LTC3310S
5V, 10A Synchronous Step Down Silent Switcher in 3mm x3mm LQFN

DESCRIPTION

Demonstration Circuit DC2629A features the LTC®3310S 10A, Low Voltage, Synchronous Step-Down Silent Switcher® 2 operating as a 2MHz 3.3V to 1.2V 10A buck regulator. The LTC3310S supports output voltages from 0.5V to V_{IN} with operating frequencies from 500kHz up to 5MHz. The LTC3310S is a compact, ultralow emission, high efficiency, and high speed synchronous monolithic step-down switching regulator. The integrated bypass capacitors optimize all the fast current loops and make it easier to minimize EMI/EMC emissions by reducing layout sensitivity. Fast minimum on-time of 35ns enables high V_{IN} to low V_{OUT} conversion at high frequency.

DC2629A is set up to run in Forced Continuous Mode with a 2MHz switching frequency but can be configured to Pulse Skip Mode and different switching frequencies. RT is connected to V_{IN} which sets the MODE/SYNC pin as an input and allows the LTC3310S 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 Skip Mode. The Efficiency vs. Load graph shows the efficiency and the power loss of the circuit with a 3.3V input in forced continuous mode operation.

The DC2629A 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 the EMI performance graphs illustrate the CISPR25 Class 5 peak limits for the conducted and radiated emission tests.

The LTC3310S data sheet gives a complete description of the part, operation and application information. The data sheet must be read in conjunction with this demo. The LTC3310S is assembled in a 3mm x 3mm LQFN 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.

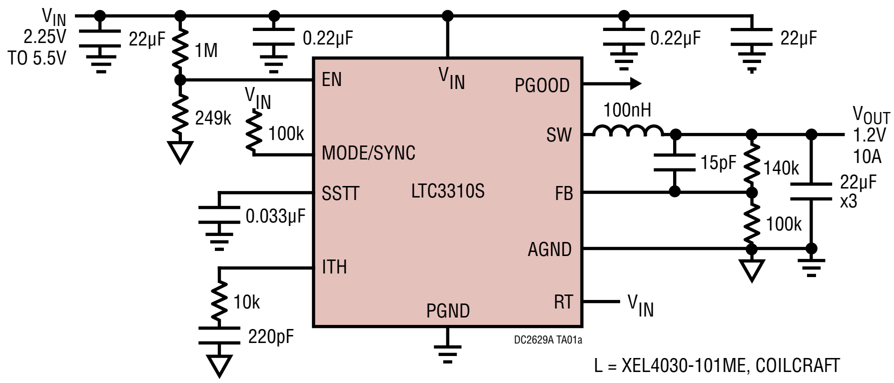
PERFORMANCE SUMMARY

Specifications are at T_A = 25°C

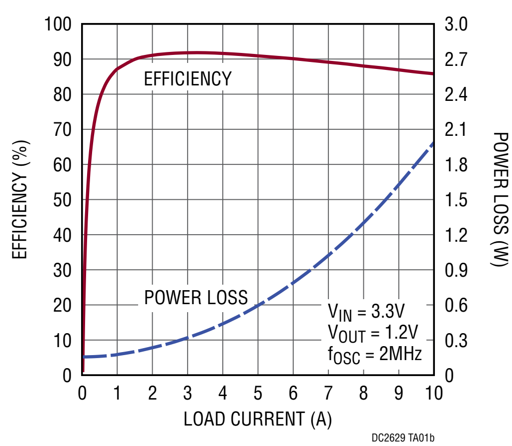
SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V_{IN}/V_{IN} EMI	DC2629A Input Voltage Range		2.25		5.5	V
V_{OUT}	DC2629A V_{OUT} Voltage Range		1.183	1.2	1.217	V
I_{OUT}	DC2629A Output Current				10	A
f_{SW}	Switching Frequency		1.8		2.2	MHz
EFF	Efficiency	V_{IN} = 3.3V, I_{OUT} = 5A		91		%

BOARD PHOTO

1.2V 10A Step-Down Converter

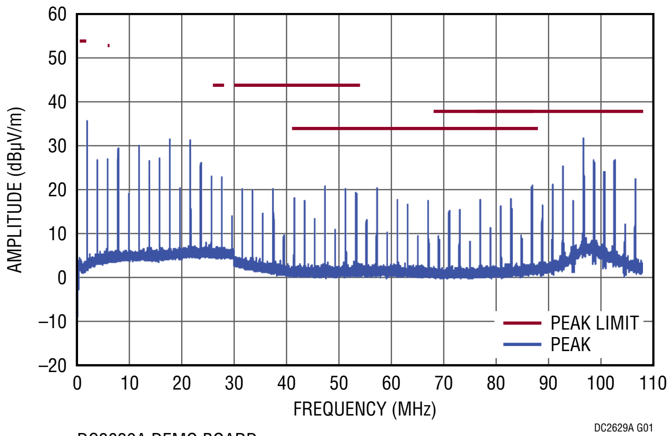


Efficiency vs Load Current



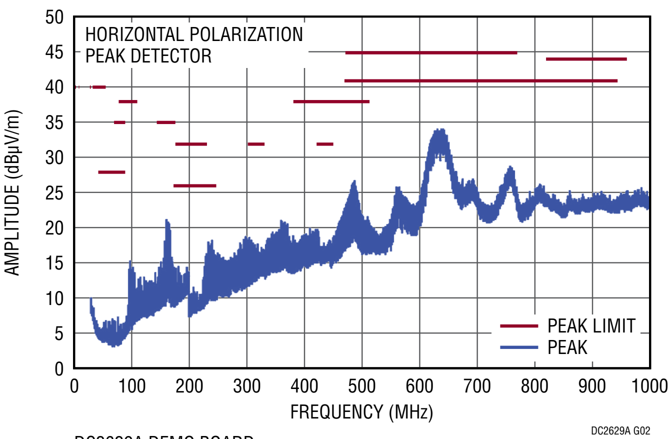
EMI TEST RESULTS

CISPR25 Conducted EMI Emmisions with Class 5 Peak Limits (Voltage Method)



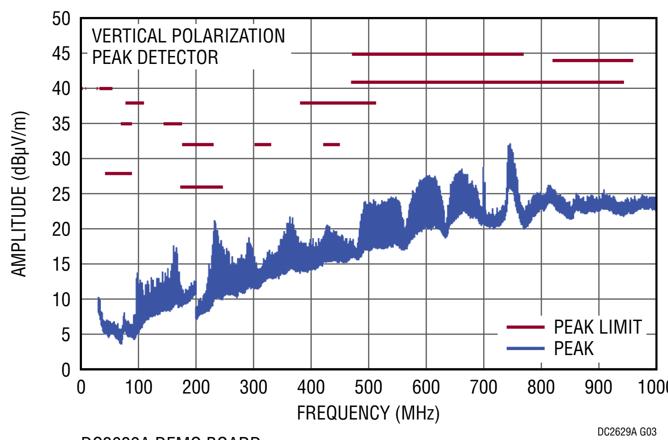
DC2629A DEMO BOARD
(WITH VOLTAGE APPLIED TO V_{IN} EMI INPUT)
3.3V INPUT TO 1.2V OUTPUT AT 7.5A, f_{SW} = 2MHz

Radiated EMI Performance (CISPR25 Radiated Emmisions Test with Class 5 Peak Limits)



DC2629A DEMO BOARD
(WITH VOLTAGE APPLIED TO V_{IN} EMI INPUT)
3.3V INPUT TO 1.2V OUTPUT AT 7.5A, f_{SW} = 2MHz

Radiated EMI Performance (CISPR25 Radiated Emmisions Test with Class 5 Peak Limits)



DC2629A DEMO BOARD
(WITH VOLTAGE APPLIED TO V_{IN} EMI INPUT)
3.3V INPUT TO 1.2V OUTPUT AT 7.5A, f_{SW} = 2MHz

QUICK START PROCEDURE

Demonstration circuit 2629A is easy to set up and evaluate the performance of the LTC3310S. Refer to Figure 1 for 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 SNSE turrets and V_{OUT} at the V_{OUT} SNSE and GND SNSE turrets as illustrated as VM1 and VM2 in Figure 1. When measuring the input or output voltage 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 2.

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. Slowly increase PS1 to 1.0V. If AM1 reads less than 20mA, increase PS1 to 3.3V. Verify that VM1 reads 3.3V and VM2 reads 1.2V. Record VM1, VM2, VM3 AM1 and AM2. Connect an oscilloscope voltage probe as shown in Figure 2. Set Channel to AC coupled, voltage scale to 20mV and time base to 10µs. Record V_{OUT} ripple voltage. Verify that PGOOD voltage is above 3V. Calculate Die temperature using formula below:

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

4. Increase the load by 1A intervals up to 10A and observe the voltage output regulation, ripple voltage, and the voltage on the SSTT turret.
5. If Pulse Skip Mode is desired, set PS1 to 0V. Install a 0Ω resistor in the R6 location or short the MODE/SYNC turret to GND. Repeat steps 1 through 4. In step 4 observe that the switching waveform is now operating in Pulse Skip Mode at low currents.
6. To change the frequency, remove R4 and R6 if installed. Install the desired RT resistor in the R7 location. Note, the MODE/SYNC pin is an output when R4 is installed and 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 LTC3310S datasheet 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 (RL shown on Figure 1). Note that the total load resistance will be RL plus R14 (100mΩ). 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, VI_STEP/100mΩ. Adjust the amplitude of the pulse to provide the desired transient. Adjust the rising and falling edge of the pulse to provide the desired ramp rate. Figure 3 shows a load step from 2A (RL = 0.51Ω) to 8A. Refer to the following equations:

$$I_{OUT} = \frac{V_{I\_STEP}}{100m\Omega} \quad (2)$$

$$V_{GS} = V_{SG\_INPUT} - V_{I\_STEP} \quad (3)$$

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

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QUICK START PROCEDURE

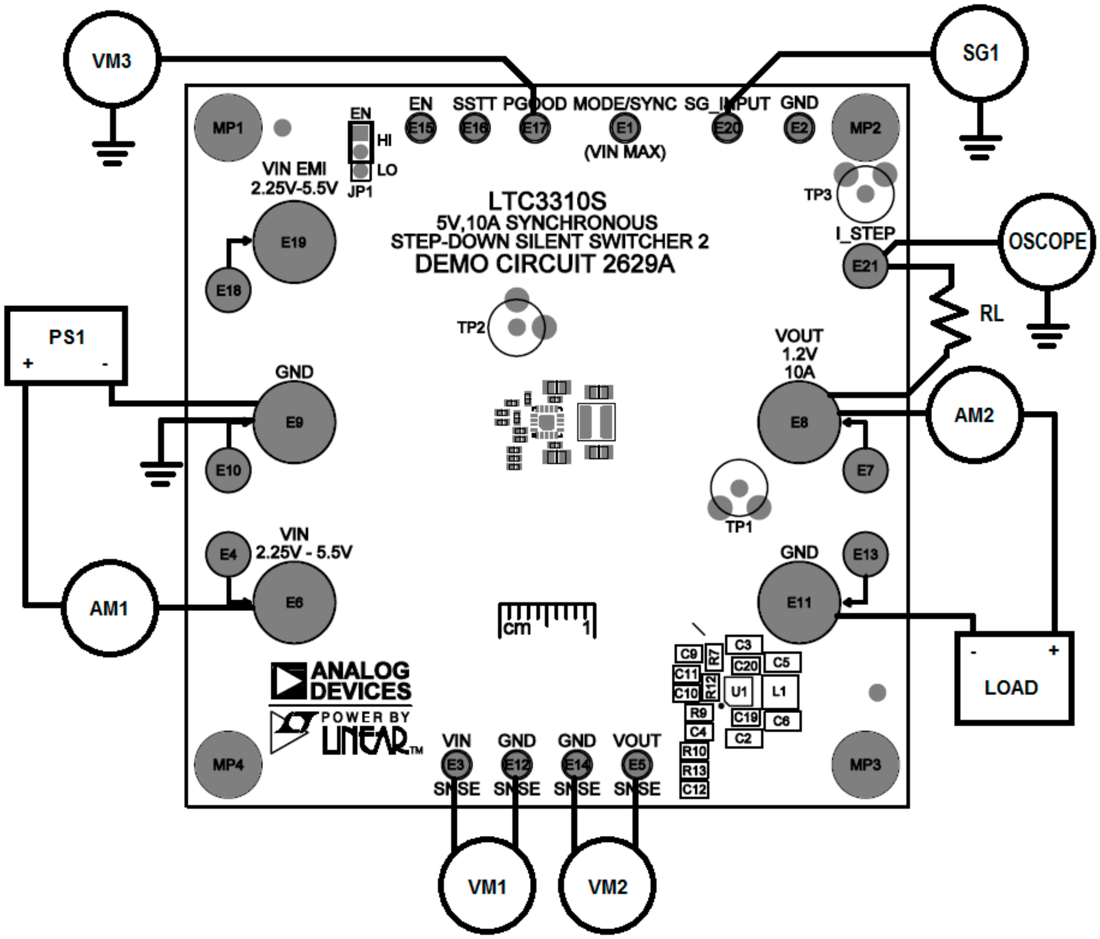


Figure 1. Test setup for the DC2629A Demo Board

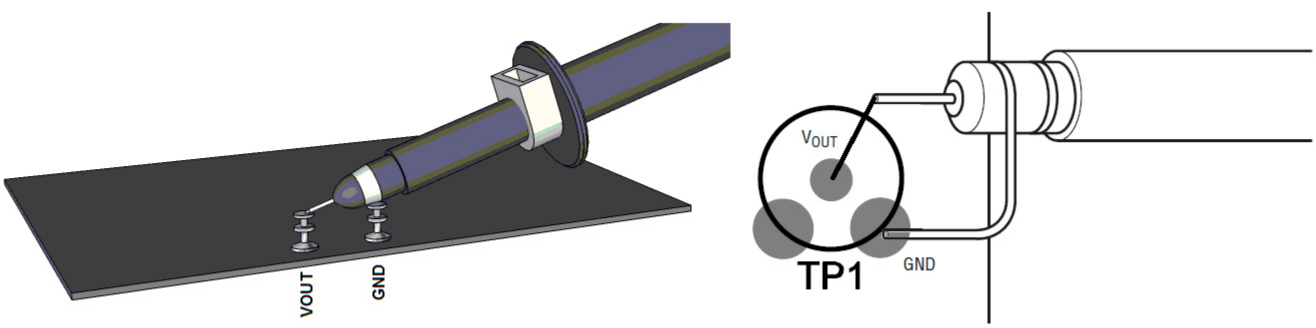


Figure 2. Technique for Measuring Output Ripple and Step Response

QUICK START PROCEDURE

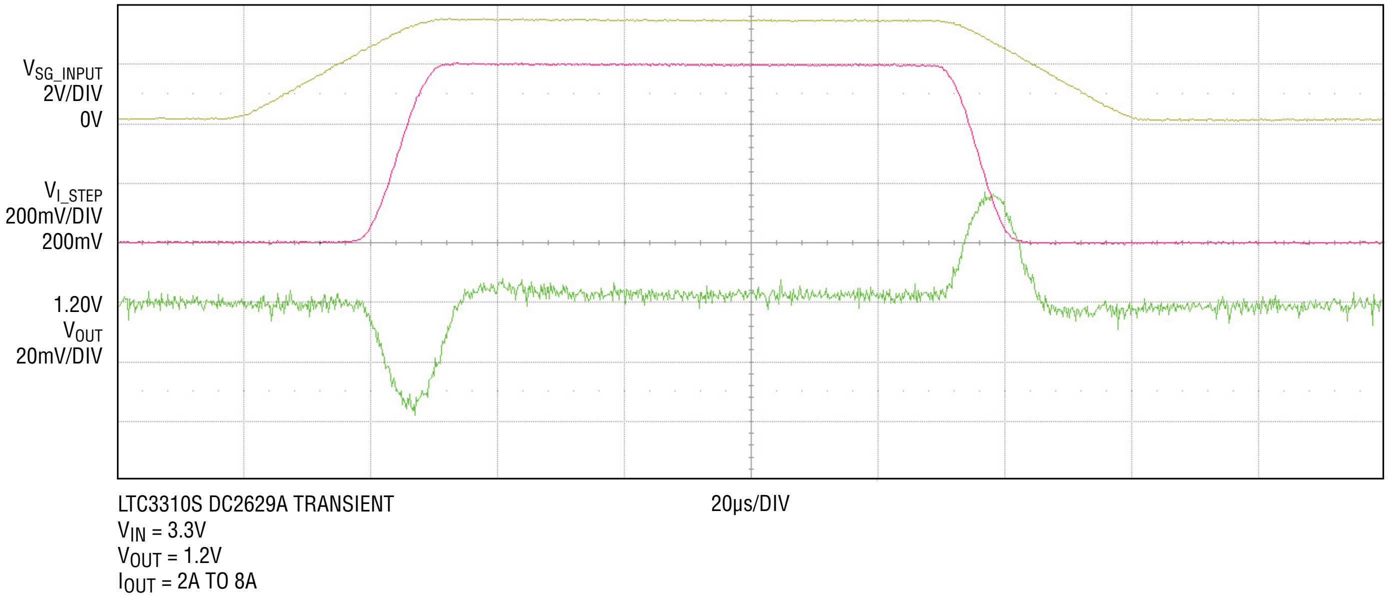


Figure 3. Technique for Measuring Load Step Response

THEORY OF OPERATION

Introduction to the DC2629A

The DC2629A demonstration circuit features the LTC3310S, a Low Voltage Synchronous Step-Down Silent Switcher. The LTC3310S is a monolithic, constant frequency, current mode step-down DC/DC converter. An oscillator, with frequency set using 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 power switch turns on until the next clock cycle begins or the 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 LT3310S 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, is a clock output or sets the PWM mode. The PWM modes of operation are either pulse skip or forced continuous. See the LTC3310S datasheet 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 the formula below.

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

Select an operating switching frequency below $f_{SW(MAX)}$. Typically, it is desired to obtain an inductor current of 30% of the maximum LTC3310S operating load, 10A. Use the formulas below to calculate the inductor value to obtain a 30% (3A) inductor ripple for the operating frequency.

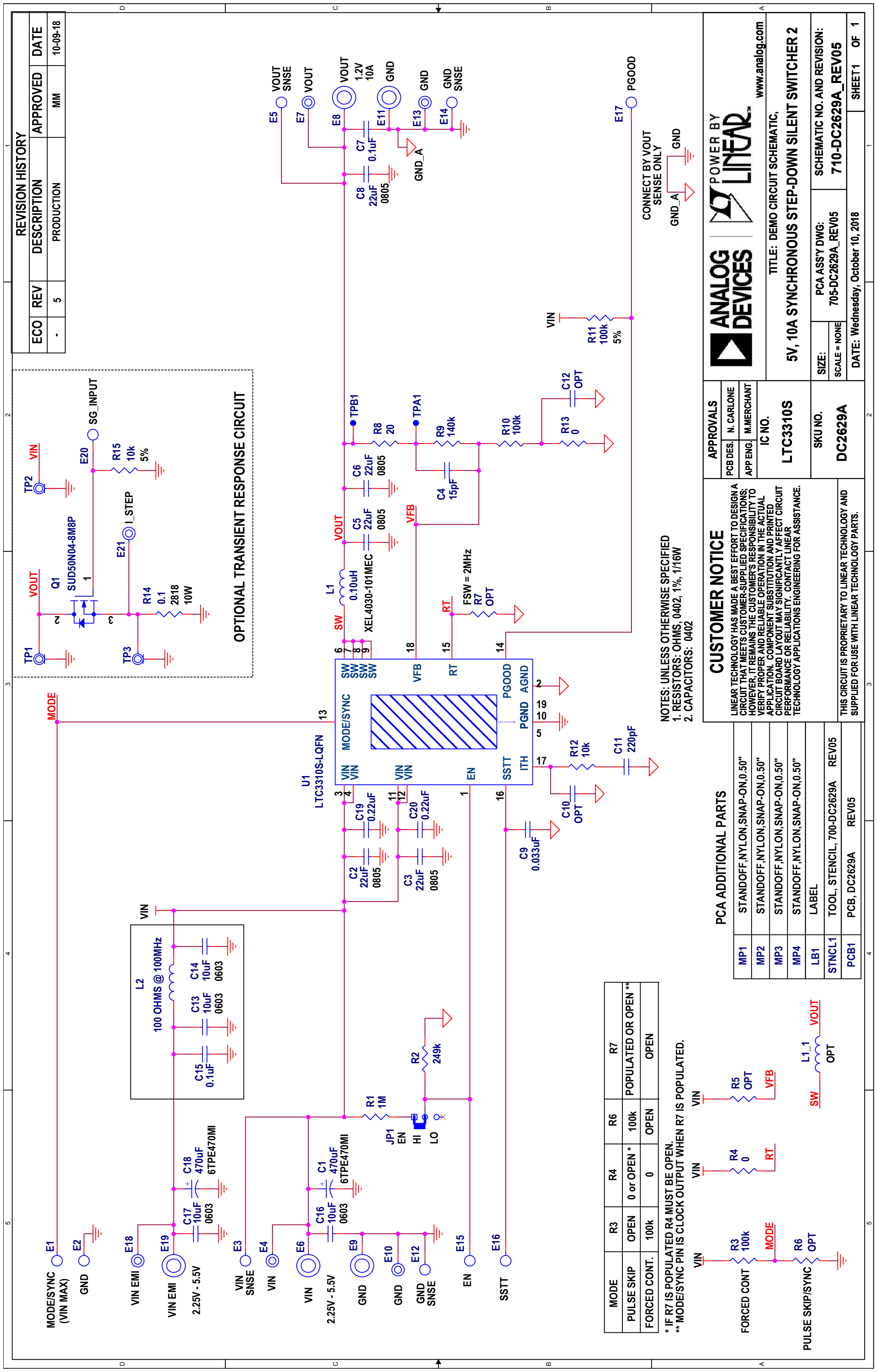
$$L \geq \frac{V_{OUT}}{3A \bullet f_{SW}} \bullet \left(1 - \frac{V_{OUT}}{V_{IN(MAX)}}\right) \text{for } \frac{V_{OUT}}{V_{IN(MAX)}} \leq 0.5 \quad (5)$$

$$L \geq \frac{0.25 \bullet V_{IN(MAX)}}{3A \bullet f_{SW}} \text{for } \frac{V_{OUT}}{V_{IN(MAX)}} > 0.5 \quad (6)$$

When determining the compensation components, C4, C10, C11 and R12, controlling the loop stability and transient response are the two main considerations. The LTC3310S has been designed to operate at a high bandwidth for fast transient response capabilities. This reduces output capacitance required 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 C11. C4 along with R4 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 the 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.

SCHEMATIC DIAGRAM



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PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	4	C2, C3, C5, C6	CAP., 22uF, X5R, 25V, 20%, 0805	SAMSUNG, CL21A226MAQNNNE
2	1	C4	CAP., 15pF, C0G, 50V, 5%, 0402	KEMET, C0402C150J5GAC7867
3	1	C9	CAP., 0.033uF, X7R, 25V, 10%, 0402	KEMET, C0402C333K3RACTU
4	1	C11	CAP., 220pF, X7R, 50V, 10%, 0402	YAGEO, CC0402KRX7R9BB221
5	2	C13, C14	CAP., 10uF, X5R, 10V, 20%, 0603	AVX, 0603ZD106MAT2A
6	1	L1	IND., 0.10uH 20% SHEILDED POWER INDUCTOR	COILCRAFT, XEL4030-101MEC
7	1	R9	RES., 140k OHMS, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402140KFKED
8	1	R10	RES., 100k OHMS, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402100KFKED
9	1	R12	RES., 10k OHMS, 1%, 1/10W, 0402, AEC-Q200	PANASONIC, ERJ2RKF1002X
10	1	U1	IC, Low Voltage Syn. Stepdown Reg., LQFN-18	ANALOG DEVICES, LTC3310SEV#PBF
Additional Demo Board Circuit Components				
1	2	C1, C18	CAP., 470uF, TANT. POSCAP, 6.3V, 20%, 7343, 18mOHMS, TPE	PANASONIC, 6TPE470MI
2	2	C7, C15	CAP., 0.1uF, X5R, 25V, 10%, 0402	AVX, 04023D104KAT2A
3	1	C8	CAP., 22uF, X5R, 25V, 20%, 0805	SAMSUNG, CL21A226MAQNNNE
4	2	C16, C17	CAP., 10uF, X5R, 10V, 20%, 0603	AVX, 0603ZD106MAT2A
5	2	C19, C20	CAP., 0.22uF, X7R, 16V, 10%, 0402, AEC-Q200	MURATA, GCM155R71C224KE02D
6	1	L2	IND., 100 OHMS @ 100MHz, FERRITE BEAD, 25%, 8A, 6mOHMS, 1812	WURTH ELEKTRONIK, 74279226101
7	1	Q1	XSTR., MOSFET, N-CH, 40V, TO-252 (DPAK)	VISHAY, SUD50N04-8M8P-4GE3
8	1	R1	RES., 1M OHMS, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW04021M00FKED
9	1	R2	RES., 249k OHMS, 1%, 1/16W, 0402	VISHAY, CRCW0402249KFKED
10	2	R3, R11	RES., 100k OHMS, 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW0402100KJNED
11	2	R4, R13	RES., 0 OHM, 1/16W, 0402, AEC-Q200	VISHAY, CRCW04020000Z0ED
12	1	R8	RES., 20 OHMS, 1%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW040220R0FKED
13	1	R14	RES 0.1 OHM 1% 10W 2818	VISHAY DALE, WSHP2818R1000FEA
14	1	R15	RES., 10k OHMS, 5%, 1/16W, 0402, AEC-Q200	VISHAY, CRCW040210K0JNED
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	TEST POINT, TURRET, 0.094", MTG. HOLE	MILL-MAX, 2501-2-00-80-00-00-07-0
3	5	E6, E8, E9, E11, E19	CONN., BANANA JACK, FEMALE, THT, NON-INSULATED, SWAGE	KEYSTONE, 575-4
4	1	JP1	CONN., HDR, MALE, 1x3, 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

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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