

LTC2972

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

DESCRIPTION

The DC2739A is a two-board demonstration system consisting of the DC2675A and DC2363A. The DC2675A contains all the circuitry needed to use two LTC[®]2972 Power System Managers to control four power supplies. The DC2363A contains four power supplies (LTM[®]4644-1 quad 4A μ Module[®] regulator) which are configured to be controlled by the two LTC2972 devices. The DC2363A and DC2675A demo boards together provide a sophisticated 4-channel digitally programmable power supply system.

The LTC2972 is a 2-channel I²C/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 DC2675A demonstrates the ability of the LTC2972 to sequence, trim, margin, supervise, monitor, and log faults for four power supplies. The LTC2972 monitors each channel's output voltage and output current and also 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 is pre-configured with 1.0V, 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 LTC2972. Together, the LTpowerPlay software and DC2739A hardware system create a powerful development environment for designing and testing configuration settings of the LTC2972. LTpowerPlay stores these settings in the LTC2972'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 LTC2972. The board comes pre-programmed with the EEPROM values appropriate for the four power supply rails on the DC2739A. Just plug and play!

Multiple DC2739A boards can be cascaded together to form a high channel count power supply (see Multi-Board Arrays). This cascaded configuration demonstrates features of the

ADI Power System Management ICs which enable timing and fault information that is shared across multiple Power System Management ICs. The user can configure up to eight DC2739A boards, thereby controlling up to 32 separate power supply rails. Larger board arrays can be built using programmable I²C base addresses or bus segmentation.

Order preprogrammed devices from Linear Express using LTpowerPlay.

The following items are required:

- +12VDC Power Supply
- USB-to-I²C/SMBus/PMBus Controller (DC1613)
- LTpowerPlay Software

DC2739A 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
- Multichannel Fault Management
- Automatic Fault Logging to Internal EEPROM
- Operates Autonomously without Additional Software
- Monitors: Voltage, Current, Power, Temperature
- 4-Channel Time-Based Output Sequencer
- I²C/SMBus Serial Interface
- Powered from 4.5V to 14V

Design files for this circuit board are available at
<http://www.analog.com/DC2739A>

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DEMO MANUAL DC2739A

PERFORMANCE SUMMARY Specifications are at T_A = 25°C

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
V _{PWR} Supply Input Operating Range		4.5		15	V
V _{DD33} Supply Input Operating Range		3.13		3.47	V
ADC Total Unadjusted Error	V _{IN} ≥ 1V		±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	0V ≤ V _{IN_ADC} ≤ 6V		122		μV/LSB
ADC Current Sense Resolution	0mV < V _{IN_ADC} < 16mV		15.6		μV/LSB
	16mV < V _{IN_ADC} < 32mV		31.25		μV/LSB
	32mV < V _{IN_ADC} < 63.9mV		62.5		μV/LSB
	63.9mV < V _{IN_ADC} < 127.9mV		125		μV/LSB
	127.9mV < V _{IN_ADC}		250		μV/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		°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)	2V < V _{IN_VS} < 6V, Low Resolution Mode		±1.25		%
	1.5V < V _{IN_VS} < 3.8V, High Resolution Mode		±1.0		%
	0.8V < V _{IN_VS} < 1.5V, High Resolution Mode		±1.5		%
I ² C Serial Clock Frequency		10		400	kHz

Table 1. DC2363 System Specifications

	NOMINAL UNTRIMMED V _{OUT}	TOP FEEDBACK RESISTOR	BOTTOM FEEDBACK RESISTOR	R _{DAC}	MARGIN RANGE
CH0	1.0V ±1.5%	60.4k	90.9k	237k	±15%
CH1	1.5V ±1.5%	60.4k	40.2k	158k	±15%
CH2	2.5V ±1.5%	60.4k	19.1k	95.3k	±15%
CH3	3.3V ±1.5%	60.4k	13.3k	73.2k	±15%

Notes:

- Load current <4A is recommended.
- Output voltages can be margined by ±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 LTC2972 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: Nonvolatile 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 LTC2972 supervises.

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

Trim: The act of adjusting the final output voltage. A servo loop trims the output 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 by modifying: nominal output voltages, range and resolution of margining, sequencing, OV/UV limits, and OC limits.
- Create your own configuration: store in the LTC2972 EEPROM or save to a project file. Order preprogrammed parts.
- Test fault scenarios. Short outputs to ground, and observe system response and faults.

Demo System Hardware

Hardware required:

1. DC2739A = DC2363A plus DC2675A
2. PC and USB cable
3. 12V, >1A power supply
4. USB to I²C/SMBus/PMBus Controller

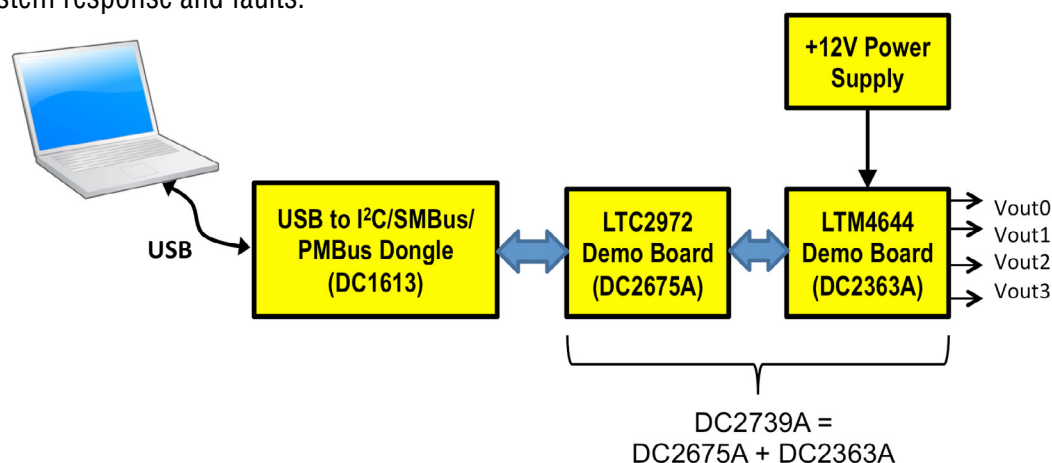


Figure 1. DC2739A Demo Setup

LTPowerPLAY GUI SOFTWARE

LTpowerPlay is a powerful Windows-based development environment that supports Analog Devices Power System Management ICs with EEPROM, including the LTC2972 4-channel Power System Manager. 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 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 DC2739A 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 [LTpowerPlay](#).

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

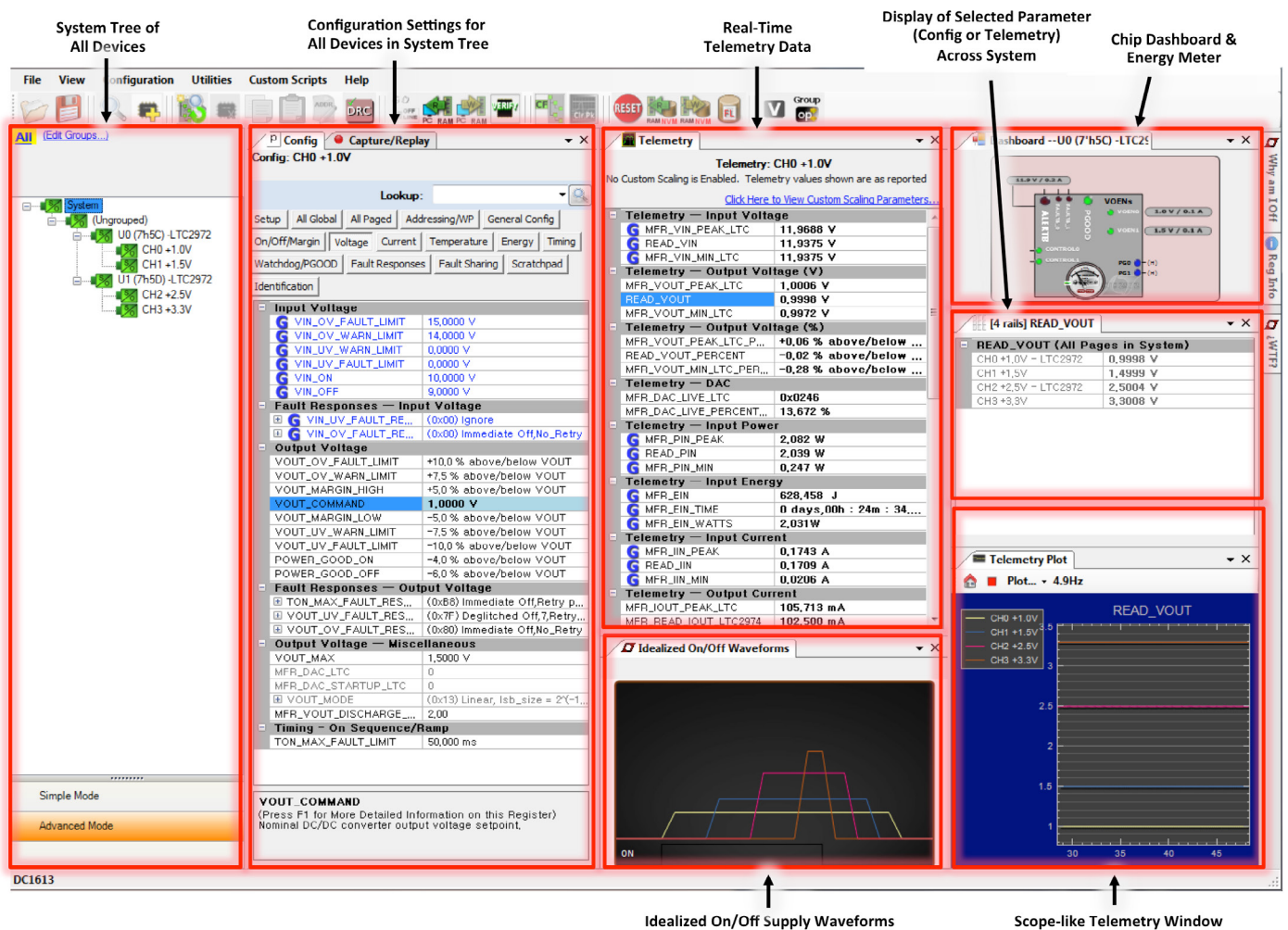


Figure 2. Screenshot of the LTpowerPlay GUI

QUICK START PROCEDURE

The following procedure describes how to set up a DC2739A demo system.

1. Download and install the [LTpowerPlay GUI](#):
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 DC2675A 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 RUN position.
 - b. On the DC2675A board, set U0 ASEL jumpers to LOW (address 0x5C), set U1 ASEL1 to LOW and ASEL0 to FLOAT (address 0x5E), and VDDIO jumper to 3.3V.
 - 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. Devices U0 and U1 should power up with the LED1 illuminated green, and the four PG LEDs should be illuminated red.
5. Connect a +12VDC power supply with >1A capacity to the V_{IN} input jack of the DC2363A board. The four outputs will power up and the green LEDs will illuminate. The PG LEDs on the DC2675A board should be illuminated blue, indicating a logic '1' on the PG pins.
6. Launch the LTpowerPlay GUI.
 - a. The GUI automatically identifies the DC2675A and builds a system tree for each I²C device. The system tree on the left hand side will look like this:

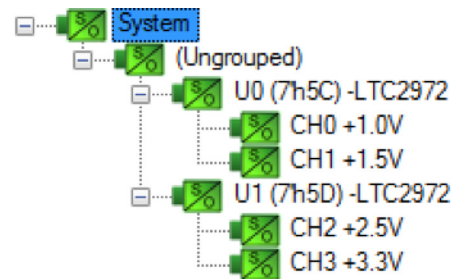
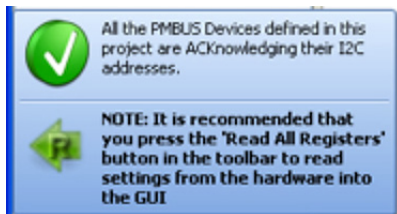


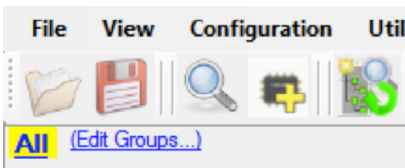
Figure 3. Connecting DC2363A/DC2675A Boards and the DC1613 USB to I²C/SMBus/PMBus Controller

QUICK START PROCEDURE

- b. A green message box will be displayed momentarily in the lower left hand corner confirming that the DC2675A 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 > DC2675A_Defaults. This writes the board defaults into the LTC2972's RAM and automatically to NVM as well.

- 7. The LTC2972 is configured to use the CONTROL switches to turn on/off the channels individually. Slide the switch to RUN 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 LTC2972 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 LTC2972.

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



DC2739A - DETAILS (DC2363A + DC2675A)

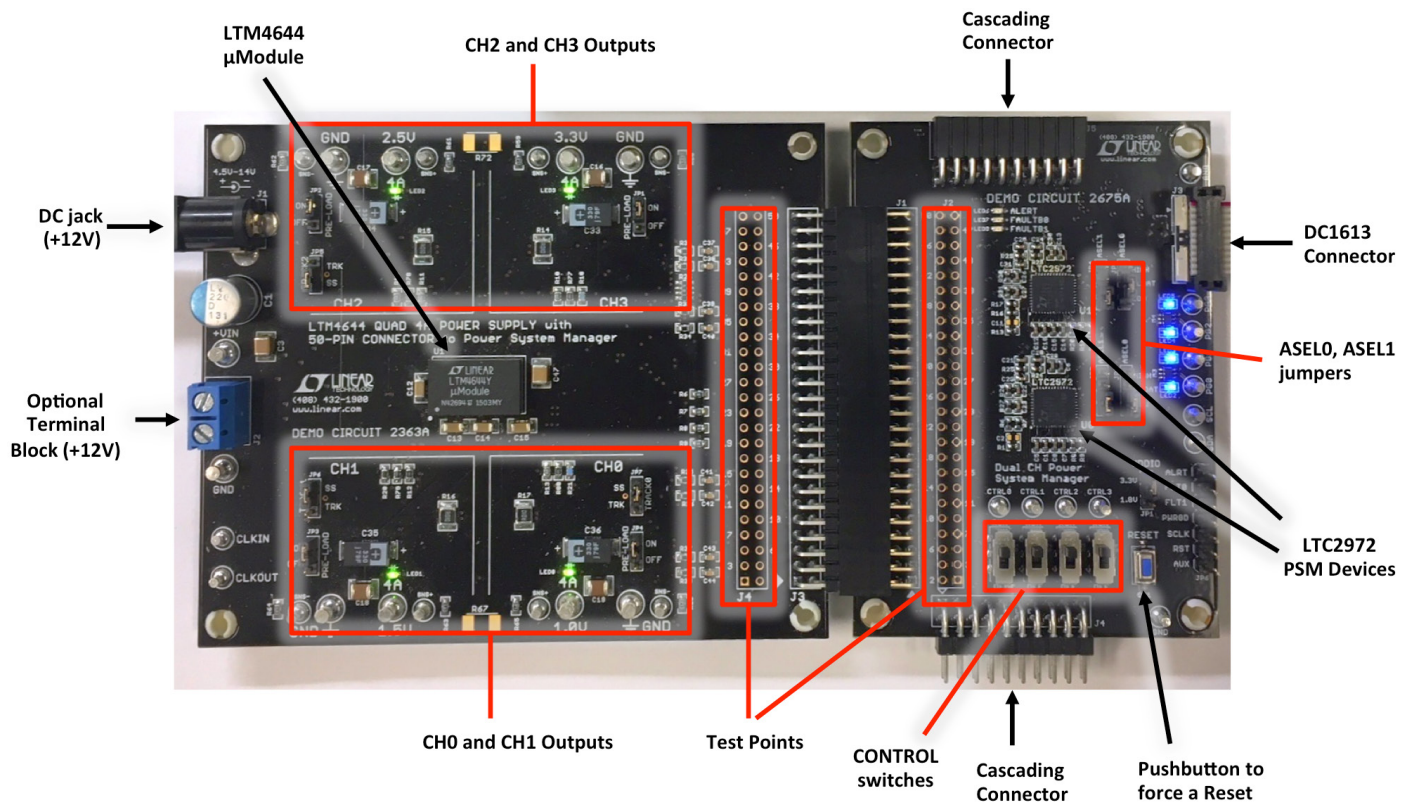


Figure 4. DC2739A Details

COMMON BOARD OPERATIONS

Overview

The two boards are represented in Figure 5 in a simplified block diagram. The LTC2972 measures input current with a 10mΩ 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 DC2675A board is powered either from the DC1613's 3.3V power or the DC2363A if VIN is applied. The board automatically selects the power source for the LTC2972 devices. This allows LTpowerPlay

to communicate (view or change configuration settings) with the LTC2972 devices without main board power.

DC2675A LEDs

The LED1 illuminates when the LTC2972 is powered from the USB controller or the DC2363A external power. Each PG pin has an associated blue-red LED which indicates the logic state of the pin. Logic low = red, logic high = blue. The FAULT and ALERT LEDs are red, indicating 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.

COMMON BOARD OPERATIONS

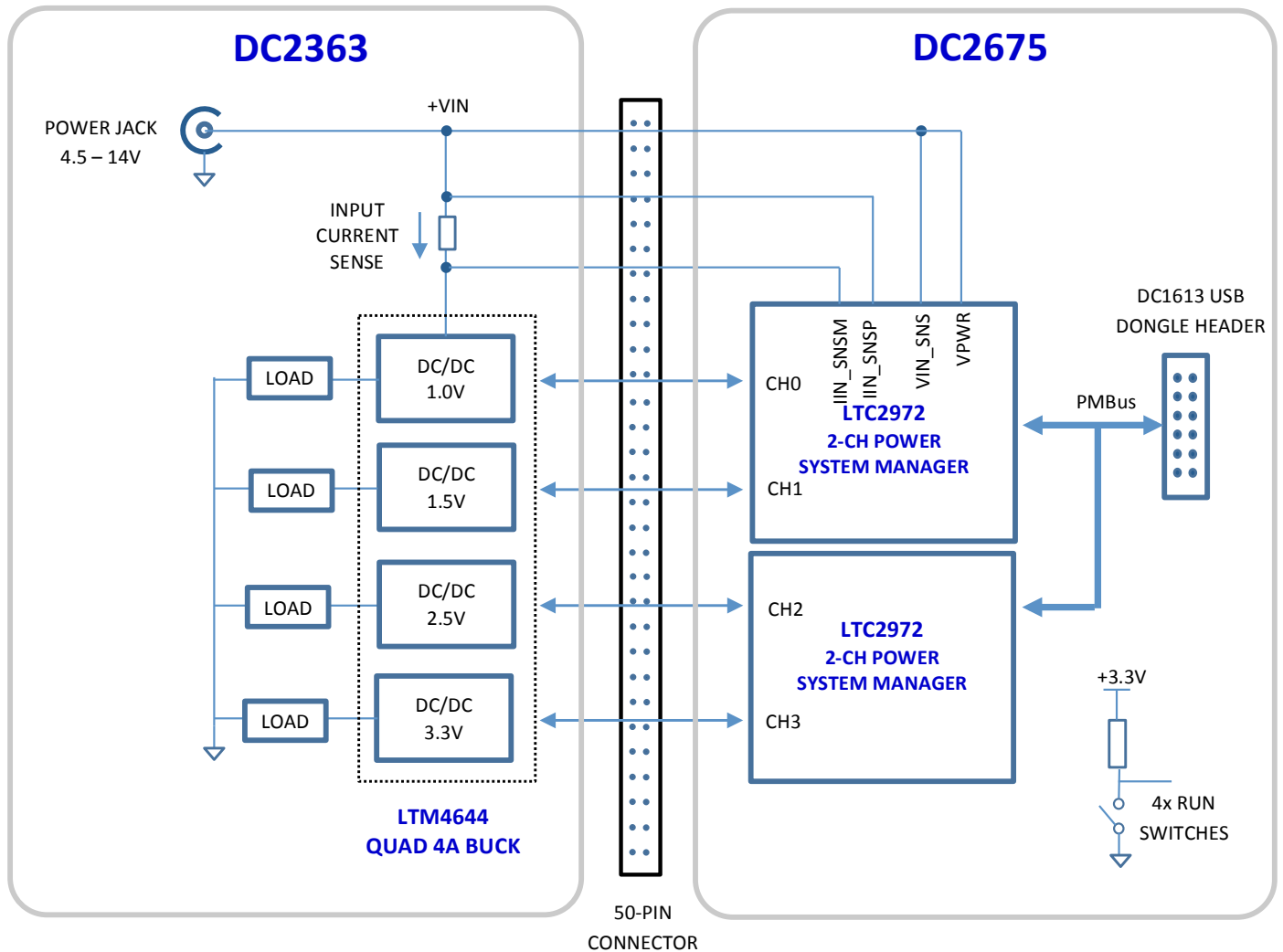


Figure 5. Simplified Block Diagram of the DC2739A

Reset the LTC2972

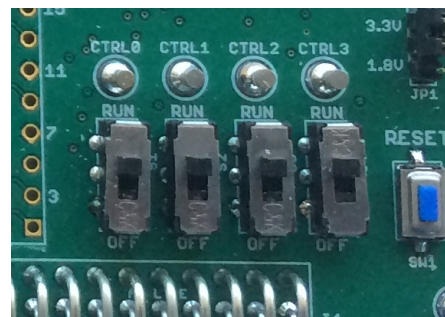
To reset the LTC2972 and reload the EEPROM contents into operating memory (RAM), press the pushbutton switch SW1 on the DC2675A.

Preload the Outputs

Each of the outputs on the DC2363A board has a jumper to preload the output. When enabled, the load current is predefined 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 DC2675A board comes with each of the four CTRL switches configured to enable its respective channel.



COMMON BOARD OPERATIONS

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.

<input type="checkbox"/> MFR_CONFIG_LTC2972	(0x0080) Expand for Detail...
track_en	<input type="checkbox"/> 0x0 (Channel is not a slave i...
cascade_on	<input type="checkbox"/> 0x0 (This channel's control ...
controln_sel	<input checked="" type="radio"/> 0x0 (CONTROL0 is Selected) <input type="radio"/> 0x1 (CONTROL1 is Selected)
fast_servo_off	<input type="checkbox"/> 0x0 (fast-servo enabled)
...	...

You will also need to connect turrets CTRL0 and CTRL2 together. Be sure to keep CTRL2 in the RUN position. The LTC2972 are preconfigured 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.

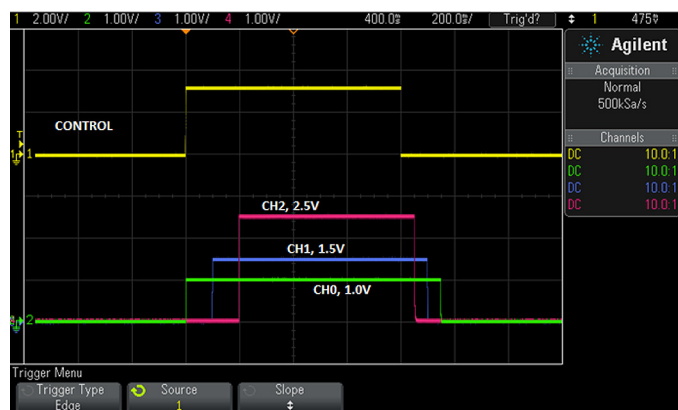


Figure 6. Sequencing Output Channels On/Off

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.

For the LTC2972, the TON_DELAY and TOFF_DELAY values extend to 13.1 seconds, providing a large range for sequencing on and off of power supply rails.

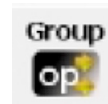
TON_DELAY (All Pages in System)	
U0:0 - LTC2975	0,000 ms
U0:1	100,000 ms
U0:2	200,000 ms
U0:3	300,000 ms

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

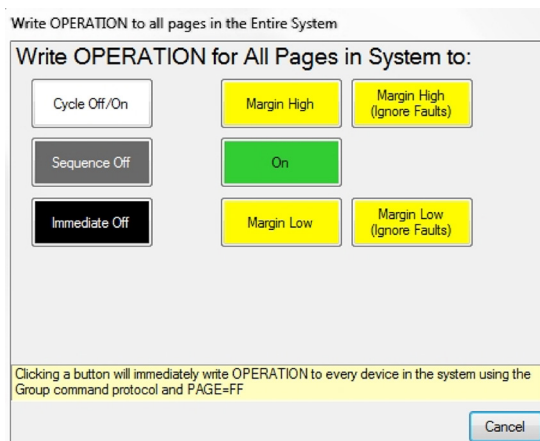
Figure 7. TON_DELAY and TOFF_DELAY Settings

Margin All Rails

The LTC2972 Power System Manager on the DC2675A 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.



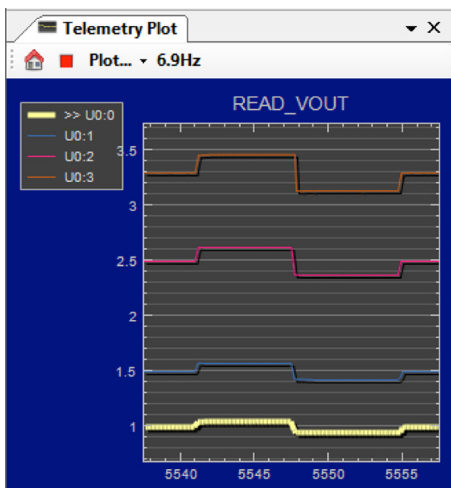
The buttons labeled ignore faults will margin without creating a fault even if the fault limits are exceeded.



A look at the telemetry window shows the effect of the margin high or margin low operation. The following

COMMON BOARD OPERATIONS

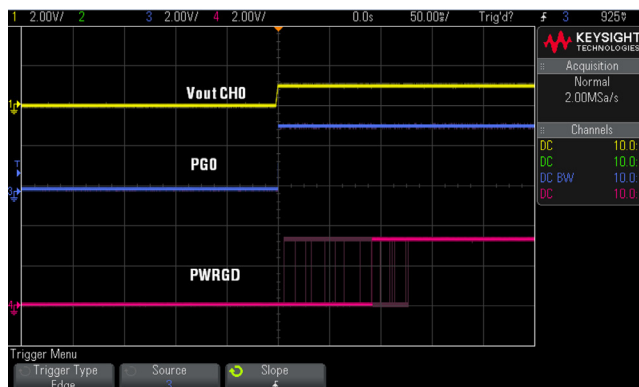
screen shot shows all rails going from nominal setpoints to margin high, margin low, and back to nominal voltages.



The LTC2972 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 multichannel 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 100ms.

Programmable PG Pins

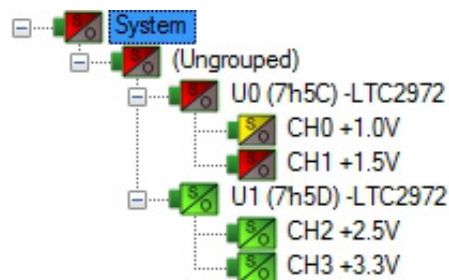
The LTC2972 has a PWRGD pin and two PG pins. The PWRGD pin has the same functionality as previous devices in the family. It releases when all channels (as configured) report their V_{OUT} voltage rises above the $POWER_GOOD_ON$ threshold. Whereas the PWRGD pin is driven from ADC results, the PG pins respond to comparator-based circuits resulting in faster signal assertion. The PG pins are also more configurable, similar to GPIO pins. They can be used to assert upon any combination of V_{OUT} OV/UV, V_{IN} OV/UV, OT/UT, and TON_MAX_FAULT . The V_{OUT} OV/UV has an optional deglitch time that may be added to the assertion time. A PG pin may be used solely as a hardware pin that pulls low upon an overtemperature or V_{IN} UV condition. The DC2375 board has a red-blue LED next to each of the PG turrets. Blue indicates the PG pin is a logic high level and red indicates a logic low level.



The scope shot shows V_{OUT} CH0, PGO, and PWRGD signals with infinite persistence. Multiple triggers show that PG asserts immediately and PWRGD assertions are not only slower than PG but also variable.

Creating A Fault

Any one of the channels on the DC2363A board may be faulted to demonstrate the LTC2972'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. The DC2675A board has two separate fault zones since there are two LTC2972 Power System Managers. When an output is faulted, the channels in that fault zone will power down immediately and the GUI's system tree indicates the color red for the Status portion of the faulted channel. In this example, CH1, the 1.5V output has faulted. You should see CH0 and CH1 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.



COMMON BOARD OPERATIONS

Clearing A Fault

To clear a fault, you can click the CF icon in the GUI or simply push the RESET pushbutton on the DC2675A 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 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 will be rearmed. 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.

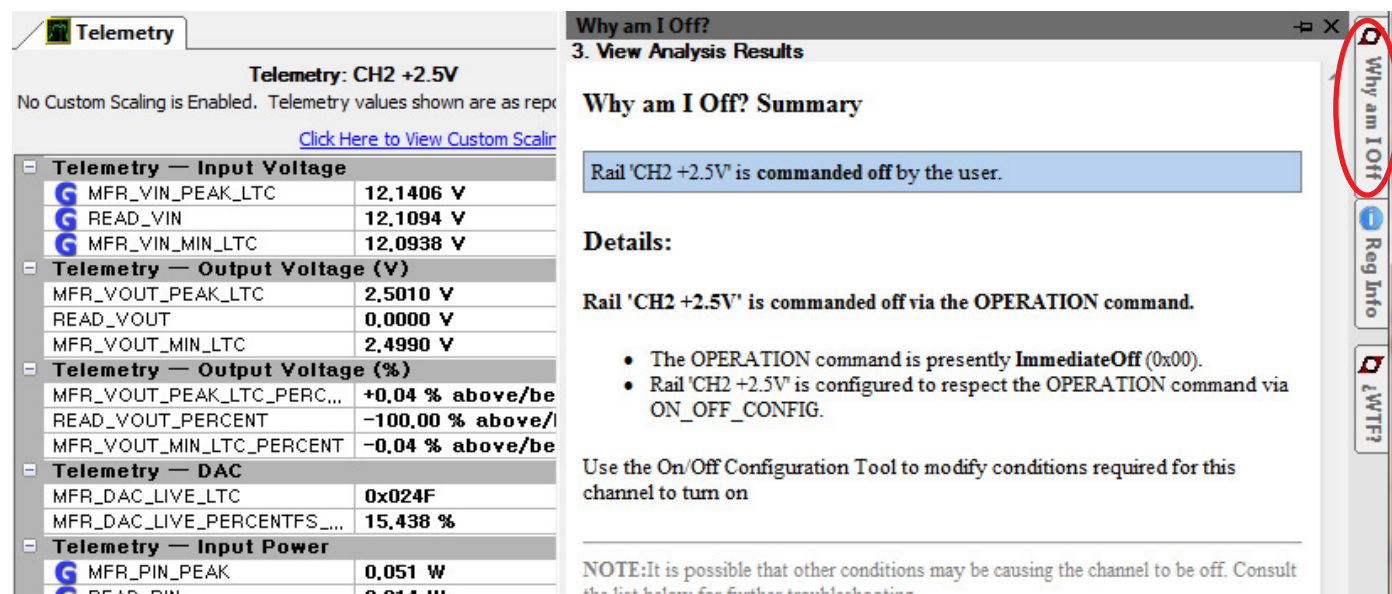


Figure 8. Why Am I Off Tool in the LTpowerPlay GUI

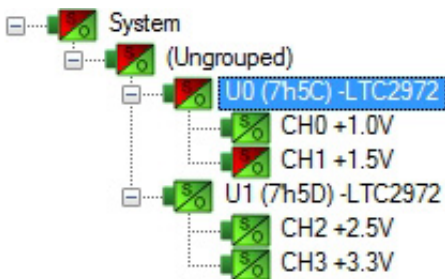
ADVANCED DEMO BOARD OPERATIONS

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 LTC2972. 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 LTC2972 on the DC2675A 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 LTC2972 chip. We are ready to work with the fault log.

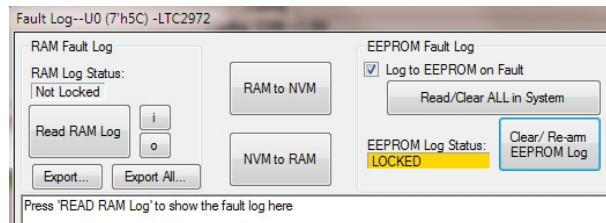


Working with the Fault Log

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.

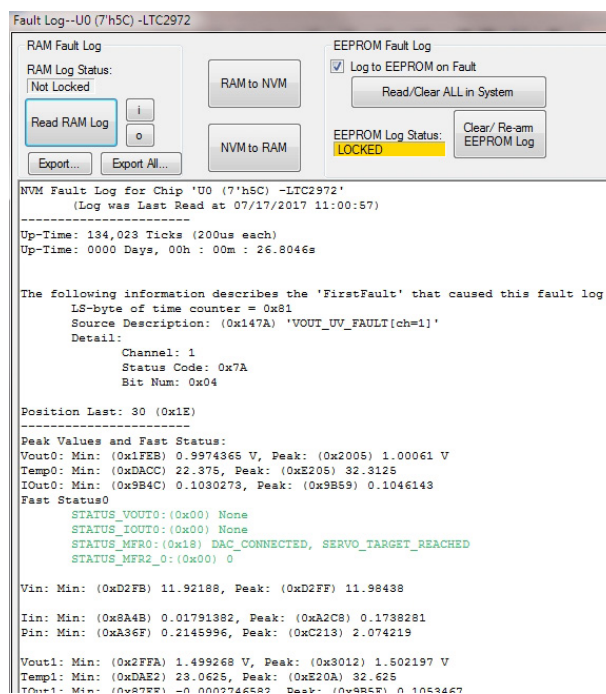


Note that it is a context sensitive icon. If multiple DC2675A boards are connected, be sure that the desired device is selected in the system tree.



Once a fault occurs, the device will automatically write the fault log data to the EEPROM (NVM). At this point, the EEPROM 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 fault log data will appear in the text box below.



The log contains timestamp, uptime, 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 uptime indicates, at the time of fault, the amount of time the device had been powered up or time since the previous reset.

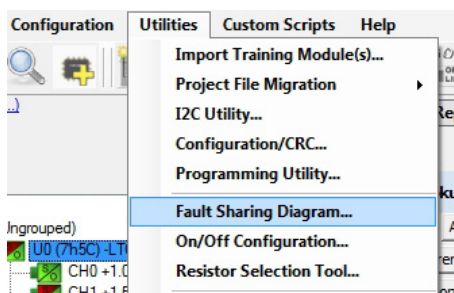
ADVANCED DEMO BOARD OPERATIONS

In this case, the fault log shows 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 (1.5V). 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 System Manager to other Power System Managers via FAULT pins. Use the Fault Sharing Setup Tool to configure the fault sharing in the GUI. Select the LTC2972 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. By default, only the FAULTB0 Response and Propagate switches are closed on device U0. Similarly only the FAULTB1 Response and Propagate switches are closed on device U1. This creates two fault zones. In this configuration, a fault on a channel will shut down the channels in that zone. For example if you short the CH0's output to GND, both CH0 and CH1 will shut off because CH0 is propagating its fault via the FAULTB0 pin and CH1 is responding to FAULTB0. You may use a coin or a jumper to temporarily connect an output to the GND turret.

There are two types of actions to fault behaviors: How a channel responds to another channel's fault and whether a particular channel propagates its fault to other channels. FAULT pins are bidirectional, meaning the device may drive its fault pin low (output) or may respond to the fault pin

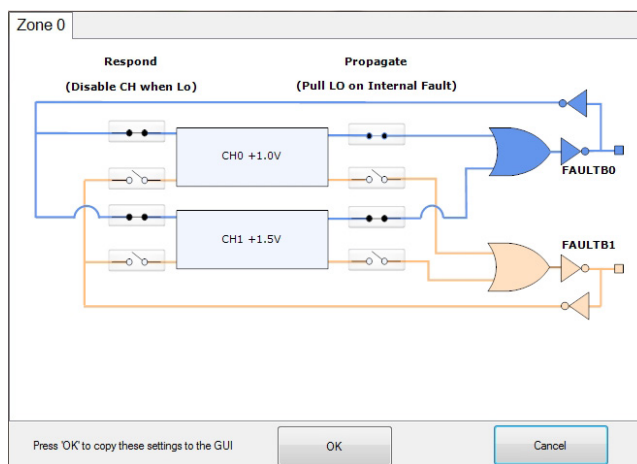


Figure 9. Fault Sharing Utility in LTpowerPlay GUI

when another device drives it low (input). Because the two fault pins are separated on the DC2675A, this allows you to configure the fault settings on a channel-by-channel basis. By default, the LTC2972 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 Examples

Let's explore two different examples. Suppose we do not want channel CH0 to propagate its fault to the other channels when it faults. And suppose we do not want channel CH1 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 and click the PC->RAM icon to write the changes to the DC2675A.

We can now create a fault on CH0 by shorting the output to ground. You will notice that the channel shuts off but CH1 remains powered up because it is not responding to either fault line. After the retry period, channel CH0 will power back up. We can now observe the effect of changing the response setting on CH1. When CH1 is shorted to GND, both CH0 and CH1 are shut off because CH1 propagates its fault and CH0 is responding to FAULTB0.

ADVANCED DEMO BOARD OPERATIONS

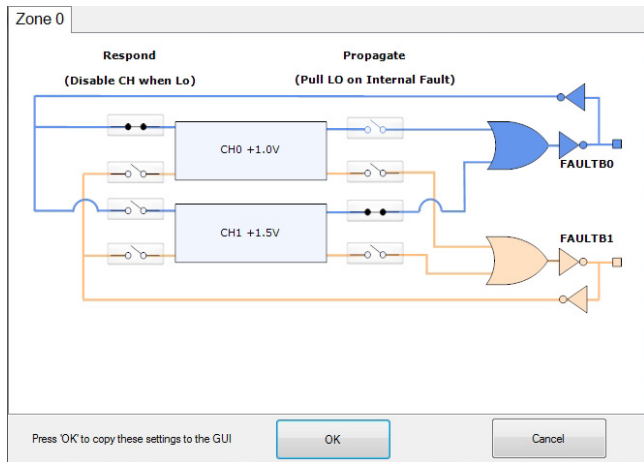


Figure 10. Updated Fault Sharing Configuration

Without any hardware changes, you may create a single fault zone by closing the propagate switches on all channels and reverting CH1 to respond to FAULTB0. If you short any output to ground, all rails will shut down. By separating the fault pins, you have the flexibility to create independent zones or a single fault zone with a simple change to the LTC2972 configuration.

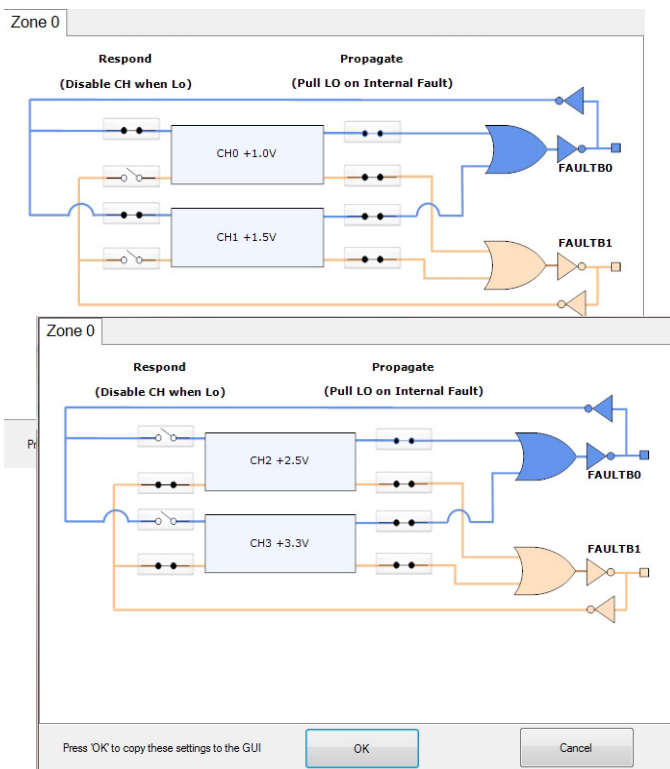
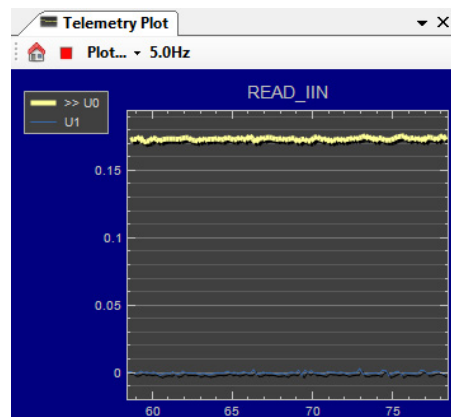


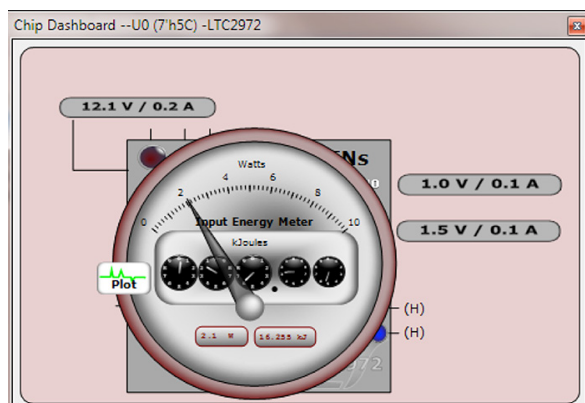
Figure 11. All Channels Share Faults

Energy Metering

The LTC2972 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 ~170mA 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 is the product of power and time, accumulated energy is provided based on the manager’s internal time base.



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 LTC2972 is able to moni-

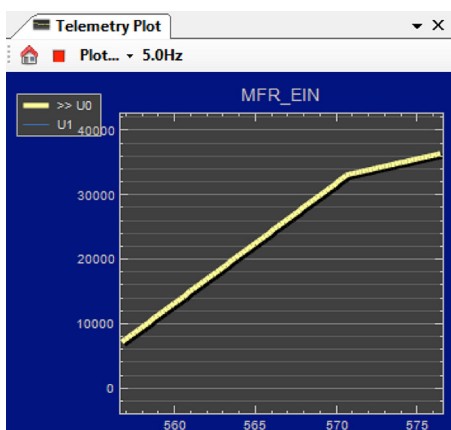
ADVANCED DEMO BOARD OPERATIONS

tor 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	2,133 W
READ_PIN	2,078 W
MFR_PIN_MIN	1,691 W
Telemetry — Input Energy	
MFR_EIN	14,604 kJ
MFR_EIN_TIME	0 days, 01h : 57m : 4...
MFR_EIN_WATTS	2,085W
Telemetry — Input Current	
MFR_IIN_PEAK	0,1785 A
READ_IIN	0,1704 A
MFR_IIN_MIN	0,1416 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 CH2 and CH3 by setting the 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 CH0 and CH1 remain enabled.



Note that the input current has changed from about 170mA down to ~50mA 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 • 170mA or 2.03W. You can confirm this by clicking these three registers one by one and view them in 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}).

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

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

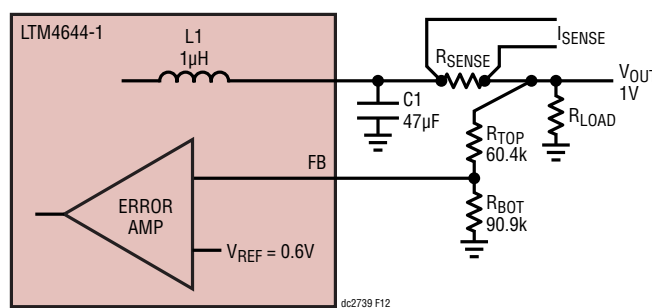


Figure 12. Output Voltage Set by Feedback Resistors

Use the LTpowerPlay's Resistor Selection Tool (Figure 13) 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 DC2363 board uses the LTM4644-1 µModule which allows us to use an external sense resistor in the output path to measure output current. The topside feedback resistor R_{TOP} is wired from the output turret, keeping

ADVANCED DEMO BOARD OPERATIONS

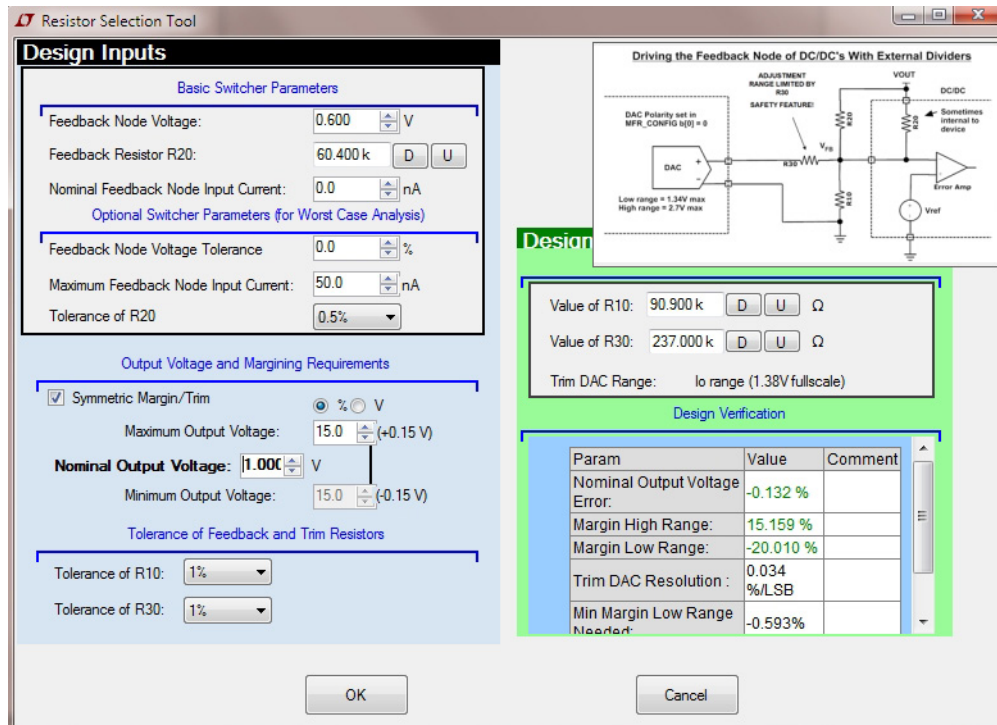


Figure 13. LTpowerPlay's Resistor Selection Tool

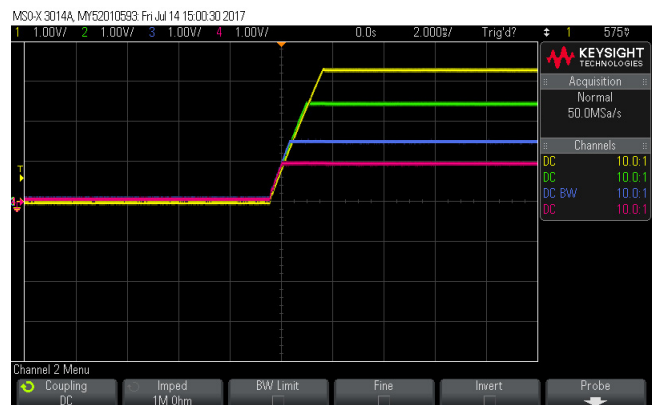
R_{SENSE} inside the feedback loop and minimizes the IR drop of the sense element.

The bottom feedback resistors (R_{BOT}) for each channel are R10 to 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 to R21. Table 1 shows a summary of the feedback resistor values and DAC resistor values.

Tracking Outputs

The DC2363A board offers output tracking capability which allows the startup ramp of all channels to track together. The LTC2972 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 supplies that track 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 LTC2972 data sheet for further description of timing rules, fault behavior, and register configuration settings.



The DC2363A and DC2675A boards are configured to demonstrate tracking as described below. CH3 (3.3V) is the master channel and CH0 to CH2 are slave channels. Any of the four CTRL switches will act as the master enable, as long as the other three are set to RUN. In addition the user may command any channel off using the OPERATION command.

ADVANCED DEMO BOARD OPERATIONS

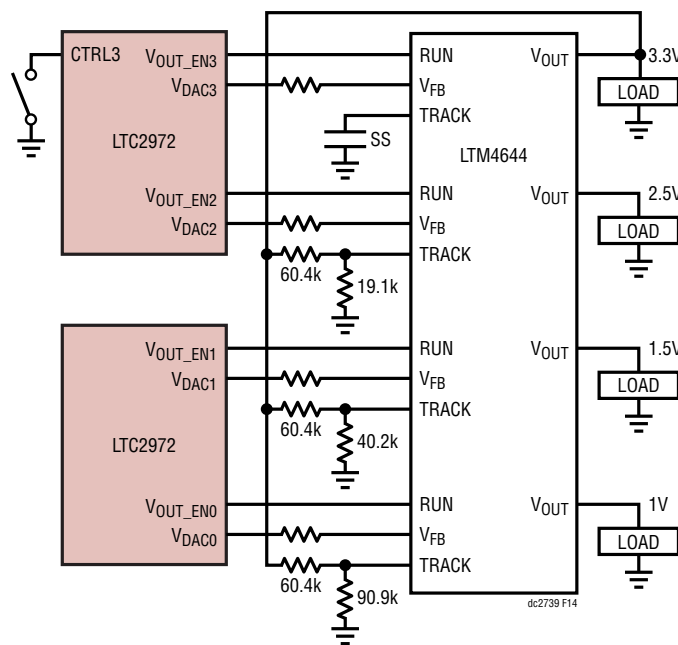


Figure 14. LTC2972 Configured for Power Supply Tracking

To demonstrate tracking:

1. Set all three TRACK jumpers to the TRK position, and set CH3's preload jumper to ON.
2. On the DC2675A board, solder 0Ω jumpers (R21, R22, R23) in place.
3. In LTpowerPlay, select Demo>DC2675A_tracking from the GUI's menu.

The following register screen shots document the relevant configuration settings.

Cascaded Sequencing

The DC2739A 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 LTC2972'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 15. For each slave channel, the mfr_config_cascade_on bit is set (logic '1') and the associated control input is connected 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.

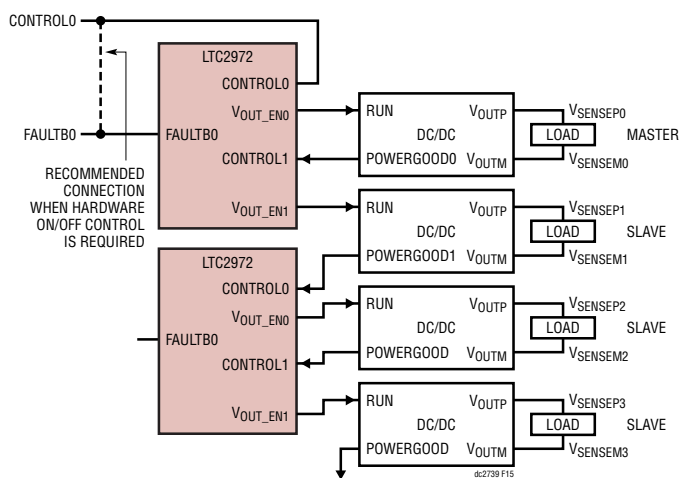


Figure 15. LTC2972 Configured for Cascaded Sequencing

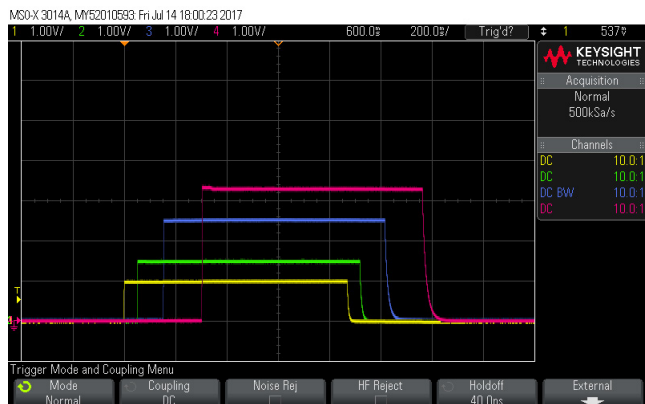
MFR_CONFIG3_L... (0x07) track_en_chan2, tra... uc_fault_response_c... <input type="checkbox"/> 0x0 (No Action on IOUT... uc_fault_response_c... <input type="checkbox"/> 0x0 (No Action on IOUT... uc_fault_response_c... <input type="checkbox"/> 0x0 (No Action on IOUT... track_en_chan3 <input type="checkbox"/> 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 ...		MFR_CONFIG_LTC29... (0x3080) Expand for Detai... RESERVED15 <input type="checkbox"/> 0x0 (Reserved) cascade_on <input checked="" type="checkbox"/> 0x0 (This channel's c... controln_sel <input checked="" 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...	
---	--	---	--

TON_DELAY (All Pages in System)	
CH0 +1.0V - LTC2972	0,000 ms
CH1 +1.5V	0,000 ms
CH2 +2.5V - LTC2972	0,000 ms
CH3 +3.3V	10,000 ms

TON_RISE (All Pages in System)	
CH0 +1.0V - LTC2972	40,000 ms
CH1 +1.5V	40,000 ms
CH2 +2.5V - LTC2972	40,000 ms
CH3 +3.3V	20,000 ms

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



The channels cascade on/off via the CTRL0 switch on the DC2675A board, or command CH0's OPERATION register on/off. The LTC2972 configuration is such that the control_{n_sel} bit is set to its respective channel. The cascade_{on} bit is set for the three slave channels (CH1 to CH3) and cleared on the master channel (CH0).

To demonstrate cascade sequencing:

1. Set the three TRACK jumpers to SS on the DC2363A board.
2. Solder the 0Ω jumpers (R51, R52, R53) on the DC2675A board.
3. In LTpowerPlay, select Demo > DC2675A_cascade_seq from the GUI's menu.

TON_DELAY (All Pages in System)	
CH0 +1,0V - LTC2972	0,000 ms
CH1 +1,5V	50,000 ms
CH2 +2,5V - LTC2972	100,000 ms
CH3 +3,3V	150,000 ms

TOFF_DELAY (All Pages in System)	
CH0 +1,0V - LTC2972	0,000 ms
CH1 +1,5V	50,000 ms
CH2 +2,5V - LTC2972	100,000 ms
CH3 +3,3V	150,000 ms

SETUP PROCEDURE FOR MULTI-BOARD ARRAYS

Multiple DC2739As can be combined to control as many nine board pairs.

1. Connect DC2363A to DC2675A to pair them.
2. Connect the two board pairs together via the J4/J5 cascading connectors.
3. Set unique addresses for each LTC2972 in the array using ASELO and ASEL1 jumpers. See the following section for further details.
4. Plug the ribbon cable of the DC1613 into one of the DC2675As.
5. Connect a power supply to each of the DC2363A boards. Power is not distributed to other board pairs via the J4/J5 cascading connector.

Selecting a Device Address

The DC2675A jumpers are labeled ASELO and ASEL1 which allow the user to select one of nine I²C addresses.

The LTC2972 labeled U0 has two jumpers (JP2, JP3) and U1 has two jumpers (JP4, JP5). The I²C/SMBus address of the LTC2972 equals the base address + N where N is a number from 0 to 8. N is configured by setting the ASELO and ASEL1 pins to V_{DD33}, GND or FLOAT. See Table 2. Using one base address and the nine different values of N, nine LTC2972s can coexist on the same I²C bus to control 18 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.

SETUP PROCEDURE FOR MULTI-BOARD ARRAYS

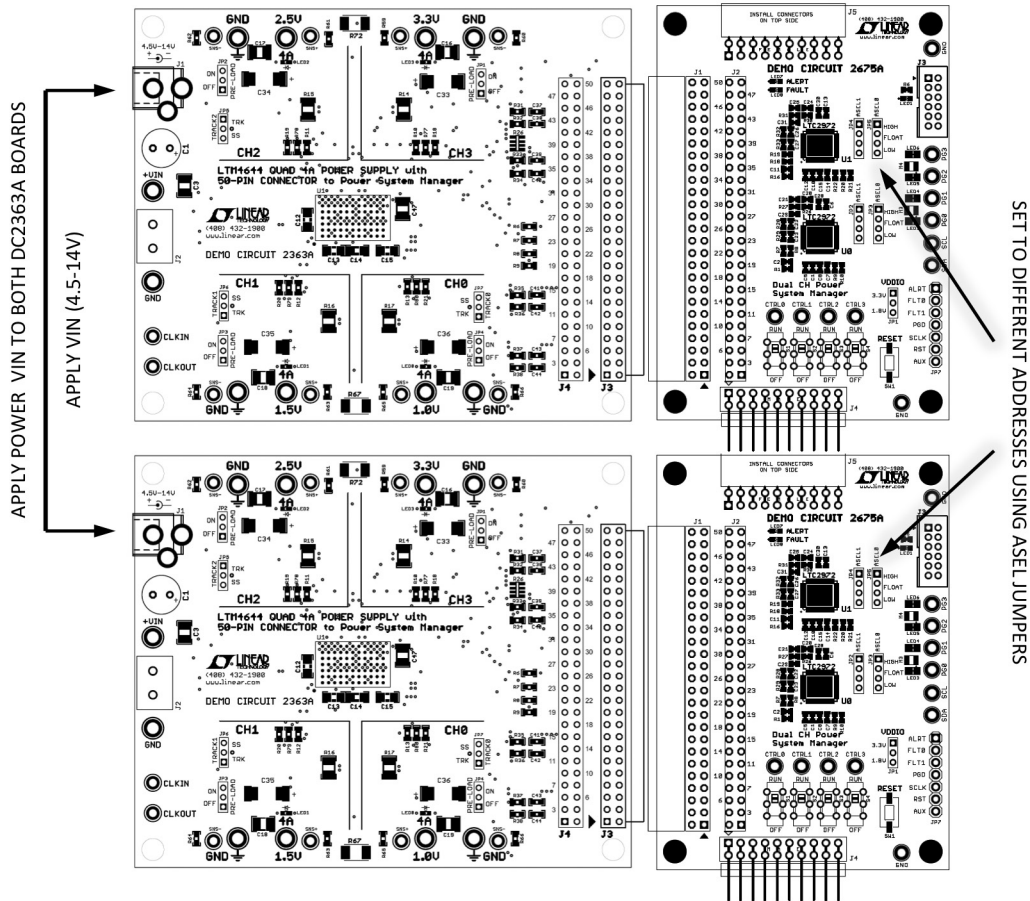
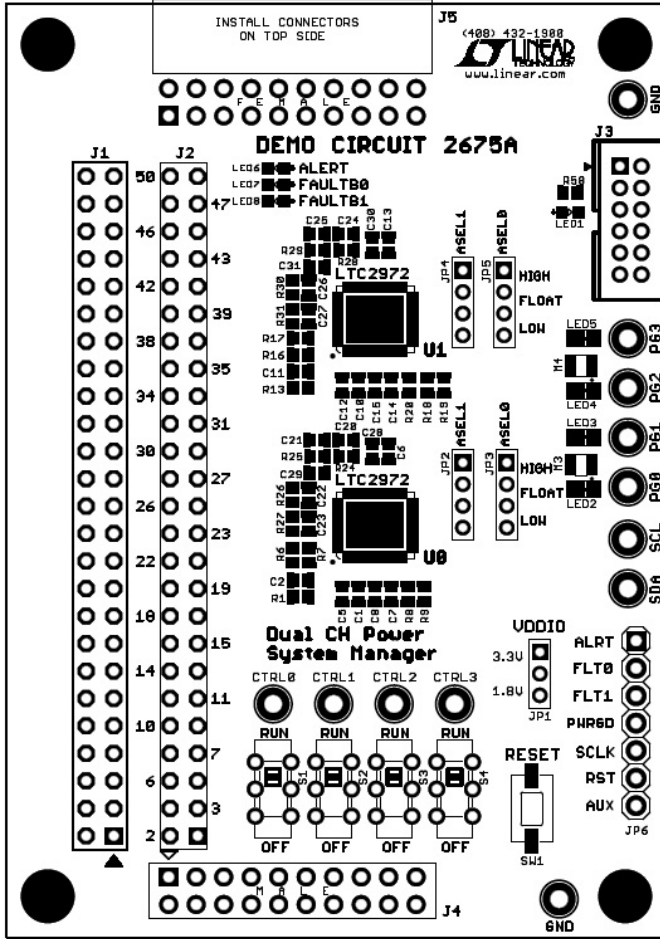


Figure 16. Array of Multiple Board Sets

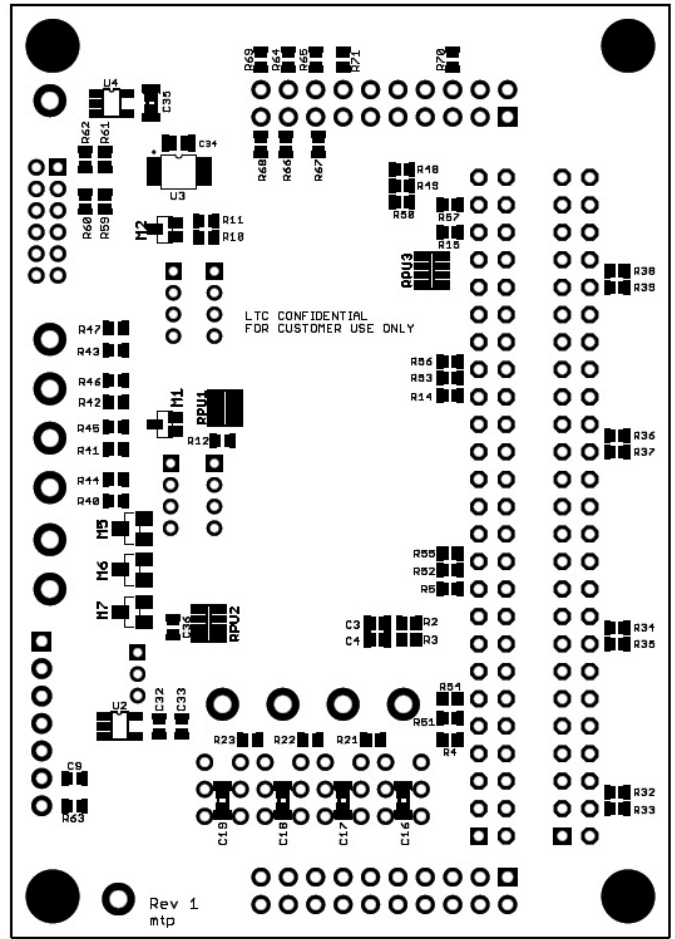
Table 2. Address Selection of LTC2972 Devices

I ² C ADDRESS (7-BIT)	U0			U1		
	ASEL1	ASEL0	DEFAULT	ASEL1	ASEL0	DEFAULT
0x5C	L	L	✓	L	L	
0x5D	L	Z		L	Z	✓
0x5E	L	H		L	H	
0x5F	Z	L		Z	L	
0x60	Z	Z		Z	Z	
0x61	Z	H		Z	H	
0x62	H	L		H	L	
0x63	H	Z		H	Z	
0x64	H	H		H	H	

DC2675A PCB LAYOUT



DC2675A Top Layer

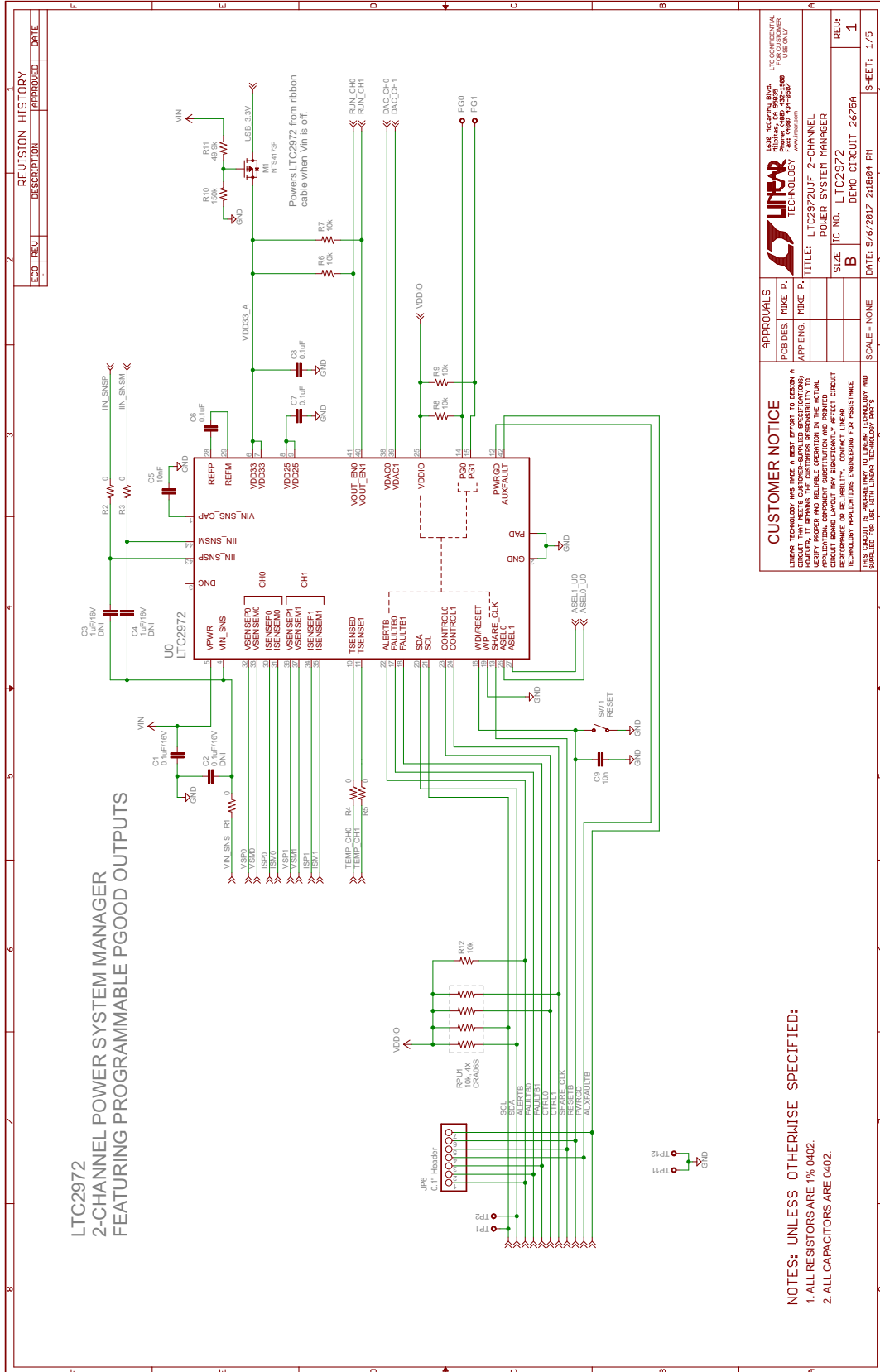


DC2675A Bottom Layer

Table 3. Default Jumper and Switch Configuration

REFERENCE DESIGNATOR	SIGNAL NAME	USAGE	DEFAULT
JP2, JP3	ASEL0, ASEL1	Set the address offset of U0 (LTC2972).	Low, Low
JP4, JP5	ASEL0, ASEL1	Set the address offset of U1 (LTC2972).	Low, Float
R21, R22, R23	CTRL0, CTRL1, CTRL2, CTRL3	0Ω jumpers R21 to R23 may be populated to connect CTRL switches together to support tracking by using CH3 as master.	All DNI
R51, R52, R53	CTRL1, CTRL2, CTRL3	0Ω jumpers R51 to R53 may be populated to implement cascade sequencing by connecting power good signals from DC2363 to the control pins.	All DNI
S1, S2, S3, S4	CTRL0, CTRL1, CTRL2, CTRL3	Switches used to enable channels. Switch behavior is dependent on 0Ω jumper settings R21 to R23.	HI, HI, HI, HI

DC2675A SCHEMATIC DIAGRAM



ECO ID	REV	DESCRIPTION	APPROVED	DATE

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APPROVALS
PCB DES: []
APP ENG: []

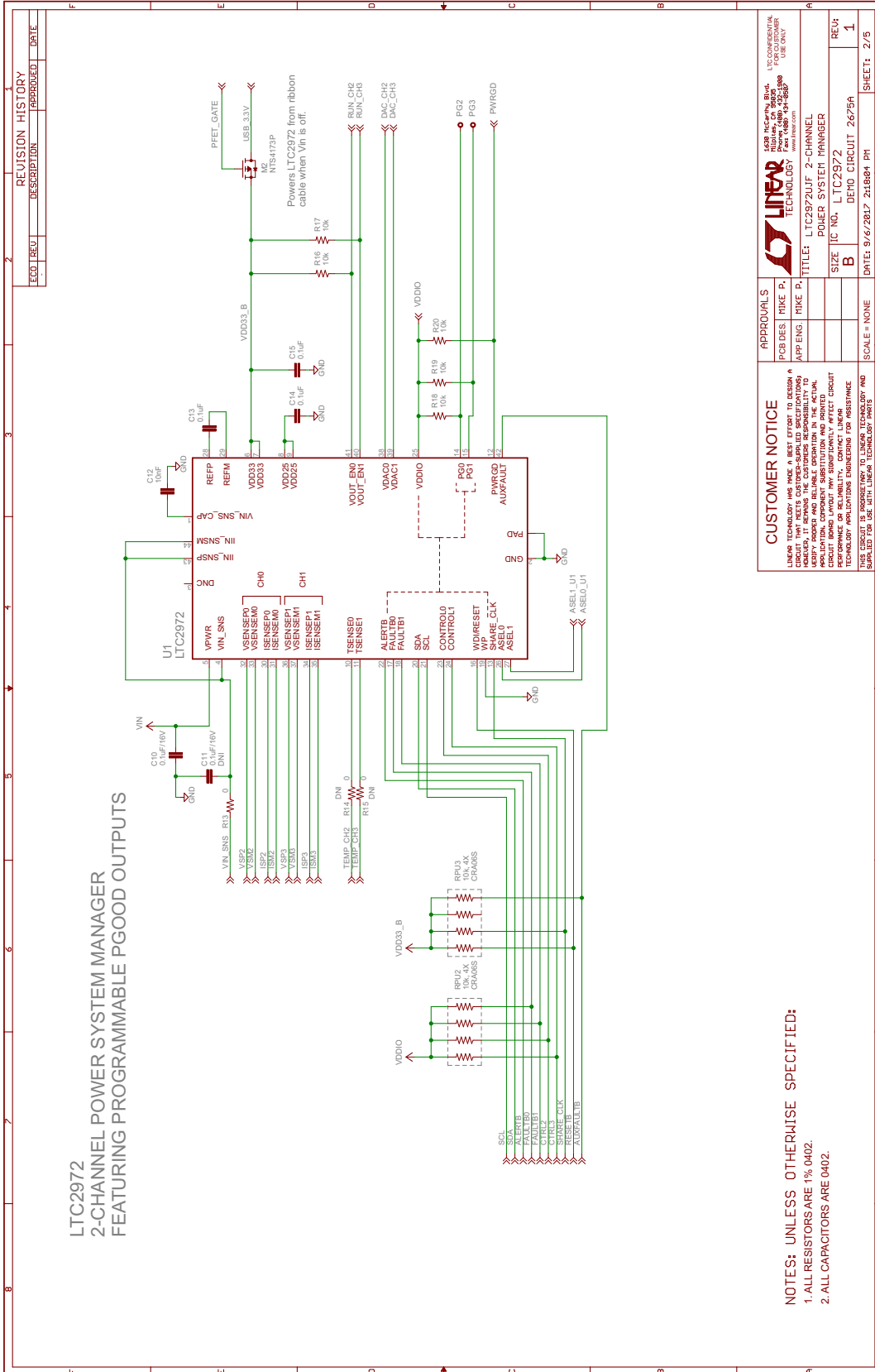
LINEAR TECHNOLOGY
4330 McCarty Blvd.,
Folsom, CA 95630
Phone: 916.961.6000
Fax: 916.961.6001
www.linear.com

TITLE: LTC2972UUF 2-CHANNEL POWER SYSTEM MANAGER
SIZE: IC NO. LTC2972
SCALE: NONE
DATE: 9/6/2017 21:08:04 PM

REU: 1
DEMO CIRCUIT: 26278A
SHEET: 1/5

DEMO MANUAL DC2739A

DC2675A SCHEMATIC DIAGRAM

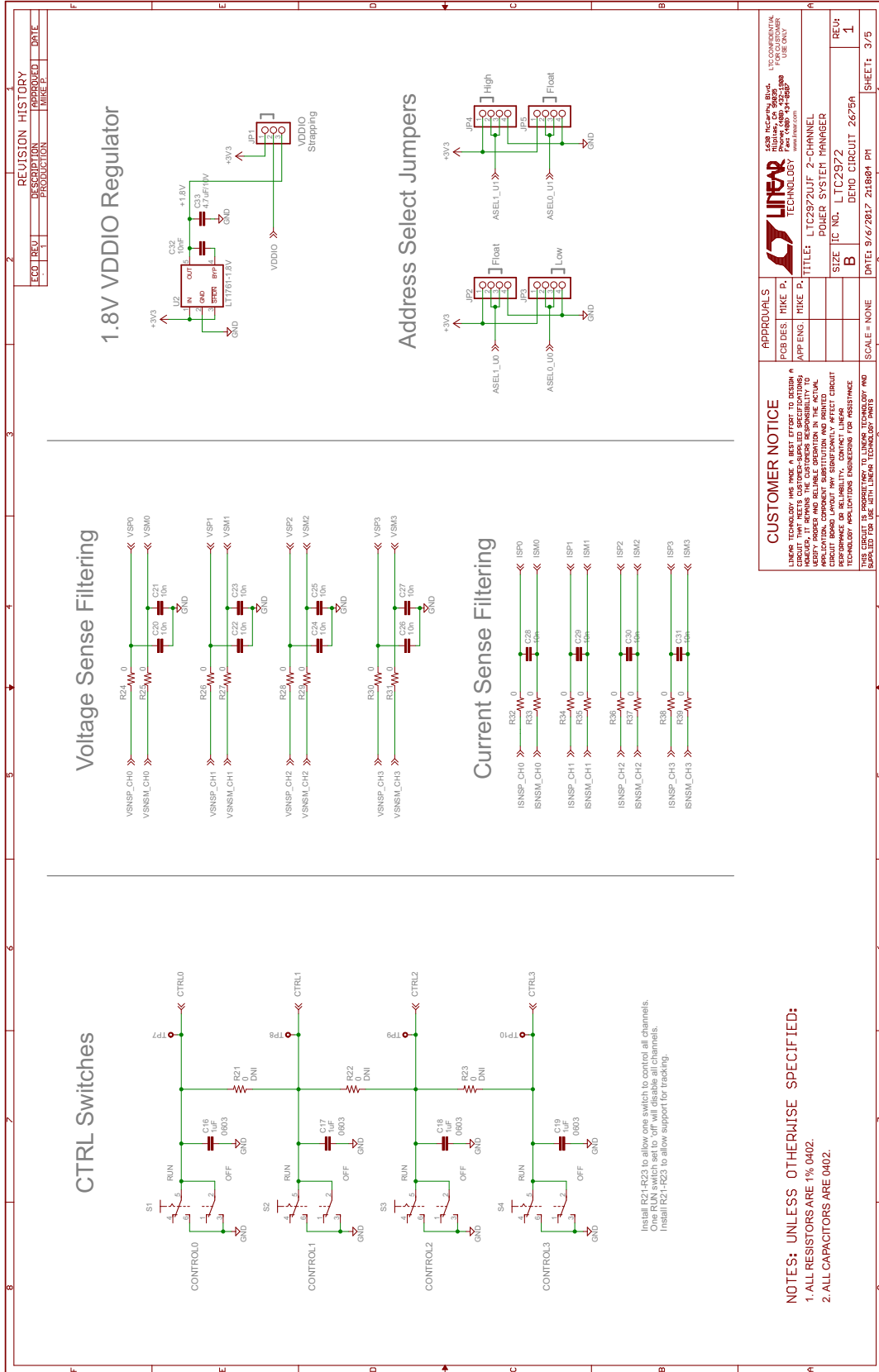


ECO1	REV1	DESCRIPTION	APPROVED	DATE

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<p>LINEAR TECHNOLOGY AND ITS DESIGNATED DISTRIBUTORS MAKE NO REPRESENTATION OR WARRANTY, EITHER EXPRESS OR IMPLIED, THAT THIS CIRCUIT MEETS YOUR APPLICATIONS. YOU ARE RESPONSIBLE FOR VERIFYING THAT THIS CIRCUIT MEETS YOUR APPLICATIONS. YOU AGREE TO HOLD LINEAR TECHNOLOGY HARMLESS FROM ANY AND ALL CLAIMS, DAMAGES, LOSSES AND EXPENSES, INCLUDING REASONABLE ATTORNEY'S FEES, ARISING FROM OR OUT OF YOUR USE OF THIS CIRCUIT, WHETHER OR NOT SUCH CLAIMS, DAMAGES, LOSSES AND EXPENSES ARE CAUSED IN WHOLE OR IN PART BY A DEFECTIVE PRODUCT.</p>			
FCB DES:	MIKE P.	APPROVED:	MIKE P.
APPENS:		TITLE:	LTC2972UJF 2-CHANNEL POWER SYSTEM MANAGER
SIZE:	B	IC NO.:	LTC2972
REV:	1	DATE:	9/6/2017 2:18:04 PM
SCALE:	NONE	SHEET:	2/5

NOTES: UNLESS OTHERWISE SPECIFIED:
 1. ALL RESISTORS ARE 1% 0402.
 2. ALL CAPACITORS ARE 0402.

DC2675A SCHEMATIC DIAGRAM



REVISION HISTORY

ECO#	REV	DESCRIPTION	DATE
	1	PRODUCTION	

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APPROVALS

PCB DES	HKR P.
APP ENG	HKR P.

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 6090 Rockledge Blvd.,
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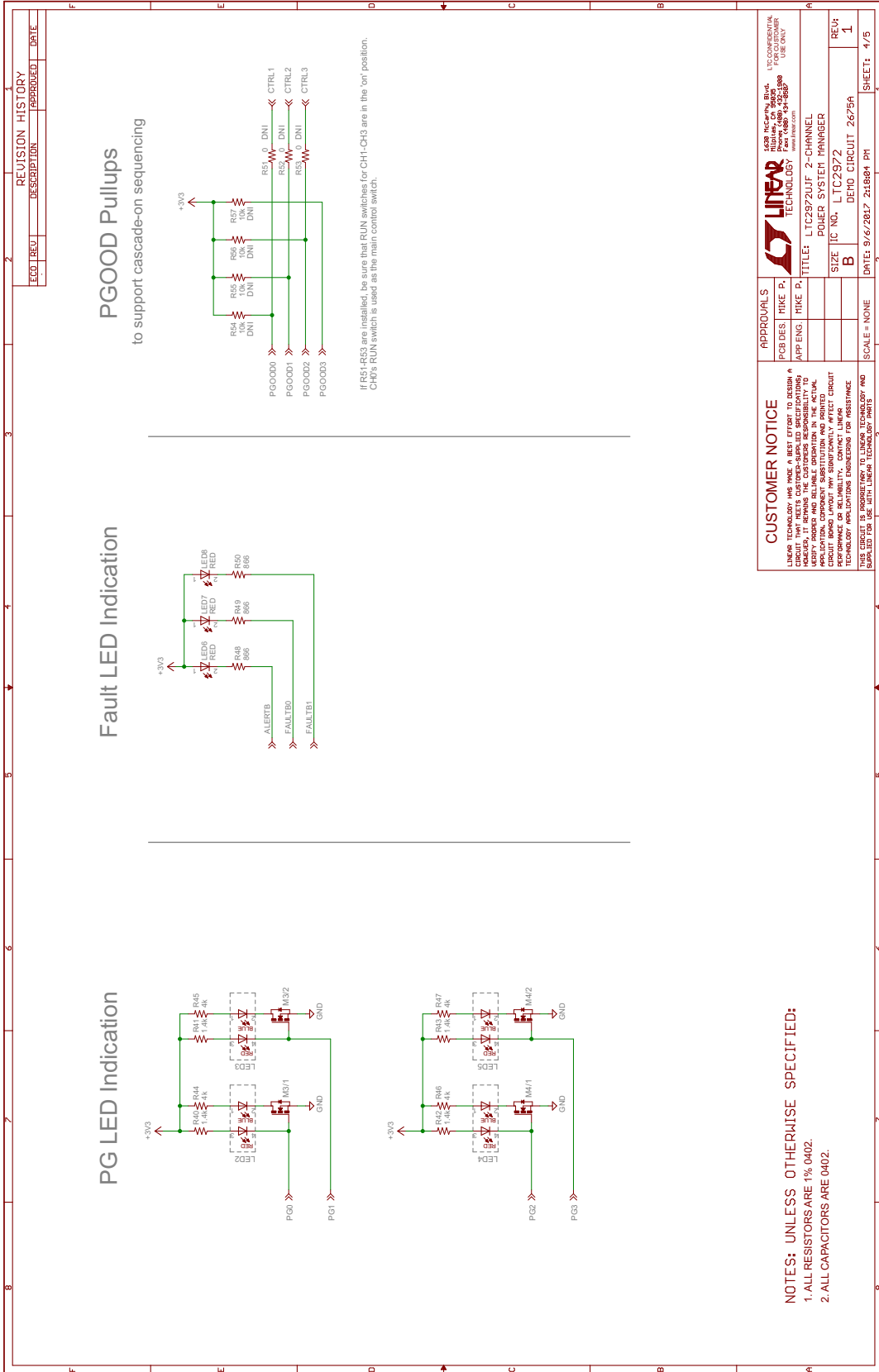
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SCALE: NONE
DATE: 9/6/2017 21:08:01 PM
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SHEET: 3/5

NOTES: UNLESS OTHERWISE SPECIFIED:
 1. ALL RESISTORS ARE 1% 0402.
 2. ALL CAPACITORS ARE 0402.

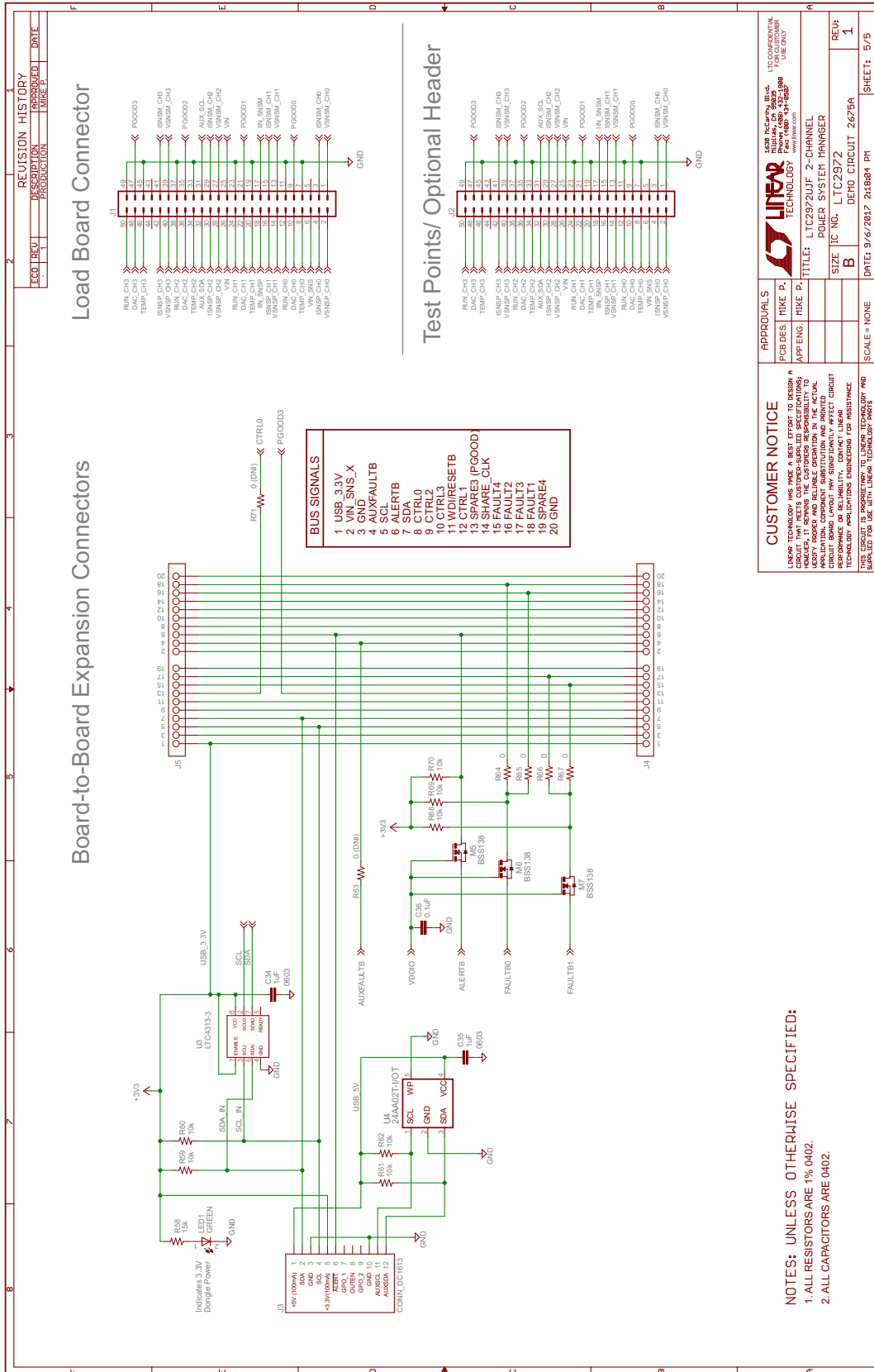
Install R21-R23 to allow one switch to control all channels.
 Install R24-R26 to allow one switch to control two channels.
 Install R27-R29 to allow support for tracking.

DEMO MANUAL DC2739A

DC2675A SCHEMATIC DIAGRAM

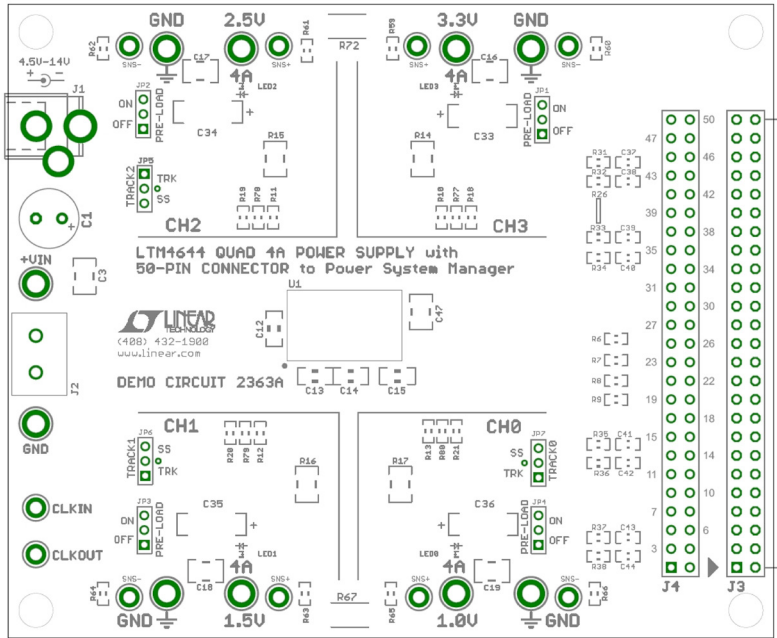


DC2675A SCHEMATIC DIAGRAM

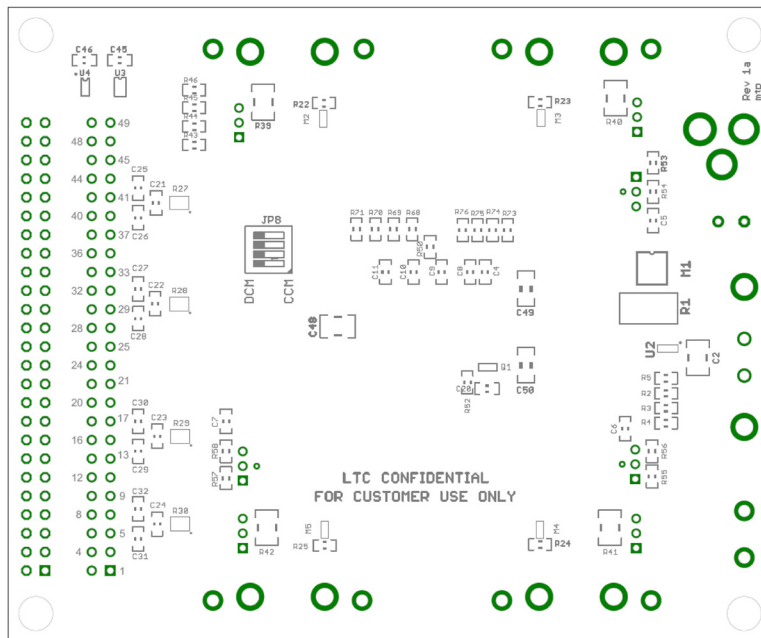


DEMO MANUAL DC2739A

DC2363A PCB LAYOUT



DC2363A Top

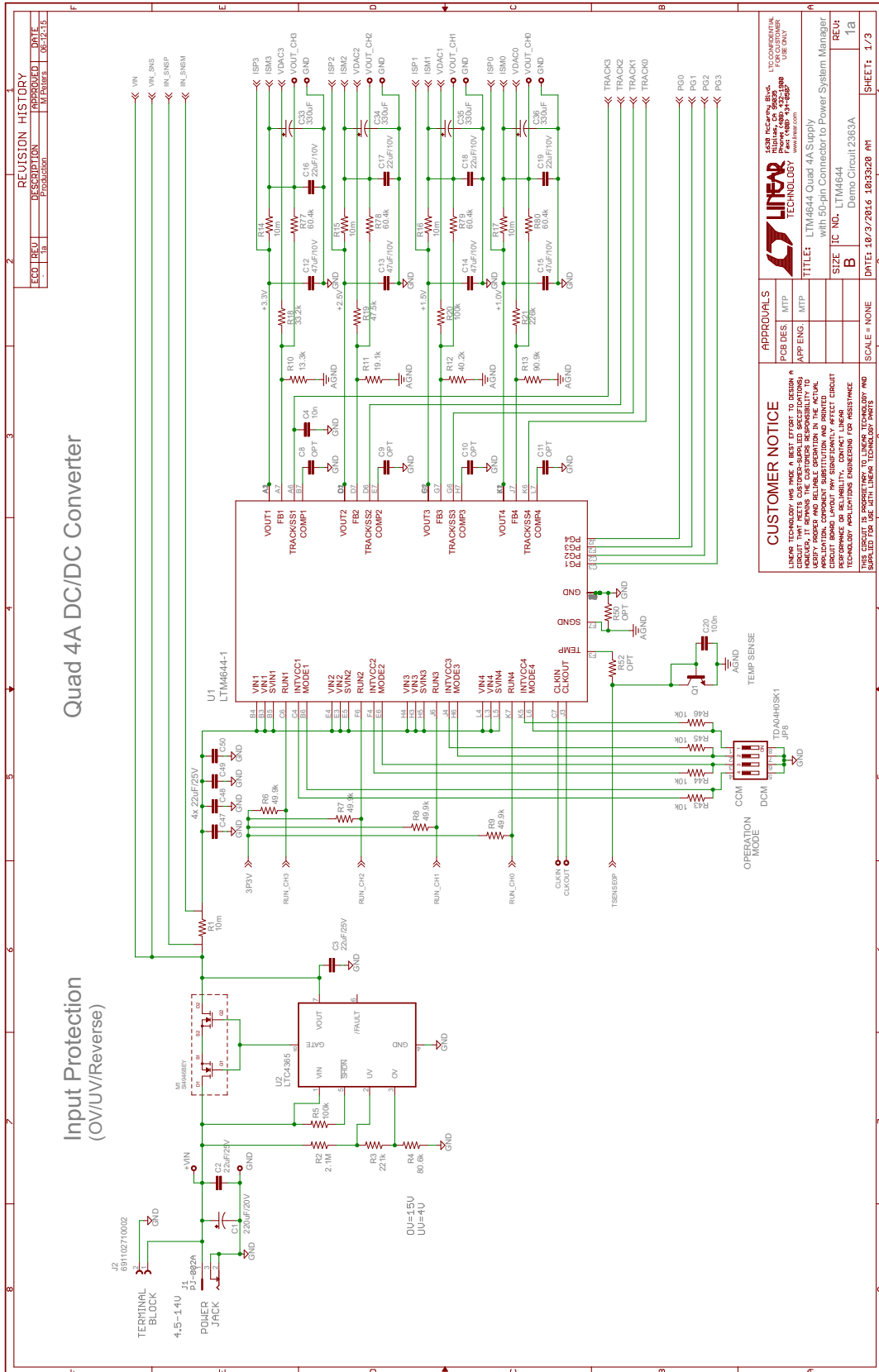


DC2363A Bottom

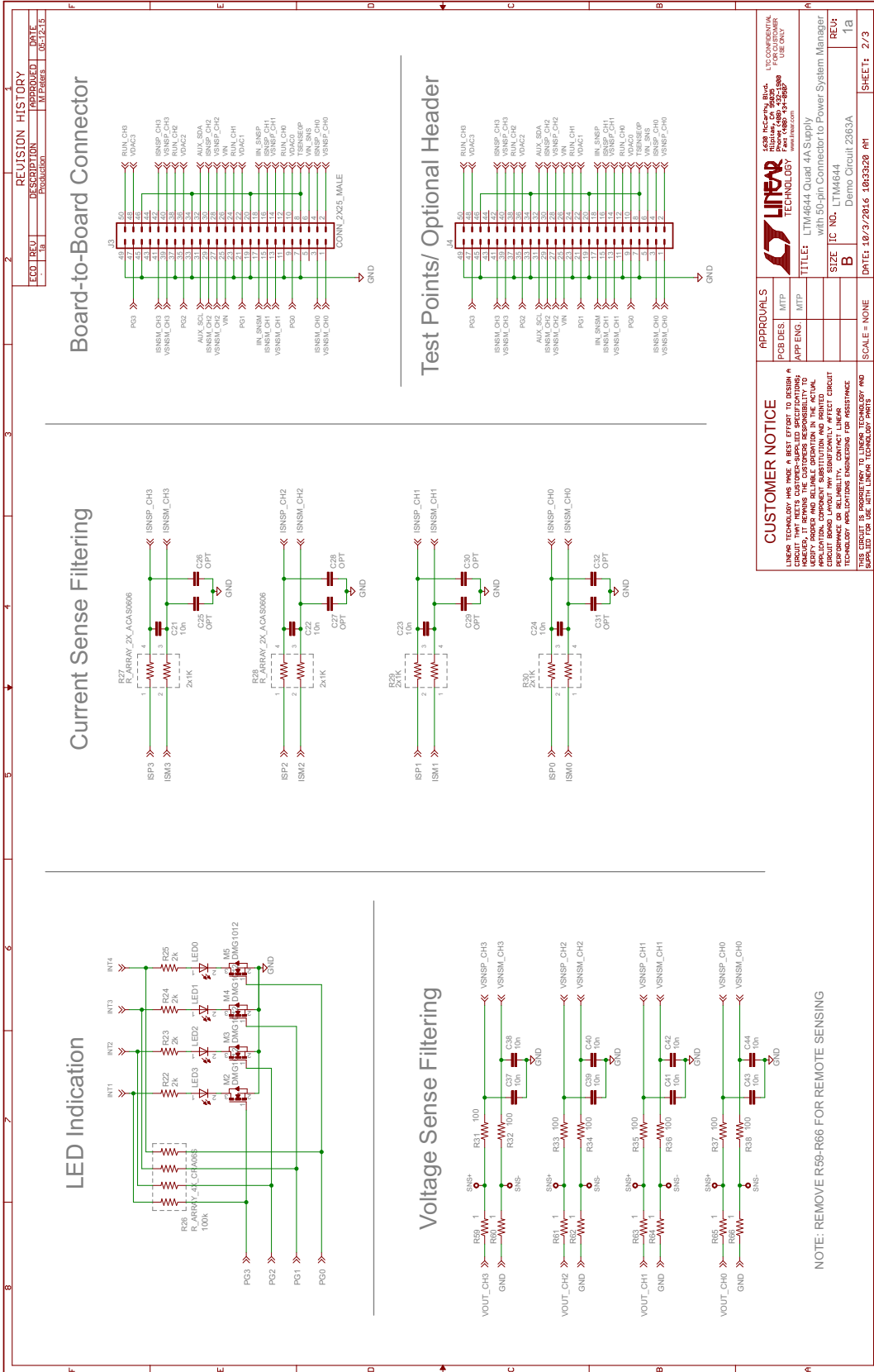
Table 4. Default Jumper Settings

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

DC2363A SCHEMATIC DIAGRAM



DC2363A SCHEMATIC DIAGRAM

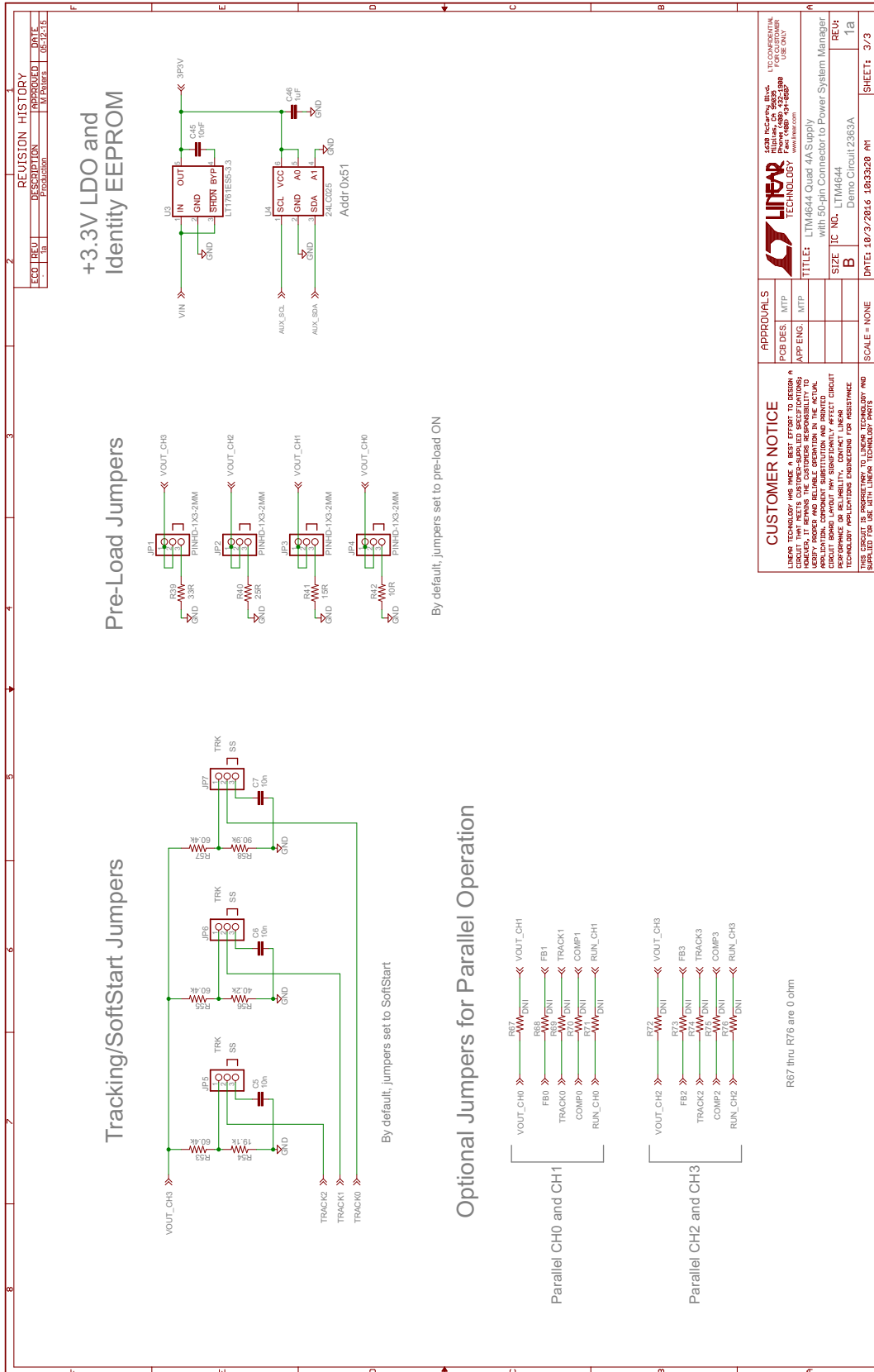


REVISION HISTORY	
ECO#	DESCRIPTION
1	Initial Release
2	Update to Rev. 1.1
3	Update to Rev. 1.2
4	Update to Rev. 1.3
5	Update to Rev. 1.4
6	Update to Rev. 1.5
7	Update to Rev. 1.6
8	Update to Rev. 1.7
9	Update to Rev. 1.8
10	Update to Rev. 1.9
11	Update to Rev. 2.0
12	Update to Rev. 2.1
13	Update to Rev. 2.2
14	Update to Rev. 2.3
15	Update to Rev. 2.4
16	Update to Rev. 2.5
17	Update to Rev. 2.6
18	Update to Rev. 2.7
19	Update to Rev. 2.8
20	Update to Rev. 2.9
21	Update to Rev. 3.0
22	Update to Rev. 3.1
23	Update to Rev. 3.2
24	Update to Rev. 3.3
25	Update to Rev. 3.4
26	Update to Rev. 3.5
27	Update to Rev. 3.6
28	Update to Rev. 3.7
29	Update to Rev. 3.8
30	Update to Rev. 3.9
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37	Update to Rev. 4.6
38	Update to Rev. 4.7
39	Update to Rev. 4.8
40	Update to Rev. 4.9
41	Update to Rev. 5.0
42	Update to Rev. 5.1
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49	Update to Rev. 5.8
50	Update to Rev. 5.9

APPROVALS	DATE: 10/3/2014 10:32:28 AM	SHEET: 2/3
FCB DES: MTP		
APP ENG: MTP		
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<p>APPROVALS</p> <p>FCB DES: MTP</p>		
<p>APP ENG: MTP</p>		
<p>TITLE: LTM4644 Quad 4A Supply</p>		
<p>with 50-pin Connector to Power System Manager</p>		
<p>IC NO. LTM4644</p>		
<p>SIZE: 1a</p>		
<p>REV: 1a</p>		
<p>SCALE: NONE</p>		

NOTE: REMOVE R59-R66 FOR REMOTE SENSING

DC2363A SCHEMATIC DIAGRAM





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.

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