

## MAX86150 Evaluation System

Evaluates: MAX86150

### General Description

The MAX86150 Evaluation System (EV system) provides a proven platform to evaluate the MAX86150 integrated photoplethysmogram (PPG) and 1-lead electrocardiogram (ECG) sensor module. The EV system consists of two boards that connect through header pins: a MAX32630FTHR microcontroller board and a MAX86150 evaluation kit (EV kit). The MAX32630FTHR houses a microcontroller with preloaded firmware, Bluetooth communication, and power management. The sensor board contains the MAX86150 module and two stainless steel dry electrodes for ECG measurement. The EV kit is powered by the included lithium ion battery, which is charged with a micro-USB cable.

### Features

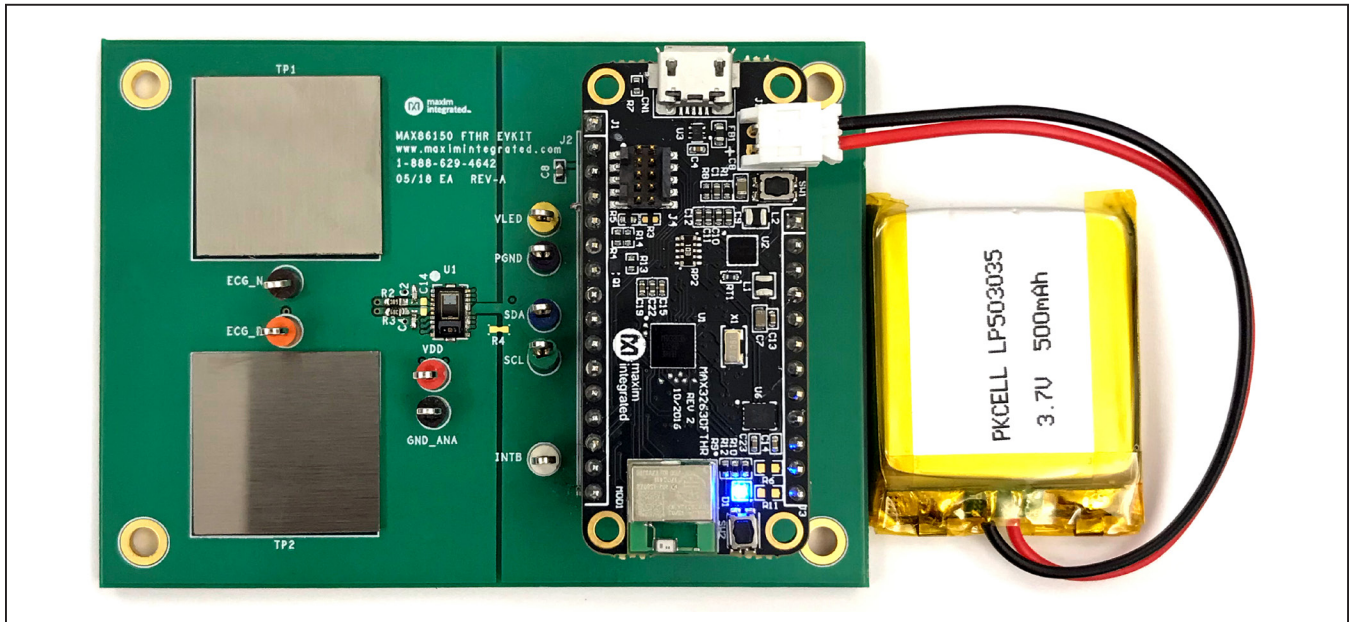
- Real-Time Monitoring of PPG and 1-Lead ECG
- Data-Logging Capability
- Windows® 10 Compatible GUI Software
- Integrated Dry Electrodes
- Fully Assembled and Tested

### EV System Contents

- MAX86150 EV kit
- MAX32630FTHR
- Pico programming adapter
- 2 x USB A to micro-USB cables
- 500mAh lithium polymer battery

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

### MAX86150 EV System Photo



### MAX86150 EV System Files

FILE	DESCRIPTION
SetupECPPG_EvKit.msi	EV Software Installer
MAX86150EVSYS_Firmware.msbl	EV System Firmware

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## Quick Start

### Required Equipment

**Note:** In the following section, **text in bold refers to items directly from the install of EV software. Text in bold with underline refers to items from the Windows operating system.**

- MAX86150 EV system
- Windows 10 PC with integrated Bluetooth or Bluetooth adapter (not included)

### Procedure

The EV kit is fully assembled and tested. Follow the steps below to verify board operation:

- 1) Install the EV software.
  - Download and extract the latest EV software from the MAX86150 Design Resources page (MAX86150EVSYS\_PcGuiWin.zip)
  - **Double-click the SetupECPPG EvKit.msi file** to run the installer. If a message box stating “The publisher could not be verified. Are you sure you want to run this software?” appears, **select Yes**.
  - When the installer GUI appears, read and accept the License Agreement, and **click Install**. When the installation completes, **click Finish**. The installed software is named DeviceStudio5, and a shortcut is automatically added to your desktop.
- 2) Turn on the EV kit.
  - Connect the battery to the plastic connector as shown in the [MAX86150 EV System Photo](#).
  - Press and hold SW1 for 400ms. LED indicator D1 flashes red to indicate that the Bluetooth is ready to pair.
- 3) Pair the EV kit to your Windows PC.
  - If your PC does not have integrated Bluetooth hardware, a generic Windows 10 USB Bluetooth adapter can be used. Install any necessary software and connect the adapter before proceeding.
  - **Open the Bluetooth settings panel** on your PC and **click Add Bluetooth or other device. Scan for Bluetooth devices and select MAX86150EVSYS#**. The scanning process can take up to one minute to recognize the EV kit.
  - When Windows prompts you to match the device PIN, **click Connect**.
- 4) Connect the EV kit to the EV software.
  - **Open DeviceStudio5** and **click the Scan button**. The software connects to the EV kit and displays hardware and software information. Once connected, the EV kit LED flashes blue.
  - In the Tools section, **click Launch Tool**.
- 5) **Click Start Monitoring** to view live ECG and PPG data. Place one finger from each hand on the stainless-steel electrodes to measure ECG (see the [ECG Measurement](#) section) and rest a finger over the sensor module to measure PPG (see the [PPG Measurement](#) section). If measuring both signals simultaneously, take care not to touch any metal components or bare solder near the module because doing so degrades the ECG signal.

### Detailed Description of Software

The EV software provides a graphical user interface (GUI) to interact with the EV system hardware and visualize the measurement data. There are three main GUI pages: Device Info, ECG and PPG Evaluation kit, and Register Map, which can be viewed through the View menu and are detailed in the following sections.

### Device Info

The Device Info page, shown in [Figure 1](#), is used to scan for connected devices and display the software, firmware, and hardware versions. Click Scan to detect any devices using USB or Bluetooth. Once detected, click Launch Tool to open to open the PPG and ECG Evaluation Kit page.

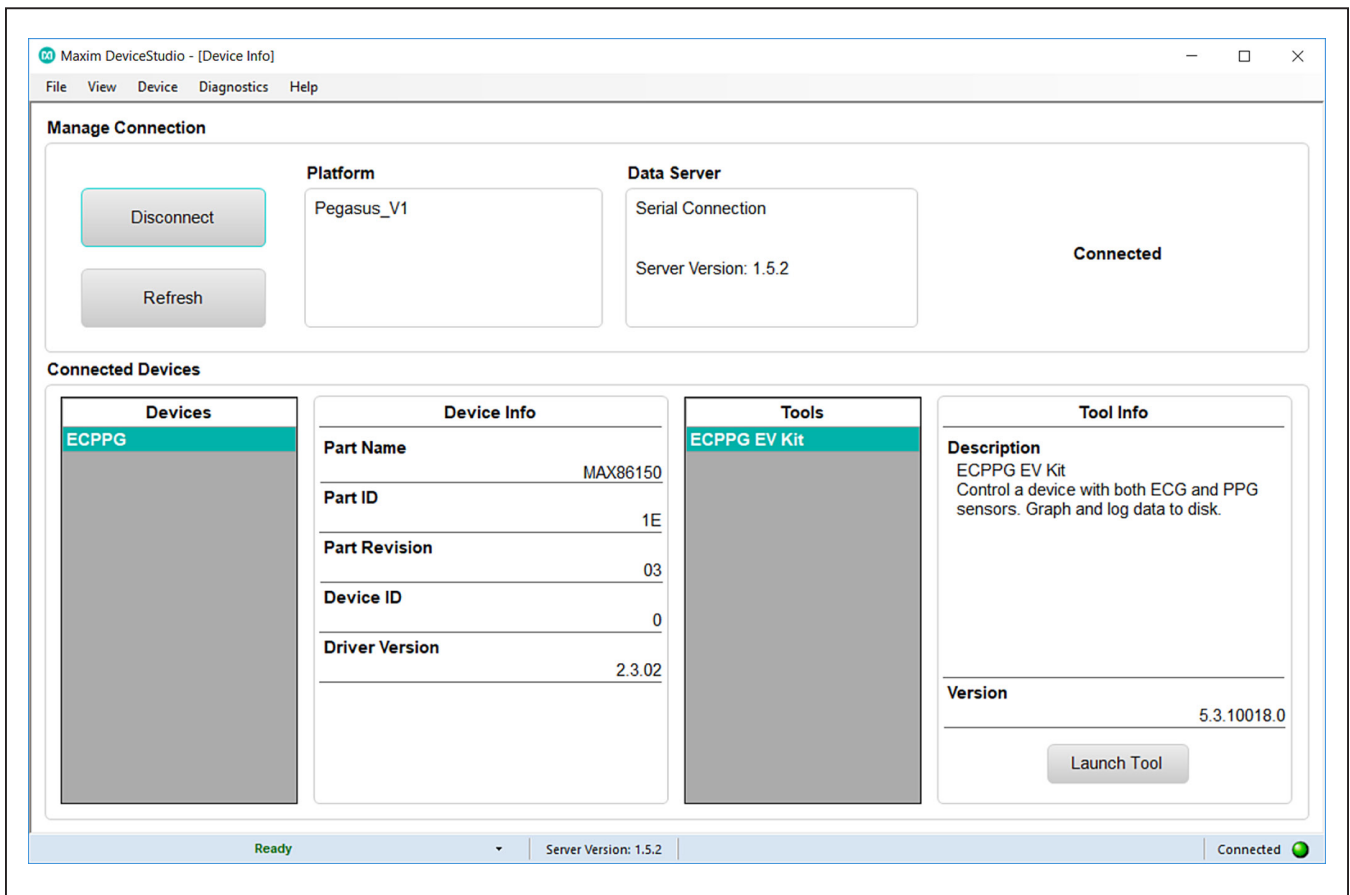


Figure 1. The Device Info Page Is Used to Connect with the EV System

### PPG and ECG Evaluation Kit

This page, shown in in [Figure 2](#), gives control of device register settings, displays live sensor data, and allows data logging. Each function is detailed in the subsections below. Click Start Monitoring to begin viewing live sensor data and click Stop Monitoring to halt data collection. Settings can only be modified when monitoring is not active.

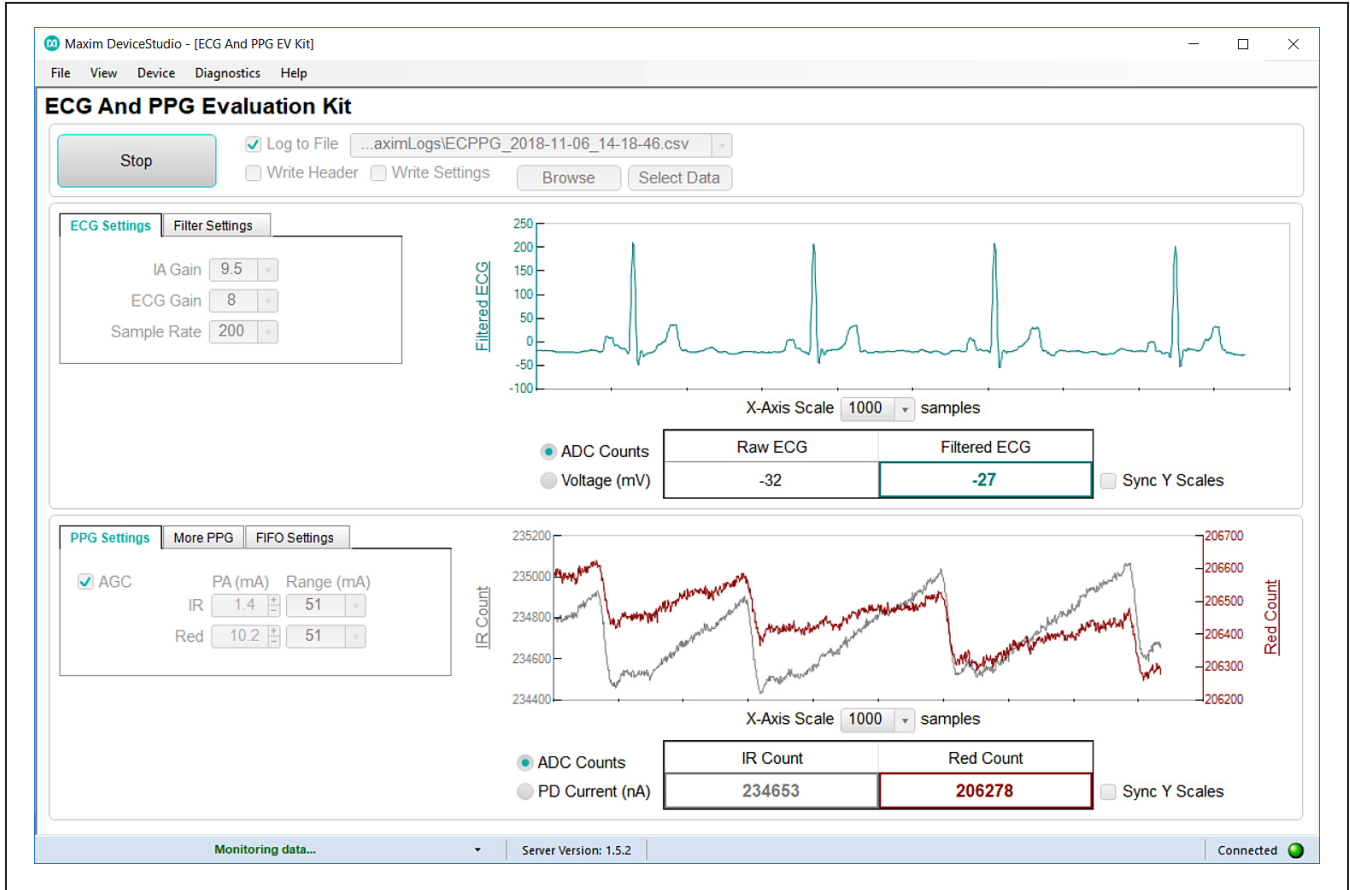


Figure 2. The ECG and PPG EV Kit Page Is Used to Control the EV System and View Live Data.

### ECG and Filter Settings

The ECG Settings, shown in [Figure 3](#), control registers corresponding to the ECG analog front end. See [Table 1](#) for details. The Filter Settings, shown in [Figure 3](#), control software filters that are applied to the Filtered ECG signal. The Filtered ECG signal is delayed 17 samples from the Raw ECG signal. See [Table 2](#) for details.

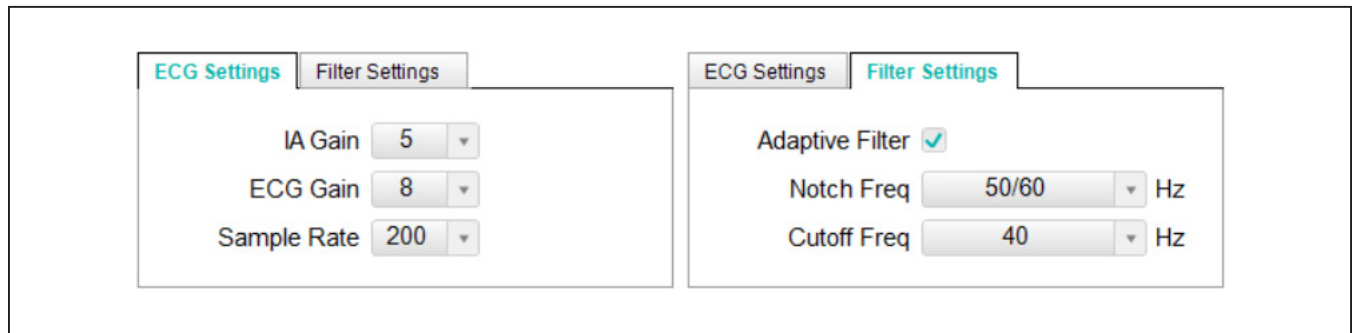


Figure 3. ECG and Filter Settings

**Table 1. ECG Settings Details**

ECG SETTING	REGISTER [BITS]	ADDR	DESCRIPTION
IA Gain	ECG Configuration 3 [1:0]	0x3E	Differential input chopping instrumentation amplifier gain setting (mV/mV)
ECG Gain	ECG Configuration 3 [3:2]	0x3E	PGA gain (mV/mV)
Sample Rate	ECG Configuration 1 [2:0]	0x3C	Delta sigma ADC output data rate (sps)

**Table 2. Filter Settings Details**

FILTER SETTING	DESCRIPTION
Adaptive Filter	Enables the adaptive hybrid-time-domain software filter.
Notch Freq	Sets the frequency of the software notch filter. Set to the AC main frequency in your region for best performance.
Cutoff Freq	Sets the cutoff frequency for the software low-pass filter.

**PPG and FIFO Settings**

The PPG Settings tabs, shown in [Figure 4](#), control configuration registers for the PPG analog front end. The FIFO Settings tab, shown in [Figure 4](#), controls FIFO configuration register in the digital interface. See [Table 3](#) for details.

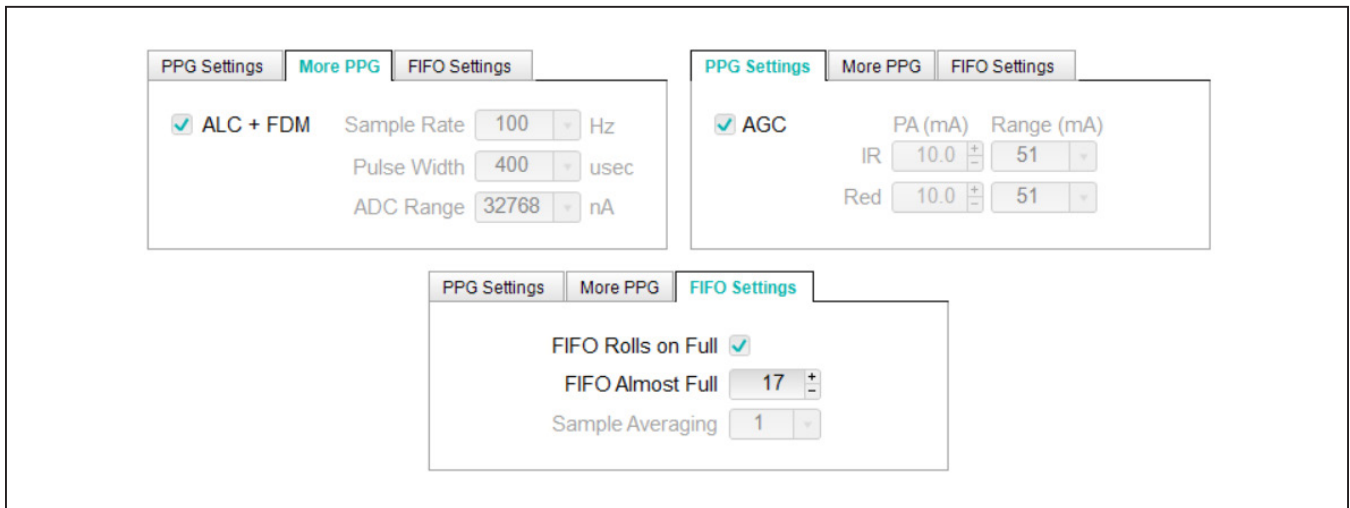


Figure 4. PPG and FIFO Settings

**Table 3. PPG and FIFO Settings Details**

PPG SETTING	REGISTER [BITS]	ADDR	DESCRIPTION
AGC	N/A	N/A	Enables automatic gain control, which allows the EV software to dynamically adjust the LED current and ADC range.
IR PA	LED2 PA [7:0]	0x12	Adjusts the IR LED current amplitude in conjunction with IR Range
Red PA	LED1 PA [7:0]	0x11	Adjusts the Red LED current amplitude in conjunction with Red Range
IR Range	LED Range [3:2]	0x14	IR LED current range
Red Range	LED Range [1:0]	0x14	Red LED current range
ALC + FDM	PPG Configuration 1 [7]	0x0F	Enables ambient light cancellation
Sample Rate	PPG Configuration 1 [5:2]	0x0E	PPG sample rate
Pulse Width	PPG Configuration 1 [1:0]	0x0E	LED current pulse width
ADC Range	PPG Configuration 1 [7:6]	0x0E	Photodiode ADC full-scale range
FIFO Rolls on Full	FIFO Configuration [4]	0x1F	When the FIFO is full, new samples overwrite existing unread samples.
FIFO Almost Full	FIFO Configuration [3:0]	0x1F	Controls the number of unread samples in the FIFO that causes an alert.
Sample Averaging	PPG Configuration 2 [1:0]	0x19	Controls the PPG averaging filter width. Only available when AGC is disabled.

**Plot Controls**

Each plot can hold two data series on the same Y-axis or two Y-axes. Click on the value box for a data type to cycle between the primary Y-axis, secondary Y-axis, and hidden. By default, the two axes auto-scale independently. If Sync Y Scales is enabled, the vertical axes have the same vertical scale, but the vertical offsets remain independent.

**Data Logging**

Enable Log to File to record the desired data to a CSV file. Enable Write Header to include a row of data labels and enable Write Settings to include a list of GUI settings at the top of the log file. Click Browse to designate a file location and click Select Data to choose which data to include in the log file, as shown in [Figure 5](#).

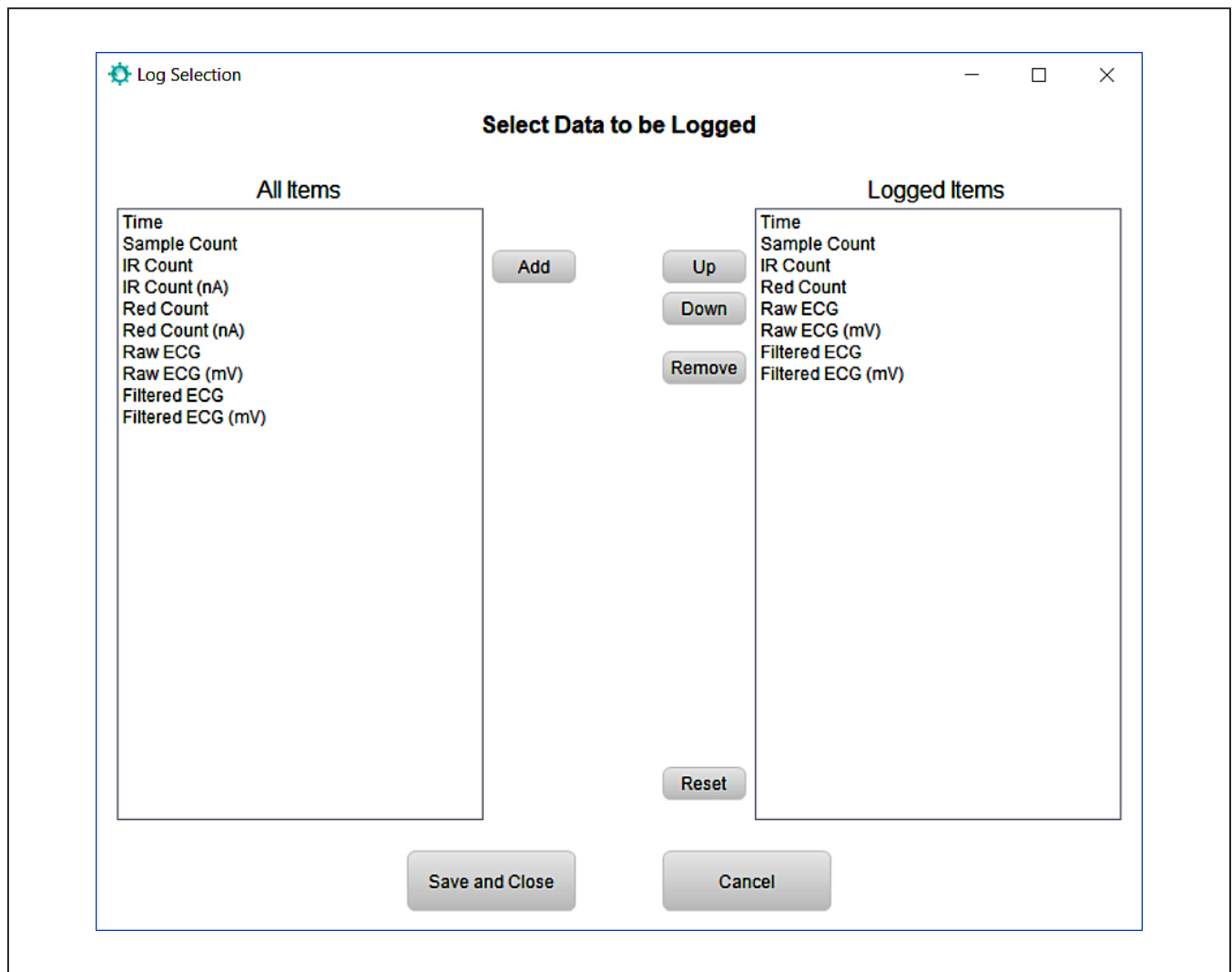


Figure 5. Data Log Selection Window

### Register Map

This page, shown in [Figure 6](#), shows the contents of each register in the MAX86150 and allows them to be written to user values. Clicking on the fields for each register allows you to change the decimal value, the hexadecimal value, or individual bits. For changes to take effect, change the Update Registers option to Selected, and click Set Reg. Registers can be manually read and set using the Manual Update section.

The screenshot shows the 'Register Map' application window for device 'MAX86908'. It features a table of registers with columns for Address, Address Hex, Name, Value, Value Hex, bit fields [7] through [0], and Access. A 'Description' panel on the right shows details for 'Slot 2' with a value of 'OFF (b'0000)'. At the bottom, there are 'Update Registers' buttons (Read Reg, Set Reg) with radio buttons for 'All' and 'Selected', and a 'Manual Update' section with 'Address' (0xFF) and 'Value' (0xFFFFFFFF) input fields and 'Read' and 'Set' buttons. A 'Status' field is also present.

Address	Address Hex	Name	Value	Value Hex	[7]	[6]	[5]	[4]	[3]	[2]	[1]	[0]	Access	
0	00	Interrupt Status 1	1	01	A FU...	PPG ...	ALC...	PRO...	0	0	0	PWR...	RO	
1	01	Interrupt Status 2	0	00	VDD...	0	0	0	0	ECG/...	DIE ...	0	RO	
2	02	Interrupt Enable 1	0	00	A FU...	PPG ...	ALC...	PRO...	0	0	0	0	RW	
3	03	Interrupt Enable 2	0	00	VDD...	0	0	0	0	ECG/...	DIE ...	0	RW	
4	04	FIFO Write Pointer	0	00	0	0	0	FIFO WR PTR = b'00000				RW		
5	05	Over Flow Counter	0	00	0	0	0	OVF Counter = b'00000				RO		
6	06	FIFO Read Pointer	0	00	0	0	0	FIFO RD PTR = b'00000				RW		
7	07	FIFO Data Register	20	14	FIFO Data = b'00010100							RW		
8	08	FIFO Configuration	15	0F	0	A Fu...	A Fu...	FIFO...	FIFO A Full = 17				RW	
9	09	FIFO Data Control Register 1	0	00	Slot 2 = OFF				Slot 1 = OFF				RW	
10	0A	FIFO Data Control Register 2	0	00	Slot 4 = OFF				Slot 3 = OFF				RW	
13	0D	System Control	0	00	0	0	0	0	0	FIFO...	SHD...	RES...	RW	
14	0E	PPG Configuration 1	211	D3	PPG ADC Ra...	PPG Samplerate = 100Hz		LED Pulsewi...				RW		
15	0F	PPG Configuration 2	24	18	ALC...	0	0	1	1	Sample Avg = 1				RW
16	10	Prox Interrupt Threshold	0	00	Prox Interrupt Thresh = b'00000000							RW		
17	11	LED1 PA	50	32	LED1 Pulse Amplitude = 10mA							RW		
18	12	LED2 PA	50	32	LED2 Pulse Amplitude = 10mA							RW		
19	13	LED3 PA	0	00	LED3 Pulse Amplitude = 0mA							RW		
20	14	LED Range	0	00	0	0	LED3 Range ...	LED2 Range ...	LED1 Range ...				RW	
21	15	LED PILOT PA	0	00	Pilot Pulse Amplitude = b'00000000							RW		
60	3C	ECG IMP Configuration 1	3	03	0	0	0	0	0	ECG Samplerate = 20...				RW

Figure 6. The Register Map Page Allows the User to Read and Write the MAX86150 Registers



**Prerequisite for HDK Adapter ONLY**

Depending on the build date, the MAX86150EVSYS ships with either a MAX32625PICO or a Maxim HDK board. The HDK adapter firmware image needs to be updated to enable drag-and-drop programming to the MAX32630FTHR board. This update only needs to be performed once, and then the HDK can be used to update the MAX32630FTHR by following the Firmware Update Procedure.

- 1) Start with the HDK adapter unplugged from both the PC and the EVKIT. Open File Explorer on your PC to see a list of active drives.
- 2) While holding down the button on the HDK adapter, connect the HDK port to your PC with a USB-A to micro-USB cable. Continue to hold the button until a drive named MAINTENANCE appears in File Explorer.
- 3) Download the DAPLINK image from this link: [https://os.mbed.com/media/uploads/switches/max32620\\_daplink\\_max32630fthr.bin](https://os.mbed.com/media/uploads/switches/max32620_daplink_max32630fthr.bin)
- 4) Drag and drop the downloaded file onto the MAINTENANCE drive. After the file transfer completes, the MAINTENANCE drive disappears and is replaced by a DAPLINK drive a few seconds later. Once the DAPLINK drive appears, continue to step 2.

**Updating the EV System Firmware**

The EV software allows firmware updates to be flashed to the microcontroller via the included programming adapter. Follow the steps below to update the firmware:

- 1) Connect the programming adapter.
  - Connect the programming adapter to the MAX32630FTHR with the 10-pin JTAG connector as shown in [Figure 7](#).
  - Connect a micro-USB cable between the HDK port on the programming adapter and your PC. For the HDK, use the port labeled HDK.
  - Connect a battery or a micro-USB cable to the MAX32630FTHR to supply power. Power is not supplied via the 10-pin JTAG connector. If the MAX32630FTHR LED is not flashing, press and hold SW1 for two seconds to power on the board.
- 2) Flash the new firmware.
  - Download and extract the latest EV system firmware from the MAX86150’s Design Resources page (MAX86150EVSYS\_PC\_GUI\_Win10.zip)
  - Drag and drop the “MAX86150EVSYS\_FTHR\_FW.bin” file onto the DAPLINK drive and wait for the file transfer to complete. The red LED on the programming adapter flashes to indicate the firmware flash ins in progress.
  - Open the file transfer is complete and the adapter has stopped flashing, press the button on the adapter to reset the MAX32630FTHR. The firmware update is not complete.
- 3) When the update is complete, reassemble the EV system and unplug the programming adapter. Power cycle the EV system and follow the [Quick Start](#) section to reconnect it.

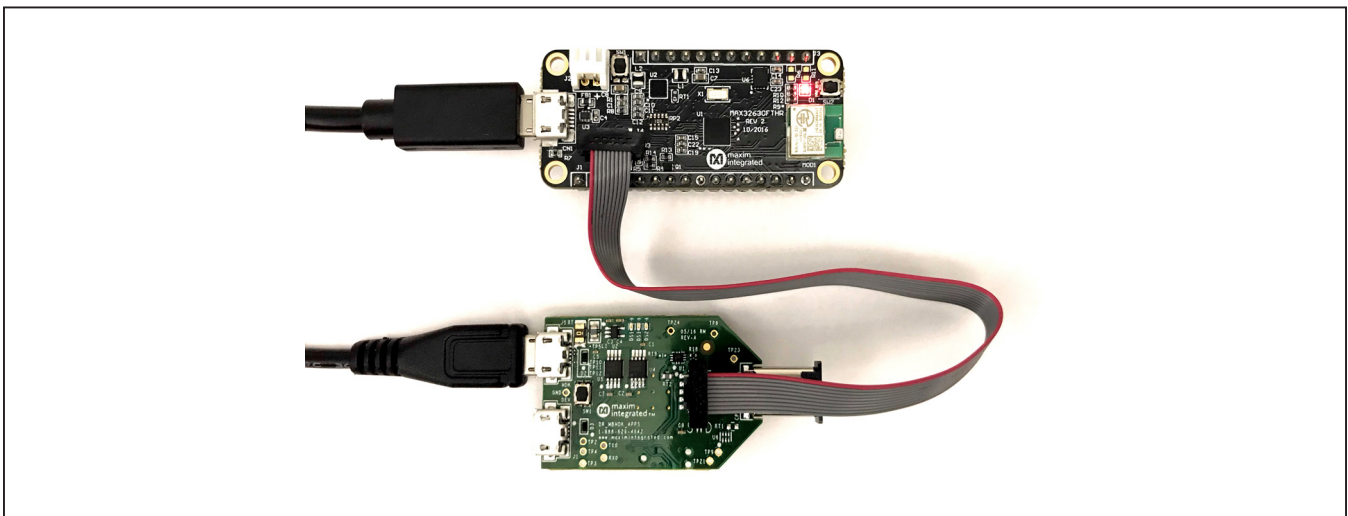


Figure 7. Programming Adapter Connections

## Detailed Description of Hardware

The MAX86150 EV system hardware provides a platform to evaluate the PPG and ECG measurement capabilities of the MAX86150. The EV kit board contains the MAX86150 module with supporting components, stainless steel dry electrodes for ECG measurement, a passive ECG filter, and a header pin socket for the MAX32630FTHR. The MAX32630FTHR Cortex-M4F Microcontroller for Wearables provides an interface between the MAX86150 and the EV kit software as well as power for the system.

## Powering the EV System

The EV system is powered by a lithium ion or lithium polymer battery and the MAX14690 power management IC (PMIC) included on the MAX32630FTHR. The PMIC turns on power to the system when SW1 is pressed for at least 400ms and turn off power when SW1 is held for 12s. When powered on, the PMIC supplies the rest of the MAX32630FTHR with power and supplies 3.3V to VLED on the EV kit board via an internal LDO. The EV kit has a MAX8511 ultra-low-noise linear regulator to step VLED down to 1.8V for the VDD analog supply. The PMIC also has an integrated battery charger and is configured to automatically charge the battery at 100mA when a micro-USB cable is connected. Note: The micro-USB cable should not be connected when measuring ECG, as the noise introduced by the cable will obscure the sensitive ECG signal.

## ECG Analog Filter

The EV kit has a passive first-order common-mode and differential filter at the ECG inputs to the MAX86150. The board comes populated with components that implement a common-mode lowpass filter with a corner frequency of 319kHz (R2, R3, C2, and C4). The differential-mode capacitor is not populated as it is not needed in most applications. The purpose of this analog filter is to reject high-frequency EMI; low-frequency filtering is done by the internal filters of the MAX86150. The filter components were chosen as a tradeoff between input impedance and component size, and the corner frequency is not critical.

## ECG Measurement

After following the steps in the [Quick Start](#) section, measure ECG lead I by firmly placing a right-hand finger on the ECG\_N electrode (TP1) and a left-hand finger on the ECG\_P electrode (TP2), as shown in [Figure 8](#). Alternately, an ECG signal generator can be connected to the ECG\_N and ECG\_P test loops to simulate contact. To achieve the best ECG signal performance, be careful not to touch any other conductive points on the EV kit board or conductive surfaces in the environment. The micro-USB cable should be detached to isolate the board from EMI transmitted through the cable.

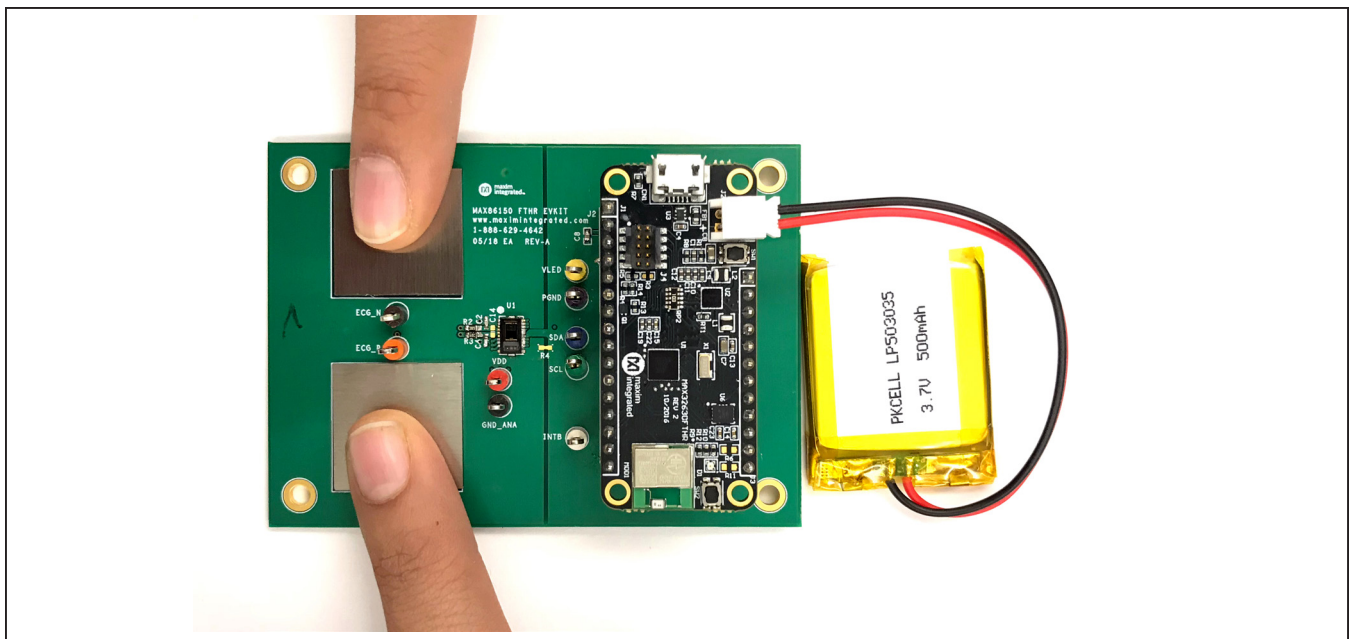


Figure 8. Finger Placement for ECG Measurement

**PPG Measurement**

After following the steps in the [Quick Start](#) section, measure PPG by lightly resting a finger from either hand on the MAX86150 module, as shown in [Figure 9](#). When monitoring is active, the module uses IR proximity mode

to detect a finger, so the red LED will not turn on until a finger is near the module. To measure ECG and PPG simultaneously, place fingers as shown in [Figure 10](#) being careful not to touch any nearby components or test points.

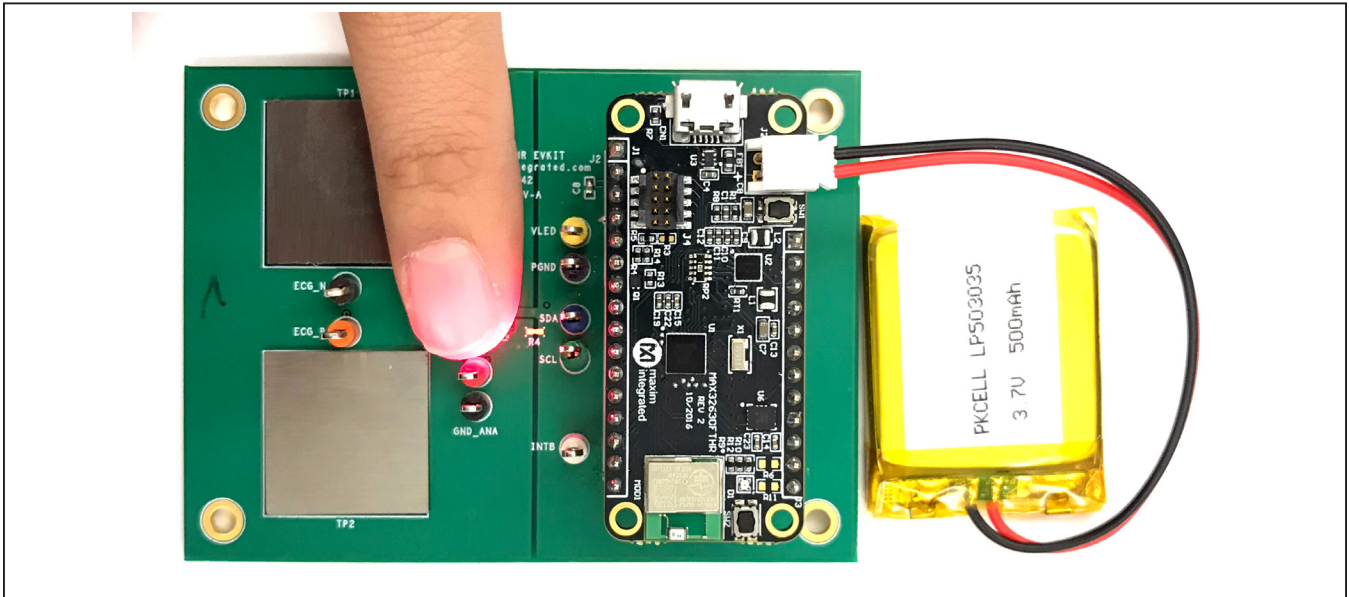


Figure 9. Finger Placement for PPG Measurement

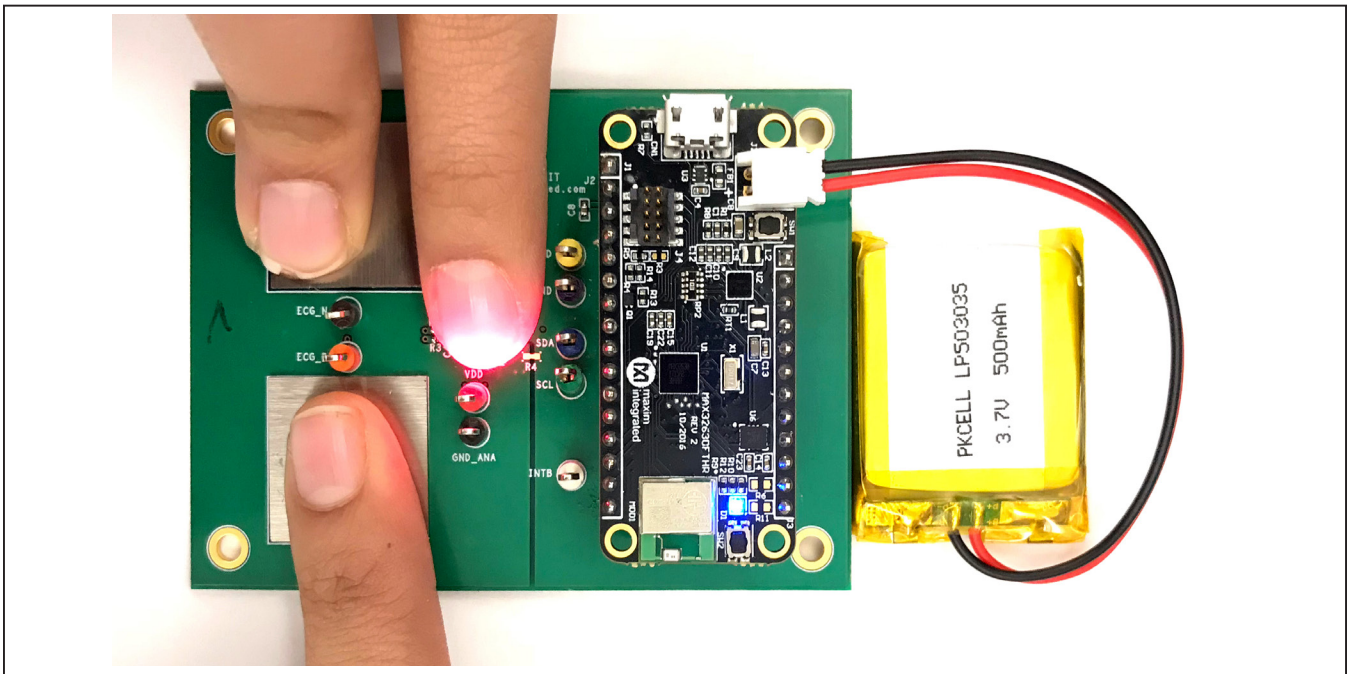


Figure 10. Finger Placement for ECG and PPG Measurement

## Ordering Information

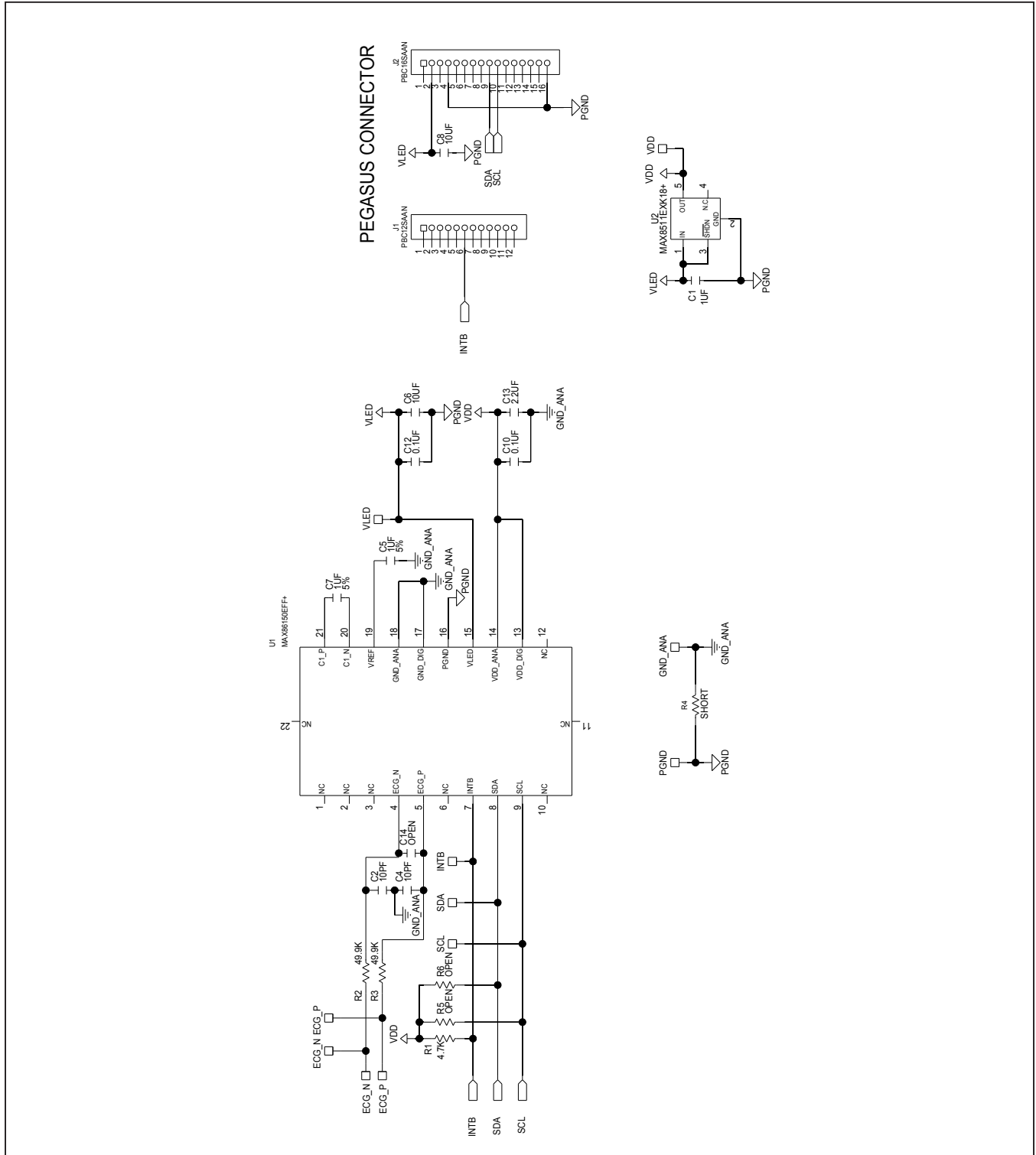
PART	TYPE
MAX86150EVSYS#	EV SYSTEM

#Denotes RoHS compliant.

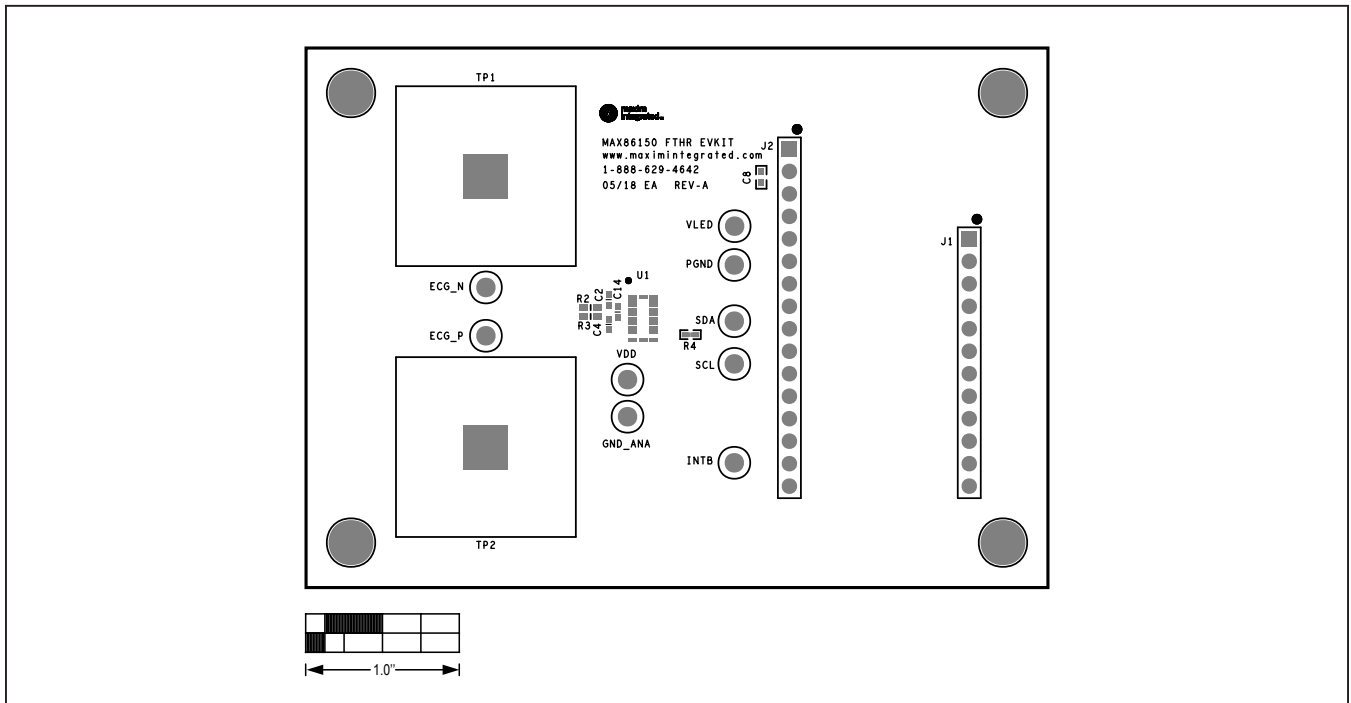
## MAX86150 EV System Bill of Materials (BOM)

ITEM	QTY	REF DES	MFG PART #	MANUFACTURER	VALUE	DESCRIPTION
1	1	C1	JMK063ABJ105MP	TAIYO YUDEN	1UF	CAPACITOR; SMT (0201); CERAMIC CHIP; 1UF; 6.3V; TOL = 20%; MODEL = ; TG = -25°C TO +85°C; TC = X5R
2	2	C2, C4	C0402C100K4GACTU	KEMET	10PF	CAPACITOR; SMT (0402); CERAMIC CHIP; 10PF; 16V; TOL = 10%; TG = -55°C TO +125°C; TC = COG
3	2	C5, C7	C0402X5R6R3-105JNP	VENKEL LTD.	1UF	CAPACITOR; SMT; 0402; CERAMIC; 1uF; 6.3V; 5%; X5R; -55°C to + 85°C; 0 ±15%°C MAX.; USE 20-0001u-B8 FOR NEW DESIGN
4	2	C6, C8	CL05A106MP5NUNC	SAMSUNG ELECTRONICS	10UF	CAPACITOR; SMT (0402); CERAMIC CHIP; 10UF; 10V; TG = -55°C TO +85°C; TC = X5R
5	2	C10, C12	GRM155R71A104KA01; C1005X7R1A104K; C0402C104K8RAC	MURATA;TDK;KEMET	0.1UF	CAPACITOR; SMT (0402); CERAMIC CHIP; 0.1UF; 10V; TOL = 10%; MODEL = GRM SERIES; TG = -55°C TO +125°C; TC = X7R; NOT RECOMMENDED FOR NEW DESIGN-USE 20-000u1-04A
6	1	C13	CL05A225KP5NSN	SAMSUNG ELECTRONICS	2.2UF	CAPACITOR; SMT (0402); CERAMIC; 2.2UF; 10V; TOL=10%; TG = -55°C TO +85°C; TC = X5R
7	9	ECG_N, ECG_P, GND_ANA, INTB, PGND, SCL, SDA, VDD, VLED	5006	KEYSTONE	N/A	TEST POINT; PIN DIA = 0.125IN; TOTAL LENGTH = 0.35IN; BOARD HOLE = 0.063IN; BLACK; PHOSPHOR BRONZE WIRE SILVER PLATE FINISH; RECOMMENDED FOR BOARD THICKNESS = 0.062IN; NOT FOR COLD TEST
8	1	J1	PBC12SAAN	SULLINS ELECTRONICS CORP.	PBC12SAAN	CONNECTOR; MALE; THROUGH HOLE; BREAKAWAY; STRAIGHT; 12PINS; -65°C TO +125°C
9	1	J2	PBC16SAAN	SULLINS ELECTRONICS CORP.	PBC16SAAN	CONNECTOR; MALE; THROUGH HOLE; BREAKAWAY; STRAIGHT; 16PINS; -65°C TO +125°C
10	1	R1	CRCW04024K70FK	VISHAY DALE	4.7K	RESISTOR, 0402, 4.7KΩ, 1%, 100PPM, 0.0625W, THICK FILM
11	2	R2, R3	288-0603-49.9K-RC	XICON	49.9K	RESISTOR, 0603, 49.9KΩ, 0.1%, 10PPM, 1/16W, THIN FILM
12	1	U1	MAX86150EFF+	MAXIM	MAX86150EFF+	EVKIT PART-IC; MAX86150EFF+; OLGA22 3.3X5.6X1.3; 0.5MM PITCH
13	1	U2	MAX8511EXK18+	MAXIM	MAX8511EXK18+	IC; VREG; ULTRA-LOW-NOISE; HIGH PSRR; LOW = DROPOUT; LINEAR REGULATOR; SC70-5
14	1	PCB	MAX86150FTHR	MAXIM	PCB	PCB:MAX86150FTHR

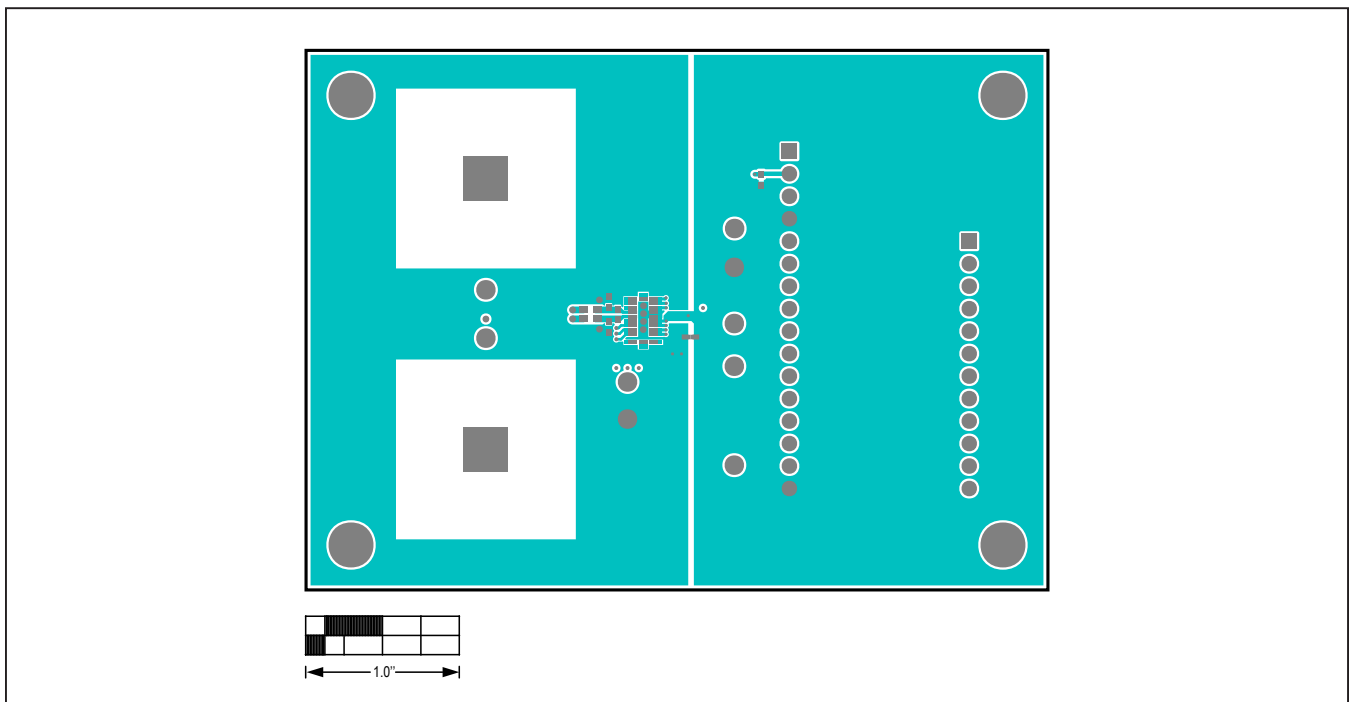
MAX86150 EV System Schematic



MAX86150 EV System PCB Layout Diagrams

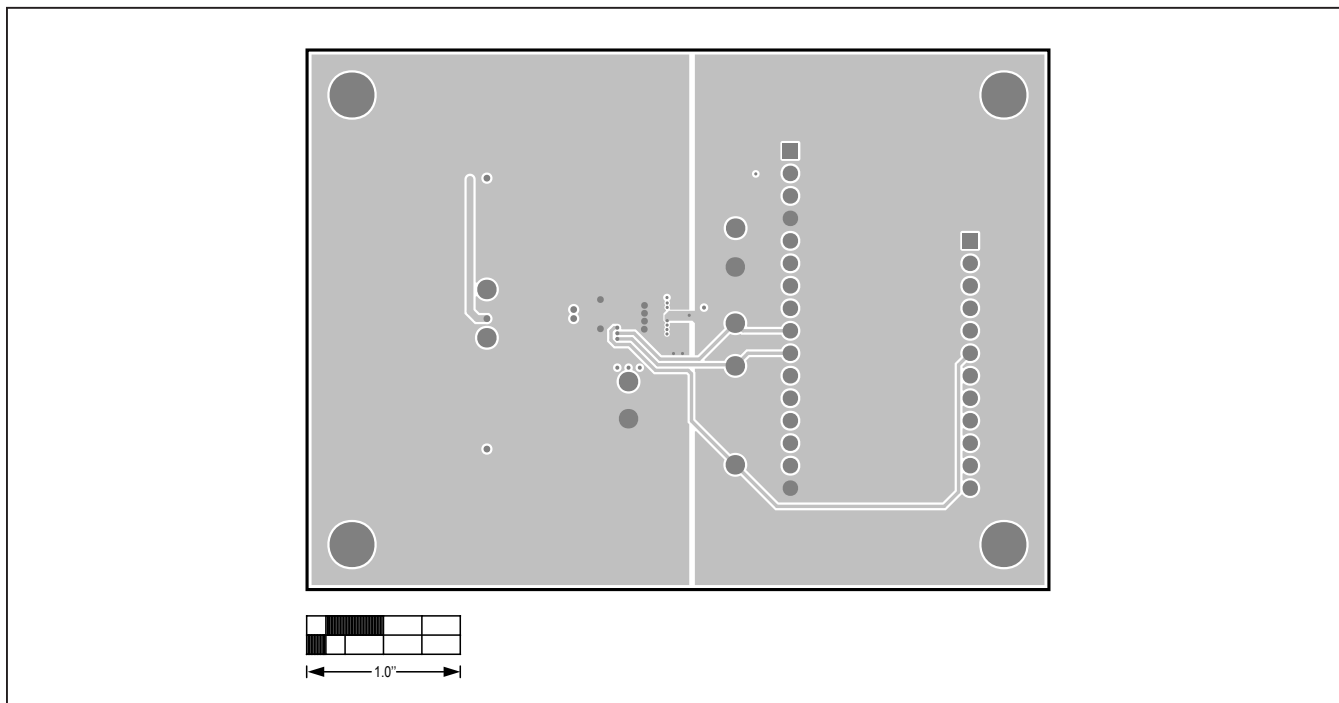


MAX86150 EV System—Top Silkscreen

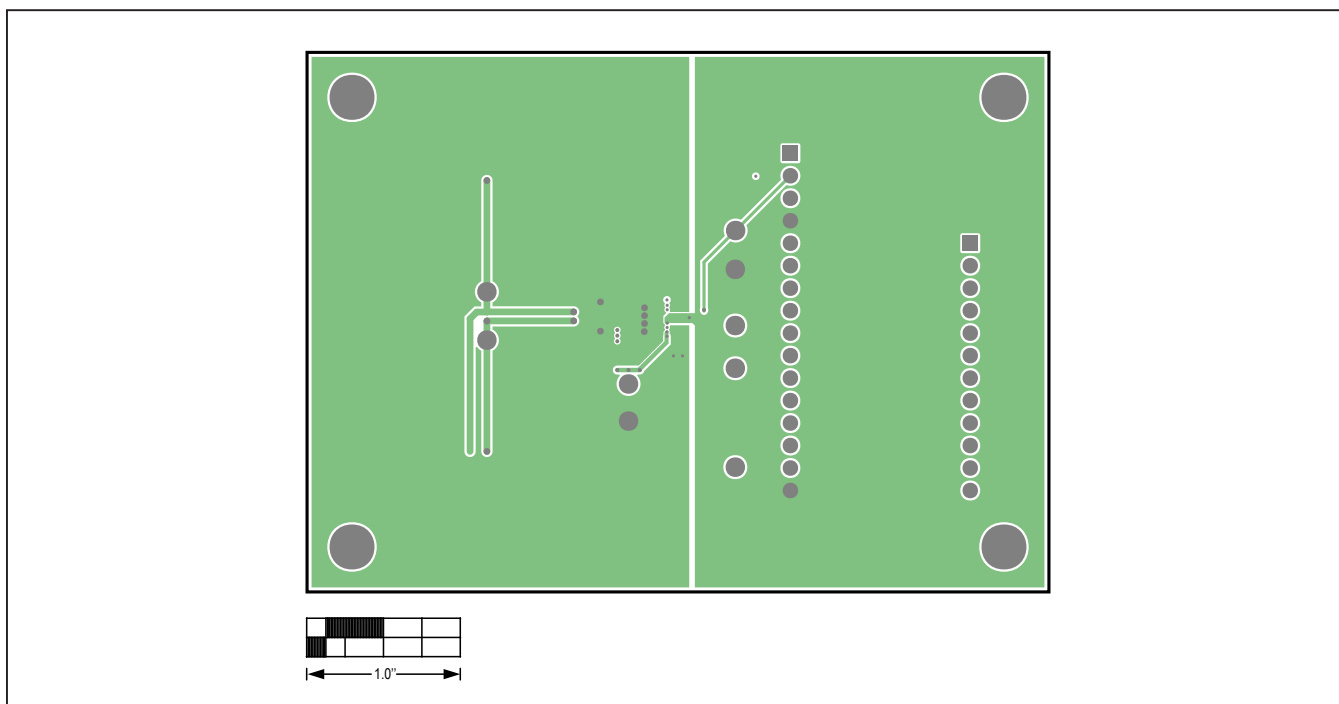


MAX86150 EV System—Top Layer

MAX86150 EV System PCB Layout Diagrams (continued)

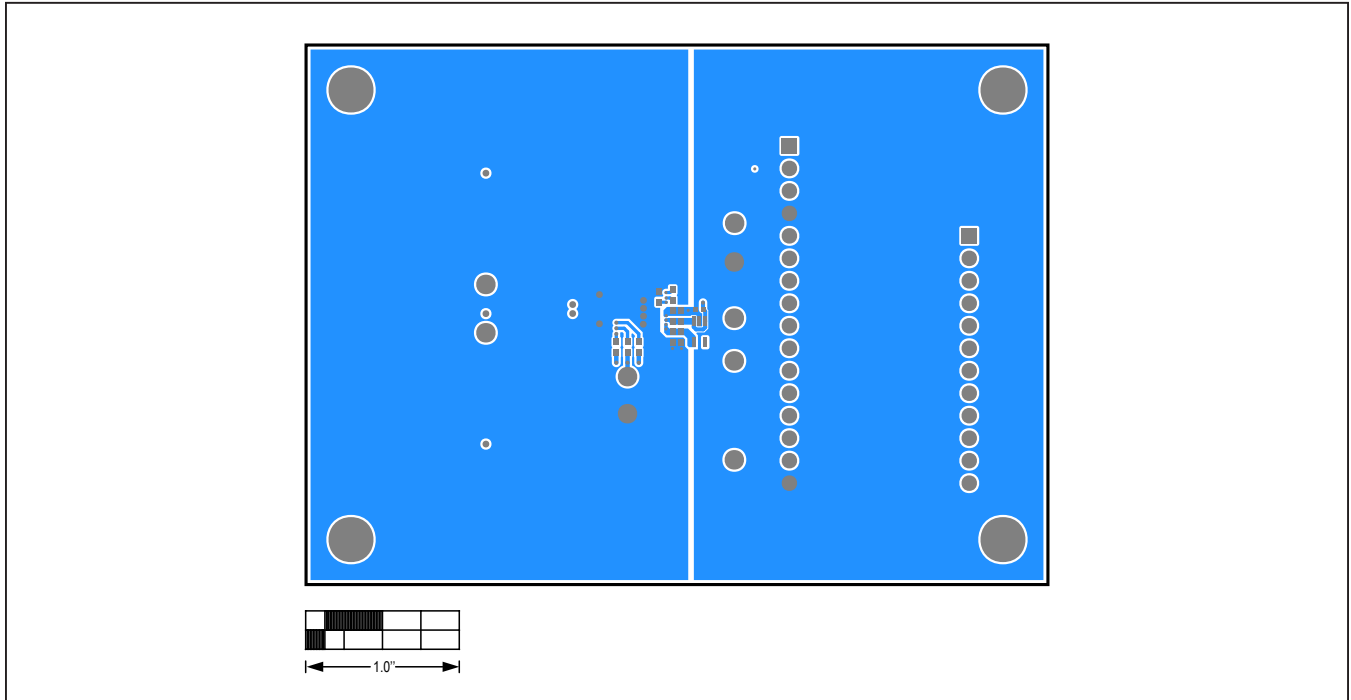


MAX86150 EV System—Layer 2

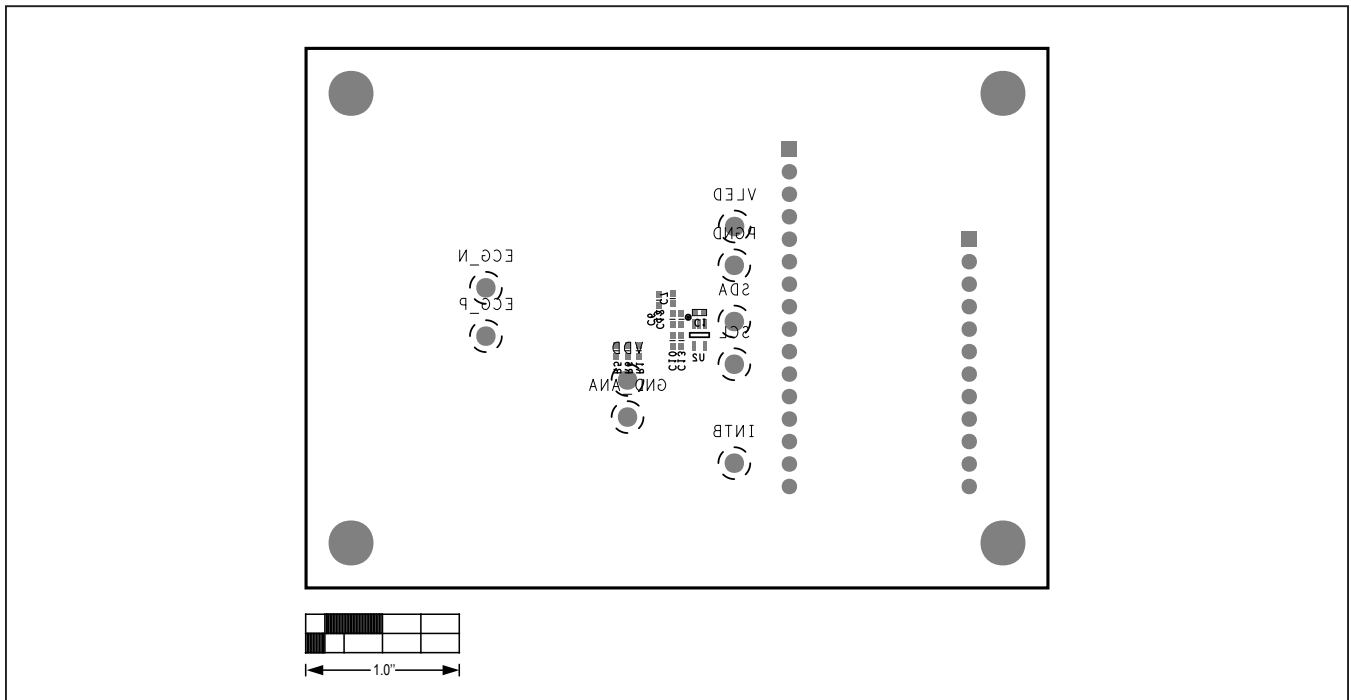


MAX86150 EV System—Layer 3

MAX86150 EV System PCB Layout Diagrams (continued)



MAX86150 EV System—Bottom Layer



MAX86150 EV System—Bottom Silkscreen



## Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	4/17	Initial release	—
1	11/17	Updated <i>Ordering Information</i> and <i>General Description</i>	1, 12
2	11/18	Replaced all figures and sections to reflect updated hardware and software updates	1–17
3	6/19	Updated the <i>Updating the EV System Firmware</i> section and added the <i>Prerequisite for HDK Adapter ONLY</i> section	9

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