

# LT8708 80V V<sub>IN</sub> and V<sub>OUT</sub> 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<sup>®</sup>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<sub>IN</sub>, V<sub>OUT</sub>, I<sub>IN</sub> and/or I<sub>OUT</sub>.

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<sup>®</sup> 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<sub>IN</sub> pin), and when it is running it will draw current from the EXTV<sub>CC</sub> 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<sub>CC</sub> > 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>**

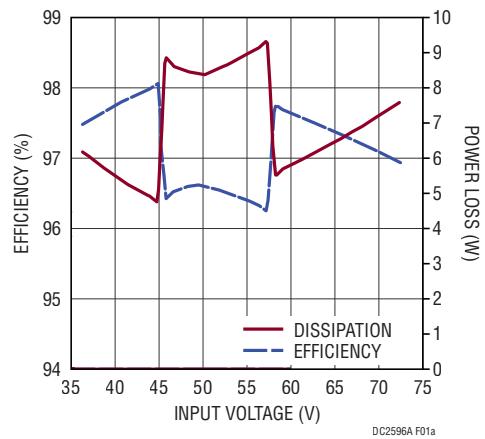
All registered trademarks and trademarks are the property of their respective owners.

# DEMO MANUAL DC2596A

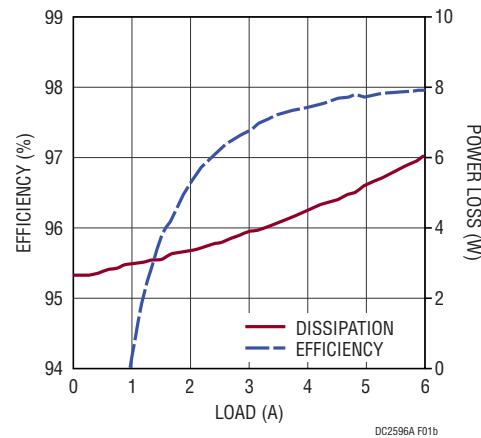
## PERFORMANCE SUMMARY

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.

For reverse power flow testing, see data sheet. When measuring input/output voltages, measure at the input/output terminals of the board to avoid measurement error caused by voltage drops in cables.

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.

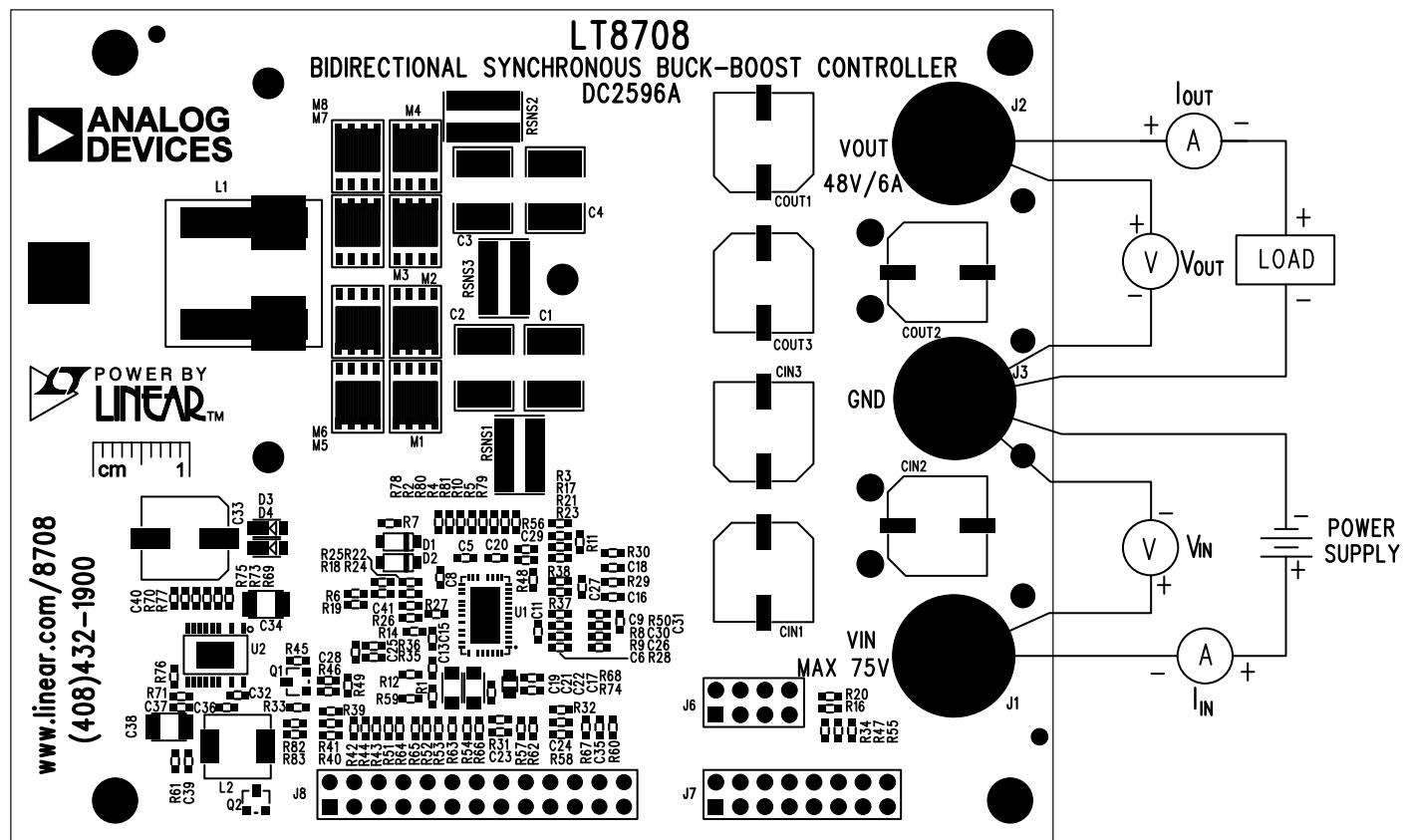


Figure 2. Test Setup

# DEMO MANUAL DC2596A

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Required Circuit Components</b>				
1	6	CIN1-CIN3, COUT1-COUT3	CAP, ALUM., 33µF, 80V, 20%	PANASONIC, EEHZA1K330P
2	4	C1, C2, C3, C4	CAP, 10µF, X7S, 100V, 20%, 2220	TDK, CKG57KX7S2A106M335JH
3	4	C5, C8, C13, C15	CAP, 0.22µF, X7R, 16V, 10%, 0603	MURATA, GRM188R71C224KA01D
4	2	C6, C9	CAP, 1000pF, 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, 4.7µF, X7R, 16V, 10%, 0805	MURATA, GRM21BR71C475KA73L
7	2	C19, C21	CAP, 4.7µF, X7S, 100V, 10%, 1206	AVX, 12061Z475KAT2A
8	2	C20, C22	CAP, 4.7µF, X5R, 10V, 10%, 0603	MURATA, GRM188R61A475KE15D
9	1	C26	CAP, 1µF, X7R, 25V, 10%, 0603	MURATA, GRM188R71E105KA12D
10	1	C30	CAP, 220pF, COG, 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, 22µH	COILCRAFT, XAL1510-223MEB
14	4	M1, M2, M3, M4	XSTR., MOSFET, N-CH, 80V, 100A, PG-TDS0N-8	INFINEON, BSC047N08NS3 G
15	1	RSNS1	SENSE RES., 0.006Ω, 3W, 1%, 2512	SUSUMU, KRL6432E-M-R006-F-T1
16	1	RSNS2	SENSE RES., 0.008Ω, 3W, 1%, 2512	SUSUMU, KRL6432E-M-R008-F-T1
17	1	RSNS3	SENSE RES., 0.007Ω, 3W, 1%, 2512	SUSUMU, KRL6432E-M-R007-F-T1
18	1	R7	RES, CHIP, 3.3Ω, 1/10W, 1%, 0603	VISHAY, CRCW06033R30FKEA
19	2	R8, R9	RES, CHIP, 10Ω, 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, 200Ω, 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

# DEMO MANUAL DC2596A

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Additional Demo Board Circuit Components</b>				
1	0	C11 (OPT)	CAP, 0603	
2	1	C35	CAP, 10nF, X7R, 25V, 10%, 0603	MURATA, GRM188R71E103KA01D
3	3	C28, C29, C41	CAP, 100pF, COG, 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, COG, 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, CRCW0603000Z0EA
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

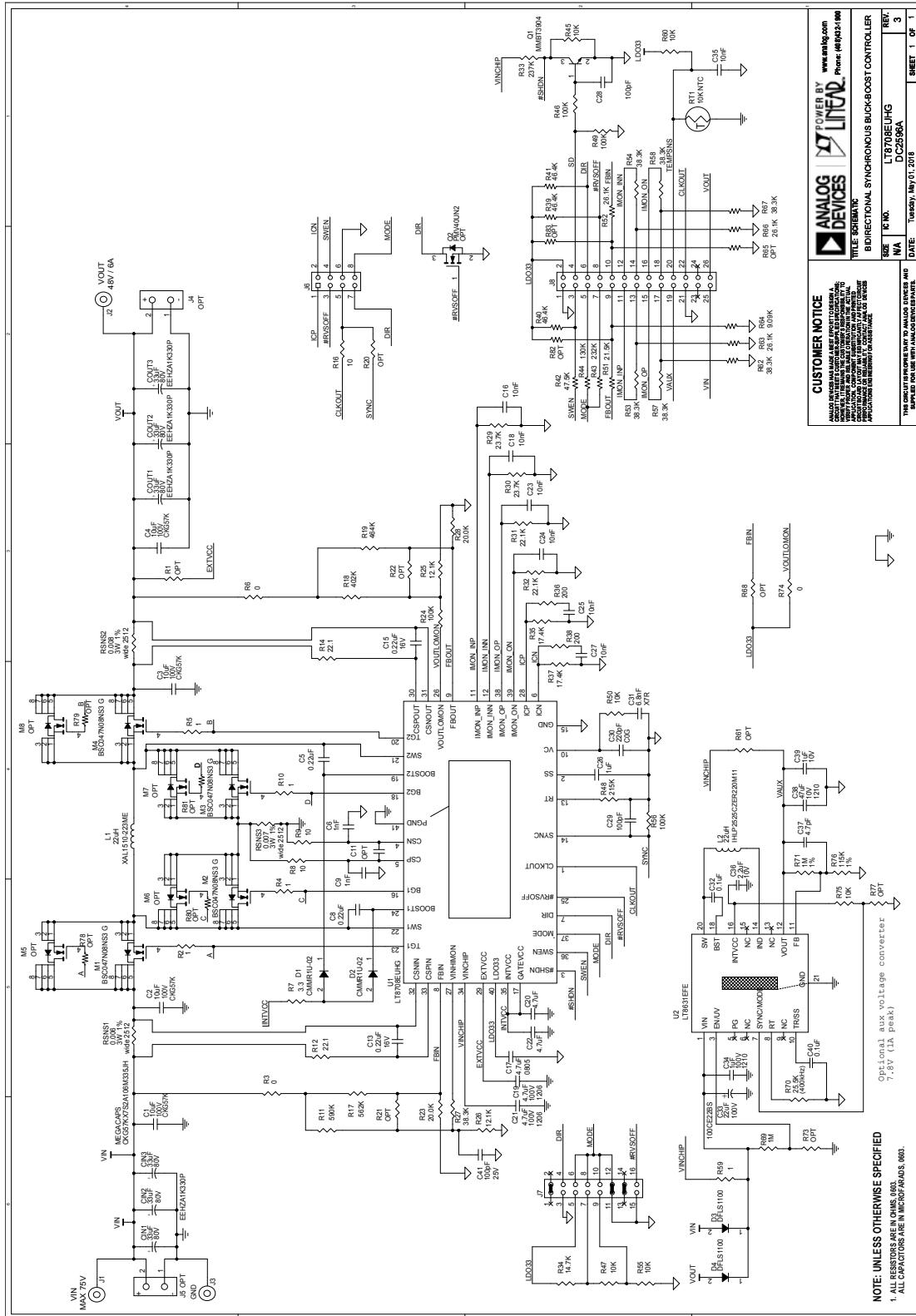
---

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Hardware for Demo Board Only</b>				
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 x 2 PIN 0.100 DOUBLE ROW	WURTH ELEKTRONIK, 61300821121
7	1	J7	HEADER 8 x 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 x 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)	

# DEMO MANUAL DC2596A

## SCHEMATIC DIAGRAM



Information furnished by Analog Devices is believed to be accurate and reliable. However, no responsibility is assumed by Analog Devices for its use, nor for any infringements of patents or other rights of third parties that may result from its use. Specifications subject to change without notice. No license is granted by implication or otherwise under any patent or patent rights of Analog Devices.

# DEMO MANUAL DC2596A

---



## 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.

---

## Legal Terms and Conditions

By using the evaluation board discussed herein (together with any tools, components documentation or support materials, the "Evaluation Board"), you are agreeing to be bound by the terms and conditions set forth below ("Agreement") unless you have purchased the Evaluation Board, in which case the Analog Devices Standard Terms and Conditions of Sale shall govern. Do not use the Evaluation Board until you have read and agreed to the Agreement. Your use of the Evaluation Board shall signify your acceptance of the Agreement. This Agreement is made by and between you ("Customer") and Analog Devices, Inc. ("ADI"), with its principal place of business at One Technology Way, Norwood, MA 02062, USA. Subject to the terms and conditions of the Agreement, ADI hereby grants to Customer a free, limited, personal, temporary, non-exclusive, non-sublicensable, non-transferable license to use the Evaluation Board FOR EVALUATION PURPOSES ONLY. Customer understands and agrees that the Evaluation Board is provided for the sole and exclusive purpose referenced above, and agrees not to use the Evaluation Board for any other purpose. Furthermore, the license granted is expressly made subject to the following additional limitations: Customer shall not (i) rent, lease, display, sell, transfer, assign, sublicense, or distribute the Evaluation Board; and (ii) permit any Third Party to access the Evaluation Board. As used herein, the term "Third Party" includes any entity other than ADI, Customer, their employees, affiliates and in-house consultants. The Evaluation Board is NOT sold to Customer; all rights not expressly granted herein, including ownership of the Evaluation Board, are reserved by ADI. CONFIDENTIALITY. This Agreement and the Evaluation Board shall all be considered the confidential and proprietary information of ADI. Customer may not disclose or transfer any portion of the Evaluation Board to any other party for any reason. Upon discontinuation of use of the Evaluation Board or termination of this Agreement, Customer agrees to promptly return the Evaluation Board to ADI. ADDITIONAL RESTRICTIONS. Customer may not disassemble, decompile or reverse engineer chips on the Evaluation Board. Customer shall inform ADI of any occurred damages or any modifications or alterations it makes to the Evaluation Board, including but not limited to soldering or any other activity that affects the material content of the Evaluation Board. Modifications to the Evaluation Board must comply with applicable law, including but not limited to the RoHS Directive. TERMINATION. ADI may terminate this Agreement at any time upon giving written notice to Customer. Customer agrees to return to ADI the Evaluation Board at that time. LIMITATION OF LIABILITY. THE EVALUATION BOARD PROVIDED HEREUNDER IS PROVIDED "AS IS" AND ADI MAKES NO WARRANTIES OR REPRESENTATIONS OF ANY KIND WITH RESPECT TO IT. ADI SPECIFICALLY DISCLAIMS ANY REPRESENTATIONS, ENDORSEMENTS, GUARANTEES, OR WARRANTIES, EXPRESS OR IMPLIED, RELATED TO THE EVALUATION BOARD INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTY OF MERCHANTABILITY, TITLE, FITNESS FOR A PARTICULAR PURPOSE OR NONINFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS. IN NO EVENT WILL ADI AND ITS LICENSORS BE LIABLE FOR ANY INCIDENTAL, SPECIAL, INDIRECT, OR CONSEQUENTIAL DAMAGES RESULTING FROM CUSTOMER'S POSSESSION OR USE OF THE EVALUATION BOARD, INCLUDING BUT NOT LIMITED TO LOST PROFITS, DELAY COSTS, LABOR COSTS OR LOSS OF GOODWILL. ADI'S TOTAL LIABILITY FROM ANY AND ALL CAUSES SHALL BE LIMITED TO THE AMOUNT OF ONE HUNDRED US DOLLARS (\$100.00). EXPORT. Customer agrees that it will not directly or indirectly export the Evaluation Board to another country, and that it will comply with all applicable United States federal laws and regulations relating to exports. GOVERNING LAW. This Agreement shall be governed by and construed in accordance with the substantive laws of the Commonwealth of Massachusetts (excluding conflict of law rules). Any legal action regarding this Agreement will be heard in the state or federal courts having jurisdiction in Suffolk County, Massachusetts, and Customer hereby submits to the personal jurisdiction and venue of such courts. The United Nations Convention on Contracts for the International Sale of Goods shall not apply to this Agreement and is expressly disclaimed.

UG-1357 Rev 0