

LTC4282

High Current Hot Swap Controller with I²C Compatible Monitoring

DESCRIPTION

Demonstration circuit 2024A features the [LTC®4282](#) high current Hot Swap controller. The LTC4282 is well suited to high power applications because the precise monitoring capability and accurate current limiting reduces the extremes in which both loads and power supplies must safely operate. Non-volatile configuration allows for flexibility in the autonomous generation of alerts and response to faults. The LTC4282 provides a rich set of features to support Hot Swap applications including:

- 12-/16-Bit ADC Monitors Current, Voltage, Power and Energy
- Controls Two Sets of Parallel MOSFETs for High Current Applications
- I²C/SMBus Interface

- Non-Volatile Configuration and Logging Functions
- Generates Alerts on ADC Measurements Outside Limits
- Software Adjustable Current Limit with Foldback
- Three General Purpose Input/Outputs

Available in a 32-pin 5mm × 5mm QFN package, the LTC4282 is showcased on DC2024A configured for a 12V/100A application. The DC2024A-B has an included programming socket to allow programming an LTC4282 for prototyping purposes prior to its permanent installation on a PCB. The DC2024A-A does not have this socket. By changing a few passive components, 2.9V to 30V applications can easily be evaluated.

Design files for this circuit board are available at <http://www.linear.com/demo/DC2024A>

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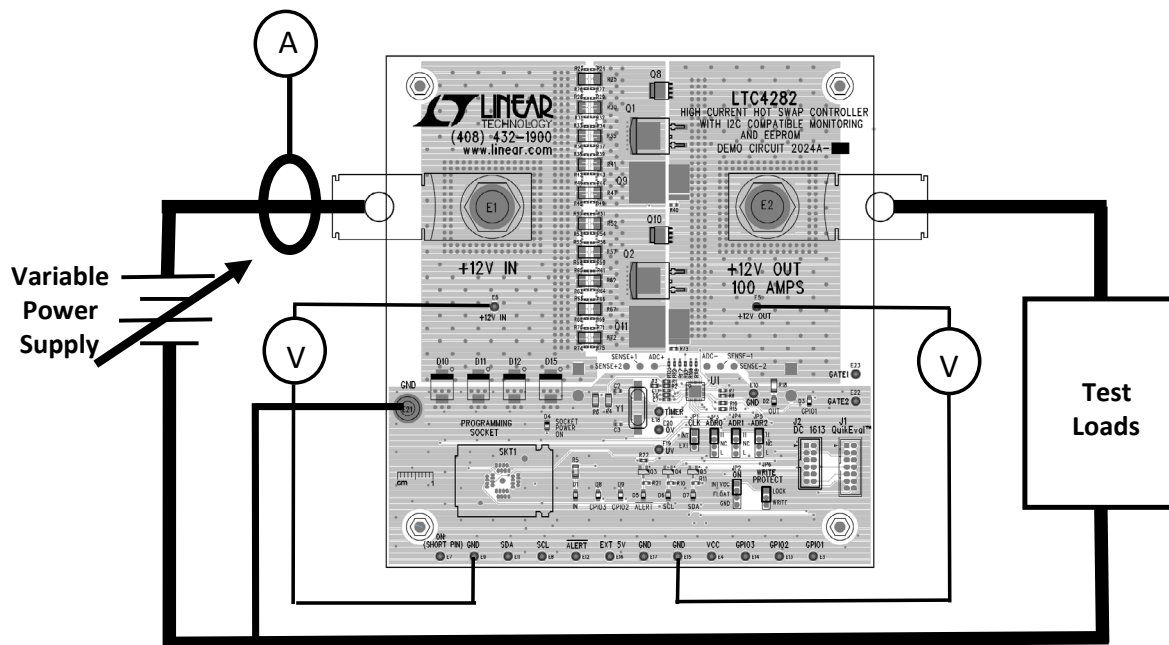


Figure 1. Proper Measurement Equipment Setup

DEMO MANUAL DC2024A

PERFORMANCE SUMMARY

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

PARAMETER	CONDITIONS	VALUE
Input Supply Voltage Range		2.9V to 30V
Nominal Operating Voltage		12.0V
Overvoltage Lockout	Nominal	15.0V
Undervoltage Lockout	Nominal	11.1V
Output Current Limit	Nominal	100A
Maximum Load Capacitance	Nominal	10,000 μF
Timer Expiration Period	Nominal	4ms

QUICK START PROCEDURE

Table. Power Input and Output Connections

NOMENCLATURE	CONNECTOR	DESCRIPTION
12V _{IN}	E1	12V Power In
12V _{OUT} 100A	E2	12V Power Out
GND	E21 (Banana)	Power Supply Common

Table 2. Test Points, Turrets

NOMENCLATURE	TURRET	DESCRIPTION
GPIO1	E3	GPIO1 Pin I/O
V _{CC}	E4	Internal V _{CC}
12V _{OUT}	E5	12V _{OUT} Monitor
12V _{IN}	E6	12V _{IN} Monitor
ON (SHORT PIN)	E7	ON Pin Monitor/Input
SCL	E8	I ² C Serial Clock Input
GND	E9, E10, E15, E17	Ground
SDA	E11	I ² C Serial Data Input/Output
ALERT	E12	ALERT Pin
GPIO2	E13	GPIO2 Pin I/O
GPIO3	E14	GPIO3 Pin I/O
EXT 5V	E16	
TIMER	E18	TIMER Pin
UV	E19	UV Pin
OV	E20	OV Pin
GATE2	E22	GATE 2 Pin
GATE1	E23	GATE 1 Pin

Table 3. LED Indicators

NOMENCLATURE	LED	DESCRIPTION
IN	D1 (Green)	Input Power Indicator
OUT	D2 (Green)	Output Power Indicator
GPIO1	D3 (Green)	GPIO1 Logic Low Indicator

QUICK START PROCEDURE

Table 3. LED Indicators

SOCKET POWER ON	D4 (Red)	Programming Socket SKT1 Powered
ALERT	D5 (Red)	ALERT Pin Logic Low
SCL	D6 (Green)	Serial Clock Active
SDA	D7 (Green)	Serial Data Active
GPIO3	D8 (Green)	GPIO3 Logic Low
GPIO2	D9 (Green)	GPIO2 Logic Low

Table 4. Jumpers

NOMENCLATURE	JUMPER	DESCRIPTION
CLK: INT, EXT	JP1	Internal/External Clock Select
ON: INTV _{CC} , FLOAT, GND	JP2	ON Input Select, V _{CC} , Float (External), GND
ADRO: H, NC, L	JP3	Address Pin ADRO Select
ADR1: H, NC, L	JP4	Address Pin ADR1 Select
ADR2: H, NC, L	JP5	Address Pin ADR2 Select
WRITE PROTECT: LOCK, WRITE	JP6	Write Protect for EEPROM

Table 5. Connectors

NOMENCLATURE	CONNECTOR	DESCRIPTION
DC590	J1	Connection for DC590 Aux Demo Board
DC1613	J2	Connection for DC1613 Aux Demo Board

Operating Principles

The LTC4282 is a low voltage, high current Hot Swap controller that has a 2.9V to 33V operating range and a 45V absolute maximum voltage for the V_{DD} pin. This demo circuit is populated for 12V operation, but it can easily be readjusted for any voltage between 2.9V and 30V by replacing R1, R2, and R7 (top resistors in the UV/OV divider and the FB divider). The DC2024A as supplied by the factory is populated with a pair of PSMN1R5-30BLE MOSFETs in D2PAK packages. A total of ten 3mΩ sense resistors are used providing typically 100A of load current. The current limit and circuit breaker thresholds can be adjusted by changing the sense resistors R25, R30, R35, R41, R47, R52, R57, R62, R67, and R72 and/or the value of ΔV_{SENSE} via addressable registers in the LTC4282. Several locations for MOSFET packages as well as additional sense resistors are available on the front and rear of the PCB for higher current configurations.

Quick Start Procedure (Without Software)

DC2024A is easy to set up to evaluate the performance of the LTC4282. Refer to Figure 1 for proper measurement equipment setup and follow the procedure below.

WARNING

The DC2024A is capable of operation in excess of 100A. At this current and power level, there is a danger of serious personal injury and equipment damage if proper techniques are not used. All cabling between the power supply and the load should be capable of handling the current levels used.

Additionally, the high currents and fast transients can cause unexpected voltage drops in cables connecting the test equipment to the DC2024A due to parasitic resistance and inductance. The cable drops may cause ground loops for the current via various cables and scope probes. This will cause unexplained ringing, distorted oscilloscope waveforms, voltage and current spikes, and signals appearing to be below ground.

QUICK START PROCEDURE

A common sneak path for current is the third wire grounds used on power cords of test equipment in use. Using ground lifting connectors at the wall outlet won't necessarily alleviate these effects since most equipment has line bypassing capacitors between the mains voltage and local chassis ground. Isolating test equipment using line isolation transformers with low primary to secondary capacitance is recommended. Probe ground leads may intercept induced fields from the high current paths and should be minimized or avoided.

Another method to remove these artifacts is the use of a differential scope probe connected between the signal to be observed and a ground connection located close to the point of measurement.

Also be careful to not allow an open ground from the power supply or load to cause return current through the grounds of the various devices connected to the demo board. This may present a fire hazard or cause damage to the test equipment.

The DC2024A is set up to operate in a 12V system at current levels up to 100A. At 100A, the MOSFETs are dissipating 3.75W each and additional air flow may be needed to keep them within safe thermal operating limits for continuous operation. If additional current is required without sufficient air flow, multiple MOSFETs should be connected in parallel with the existing MOSFETs to lower the I^2R losses.

Jumper Positions

JUMPER	NAME	POSITION
JP1	CLK	EXT
JP2	ON	INTV _{CC}
JP3	ADR0	NC
JP4	ADR1	NC
JP5	ADR2	NC
JP6	WRITE PROTECT	LOCK

Powering Up

Connect power supply capable of 120A at 0V to 20V to the 12V input as shown in Figure 1. Verify cabling shown in extra bold lines is capable of carrying 100A safely. The GND connection does not handle high current so no high current cabling is required.

Generally, an electronic load will be used. If this is true, use it in the constant resistance mode. Use in constant current will prevent start up because of current foldback in the LTC4282. Current foldback is used to minimize dissipation in the MOSFETs used as pass devices with the LTC4282. To effect this, current is initially limited to approximately 1/3 of full limit until the output voltage is above 10V. If a constant current load is used and set to 100A, the LTC4282 will not start up and a current fault will be reported.

UV/OV Thresholds

With no load on the output, slowly increase the voltage on the input to the board. Observe the input voltage when LED D2 (OUT) illuminates. This voltage should be between 10.7V and 11.4V. Continue increasing the voltage until D2 is extinguished. This should occur between 14.4V and 15.3V.

Output Voltage Slew Rate

With no load connected, observe the output voltage between turret 12V_{OUT} (E5), and GND. Apply 12V to the 12V_{IN} connector. The output voltage should slew from 0V to 12V in 10ms to 25ms.

Output Current Limit

Turn off power supply and connect electronic load to the DC2024 as shown in Figure 1. Disable electronic load. Adjust power supply to 12V and verify its current level is set to >120A.

Slowly increase conductance of the electronic load while monitoring current. As the load increases to around 100A, the output voltage and current will fall to zero. Note the current where this occurs. This should be 95A to 105A.

Ability to Charge Output Capacitor

Turn off power supply and disconnect electronic load. Replace load with a 10,000μF capacitor rated at 15V or greater. Turn on power supply and observe that the output voltage rises to 12V indicating the DC2024 has connected to the load and successfully charged the output capacitance. Monitor the current during the period when the capacitor is charging, it should be a maximum of 12A.

QUICK START PROCEDURE

Software Control with LTpowerPlay™

LTpowerPlay is a convenient PC software GUI that gives complete access to the registers of the LTC4282, and many other Linear Technology power system management parts. Use it in offline mode to build a system configuration file even with no hardware plugged-in, and use it with hardware connected to configure and debug your application. LTpowerPlay communicates using the I²C bus in the demo system (covered in this manual), or in your real-world product environment. It provides unprecedented control over the Linear Technology ICs on the I²C bus.

Use it during board bring-up to tune and optimize the power system parameters. Use it during system debug to view critical system information and troubleshoot board design or manufacturing issues. LTpowerPlay includes extensive help and documentation under the help menu. Online help includes quick start videos and tutorials, and detailed technical documentation from the Linear Technology website. Getting started with LTpowerPlay is easy. Simply download and install the PC software from here:

<http://www.linear.com/ltpowerplay>

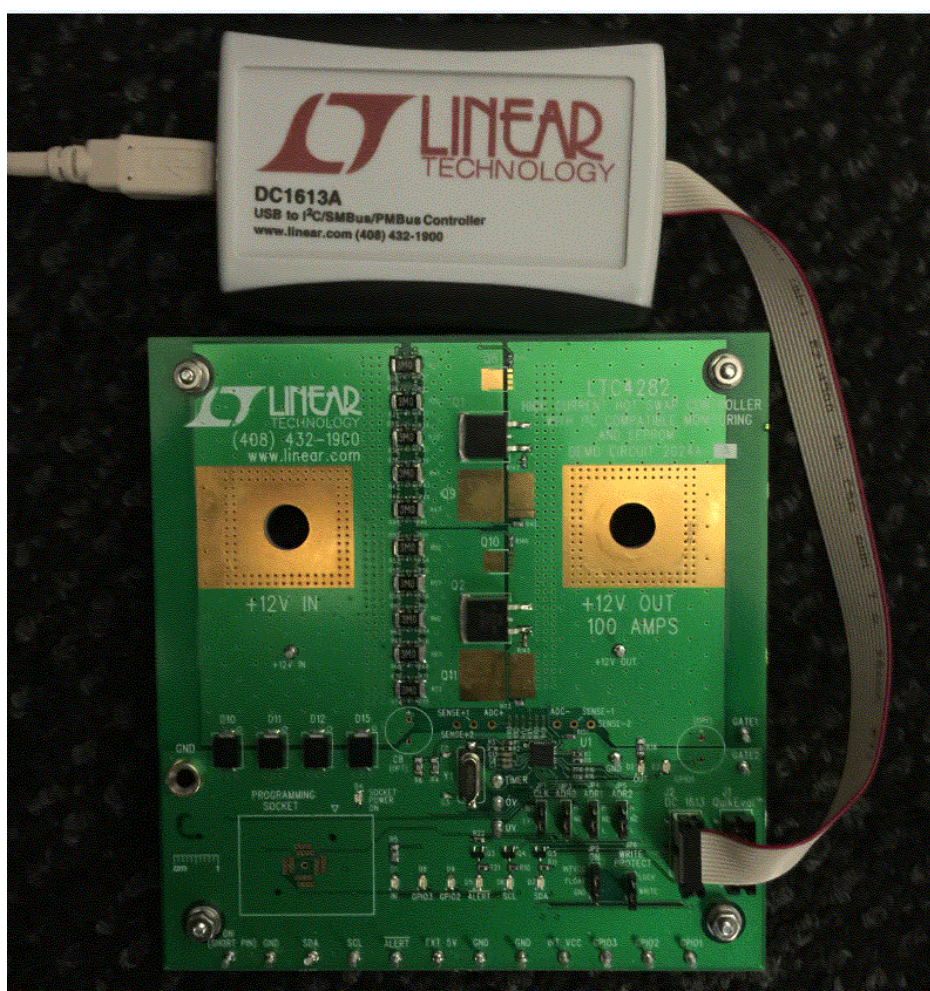


Figure 2. DC2024A-A Demo Board Connected to DC1613 I²C-to-USB Converter

QUICK START PROCEDURE

The DC1613 USB-to-I²C adapter interfaces the PC running LTpowerPlay to the DC2024A board. Connect the DC1613 adapter to the PC through a USB cable, and connect the DC2024A board through the ribbon cable to connector J2.

Launch the LTpowerPlay GUI on the PC. The software identifies the DC1613 controller, then the DC2024A board, and begins communicating through the I²C bus with the LTC4282. Once this communication has been established, the GUI displays its main window (Figure 3).

The LTpowerPlay GUI divides information into separate panes in the window. On the left is the system tree pane (Figure 4), displaying a list of all Linear Technology devices identified on the I²C bus. For a single LTC4282 device, the tree is small, but if other supported devices are present on the I²C bus, LTpowerPlay will add them. Click on a device in this list to selectively access it. Information in other panes pertains to the selected device.

LTpowerPlay System Tree

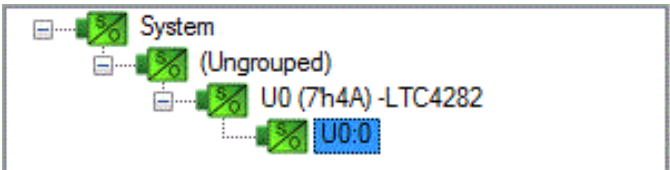


Figure 4. LTpowerPlay System Tree

To the right of the system tree is the configuration register pane. The Figure 5 view shows all of the writable user-configurable registers available on the selected device. The GUI offers clickable buttons and fields to edit the information in these registers.

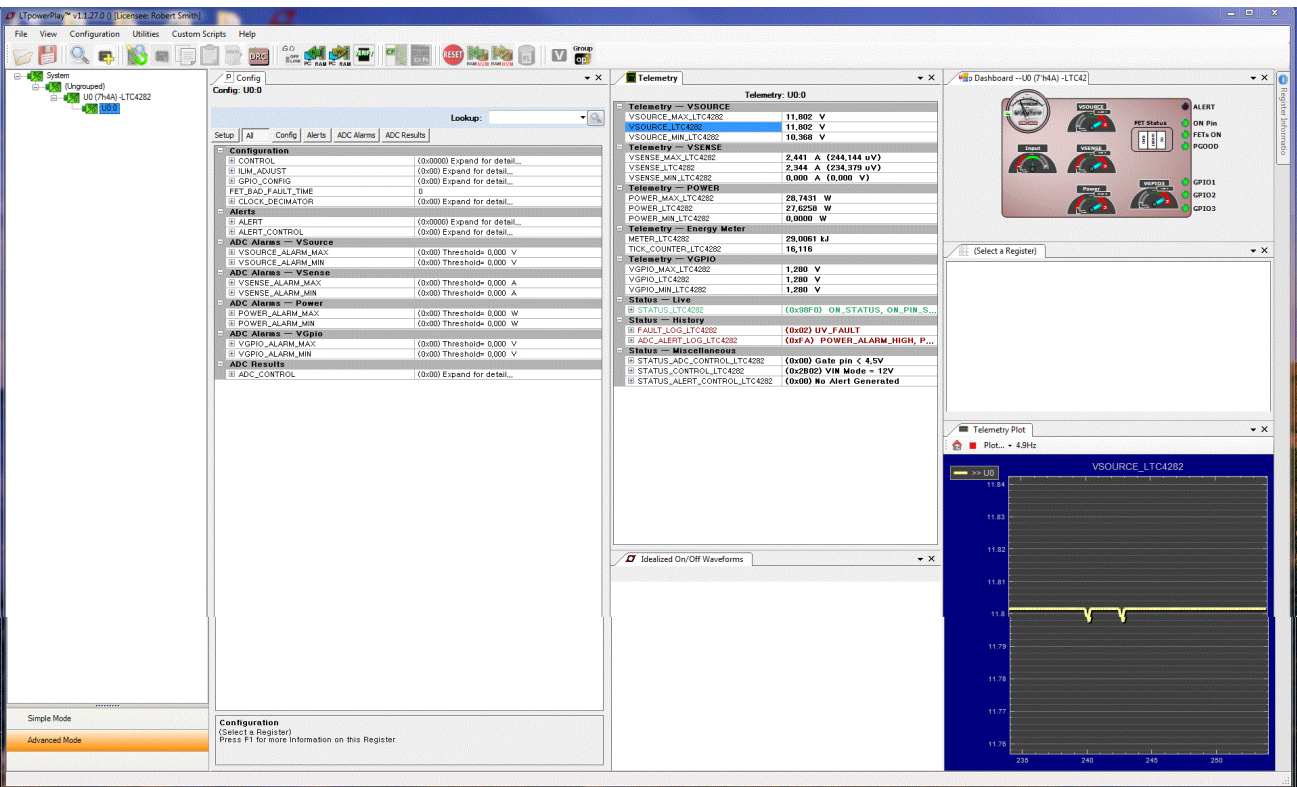


Figure 3. LTpowerPlay GUI Window

QUICK START PROCEDURE

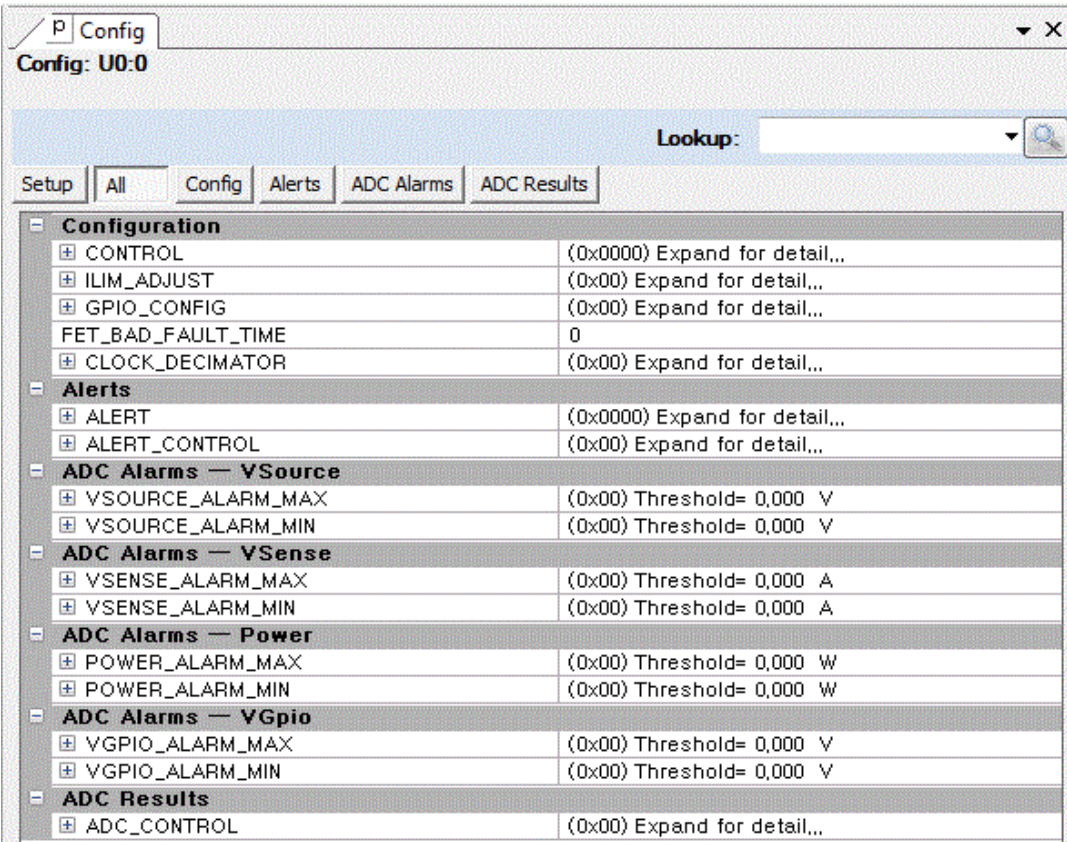


Figure 5. LTpowerPlay Configuration Registers

Update register contents by clicking or typing to change the desired registers. Then selecting the PC to RAM button in the top toolbar (Figure 6). LTpowerPlay writes changes to the updated registers.



Figure 6. PC to RAM Button

Right of center in LTpowerPlay is the telemetry pane (Figure 7), displaying read-only information contained in the status registers of the selected part. The GUI periodically polls the I²C bus and updates the telemetry content, along with a user-friendly interpretation of the bits.

QUICK START PROCEDURE

Telemetry	
Telemetry: U0:0	
Telemetry — VSOURCE	
VSOURCE_MAX_LTC4282	11.802 V
VSOURCE_LTC4282	11.798 V
VSOURCE_MIN_LTC4282	10.368 V
Telemetry — VSENSE	
VSENSE_MAX_LTC4282	2.441 A (244,144 uV)
VSENSE_LTC4282	2.344 A (234,379 uV)
VSENSE_MIN_LTC4282	0.000 A (0,000 V)
Telemetry — POWER	
POWER_MAX_LTC4282	28.7431 W
POWER_LTC4282	27.6258 W
POWER_MIN_LTC4282	0.0000 W
Telemetry — Energy Meter	
METER_LTC4282	122.9659 kJ
TICK_COUNTER_LTC4282	68,243
Telemetry — VGPI0	
VGPI0_MAX_LTC4282	1.280 V
VGPI0_LTC4282	1.280 V
VGPI0_MIN_LTC4282	1.280 V
Status — Live	
STATUS_LTC4282	(0x98F0) ON_STATUS, ON_PIN_S...
Status — History	
FAULT_LOG_LTC4282	(0x02) UV_FAULT
ADC_ALERT_LOG_LTC4282	(0xFA) POWER_ALARM_HIGH, P...
Status — Miscellaneous	
STATUS_ADC_CONTROL_LTC4282	(0x00) Gate pin < 4.5V
STATUS_CONTROL_LTC4282	(0x2B02) VIN Mode = 12V
STATUS_ALERT_CONTROL_LTC4282	(0x00) No Alert Generated

Figure 7. LTpowerPlay Telemetry

In the upper right corner of LTpowerPlay is the chip dashboard pane (Figure 8), displaying a graphical representation of the part status in a friendly, easy-to-understand format. The meter in the upper left of the panel displays the static input energy to the card in watts. The small dials in the center of the input energy meter display the energy used in kilojoules. The VSOURCE meter displays the voltage at the SOURCE pin of the LTC4282, which is the same as V_{OUT} . The Input meter displays the voltage input at the V_{DD} pin of the LTC4282. VSENSE indicates the input current derived by dividing the voltage measured across the sense resistor by the value of the sense resistor. The power meter displays the SOURCE voltage multiplied

by the current sense voltage and scaled to indicate the power in watts. VGPI03 displays the voltage at GPI03 when it is configured as an analog input. The FET Status annunciators show the status of the pass MOSFETs as described in the FET-BAD Fault section of the data sheet. GPI01, GPI02 and GPI03 show the status of the general purpose input/output pins.

On the lower right of the GUI window is the telemetry plot pane (Figure 9). By selecting various measurement functions in the telemetry pane, a graphic display of that function versus time is displayed. This gives an instant indication on how that function varies with time.

QUICK START PROCEDURE

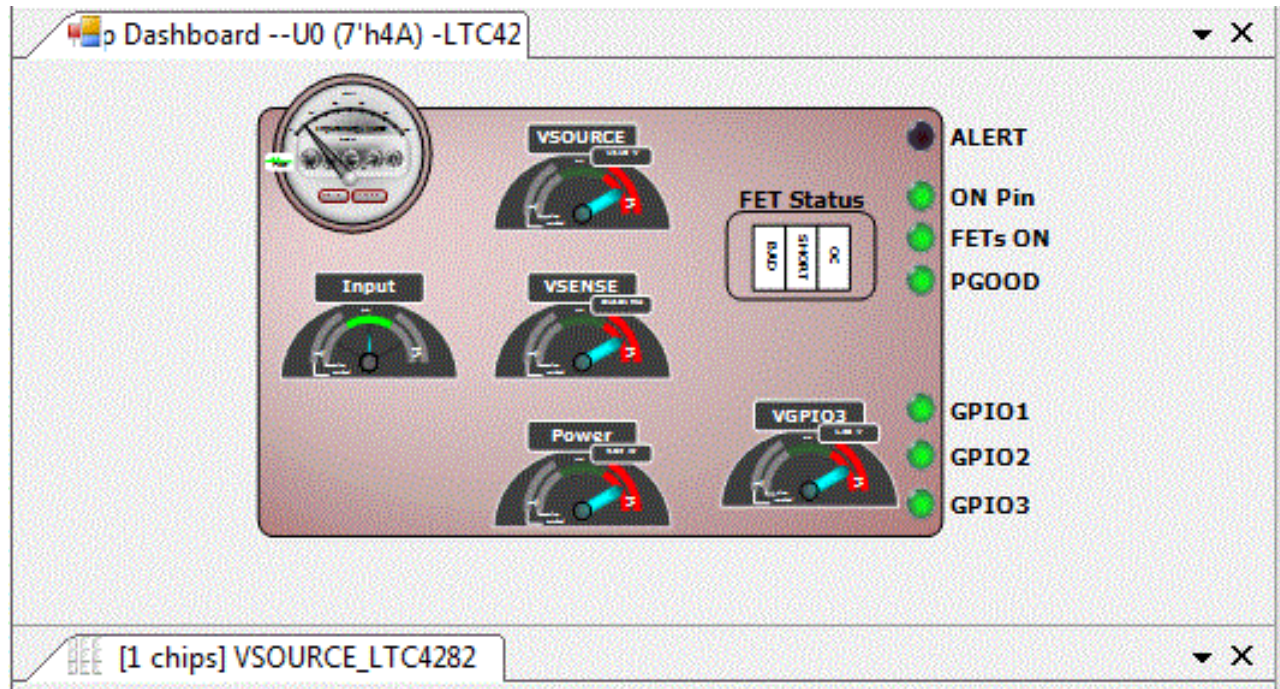


Figure 8. LTpowerPlay Chip Dashboard

QUICK START PROCEDURE

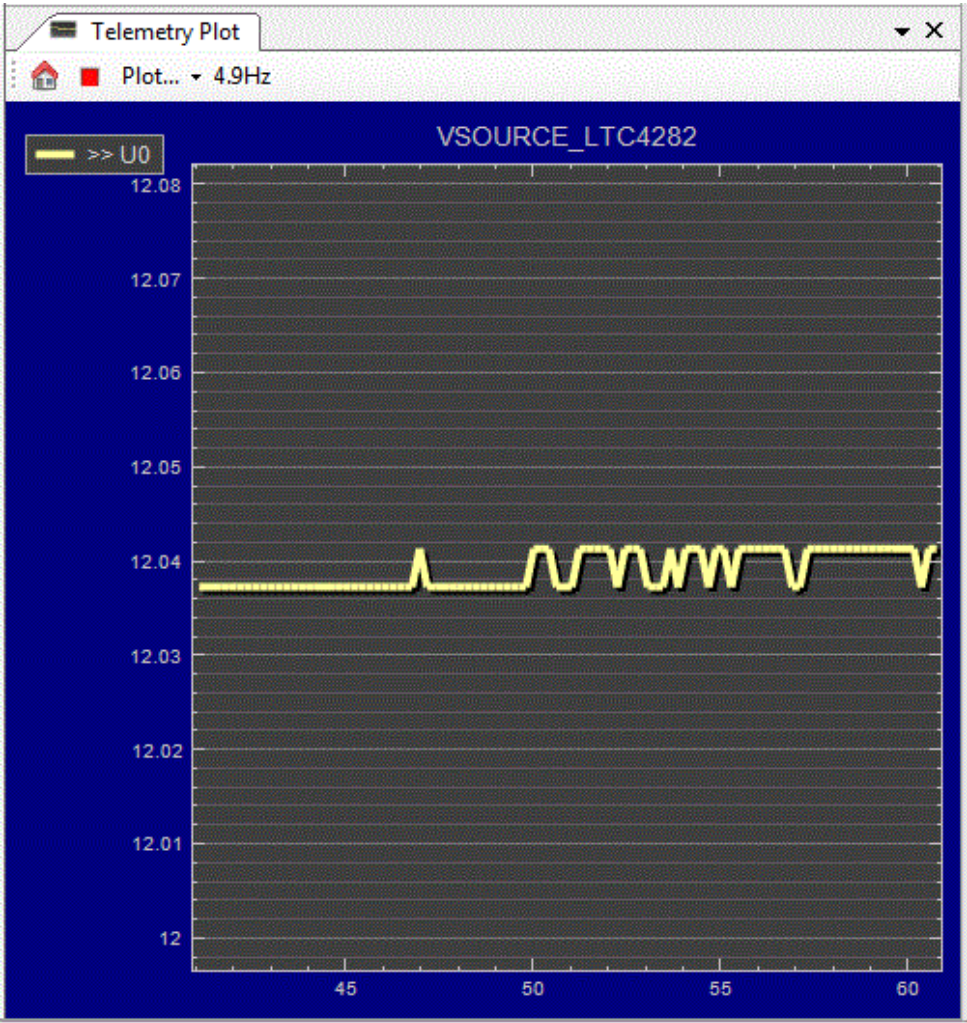


Figure 9. LTpowerPlay Telemetry Plot

QUICK START PROCEDURE

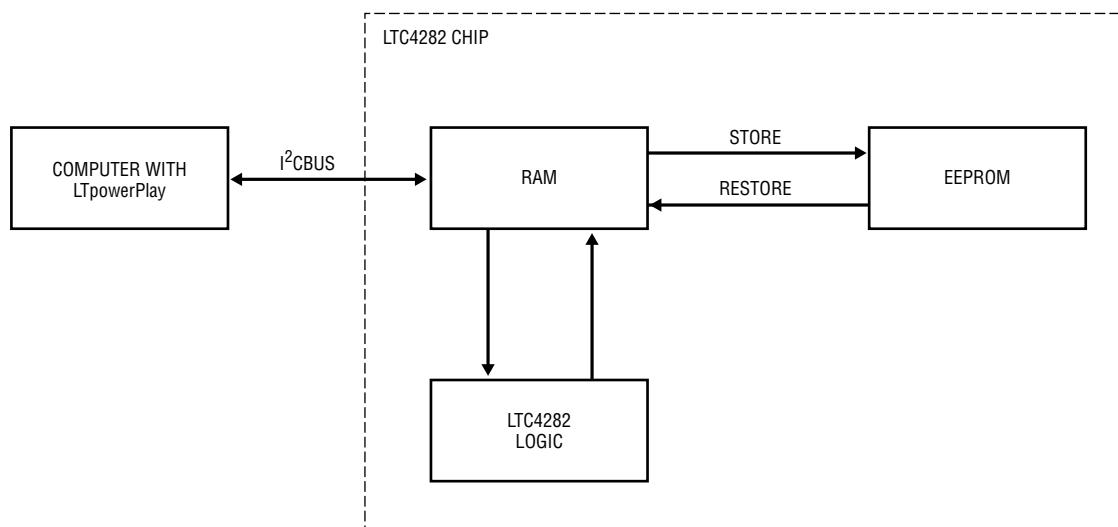


Figure 10. LTC4282 RAM and Non-Volatile Memory

The LTC4282 is highly configurable through its register set. Refer to the LTC4282 data sheet for a complete discussion of the registers and functions available. Get immediate access to detailed help for the selected register in LTpowerPlay by pressing the F1 key on your keyboard.

The LTC4282 features non-volatile EEPROM that holds device configuration information and a snapshot of past fault information. When the part receives power it executes a power-on reset, and restores the contents of the EEPROM to its operating RAM. Following this power-on restore, operating RAM can be modified with I²C bus commands that modify the part behavior. These modifications are effected by using the PC>RAM button in the toolbar. Also included in the toolbar are buttons for reading the internal RAM data on the PC by using the RAM>PC button on the toolbar. Similarly, there are buttons for moving the contents of the RAM to the NVM (EEPROM) and vice versa using the RAM>NVM and NVM>RAM buttons on the toolbar.

Programming Socket

The DC2024A-B board includes a programming socket. This socket in conjunction with the LTpowerPlay software GUI and DC1613 USB-to-I²C adapter may be used to program the EEPROM of multiple LTC4282 ICs prior to their installation on a PC board.

Please refer to Application Note 145, <http://cds.linear.com/docs/en/application-note/AN145f.pdf>, and refer to Option 1A. Use the device address 0x88, which is the address to which the programming socket is hard wired. Also verify that the LTC4282 already soldered on the board (U1) is set to a different address than 0x88 to prevent a conflict.

Follow the instructions for Option 1A on page 3 of Application Note 145.



Figure 11. Read Write NVM Buttons on Toolbar

DEMO MANUAL DC2024A

PARTS LIST

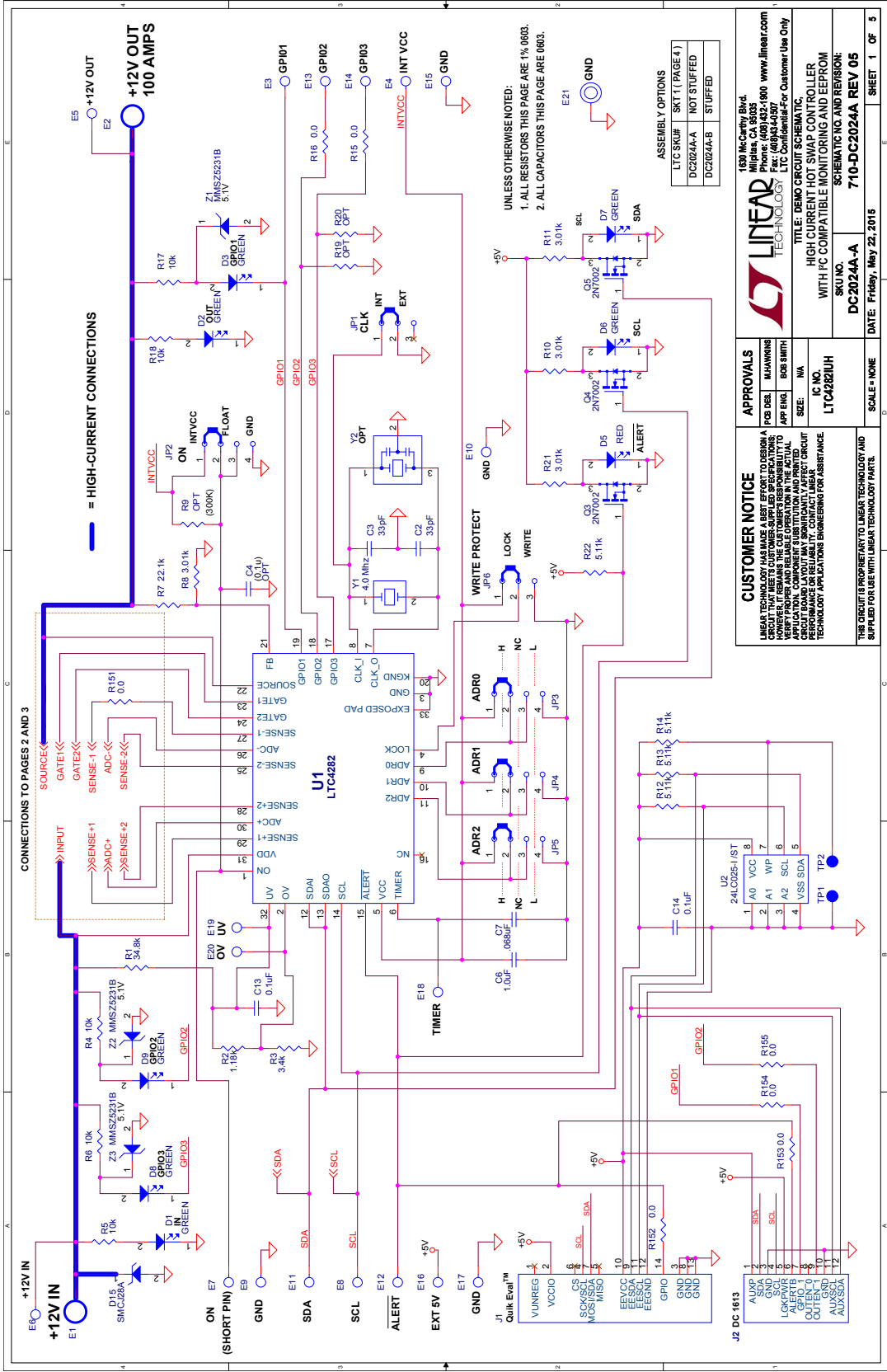
ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
1	2	C1, C8	CAP., POLARIZED, OPTION	NICHICON, UVR1E102MPD OR EQUIVALENT
2	2	C2, C3	CAP., 33pF, X7R, 16V, 5%, 0603	AVX, 0603YC330JAT2A
3	1	C4	CAP., OPTION, 0603	N/A
4	2	C5, C14	CAP., 0.1µF, X7R, 16V, 10%, 0603	AVX, 0603YC104KAT2A
5	1	C6	CAP., 1µF, X7R, 16V, 10%, 0603	AVX, 0603YC105KAT2A
6	1	C7	CAP., 0.47µF, X7R, 16V, 10%, 0603	TDK, C1608X7R1C474K
7	2	C9, C10	CAP., 0.01µF, X7R, 50V, 10%, 0603	AVX, 06035C103KAT2A
8	2	C11, C12	CAP., 0.022µF, X7R, 50V, 5%, 0805	KEMET, C0805C223J5RACTU
9	1	C13	CAP., 0.1µF, X7R, 25V, 20%, 0603	TDK, C1608X7R1E104M080AA
10	7	D1-D3, D6-D9	LED, GREEN, WATERCLEAR, 0805	WURTH, 150080GS75000
11	2	D4, D5	LED, RED, WATERCLEAR, 0805	WURTH, 150080RS75000
12	4	D10-D12, D15	DIODE, TVS, 28V, SMC	DIODES INC./ZETEX, SMCJ28A-13
13	0	D13, D14	NO STUFF	NO STUFF
14	2	E1, E2	ONE-HOLE, OFFSET FLOATING TONGUE LUG	PANDUIT, CB175-38-QY
15	20	E3-E20, E22, E23	TEST POINT, TURRET, .064 MTG. HOLE, .125" THICK PCB	MILL-MAX, 2308-4-00-80-00-00-07-0
16	1	E21	BANANA JACK, NON-INSULATED	KEYSTONE, 575-4
17	1	J1	CONN., HEADER, 2x7, 2mm, SHROUDED, THRU-HOLE, VERTICAL	MOLEX, 87831-1420
18	1	J2	CONN., HEADER, 12 POS 2mm	FCI, 98414-G06-12ULF
19	2	JP1, JP6	CONN., HEADER, 1x3, 2mm, THRU-HOLE, VERTICAL	SAMTEC, TMM-103-02-L-S
20	4	JP2-JP5	CONN., HEADER, 1x4, 2mm, THRU-HOLE, VERTICAL	SAMTEC, TMM-104-02-L-S
21	4	MP1-MP4	BUMPER, RECESSED, #4 SCREW, BLACK	KEYSTONE, 727
22	4	MP5-MP8	WASHER, FLAT, SS 18-8, #4	BOLT DEPOT, 5563
23	4	MP9-MP12	MACHINE SCREW, #4-40 x 1/2 PHILLIPS PAN HEAD, ZINC	BOLT DEPOT, 7593
24	4	MP13-MP16	LOCK WASHER, INT. TOOTH, ZINC, #4	BOLT DEPOT, 3011
25	4	MP17-MP20	HEX NUT, #4-40, SS 18-8	BOLT DEPOT, 4115
26	2	MP21, MP22	HEX NUT, FULL, 3/8-16, 9/16 IN.	GRAINGER, 1WB27
27	2	MP23, MP25	FLAT WASHER, SS 18-8, 3/8 IN.	GRAINGER, 6FDG6
28	2	MP26, MP27	LOCK WASHER, INT., 0.398 IN. ID	GRAINGER, 2DE18
29	2	MP28, MP29	HEX HEAD BOLT, 3/8-16 x 1-1/8 IN.	GRAINGER, 30Z861
30	2	Q1, Q2	TRANSISTOR, MOSFET, D2PAK	NXP, PSMN1R5-30BLE,118
31	3	Q3-Q5	TRANS., MOSFET N-CH., 60V SOT-23	VISHAY SILICONIX, 2N7002K-T1-GE3
32	0	Q6, Q7	NO STUFF	NO STUFF
33	0	Q8, Q10, Q13, Q15	NO STUFF	NO STUFF
34	0	Q9, Q11, Q12, Q14	NO STUFF	NO STUFF
35	1	R1	RES., 34.8k, 1/10W, 1%, 0603	YAGEO, RC0603FR-0734K8L
36	1	R2	RES., 1.18k, 1/10W, 1%, 0603	YAGEO, RC0603FR-071K18L
37	1	R3	RES., 3.4k, 1/10W, 1%, 0603	YAGEO, RC0603FR-073K4L
38	5	R4-R6, R17, R18	RES., 10k, 1/4W, 5%, 1206	PANASONIC, ERJ-8GEYJ103V

dc2024afa

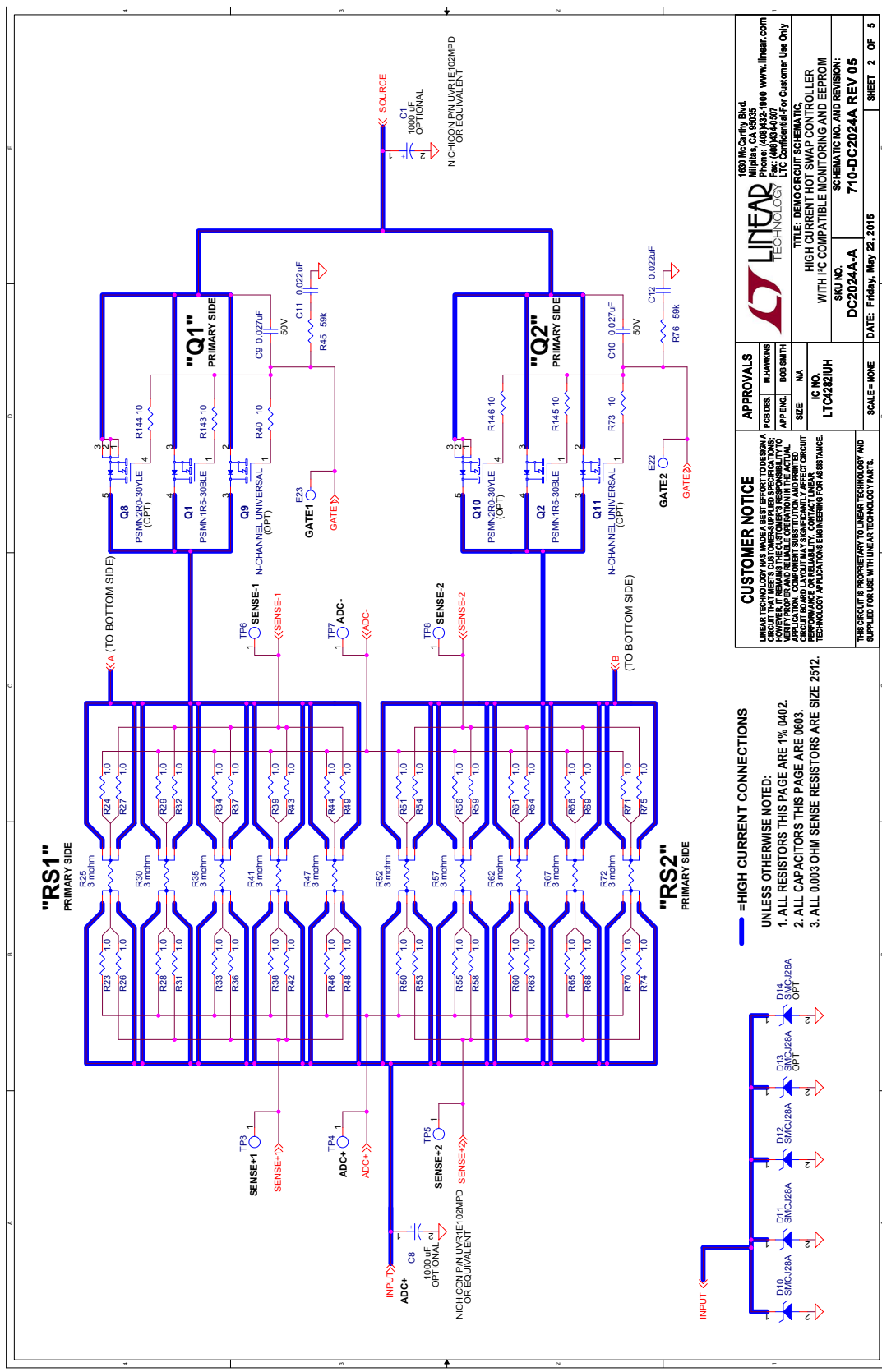
PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
39	1	R7	RES., 22.1k, 1/10W, 1%, 0603	YAGEO, RC0603FR-0722K1L
40	4	R8, R10, R11, R21	RES., 3.01k, 1/10W, 1%, 0603	YAGEO, RC0603FR-073K01L
41	3	R9, R19, R20	RES., OPTION, 0603	N/A
42	4	R12-R14, R22	RES., 5.11k, 1/10W, 1%, 0603	YAGEO, RC0603FR-075K11L
43	11	R15, R16, R135, R140-R142, R151-R155	RES., 0 Ω , 1/10W, 0603	YAGEO, RC0603JR-070RL
44	40	R23, R24, R26-R29, R31-R34, R36-R39, R42-R44, R46, R48-R51, R53-R56, R58-R61, R63-R66, R68-R71, R74, R75	RES., 1 Ω , 1/16W, 1%, 0402	VISHAY, CRCW04021R00FKED
45	10	R25, R30, R35, R41, R47, R52, R57, R62, R67, R72	RES., 0.003 Ω , METAL ELEMENT, 1%, 2W 2512	OPTEK TECHNOLOGY (TT ELECTRONICS), LRMAT2512-R003FT4
46	10	R40, R73, R143-R150	RES., 10 Ω , 1/10W, 5%, 0603	YAGEO, RC0603JR-0710RL
47	2	R45, R76	RES., 59k, 1/10W, 1%, 0603	VISHAY DALE, CRCW060359K0FKEA
48	0	R77, R78, R80-R83, R85-R88, R90-R95, R97-R100, R102, R103, R105-R108, R110-R113, R115-R120, R122-R125, R127-R130, R132, R133	NO STUFF	NO STUFF
49	0	R79, R84, R89, R96, R101, R109, R114, R121, R126, R131	NO STUFF	NO STUFF
50	0	R104, R134	NO STUFF	NO STUFF
51	1	R136	RES., 2k, 1/10W, 1%, 0603	YAGEO, RC0603FR-072KL
52	0	R137-R139	NO STUFF	NO STUFF
53	0	SKT1	NO STUFF -A, SOCKET -B	PLASTRONICS, 32QN50515050-E
54	0	TP1-TP8	NO STUFF	NO STUFF
55	1	U1	IC, HI-CURRENT HOT SWAP CONTROLLER, QFN	LINEAR TECH., LTC4282CUH#PBF
56	1	U2	IC, SERIAL EEPROM, 2k BIT, 400kHz, TSSOP-8	MICROCHIP TECH., 24LC025-I/ST
57	6	XJP4-XJP6, XJP10-XJP12	SHUNT, 2mm	SAMTEC, 2SN-BK-G
58	1	Y1	CRYSTAL, 4MHz, SMT	ABRACON, ABL5-4.000MHZ-B4-T
59	0	Y2	NO STUFF	NO STUFF
60	3	Z1-Z3	DIODE, ZENER 5.1V 500mW SOD-123	FAIRCHILD, MMSZ5231B

SCHEMATIC DIAGRAM

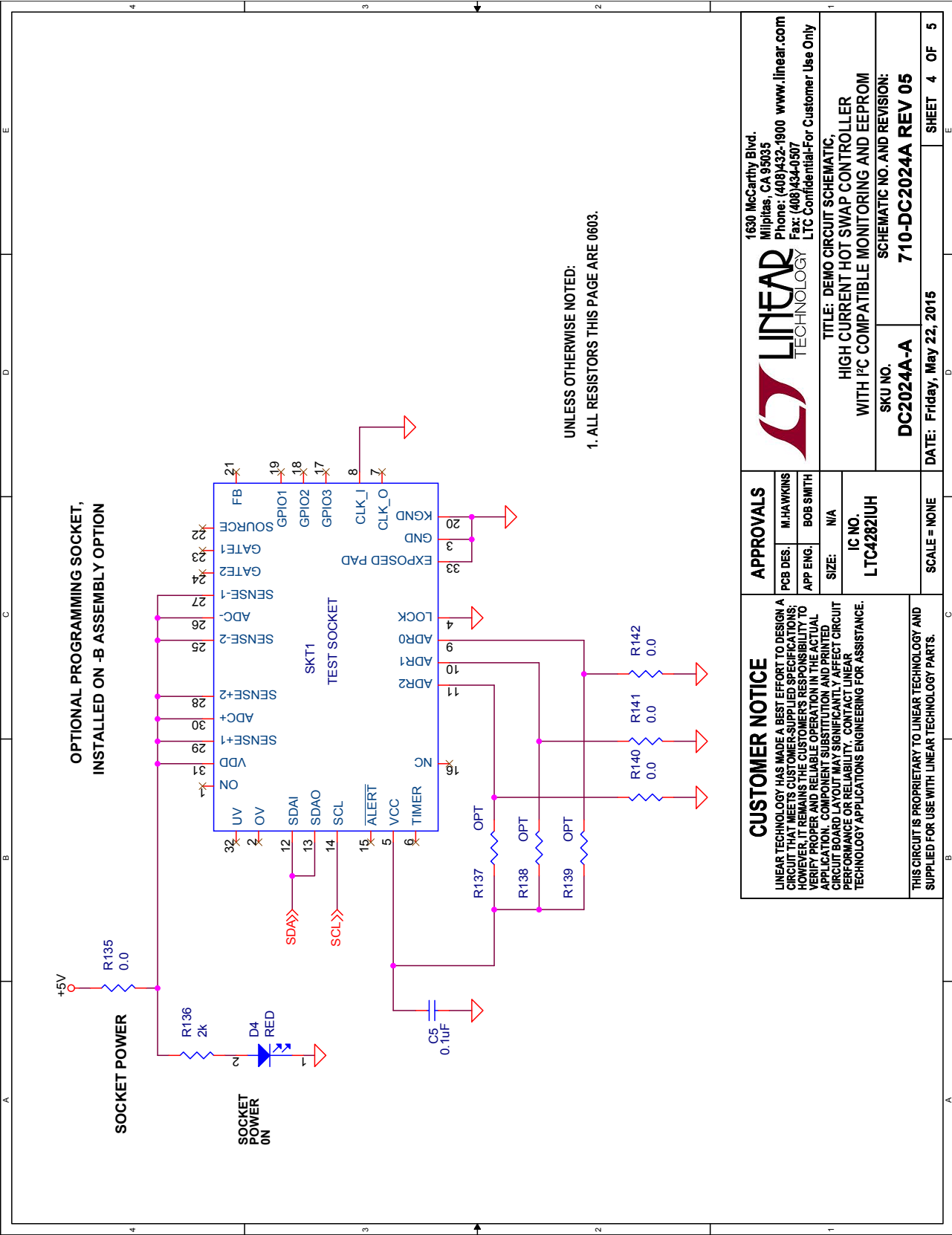


SCHEMATIC DIAGRAM





SCHEMATIC DIAGRAM



DEMO MANUAL DC2024A

DEMONSTRATION BOARD IMPORTANT NOTICE

Linear Technology Corporation (LTC) provides the enclosed product(s) under the following **AS IS** conditions:

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