 | 1 | 3.3V 50mA linear regulator (8 SO-EP)<br>Maxim MAX15006AASA+ |
| — | 3 | Shunts (JU1, JU2, JU3) |
| — | 1 | PCB: MAX5977A EVALUATION KIT# |

*PowerDI is a trademark of Diodes Incorporated.*

## Component Suppliers

| SUPPLIER | PHONE | WEBSITE |
|---|---|---|
| Central Semiconductor Corp. | 631-435-1110 | www.centralsemi.com |
| Diodes Incorporated | 805-446-4800 | www.diodes.com |
| Fairchild Semiconductor | 888-522-5372 | www.fairchildsemi.com |
| Murata Electronics North America, Inc. | 770-436-1300 | www.murata-northamerica.com |
| Vishay | 402-563-6866 | www.vishay.com |

***Note:*** *Indicate that you are using the MAX5977A when contacting these component suppliers.*

## Quick Start

### Required Equipment

- MAX5977A EV kit
- 12V, 50A DC power supply
- Three voltmeters

### Procedure

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

1) Verify that shunts are installed across pins 1-2 on jumpers JU1 and JU3.
2) Verify that a shunt is installed on jumper JU2.
3) Verify that switches SW1 and SW2 are set to the on position.
4) Utilizing four short parallel-connected 16 AWG wire, connect the positive terminal of the power supply to the VIN connector. Utilizing four short parallel-connected 16 AWG wire, connect the negative terminal of the power supply to the GND connector.
5) Connect the first voltmeter positive and negative terminals to the VOUT and GND test points, respectively.
6) Connect the second voltmeter positive and negative terminals to the VIO and GND PCB pads, respectively.
7) Connect the third voltmeter positive and negative terminals to the CSBUF and the GND PCB pads, respectively.
8) Enable the power supply.
9) Verify that the voltmeters at VOUT, VIO, and CSBUF display 12V, 3.3V, and 2.5V, respectively.

## Detailed Description of Hardware

The MAX5977A EV kit is a hot-swap controller circuit board providing a controlled turn-on for high-power, high-capacitance loads, thus preventing glitches on the power-supply rail. The EV kit is designed to operate from a 1V to 16V DC power supply that provides up to 50A of current. The MAX5977A IC is available in a 20-pin (4mm x 4mm) TQFN package with an exposed pad.

The EV kit circuit uses a latching hot-swap controller IC that operates with a 1V to 16V input source range connected at the VIN and GND terminal connectors. The EV kit features two external n-channel MOSFETs (N1, N2) for delivering up to 40A of continuous load current at the VOUT and GND terminal connectors. The circuit continually monitors the load current across resistor R8 for current-limit faults. The IC's VariableSpeed/BiLevel™ circuit-protection function prevents the EV kit circuit from exceeding the programmed 42A and 45A slow and fast current-limit fault thresholds, respectively. The EV kit circuit also ensures that the output voltage is stable within the undervoltage (UV) and overvoltage (OV) thresholds, which are configured to 9V and 15V, respectively.

The EV kit provides CSOUT and GND PCB pads for monitoring the IC's transconductance current-sense amplifier output. The amplifier has a 2.5 x $10^{-3}$S gain that is applied across resistor R8 to monitor the EV kit load current. The amplifier gain is also applied across the IC's IN and CALSENSE inputs when the EV kit is configured for calibration mode. See the *Transconductance Amplifier/Calibration Mode* section for additional information. An on-board MAX4236 op amp (U3) is available for buffering the current-sense amplifier output and can be used for driving external circuitry at the CSBUF and GND PCB pads.

*VariableSpeed/BiLevel is a trademark of Maxim Integrated Products, Inc.*

Slide switch SW1 is provided to configure the EV kit in calibration mode. Slide switch SW2 is provided to disable the hot-swap controller or to reset (unlatch) the output after a current-limit fault has been removed. Green LED D5 indicates power-good status and red LED D4 indicates a current-limit fault condition. The EV kit circuit also uses the MAX15006A high-voltage input linear regulator (U4), which can provide a 3.3V logic supply for the EV kit digital signals.

The EV kit is designed on a four-layer, 2oz PCB, providing enhanced thermal dissipation for the power MOSFETs during turn-on and turn-off events. The EV kit also utilizes screw-terminal connectors at VIN, VOUT, and GND for facilitating the circuit high-current capability.

### Current Limiting

The IC employs fast and slow current-limit comparators that compare the voltage across sense resistor R8. The IC's slow current-limit threshold is set to 42A by resistor R7 and the fast current-limit threshold is set to 45A by resistor R6.

When an overcurrent event occurs that is longer than the slow and fast comparator-response times, the hot-swap controller latches off the channel by turning off MOSFETs N1 and N2. After the fault has been removed, the controller can be reset by recycling the VIN power supply, or by pulling UV low and then high using slide switch SW2.

Refer to the *Programmable Slow and Fast Current Limit* section in the MAX5977A/MAX5977B IC data sheet for information on selecting resistors when reconfiguring the EV kit current-limit thresholds.

### Gate Voltage

The IC integrates a charge pump that drives the GATE pin to 5V above the SOURCE pin voltage (VOUT) to fully enhance the external n-channel MOSFETs (N1 and N2). The gate voltage is high when the input voltage is between the UV and OV thresholds and the output current has not exceeded the current-limit thresholds. The GATE voltage can be monitored at the GATE and TP5 test points.

## Table 1. U4 Input Power Source (JU1)

| SHUNT POSITION | U4 IN PIN | U4 INPUT POWER SOURCE |
|---|---|---|
| 1-2 | Connected to VIN | VIN |
| 2-3 | Connected to VOUT | VOUT |
| Not installed | Not connected | No power applied |

### Digital Supply Configuration

The EV kit circuit includes the option of selecting the circuit digital supply voltage using the on-board 3.3V linear regulator (U4) or using an external supply. See Tables 1 and 2 for proper JU1 and JU2 jumper configurations.

### U4 Linear Regulator Input Source (JU1)

The EV kit features an option to select the input power source for the U4 3.3V linear regulator output. Jumper JU1 sets the U4 input-voltage supply using the power source applied at the VIN and GND connectors or the hot-swap controller output (VOUT). Install a shunt across pins 1-2 to use the power source applied at the VIN and GND connectors. Install a shunt across pins 2-3 to use VOUT as the power source. See Table 1 for JU1 configuration.

### VIO Digital Supply Input Source (JU2)

Jumper JU2 selects the VIO digital supply voltage using the U4 linear regulator's 3.3V output, or by applying an external supply at the VIO and GND PCB pads. Install a shunt on jumper JU2 to set the VIO supply to 3.3V. Remove the shunt on JU2 and apply a 1.8V to 5.5V external supply at the VIO and GND PCB pads. See Table 2 for JU2 configuration.

### Input Power Selection (JU3)

The EV kit circuit features an option to select the power source for the IC's PWR power-supply input. Jumper JU3 selects the input-power voltage source for the IC's hot-swap controller. Place a shunt across pins 1-2 to power the hot-swap controller using the power source applied at the VIN and GND connectors. Place a shunt across pins 2-3 to power the hot-swap controller using the VIO power source. See Table 3 for JU3 configuration.

## Table 2. VIO Digital Supply Selection (JU2)

| SHUNT POSITION | VIO DIGITAL SUPPLY |
|---|---|
| Installed | 3.3V |
| Not installed* | External voltage applied at VIO and GND PCB pads |

**Jumper JU1 shunt should not be installed for this option.*

## Table 3. PWR Input Configuration (JU3)

| SHUNT POSITION | IC PWR PIN | PWR INPUT RANGE (V) |
|---|---|---|
| 1-2 | Connected to VIN through R19 | 2.7 to 16 |
| 2-3 | Connected to VIO through R19 | 2.7 to 5.5 |

***Note:*** *The IC requires a minimum 2.7V at the PWR input for operation.*

### Transconductance Amplifier/Calibration Mode (SW1)

Slide switch SW1 is available to monitor the EV kit load current or to operate the IC in calibration mode. Set SW1 to the off position to monitor the circuit-load current. The voltage across resistor R8 is multiplied by the IC transconductance current-sense amplifier gain ($2.5 \times 10^{-3}$S). Set SW1 to the on position to operate the EV kit in calibration mode. In calibration mode, the EV kit circuit uses the MAX6033 2.5V voltage reference (U2) and various other components to provide a precision current source for setting the differential voltage between the IC's IN and CALSENSE inputs to 25mV. This differential voltage is multiplied by the transconductance gain.

The transconductance amplifier output current is applied across external resistors R9 and R13, with the voltage available for monitoring at the CSOUT and GND PCB pads.

When the EV kit is configured for monitoring the load current, use the formula below to verify the load current:

$$I_{OUT}(A) \approx \frac{V_{CSOUT}}{R8 \times (R9 + R13) \times G_M}$$

where:

$V_{CSOUT}$ is the voltage at the CSOUT PCB pad in volts.

$I_{OUT}$ is the circuit's load current in amps.

R8 is the sense resistor in ohms.

R9 and R13 are the series resistors connected to the IC's CSOUT output in ohms.

$G_M$ is the IC's transconductance gain.

In calibration mode, the precision 25mV input signal between IN and CALSENSE causes CSOUT to source 62.5µA, or 2.5V across resistors R9 and R13. The 2.5V can be monitored at the CSOUT and GND test points. See Table 4 for slide switch SW1 configuration.

The EV kit circuit provides a MAX4236 op amp (U3) for buffering the current-sense amplifier output (CSOUT). The buffered output can be used for driving external circuitry at the CSBUF and GND PCB pads.

### Undervoltage and Overvoltage Thresholds

The EV kit UV threshold is programmed to 9V using resistors R14 and R16. The EV kit OV threshold is programmed to 15V using resistors R5 and R11.

If the voltage at VIN drops below the UV threshold or exceeds the OV threshold, the IC's controller turns off MOSFETs N1/N2 and LED D5. The controller returns to normal operation when the input voltage returns within the circuit UV and OV thresholds.

The UV and OV thresholds can be reconfigured by replacing resistors R14/R16 and R5/R11, respectively. Refer to the MAX5977A/MAX5977B IC data sheet for additional information for reconfiguring the UV and OV thresholds.

### Power-Good Output

The IC's power-good (PG) output signal is asserted high and LED D5 is on when the following conditions are met:

- VIN is within the UV and OV programmed limits.
- VIN - VOUT is less than 100mV.
- $V_{GATE}$ - VOUT is greater than 4V.

The PG output signal can be monitored at the PG and TP6 (ground) test points.

### $\overline{FAULT}$ Output

The IC's $\overline{FAULT}$ output signal is asserted low and LED D4 is on whenever a slow or fast current-limit fault has occurred. The $\overline{FAULT}$ output signal can be monitored at the $\overline{FAULT}$ and TP7 (ground) test points.

### Latch-Fault Resetting (SW2)

The EV kit features slide switch SW2 to reset the controller after a fault condition has been removed by pulling the UV pin below its 590mV (typ) threshold. The switch resets the channel and unlatches the fault when toggled from on to off. Recycling the supply applied at VIN also resets the controller.

### Evaluating the MAX5977B

The EV kit can also be used to evaluate the MAX5977B autoretry hot-swap controller. The MAX5977A (U1) must be removed and replaced with the MAX5977B. Request a free sample when ordering the EV kit.

**Table 4. Calibration Mode Configuration (SW1)**

| POSITION | CAL PIN | EV KIT OPERATION |
|---|---|---|
| On | Connected to VIO through R22 | Calibration mode: Transconductance gain applied across IN and CALSENSE |
| Off | Connected to ground | Transconductance gain applied across resistor R8 |

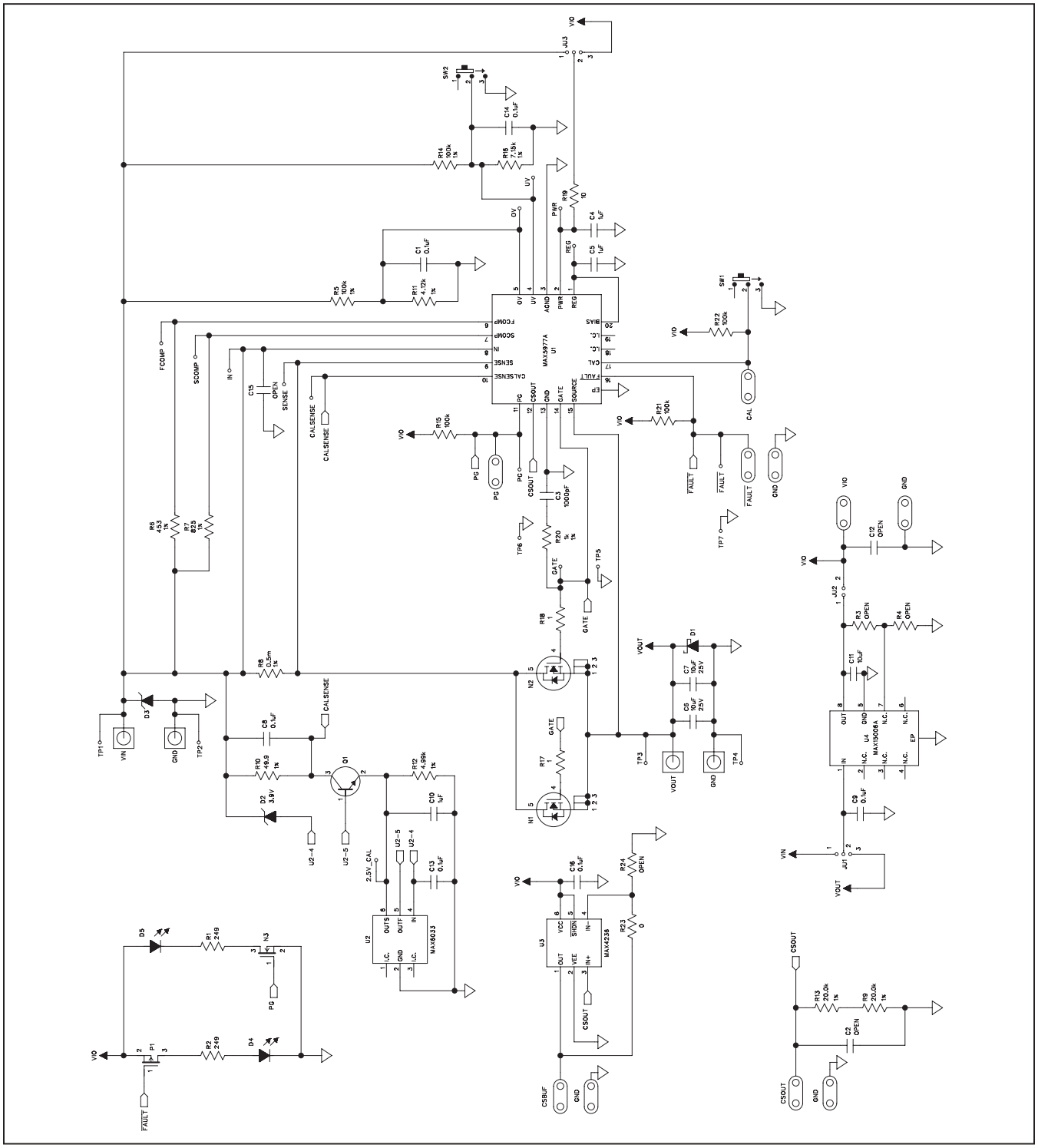

*Figure 1. MAX5977A EV Kit Schematic*

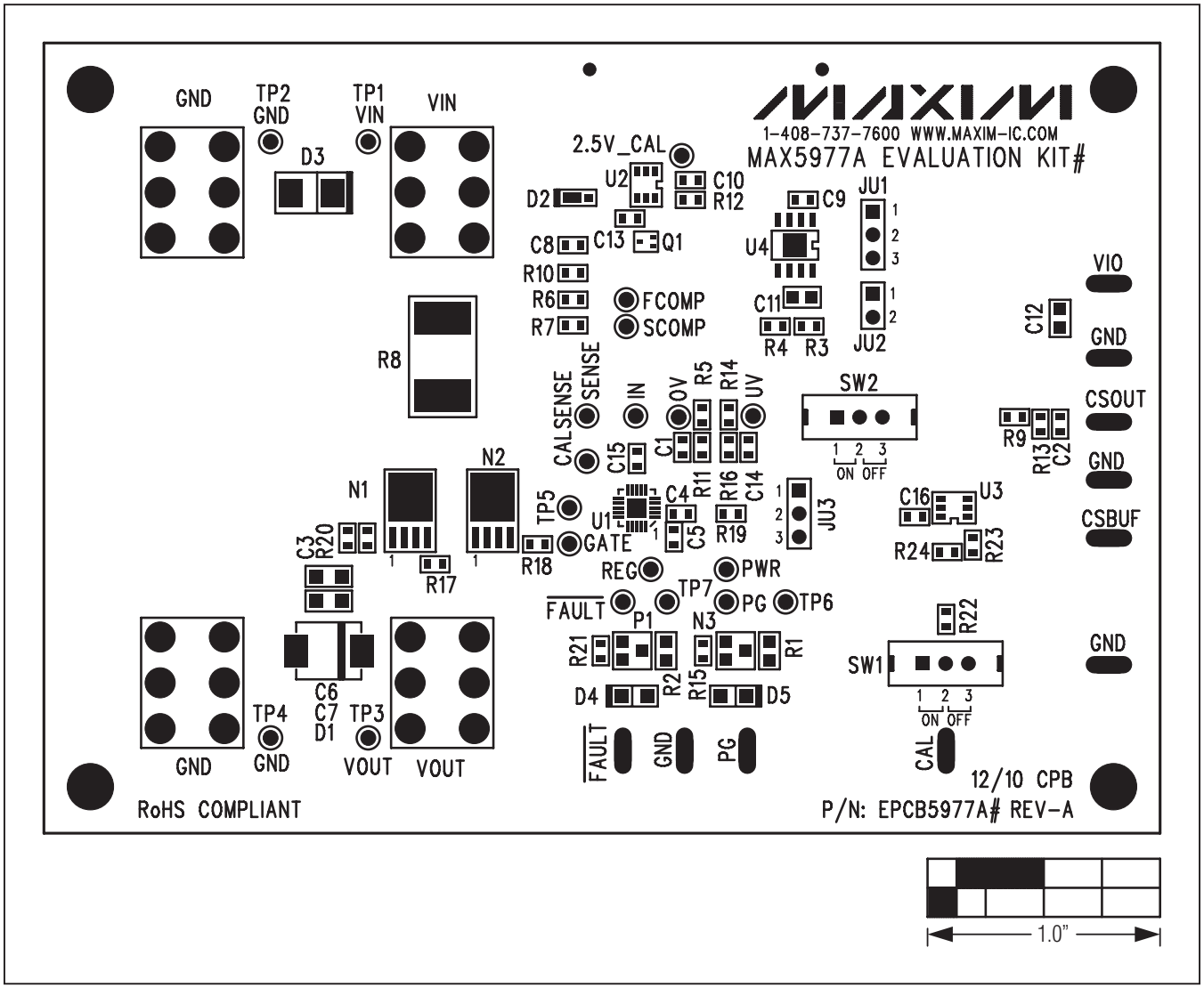


*Figure 2. MAX5977A EV Kit Component Placement Guide—Component Side*

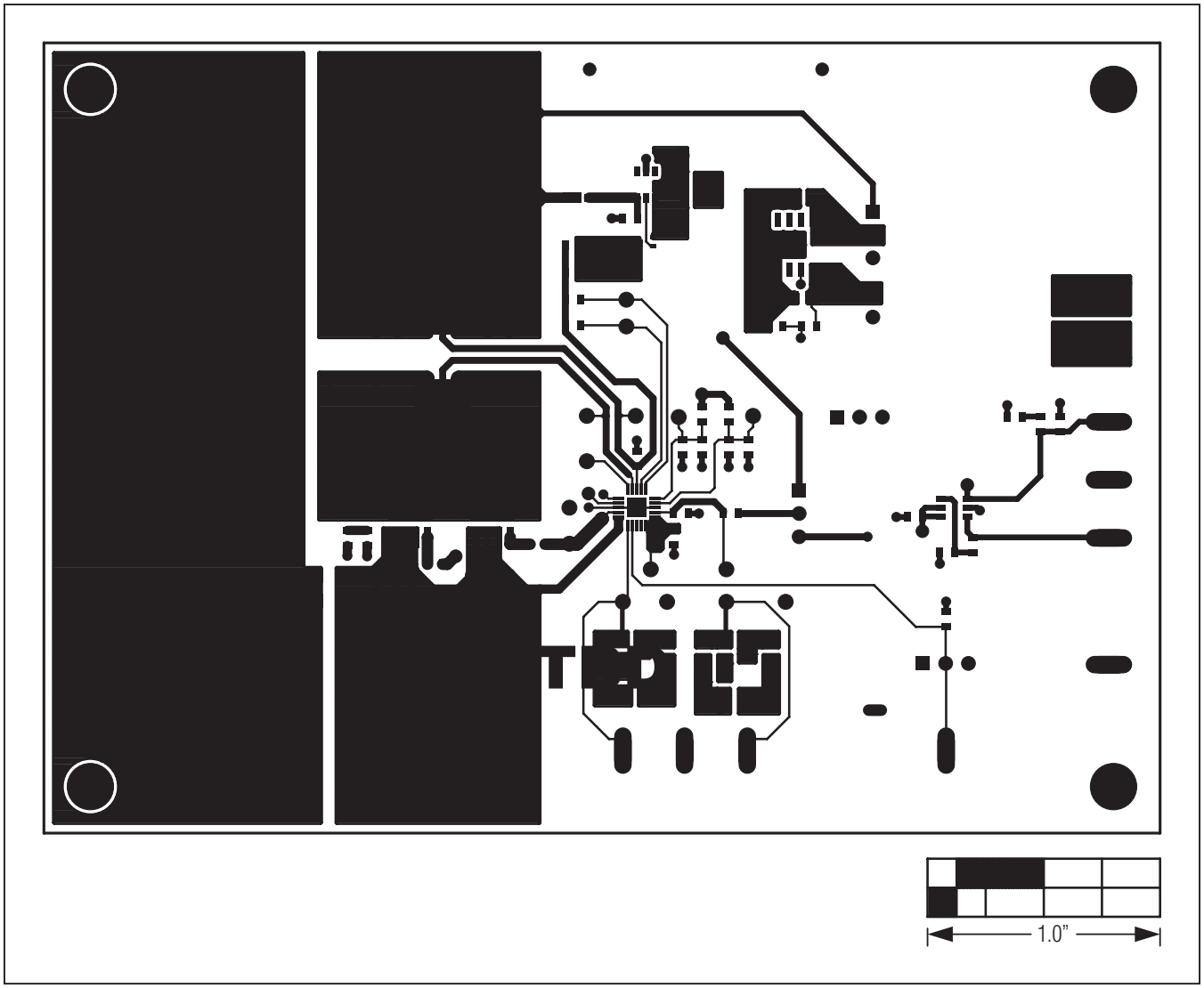


*Figure 3. MAX5977A EV Kit PCB Layout—Component Side*

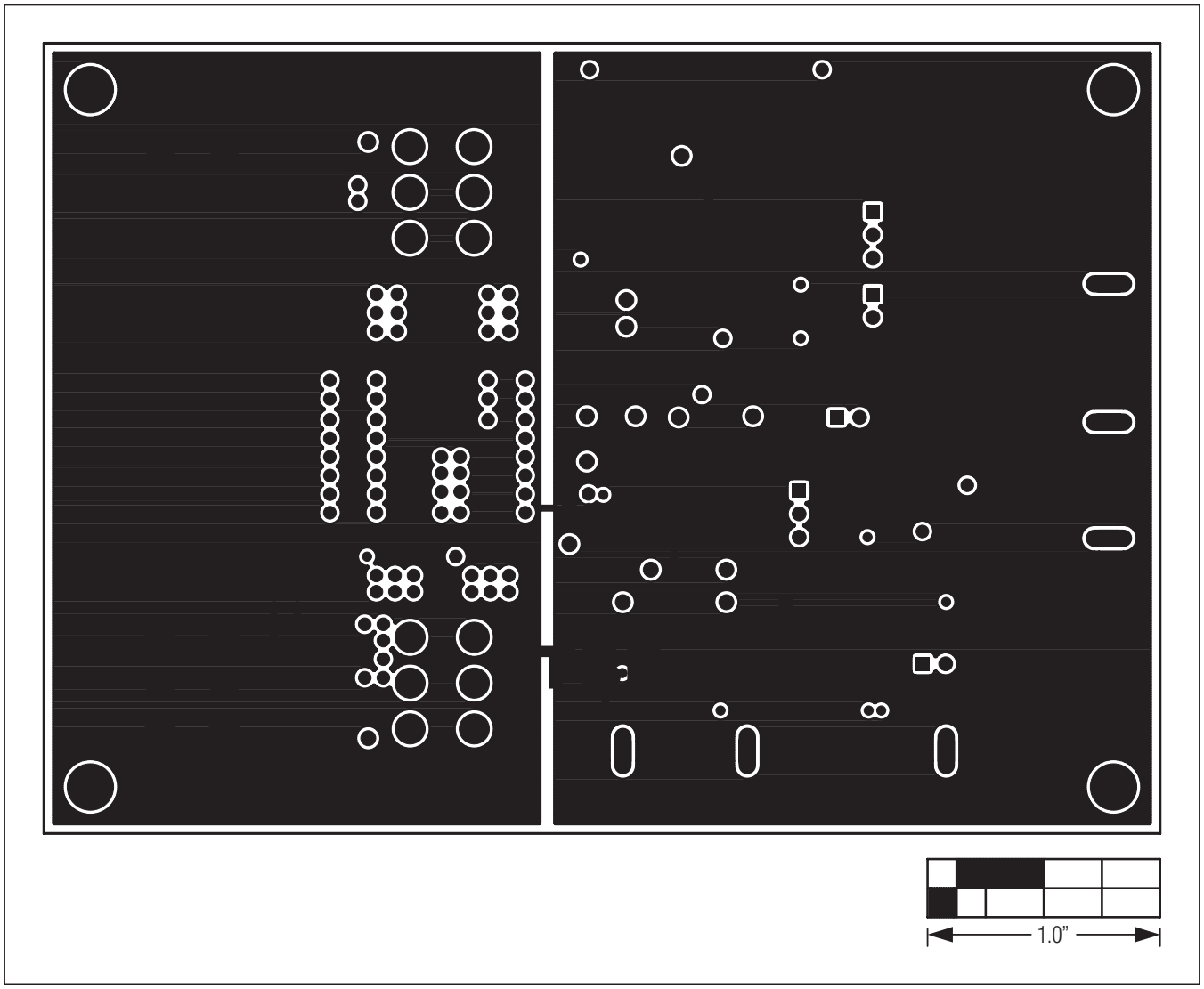


*Figure 4. MAX5977A EV Kit PCB Layout—Inner Layer 2*

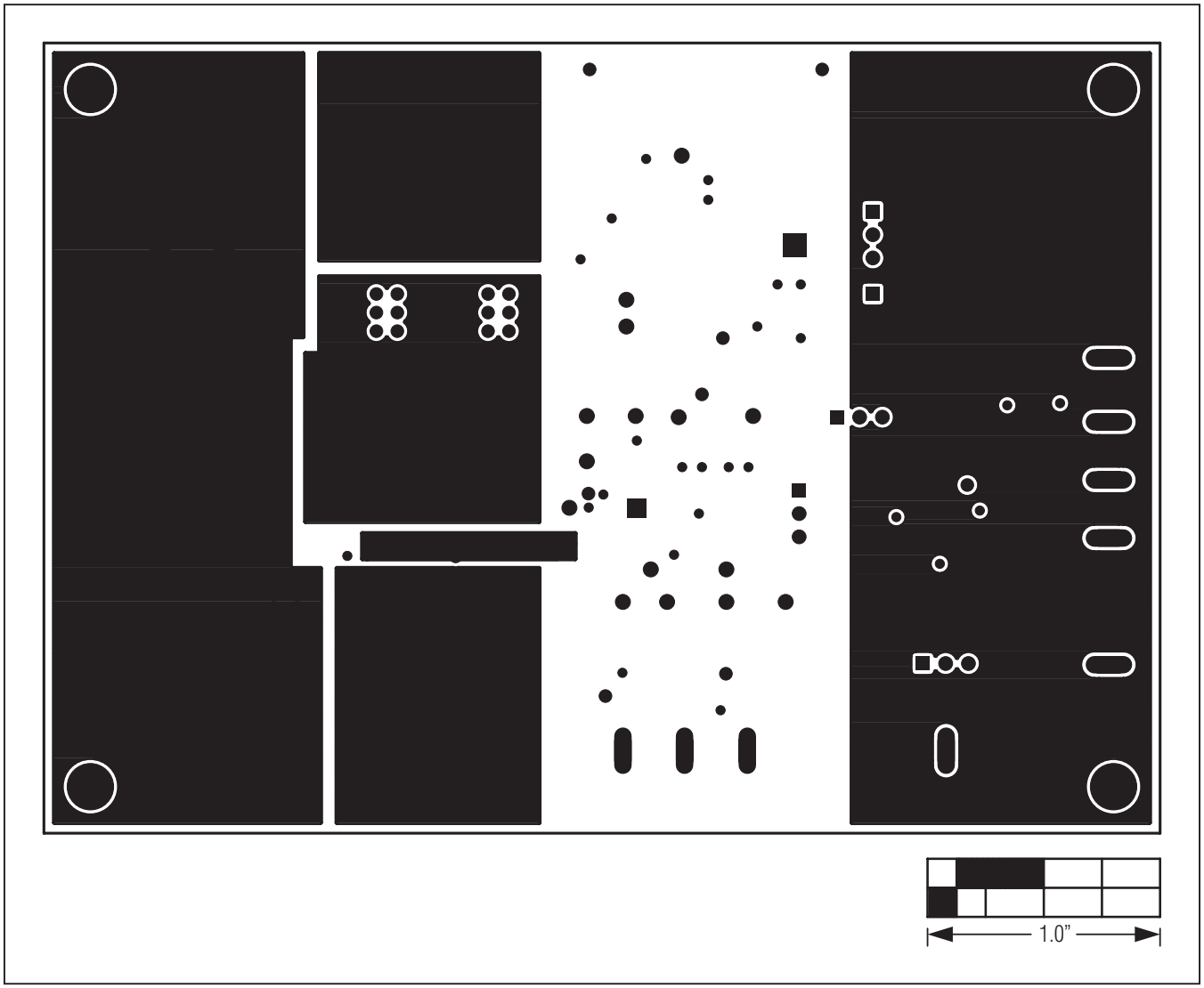


*Figure 5. MAX5977A EV Kit PCB Layout—Inner Layer 3*

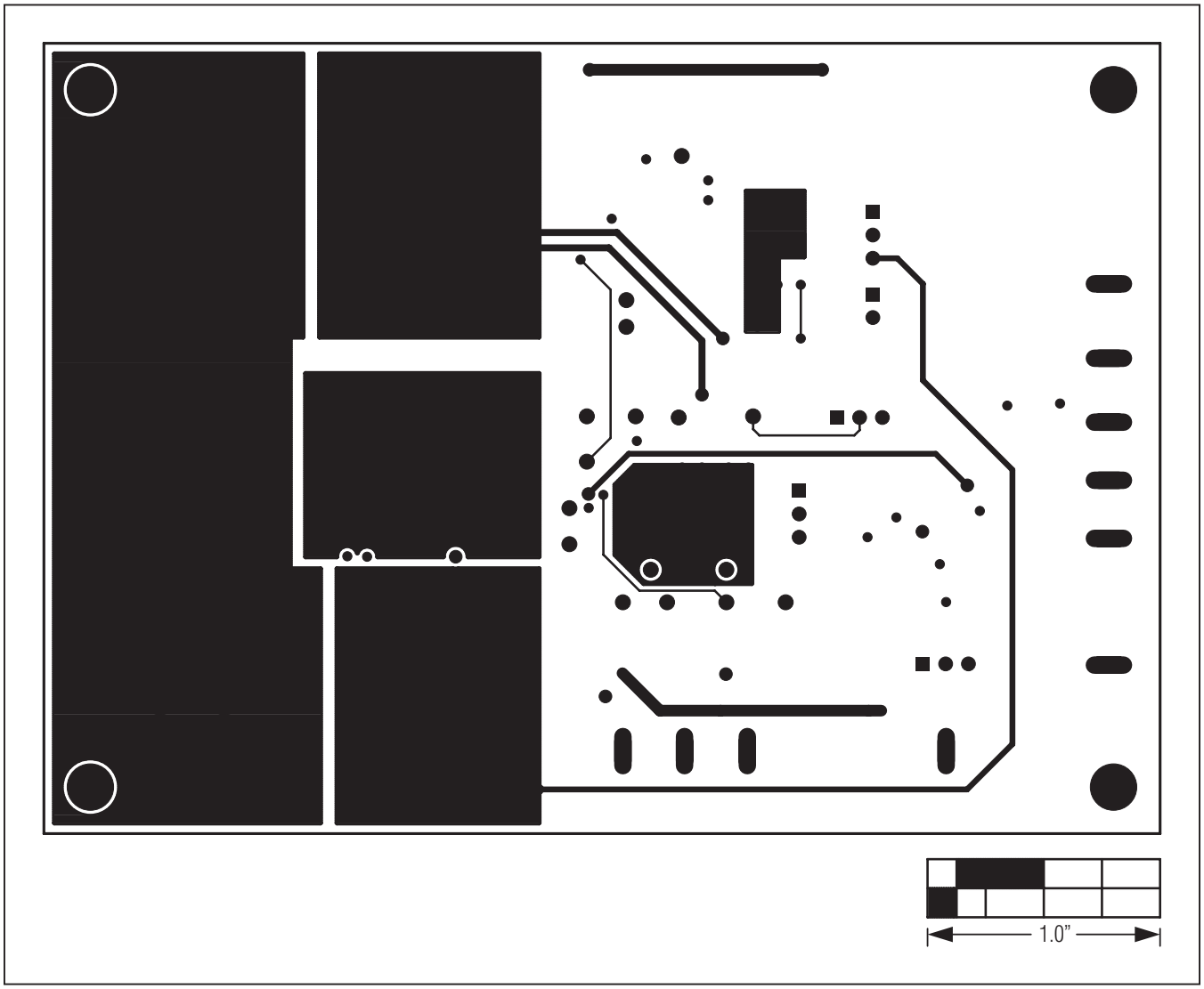


*Figure 6. MAX5977A EV Kit PCB Layout—Solder Side*

## Ordering Information

| PART | TYPE |
|---|---|
| MAX5977AEVKIT# | EV Kit |

*#Denotes RoHS compliant.*

## Revision History

| REVISION NUMBER | REVISION DATE | DESCRIPTION | PAGES CHANGED |
|---|---|---|---|
| 0 | 1/11 | Initial release | — |