Evaluation Board User Guide

MAX78000CAM02

Evaluates: MAX78000

General Description

The MAX78000CAM02 is a miniature artificial intelligence (AI) at the edge development platform designed for image processing applications. Measuring just 0.4in by 0.9in, it is ideal for developing and prototyping edge AI applications. The platform is built around the MAX78000 microcontroller, which features an Arm® Cortex®-M4F core with a convolutional neural network (CNN) accelerator.

Additionally, the board includes a VGA resolution CMOS image sensor. This configuration allows for capturing images and processing them with AI models directly on the board without the need for external hardware or communication links.

The platform operates with a single 3.3V DC power source with all necessary power circuits integrated on the board, and it uses a JST SH 4-pin connector for the power supply connection.

To get started developing with this board, go to *Analog Devices MSDK Documentation*.

MAX78000CAM02 EV Kit Contents

- MAX78000CAM02 Board with Camera Module
- MAX32625PICO Debugger with Cables
- Insert Card
- JST SH 4-Pin to Female Sockets Cable
- JST SH 4-Pin to Male Headers Cable
- JST SH 4-Pin to JST SH 4-Pin Cable

Features

- MAX78000 Microcontroller
  - Dual Core: Arm Cortex-M4 Processor with FPU and RISC-V Coprocessor
  - 512KB Flash Memory
  - 128KB SRAM
  - 16KB Cache
  - CNN Accelerator
- CMOS VGA (640×480) Image Sensor Module
- Single 3.3V Power Supply Input
- Additional On-Board CNN Power Supply
- SWD 10-Pin Header for Programming and Debug
- JST SH 4-Pin Connector
- I^2C Controller/Target Operation
- Full-Duplex UART
- Two Indicator LEDs

Ordering Information

PART	TYPE
MAX78000CAM02#	Evaluation Board

One Analog Way, Wilmington, MA 01887-2356, U.S.A. | Tel: 781.329.4700

MAX78000CAM02 EV Kit Board

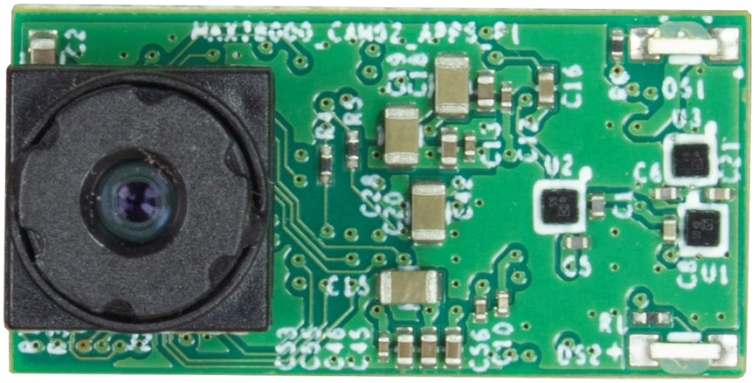


Figure 1. MAX78000CAM02 EV Kit Board—Bottom

Figure 2. MAX78000CAM02 EV Kit Board—Top

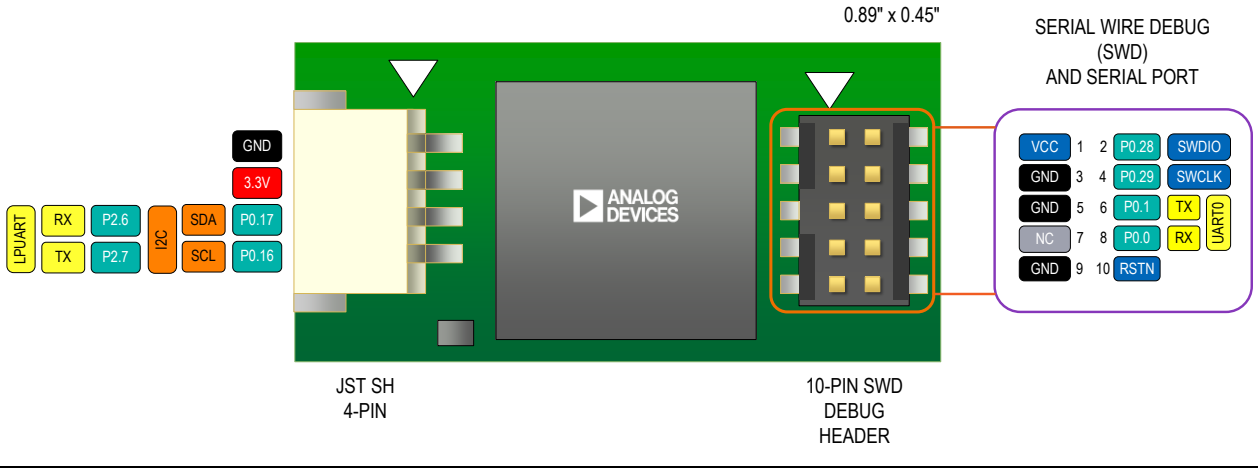


Figure 3. MAX78000CAM02—Top View

Quick Start

Required Equipment

- MAX78000CAM02 EV Kit
- MAX32625PICO
- JST SH 4-Pin Cable
- 3.3V DC Power Supply

Procedure

This evaluation board was thoroughly assembled and tested. Verify the board's operation using the following steps:

1. Carefully remove the board from its packaging, considering ESD safety rules and practices. Ensure the board sustained no damage during transit.
2. Remove the protective film from the camera sensor.
3. The camera module is not soldered to the PCB. The module uses a board-to-board connector for the connection. Ensure the camera module is properly aligned with the MAX78000CAM02 board. Verify that the PCB and the camera module are parallel, and that the camera module is fully inserted into the board-to-board connector. See *Figure 4* for the correct alignment of the camera module with respect to the PCB.

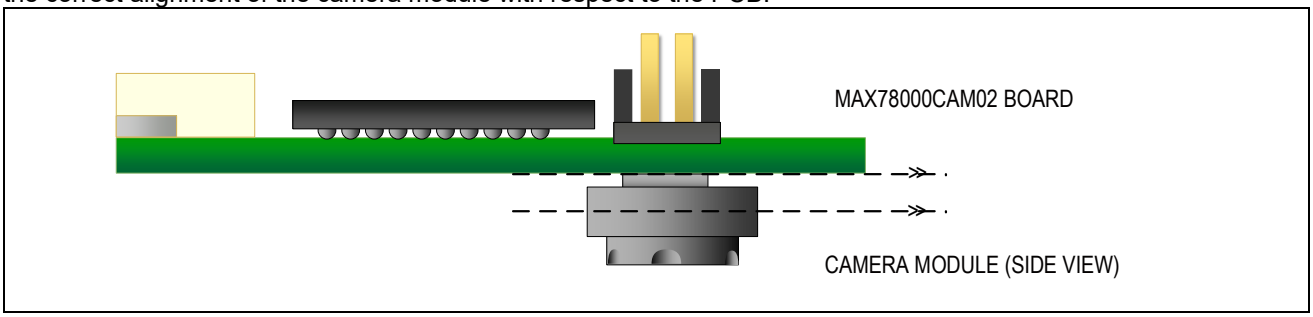


Figure 4. MAX78000CAM02 Board and Camera Module—Side View

4. If the camera module is not plugged in properly, make certain that pin 1 on the connector and the camera module match each other. The pin 1 locations for both the PCB and the camera module are shown in *Figure 5*. When installed, pin 1 is on the left.

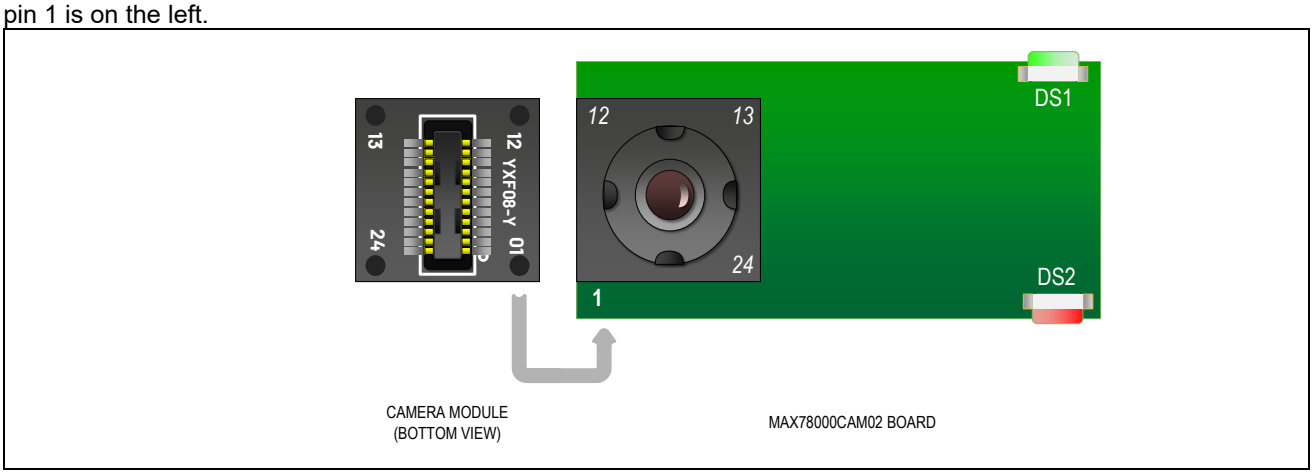


Figure 5. MAX78000CAM02 Board and Camera Module Alignment

5. Apply 3.3V DC power to the board by connecting a power supply to the JST SH 4-pin connector (J1) using one of the included cables, as shown in *Figure 6*. Pin 1 of the JST SH 4-pin connector (J1) is the ground connection and pin 2 is the 3.3V DC input positive terminal.
   Note: There is no reverse voltage protection on the board. Ensure that the polarity for the 3.3V supply is always correct to prevent damage to the board.

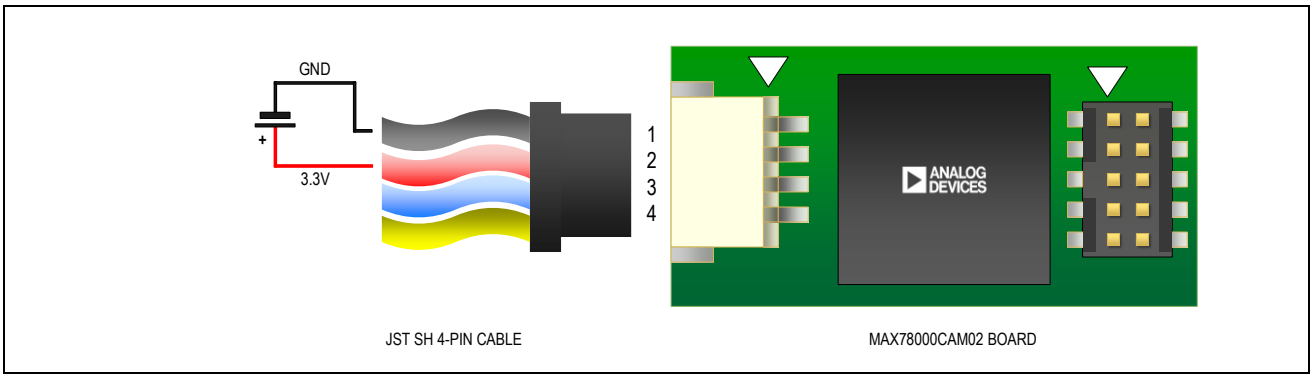


Figure 6. MAX78000CAM02 Power Connection

6. When power is applied to the board, the green LED (DS1) begins to blink. This LED indicates the MAX78000 microcontroller is running the demo software. See *Figure 7* for the location of the LED (DS1).

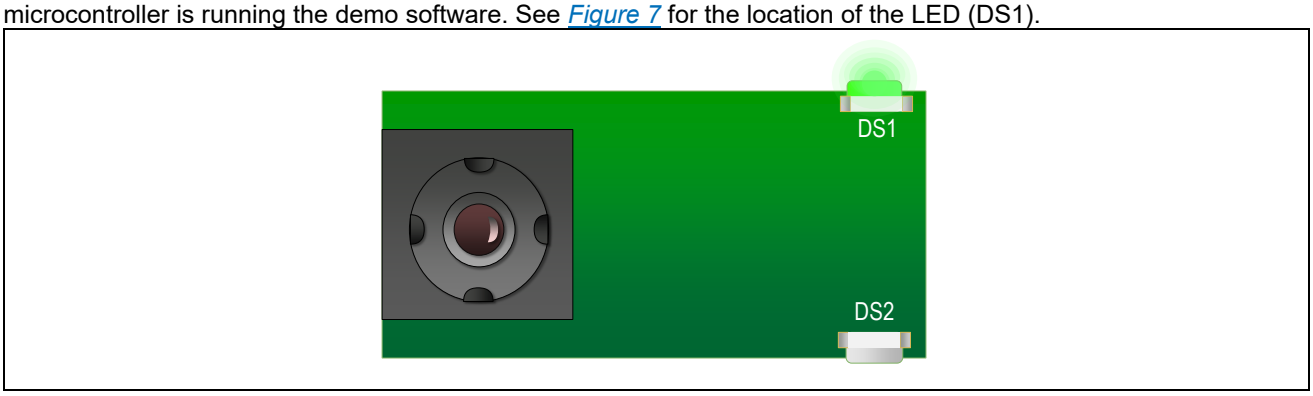


Figure 7. MAX78000CAM02 LED Location

7. The preloaded application captures an image using the image sensor and performs inference operations with the embedded CNN model. The factory-loaded CNN model is a simple face-detection model.

   Point the camera at a face from a distance of approximately 80cm. Ensure the camera lens is centered on the face. The board should be oriented as shown in *Figure 8*. The camera lens is at the top and the LEDs are at the bottom. Proper distance, alignment, and illumination of the face are crucial for the face detection model to function correctly.

   The blinking green LED (DS1) indicates an image capture and interference. The red LED (DS2) is on when a face is detected.

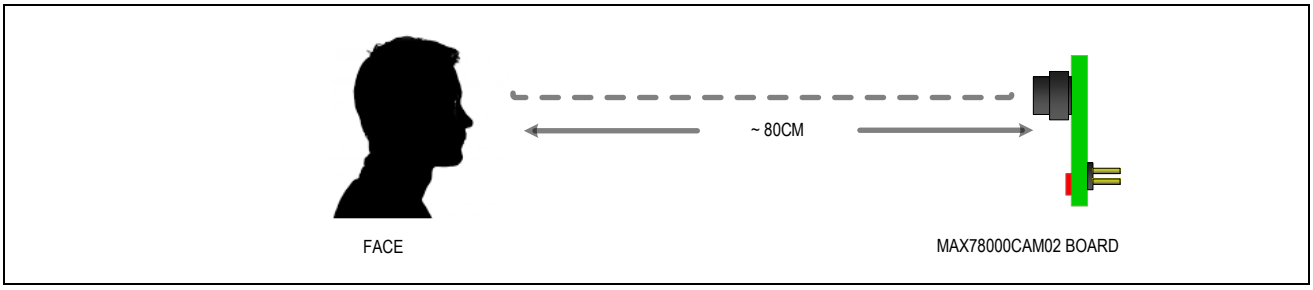


Figure 8. Camera Module and Face Alignment

Typical AI Vision Application

The MAX78000CAM02 board includes the essential components for edge AI vision applications. The board features the MAX78000 Arm Cortex-M4F microcontroller and a CMOS camera module with parallel camera interface (PCIF) and serial camera control bus (SCCB) interfaces. When the board is powered by connecting a 3.3V DC power supply to the JST SH 4-pin connector (J1), the MAX78000 microcontroller starts running the software loaded in its internal flash memory.

A typical AI vision application on the MAX78000CAM02 board follows these steps:

1. **Initialization:** During the power-up initialization, the MAX78000 and the image sensor are configured.
   a. The software configures the internal clocks, general-purpose input/output (GPIO) pins, and on-chip peripherals. This is generally done in the board support file.
   b. The image sensor is powered by setting MAX78000 P0.2 high.
   c. The camera module is initialized using the SCCB interface. This step utilizes the camera driver in the MSDK library, which writes initialization parameters including pixel format, resolution, exposure time, and gain to the image sensor registers, and then starts image capture.
2. **Model Loading:** The model is loaded from the flash memory to the CNN memory.
3. **Image Capture:** The software starts capturing images using the camera driver through the PCIF to the internal SRAM. If needed, image pre-processing can be performed during this step.
4. **Inference:** Captured images are fed to the machine learning (ML) model's input for inference.
5. **Post-Processing:** Once the inference is completed, the software takes the output of the model and performs post-processing. This step is specific to the model and the application. Based on the post-processing results, actions can be triggered such as controlling LED status, sending UART or I^2C messages, or controlling an external device using a GPIO.
6. **Low-Power Mode:** After this cycle is completed, the application can enter one of the low-power modes until the next processing cycle. During the low-power SLEEP mode state, powering down the image sensor and the external CNN power supply reduces the power consumption of the board. Powering off the image sensor requires reinitialization during wake-up. The image sensor can be put into power-down mode by setting the MAX78000 P0.3 pin high. When the pin is low, the sensor remains in active mode.

Detailed Description of Hardware

MAX78000

The MAX78000 is an advanced system-on-chip featuring an Arm Cortex M4 with FPU CPU, designed for efficient system control alongside an ultra-low-power deep neural network accelerator. The software for the MAX78000 is stored in the 512KB on-chip flash program memory.

The MAX78000 is powered through its V_{REGI} pins. These pins supply power to the internal SIMO, which in turn provides power to the internal Arm core, peripherals, and CNN accelerator through three outputs: V_{REGO_A}, V_{REGO_B}, and V_{REGO_C}. The 3.3V power supply input at the JST SH 4-pin connector is directly connected to the V_{REGI} pins. On the MAX78000CAM02 board, the V_{REGO_C} output powers the CNN accelerator through the V_{COREA} pins.

In most cases, the integrated single-inductor multiple-output (SIMO) power supply of the MAX78000 is sufficient to power the V_{COREA} CNN input. However, large neural network models may increase the I_{COREA} current, requiring an external regulator. The Analog Devices ADP172ACBZ-1.2 (U1), a 1.2V LDO, provides additional power for the on-chip CNN accelerator. By default, this LDO is disabled. To enable it, set the MAX78000 P2.5 pin high, which powers the LDO, and then set P2.4 pin high to activate the load switch that connects the 1.2V LDO to the CNN module's power input. If the SIMO power supply is sufficient for the current model, disabling both the LDO and the load switch (U3, ADP195ACBZ) will reduce standby power consumption.

During power-up initialization, the software should configure the clocking scheme, typically done in the board support file in the MSDK toolchain. For further information, refer to the *System, Power, Clocks, Reset* section of the *MAX78000 User Guide*.

A pull-up resistor (R2) is connected between the MAX78000 P0.0/UART_RX pin and the V_{REG_A} supply, ensuring that the on-chip ROM UART bootloader is not invoked at power-up. For more details, refer to the *Bootloader* section of the *MAX78000 User Guide*.

Key on-chip peripherals such as the PCIF, I2C, and UART enable the development of single-chip, standalone edge AI vision solutions. These peripherals facilitate seamless integration and communication with external devices, making the MAX78000 ideal for ultra-low power edge computing applications.

The MAX78000 has two I/O power supply rails: V_{DDIO} (1.8V) and V_{DDIOH} (3.3V). Each GPIO pin of the MAX78000 can be individually programmed to use one of these rails. The board support files in the MSDK toolchain set the appropriate power supply rail for the GPIO pins utilized on the MAX78000CAM02 board.

Camera Module

The MAX78000CAM02 uses a GalaxyCore GC0308 1/6.5" VGA CMOS image sensor-based camera module. The YFX08-77 is an 8mm x 8mm x 4.2mm camera module assembly with a 77° (diagonal) angle of view lens. The effective focal length (EFL) is 1.79mm, and the F-number is 2.2. The module is powered by a single 2.8V power supply. The power supply, parallel 8-bit image output bus, and SCCB interface are connected through a 24-pin miniature board-to-board connector.

The GC0308 image sensor features an array of 648x492 (640x480) active pixels. The pixel array utilizes a BG/GR Bayer pattern color filter arrangement. The first row (row 0) starts with an RGRG… sequence.

The GC0308 is equipped with an on-chip 10-bit ADC and an integrated image signal processing (ISP) block. The sensor supports various data formats including Bayer RGB, RGB565, and YCbCr 4:2:2. The Bayer pattern color filter interpolation, denoising, color correction, and gamma correction operations can be handled by the integrated ISP.

The integrated ISP is configured using the SCCB interface of the GC0308 image sensor. On the MAX78000CAM02 board, the MAX78000 P0.31/I2C2_SDA and MAX78000 P0.30/I2C2_SCL pins are dedicated for the SCCB interface.

The camera module is powered by a 2.8V LDO regulator (ADP160ACBZ-2.8-R7, U2). By default, this regulator is disabled, meaning the camera module is not powered. The image sensor configuration over the SCCB interface and image acquisition using the PCIF interface must be done while this LDO regulator is enabled by setting the MAX78000 P0.2 pin to a high state. Refer to the MSDK toolchain examples for further information.

Table 1. Camera Module Connector (J2) Pinout

PIN	YXF08-77 MODULE NAME	GC0308 IMAGE SENSOR IC PIN NAME	PIN AND DESCRIPTION
1	N/C	N/A	Not connected
2	DGND	GND	Digital ground
3	SDA	SBDA	MAX78000 P0.31/I2C2_SDA SCCB SDA line requires a 4.7kΩ pull-up resistor to 2.8V for proper operation
4	NC	N/A	Not connected
5	SCL	SDCL	MAX78000 P0.30/I2C2_SCL SCCB SCL line requires a 4.7 kΩ pull-up resistor to 2.8V for proper operation
6	RESET	RESETB	MAX78000 P0.4 Chip reset control; active low
7	VSYNC	VSYNC	PCIF_VSYNC Vertical (frame) synchronization output.
8	PWDN	PWDN	MAX78000 P0.3 Sensor power down control; active high
9	HREF	HSYNC	PCIF_HSYNC Horizontal (line) synchronization output
10	NC	N/A	Not connected
11	DOVDD	DVDD28	2V8_CAM Main power supply pin

PIN	YXF08-77 MODULE NAME	GC0308 IMAGE SENSOR IC PIN NAME	PIN AND DESCRIPTION
12	D7	D<7>	PCIF_IO7 PCIF parallel data bit 7 (MSB)
13	MCLK	INCLK	PCIF_MCLK Main clock
14	D6	D<6>	PCIF_IO6 PCIF parallel data bit 6
15	DGND	GND	GND Digital ground
16	D5	D<5>	PCIF_IO5 PCIF parallel data bit 5
17	PCLK	PCLK	PCIF_PCLK Pixel clock output
18	D4	D<4>	PCIF_IO4 PCIF parallel data bit 4
19	D0	D<0>	PCIF_IO0 PCIF parallel data bit 0 (LSB)
20	D3	D<3>	PCIF_IO3 PCIF parallel data bit 3
21	D1	D<1>	PCIF_IO1 PCIF parallel data bit 1
22	D2	D<2>	PCIF_IO2 PCIF parallel data bit 2
23	NC	N/A	Not connected
24	NC	N/A	Not connected

Power and Interface Connector

The JST SH 4-pin connector (J1) provides connections for powering the board through a 3.3V power source and offers an interface to interact with external sensors or host boards, or to control actuators such as motors, as shown in *Table 2*.

Table 2. JST SH 4-Pin Connector (J1) Pinout

PIN	NAME	DESCRIPTION
1	GND	Ground
2	3V3	3.3V DC power supply unit
3	I2C1 SDA/LPUART Rx	I²C SDA (controller or target) (MAX78000 P0.17) or LPUART Rx (MAX78000 P2.6)
4	12C1 SCL/LPUART Tx	I²C SCL (controller or target) (MAX78000 P0.16) or LPUART Tx (MAX78000 P2.7)

Pin 3 and pin 4 of the connector are connected to the MAX78000 P0.17/I2C1_SDA signal and the MAX78000 P0.18/I2C1_SCL pins, respectively. These pins can be used as GPIO inputs to detect actions such as trigger signals and button presses, or they can be programmed as GPIO outputs to trigger external devices.

Pin 3 and pin 4 are also connected to the MAX78000 P2.6 and the MAX78000 P2.7 pins, respectively, through two 0Ω resistors (R4 and R5). This configuration allows users to utilize the LPUART peripheral of the MAX78000. These signals are shared with the MAX78000 P0.17/I2C1_SDA and MAX78000 P0.18/I2C1_SCL pins. Therefore, when using the MAX78000 P2.6 and MAX78000 P2.7 pins, the other pair of pins (MAX78000 P0.17/I2C1_SDA and MAX78000 P0.18/I2C1_SCL) must be configured as high-impedance inputs, and vice versa. The MAX78000CAM02 board main power input is available on the JST SH 4-pin connector.

When configured as I²C, these pins use the I2C1 peripheral of the MAX78000. This configuration supports both I²C target and I²C controller modes. MSDK examples for the MAX78000 include demonstrations of utilizing the I²C peripheral in both controller and target configurations.

The I2C signal lines do not include on-board pull-up resistors. External hardware should include I2C pull-up resistors configured to either 1.8V or 3.3V as needed.

Serial Wire Debug (SWD) Connector

The MAX78000 microcontroller on the MAX78000CAM02 board can be flashed using the SWD interface accessible by connecting to the SWD 10-pin header (J5). This interface also allows debugging using the MSDK toolchain. The MAX32625PICO DAPLink adapter included with the MAX78000CAM02 kit can be used as a debug adapter. Refer to the MSDK documentation for detailed information on debugging, programming tools, and IDE integration.

Access to the RISC-V coprocessor through a JTAG interface is not available on the MAX78000CAM02. This feature is available on the MAX78000EVKIT and MAX78000FTHR platforms.

The SWD interface connection between the MAX32625PICO DAPLink adapter and the MAX78000CAM02 board is established using a 10-pin ribbon cable. This cable features 1.27mm, 2x5 pin female connectors at both ends. When connecting the debug connector, ensure that pin 1 on the cable matches pin 1 on the male header connectors on both boards. Otherwise, the debug tool cannot establish a connection with the MAX78000. See *Figure 9* for proper connection.

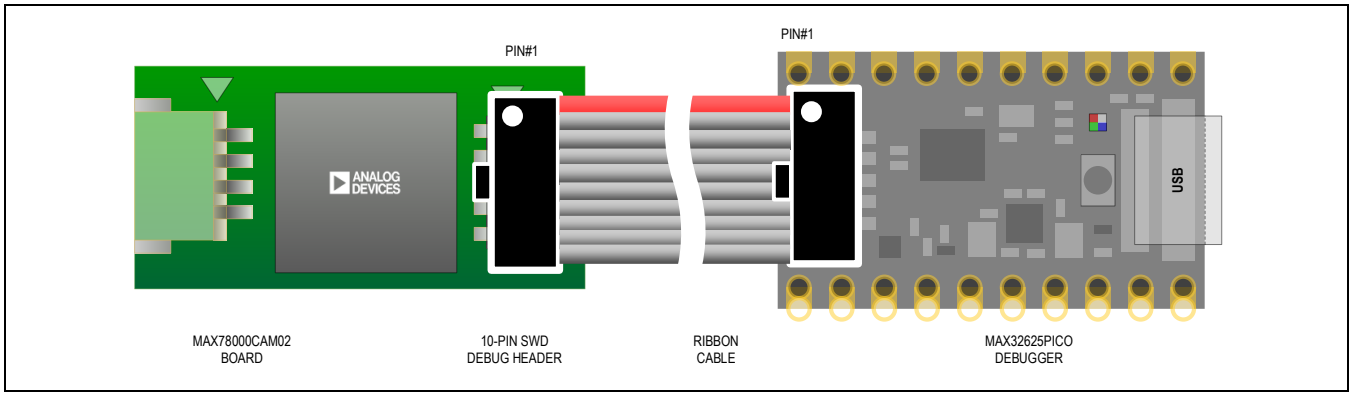


Figure 9. MAX78000CAM02 SWD Debugger Connection

In addition to the SWD connection, the SWD 10-pin header (J5) also provides access to the UART0 peripheral of the MAX78000. This UART interface can be used as a console interface during application development. The MAX32625PICO DAPLink firmware integrates a UART-to-USB bridge, allowing communication with the MAX78000CAM02 board without **requiring** additional USB to serial bridge hardware or cables, thus enabling debugging or programming through the MAX32625PICO board alone. When the MAX32625PICO is connected to a computer, it will enumerate as a COM port. Once enumerated, configure a terminal application to use the assigned COM port to access the UART0 peripheral of the MAX78000. The pinout for the debug connector and the UART0 peripheral is provided in *Table 3*.

Table 3. SWD 10-pin Header (J5) Pinout

PIN	NAME	DESCRIPTION
1	VCC	1.8V reference voltage. Do not apply power externally. If applied, it may damage the board.
2	SWDIO/TMS	SWD data I/O (MAX78000 P0.28)
3	GND	Ground
4	SWDCLK/TCK	SWD clock (MAX78000 P0.29)
5	GND	Ground
6	SWO/TDO	UART0 Tx (MAX78000 P0.1)
7	KEY	Not connected
8	NC/TDI	UART0 Rx (MAX78000 P0.0)

PIN	NAME	DESCRIPTION
9	GND_DETECT	Ground
10	NRESET	Active-low reset line; internally pulled-up to 3.3V

Note: The default I/O level is 1.8V for all I/Os that are accessible through the SWD 10-pin header (J5). If connecting an external USB-to-serial bridge other than the MAX32625PICO, ensure that the UART0 pins are configured correctly. Failure to do so can damage the MAX78000CAM02.

Indicator LEDs

The MAX78000CAM02 board has two programmable LEDs available for user applications. Both LEDs are right-angle SMD LEDs controlled using their respective GPIOs:

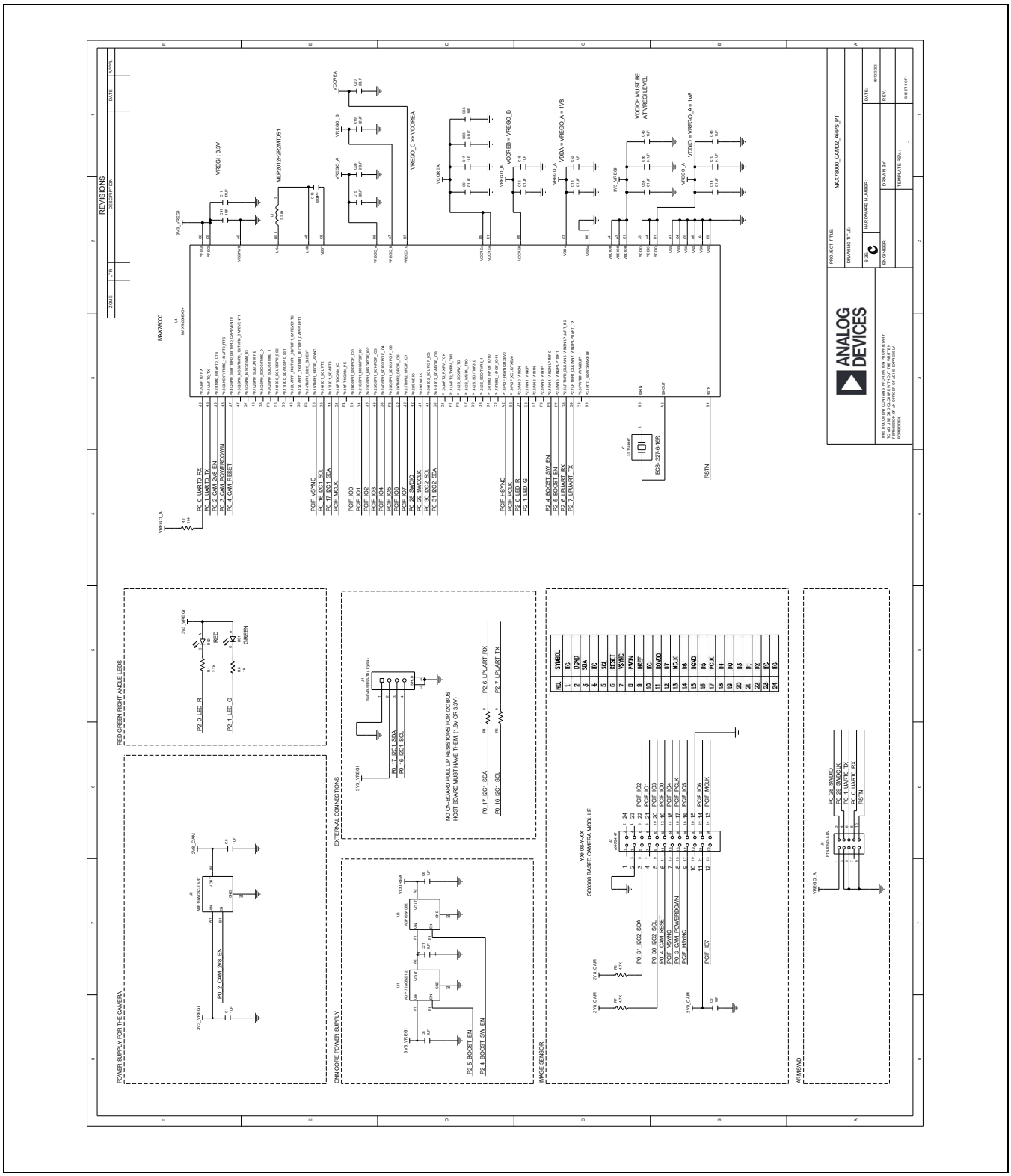
- MAX78000 P2.0 controls the RED LED.
- MAX78000 P1.1 controls the GREEN LED.

Since the GPIOs control the low side of the LEDs, the control logic is inverted. To turn on an LED, the corresponding GPIO port must be set to low. To turn off the LED, the respective GPIO port must be set to high. The LEDs are powered by the main 3.3V supply input of the board. The LED control GPIOs must be configured to use V_{DDIOH} as their I/O power supply rail.

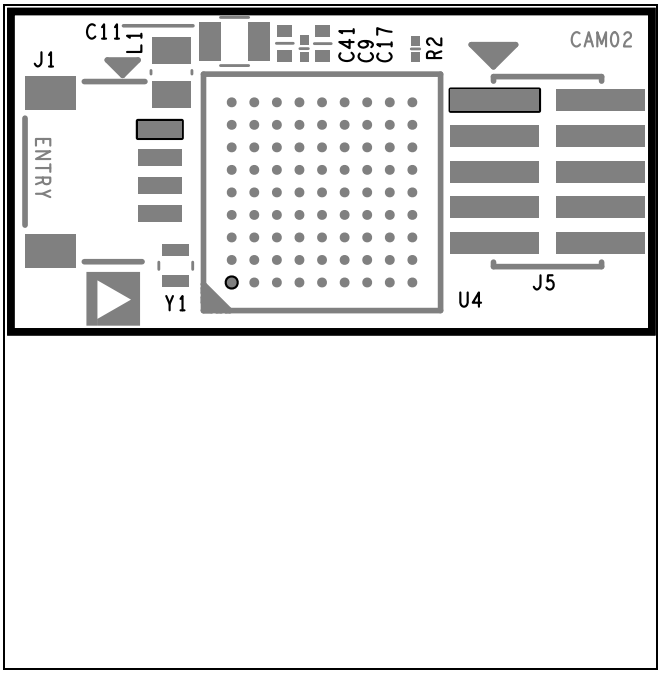
MAX78000CAM02 EV Kit Bill of Materials

ITEM	REF_DES	QTY	MFG PART#	MANUFACTURER	VALUE	DESCRIPTION
1	C1, C5	2	GRM033R61A105ME15	MURATA	1UF	CAP
2	C2	1	C1608X5R1E105M080AC	TDK	1UF	CAP
3	C6, C8, C21	3	CL03A105MO3NRN	SAMSUNG ELECTRONICS	1UF	CAP
4	C9, C10, C12-C14, C53, C54, C56	8	GRM033R61C104K	MURATA	0.1UF	CAP
5	C11	1	GRM21BR61A476ME15	MURATA	47UF	CAP
6	C15, C19, C20, C28	4	CL10A226MO7JZNC	SAMSUNG ELECTRONICS	22UF	CAP
7	C16	1	GRM155R71H332KA01	MURATA	3300PF	CAP
8	C17, C18, C41, C42, C45, C46, C55	7	C0402C105K8PAC	KEMET	1UF	CAP
9	DS1	1	APA2107CGCK	KINGBRIGHT	—	DIODE
10	DS2	1	APA2107SURCK	KINGBRIGHT	—	DIODE
11	J1	1	SM04B-SRSS-TB(LF)(SN)	JST MANUFACTURING	—	CONNECTOR
12	J2	1	AXK724147	PANASONIC	—	CONNECTOR
13	J5	1	FTS-105-01-L-DV	SAMTEC	—	CONNECTOR
14	L1	1	MLP2012H2R2MT0S1	TDK	2.2UH	INDUCTOR
15	R1	1	ERJ-1GEF2701	PANASONIC	2.7K	RES
16	R2	1	CRCW020110K0FK	VISHAY DALE	10K	RES
17	R3, R7	2	ERJ-1GNF4701	PANASONIC	4.7K	RES
18	R4, R5	2	ERJ-1GNF4701	VISHAY DALE	0	RES
19	R6	1	CRCW02011K00FK	VISHAY DALE	1K	RES
20	U1	1	ADP172ACBZ-1.2	ANALOG DEVICES	—	IC
21	U2	1	ADP160ACBZ-2.8-R7	ANALOG DEVICES	—	IC
22	U3	1	ADP195ACBZ	ANALOG DEVICES	—	IC
23	U4	1	MAX78000EXG+	ANALOG DEVICES	—	IC
24	Y1	1	ECS-.327-6-16R	ESC INC	32.768KHZ	CRYSTAL

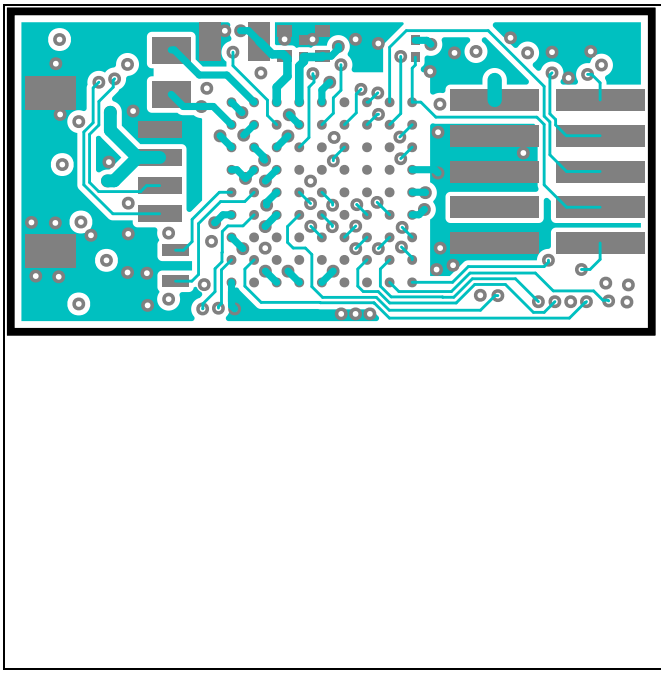
MAX78000CAM02 EV Kit Schematic



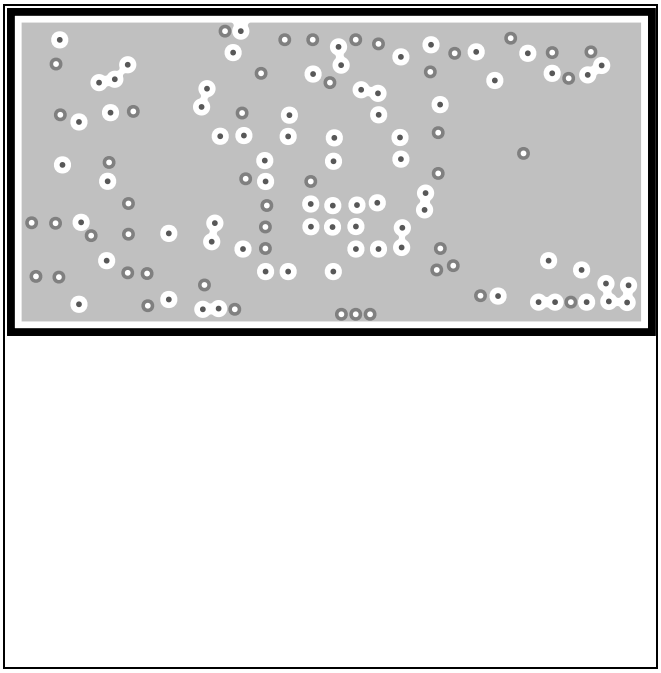
MAX78000CAM02 EV Kit PCB Layouts



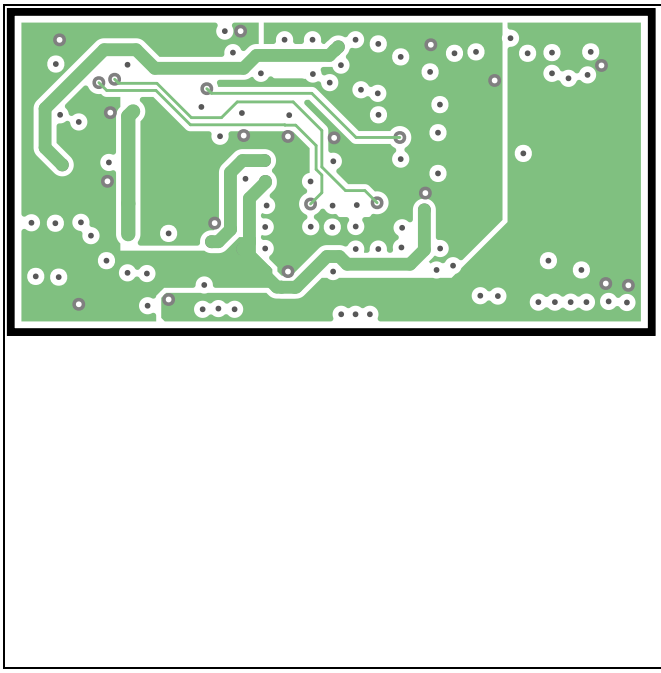
MAX78000CAM02 EV Kit PCB Layout—Top Silkscreen



MAX78000CAM02 EV Kit PCB Layout—Layer 1 (Top Layer)

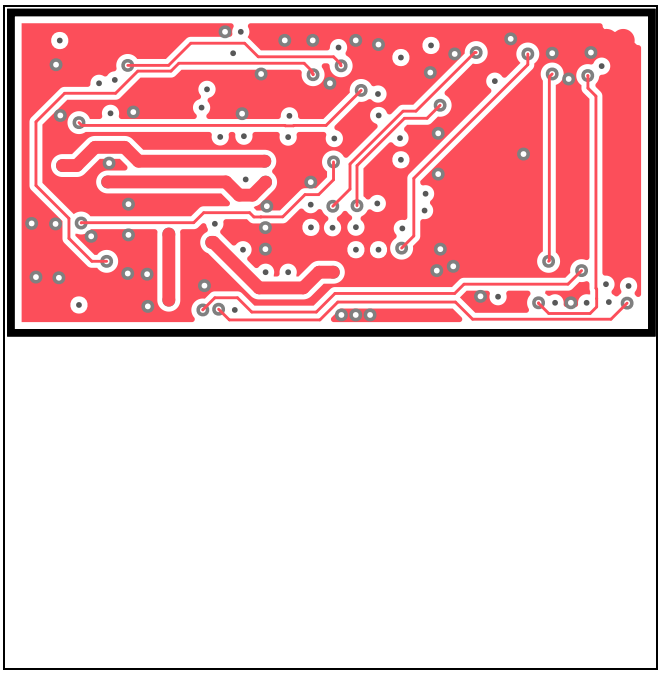


MAX78000CAM02 EV Kit PCB Layout—Layer 2 (Ground Layer)

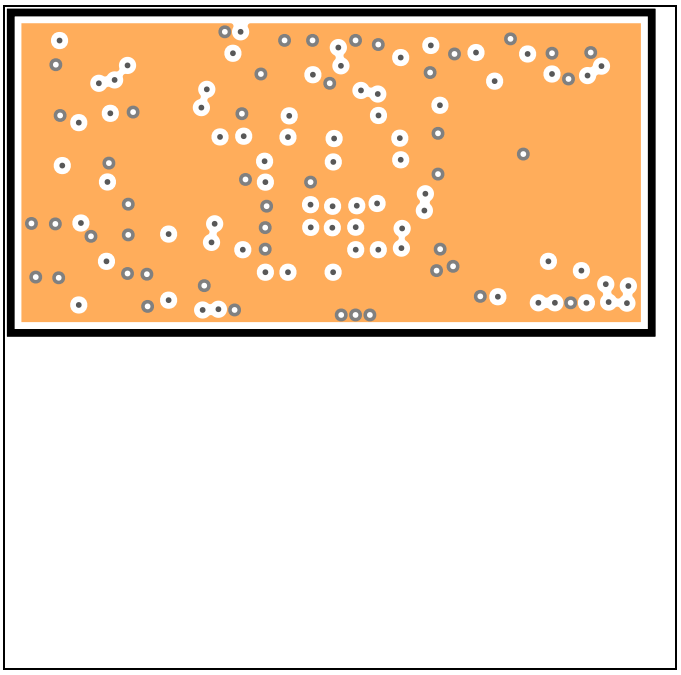


MAX78000CAM02 EV Kit PCB Layout—Layer 3

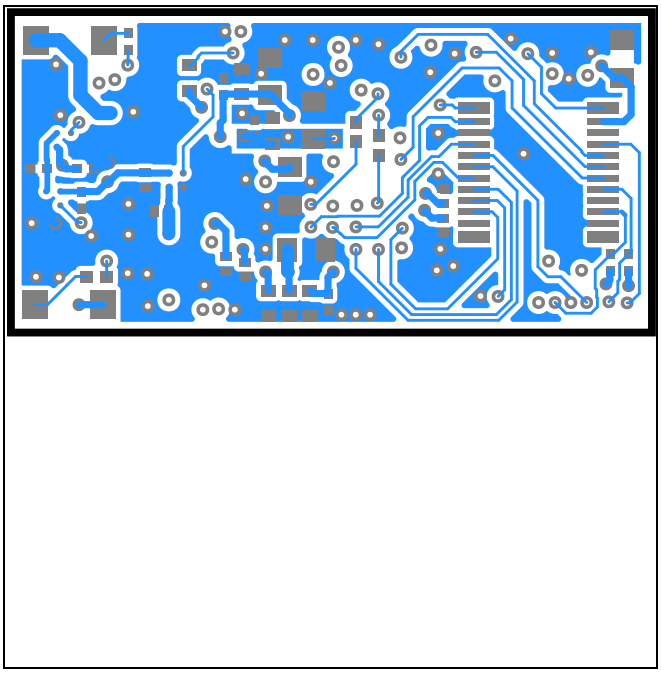
MAX78000CAM02 EV Kit PCB Layouts (continued)



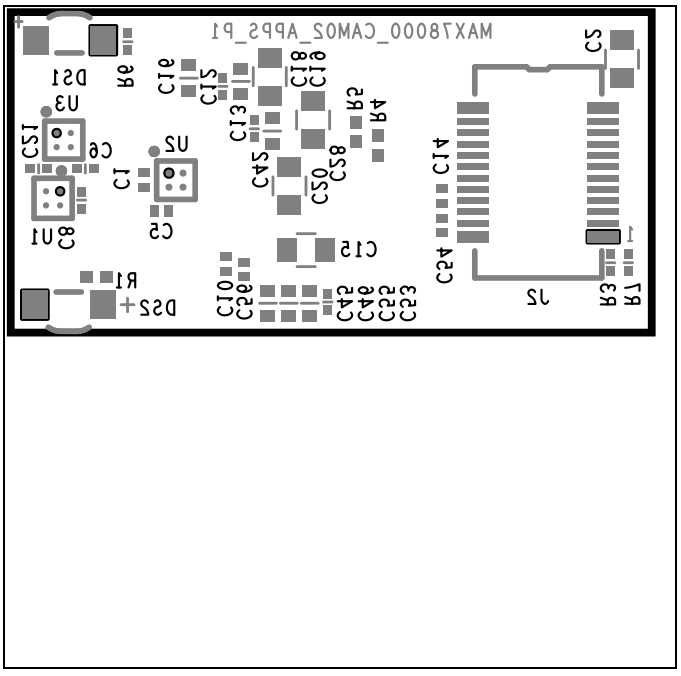
MAX78000CAM02 EV Kit PCB Layout—Layer 4



MAX78000CAM02 EV Kit PCB Layout—Layer 5 (Ground Layer)



MAX78000CAM02 EV Kit PCB Layout—Layer 6 (Bottom Layer)



MAX78000CAM02 EV Kit PCB Layout—Bottom Silkscreen

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	11/24	Initial release	—

Notes