

LT8333

Low I_Q Boost/SEPIC Inverting
Converter with 3A, 40V Switch**DESCRIPTION**

Evaluation circuit EVAL-LT8333-BZ features the [LT®8333](#) in a **Boost** configuration. It operates with a switching frequency of 2MHz and is designed to convert a 4.5V to 20V source to 24V output. The converter can output up to 2A depending on the input voltage (see Figure 3 Maximum Output Current vs V_{IN} curve).

This evaluation circuit features Spread-Spectrum Frequency Modulation (SSFM) and EMI filters to provide optimum EMI performance. This PCB layout is optimized for good EMI performance and small solution size. The evaluation board contains a selectable jumper, JP1, to aid in the selection of the desired SYNC pin mode of operation. At light load, either pulse-skipping (PULSE SKIP) or low-ripple Burst Mode® operation (BURST) can be selected to improve the efficiency.

The LT8333 boost/SEPIC/inverting converter IC operates over an input range of 2.8V to 40V, suitable for

automotive, telecom, and industrial applications. The converter provides adjustable and synchronizable operation from 300kHz to 2MHz with SSFM option. The LT8333 packs other popular features such as soft-start, bias pin, input undervoltage lockout. The IC can exhibit a low quiescent current down to 9 μ A in BURST mode and 1 μ A in shutdown, which makes it ideal for battery-operated systems. The LT8333 is assembled in a thermally enhanced 10-lead 3mm \times 3mm DFN package.

The data sheet gives a complete description of the device, operation, and application information. The data sheet must be read in conjunction with this demo manual for EVAL-LT8333-BZ.

There is another evaluation board [EVAL-LT8333-AZ](#) featuring the LT8333 in a SEPIC configuration.

[Design files for this circuit board are available.](#)

All registered trademarks and trademarks are the property of their respective owners.

DEMO MANUAL

EVAL-LT8333-BZ

PERFORMANCE SUMMARY Specifications are at $T_A = 25^\circ\text{C}$

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNIT
Input Voltage (V_{IN})	$V_{OUT} = 24\text{V}$	4.5		20	V
Output Voltage (V_{OUT})	$R1 = 1\text{M}\Omega$, $R2 = 71.5\text{k}\Omega$		24		V
Output Voltage Ripple (ΔV_{OUT})	$V_{IN} = 12\text{V}$, $V_{OUT} = 24\text{V}$, $I_{OUT} = 1.1\text{A}$ (Measured at C2)		40		mV
Maximum Output Current (I_{OUT})	$V_{OUT} = 24\text{V}$, $V_{IN} = 9\text{V}$		850		mA
	$V_{OUT} = 24\text{V}$, $V_{IN} = 12\text{V}$		1.1		A
	$V_{OUT} = 24\text{V}$, $V_{IN} = 16\text{V}$		1.5		A
Switching Frequency (f_{sw})	$R5 = 20.0\text{k}\Omega$, SSFM OFF		2		MHz
	$R5 = 20.0\text{k}\Omega$, SSFM ON	2		2.4	MHz
Input EN Voltage (Rising)	$R3 = 1\text{M}\Omega$, $R4 = 549\text{k}\Omega$		4.7		V
Input UVLO Voltage (Falling)	$R3 = 1\text{M}\Omega$, $R4 = 549\text{k}\Omega$		4.5		V
Typical Efficiency (with EMI filters)	$V_{IN} = 9\text{V}$, $V_{OUT} = 24\text{V}$, $I_{OUT} = 850\text{mA}$		91		%
	$V_{IN} = 12\text{V}$, $V_{OUT} = 24\text{V}$, $I_{OUT} = 1.1\text{A}$		93		%
	$V_{IN} = 16\text{V}$, $V_{OUT} = 24\text{V}$, $I_{OUT} = 1.5\text{A}$		95		%
Zero Load Quiescent Current ($V_{OUT} = 24\text{V}$)* $R1 = 1\text{M}\Omega$, $R2 = 71.5\text{k}\Omega$; $R3 = 1\text{M}\Omega$, $R4 = 549\text{k}\Omega$	$V_{IN} = 9\text{V}$, JP1 = BURST		96		μA
	$V_{IN} = 9\text{V}$, JP1 = PULSE SKIP		1.33		mA
	$V_{IN} = 12\text{V}$, JP1 = BURST		76		μA
	$V_{IN} = 12\text{V}$, JP1 = PULSE SKIP		1.22		mA

*Please see PULSE SKIP, BURST, SSFM, SYNC section on how to achieve lower quiescent current.

QUICK START PROCEDURE

Evaluation circuit EVAL-LT8333-BZ is easy to set up to evaluate the performance of the LT8333. Refer to Figure 1 for proper measurement equipment setup and follow the procedure below.

NOTE: Make sure that the input voltage is always with the specification.

1. Connect EN/UVLO turret to GND.
2. With power off, connect the input power supply to VIN and GND terminals of the board. Include voltage and current meters as shown in Figure 1 if desired.
3. Connect the load to the VOUT and GND terminals.
4. Turn on the power at the input. Increase VIN slowly to 12V.
5. Disconnect EN/UVLO turret from GND and the output turns on.

6. Check for the proper output voltage. The output should be regulated at 24V.

If there is no output, temporarily disconnect the load to make sure that the load is not set too high.

7. Once the proper output voltage is established, adjust the input voltage and load current within the operating range and observe the output voltage regulation, ripple voltage, efficiency, and other parameters.

NOTE: When measuring the input or output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the input or output voltage ripple by touching the probe tip directly across the input and output capacitors.

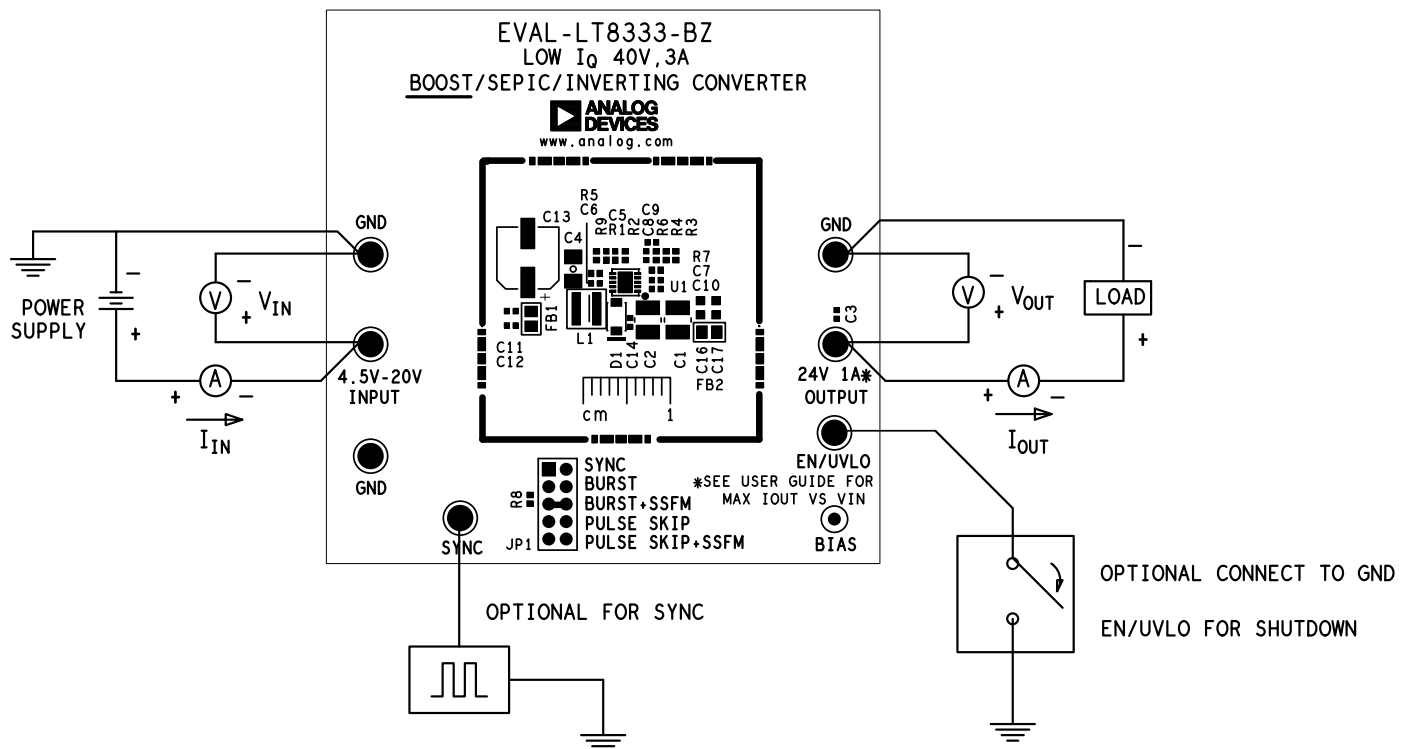


Figure 1. Proper Equipment Setup for EVAL-LT8333-BZ

QUICK START PROCEDURE

Output Voltage and Power

The LT8333 is a low I_Q non-synchronous DC/DC converter that can be configured in boost, SEPIC, or inverting converters. Although EVAL-LT8333-BZ is designed to regulate 24V output from a 4.5V to 20V source, the feedback resistors R1 and R2 can be easily adjusted for higher or lower output voltage. In addition to adjusting feedback resistors, the input and output capacitors should be sized appropriately. The catch diode, D1, must also be able to handle the switch voltage.

The 3A peak switch current and EMI filters limit a maximum 2A output current at $20V_{IN}$. Figure 3 shows the maximum output current versus V_{IN} .

PULSE SKIP, BURST, SSFM, SYNC

The LT8333 achieves low power consumption at light loads. The different SYNC/MODE pin states can be evaluated by changing the position of jumper JP1. It is easy to change from BURST to PULSE SKIP and to explore SSFM ON, SSFM OFF, and external SYNC with this jumper.

PULSE SKIP allows low quiescent current at light load consumption without changing switching frequency until a very light load. BURST allows the lowest light load power consumption and has a unique low ripple feature on the LT8333. These two features can be explored further in the data sheet of the LT8333. The feedback resistors, R1 and R2, can be replaced with higher resistance values

for better no-load input current results. For the lowest no-load input current, the EN/UVLO pin should be shorted to V_{IN} and the R4 resistor should be removed.

Spread-Spectrum Frequency Modulation (SSFM) can be enabled to reduce the emissions of the converter. SSFM spreads the frequency between the RT-programmed frequency and +20% higher.

If an external SYNC signal is provided, the SYNC option of JP1 can be used to synchronize with an external clock. The clock frequency should be slightly higher than the RT-programmed frequency for best performance.

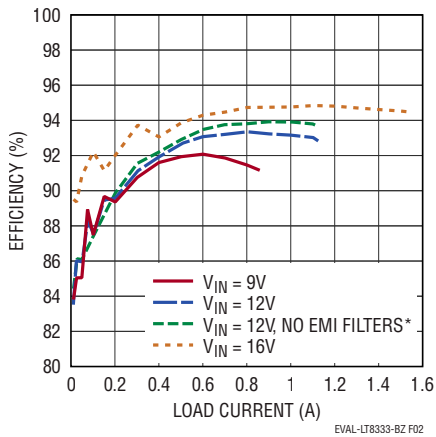
EN/UVLO

R3 and R4 set the undervoltage lockout falling and enable rising thresholds. The LT8333 data sheet gives a formula for calculating these values. EVAL-LT8333-BZ has a falling UVLO threshold of 4.5V and a rising EN threshold of 4.7V. This threshold can easily be adjusted by changing resistors R3 and R4 according to the data sheet equations.

BIAS

In this evaluation circuit, the bias pin is unused and tied to GND through R7. However, the bias pin can be connected to an auxiliary input supply for powering $INTV_{CC}$ to improve efficiency when $4.4V \leq BIAS \leq V_{IN}$. To use the BIAS pin, R7 needs to be replaced by an 0402 sized ceramic capacitor with a value of at least $1\mu F$, and BIAS terminal should be connected to an auxiliary source.

TEST RESULTS



*FB1 AND FB2 REPLACED WITH 0Ω RESISTORS, C13 REMOVED

Figure 2. EVAL-LT8333-BZ Efficiency with and without EMI Filters (JP1 = BURST)

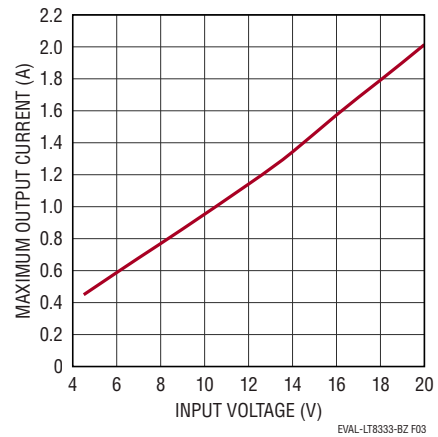
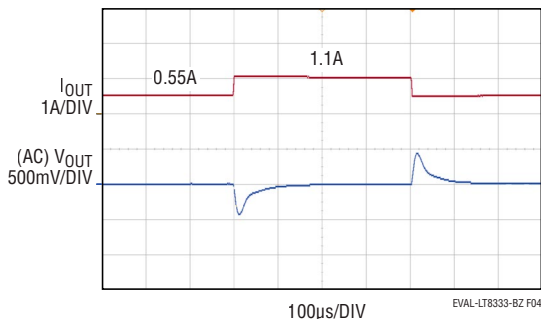
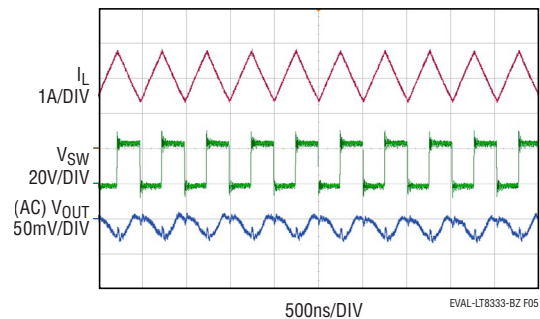


Figure 3. EVAL-LT8333-BZ Steady State Maximum Output Current vs Input Voltage



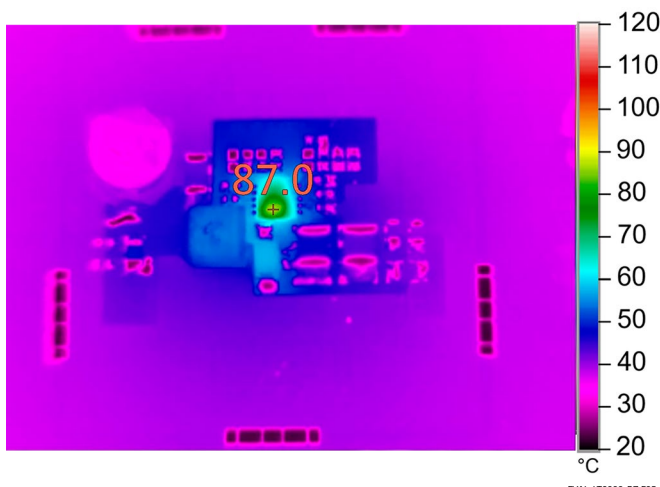
$V_{IN} = 12V, V_{OUT} = 24V, I_{OUT} = 0.55A \text{ TO } 1.1A$

Figure 4. EVAL-LT8333-BZ V_{OUT} Transient Response; EMI Filters Are Not Installed (JP1 = PULSE SKIP)

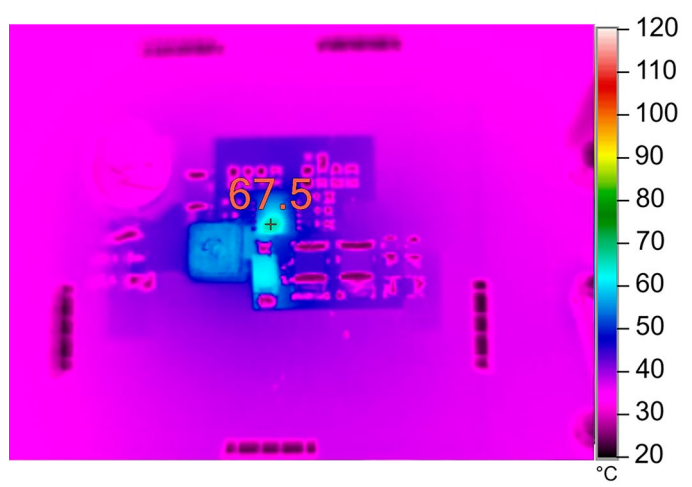


ΔV_{OUT} ACROSS C2 at $V_{IN} = 12V, V_{OUT} = 24V, I_{OUT} = 1.1A$

Figure 5. EVAL-LT8333-BZ Output Voltage Ripple (SSFM is OFF)



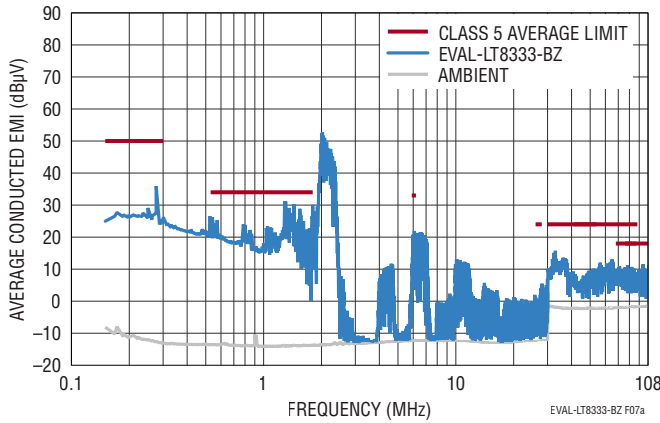
(a) $V_{IN} = 5V, V_{OUT} = 24V, I_{OUT} = 0.5A$



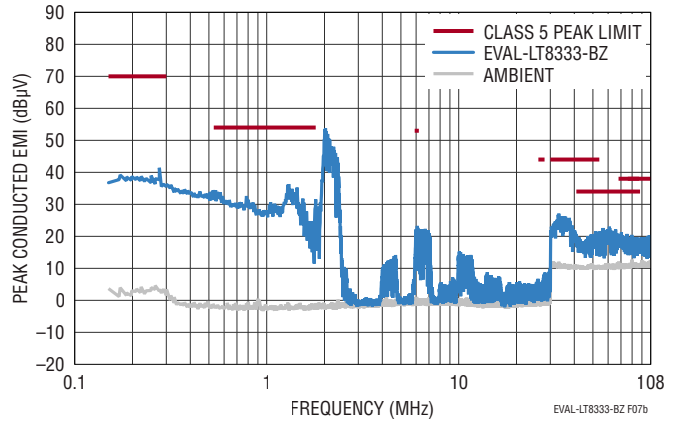
(b) $V_{IN} = 12V, V_{OUT} = 24V, I_{OUT} = 1.1A$

Figure 6. EVAL-LT8333-BZ Thermals

TEST RESULTS

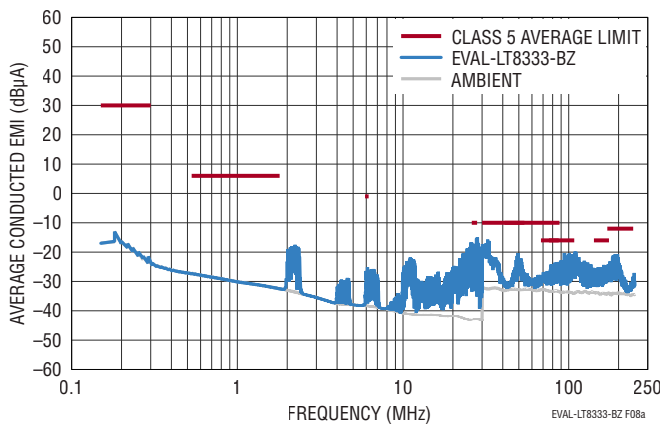


(a) CISPR25 Average Conducted EMI – Voltage Method

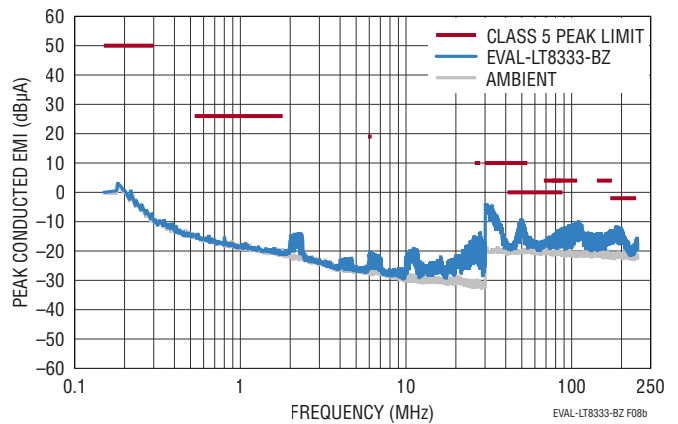


(b) CISPR25 Peak Conducted EMI – Voltage Method

Figure 7. EVAL-LT8333-BZ Conducted Emissions (Voltage Method): $V_{IN} = 12V$, $V_{OUT} = 24V$, $I_{OUT} = 1A$, JP1 = BURST + SSFM

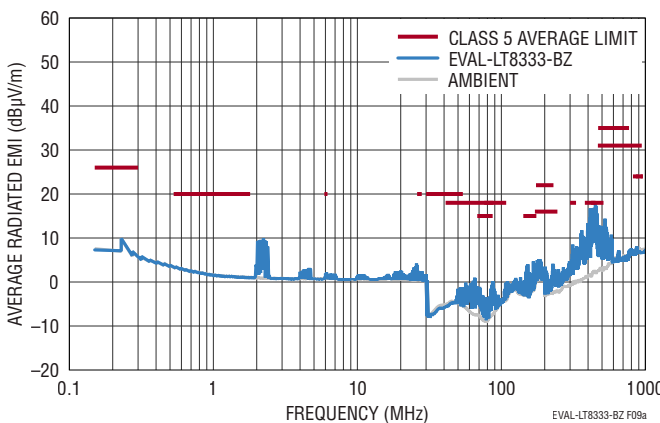


(a) CISPR25 Average Conducted EMI – Current Method

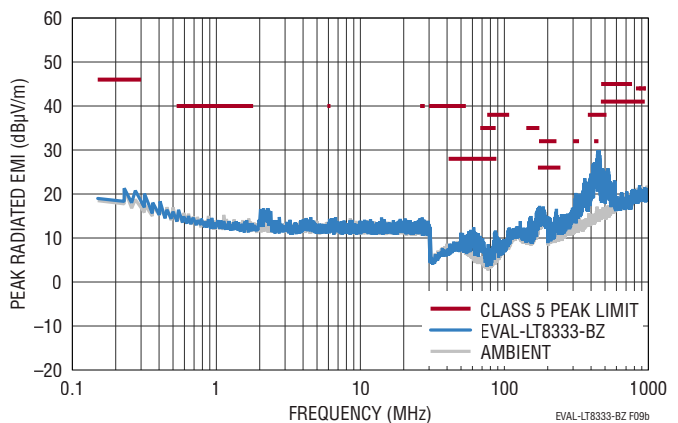


(b) CISPR25 Peak Conducted EMI – Current Method

Figure 8. EVAL-LT8333-BZ Conducted Emissions (Current Method): $V_{IN} = 12V$, $V_{OUT} = 24V$, $I_{OUT} = 1A$, JP1 = BURST + SSFM



(a) CISPR25 Average Radiated EMI



(b) CISPR25 Peak Radiated EMI

Figure 9. EVAL-LT8333-BZ Radiated Emissions: $V_{IN} = 12V$, $V_{OUT} = 24V$, $I_{OUT} = 1A$, JP1 = BURST + SSFM

EMISSIONS SHIELD (OPTION)

For the ultimate lowest emissions, an EMI shield can be attached to EVAL-LT8333-BZ. The PCB was fabricated with placeholders for five shield clips which can hold a 32mm × 32mm metal shield. Part numbers for an example shield are provided in the Parts List section in

the Hardware list. The top silkscreen picture (Figure 10) shows the placeholders for the five surface mount shield clips. Then the emissions of the board can be tested with and without the removable clip-shield.

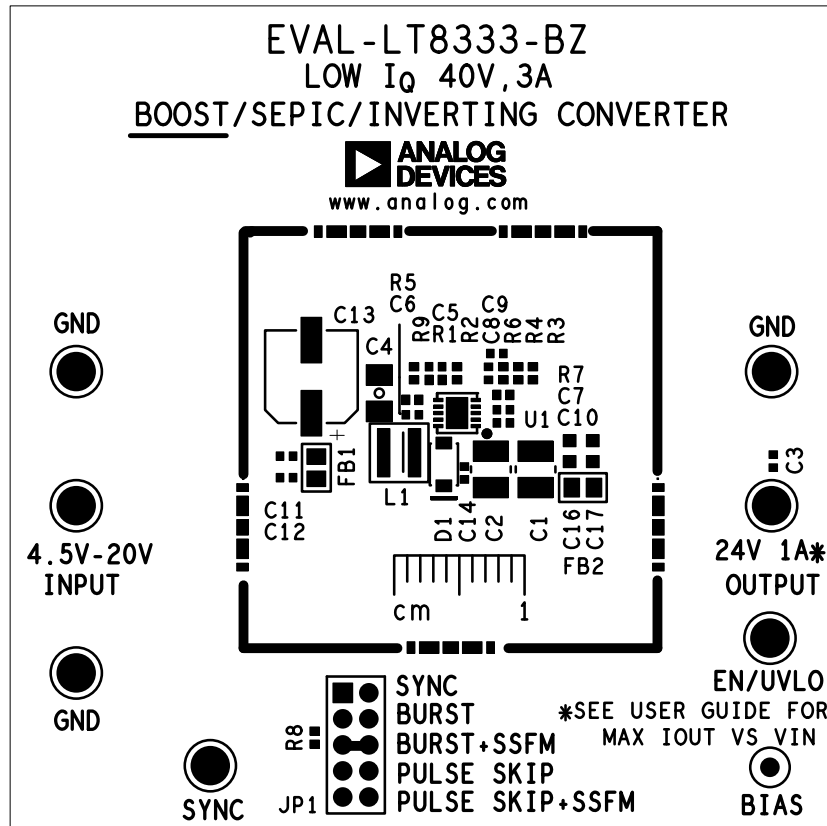


Figure 10. Top Silkscreen Outlining Placement of Shield Clips and EMI Shield on PCB

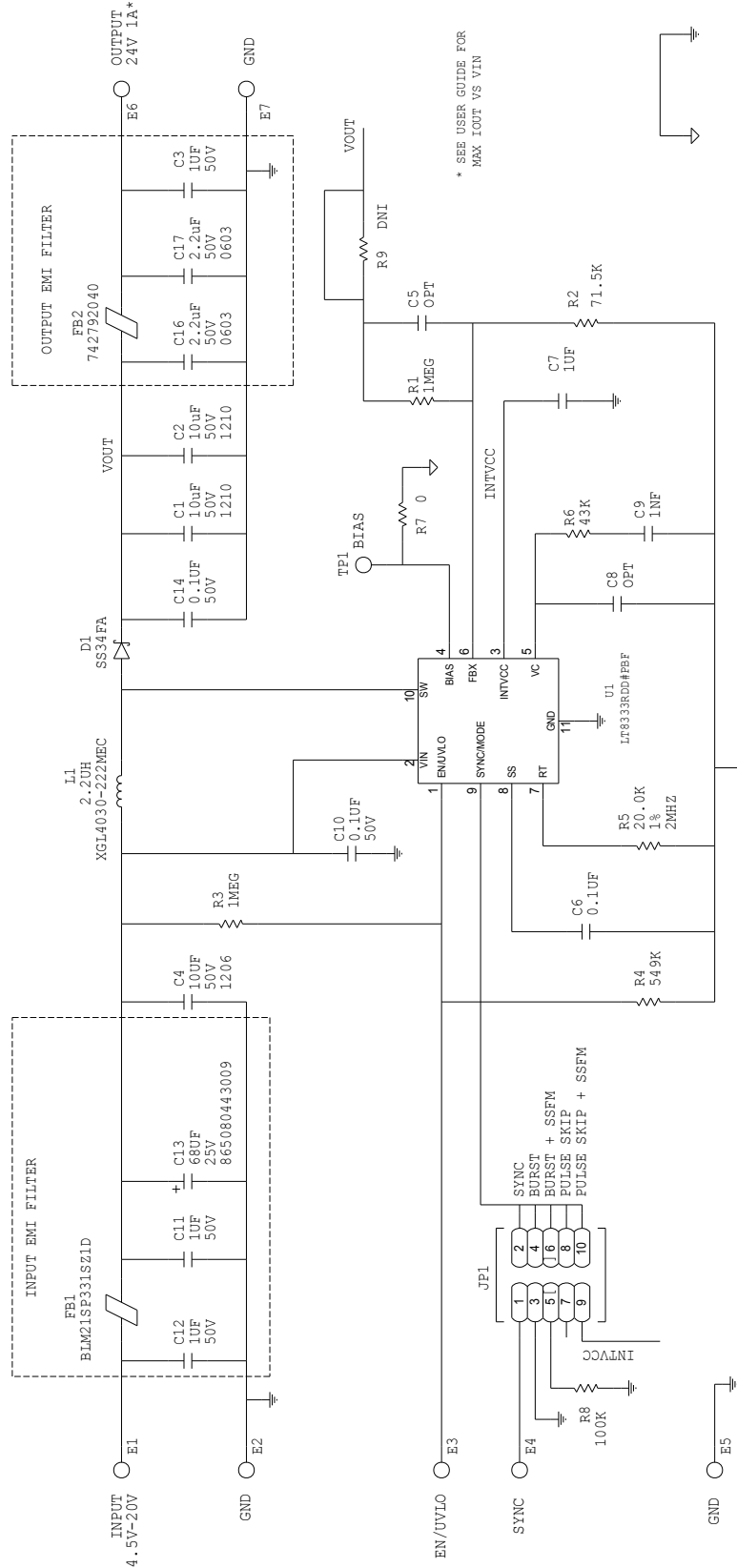
DEMO MANUAL

EVAL-LT8333-BZ

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Electrical Components				
1	2	C1, C2	CAP CER 10 μ F 50V 10% X7R 1210 AEC-Q200	AVX CORPORATION, 12105C106K4T2A
2	1	C10	CAP CER 0.1 μ F 50V 10% X7R 0402 AEC-Q200	MURATA, GCM155R71H104KE02D
3	1	C4	CAP CER 10 μ F 50V 10% X5R 1206 AEC-Q200	MURATA, GRT31CR61H106KE01L
5	1	C6	CAP CER 0.1 μ F 25V 10% X7R 0402 AEC-Q200	TAIYO YUDEN, TMK105B7104KVHF
6	1	C7	CAP CER 1 μ F 25V 10% X5R 0402 AEC-Q200	MURATA, GRT155R61E105KE01D
7	1	C9	CAP CER 1nF 25V 10% X7R 0402	AVX CORPORATION, 04023C102KAT2A
8	1	D1	DIODE SCHOTTKY 40V 3A SOD123FA	ONSEMI, SS34FA
9	1	L1	IND. POWER SHIELDED WIREWOUND 2.2 μ H 20% 1MHz 8.7A 0.015 Ω , AEC-Q200	COILCRAFT, XGL4030-222MEC
10	2	R1, R3	RES. SMD 1M 1% 1/16W 0402 AEC-Q200	VISHAY, CRCW04021M00FKED
11	1	R2	RES. SMD 71.5k 1% 1/16W 0402 AEC-Q200	VISHAY, CRCW040271K5FKED
12	1	R4	RES. SMD 549k 1% 1/16W 0402	YAGEO, RC0402FR-07549KL
13	1	R5	RES. SMD 20k 1% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2RKF2002X
14	1	R6	RES. SMD 43k 1% 1/16W 0402	YAGEO, RC0402FR-0743KL
15	1	U1	IC, BOOST/SEPIC/INVERTG CONVERTER, 3mm \times 3mm, DFN	ANALOG DEVICES, LT8333RDD#PBF
Optional Low EMI Components				
1	1	FB1	FERRITE BEAD 330 Ω 25% 100MHz 2.8A 0.04 Ω DCR 0805 AEC-Q200	MURATA, BLM21SP331SZ1D
2	1	FB2	IND. FERRITE BEAD 600 Ω 25% 100MHz 2A 0.15 Ω 0805 AEC-Q200	WURTH ELEKTRONIK, 742792040
3	3	C3, C11, C12	CAP CER 1 μ F 50V 20% X5R 0402	TAIYO YUDEN, UMK105CBJ105MV-F
4	1	C13	CAP ALUM ELECT 68 μ F 25V 20% 6.6mm \times 6.6mm	WURTH ELEKTRONIK, 865080443009
5	2	C16, C17	CAP CER 2.2 μ F 50V 20% X5R 0603 AEC-Q200	MURATA, GRT188R61H225ME13D
6	1	C14	CAP CER 0.1 μ F 50V 10% X7R 0402 AEC-Q200	MURATA, GCM155R71H104KE02D
Optional Electrical Components				
1	0	C5	CAP OPTION 0402	
2	0	C8	CAP OPTION 0402	
3	0	R9	RES. OPTION 0402	
4	1	R8	RES. SMD 100k 1% 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2RKF1003X
5	1	R7	RES. SMD 0 Ω JUMPER 1/10W 0402 AEC-Q200	PANASONIC, ERJ-2GE0R00X
Hardware: For Demo Board Only				
1	7	E1-E7	CONN-PCB SOLDER TERMINAL TURRETS	MILL-MAX, 2501-2-00-80-00-00-07-0
2	1	JP1	CONN-PCB 2mm P DIL, LOW PROFILE HDR	SAMTEC, TMM-105-01-F-D
3	1	TP1	CONN-PCB TST PNT BLK	KEYSTONE, 5001
4	1	XJP1	SHUNT, 2mm JUMPER WITH TEST POINT	WURTH ELEKTRONIK, 60800213421
5	0	CL1-CL5	FIVE EMI SHIELD CLIPS	WURTH ELEKTRONIK, 36900000
6	0	SH1	EMI SHIELD 32mm \times 32mm	WURTH ELEKTRONIK, 36906326S

SCHEMATIC DIAGRAM



* SEE USER GUIDE FOR
MAX IOUT VS VIN

NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL RESISTORS ARE 0402
2. ALL CAPACITORS ARE 0402



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.

Legal Terms and Conditions

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at One Technology Way, Norwood, MA 02062, USA. Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. CONFIDENTIALITY. This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. ADDITIONAL RESTRICTIONS. Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. TERMINATION. ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. LIMITATION OF LIABILITY. THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS (\$100.00). EXPORT. Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.