

LT8708 80V V_{IN} and V_{OUT} Synchronous 4-Switch Buck-Boost DC/DC Controller with Flexible Bidirectional Capability

DESCRIPTION

Demonstration circuit 2596A is a high performance bidirectional buck-boost converter featuring the **LT[®]8708** that can operate from input voltages above, below or equal to the output voltage. The demo board input range is 36V to 75V. The output voltage is set at 48V and the output current limit at 6A.

The controller has integrated input voltage and output voltage regulators and two sets of input and output current regulators that control current flow in forward or reverse direction. Features are included that simplify bidirectional power conversion in battery/capacitor backup systems and other applications that may need regulation of V_{IN} , V_{OUT} , I_{IN} and/or I_{OUT} .

While the current mode control limits the inductor current both in normal and in reverse direction these current limits have some variation as input/output voltage changes. The forward and reverse input and output current regulators offer four accurate current limits that can be set individually.

The input voltage regulator is often used in applications with high impedance power sources and will reduce the forward current if the input voltage drops below the set point. When operating with reverse current flow the input voltage regulator regulates the voltage at the input side.

The operating mode of the controller is determined through the MODE pin (jumper JP7 Pins 5 to 12) and can be set to discontinuous mode, hybrid discontinuous mode, forced continuous mode and Burst Mode[®] Operation.

The LT8708 is capable of bidirectional operation when operating in the continuous conduction mode (CCM). DCM, HCM and Burst Mode operation only allow power to flow in one direction. Additional circuitry may be needed depending on the application.

By feeding the LT8708 from a separate low voltage supply the power dissipation can be reduced. The LT8708 will start when >5.5V voltage is applied at the input (V_{IN} pin), and when it is running it will draw current from the EXTV_{CC} pin if the voltage at the pin is > 6.4V.

Typical efficiency with 5A load is above 96.3% across a 36V to 75V input range.

The LT8708 data sheet gives a complete description of the part, operation and application information. The data sheet should be read in conjunction with this quick start guide for DC2596A. The input voltage range of the LT8708 itself is 2.8V (need EXTV_{CC} > 6.4V) to 80V and the output range is 1.3V to 80V.

The LT8708EUHG is assembled in a 40-Lead (5mm × 7mm) plastic QFN package with a thermal pad underneath the chip. Proper board layout is essential for maximum thermal and electrical performance. See the data sheet Circuit Board Layout Checklist section.

Design files for this circuit board are available at <http://www.analog.com/DC2596A>

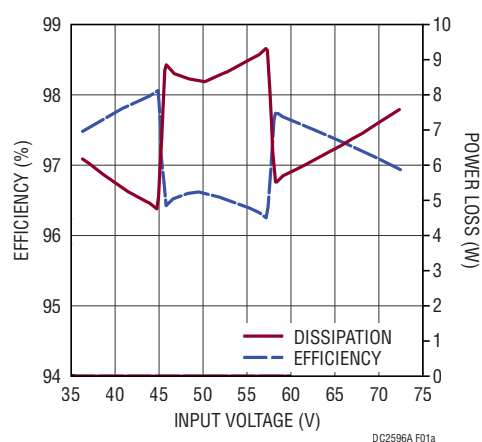
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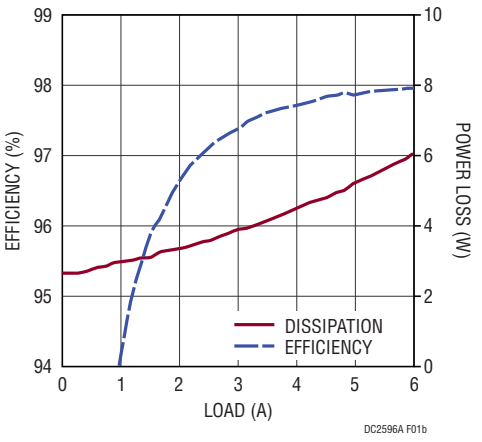
PERFORMANCE SUMMARY

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

| SYMBOL | PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|-----------|------------------------|--|-----|----------------------|-----|-------------|
| V_{IN} | Input Supply Range | | 36 | 48 | 75 | V |
| V_{OUT} | Output Voltage | | | 48 | | V |
| I_{IN} | Input Current Limit | | | 8.2 | | A |
| I_{OUT} | Output Current Limit | | | 6 | | A |
| f_{SW} | Switching Frequency | | | 200 | | kHz |
| EFF | Efficiency at DC input | $V_{IN} = 36\text{V}, V_{OUT} = 48\text{V}, I_{OUT} = 5\text{A}$ $V_{IN} = 48\text{V}, V_{OUT} = 48\text{V}, I_{OUT} = 5\text{A}$ $V_{IN} = 72\text{V}, V_{OUT} = 48\text{V}, I_{OUT} = 5\text{A}$ | | 97.5 96.5 97.0 | | % % % |



(a) As Function of Increasing Input Voltage at 5A Load, Forward CCM Mode



(b) Forward CCM Buck Mode, $V_{IN} = 56\text{V}$

Figure 1. Efficiency and Power Loss

QUICK START PROCEDURE

1. Demonstration circuit 2596A is easy to set up to evaluate the performance of the LT8708. Refer to Figure 2 for proper measurement equipment setup and follow the procedure below.
2. With power off, connect the input power supply to V_{IN} (J1) and GND (J3). Attach the load to V_{OUT} (J2) and GND (J3).
3. Set the power supply at 48V. The power source must have the current limit set at 9A or higher if you want to evaluate the board with full load over the input range.
4. Once the proper output voltage is established, adjust the load and the input voltage within the operating range and observe the output voltage regulation, ripple voltage and efficiency and other parameters as needed.
5. To measure input/output voltage ripple, avoid a long ground lead on the oscilloscope probe, as it may pick up switching noise. A commonly accepted method is to remove the oscilloscope probe end cap and ground lead and set the 20MHz bandwidth limit on the oscilloscope. Measure the input/output voltage ripple by touching the probe tip directly to the positive terminal of the input or output capacitor. Connect the probe ground terminal to the board's GND plane near the capacitor with a very short wire.

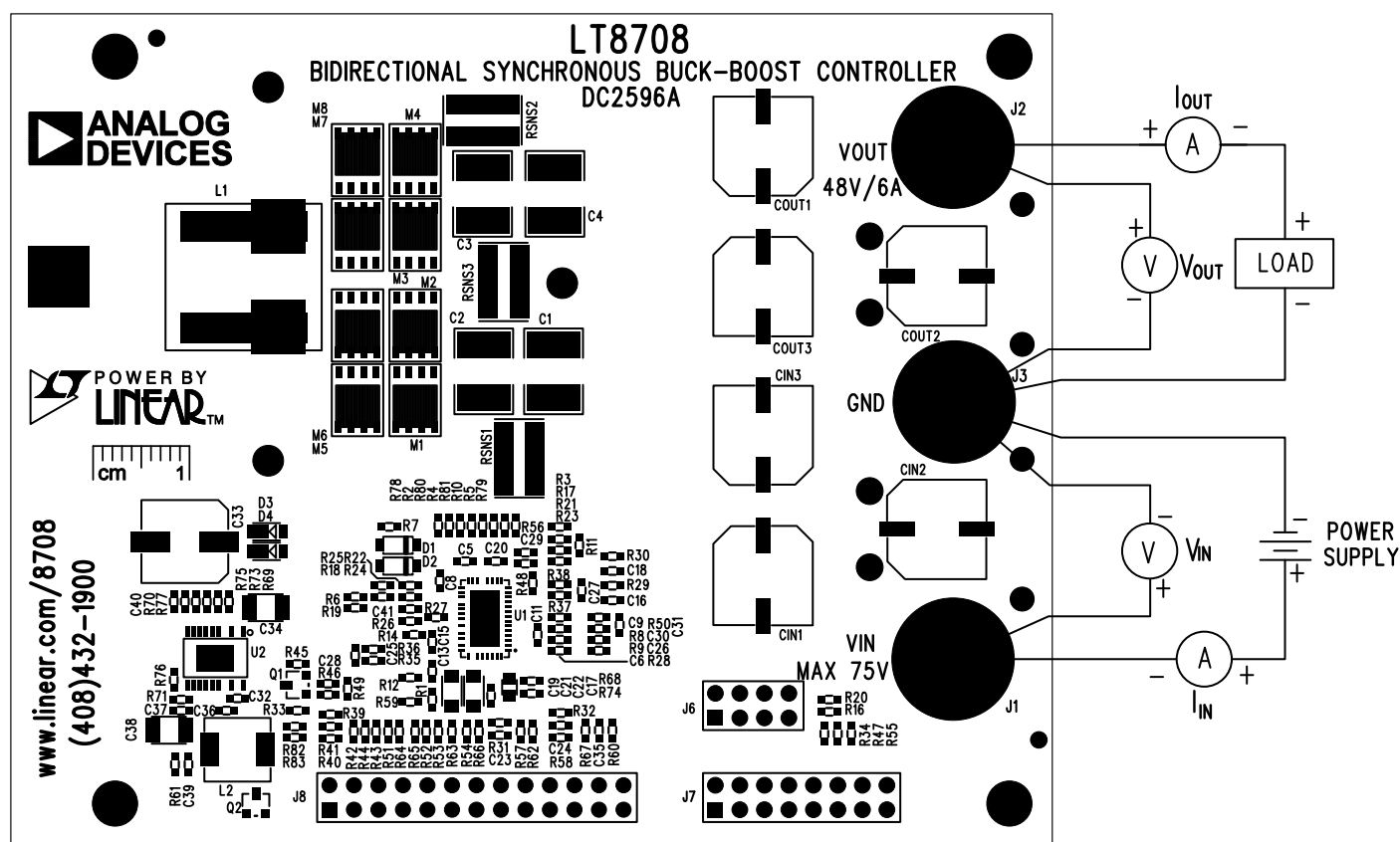


Figure 2. Test Setup

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PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|------------------------------------|-----|------------------------|--|--------------------------------------|
| Required Circuit Components | | | | |
| 1 | 6 | CIN1-CIN3, COUT1-COUT3 | CAP., ALUM., 33 μ F, 80V, 20% | PANASONIC, EEHZA1K330P |
| 2 | 4 | C1, C2, C3, C4 | CAP., 10 μ F, X7S, 100V, 20%, 2220 | TDK, CKG57KX7S2A106M335JH |
| 3 | 4 | C5, C8, C13, C15 | CAP., 0.22 μ F, X7R, 16V, 10%, 0603 | MURATA, GRM188R71C224KA01D |
| 4 | 2 | C6, C9 | CAP., 1000 μ F, X7R, 25V, 10%, 0603 | MURATA, GRM188R71E102KA01D |
| 5 | 6 | C16, C18, C23-C25, C27 | CAP., 10nF, X7R, 25V, 10%, 0603 | MURATA, GRM188R71E103KA01D |
| 6 | 1 | C17 | CAP., 4.7 μ F, X7R, 16V, 10%, 0805 | MURATA, GRM21BR71C475KA73L |
| 7 | 2 | C19, C21 | CAP., 4.7 μ F, X7S, 100V, 10%, 1206 | AVX, 12061Z475KAT2A |
| 8 | 2 | C20, C22 | CAP., 4.7 μ F, X5R, 10V, 10%, 0603 | MURATA, GRM188R61A475KE15D |
| 9 | 1 | C26 | CAP., 1 μ F, X7R, 25V, 10%, 0603 | MURATA, GRM188R71E105KA12D |
| 10 | 1 | C30 | CAP., 220pF, C0G, 25V, 5%, 0603 | WURTH ELEKTRONIK, 885012006040 |
| 11 | 1 | C31 | CAP., 6.8nF, X7R, 25V, 10%, 0603 | MURATA, GRM188R71E682KA01D |
| 12 | 2 | D1, D2 | DIODE, 200V, 1A, SOD123F | CENTRAL SEMI., CMMR1U-02 TR |
| 13 | 1 | L1 | IND., SHIELDED POWER INDUCTOR, 22 μ H | COILCRAFT, XAL1510-223MEB |
| 14 | 4 | M1, M2, M3, M4 | XSTR., MOSFET, N-CH, 80V, 100A, PG-TDSON-8 | INFINEON, BSC047N08NS3 G |
| 15 | 1 | RSNS1 | SENSE RES., 0.006 Ω , 3W, 1%, 2512 | SUSUMU, KRL6432E-M-R006-F-T1 |
| 16 | 1 | RSNS2 | SENSE RES., 0.008 Ω , 3W, 1%, 2512 | SUSUMU, KRL6432E-M-R008-F-T1 |
| 17 | 1 | RSNS3 | SENSE RES., 0.007 Ω , 3W, 1%, 2512 | SUSUMU, KRL6432E-M-R007-F-T1 |
| 18 | 1 | R7 | RES, CHIP, 3.3 Ω , 1/10W, 1%, 0603 | VISHAY, CRCW06033R30FKEA |
| 19 | 2 | R8,R9 | RES, CHIP, 10 Ω , 1/10W, 1%, 0603 | VISHAY, CRCW060310R0FKEA |
| 20 | 1 | R19 | RES, CHIP, 464k, 1/10W, 1%, 0603 | VISHAY, CRCW0603464KFKEA |
| 21 | 1 | R28 | RES, CHIP, 20.0k, 1/10W, 1%, 0603 | VISHAY, CRCW060320K0FKEA |
| 22 | 2 | R29, R30 | RES, CHIP, 23.7k, 1/10W, 1%, 0603 | VISHAY, CRCW060323K7FKEA |
| 23 | 2 | R31, R32 | RES, CHIP, 22.1k, 1/10W, 1%, 0603 | VISHAY, CRCW060322K1FKEA |
| 24 | 2 | R35, R37 | RES, CHIP, 17.4k, 1/10W, 1%, 0603 | VISHAY, CRCW060317K4FKEA |
| 25 | 2 | R36, R38 | RES, CHIP, 200 Ω , 1/10W, 1%, 0603 | VISHAY, CRCW0603200RFKEA |
| 26 | 3 | R39, R40, R41 | RES, CHIP, 46.4k, 1/10W, 1%, 0603 | VISHAY, CRCW060346K4FKEA |
| 27 | 1 | R42 | RES, CHIP, 47.5k, 1/10W, 1%, 0603 | VISHAY, CRCW060347K5FKEA |
| 28 | 1 | R50 | RES, CHIP, 10k, 1/10W, 1%, 0603 | VISHAY, CRCW060310K0FKEA |
| 29 | 1 | R48 | RES, CHIP, 215k, 1/10W, 1%, 0603 | VISHAY, CRCW0603215KFKEA |
| 30 | 1 | U1 | IC., BUCK-BOOST DC/DC CONTROLLER. 40L-5X8-UHG | ANALOG DEVICES, INC., LT8708EUHG#PBF |

PARTS LIST

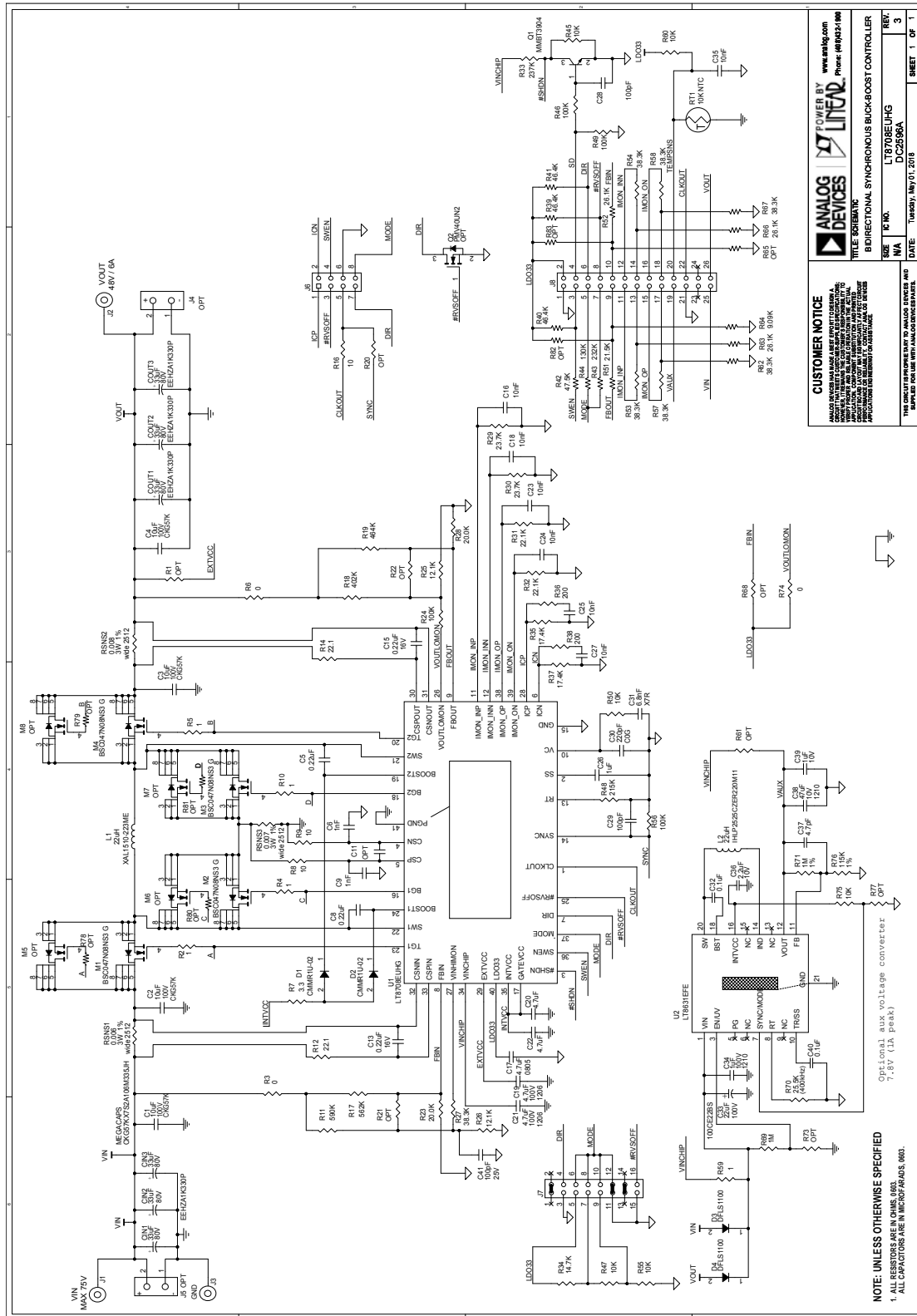
| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|---|-----|--|--------------------------------------|-------------------------------------|
| Additional Demo Board Circuit Components | | | | |
| 1 | 0 | C11 (OPT) | CAP., 0603 | |
| 2 | 1 | C35 | CAP., 10nF, X7R, 25V, 10%, 0603 | MURATA, GRM188R71E103KA01D |
| 3 | 3 | C28, C29, C41 | CAP., 100pF, C0G, 25V, 5%, 0603 | WURTH ELEKTRONIK, 885012006038 |
| 4 | 2 | C32, C40 | CAP., 0.1µF, X7R, 25V, 10%, 0603 | MURATA, GRM188R71E104KA01D |
| 5 | 1 | C33 | CAP., ALUM., 22µF, 100V, 20% | SUNCON, 100CE22BS |
| 6 | 1 | C34 | CAP., 1µF, X7R, 100V, 10%, 1210 | MURATA, GRM32ER72A105KA01L |
| 7 | 1 | C36 | CAP., 2.2µF, X5R, 10V, 10%, 0603 | MURATA, GRM188R61A225KE34D |
| 8 | 1 | C37 | CAP., 4.7pF, C0G, 50V, ±0.25pF, 0603 | MURATA, GRM1885C1H4R7CA01D |
| 9 | 1 | C38 | CAP., 47µF, X5R, 10V, 10%, 1210 | MURATA, GRM32ER61A476KE20L |
| 10 | 1 | C39 | CAP., 1µF, X7R, 10V, 10%, 0603 | MURATA, GRM188R71A105KA61D |
| 11 | 2 | D3, D4 | DIODE, SCHOTTKY, 100V, POWERDI123 | DIODES INC., DFLS1100-7 |
| 12 | 1 | L2 | IND., PWR., 22µH | VISHAY, IHLP2525CZER220M11 |
| 13 | 0 | M5, M6, M7, M8 (OPT) | N-CH, PG-TDSON-8 | |
| 14 | 1 | Q1 | TRANS, NPN, 40V, 0.2A, SOT-23 | FAIRCHILD SEMI., MMBT3904 |
| 15 | 0 | Q2 (OPT) | TRANSISTOR, SOT-23 | |
| 16 | 1 | RT1 | THERMISTOR, 10k, NTC, 0603 | MURATA, NCP18XH103J6SRB |
| 17 | 0 | R1, R20, R21, R22, R61, R65, R68, R73, R77-R83 (OPT) | RES., OPTION, 0603 | OPTION |
| 18 | 5 | R2, R4, R5, R10, R59 | RES, CHIP, 1Ω, 1/10W, 1%, 0603 | VISHAY, CRCW06031R00FKEA |
| 19 | 3 | R3, R6, R74 | RES, CHIP, 0Ω, 1/10W, 1%, 0603 | VISHAY, CRCW06030000Z0EA |
| 20 | 1 | R16 | RES, CHIP, 10Ω, 1/10W, 1%, 0603 | VISHAY, CRCW060310R0FKEA |
| 21 | 1 | R11 | RES, CHIP, 590k, 1/10W, 1%, 0603 | VISHAY, CRCW0603590KFKEA |
| 22 | 2 | R12, R14 | RES, CHIP, 22.1Ω, 1/10W, 1%, 0602 | VISHAY, CRCW060322R1FKEA |
| 23 | 1 | R17 | RES, CHIP, 562k, 1/10W, 1%, 0603 | VISHAY, CRCW0603562KFKEA |
| 24 | 1 | R18 | RES, CHIP, 402k, 1/10W, 1%, 0603 | VISHAY, CRCW0603402KFKEA |
| 25 | 1 | R23 | RES, CHIP, 20.0k, 1/10W, 1%, 0603 | VISHAY, CRCW060320K0FKEA |
| 26 | 4 | R24, R46, R49, R56 | RES, CHIP, 100k, 1/10W, 1%, 0603 | VISHAY, CRCW0603100KFKEA |
| 27 | 2 | R25, R26 | RES, CHIP, 12.1k, 1/10W, 1%, 0603 | VISHAY, CRCW060312K1FKEA |
| 28 | 7 | R27, R53, R54, R57, R58, R62, R67 | RES, CHIP, 38.3k, 1/10W, 1%, 0603 | VISHAY, CRCW060338K3FKEA |
| 29 | 1 | R33 | RES, CHIP, 237k, 1/10W, 1%, 0603 | VISHAY, CRCW0603237KFKEA |
| 30 | 1 | R34 | RES, CHIP, 14.7k, 1/10W, 1%, 0603 | VISHAY, CRCW060314K7FKEA |
| 31 | 1 | R43 | RES, CHIP, 232k, 1/10W, 1%, 0603 | VISHAY, CRCW0603232KFKEA |
| 32 | 1 | R44 | RES, CHIP, 130k, 1/10W, 1%, 0603 | VISHAY, CRCW0603130KFKEA |
| 33 | 5 | R45, R47, R55, R60, R75 | RES, CHIP, 10k, 1/10W, 1%, 0603 | VISHAY, CRCW060310K0FKEA |
| 34 | 1 | R51 | RES, CHIP, 21.5k, 1/10W, 1%, 0603 | VISHAY, CRCW060321K5FKEA |
| 35 | 3 | R52, R63, R66 | RES, CHIP, 26.1k, 1/10W, 1%, 0603 | VISHAY, CRCW060326K1FKEA |
| 36 | 1 | R64 | RES, CHIP, 9.09k, 1/10W, 1%, 0603 | VISHAY, CRCW06039K09FKEA |
| 37 | 2 | R69, R71 | RES, CHIP, 1MΩ, 1/10W, 1%, 0603 | VISHAY, CRCW06031M00FKEA |
| 38 | 1 | R70 | RES, CHIP, 25.5k, 1/10W, 1%, 0603 | VISHAY, CRCW060325K5FKEA |
| 39 | 1 | R76 | RES, CHIP, 115k, 1/10W, 1%, 0603 | VISHAY, CRCW0603115KFKEA |
| 40 | 1 | U2 | I.C. REGULATOR, 20-TSSOP | ANALOG DEVICES, INC., LT8631EFE#PBF |

DEMO MANUAL DC2596A

PARTS LIST

| ITEM | QTY | REFERENCE | PART DESCRIPTION | MANUFACTURER/PART NUMBER |
|------------------------------|-----|----------------------------------|------------------------------------|-------------------------------|
| Hardware for Demo Board Only | | | | |
| 1 | 3 | J1, J2, J3 | STUD, TEST PIN | PEM, KFH-032-10ET |
| 2 | 3 | J1, J2, J3 | NUT, BRASS NUTS #10-32 | ANY #10-32M/S BR PL |
| 3 | 3 | J1, J2, J3 | RING, LUG RING #10 | KEYSTONE, 8205 |
| 4 | 3 | J1, J2, J3 | WASHER, TIN PLATED BRASS | ANY, #10 EXT BZ TN |
| 5 | 0 | J4, J5 (OPT) | CON., 2-PIN | |
| 6 | 1 | J6 | HEADER 4 × 2 PIN 0.100 DOUBLE ROW | WURTH ELEKTRONIK, 61300821121 |
| 7 | 1 | J7 | HEADER 8 × 2 PIN 0.100 DOUBLE ROW | WURTH ELEKTRONIK, 61301621121 |
| 8 | 3 | J7 (1-2), J7 (11-12), J7 (13-14) | SHUNT, 0.1" CENTER | WURTH ELEKTRONIK, 60900213421 |
| 9 | 1 | J8 | HEADER 13 × 2-PIN 0.100 DOUBLE ROW | WURTH ELEKTRONIK, 61302621121 |
| 10 | 4 | MH1-MH4 | STAND-OFF, NYLON 0.375" | WURTH ELEKTRONIK, 702933000 |
| 11 | 1 | | PCB, DC2596A | ANALOG DEVICES, INC., DC2596A |
| 12 | 2 | | STENCIL (TOP AND BOTTOM) | |

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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