

LTC7880

High Voltage Dual Step-up DC/DC Converter with Digital Power System Management

DESCRIPTION

Demonstration circuit 2728A is a high voltage, dual output boost converter with 12V to 24V input range. The output voltage is adjustable from V_{IN} to 48V. Each output can supply 5A maximum load current. The demo board has a [LTC®7880](#) controller, which is a 60V dual output step-up controller with digital power system management. Please see LTC7880 data sheet for more detailed information.

DC2728A powers up to default settings and produces power based on configuration resistors or its nonvolatile memory (NVM) 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 LTC7880 Quick Start Guide.

Design files for this circuit board are available.

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BOARD PHOTO

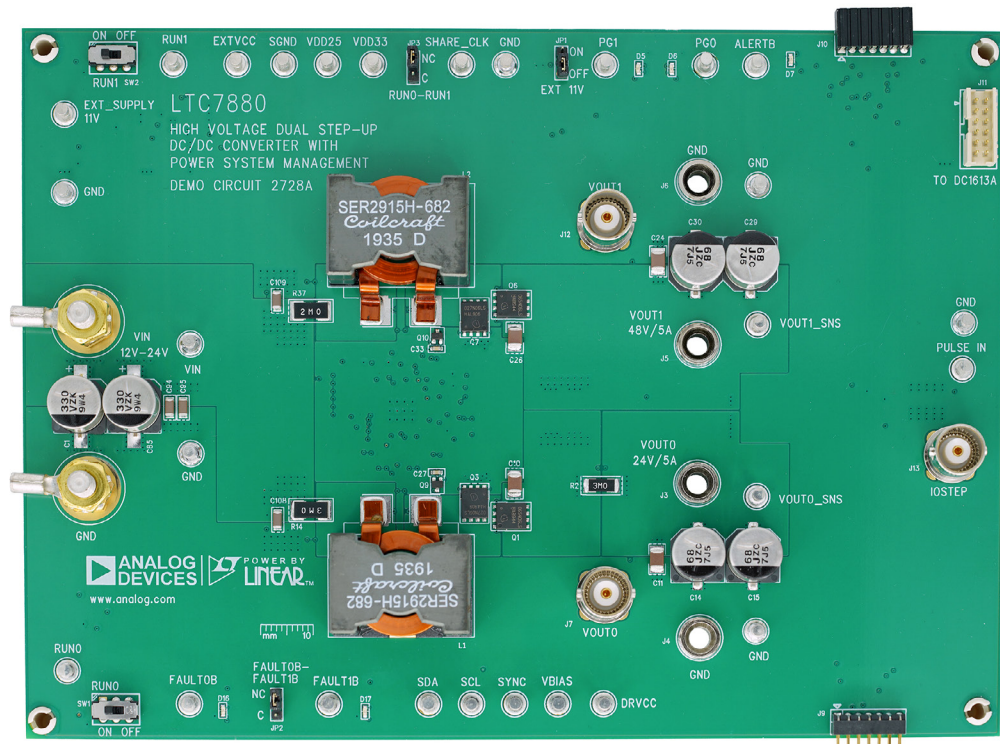


Figure 1. Dual Output LTC7880/DC2728A Demo Circuit

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

PARAMETER	CONDITIONS	VALUE
Input Voltage Range		12V to 24V
Output Voltage, V_{OUT0}	$V_{IN} = 12\text{V to } 24\text{V}$, $I_{OUT0} = 0\text{A to } 5\text{A}$	24V to 48V, Default: 24V
Maximum Output Current, I_{OUT0}	$V_{IN} = 12\text{V to } 24\text{V}$, $V_{OUT0} = 24\text{V to } 48\text{V}$	5A
Output Voltage, V_{OUT1}	$V_{IN} = 12\text{V to } 24\text{V}$, $I_{OUT1} = 0\text{A to } 5\text{A}$	24V to 48V, Default: 48V
Maximum Output Current, I_{OUT1}	$V_{IN} = 12\text{V to } 24\text{V}$, $V_{OUT1} = 24\text{V to } 48\text{V}$	5A
Typical Efficiency of CH0	$V_{IN} = 12\text{V}$, $V_{OUT0} = 24\text{V}$, $I_{OUT0} = 5\text{A}$	98.1% (See Figure 5)
Typical Efficiency of CH1	$V_{IN} = 12\text{V}$, $V_{OUT1} = 48\text{V}$, $I_{OUT1} = 5\text{A}$	97.1% (See Figure 6)
Default Switching Frequency		150kHz

QUICK START PROCEDURE

Demonstration circuit 2728A is easy to set up to evaluate the performance of the LTC7880. 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} (12V to 24V) and GND (input return). Make sure the input power supply is capable of 35A at 12V.
2. Connect the 24V output load between V_{OUT0} and GND (Initial Load: no load).
3. Connect the 48V output load between V_{OUT1} and GND (Initial Load: no load).
4. Connect the DVMs to the input and outputs. Set default jumper position: SW1: ON; SW2: ON; JP1: OFF; JP2: NC; JP3: NC.
5. Turn on the input power supply and check for the proper output voltages. V_{OUT0} should be $24\text{V} \pm 0.5\%$, and V_{OUT1} should be $48\text{V} \pm 0.5\%$.

6. 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.
7. Connect the dongle and control the output voltages from the GUI. See the LTpowerPlay GUI for the LTC7880 Quick Start Guide for details.

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

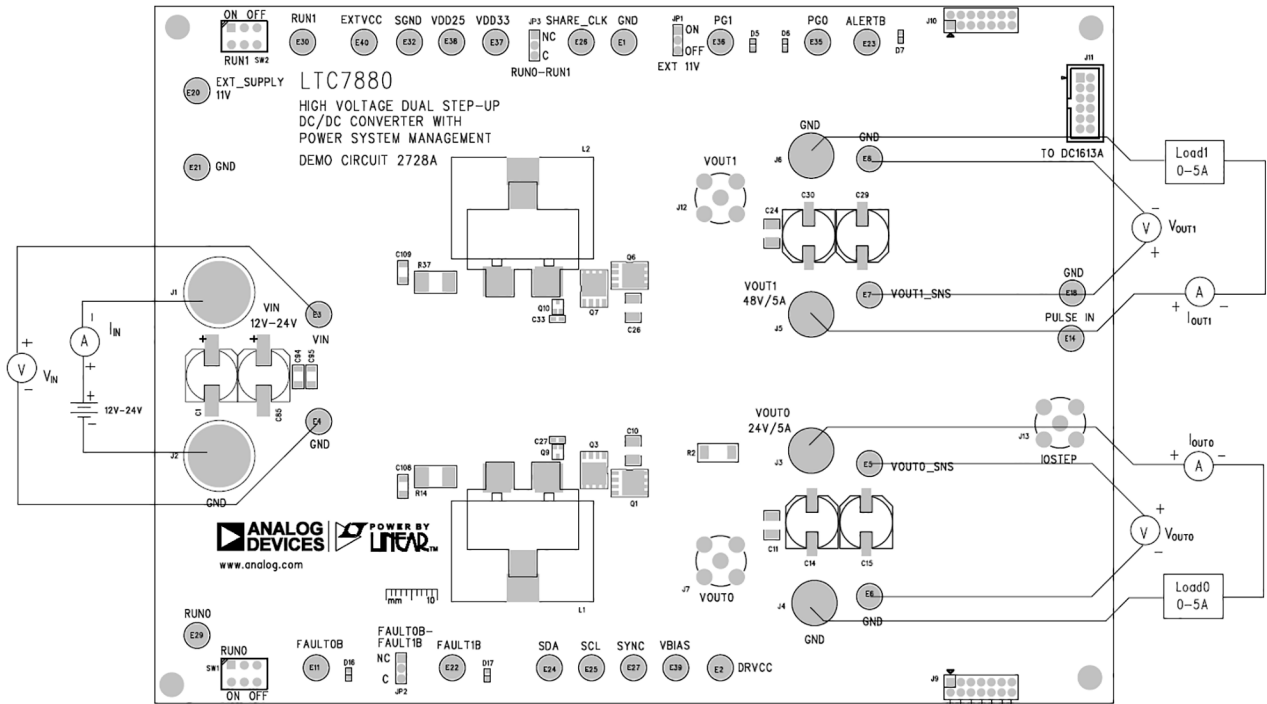


Figure 2. Proper Measurement Equipment Setup

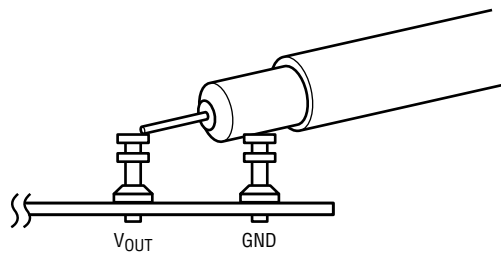


Figure 3. Proper Measurement Equipment Setup

DEMO MANUAL DC2728A

QUICK START PROCEDURE

Connecting a PC to DC2728A

You can use a PC to reconfigure the power management features of the LTC7880 such as: nominal V_{OUT} , 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 V_{IN} is present.

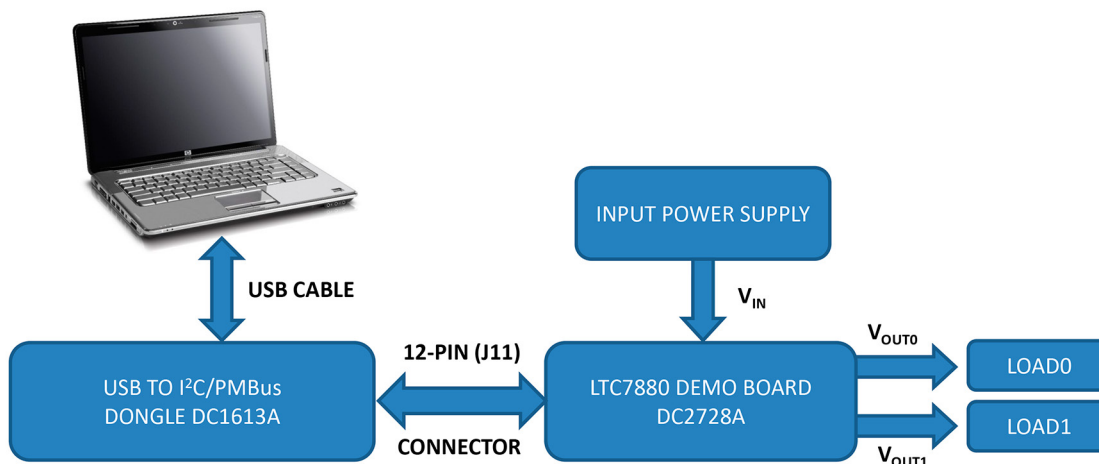


Figure 4. Demo Setup with PC

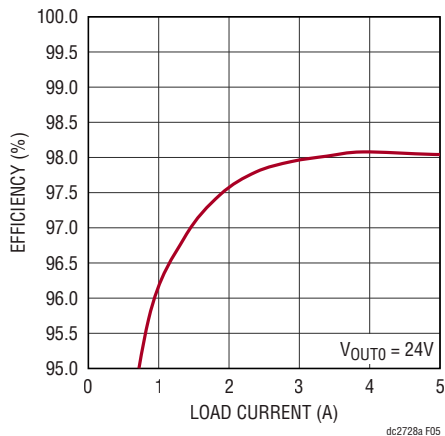


Figure 5. Efficiency vs Load Current on CH0 (CH1 is Disabled)

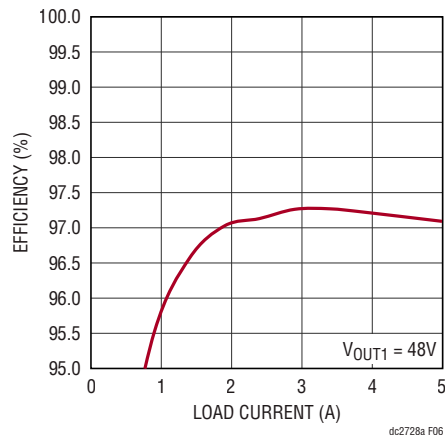


Figure 6. Efficiency vs Load Current on CH1 (CH0 is Disabled)

QUICK START PROCEDURE

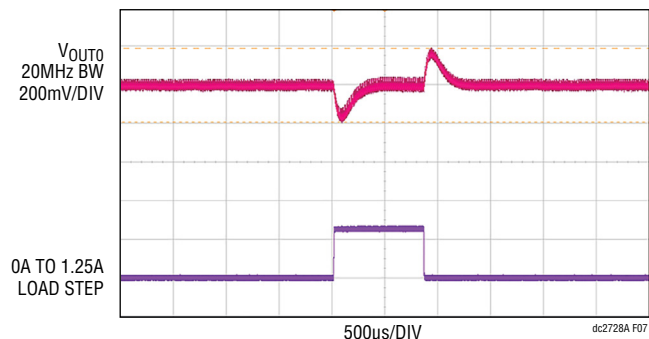


Figure 7. V_{OUT0} Load Transient Response at $V_{IN} = 12V$, $V_{OUT0} = 24V$

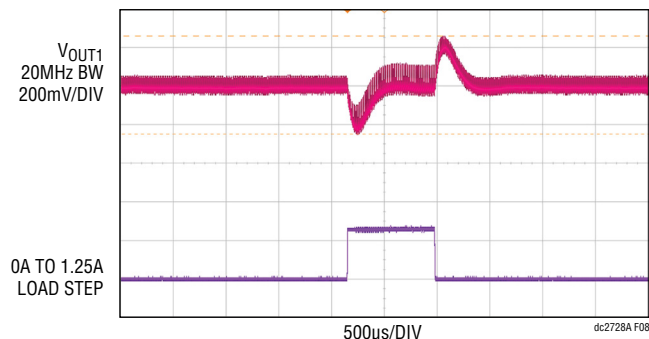


Figure 8. V_{OUT1} Load Transient Response at $V_{IN} = 12V$, $V_{OUT1} = 48V$

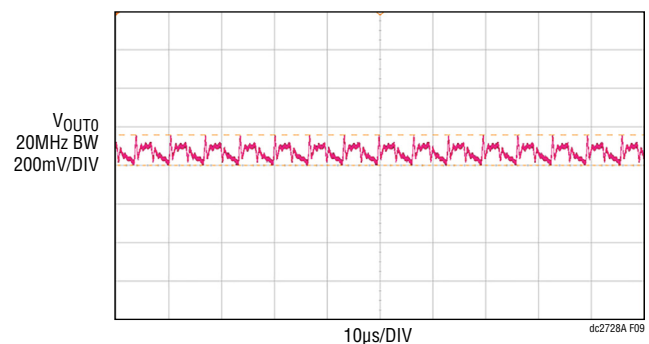


Figure 9. V_{OUT0} Voltage Ripple at $V_{IN} = 12V$, $V_{OUT0} = 24V$, $I_{OUT0} = 5A$

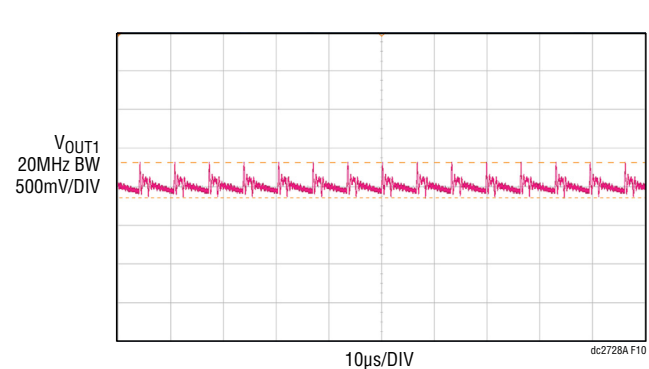


Figure 10. V_{OUT1} Voltage Ripple at $V_{IN} = 12V$, $V_{OUT1} = 48V$, $I_{OUT1} = 5A$

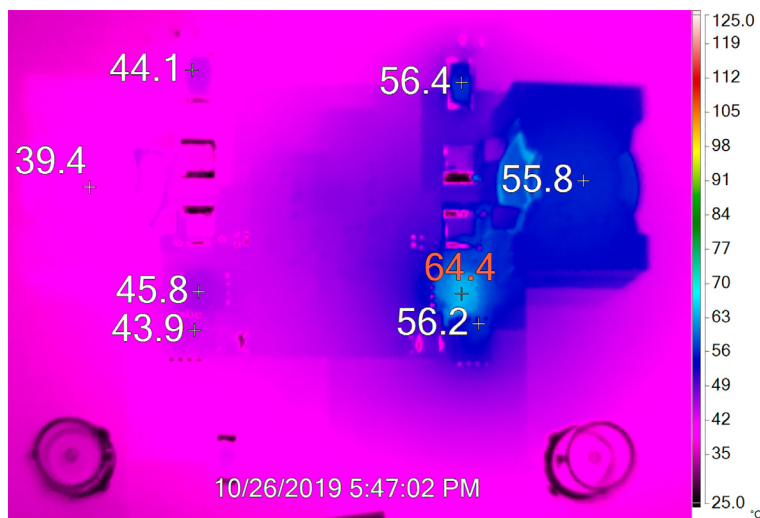


Figure 11. Thermal at $V_{IN} = 12V$, $V_{OUT0} = 24V$, $I_{OUT0} = 5A$, $V_{OUT1} = 48V$, $I_{OUT1} = 5A$, $T_A = 25^\circ C$, No Airflow

DEMO MANUAL DC2728A

LTPowerPLAY SOFTWARE GUI

LTpowerPlay is a powerful Windows-based development environment that supports Analog Devices power system management ICs and μ Module[®] products, including LTM4675, LTM4676, LTM4677, LTM4678, LTM4680, LTM4676, LTM4677, LTM4678, LTM4680, LTM4700, LTM4664, LTC3880, LTC3882, LTC3883, LTC3884 and LTC7880. 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 LTM4675, LTM4676, LTM4677, LTM4678, LTM4680, LTM4700, LTM4664, LTC3880, LTC3882, LTC3883, LTC3884 and LTC7880'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.

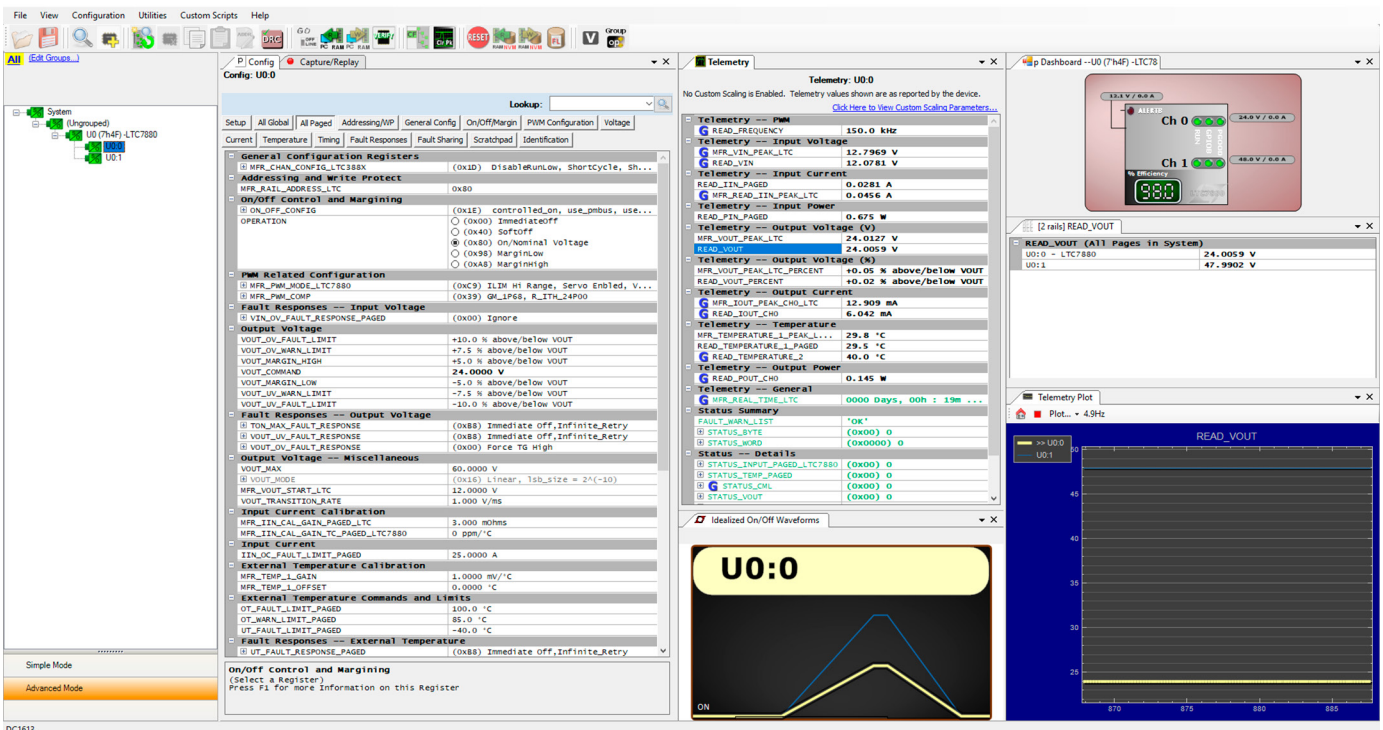


Figure 12. LTpowerPlay Main Interface

LTPowerPLAY QUICK START PROCEDURE

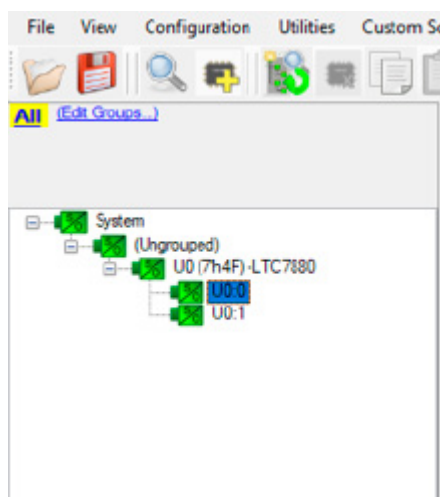
The following procedure describes how to use LTpowerPlay to monitor and change the settings of LTC7880.

1. Download and install the LTPowerPlay GUI:

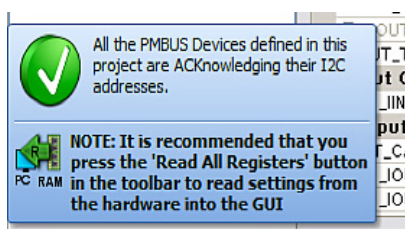
[LTpowerPlay](#)

2. Launch the LTpowerPlay GUI.

- a. The GUI should automatically identify the DC2728A. The system tree on the left-hand side should look like this:



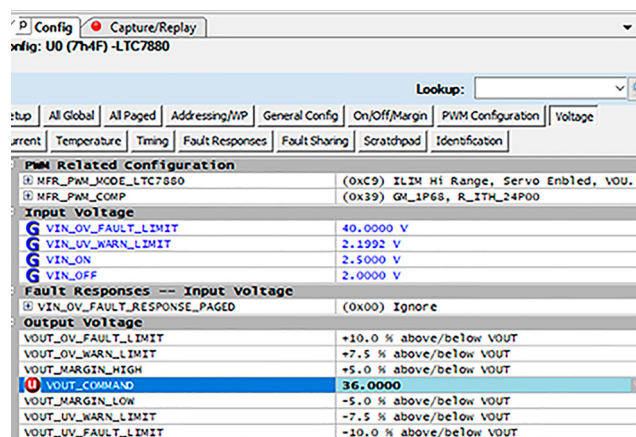
- b. A green message box shows for a few seconds in the lower left hand corner, confirming that LTC7880 is communicating:



- c. In the Toolbar, click the “R” (RAM to PC) icon to read the RAM from the LTC7880. This reads the configuration from the RAM of LTC7880 and loads it into the GUI.



- d. If you want to change the output voltage to a different value, like 36V. In the Config tab, type in 36 in the VOUT_COMMAND box, like this:



Then, click the “W” (PC to RAM) icon to write these register values to the LTC7880. After finishing this step, you will see the output voltage will change to 36V.



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



- e. You can save the changes into the NVM. In the tool bar, 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.

DEMO MANUAL DC2728A

PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	2	C1, C85	CAP, 330 μ F, HYBRID, 35V, 20%, SMD	PANASONIC, EEHZK1V331P
2	3	C3, C37, C38	CAP, 2.2 μ F, X5R, 50V, 10%, 0603	MURATA, GRM188R61H225KE11D
3	4	C4, C5, C27, C33	CAP, 0.01 μ F, X7R, 100V, 10%, 0603	AVX, 06031C103KAT2A
4	3	C6, C13, C28	CAP, 0.001 μ F, X7R, 100V, 10%, 0603	AVX, 06031C102KAT2A
5	2	C9, C23	CAP, 0.1 μ F, X7R, 100V, 10%, 0603	AVX, 06031C104KAT2A
6	8	C10-C12, C24-C26, C88, C93	CAP, 4.7 μ F, X7S, 100V, 10%, 1210	TDK, C3225X7S2A475K200AB
7	8	C14, C15, C16, C17, C29, C30, C31, C32	CAP, 68 μ F, ALUM. ELECT., 63V, 20%, 10mm \times 10.2mm SMD, AEC-Q200	PANASONIC, EEZC1J680P
8	2	C18, C34	CAP, 0.0047 μ F, X7R, 50V, 10%, 0603	SAMSUNG, CL10B472KB8NUNC
9	2	C20, C36	CAP, 100pF, C0G, 50V, 5%, 0603	AVX, 06035A101JAT2A
10	2	C39, C40	CAP, 4.7 μ F, X5R, 35V, 10%, 0603	MURATA, ZRB18AR6YA475KE05L
11	1	C77	CAP, 1000pF, C0G, 100V, 5%, 0805	MURATA, GRM2195C2A102JA01D
12	8	C94, C95, C104-C109	CAP, 22 μ F, 20%, 35V, JB, 1206	TDK, C3216JB1V226M160AC
13	3	D1, D2, D15	DIODE, SCHOTTKY, 100V, 1A, POWER DI-123, AEC-Q101	DIODES, INC., DFSL1100-7
14	2	L1, L2	IND., 6.8 μ H, HIGH CURRENT, 10%, 30A, 2.06m Ω , 2815 SMD	COILCRAFT, SER2915H-682KL
15	4	Q1, Q2, Q5, Q6	MOSFET, N-CH, 60V, 64A, PG-TDSON-8	INFINEON, BSC065N06LS5ATMA1
16	4	Q3, Q4, Q7, Q8	MOSFET, N-CH, 60V, 100A, PG-TDSON-8	INFINEON, BSC027N06LS5ATMA1
17	2	Q9, Q10	MOSFET, PNP, 40V, 0.2A, SC70-3	DIODES, INC., MMST3906-F
18	1	R2	RES., 0.003 Ω , 1%, 1W, 2010	PANASONIC, ERJMP3MF3M0U
19	2	R3, R4	RES., 1k, 5%, 1/10W, 0603, AEC-Q200	VISHAY, CRCW06031K00JNEA
20	9	R10, R11, R13, R15, R16, R18, R23, R25, R28	RES., 10k, 5%, 1/10W, 0603	VISHAY, CRCW060310K0JNEA
21	2	R12, R38	RES., 2 Ω , 5%, 1/10W, 0603	VISHAY, CRCW06032R00JNEA
22	1	R14	RES., 0.003 Ω , 1%, 3W, 2512	PANASONIC, ERJMP4QF3M0U
23	10	R17, R21, R22, R30, R43-R45, R175, R177, R178	RES., 0 Ω , 1/10W, 0603	VISHAY, CRCW06030000Z0EA
24	4	R24, R26, R50, R51	RES., 10 Ω , 5%, 1/10W, 0603	VISHAY, CRCW060310R0JNEA
25	1	R37	RES., 0.002 Ω , 1%, 3W, 2512	PANASONIC, ERJMP4QF2M0U
26	1	R92	RES., 1.0 Ω , 5%, 1/2W, 0805	PANASONIC, ERJ6DQJ1R0V
27	1	U1	IC, 60V DUAL OUTPUT STEP-UP CONTROLLER WITH PSM, 52-LEAD (7mm \times 8mm), QFN	ADI., LTC7880IUKG#PBF
Additional Demo Board Circuit Components				
1	0	C19, C35, C71, C73	OPT, 0603	
2	2	C70, C103	CAP, 1.0 μ F, X7S, 100V, 10%, 0805	MURATA, GRJ21BC72A105KE11L
3	1	C72	CAP, 0.047 μ F, X7R, 25V, 10%, 0603	AVX, 06033C473KAT2A
4	1	C74	CAP, 2.2 μ F, X7R, 100V, 10%, 1210	AVX, 12101C225KAT2A
5	0	C75	OPT, 1210	
6	1	C76	CAP, 0.1 μ F, X7R, 100V, 10%, 0603	AVX, 06031C104KAT2A
7	1	C78	CAP, 0.22 μ F, X7R, 100V, 10%, 0805	MURATA, GRM21AR72A224KAC5L

PARTS LIST

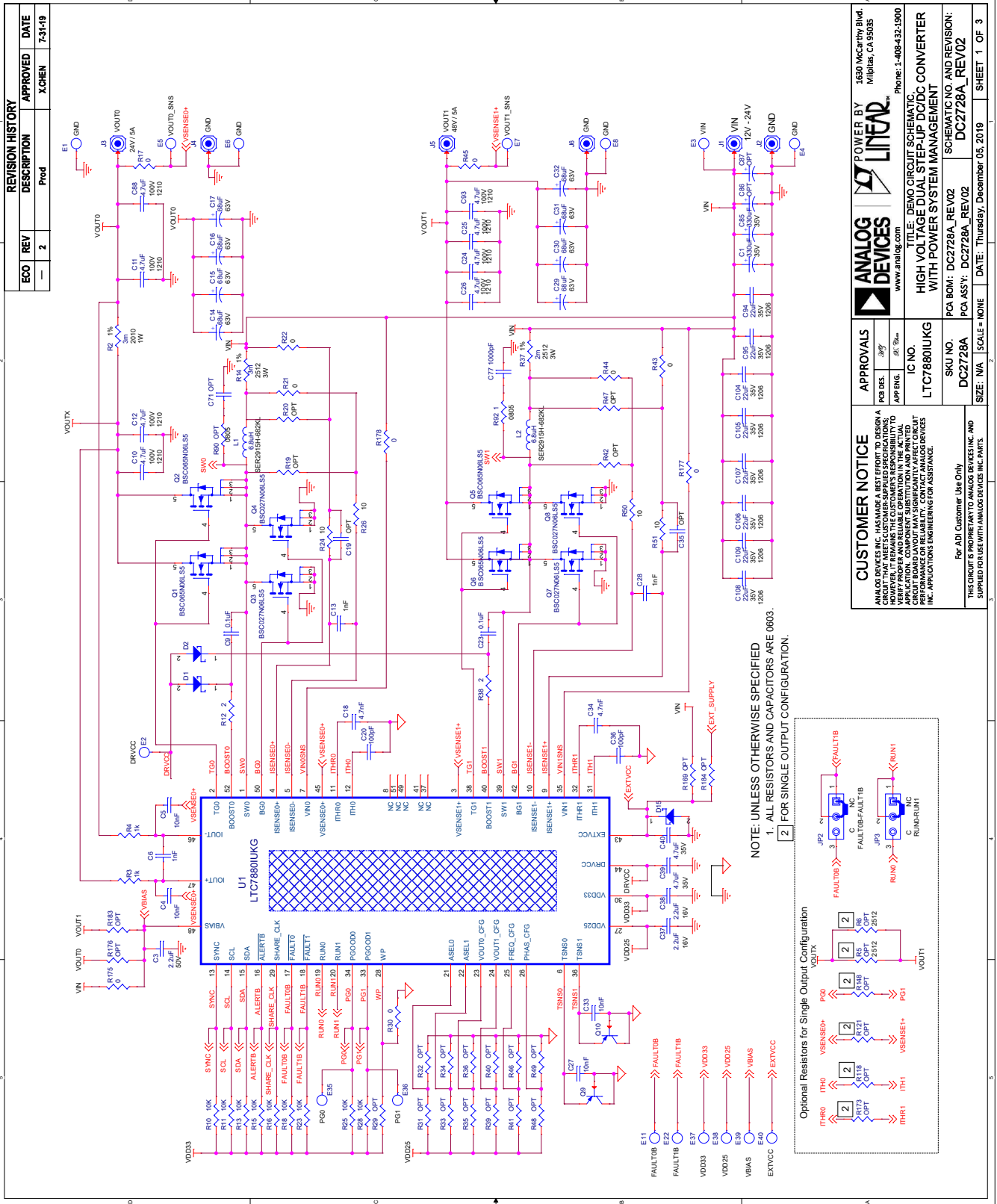
ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
8	2	C79, C80	CAP., 100µF, X5R, 16V, 20%, 1210	TAIYO YUDEN, EMK325ABJ107MM-T
9	1	C81	CAP., 220pF, X7R, 50V, 10%, 0603	AVX, 06035C221KAT2A
10	2	C82, C83	CAP., 0.01µF, X7R, 100V, 10%, 0603	AVX, 06031C103KAT2A
11	1	C84	CAP., 0.1µF, 20%, 25V, X5R, 0603	AVX, 06033D104KAT2A
12	0	C86, C87	OPT, 10mm × 10.2mm	
13	1	C110	CAP., 1µF, X5R, 50V, 10%, 0603	MURATA, GRT188R61H105KE13D
14	2	D5, D6	LED, GREEN, COLORLESS DIFFUSED, 0603	OSRAM, LS L29K-G2J1-24-Z
15	3	D7, D16, D17	LED, RED, COLORLESS DIFFUSED, 0603	OSRAM, LS L29K-H1J2-1-Z
16	3	D8, D9, D12	OPT	
17	1	L5	IND., 68µH, PWR, ±30%, 1.65A, 201mΩ, SMD 10.5mm × 10.3mm × 5.1mm	SUMIDA, CDRH105RNP-680NC
18	1	Q19	MOSFET, N-CH 80V TO-263	INFINEON, IPB031N08N5
19	3	Q20, Q30, Q31	MOSFET, P-CH, 20V, 5.9A, SOT-23, TO-236	VISHAY, SI2365EDS-T1-GE3
20	2	Q22, Q23	MOSFET, N-CHAN, 60V, 115mA, SOT-23	FAIRCHILD SEMI., 2N7002
21	0	Q27	OPT, SOT23	
22	0	R5, R6	OPT, 2512	
23	0	R19, R20, R29, R31-R36, R39-R42, R46-R48, R49, R100-R105, R108, R110, R111, R116-R118, R121, R144, R145, R147, R148, R169, R173, R176, R183, R184	OPT, 0603	
24	2	R87, R88	RES., 200Ω, 5%, 1/10W, 0603	VISHAY CRCW0603200RJNEA
25	4	R89, R97, R112, R113	RES., 10k, 5%, 1/10W, 0603	VISHAY, CRCW060310K0JNEA
26	0	R90	OT, 0805	
27	1	R91	RES., 1Ω, 1%, 1W, 2010, SENSE, AEC-Q200	WELWYN COMPONENTS/TT ELECT., LRC-LR2010-01-1R00-F
28	3	R93, R179, R180	RES., 127Ω, 1%, 1/10W, 0603	VISHAY CRCW0603127RFKEA
29	1	R96	RES., 127k, 1%, 1/10W, 0603, AEC-Q200	PANASONIC, ERJ-3EKF1273V
30	3	R98, R106, R109, R132, R174	RES., 0Ω, 1/10W, 0603	VISHAY CRCW06030000Z0EA
31	1	R99	RES., 220k, 5%, 1/10W, 0603	VISHAY CRCW0603220KJNEA
32	0	R107, R163	OPT, 1206	
33	2	R114, R115	RES., 10Ω, 5%, 1/10W, 0603	VISHAY CRCW060310R0JNEA
34	2	R119, R120	RES., 4.99k, 1%, 1/10W, 0603	VISHAY CRCW06034K99FKEA
35	1	R146	RES., 4.7Ω, 1%, 1/8W, 0805	VISHAY, CRCW08054R70FKEA
36	1	R157	RES., 2Ω, 5%, 1/10W, 0603	VISHAY CRCW06032R00JNEA
37	2	R162, R185	RES, 0Ω, JUMPER 1206	VISHAY CRCW12060000Z0EA
38	1	U3	IC, SYNCHR. STEP-DOWN CONVERTER, MSOP-16	ANALOG DEVICES, LTC3630EMSE#PBF
39	1	U4	IC, MEMORY, EEPROM, 2Kb (256×8), TSSOP-8, 400kHz	MICROCHIP, 24LC025-I/ST

DEMO MANUAL DC2728A

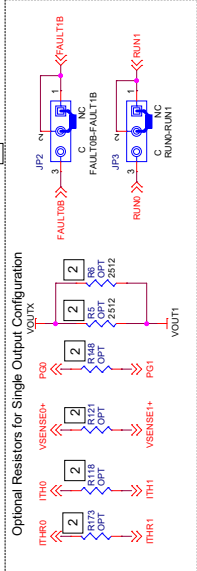
PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Hardware: For Demo Board Only				
1	27	E1-E8, E11, E14, E18, E20-E27, E29, E30, E32, E35-E40	TEST POINT, TURRET, 0.094, MTG. HOLE	MILL-MAX, 2501-2-00-80-00-00-07-0
2	3	JP1, JP2, JP3	CONN.,HDR,MALE,1x3, 2mm, THT, STR	WURTH ELEKTRONIK, 62000311121
3	2	J1, J2	STUD, FASTENER, #10-32	PENNINGENGINEERING, KFH-032-10ET
4	4	J1, J2 x2	NUT, BRASS 10-32	ANY, 10-32M/S BR PL
5	2	J1, J2	RING, LUG #10	KEYSTONE, 8205
6	2	J1, J2	WASHER, TIN PLATED BRASS #10	ANY, #10EXT BZ TN
7	4	J3, J4, J5, J6	CONN.,BANANA JACK, FEMALE, THT, NON-INSULATED, SWAGE	KEYSTONE, 575-4
8	3	J7, J12, J13	CONN., RF, BNC, RCPT,THT, STR, 5-PIN	AMPHENOL CONNEX, 112404
9	1	J9	CONN.,HDR, MALE, 2x7,2mm, R/A THT	MOLEX, 87760-1416
10	1	J10	CONN.,HDR, FEMALE, 2x7, 2mm, R/A THT	SULLINS, NPPN072FJFN-RC
11	1	J11	CONN.,HDR, SHROUDED, 2x6, 2mm, THT, VERT	FCI, 98414-G06-12ULF
12	3	XJP1, XJP2, XJP3	CONN., SHUNT, FEMALE, 2 POS, 2mm	WURTH ELEKTRONIK, 60800213421
13	4	STANDOFF	STANDOFF, NYLON, SNAP-ON, 0.625 (15.9mm)	KEYSTONE, 8834
14	1	SW1,SW2	SWITCH, SUB-MINIATURE SLIDE, DPDT, 0.3A, 6VDC, THT	C&K COMPONENTS, JS202011CQN

SCHEMATIC DIAGRAM



NOTE: UNLESS OTHERWISE SPECIFIED
 1. ALL RESISTORS AND CAPACITORS ARE 0603.
 2. FOR SINGLE OUTPUT CONFIGURATION.



REVISION HISTORY		
ECO	REV	DESCRIPTION
—	2	Prod

APPROVED	DATE
XCHEN	7-31-19

CUSTOMER NOTICE
 ANALOG DEVICES INC. HAS MADE A BEST EFFORT TO DESIGN A CIRCUIT THAT MEETS CUSTOMER-SPECIFIED REQUIREMENTS. ANALOG DEVICES INC. DOES NOT WARRANT THE ACTUAL PERFORMANCE OR RELIABILITY OF THE CIRCUIT IN THE ACTUAL APPLICATION. ANALOG DEVICES INC. APPLICATION ENGINEERING FOR ASSISTANCE.

APPROVALS
 PRO DES: [Signature]
 APP ENGR: [Signature]

ANALOG DEVICES
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POWER BY LINEAR
 1650 McCarthy Blvd.
 Milpitas, CA 95035
 Phone: 1-408-432-1900

**TITLE: DEMO CIRCUIT SCHEMATIC
 HIGH VOLTAGE DUAL STEP-UP DC/DC CONVERTER
 WITH POWER SYSTEM MANAGEMENT**

IC NO.
 LTC7801UKG

SKU NO.
 DC2728A_REV02

PCA BOM: DC2728A_REV02

SCHEMATIC NO. AND REVISION: DC2728A_REV02

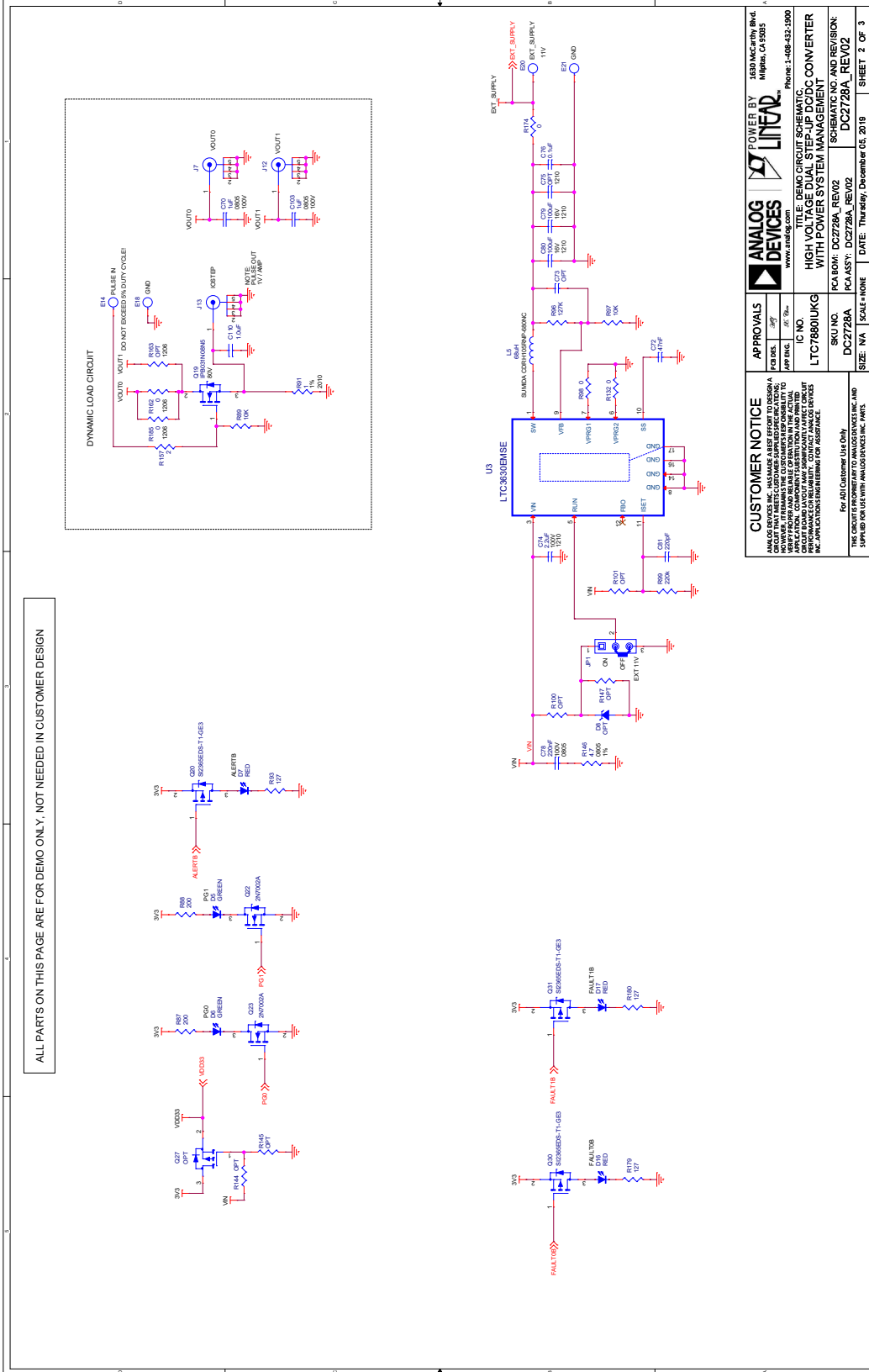
DATE: Thursday, December 05, 2019

SIZE: NA | **SCALE:** NONE | **SHEET:** 1 OF 3

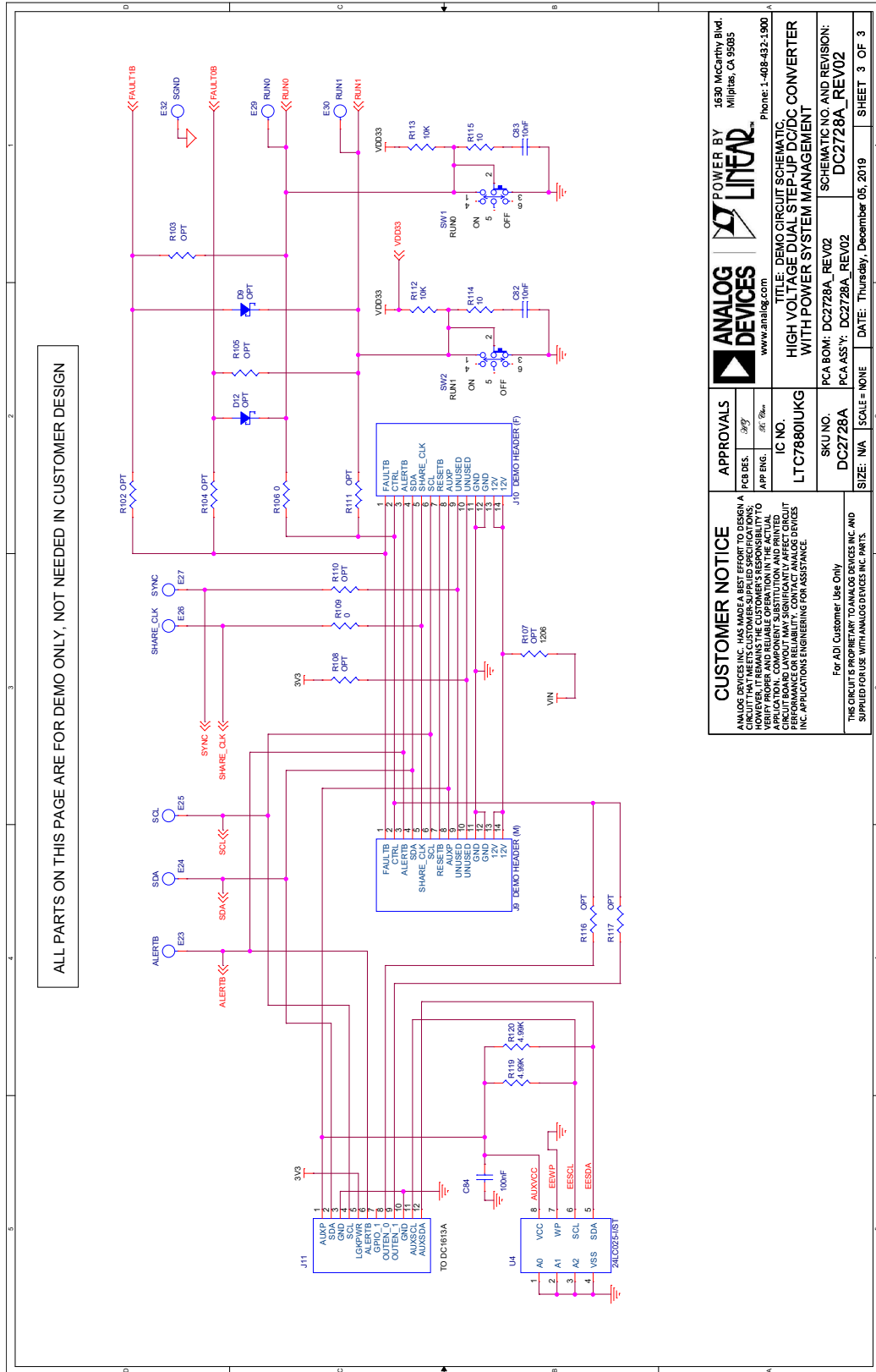
For ADI Customer Use Only
 THIS CIRCUIT IS PROPRIETARY TO ANALOG DEVICES INC. AND SUPPLIED FOR USE WITH ANALOG DEVICES INC. PARTS.

DEMO MANUAL DC2728A

SCHEMATIC DIAGRAM



SCHEMATIC DIAGRAM



CUSTOMER NOTICE		APPROVALS	
ANALOG DEVICES INC. HAS MADE A BEST EFFORT TO DESIGN A CIRCUIT THAT MEETS CUSTOMER-SUPPLIED SPECIFICATIONS. CUSTOMERS ARE RESPONSIBLE FOR VERIFYING THE ACTUAL APPLICATION COMPONENT SUBSTITUTION AND PRINTED PERFORMANCE OR RELIABILITY. CONTACT ANALOG DEVICES INC. APPLICATIONS ENGINEERING FOR ASSISTANCE.		PCB DES. <i>09/17</i>	IC NO. <i>08/16</i>
For AdI Customer Use Only THIS CIRCUIT IS PROPRIETARY TO ANALOG DEVICES INC. AND SUPPLIED FOR USE WITH ANALOG DEVICES INC. PARTS.		LTCT7880IUGG	SKU NO. DC2728A
POWER BY ANALOG DEVICES LINEAR		TITLE: DEMO CIRCUIT SCHEMATIC. HIGH VOLTAGE DUAL STEP-UP DC/DC CONVERTER WITH POWER SYSTEM MANAGEMENT	
1630 McCarthy Blvd. Milpitas, CA 95035 Phone: 1-408-432-1900 www.analog.com		PCA BOM: DC2728A_REV02 PCA ASSY: DC2728A_REV02	
SCHEMATIC NO. AND REVISION: DC2728A_REV02		DATE: Thursday, December 05, 2019	
SHEET 3 OF 3			



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.