



# MAX5963 Evaluation Kit

Evaluates: MAX5963

## General Description

The MAX5963 evaluation kit (EV kit) circuit demonstrates the dual hot-swap, current-limit/circuit-breaker, and ORing functions of the MAX5963 controller. The MAX5963 EV kit operates from a 7.5V to 40V DC source. The MAX5963 controls three separate dual n-channel MOSFETs to regulate load current from an input power supply providing up to 2A, and performs low-voltage-drop power-supply ORing for two independent outputs.

The MAX5963 EV kit features several jumpers to evaluate different configurations of the MAX5963. The output current-limit threshold, current-limit timeout period, circuit-breaker threshold and timeout period, ORing threshold, and fault-management features are programmable. Shutdown mode is controlled with on-board jumpers or user-supplied external logic signals. FAULT output signals are also provided for fault-condition monitoring. The EV kit circuit is configurable for evaluating the MAX5963 latching or autoretry function and late V<sub>G</sub> protection feature.

## Features

- ◆ Safely Hot Swaps 7.5V to 40V Power Supplies
- ◆ Low-Voltage-Drop Power-Supply ORing
- ◆ Demonstrates Active-Current-Limit and Circuit-Breaker Features
- ◆ Programmable Current-Limit and Circuit-Breaker Timers
- ◆ Programmable Output-Load Current Limit
- ◆ Demonstrates Fast Current-Limit Response Time
- ◆ Evaluates Late V<sub>G</sub> Protection Feature
- ◆ Demonstrates Latching and Autoretry Fault Management
- ◆ Overcurrent FAULT Output Status LED Indicators
- ◆ Surface-Mount Construction
- ◆ Lead(Pb)-Free and RoHS Compliant
- ◆ Fully Assembled and Tested

## Ordering Information

PART	TYPE
MAX5963EVKIT+	EV Kit

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

## Component List

DESIGNATION	QTY	DESCRIPTION
C1, C12, C13	0	Not installed, ceramic capacitors (2220)
C2	1	1 $\mu$ F $\pm$ 10%, 50V X7R ceramic capacitor (1206) Murata GRM31MR71H105KA
C3	1	220pF $\pm$ 5%, 50V C0G ceramic capacitor (0805) Murata GRM2165C1H221J
C4, C5, C7, C9, C10, C11	0	Not installed, ceramic capacitors (0805)
C6	1	0.1 $\mu$ F $\pm$ 10%, 50V X7R ceramic capacitor (0805) Murata GRM21BR71H104K
C8	1	1 $\mu$ F $\pm$ 10%, 50V X7R ceramic capacitor (0805) Murata GRM21BR71H105K
C14, C15, C16	0	Not installed, ceramic capacitors (0603)
D1, D2	2	Yellow surface-mount LEDs (1206)
GND (x4)	4	PC test points, black

DESIGNATION	QTY	DESCRIPTION
GND (x3), PWR, OUTA, OUTB	6	Uninsulated banana jacks
J1	1	11-pin header
JU1–JU4, JU7, JU8	6	3-pin headers
JU5, JU6, JU9	3	2-pin headers
N1–N3	3	40V, 10.3A dual n-channel MOSFETs (PowerPAK SO8) Vishay Si7958DP-T1-E3
R1	1	13.7k $\Omega$ $\pm$ 1% resistor (0805)
R2	1	10k $\Omega$ $\pm$ 1% resistor (0805)
R3, R5	2	100k $\Omega$ $\pm$ 1% resistors (0805)
R4	1	18.2k $\Omega$ $\pm$ 1% resistor (0805)
R6	1	18.2k $\Omega$ $\pm$ 1% resistor (0805)
R7	1	130k $\Omega$ $\pm$ 1% resistor (0805)
R8	1	16.5k $\Omega$ $\pm$ 1% resistor (0805)
R9–R12	4	4.7k $\Omega$ $\pm$ 5% resistors (1812) Panasonic ERJ12YJ472U



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## Component List (continued)

DESIGNATION	QTY	DESCRIPTION
R13–R16, R22, R23	0	Not installed, resistors (0805)
R17, R21	2	0.02Ω ±1%, 0.5W sense resistors (1206) IRC LRC-LRF1206LF-01-R020-F
R18	1	221Ω ±1% resistor (0805)
R19	1	1kΩ ±1% resistor (0805)
R20	1	100Ω ±1% resistor (0805)
TP1–TP9	9	PC mini test points, red

DESIGNATION	QTY	DESCRIPTION
U1	1	Dual hot-swap and diode ORing controller (40 TQFN-EP*) Maxim MAX5963UTL+
—	4	Rubber bumpers 3M SJ-5003
—	9	Shunts (JU1–JU9)
—	1	PCB: MAX5963 Evaluation Kit+

\*EP = Exposed pad.

## Component Suppliers

SUPPLIER	PHONE	WEBSITE
IRC, Inc.	361-992-7900	www.irctt.com
Murata Electronics North America, Inc.	770-436-1300	www.murata-northamerica.com
Panasonic Corp.	800-344-2112	www.panasonic.com
Vishay	402-563-6866	www.vishay.com

**Note:** Indicate that you are using the MAX5963 when contacting these component suppliers.

## Quick Start

### Required Equipment

- One 8V to 40V DC power supply capable of supplying up to 3A
- Two voltmeters

### Procedure

The MAX5963 EV kit is a fully assembled and tested surface-mount board. Follow the steps below for board operation. **Caution: Do not turn on the power supply until all connections are completed.**

- 1) Verify that shunts are installed across pins 1-2 of jumpers JU1, JU2, JU3 (MAX5963 enabled), and JU4 (PWR for ON<sub>L</sub>).
- 2) Verify that shunts are installed on jumpers JU5 and JU6 (ONA and ONB UVLO enabled).
- 3) Verify that a shunt is not installed on jumper JU9 (latchoff mode).
- 4) Verify that shunts are installed across pins 2-3 of jumpers JU7 (26ms circuit-breaker timeout) and JU8 (3.3ms current-limit timeout).
- 5) Connect a voltmeter across the OUTA and GND banana jacks.
- 6) Set the power supply to 18V and then disable the output.
- 7) Connect the positive terminal of the power supply to the PWR banana jack. Connect the ground terminal of this power supply to the GND banana jack.
- 8) Connect a voltmeter or an oscilloscope to the header J1-9 FAULTA pin to capture fault signals and the ground lead to the J1-11 GND pin.
- 9) Turn on the power supply and enable the output.
- 10) Verify that the voltmeter connected to the OUTA output measures 18V.
- 11) Verify that FAULTA measures approximately 17.3V.
- 12) The EV kit is ready for further testing.

## Detailed Description of Hardware

The MAX5963 evaluation kit (EV kit) circuit demonstrates the ORing and independent dual hot-swap, current-limit/circuit-breaker functions of the MAX5963 controller in a 40-pin TQFN package with an exposed pad. The MAX5963 controls three separate dual n-channel MOSFETs to implement hot-swapping, ORing and current regulation between the input power source and two independent output loads on channels A and B. The MAX5963 implements the low-drop ORing function

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used for power-supply redundancy and fault isolation in highly reliable power systems. The MAX5963 EV kit is designed to operate in 7.5V to 40V systems and up to 1A per channel.

During a startup cycle, the two dual n-channel MOSFETs (N2, N3) are off until the PS voltage exceeds the internal 6.5V (typ) and the programmed 1.24V (typ) ON\_ undervoltage lockout thresholds. There are two ways for the MAX5963 channels to turn on, one is if PWR is higher than the UVLO and ON\_ is higher than 1.25V. When the system power (GATEPS) MOSFET N1-A is on, the body diode of GATEOR (MOSFET N1-B) conducts and brings up PS. GATEPS turns on when PWR is > 6.5V (typ) and the combination logic of the ENX, EXY, and ENZ pin signals are positive. The other way for the channels to turn on is if power is applied to the channel itself (either A or B). Then PS will power up through the body diodes of N2A/N2B or N3A/N3B. Once PS exceeds the PS UVLO, and ON\_ is higher than 1.25V, both channels will turn on. In this power mode, current flows from one channel to the other channel. Once the total current in channel A and channel B exceed a threshold, GATEOR is turned on to short out its body diode and minimize its power dissipation. Channel A's current is sensed by resistor R17 and channel B by resistor R21.

The controller continually monitors the output current of both channels. If the output current is not lowered to below the programmed threshold, the controller lowers the respective channel's gate-drive voltage of MOSFET N2 or N3 to regulate the output current at the limit. If the output current is not lowered below the programmed threshold within the timeout period, the controller turns off MOSFETs N2 and N3 and asserts a logic-low on the respective FAULT\_ header J1-9 or J1-10 pin to signal an overcurrent fault condition. Both channels operate independent and identical.

The MAX5963 current-limit timeout period is programmed by resistor R8, and the circuit-breaker timeout period is programmed by resistor R7. Output current-limit, circuit-breaker, and ORing voltage thresholds are programmed by resistor/capacitor networks R19/C15, R18/C14, and R20/C16, respectively, for both channels. The fault-management function can also be programmed to autoretry or latching mode by configuring jumper JU9. The ONA and ONB undervoltage lockout thresholds are reconfigured by jumpers or changing resistors on the EV kit. Shutdown mode is controlled by on-board jumpers or with an external logic signal connected to header J1, ENX, ENY, and ENZ, and GND pins. Various other signals are also available at header J1.

## Input Source

The MAX5963 EV kit operates from a 7.5V to 40V input source connected across the PWR and GND terminals. The input source must deliver up to 2A of current to the EV kit. The MAX5963 EV kit controller starts to function when the PWR voltage exceeds the MAX5963 UVLO voltage threshold of 6.5V (typ), ON\_ UVLO threshold, and all the positive combinations of the ENX, ENY, and ENZ pin signals are positive logic (Table 1).

## Current-Limit and Threshold Configuration

The MAX5963 limits load current by monitoring voltage across channel A's current-sense resistor R17 and R21 for channel B. The respective channel's MAX5963 GATE\_A or GATE\_B pin voltage is controlled so the respective output load current does not exceed the programmed current-limit threshold ( $I_{LIM}$ ). The current-limit threshold is programmed by resistor/capacitor network R19/C15 for both channels. When the load current is <  $I_{LIM}$ , the respective dual MOSFET N2 or N3 is fully enhanced. When the load current exceeds  $I_{LIM}$ , the respective MOSFET's gate voltage is reduced to regulate the current, causing the MOSFET to act as a current source. If the load current demand exceeds  $I_{LIM}$  for longer than the current-limit timeout period, the respective dual MOSFET (N2 or N3) is turned off to disconnect the load. The channel's FAULT\_ signal is also asserted low at the header J1-9 pin for channel A or J1-10 pin for channel B.

The output current limit is determined by the value of sense resistor R17 or R21 and the programmed current-limit voltage threshold across the sense resistor. The output current limit can be reconfigured by replacing current-sense resistors R17 or R21. Choose sense resistors that are rated for the new power dissipation levels and verify that the power ratings for MOSFETs N1, N2, and N3 meet the new operating conditions.

The current-limit threshold is programmed by resistor/capacitor network R19/C15 for both channels. To reconfigure the EV kit for a different current-limit threshold, refer to the *Current-Limit Threshold* section in the MAX5963 IC data sheet for more information on selecting a new value for the R19/C15 network.

## Circuit-Breaker Configuration

The MAX5963 circuit breaker monitors current across current-sense resistors R17 (channel A) and R21 (channel B). Once the output exceeds the circuit-breaker limit, the circuit-breaker timer begins. When the circuit-breaker timers time out, the respective channel's GATE\_A or GATE\_B pin voltage is pulled low, turning

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off the respective dual MOSFET (N2 or N3). The circuit-breaker limit is determined by the value of sense resistor R17 or R21 and the programmed circuit-breaker voltage threshold across the sense resistor. The circuit-breaker voltage threshold is programmed by resistor/capacitor network R18/C14 for both channels. The circuit-breaker limit can be reconfigured by replacing current-sense resistors R17 or R21, however, note that this will also change the current limit. Choose current-sense resistors that are rated for the new power-dissipation levels. Additionally, verify that the power ratings for MOSFETs N1, N2, and N3 meet the new operating conditions.

To reconfigure the EV kit for a different circuit-breaker threshold, refer to the *Circuit-Breaker Threshold* section in the MAX5963 IC data sheet for more information on selecting a new value for the R18/C14 resistor/capacitor network.

## Power-Supply Control and ORing Configuration

The MAX5963 provides a low-voltage-drop ORing function fault isolation and the EV kit is designed to operate in 7.5V to 40V systems while providing up to 1A per channel. During a startup cycle, the two dual n-channel MOSFETs (N2, N3) are off until the PS voltage exceeds the internal 6.5V (typ) and the programmed 1.24V (typ) ON\_ undervoltage lockout thresholds. There are two ways for the MAX5963 channels to turn on, one is if PWR is higher than the UVLO and ON\_ is higher than 1.25V. When the system power (GATEPS) MOSFET N1-A is on, the body diode of GATEOR (MOSFET N1-B) conducts and brings up PS. GATEPS turns on when PWR is > 6.5V (typ) and the combination logic of the ENX, ENY, and ENZ pin signals are positive.

The other way for the channels to turn on is if power is applied to the channel itself (either A or B). Then PS will power up through the body diodes of N2A/N2B or N3A/N3B. Once PS exceeds the PS UVLO and ON\_ is higher than 1.25V, both channels will turn on. In this power mode, current flows from one channel to the other. Once the total current in channel A and channel B exceeds a threshold, GATEOR is turned on to short out its body diode and minimize its power dissipation. Channel A's current is sensed by resistor R17 and channel B's current is sensed by resistor R21.

The controller continues to monitor the average voltage across sense resistors R17 and R21 and turns off GATEOR when that voltage drops below the V<sub>OR</sub> threshold. When GATEOR is turned off, current cannot backdrive the input source PWR if the voltage at OUT is higher than the PWR voltage.

The V<sub>OR</sub> threshold is programmed by resistor R20 and capacitor C16. The V<sub>OR</sub> threshold is reprogrammed by replacing resistor R20 with a new value. Refer to the *Power-Supply ORing (GATEPS and GATEOR)* section in the MAX5963 IC data sheet.

## Jumper Selection

The MAX5963 EV kit features several jumpers to reconfigure the enable/disable, UVLO, current-limit timer, and other fault-management functions.

## Shutdown, Standby, and Enabled Modes

The MAX5963 EV kit features three jumpers to reconfigure the enable/disable MAX5963 inputs and the power-on/power-off control. The MAX5963 can be configured for three modes of operation, shutdown, standby, and enabled. The ENZ provides the power-on/power-off control. The MAX5963 logically combines the ENX, ENY, ENZ signals (e.g., [(ENX or ENY) and ENZ]) to control GATEPS, the system power MOSFET, N1A. On-board jumpers JU1, JU2, and JU3 control the EV kit's mode of operation; an external controller can also be used. See Table 1 to reconfigure jumpers JU1, JU2, and JU3 for the desired mode of operation.

Alternatively, the EV kit can be controlled by an external logic signal connected to header J1 using the ENX, ENY, and ENZ, and GND header pins. Remove the shunts from jumpers JU1, JU2, and JU3 and use an external controller with a logic signal that provides a logic-low ( $\leq 0.7V$ ) or logic-high ( $\geq 1.8V$ ) signal to set the mode of operation for the EV kit. Refer to the *Power-Supply Enables (ENX, ENY, and ENZ)* section in the MAX5963 IC data sheet for more information on using the MAX5963 ENX, ENY, and ENZ functions.

## ONA and ONB Undervoltage Lockout Thresholds and Disable

The MAX5963 EV kit features three jumpers to configure the UVLO for channels A and B. The UVLO threshold (6.5V default) must be exceeded for normal operation. If the voltage at the ON\_ input drops below the 1.24V threshold, the MAX5963 controller turns off the respective MOSFET's N2 or N3 to disconnect the input power supply from the respective output. The controller returns to normal operation if the input voltage exceeds the default UVLO threshold. The ONA and ONB signals are available at header J1 using the ONA, ONB, and GND header pins. See Table 2 for reconfiguring the channel A and B UVLO using jumpers JU4, JU5, and JU6.

The MAX5963 EV kit ONA and ONB UVLO threshold is 1.24V and the turn-on voltage is programmable with resistors. The turn-on voltage can be reconfigured to a value > 7.5V by changing resistor R4 (ONA) for channel

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**Table 1. Shutdown, Standby and Enabled Configuration (JU1, JU2, JU3)**

SHUNT POSITION			OUTA AND/OR OUTB	GATEPS MOSFET N1-A	MAX5963 MODE OF OPERATION
JU1 (ENX)	JU2 (ENY)	JU3 (ENZ)			
1-2	1-2 or 2-3	1-2	Load	Enabled	Power flows from PWR to channels
1-2 or 2-3	1-2	1-2	Load	Enabled	Power flows from PWR to channels
2-3	2-3	1-2 or 2-3	Load	Disabled	Shutdown
1-2 or 2-3	1-2 or 2-3	2-3	Load	Disabled	Shutdown
1-2	1-2 or 2-3	1-2	Powered	Enabled	PS receives power from ports
1-2 or 2-3	1-2	1-2	Powered	Enabled	PS receives power from ports
2-3	2-3	1-2 or 2-3	Powered	Disabled	Standby (PS receives power from ports)
1-2 or 2-3	1-2 or 2-3	2-3	Powered	Disabled	Standby (PS receives power from ports)
Not installed	Not installed	Not installed	—	Operation controlled by connections at header J1	

**Table 2. UVLO Configuration (JU4, JU5, JU6)**

SHUNT POSITION			EV KIT UVLO MODE
JU4 (SOURCE)	JU5 (ONA)	JU6 (ONB)	
1-2 (PWR) or 2-3 (PS)	Installed	Installed	Channels A and B UVLO enabled
1-2 (PWR) or 2-3 (PS)	Installed	Not installed	Only channel A UVLO enabled
1-2 (PWR) or 2-3 (PS)	Not installed	Installed	Only channel B UVLO enabled
1-2 (PWR) or 2-3 (PS)	Not installed	Not installed	Both channels disabled
Not installed	Not installed	Not installed	Disabled

A, or resistor R6 (ONB) for channel B. Use the following equation to select the new value:

$$R4, R6 = \frac{R_{top}}{\left(\frac{V_{TURN-ON}}{1.24V} - 1\right)}$$

where  $V_{TURN-ON}$  is the desired turn-on voltage,  $R_{top}$  is resistor R3 or R5 and is typically 100kΩ.

Refer to the *Undervoltage Lockout* section in the MAX5963 IC data sheet for more information on using the MAX5963 ONA and ONB pins.

### Circuit-Breaker Timer

The MAX5963 controller features a programmable circuit-breaker timeout function. If either channel's output current exceeds the circuit-breaker limit, the circuit-breaker timer begins timing. If the timer exceeds the programmed timeout period, the MAX5963 disconnects the input power supply from the load by turning off the respective channel's MOSFET, N2 for channel A or N3 for channel B. The timeout period is programmed by

resistor R7 and jumper JU7. The MAX5963 EV kit time-out period can be programmed by configuring jumper JU7. See Table 3 to reconfigure jumper JU7.

**Table 3. Circuit-Breaker Timer Configuration (JU7)**

SHUNT POSITION	TCB PIN CONNECTION	CIRCUIT-BREAKER TIMEOUT PERIOD (ms)
2-3	Connected to R7	26
1-2	Connected to BP	3

The circuit-breaker timeout period can also be configured for a different timeout interval by replacing resistor R7. Refer to Figure 3 in the MAX5963 IC data sheet to select a new resistance value for R7.

Refer to the *Circuit-Breaker Timeout* section in the MAX5963 IC data sheet for more information. **Note:** When reconfiguring the circuit-breaker timer or operating in autoretry mode, may produce excessive heating and electrical stresses in resistors R17, R21,

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MOSFETs N1, N2, N3, and other components in the power path. Verify that the components on the board can handle the electrical and thermal stresses with the new timeout period.

### Current-Limit Timer

The MAX5963 controller features a programmable current-limit timeout function. If the current-limit fault exceeds the programmed timeout period, the MAX5963 disconnects the input power supply from the load by turning off the respective channel's MOSFET, N2 for channel A or N3 for channel B. The timeout period is programmed by resistor R8 and jumper JU8. The MAX5963 EV kit timeout period can be programmed by configuring jumper JU8. See Table 4 to reconfigure jumper JU8 and program the current-limit timeout period.

**Table 4. Current-Limit Timer Configuration (JU8)**

SHUNT POSITION	TCL PIN CONNECTION	CURRENT-LIMIT TIMEOUT PERIOD (ms)
2-3	Connected to R8	3.3
1-2	Connected to BP	1

The current-limit timeout period can be configured for a different timeout interval by replacing resistor R8. Refer to Figure 3 in the MAX5963 IC data sheet to select a new resistance value for R8.

Refer to the *Current-Limit Timeout* section in the MAX5963 IC data sheet for more information. **Note:** When operating in autoretry mode, may produce excessive heating and electrical stresses in resistors R17, R21, MOSFETs N1, N2, N3, and other components in the power path. Verify that the components on the board can handle the electrical and thermal stresses with the new timeout period.

### $\overline{FAULTA}$ , $\overline{FAULTB}$ , and Autoretry/Latchoff Modes

The MAX5963 EV kit  $\overline{FAULTA}$  and  $\overline{FAULTB}$  outputs are asserted low to GND when a current-limit fault condition has occurred. The respective channel's  $\overline{FAULT}_$  output is pulled up to PS by LED biasing resistor pairs, R9/R10 or R11/R12 during normal operating conditions. During a fault, the MAX5963 turns off the respective MOSFET (N2 or N3) and asserts a logic-low signal on the respective  $\overline{FAULT}_$  output header pin, J1-9 pin for  $\overline{FAULTA}$  and J1-10 for  $\overline{FAULTB}$ .

The MAX5963 fault mode can be programmed for latchoff or autoretry mode. In latchoff fault mode, the MAX5963 turns off dual MOSFET N2 or N3 where the fault occurred. The MAX5963 EV kit circuit can be reset to normal operation by removing the fault condition and cycling the respective channel's ON\_ pin low and then high. Cycling the ON\_ pin can be achieved by applying a low-to-high transition at the ON\_ header pin with a microcontroller. The MAX5963 will not enter a startup cycle until its timer  $t_{OFF}$  ( $t_{OFF} = 128 \times t_{TCL}$ ) or ( $128 \times t_{TCL}$ ) has expired. The latchoff fault can also be reset by turning the input power supply off and on. This method allows the circuit to restart without a timer wait period of  $t_{OFF}$ .

In autoretry mode, after a fault condition has occurred, the MAX5963 controller automatically attempts to restart after the  $t_{OFF}$  period of ( $128 \times t_{TCB}$ ) or ( $128 \times t_{TCL}$ ). All  $\overline{FAULT}_$  outputs deassert every restart cycle. The autoretry and latchoff modes are set by configuring jumper JU9. See Table 5 to reconfigure jumper JU9 for the desired mode of operation.

**Table 5. Autoretry/Latchoff Configuration (JU9)**

SHUNT POSITION	RETRY PIN CONNECTION	EV KIT FAULT MODE
Installed	Connected to BP	Autoretry
Not Installed	Not Connected	Latchoff

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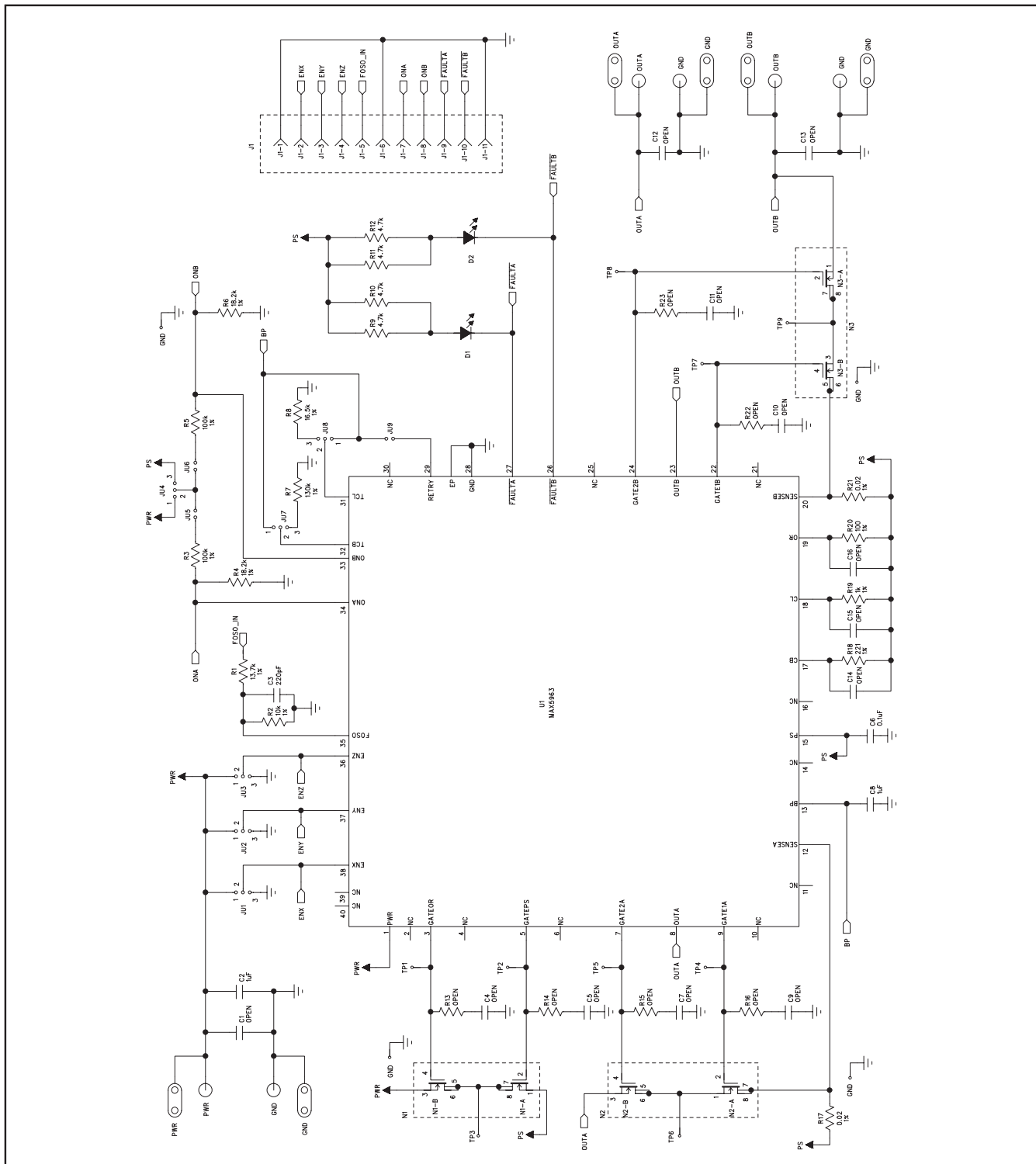


Figure 1. MAX5963 EV Kit Schematic

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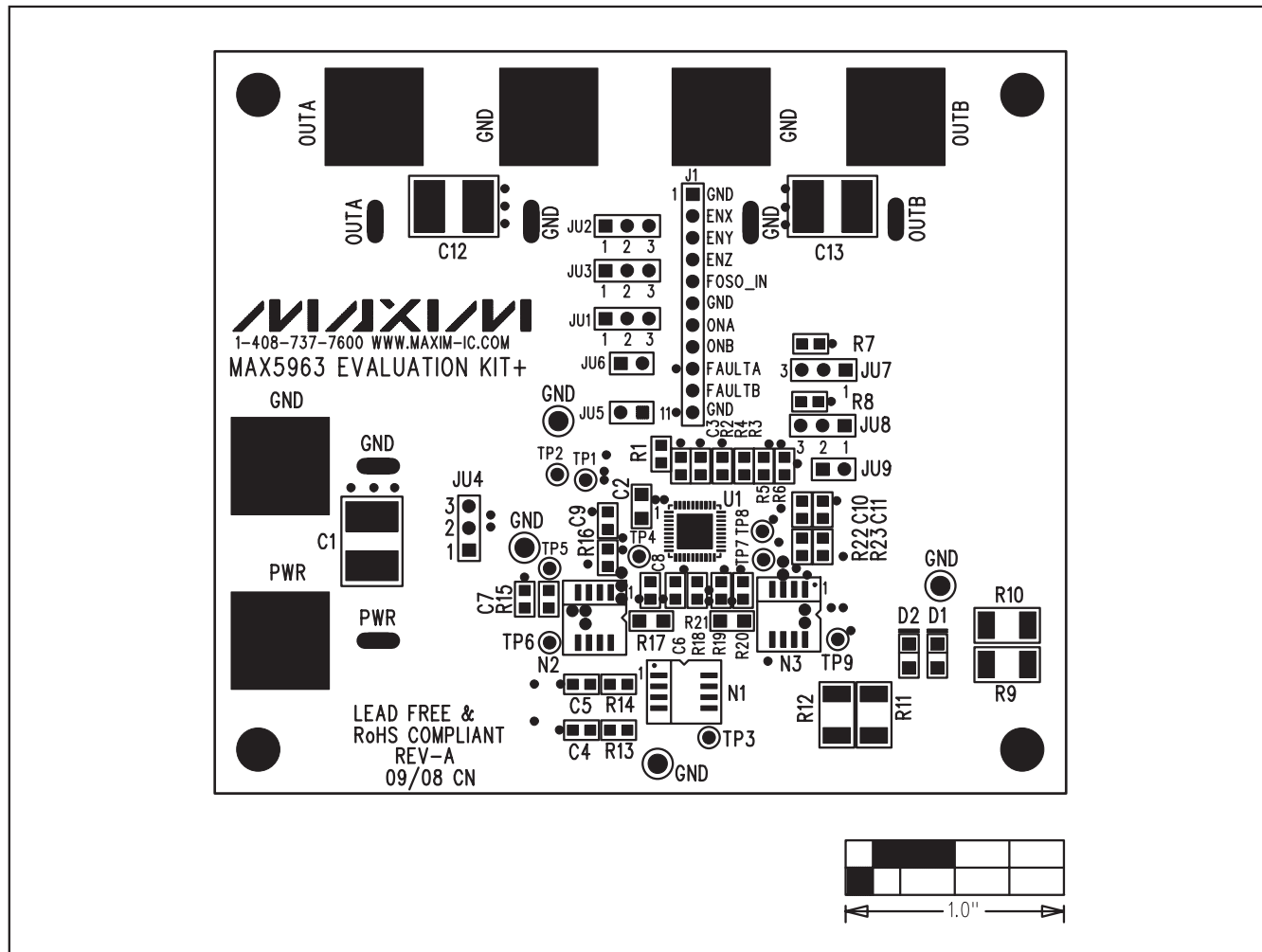


Figure 2. MAX5963 EV Kit Component Placement Guide—Component Side



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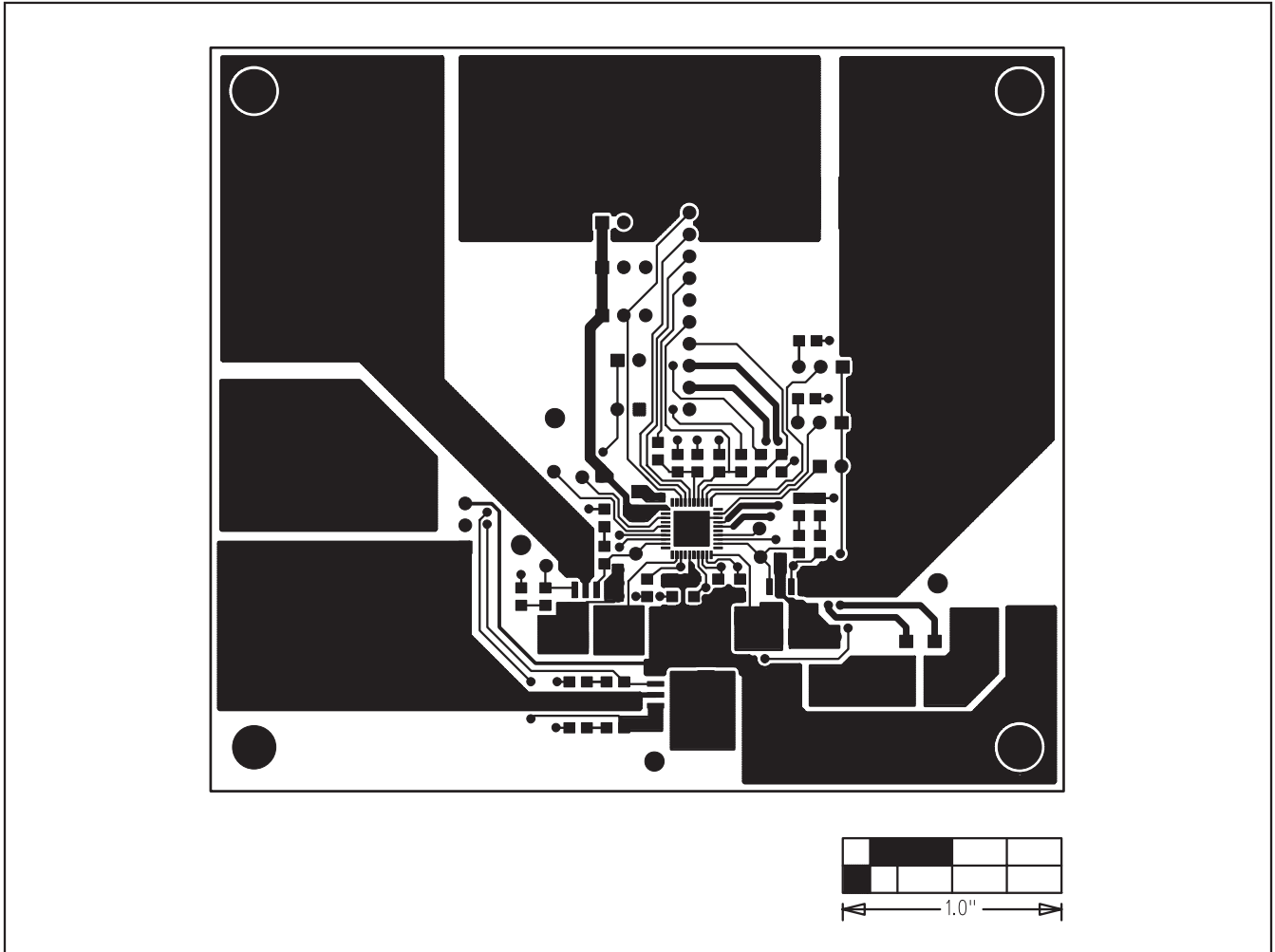


Figure 3. MAX5963 EV Kit PCB Layout—Component Side

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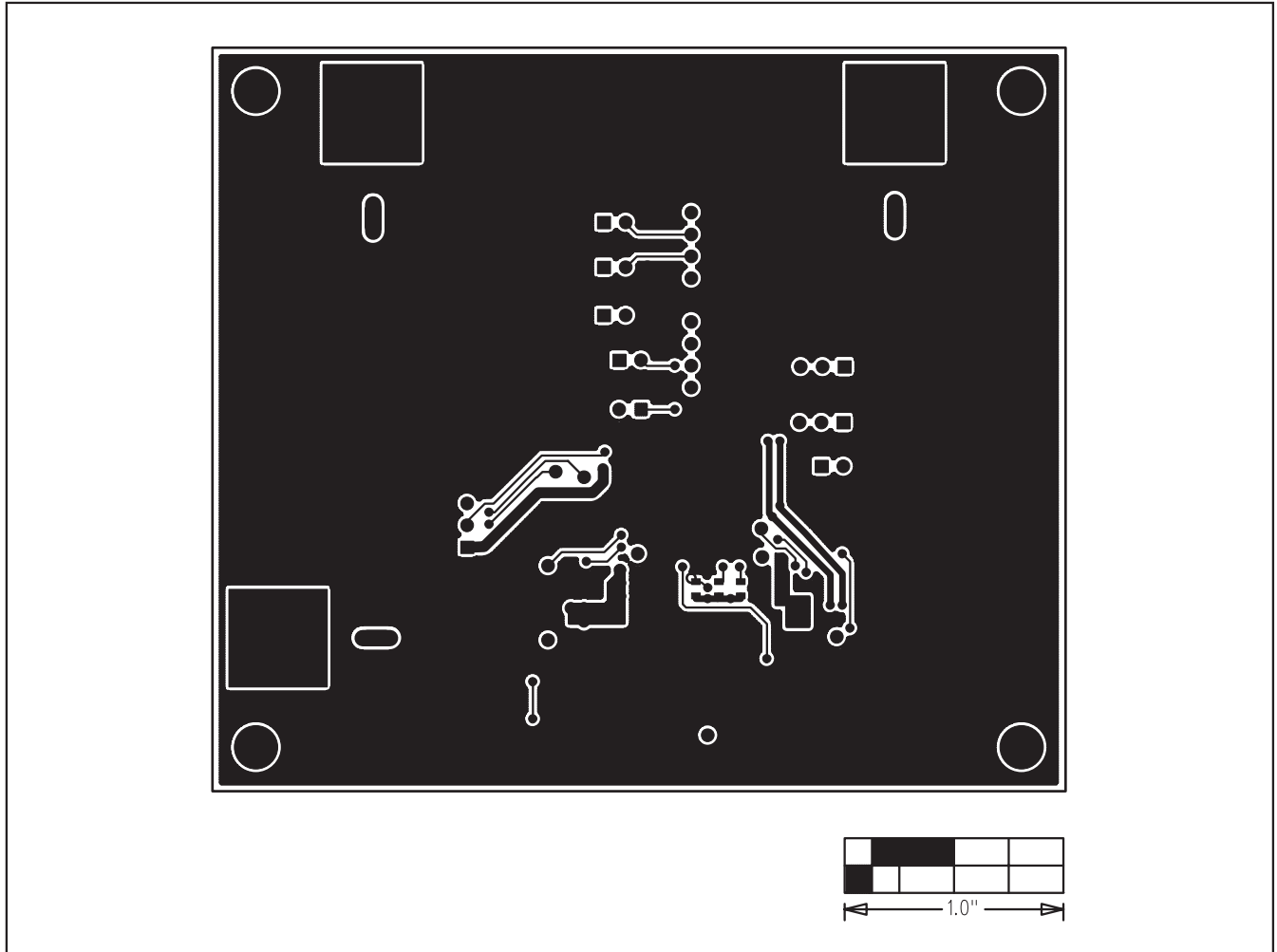


Figure 4. MAX5963 EV Kit PCB Layout—Solder Side

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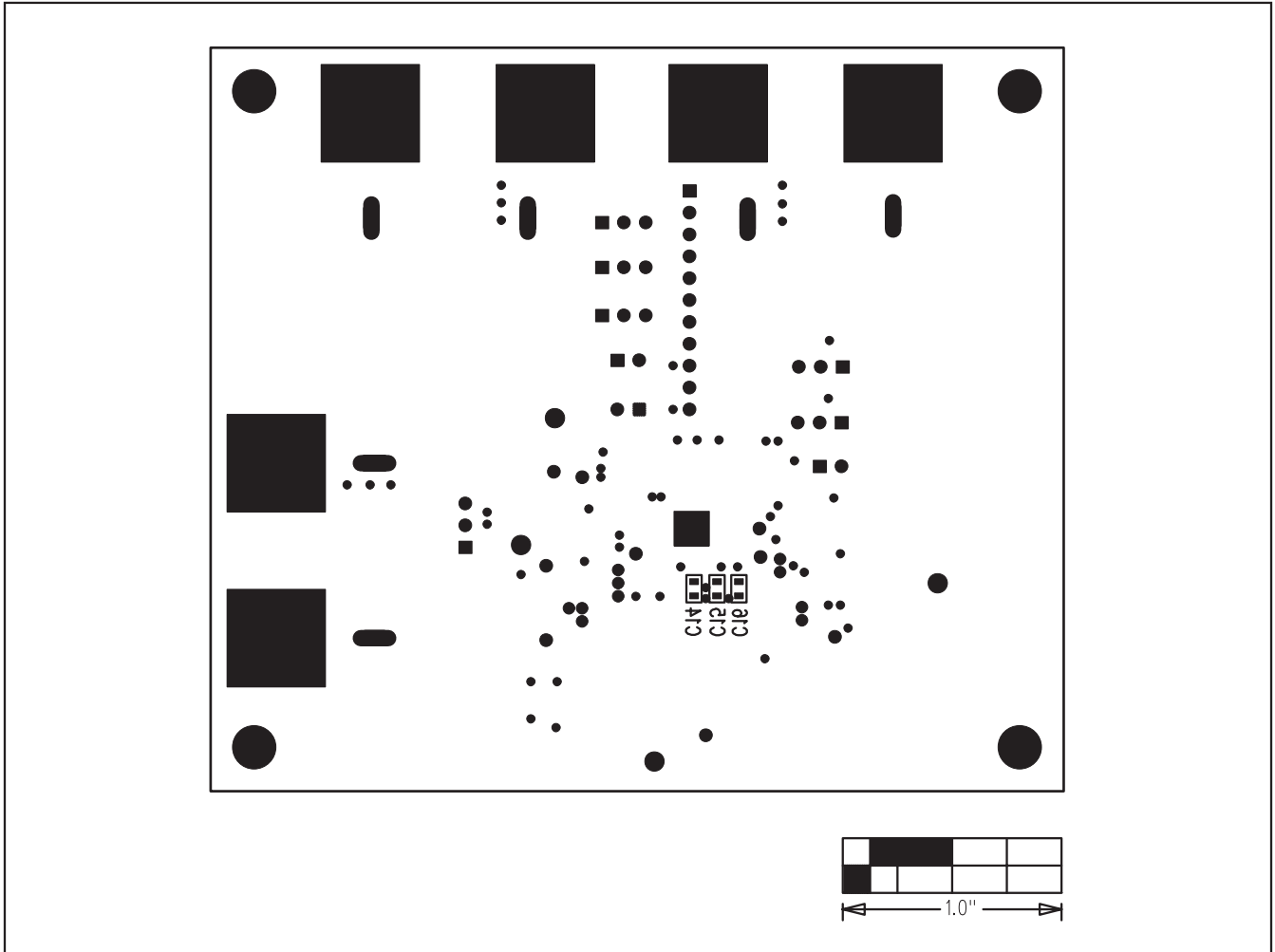


Figure 5. MAX5963 EV Kit Component Placement Guide—Solder Side

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## **Revision History**

<b>REVISION NUMBER</b>	<b>REVISION DATE</b>	<b>DESCRIPTION</b>	<b>PAGES CHANGED</b>
0	11/08	Initial release	—
1	3/09	Changed maximum current specification from 5A per channel to 1A.	1-4

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12 \_\_\_\_\_ **Maxim Integrated Products, 120 San Gabriel Drive, Sunnyvale, CA 94086 408-737-7600**