

LTM4700 High Current, PolyPhase Step-Down Power μ Module Supply with Digital Power System Management 3xLTM4700, 300A

DESCRIPTION

Demonstration circuit 2784A-B is a high efficiency, high density, μ Module regulator with 4.5V to 16V input range. The output voltage is adjustable from 0.5V to 1.8V and it can supply 300A maximum load current. The demo board has three LTM4700 μ Module regulators, which is a dual 50A or single 100A step-down regulator with digital power system management. Please see LTM4700 data sheet for more detailed information.

DC2784A-B powers up to default settings and produces power based on configuration resistors without the need for any serial bus communication. This allows easy evaluation of the DC/DC converter. To fully explore the extensive power system management features of the part, download

the GUI software LTpowerPlay® onto your PC and use ADI's I²C/SMBus/PMBus dongle DC1613A to connect to the board. LTpowerPlay allows the user to reconfigure the part on the fly and store the configuration in EEPROM, view telemetry of voltage, current, temperature and fault status.

GUI Download

The software can be downloaded from [LTpowerPlay](#).

For more details and instructions of LTpowerPlay, please refer to LTpowerPlay GUI for LTM4700 Quick Start Guide.

Design files for this circuit board are available.

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BOARD PHOTO

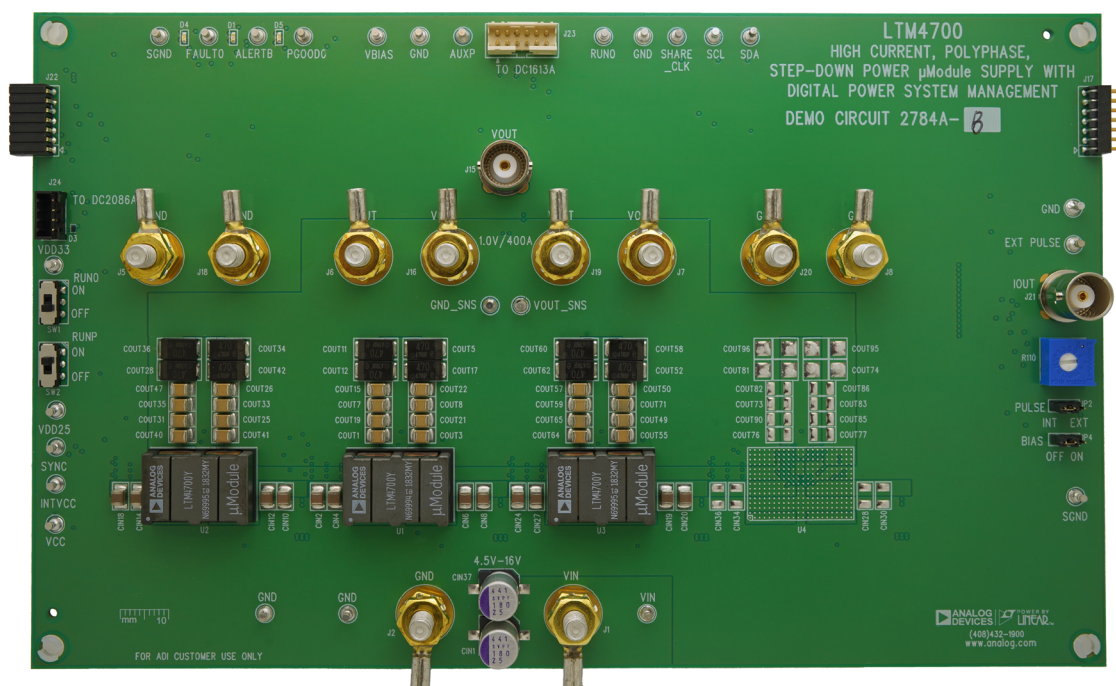


Figure 1. 3x LTM4700; 300A DC2784A-B Demo Circuit

DEMO MANUAL DC2784A-B

PERFORMANCE SUMMARY

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

PARAMETER	CONDITIONS	VALUE
Input Voltage Range		4.5V to 16V
Output Voltage, V_{OUT}	$V_{IN} = 4.5\text{V to } 16\text{V}$, $I_{OUT} = 0\text{A to } 300\text{A}$	0.5V to 1.8V, Default: 1.0V
Maximum Output Current, I_{OUT}	$V_{IN} = 4.5\text{V to } 16\text{V}$, $V_{OUT} = 0.5\text{V to } 1.8\text{V}$	300A
Typical Efficiency	$V_{IN} = 12\text{V}$, $V_{OUT} = 1.0\text{V}$, $I_{OUT} = 300\text{A}$	88.7% (See Figure 5)
Default Switching Frequency		350kHz

QUICK START PROCEDURE

Table 1. LTM4700 Demo Boards for Up to 400A Point-of-Load Regulation

MAXIMUM OUTPUT CURRENT	NUMBER OF OUTPUTS	NUMBER OF LTM4676 μ MODULE REGULATORS ON THE BOARD	DEMO BOARD NUMBER
50A	2	1	DC2702A-A
100A	1	1	DC2702A-B
200A	1	2	DC2784A-A
300A	1	3	DC2784A-B
400A	1	4	DC2784A-C

Demonstration circuit 2784A-B is easy to set up to evaluate the performance of the LTM4700EY. Refer to Figure 2 for the proper measurement equipment setup and follow the procedure below.

1. With power off, connect the input power supply to V_{IN} (4.5V to 16V) and GND (input return).
2. Connect the 1.0V output load between V_{OUT} and GND (initial load: no load).
3. Connect the DVMs to the input and outputs. Set default jumper position: JP1: ON; JP2: ON; JP3: ON.

4. Turn on the input power supply and check for the proper output voltages. V_{OUT} should be $1.0\text{V} \pm 0.5\%$.
5. Once the proper output voltages are established, adjust the loads within the operating range and observe the output voltage regulation, ripple voltage and other parameters.
6. Connect the dongle and control the output voltages from the GUI. See “LTpowerPlay GUI for the LTM4700 Quick Start Guide” for details.

Note: Internal bias circuit is enabled when $V_{IN} > 7\text{V}$ and JP3 is ON.

Note: When measuring the output or input voltage ripple, do not use the long ground lead on the oscilloscope probe. See Figure 3 for the proper scope probe technique. Short, stiff leads need to be soldered to the (+) and (–) terminals of an output capacitor. The probe’s ground ring needs to touch the (–) lead and the probe tip needs to touch the (+) lead.

QUICK START PROCEDURE

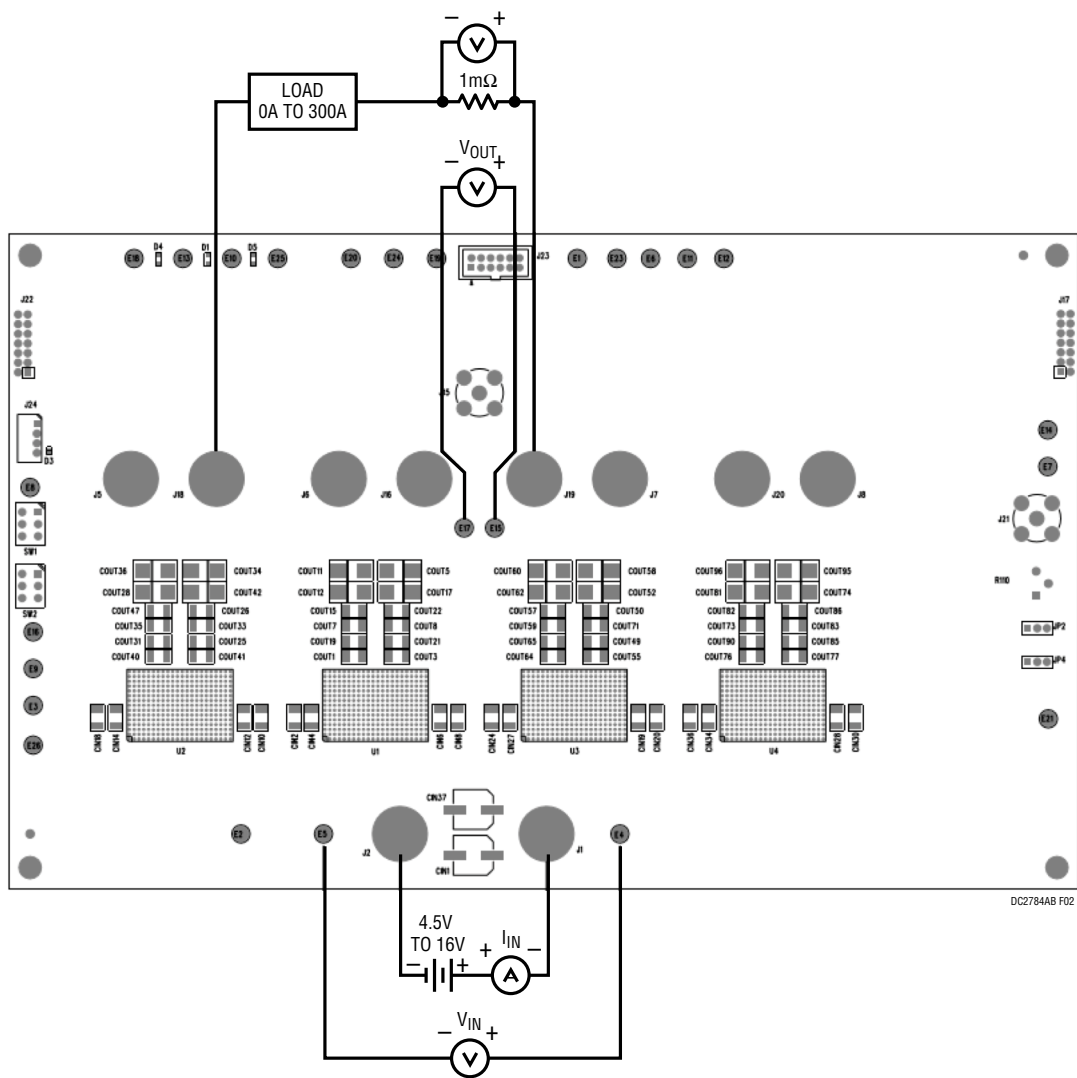


Figure 2. Proper Measurement Equipment Setup

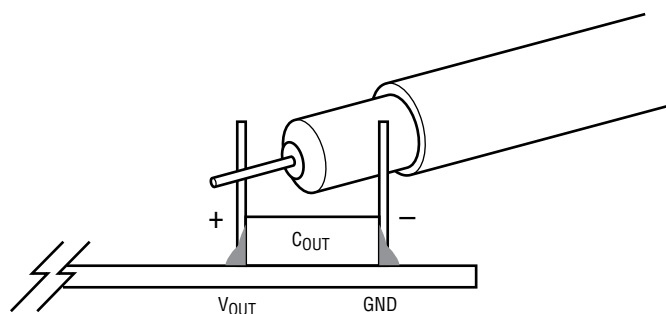


Figure 3. Measuring Output Voltage Ripple

QUICK START PROCEDURE

Connecting a PC to DC2784A-B

You can use a PC to reconfigure the power management features of the LTM4700 such as: nominal VOUT, margin set points, OV/UV limits, temperature fault limits,

sequencing parameters, the fault log, fault responses, GPIOs and other functionalities. The DC1613A dongle may be plugged when VIN is present.

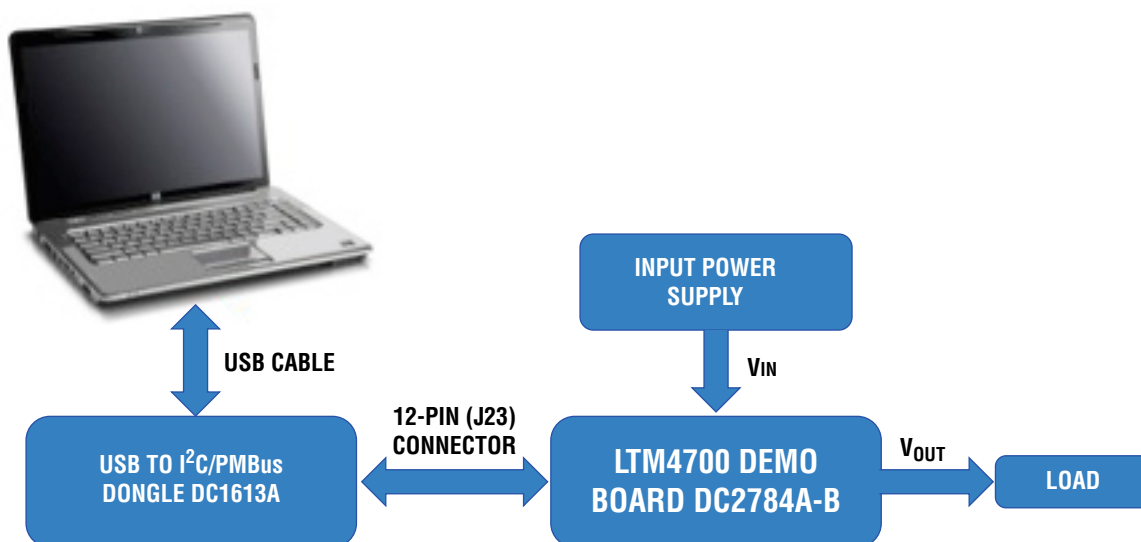


Figure 4. Demo Setup with PC

QUICK START PROCEDURE

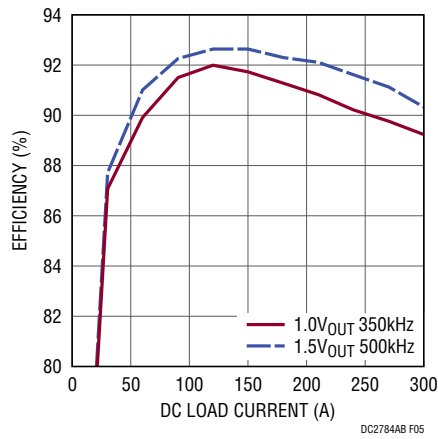


Figure 5. Efficiency vs Load Current at $V_{IN} = 12V$ (RUNP is ON)

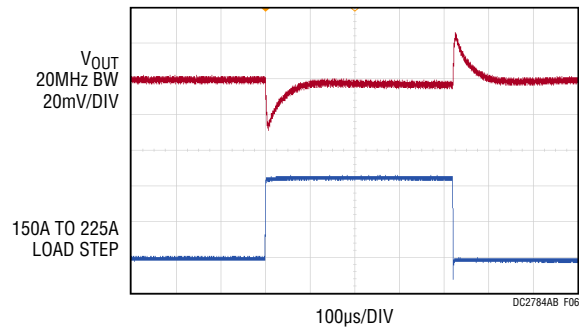


Figure 6. Output Voltage vs Load Current at $V_{IN} = 12V$, $V_{OUT} = 1.0V$

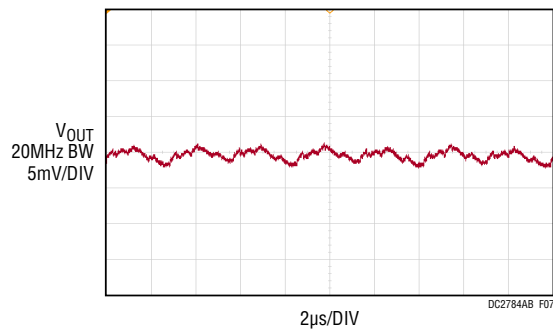


Figure 7. Output Voltage Ripple at $V_{IN} = 12V$, $V_{OUT} = 1.0V$, $I_{OUT} = 300A$

QUICK START PROCEDURE

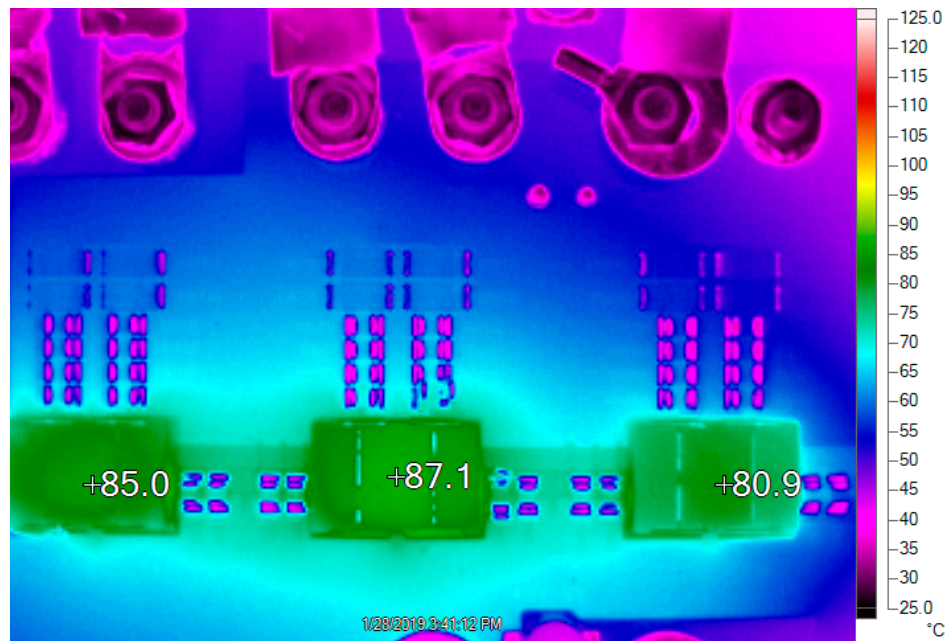


Figure 8. Thermal at $V_{IN} = 12V$, $V_{OUT} = 1.0V$, $I_{OUT} = 195A$, $T_A = 25^\circ C$, No Airflow

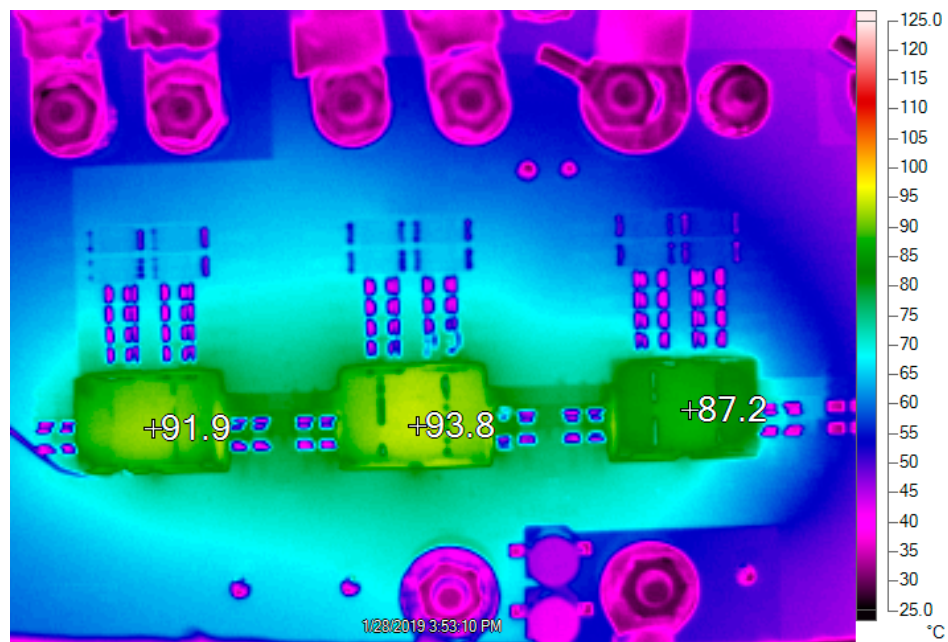


Figure 9. Thermal at $V_{IN} = 12V$, $V_{OUT} = 1.0V$, $I_{OUT} = 300A$, $T_A = 25^\circ C$, 400LFM Airflow

LTpowerPlay SOFTWARE GUI

LTpowerPlay is a powerful Windows based development environment that supports Analog Devices power system management ICs and μ Modules, including the LTM4675, LTM4676, LTM4677, LTM4678, LTC3880, LTC3882 and LTC3883. The software supports a variety of different tasks. You can use LTpowerPlay to evaluate Analog Devices ICs by connecting to a demo board system. LTpowerPlay can also be used in an offline mode (with no hardware present) in order to build a multichip configuration file that can be saved and reloaded at a later time. LTpowerPlay provides unprecedented diagnostic and debug features. It becomes a valuable diagnostic tool during board bring-up to program or tweak the power

management scheme in a system, or to diagnose power issues when bringing up rails. LTpowerPlay utilizes the DC1613A USB-to-SMBus controller to communicate with one of many potential targets, including the LTM4675, LTM4676, LTM4677, LTM4678, LTC3880, LTC3882, LTC3883's demo system, or a customer board. The software also provides an automatic update feature to keep the software current with the latest set of device drivers and documentation. The LTpowerPlay software can be downloaded from [LTpowerPlay](#).

To access technical support documents for ADI Digital Power Products visit the LTpowerPlay Help menu. Online help also available through the LTpowerPlay.

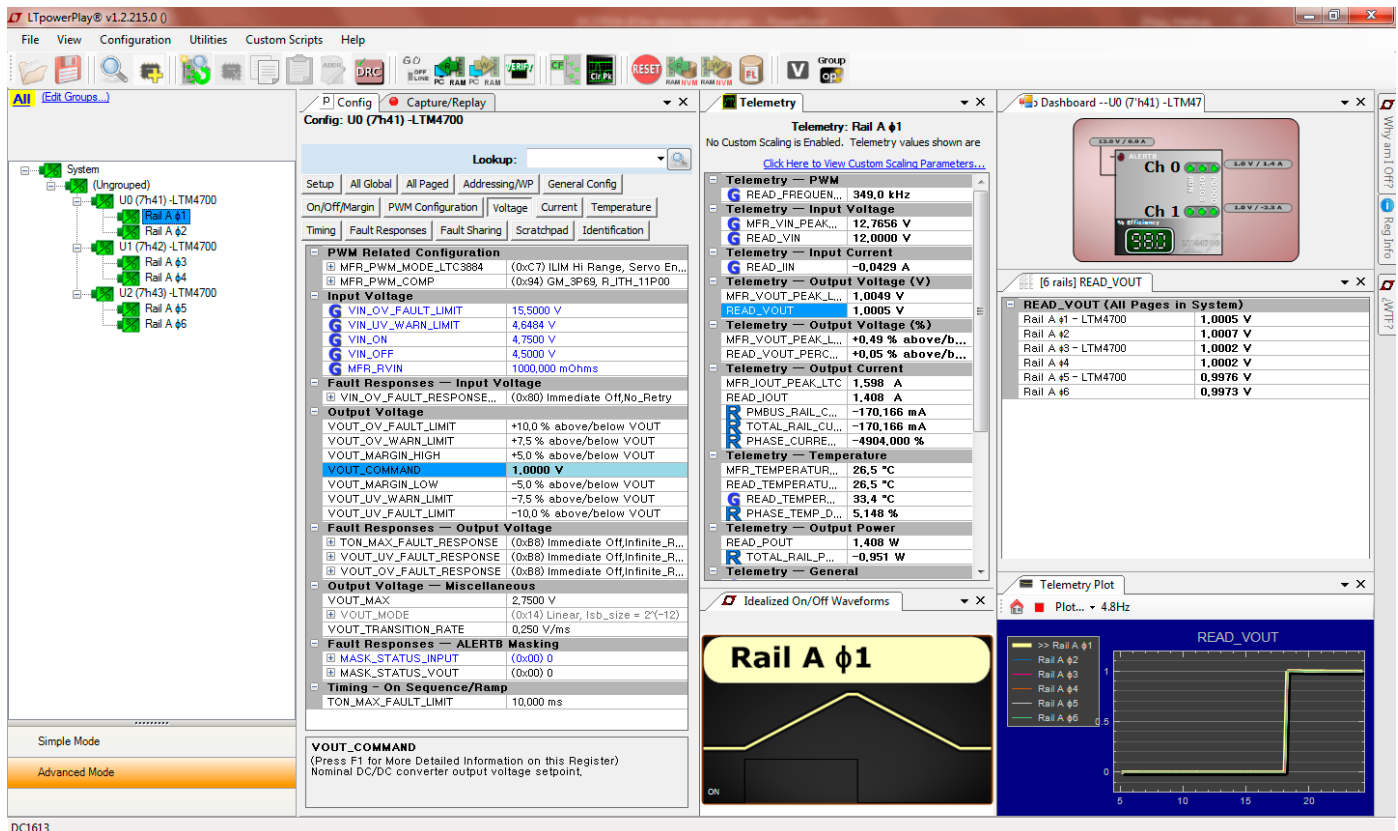


Figure 10. LTpowerPlay Main Interface

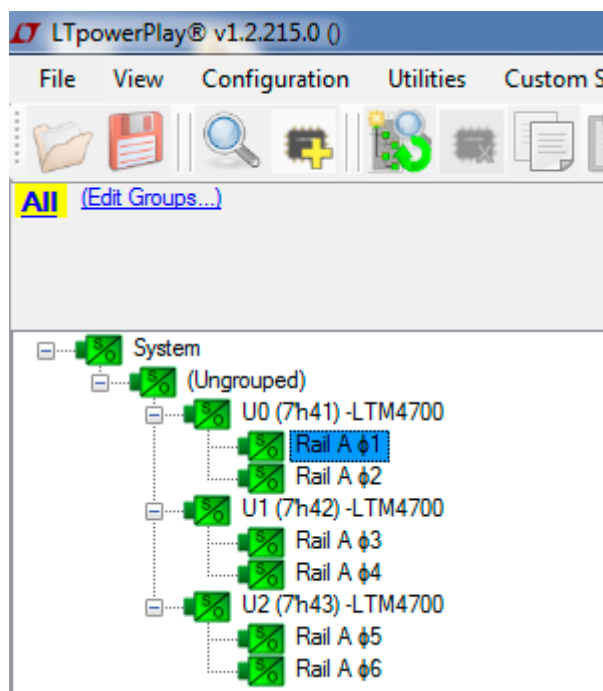
DEMO MANUAL DC2784A-B

LTpowerPlay QUICK START PROCEDURE

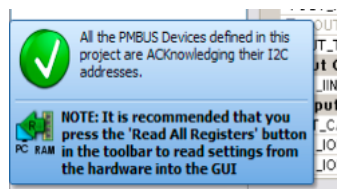
The following procedure describes how to use LTpowerPlay to monitor and change the settings of LTM4700.

1. Download and install the LTpowerPlay GUI: [LTpowerPlay](#)
2. Launch the LTpowerPlay GUI.

- a. The GUI should automatically identify the DC2784A-B. The system tree on the left hand side should look like this:



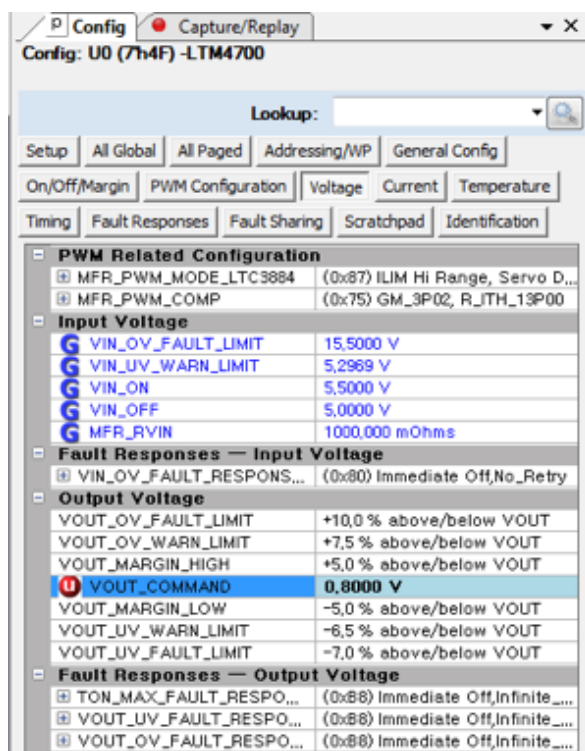
- b. A green message box shows for a few seconds in the lower left hand corner, confirming that LTM4700 is communicating:



- c. In the Toolbar, click the “R” (RAM to PC) icon to read the RAM from the LTM4700. This reads the configuration from the RAM of LTM4700 and loads it into the GUI.



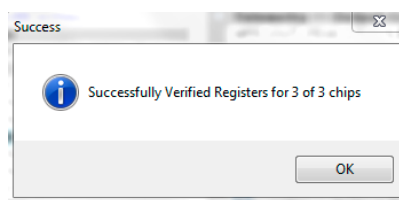
- d. If you want to change the output voltage to a different value, like 0.8V. In the Config tab, type in 0.8 in the VOUT_COMMAND box, like this:



Then, click the “W” (PC to RAM) icon to write these register values to the LTM4700. After finishing this step, you will see the output voltage will change to 0.8V.



If the write is successful, you will see the following message:



- e. You can save the changes into the NVM. In the toolbar, click “RAM to NVM” button, as following



- f. Save the demo board configuration to a (*.proj) file. Click the Save icon and save the file. Name it whatever you want.

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	4	CIN1, CIN16, CIN37, CIN38	CAP., 180μF, ALUM. POLY., 25V, 20%, 8x12mm SMD, E12	PANASONIC, 25SVPF180M
2	16	CIN2, CIN3, CIN4, CIN5, CIN6, CIN7, CIN8, CIN9, CIN10, CIN11, CIN12, CIN13, CIN14, CIN15, CIN17, CIN18	CAP., 22μF X6S 25V 10% 1210;	MURATA, GRM32EC81E226KE15L
3	8	CIN19, CIN20, CIN21, CIN22, CIN23, CIN24, CIN26, CIN27	CAP., 22μF X6S 25V 10% 1210	MURATA, GRM32EC81E226KE15L
4	54	COUT1, COUT2, COUT3, COUT6, COUT7, COUT8, COUT14, COUT15, COUT16, COUT18, COUT19, COUT20, COUT21, COUT22, COUT23, COUT24, COUT25, COUT26, COUT27, COUT29, COUT30, COUT31, COUT32, COUT33, COUT35, COUT37, COUT40, COUT41, COUT43, COUT46, COUT47, COUT93, COUT97, COUT98, COUT99, COUT100, COUT101, COUT102, COUT49, COUT50, COUT51, COUT53, COUT54, COUT55, COUT56, COUT49, COUT50, COUT51, COUT53, COUT54, COUT55, COUT56, COUT57, COUT59, COUT61, COUT64, COUT65, COUT67, COUT70, COUT71, COUT72	CAP., 100μF X6S 6.3V 20% 1210	MURATA, GRM32EC80J107ME20L
5	24	COUT4, COUT5, COUT9, COUT10, COUT11, COUT12, COUT13, COUT17, COUT28, COUT34, COUT36, COUT38, COUT39, COUT42, COUT44, COUT45, COUT52, COUT58, COUT60, COUT62, COUT63, COUT66, COUT68, COUT69,	CAP., 470μF, ALUM POLY, 2.5V, 20% SMD D3L	PANASONIC, EEF-GX0E471R
6	1	C15	CAP., X7R, 0.022μF, 25V, 5%, 0603	AVX, 06033C223JAT2A
7	3	C28, C73, C74	CAP., X7R, 0.01μF, 25V, 5%, 0603	AVX, 06033C103JAT2A
8	4	C33, C35, C45, C57	CAP., X6S, 22μF, 6.3V, 20%, 0603	MURATA, GRM188C80J226ME15D
9	1	C64	CAP., X5R, 4.7μF, 16V, 10%, 0603	TDK, C1608X5R1C475K080AC
10	2	C65, C68	CAP., X7R, 1μF, 25V, 10%, 1206	KEMET, C1206C105K3RACTU
11	1	C66	CAP., X7R, 0.22μF, 16V, 10%, 0805	TDK, C2012X7R1C224K
12	1	C67	CAP., X5R, 0.1μF, 16V, 10%, 1206	AVX, 1206YD104KAT2A
13	1	C69	CAP., X7R, 1800pF, 25V, 5%, 0603	AVX, 06033C182JAT2A
14	1	C70	CAP., X7R, 1μF, 25V, 10%, 0805	AVX, 08053C105KAT2A
15	1	C71	CAP., X5R, 0.1μF, 16V, 10%, 0603	AVX, 0603YD104KAT2A
16	1	D1	LED, SUPER RED, WATERCLEAR, 0603	WURTH ELEKTRONIK, 150060SS75000
17	1	D3	DIODE SCHOTTKY 20V 500mA SOD882	NXP, PMEG2005AEL
18	2	D4, D5	LED, GREEN, WATERCLEAR, 0603	WURTH ELEKTRONIK, 150060GS75000
19	1	Q1	XSTR., MOSFET, P-CH, 20V, 5.9A, TO-236 (SOT-23)	VISHAY, Si2365EDS-T1-GE3
20	2	Q2, Q3	MOSFET N-CHANNEL 30V 90A TO252	TAIWAN SEMICONDUCTOR CORPORATION, TSM040N03CP ROG
21	1	Q4	XSTR., MOSFET, P-CH, 30V, 3.5A, SOT-23, AEC-Q101	DIODES INC., DMP3130L-7

DEMO MANUAL DC2784A-B

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
22	2	Q5, Q6	XSTR., MOSFET, N-CH, 60V, 300mA, SOT-23	FAIRCHILD SEMI., 2N7002K
23	15	R10, R11, R12, R13, R14, R15, R18, R24, R94, R106, R116, R126, R142, R154, R210	RES., 10k, 5%, 1/10W, 0603	VISHAY, CRCW060310K0JNEA
24	5	R25, R32, R70, R125, R237	RES., 10 Ω , 1%, 1/10W, 0603	VISHAY, CRCW060310R0FKEA
25	1	R26	RES., 787 Ω , 1%, 1/10W, 0603	VISHAY, CRCW0603787RFKEA
26	1	R86	RES., 127 Ω , 1%, 1/10W, 0603	VISHAY, CRCW0603127RFKEA
27	4	R90, R108, R133, R159	RES., 0.001 Ω , 2W, 1%, 2512, SENSE, AEC-Q200	BOURNS INC., CRF-2512-FZ-R001ELF
28	1	R110	RES., 5k, 10%, 1/2W, THT 3/8" SQUARE, SINGLE TURN, TOP ADJ., TRIMPOT	BOURNS, 3386P-1-502-LF
29	2	R111, R115	RES., 20k, 5%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW060320K0JNEA
30	1	R113	RES., 1.65k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06031K65FKEA
31	2	R118, R232	RES 0.003 Ω 1% 1/2W 2010	VISHAY, WSL20103L000FEA
32	1	R123	RES., 1M, 5%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06031M00JNEA
33	2	R124, R224	RES., 200 Ω , 1%, 1/10W, 0603	VISHAY, CRCW0603200RFKEA
34	1	R137	RES., 2.43k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06032K43FKEA
35	1	R148	RES., 3.24k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06033K24FKEA
36	1	R203	RES., 681k, 1%, 1/10W, 0603	VISHAY, CRCW0603681KFKEA
37	1	R204	RES., 3.3 Ω , 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06033R30FKEA
38	1	R205	RES., 82.5 Ω , 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW060382R5FKEA
39	2	R213, R223	RES., 4.99k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06034K99FKEA
40	1	R220	RES., 15.8k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW060315K8FKEA
41	1	R229	RES., 100k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603100KFKEA
42	1	R233	RES., 100 Ω , 1%, 1W, 0603, AEC-Q200	VISHAY, CRCW0603100RFKEA
43	1	R234	RES., 1.4k, 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06031K40FKEA
44	1	R235	RES., 154k, 5%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW0603154KJNEA
45	1	R236	RES., 2 Ω , 1%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06032R00FKEA
46	2	SW1, SW2	SWITCH, SUBMINATURE SLIDE	C&K COMPONENTS, JS202011CQN
47	2	U1, U2	IC, LTM4700EY	ANALOG DEVICES, LTM4700EY#PBF
48	1	U3	IC, LTM4700EY	ANALOG DEVICES, LTM4700EY#PBF
49	1	U5	IC, MEMORY, EEPROM, 2Kb (256x8), TSSOP-8, 400kHz	MICROCHIP, 24LC025-I/ST
50	1	U6	IC, μ PWR LDO REG w/SHUTDOWN, SO-8	ANALOG DEVICES, LT1129CS8-5#PBF
51	1	U7	IC, TimerBlox: Voltage-Ctrl. PWM, TSOT23-6	ANALOG DEVICES, LTC6992CS6-1#PBF
52	1	U8	IC, SINGLE 100V, 85MHz, OP AMP, TSOT-23-5	ANALOG DEVICES, LT1803IS5#PBF

PARTS LIST

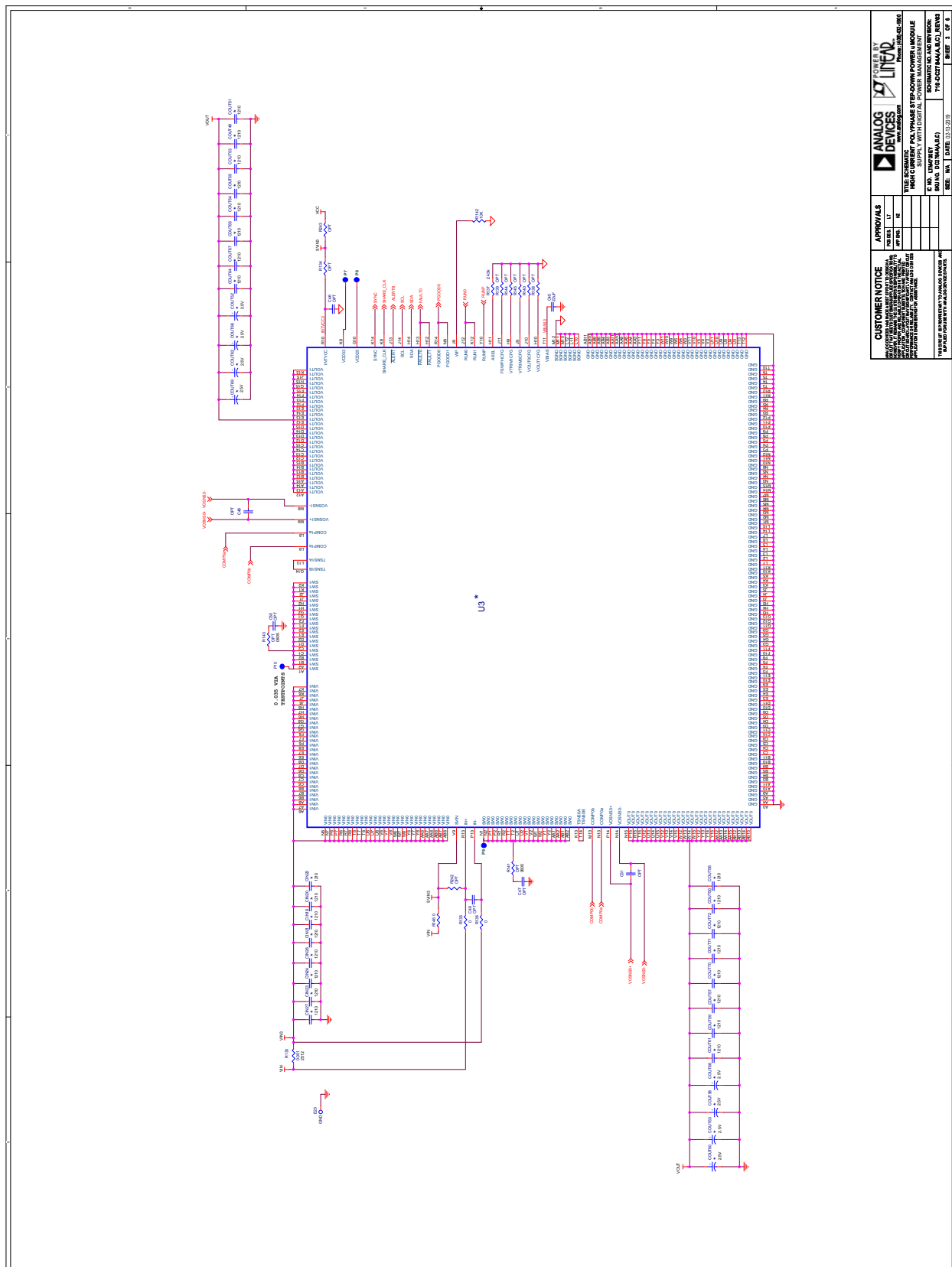
ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Additional Demo Board Circuit Components				
1	0	COUT73, COUT76, COUT77, COUT79, COUT82, COUT83, COUT84, COUT85, COUT86, COUT87, COUT89, COUT90, COUT91, COUT92, COUT48, COUT94, CIN28, CIN29, CIN30, CIN31, CIN32, CIN34, CIN35, CIN36	CAP, OPT, 1210	OPT
2	0	c14, C16, C17, C29, C31, C32, C34, C36, C40, C41, C42, C43, C44, C46, C47, C48, C49, C50, C51, C52, C53, C54, C55, C56, C58	CAP, OPTION 0603	OPTION
3	0	D2	DIODE, OPTION, SOD-323	OPTION
4	0	R8, R27, R28, R29, R30, R31, R109, R117, R120, R121, R127, R130, R134, R138, R139, R140, R144, R145, R150, R151, R152, R155, R157, R160, R208, R216, R218, R219, R221, R226, R238, R239, R240, R241, R242, R243, R244, R245	RES., OPTION, 0603	OPTION
5	17	R9, R91, R92, R112, R114, R132, R135, R136, R146, R147, R149, R158, R202, R211, R215, R222, R227	RES., 0Ω, 1/10W, 0603	VISHAY, CRCW06030000Z0EA
6	0	R104, R105, R122, R128, R141, R143, R153, R156	RES., OPTION, 0805	OPTION
7	0	R217	RES., OPTION, 1206	OPTION
8	0	R230, R231	RES., OPTION, 2512	OPTION
9	0	U4	IC, OPT	OPT
10		COUT74, COUT75, COUT78, COUT80, COUT81, COUT88, COUT95, COUT96	OPT, D3L	OPTION
Hardware: For Demo Board Only				
1	25	E1-E21, E23, E24, E25, E26	TEST POINT, TURRET, 0.064", MTG. HOLE	MILL-MAX, 2308-2-00-80-00-00-07-0
2	2	JP2, JP4	CONN., HEADER, 1X3, 2mm	WURTH ELEKTRONIK, 62000311121
3	2	XJP2, XJP4	CONN., SHUNT, FEMALE, 2 POS, 2mm	WURTH ELEKTRONIK, 60800213421
4	10	J1, J2, J5, J6, J7, J8, J16, J18, J19, J20	STUD, FASTENER, #10-32	PENNGENGINEERING, KFH-032-10ET
5	20	J1, J2, J5, J6, J7, J8, J16, J18, J19, J20 (X2)	NUT, HEX, STEEL, ZINC PLATE, 10-32	KEYSTONE, 4705
6	10	J1, J2, J5, J6, J7, J8, J16, J18, J19, J20	RING, LUG, CRIMP, #10, NON-INSULATED, SOLDERLESS TERMINALS	KEYSTONE, 8205
7	10	J1, J2, J5, J6, J7, J8, J16, J18, J19, J20	WASHER, FLAT, STEEL, ZINC PLATE, OD: 0.436 [11.1]	KEYSTONE, 4703
8	2	J15, J21	CONN., RF, BNC, RCPT, THT, STR, 5-PIN	AMPHENOL CONNEX, 112404
9	1	J17	CONN., HDR, MALE, 2x7, 2mm, R/A THT	MOLEX, 87760-1416
10	1	J22	CONN., HDR, FEMALE, 2x7, 2mm, R/A THT	SULLINS CON., NPPN072FJFN-RC
11	1	J23	CONN., HDR, SHROUDED, 2x6, 2mm, THT, VERT	FCI, 98414-G06-12ULF
12	1	J24	CONN., HDR, SHROUDED, 1x4, 2mm, R/A THT STR	HIROSE ELECTRIC CO., LTD., DF3A-4P-2DSA
13	4	MH1, MH2, MH3, MH4	STANDOFF, NYLON, SNAP-ON, 0.50"	WURTH ELEKTRONIK, 702935000

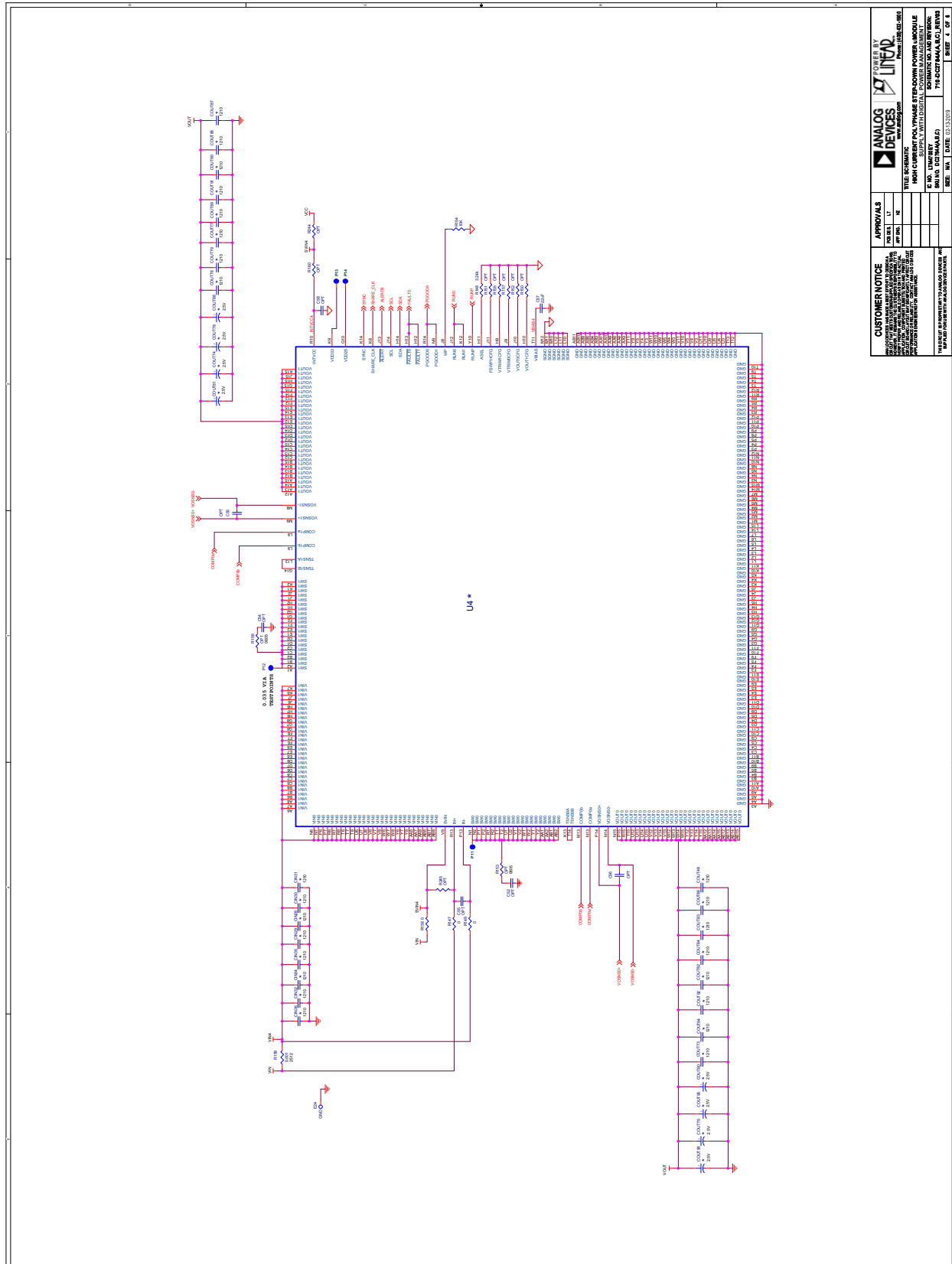
SCHEMATIC DIAGRAM





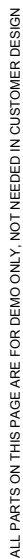
SCHEMATIC DIAGRAM





SCHEMATIC DIAGRAM





DEMO MANUAL DC2784A-B



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.

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