

## Evaluating the LTC3313 5 V, 15 A Synchronous Step-Down Silent Switcher in 3 mm × 3 mm LQFN

### FEATURES

- ▶ EVAL-LTC3313EV-A-Z evaluation board
- ▶ Transient circuit included for load transient evaluation
- ▶ EMI filter included to reduce noise in EMI emission tests
- ▶ MODE pin pull-up option for pulse-skipping mode evaluation

### EVALUATION KIT CONTENTS

- ▶ EVAL-LTC3313EV-A-Z evaluation board

### DOCUMENTS NEEDED

- ▶ [LTC3313](#) data sheet
- ▶ EVAL-LTC3313EV-A-Z user guide

### EQUIPMENT NEEDED

- ▶ A DC voltage source
- ▶ An electronic load
- ▶ A multimeter

### GENERAL DESCRIPTION

The EVAL-LTC3313EV-A-Z features the LTC3313, 15 A low voltage synchronous step-down Silent Switcher<sup>®</sup> that operates as a 2 MHz, 2.25 V to 5.5 V input, 1.2 V, 15 A output buck regulator. The LTC3313 supports an output voltage ( $V_{OUT}$ ) from 0.5 V to the input voltage ( $V_{IN}$ ) with operating frequencies from 500 kHz up to 5 MHz. The LTC3313 is a compact, ultralow emission, high-efficiency, and high speed synchronous monolithic step-down switching regulator. The Silent Switcher technology optimizes fast-current loops and makes it easier to minimize electromagnetic interference (EMI) and electromagnetic compatibility (EMC) emissions. The minimum on-time of 35 ns typical enables high  $V_{IN}$  to low  $V_{OUT}$  conversion at a high frequency.

The EVAL-LTC3313EV-A-Z runs in forced continuous mode with a 2 MHz switching frequency ( $f_{SW}$ ); however, it can be configured to run at different switching frequencies or in pulse-skipping mode. The LTC3313 oscillator can also synchronize to an external clock using a MODE/SYNC turret, with the EVAL-LTC3313EV-A-Z default setup. [Figure 4](#) shows the efficiency and power loss of the EVAL-LTC3313EV-A-Z with a 3.3 V input in both operation modes.

The EVAL-LTC3313EV-A-Z also has an EMI filter to reduce conducted EMI. This EMI filter can be included by applying the input voltage at the  $V_{IN}$  EMI terminal. The EMI performance of the board-EVAL-LTC3313EV-A-Z is shown in the [EMI Test Results](#) section. The red lines in the EMI performance graphs illustrate the CISPR25 Class 5 peak limits for the conducted and radiated emission tests.

### EVALUATION BOARD PHOTOGRAPH

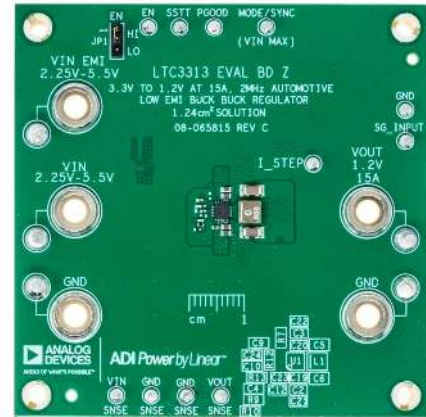


Figure 1. EVAL-LTC3313EV-A-Z Board Photograph

The LTC3313 data sheet gives a complete description of the device and its application information. The data sheet must be read in conjunction with this evaluation board user guide. The LTC3313 is assembled in a 3 mm × 3 mm LQFN package with an exposed pad for low thermal resistance. The layout recommendations for low EMI operation and maximum thermal performance are available in the LTC3313 data sheet.

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**REVISION HISTORY****1/2023—Revision 0: Initial Version**

**PERFORMANCE SUMMARY**

$T_A = 25^\circ\text{C}$ .

**Table 1. Performance Summary**

Parameter	Test Conditions/Comments	Min	Typ	Max	Unit
$V_{IN}/V_{IN\ EMI}$		2.25		5.5	V
$V_{OUT}$		1.176	1.200	1.224	V
Output Current, $I_{OUT}$				15	A
$f_{SW}$		1.8	2	2.2	MHz
Efficiency	$V_{IN} = 3.3\text{ V}, I_{OUT} = 5\text{ A}$		92.5		%

EVALUATION BOARD HARDWARE

INTRODUCTION TO THE EVAL-LTC3313EV-A-Z

The EVAL-LTC3313EV-A-Z evaluation board features the LTC3313, a low voltage, synchronous step-down Silent Switcher. The LTC3313 is a monolithic, constant frequency, current mode step-down DC/DC converter. An oscillator turns on the internal top power switch at the beginning of each clock cycle. Current in the inductor then increases until the top switch comparator trips and turns off the top power switch. The peak inductor current, at which the top switch turns off, is controlled by the voltage on the ITH node. The error amplifier servos the ITH pin by comparing the voltage on the internal VFB pin with an internal 500 mV reference. When the load current increases, it causes a reduction in the feedback voltage relative to the reference, leading the error amplifier to raise the ITH voltage until the average inductor current matches the new load current. When the top switch turns off, the synchronous bottom power switch turns on until the next clock cycle begins. In pulse-skipping mode, the bottom switch also turns off when inductor current falls to zero. If overload conditions result in excessive current flowing through the bottom switch, the next clock cycle will be delayed until the switch current returns to a safe level.

If the EN pin is low, the LTC3313 is in a shutdown state with a low quiescent current. When the EN pin is more than its threshold, the switching regulator enables.

The MODE/SYNC pin synchronizes the switching frequency to an external clock that can be a clock output for multiphase operation. The MODE/SYNC pin also sets the regulator operation modes. The operation modes are either forced continuous or pulse-skipping. See the LTC3313 data sheet for more detailed information.

The maximum allowable operating frequency ( $f_{SW(MAX)}$ ) is influenced by the minimum on time ( $t_{ON(MIN)}$ ) of the top switch, the ratio of  $V_{OUT}$  to  $V_{IN}$  and the inductance of the output inductor. Use the following equation to calculate the maximum allowable operating frequency:

$$f_{SW(MAX)} = \frac{V_{OUT}}{V_{IN(MAX)} \times t_{ON(MIN)}} \tag{1}$$

Select an operating switching frequency below  $f_{SW(MAX)}$ . It is desired to obtain an inductor current of 30% of the maximum LTC3313 operating load, 15 A. Use the following equations to calculate the inductor value to obtain a 30% (4.5 A) inductor ripple for the operating frequency:

$$L \geq \frac{V_{OUT}}{3.75 \text{ A} \times f_{SW}} \times \left(1 - \frac{V_{OUT}}{V_{IN(MAX)}}\right) \tag{2}$$

$$\text{for } \frac{V_{OUT}}{V_{IN(MAX)}} \leq 0.5$$

$$L \geq \frac{0.25 \times V_{IN(MAX)}}{3.75 \text{ A} \times f_{SW}} \text{ for } \frac{V_{OUT}}{V_{IN(MAX)}} > 0.5 \tag{3}$$

When determining the compensation components, C4, C10, C24, and R12, controlling the loop stability and transient response are the two main considerations. The LTC3313 was designed to operate at a high bandwidth for fast transient response capabilities, which reduces the required output capacitance to meet the desired transient voltage range. The midband gain of the loop increases with R12 and the bandwidth of the loop increases by decreasing C24. C4 and R9 provide a phase lead that improves the phase margin. C10 and R12 provide a high-frequency pole to reduce the high-frequency gain.

Loop stability is generally measured using the Bode plot method of plotting loop gain in decibels and phase shift in degrees. The 0 dB crossover frequency must be less than 1/6 of the operating frequency to reduce the effects of the added phase shift of the modulator. The control-loop phase margin goal must be 45° or greater, and the gain margin goal must be 8 dB or greater.

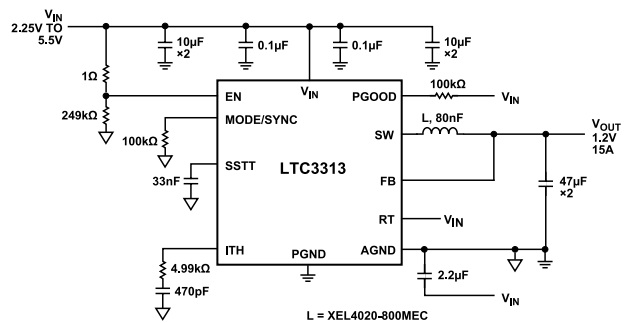


Figure 2. LTC3313, 1.2 V/15 A Step-Down Converter Typical Solution

## QUICK START PROCEDURE

Before following the quick start procedure, note that for accurate  $V_{IN}$ ,  $V_{OUT}$ , and efficiency measurements, measure  $V_{IN}$  at the VIN SNSE and GND SNSN turrets and measure  $V_{OUT}$  at the VOUT SNSE and GND SNSE turrets, which are illustrated as VM1 and VM2 in [Figure 6](#). In addition, when measuring the input or output ripple, avoid a long ground lead on the oscilloscope probe.

Refer to [Figure 6](#) for the proper measurement equipment test setup and also take the following steps:

1. Set the JP1 jumper to the HI position.
2. With power off, connect the input power supply to  $V_{IN}$  and GND. If the input EMI filter is desired, connect the input power supply to  $V_{IN}$  EMI and GND.
3. Set the power supply (PS1) current limit to 10 A.
4. Set the electronic load (LD1) to CC mode and a 0 A current.
5. Slowly increase PS1 to 1.0 V. If the PS1 output current reads less than 20 mA, increase PS1 to 3.3 V.
6. Verify that VM1 reads 3.3 V and that VM2 reads approximately 1.2 V.
7. Check VM1, VM2, VM3, the PS1 output current, and the LD1 input current.
8. Connect an oscilloscope voltage probe as shown in [Figure 7](#) or [Figure 8](#).
9. Set the channel to AC-coupled, the voltage scale to 20 mV, and the time base to 10  $\mu$ s. Also, check the  $V_{OUT}$  ripple and verify that the PGOOD voltage is more than 3 V.
10. Increase the load by 1 A intervals up to 15 A and observe the voltage output regulation, ripple voltage, and the voltage on the SSTT turret.
11. Use the following equation to calculate the die temperature:
 
$$T_J(^{\circ}C) = \frac{V_{SSTT}}{4 \text{ mV}} - 273 \quad (4)$$
12. If pulse-skipping mode is desired, set PS1 to 0 V, install a 0  $\Omega$  resistor in the R3 location, and remove R6. Repeat Step 1 through Step 11. In step 11, observe that the switching waveform is now in pulse-skipping mode at light load.
13. Optionally, to change the frequency, remove R3 and R4, if installed. Install the desired RT resistor in the R7 location. Note that the MODE/SYNC pin must have high impedance to GND and  $V_{IN}$ . Size the inductor, output capacitors, and compensation components to provide the desired inductor ripple and a stable output. Refer to the [LTC3313](#) data sheet and [LTpowerCAD](#) for more information on choosing the required components.
14. To test the transient response with a base load, add the desired resistor to produce a minimum load between the  $V_{OUT}$  and the I\_STEP turrets (RL shown on [Figure 6](#)). Note that the total load resistance is  $R_L + R_{14}$  (20 m $\Omega$ ). Adjust a signal generator with a 10 ms period, a 10% duty cycle, and an amplitude from 1 V to 2 V to start.
15. Measure the I\_STEP voltage to observe the current,  $V_{I\_STEP}/20$  m $\Omega$ . Adjust the amplitude of the pulse to provide the desired transient. Connect the signal generator (SG\_INPUT) between the SG\_INPUT and GND turrets. Adjust the rising and falling edge of the pulse to provide the desired ramp rate. [Figure 5](#) shows a load step from 5 A to 10 A. Refer to the following equations:
 
$$I_{OUT} = \frac{V_{I\_STEP}}{20 \text{ m}\Omega} \quad (5)$$

$$V_{GS} = V_{SG\_INPUT} - V_{I\_STEP} \quad (6)$$
16. When done, turn off SG\_INPUT, PS1, and the load, and remove all the connections to the EVAL-LTC3313EV-A-Z.

TYPICAL PERFORMANCE CHARACTERISTICS

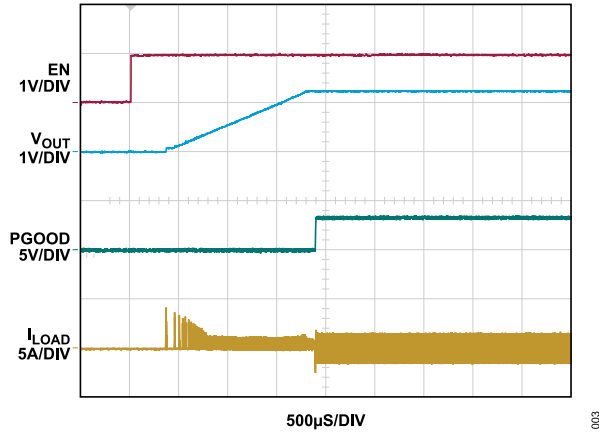


Figure 3. Start-Up Waveforms with Light Load ( $I_{LOAD}$  is the Load Inductance.)

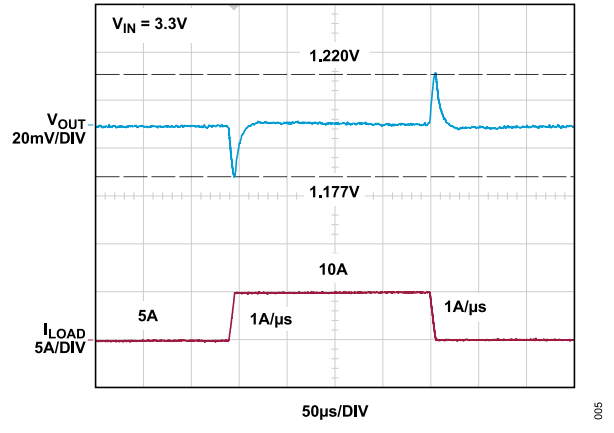


Figure 5. Load Step Response

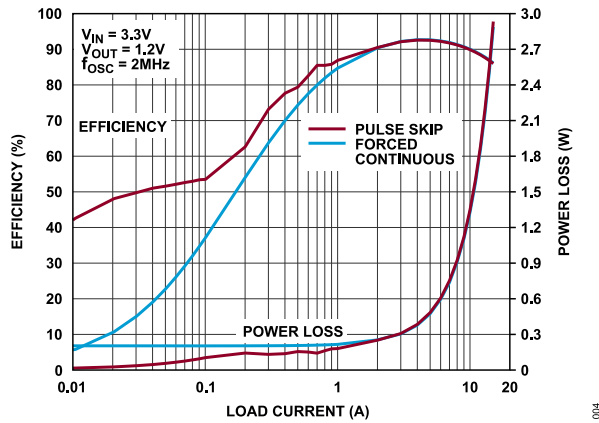


Figure 4. Efficiency vs. Load Current

TEST SETUP

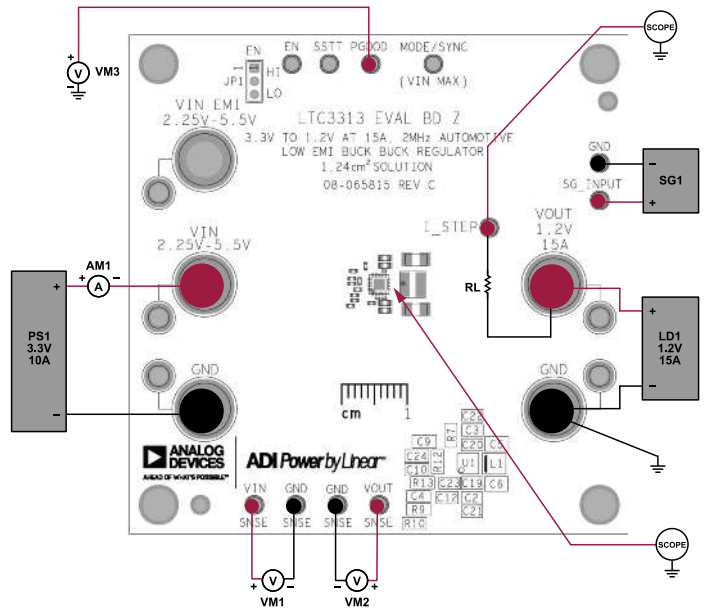


Figure 6. Test Setup for EVAL-LTC3313EV-A-Z

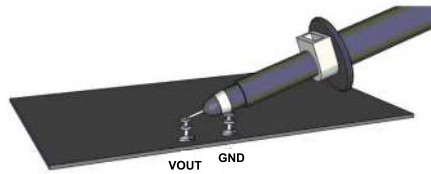


Figure 7. Technique for Measuring Output Ripple and Step Response with a Scope Probe



Figure 8. Technique for Measuring Output Ripple and Step Response with a Low Inductance Connector (Not Supplied)

EMI TEST RESULTS

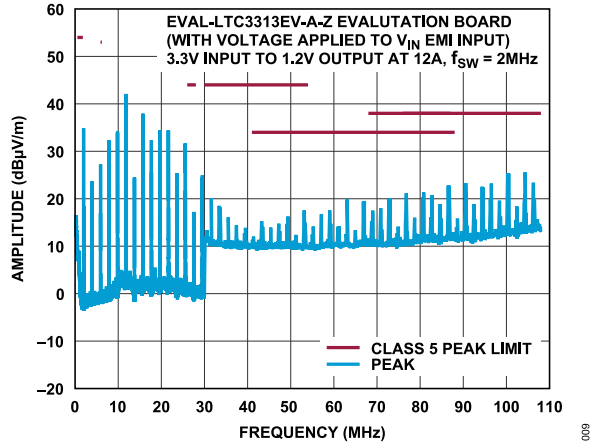


Figure 9. EVAL-LTC3313EV-A-Z CISPR25 Conducted Emission with Class 5 Peak Limits (Voltage Method)

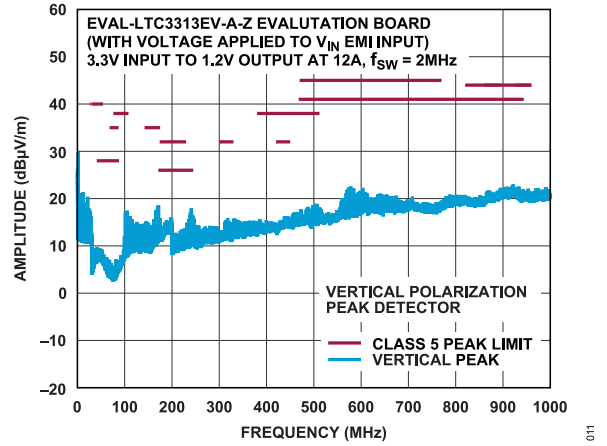


Figure 11. EVAL-LTC3313EV-A-Z CISPR25 Radiated Emission (Vertical)

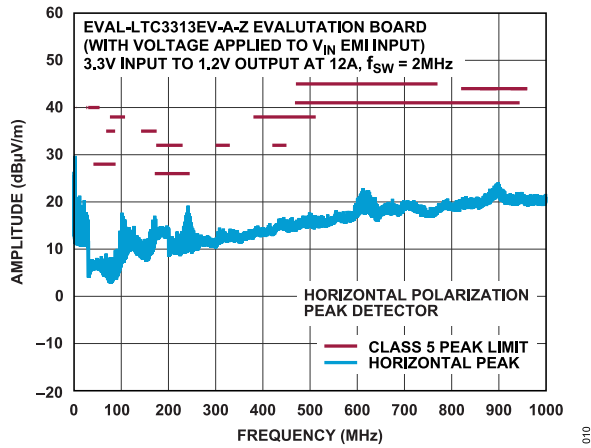


Figure 10. EVAL-LTC3313EV-A-Z CISPR25 Radiated Emission (Horizontal)



EVALUATION BOARD SCHEMATIC

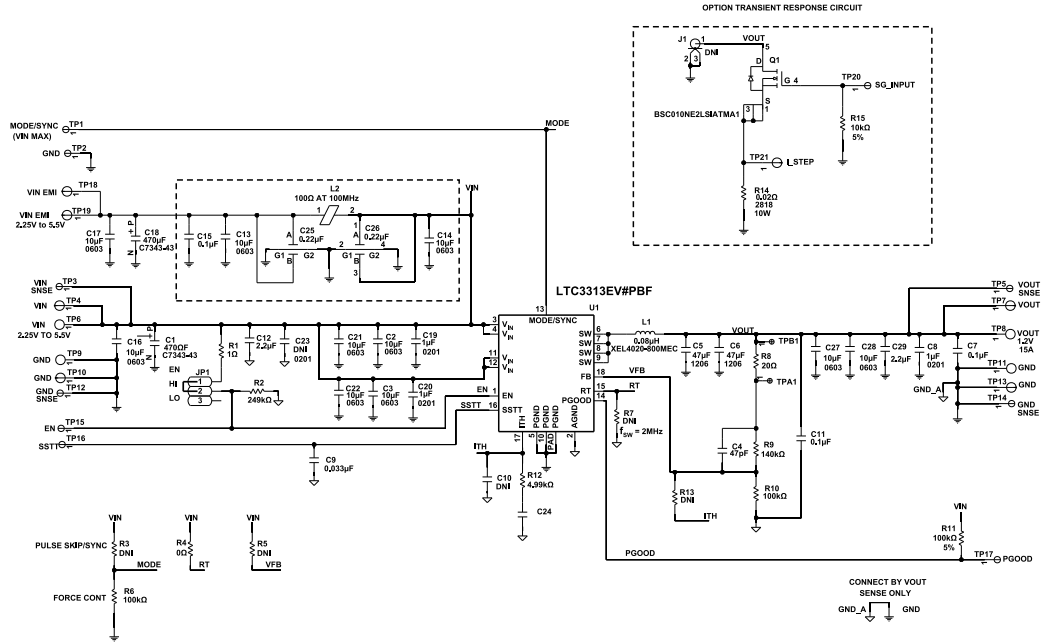


Figure 12. EVAL-LTC3313EV-A-Z Evaluation Board Schematic

## ORDERING INFORMATION

## BILL OF MATERIALS

Table 2. Bill of Materials

Quantity	Circuit Component	Description	Manufacturer/Part Number
<b>Required</b>			
4	C2, C3, C21, C22	10 $\mu$ F ceramic capacitors, 6.3 V, 20%, X7S, 0603, low effective series resistance (ESR)	TDK, C1608X7S0J106M080AC
1	C4	47 pF ceramic capacitor, 50 V, 5%, C0G, 0402, AEC-Q200	Murata, GCM1555C1H470JA16D
2	C5, C6	47 $\mu$ F capacitors, X7S, 6.3 V, 20%, 1206	TDK, C3216X7S0J476M160AC
3	C8, C19, C20	1 $\mu$ F ceramic capacitors, 6.3 V, 20%, X7T, 0201	Murata, GRM033D70J105ME01D
1	C9	0.033 $\mu$ F ceramic capacitor, 25 V, 10%, X7R, 0402, AEC-Q200	Murata, GCM155R71E333KA55D
1	C12	2.2 $\mu$ F ceramic capacitor, 10 V, 10%, X7S, 0402, AEC-Q200	Murata, GRT155C71A225KE13D
1	C24	470 pF ceramic capacitor, 50 V, 5%, C0G, 0402	Murata, GRM1555C1H471JA01D
1	L1	0.08 $\mu$ H inductor, power shielded, 20%, AEC-Q200	Coilcraft, XEL4020-800MEC
1	R9	140 k $\Omega$ resistor, surface-mounted device (SMD), 1%, 1/16 W, 0402, AEC-Q200	Vishay, CRCW0402140KFKED
1	R10	100 k $\Omega$ resistor, SMD, 1%, 1/10 W, 0402, AEC-Q200	Panasonic, ERJ-2RKF1003X
1	R12	4.99 k $\Omega$ resistor, SMD, 1%, 1/10 W, 0402, AEC-Q200	Panasonic, ERJ-2RKF4991X
1	U1	5 V, 15 A, synchronous step-down Silent Switcher in 3 mm x 3 mm LQFN	Analog Devices, Inc., <a href="#">LTC3313EV#PBF</a>
<b>Additional</b>			
2	C1, C18	470 $\mu$ F tantalum capacitors, 6.3 V, 20%, 7343-40, very low ESR, 0.005 $\Omega$	Kemet, T530Y477M006ATE005
2	C7, C15	0.1 $\mu$ F ceramic capacitors, 16 V, 10%, X7R, 0402, AEC-Q200	Murata, GCM155R71C104KA55D
1	C11	0.1 $\mu$ F ceramic capacitor, 50 V, 10%, X7R, 0402, AEC-Q200, low ESR	TDK, CGA2B3X7R1H104K050BB
4	C13, C14, C16, C17	10 $\mu$ F ceramic capacitors, 6.3 V, 20%, X7R, 0603	Samsung, CL10B106MQ8NRNC
2	C25, C26	0.22 $\mu$ F ceramic capacitors, 6.3 V, 20%, X7R, 0603, feed through	Johanson Dielectrics, 6R3X14W224MV4T
2	C27, C28	10 $\mu$ F ceramic capacitors, 6.3 V, 20%, X7S, 0603, low ESR	TDK, C1608X7S0J106M080AC
1	C29	2.2 $\mu$ F ceramic capacitor, 10 V, 10%, X7S, 0402, AEC-Q200	Murata, GRT155C71A225KE13D
1	L2	Inductor, EMI, ferrite bead, 8 A	Würth Elektronik, 74279226101
1	Q1	Transistor, metal-oxide semiconductor field-effect transistor (MOSFET), N channel, 25 V, 38 A, 8-lead TDSON, EP	Infineon, BSC010NE2LSIATMA1
1	R1	1 M $\Omega$ resistor, SMD, 1%, 1/16 W, 0402, AEC-Q200	Vishay, CRCW04021M00FKED
1	R2	249 k $\Omega$ resistor, SMD, 1%, 1/16 W, 0402, AEC-Q200	Stackpole, RMCF0402FT249K
1	R4	0 $\Omega$ resistor, SMD, jumper, 1/10 W, 0402, AEC-Q200	Panasonic, ERJ-2GE0R00X
2	R6, R11	100 k $\Omega$ resistors, SMD, 5%, 1/16 W, 0402, AEC-Q200	Vishay, CRCW0402100KJNED
1	R8	20 $\Omega$ resistor, SMD, 1%, 1/10 W, 0402, AEC-Q200	Panasonic, ERJ-2RKF20R0X
1	R14	0.02 $\Omega$ resistor, SMD, 1%, 10 W, 2818, AEC-Q200	Vishay, WSHP2818R0200FEA
1	R15	10 k $\Omega$ resistor, SMD, 5%, 1/16 W, 0402, AEC-Q200	Vishay, CRCW040210K0JNED
1	J1	Connector, U.FL, receptor, straight, SMD, 0 Hz to 6 GHz, 50 $\Omega$	Hirose Electric, U.FL-R-SMT-1(10)
<b>Required Hardware</b>			
11	TP1 to TP3, TP5, TP12, TP14 to TP17, TP20, TP21	Printed circuit board (PCB) connectors, solder terminal turrets for clip leads	Mill-Max, 2308-2-00-80-00-00-07-0

## ORDERING INFORMATION

Table 2. Bill of Materials (Continued)

Quantity	Circuit Component	Description	Manufacturer/Part Number
5	TP4, TP7, TP10, TP13, TP18	PCB connectors, solder terminal turrets	Mill-Max, 2501-2-00-80-00-00-07-0
5	TP6, TP8, TP9, TP11, TP19	PCB connectors, banana jack	Keystone Electronics, 575-4
1	JP1	Connector, header, male, 1 x 3, 2 mm, vertical, straight, THT	Wurth Elektronik, 62000311121
4	MP1 to MP4	Standoffs, nylon, snap-on, 0.50"	Keystone Electronics, 8833
1	XJP1	Connector, shunt, female, 2-position, 2 mm	Wurth Elektronik, 60800213421

**ESD Caution**

**ESD (electrostatic discharge) sensitive device.** Charged devices and circuit boards can discharge without detection. Although this product features patented or proprietary protection circuitry, damage may occur on devices subjected to high energy ESD. Therefore, proper ESD precautions should be taken to avoid performance degradation or loss of functionality.

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