

LT8356-1  
100V<sub>IN</sub>/120V<sub>OUT</sub> LED  
Controller with SSFM

## DESCRIPTION

Evaluation board EVAL-LT8356-1-AZ is a high voltage LED controller featuring the [LT<sup>®</sup>8356-1](#). It is assembled as a buck-boost mode LED driver but can be altered to a boost LED driver by adjusting the FB network and LED-connection. EVAL-LT8356-1-AZ drives a single string of LEDs up to 36V at 1A when the input is between 8V and 36V. It has an undervoltage lockout (UVLO) set at 6.5V falling and 7.5V rising. The evaluation board features PWM dimming, analog dimming, shutdown, open LED and short LED fault protection and reporting.

EVAL-LT8356-1-AZ runs at 250kHz switching frequency and features spread spectrum frequency modulation (SSFM) modulating its switching frequency from 250kHz to 310kHz to reduce EMI emissions. Small ceramic input and output capacitors are used to save space and cost. A high voltage 100V external power switch and 100V catch diode are used for up to 36W buck-boost mode output as assembled. The open LED overvoltage protection (OVP) uses the IC's constant voltage regulation loop to limit the LED+ to LED- voltage to approximately 41V if the LED string is opened. The V<sub>OUT</sub>, if referenced to GND, will jump to V<sub>IN</sub> + 41V if the LED string is opened.

The input and output filters on EVAL-LT8356-1-AZ help further reduce its EMI. These filters consist of a small ferrite bead or inductor and high frequency ceramic capacitors. A small resistor on the gate pin of the power MOSFET is used to reduce high frequency EMI. These filters, combined with proper board layout and SSFM, are very effective in reducing EMI to comply with CISPR25 class 5 limits. Please follow the recommended layout and the four-layer PCB thickness of EVAL-LT8356-1-AZ. For best efficiency and PWM dimming performance, the EMI filters can be removed.

The LT8356-1's integrated PWMTG high-side PMOS driver assists with PWM dimming of the connected LEDs. The LED string can be PWM-dimmed for accurate brightness control with an externally generated PWM signal for highest achievable dimming ratio. It can also utilize LT8356-1's internally generated PWM feature for up to 128:1 exponential dimming. When running PWM dimming, the SSFM aligns itself with the PWM signal for flicker-free operation of the LED string. This applies to both internal and external PWM dimming. The LT8356-1 uses CTRL and IADJ pins for two-pin analog dimming.

The input undervoltage lockout (UVLO), LED current, output overvoltage protection (OVP), and switching frequency, can all be easily adjusted with simple resistor changes to EVAL-LT8356-1-AZ. Modifications can be made to convert the board from buck-boost mode LED driver to boost and buck mode LED Driver, and maintain low EMI, PWM dimming and fault diagnostic features. Buck mode and boost LED Driver schematics are provided in the data sheet. Please consult the data sheet or the applications team regarding how to customize EVAL-LT8356-1-AZ.

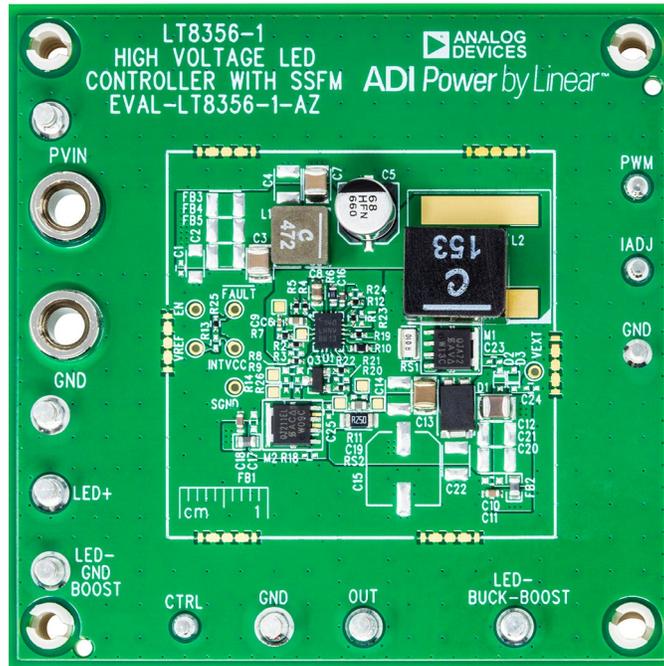
The LT8356-1 data sheet gives a complete description of the part, operation, and applications information. The data sheet must be read in conjunction with this demo manual for evaluation board EVAL-LT8356-1-AZ. The LT8356IUDCM-1 is assembled in a 20-lead side solderable plastic QFN package with a thermally enhanced exposed ground pad. Proper board layout is essential for maximum performance. See the data sheet section "Designing the Printed Circuit Board".

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

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

# DEMO MANUAL EVAL-LT8356-1-AZ

## BOARD PHOTO



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

PARAMETER	CONDITION	MIN	TYP	MAX	UNITS
Input Voltage PVIN Range	Operating	8		36	V
Switching Frequency ( $f_{\text{SW}}$ , SSFM ON)	R6 = 110k	250		310	kHz
$I_{\text{LED}}$	RS2 = 0.25 $\Omega$ , 8V < PVIN < 36V, $V_{\text{LED}} \leq 36\text{V}$ , CTRL and ADJ Turrets = Float		1		A
Open LED Protection (LED+ to LED-)	R8 = 10k, R20 = 10k, R22 = 340k		41		V
Peak Efficiency (SSFM ON)	PVIN = 12V, $V_{\text{LED}} = 36\text{V}$ , $I_{\text{LED}} = 1\text{A}$ with Filters		91.5		%
	PVIN = 12V, $V_{\text{LED}} = 36\text{V}$ , $I_{\text{LED}} = 1\text{A}$ without Filters		92		%
Peak Switch Current Limit	RS1 = 0.01 $\Omega$		10		A
Internally-Generated PWM Dimming Range	0.5V < $V_{\text{PWM}} < 1.5\text{V}$	1/128		100	%
Internally-Generated PWM Dimming Frequency	R6 = 110k		260		Hz
PVIN Undervoltage Lockout (UVLO) falling	R4 = 499k, R5 = 127k		6.5		V
PVIN Enable Turn-On (EN) rising	R4 = 499k, R5 = 127k		7.5		V

## QUICK START PROCEDURE

Evaluation board EVAL-LT8356-1-AZ is easy to set up to evaluate the performance of the LT8356-1. Follow the procedure below:

1. With power off, connect a string of LEDs that will run with forward voltage less than or equal to 36V (at 1A) to the LED+ and LED- (buck-boost) turrets on the PCB as shown in Figure 1.
2. With power off, connect the input power supply to the PVIN and GND turrets. Make sure that the DC input voltage will not exceed 36V.
3. Turn the input power supply on and make sure the voltage is between 8V and 36V for proper operation at max LED current.
4. Observe the LED string running at the programmed LED current.
5. To change the brightness with **analog dimming**, the CTRL and IADJ pins are used. The product of the offset CTRL and IADJ pin voltages set the current when the two voltages vary between 0.5V and 1.5V. Please refer to data sheet for more details.
6. To change the brightness with **external PWM dimming**, attach a rectangular waveform with varying duty cycle to the PWM turret. The ON and OFF voltages should be above 1.6V and below 0.4V, respectively.
7. To change the brightness with **internally generated PWM dimming**, adjust the voltage at the PWM pin between 0.5V and 1.5V to vary the duty ratio of the internal PWM generator.

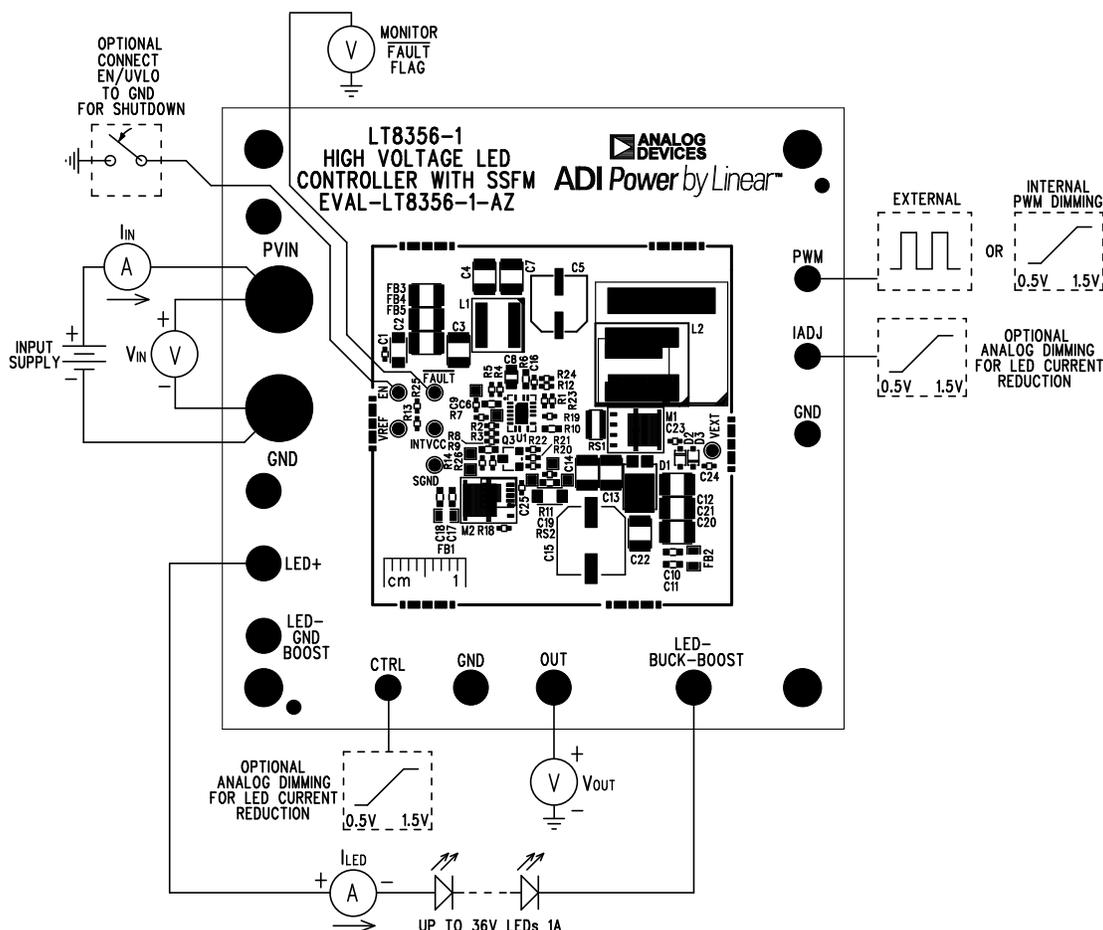


Figure 1. Setup Drawing for EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver (\*See Boost LED Driver Setup Section for More Information on Boost-Only Topology)

## BOOST LED DRIVER SETUP

EVAL-LT8356-1-AZ is assembled as a buck-boost mode LED Driver, but with minor adjustments can be reconfigured as a boost LED driver. In buck-boost mode, the LED connection is at VIN, and a level shifter is used for the FB network. In a boost LED Driver, the LED- connection is at GND and a resistor divider is used for the FB network.

**To configure EVAL-LT8356-1-AZ as a boost LED driver,** remove R20, R22, Q3, FB2, C12 and C11. Install 0Ω for

R14 and 1M for R9. Consult the data sheet for OVP calculations and details about the FB pin. Connect the LED string from LED+ to LED- (GND boost) as seen in Figure 2.

Note that when EVAL-LT8356-1-AZ is reconfigured as a boost LED Driver, other components may need to be adjusted depending on their voltage rating and power capabilities.

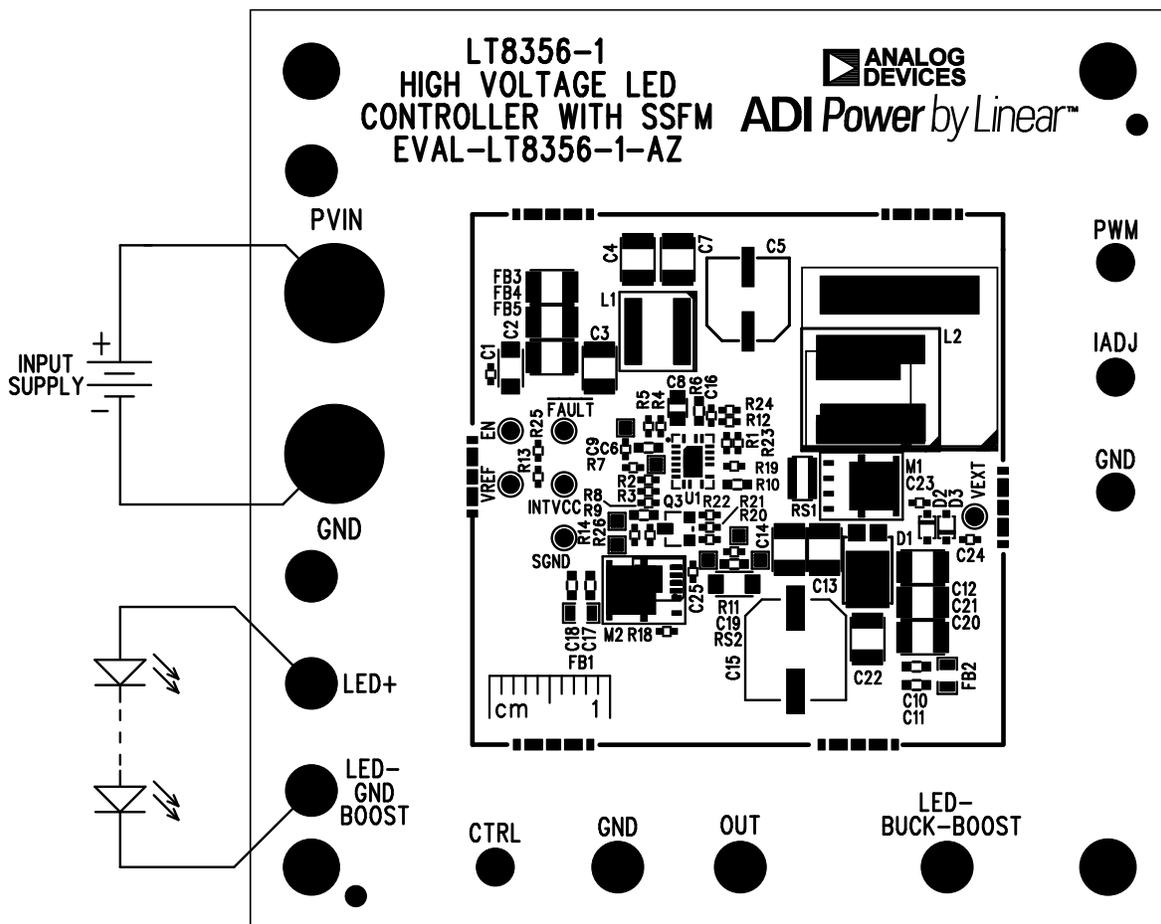
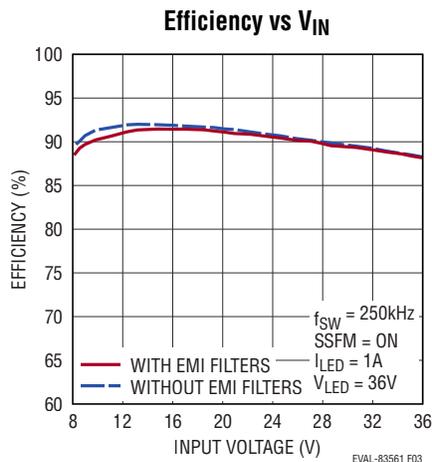
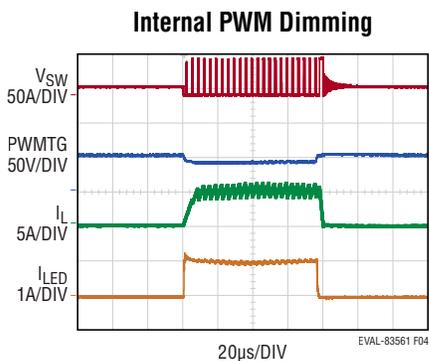


Figure 2. EVAL-LT8356-1-AZ as a Boost LED Driver

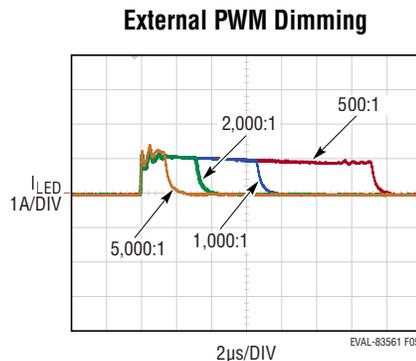
## TEST RESULTS



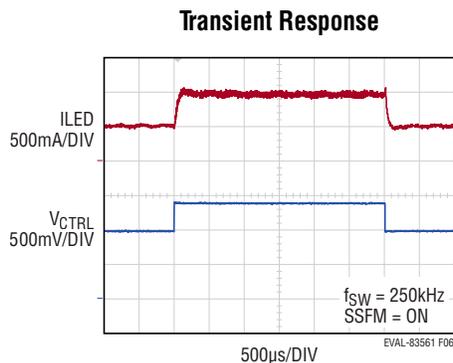
**Figure 3. EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver Efficiency vs Input Voltage**



**Figure 4. EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver Internal 260Hz 2% PWM Dimming with EMI Filters and SSFM ON: 12VIN, 36VLED, 1A**



**Figure 5. EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver External 150Hz PWM Dimming with EMI Filters and SSFM ON: 12VIN, 36VLED, 1A**



**Figure 6. EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver: 50% to 100% to 50% Load Step Transient Response, 12VIN**

## TEST RESULTS

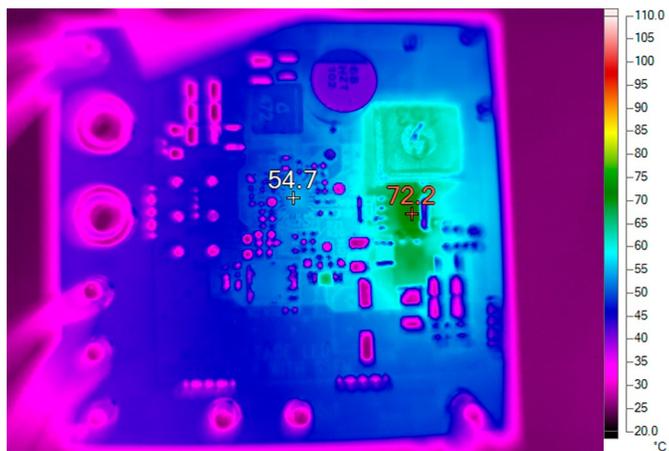
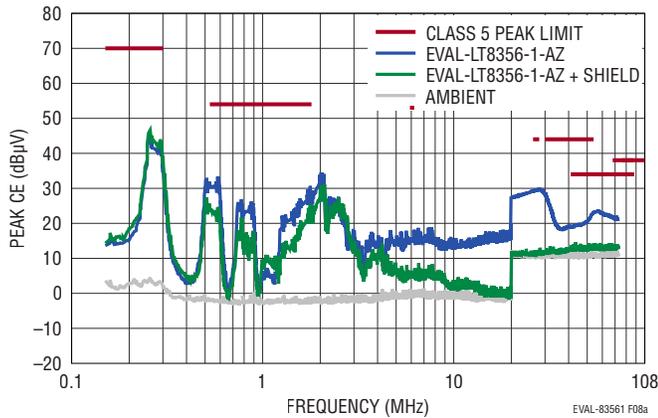
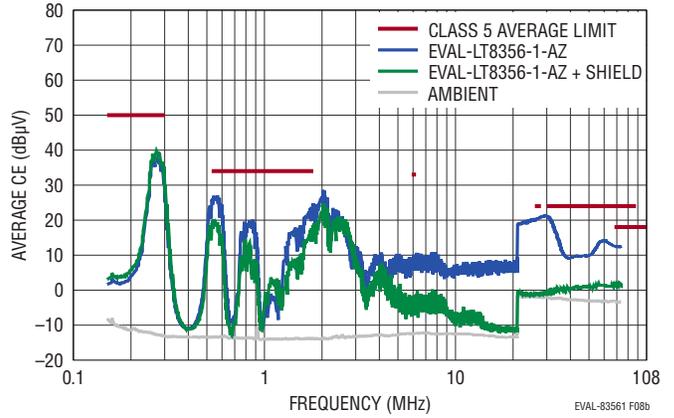


Figure 7. EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver Board  
Thermal Image with Filters and SSFM ON:  $12V_{IN}$ ,  $36V_{LED}$ , 1A

## TEST RESULTS

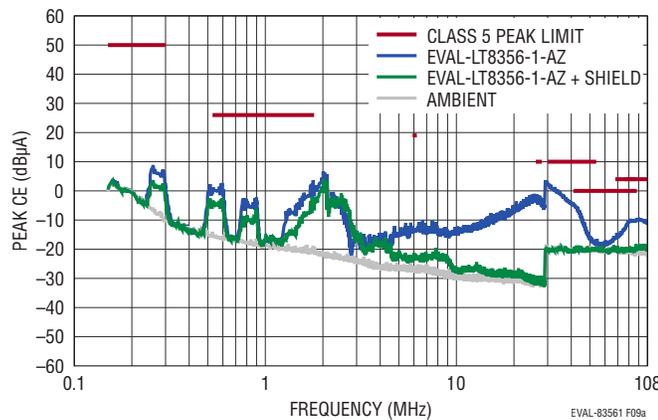


(a) CISPR25 Peak Conducted EMI – Voltage Method

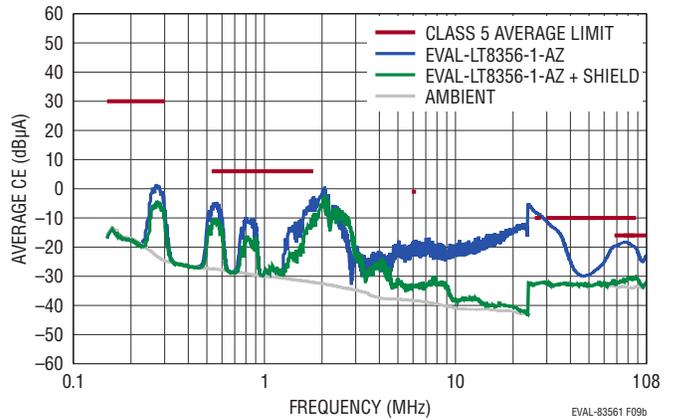


(b) CISPR25 Average Conducted EMI – Voltage Method

Figure 8. EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver Conducted Emissions (Voltage Method): 12V<sub>IN</sub>, 36V<sub>LED</sub>, 1A (SSFM ON)

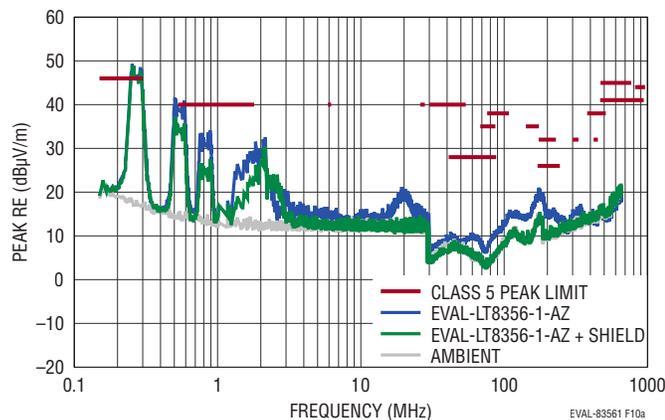


(a) CISPR25 Peak Conducted EMI – Current Method

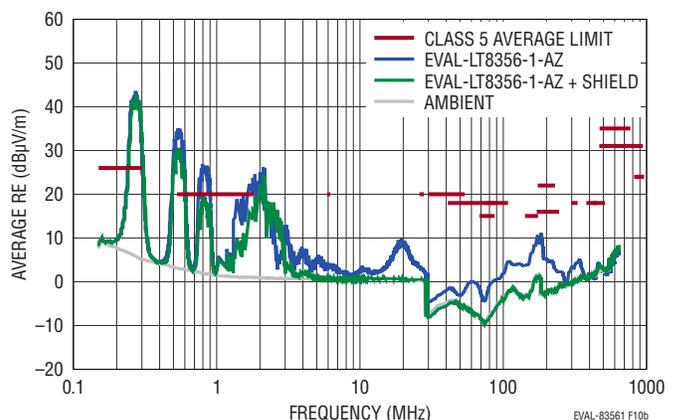


(b) CISPR25 Average Conducted EMI – Current Method

Figure 9. EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver Conducted Emissions (Current Method): 12V<sub>IN</sub>, 36V<sub>LED</sub>, 1A (SSFM ON)



(a) CISPR25 Peak Radiated EMI



(b) CISPR25 Average Radiated EMI

Figure 10. EVAL-LT8356-1-AZ as Buck-Boost Mode LED Driver Radiated Emissions: 12V<sub>IN</sub>, 36V<sub>LED</sub>, 1A (SSFM ON)

## EMISSIONS SHIELD (OPTION)

For the lowest emissions, an EMI shield can be attached to EVAL-LT8356-1-AZ. The PCB was fabricated with placeholders for six shield clips that can hold a 44mm × 44mm metal shield. Part number for an example shield can be found in the Parts List section in the Optional EMI

Filter Components section. The Top silkscreen picture, Figure 11, shows the placeholders for the six surface mount shield clips. Emissions can be tested with and without the removable clip-shield.

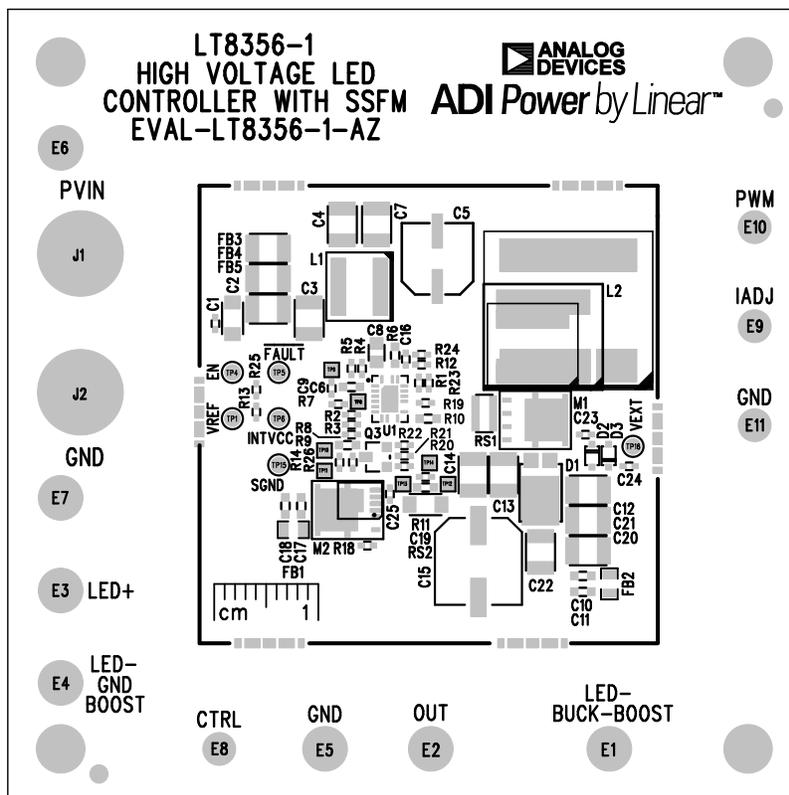


Figure 11. EVAL-LT8356-1-AZ Top Silkscreen Outlining Placement of Shield Clips and EMI Shield on PCB

## PARTS LIST

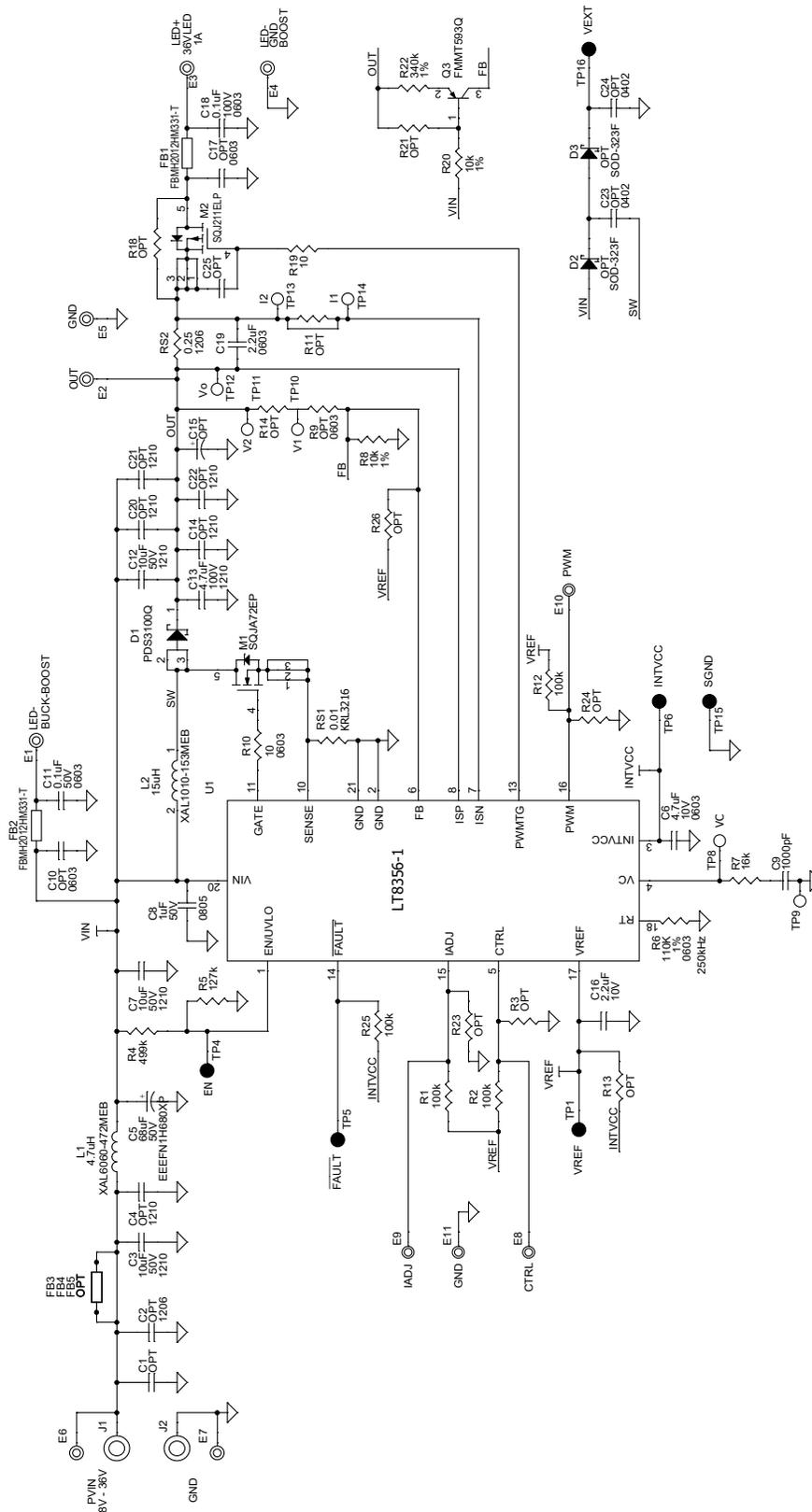
ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Required Circuit Components</b>				
1	1	C7	CAP., 10 $\mu$ F, X7S, 50V, 10%, 1210, AEC-Q200, NO SUBS ALLOWED	MURATA, GCM32EC71H106KA03L
2	1	C5	CAP., 68 $\mu$ F, ALUM ELECT, 50V, 20%, 6.3mm x 7.7mm, SMD, RADIAL, AEC-Q200	PANASONIC, EEEFN1H680XP
3	1	C6	CAP., 4.7 $\mu$ F, X5R, 10V, 10%, 0603, AEC-Q200	TAIYO YUDEN, LMK107BJ475KAHT
4	1	C8	CAP., 1 $\mu$ F, X7R, 50V, 10%, 0805, AEC-Q200	MURATA, GCM21BR71H105KA03L
5	1	C9	CAP., 1000pF, X7R, 50V, 10%, 0402, AEC-Q200	MURATA, GCM155R71H102KA37D
6	1	C12	CAP., 10 $\mu$ F, X7S, 50V, 10%, 1210, AEC-Q200	MURATA, GCM32EC71H106KA03L
7	1	C13	CAP., 4.7 $\mu$ F, X7S, 100V, 10%, 1210, AEC-Q200	MURATA, GCM32DC72A475KE02L
8	1	C16	CAP., 2.2 $\mu$ F, X6S, 10V, 10%, 0402, AEC-Q200	MURATA, GRT155C81A225KE13D
9	1	C19	CAP., 2.2 $\mu$ F, X5R, 25V, 10%, 0603, AEC-Q200	TAIYO YUDEN, TMK107BBJ225KAHT
10	1	D1	DIODE, SCHOTTKY, 100V, 3A, POWERDI5, AEC-Q101	DIODES INC., PDS3100Q-13
11	1	L2	IND., 15 $\mu$ H, PWR, SHIELDED, 20%, 13.8A, 18.6m $\Omega$ , 11.8mm x 10.5mm, XAL1010, AEC-Q200	COILCRAFT, XAL1010-153MEB
12	1	M1	XSTR., MOSFET, N-CH, 100V, 37A, PowerPAK SO-8L, AEC-Q101	VISHAY, SQJA72EP-T1_GE3
13	1	M2	XSTR., MOSFET, P-CH, 100V, 33.6A, PowerPAK SO-8L, AEC-Q101	VISHAY, SQJ211ELP-T1_GE3
14	1	Q3	XSTR., PNP, 100V, 1A, SOT-23-3, AEC-Q101	DIODES INC., FMMT593QTA
15	4	R1, R2, R12, R25	RES., 100k, 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402100KJNED
16	1	R4	RES., 499k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402499KFKED
17	1	R5	RES., 127k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402127KFKED
18	1	R6	RES., 110k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603110KFKEA
19	1	R7	RES., 16k, 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW040216K0JNED
20	2	R8, R20	RES., 10k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW040210K0FKED
21	1	R19	RES., 10 $\Omega$ , 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW040210R0JNED
22	1	R22	RES., 340k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402340KFKED
23	1	RS1	RES., 0.01 $\Omega$ , 1%, 1.5A, 1206, LONG-SIDE TERM., METAL, SENSE, AEC-Q200	SUSUMU, KRL3216E-C-R010-F-T1
24	1	RS2	RES., 0.25 $\Omega$ , 1%, 1/2W, 1206, SENSE, AEC-Q200	YAGEO, PT1206FR-7W0R25L
25	1	U1	IC, LED DRIVER CTRLR, QFN-20	ANALOG DEVICES, LT8356IUDCM-1#WPBF
<b>Optional EMI Filter Components</b>				
26	1	C3	CAP., 10 $\mu$ F, X7S, 50V, 10%, 1210, AEC-Q200, NO SUBS ALLOWED	MURATA, GCM32EC71H106KA03L
27	1	C11	CAP., 0.1 $\mu$ F, X7R, 50V, 10%, 0603, AEC-Q200	TDK, CGA3E2X7R1H104K080AA
28	1	C18	CAP., 0.1 $\mu$ F, X7S, 100V, 10%, 0603, AEC-Q200	TDK, CGA3E3X7S2A104K080AB
29	2	FB1, FB2	IND., 330 $\Omega$ AT 100MHz, FERRITE BEAD, 25%, 1.8A, 80m $\Omega$ , 0805, 1LN	TAIYO YUDEN, FBMH2012HM331-T
30	1	L1	IND., 4.7 $\mu$ H, PWR, SHIELDED, 20%, 11A, 14.4m $\Omega$ , 6.76mm x 6.56mm, XAL6060, AEC-Q200	COILCRAFT, XAL6060-472MEB
31	1	R10	RES., 10 $\Omega$ , 5%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW060310R0JNEA
32	0	FB3-FB5	IND., OPTION, FERRITE BEAD, 1210	
33	0	C1	CAP., OPTION, 0402	

# DEMO MANUAL EVAL-LT8356-1-AZ

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
34	0	C2	CAP., OPTION, 1206	
35	0	C4	CAP., OPTION, 1210	
36	0	C10, C17	CAP., OPTION, 0603	
37	0	CL1-CL6	OPTION, WE-SHC CABINET CLIP 6.5mm × 0.8mm × 1.27mm	WURTH, 369 000 00
38	0	SH1	OPTION, WE-SHC CABINET SHIELD 44.37mm × 44.37mm	WURTH, 369 074 06S
<b>Optional Electrical Components</b>				
39	0	C1, C23-C25	CAP., OPTION, 0402	
40	0	C4, C14, C20-C22	CAP., OPTION, 1210	
41	0	C15	CAP., OPTION, ALUM. ELECT., SMD	
42	0	D2, D3	DIODE, OPTION, SOD-323F	
43	0	R3, R11, R13, R14, R18, R21, R23, R24, R26	RES., OPTION, 0402	
44	0	R9	RES., OPTION, 0603	
<b>Hardware: For Demo Board Only</b>				
45	7	E1-E7	TEST POINT, TURRET, 0.094" MTG. HOLE, PCB 0.062" THK	MILL-MAX, 2501-2-00-80-00-00-07-0
46	4	E8-E11	TEST POINT, TURRET, 0.064" MTG. HOLE, PCB 0.062" THK	MILL-MAX, 2308-2-00-80-00-00-07-0
47	2	J1, J2	CONN., BANANA JACK, FEMALE, THT, NON-INSULATED, SWAGE, 0.218	KEYSTONE, 575-4
48	4	MH1-MH4	STANDOFF, NYLON, SNAP-ON, 0.50"	KEYSTONE, 8833

## SCHEMATIC DIAGRAM



NOTES: UNLESS OTHERWISE SPECIFIED.

1. ALL RESISTORS 5% 0402.

2. ALL CAPACITORS 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.