



# MAX1660 Evaluation Kit

## General Description

The MAX1660 evaluation kit (EV kit) is an assembled surface-mount demonstration board. The EV kit embodies the typical application circuit shown in Figure 8 of the MAX1660 data sheet. Additional circuitry allows an IBM-compatible personal computer to use its parallel port to emulate an Intel System Management Bus (SMBus™) interface.

## Features

- ◆ Measures 4A Currents to 1% Accuracy
- ◆ 4A Max Current, 1% Accuracy
- ◆ Proven PC Board Layout
- ◆ Convenient Test Points Provided On-Board
- ◆ Data-Logging Software
- ◆ Fully Assembled and Tested

## Ordering Information

PART	TEMP. RANGE	IC PACKAGE
MAX1660EVKIT	0°C to +70°C	16 QSOP

## Component List

DESIGNATION	QTY	DESCRIPTION
C1	1	0.33μF, 6V ceramic capacitor
C2	1	10nF, 6V ceramic capacitor
C3	1	0.1μF, 6V ceramic capacitor
C4	1	4.7nF, 6V ceramic capacitor
C5	1	10nF, 6V ceramic capacitor
C6*	0	0.33μF ceramic capacitor (option)
D1, D20, D21, D22	4	1N4148-type SOT23 signal diodes
D23-D26	4	1N5233B-type, 6V, 500mW, axial-leaded zener diodes
J1	1	DB25 male right-angle connector
J2	1	Smart battery connector AMP 787259-1 (10.8V key on left)
J3, J4	2	Uninsulated, nickel-plated standard banana jacks E. F. Johnson 108-0740
JU1	1	Unstuffed
LED1	1	Red light-emitting diode
M1, M2	2	Logic-level, P-channel, SO-8, single power MOSFET International Rectifier IRF7205

DESIGNATION	QTY	DESCRIPTION
Q20, Q21, Q22	3	2N3904 NPN equivalent, SOT23
R1	1	0.030Ω, 1%, 1W sense resistor IRC LR2512-01-R030-F or Dale WSL-2512 0.030Ω
R2, R30-R33	5	100Ω, 5%, 1/16W resistors
R3, R5	2	910kΩ, 1%, 1/16W resistors
R4, R6	2	75kΩ, 1%, 1/16W resistors
R7, R8	2	470kΩ, 5%, 1/16W resistors
R9, R10, R20, R21, R24, R25, R26	7	10kΩ, 5%, 1/16W resistors
R11	1	1MΩ, 5%, 1/16W resistor
R12*	0	51Ω, 5%, 1/16W resistor (option)
R22, R23, R27, R28, R29, R35	6	100kΩ, 5%, 1/16W resistors
R34	1	680Ω, 5%, 1/16W resistor
SW1	1	Slide switch
U1	1	Maxim MAX1660EEE
U2	1	74HC14 hex Schmitt trigger, SO-14

\*User option

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## Component Suppliers

SUPPLIER	PHONE	FAX
Dale Sense Resistors	(402) 564-3131	(402) 563-6418
International Rectifier	(310) 322-3331	(310) 322-3332
IRC	(512) 992-7900	(512) 992-3377

\*Please indicate that you are using the MAX1660 when contacting these suppliers.

## Quick Start

### Equipment Required

Before you begin, you will need the following equipment:

- A battery pack
- An appropriate charger
- An appropriate load
- An IBM PC-compatible computer running Windows 3.1™ or Windows 95™
- A spare parallel printer port (this is a 25-pin socket on the back of the computer)
- A standard 25-pin, straight-through, male-to-female cable to connect the computer's parallel port to the Maxim EV kit (optional). Or, the EV kit can be plugged directly into the parallel printer port.

### Procedure

- 1) Connect the battery pack to the board at connector J2. Total battery-pack voltage should be within the 4V to 28V range accepted by the MAX1660. The battery cells may be of any rechargeable chemistry, such as NiCd, NiMH, or Li-Ion. The battery pack will later be charged and discharged through the PACK+ and PACK- terminals; however, leave PACK+ unconnected until the software is started.  
Powering the EV kit with a power supply that is not isolated from the computer creates a ground loop, degrading measurement accuracy by 50% or more.
- 2) Connect the board to the computer's parallel printer port. The parallel port is typically labeled LPT or PRINTER. **To avoid damaging the EV kit or your computer, make sure you are using the parallel printer port and not a 25-pin SCSI port or any other connector that is physically similar to the 25-pin parallel printer port.**

Windows 3.1 and Windows 95 are trademarks of Microsoft Corp.

- 3) The MAX1660.EXE software program can be run from the floppy or from a hard drive. Simply use the Windows program manager to run the program. If desired, you may use the INSTALL.EXE program to copy the files and create icons for them in the Windows 3.1 Program Manager (or the Windows 95 Start Menu).
- 4) Start the MAX1660 program by opening its icon in the Program Manager (or Start Menu).
- 5) The program prompts you to select the correct parallel port. An auto-detect routine attempts to identify the correct port and highlights it as the default choice.
- 6) Apply the load or charger and observe the charge or discharge current readings on the main window display.

## Detailed Description of Software

The battery pack can be charged and discharged through the PACK+ and PACK- terminals. When a load is connected across the PACK+ and PACK- terminals, the discharge current is measured and displayed. If the load current exceeds the overcurrent trip threshold, MOSFET M1 turns off, disconnecting the load.

### Main Display

The charge and discharge counters are automatically displayed in either decimal or hexadecimal, along with the corresponding charge count and the calculated current values. The **Clear Counters** button commands the MAX1660 to clear its charge and discharge counters, and it also restarts the integration timer.

The display is automatically updated at the rate selected by the **Integration Time** control. This automatic update can be turned off by unchecking the **Automatically Update Displays** check-box.

The  $\overline{\text{INT}}$  signal is checked several times per second, and the **Interrupt** box indicates if it is low. To clear the interrupt, click on the **Clear Interrupt** button.

When the **Fuel Gauge Off** control is activated, the software automatically activates **Disconnect Battery** and **Disconnect Load** to protect the battery. Unchecking either **Disconnect Battery** or **Disconnect Load** automatically unchecks **Fuel Gauge Off**.

The **Calibrate** check-box controls the OFFSETMEAS bit in the configuration word. When active, the Coulomb counter is disconnected from the sense resistor, revealing the offset voltage (which appears as an offset current in this display.)

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## Register Display

The MAX1660 register values can be displayed in 32-bit binary format by selecting **Registers** from the MAX1660 menu. This command opens a window that updates five times per second, independent of the main display's integration time control. The **Compare Register** group in the main window selects the charge or discharge register.

## Sense-Resistor Value

The effect of different current-sense resistors can be shown by selecting the **Sense Resistor** command from the MAX1660 menu. This command opens a window that displays the assumed sense resistor value, as well as the conversion gain calculations resulting from that value. For correct current display, the sense-resistor value should match the actual value of  $R_{CS}$  (which is R1 on the EV kit board).

## SMBus Menu

The SMBus menu allows individual SMBus operations to be performed. The main window continues independently performing its own SMBus transactions unless the **Automatic Update Displays** box is unchecked.

The SMBus dialog boxes accept numeric data in binary, decimal, or hexadecimal. Hexadecimal numbers should be prefixed by \$ or 0x. Binary numbers must be exactly 8 or 16 digits.

## Accuracy Limitations under Windows

Charge or discharge current can be measured by sampling the counter value at intervals and calculating:

$$\text{Current} = (\text{increase in counter value}) / (\text{time interval in seconds} \times \text{conversion gain})$$

When calculating charge or discharge current, there is an inherent measurement error of one count or less in each integration period, due to fractional counts during the integration period. There is also a processor-dependent measurement uncertainty in the integration time. A crystal-controlled microcontroller with no other tasks can easily have less than 1 $\mu$ s of uncertainty, whereas the EV kit software under Windows has an uncertainty of 10,000 $\mu$ s. Longer integration time reduces this measurement error. The current measurement error due to timing jitter is displayed in the main window under the heading "uncertainty".

To accurately measure load current, the program must accurately measure the time interval between counter reads. The counter value is latched on the falling edge of the ACK clock pulse during the SMBusReadWord (address 0x83, command 0x82). Refer to the MAX1660 data sheet.

## Accuracy Limitations under DOS

To allow evaluation of the MAX1660 without the current-measurement errors caused by Windows, use the DOS1660 program. This menu-driven program provides rudimentary access to the MAX1660, with stable timing. An oscilloscope can be used to observe a read diagnostic strobe that appears on pins 5 and 13 of the parallel port. To start the DOS1660 program, click on the DOS1660 menu item, or exit Windows and run DOS1660.EXE.

## Detailed Description of Hardware

U1, the MAX1660, is a digitally controlled fuel-gauge interface that accurately monitors charge and discharge currents. C6 and C1 bypass the power supply. R1 is the noninductive current-sense resistor. It is Kelvin connected to reduce error at high currents. R3–R6 set the overcurrent trip thresholds. MOSFETs M1 and M2 are used by the overcurrent protection circuitry to interrupt the discharge and charge paths, respectively. D1 and R11 would typically be used by a microcontroller to implement a hard-shutdown mode. Refer to the MAX1660 data sheet for more discussion of the standard application circuit.

The SMBus interface circuitry consists of J1, D20–D26, LED1, Q20, Q21, Q22, R20–R35, and U2. This part of the circuit provides the 2-wire clock and data interface, as well as a GPIO output (used for shutdown control) and an interrupt input. When the board is not plugged into an IBM PC parallel port, the clock and data lines can be driven externally, and the GPIO output is controlled by switch SW1. The LED lights up whenever the interrupt signal is at a logic-low level.

If desired, the EV kit can be driven with a user-supplied SMBus 2-wire interface. Connect it to the DGND, SCL, and SDA pads on the board.

## Interface Details

A complete smart-battery solution is far beyond the scope of this manual; however, there are a few details that the software designer must know in order to successfully use this device.

## Reading 32-Bit Counters

To accurately measure supply current, the program must accurately measure the time interval between counter reads. During the read-word protocol, begin the integration time at the falling edge of the ninth clock pulse of the command byte. Not counting the start condition, this is the 18th falling edge of the clock during SMBusReadWord (address 0x8e, command 0x82).

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When reading the 32-bit charge or discharge counter value, read the low word first (command 0x82) followed by the high word (command 0x83). This sequence latches the counter value and prevents the data from being corrupted if there is a 16-bit carry during the read operation. See Listing 1.

### Soft Shutdown

When turning the fuel gauge off (SOFTSHDN = 1), disconnect the battery (OCHI = 1, ODLO = 0) and the load (ODHI = 1, ODLO = 0). When the fuel gauge is inactive, the overcurrent protection is disabled. Leaving the

battery or the load connected with the fuel gauge off can destroy the FETs if a short-circuit condition occurs. See Listing 2.

### Optional Offset Calibration

The MAX1660's input offset is quite low; however, it can be measured by setting OFFSETMEAS = 1. When offset-measurement mode is active, the charge and discharge currents cannot be monitored, so disconnect the battery (OCHI = 1, OCLO = 0) and the load (ODHI = 1, ODLO = 0). See Listing 3.

```

Read Charge or Discharge Counter
{
    IF charge_counter requested THEN
        configuration = configuration OR (0000 0000 0100 0000)
    END IF
    IF discharge_counter requested THEN
        configuration = configuration AND (1111 1111 1011 1111)
    END IF
    SMBusWriteWord (0x8E, 0x04, configuration)
    counter_low = SMBusReadWord (0x8E, 0x82)
    counter_high = SMBusReadWord (0x8E, 0x83)
}

```

Listing 1. Reading 32-Bit Counters

```

ShutDown
{
    configuration = configuration OR (0000 0010 0000 1010)    ;set bits
    SMBusWriteWord (0x8E, 0x04, configuration)
}

WakeUp
{
    configuration = configuration AND (1111 1101 1111 0000)    ;clear bits
    SMBusWriteWord (0x8E, 0x04, configuration)
}

```

Listing 2. Soft Shutdown

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```
MeasureOffset
{
    configuration = configuration OR (0000 0001 0010 1010)      ;set bits: offsetmeas, clear counter
    SMBusWriteWord (0x8E, 0x04, configuration)

    WAIT for one integration period
    (The actual integration period is between the SMBusWriteWord above and the command
    acknowledge clock falling edge in the SMBusReadWord (0x8E, 0x82) as described
    in the "Reading 32-bit Counters" section.)

    status = SMBusReadWord (0x8E, 0x84)
    IF CHARGESTATUS bit of status is set THEN
        The offset current should be subtracted from charge and added to discharge
        configuration = configuration OR (0000 0000 0100 0000)
    ELSE
        The offset current should be added to charge and subtracted from discharge
        configuration = configuration AND (1111 1111 1011 1111)
    END IF
    SMBusWriteWord (0x8E, 0x04, configuration)
    offset_low = SMBusReadWord (0x8E, 0x82)
    offset_high = SMBusReadWord (0x8E, 0x83)

    configuration = configuration AND (1111 1110 1101 0000)      ;clear bits
    SMBusWriteWord (0x8E, 0x04, configuration)
}
```

Listing 3. Measuring Offset

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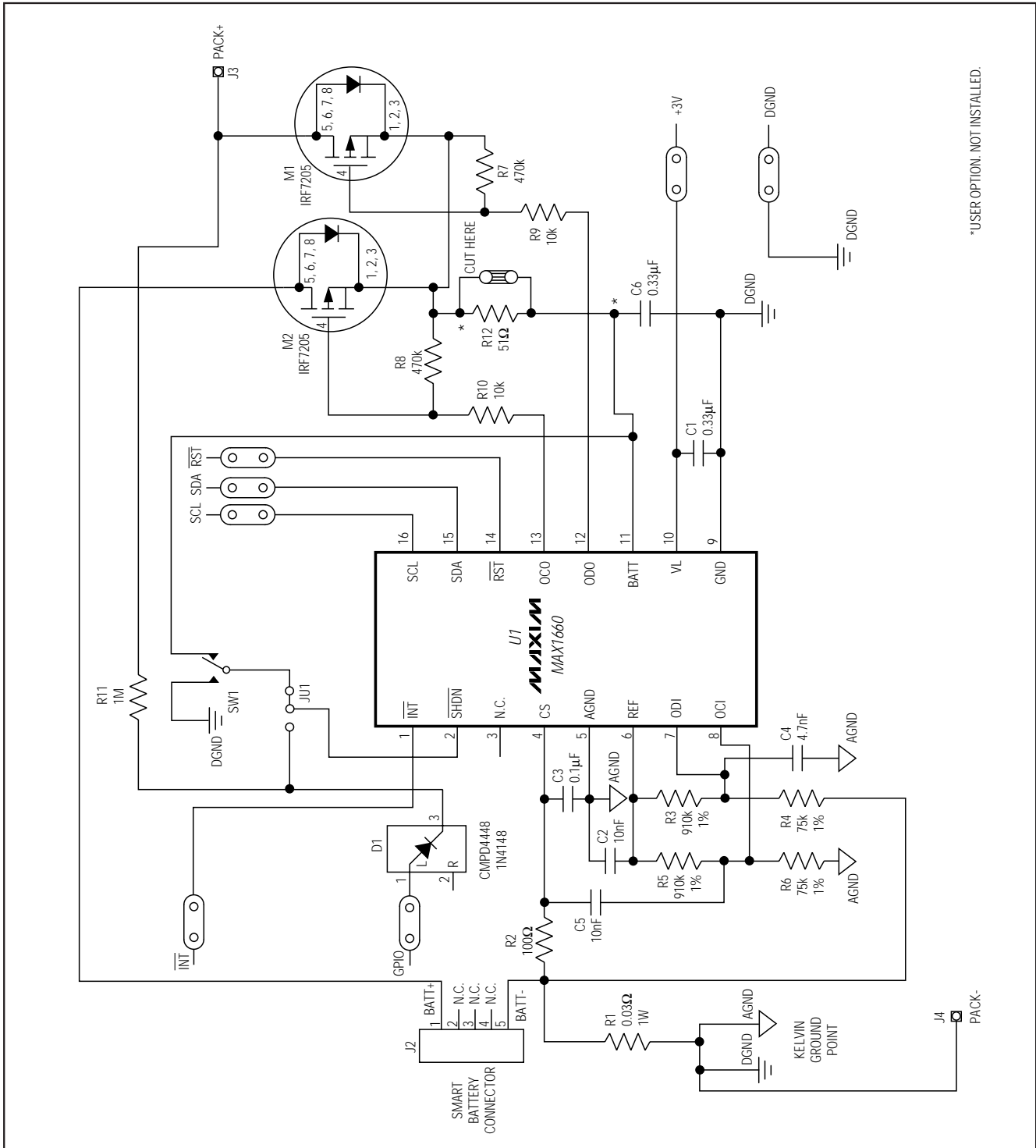


Figure 1. MAX1660 EV Kit Schematic

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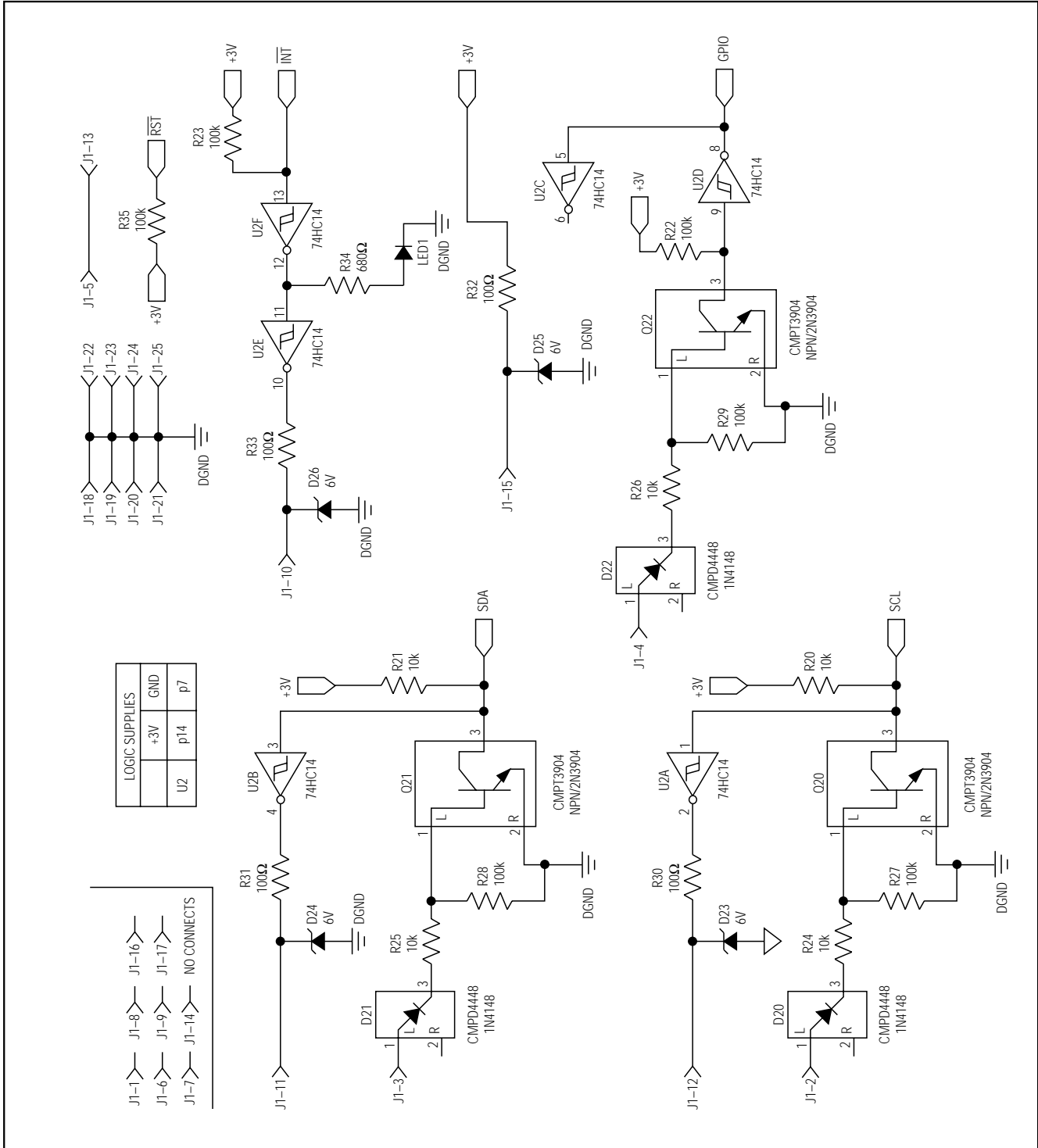


Figure 1. MAX1660 EV Kit Schematic (continued)

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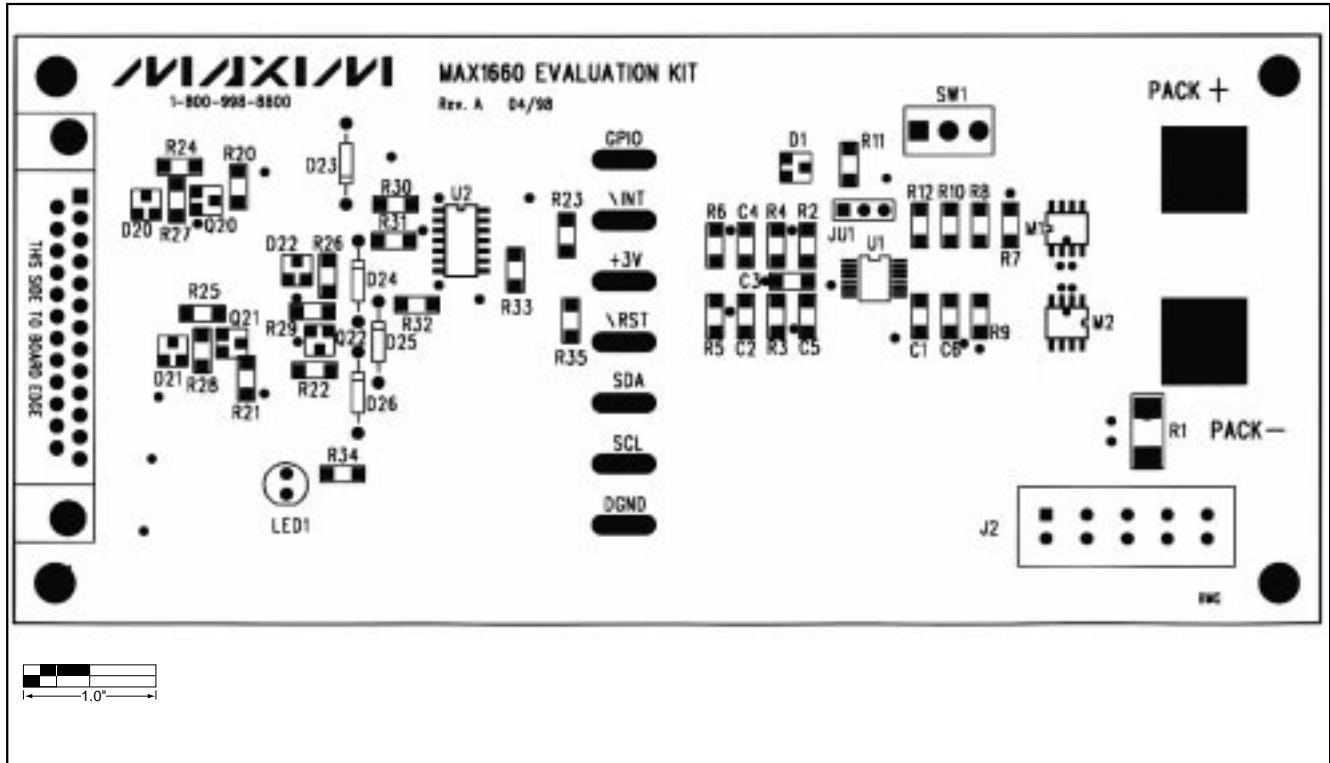


Figure 2. MAX1660 EV Kit Component Placement Guide



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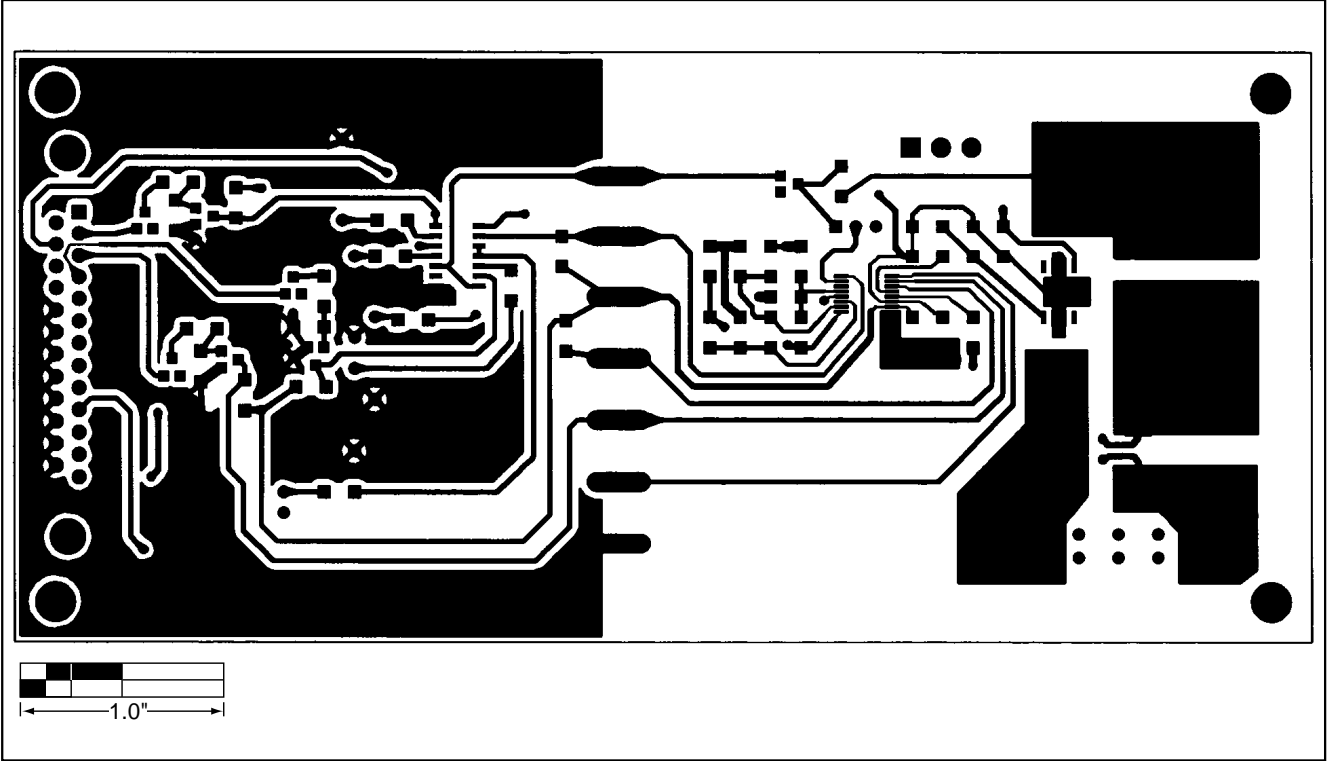


Figure 3. MAX1660 EV Kit PC Board Layout—Component Side

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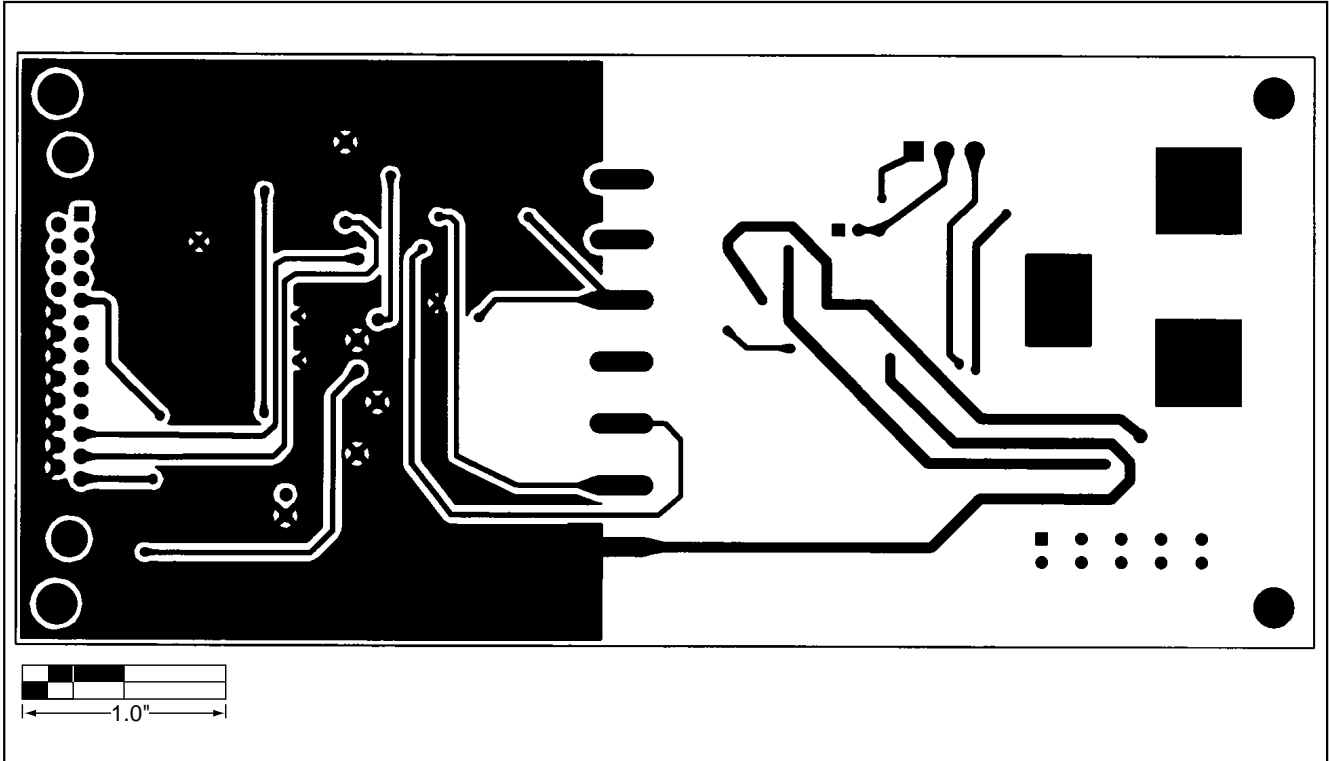


Figure 4. MAX1660 EV Kit PC Board Layout—Solder Side

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## NOTES

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