ANALOG DEVICES

LT8376
60V, 2A Silent Switcher
Synchronous Step-Down LED Driver

DESCRIPTION

Evaluation board EVAL-LT8376-AZ is a 60V, 2A synchronous Buck LED driver featuring the LT®8376. EVAL-LT8376-AZ drives a single string of LEDs up to 36V at 1.5A when V_{IN} is between 43V and 57V. EVAL-LT8376-AZ has an undervoltage lockout (UVLO) set at 40V with 2V hysteresis for turn-on. EVAL-LT8376-AZ runs at 350kHz switching frequency and features optional spread spectrum modulation (SSFM). With SSFM enabled, LT8376 modulates its switching frequency from f_{SW} to $f_{SW} + 25\%$ to reduce EMI emissions.

The LT8376 has an input voltage range of 3.6V to 60V. LT8376 has internal, synchronous 60V switches for high efficiency and small size. LT8376 has an adjustable switching frequency between 200kHz and 2MHz. The LT8376 can be synchronized with an external clock source or configured with SSFM enabled for low EMI. EVAL-LT8376-AZ includes a SYNC/SSFM jumper to configure the LT8376 for either external frequency synchronization, SSFM enabled for low EMI, or set to normal operation with SSFM disabled.

The LT8376'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 or an internally-generated PWM signal. EVAL-LT8376-AZ has jumpers that can be set to switch between internally-generated PWM signal, externally generated PWM signal, and 100% on with no PWM signal. The LT8376 can also be analog dimmed by placing a controllable DC voltage on the CTRL pin. When running PWM dimming with SSFM enabled, 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.

Small ceramic input and output capacitors are used to save space and cost. The input and output filters on EVAL-LT8376-AZ reduce its EMI. The filters consist of a small ferrite bead or inductor and high frequency ceramic capacitors. 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-LT8376-AZ. For best efficiency and PWM dimming performance, the EMI filters at the input and output can be removed.

The open LED overvoltage protection (OVP) uses the IC's constant voltage regulation loop to regulate the output to approximately 41V if the LED string is opened. The output current can be monitored through the ISMON pin. Also, the $\overline{FAULT}$ pin can be used for open and short detection.

The input undervoltage lockout (UVLO), LED current, output overvoltage protection (OVP), and switching frequency, can all be easy adjusted with simple modifications to EVAL-LT8376-AZ.

The LT8376 data sheet gives a complete description of the device, operation, and applications information. The data sheet must be read in conjunction with this demo manual for evaluation board EVAL-LT8376-AZ. The LT8376RV is assembled in a 28-lead plastic LQFN 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.

BOARD PHOTO
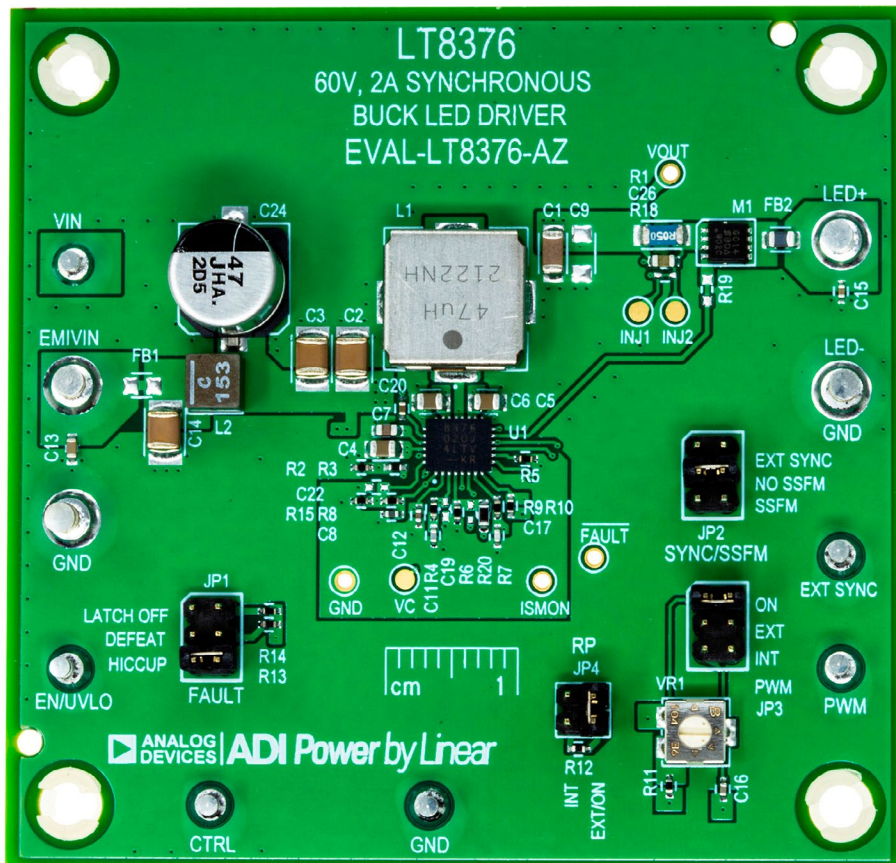
PERFORMANCE SUMMARY   Specifications are at T_A = 25°C

PARAMETER	CONDITION	MIN	TYP	MAX	UNITS
Input Voltage EMIVIN Range	Operating	43		57	V
Switching Frequency (f_{SW})	R5 = 287k, JP2 = NO SSFM		350		kHz
Spread Spectrum (SSFM) Range	R5 = 287k, JP2 = SSFM	350		440	kHz
I_{LED}	R1 = 0.05Ω, R8, R15 = 100k, 43V < V_{IN} < 57V, V_{LED} = 36V		1.5		A
Open LED Voltage V_{OUT} (OVP)	R7 = 1M, R6 = 24.9k		41		V
Typical Efficiency	V_{IN} = 50V, V_{LED} = 36V, I_{LED} = 1.5A				
	with Filters		96		%
	without Filters		96.5		%
Internally-Generated PWM Dimming Range	JP3 = INT, JP4 = INT	1/128		100	%
Internally-Generated PWM Dimming Frequency	JP3 = INT, JP4 = INT R12 = 118k, R5 = 287k		192		Hz
Peak Current Limit		3.3	3.6	3.9	A
EMIVIN Undervoltage Lockout (UVLO) Falling	R3 = 402k, R2 = 12.7k		39.8		V
EMIVIN Enable Turn-On (EN) Rising	R3 = 402k, R2 = 12.7k		42.3		V

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PROGRAMMING LED CURRENT VIA CTRL PIN

The LT8376 uses the voltage across the current sense resistor R1, and the voltage at the CTRL pin to program the LED current. The maximum current sense resistor voltage that can be programmed on the LT8376 is 100mV. When V_{CTRL} falls below 250mV, the LED current will be 0A and when V_{CTRL} is above 1.25, the LED current will be the maximum set by the current sense resistor. EVAL-LT8376-AZ uses a 50mΩ current sense resistor, and a voltage divider on the CTRL pin to regulate the LED current to 1.5A. R8 and R15 set the voltage divider from V_{REF} pin to the CTRL pin. EVAL-LT8376-AZ will produce a maximum LED current of 2A when $V_{CTRL} > 1.25V$. The LED current can be analog dimmed to another current level by adjusting R8 and R15. Please refer to the data sheet for more details.

QUICK START PROCEDURE

Evaluation board EVAL-LT8376-AZ is easy to set up to evaluate the performance of the LT8376. 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 1.5A) to the LED+ and LED– turrets on the PCB as shown in Figure 1.

2. Set JP4 to EXT/ON and JP3 to ON for 100% always on LED operation. Set JP2 to NO SSFM to run without SSFM.

3. With power off, connect the input power supply to the EMIVIN and GND turrets. Make sure that the DC input voltage will not exceed 60V.

4. Turn the input power supply on and make sure the voltage is between 43V and 57V for proper operation at max LED current.

5. Observe the LED string running at the programmed LED current.

6. To change the brightness with analog dimming, simply attach a voltage source to the CTRL test point and set the voltage between 0.25V and 1.25V. See data sheet for details.

7. To change the brightness with external PWM dimming, set JP4 to EXT/ON and JP3 to EXT. Attach a 1.5V rectangular waveform with varying duty cycle to the PWM terminal.

8. To change the brightness with internally-generated PWM dimming, set JP4 to INT and JP3 to INT. Adjust the setting of the V_{R1} variable resistor with a small flathead screwdriver to toggle between 0% and 100% PWM dimming duty cycle in 1/128 steps.

9. To enable spread spectrum frequency modulation, set JP2 to SSFM.
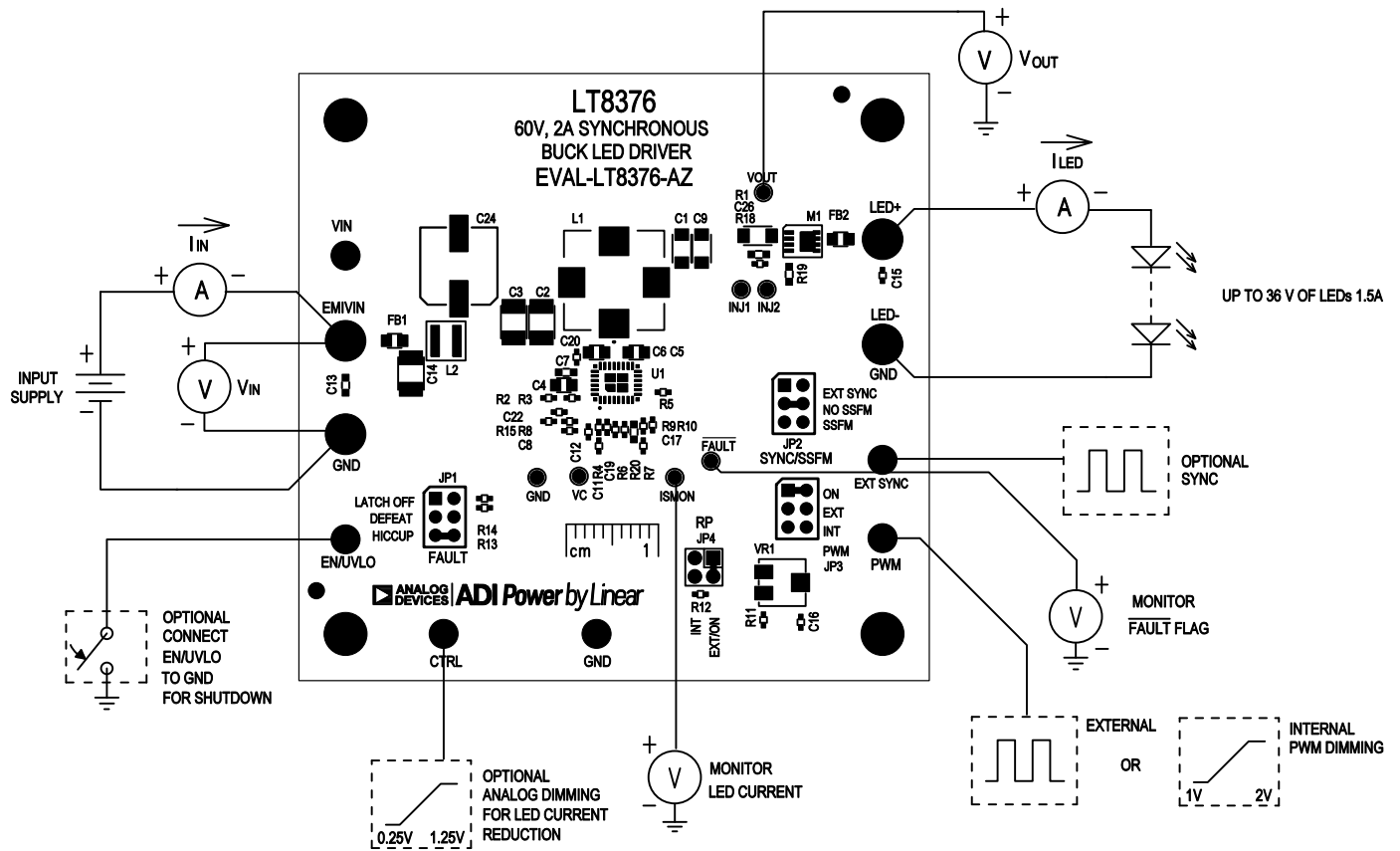
QUICK START PROCEDURE

Figure 1. Setup Drawing for EVAL-LT8376-AZ

TEST RESULTS

Efficiency vs V$_{IN}$
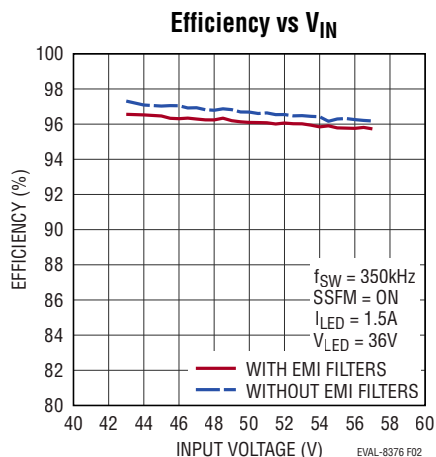

f$_{SW}$ = 350kHz
SSFM = ON
I$_{LED}$ = 1.5A
V$_{LED}$ = 36V

— WITH EMI FILTERS
-- WITHOUT EMI FILTERS

EVAL-8376 F02

Figure 2. EVAL-LT8376-AZ Efficiency vs V$_{IN}$

Internal PWM Dimming

V$_{SW}$ 50V/DIV

PWMTG 20V/DIV

I$_L$ 2A/DIV

I$_{LED}$ 2A/DIV

10µs/DIV   EVAL-8376 F03

128:1 PWM RATIO, 192Hz PWM FREQUENCY
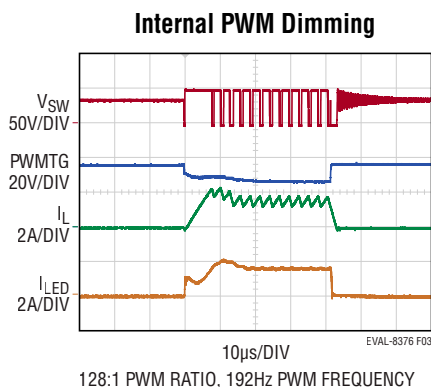
Figure 3. EVAL-LT8376-AZ Internal PWM Dimming with EMI Filters: 48V$_{IN}$, 36V$_{LED}$, 1.5A

Transient Response

I$_{LED}$ 500mA/DIV

V$_{CTRL}$ 500mV/DIV

500µs/DIV   EVAL-8376 F04
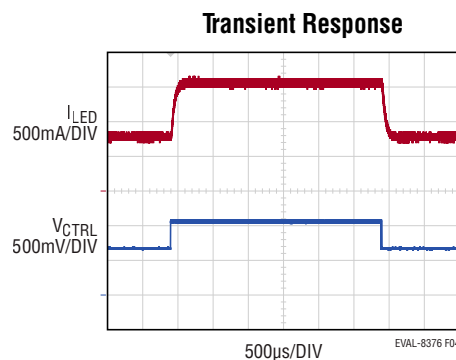
Figure 4. EVAL-LT8376-AZ: 50% to 100% to 50% Load Step Transient Response, 48V$_{IN}$
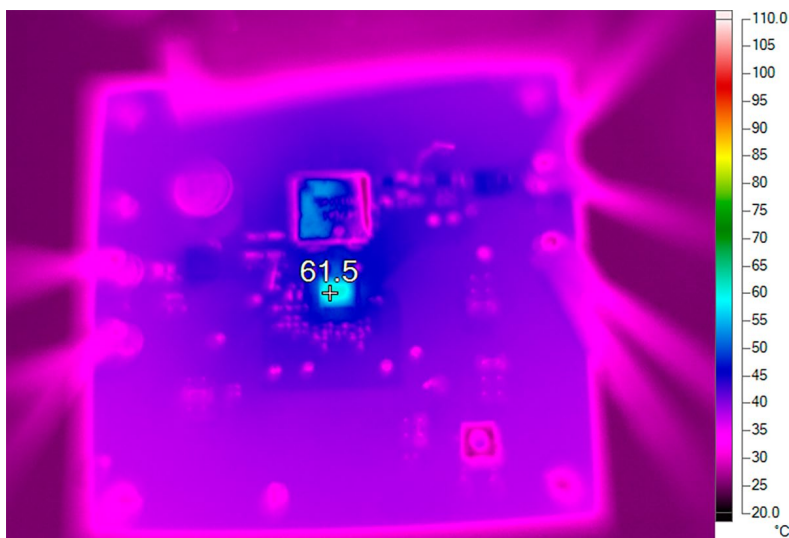
Figure 5. EVAL-LT8376-AZ Board Thermal Image: 48V$_{IN}$, 36V$_{LED}$, 1.5A (SSFM ON)

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TEST RESULTS
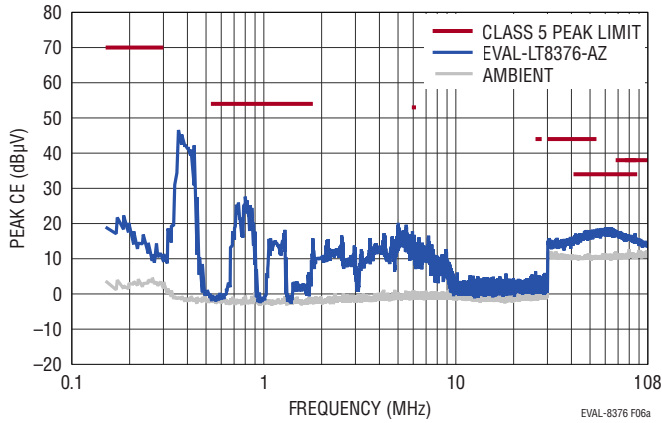
(a) CISPR25 Peak Conducted EMI – Voltage Method
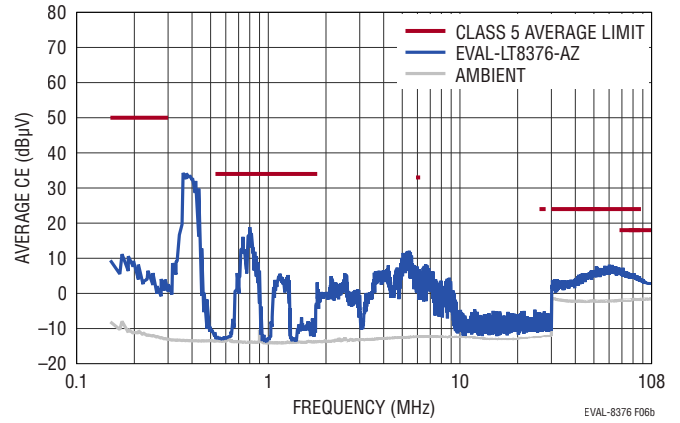
(b) CISPR25 Average Conducted EMI – Voltage Method

Figure 6. EVAL-LT8376-AZ Conducted Emissions (Voltage Method): 48V$_{IN}$, 36V$_{LED}$, 1.5A (SSFM ON)
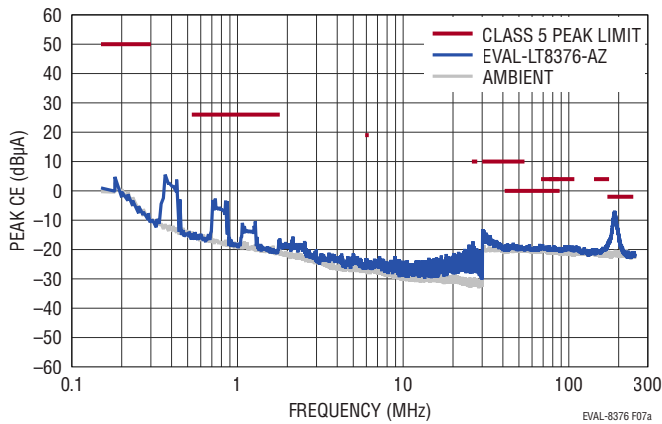
(a) CISPR25 Peak Conducted EMI – Current Method
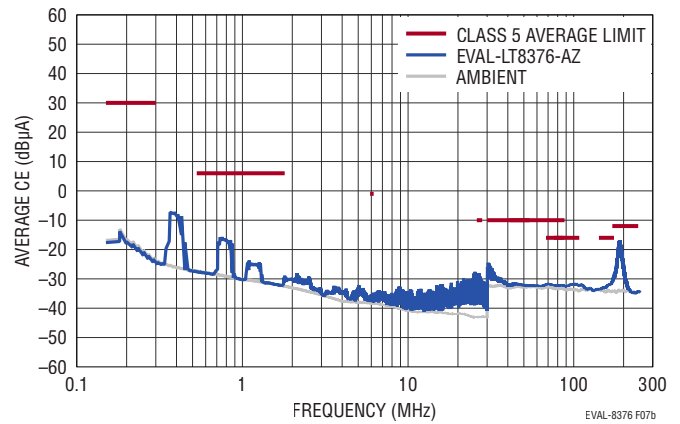
(b) CISPR25 Average Conducted EMI – Current Method

Figure 7. EVAL-LT8376-AZ Conducted Emissions (Current Method): 48V$_{IN}$, 36V$_{LED}$, 1.5A (SSFM ON)
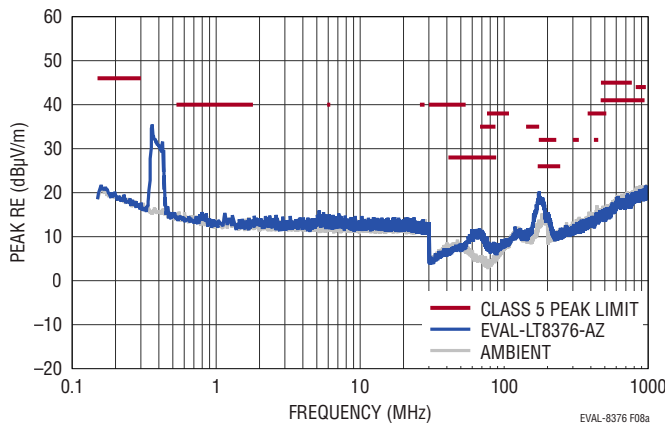
(a) CISPR25 Peak Radiated EMI
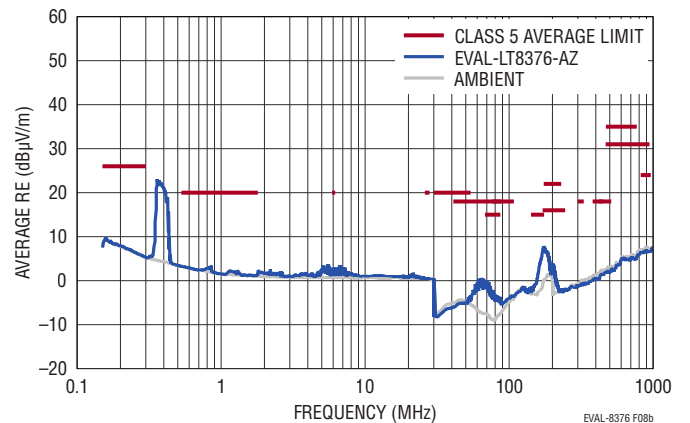
(b) CISPR25 Average Radiated EMI

Figure 8. EVAL-LT8376-AZ Radiated Emissions: 48V$_{IN}$, 36V$_{LED}$, 1.5A (SSFM ON)

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PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	1	C1	CAP., 10µF, X7R, 50V, 10%, 1206	SAMSUNG, CL31B106KBHNNNE
2	2	C2, C3	CAP., 4.7µF, X7S, 100V, 10%, 1210	SAMSUNG, CL32Y475KCVZW6E
3	3	C4-C6	CAP., 0.47µF, X7R, 100V, 10%, 0805	AVX, 08051C474KAZ2A
4	1	C7	CAP., 2.2µF, X7R, 10V, 10%, 0603	MURATA, GRM188R71A225KE15D
5	1	C8	CAP., 2.2µF, X5R, 10V, 20%, 0402	WURTH ELEKTRONIK, 885012105013
6	1	C11	CAP., 100pF, C0G, 50V, 5%, 0402, AEC-Q200	MURATA, GCM1555C1H101JA16D
7	1	C12	CAP., 0.01µF, X7R, 25V, 10%, 0402, AEC-Q200	TAIYO YUDEN, TMK105B7103KVHF
8	1	C16	CAP., 1µF, X5R, 10V, 10%, 0402	SAMSUNG, CL05A105KP5NNNC
9	1	C17	CAP., 47pF, C0G, 50V, 10%, 0402	AVX, 04025A470KAT2A
10	1	C20	CAP., 0.1µF, X5R, 100V, 10%, 0402, SMD	MURATA, GRM155R62A104KE14D
11	1	C24	CAP., 47µF, ALUM ELECT, 63V, 20%, 8mm × 10.2mm, F, SMD, RADIAL	PANASONIC, EEEHA1J470UP
12	1	C26	CAP., 2.2µF, X5R, 25V, 10%, 0603, AEC-Q200	TAIYO YUDEN, TMK107BBJ225KAHT
13	1	L1	IND., 47µH, PWR, SHIELDED, 20%, 3.1A, 4040DD, IHLE-5A SERIES, AEC-Q200	VISHAY, IHLE4040DDER470M5A
14	1	M1	XSTR., MOSFET, P-CH, 60V, 16A, PowerPAK 1212-8, AEC-Q101	VISHAY, SQ7415AEN-T1-GE3
15	1	R1	RES., 0.05Ω, 1%, 1/2W, 1206, SENSE	IRC, LRC-LR1206LF-01-R050-F
16	1	R2	RES., 12.7k, 1%, 1/16W, 0402	YAGEO, RC0402FR-0712K7L
17	1	R3	RES., 402k, 1%, 1/10W, 0402, AEC-Q200	PANASONIC, ERJ2RKF4023X
18	1	R4	RES., 16k, 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW040216K0JNED
19	1	R5	RES., 287k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402287KFKED
20	1	R6	RES., 24.9k, 1%, 1/16W, 0402, AEC-Q200	NIC, NRC04F2492TRF
21	1	R7	RES., 1M, 1%, 1/10W, 0603, AEC-Q200	NIC, NRC06F1004TRF
22	2	R8, R15	RES., 100k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402100KFKED
23	1	R9	RES., 47k, 5%, 1/16W, 0402, AEC-Q200	NIC, NRC04J473TRF
24	1	R10	RES., 100k, 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402100KJNED
25	1	R11	RES., 91k, 5%, 1/16W, 0402, AEC-Q200	NIC, NRC04J913TRF
26	1	R12	RES., 118k, 1%, 1/16W, 0402, AEC-Q200	NIC, NRC04F1183TRF
27	1	R13	RES., 1M, 1%, 1/10W, 0402	NIC, NRC04F1004TRF
28	1	R14	RES., 2M, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW04022M00FKED
29	1	U1	IC, 60V 2A, SYNCHRONOUS BUCK LED DRIVER, LQFN-28	ANALOG DEVICES, LT8376RV#PBF
30	1	VR1	RES., 100k, 20%, 1/4W, SMD 4mm SQ, 1-TURN, TOP ADJ., TRIMPOT	BOURNS, 3314J-1-104E
Optional EMI Filter Components				
31	1	C13	CAP., 0.1µF, X7R, 100V, 10%, 0603	AVX, 06031C104KAT2A
32	1	C14	CAP., 4.7µF, X7S, 100V, 10%, 1210	SAMSUNG, CL32Y475KCVZW6E
33	1	C15	CAP., 0.1µF, X7R, 50V, 10%, 0402, AEC-Q200	MURATA, GCM155R71H104KE02D
34	0	FB1	IND., 1k AT 100MHz, FERRITE BEAD, 25%, 1.5A, 150mΩ, 0805	TDK, MPZ2012S102AT000
35	1	FB2	IND., 600Ω AT 100MHz, FERRITE BEAD, 25%, 2A, 100mΩ, 0805	TDK, MPZ2012S601AT000

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
36	1	L2	IND., 15µH, PWD, 20%, 2.9A, 109mΩ, 4mm × 4mm, AEC-Q200	COILCRAFT, XAL4040-153MEB
Optional Electrical Components				
37	0	C9	CAP., 10µF, X7R, 50V, 10%, 1206	SAMSUNG, CL31B106KBHNNNE
38	0	C19, C22	CAP., OPTION, 0402	
39	0	R18	RES., 0Ω, 1/16W, 0402	NIC, NRC04Z0TRF
40	0	R19	RES., OPTION, 0603	
41	0	R20	RES., OPTION, 0402	
42	0	TP1, TP3, TP4	TESTPOINT, PCB COPPER FEATURE	N/A
43	0	TP2, TP5-TP7	TESTPOINT, PCB COPPER FEATURE	N/A
Hardware: For Demo Board Only				
44	6	E1, E6-E10	TEST POINT, TURRET, 0.064" MTG. HOLE, PCB 0.062" THK	MILL-MAX, 2308-2-00-80-00-00-07-0
45	4	E2-E5	TEST POINT, TURRET, 0.094" MTG. HOLE, PCB 0.062" THK	MILL-MAX, 2501-2-00-80-00-00-07-0
46	3	JP1-JP3	CONN., HDR, MALE, 2×3, 2mm, VERT, ST, THT	WURTH ELEKTRONIK, 62000621121
47	1	JP4	CONN., HDR, MALE, 2×2, 2mm, VERT, STR, THT	WURTH ELEKTRONIK, 62000421121
48	4	MP1-MP4	STANDOFF, NYLON, SNAP-ON, 0.375"	WURTH ELEKTRONIK, 702933000
49	4	XJP1-XJP4	CONN., SHUNT, FEMALE, 2-POS, 2mm	WURTH ELEKTRONIK, 60800213421

SCHEMATIC DIAGRAM
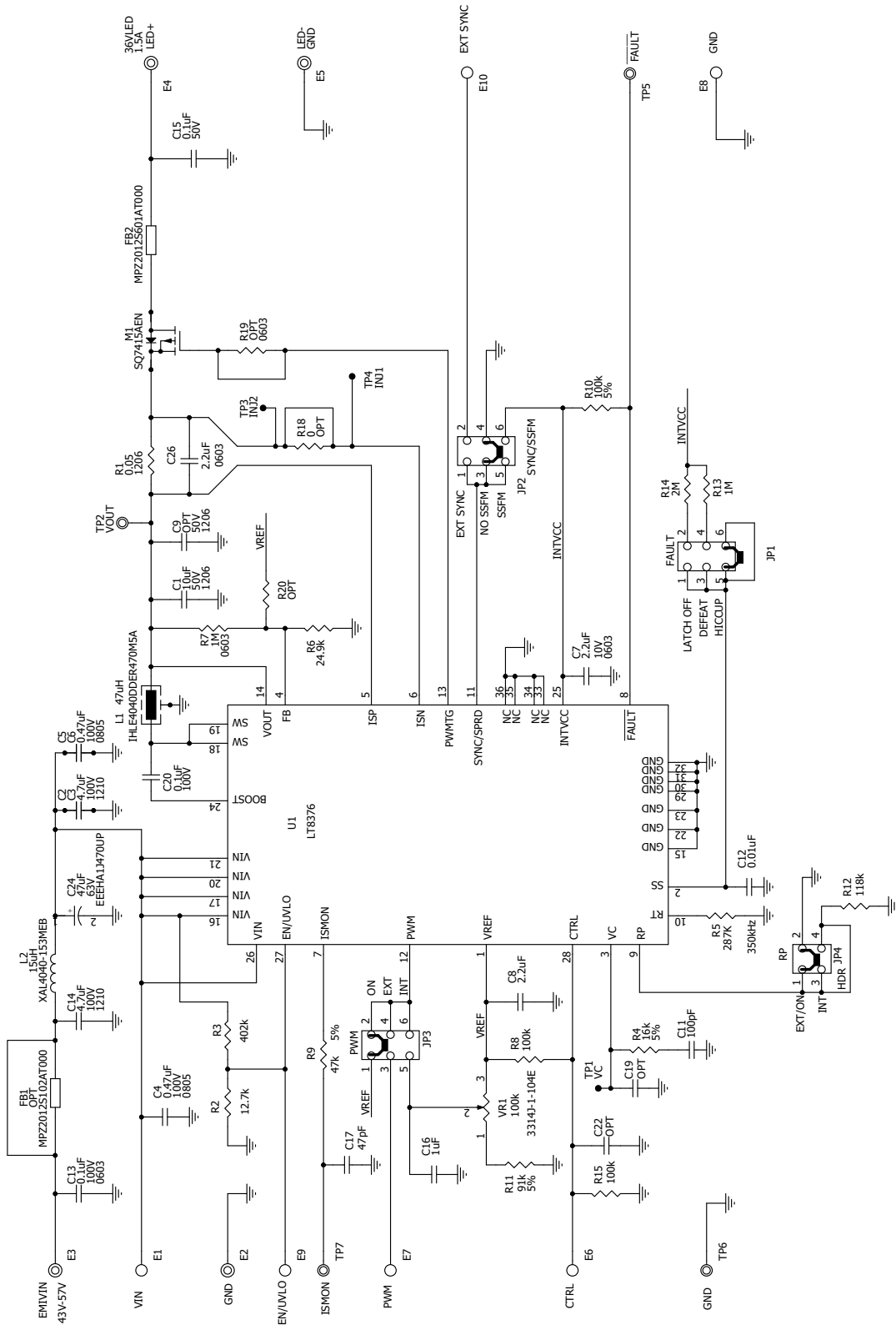
NOTE: UNLESS OTHERWISE SPECIFIED

1. ALL RESISTORS ARE 0402, 1%.
   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.