MAX20459 Evaluation Kit

Evaluates: MAX20459

General Description

The MAX20459 evaluation kit (EV kit) demonstrates the MAX20459 automotive high-current, high-efficiency, step-down DC-DC converter with integrated USB Type-C DFP controller and host-charger-adapter emulation, which provides ESD and short-to-battery protection.

The MAX20459 features integrated host-charger port-detection circuitry adhering to the USB Type-C specification, the USB-IF BC1.2 battery charging specification, Apple iPod/iPhone/iPad® and Samsung® charge-detection termination resistors, and Chinese Telecommunication Industry Standard YD/T 1591-2009.

The MAX20459 step-down, synchronous, DC-DC converter operates from a voltage of up to 28V continuous and protects against load-dump transients up to 40V. The converter is programmable for frequencies from 275kHz to 2.2MHz and can deliver 3A continuously.

The MAX20459 integrates thermal management in a two-stage approach to limit maximum die temperature. In the first stage, the standalone variant reduces the Type-C handshake and DC current limit by one step when die temperature exceeds 130°C (typ). The second stage triggers DC-DC shutdown if the die temperature continues rising and exceeds 165°C (typ).

The EV kit is populated with a standalone enabled MAX20459ATJC/V+ that is configured by pull-down resistors. The I^2C variant (MAX20459ATJA/V+) allows for flexible configuration, detailed fault diagnostics, and access to the on-chip ADC that reports die temperature, output voltage, and output current. The I^2C features are easily accessed by using the Maxim MINIQUSB module along with the provided example GUI.

Features and Benefits

- Configurable Charge-Detection Modes
  - USB-C 3.0A, 1.5A, 0.5A
  - USB-IF BC1.2 DCP
  - Apple 2.4A, 1.0A
  - Samsung 2.0A
  - China YD/T 1591-2009 Charging Specification
- Automatic USB Voltage Adjustment by Integrated DC-DC Converter (275kHz - 2.2MHz)
- Proven PCB Layout
- Fully Assembled and Tested

Quick Start (Stand-Alone Variant)

The following procedure demonstrates the MAX20459's auto-DCP function in standalone mode.

Required Equipment

- MAX20459 EV kit
- USB Type-C to Type-C cable
- 14V/2A DC Power Supply or car battery (VBAT)
- USB-C amperage meter (Plugable USBC-VAMETER recommended)
- USB-C device (smartphone recommended)
- Two jumpers: V_{BAT}, GND

Initial Setup

The EV kit is fully assembled and tested. Follow the steps below to set up the board for evaluation.

1) Verify SW1 switch is set to HVEN = 1, ENBUCK = 1, SYNC = 0, DCP_MODE = 0.
2) Set the V_{BAT} power supply to 14V output, 2A current limit. Turn the output off. Connect the negative lead to the GND test loop on EVKIT. Connect positive lead to the VBAT_FLT test loop on EVKIT.
3) Turn the V_{BAT} power supply output on.
4) Plug the USB-C amperage meter into the EVKIT.
5) Plug the USB-C to USB-C cable into the USB-C amperage meter.
6) Plug the USB-C cable into a USB Type-C device that can charge (i.e. smartphone).
7) The no-load USB output voltage should be approximately 5.15V, and the USB device should begin charging.

***Ordering Information* appears at end of data sheet.**

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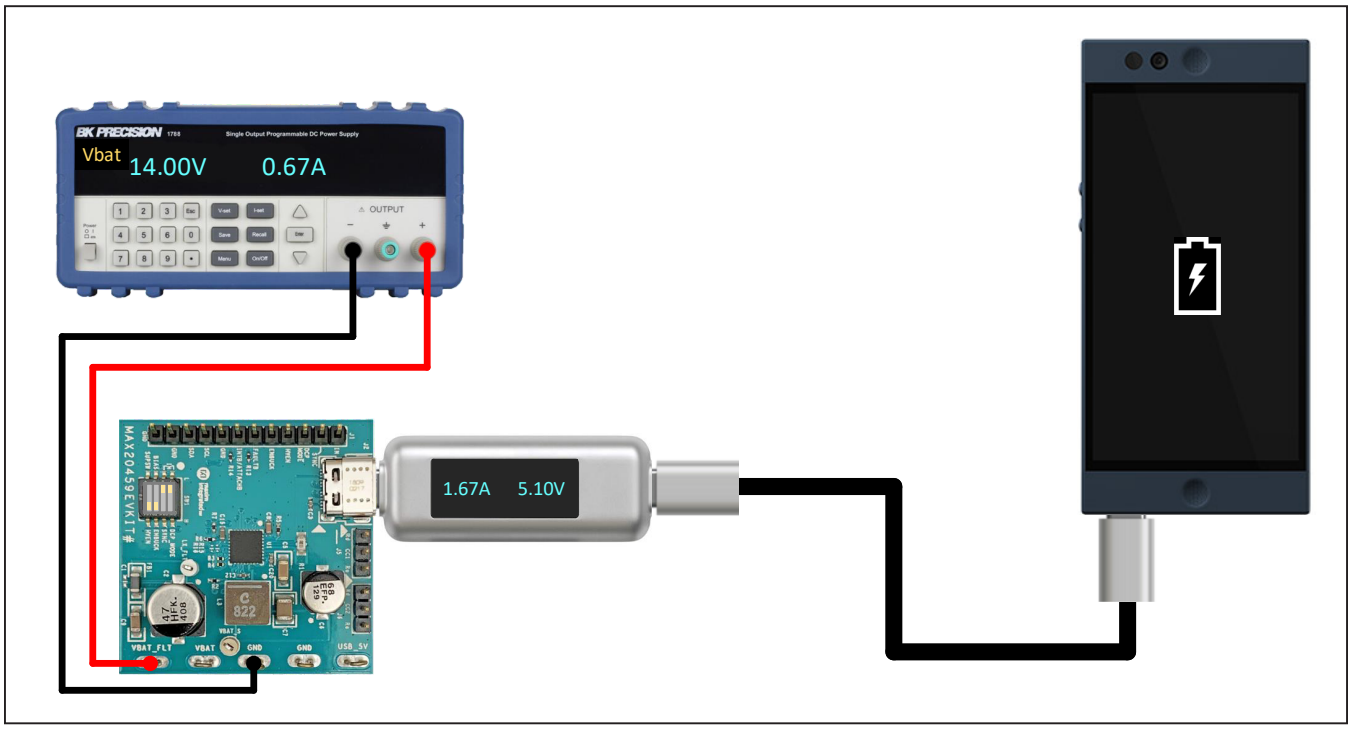


Figure 1. Standalone EV Kit Interface

USB Type-C & Legacy Apple/Samsung/USB DCP Charging

8) The amperage meter should display USB current as the device charges.
   a. Note that for most devices, maximum charging rate occurs between approximately 20-80% battery level.
9) For native USB Type-C devices, maximum charging current will follow the Type-C mode setting:
   a. 0.5A/1.5A/3.0A (see CONFIG2 and CONFIG3 Pin Table (Standalone Variant) in the MAX20459 data sheet)
10) For non-native USB Type-C devices (Apple 30-pin/ lightning and USB mini/micro-b):
   a. Apple devices will consume up to 1A or 2.4A, depending on the DCP_MODE pin (see Table 3).
   b. BC 1.2-compatible or Samsung devices will consume up to 1.5A or 2A, respectively, regardless of DCP_MODE pin state.
11) Note that some USB devices are compatible with multiple handshakes and may prefer one over the other, depending on many factors. The USB charging behavior can also depend on the version of software installed on the user's device, which may change over time.

Quick Start (I²C variant)

The following procedure demonstrates the MAX20459's auto-DCP mode and I²C interface.

Required Equipment

- MAX20459 EV kit
- USB Type-C to Type-C cable
- 14V/2A DC power supply or car battery (V_{BAT})
- MINIQUSB and MAX20459 GUI
- USB-C device (smartphone recommended)
- Two jumpers: V_{BAT}, GND
- 3 DuPont jumper wires female-female: GND, SDA, SCL

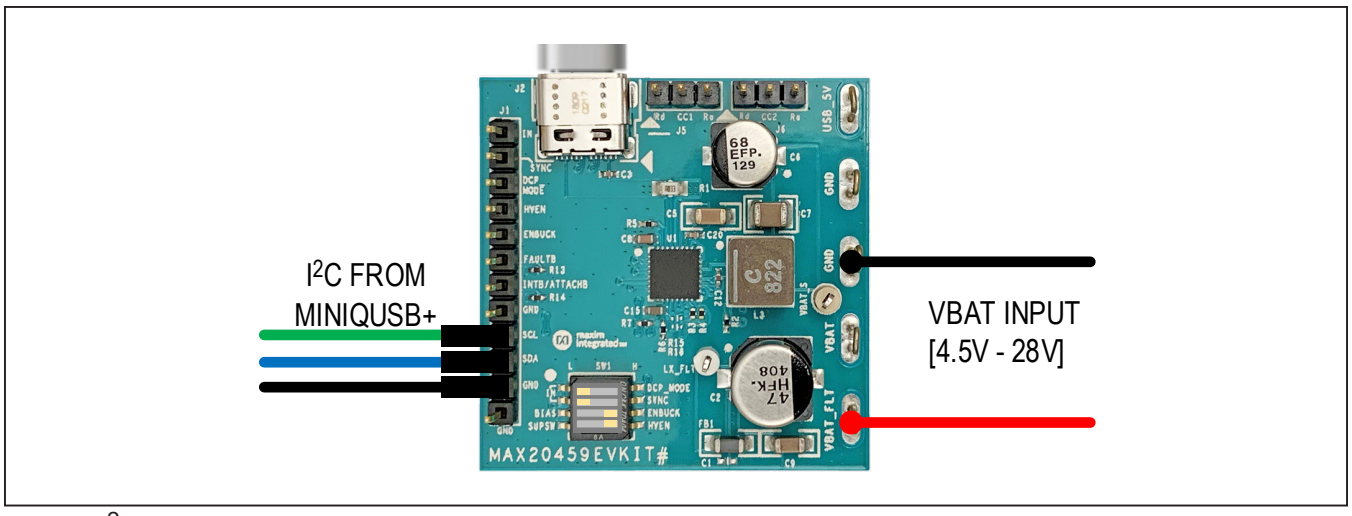


Figure 2. I2C EV Kit Interface

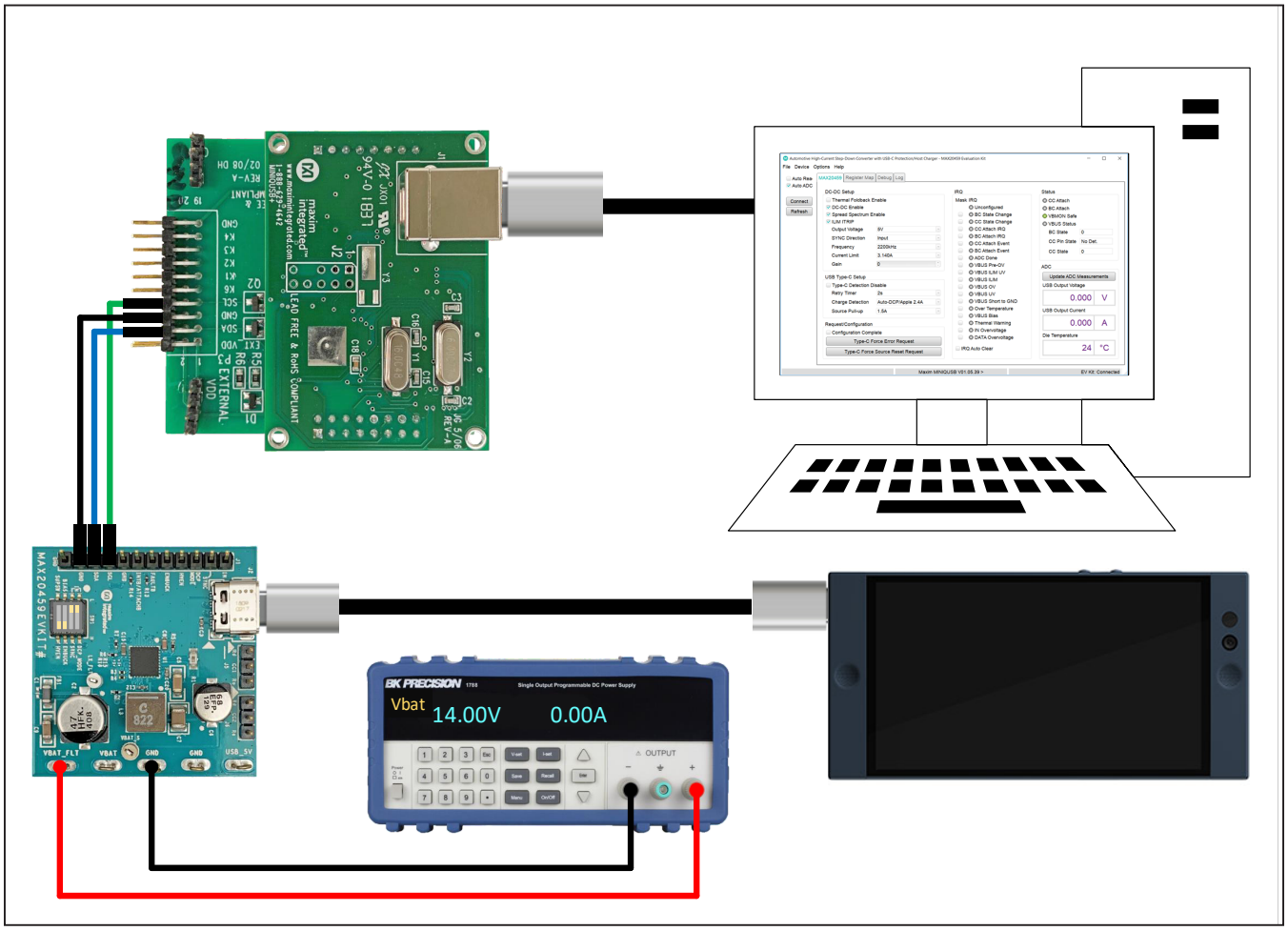


Figure 3. I2C EV Kit Setup

Initial Setup

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.

The EV kit is fully assembled and tested. Follow the steps below to set up the board for evaluation.

1) MAX20459 GUI is installed on a PC.
2) Verify the EV kit has ATJA variant of MAX20459 for I²C, and R3/R4 are removed per Table 1.
3) Verify SW1 switch is set to HVEN = ON, ENBUCK = ON, SYNC = OFF, DCP_MODE = OFF.
4) Using the jumper wires, connect the MINIQUSB to the EV kit as follows:
   - SCL to SCL
   - SDA to SDA
   - GND to GND
5) Connect the MINIQUSB to the computer and install driver if necessary.
6) Verify the MINIQUSB is recognized in the **Windows Device Manager** as **USB Serial Converter**.

7) Set the V_{BAT} power supply to 14V output, 2A current limit. Turn the output off. Connect the negative lead to the GND test loop on the EV kit. Connect the positive lead to VBAT_FLT test loop on the EV kit.
8) Turn the V_{BAT} power supply output on.
9) Plug the USB-C to USB-C cable into the EV kit.
10) Plug the USB-C cable into a USB type-C device that can charge (i.e. smartphone).

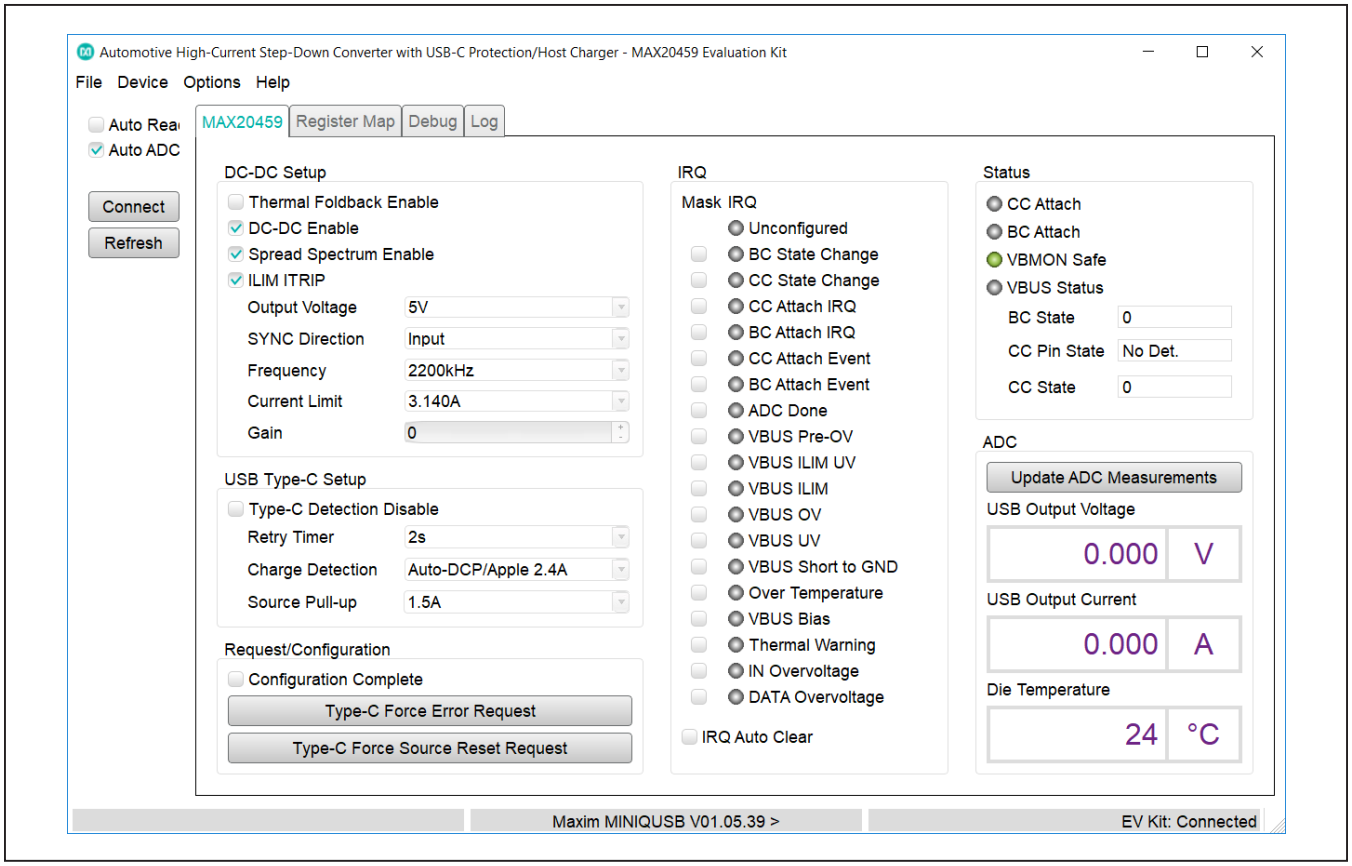


Figure 4. MAX20459 GUI Startup

11) Start the MAX20459 GUI. Look at the message bar at the bottom of the GUI to verify that both the MINIQUSB and the EV kit are detected. The GUI should look like Figure 4 upon start-up.

Click **Auto Read**, click **Thermal Foldback Enable**, change **Frequency** to 488kHz, set **Gain** to 6, set **Source Pull-up** to 3A, then click **Configuration Complete**.

Note: Every time the MAX20459 is polled by the GUI (either by the refresh button or by selecting **Auto Read**) the SENSN output voltage, USB output current, and die temperature will continuously update in the corresponding windows of the GUI. See the ADC Timing Diagram in the MAX20459 IC datasheet for the ADC polling procedure.

12) The USB output voltage should display approximately 5.15V and the USB device should begin charging.

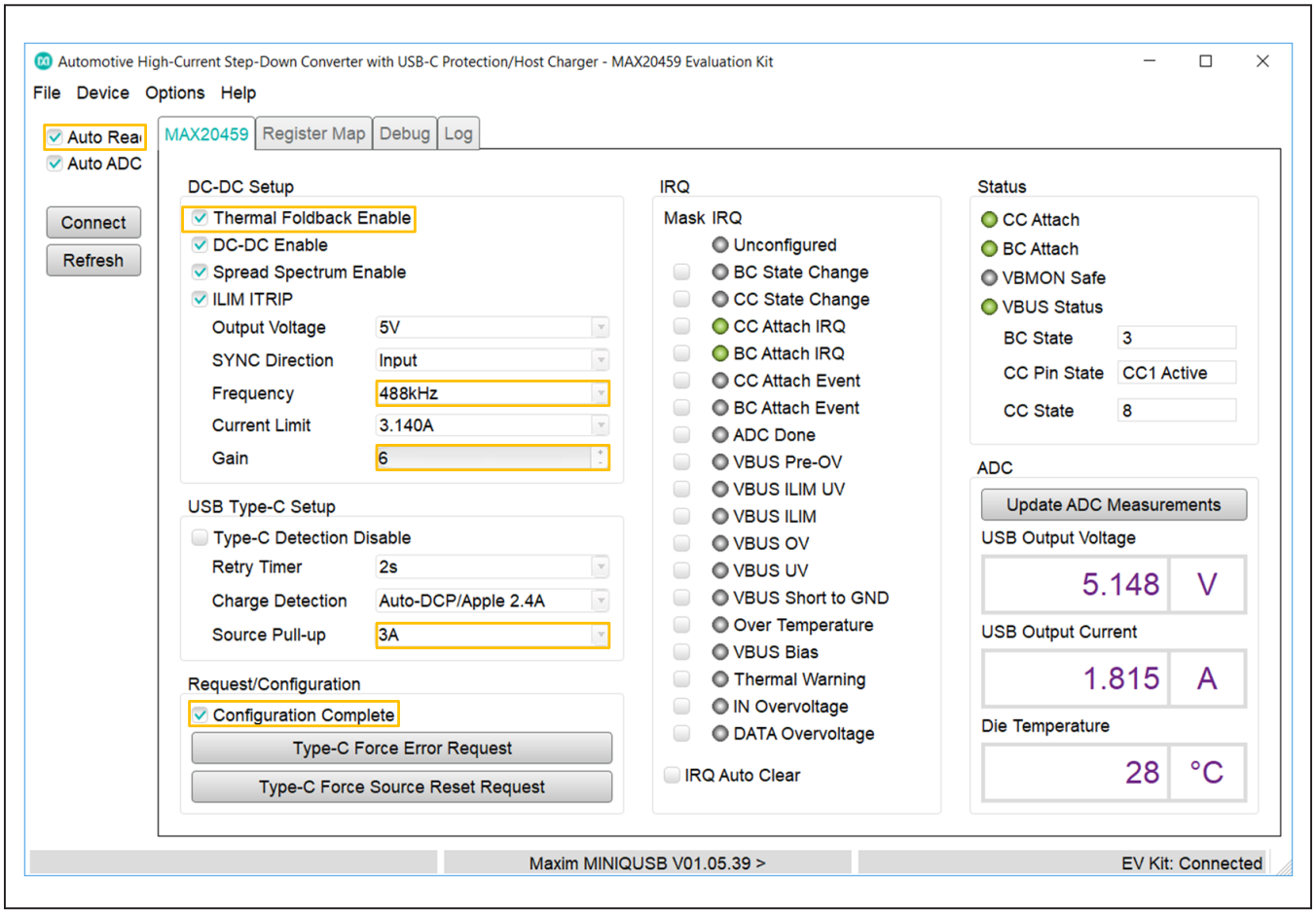


Figure 5. MAX20459 GUI Configured

USB Type-C & Legacy Apple/Samsung/USB DCP Charging

13) The GUI should display USB current as the device charges.
    a. Note that for most devices, maximum charging rate occurs between approx. 20-80% battery level.
14) For native USB type-C devices, maximum charging current will follow the **Source Pull-up** setting:
    a. 0.5A/1.5A/3.0A, see Figure 3.
15) For non-native USB Type-C devices (Apple 30-pin/ lightning and USB mini/micro-b):
    a. Apple devices will consume up to 1A or 2.4A, depending on the DCP_MODE pin (see Table 3).
    b. BC 1.2-compatible or Samsung devices will consume up to 1.5A or 2A, respectively, regardless of DCP_MODE pin state.
16) Note that some USB devices are compatible with multiple handshakes and may prefer one over the other, depending on many factors. The USB charging behavior can also depend on the version of software installed on the user's device, which may change over time.

Detailed Description

The MAX20459 EV kit comes fully assembled, tested, and installed with MAX20459ATJC/V+ for standalone operation. The I²C variant can also be used on this EV kit by changing the IC and configuration resistors (R3, R4). See table below for an example of I²C configuration. Refer to MAX20459 for further details on configuration resistors.

EV Kit Interface

The header J1 includes input and output test points for controlling the IC and evaluating its functionality. Table 2 lists the individual pins and their functions.

Table 1. I²C Configuration Example

PIN NAME	RESISTOR	VALUE	DESCRIPTION
CONFIG3	R3	Open	I²C SCL *Note: R15 can be installed if SCL pullup is needed.* *R15 not required for use with MINIQUSB.*
CONFIG2	R4	Open	I²C SDA *Note: R16 can be installed if SDA pullup is needed.* *R16 not required for use with MINIQUSB.*

Table 2. External Header

J1 PIN	NAME	DESCRIPTION
1	IN	3.3V supply for IN (input/output)
2	SYNC	Buck regulator synchronization pin (input/output)
3	DCP_MODE	Charge detection configuration pin (input)
4	HVEN	IC enable (active-high, input)
5	ENBUCK	DC-DC enable (active-high, input)
6	$\overline{\text{FAULT}}$	$\overline{\text{FAULT}}$ indicator (active low, open-drain, output)
7	$\overline{\text{INT}}$ ($\overline{\text{ATTACH}}$)	I²C: interrupt (active-low, open-drain, output) Standalone: Attach output (active-low, open-drain, output)
8	GND	EV kit ground
9	SCL (CONFIG3)	I²C: clock (input) Standalone: CONFIG3 (input)
10	SDA (CONFIG2)	I²C: data (input/output) Standalone: CONFIG2 (input)
11	GND	EV kit ground
12	GND	EV kit ground

The switch SW1 allows the user to set the voltage on the HVEN, ENBUCK, SYNC, and DCP_MODE pins. Setting a switch to the ON position ties the connected pin high, and setting a switch to the OFF position ties the pin to ground through a 100kΩ pulldown resistor. To externally control these pins through the header J1, set all switches to the OFF position. This leaves the pin connected to the header with a pulldown resistor. Table 2 describes the header and its pinout.

Basic Functionality

Connect a battery voltage supply between VBAT_FLT and GND test loops. Setting the HVEN switch to ON pulls the HVEN pin to V_{BAT} and enables the device. The ENBUCK pin must also be high for the DC-DC converter to turn on. The charge mode can be configured through I^2C or using the DCP_MODE switch or pin. If the DCP_MODE pin is high, it will override the current I^2C register setting.

Table 3. External Switch

SW1 PIN	POSITION	DESCRIPTION
HVEN	0	Device disabled
	1	Device enabled
ENBUCK	0	Buck output disabled
	1	Buck output enabled
SYNC	0	SYNC configured as an input: In Type-C mode (CC_ENB = 0): with no CC attach, DC-DC is OFF. With CC attach, DC-DC is ON (FPWM). In Type-A mode (CC_ENB = 1): DC-DC is always ON, skip mode in light/no-load is allowed, FPWM otherwise (V_{BUS} always on). See the MAX20459 data sheet for more information. SYNC configured as an output: In Type-C mode (CC_ENB = 0): with no CC attach, DC-DC is OFF. With CC attach, DC-DC is ON (FPWM). In Type-A mode (CC_ENB = 1): DC-DC is always ON (FPWM). SYNC pin generates clock output for synchronization of other devices. If enabled, spread spectrum is also present on SYNC output to reduce EMI of the device synchronized to MAX20459.
	0 with clock applied to SYNC via J1	SYNC configured as an input: In Type-C mode (CC_ENB = 0): With no CC attach, DC-DC is OFF. With CC attach, DC-DC is ON (FPWM). In Type-A mode (CC_ENB = 1): DC-DC is always ON (FPWM). MAX20459 can be synchronized to an external clock—for example, another MAX20459. Spread spectrum is not applied to external clock from SYNC pin.
	1	SYNC configured as an input: In Type-C mode (CC_ENB = 0): with no CC attach, DC-DC is OFF. With CC attach, DC-DC is ON (FPWM). In Type-A mode (CC_ENB = 1): DC-DC is always ON (FPWM). See the MAX20459 data sheet for more information.
DCP_MODE	0	Preload CD[1:0] = b10 (Auto-DCP/Apple 2.4A mode)
	1	Override CD[1:0] = b11 (Auto-DCP/Apple 1A mode)

Type-C Functionality

The headers J5 and J6 provide CC1 and CC2 pulldown resistors (Ra and Rd) used for Type-C device/charger detection. These resistors are included for validation purposes; they would typically come from a connected Type-C device or Type-C to Type-A legacy adapter. With Type-C enabled (default), the buck converter will not turn on until Rd is detected on either CC1 or CC2.

Fault Diagnostics

The $\overline{FAULT}$ pin is designed to be software compatible with Maxim Type-A Automotive USB solutions. More advanced diagnostics can be done using the I^2C bus and the $\overline{INT}$ pin. The IRQ bits have an associated IRQ_MASK bit. When the IRQ_MASK bit is set to 1, the $\overline{INT}$ pin will assert and de-assert following the IRQ bit. All IRQ bits will clear on read. IRQ bit de-assertion is controlled by the IRQ_AUTOCLR bit. When IRQ_AUTOCLR = 0 (default), the error bit will stay asserted until the register is read, even if the fault condition is no longer present. When IRQ_AUTOCLR = 1, the IRQ bit will de-assert without a read as soon as the fault criteria are no longer met.

The EV kit GUI does not connect to the $\overline{FAULT}$ or $\overline{INT}$ pins. It uses a polling mechanism to read all MAX20459 registers. A read is initiated when the refresh button is clicked, or periodically if auto read is enabled. Because of the polling mechanism, when IRQ_AUTOCLR = 1, it is possible that IRQ bit assertions will not be detected by the GUI because of quick de-assertions after a fault.

Table 4. J5 Jumper Positions

JUMPER POSITION	DESCRIPTION
1-2	CC1 pulled to ground through a 5.1kΩ resistor (Rd)
2-3	CC1 pulled to ground through a 1.2kΩ resistor (Ra)

Table 5. J6 Jumper Positions

JUMPER POSITION	DESCRIPTION
1-2	CC2 pulled to ground through a 5.1kΩ resistor (Rd)
2-3	CC2 pulled to ground through a 1.2kΩ resistor (Ra)

Ordering Information

PART	TYPE
MAX20459EVKIT#	EV Kit

 # Denotes RoHS-compliant.

IC Efficiency Measurement

The MAX20459 EV kit provides the ability to measure the efficiency of the MAX20459 buck converter itself. This method decouples the losses resulting from the output inductor, output capacitor, and PCB traces, and is accomplished by utilizing two test points: VBAT_S and LX_FLT. By measuring the DC voltages at these test points, the input current and output (load) current, IC efficiency can be calculated as follows:

$$\eta_{IC} = (V_{LX\_FLT} \times I_{OUT}) / (V_{BAT\_S} \times I_{IN})$$

PCB Layout Guidelines

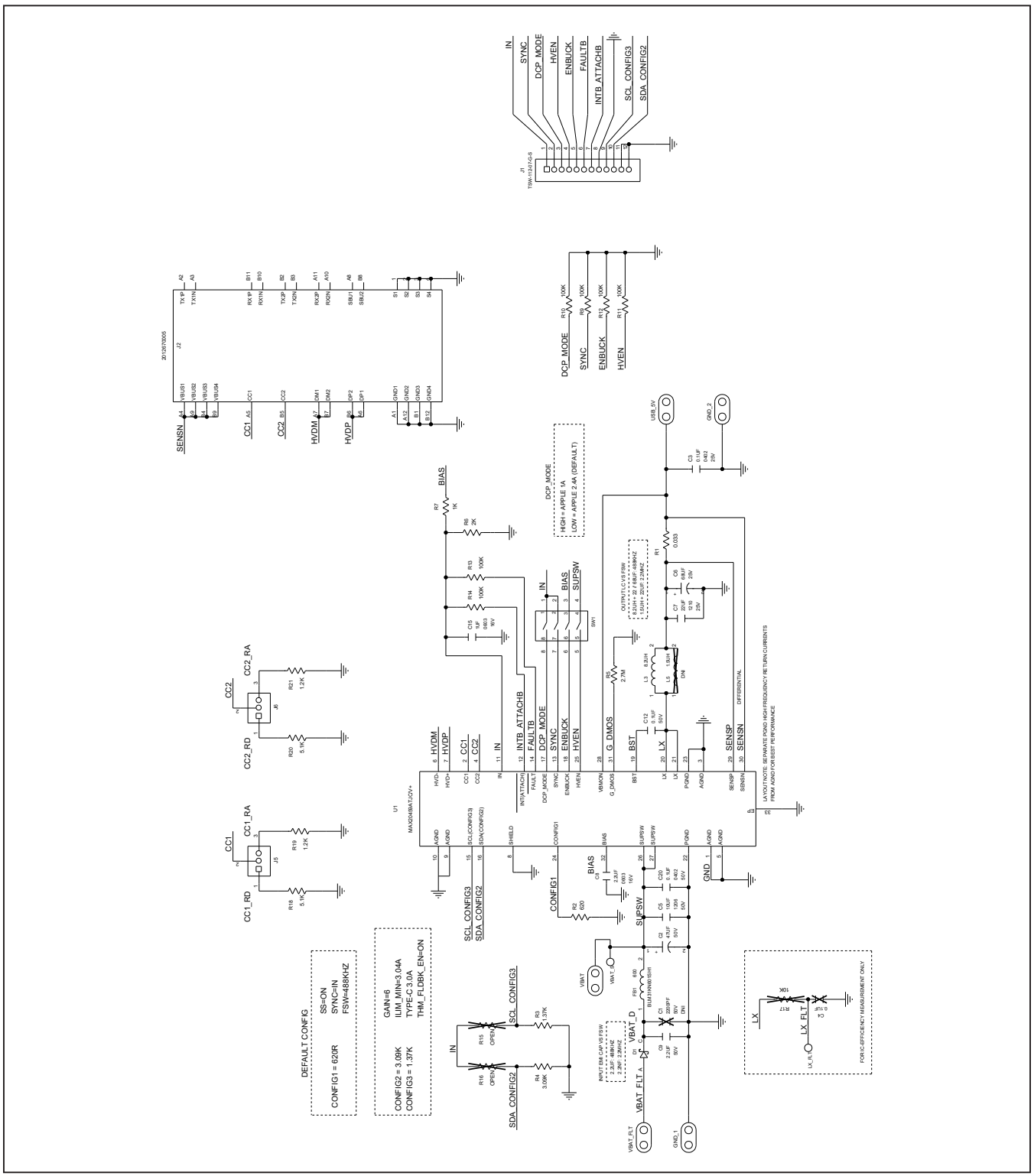
A good PCB layout is critical to proper system performance. The loop area of the DC/DC conversion circuitry must be minimized as much as possible. Place the input capacitor, power inductor, and output capacitor very close to the IC. Shorter traces should be prioritized over wider traces.

A low-impedance ground connection between the input and output capacitors is necessary (route through the ground pour on the exposed pad). Connect the exposed pad to ground. Place multiple vias in the pad to connect to all other ground layers for proper heat dissipation. (Failure to do this may result in the IC repeatedly reaching thermal shutdown.) Use a single common ground with GND vias directly adjacent to all components that via down to an adjacent ground plane. High-frequency return currents will flow directly under their corresponding traces.

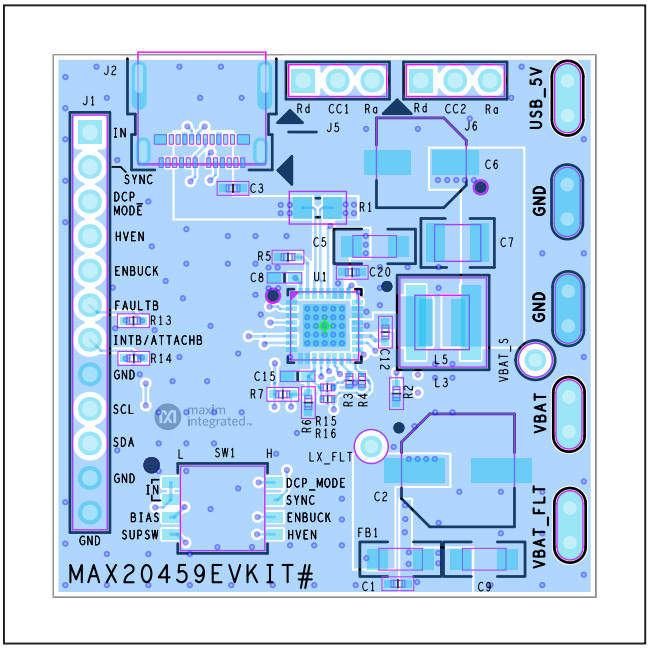
MAX20459 EV Kit Bill of Materials

QTY	REFERENCE	DESCRIPTION	MANUFACTURER	PART NUMBER
1	C1	DNP		
1	C2	ALUMINUM-ELECTROLYTIC CAPACITOR 47UF 50V 20% -55C TO 105C	PANASONIC	EEE-FK1H470P
1	C3	CERAMIC CAPACITOR (0402) 0.1uF 25V 10% X7R	TDK	CGJ2B3X7R1E104K050BB
1	C4	DNP		
2	C12, C20	CERAMIC CAPACITOR (0402) 0.1uF 50V 10% X7R	TDK	CGA2B3X7R1H104K050BE
1	C5	CERAMIC CAPACITOR (1206) 10UF 50V 10% X7R	TDK	CGA5L1X7R1H106K160AC
1	C6	ALUMINUM-ELECTROLYTIC CAPACITOR 68UF 25V 20% -55C TO 105C	PANASONIC	EEE-FP1E680AP
1	C7	CERAMIC CAPACITOR (1210) 22UF 25V 10% X7R	MURATA	GRM32ER71E226KE15
1	C8	CERAMIC CAPACITOR (0603) 2.2uF 16V 10% X7R	MURATA	GRM188Z71C225KE43
1	C9	CERAMIC CAPACITOR (1206) 2.2UF 50V 10% X7R	TAIYO YUDEN	UMK316B7225K
1	C15	CERAMIC CAPACITOR (0603) 1uF 16V 10% X7R	TDK	CGA3E1X7R1C105K080AC
1	D1	SCHOTTKY BARRIER DIODE (SMB) 60V 3A -55C TO 125C	DIODES INCORPORATED	B360B-13-F
1	FB1	FERRITE-BEAD (1206) 600R 25% 2.9A	MURATA	BLM31KN601SH1
5	GND_1, GND_2, USB_5V, VBAT, VBAT_FLT	TEST POINT	KEYSTONE	5020
1	J1	HEADER 12-PINS	SAMTEC	TSW-112-07-G-S
1	J2	USB TYPE-C RECEPTACLE	MOLEX	2012670005
2	J5, J6	HEADER 3-PINS	TE CONNECTIVITY	5-146280-3
1	L3	INDUCTOR 8.2UH 20% 9.4A	COILCRAFT	XEL6060-822ME
1	L5	DNP		
2	LX_FLT, VBAT_S	WHITE TEST POINT	KEYSTONE	5002
1	R1	RESISTOR (0805) 0.033R 1% +/-50PPM/C 0.5W	SUSUMU CO LTD.	KRL1220E-M-R033-F
1	R2	RESISTOR (0402) 620R 1% 0.063W	VISHAY DALE	CRCW0402620RFK
1	R3	RESISTOR (0402) 1.37K 1% 0.063W	VISHAY DALE	CRCW04021K37FK
1	R4	RESISTOR (0402) 3.09K 1% 0.063W	PANASONIC	ERJ-2RKF309
1	R5	RESISTOR (0402) 2.7M 1% 0.063W	VISHAY DALE	CRCW04022M70FK
1	R6	RESISTOR (0402) 2K 1% 0.063W	PANASONIC	ERA-2AEB202
1	R7	RESISTOR (0402) 1K 1% 0.063W	VISHAY DALE	CRCW04021K00FK
6	R9-R14	RESISTOR (0402) 100K 5% 0.063W	VISHAY DALE	CRCW0402100KJN
3	R15-R17	DNP		
2	R18, R20	RESISTOR (0402) 5.1K 1% 0.063W	VISHAY DALE	CRCW04025K10FK
2	R19, R21	RESISTOR (0402) 1.2K 1% 0.063W	VISHAY DALE	CRCW04021K20FK
2	SHUNT_J5, SHUNT_J6	JUMPER 0.100" 2PINS	SULLINS ELECTRONICS CORP.	QPC02SXGN-RC
1	SW1	QUAD SPST HALF-PITCH DIP SWITCH	C&K COMPONENTS	TDA04H0SB1
1	U1	MAX20459ATJC/V+	MAXIM	MAX20459ATJC/V+
1	PCB	MAX20459 revA	MAXIM	MAX20459
1	PACK-OUT	USB to I2C Interface	MAXIM	MINIQUSB+
1	PACK-OUT	Jumper Wires F-F 15cm 10PK	MikroElektronika	MIKROE-511

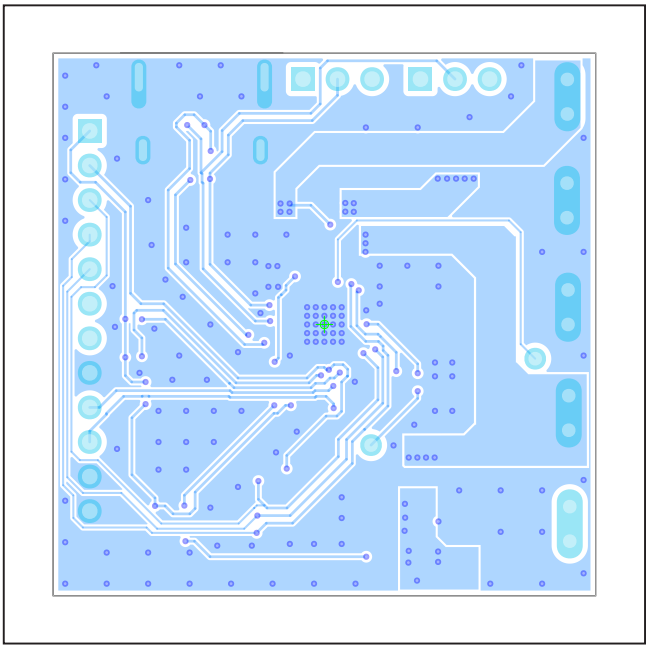
MAX20459 EV Kit Schematic



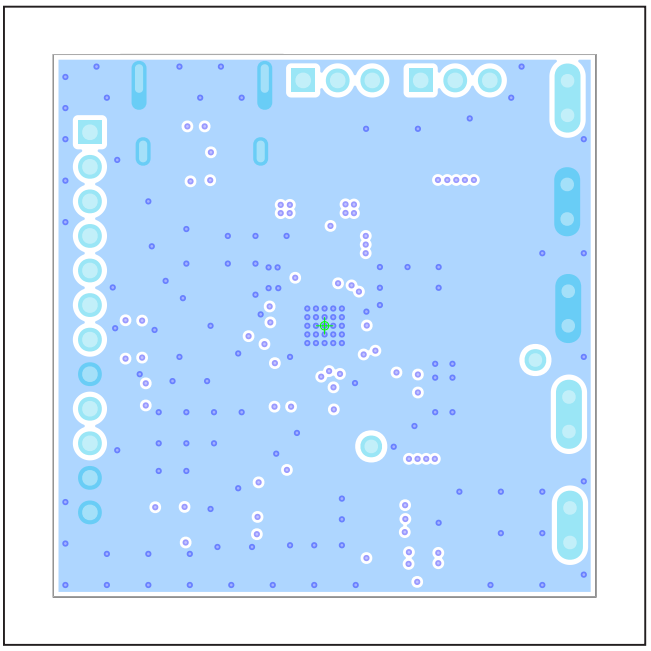
MAX20459 EV Kit Layout



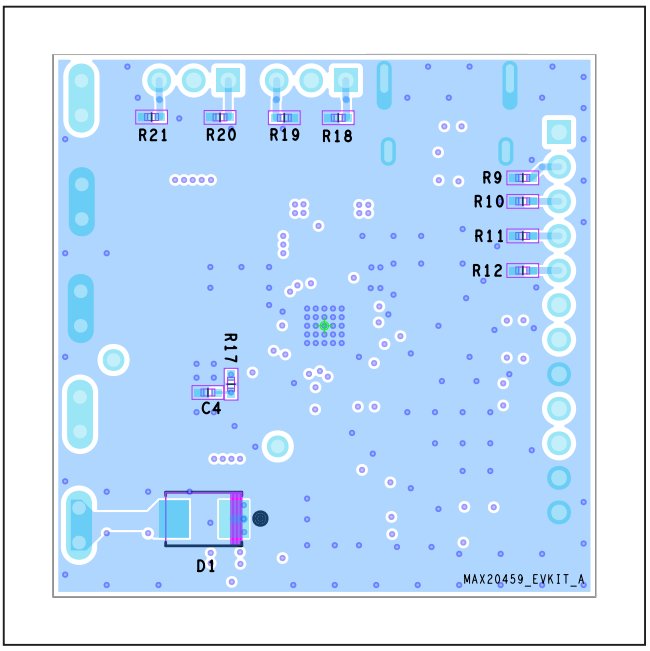
MAX20459 EV Kit PCB Layout - Top View



MAX20459 EV Kit PCB Layout - Layer 3



MAX20459 EV Kit PCB Layout - Layer 2



MAX20459 EV Kit PCB Layout - Bottom View

Revision History

REVISION NUMBER	REVISION DATE	DESCRIPTION	PAGES CHANGED
0	10/19	Initial release	—
1	3/20	Updated Figure 1, Figure 2, Figure 3, *Ordering Information* table, and the *MAX20459 EV Kit PCB Layout - Top View*	2–3, 8, 11

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