



MAX16816 Evaluation Kit

Evaluates: MAX16816

General Description

The MAX16816 evaluation kit (EV kit) demonstrates the programmable MAX16816 current-mode, high-brightness LED (HBLED) driver IC. The EV kit is configured as a step-down/step-up (buck-boost) topology circuit with peak inductor current control and DC LED current control for driving external LEDs. The EV kit operates from a DC supply voltage of 9V to 40V and is configured to deliver 1.33A of current. The maximum output voltage of the LED string can be up to 28V. The EV kit can be configured for analog PWM- or digital-PWM-controlled dimming operation using either an analog linear DC voltage or a digital PWM input signal to control the LEDs' brightness. This EV kit has an undervoltage lockout (UVLO) feature that disables the EV kit, and overvoltage protection that protects the circuit under no-load or open HBLED conditions. The EV kit circuit demonstrates the MAX16816 IC's clock output and features an input for synchronizing to an external clock.

The EV kit uses a 1-Wire[®] interface for programming the MAX16816 IC's nonvolatile EEPROM. Adjustable features include programmable LED current (binning), external MOSFET gate driver supply voltage, leading-edge blanking time, digital soft-start duration, RTSYNC oscillator enable/disable, and slope compensation. The EV kit includes Windows[®] 2000/XP/Vista[®]-compatible software that provides a simple graphical user interface (GUI) for updating the MAX16816 EEPROM. Visit www.maxim-ic.com/evkitsoftware to download the latest version of the EV kit software. The EV kit can also interface with a user-supplied 1-wire interface circuit for stand-alone MAX16816 operation.

Caution: Do not power up the MAX16816 EV kit without connecting a load to the LED+ and LED- PCB pads.

Warning: Voltages exceeding 42V may exist on the LED+ and LED- output pads.

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Windows and Windows Vista are registered trademarks of Microsoft Corp.*

DESIGNATION	QTY	DESCRIPTION
C1, C3, C4, C5, C15, C18, C20–C25	12	0.1 μ F \pm 10%, 50V X7R ceramic capacitors (0603) Murata GRM188R71H104K
C2	1	1 μ F \pm 10%, 16V X7R ceramic capacitor (0603) Murata GRM188R71C105K
C6	0	Not installed, capacitor (0603)
C7, C19	2	10 μ F \pm 10%, 16V X7R ceramic capacitors (1206) Murata GRM31CR71C106K

Features

- ◆ 9V to 40V Wide Supply Voltage Range
- ◆ 1.33A Output Current
- ◆ Analog PWM- and Digital-PWM-Controlled Dimming
- ◆ Output Overvoltage Protection
- ◆ Demonstrates Buffered Clock Output
- ◆ Programmable EEPROM Controlling
 - LED Current (Binning)
 - External MOSFET Gate Driver Supply Voltage
 - Leading-Edge Blanking Time
 - Digital Soft-Start Duration
 - RTSYNC Oscillator Enable/Disable
 - Slope Compensation
- ◆ Nonvolatile EEPROM for Saving Register Values
- ◆ USB-PC Connection (Cable Included)
- ◆ USB-Powered USB-to-1-Wire Interface Circuit
- ◆ 1-Wire Interface Terminals for Evaluating a User-Supplied 1-Wire Interface
- ◆ Windows 2000/XP/Vista (32-Bit)-Compatible Software
- ◆ Lead-Free and RoHS Compliant
- ◆ Fully Assembled and Tested

Ordering Information

PART	TYPE
MAX16816EVKIT+	EV Kit

+Denotes lead-free and RoHS compliant.

Component List

DESIGNATION	QTY	DESCRIPTION
C8	1	100 μ F \pm 20%, 50V electrolytic capacitor (10.3mm x 10.3mm) Panasonic EEEFC1H101P
C9	1	10 μ F \pm 10%, 50V X7S ceramic capacitor (1210) Taiyo Yuden UMK325BJ106KM
C10, C11, C12	3	4.7 μ F \pm 10%, 100V X7R ceramic capacitors (2220) Murata GRM55ER72A475K



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Component List (continued)

DESIGNATION	QTY	DESCRIPTION
C13	1	0.047 μ F \pm 10%, 50V X7R ceramic capacitor (0603) TDK C1608X7R1H473K
C14	1	1000pF \pm 10%, 50V X7R ceramic capacitor (0603) Murata GRM188R71H102K
C16, C17	2	100pF \pm 5%, 50V COG ceramic capacitors (0603) Murata GQM1885C1H101J
C26, C27	2	27pF \pm 5%, 50V COG ceramic capacitors (0402) Murata GRM1555C1H270J or Panasonic ECJ0EC1H270J
C28	1	3300pF \pm 10%, 50V X7R ceramic capacitor (0603) TDK C1608X7R1H332K
C29, C30	2	470pF \pm 5%, 50V COG ceramic capacitors (0603) Murata GRM1885C1H471J
D1	1	100V, 300mA diode (SOD123) Diodes Inc. 1N4148W-7-F (Top Mark: T4)
D2	0	Not installed, diode (SOD123)
D3	1	100V, 3A Schottky diode (PowerDI 5) Diodes Inc. PDS3100
D4	1	100V, 1A Schottky diode (SMA) Diodes Inc. B1100-13-F
FB1	0	Not installed, ferrite-bead inductor (0603)
JU1	1	2-pin header
L1	0	Not installed, inductor (14.9mm x 14.9mm)
L2	1	10 μ H, 9.2A inductor (14.9mm x 14.9mm) Sumida CDEP147NP-100MC-125
N1	1	60V, 3.2A n-channel MOSFET (6 TSOP) Vishay Si3458DV-T1-E3 (Top Mark: 58)
N2	1	100V, 42A n-channel MOSFET (D-Pak) International Rectifier IRLR3110ZPBF
N3	0	Not installed, MOSFET (D-Pak)
N4, N5	2	60V, 115mA n-channel MOSFET (SOT23) Fairchild 2N7002

DESIGNATION	QTY	DESCRIPTION
R1	1	73.2k Ω \pm 1% resistor (0603)
R2	1	12.4k Ω \pm 1% resistor (0603)
R3	1	0.1 Ω \pm 1%, 500mW sense resistor (1206) IRC LRC-LR-1206LF-01-R100-F
R4	1	100 Ω \pm 5% resistor (0603)
R5	1	1 Ω \pm 5% resistor (0805)
R6, R7	2	0.04 Ω \pm 1%, 2W sense resistors (2512) IRC LRC-LR-2512LF-01-R040-F
R8	0	Not installed, resistor (0805)
R9	1	280k Ω \pm 1% resistor (0603)
R10, R15	2	4.99k Ω \pm 1% resistors (0603)
R11, R28	2	1k Ω \pm 1% resistors (0603)
R12	1	3.32k Ω \pm 1% resistor (0603)
R13	1	42.2k Ω \pm 1% resistor (0603)
R14	1	100k Ω single-turn potentiometer
R16, R17	2	27 Ω \pm 5% resistors (0603)
R18	1	1.5k Ω \pm 5% resistor (0603)
R19	1	470 Ω \pm 5% resistor (0603)
R20, R21	2	10k Ω \pm 5% resistors (0603)
R22	1	3.24k Ω \pm 5% resistor (0603)
R23	1	2.2k Ω \pm 5% resistor (0603)
R25, R26, R27	3	0 Ω \pm 5% resistors (0603)
TP1	0	Not installed, small PCB test point
U1	1	Current-mode HBLED driver (32 TQFN-EP*) Maxim MAX16816ATJ+
U2	1	UART- to-USB converter (32 TQFP)
U3	1	93C46 3-wire 16-bit EEPROM (8 SO)
USB	1	USB type-B right-angle female receptacle
Y1	1	6MHz crystal
—	1	Shunt (JU1)
—	1	USB high-speed A-to-B cable, 6ft
—	1	PCB: MAX16816 Evaluation Kit+

*EP = Exposed pad.

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Component Suppliers

SUPPLIER	PHONE	WEBSITE
Diodes Inc.	805-446-4800	www.diodes.com
Fairchild Semiconductor	888-522-5372	www.fairchildsemi.com
International Rectifier	310-322-3331	www.irf.com
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
Sumida Corp.	847-545-6700	www.sumida.com
Taiyo Yuden	800-348-2496	www.t-yuden.com
TDK Corp.	847-803-6100	www.component.tdk.com
Vishay	402-563-6866	www.vishay.com

Note: Indicate that you are using the MAX16816 when contacting these component suppliers.

MAX16816 EV Kit Files

FILE	DESCRIPTION
INSTALL.EXE	Installs the EV kit files on your computer
MAX16816.EXE	Application program
FTD2XX.DLL	USB device driver file
UNINST.INI	Uninstalls the EV kit software

Quick Start

Required Equipment

Before beginning, the following equipment is needed:

- MAX16816 EV kit (USB cable included)
- A user-supplied Windows 2000/XP/Vista PC with a spare USB port
- 9V to 40V, 4A DC power supply
- A series-connected LED string rated at 1.5A (28V max)
- A digital multimeter (DMM) fused for 10A current measurement

Note: In the following sections, software-related items are identified by bolding. Text in **bold** refers to items directly from the EV kit software. Text in **bold and underlined** refers to items from the Windows operating system.

Procedure

The MAX16816 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 and do not power up the MAX16816 EV kit without connecting a load to the LED+ and LED- PCB pads.

Warning: Voltages exceeding 42V may exist on the LED+ and LED- output pads.

- 1) Visit www.maxim-ic.com/evkitsoftware to download the latest version of the EV kit software, 16816Rxx.ZIP. Save the EV kit software to a temporary folder and uncompress the ZIP file.
- 2) Install the EV kit software on your computer by running the INSTALL.EXE program inside the temporary folder. The program files are copied and icons are created in the Windows **Start | Programs** menu. Do not run the EV kit software until step 15.
- 3) Connect the USB cable from the PC to the EV kit board. A **New Hardware Found** window pops up when installing the USB driver for the first time. If you do not see a window that is similar to the one described above after 30s, remove the USB cable from the board and reconnect it. Administrator privileges are required to install the USB device driver on Windows.
- 4) Follow the directions of the **Add New Hardware Wizard** to install the USB device driver. Choose the **Search for the best driver for your device** option. Specify the location of the device driver to be **C:\Program Files\MAX16816** (default installation directory) using the **Browse** button. During device driver installation, Windows might show a warning message indicating that the device driver Maxim uses does not contain a digital signature. This is not an error condition and it is safe to proceed with installation.
- 5) Once the hardware installation is complete, disconnect the USB cable from the EV kit.
- 6) Verify that a shunt is installed across jumper JU1 (analog PWM-dimming control).

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- 7) Connect the anode of the LED string to the LED+ PCB pad and the cathode to the DMM's positive-current terminal.
- 8) Connect the DMM's negative-current terminal to the LED- PCB pad.
- 9) Set the power-supply output to 12V and disable the power-supply output.
- 10) Connect the power supply's positive terminal to the VIN PCB pad and the negative terminal to the PGND PCB pad.
- 11) Connect the USB cable to the EV kit.
- 12) Enable the power-supply output.
- 13) Adjust potentiometer R14 clockwise by one full turn to obtain a 100% duty cycle.
- 14) Verify that the DMM measures an LED current of 1.33A DC.
- 15) Start the MAX16816 EV kit software by opening its icon in the **Start | Programs** menu. The EV kit software main window appears, as shown in Figure 1.

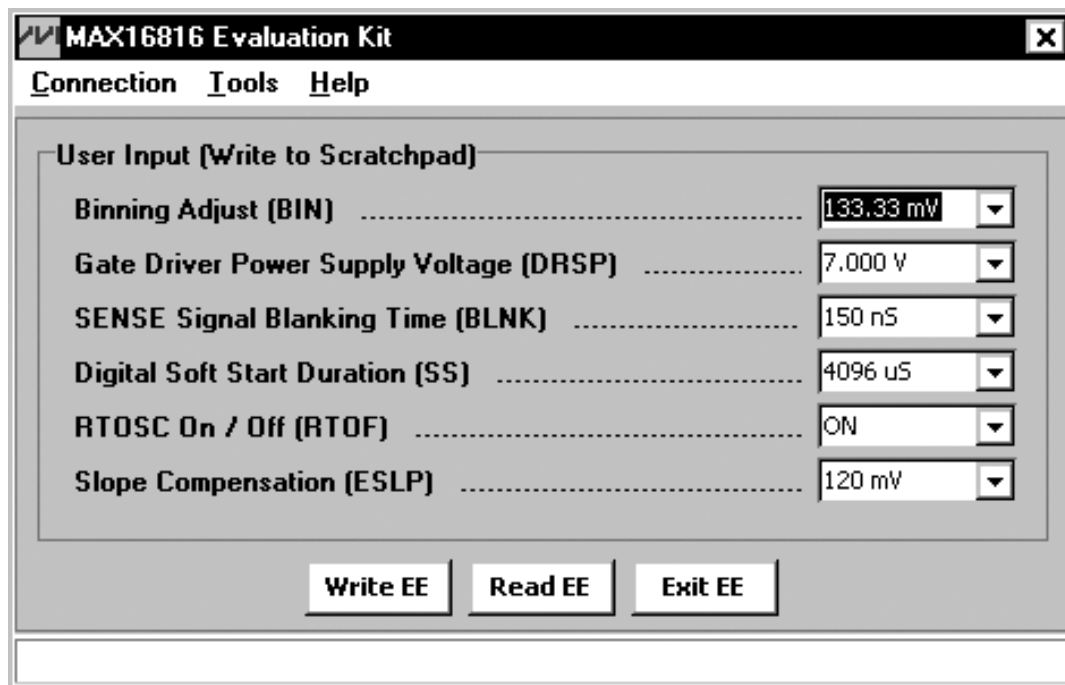


Figure 1. MAX16816 EV kit Software Main Window

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Detailed Description of Software

The main window of the MAX16816 EV kit software (Figure 1) displays a drop-down list for each of the MAX16816 IC's programmable features. The drop-down lists adjust the following programmable features: LED current (binning), external MOSFET gate driver supply voltage, leading-edge blanking time, digital soft-start duration, RTSYNC oscillator enable/disable, and slope compensation.

Upon software startup, the EV kit USB-to-I²C circuit and EV kit software force the MAX16816 IC U1 into programming mode by starting communication with U1. In programming mode, the USB programming circuit controls the U1 UVEN pin, for enabling/disabling U1, and the U1 FAULT pin as a 1-wire data/clock port. The software initially reads the U1's scratchpad registers and displays the active values in the drop-down lists. These values are loaded to the scratchpad registers from U1's non-volatile EEPROM upon IC power-up. Selecting a value from any of the drop-down lists writes to the IC's scratchpad registers, modifying the EV kit's active values.

Press the **Write EE** button to write the scratchpad register values to U1's EEPROM. Press the **Read EE** button to read the EEPROM values. Pressing the **Read EE** button prior to pressing the **Write EE** button overwrites the current drop-down list values. Press the **Exit EE** button to exit programming mode, restoring the UVEN and FAULT pins' standard functionality. Refer to the *EEPROM and Programming* section in the MAX16816 IC data sheet for more information.

Connection Settings and Tools

Click the **Connection** menu item to attempt a reconnect with the EV kit or to exit the software. Click the **Tools** menu item to view the software message log or to set the 1-wire clock speed.

Binning Adjustment Voltage

Set a value of V_{SS} (binning adjustment voltage) between 100mV and 166.67mV using the **Binning Adjust (BIN)** drop-down list. Refer to the *Load Current Sense* section in the MAX16816 IC data sheet for additional information on adjusting the binning voltage.

Gate Driver Supply Voltage

Select a REG2 output voltage between 5V to 15V by using the **Gate Driver Power Supply Voltage (DRSP)** drop-down list. On the EV kit, the REG2 output voltage is the supply voltage for the primary switching MOSFET driver (DRV). Refer to the *Regulators (REG1, REG2, CLAMP)* section in the MAX16816 IC data sheet for more information on setting the REG2 output voltage.

Leading-Edge Blanking Time

The MAX16816 IC features a programmable built-in blanking circuit for the current-sense signal that prevents premature termination of the on cycles. Set a blanking time by selecting a value between 75ns and 150ns using the **SENSE Signal Blanking Time (BLNK)** drop-down list. To increase blanking time beyond 150ns, install a 0603 ceramic capacitor at C6 between 100pF and 1000pF.

Refer to the *Blanking Time Adjustment Register (BLNK)* section in the MAX16816 IC data sheet for additional information.

Digital Soft-Start

Select a soft-start delay time between 0 (no delay) to 4.096ms by using the **Digital Soft Start Duration (SS)** drop-down list. Setting the soft-start delay time to a low value could cause improper LED driver startup. Refer to the *Soft-Start* section in the MAX16816 IC data sheet for more information on this feature.

Oscillator Settings

Select **OFF** from the **RTOSC On / Off (RTOF)** drop-down list to enable the MAX16816 IC's internal 125kHz oscillator. Select **ON** from the **RTOSC On / Off (RTOF)** drop-down list to enable the RTSYNC oscillator.

Slope Compensation

Select a peak ramp voltage for slope compensation between 0 and 300mV by using the **Slope Compensation (ESLP)** drop-down list. Refer to the *Slope Compensation* section in the MAX16816 IC data sheet for more information on choosing a value.

Detailed Description of Hardware

The MAX16816 EV kit demonstrates the MAX16816 current-mode HBLED driver IC. The EV kit is configured in a step-down/step-up (buck-boost) topology with peak current control and DC current control for a string of user-supplied HBLEDs. The EV kit operates from a DC supply voltage of 9V to 40V and requires up to 4A. The circuit is configured to deliver 1.33A of current into a series LED string with a maximum of 28V forward voltage.

The EV kit sets the maximum peak-series inductor current to 8.3A using parallel resistors R6 and R7. The DC LED current is set to 1.33A using resistor R3. A CLKOUT PCB pad is available to monitor the oscillator frequency. A DIM PCB pad is also provided for analog PWM- or digital PWM-dimming operation of the external LEDs, and to monitor the analog DC voltage applied to the MAX16816 IC DIM pin.

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Peak Inductor Current-Limit Setting

The parallel combination of current-sense resistors R6 and R7 sets the EV kit's peak inductor current limit to 8.3A. Use the following equation to calculate the total parallel resistance needed to reconfigure the inductor peak current limit:

$$R_{\text{SENSE}} = \frac{160\text{mV}}{I_{\text{PEAK}}}$$

where R_{SENSE} is the total parallel resistance placed at the R6 and R7 PCB pads and I_{PEAK} is the desired inductor peak current.

Refer to the *ILIM and HICCUP Comparator* section in the MAX16816 IC data sheet for additional information on setting the peak current-limit threshold.

Setting External LED Current

Resistor R3 sets the MAX16816 EV kit's DC LED current to 1.33A. Use the following equation to calculate R3 when reconfiguring the LED current:

$$R13 = \frac{V_{\text{SS}}}{I_{\text{LED}}}$$

where V_{SS} is the binning adjustment voltage (software configurable) and I_{LED} is the desired DC LED current. Set the value of V_{SS} by selecting a value between 100mV and 166.67mV using the **Binning Adjust (BIN)** drop-down list.

Oscillator Settings

Select **ON** from the **RTOSC On / Off (RTOF)** drop-down list to enable the RTSYNC oscillator and/or synchronize the MAX16816 EV kit to an external clock.

The EV kit is configured for a 300kHz RTSYNC oscillator frequency. Program the RTSYNC oscillator switching frequency between 125kHz and 500kHz using R13 and the equation below:

$$R13 = \frac{500\text{kHz}}{f_{\text{SW}}} \times 25\text{k}\Omega$$

where f_{SW} is the switching frequency in kilohertz and R13 is in kilohms.

The EV kit can synchronize the RTSYNC oscillator frequency to an external 125kHz to 500kHz clock signal with a 2.8V to 5.5V logic level after five successive clock edges. Connect the external clock signal across the RTSYNC and AGND PCB pads.

The CLKOUT PCB pad provides a buffered digital clock output that can drive the SYNC input of another device (e.g., RTSYNC of another MAX16816 IC) and a 500pF load.

Refer to the *Oscillator, Clock, and Synchronization* section in the MAX16816 IC data sheet for information on setting the MAX16816 IC PWM frequency.

LED Dimming Control

LED dimming can be achieved on the MAX16816 EV kit by applying a digital PWM signal or an analog DC voltage at the DIM PCB input pad. Jumper JU1, potentiometer R14, resistor R15, and capacitor C15 configure the MAX16816 EV kit for analog PWM-controlled dimming operation.

Place a shunt across jumper JU1 to set the EV kit for analog PWM-controlled dimming and adjust potentiometer R14. The analog DC voltage at the DIM PCB pad sets the duty cycle of the LED current, which controls the external LED brightness. The MAX16816 IC DIM pin voltage can be monitored by placing a voltmeter across the DIM and AGND PCB pads.

Use the following equation to calculate the voltage at the DIM PCB pad, which is necessary to program the LED output current duty cycle (D):

$$V_{\text{DIM}} \cong (D \times 2.6\text{V}) + 0.2\text{V}$$

where V_{DIM} is the analog DC voltage at the MAX16816 EV kit DIM PCB pad in volts, and D is the desired duty cycle of the LED output current.

When operating the MAX16816 EV kit with analog PWM-controlled dimming, the LED dimming frequency is internally set by the MAX16816 IC to 200Hz.

Remove the shunt at jumper JU1 to control LED dimming using a digital PWM signal at the DIM PCB pad. Apply a digital PWM signal with a 3.2V to 15V logic-high level in the 200Hz to 2kHz frequency range and adjust the duty cycle to adjust the LED brightness. See Table 1 to set LED dimming operation.

Table 1. MAX16816 LED Dimming Operation (Jumper JU1)

SHUNT POSITION	DIM PIN CONNECTED TO	EV KIT DIMMING OPERATION
Not installed	DIM PCB pad	Digital PWM signal applied at DIM PCB pad
Installed	Potentiometer R14, pin 2	Analog DC voltage adjusted using R14

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Undervoltage Lockout (UVLO)

The MAX16816 EV kit's UVLO threshold is configured to 8.3V using resistors R1 and R2. The UVEN PCB pad can be used to disable the EV kit circuit by connecting UVEN to AGND. To configure the circuit to a different UVLO threshold, refer to the *Setting the UVLO Threshold* section in the MAX16816 IC data sheet.

Output Overvoltage Protection

The maximum voltage on the LED+ PCB pad is limited to 70.8V, with respect to AGND, by a feedback network formed by resistors R9 and R10. When the voltage at

LED+ exceeds the programmed 70.8V threshold, PWM switching is terminated and no further energy is transferred to the load connected between LED+ and LED-. Refer to the *Setting the Overvoltage Threshold* section in the MAX16816 IC data sheet for setting the overvoltage threshold.

Warning: If the EV kit is turned on with no load, the voltage at LED+ might rise to unsafe levels. Even though the EV kit has overvoltage protection, connect the specified load before powering up the EV kit.

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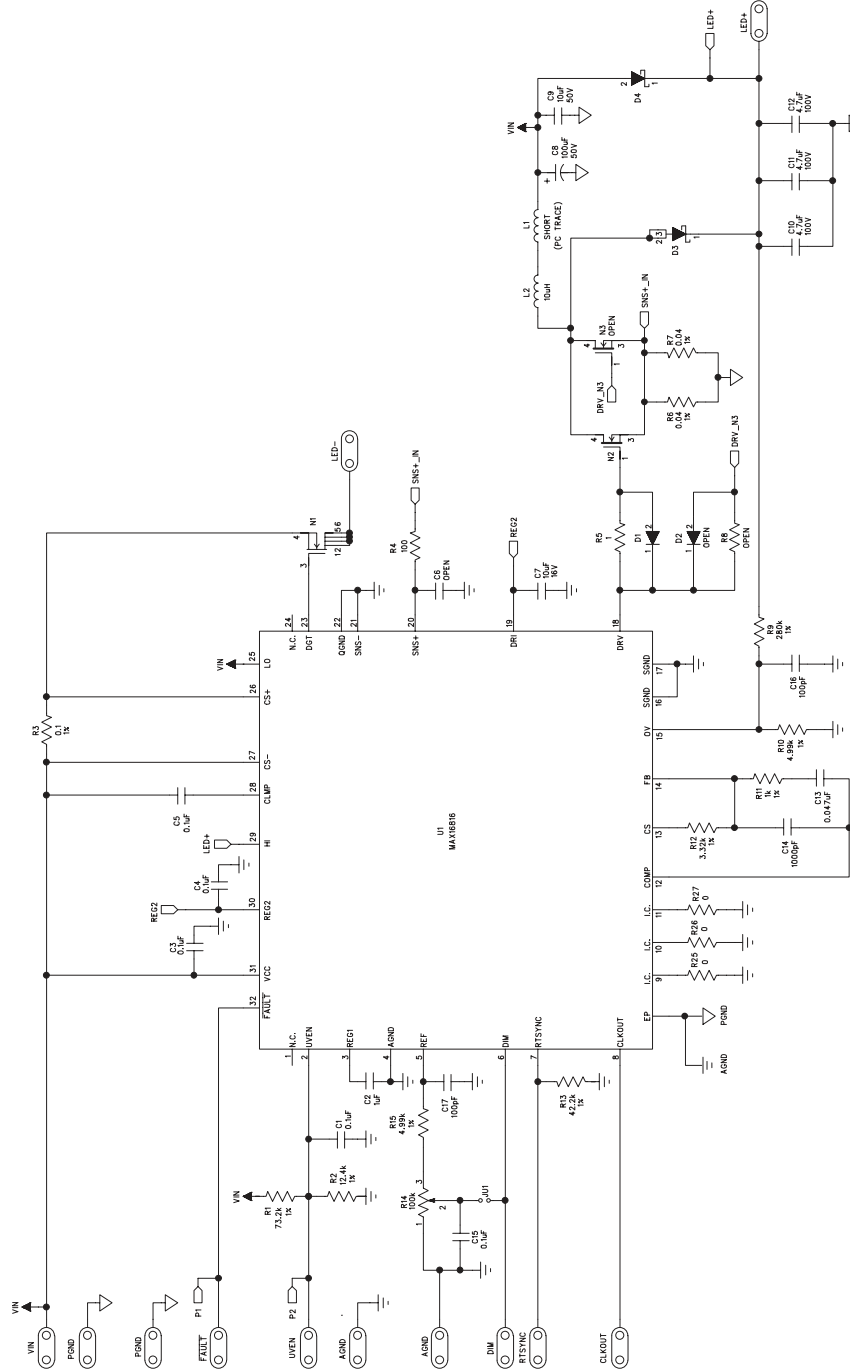


Figure 2. MAX16816 EV Kit Schematic—Application Circuit

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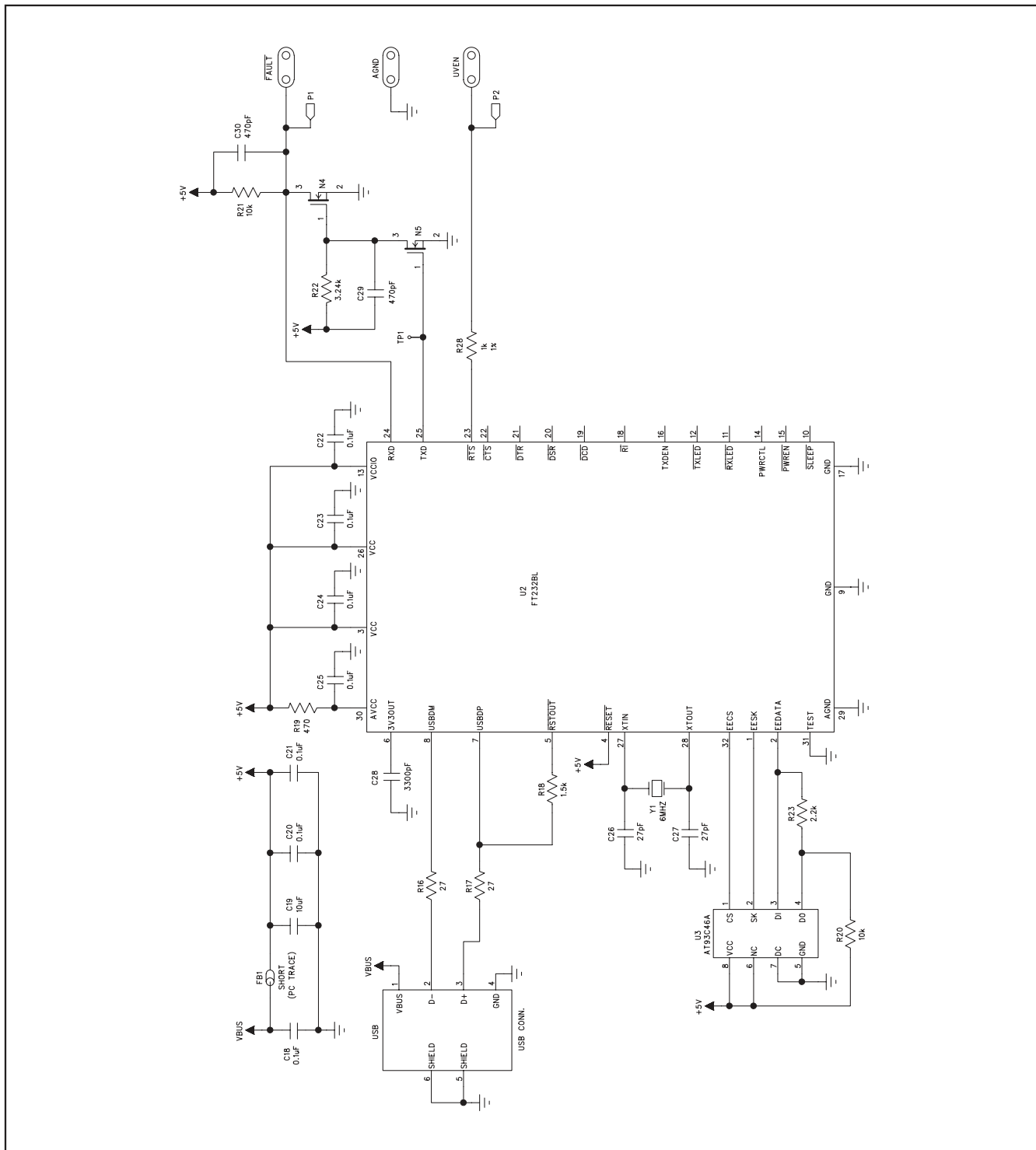


Figure 3. MAX16816 EV Kit Schematic—USB-to-I²C Circuit

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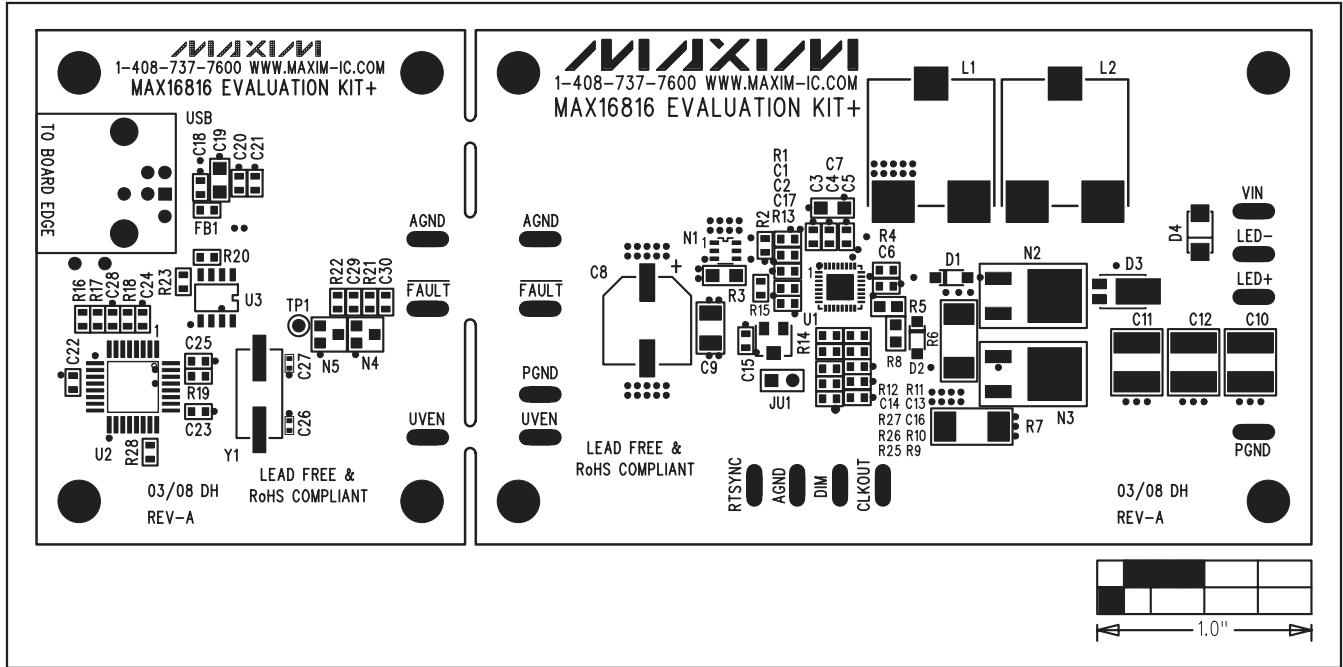


Figure 4. MAX16816 EV Kit Component Placement Guide—Component Side

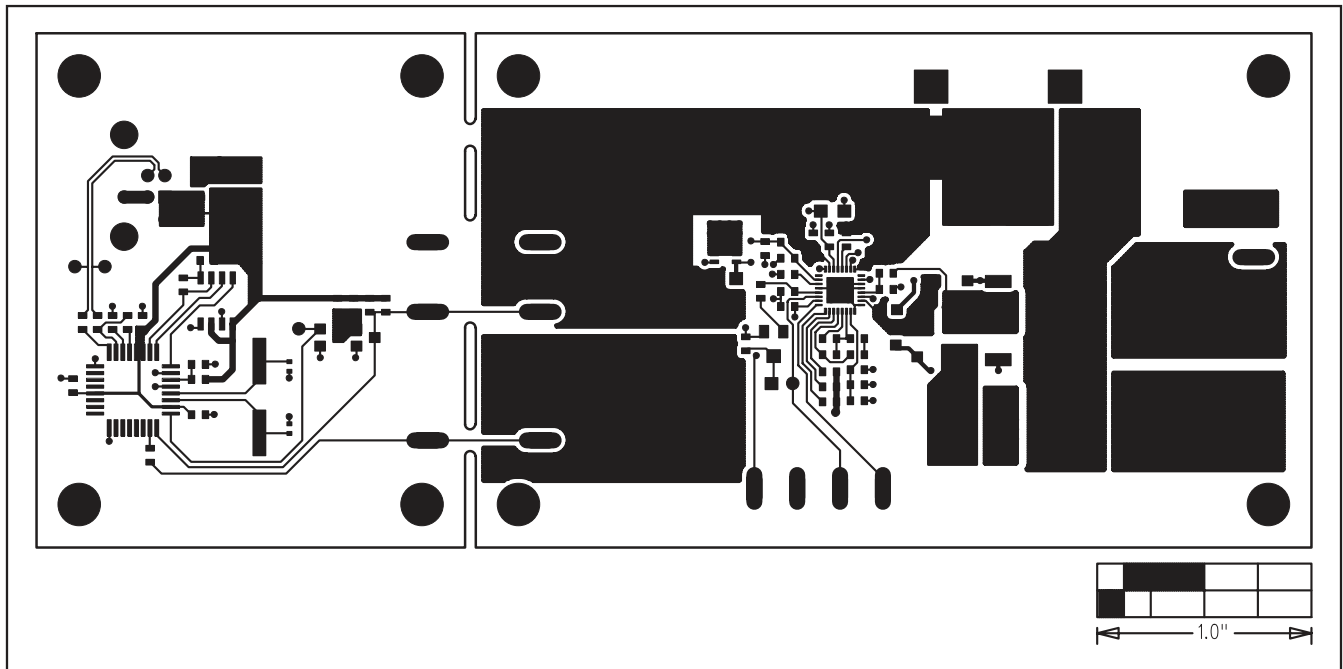


Figure 5. MAX16816 EV Kit PCB Layout—Component Side

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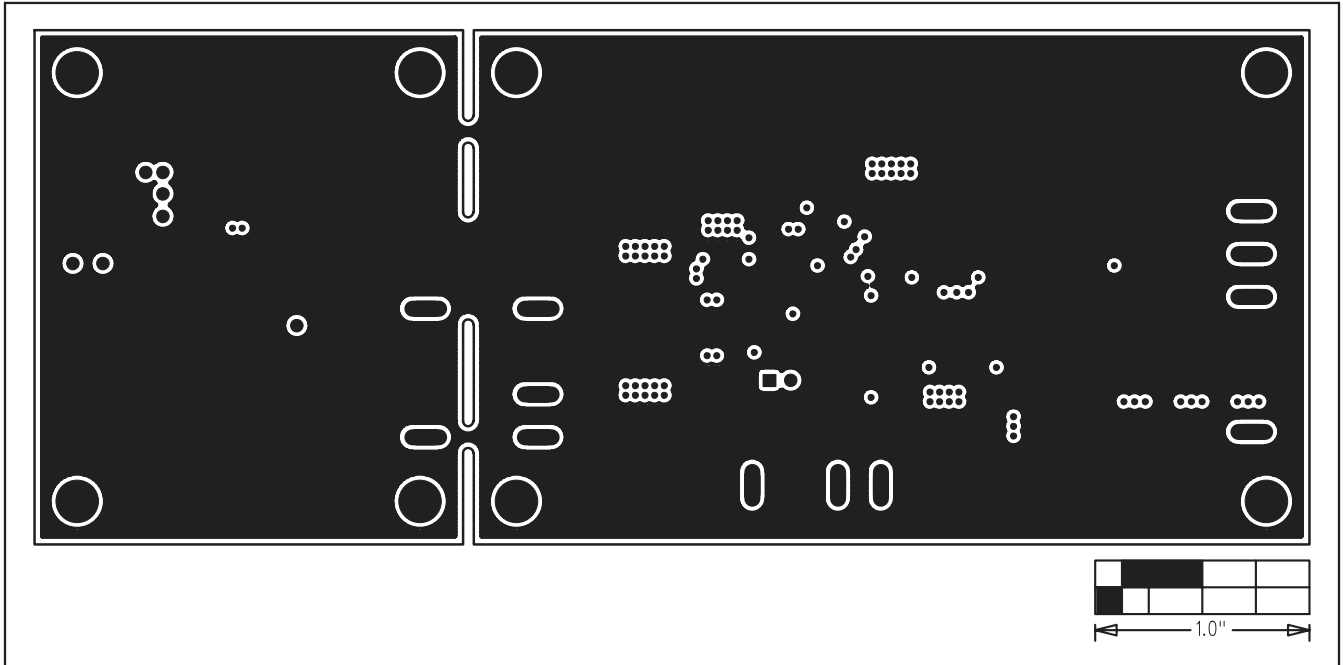


Figure 6. MAX16816 EV Kit PCB Layout—Layer 2

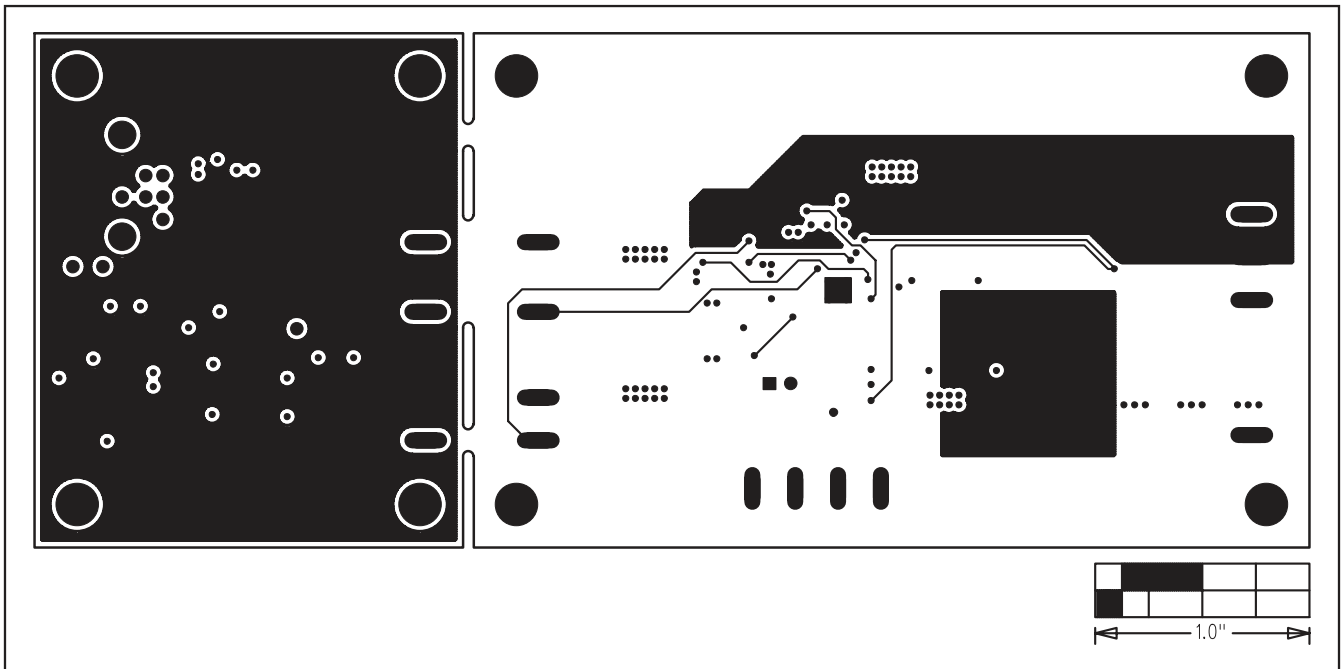


Figure 7. MAX16816 EV Kit PCB Layout—Layer 3

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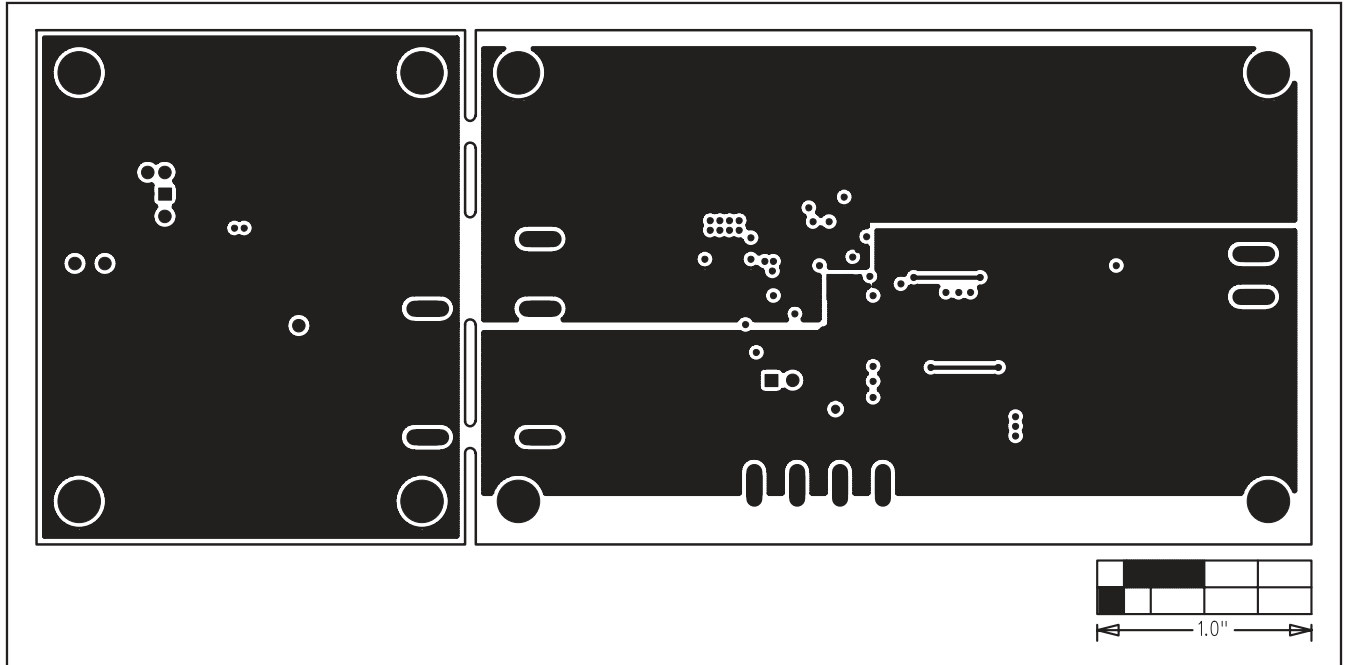


Figure 8. MAX16816 EV Kit PCB Layout—Solder Side

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