

# LTC3309B

## 3.3V to 1.8V at 6A, 6.6MHz Low EMI Buck Regulator in a 0.47cm<sup>2</sup> Solution

### DESCRIPTION

Demonstration circuit 3054A-C features the **LTC®3309B** 5V, 6A synchronous step-down Silent Switcher® operating as a 6.6MHz, 3.3V to 1.8V 6A buck regulator. The LTC3309B supports adjustable output voltages from 0.5V to  $V_{IN}$ , and operating frequencies from 3MHz up to 10MHz. The LTC3309B is a compact, ultralow emission, high efficiency, and high speed synchronous monolithic step-down switching regulator. A minimum on-time of 22ns enables high  $V_{IN}$  to low  $V_{OUT}$  conversion ratios at high switching frequencies.

The DC3054A-C operating mode may be selected as Burst Mode® operation, skip or forced continuous (FC) mode. Setting JP1 to the FC/SYNC position will allow the LTC3309B to sync to a clock frequency from 3MHz to 10MHz. The LTC3309B operates in forced continuous mode when syncing to an external clock. The DC3054A-C is set to a fixed 6.6MHz.

The DC3054A-C is set to a fixed 6.6MHz frequency by connecting RT to  $V_{IN}$  through a 0Ω resistor, R9. The frequency can be easily changed by removing R9 and setting an appropriate resistor in the R4 location to obtain the desired frequency. Refer to the LTC3309B data sheet for the proper  $R_T$  value for a desired switching frequency.

The DC3054A-C 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 LTC3309B 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 LTC3309B is assembled in a 2mm × 2mm 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.

The Efficiency vs Load graph shows the efficiency and the power loss of the circuit with a 3.3V input in Burst Mode operation.

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

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

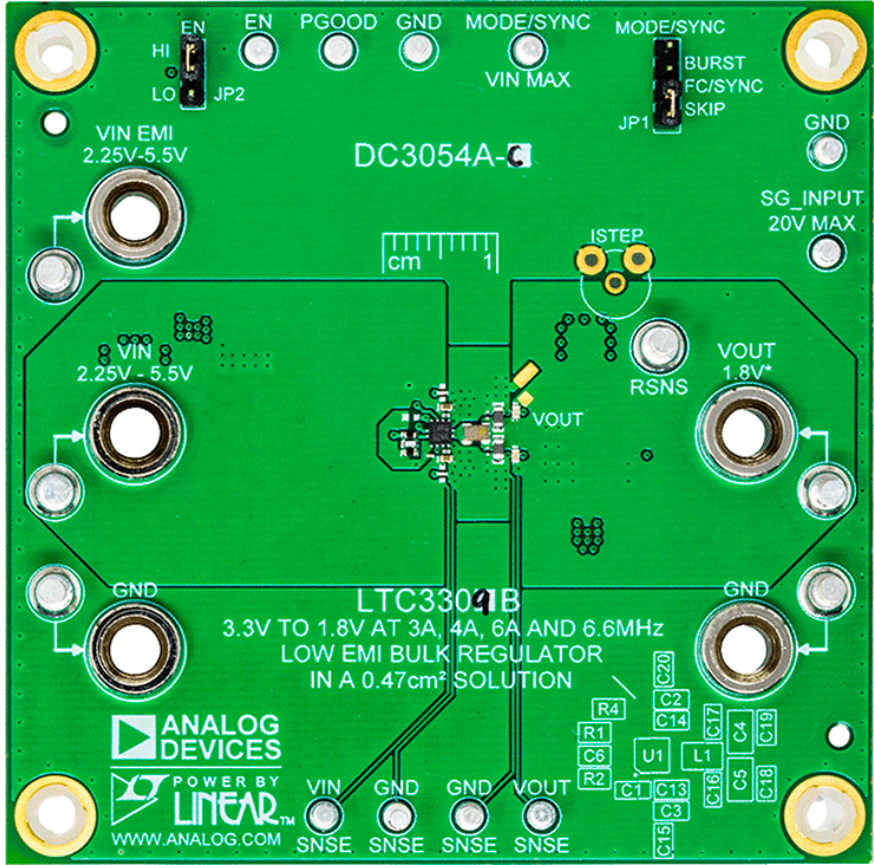
| SYMBOL     | PARAMETER                  | CONDITIONS         | MIN   | TYP | MAX   | UNITS |
|------------|----------------------------|--------------------|-------|-----|-------|-------|
| $V_{IN}$   | Input Voltage Range        |                    | 2.25  |     | 5.5   | V     |
| $V_{OUT}$  | $V_{OUT}$ Voltage Range*   |                    | 1.774 | 1.8 | 1.826 | V     |
| $I_{OUT}$  | OUTPUT Current             | $V_{IN} \geq 2.5V$ |       |     | 6     | A     |
| $f_{SW}$   | Switching Frequency        |                    | 3     | 6.6 | 10    | MHz   |
| $t_{ON}$   | Top Switch Minimum On Time |                    |       | 22  |       | ns    |
| Duty Cycle | Top Switch Duty Cycle      |                    |       |     | 100   | %     |

\*With 1% resistors. Accuracy will improve to within 1% using 0.1% FB resistors.

# DEMO MANUAL

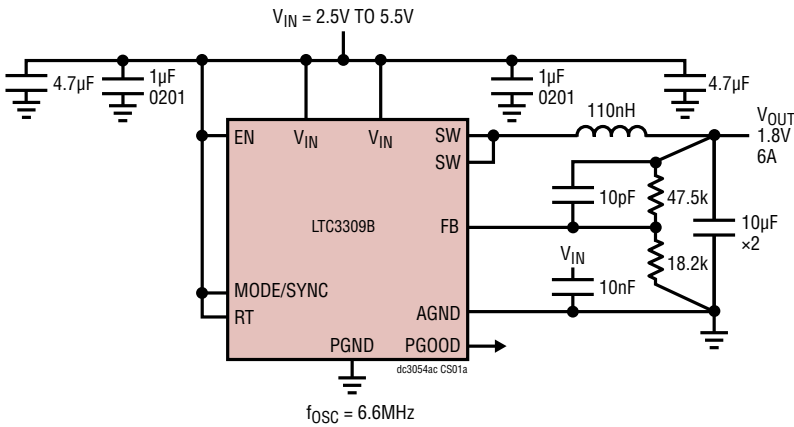
## DC3054A-C

### BOARD PHOTO

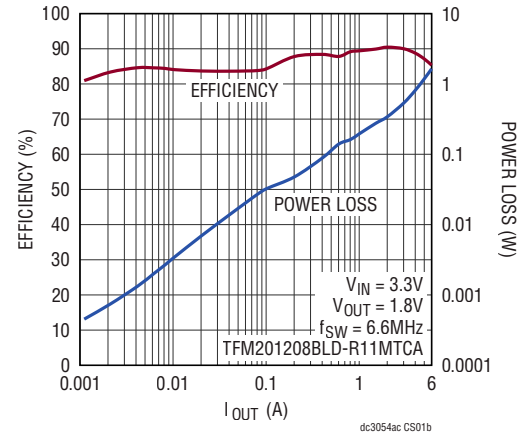


### CIRCUIT SCHEMATIC

High Efficiency, 6.6MHz, 1.8V 6A Step-Down Converter

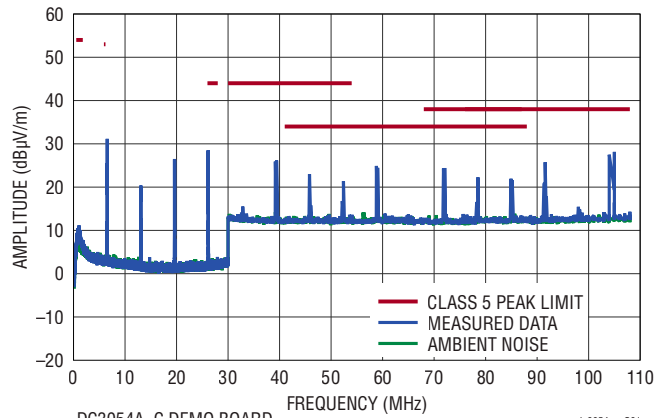


LTC3309B 3.3V to 1.8V Efficiency and Power Loss DC3054A-C in Burst Mode



### EMI TEST RESULTS

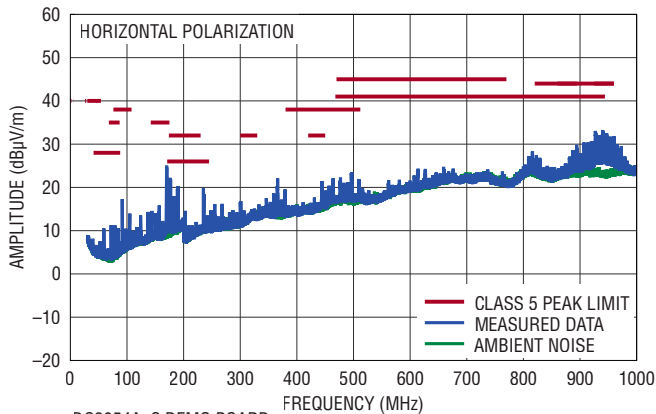
**CISPR25 Conducted Emissions with Class 5 Peak Limits (Voltage Method)**



DC3054A-C DEMO BOARD  
(WITH EMI FILTER INSTALLED)  
3.3V INPUT TO 1.8V OUTPUT AT 4.8A,  $f_{SW} = 6.6\text{MHz}$

dc3054a-c G01

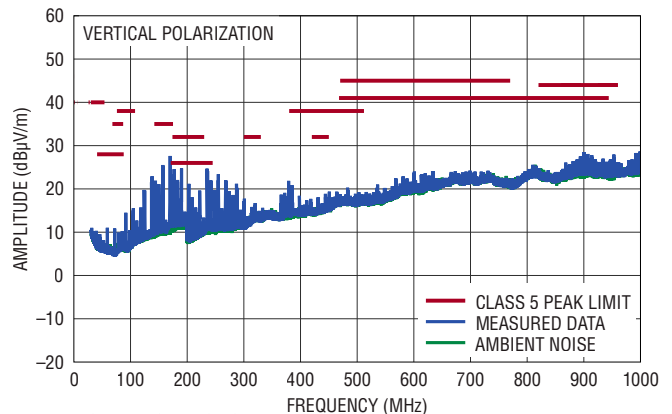
**Radiated EMI Performance (CISPR25 Radiated Emissions Test with Class 5 Peak Limits)**



DC3054A-C DEMO BOARD  
(WITH EMI FILTER INSTALLED)  
3.3V INPUT TO 1.8V OUTPUT AT 4.8A,  $f_{SW} = 6.6\text{MHz}$

dc3054a-c G02

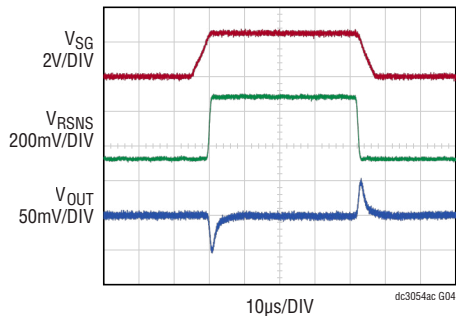
**Radiated EMI Performance (CISPR25 Radiated Emissions Test with Class 5 Peak Limits)**



DC3054A-C DEMO BOARD  
(WITH EMI FILTER INSTALLED)  
3.3V INPUT TO 1.8V OUTPUT AT 4.8A,  $f_{SW} = 6.6\text{MHz}$

dc3054a-c G03

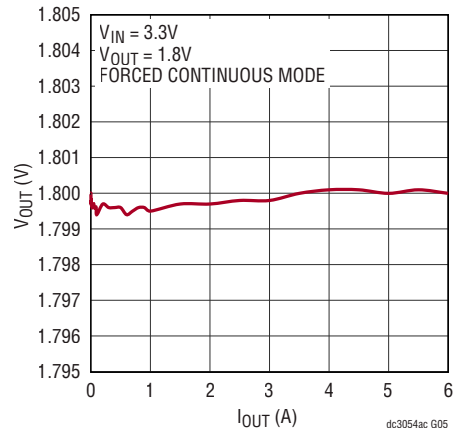
**Load Transient Response Forced Continuous Mode**



3.3V<sub>IN</sub> TO 1.8V<sub>OUT</sub>  
LOADSTEP 1.2A TO 4.8A 1A/µs

dc3054ac G04

**LTC3309B Load Regulation**



dc3054ac G05

### QUICK START PROCEDURE

Demonstration circuit 3054A-C is easy to set up and use to evaluate the performance of the LTC3309B. 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.

1. Set the JP1 Jumper to the SKIP position and JP2 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.
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 1.8V.
4. Connect an oscilloscope voltage probe as shown in Figure 2 in parallel with VM2. Set Channel to AC-coupled, voltage scale to 20mV and time base to 100ns. Observe the  $V_{OUT}$  ripple voltage.

NOTE: Measure the output voltage ripple by touching the probe tip directly across the output turrets or to TP1 as shown in Figure 2. TP1 is designed for a 50 $\Omega$  coax cable to reduce any high frequency noise that might couple into the oscilloscope probes.

5. Verify that PGOOD turret is high.
6. Increasing the load by 1A intervals up to 6A and record VM1, VM2, AM1 and AM2 for each interval.
7. Repeat step 6 for PS1 set to 2.5V and again for PS1 set to 5.0V.
8. Set the load to a constant 6A. Remove the oscilloscope voltage probe from  $V_{OUT}$ . Place a ground clip on PGND terminal and set the voltage scale to 1V and the time scale to 500ns/Division. Trigger on the rising edge of the voltage probe. Using a tip on the voltage probe, contact the SW node on the pad of L1. Observe the

duty cycle and the period of the switching waveform (~152 nanoseconds).

9. Set the load current to 0.5A and repeat step 8. Observe that the switching waveform is now operating in Pulse Skip Mode.
10. Move the jumper on JP2 to LO. Verify that  $V_{OUT}$  reads 0V and verify that PGOOD is low. Return jumper on JP2 to HI and verify VM2 is 1.8V and verify PGOOD2 is high.
11. If forced continuous or Burst Mode operation is desired, set PS1 to 0V. Move JP1 to FC/SYNC or BURST. Repeat steps 3 through 9. In step 9 observe that the switching waveform is now operating in forced continuous or Burst Mode operation.
12. To change the frequency, remove R9 if installed. Install the desired  $R_T$  resistor in the R4 location. Size the inductor and output capacitors to provide the desired inductor ripple and a stable output. Refer to the LTC3309B data sheet and [LTPowerCAD](#) for more information on choosing the required components.
13. To test the transient response with a base load, add the desired resistor to produce a minimum load between  $V_{OUT}$  and RSNS turrets ( $R_L$  shown on Figure 1). Note that the total load resistance will be  $R_L$  plus R11 (100m $\Omega$ ).
14. Adjust a signal generator with a 10ms period, 10% duty cycle and an amplitude from 1V to 2V to start.
15. Measure the RSNS voltage to observe the current,  $V_{RSNS}/100m\Omega$ . 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. Refer to the following equations and the optional transient response circuit shown in Figure 3:

$$I_{OUT} = V_{RSNS}/100m\Omega \quad (2)$$

where

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

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

**QUICK START PROCEDURE**

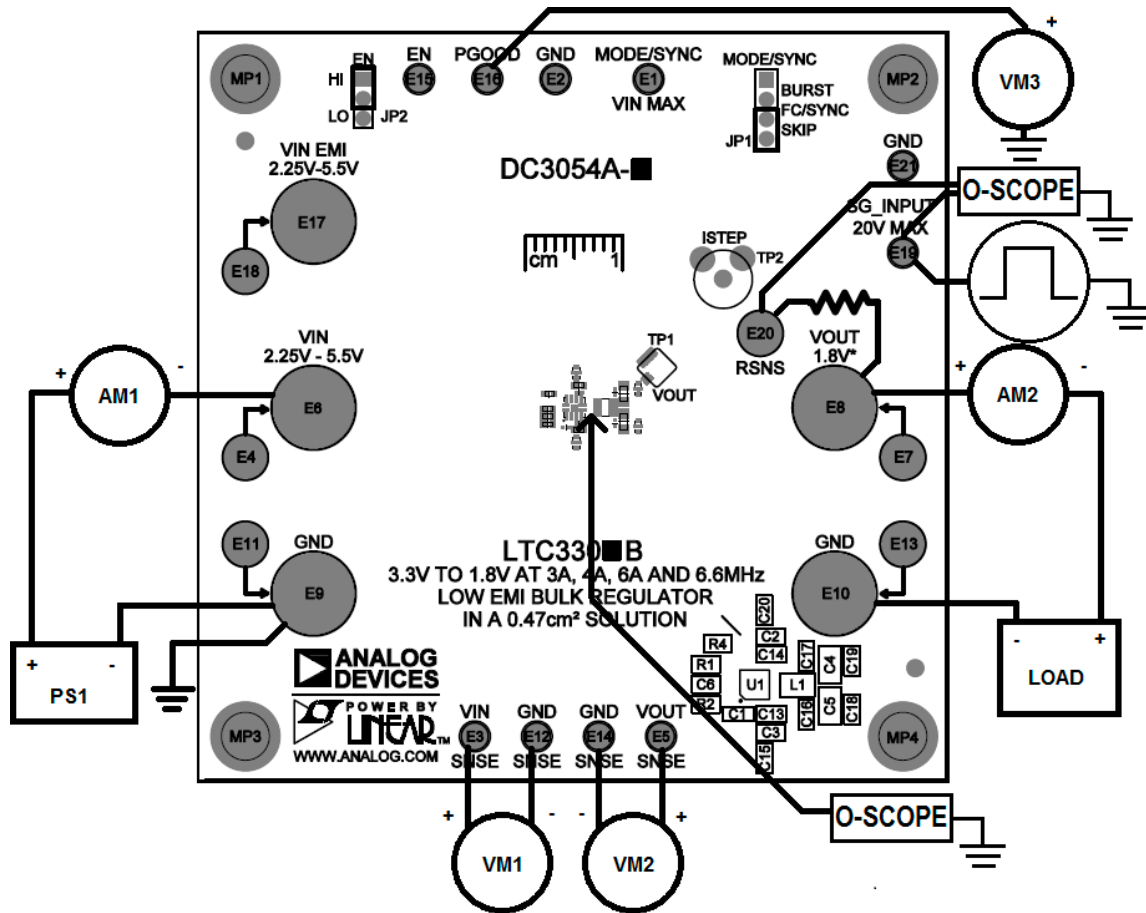


Figure 1. Test Setup for the DC3054A-C Demo Board





## THEORY OF OPERATION

### Introduction to the DC3054A-C

The DC3054A-C demonstration circuit features the LTC3309B, a low voltage synchronous step-down silent switcher. The LTC3309B 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. If the EN pin is low, the LTC3309B 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 sets the switching mode to pulse skip, forced continuous, or Burst Mode operation. If an external 3MHz to 10MHz clock is connected to the MODE/SYNC turret while the JP1 is set to the FC/SYNC position, the LTC3309B switching frequency will sync to the external clock while operating in forced continuous mode. See the LTC3309B 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  $V_{IN}$ . The maximum allowable operating frequency may be calculated using a minimum  $t_{ON}$  of 22ns in the formula below.

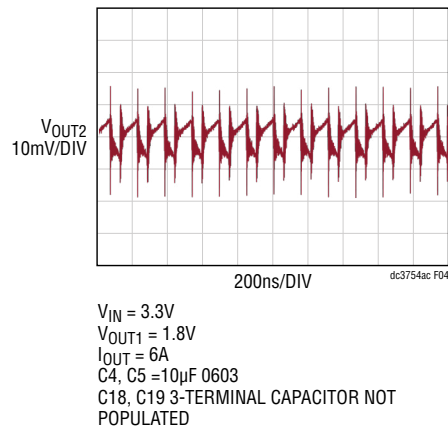
$$f_{SW(MAX)} = \frac{V_{OUT}}{V_{IN(MAX)} \cdot t_{ON(MIN)}}$$

Select an operating switching frequency below  $f_{SW(MAX)}$ . The recommended ripple current in the output inductor is 1.8A peak-to-peak for the LTC3309B. This determines the recommended inductor value for the application.

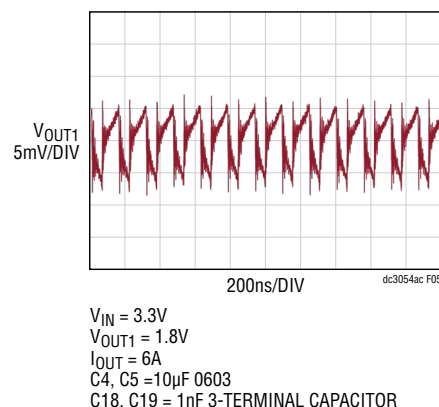
### Accurately Measuring Output Ripple of the LTC3309B

With the fast edge rates of the circuit, high frequency noise can be observed when measuring the output voltage with 1M $\Omega$  terminated oscilloscope probes. To better view the output ripple with oscilloscopes of 400MHz bandwidth and above a 50 $\Omega$  coax cable connected as close to the output caps as possible should be used with the oscilloscope channel terminated to 50 $\Omega$  at the scope. This will

help to reduce the noise coupling onto and displaying on the scope. The demo board is set up to solder an U.FL, RECEPT, ST SMD, 0Hz to 6GHz 50 $\Omega$  connector (TP1) near the output cap C4. These pads can also be used to solder a coax cable or other oscilloscope probe connector if desired.



The DC3054A-B uses 3-terminal capacitors, C18 and C19, on the output to reduce the high frequency spikes that can be observed with high bandwidth oscilloscopes. 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. The step can be reduced by choosing low ESL capacitors as close to the inductor as possible. The high frequency spikes are reduced with using a small low ESL 3-terminal capacitor with the self-resonant frequency close to the high frequency spikes. Below is the output ripple using a 500MHz scope, 50 $\Omega$  probe measured at TP1 on with the 3-terminal capacitor populated.



# DEMO MANUAL

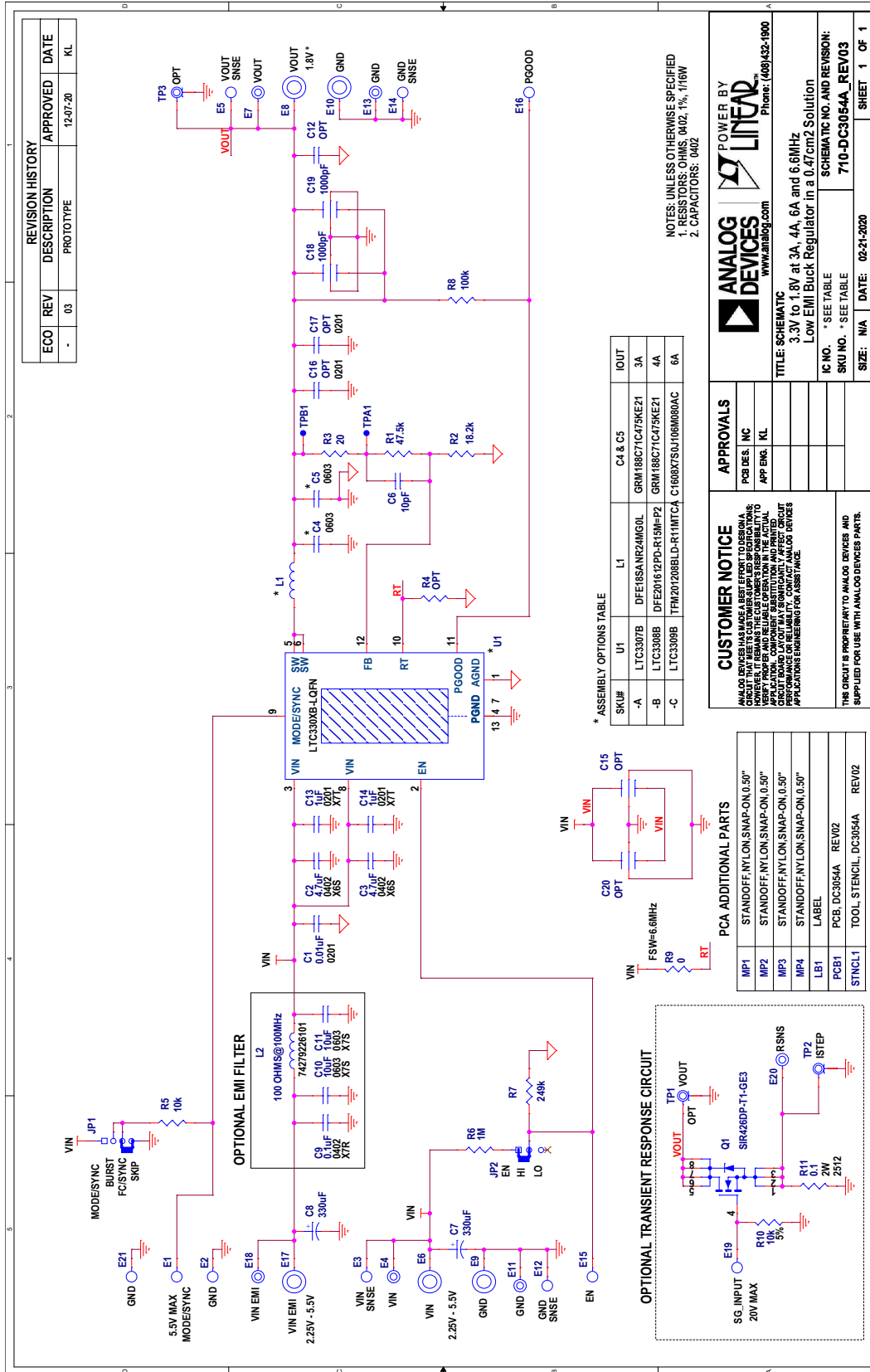
## DC3054A-C

### PARTS LIST

| ITEM  | QTY | REFERENCE                         | PART DESCRIPTION  | MANUFACTURER/PART NUMBER             |
|---|-----|-----------------------------------|---|--------------------------------------|
| <b>Required Circuit Components</b>              |     |                                   |   |                                      |
| 1   | 2   | C2, C3                            | CAP, 4.7 $\mu$ F, X6S, 6.3V, 20%, 0402  | MURATA, GRM155C80J475MEAAD           |
| 2   | 2   | C4, C5                            | CAP, 10 $\mu$ F, X7S, 6.3V, 20%, 0603   | TDK, C1608X7S0J106M080AC             |
| 3   | 1   | C6                                | CAP, 10pF, C0G, 50V, 5%, 0402   | MURATA, GJM1555C1H100JB01D           |
| 4   | 2   | C13, C14                          | CAP, 1 $\mu$ F, X7T, 6.3V, 20%, 0201  | MURATA, GRM033D70J105ME01D           |
| 5   | 1   | L1                                | IND., 0.11 $\mu$ H, PWR, 20%, 8.8A, 0.01 $\Omega$ , 0805                              | TDK, TFM201208BLD-R11MTCA            |
| 6   | 1   | R1                                | RES., 47.5k, 1%, 1/16W, 0402  | VISHAY, CRCW040247K5FKED             |
| 7   | 1   | R2                                | RES., 18.2k, 1%, 1/16W, 0402, AEC-Q200  | VISHAY, CRCW040218K2FKED             |
| 8   | 1   | U1                                | IC, 5V, 6A SYNCHRONOUS STEP-DOWN Silent Switcher, 2mm x 2mm LQFN                      | ANALOG DEVICES, LTC3309BEV#PBF       |
| <b>Additional Demo Board Circuit Components</b> |     |                                   |   |                                      |
| 1   | 1   | C1                                | CAP, 0.01 $\mu$ F, X5R, 10V, 10%, 0201  | MURATA, GRM033R61A103KA01D           |
| 2   | 2   | C7, C8                            | CAP, 330 $\mu$ F, TANT, POSCAP, 6.3V, 20%, 7343, 25m $\Omega$ , TPE, NO SUBS. ALLOWED | PANASONIC, 6TPE330ML                 |
| 3   | 1   | C9                                | CAP, 0.1 $\mu$ F, X7R, 10V, 10%, 0402, AEC-Q200                                       | MURATA, GCM155R71A104KA55D           |
| 4   | 2   | C10, C11                          | CAP, 10 $\mu$ F, X7S, 6.3V, 20%, 0603   | TDK, C1608X7S0J106M080AC             |
| 5   | 0   | C12                               | CAP, OPTION, 0402   |                                      |
| 6   | 2   | C18, C19                          | CAP, 1000pF, X7R, 50V, 20%, 0402, 3-TERM, X2Y EMI FILTER                              | JOHANSON DIELECTRICS, 500X07W102MV4T |
| 7   | 0   | C15, C20                          | CAP, 1000pF, X7R, 50V, 20%, 0402, 3-TERM, X2Y EMI FILTER                              | JOHANSON DIELECTRICS, 500X07W102MV4T |
| 8   | 0   | C16, C17                          | CAP, OPTION, 0201   |                                      |
| 9   | 1   | L2                                | IND., 100 $\Omega$ AT 100MHZ, FERRITE BEAD, 25%, 8A, 6m $\Omega$ , 1812               | WURTH ELEKTRONIK, 74279226101        |
| 10  | 1   | Q1                                | XSTR., MOSFET, N-CH, 40V, 15.9A, PPAK SO-8  | VISHAY, SIR426DP-T1-GE3              |
| 11  | 1   | R3                                | RES., 20 $\Omega$ , 1%, 1/16W, 0402, AEC-Q200   | VISHAY, CRCW040220R0FKED             |
| 12  | 0   | R4                                | RES., OPTION, 0402  |                                      |
| 13  | 1   | R5                                | RES., 10k, 5%, 1/16W, 0402, AEC-Q200  | VISHAY, CRCW040210K0JNED             |
| 14  | 1   | R6                                | RES., 1M $\Omega$ , 1%, 1/16W, 0402, AEC-Q200   | VISHAY, CRCW04021M00FKED             |
| 15  | 1   | R7                                | RES., 249k, 1%, 1/16W, 0402, AEC-Q200   | NIC, NRC04F2493TRF                   |
| 16  | 1   | R8                                | RES., 100k, 5%, 1/16W, 0402   | YAGEO, RC0402JR-07100KL              |
| 17  | 1   | R9                                | RES., 0 $\Omega$ , 1/16W, 0402  | VISHAY, CRCW04020000Z0ED             |
| 18  | 1   | R10                               | RES., 10k, 5%, 1/10W, 0402, AEC-Q200  | PANASONIC, ERJ2GEJ103X               |
| 19  | 1   | R11                               | RES., 0.1 $\Omega$ , 1%, 2W, 2512, SENSE, AEC-Q200                                    | IRC, LRC-LR2512LF-01-R100-F          |
| 20  | 0   | TP1, TP3                          | CONN., U.FL, RECEPT, ST SMD, 0Hz TO 6GHz 50 $\Omega$                                  | HIROSE ELECTRIC, U.FL-R-SMT-1(10)    |
| <b>Hardware</b>                                 |     |                                   |   |                                      |
| 1   | 10  | E1-E3, E5, E12, E14-E16, E19, E21 | TEST POINT, TURRET, 0.064" MTG. HOLE, PCB 0.062" THK                                  | MILL-MAX, 2308-2-00-80-00-00-07-0    |
| 2   | 6   | E4, E7, E11, E13, E18, E20        | TEST POINT, TURRET, 0.094" MTG. HOLE, PCB 0.062" THK                                  | MILL-MAX, 2501-2-00-80-00-00-07-0    |
| 3   | 5   | E6, E8-E10, E17                   | CONN., BANANA JACK, FEMALE, THT, NON-INSULATED, SWAGE, 0.218"                         | KEYSTONE, 575-4                      |
| 4   | 1   | JP1                               | CONN., HDR, MALE, 1x4, 2mm, VERT, ST, THT   | WURTH ELEKTRONIK, 62000411121        |
| 5   | 1   | JP2                               | CONN., HDR, MALE, 1x3, 2mm, VERT, ST, THT   | WURTH ELEKTRONIK, 62000311121        |
| 6   | 4   | MP1-MP4                           | STANDOFF, NYLON, SNAP-ON, 0.50"   | WURTH ELEKTRONIK, 702935000          |
| 7   | 0   | TP2                               | CONN., TEST JACK, PLUG, 1POS, THT, VERT   | TELEDYNE, PK5-2.5MM-113              |
| 8   | 2   | XJP1, XJP2                        | CONN., SHUNT, FEMALE, 2POS, 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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