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## Contact us

Tel: +86-755-8981 8866 Fax: +86-755-8427 6832

Email & Skype: info@chipsmall.com Web: www.chipsmall.com

Address: A1208, Overseas Decoration Building, #122 Zhenhua RD., Futian, Shenzhen, China



## 60V Synchronous 4-Switch Buck-Boost Led Controller with Spread Spectrum

### DESCRIPTION

Demonstration circuit 2345A is a 60V synchronous 4-switch buck-boost LED controller with spread spectrum featuring the **LT<sup>®</sup>8391** LED driver. It accepts an input voltage from 4V to 60V and drives a single string of LEDs up to 25V at 2A. DC2345A runs at 400kHz switching frequency without spread spectrum, but spread spectrum frequency modulation (SSFM) can be enabled with a simple jumper. SSFM spreads the switching frequency to  $f_{sw} \pm 15\%$  for reduced EMI.

The LT8391 has a wide input voltage range down to 4V and up to 60V. It has adjustable switching frequency between 150kHz and 600kHz. There is a simple jumper option for external frequency synchronization, spread spectrum frequency modulation, or neither.

The LT8391 can be PWM dimmed with an external PWM signal and an internally-generated PWM signal. DC2345A has a jumper that can be set to switch between internally-generated PWM signal, externally-generated PWM signal, and no PWM signal (100% on). It can be analog dimmed with a control voltage on either of its two control pins. LT8391 features both open LED and short LED (LED+ to GND) protection as well as a fault output flag.

When run with both PWM dimming and spread spectrum, the spread spectrum aligns itself with the PWM signal for flicker-free operation.

Small ceramic input and output capacitors are used to save space and cost. The board is designed with capacitors on


both sides of the synchronous switches for a reduction in radiated EMI. The open LED overvoltage protection uses the IC's constant voltage regulation loop to regulate the output to approximately 29.7V if the LED string is opened although it may reach 32V peak during transient from running LEDs to open. There is a protection diode from LED+ to GND to prevent negative ringing during a short-circuit with long wires.

Undervoltage lockout can be adjusted on the circuit with a few simple resistor choices.

There is an EMI filter on the input of DC2345A. This filter has a 3.2 $\mu$ H inductor and two 4.7 $\mu$ F capacitors. It is effective in reducing the conducted EMI in the AM band to pass CISPR25 class 5 regulations. When run with SSFM, DC2345A has low conducted EMI.

The LT8391 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 demonstration circuit DC2345A. The LT8391EFE is assembled in a 28-lead plastic TSSOP (FE) package with a thermally enhanced ground pad. Proper board layout is essential for maximum thermal performance. See the data sheet section 'Layout Considerations'.

**Design files for this circuit board are available at <http://www.linear.com/demo/DC2345A>**

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# DEMO MANUAL DC2345A

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

PARAMETER	CONDITIONS	MIN	TYP	MAX
Input Voltage EMIVIN Range	Operating $V_{LED} = 25\text{V}$	4V		60V
Switching Frequency	$R3 = 100\text{k}$		400kHz	
$I_{LED}$	$R1 = 0.05\Omega$ $7.0\text{V} < PV_{IN} < 60\text{V}$ $V_{LED} = 25\text{V}$		2.0A	
$V_{LED}$ range	$R5 = 1\text{M}$ $R6 = 34.8\text{k}$			26V
Open LED Voltage $V_{OUT}$	$R5 = 1\text{M}$ $R6 = 34.8\text{k}$		29.7V	
Typical Efficiency (100% PWM DC)	$PV_{IN} = 14\text{V}$ $V_{LED} = 25\text{V}$ $I_{LED} = 2.0\text{A}$		97%	
Internally-Generated PWM Dimming Range	Operating $JP3 = \text{INT}$ $JP1 = \text{INT}$	1/128		100%
Internally-Generated PWM Dimming Frequency	Operating $JP3 = \text{INT}$ $JP1 = \text{INT}$ $R16 = 200\text{k}$		200Hz	
Peak Switch Current Limit Boost Region	$R2 = 0.004\Omega$		12.5A	
Peak Switch Current Limit Buck Region	$R2 = 0.004\Omega$		12.5A	

## QUICK START PROCEDURE

Demonstration circuit DC2345A is easy to set up to evaluate the performance of the LT8391. Follow the procedure below:

1. With power off, connect a string of LEDs that will run with forward voltage less than or equal to 25V (at 2A) to the LED+ and GND banana jacks on the PCB as shown in Figure 1.
2. Connect the EN/UVLO terminal to GND.
3. Set JP1 to EXT/ON and JP3 to ON for 100% always-on LED operation. Set JP2 to NO SPREAD/SYNC to run without SSFM or external synchronization.
4. With power off, connect the input power supply to the EMIVIN and GND banana jacks. Make sure that the DC input voltage will not exceed 60V.
5. Turn the input power supply on and make sure the voltage is between 4V and 60V for proper operation.
6. Release the EN/UVLO-to-GND connection.
7. Observe the LED string running at the programmed LED current.
8. To change the brightness with analog dimming, simply attach a voltage source to either the CTRL1 or CTRL2 terminal and set the voltage between 0V and 1.5V. See data sheet for details.
9. To change brightness with external PWM dimming, set JP1 to EXT/ON and JP3 to EXT. Attach a 3V rectangular waveform with varying duty cycle to the PWM terminal.
10. To change brightness with internally-generated PWM dimming, set JP1 to INT and JP3 to INT. Adjust the setting of the VR1 variable resistor with a small flat-head screwdriver to toggle between 0% and 100% PWM dimming duty cycle in 1/128 steps.
11. To enable spread spectrum frequency modulation, set JP2 to SPREAD ON.

**QUICK START PROCEDURE**

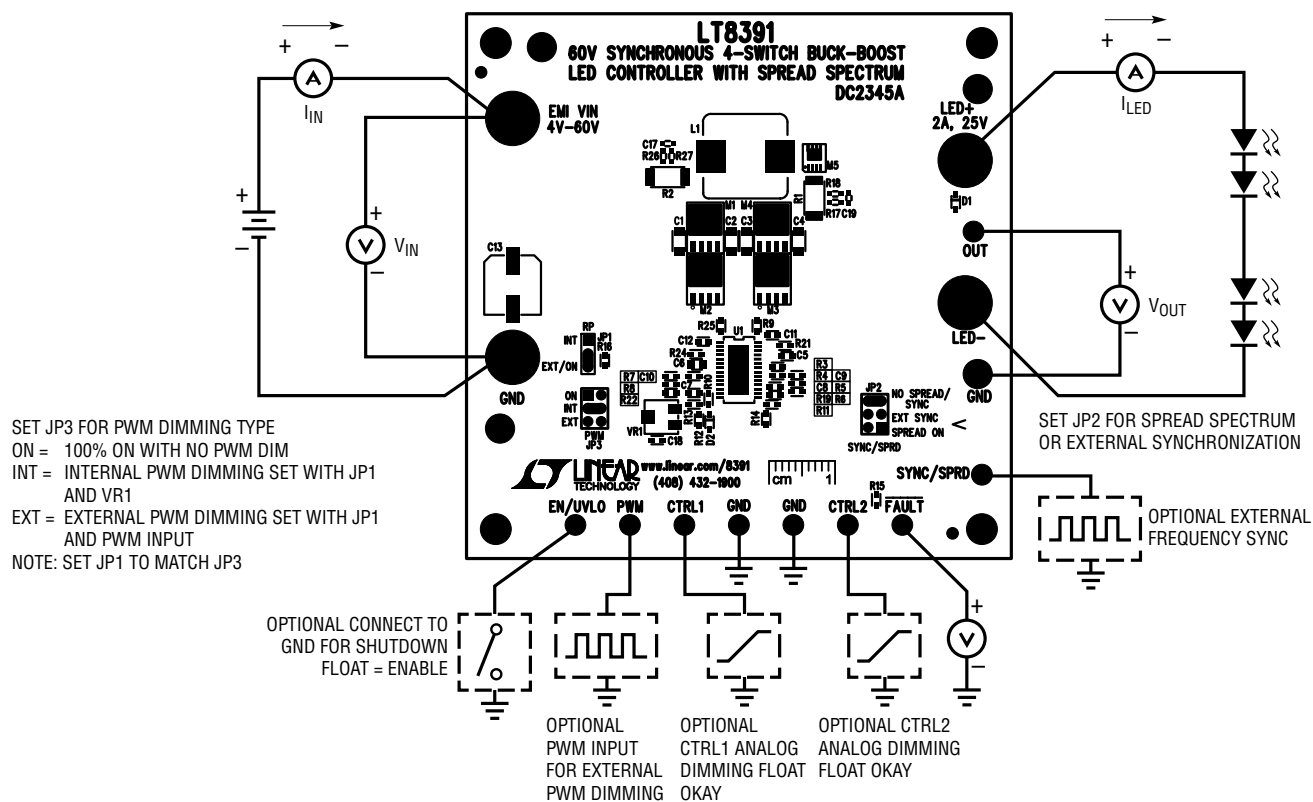
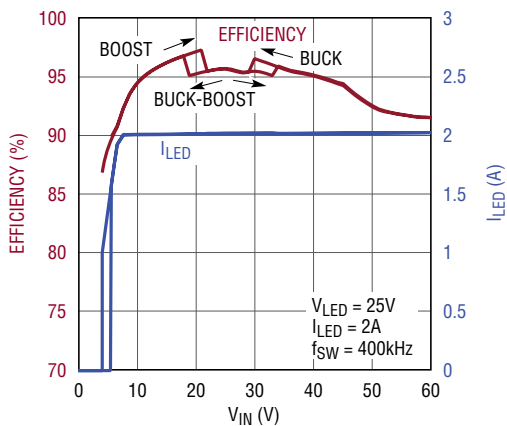
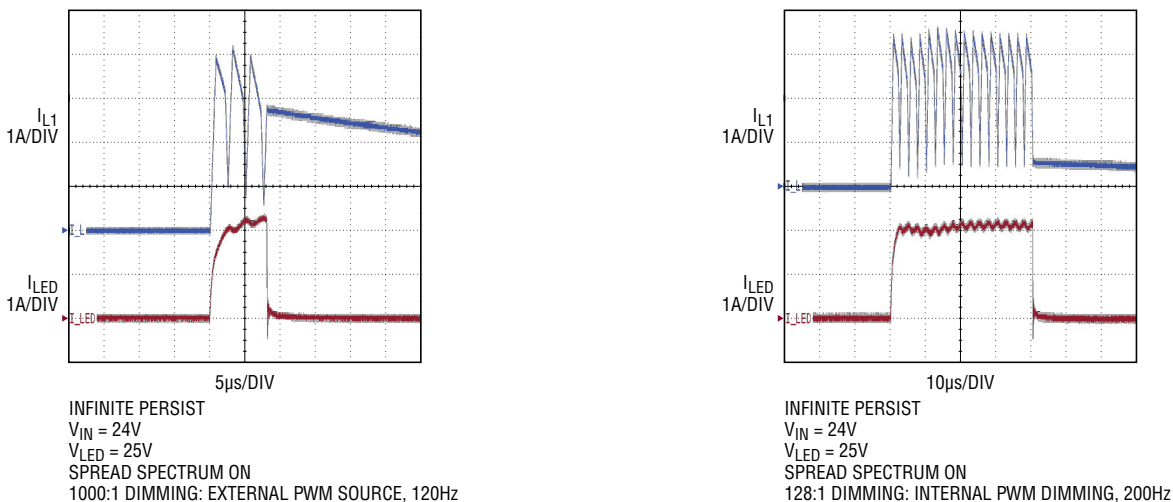


Figure 1. Test Procedure Setup Drawing for DC2345A

## QUICK START PROCEDURE



**Figure 2. DC2345A Efficiency and LED Current Versus Input Voltage for 25V 2A LED Load. Efficiency Peaks at 98% and Doesn't Stray Far from That Peak, Ranging from 95% to 97% Throughout the Typical 9V-16V Automotive Input Range. Also Shown, the LT8391 Peak Inductor Current Limit Can Maintain Stable Output with Reduced Output Power at Low  $V_{IN}$ .**



**Figure 3. Infinite-Persist Scope Traces Show PWM Dimming and SSFM Working Together for Flicker-Free Brightness Control with Both Externally and Internally Generated PWM Dimming.**

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Required Circuit Components</b>				
1	2	C1, C2	CAP, CER., 4.7 $\mu$ F, X7S, 100V, 10%, 1206	AVX, 12061Z475KAT2A
2	2	C3, C4	CAP, CER., 10 $\mu$ F, X5R, 50V, 10%, 1206	MURATA, GRM31CR61H106KA12L
3	1	C5	CAP, CER., 1 $\mu$ F, X5R, 50V, 10%, 0603	MURATA, GRM188R61H105KAALD
4	1	C6	CAP, CER., 1 $\mu$ F, X7S, 100V, 10%, 0805	TDK, C2012X7S2A105K125AB
5	1	C7	CAP, CER., 0.47 $\mu$ F, X7R, 16V, 10%, 0603	MURATA, GRM188R71C474KA88D
6	3	C8, C11, C12	CAP, CER., 0.1 $\mu$ F, X7R, 16V, 10%, 0603	MURATA, GRM188R71C104KA01D
7	2	C9, C17	CAP, CER., 10nF, X7R, 16V, 10%, 0603	AVX, 0603YC103KAT2A
8	1	C10	CAP, CER., 4.7 $\mu$ F, X5R, 10V, 10%, 0603	MURATA, GRM188R61A475KE15D
9	1	L1	IND., 4.7 $\mu$ H, 13.00 $\times$ 12.80mm	WURTH ELEKTRONIK, 7443550480
10	1	M1	MOSFET, 60V, TDSO8	INFINEON, BSC067N06LS3
11	1	M2	MOSFET, 60V, TDSO8	INFINEON, BSC100N06LS3
12	2	M3, M4	MOSFET, 40V, TDSO8	INFINEON, BSC093N04LS
13	1	M5	MOSFET, P-CH, 40V, POWERPAK-1212-8	VISHAY, SI7611DN-T1-GE3
14	1	R1	RES., SENSE, 0.05 $\Omega$ , 1W, 1%, 2010	TT Electronics, LRC-LR2010LF-01-R050F
15	1	R2	RES., SENSE, 0.004 $\Omega$ , 1W, 1%, 2010	ROHM, PMR50HZPFV4L00
16	1	R3	RES, CHIP, 100k, 1/10W, 5%, 0603	VISHAY, CRCW0603100K0JNEA
17	1	R4	RES, CHIP, 2.2k, 1/10W, 1%, 0603	VISHAY, CRCW06032K20FKEA
18	1	R5	RES, CHIP, 1M, 1/10W, 1%, 0603	VISHAY, CRCW06031M00FKEA
19	1	R6	RES, CHIP, 34.8k, 1/10W, 1%, 0603	VISHAY, CRCW060334K8FKEA
20	1	R9	RES, CHIP, 5.1, 1/10W, 5%, 0603	VISHAY, CRCW06035R10JNEA
21	1	R26, R27	RES, CHIP, 10 $\Omega$ , 1/10W, 5% 0603	VISHAY, CRCW060310R0FKEA
22	1	U1	I.C., LED CONTROLLER, TSSOP28FE-EA	LINEAR TECH., LT8391EFE#PBF
<b>Optional Electrical Components</b>				
1	1	C13	CAP, ALUM., 33 $\mu$ F, 63V, 20%, 8 $\times$ 10.2mm	SUN ELECTRONIC INDUSTRIES CORPORATION, 63CE33BS
2	2	C14, C15	CAP, CER., 4.7 $\mu$ F, X7S, 100V, 10%, 1206	AVX, 12061Z475KAT2A
3	1	C16	CAP, CER., 0.1 $\mu$ F, X5R, 100V, 10%, 0402	MURATA, GRM155R62A104KE14D
4	0	C18, C19, C20, C21 (OPT)	CAP, OPTION, 0603	
5	1	D1	DIODE, SCHOTTKY, 60V, 1A, SOD323F	NXP, PMEG6010CEJ,115
6	0	D2 (OPT)	DIODE, ZENER, 5.1V, 250MW, SOD323	CENTRAL SEMI., CMDZ5231B TR
7	0	FB1 (OPT)	CHIP BEAD, OPTION, 1206	
8	1	L2	IND., 3.2 $\mu$ H, 13.00 $\times$ 12.80mm	WURTH ELEKTRONIK, 7443550320
9	3	R10, R11, R15	RES, CHIP, 100k, 1/10W, 5%, 0603	VISHAY, CRCW0603100K0JNEA
10	1	R7	RES, CHIP, 499k, 1/10W, 1%, 0603	VISHAY, CRCW0603499KFKEA
11	1	R8	RES, CHIP, 221k, 1/10W, 1%, 0603	VISHAY, CRCW0603221KFKEA
12	0	R12, R13, R14, R17, R18, R19, R20, R23 (OPT)	RES., OPTION, 0603	
13	1	R16	RES, CHIP, 200k, 1/10W, 1%, 0603	VISHAY, CRCW0603200KFKEA
14	3	R21, R24, R25	RES, CHIP, 0 $\Omega$ , 1/10W, 1%, 0603	VISHAY, CRCW06030000Z0EA
15	1	R22	RES, CHIP, 91k, 1/10W, 5%, 0603	VISHAY, CRCW060391K0FKEA
16	1	VR1	TRIMMER., 100k, 0.25W, SMD	Bourns, 3314J-1-104E

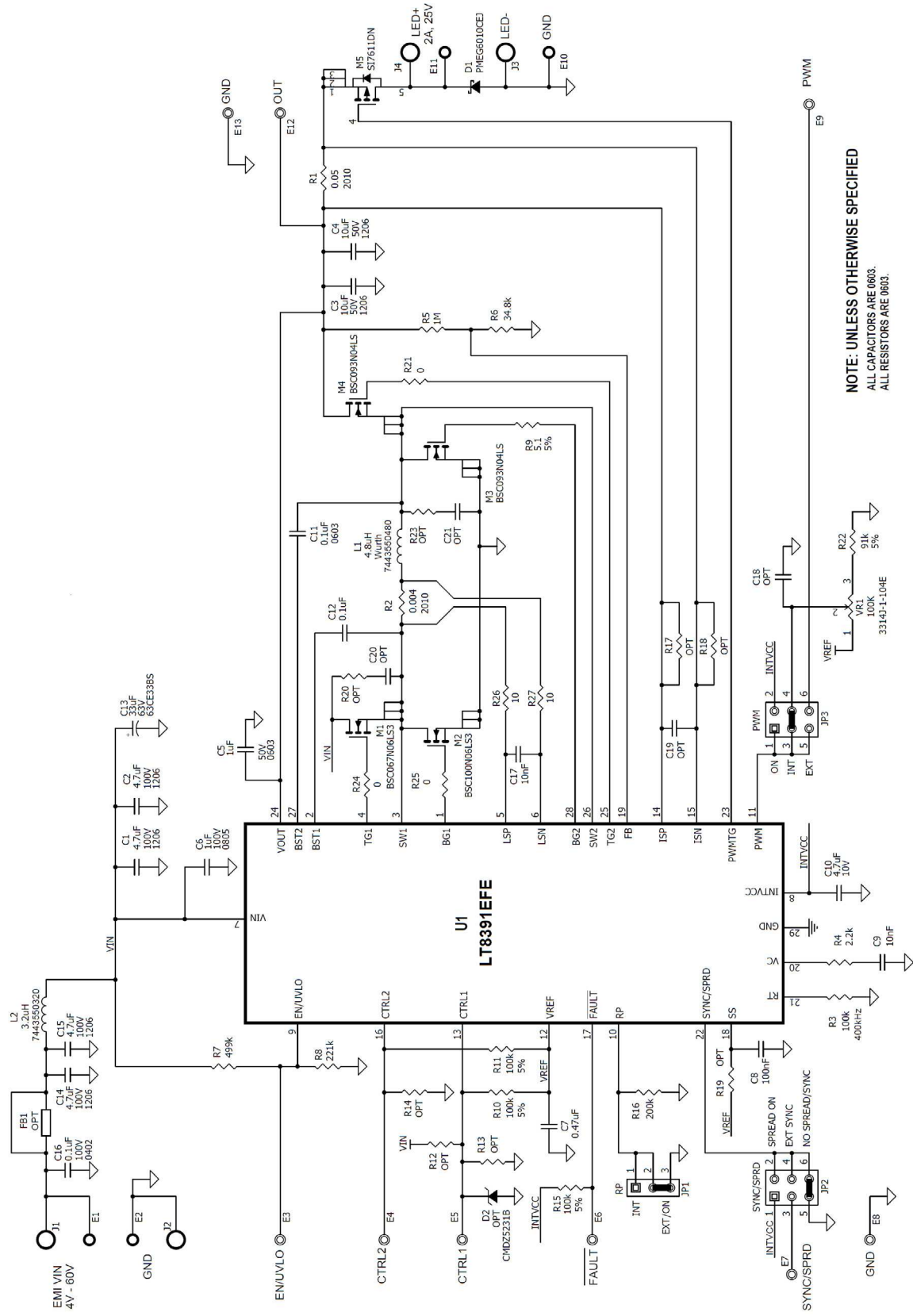
# DEMO MANUAL DC2345A

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## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Additional Hardware</b>				
1	4	E1, E2, E10, E11	TEST POINT, TURRET, .094" MTH HOLE	MILL-MAX, 2501-2-00-80-00-00-07-0
2	9	E3, E4, E5, E6, E7, E8, E9, E12, E13	TEST POINT, TURRET, .061" MTG. HOLE	MILL-MAX, 2308-2-00-80-00-00-07-0
3	1	JP1	CONN., HEADER, 1 x 3, 2mm	WURTH ELEKTRONIK, 62000311121
4	2	JP2, JP3	CONN., HEADER, 2 x 3, 2mm	WURTH ELEKTRONIK, 62000621121
5	3	XJP1, XJP2, XJP3	SHUNT, 2mm	WURTH ELEKTRONIK, 60800213421
6	4	J1, J2, J3, J4	CONN., JACK, BANANA, Non-Insulated, 0.218"	KEYSTONE, 575-4

## SCHEMATIC DIAGRAM



**NOTE: UNLESS OTHERWISE SPECIFIED**  
 ALL CAPACITORS ARE 0603.  
 ALL RESISTORS ARE 0603.



# DEMO MANUAL DC2345A

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Mailing Address:

Linear Technology  
1630 McCarthy Blvd.  
Milpitas, CA 95035

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