

4-Channel PMBus Power System Manager with LTM4644 Quad 4A Power Supply

DESCRIPTION

The DC2428A is a two-board demonstration system for the [LTC®2975](#) Power System Manager and LTM4644 quad 4A μ Module regulator. The DC2382A contains all the circuitry needed to use the LTC2975 in a power system and control four power supplies. The DC2363A contains four power supplies (LTM4644) that the LTC2975 configures and controls. The DC2363A and DC2382A demo boards together provide a sophisticated 4-channel digitally programmable power supply system.

The LTC2975 is a 4-channel I^2C /SMBus/PMBus power system manager that features accurate input current and energy measurement. The device monitors input current and input voltage, and calculates input power and energy. The DC2382A demonstrates the ability of the LTC2975 to sequence, trim, margin, supervise, monitor, and log faults for four power supplies. Each power supply channel's output voltage and output current is monitored and the LTC2975 monitors its own internal die temperature.

The DC2363A is a single circuit board that contains four independent power supply rails. The board employs a single LTM4644 4-channel 4A DC/DC regulator. The board comes pre-configured with 1V, 1.5V, 2.5V, and 3.3V supply rails and may be reconfigured with feedback resistors.

The LTpowerPlay™ graphical user interface (GUI) supports this demonstration system and enables complete control of all the features of the LTC2975. Together, the LTpowerPlay software and DC2428A hardware system create a powerful development environment for designing and testing configuration settings of the LTC2975. LTpowerPlay stores these settings in the LTC2975's internal EEPROM or in a project file. The software displays all of the configuration settings and real time measurements from the Power System Management IC. Telemetry allows easy access and decoding of the fault log created by the LTC2975. The board comes pre-programmed with the EEPROM

values appropriate for the four power supply rails on the DC2428A. Just plug and play!

The following items are required:

- +12VDC Power Supply
- USB-to- I^2C /SMBus/PMBus Controller (DC1613)
- LTpowerPlay Software

DC2428A Features

- Sequence, Trim, Margin, and Supervise Four Power Supplies
- Manage Faults, Monitor Telemetry, and Create Fault Logs
- PMBus Compliant Command Set
- Supported by LTpowerPlay GUI
- Margin or Trim Supplies to 0.25% Accuracy
- Four I_{OUT} and One I_{IN} Monitor
- Input Power Measurement and Energy Accumulation
- Fast OV/UV Supervisors Per Channel
- Multi-Channel Fault Management
- Automatic Fault Logging to Internal EEPROM
- Operates Autonomously without Additional Software
- Monitors: Voltage, Current, Power, Temperature
- 4-Channel Time-Based Output Sequencer
- I^2C /SMBus Serial Interface
- Powered from 4.5V to 14V

Design files for this circuit board are available at
<http://www.linear.com/demo/DC2428A>

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DEMO MANUAL DC2428A

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

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
VPWR Supply Input Operating Range		4.5		15	V
VDD33 Supply Input Operating Range		3.13		3.47	V
ADC Total Unadjusted Error	$V_{IN} \geq 1\text{V}$		± 0.25		%
ADC Voltage Sensing Input Range		-0.1		6	V
ADC Current Sensing Input Range	Differential Current Sense Voltage	-170		170	mV
ADC Voltage Sensing Resolution	$0\text{V} \leq V_{IN_ADC} \leq 6\text{V}$		122		$\mu\text{V}/\text{LSB}$
ADC Current Sense Resolution	$0\text{mV} < V_{IN_ADC} < 16\text{mV}$		15.6		$\mu\text{V}/\text{LSB}$
	$16\text{mV} < V_{IN_ADC} < 32\text{mV}$		31.25		$\mu\text{V}/\text{LSB}$
	$32\text{mV} < V_{IN_ADC} < 63.9\text{mV}$		62.5		$\mu\text{V}/\text{LSB}$
	$63.9\text{mV} < V_{IN_ADC} < 127.9\text{mV}$		125		$\mu\text{V}/\text{LSB}$
	$127.9\text{mV} < V_{IN_ADC} $		250		$\mu\text{V}/\text{LSB}$
DAC Resolution			10		bits
DAC Full-Scale Output Voltage	Buffer gain setting 0		1.38		V
	Buffer gain setting 1		2.65		V
Temperature Sensor TUE			± 1		$^\circ\text{C}$
Voltage Supervisor Input Voltage Range (Programmable)	$V_{SENSE[n]}$ (Low Resolution)	0		6	V
	(High Resolution)	0		3.8	V
Voltage Supervisor Sensing Resolution	0V to 3.8V range: 4.096/1024		4		mV/LSB
	0V to 6V range: 8.192/1024		8		mV/LSB
Voltage Supervisor Total Unadjusted Error (TUE)	$2\text{V} < V_{IN_VS} < 6\text{V}$, Low Resolution Mode		± 1.25		%
	$1.5\text{V} < V_{IN_VS} < 3.8\text{V}$, High Resolution Mode		± 1.0		%
	$0.8\text{V} < V_{IN_VS} < 1.5\text{V}$, High Resolution Mode		± 1.5		%
I ² C Serial Clock Frequency		10		400	kHz

Table 1. Demo Board System Specifications

	NOMINAL UNTRIMMED V_{OUT}	TOP EXT. FEEDBACK RESISTOR (k)	BOTTOM FEEDBACK RESISTOR (k)	R_{DAC} (k)	MARGIN RANGE (%)
CH0	$1.0\text{V} \pm 1.5\%$	6.04	8.25	20.5	± 15
CH1	$1.5\text{V} \pm 1.5\%$	6.04	3.65	14.3	± 15
CH2	$2.5\text{V} \pm 1.5\%$	6.04	1.74	8.25	± 15
CH3	$3.3\text{V} \pm 1.5\%$	6.04	1.21	6.81	± 15

Notes:

- Load current <4A is recommended.
- Output voltages can be margined by $\pm 15\%$ from nominal with the default resistor values on the DC2363A. These values can be easily changed. See section Changing Nominal Output Voltages. Use the LTC2975 Resistor Selection Tool which is accessed from LTpowerPlay.

GLOSSARY OF TERMS

The following list contain terms used throughout the document.

Channel: The collection of functions that monitor, supervise, and trim a given power supply rail.

EEPROM: Non-volatile memory (NVM) storage used to retain data after power is removed.

Margin: Term used typically in board level testing that increases/decreases the output voltage to look for sensitivity/marginality problems.

Monitor: The act of measuring voltage, current, and temperature readings.

NVM: Non-volatile memory, see EEPROM.

OV: Overvoltage, the result of a voltage comparison that a pin voltage is above a programmable threshold voltage.

PMBus: An industry standard power-management protocol with a fully defined command language that facilitates communication with power converters and other devices in a power system.

Rail: The final output voltage that the LTC2975 supervises.

Supervise: The act of quickly responding (compared to a fault setting) to a voltage and current condition that is compared to pre-programmed values.

Trim: The act of adjusting the final output voltage. A servo loop is typically used to trim the voltage.

UV: Undervoltage, the result of a voltage comparison that a pin voltage is below a programmable threshold voltage.

What this Demo System Can Do

- Prototype your system. You can change the nominal output voltages to match your system. You can also change the range and resolution of margining. Set sequencing. Set OV/UV limits. Set OC limits.
- Create your own configuration that you can store in the EEPROM of the LTC2975 or save to a file. This file can be used to order pre-programmed parts.
- Test most conceivable fault scenarios. All outputs can be shorted.

Demo System Hardware

Hardware required:

1. PC + USB cable
2. 12V, >1A power supply
3. USB to I²C/SMBus/PMBus Controller
4. DC2428A = DC2363A + DC2382A

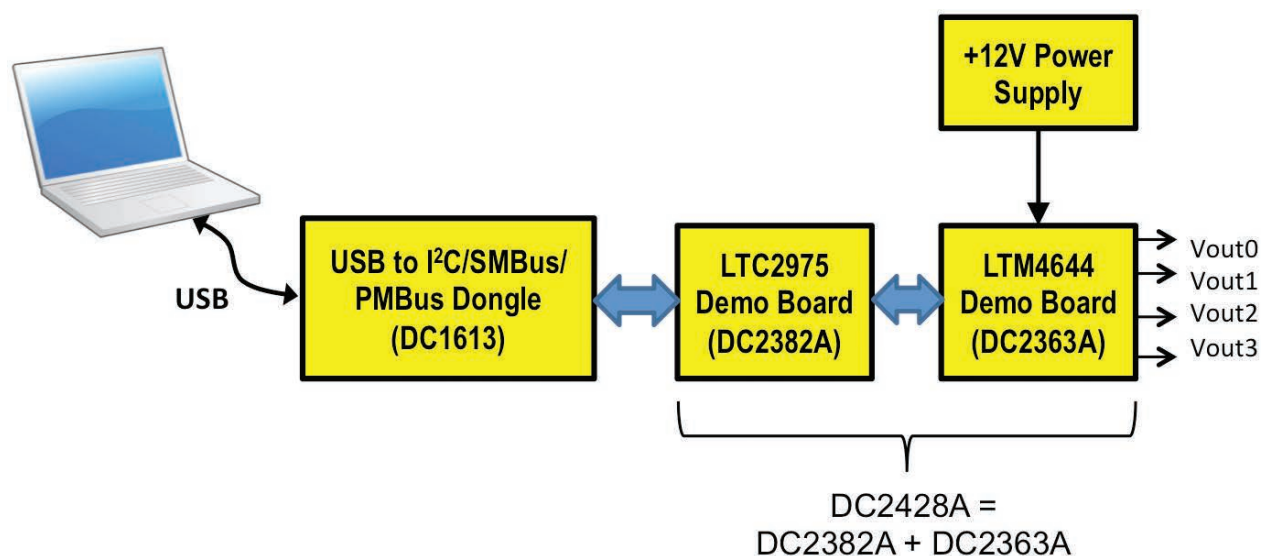


Figure 1. Single LTC2975 Demo Setup Using DC2428A

LTpowerPlay GUI SOFTWARE

LTpowerPlay is a powerful Windows-based development environment that supports Linear Technology Power System Management ICs with EEPROM, including the LTC2975 4-Channel Power System Manager. The software supports a variety of different tasks. You can use LTpowerPlay to evaluate Linear Technology ICs by connecting to a demo board system. LTpowerPlay features an offline mode to build a multi-chip configuration file for later use with hardware. LTpowerPlay provides unprecedented system level 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 DC1613 I²C/SMBus/PMBus Controller to communicate with one of many potential targets, including the DC2428A 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. Download the software from:

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

Select Help, View Online Help from the LTpowerPlay menu to access technical documents.

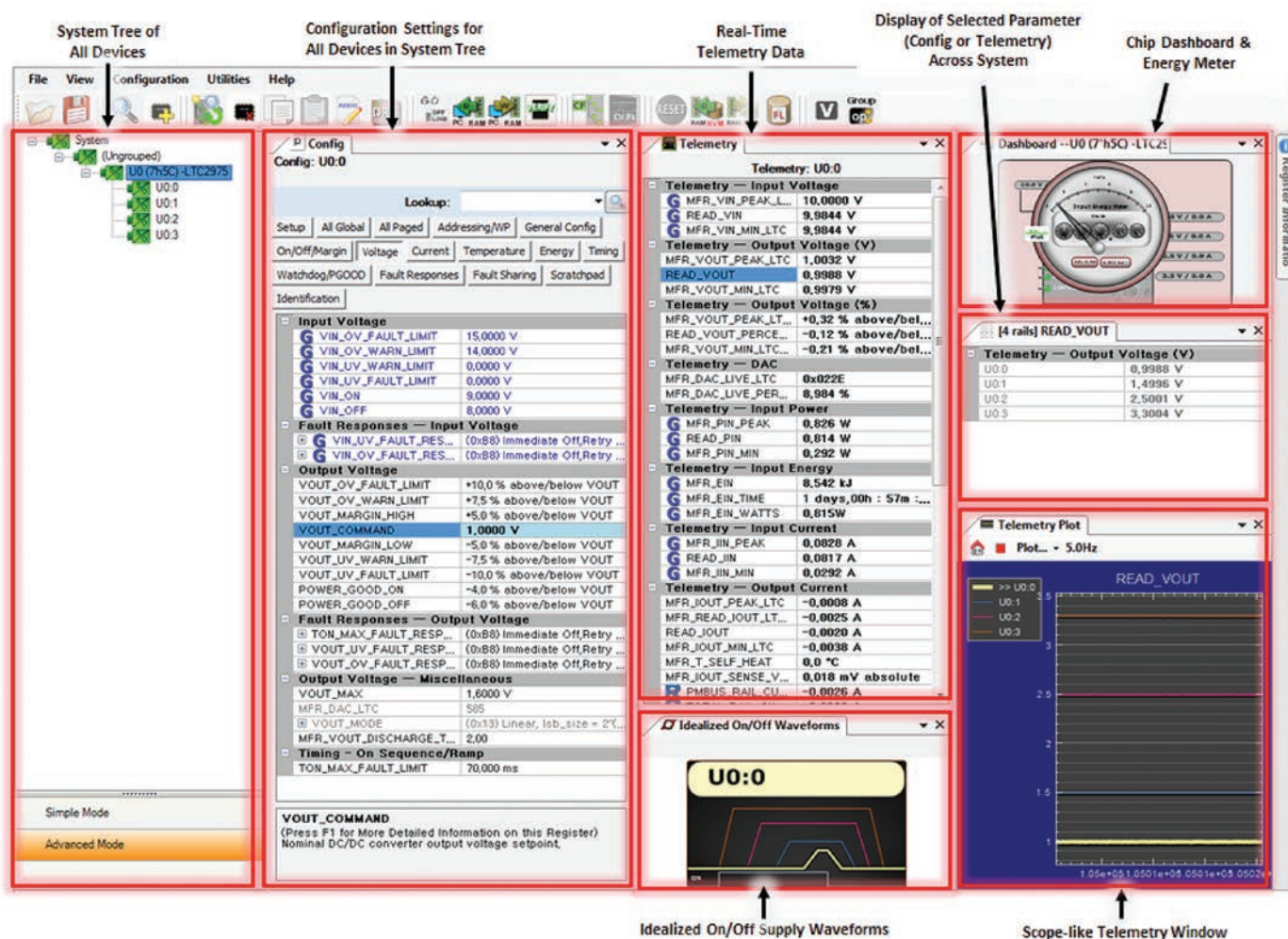


Figure 2. Screenshot of the LTpowerPlay GUI

QUICK START PROCEDURE

The following procedure describes how to set up a DC2428A demo system.

1. Download and install the LTpowerPlay GUI:

www.linear.com/ltpowerplay

2. Remove the board from the ESD protective bag and place it on a level surface. Connect the DC1613 I²C/SMBus/PMBus Controller to the DC2382A board using the 12-pin ribbon cable.

3. Confirm that all jumpers and switches are set as follows:

- a. The CONTROL switches are set to the HI position.

- b. On the DC2382A board, set ASEL jumpers to LOW, CONTROL jumpers to SW0-SW3, and WRITE-PROTECT jumper to OFF.

- c. On DC2363A board, set PRE-LOAD jumpers to ON, and TRACK jumpers to SS.

4. Plug the USB-to-I²C/SMBus/PMBus Controller into a USB port on your PC. The board should power up with the LED labeled *LTC2975 ON* illuminated green.

5. Connect a +12VDC power supply with > 1A capacity

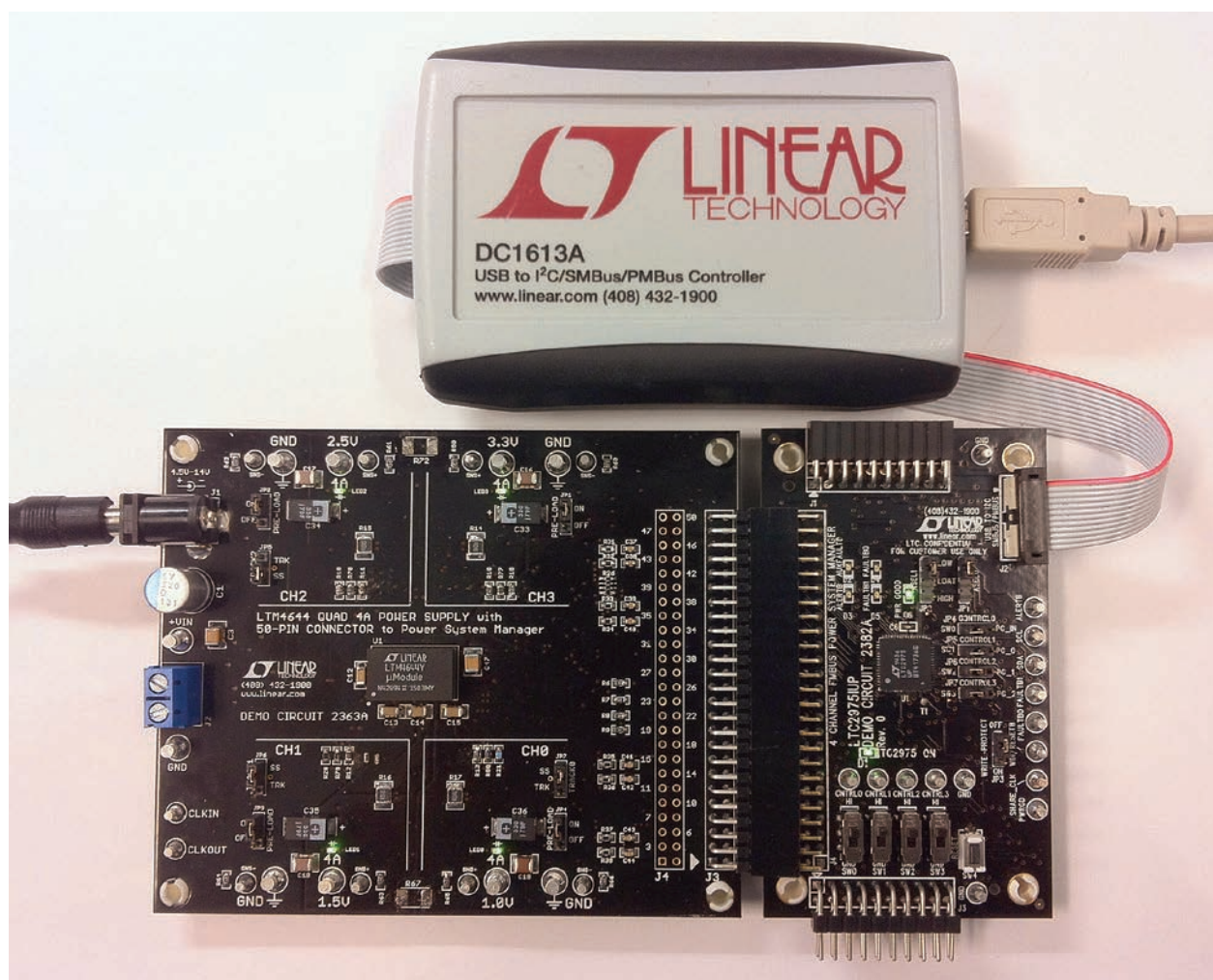


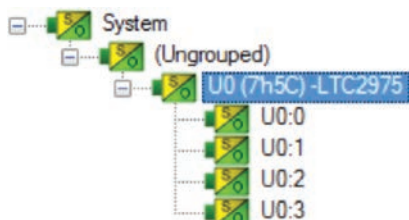
Figure 3. Connecting DC2363A/DC2382A Boards and the DC1613 USB to I²C/SMBus/PMBus Controller

QUICK START PROCEDURE

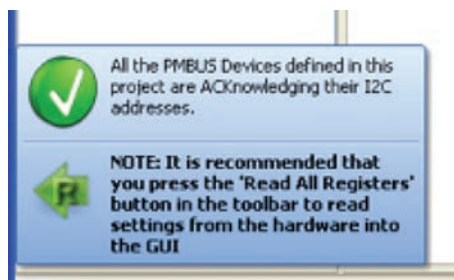
to the V_{IN} input jack of the DC2363A board. The four outputs will power up and the green LEDs will illuminate. The PWR GOOD LED (D6) on the DC2382A board will illuminate.

6. Launch the LTpowerPlay GUI.

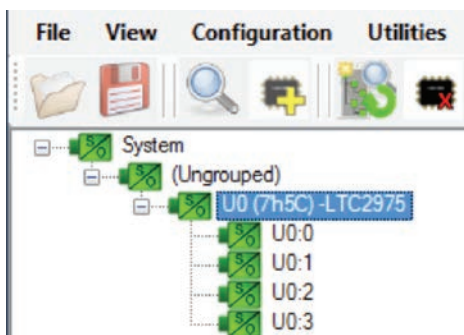
a. The GUI automatically identifies the DC2382A and builds a system tree for each I²C device. The system tree on the left hand side will look like this:



b. A green message box will be displayed momentarily in the lower left hand corner confirming that the DC2382A is communicating.



c. You may make configuration changes. When you update registers in the GUI by using either function key F12 to write an individual register or use the Write All icon to write all registers, you may need these settings for future use. Save the demo board configuration to a (*.proj) file by clicking the Save icon. This creates a backup file on your C: drive. Name it whatever you like.



If you need to load the original board default configuration, select the GUI menu pulldown item DEMO > DC2382A_Defaults. This writes the board defaults into the LTC2975's RAM and automatically to NVM as well.

7. The CONTROL switches are configured to control the channels individually. Slide the switch to HI to enable, GND to disable each channel. To demonstrate channel sequencing, one CONTROL switch may be used to turn all channels on/off. Configuration changes to the LTC2975 are needed. This is covered later in the document.

Loading a Configuration (*.proj) File with the GUI

To load a previously saved proj file:

1. In the upper left hand corner of the GUI, File > Open > browse to your *.proj file. This will load the file into the GUI.
2. Click on the GO ONLINE icon,



then click on the PC RAM icon to write all registers.



This loads the configuration into the working RAM of the LTC2975.

3. To store the configuration to NVM (EEPROM), click on the RAM NVM icon.



DC2428A - DETAILS (DC2363A + DC2382A)

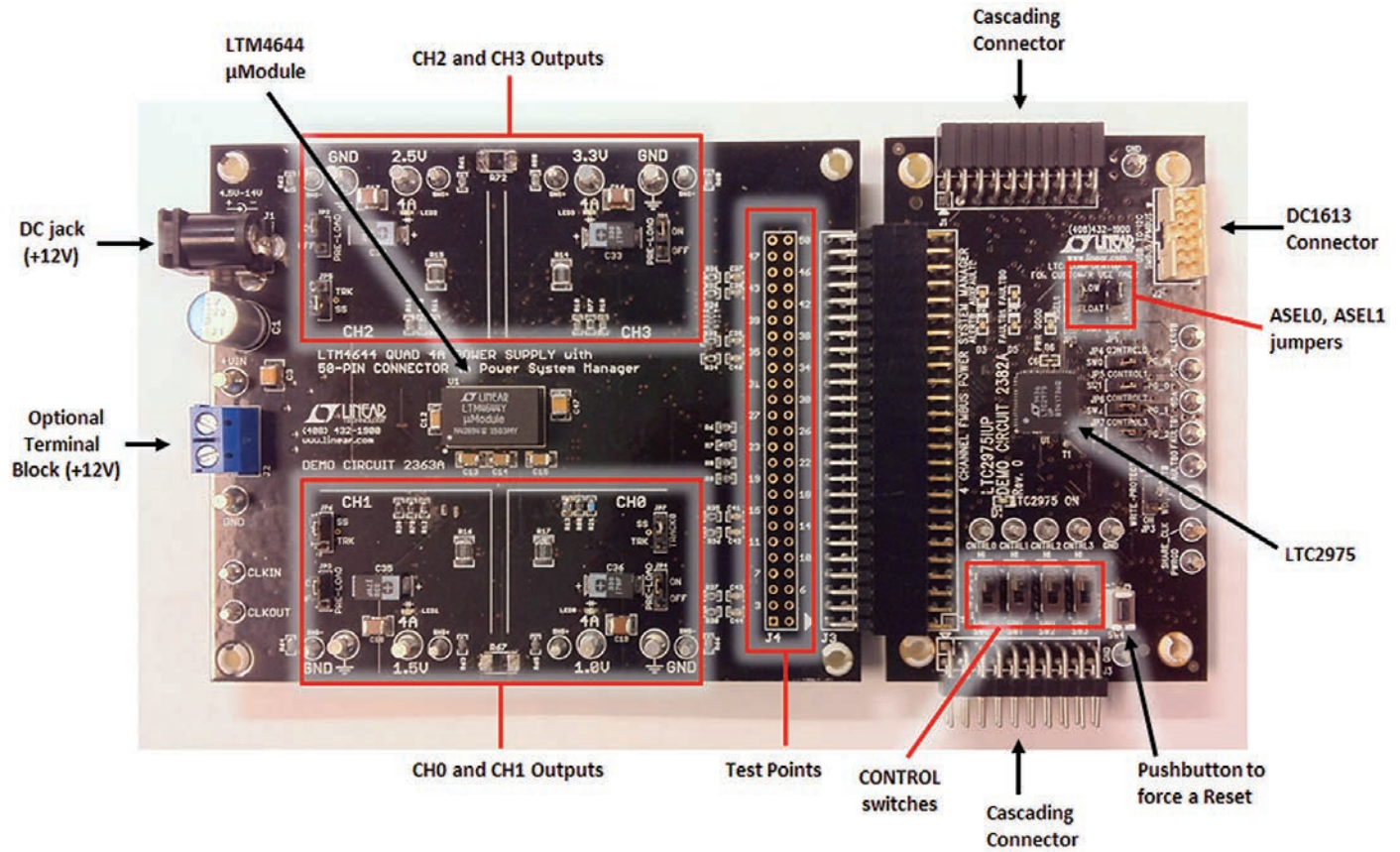


Figure 4. DC2428A Details

COMMON BOARD OPERATIONS

Overview

The two boards are represented below in a simplified block diagram. The LTC2975 measures input current with a 10 milliohm sense resistor. It also controls, monitors, and supervises all four LTM4644 outputs through the 50-pin connector.

Powering the Boards

The DC2363A board is powered from a wall-powered 12V supply. The supply must be capable of delivering > 1A. If the four channels are loaded with 1A each, the input current will be nearly 1A. The DC2382A board is powered either from the DC1613's 3.3V power or the DC2363A if V_{IN} is applied.

DC2382A LEDs

The LTC2975 ON LED (D1) illuminates when the LTC2975 is powered from the USB controller or the DC2363A external power. The green LED (D6) is the LTC2975 PWRGD signal. The red LEDs on ALERTB, FAULTB0, FAULTB1 and AUXFAULTB (D3, D4, D5, D2) indicate a fault or warning has occurred.

DC2363A LEDs

Each individual channel on DC2363A has its own green LED which indicates that the channel is enabled.

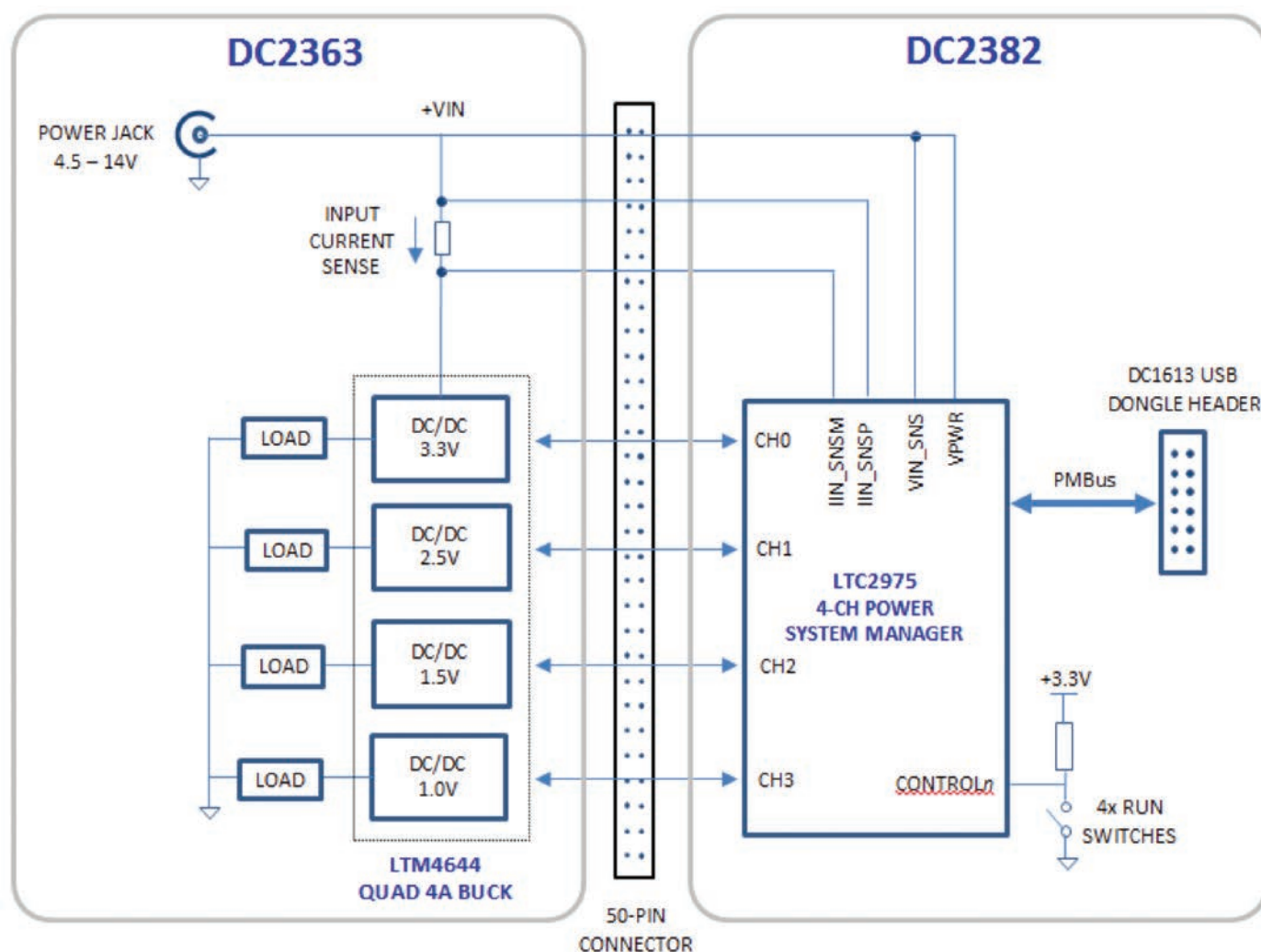


Figure 5. Simplified Block Diagram of the DC2428A

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COMMON BOARD OPERATIONS

Reset the LTC2975

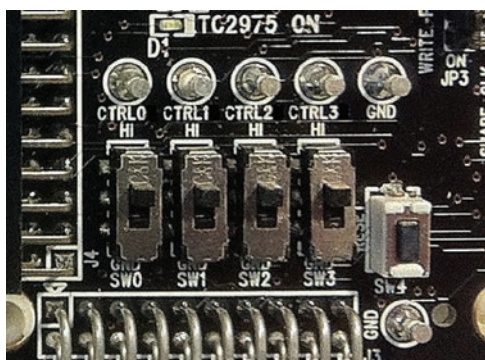
To reset the LTC2975 and reload the EEPROM contents into operating memory (RAM), press SW4 on the DC2382A.

Pre-Load the Outputs

Each of the outputs on the DC2363A board has a jumper to pre-load the output. When enabled, the load current is pre-defined to be 100mA. This ensures an unloaded output voltage decays to GND quickly when the channel is disabled. This is useful when sequencing off then on quickly.

Controlling/Sequencing Channels

By default the DC2382A board comes with each of the four CTRL switches configured to enable its respective channel.



To demonstrate time-based sequencing, let's use the CTRL0 switch as the master enable. Select CONTROL0 for each channel as shown. Click the All Paged button and expand the MFR_CONFIG register. Change the *controln_sel* bit for each channel using in the GUI's system tree.

MFR_CONFIG_LTC29...	(0x0080) Expand for Detail...
RESERVED15	<input type="checkbox"/> 0x0 (Reserved)
cascade_on	<input type="checkbox"/> 0x0 (This channel's contro...
controln_sel	<input checked="" type="radio"/> 0x0 (CONTROL0 is Selected) <input type="radio"/> 0x1 (CONTROL1 is Selected) <input type="radio"/> 0x2 (CONTROL2 is Selected) <input type="radio"/> 0x3 (CONTROL3 is Selected)

The LTC2975 are pre-configured with different TON_DELAY values for each channel. The TON_DELAY parameter is

applied to each of the channels relative to the CONTROL0 pin. The same applies to TOFF_DELAY values. When the CONTROL switch is set to the OFF position, all rails will power down sequentially based device's TOFF_DELAY values. Figure 6 shows an oscilloscope screen capture of three output rails sequencing up and down in response to the CONTROL pin.



Figure 6. Sequencing Output Channels On/Off

Each channel has an LED which visually indicates if the channel has power. When the CONTROL pin is switched on and off, you will observe the relative on/off timing of the four channels.

TON_DELAY (All Pages in System)	
U0:0 - LTC2975	0,000 ms
U0:1	100,000 ms
U0:2	200,000 ms
U0:3	300,000 ms

TOFF_DELAY (All Pages in System)	
U0:0 - LTC2975	150,000 ms
U0:1	100,000 ms
U0:2	50,000 ms
U0:3	0,000 ms

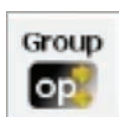
Figure 7. TON_DELAY and TOFF_DELAY Settings

For the LTC2975, the TON_DELAY and TOFF_DELAY values extend to 655ms, providing a reasonable range for sequencing on and off of power supply rails.

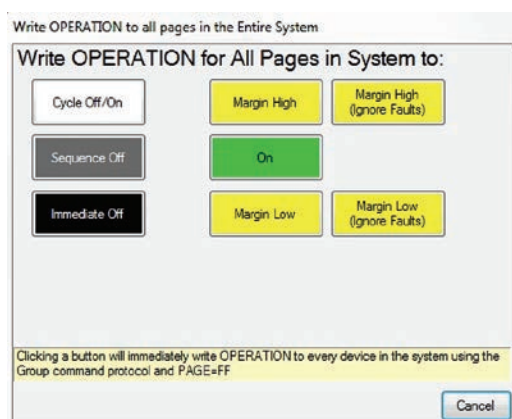
COMMON BOARD OPERATIONS

Margin All Rails

The LTC2975 power system manager on the DC2382A not only monitors each of the four outputs but can margin the outputs either high or low. Margining is the operation that moves a rail up or down for testing purposes. It allows a system to be fully characterized over supply limits without the use of external hardware or resources. The GUI provides an easy way to margin all rails high or all low by clicking one of four buttons. To invoke the margining dialog, click the GroupOp icon in the toolbar.

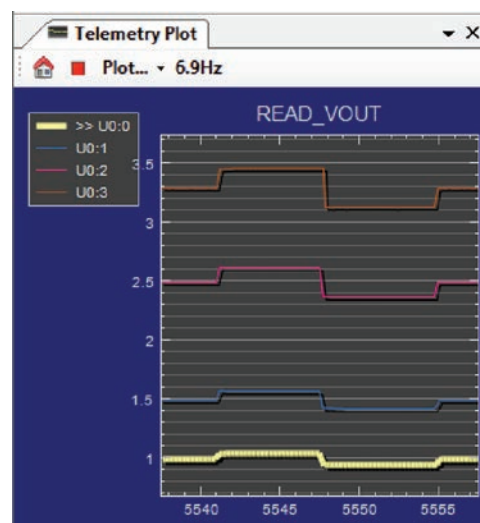


The buttons labeled ignore faults will margin without creating a fault even if the fault limits are exceeded.



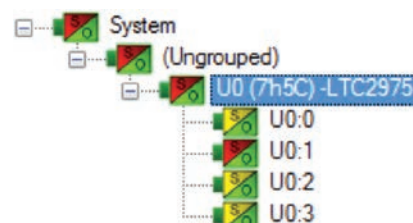
A look at the telemetry window shows the effect of the margin high or margin low operation. The following screen shot shows all rails going from nominal setpoints to margin high, margin low, and back to nominal voltages.

The LTC2975 has a multiplexed ADC that is used to provide voltage, current, and temperature readback values. The telemetry plot in the GUI is similar to a multi-channel oscilloscope which is capable of displaying any parameter that is displayed in the telemetry window. Due to the nature of a multiplexed ADC converter, it has an associated ADC loop time of approximately 150ms.



Creating a Fault

Any one of the channels on the DC2363A board may be faulted to demonstrate the demo board's ability to detect it and respond according to the configuration. An output may be shorted to ground with a jumper wire or coin applied to the output and GND turrets. When faulted, all channels power down immediately and the GUI's system tree indicates the color red for the Status portion of that channel. In this example, GUI channel U0:1, the 1.5V output. You should see all outputs power off, the fault LED momentarily illuminate, the alert LED illuminate continuously, and all rails sequence back on after a retry period. You may also short any power supply output indefinitely. This is a good way to induce UV faults and shows that a shorted channel will not be damaged.



Clearing a Fault

To clear a fault, you can click the CF icon in the GUI or simply push the RESET pushbutton (SW4) on the DC2382A demo board. In both cases, the red (+) on the CF icon and alert LED on the board are both cleared. Notice that all rails are automatically re-enabled after a programmable

COMMON BOARD OPERATIONS

retry period. A dialog box may pop up after clicking the Clear Faults (CF) icon.



If a fault log is present, a dialog will ask if you would like to clear the fault log as well as clear system faults. After clearing faults, the system tree will return to green and fault logs re-armed. For further information, see the Working with the Fault Log section.

Why am I Off? Tool

Use the Why am I Off tool in the LTpowerPlay GUI to diagnose the cause for a power supply channel being in an off state. The tool is located in the top right corner of the GUI, above the Register Information tab. Hover your cursor over the tab to show the tool.

First select an output channel in the system tree. The tool collects various status information and provides a diagnosis.

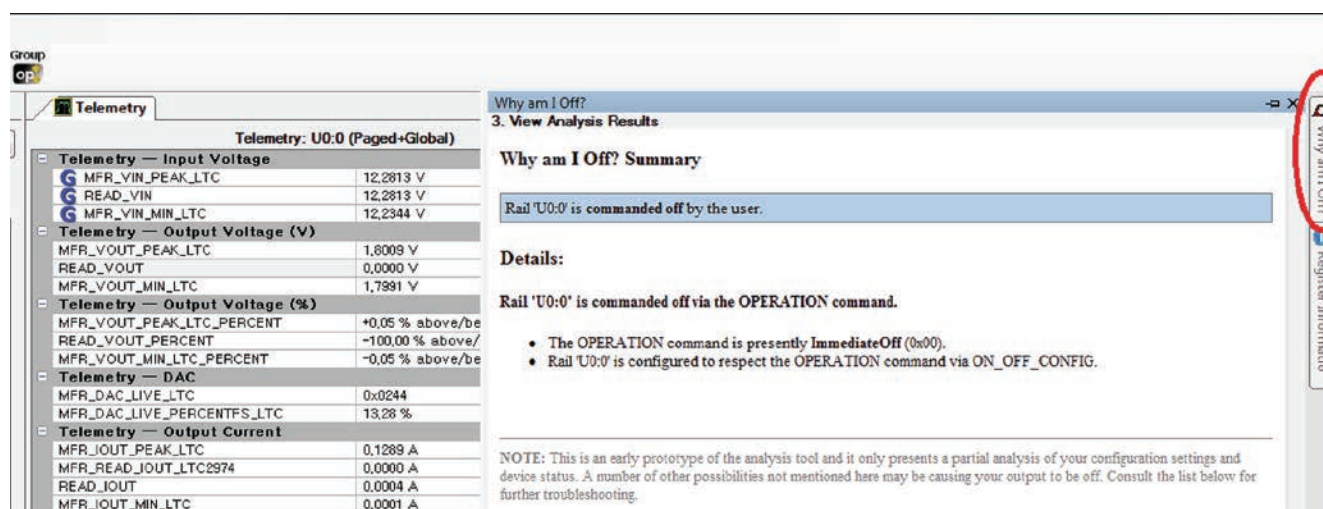


Figure 8. Why am I Off Tool in the LTpowerPlay GUI

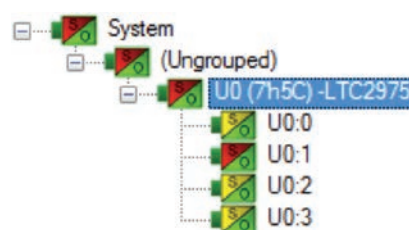
ADVANCED DEMO BOARD OPERATIONS

What Is a Fault Log?

A fault log is a non-volatile record of the power system leading up to the time of fault. Telemetry data is continuously updated in a circular RAM buffer in the LTC2975. When a fault occurs, the contents of the RAM buffer are automatically written to NVM. The most recent monitored values (uptime, voltage, current, temperature) provide additional context preceding the fault. It is a powerful diagnostic feature of the LTC2975 on the DC2382A demo board.

Create a Fault Log

To create a fault log, check that the *fault_log_enable* bit is set in the MFR_CONFIG_ALL register. Then, create a fault, as described in the section Creating A Fault. If multiple boards are configured, select the appropriate device in the system tree by clicking on the appropriate LTC2975 chip. We are ready to work with the fault log.

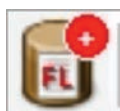


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ADVANCED DEMO BOARD OPERATIONS

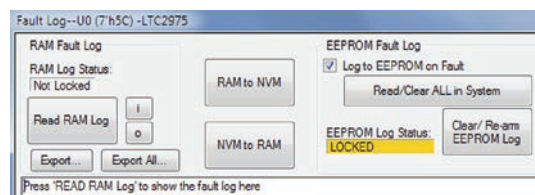
Working with the Fault Log

Once a fault has occurred, the Fault Log (FL) icon will show a red (+) sign on it, indicating that the GUI has detected a fault log in the device. Clicking the icon will bring up a dialog box.

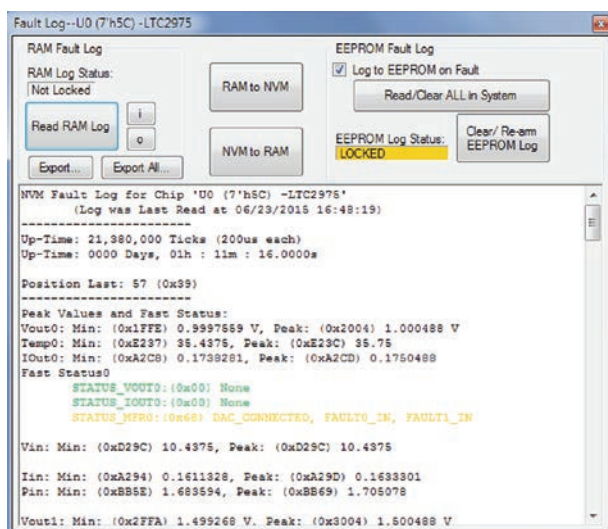


Note that it is a context sensitive icon. If multiple DC2382A boards are connected, be sure that the desired device is selected in the system tree.

Once a fault occurs, the device will automatically write the fault log data to EEPROM (NVM). At this point, the log is locked and will not change until it is cleared by the user.

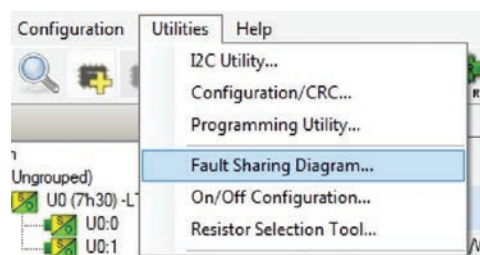


It is a 2-step process to read the fault log. First click the NVM to RAM button. At this point the RAM Log is locked. Click the Read NVM Log button. The log data will appear in the text box below.



The log contains timestamp, up-time, channel voltage readings, an input voltage reading, an on-chip temperature reading, etc. There will be a number of loops; each loop

contains data obtained in one ADC loop time with the most recent ADC loop data on top and the oldest data at the bottom of the log. The up-time indicates, at the time of fault, the amount of time the device had been powered up or time since the previous reset.



In this case, the fault log will show that channel U0:1 faulted due to a VOUT_UV_FAULT condition. On the previous telemetry loop, the channel voltage reading was a nominal value (3.3V). You can save the fault log to a file (.rtf) by clicking the Export button.

To clear the fault log, click the Clear/Rearm EEPROM Log button. This allows the selected device to be ready for a new fault event. To clear all faults, click the Clear Faults (CF) icon.

Fault Sharing Setup in the GUI

Fault sharing provides a means of propagating a fault detected by a power manager to other power managers via FAULT pins. Use the Fault Sharing Setup Tool to configure the fault sharing in the GUI. Select the LTC2975 in the system tree. Go to Utilities > Fault Sharing Diagram. (For more details on this topic, please refer to the Fault Management section in the data sheet.)

The fault sharing dialog will appear as shown in Figure 9. All Response and all Propagate switches are closed by default. In this configuration, a fault on a channel will shut down not only the faulted channel but all other channels since the Propagate switches are closed.

There are two types of actions to fault conditions: How a channel responds to another channel's fault and whether a particular channel propagates its fault to other channels. FAULT pins are bi-directional, meaning the device may drive its fault pin low (output) or may respond to the fault pin when another device drives it low (input). Because the two fault pins are separated on the DC2382A, this allows you

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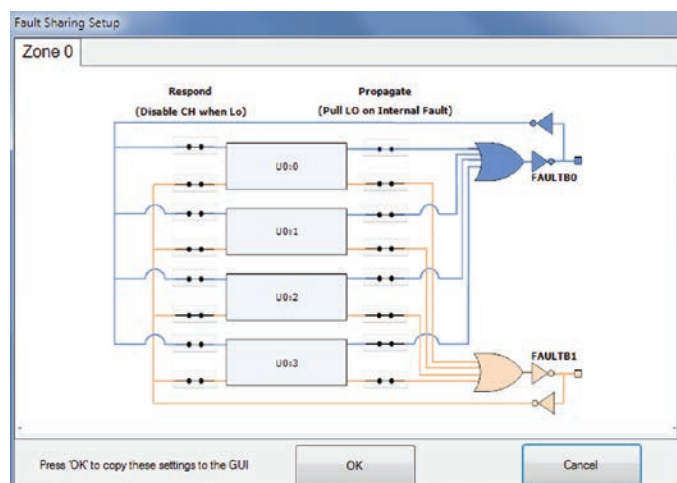


Figure 9. Fault Sharing Utility in LTpowerPlay GUI

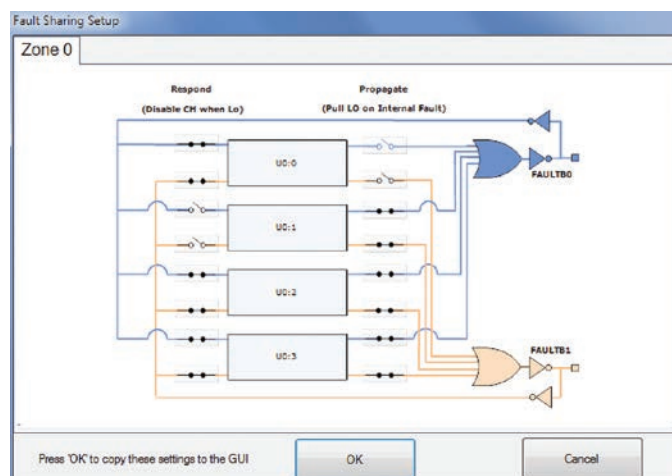


Figure 10. Updated Fault Sharing Configuration

to configure the fault settings on a channel-by-channel basis. By default, the LTC2975 is configured to shut down its channels if the FAULT pin is low and to propagate its own fault by driving the FAULT pin low. You can think of the Response switches as *shut this channel down* when another channel faults, and the Propagate switches as *drive the fault pin* to broadcast to other channels that this channel faulted.

Fault Configuration Example

Let's explore two different examples. Suppose we do not want channel U0:0 (CH0 1.0V rail) to propagate its fault to the other channels when it faults. And suppose we do not want channel U0:1 (CH1 1.5V rail) to shut down in response to another channel's fault. We can configure the switches as shown in Figure 10. Simply click the switches to open/close. Click OK to close the dialog box.

Click the PC RAM icon to write the changes to the DC2382A.



We can now create a fault on U0:0 (CH0) by shorting the output to ground. You may use a coin or a jumper to temporarily connect CH0 to the GND turret. You will notice that the channel shuts off but the other channels remain powered up because its fault is not propagated to the other channels. After the retry period, channel U0:0

(CH0) will power back up. We can now observe the effect of changing the response setting on U0:1 (CH1). If you short U0:3 (CH3 3.3V rail) to ground, notice that all rails shut down except U0:1 (CH1). This is an example of a keep-alive channel that remains powered up independent of faults to other channels.

The LTC2975 is capable of high-side current sensing of the input power supply. This feature allows the manager to measure input supply current. Select the READ_IIN register to display the telemetry plot. The input current reading will be ~160mA if all channels are enabled, pre-loaded, and $V_{IN} = 12V$. Notice the current reading move lower as you turn channels off.

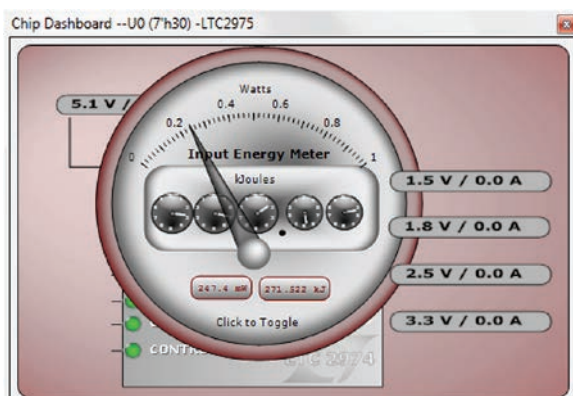


The manager also measures input supply voltage and is therefore able to report input power as well. Since energy

ADVANCED DEMO BOARD OPERATIONS

is the product of power and time, accumulated energy is provided based on the manager's internal timebase.

The meter displayed in the upper right hand corner of the GUI provides a number of bits of information. The needle is a real-time indicator of input power and the smaller five dials show the total accumulated energy similar to a home electricity meter. Digital readouts are also provided for convenience.



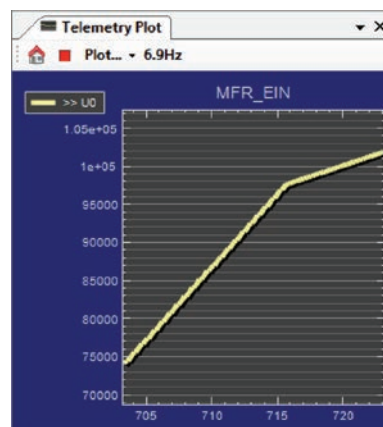
The DC2363A demo board has power supplies that are capable of high current. The LTC2975 is able to monitor and measure four outputs and its input power supply. LTpowerPlay offers a simple and easy to understand interface that brings together input and output current, voltage, power, and energy readings.

Telemetry — Input Power	
MFR_PIN_PEAK	0.253 W
READ_PIN	0.243 W
MFR_PIN_MIN	0.242 W
Telemetry — Input Energy	
MFR_EIN	271.487 kJ
MFR_EIN_TIME	7 days, 19h : 57m : 19.867s
MFR_EIN_WATTS	0.244W
Telemetry — Input Current	
MFR_IIN_PEAK	0.0502 A
READ_IIN	0.0482 A
MFR_IIN_MIN	0.0479 A

You may also view the input current, input voltage, input power, and input energy together in tabular format. These appear in the telemetry portion of the GUI. The MFR_EIN register holds the accumulated energy value in milliJoules. There is also a total time that the energy accumulator has been active and is shown as the MFR_EIN_TIME register. The GUI will automatically update the displayed SI prefix as the units change from mJ to J to kJ.

To demonstrate the meter readings and register values,

first select the MFR_EIN register to display the energy in the telemetry plot. Turn off channels 2 and 3 by setting those CTRL switches off. You will notice that the slope has changed. The accumulated energy rate is the slope. Energy is still being accumulating but at a lower rate since channels 0 and 1 remain enabled. Note that the input current has changed from about 160mA down to 48mA as seen in the READ_IIN register. The MFR_EIN_WATTS register displays the input power that is being drawn. This register is the product of the READ_VIN and READ_IIN values. Since the input voltage is 12V, the input power is 12V • 160mA or 1.92W. You can confirm this by clicking these three registers one by one and view the telemetry window.



The MFR_EIN and MFR_EIN_TIME registers may be reset by right-clicking the MFR_EIN register which displays an option menu to Clear HW Register. It may also be reset by writing the MFR_EIN_CONFIG register.

Changing Nominal Output Voltages

The nominal output voltage of any channel on the DC2363A can be adjusted by changing feedback resistors. There are two external resistors that set the floating voltage, a topside feedback resistor (R_{TOP}) and a bottom feedback resistor (R_{BOT}). Note that these feedback resistors provide compensation for the IR drop of the sense resistor in the output path.

The equation that relates feedback resistors and V_{OUT} is as follows:

$$V_{OUT} = ((60.4k||R_{TOP})/R_{BOT} + 1) \cdot 0.6V$$

ADVANCED DEMO BOARD OPERATIONS

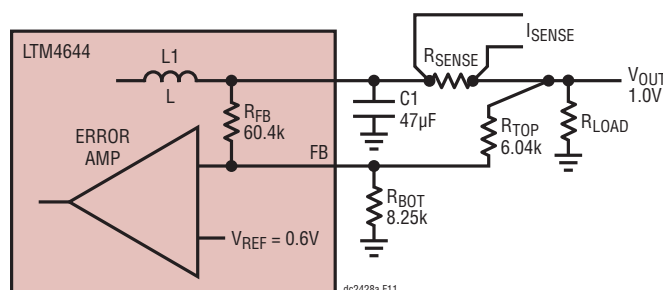


Figure 11. Output Voltage Set by Feedback Resistors

Use the LTpowerPlay's Resistor Selection Tool to calculate resistor values and to display the proper DAC range settings. The Resistor Selection Tool refers to R10, R20, and R30. R10 is the bottom feedback resistor, R20 is the top feedback resistor, and R30 is the DAC resistor. The

tool's R20 value that is entered is the parallel combination of the internal and external topside resistors. The resistor R_{FB} is 60.4k which is inside the LTM4644 μ Module. There is an external sense resistor in the output path for the purpose of measuring current. An external topside feedback resistor R_{TOP} is wired from the output turret to the FB node. All four channels use a 6.04k R_{TOP} feedback resistor. These are: R78-R80. The parallel combination ($60.4k || 6.04k$) is 5.49k.

The bottom feedback resistors (R_{BOT}) for each channel are R10-R13. The output trim resolution and range can be adjusted for any output on the DC2363A by simply changing the R_{DAC} resistor value. The DAC resistors (R30) are R18-R21. Table 2 on shows a summary of the feedback resistor values and DAC resistor values.

Design Inputs

Basic Switcher Parameters

Feedback Node Voltage: 0.600 V

Feedback Resistor R20: 5.490 k

Nominal Feedback Node Input Current: 0.0 nA

Optional Switcher Parameters (for Worst Case Analysis)

Feedback Node Voltage Tolerance: 0.0 %

Maximum Feedback Node Input Current: 50.0 nA

Tolerance of R20: 0.5 %

Output Voltage and Margining Requirements

☒ Symmetric Margin/Trim

Maximum Output Voltage: 15.0 V (+0.15 V)

Nominal Output Voltage: 1.000 V

Minimum Output Voltage: 15.0 V (-0.15 V)

Tolerance of Feedback and Trim Resistors

Tolerance of R10: 1 %

Tolerance of R30: 1 %

Design Verification

Param	Value	Comment
Nominal Output Voltage Error:	-0.073 %	
Margin High Range:	15.248 %	
Margin Low Range:	-19.990 %	
Trim DAC Resolution :	0.034 %/LSB	
Min Margin Low Range Needed:	-0.593 %	

Figure 12. LTpowerPlay's Resistor Selection Tool

ADVANCED DEMO BOARD OPERATIONS

Tracking Outputs

The DC2363A board offers output tracking capability which allows the startup ramp of all channels to track together. The LTC2975 supports tracking power supplies that have a tracking pin and are configured for tracking. A tracking power supply uses a secondary feedback terminal (TRACK) to allow its output voltage to be scaled to an external master voltage. Typically, the external voltage is generated by the supply with the highest voltage in the system, which is fed to the slave track pins. Any supply that tracks a master supply must be enabled before the master supply comes up and disabled after the master supply comes down, so that they will properly track the master and not produce unwanted faults. Refer to the LTC2975 data sheet for further description of timing rules, fault behavior, and register configuration settings.



The DC2363A and DC2382A boards are configured to demonstrate tracking as described below. CH3 (3.3V) is the master channel and CH0-2 are slave channels. The

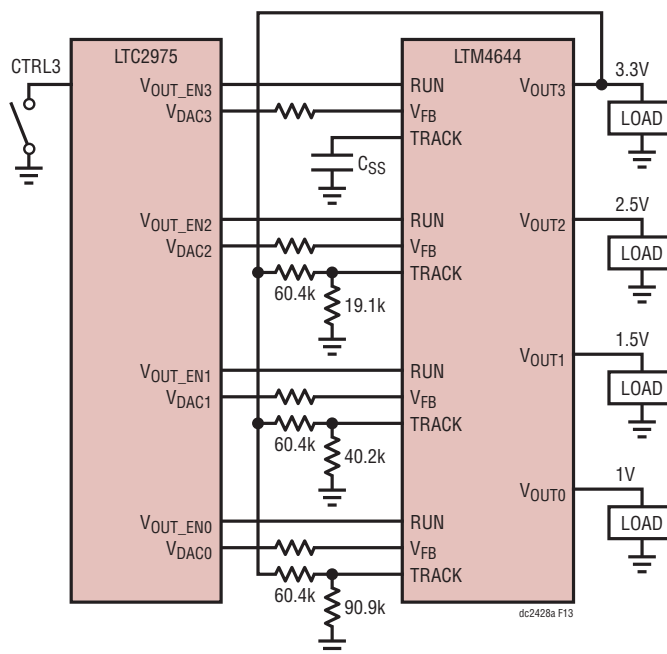


Figure 13. LTC2975 Configured for Power Supply Tracking

DC2382A's CTRL3 switch acts as the master enable, in addition to commanding CH3's OPERATION register.

To demonstrate tracking:

1. Set all three TRACK jumpers to the TRK position, and set CH3's pre-load jumper to ON.
2. On the DC2382A board, ensure that jumper JP7 is set to SW3.
3. In LTpowerPlay, select Demo>DC2382A_tracking from the GUI's menu.

The following register screen shots document the relevant configuration settings.

<input type="checkbox"/> MFR_CONFIG3_L... (0x07) track_en_chan2, tra...	<input type="checkbox"/> uc_fault_response_c... <input type="checkbox"/> 0x0 (No Action on IOUT_...	<input type="checkbox"/> uc_fault_response_c... <input type="checkbox"/> 0x0 (No Action on IOUT_...	<input type="checkbox"/> uc_fault_response_c... <input type="checkbox"/> 0x0 (No Action on IOUT_...	<input type="checkbox"/> uc_fault_response_c... <input type="checkbox"/> 0x0 (No Action on IOUT_...
track_en_chan3	<input type="checkbox"/> 0x0 (Channel is NOT a sl...			
track_en_chan2	<input checked="" type="checkbox"/> 0x1 (Channel is a slave ...			
track_en_chan1	<input checked="" type="checkbox"/> 0x1 (Channel is a slave ...			
track_en_chan0	<input checked="" type="checkbox"/> 0x1 (Channel is a slave ...			

<input type="checkbox"/> MFR_CONFIG_LTC29... (0x3080) Expand for Detai...	<input type="checkbox"/> RESERVED15 <input type="checkbox"/> 0x0 (Reserved)
cascade_on	<input type="checkbox"/> 0x0 (This channel's c...
controln_sel	<input type="radio"/> 0x0 (CONTROL0 is Sel...
	<input type="radio"/> 0x1 (CONTROL1 is Sel...
	<input type="radio"/> 0x2 (CONTROL2 is Sel...
	<input checked="" type="radio"/> 0x3 (CONTROL3 is Sel...

<input type="checkbox"/> TON_DELAY (All Pages in System)	
U0:0 - LTC2975	0,000 ms
U0:1	0,000 ms
U0:2	0,000 ms
U0:3	30,000 ms

<input type="checkbox"/> TON_RISE (All Pages in System)	
U0:0 - LTC2975	50,000 ms
U0:1	50,000 ms
U0:2	50,000 ms
U0:3	25,000 ms

<input type="checkbox"/> TOFF_DELAY (All Pages in System)	
U0:0 - LTC2975	30,000 ms
U0:1	30,000 ms
U0:2	30,000 ms
U0:3	0,000 ms

ADVANCED DEMO BOARD OPERATIONS

Cascaded Sequencing

The DC2363A/DC2382A board set also offers cascaded sequencing capability. Cascade sequencing allows a master power supply to sequence ON a series of slave supplies by connecting each power supply's power good output to the control pin of the next power supply in the chain. Note that the power good signal is that of the power supply and not derived from the LTC2975's internal power good processing. Power good based cascade sequence OFF is not supported. OFF sequencing must be managed using immediate-off or time-based sequencing. A cascade sequence wiring diagram is shown in Figure 14. For each slave channel, the `mfr_config_cascade_on` bit is set (high) and the associated control input connects to the power good output of the previous power supply. In this configuration each slave channel's startup is dependent on the previous supply being powered up.

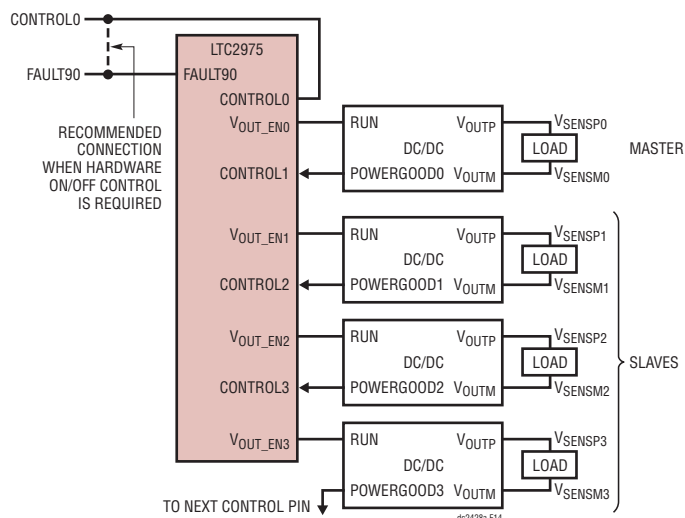


Figure 14. LTC2975 Configured for Cascaded Sequencing

The channels cascade on/off via the CTRL0 switch on the DC2382A board, or command CH0's OPERATION register on/off. The LTC2975 configuration is such that the `controln_sel` bit is set to its respective channel. The `cascade_on` bit is set for the three slave channels (CH1-3) and cleared on the master channel (CH0).

To demonstrate cascade sequencing:

1. Set the three TRACK jumpers to SS on the DC2363A board.
2. Set JP5-JP7 to the PG setting on the DC2382A board.
3. In LTpowerPlay, select Demo>DC2382A_cascade_seq from the GUI's menu.

TON_DELAY (All Pages in System)	
U0:0 - LTC2975	0,000 ms
U0:1	0,000 ms
U0:2	0,000 ms
U0:3	0,000 ms

TOFF_DELAY (All Pages in System)	
U0:0 - LTC2975	0,000 ms
U0:1	10,000 ms
U0:2	10,000 ms
U0:3	10,000 ms

SETUP PROCEDURE FOR MULTI-BOARD ARRAYS

Multiple DC2428As can be combined to control as many nine board pairs.

1. Connect DC2363A/DC2382A to pair them.
2. Plug DC2382A's together.
3. Set a unique address for each DC2382A in the array using ASEL0 and ASEL1 (JP1, JP2). See the following section for further details.
4. Plug the ribbon cable of the DC1613 into one of the DC2382As.
5. Connect a power supply to each of the DC2363A boards. Power is not distributed to other board pairs via the J1/J3 cascading connector.

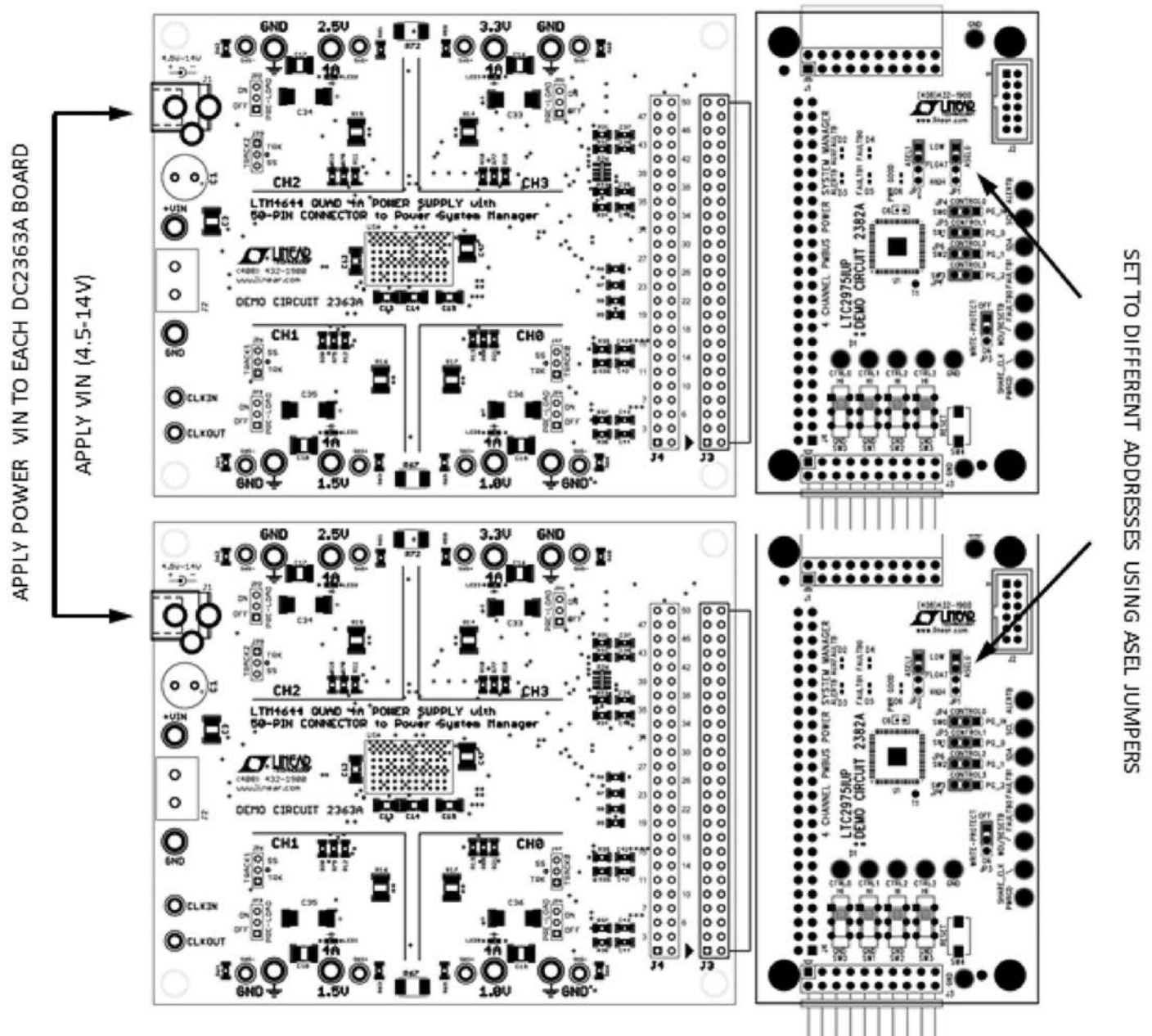


Figure 15. Array of Multiple Board Sets

dc2428af

SETUP PROCEDURE FOR MULTI-BOARD ARRAYS

Selecting a Device Address

The DC2382A jumpers (JP1, JP2) are labeled ASEL0 and ASEL1 which allow the user to select one of nine I²C addresses. The I²C/SMBus address of the LTC2975 equals the base address + N where N is a number from 0 to 8. N is configured by setting the ASEL0 and ASEL1 pins to V_{DD33}, GND or FLOAT. See Table 3 below. Using one base address and the nine different values of N, nine LTC2975s can co-exist on the same I²C bus to control 36 outputs. The base address is stored in the MFR_I2C_BASE_ADDRESS register. The base address can be written to any value, but generally should not be changed unless the desired range of addresses overlap existing addresses. Be careful that the address range does not overlap with other I²C/SMBus device or global addresses, including I²C/SMBus multiplexers and bus buffers.

NOTE: Regardless of the jumper setting, the part will always respond to the I²C global 7-bit address 0x5B.

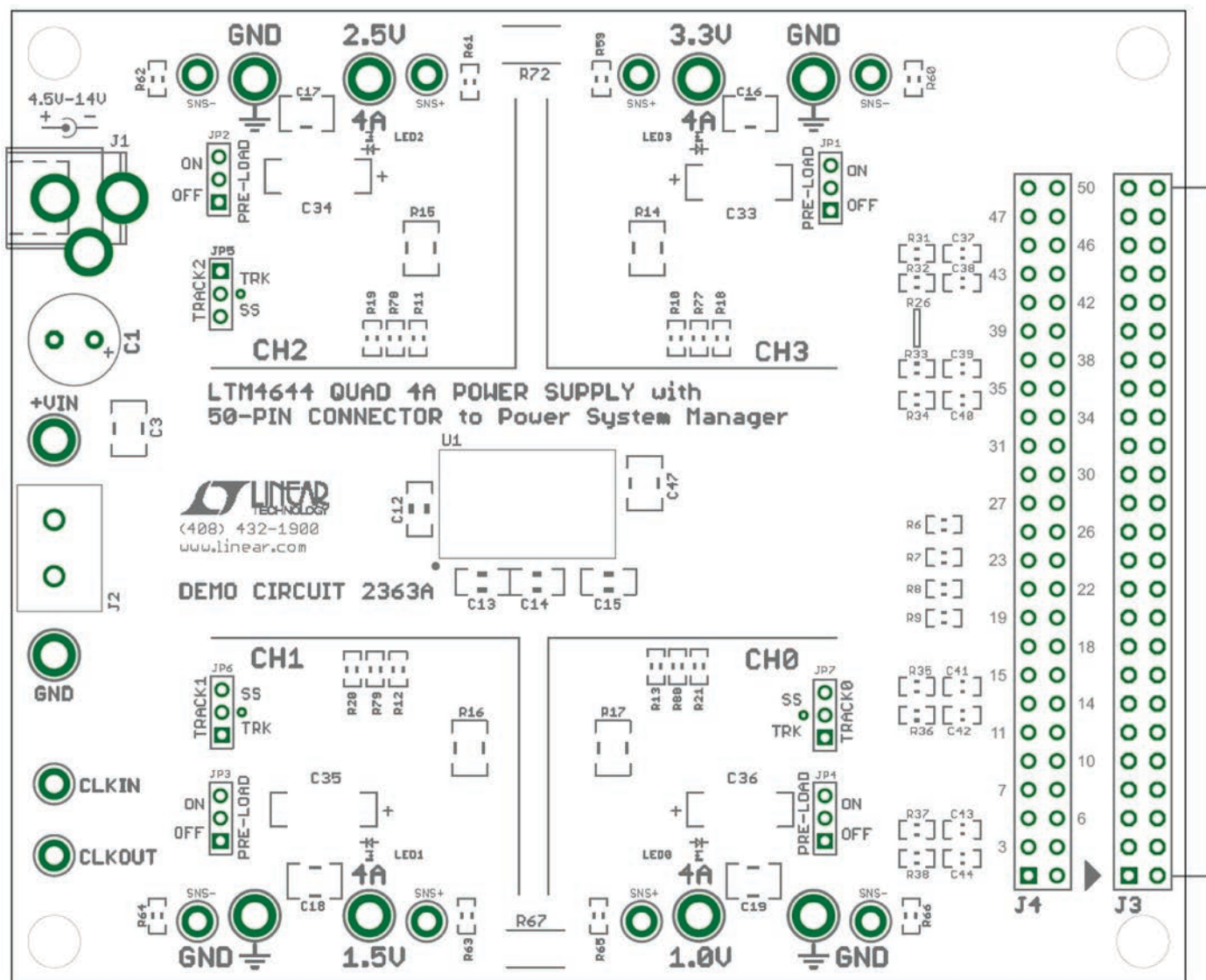
Table 3. Address Selection of LTC2975

I ² C ADDRESS (7-BIT)	ASEL1 POSITION	ASEL0 POSITION	DEFAULT
0x5C	L	L	✓
0x5D	L	Z	
0x5E	L	H	
0x5F	Z	L	
0x60	Z	Z	
0x61	Z	H	
0x62	H	L	
0x63	H	Z	
0x64	H	H	



REFERENCE DESIGNATOR	SIGNAL NAME	USAGE	DEFAULT
JP1, JP2	ASEL0, ASEL1	Set the address offset of LTC2975.	Low, Low
JP3	WRITE PROTECT	Write protect the LTC2975 EEPROM.	Off
JP4, JP5, JP6, JP7	CONTROL0, CONTROL1, CONTROL2, CONTROL3	Jumpers that connect LTC2975 CONTROL pins to CTRL switches or to PG signals from DC2363A board. Implement cascade sequencing by connecting power good signals to the control pins, or connect CONTROL pins directly to the CTRL switches.	SW0, SW1, SW2, SW3
SW0,SW1,SW2,SW3	CTRL0, CTRL1, CTRL2, CTRL3	Switches used to enable channels. Switch behavior is dependent on jumper settings JP4-JP7.	HI, HI, HI, HI

PCB LAYOUT

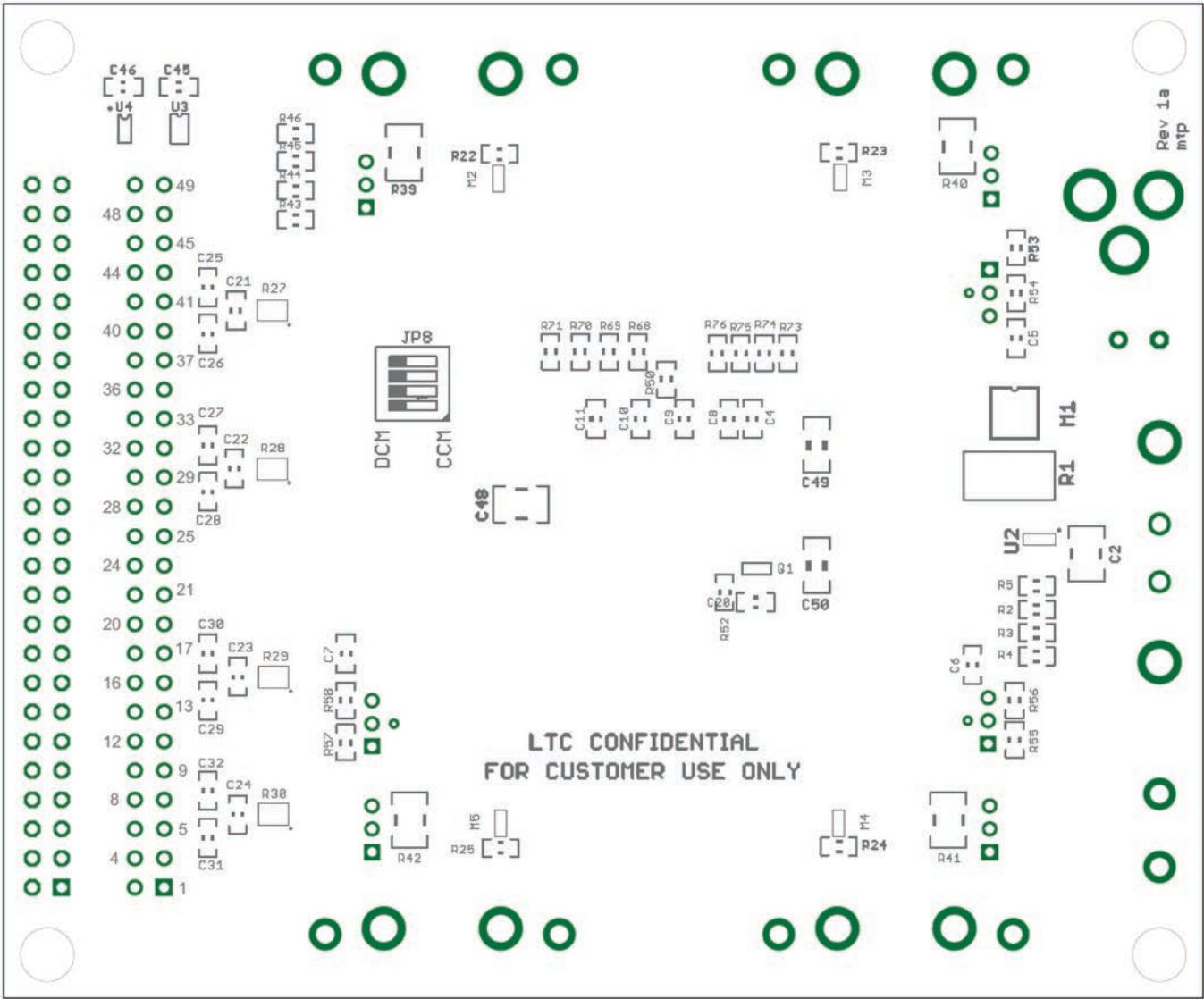


DC2363A Top Layer

Table 5. Default Jumper Settings

REFERENCE DESIGNATOR	SIGNAL NAME	USAGE	DEFAULT
JP1-JP4	VOUT_CH0, VOUT_CH1, VOUT_CH2, VOUT_CH3	Enable/Disable 100mA pre-load on CH0-CH3 outputs.	All On
JP5-JP7	TRACK0, TRACK1, TRACK2	Select Soft-Start (SS) or Tracking feature of Slave Channels (CH0-CH2).	All SS

PCB LAYOUT



DC2363A Bottom Layer

DC2382A PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	1	U1	IC 4-CH POWER SYSTEM MANAGER 64QFN	LINEAR TECH: LTC2975IUP#PBF
Additional Demo Board Circuit Components				
2	9	C1, C2, C3, C4, C6, C8, C9, C12, C15	CAP CERAMIC 0.1 μ F 16V X7R 0402	AVX: 0402YC104KAT2A
3	6	C5, C10, C11, C13, C14, C20	CAP 0.01 μ F 25V CERAMIC X7R 0402	AVX: 04023C103KAT2A
4	1	C7	CAP CER 0.1 μ F 25V X5R 0402	AVX: 04023D104KAT2A
5	8	C23, C24, C25, C26, C28, C29, C30, C31	CAP 2.2nF 16V CERAMIC X7R 0402	AVX: 04023C222KAT2A
6	2	D1, D6	LED GREEN HI-BRT SMD 0603	PANASONIC: LNJ326W83RA
7	4	D2, D3, D4, D5	LED RED SMD 0603	PANASONIC: LNJ237W82RA
8	1	Q1	MOSFET P-CH 20V 200M Ω SOT323-3	ON SEMI: NTS4173PT1G
9	1	Q2	MOSFET N-CH 60V 115MA SOT-23	FAIRCHILD: 2N7002
10	15	R1, R3, R4, R6-R15, R32, R34	RES 10.0k 1/10W 1% 0402 SMD	VISHAY: CRCW040210K0FKED
11	5	R2, R18, R23, R31, R36	RES 100 Ω 1/10W 1% 0402 SMD	VISHAY: CRCW0402100RFKED
12	1	R5	RES 5.49k 1/10W 1% 0402 SMD	VISHAY: CRCW04025K49FKED
13	1	R16	RES 150k 1/10W 1% 0402 SMD	VISHAY: CRCW0402150KFKED
14	1	R17	RES 49.9k 1/10W 1% 0402 SMD	VISHAY: CRCW040249K9FKED
15	4	R19, R20, R27, R35	RES 100k 1/10W 1% 0402 SMD	VISHAY: CRCW0402100KFKED
16	7	R21, R24, R25, R26, R28, R30, R33 (OPT)	RES 0.0 Ω 1/10W 0402 SMD	DO NOT INSTALL!
17	2	R22, R29	RES 0.0 Ω 1/10W 0402 SMD	VISHAY: CRCW04020000Z0ED
18	6	R37, R38, R39, R40, R41, R42	RES 1.4k 1/10W 5% 0402 SMD	VISHAY: CRCW04021K40JNED
19	1	U2	IC EEPROM 2KBIT 400Khz 8TSSOP	MICROCHIP: 24LC025-I/ST
20	2	U4, U5	IC BUFF/DVR DL NON-INV SC70-6	TEXAS INSTR: SN74LVC2G07DCKR
Hardware: For Demo Board Only				
21	1	J1	CONN SOCKET 20POS DUAL ROW	MILL MAX 803-43-020-20-001000
22	1	J2	CONN HEADER 12POS 2MM STR DL PCB	FCI: 98414-G06-12ULF
23	1	J3	CONN PIN HEADER 20POS DUAL ROW	MILL MAX 802-40-020-20-001000
24	1	J4	CONN FEMALE 50POS DL 0.1" R/A GOLD	SULLINS: PPPG252LJBN-RC
25	2	JP1, JP2	CONN HEADER 4POS 2MM VERT T/H	WURTH: 620 004 111 21
26	5	JP3-JP7	CONN HEADER 3POS 2MM VERT T/H	WURTH: 620 003 111 21
27	4	MH1-MH4	SPACER STACKING #4 SCREW NYLON	KEYSTONE: 8831
28	4	SW0-SW3	SW SLIDE DPDT 6VDC 0.3A PCMNT	C&K: JS202011CQN
29	1	SW4	PUSHBUTTON SWITCH 3.5x6 100GF SMD	PANASONIC: EVQ-PJS04K
30	7	SH1-SH7	CONN SHUNT 2MM 2POS BLACK	WURTH: 608 002 134 21
31	15	TP1-TP15	TERM SOLDER TURRET 0.156"H 0.084"L	MILL MAX: 2308-2-00-80-00-00-07-0

DEMO MANUAL DC2428A

DC2363A PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	1	U1	QUAD 4A BUCK REGULATOR μ MODULE BGA77	LINEAR: LTM4644EY#PBF
Additional Demo Board Circuit Components				
2	1	C1	CAP ALUM POLY 220 μ F 20V 20% 3.5X8	NICHICON: PLV1D221MDL1TD
3	4	C2, C3, C47, C48	CAP CER 22 μ F 25V 10% X5R 1210	MURATA: GRM32ER61E226KE15L
4	17	C4, C5, C6, C7, C21, C22, C23, C24, C37, C38, C39, C40, C41, C42, C43, C44, C45	CAP CER 10nF 50V 10% X7R 0603	MURATA: GRM188R71E103KA01D
5	4	C8, C9, C10, C11 (OPT.)	CAP CER 0603 (OPTIONAL)	-
6	4	C12, C13, C14, C15	CAP CER 47 μ F 10V 20% X5R 1206	MURATA: GRM31CR61A476ME15L
7	4	C16, C17, C18, C19	CAP CER 22 μ F 10V 10% X7R 1210	TDK: C3225X7R1A226K230AC
8	1	C20	CAP CER 100nF 16V 10% X7R 0603	MURATA: GRM188R71C104KA01D
9	8	C25-C32 (OPT.)	CAP CER 2.2nF 50V 10% C0G 0603 (OPTIONAL)	MURATA: GRM1885C1H222JA01D
10	4	C33-C36	CAP TANT POLY 330 μ F 6.3V 20% 2917 (7343)	PANASONIC: 6TPF330M9L
11	1	C46	CAP CER 1 μ F 10V 10% X7R 0603	TAIYO YUDEN: EMK107B7105KA-T
12	2	C49, C50	CAP CER 22 μ F 25V 10% X5R 1206	MURATA: GRM31CR61E226KE15L
13	4	LED0, LED1, LED2, LED3	LED GREEN SS TYPE BRIGHT SMD	PANASONIC: LNJ326W83RA
14	1	M1	MOSFET DUAL N-CH 60V SOIC8	VISHAY: SI4946BEY-T1-GE3
15	4	M2, M3, M4, M5	MOSFET N-CH 30V 900MA SOT323-3	DIODES INC: DMG1012UW-7
16	1	Q1	TRANS GP NPN 40V	ON SEMI: MMBT3904WT1G
17	1	R1	RES CURRENT SENSE 0.01 1W 2512 SMD	VISHAY: WSK2512R0100FEA
18	1	R2	RES 2.1M 0.1W 1% 0603 SMD	VISHAY: CRCW06032M10FKEA
19	1	R3	RES 221k 0.1W 1% 0603 SMD	VISHAY: CRCW0603221KFKEA
20	1	R4	RES 80.6k 0.1W 1% 0603 SMD	VISHAY: CRCW060380K6FKEA
21	1	R5	RES 100k 0.1W 1% 0603 SMD	VISHAY: CRCW0603100KFKEA
22	4	R6, R7, R8, R9	RES 49.9k 0.1W 1% 0603 SMD	VISHAY: CRCW060349K9FKEA
23	1	R10	RES 1.21k 0.1W 1% 0603 SMD	VISHAY: CRCW06031K21FKEA
24	1	R11	RES 1.74k 0.1W 1% 0603 SMD	VISHAY: CRCW06031K74FKEA
25	1	R12	RES 3.65k 0.1W 1% 0603 SMD	VISHAY: CRCW06033K65FKEA
26	2	R13, R19	RES 8.25k 0.1W 1% 0603 SMD	VISHAY: CRCW06038K25FKEA
27	4	R14, R15, R16, R17	RES CURRENT SENSE 0.01 0.5W 1210 SMD	YAGEO: RL1210FR-070R01L
28	1	R18	RES 6.81k 0.1W 1% 0603 SMD	VISHAY: CRCW06036K81FKEA
29	1	R20	RES 14.3k 0.1W 1% 0603 SMD	VISHAY: CRCW060314K3FKEA
30	1	R21	RES 20.5k 0.1W 1% 0603 SMD	VISHAY: CRCW060320K5FKEA
31	4	R22-R25	RES 2.0k 0.1W 1% 0603 SMD	VISHAY: CRCW06032K00JNEA
32	1	R26	100k RESISTOR ARRAY, 4 RES, 1206	VISHAY: CRA06S083100KJTA
33	4	R27-R30	1k RESISTOR ARRAY, 2 RES, 0606	PANASONIC: EXB-V4V102JV
34	8	R31-R38	RES 100 Ω 0.1W 1% 0603 SMD	VISHAY: CRCW0603100RFKEA
35	1	R39	RES 33 Ω 0.5W 1% 1210 SMD	VISHAY: CRCW121033R0JNEA
36	1	R40	RES 24.9 Ω 0.5W 1% 1210 SMD	VISHAY: CRCW121024R9FKEA
37	1	R41	RES 15 Ω 0.5W 1% 1210 SMD	VISHAY: CRCW121015R0FKEA
38	1	R42	RES 10 Ω 0.5W 1% 1210 SMD	VISHAY: CRCW121010R0JNEA
39	4	R43-R46	RES 0 Ω 0.1W 0603 SMD	VISHAY: CRCW06030000Z0EA

dc2428af

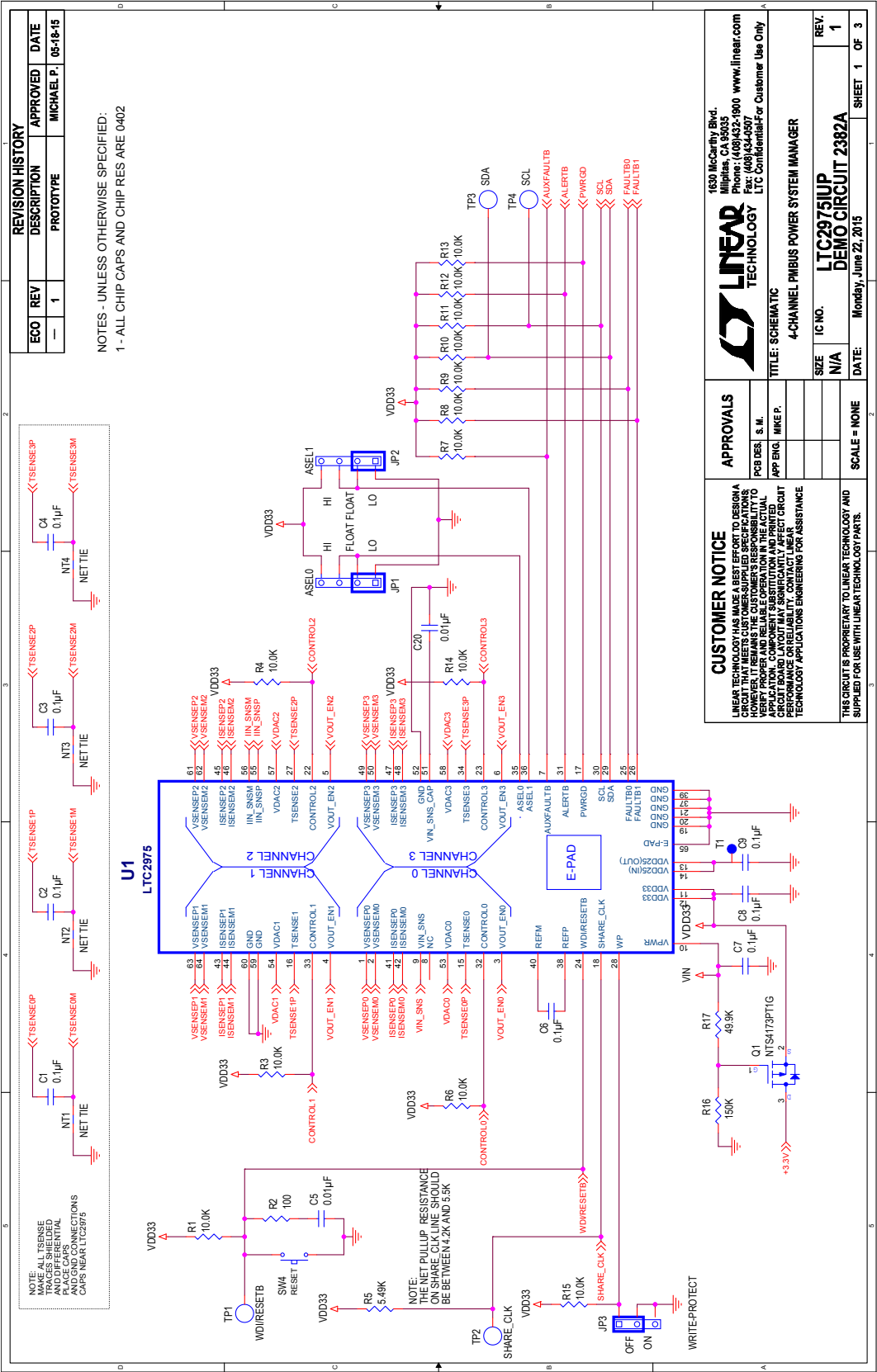
DC2363A PARTS LIST

ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
40	10	R50, R52, R68-R71, R73-R76 (OPT)	RESISTOR (OPTIONAL)	VISHAY: CRCW06030000Z0EA
41	3	R53, R55, R57	RES 60.4k 0.1W 1% 0603 SMD	VISHAY: CRCW060360K4FKEA
42	1	R54	RES 19.1k 0.1W 1% 0603 SMD	VISHAY: CRCW060319K1FKEA
43	1	R56	RES 40.2k 0.1W 1% 0603 SMD	VISHAY: CRCW060340K2FKEA
44	1	R58	RES 90.9k 0.1W 1% 0603 SMD	VISHAY: CRCW060390K9FKEA
45	8	R59-R66	RES 1.0 Ω 0.1W 1% 0603 SMD	VISHAY: CRCW06031R00JNEA
46	2	R67, R72 (OPT)	RES 0 Ω 1W 2010 SMD (OPTIONAL)	ROHM: MCR50JZHJ000
47	4	R77-R80	RES 6.04k 0.1W 1% 0603 SMD	VISHAY: CRCW06036K04FKEA
48	1	U2	OV/UV SUPPLY PROTECTION CONTROLLER	LINEAR: LTC4365ITS8#PBF
49	1	U3	FIXED 3.3V 100mA MICROPOWER LDO	LINEAR: LT1761ES5-3.3#PBF
50	1	U4	2KBIT I2C SERIAL EEPROM SOT23-6	MICROCHIP: 24LC025T-I/OT

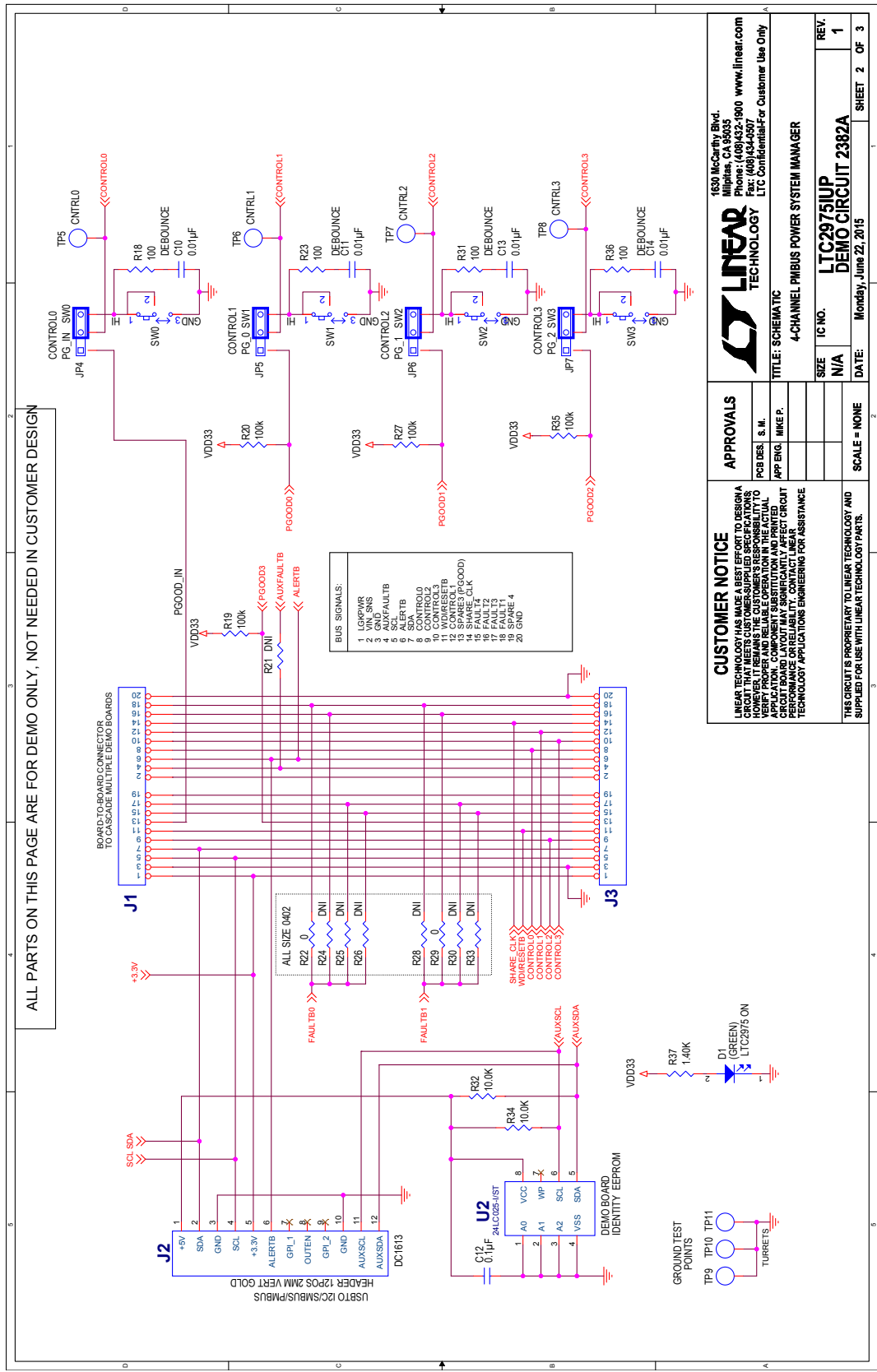
Hardware: For Demo Board Only

51	1	J1	POWER JACK FROM CUI INC. PJ-002A	CUI INC: PJ-002AH
52	1	J2	TERMINAL BLOCK 5mm HORZ ENTRY 2POS	WURTH: 691102710002
53	1	J3	CONN HEADER 50POS 0.050 RIGHT ANGLE	MOLEX: 90122-0785
54	7	JP1, JP2, JP3, JP4, JP5, JP6, JP7	2MM PIN HEADER 1X3	WURTH: 620 003 111 21
55	1	JP8	4POS DIP SWITCH	C&K: TDA04H0SB1R
55	4	MH1-MH4	SPACER STACKING #4 SCREW NYLON	KEystone: 8831
56	7	SH1-SH7	CONN SHUNT 2MM 2POS BLACK	WURTH: 608 002 134 21
57	10	TP1-TP10	TERM SOLDER TURRET 0.219"H 0.109"L	MILL MAX : 2501-2-00-80-00-00-07-0
58	10	TP11, TP12, TP17-TP24	TERM SOLDER TURRET 0.156"H 0.084"L	MILL MAX : 2308-2-00-80-00-00-07-0

SCHEMATIC DIAGRAM

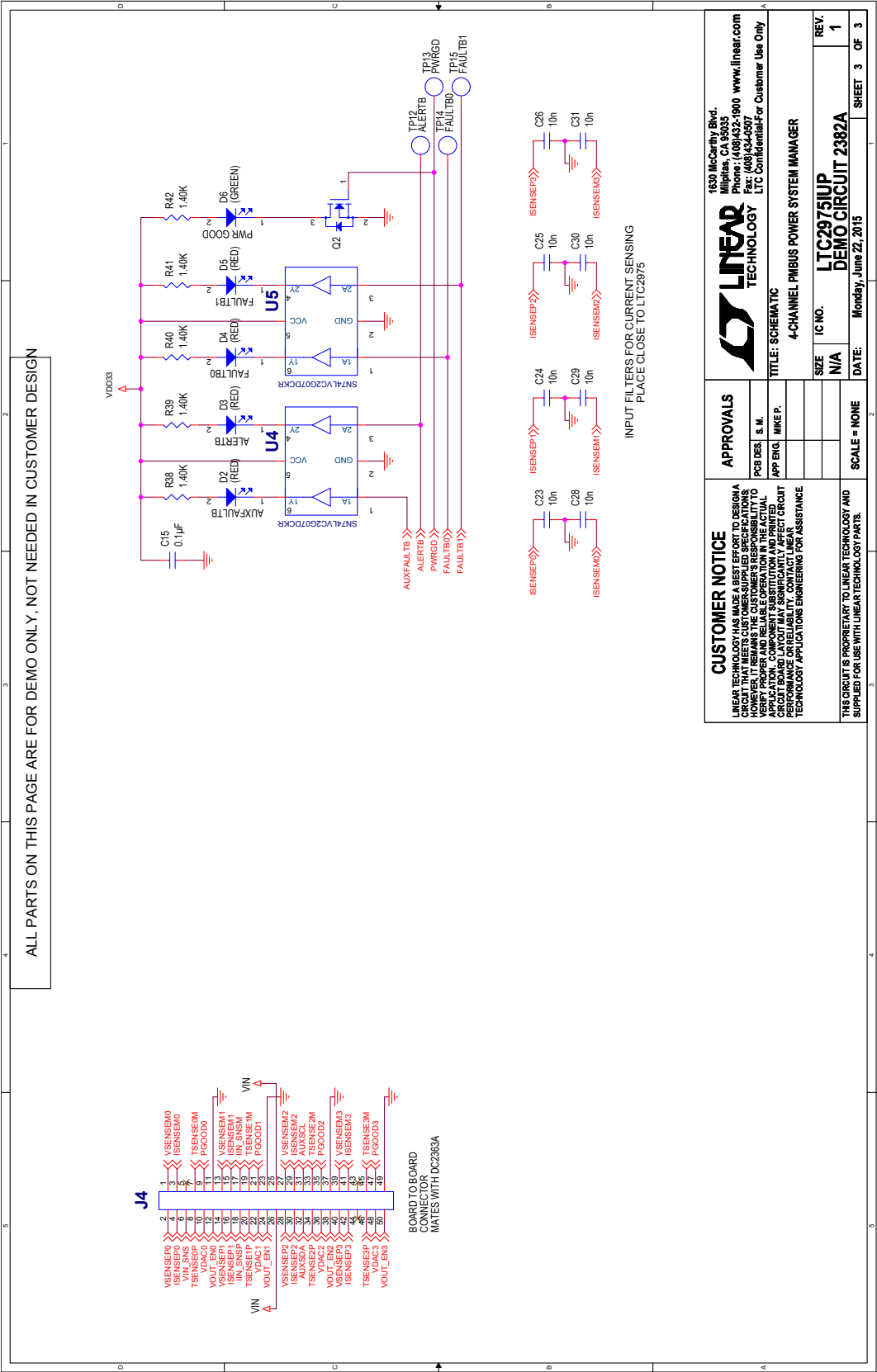


SCHEMATIC DIAGRAM



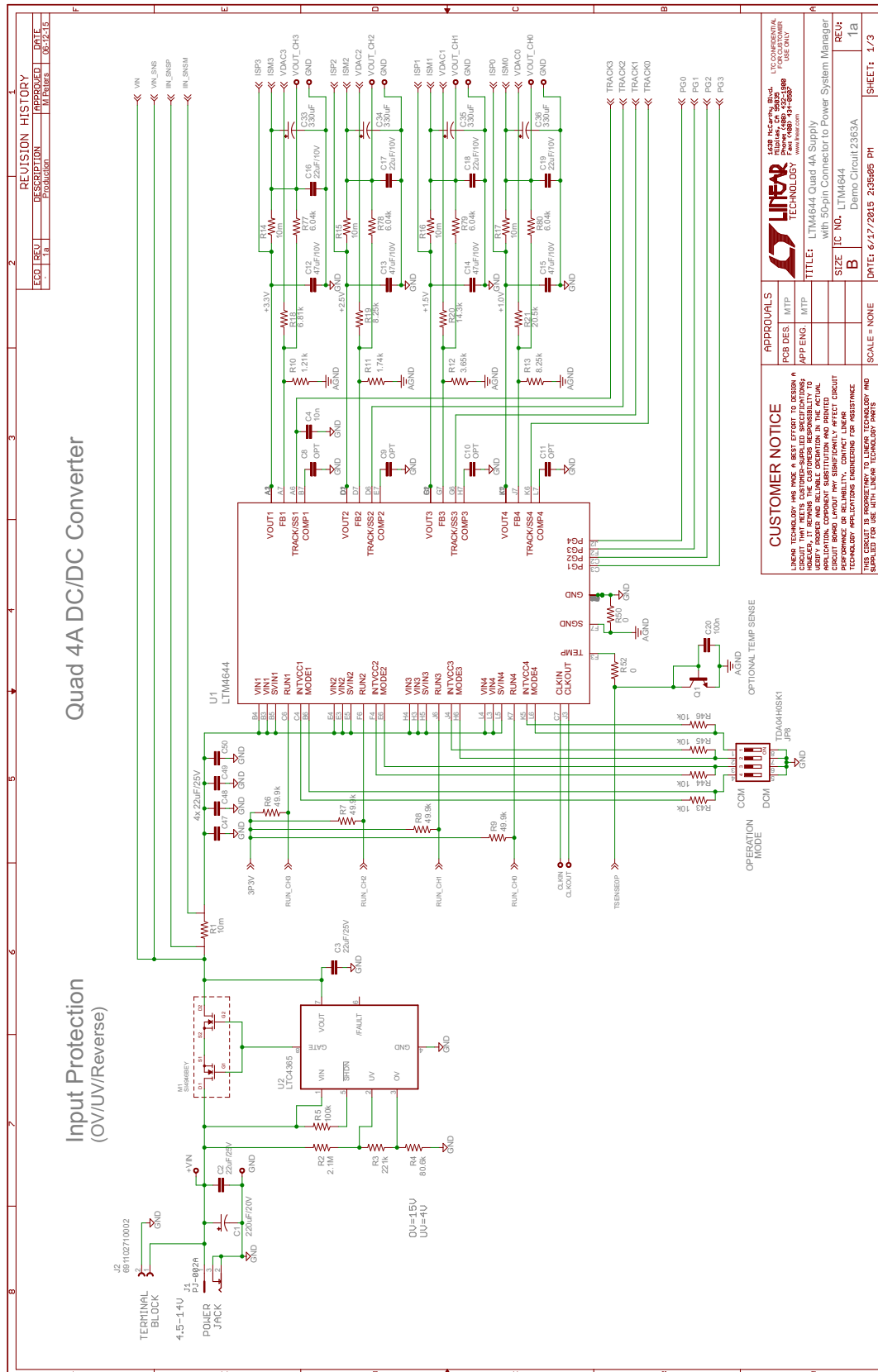
DC2382A

SCHEMATIC DIAGRAM



DC2382A

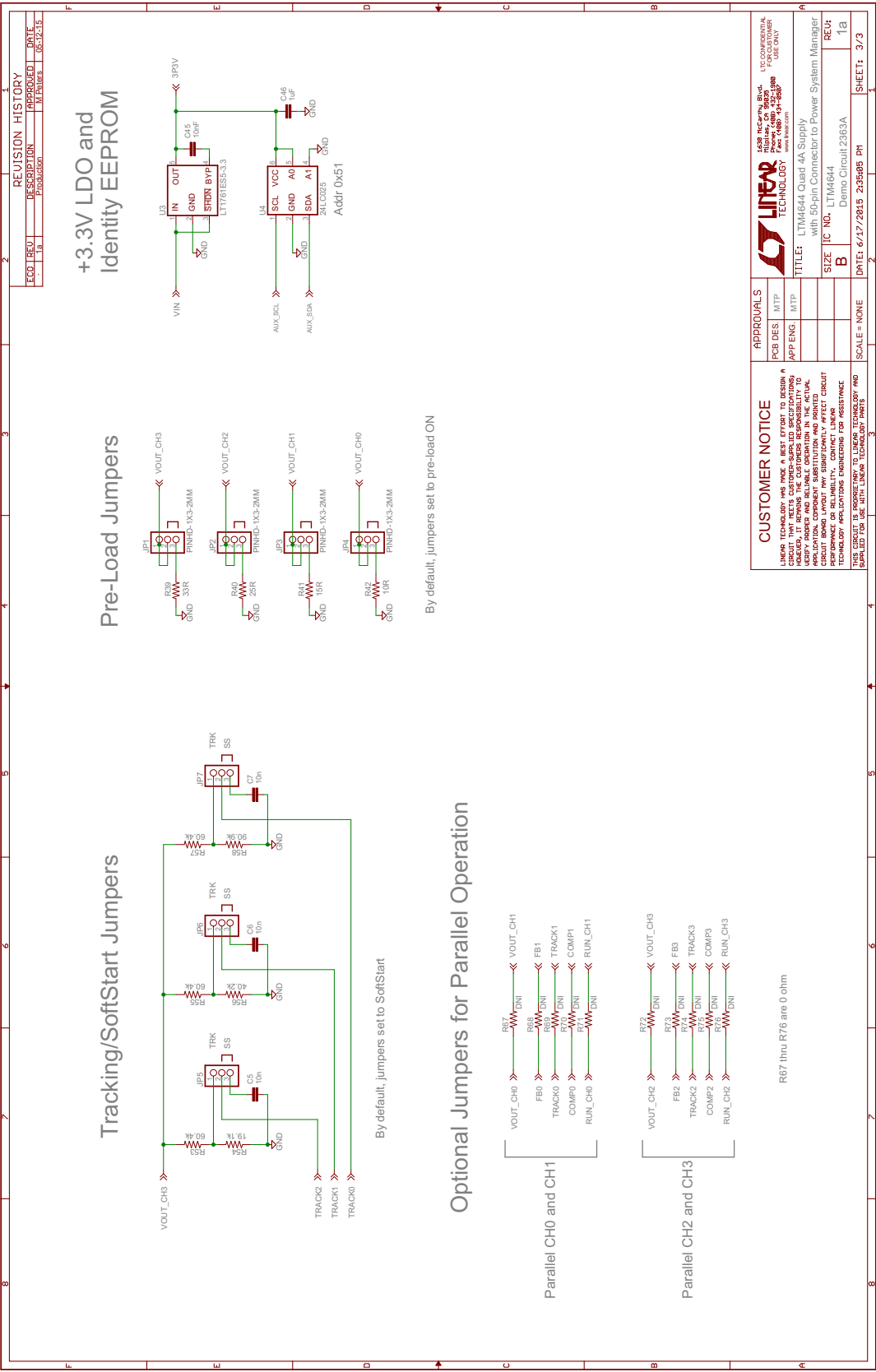
SCHEMATIC DIAGRAM



DC2363A



SCHEMATIC DIAGRAM



DEMO MANUAL DC2428A

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This notice contains important safety information about temperatures and voltages. For further safety concerns, please contact a LTC application engineer.

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