

LTC3311

3.3V to 1.2V at 12.5A, 2MHz Automotive Low EMI Buck Regulator in a 1.22cm² Solution

DESCRIPTION

Demonstration circuit 3056A features the [LTC®3311](#), 12.5A, low voltage synchronous step-down Silent Switcher® operating as a 2MHz, 2.25V–5.5V input, 1.2V 12.5A output buck regulator. The LTC3311 supports output voltages from 0.5V to V_{IN} with operating frequencies from 500kHz up to 5MHz. The LTC3311 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 EMI/EMC emissions. Fast minimum on-time of 35ns enables high V_{IN} to low V_{OUT} conversion at high frequency.

DC3056A is set up to run in forced continuous mode with a 2MHz switching frequency but can be configured to pulse-skipping mode and different switching frequencies. RT is connected to V_{IN} which sets the MODE/SYNC pin as an input and allows the LTC3311 to sync from an external clock. Connecting the MODE/SYNC pin to V_{IN} sets the mode to forced continuous mode and connecting the MODE/SYNC pin to GND sets the mode to pulse-skipping.

Figure 5 shows the efficiency and power loss of the circuit with a 3.3V input in forced continuous mode operation.

The DC3056A 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 is shown in the EMI Test Results section. The red lines in Figure 7 through Figure 9 illustrate the CISPR25 Class 5 peak limits for the conducted and radiated emission tests.

The LTC3311 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. The LTC3311 is assembled in a 3mm × 3mm LQFN-18 package with exposed pads for low thermal resistance. The layout recommendations for low EMI operation and maximum thermal performance are available in the data sheet section Low EMI PCB Layout.

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

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PERFORMANCE SUMMARY

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

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{IN}/V_{IN\ EMI}$	DC3056A Input Voltage Range		3.0		5.5	V
V_{OUT}	DC3056A Output Voltage Range		1.176	1.200	1.224	V
I_{OUT}	DC3056A Output Current				12.5	A
f_{SW}	Switching Frequency		1.8		2.2	MHz
EFF	Efficiency	$V_{IN} = 3.3\text{V}$, $I_{OUT} = 5\text{A}$		91		%

BOARD PHOTO

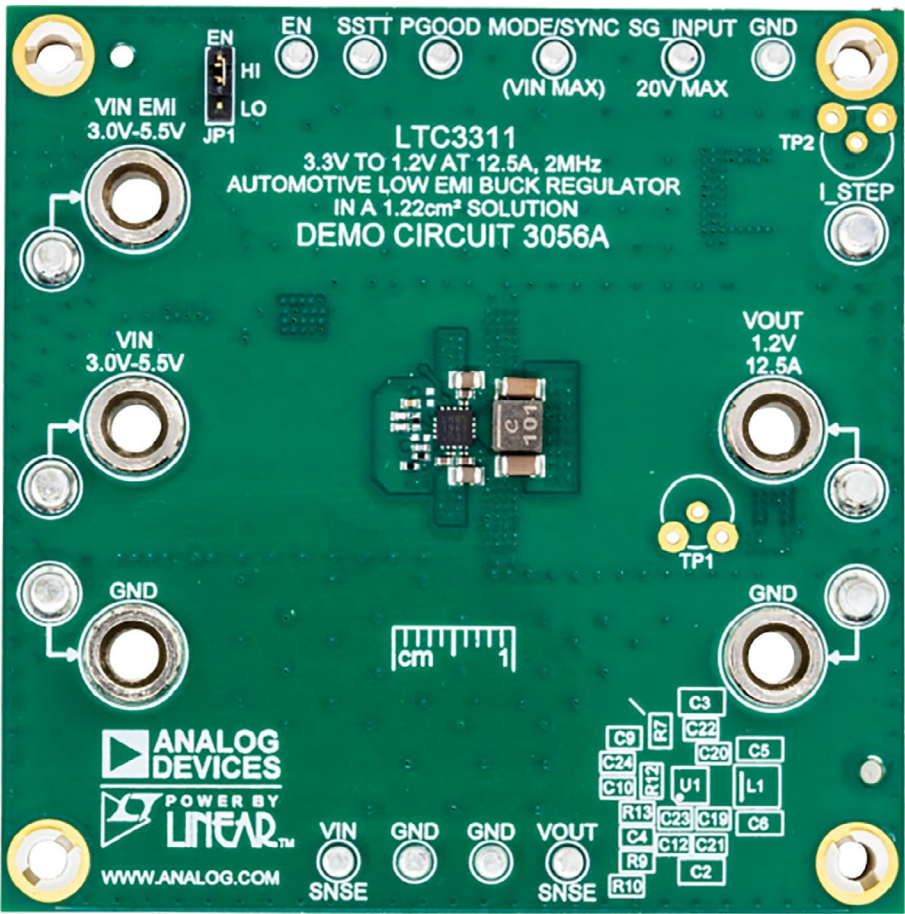


Figure 1. DC3056A Board Photo

QUICK START PROCEDURE

Refer to Figure 2 for the proper measurement equipment setup and follow the procedure below.

NOTE: For accurate V_{IN} , V_{OUT} and efficiency measurements, measure V_{IN} at the V_{IN} SNSE and GND turrets, and measure V_{OUT} at the V_{OUT} SNSE and GND turrets, as illustrated as VM1 and VM2 in Figure 2. When measuring the input or output ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the output voltage ripple by touching the probe tip directly across the output turrets or to TP1 as shown in Figure 3.

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 power supply PS1 current limit to 10A. Set the electronic load LD1 to CC mode and 0A current. Slowly increase PS1 to 1V. If PS1 output current reads less than 20mA, increase PS1 to 3.3V. Verify that VM1 reads 3.3V and VM2 reads 1.2V. Check V_{M1} , VM2, VM3, PS1 output current and LD1 input current. Connect an oscilloscope voltage probe as shown in Figure 3. Set channel to AC-coupled, voltage scale to 20mV and time base to 10 μ s. Check V_{OUT} ripple voltage. Verify that PGOOD voltage is above 3V.

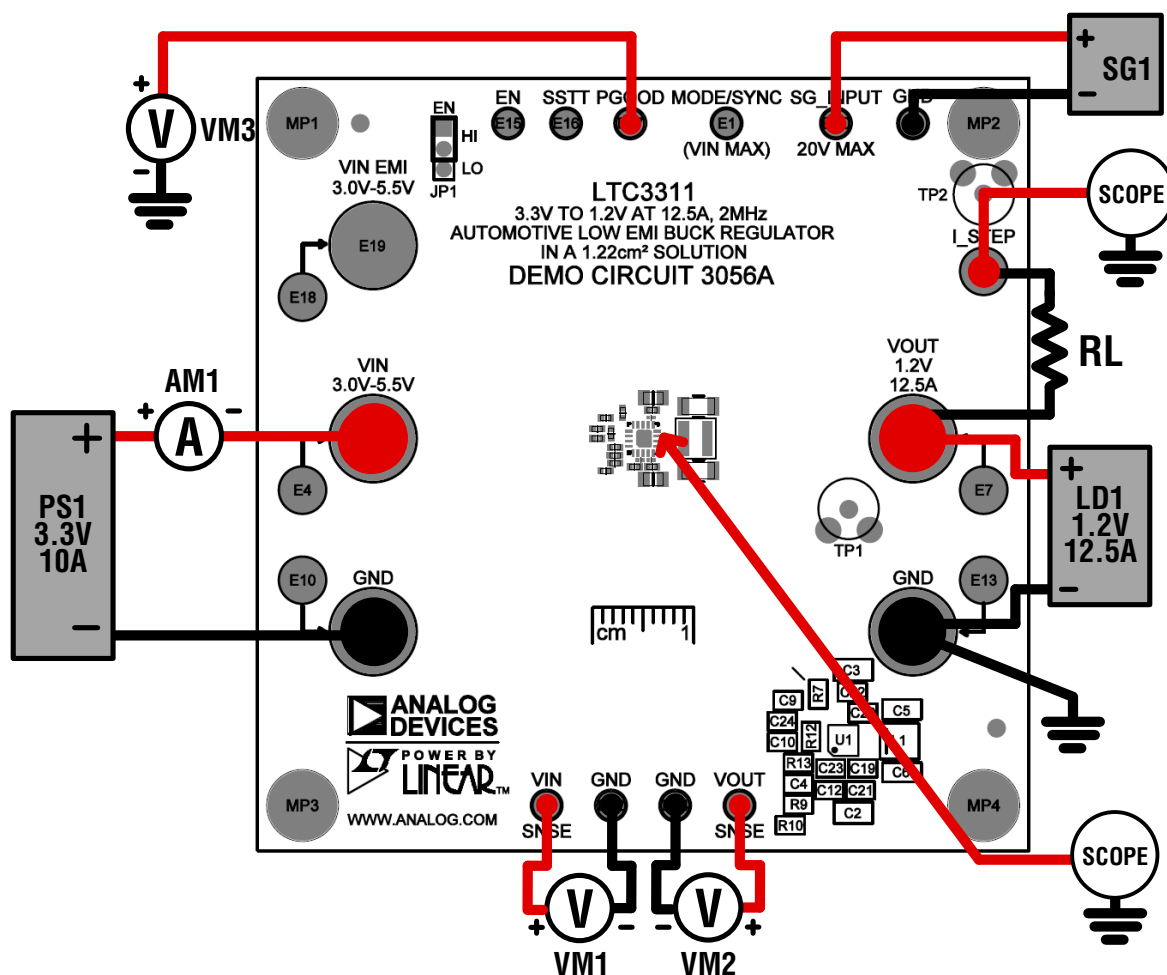


Figure 2. Test Setup for DC3056A Demo Board

QUICK START PROCEDURE

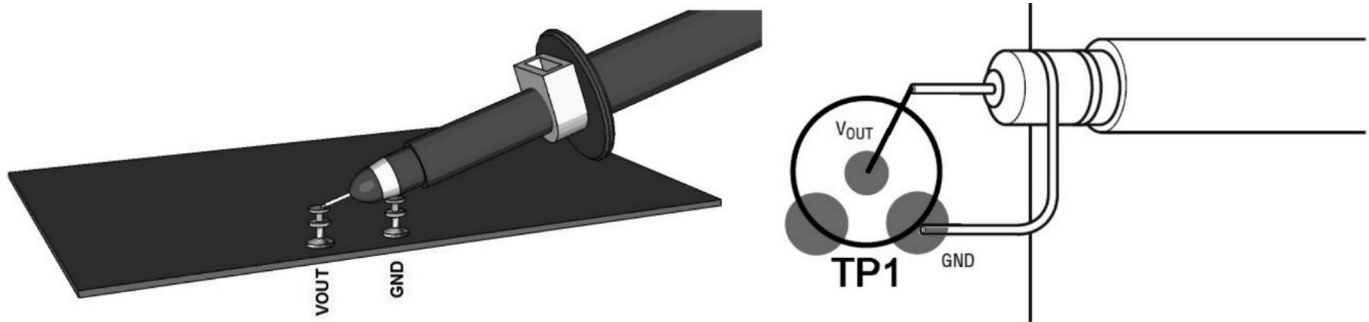


Figure 3. Technique for Measuring Output Ripple and Step Response

4. Increase the load by 1A intervals up to 12.5A and observe the voltage output regulation, ripple voltage, and the voltage on the SSTT turret. Calculate die temperature using Equation 1.

$$T_J (^{\circ}\text{C}) = \frac{V_{\text{SSTT}}}{4\text{mV}} - 273 \quad (1)$$

5. If pulse-skipping mode is desired, set PS1 to 0V. Move the 100k resistor from R6 to R3. Repeat steps 1 through 4. In step 4, observe that the switching waveform is now in pulse-skipping mode at low current.
6. OPTIONAL: To change the frequency, remove R3 and R4, if installed. Install the desired R_T resistor in the R7 location. Note that the MODE/SYNC pin should 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 LTC3311 data sheet and [LTpowerCAD](#) for more information on choosing the required components.

7. To test the transient response with a base load, add the desired resistor to produce a minimum load between V_{OUT} and I_{STEP} turrets (R_L shown on Figure 2). Note that the total load resistance will be R_L plus R_{16} (50m Ω). Adjust a signal generator with a 10ms period, 10% duty cycle and an amplitude from 1V to 2V to start.
8. Measure the I_{STEP} voltage to observe the current, $V_{I_{\text{STEP}}}/50\text{m}\Omega$. Adjust the amplitude of the pulse to provide the desired transient. Connect signal generator SG1 between SG_INPUT and GND turrets. Adjust the rising and falling edge of the pulse to provide the desired ramp rate. Figure 6 shows a load step from 2A to 10A. Refer to Equation 2 and Equation 3.

$$I_{\text{OUT}} = \frac{V_{I_{\text{STEP}}}}{50\text{m}\Omega} \quad (2)$$

$$V_{\text{GS}} = V_{\text{SG_INPUT}} - V_{I_{\text{STEP}}} \quad (3)$$

9. When done, turn off SG1, PS1 and Load. Remove all the connections to the demo board.

THEORY OF OPERATION

Introduction to the DC3056A

The DC3056A demonstration circuit features the LTC3311, a low voltage synchronous step-down Silent Switcher. The LTC3311 is a monolithic, constant frequency, current mode step-down DC/DC converter. An oscillator, with frequency set by a resistor on the RT pin, 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 internal ITH node. The error amplifier servos the ITH node by comparing the voltage on the V_{FB} pin with an internal 500mV 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 LTC3311 is in shutdown and in a low quiescent current state. When the EN pin is above its threshold, the switching regulator will be enabled.

The MODE/SYNC pin synchronizes the switching frequency to an external clock. It can be a clock output for multiphase operation. It also sets the PWM mode. The PWM modes of operation are either pulse-skipping or forced continuous. See the LTC3311 data sheet for more detailed information.

The maximum allowable operating frequency is influenced by the minimum on-time of the top switch, the ratio of V_{OUT} to V_{IN} and the available inductor values. The

maximum allowable operating frequency may be calculated in Equation 4.

$$f_{SW(MAX)} = \frac{V_{OUT}}{V_{IN(MAX)} \cdot t_{ON(MIN)}} \quad (4)$$

Select an operating switching frequency below f_{SW(MAX)}. Typically, it is desired to obtain an inductor current of 30% of the maximum LTC3311 operating load, 12.5A. Use Equation 5 and Equation 6 to calculate the inductor value to obtain a 30% (3A) inductor ripple for the operating frequency.

$$L \approx \frac{V_{OUT}}{3.75A \cdot f_{SW}} \cdot \left(1 - \frac{V_{OUT}}{V_{IN(MAX)}} \right) \text{ for } \frac{V_{OUT}}{V_{IN(MAX)}} \leq 0.5 \quad (5)$$

$$L \approx \frac{0.25 \cdot V_{IN(MAX)}}{3.75A \cdot f_{SW}} \text{ for } \frac{V_{OUT}}{V_{IN(MAX)}} > 0.5 \quad (6)$$

When determining the compensation components, C4, C10, C24 and R12, controlling the loop stability and transient response are the two main considerations. The LTC3311 has been designed to operate at a high bandwidth for fast transient response capabilities. This reduces required output capacitance to meet the desired transient voltage range. The mid-band gain of the loop increases with R12 and the bandwidth of the loop increases with decreasing C24. C4 along with R9 provides a phase lead which will improve the phase margin. C10 along with R12 provides 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 dB and phase shift in degrees. The 0dB crossover frequency should be less than 1/6 of the operating frequency to reduce the effects of added phase shift of the modulator. The control loop phase margin goal should be 45° or greater and a gain margin goal of 8dB or greater.

TYPICAL PERFORMANCE CHARACTERISTICS

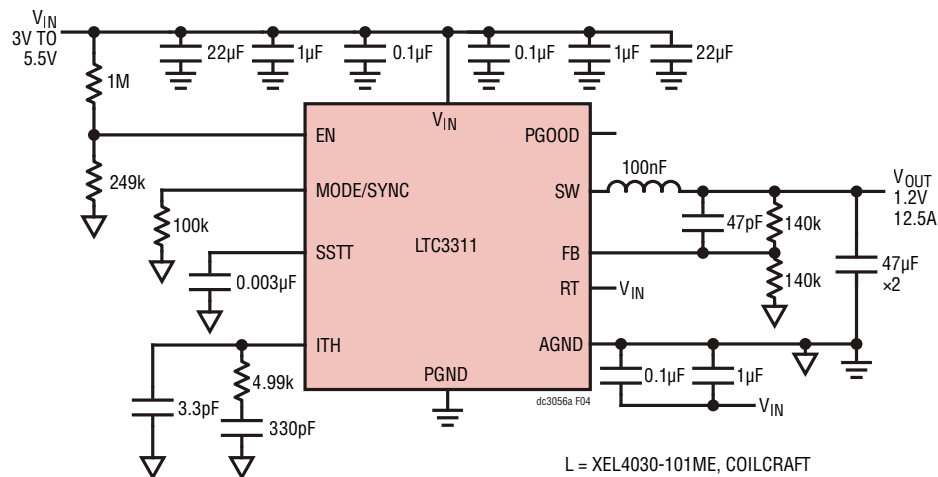


Figure 4. DC3056A Simplified Schematic

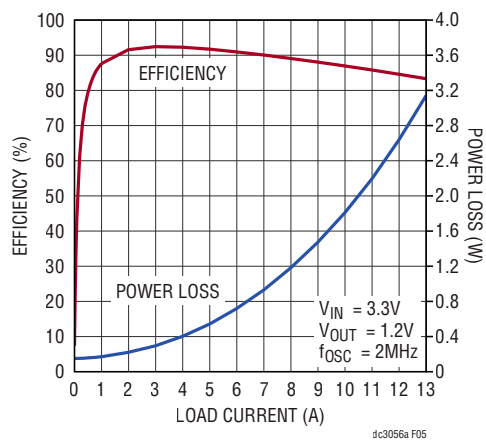


Figure 5. Efficiency vs Load Current

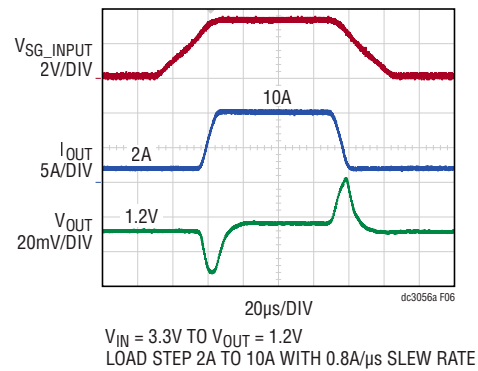
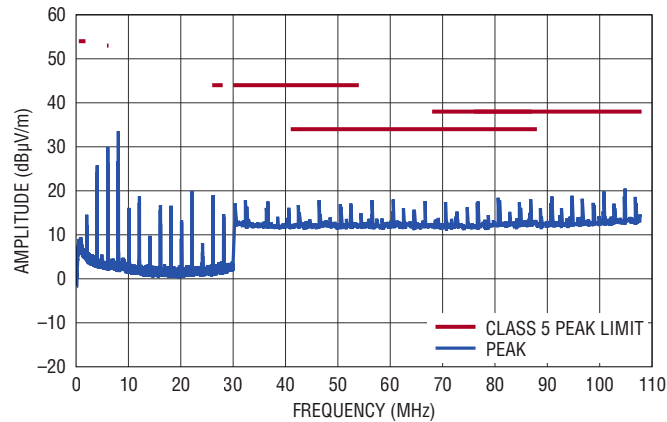


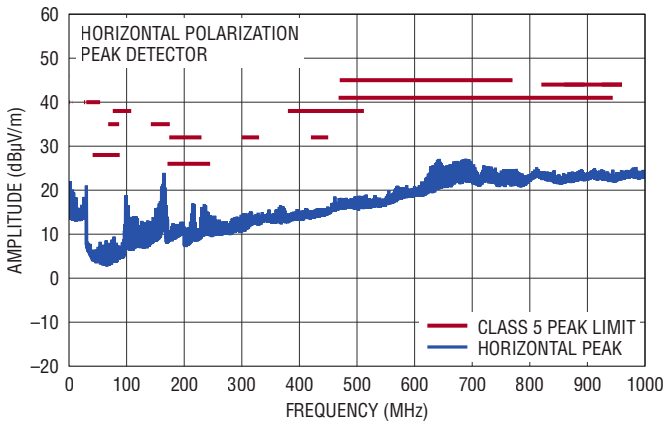
Figure 6. Load Step Response

EMI TEST RESULTS



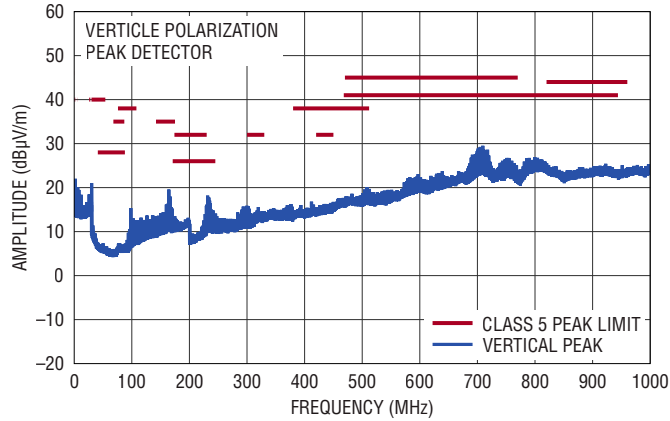
DC3056A DEMO BOARD
(WITH VOLTAGE APPLIED TO V_{IN} EMI INPUT)
3.3V INPUT TO 1.2V OUTPUT AT 10A, $f_{SW} = 2\text{MHz}$

Figure 7. CISPR25 Conducted Emission Test with Class 5 Peak Limits (Voltage Method)



DC3056A DEMO BOARD
(WITH VOLTAGE APPLIED TO V_{IN} EMI INPUT)
3.3V INPUT TO 1.2V OUTPUT AT 10A, $f_{SW} = 2\text{MHz}$

Figure 8. CISPR25 Conducted Emission Test with Class 5 Peak Limits (Horizontal)



DC3056A DEMO BOARD
(WITH VOLTAGE APPLIED TO V_{IN} EMI INPUT)
3.3V INPUT TO 1.2V OUTPUT AT 10A, $f_{SW} = 2\text{MHz}$

Figure 9. CISPR25 Conducted Emission Test with Class 5 Peak Limits (Vertical)

DEMO MANUAL DC3056A

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	2	C2, C3	CAP., 22 μ F, X7S, 6.3V, 20%, 0805	TDK, C2012X7S0J226M125AC
2	1	C4	CAP., 47pF, C0G/NP0, 50V, 5%, 0402	KEMET, C0402C470J5GAC7867
3	2	C5, C6	CAP., 47 μ F, X7S, 6.3V, 20%, 1206	TDK, C3216X7S0J476M160AC
4	1	C9	CAP., 0.033 μ F, X7R, 25V, 10%, 0402	KEMET, C0402C333K3RACTU
5	1	C10	CAP., 4.7pF, C0G, 50V, \pm 0.25pF, 0402	AVX, 04025A4R7CAT2A
6	3	C12, C21, C22	CAP., 1 μ F, X7S, 10V, 10%, 0402, AEC-Q200	MURATA, GCM155C71A105KE38D
7	3	C19, C20, C23	CAP., 0.1 μ F, X7S, 16V, 10%, 0201	MURATA, GRM033C71C104KE14D
8	1	C24	CAP., 330pF, C0G, 50V, 5%, 0402	MURATA, GRM1555C1H331JA01D
9	1	L1	IND., 0.10 μ H 20% SHIELDED POWER INDUCTOR	COILCRAFT, XEL4030-101MEC
10	1	R9	RES., 140k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402140KFKED
11	1	R10	RES., 100k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402100KFKED
12	1	R12	RES., 4.99k, 1%, 1/16W, 0402	VISHAY, CRCW04024K99FKED
13	1	U1	IC, LOW VOLTAGE SYN. STEP-DOWN REG., LQFN-18, 12.5A	ANALOG DEVICES, LTC3311JV#PBF

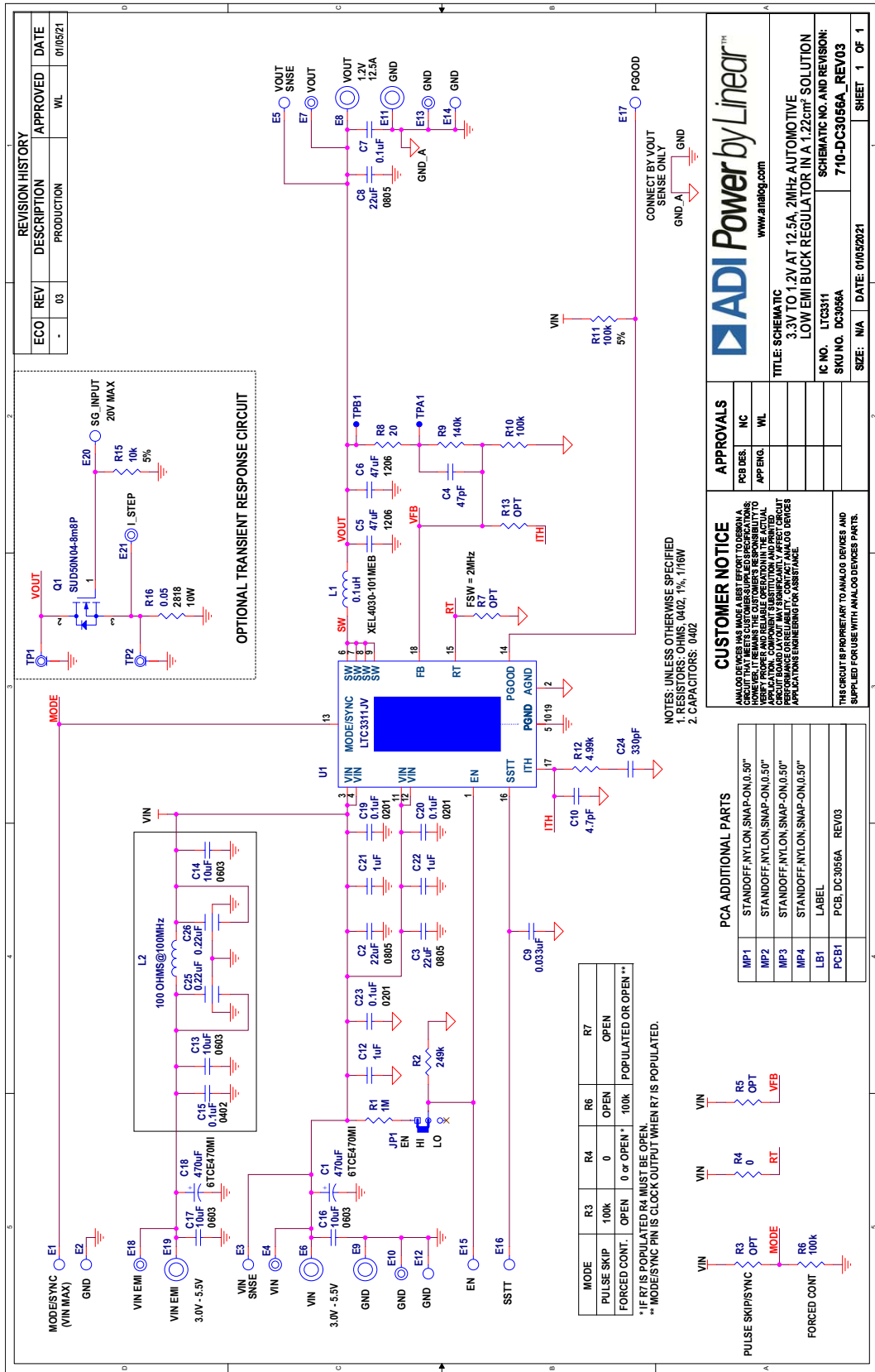
Additional Demo Board Circuit Components

1	2	C1, C18	CAP., 470 μ F, TANT POLY, 6.3V, 20%, 2917	PANASONIC, 6TCE470MI
2	2	C7, C15	CAP., 0.1 μ F, X7R, 50V, 10%, 0402, AEC-Q200	MURATA, GCM155R71H104KE02D
3	1	C8	CAP., 22 μ F, X7S, 6.3V, 20%, 0805	TDK, C2012X7S0J226M125AC
4	4	C13, C14, C16, C17	CAP., 10 μ F, X7S, 6.3V, 20%, 0603	TDK, C1608X7S0J106M080AC
5	2	C25, C26	CAP., 0.22 μ F, X7R, 6.3V, 20%, 0603	JOHANSON DIELECTRICS, 6R3X14W224MV4T
6	1	L2	IND., 100 Ω AT 100MHz, FERRITE BEAD, 25%, 8A, 6m Ω , 1812	WURTH ELEKTRONIK, 74279226101
7	1	Q1	XSTR., MOSFET, N-CH, 40V, 14A, TO-252 (DPAK)	VISHAY, SUD50N04-8M8P-4GE3
8	1	R1	RES., 1M, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW04021M00FKED
9	1	R2	RES., 249k, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402249KFKED
10	1	R4	RES., 0 Ω , 1/16W, 0402, AEC-Q200	VISHAY, CRCW04020000Z0ED
11	2	R6, R11	RES., 100k, 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402100KJNED
12	1	R8	RES., 20 Ω , 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW040220R0FKED
13	1	R15	RES., 10k, 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW040210K0JNED
14	1	R16	RES., 0.05 Ω , 1%, 10W, 2818, AEC-Q200	VISHAY, WSHP2818R0500FEA

Hardware: For Demo Board Only

1	10	E1-E3, E5, E12, E14-E17, E20	TEST POINT, TURRET, 0.064", MTG. HOLE	MILL-MAX, 2308-2-00-80-00-00-07-0
2	6	E4, E7, E10, E13, E18, E21	CAP., 0.1 μ F, X7R, 50V, 10%, 0402, AEC-Q200	MURATA, GCM155R71H104KE02D
3	5	E6, E8, E9, E11, E19	CONN., BANANA JACK, FEMALE, THT, NON-INSULATED SWAGE	KEYSTONE, 575-4
4	1	JP1	CONN., HDR, MALE, 1 \times 3, 2mm, VERT, STR, THT	WURTH ELEKTRONIK, 62000311121
5	4	MP1-MP4	STANDOFF, NYLON, SNAP-ON, 0.50"	KEYSTONE, 8833
6	1	XJP1	CONN., SHUNT, FEMALE, 2 POS, 2mm	WURTH ELEKTRONIK, 60800213421

SCHEMATIC DIAGRAM



**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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