Evaluating the LTC3306 3.3 V to 1.2 V at 1.75 A, 2 MHz Synchronous Step-Down Regulator in an 11 mm² Solution

FEATURES

- DC3109A evaluation board
- Transient circuit included for load-transient evaluation
- EMI filter included to reduce noise in EMI emission tests

EVALUATION KIT CONTENTS

- DC3109A evaluation board

DOCUMENTS NEEDED

- LTC3306 data sheet

EQUIPMENT NEEDED

- DC voltage source
- An electronic load
- A multimeter

GENERAL DESCRIPTION

Demonstration circuit DC3109A is a 2 MHz, 2.5 V to 5.5 V input, 1.2 V/1.75 A output buck regulator, featuring the LTC3306, 1.75 A, synchronous step-down regulator in 1.6 mm x 1 mm WLCSP. The LTC3306 is a small size, high efficiency, low noise monolithic synchronous step-down DC-DC converter. Low minimum on-time of 22 ns enables high V_{IN} to low V_{OUT} conversion at high frequency. The LTC3306 supports fixed output voltages ranging from 0.5 V to 3.65 V.

The demo circuit features the adjustable version of LTC3306. Output voltage is adjusted to 1.2 V with external feedback resistors. The DC3109A-A is set up to run in Burst Mode with LTC3306A. The DC3109A-C is set up to run in forced continuous mode with LTC3306C. The high precision PGOOD signal shows the status of the output voltage.

The DC3109A also has an EMI filter to reduce the 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.

Full specifications on the LTC3306 are available in the LTC3306 data sheet available from Analog Devices, Inc., and must be consulted with this user guide when using the DC3109A evaluation board. The LTC3306 is assembled in a 6-ball, 1.6 mm x 1 mm, 0.5 mm pitch WLCSP package.

OPTION TABLE

Table 1. Option Table

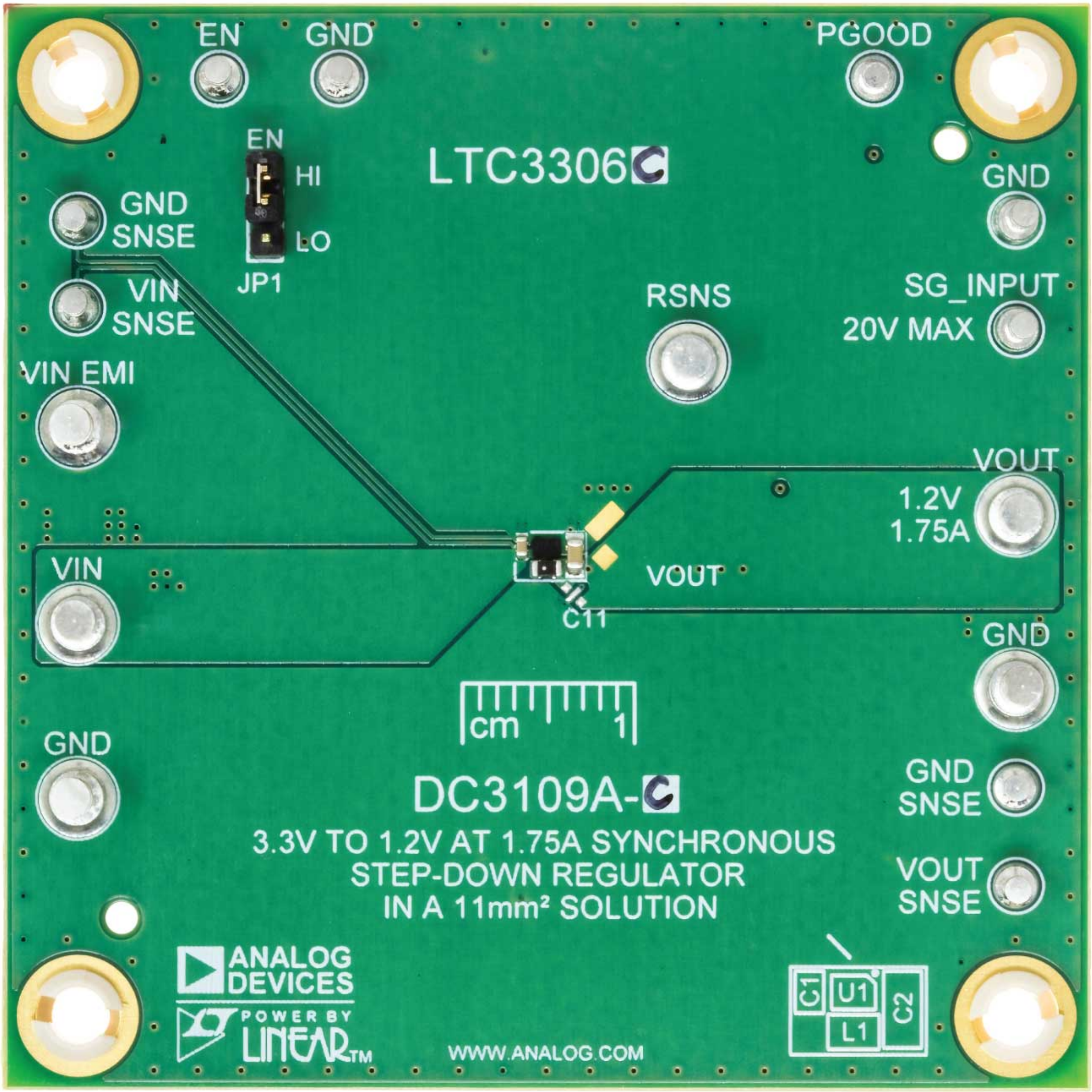
Demo Board	Featured IC	Operation Mode
DC3109A-A	LTC3306A	Burst
DC3109A-C	LTC3306C	Forced continuous

TABLE OF CONTENTS

REVISION HISTORY

1/2024—Revision 0: Initial Version

DC3109A EVALUATION BOARD PHOTOGRAPH



015

Figure 1. DC3109A Evaluation Board Photograph

PERFORMANCE SUMMARY

Specification are at T_A = 25°C, unless otherwise noted.

Table 2. Performance Summary

Parameter	Symbol	Test Conditions/Comments	Min	Typ	Max	Unit
VOLTAGE RANGE						
Input	V_{IN}/V_{IN} EMI		2.25		5.5	V
Output[1]	V_{OUT}		1.188	1.200	1.212	V
OUTPUT CURRENT	I_{OUT}				1.75	A
SWITCHING FREQUENCY	f_{SW}		1.9		2.1	MHz
EFFICIENCY		V_{IN} = 3.3 V, I_{OUT} = 0.5 A		91		%

[1] This output voltage range is with DC3109A-C running in continuous conduction mode.

QUICK START PROCEDURE

For the proper measurement equipment setup, see Figure 3, 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 SNSN turrets, and measure V_{OUT} at the V_{OUT} SNSE and GND SNSE turrets, as shown as VM1 and VM2 in Figure 3. 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 as shown in Figure 4 or use TP1 high frequency probe as shown in Figure 5.

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 required, connect the input power supply to V_{IN} EMI and GND.
3. Set power supply PS1 current limit to 1 A. Set the electronic load LD1 to CC mode and 0 A current. Slowly increase PS1 to 1.0 V. If PS1 output current reads less than 20 mA, increase PS1 to 3.3 V. Verify that VM1 reads 3.3 V and VM2 reads 1.2 V. Check VM1, VM2, VM3, PS1 output current, and LD1 input current. Connect an oscilloscope voltage probe as shown in Figure 4 or a high frequency probe as shown in Figure 5. Set channel to AC-coupled, voltage scale to 20 mV and time base to 10 µs. Check V_{OUT} ripple voltage.
4. To test the transient response with a base load, add the required resistor to produce a minimum load between V_{OUT} and RSNS turrets (RL shown in Figure 3). Note that the total load resistance is RL plus R8 (100 mΩ). Adjust a signal generator with a 10 ms period, 10% duty cycle and, an amplitude from 1 V to 2 V to start.
5. Measure the RSNS voltage to observe the current, V_{I_STEP} /100 mΩ.
6. 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.

$$I_{OUT} = \frac{V_{RSNS}}{100m\Omega} \quad (1)$$

$$V_{GS} = V_{SG\_INPUT} - V_{RSNS} \quad (2)$$

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

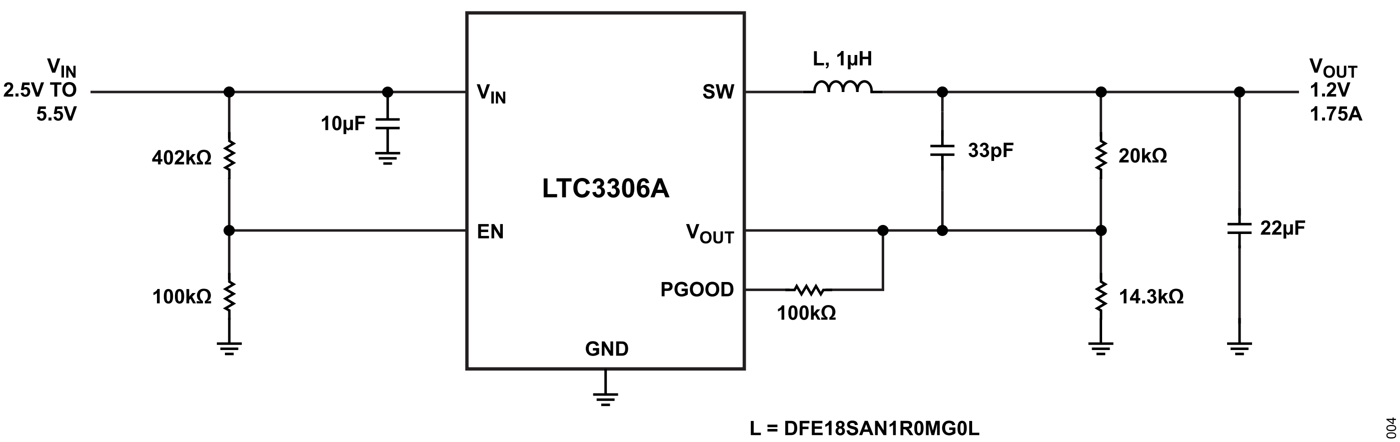


Figure 2. DC3109A Simplified Schematic

TEST SETUP

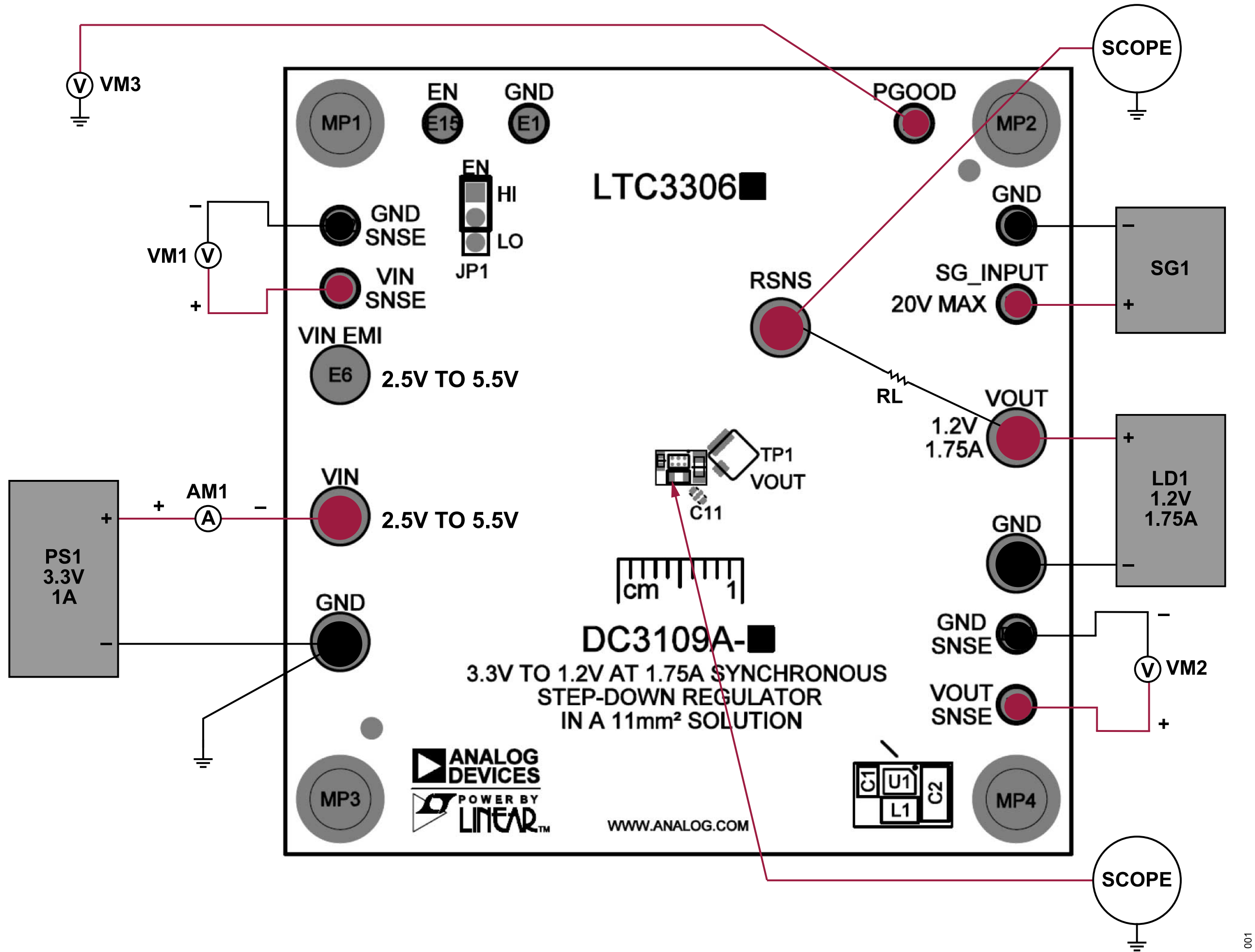


Figure 3. Test Setup for DC3109A Demo Board

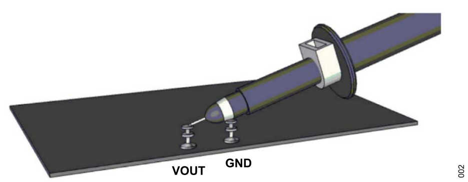


Figure 4. Technique for Measuring Output Ripple and Step Response with a Scope Probe

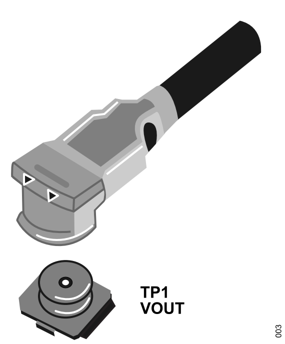


Figure 5. Technique for Measuring Output Ripple and Step Response with a Low Inductance Connector (Not Supplied)

TYPICAL PERFORMANCE CHARACTERISTICS

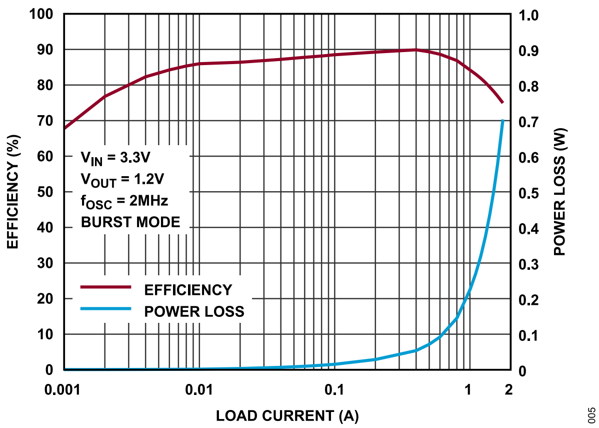


Figure 6. DC3109A-A Efficiency vs. Load Current

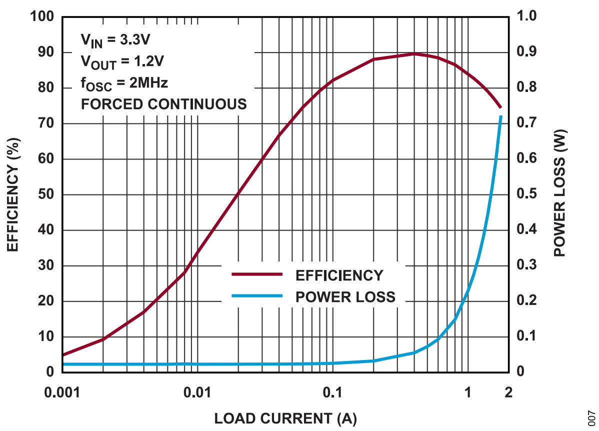


Figure 7. DC3109A-C Efficiency vs. Load Current

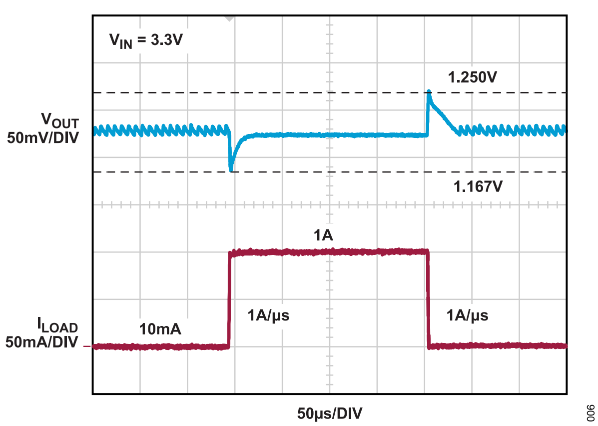


Figure 8. DC3109A-A Load-Step Response

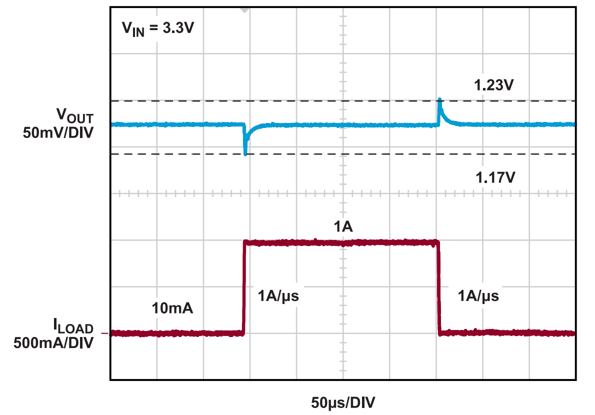


Figure 9. DC3109A-C Load-Step Response

EMI TEST RESULTS

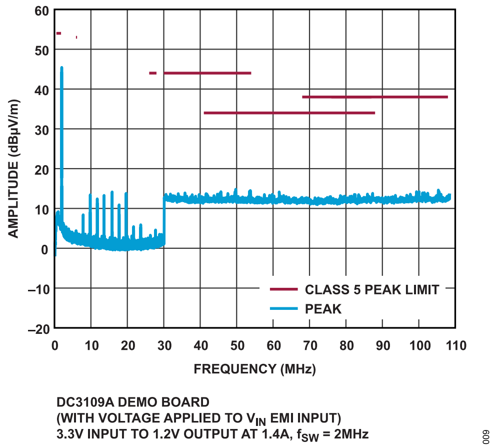


Figure 10. CISPR25 Conducted Emission Test with Class 5 Peak Limits (Voltage Method)

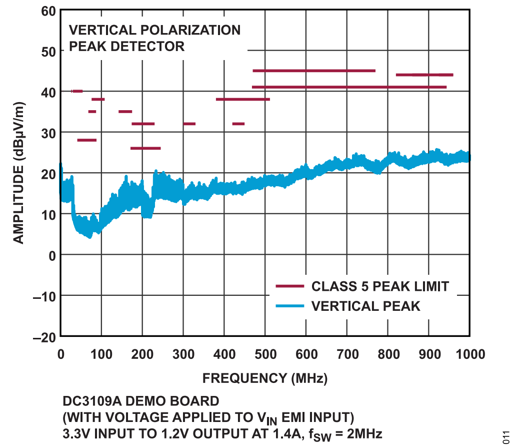


Figure 12. CISPR25 Conducted Emission Test with Class 5 Peak Limits (Vertical)

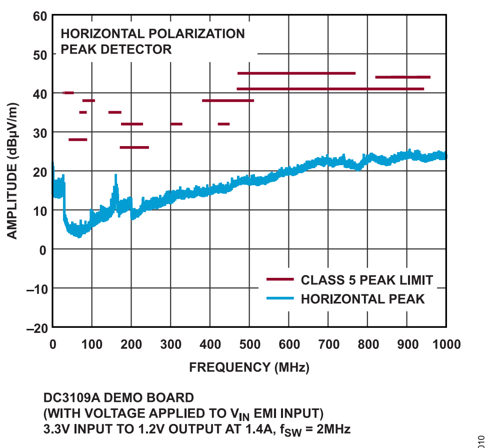


Figure 11. CISPR25 Conducted Emission Test with Class 5 Peak Limits (Horizontal)

EVALUATION BOARD HARDWARE

INTRODUCTION TO THE DC3109A

The DC3109A demonstration circuit features the LTC3306, a 1.75 A, synchronous step-down Regulator in 1.6 mm x 1 mm WLCSP. The DC3109A has two options. The DC3109A-A features the LTC3306A, operating in Burst Mode. The DC3109A-C features the LTC3306C, operating in forced continuous mode at 2 MHz.

The LTC3306 is a monolithic, constant frequency, current mode step-down DC-DC converter. A fixed frequency oscillator 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. If the EN pin is low, the LTC3306 is in shutdown and in a low quiescent current state. When the EN pin is above its threshold, the switching regulator is enabled.

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. Equation (3) shows the maximum allowable operating frequency:

$$f_{SW(MAX)} = \frac{V_{OUT}}{V_{IN(MAX)} \times T_{ON(MIN)}} \quad (3)$$

ACCURATELY MEASURING OUTPUT RIPPLE OF THE LTC3306

With the fast edge rates of the circuit, high frequency noise can be observed when measuring the output voltage with 1 mΩ terminated oscilloscope probes. To better view the high frequency output ripple, TP1, an U.FL, RECEPT, ST SMD, 0 Hz to 6 GHz, 50 Ω connector, should be populated. The output ripple should be tested with oscilloscopes of 400 MHz bandwidth and above, with a 50 Ω coax cable connected as close to the output capacitor as possible, and with oscilloscope channel terminated to 50 Ω at the scope. This helps to reduce the noise coupling onto and displaying on the scope.

The high frequency spikes are partially attributed to the interwinding capacitance of the inductor and the voltage step is partially attributed to the inductance in the output capacitors. This can be reduced by choosing low ESL capacitors or adding small low ESL capacitors in parallel to the output capacitors as close to the inductor as possible. To reduce the high frequency noise, optional C11 should be populated with a 10 nF, 0402, X2Y capacitor. Adding capacitors close to the load creates a π filter between the output capacitors, trace inductance, and load decoupling capacitors and also helps to reduce the ripple.

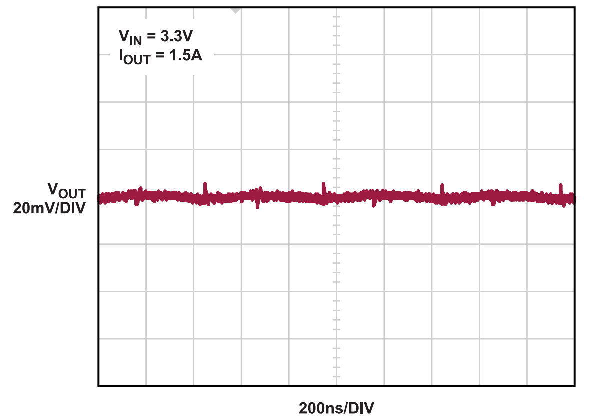


Figure 13. Output Ripple Without C11

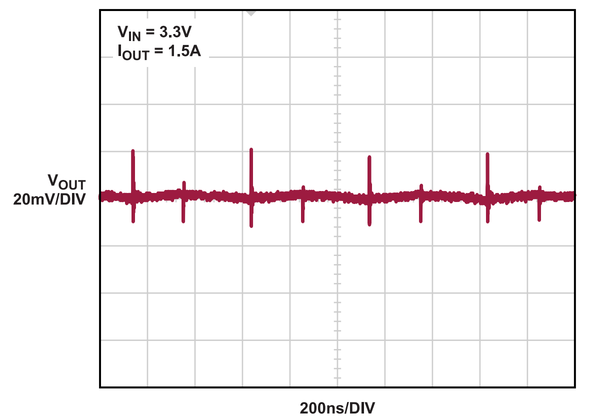
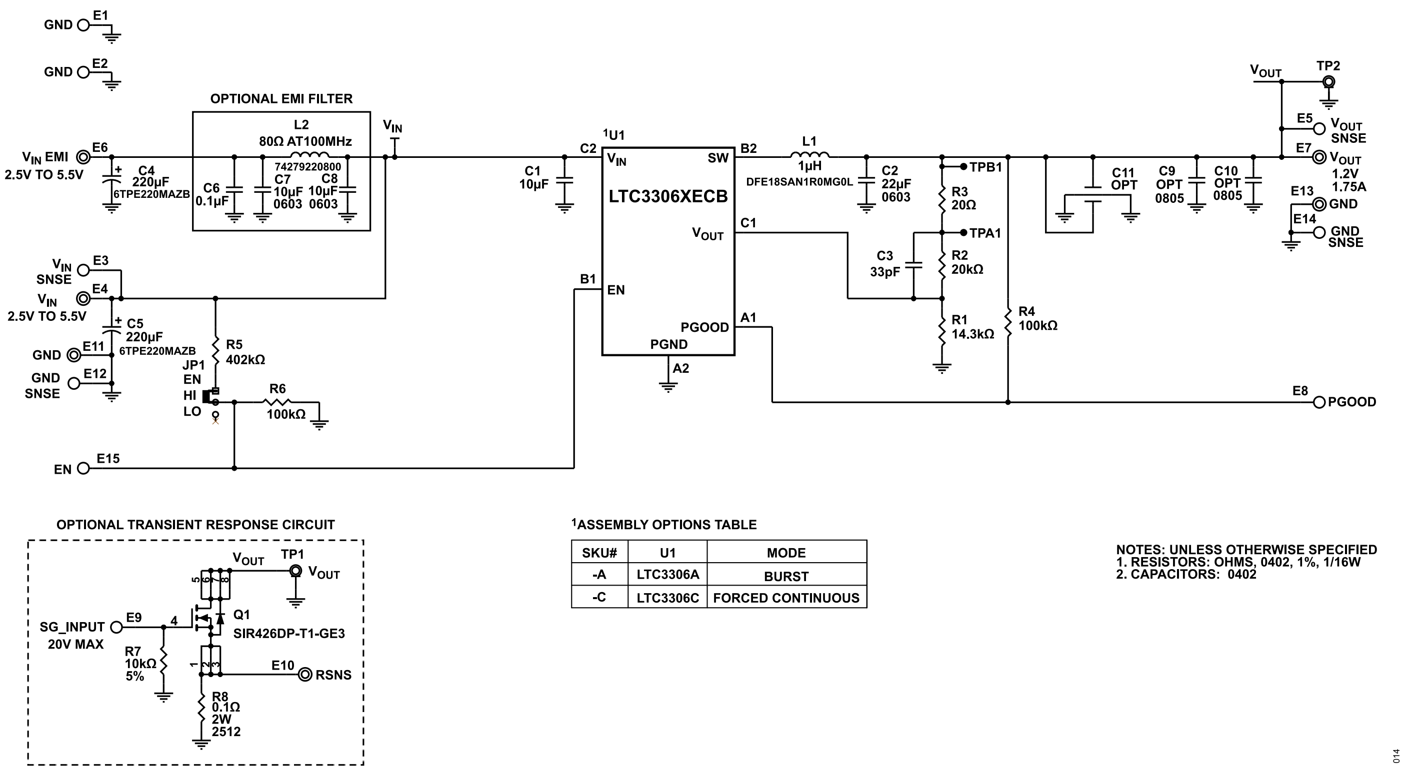


Figure 14. Output Ripple with C11

EVALUATION BOARD SCHEMATIC



1ASSEMBLY OPTIONS TABLE

SKU#	U1	MODE
-A	LTC3306A	BURST
-C	LTC3306C	FORCED CONTINUOUS

Figure 15. DC3109A Schematic Diagram

ORDERING INFORMATION

BILL OF MATERIALS

Table 3. DC3109A Bill of Materials

Item	Quantity	Reference Designator	Part Description	Manufacturer, Part Number
Required Circuit Components				
1	1	C1	Capacitor, 10 µF, X5R, 6.3 V, 10%, 0402	KEMET, C0402C106M9PACTU
2	1	C2	Capacitor, 22 µF, X5R, 6.3 V, 20%, 0603	Murata, GRM188R60J226MEA0D
3	1	C3	Capacitor, 33 pF, C0G, 50 V, 5%, 0402	AVX, 04025A330JAT2A
4	1	L1	Fixed inductor 1UH 1.7 A 128 MOHM SMD	Murata, DFE18SAN1R0MG0L
5	1	R1	Resistor, 14.3 kΩ, 1%, 1/16 W, 0402	Vishay, CRCW040214K3FKED
6	1	R2	Resistor, 20 kΩ, 1%, 1/16 W, 0402, AEC-Q200	Vishay, CRCW040220K0FKED
7	1	U1 (For DC3109A-A)	IC, 1.75 A synchronous step-down regulator, WLCSP-6	Analog Devices Inc., LTC3306AACBZ-R7
8	1	U1 (For DC3109A-C)	IC, 1.75 A synchronous step-down regulator, WLCSP-6	Analog Devices Inc., LTC3306CACBZ-R7
Additional Demo Board Circuit Components				
1	2	C4, C5	Capacitors, 220 µF, TANT. POSCAP, 6.3 V, 20%, 3528, 25 Ω, TPE, no substitute allowed	Panasonic, 6TPE220MAZB
2	1	C6	Capacitor, 0.1 µF, X7R, 16 V, 10%, 0402, AEC-Q200	Murata, GCM155R71C104KA55D
3	2	C7, C8	Capacitors, 10 µF, X7S, 6.3 V, 20%, 0603	TDK, C1608X7S0J106M080AC
4	0	C11	Capacitor, 10000 pF, X7R, 50 V, 20%, 0402, 3-Term, X2Y EMI filter	Johanson Dielectrics, 500R07W103KV4T
5	1	L2	Inductor, 80 Ω, ferrite bead, 25%, 4 A, 0.0180 Ω, 0805, 100 MHz	Wurth Elektronik, 74279220800
6	1	Q1	Transistor, N-MOSFET, 40 V, 15.9 A, PPAK SO-8	Vishay, SIR426DP-T1-GE3
7	1	R3	Resistor, 20 Ω, 1%, 1/16 W, 0402, AEC-Q200	NIC, NRC04F20R0TRF
8	1	R4	Resistor, 100 kΩ, 5%, 1/16 W, 0402	Yageo, RC0402JR-07100KL
9	1	R5	Resistor, 402 kΩ, 1%, 1/10 W, 0402, AEC-Q200	Panasonic, ERJ2RKF4023X
10	1	R6	Resistor, 100 kΩ, 1%, 1/16 W, 0402, AEC-Q200	Vishay, CRCW0402100KFKED
11	1	R7	Resistor, 10 kΩ, 5%, 1/10 W, 0402, AEC-Q200	Panasonic, ERJ2GEJ103X
12	1	R8	Resistor, 0.1 Ω, 1%, 2 W, 2512, sense, AEC-Q200	TT Electronics, LRC-LR2512LF-01-R100-F
13	2	TP1, TP2	Connectors, U.FL, RECEPT, ST SMD, 0 Hz to 6 GHz, 50 Ω	Hirose Electric, U.FL-R-SMT-1(10)
14	1	TP1, TP2 mating connector	U.FL (UMCC) connector plug	Hirose Electric, U.FL-PR-SMT2.5-1(10)
Hardware: For Demo Board Only				
1	9	E1 to E3, E5, E8, E9, E12, E14, E15	Test points, turret, 0.064" MTG. hole, PCB 0.062" THK	Mill-Max, 2308-2-00-80-00-00-07-0
2	6	E4, E6, E7, E10, E11, E13	Test points, turret, 0.094" MTG. hole, PCB 0.062" THK	Mill-Max, 2501-2-00-80-00-00-07-0
3	1	JP1	Connector, header, male, 1 × 3, 2 mm, vertical, straight, THT	Wurth Elektronik, 62000311121
4	4	MP1 to MP4	Standoff, nylon, snap-on, 0.256" (6.4 mm)	Keystone, 8831

ORDERING INFORMATION

Table 3. DC3109A Bill of Materials (Continued)

Item	Quantity	Reference Designator	Part Description	Manufacturer, Part Number
5	1	XJP2	Connector, shunt, female, 2 position, 2 mm	Wurth Elektronik, 60800213421