

## General Description

The MAX20070 evaluation kit (EV kit) demonstrates the MAX20070 IC, which is a highly integrated power supply plus LED backlight driver for automotive TFT-LCD applications. The EV kit is a fully assembled and tested surface-mount PCB that provides a complete power-management solution for small-size automotive displays. The EV kit demonstrates one buck-boost converter, one boost converter, two gate-voltage controllers, and a boost converter that powers a dual-string LED driver.

The DC-DC converter portion of the EV kit operates from a 2.7V to 5.5V DC supply voltage. The step-up switching regulator (POS) is configured for a 6.5V or 15V output that provides 100mA. The inverting buck-boost converter (NEG) generates a negative output that tracks the positive output and provides 100mA. The gate-driver power supplies consist of regulated charge pumps that generate +16V (GVDD) and -7V (GVEE) and can deliver up to 3mA each. It is also possible to completely turn off the inverting buck-boost regulator by changing the value of the R15 resistor to 140k $\Omega$ .

The LED driver section demonstrates a step-up DC-DC preregulator followed by two channels of linear current sinks. The step-up preregulator switches at 1MHz and operates as a current-mode-controlled regulator capable of providing up to 300mA for the linear circuits. Each channel is capable of operating up to 38V and provides up to 160mA. The channels are configurable for 80mA or 160mA HB LED output current.

The LED driver portion of the EV kit operates from a DC supply voltage of 4.5V up to the HB LED string-forward voltage. The EV kit can withstand a 40V load-dump condition. The EV kit also demonstrates the IC's features, such as adaptive voltage optimization, overvoltage protection (OVP), cycle-by-cycle current limit, thermal shutdown, and digital PWM dimming operation using a digital PWM input signal to control the brightness of the HB LEDs.

The EV kit is shipped with the MAX20070, but can also be used to evaluate the MAX20070B with IC replacement of U1.

## Features

- 2.7V to 5.5V Input Range for TFT Power Section
- 4.5V to 16V Input Range for LED Driver Section
- 1MHz Boost and Inverted Buck-Boost Switching Frequency on TFT Power Section
- TFT Section Output Voltages
  - +6.5V Output at 100mA (Step-Up Switching Regulator)
  - -6.5V Output at 100mA (Inverting Buck-Boost Switching Regulator)
  - +16V Output at 3mA (Positive-Charge Pump)
  - -7V Output at 3mA (Negative-Charge Pump)
- HB LED String Output Currents Configurable for 80mA or 160mA
- Demonstrates Cycle-by-Cycle Current-Limit and Thermal-Shutdown Features on Boost LED Driver
- Demonstrates Adaptive Voltage Optimization on LED Driver Section
- Proven PCB Layout and Thermal Design
- Fully Assembled and Tested

*[Ordering Information](#) appears at end of data sheet.*

## Quick Start

### Required Equipment

- MAX20070 EV kit
- 2.7V to 5.5V DC supply
- 4V to 18V DC supply
- Voltmeter
- Two series-connected HB LED strings rated to no less than 160mA
- Current probe to measure the HB LED current

### Procedure

The 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) Verify that a shunt is installed on jumpers JP2, JP3, and JP5.
- 2) Verify that jumpers JP1 and JP4 are open.
- 3) Connect the positive terminal of the (2.7V to 5.5V) power supply to the TFT\_POWER\_INPUT PCB pad. Connect the negative terminal of the same power supply to the PGND PCB pad close to the TFT\_POWER\_INPUT PCB pad.
- 4) Turn on the power supply.
- 5) Verify that the step-up switching regulator output ( $V_{POS}$ ) to GND is +6.5V.
- 6) Verify that the step-up switching regulator output ( $V_{NEG}$ ) to GND is -6.5V.
- 7) Verify that the positive charge-pump supply ( $V_{DGVD}$ ) is approximately +16V.
- 8) Verify that the negative charge-pump supply ( $V_{DGVVE}$ ) is approximately -7V.
- 9) Connect the positive of the (4.0V to 16V) power supply to the BATTERY INPUT PCB pad and the power supply's ground to the LGND PCB pad next to the BATTERY INPUT PCB pad.
- 10) Connect the digital voltmeter across the OUT1 and LGND PCB pads. The LGND PCB pad is close to the OUT PCB pad.
- 11) Connect each HB LED string as follows:  
Channel 1: Connect an HB LED string anode to the OUT PCB pad and the cathode to the OUT1 PCB pad.  
Channel 2: Connect an HB LED string anode to the OUT PCB pad and the cathode to the OUT2 PCB pad.
- 12) Clip the current probe across the channel 1 HB LED+ wire to measure the HB LED current.
- 13) Turn on the power supply and set it to 10V.
- 14) Measure the voltage from the OUT1–OUT2 PCB pads to GND and verify that the lowest voltage is approximately 0.75V.
- 15) Measure the HB LED current using the current probe and verify all channels.

### Detailed Description of Hardware

The MAX20070 EV kit LED driver section demonstrates the MAX20070 HB LED driver with an integrated step-up DC-DC preregulator followed by two channels of linear current sinks. The preregulator switches at 1MHz and operates as a current-mode-controlled regulator, providing up to 320mA for the linear circuit while providing OVP. Cycle-by-cycle current limit is set by resistors R5 and R7, while resistors R2, R4, and R16 set the OVP voltage to 41.6V. The preregulator power section consists of inductor L2, power-sense resistors R5 and R7, and switching diode D1.

The EV kit circuit operates from a DC supply voltage of 4.5V up to the HB LED forward-string voltage. The circuit handles load-dump conditions up to 40V.

Each of the two linear channels (OUT1 and OUT2) is capable of operating up to 40V and sinks up to 160mA per channel. Each of the two channel's linear current sinks are configurable for 160mA or 80mA, or can be disabled independently by shorting the respective OUT\_ channel to ground before power-up with the LED string connected to the corresponding OUT\_ channel removed. Resistors R6, R8, and jumper JP1 configure the linear current setting for the IC's ISET pin, which sets the HB LED string current.

The EV kit features PCB pads to facilitate connecting HB LED strings for evaluation. The OUT\_ PCB pads provide connections for connecting each HB LED string's anode to the DC-DC preregulator output. The OUT1 and OUT2 PCB pads provide connections for connecting each HB LED string's cathode to the respective linear channel's current sink. Capacitors C16 and C32 are included on the design to prevent oscillations and provide stability when using long, untwisted HB LED connecting cables during lab evaluation. These capacitors are not required on a typical HB LED design.

A DIM\_IN PCB pad is provided for using a digital PWM signal to control the brightness of the HB LEDs.

### Enable Input (EN)

The IC's source-driver and gate-driver outputs ( $V_{POS}$ ,  $V_{NEG}$ ,  $V_{DGVD}$ , and  $V_{DGVVE}$ ) are controlled by driving the EN pin. The LED driver section is also enabled by the EN input. When EN is left open, all the outputs are disabled. When EN is connected to a 2.1V logic-high (or greater) level, all the outputs are enabled.

### Source-Driver Output-Voltage Selection

The EV kit's step-up switching-regulator output (POS) is set by feedback resistors R11, R12, and R18. If R12 is 0Ω, the output voltage is set to 6.5V independent of the state of JP2. If R12 is changed to 10kΩ and JP2 is open, the output voltage is 15V. To generate output voltages other than 6.5V or 15V, open JP2 and select different external voltage-divider resistors for R11 and R12. The negative source-driver supply voltage (NEG) is automatically tightly regulated to -POS within +50mV. NEG cannot be adjusted independently of POS. Refer to the *Source Driver Power Supplies* section in the MAX20070/MAX20070B IC data sheet for more information.

### Gate-Driver Output-Voltage Selection

The EV kit's positive gate-driver power supply (GVDD) is set to +16V by feedback resistors R9 and R10. To generate output voltages other than 16V, select different external voltage-divider resistors for R9 and R10. The negative gate-driver power supply (GVEE) is set to -7V by feedback resistors R13 and R14. To generate output voltages other than -7V, select different external voltage-divider resistors for R13 and R14. Refer to the *Gate-Driver Power Supplies* section in the MAX20070/MAX20070B IC data sheet for more information.

### HB LED Current

The EV kit features a jumper to reconfigure the IC's LED current sinks on both channels. When inserted, jumper JP1 configures the current sink to 160mA; removing the jumper configures the current sink to 80mA. See [Table 1](#) for jumper JP1 settings. To reconfigure the circuit for another current-sink threshold, replace resistor R6 and use the following equation to calculate a new value for the desired current:

$$R6 = \frac{1500}{I_{LED}}$$

where  $I_{LED}$  is the desired HB LED current in amps and R6 is the new resistor value for obtaining the desired HB

**Table 1. HB LED Current (JP1)**

SHUNT POSITION	ISET PIN	HB LED CURRENT-SINK LIMITS (mA)
Not installed*	Connected to R6	80
Installed	Connected to R6 and R8	160

\*Default position.

LED current. Remove jumper JP1 when configuring for another current-sink threshold. If the HB LED current is reconfigured for a different current, other components on the EV kit may need to be modified. Refer to the MAX20070/MAX20070B IC data sheet to calculate other component values.

### HB LED Digital Dimming Control

The EV kit features a DIM\_IN PCB input pad for connecting an external digital PWM signal. The DIM\_IN input is pulled up internally to  $V_{CC}$  by an internal current source of 5μA. Apply a digital PWM signal with a 0.8V logic-low (or less) and 2.1V logic-high (or greater) level, and frequencies from 200Hz to 20kHz. To adjust the HB LED brightness, vary the signal duty cycle from 0 to 100% and maintain a minimum pulse width of 1μs. Apply the digital PWM signal to the DIM\_IN PCB pad. Refer to the *LED Dimming Control* section in the MAX20070/MAX20070B IC data sheet for additional information on the dimming feature.

### FLT Signal

The EV kit features a  $\overline{FLT}$  signal. The  $\overline{FLT}$  signal is pulled up to TFT\_POWER\_INPUT if JP5 is installed. Refer to the *Short Led Detection* and the *Fault Protection on the TFT Section* sections in the MAX20070/MAX20070B IC data sheet for further information on the  $\overline{FLT}$  signal.

### OVP Configuration

The IC's LED driver OVP resistors (R2, R4, and R16) are configured for an OVP of 41.6V. This sets the maximum channel ( $V_{OUT}$ ) voltage at 41.6V. Capacitor C31 provides noise filtering to the OVP signal. To reconfigure the circuit for a different OVP voltage, replace resistors R2 and R16 with a different value using the following equation:

$$(R2 + R16) = \left( \frac{OVP}{1.25V} - 1 \right) \times R4$$

where R4 is 7.5kΩ, OVP is the overvoltage-protection voltage desired, and R2 + R16 is the new resistor value for obtaining the desired overvoltage protection. Refer to the *Open-LED Management and Overvoltage Protection* section in the MAX20070/MAX20070B IC data sheet for additional information on the OVP feature. Use the N1 MOSFET, in series with resistor R4, to lower the current drawn from the BATTERY\_INPUT when EN is low.

## Component List

PART	QTY	DESCRIPTION
C1	1	10 $\mu$ F $\pm$ 20%, 50V aluminum electrolytic capacitor Panasonic EEEFK1H100P
C2	1	33 $\mu$ F $\pm$ 20%, 50V aluminum electrolytic capacitor Suncon 50HVH33M
C3	1	1 $\mu$ F $\pm$ 10%, 50V X7R ceramic capacitor (0805)
C4	1	2.2 $\mu$ F $\pm$ 10%, 50V X7R ceramic capacitor (1210)
C5, C28, C30	3	1 $\mu$ F $\pm$ 10%, 50V X7R ceramic capacitors (1210)
C6, C7, C34	3	10 $\mu$ F $\pm$ 10%, 6.3V X7R ceramic capacitors (0805)
C8, C17, C18, C25, C26	5	4.7 $\mu$ F $\pm$ 10%, 25V X7R ceramic capacitors (0805)
C9, C14, C19	3	1 $\mu$ F $\pm$ 10% , 25V X7R ceramic capacitors (0805)
C10–C12, C15, C20, C21, C27, C33, C37, C38	10	0.1 $\mu$ F $\pm$ 10%, 50V X7R ceramic capacitors (0603)
C13	1	33nF $\pm$ 10%, 50V X7R ceramic capacitor (0805)
C16, C32	0	Not installed, ceramic capacitors (0603)
C22, C24, C35, C36	4	2.2 $\mu$ F $\pm$ 10%, 25V X7R ceramic capacitors (0805)
C23	1	0.22 $\mu$ F $\pm$ 10%, 50V X7R ceramic capacitor (0603)
C29	1	470pF $\pm$ 10%, 50V X7R ceramic capacitor (0603)
C31	1	1nF $\pm$ 1%, 50V, C0G ceramic capacitor (0603)
C39	1	220pF $\pm$ 5%, 50V C0G ceramic capacitor (0603)
C40, C41	2	100pF $\pm$ 5%, 25V C0G ceramic capacitors (0603)

PART	QTY	DESCRIPTION
D1	1	60V, 3A Schottky diode (SMB)
D2	1	60V, 2A Schottky diode (DO-220AA) SS2P6-M3/84A
D6, D9	2	30V, 0.2A dual-in series zener diodes (SOT23) BAT54S
D10, D11	2	75V, 0.6A dual-in series zener diodes (SOT23) MMBD4148SE
D12	1	30V, 0.5A Schottky diode (SOD323) (B0530)
D17	1	40V, 0.5A Schottky diode (SOD323) (CMHSH05-4)
FB1	1	0 $\Omega$ , 0.25W resistor (1206)
JP1–JP5	5	2-pin headers
L1	1	0.56 $\mu$ H $\pm$ 20%, 2.8A inductor Coilcraft LPS4018-561MR
L2	1	4.7 $\mu$ H $\pm$ 20%, 6.9A inductor Coilcraft MSS1048-472ML
L3, L4	2	10 $\mu$ H $\pm$ 20%, 1.25A inductors Coilcraft LPS4018-103MR
N1	1	30V, 1.4A n-channel MOSFET SuperSot-3 (NDS351AN)
R1	1	10 $\Omega$ $\pm$ 1%, 0.25W resistor (1206)
R2, R16	2	121k $\Omega$ $\pm$ 1%, 0.1W resistors (0603)
R3	1	2.55k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R4	1	7.5k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R5, R7	2	0.082 $\Omega$ $\pm$ 1%, 0.5W resistors (1210)
R6, R8	2	18.7k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R10	1	16.9k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R11, R18	2	110k $\Omega$ $\pm$ 1%, 0.1W resistors (0603)
R12	1	0 $\Omega$ , 0.1W resistor (0603)

## Component List (continued)

PART	QTY	DESCRIPTION
R13	1	845k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R14	1	150k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R15	1	20k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R17	1	10k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R19	1	4.99k $\Omega$ $\pm$ 1%, 0.1W resistor (0603)
R20	0	Not installed, resistor (0603)
R21, R22	2	32 $\Omega$ $\pm$ 1%, 0.25W resistors (1206)

PART	QTY	DESCRIPTION
R23, R24	2	100k $\Omega$ $\pm$ 1%, 0.1W resistors (0603)
U1	1	Integrated TFT power supply and LED backlight driver (32 TQFN-EP*) Maxim MAX20070GTJ/V+
—	1	PCB: MAX20070 EVKIT+

\*EP = Exposed pad.

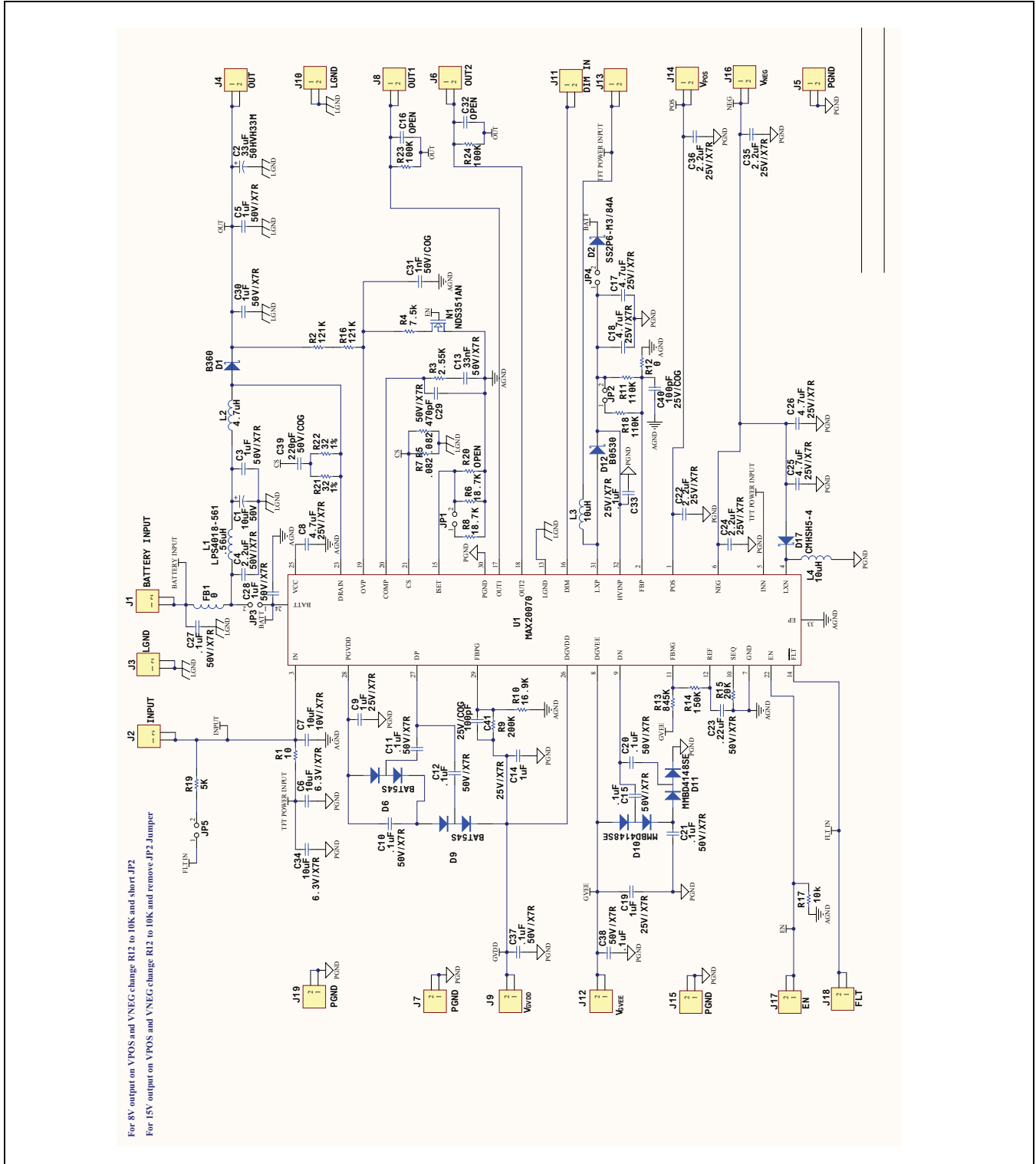


Figure 1. MAX20070 EV Kit Schematic

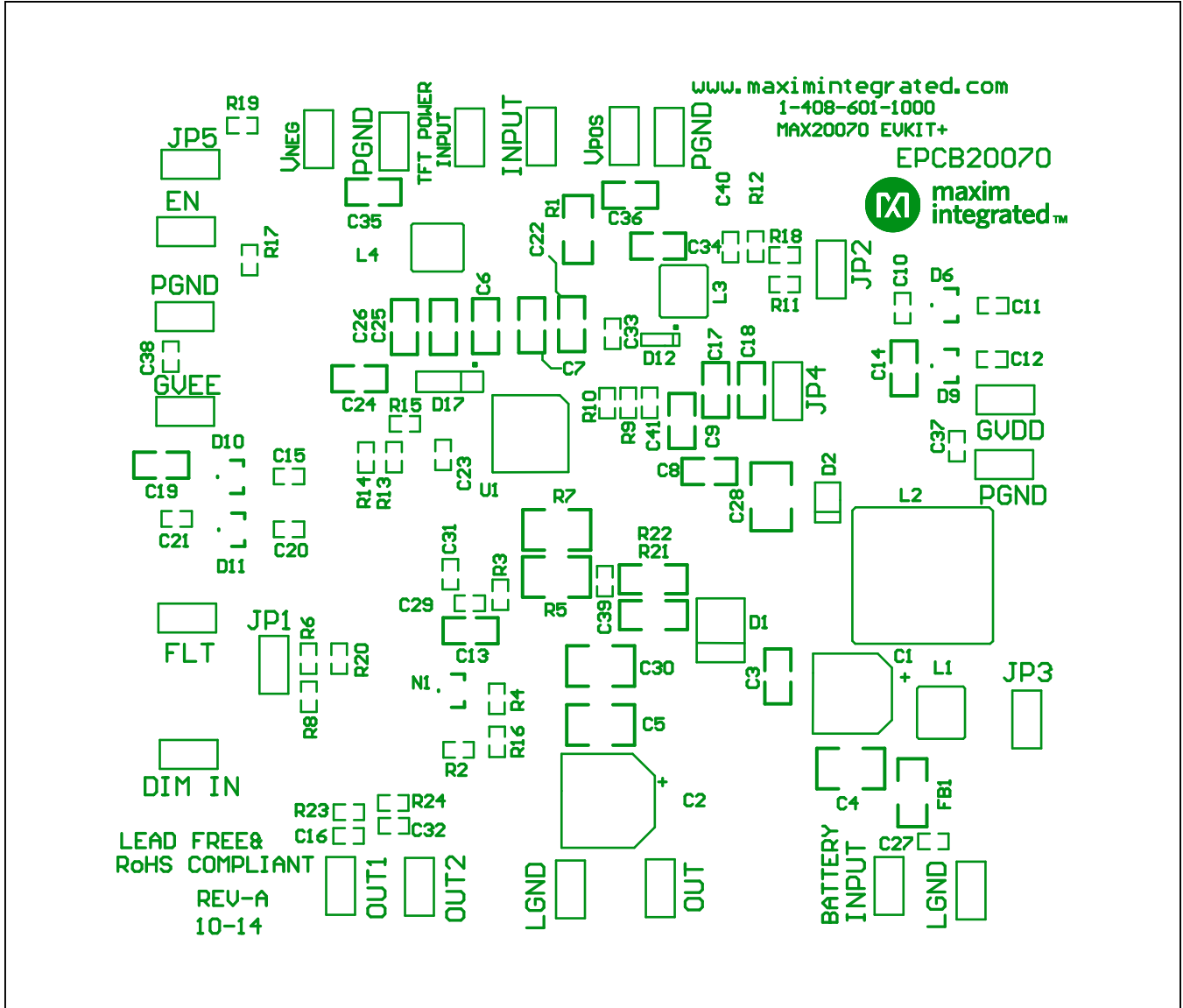


Figure 2. MAX20070 EV Kit Component Placement Guide—Component Side

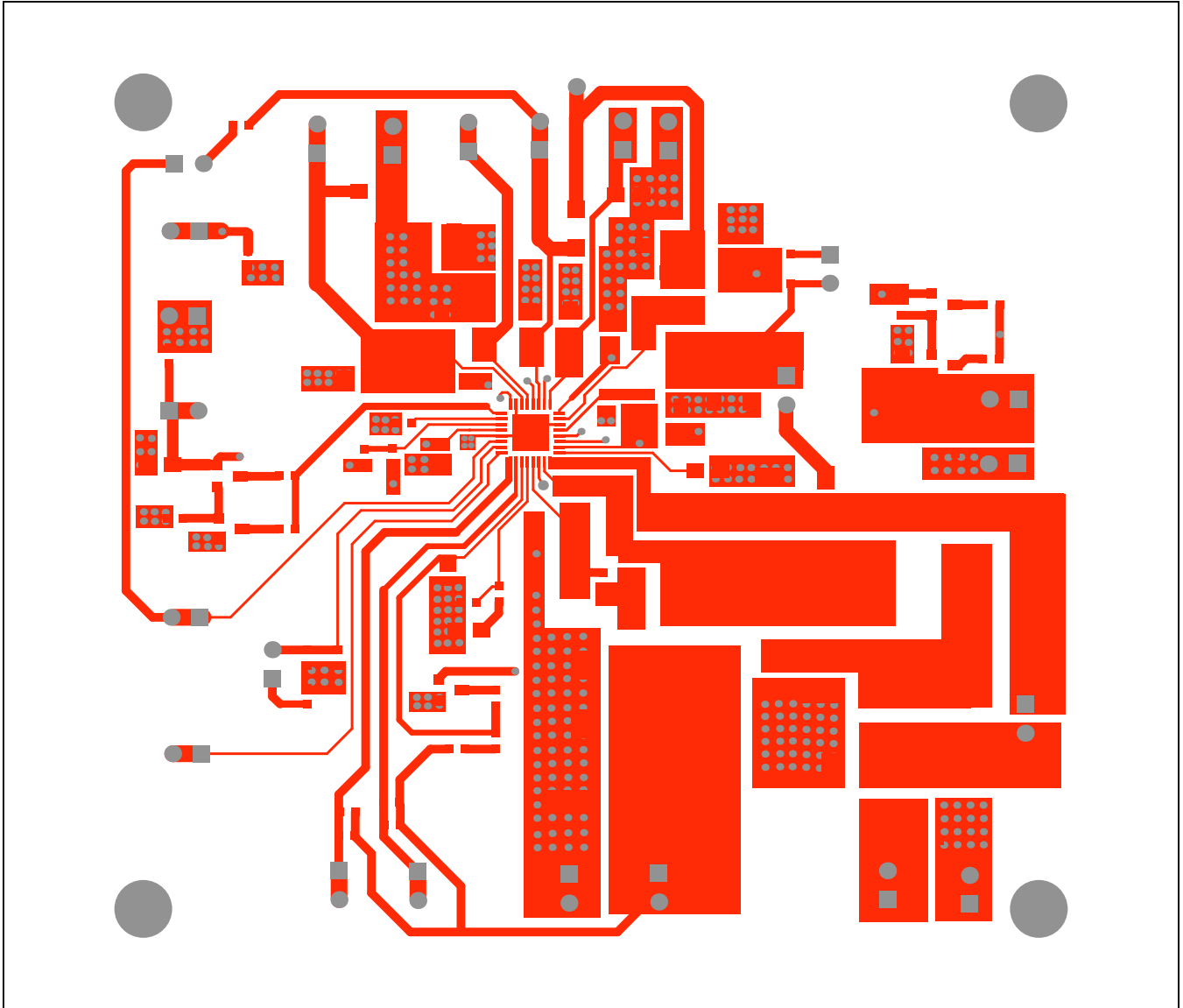


Figure 3. MAX20070 EV Kit PCB Layout—Component Side



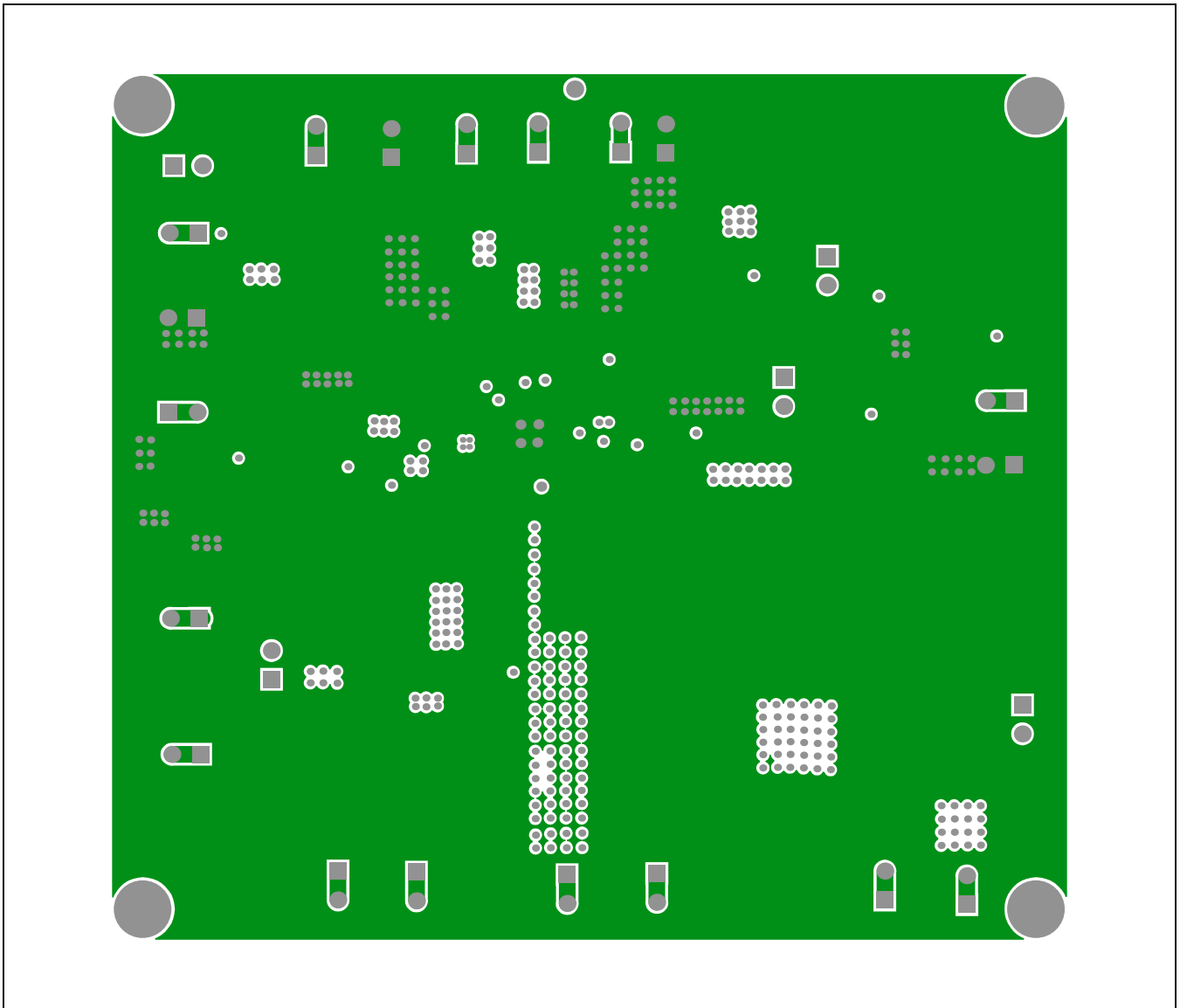


Figure 4. MAX20070 EV Kit PCB Layout—PGND Layer 2

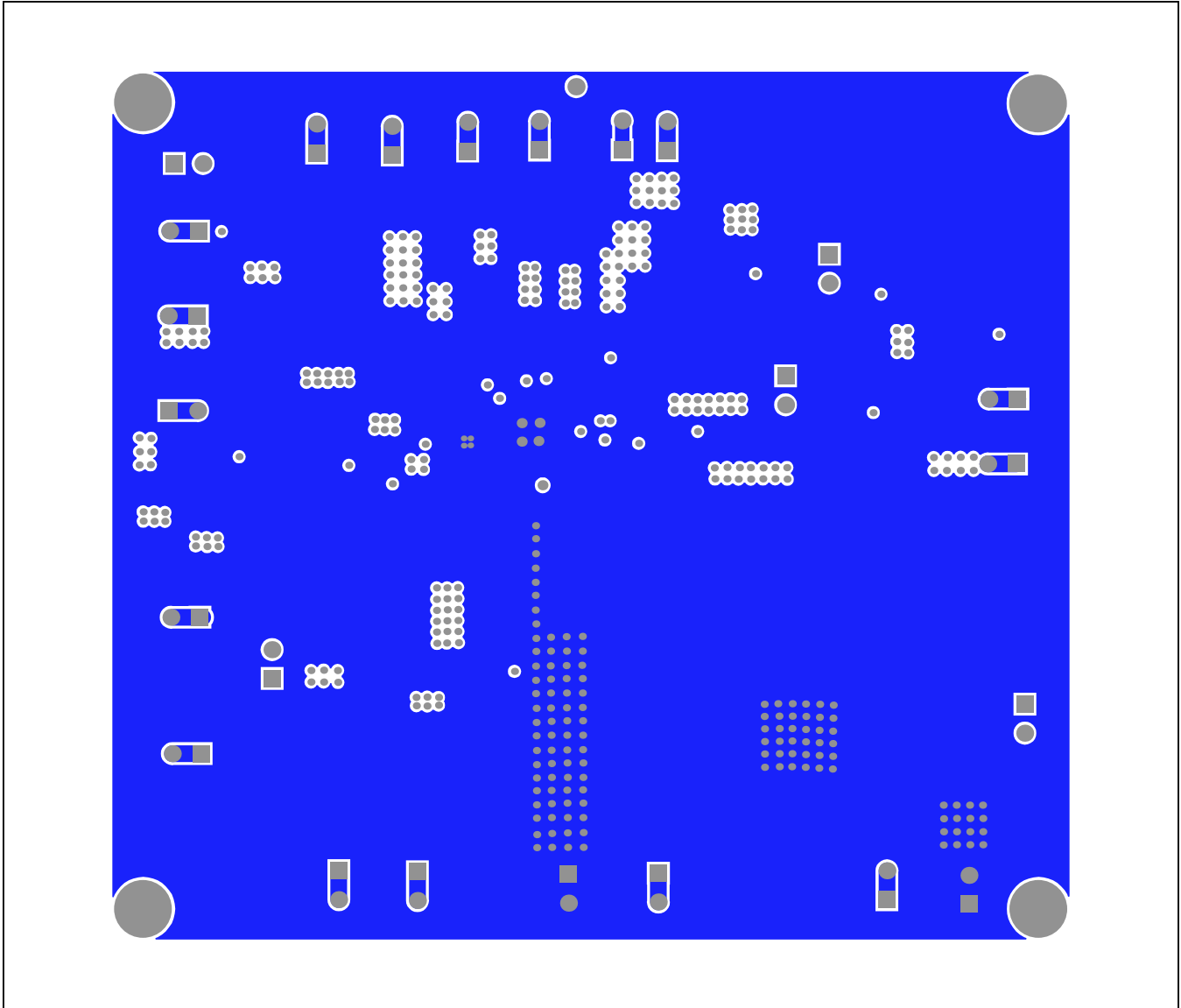


Figure 5. MAX20070 EV Kit PCB Layout—LGND Layer 3

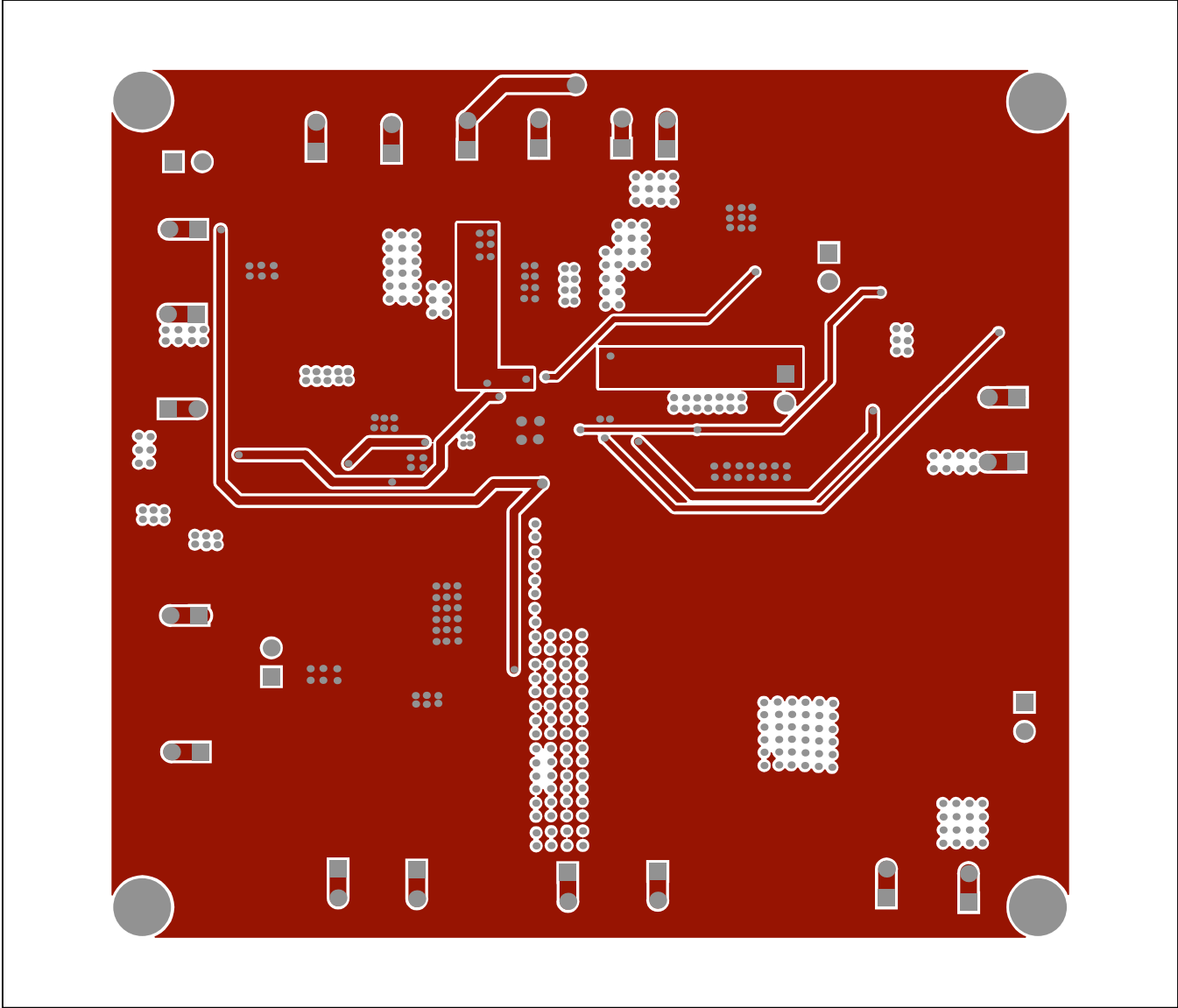


Figure 6. MAX20070 EV Kit PCB Layout—Solder Side

### Ordering Information

PART	TYPE
MAX20070EVKIT#	EV Kit

#Denotes RoHS compliant.

## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	3/15	Initial release	—
1	9/15	Added MAX20070B to data sheet	1–13

For pricing, delivery, and ordering information, please contact Maxim Direct at 1-888-629-4642, or visit Maxim Integrated's website at [www.maximintegrated.com](http://www.maximintegrated.com).

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Телефон: 8 (812) 309-75-97 (многоканальный)

Факс: 8 (812) 320-03-32

Электронная почта: [ocean@oceanchips.ru](mailto:ocean@oceanchips.ru)

Web: <http://oceanchips.ru/>

Адрес: 198099, г. Санкт-Петербург, ул. Калинина, д. 2, корп. 4, лит. А