

# LTM4655 Low EMI Dual 13V to 28V<sub>IN</sub>, +12V/4A<sub>OUT</sub> and -12V/2.2A<sub>OUT</sub> Negative $\mu$ Module Regulator

## DESCRIPTION

Demonstration circuit 2594A is a step-down DC/DC converter and an inverting DC/DC converter with a 13V to 28V input voltage range, +12V at 4A, and -12V at up to 2.5A outputs featuring the LTM®4655. The LTM4655 is a EN55022B compliant 40V, dual 4A or single 8A step-down or 50W inverting DC/DC  $\mu$ Module® Regulator.

The switching frequencies of both channels are set at 1.2MHz on DC2594A. If the output voltage collapses sufficiently due to an overload or short-circuit condition, the internal oscillator will fold-back to one-fifth of the LTM4655's programmed switching frequency, protecting the power switch from damage.

Key features of this board include:

- SSFM Jumper for Spread Spectrum Options
- CLKIN Inputs for External Sync
- PGOOD Signals for Each Output

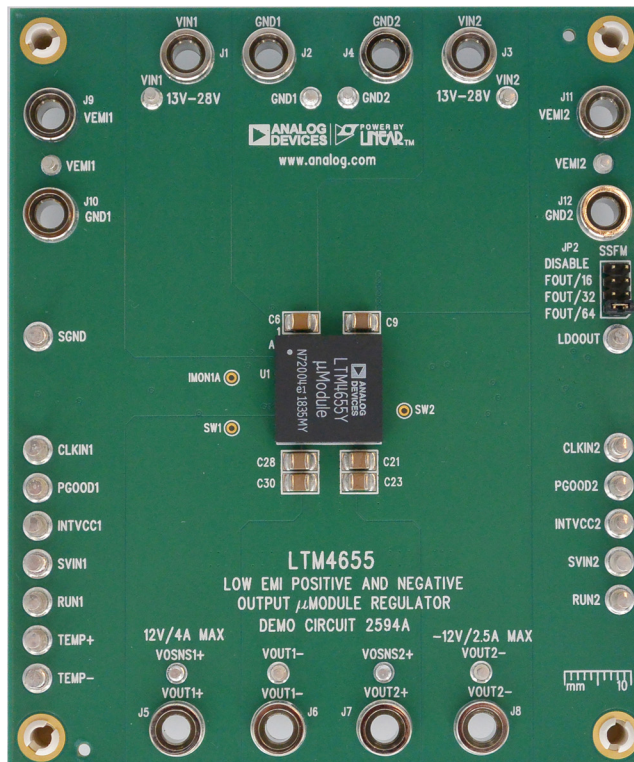
The two channels can be paralleled for higher output current. See the data sheet for more information on setting-up the board for paralleling the two outputs.

The LTM4655 data sheet gives a complete description of the device, its operation and application information. The data sheet must be read in conjunction with this demo manual prior to working on or modifying DC2594A.

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

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

## BOARD PHOTO



# DEMO MANUAL DC2594A

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

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
$V_{IN}$	Input Supply Range		13		28	V
$f_{SW}$	Switching Frequency			1.2		MHz
$V_{OUT1}$	Output 1 Voltage	$V_{IN} = 14\text{V} - 28\text{V}$ , $I_{OUT} = 0\text{A} - 4\text{A}$	11.9	12	12.1	V
$I_{OUT1}$	Output 1 Current	$V_{IN} = 13.5\text{V}$	0		4	A
$V_{OUT1(AC)}$	Output 1 Ripple (Across C30), 20MHz	$V_{IN} = 28\text{V}$ , $I_{OUT} = 4\text{A}$ , 20MHz		10		mV <sub>P-P</sub>
$\eta_1$	Efficiency, Output 1	$V_{IN} = 28\text{V}$ , $I_{OUT} = 4\text{A}$		89.5		%
$V_{OUT2}$	Output 2 Voltage	$V_{IN} = 14\text{V} - 28\text{V}$ , $I_{OUT} = 0\text{A} - 2.5\text{A}$	-11.9	-12	-12.1	V
$I_{OUT2}$	Output 2 Current	$V_{IN} = 13\text{V}$	0		-2.2	A
$I_{OUT2}$	Output 2 Current	$V_{IN} = 28\text{V}$	0		-2.5	A
$V_{OUT2(AC)}$	Output 2 Ripple (Across C23), 20MHz	$V_{IN} = 28\text{V}$ , $I_{OUT} = 2.5\text{A}$		30		mV <sub>P-P</sub>
$\eta_2$	Efficiency, Output 2	$V_{IN} = 28\text{V}$ , $I_{OUT} = 2.5\text{A}$		88.0		%

## QUICK START PROCEDURE

Demo circuit 2594A is an easy way to evaluate the performance of the LTM4655. Refer to Figure 1 for proper measurement equipment setup, and follow the procedure below.

1. With power off, connect the input power supply “+” to  $V_{IN1}$  and  $V_{IN2}$  and “-” to GND1 and GND2. Connect the loads from  $V_{OUT1}^+$  to  $V_{OUT1}^-$ , and  $V_{OUT2}^+$  to  $V_{OUT2}^-$ .
2. Set voltage of the DC power supply at 14V. Turn on the power at the input.

NOTE: Make sure that the input voltage does not exceed 28V.

3. Check for the proper output voltage between  $V_{OUT1}^+$  and  $V_{OUT1}^-$  ( $V_{OUT1}^+ = 12\text{V}$ ). Check for the proper output voltage between  $V_{OUT2}^+$  and  $V_{OUT2}^-$  ( $V_{OUT2}^- = -12\text{V}$ ).

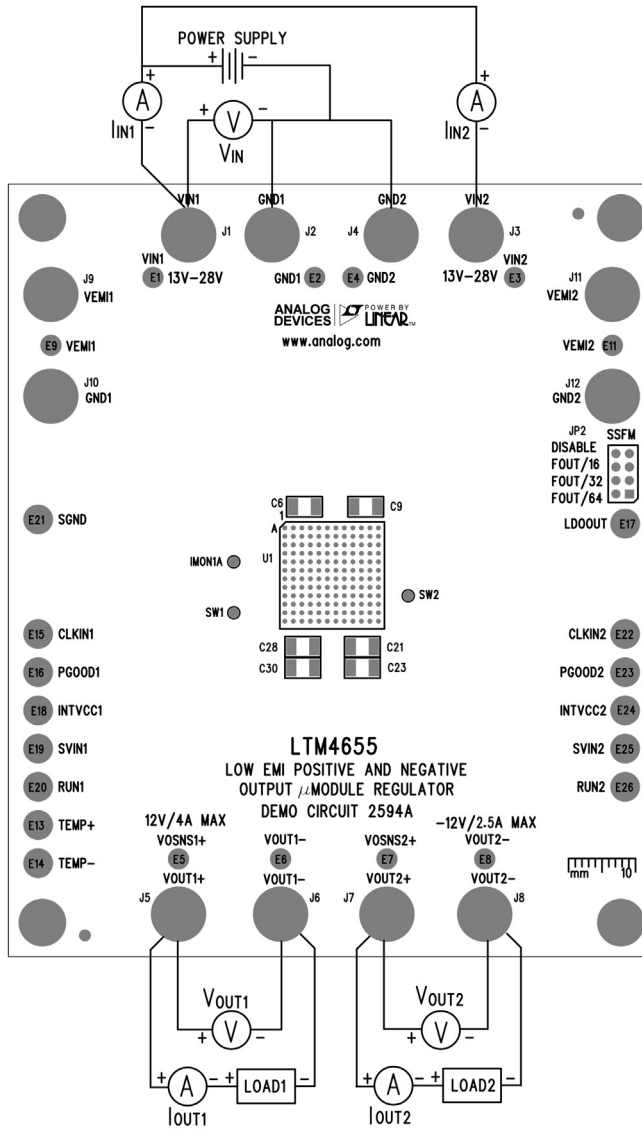
NOTE: If there is no output, or output voltage value is out of the spec, temporarily disconnect the load to make sure that the load is not set too high.

NOTE: The circuit features frequency foldback to protect the power switches during a fault or output current overload.

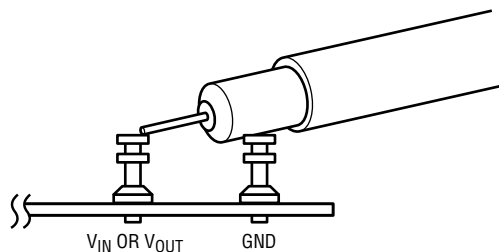
4. Once the proper output voltage at each channel is established, adjust the load within the operating range and measure the output voltage regulation, ripple voltage, efficiency and other parameters.

NOTE: When measuring the input or output voltage ripple, care must be taken to avoid a long ground lead on the oscilloscope probe. Measure the input or output voltage ripple by touching the probe tip directly across the  $V_{IN1}$  or  $V_{IN2}$  and GND terminals,  $V_{OUT1}^+$  and  $V_{OUT1}^-$  terminals, or  $V_{OUT2}^+$  and  $V_{OUT2}^-$  terminals. See Figure 2 for proper scope probe technique.

**QUICK START PROCEDURE**



**Figure 1. DC2594A Proper Equipment Setup**



**Figure 2. Measuring Input or Output Ripple**

## QUICK START PROCEDURE

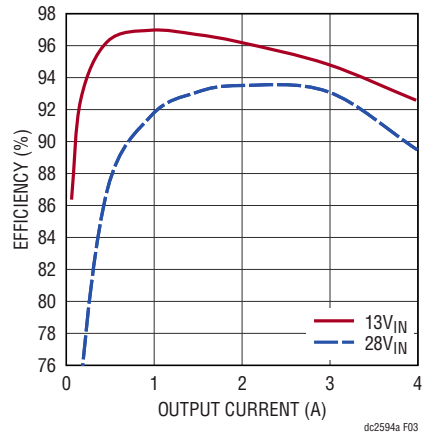


Figure 3. DC2594A +12V Output Efficiency vs Load Current ( $T_A = 25^\circ\text{C}$ )

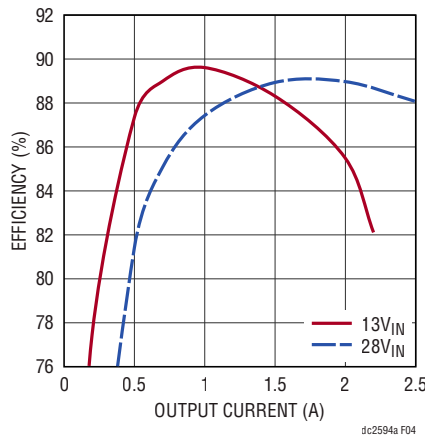


Figure 4. DC2594A -12V Output Efficiency vs Load Current ( $T_A = 25^\circ\text{C}$ )

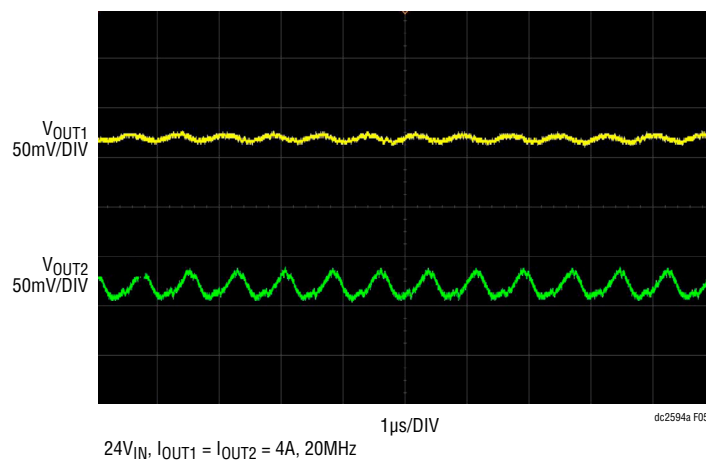
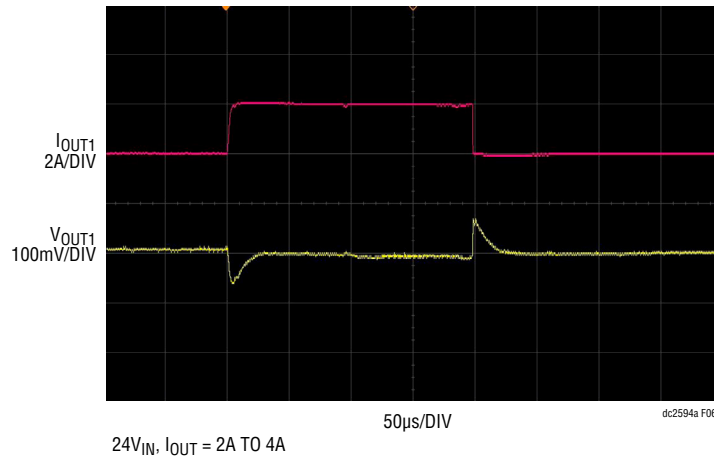
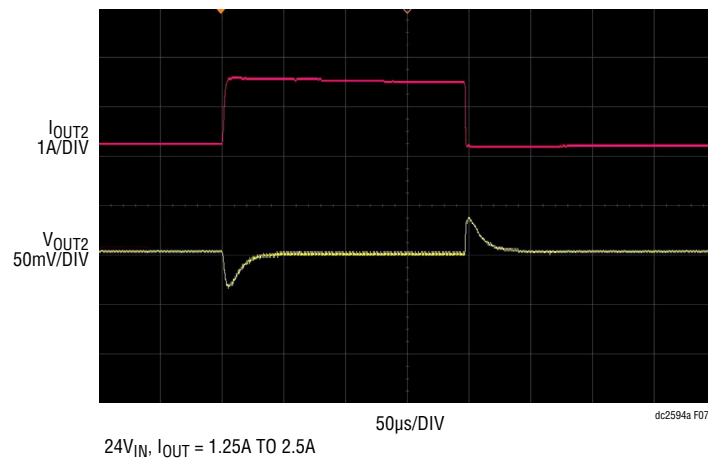


Figure 5. DC2594A Output 1 (+12V) and Output 2 (-12V) Output Ripple

**QUICK START PROCEDURE**



**Figure 6. DC2594A +12V Output Transient Response**



**Figure 7. DC2594A -12V Output Transient Response**

## QUICK START PROCEDURE

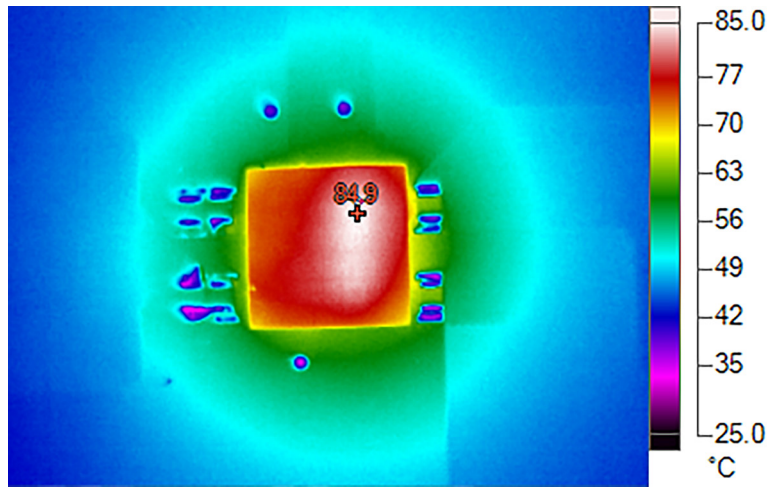


Figure 8. DC2594A Thermal Performance ( $14V_{IN}$ ,  $I_{OUT1} = 3.6A$ ,  $I_{OUT2} = 1.8A$ ,  $T_A = 25^\circ C$ , Free Air)

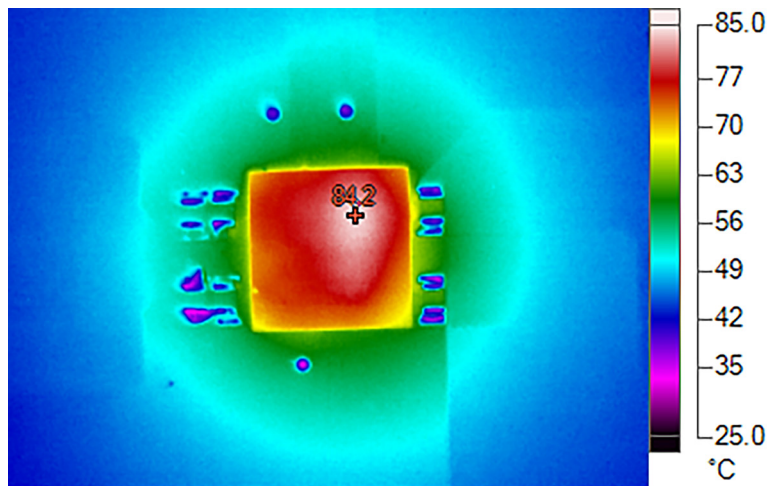
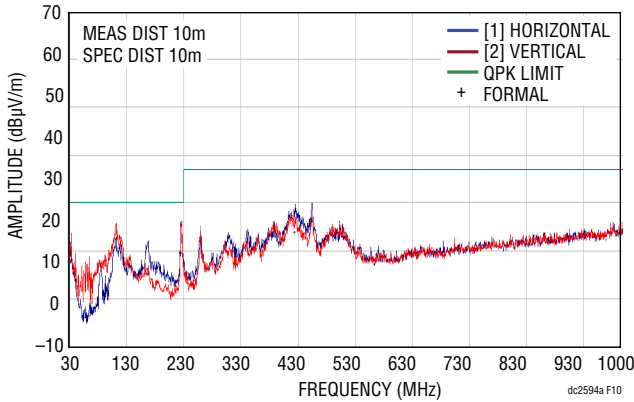
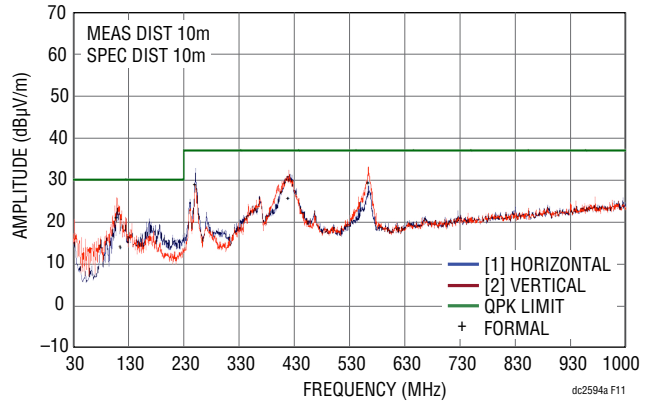


Figure 9. DC2594A Thermal Performance ( $24V_{IN}$ ,  $I_{OUT1} = 3.7A$ ,  $I_{OUT2} = 1.9A$ ,  $T_A = 25^\circ C$ , Free Air)

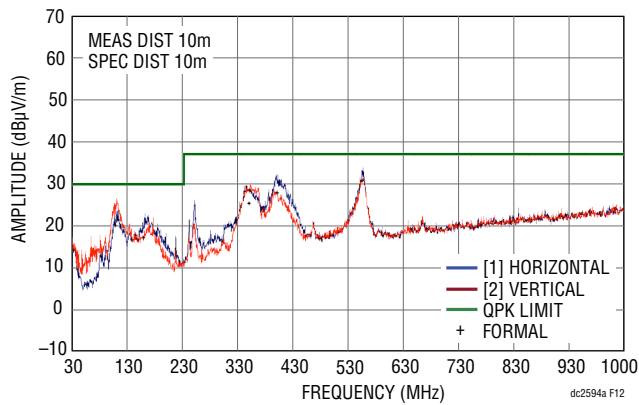
**QUICK START PROCEDURE**



**Figure 10. Radiated Emissions Scan of the LTM4655. Producing 24V<sub>OUT</sub> at 7A, from 36V<sub>IN</sub>. DC2898A Hardware. f<sub>SW</sub> = 1.2MHz. Measured in a 10m Chamber. Peak Detect Method**



**Figure 11. Radiated Emissions Scan of the LTM4655. Producing -24V<sub>OUT</sub> at 2A, from 12V<sub>IN</sub>, DC2899A Hardware. f<sub>SW</sub> = 1.2MHz. Measured in a 10m Chamber. Peak Detect Method**



**Figure 12. Radiated Emissions Scan of the LTM4655. Producing -12V<sub>OUT</sub> at 4A, from 12V<sub>IN</sub>. DC2899A Hardware. f<sub>SW</sub> = 700kHz. Measured in a 10m Chamber. Peak Detect Method**

# DEMO MANUAL DC2594A

## PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
<b>Required Circuit Components</b>				
1	2	C1, C16	CAP., 47 $\mu$ F, ALUM POLY HYB, 63V, 20%, SMD 10mm $\times$ 10.5mm, AEC-Q200, HVP Series	SUN ELECTRONIC INDUSTRIES CORP, 63HVP47M
2	6	C2, C3, C4, C13, C14, C15	CAP., 10 $\mu$ F, X7R, 50V, 10%, 1210, NO SUBS. ALLOWED	MURATA, GRM32ER71H106KA12L
3	4	C5, C17, C20, C37	CAP., 1 $\mu$ F, X5R, 50V, 10%, 0603, NO SUBS. ALLOWED	MURATA, GRM188R61H105KAALD
4	2	C6, C7	CAP., 2.2 $\mu$ F, X7R, 100V, 10%, 1210	AVX, 12101C225KAT2A
5	3	C9, C11, C54	CAP., 4.7 $\mu$ F, X7R, 80V, 10%, 1210	MURATA, GRM32ER71K475KE14L
6	4	C21, C23, C28, C30	CAP., 22 $\mu$ F, X7R, 25V, 10%, 1210, NO SUBS. ALLOWED	SAMSUNG, CL32B226KAJNNNE
7	1	C26	CAP., 82 $\mu$ F, ALUM, OS-CON, 35V, 20%, SMD 8mm $\times$ 11.9mm, E12, SVPF Series	PANASONIC, 35SVPF82M
8	1	C27	CAP., 100 $\mu$ F, ALUM POLY HYB, 35V, 20%, SMD 8mm $\times$ 10.5mm, AEC-Q200, HVP Series	SUN ELECTRONIC INDUSTRIES CORP, 35HVP100M
9	2	C35, C36	CAP., 2200pF, X7R, 50V, 10%, 0603	AVX, 06035C222KAT2A
10	1	C38	CAP., 220pF, X7R, 50V, 10%, 0603	AVX, 06035C221KAT2A
11	1	C39	CAP., 100pF, X7R, 50V, 10%, 0603	AVX, 06035C101KAT2A
12	2	R1, R9	RES., 100k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF1003V
13	1	R2	RES., 82.5k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF8252V
14	2	R3, R8	RES., 95.3k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF9532V
15	2	R10, R11	RES., 261k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF2613V
16	2	R12, R13	RES., 28k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF2802V
17	2	R18, R23	RES., 49.9 $\Omega$ , 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF49R9V
18	2	R19, R20	RES., 10 $\Omega$ , 1%, 1/10W, 0603	PANASONIC, ERJ3EKF10R0V
19	2	R26, R28	RES., 240k, 1%, 1/10W, 0603	VISHAY, CRCW0603240KFKEA
20	1	R30	RES., 4.64k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF4641V
21	1	R32	RES., 3.32k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ3EKF3321V
22	2	R36, R37	RES., 124k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603124KFKEA
23	1	U1	IC, DC/DC REGULATOR, BGA-144 (16mm $\times$ 16mm $\times$ 5.01mm)	ANALOG DEVICES, LTM4655EY#PBF
<b>Additional Demo Board Circuit Components</b>				
1	0	C8, C10, C12, C22, C24, C25, C29, C31, C32, C44, C45, C46, C49, C50, C51	CAP., OPTION, 1210	
2	0	C18, C19, C33, C34, C40, C41, C42	CAP., OPTION, 0603	
3	0	C43, C52	CAP., OPTION, 0805	
4	0	D1	DIODE, OPTION, SMA	
5	0	L1, L4	IND., OPTION, 1206	
6	0	L2, L3	IND., OPTION, IHLP3232CZ-01	
7	0	R6, R16, R17, R22, R27, R29, R31, R33, R35, R38	RES., OPTION, 0603	
8	10	R4, R5, R7, R14, R15, R21, R24, R25, R34, R39	RES., 0 $\Omega$ , 1/10W, 0603, AEC-Q200	VISHAY, CRCW06030000Z0EA
9	0	R40	RES., OPTION, 2512	



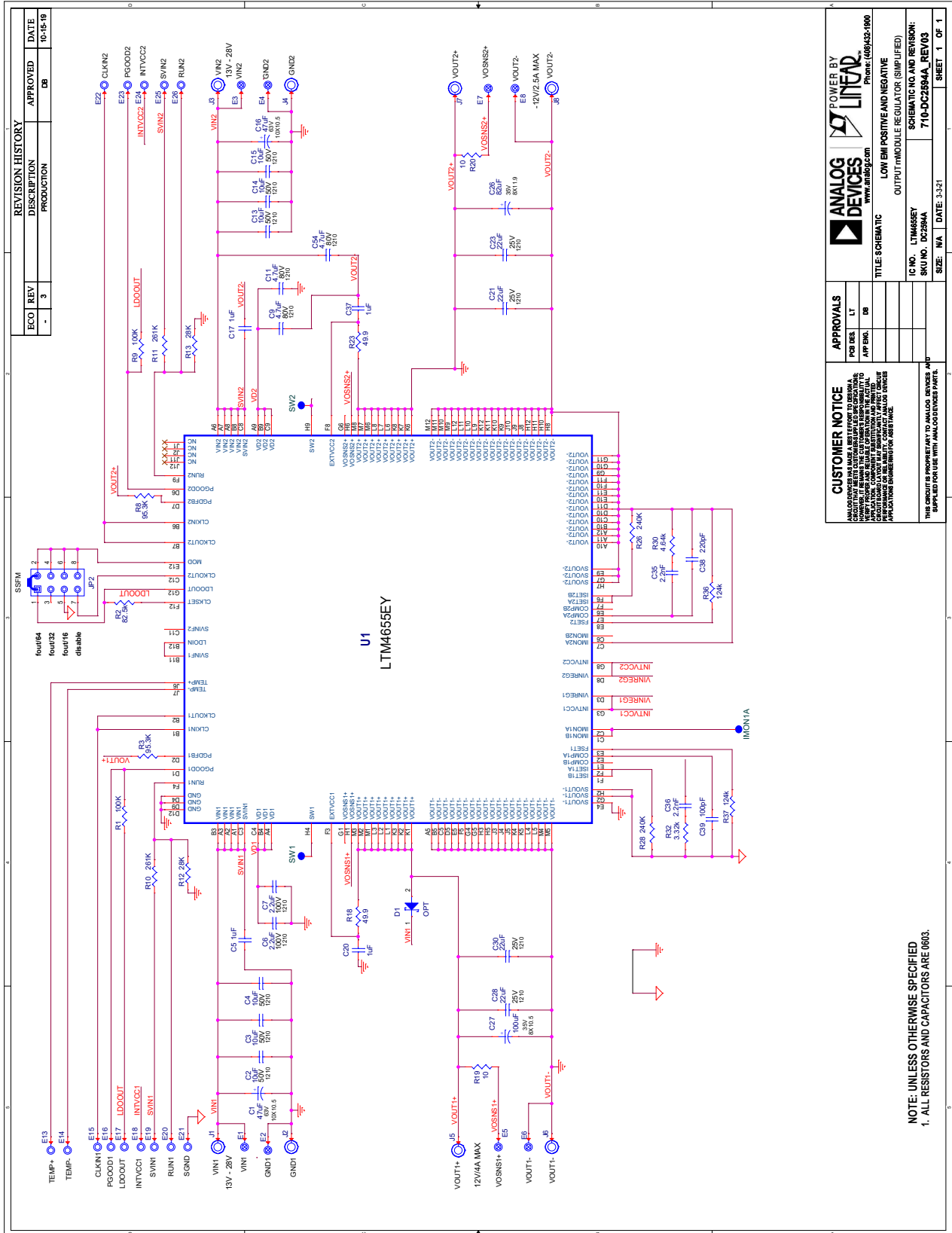
## PARTS LIST

### Hardware

1	10	E1, E2, E3, E4, E5, E6, E7, E8, E9, E11	TEST POINT, TURRET, 0.064 MTG. HOLE, PCB 0.062" THK	MILL-MAX, 2308-2-00-80-00-00-07-0
2	14	E13, E14, E15, E16, E17, E18, E19, E20, E21, E22, E23, E24, E25, E26	TEST POINT, TURRET, 0.094 MTG. HOLE, PCB 0.062" THK	MILL-MAX, 2501-2-00-80-00-00-07-0
3	12	J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11, J12	CONN., BANANA JACK, FEMALE, THT, NON-INSULATED, SWAGE, 0.218"	KEYSTONE, 575-4
4	1	JP2	CONN., HDR, MALE, 2x4, 2mm, VERT, ST, THT	WURTH, 62000821121
5	4	MH1, MH2, MH3, MH4	STANDOFF, NYLON, SNAP-ON, 0.50"	KEYSTONE, 8833
6	1	XJP2	CONN., SHUNT, FEMALE, 2-POS, 2mm	WURTH, 60800213421

# DEMO MANUAL DC2594A

## SIMPLIFIED SCHEMATIC DIAGRAM



REVISION HISTORY		APPROVED	DATE
ECO	REV	DESCRIPTION	PRODUCTION
-	3		10-18-09

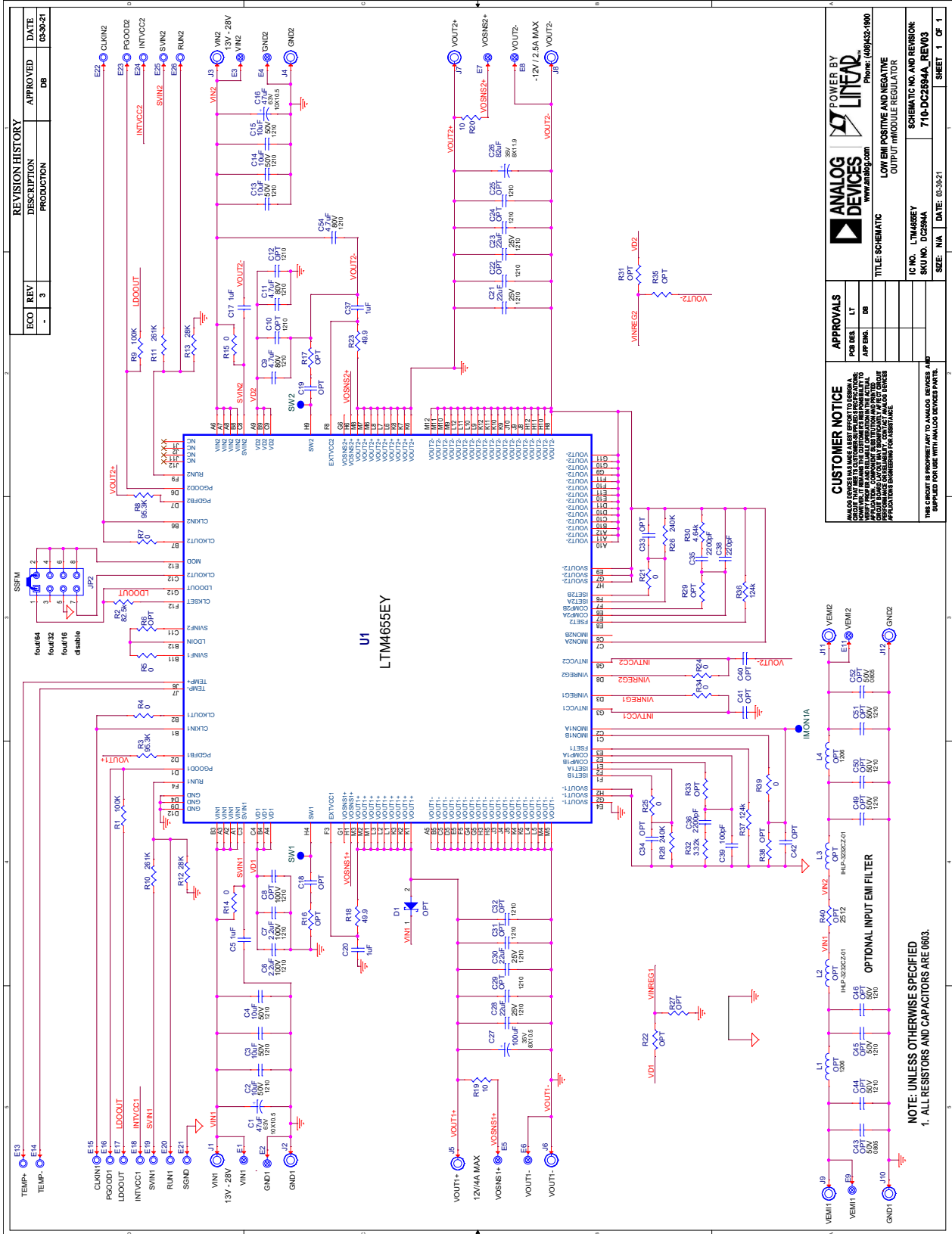
APPROVALS		ANALOG DEVICES		POWER BY	
FOR DES	LT	www.analog.com		LINAR	
APP ENG	DB	www.analog.com		Phone: (609)432-1900	
TITLE: SCHEMATIC				LOW EMI POSITIVE AND NEGATIVE OUTPUT MODULE REGULATOR (SIMPLIFIED)	
IC NO: LTM465EY				SCHEMATIC AND REVISION:	
SKU NO: DC2594A				710-DC2594A_REV03	
SIZE	MA	DATE	3-3-21	SHEET 1 OF 1	

**CUSTOMER NOTICE**  
 ANALOG DEVICES MAKES NO REPRESENTATION OR WARRANTY, EXPRESS OR IMPLIED, REGARDING THE SUITABILITY OF THIS SCHEMATIC FOR ANY PARTICULAR APPLICATION. THE USER SHALL BE RESPONSIBLE FOR VERIFYING THE SCHEMATIC IS SUITABLE FOR THE INTENDED APPLICATION AND FOR OBTAINING NECESSARY APPROVALS FROM THE APPROPRIATE ENGINEERING DEPARTMENT FOR USE IN THE FIELD.

This document is proprietary to Analog Devices and should not be distributed outside your firm.

NOTE: UNLESS OTHERWISE SPECIFIED  
 1. ALL RESISTORS AND CAPACITORS ARE 0603.

FULL 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.



## 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 NON-INFRINGEMENT 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.