LTC2975

4-Channel Power Supply System Featuring the Power System Manager with Input Energy Accumulation

DESCRIPTION

The DC2022A is a demonstration system that showcases the LTC®2975, a 4-channel I²C/SMBus/PMBus power system manager with EEPROM. The LTC2975 monitors and controls four power supply rails. The LTC2975 also monitors input current and input voltage, which are used to calculate input power and accumulate energy. The DC2022A 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 is monitored and the LTC2975 monitors its own internal die temperature.

The DC2022A is a single circuit board that contains four independent power supply rails. The board employs four LTC3405A 300mA switch-mode regulators, which are configured to be controlled by the LTC2975. The DC2022A demo board provides a sophisticated 4-channel digitally programmable power supply system. The rail voltages are programmable within the trim range shown in the Performance Summary table.

This demonstration system is supported by the LTpowerPlay™ graphical user interface (GUI) which enables complete control of all the features of the device. Together, the LTpowerPlay software and DC2022A hardware system create a powerful development environment for designing and testing configuration settings of the LTC2975. These settings can be stored in the device's internal EEPROM or in a file. This file can later be used to order pre-programmed devices or to program devices in a production environment. 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 DC2022A. Just plug and play!

Multiple DC2022A boards can be cascaded together to form a high channel count power supply (see the Multi-Board Arrays section). This cascaded configuration demonstrates features of the LTC Power System Management ICs which enable timing and fault information to be shared across multiple power system management ICs. The user can configure up to eight DC2022A boards, thereby controlling up to 32 separate power supply rails. Larger board arrays can be built using programmable I²C base addresses or bus segmentation.

The DC2022A demo board can be powered by an external power supply, such as a +12VDC supply. Communication with the software is provided through the DC1613 USB-to-I²C/SMBus/PMBus Controller. The following is a checklist of items which can be obtained from the LTC website or LTC Field Sales.

■ USB-to-I²C/SMBus/PMBus Controller (DC1613)

■ LTpowerPlay Software

Design files for this circuit board are available at http://www.linear.com/demo/DC2022A

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
- Supports Multi-Channel Fault Management
- Automatic Fault Logging to Internal EEPROM
- Operates Autonomously without Additional SW
- Telemetry Reads Back V_{IN}, V_{OUT}, and Temperature
- 4-Channel Time-Based Output Sequencer
- I^2C/SMBus Serial Interface
- Powered from 6V to 14V
- LTC2975 Available in 64-Lead QFN Package

PERFORMANCE SUMMARY

Specifications are at T_A = 25°C. Common characteristics specifications valid over full operating temperature range.

POWER SUPPLY CHANNEL	CH(0:3)
Manager/Controller	LTC2975
Nominal Untrimmed Output Voltages	1.5V, 1.8V, 2.5V, 3.3V
Rated Output Current	0.3A
Default Margin Range	±5%
Output Trim Range (V_{FS_VDAC} = 1.38V)	+15%/–11%
Temperature	±1°C Internal

Common Characteristics

PARAMETER	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Input Voltage Range		6		14	V
ADC Total Unadjusted Error	$V_{IN\_ADC} \geq 1V$			±0.25	%
ADC Voltage Sensing Input Range	Differential Voltage: V_{IN_ADC} = ($V_{SENSEP[n]}$ – $V_{SENSEM[n]}$)	0		6	V

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.

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 power supply controller manages.

Supervise – The act of quickly responding (warning or faulting) to a voltage, current, temperature 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.

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 PMBus 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 can also be used in an offline mode (with no hardware present) in order to build a multi-chip configuration file that can be saved and re-loaded at a later time. 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 manage-

ment scheme in a system or to diagnose power issues when bringing up rails. LTpowerPlay utilizes the DC1613 I^2C/SMBus/PMBus Controller to communicate with one of many potential targets, including the DC2022A demo system or a customer board. The software also provides an automatic update feature to keep the software current with the latest set of device drivers and documentation. The LTpowerPlay software can be downloaded from:

http://www.linear.com/ltpowerplay

To access technical support documents for LTC Power System Management Products visit "Help, View Online help" on the LTpowerPlay menu.
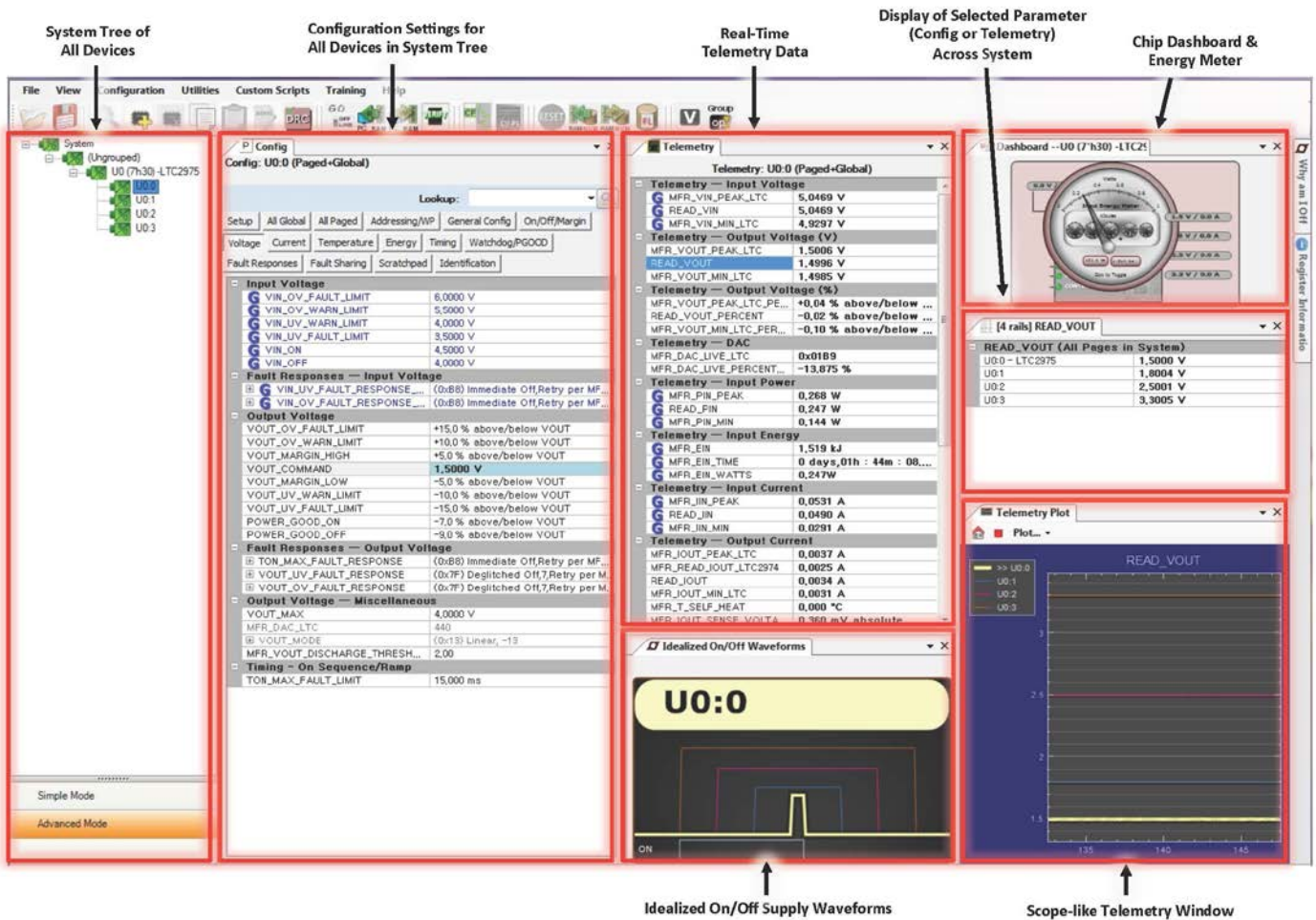

Figure 1. Screenshot of the LTpowerPlay GUI

QUICK START PROCEDURE

The following procedure describes how to set up a DC2022A 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 I^{2}C/SMBus/PMBus Controller to the DC2022A board using the 12-pin ribbon cable.

3. Confirm that the CONTROL switch is set to the RUN position.

4. Plug the USB-to-I^{2}C/SMBus/PMBus Controller into a USB port on your PC. The board should power up with all power good LEDs and 5V LED illuminated green. The USB-to-I^{2}C/SMBus/PMBus Controller supplies ~100mA of current which should be sufficient for a single demo board.

5. If multiple boards are being powered, connect a +12VDC power supply with > 0.5A capacity to the V$_{IN}$ input jack of the DC2022A.

6. Launch the LTpowerPlay GUI.

a. The GUI automatically identifies the DC2022A and builds a system tree for each power manager. The system tree on the left hand side will look as shown below.

Note: For multiple board arrays, the GUI automatically ensures each device has a unique address. In this scenario, it is recommended at this point to store these addresses to NVM (EEPROM) by clicking the RAM to NVM icon in the toolbar.
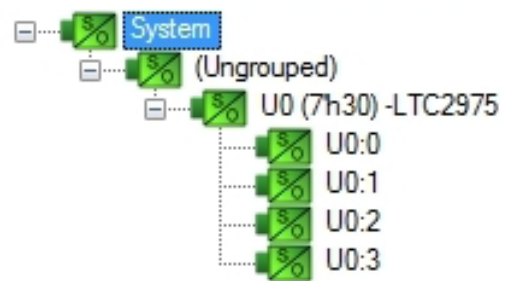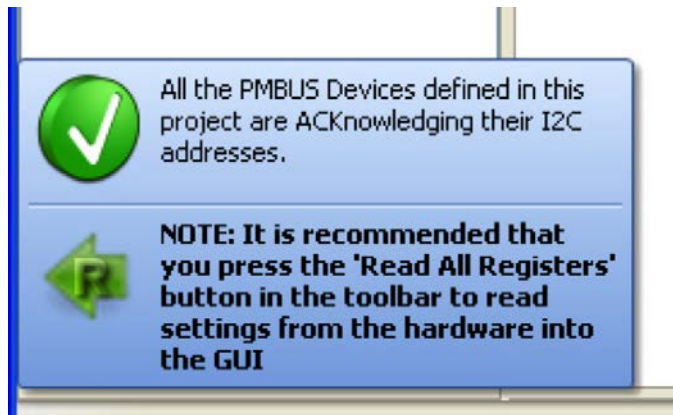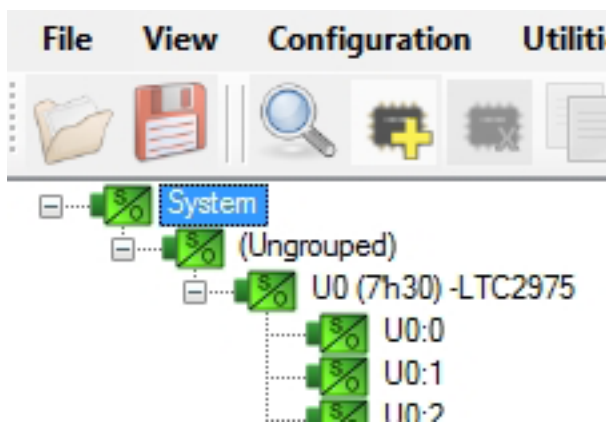

Figure 2. Connecting DC2022A Board and the DC1613 I^{2}C/SMBus/PMBus Controller

QUICK START PROCEDURE

b. A green message box will be displayed momentarily in the lower left hand corner confirming that the DC2022A is communicating.

c. Save the demo board configuration to a (*.proj) file by clicking the "Save" icon. This creates a backup file. Name it whatever you want.

7. The CONTROL switch is configured to control all 4 channels. Slide the switch to RUN to enable, OFF to disable all channels. For multiple board arrays, the CONTROL switch is wired to a signal that is common across all boards. All CONTROL switches must be set to the RUN position to enable all boards.

Loading a DC2022A Configuration (*.proj) File with the GUI

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 . 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 .
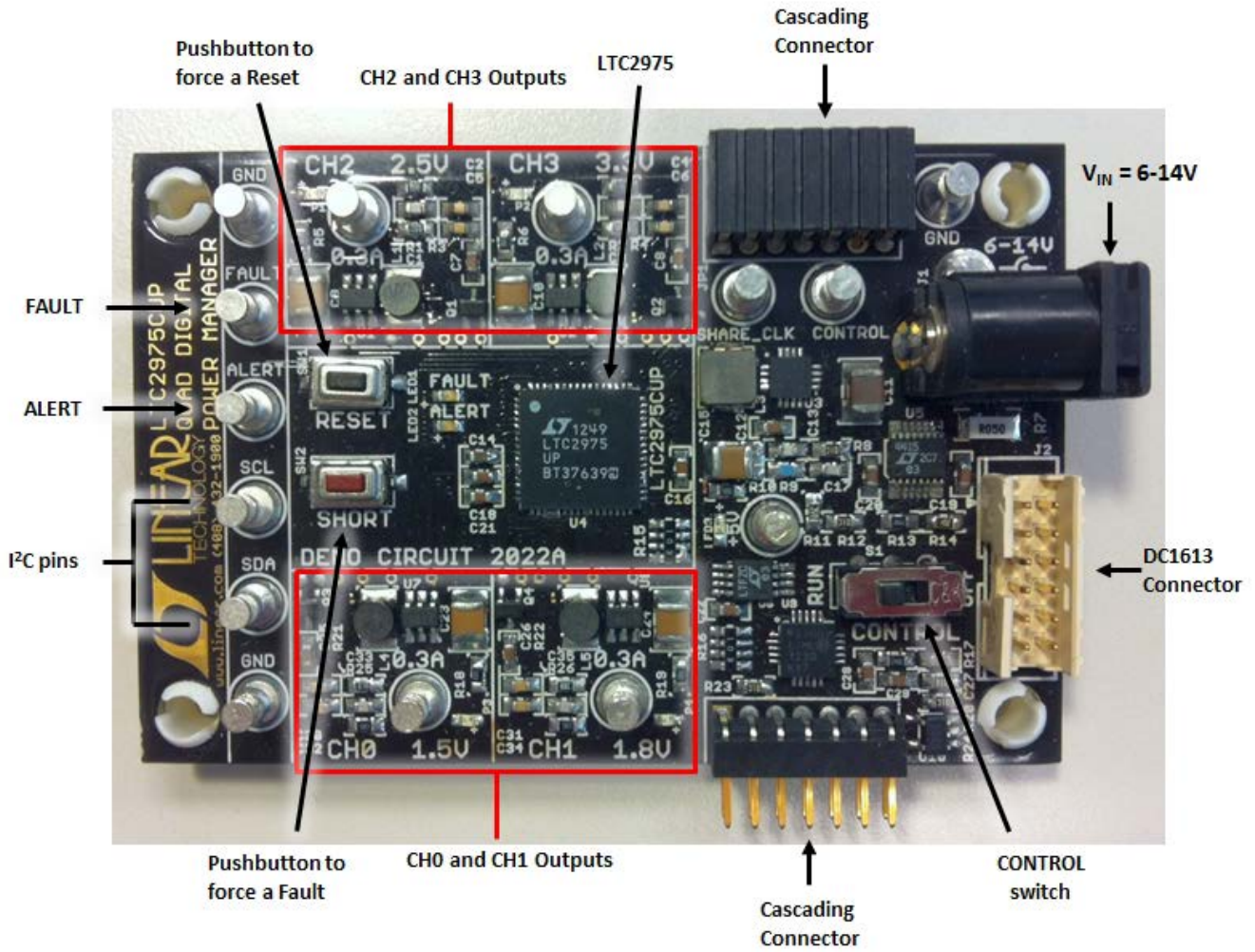
DETAILS - TOP SIDE

Figure 3. DC2022A Top Side Details

COMMON DEMO BOARD OPERATIONS

Margin All Rails

The LTC2975 power manager on the DC2022A 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 either 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.
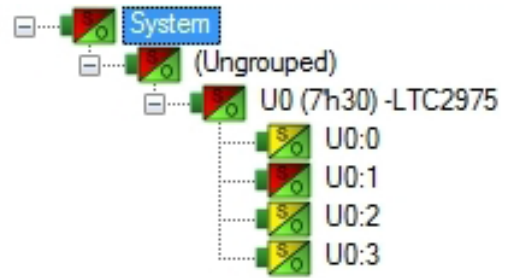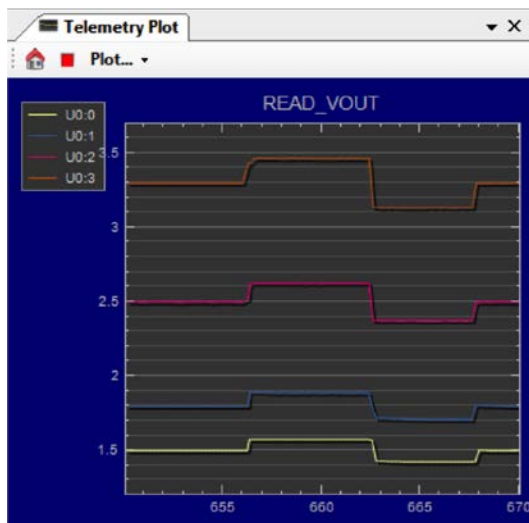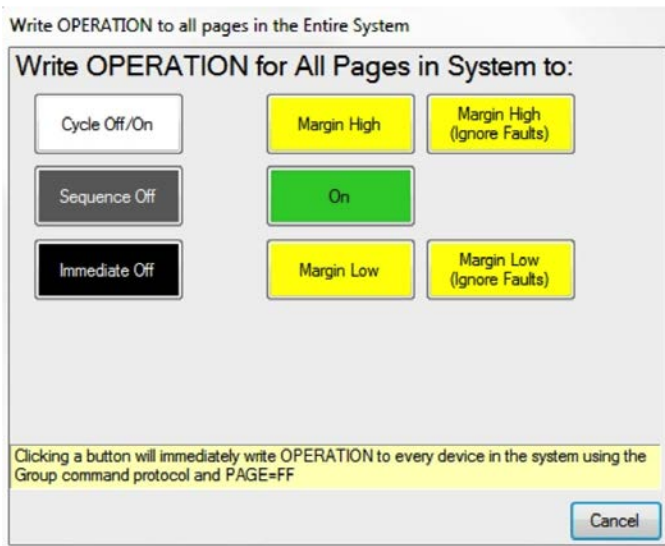
A look at the telemetry window shows the effect of the margin high or margin low operation. The following screen shot shows all rails going from nominal setpoints to margin high, margin low, and back to nominal voltages.

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. The total ADC loop time (~100ms to 160ms) for a given channel is dependent on the device's configuration.

Creating a Fault

There is a pushbutton on the DC2022A board that is used to force a fault and demonstrate the demo board's ability to detect it and respond according to the configuration. When depressed, the pushbutton creates a fault (short to ground) on channel 3, the 3.3V output (GUI channel U0:3). The user 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. The user 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. Use a jumper wire or a coin to short any output.

Clearing a Fault

To clear a fault, the user may click the CF icon in the GUI or simply push the RESET pushbutton on the demo board. In both cases, the red (+) on the CF icon and alert LED on the board will be cleared. You will notice that all rails are automatically re-enabled after a programmable retry period. The alert LED may be cleared by clicking the

COMMON DEMO BOARD OPERATIONS

clear faults (CF) icon in the GUI. After clearing faults, the system tree may remain yellow if any non-volatile fault logs are present. For further information, see the Working with the Fault Log section.

Resetting the DC2022A

A reset pushbutton is provided on the board. To reset all devices on the DC2022A board and reload the EEPROM contents into operating memory (RAM), press RESET (SW1) on the DC2022A.

DC2022A LEDs

Each individual channel on DC2022A also has its own green power good LED (CH0 through CH3). When USB power (DC1613 Controller) or external power (6V to 14V jack) is applied, the +5V green LED will illuminate, indicating that the LTC2975 power system manager is powered. The red LEDs will illuminate when an alert or a fault has occurred.

Sequencing Output Channels

The LTC2975 has been pre-configured with different TON_DELAY values for each channel. The TON_DELAY parameter is applied to each device relative to the respective CONTROL pin. When multiple demo boards are connected together, all CONTROL pins are wire OR'd. Therefore the TON delays are enforced relative to one edge. The same applies to TOFF_DELAY values. When the CONTROL switch is set to the OFF position, all rails will power down sequentially based on each of the device's TOFF_DELAY values. Figure 4 shows an oscilloscope screen capture of three output rails sequencing up and down in response to the CONTROL pin.

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 4 channels. For the LTC2975, the TON_DELAY and TOFF_DELAY values are limited to 655ms.
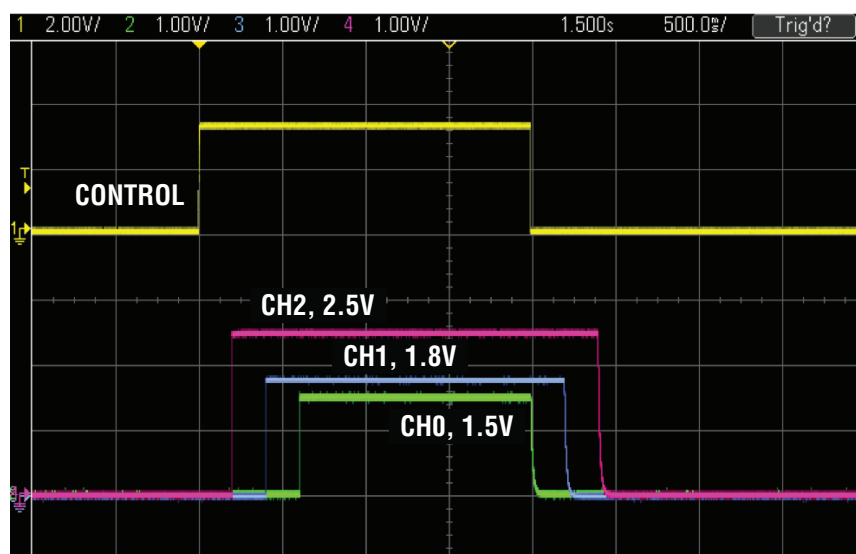

Figure 4. Sequencing Output Channels with DC2022A Using TON_DELAY and TOFF_DELAY

TON_DELAY (All Pages in System)	
U0:0 – LTC2975	600,000 ms
U0:1	400,000 ms
U0:2	200,000 ms
U0:3	0,000 ms

Figure 5. TON_DELAY Configuration

TOFF_DELAY (All Pages in System)	
U0:0 – LTC2975	0,000 ms
U0:1	200,000 ms
U0:2	400,000 ms
U0:3	600,000 ms

Figure 6. TOFF_DELAY Configuration

COMMON DEMO BOARD OPERATIONS

"Why Am I Off?" Tool

Use the "Why am I Off?" tool in the LTpowerPlay GUI to diagnose the reason a power supply channel is turned off.

The tool can be located in the top right corner of the GUI, above the "Register Information" tab. Hover your cursor over this tab to show the tool.
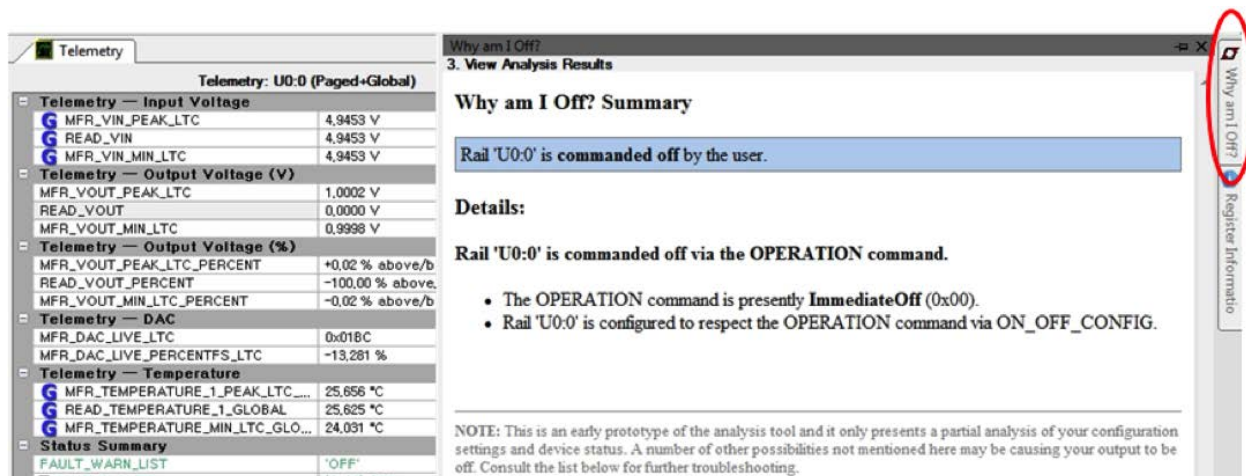

Figure 7. "Why Am I Off" Tool in the LTpowerPlay GUI

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. It holds the most recent monitored values (uptime, voltage, current, temperature) that can be analyzed to help determine the cause of the fault. It is a powerful diagnostic feature of the LTC2975 on the DC2022A demo board.
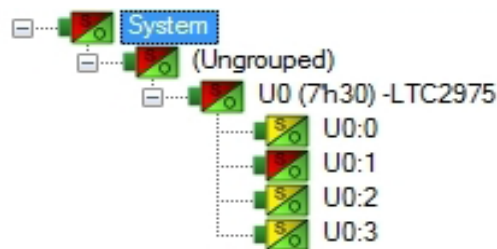
Create a Fault Log

To create a fault log, you must create a fault, as described in the Creating a Fault section. If multiple boards are configured, select the appropriate device in the system tree by clicking on the appropriate LTC2975 chip. We will proceed 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 context sensitive. If

multiple DC2022A boards are connected, be sure that the desired device is selected in the system tree.

Notice that the checkbox "Log to EEPROM on Fault" is checked. 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. To read the EEPROM log data, first click the "EEPROM to RAM" button. At this point the RAM Log is locked and not updated even though the telemetry readings continue. Click the "Read NVM Log" button. The log data will appear in the text box below.

dc2022af

ADVANCED DEMO BOARD OPERATIONS
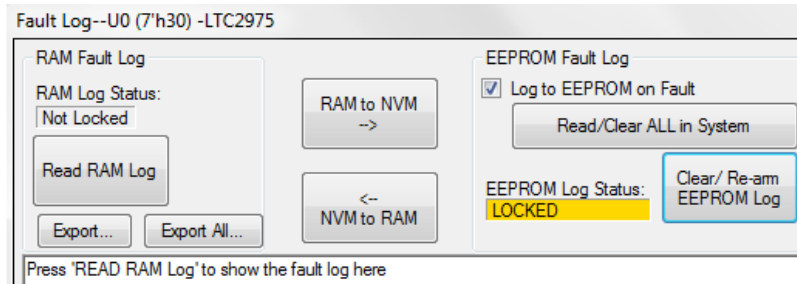
The log contains timestamp, up-time, channel voltage readings, an input voltage reading, an on-chip temperature reading, etc. There will be a number of loops; each loop contains data obtained in one ADC loop time with the most recent ADC loop data on top and the oldest data at the bottom of the log. 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 U0:7 faulted due to a VOUT_UV_FAULT condition. On the previous telemetry loop, the channel voltage reading was a nominal value (3.3V).

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.
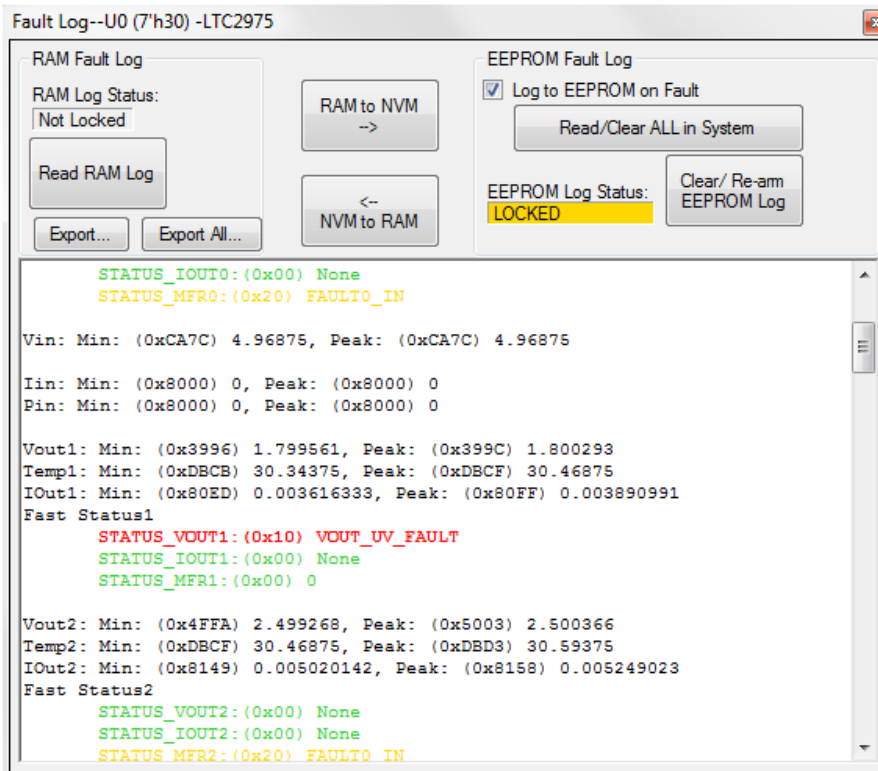
ADVANCED DEMO BOARD OPERATIONS

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.
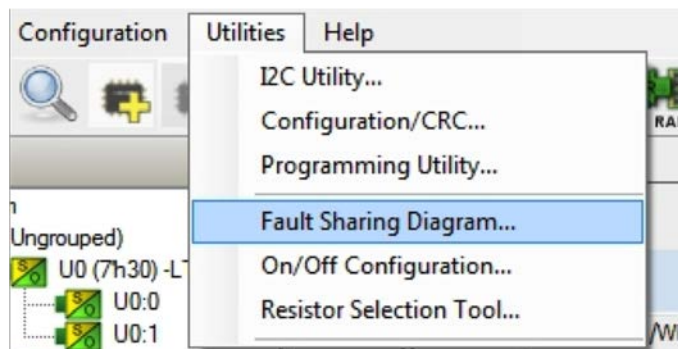
The fault sharing dialog will appear as shown in Figure 8. All Response and all Propagate switches are closed by default. In this configuration, a fault on a channel will shut down all LTC2975 channels, and a fault on any given channel will propagate to all channels on the DC2022A demo board since the fault pins are tied together.

NOTE: All FAULT pins of the LTC2975 are tied together on the DC2022A demo board. These pins are open drain and have a common pull-up resistor to provide a logic high level (inactive). All FAULT pins are active low.

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 all fault pins are wire OR'd on the DC2022A, this hardware configuration allows one to program each device's fault settings on a channel-by-channel basis. By default, the LTC2975 is configured to shut down its channels if other devices fault and to propagate its own fault via the FAULT pins. A fault on these channels will cause only that channel to fault off. You can think of the response switches as "shut this channel down when another channel faults," and the propagate switches as "drive a fault pin to broadcast to other channels that this channel faulted."
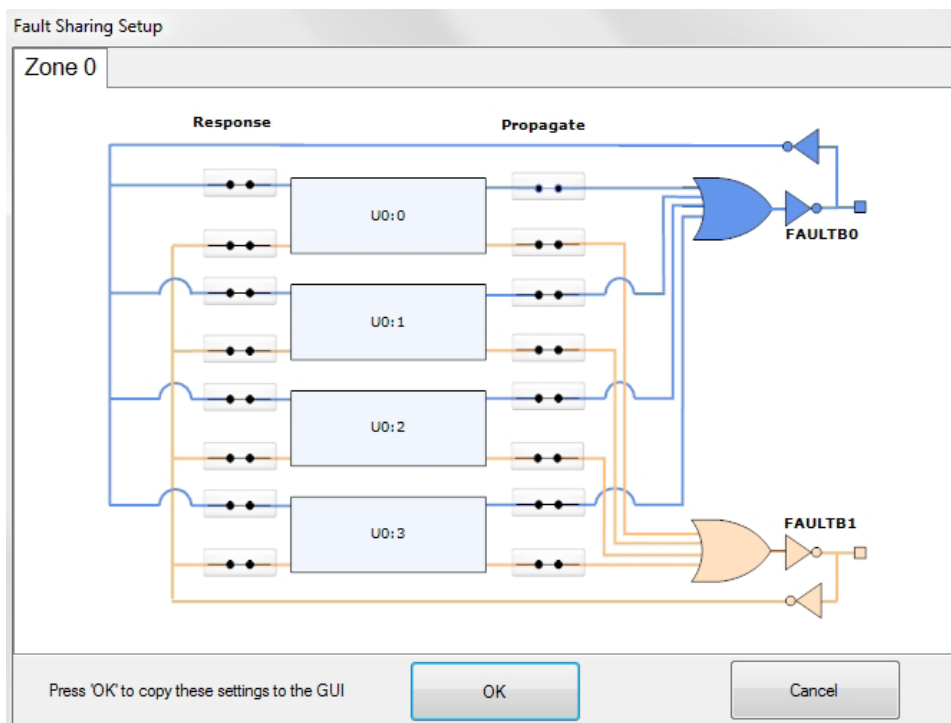

Figure 8. Fault Sharing Utility in LTpowerPlay GUI

ADVANCED DEMO BOARD OPERATIONS

Fault Configuration Example

Let's explore two different examples. Suppose we do not want channel U0:0 (CH0 1.5V rail) to propagate its fault to the other channels when it faults. And suppose we do not want channel U0:1 (CH1 1.8V rail) to shut down in response to another channel's fault. We can configure the switches as shown in Figure 9. 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 DC2022A.

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.

Energy Metering

In the LTC Power System Manager family, the LTC2975 employs a new feature: high-side current sensing of the input power supply. This feature allows the manager to measure input supply current. The manager also measures
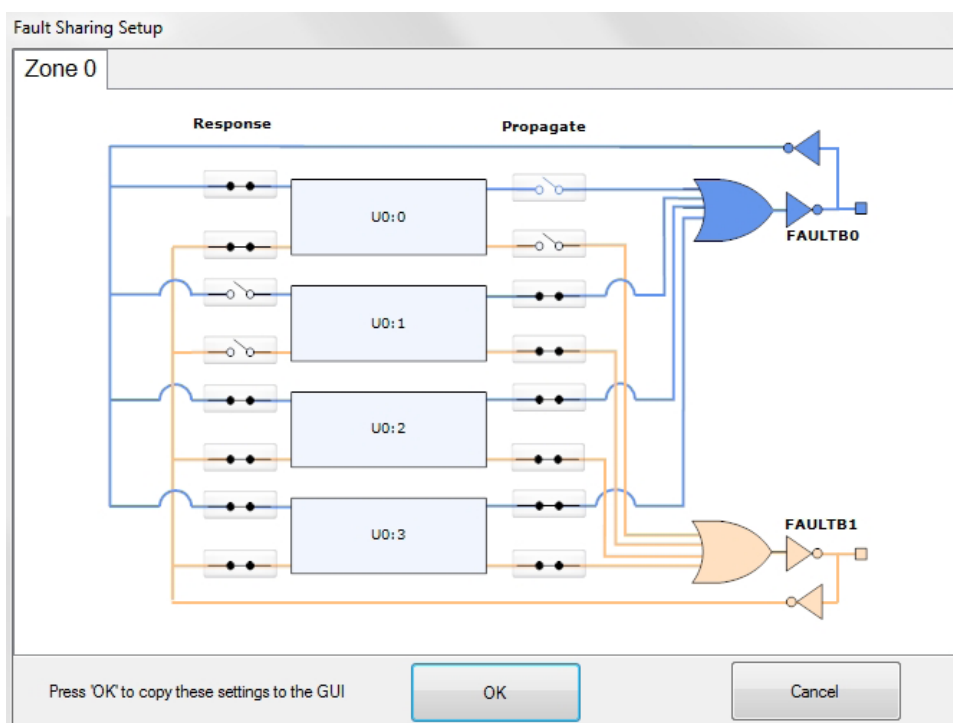

Figure 9. Updated Fault Sharing Configuration

ADVANCED DEMO BOARD OPERATIONS

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 5 dials show the total accumulated energy similar to a home electricity meter.
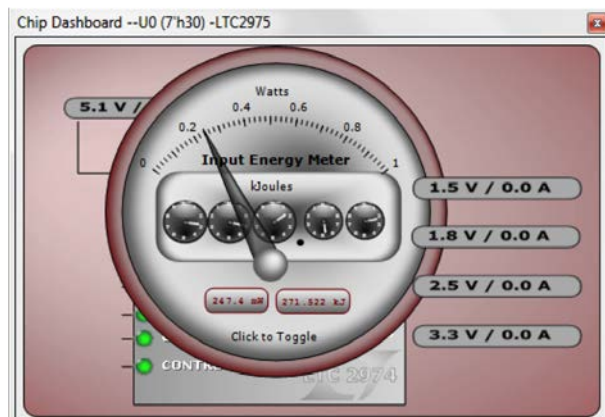
The DC2022A demo board does not have power supplies that are capable of high current. However, conceptually the LTC2975 is able to monitor and measure an entire large power system with ease. LTpowerPlay offers a simple and easy to understand interface that brings together input and output current, voltage, power, and energy readings.

You may also view the input current, input voltage, input power, and input energy in numeric 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 multiplier as the units go from mJ to J to kJ.

The DC2022A board provides power to the LTC2975 manager via a 5V supply, whether power comes from the USB ribbon cable or from the 6V to 14V power jack. See Figure 10 for a simplified block diagram.

To demonstrate the meter readings and register values, first select the MFR_EIN register to display the energy in the telemetry window (GUI's lower right). Turn off all

channels by switching the RUN switch to off. You will notice that the slope has changed. The accumulated energy rate is the slope. Energy is still being consumed to power the LTC4415 power switch and the LTC2975 power manager. Note that the input current has changed from about 40mA down to 17mA 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. When all the channels are powered up, the input current is about 40mA. Since the input voltage is 5V, the input power is 5V•40mA or 200mW. 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 writing the MFR_EIN_CONFIG register.
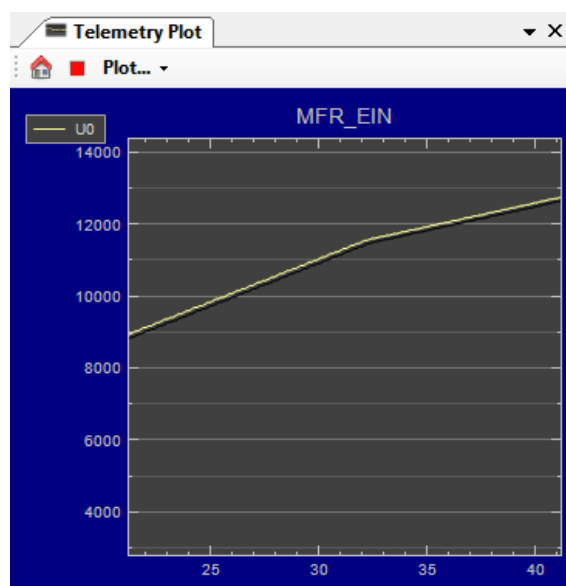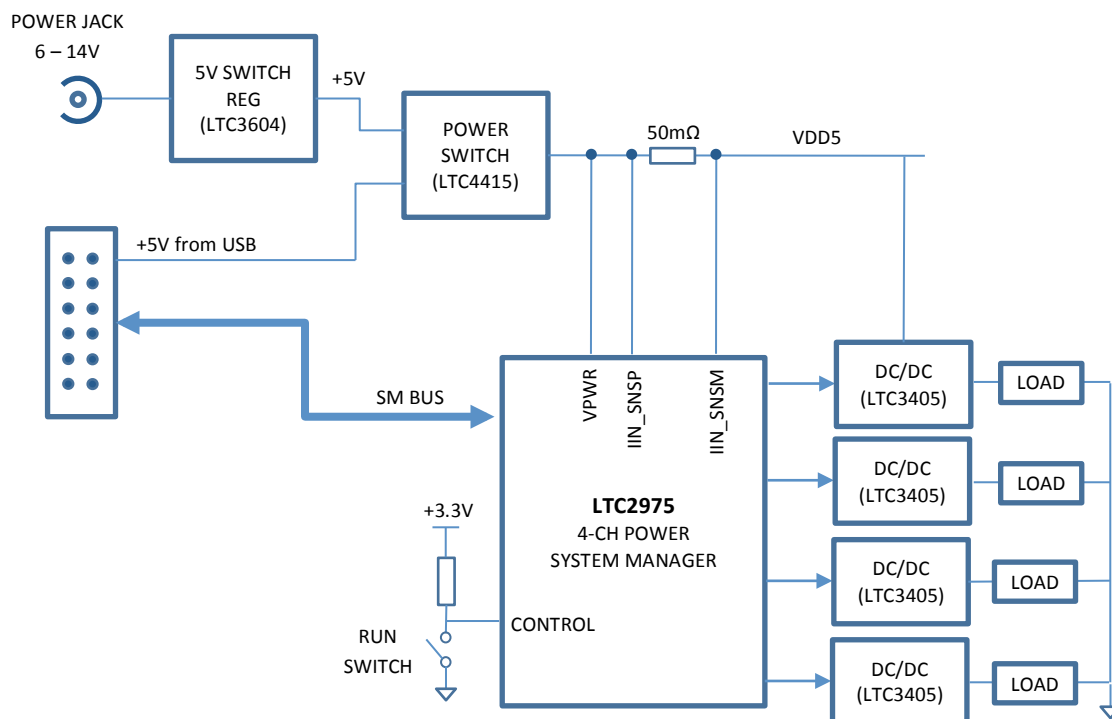
ADVANCED DEMO BOARD OPERATIONS

Figure 10. DC2022A Simplified Block Diagram

SETUP PROCEDURE FOR MULTIBOARD ARRAYS

Up to eight DC2022A boards can be cascaded to control up to 32 independent power supplies. The number of boards is limited by an I/O expander chip that has three address pins, allowing eight different combinations. This setup demonstrates the coordinated fault responses and accurate time base shared across multiple power system managers.

Procedure

1. Stack the boards side-by-side by plugging JP1 of one board into JP2 of another DC2022A board.

2. Ensure different slave address settings for each of the boards. The address of each DC2022A board is set by the DIP switch JP1 on the backside of the board. The setting must be unique for each board in the array.

3. Plug in the 12V V_{IN} power into one of the boards as shown in Figure 11. Only one 12V power source is allowed.

4. The USB-to-I^{2}C/SMBus/PMBus Controller may be plugged into any board. If no DC2022A boards

show up in the GUI, click the magnifying glass icon to enumerate the I^{2}C bus and find the addresses of the parts. Go to step #2 to ensure that each board has a unique DIP switch setting.

5. Since the individual CONTROL lines are connected across the boards (CTRL is a common signal across all boards in the array), make sure that all CONTROL switches are set to the RUN position.

6. Re-launch LTpowerPlay. After launching, LTpowerPlay will enumerate the entire board array and build a representative system tree and read all hardware settings into the GUI.

ATTENTION: Once the GUI has launched, click the RAM->NVM button in the toolbar to ensure that the slave addresses are retained after a power off or reset. Otherwise you may lose communication with the slaves after a power cycle or reset event.

Figure 11. Array of Multiple DC2022A Demo Boards

SETUP PROCEDURE FOR MULTIBOARD ARRAYS

Ensuring Slave Addresses Do Not Conflict

There is a small DIP switch on the backside of the DC2022A. It is used to set the slave address of an I/O expander which allows the addition of multiple boards to a setup. The I/O expander has a base address of 0x20. The DIP switch settings set the offset. The three switches that may be changed are labeled A0, A1, A2. Examples below set the boards to address 0x20 and 0x27.
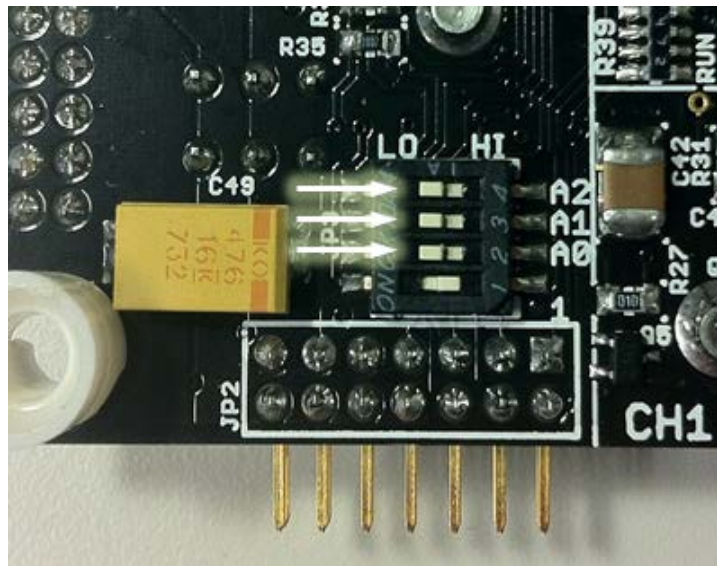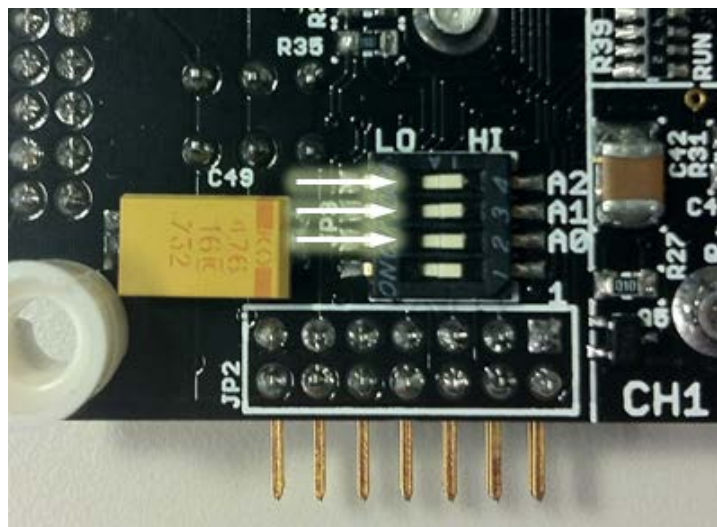

Figure 12. DIP Switch Set to All 0's

Figure 13. DIP Switch Set to All 1's

DC2022A DETAILS - TOP

Test point turrets for the control signals

CREATE FAULT switch

RESET switch

Connector for cascading multiple DC2022A

CONTROL switch

ALERT and FAULT LEDs

LED indicating +5V input power to LTC2975

Connector for cascading multiple DC2022A
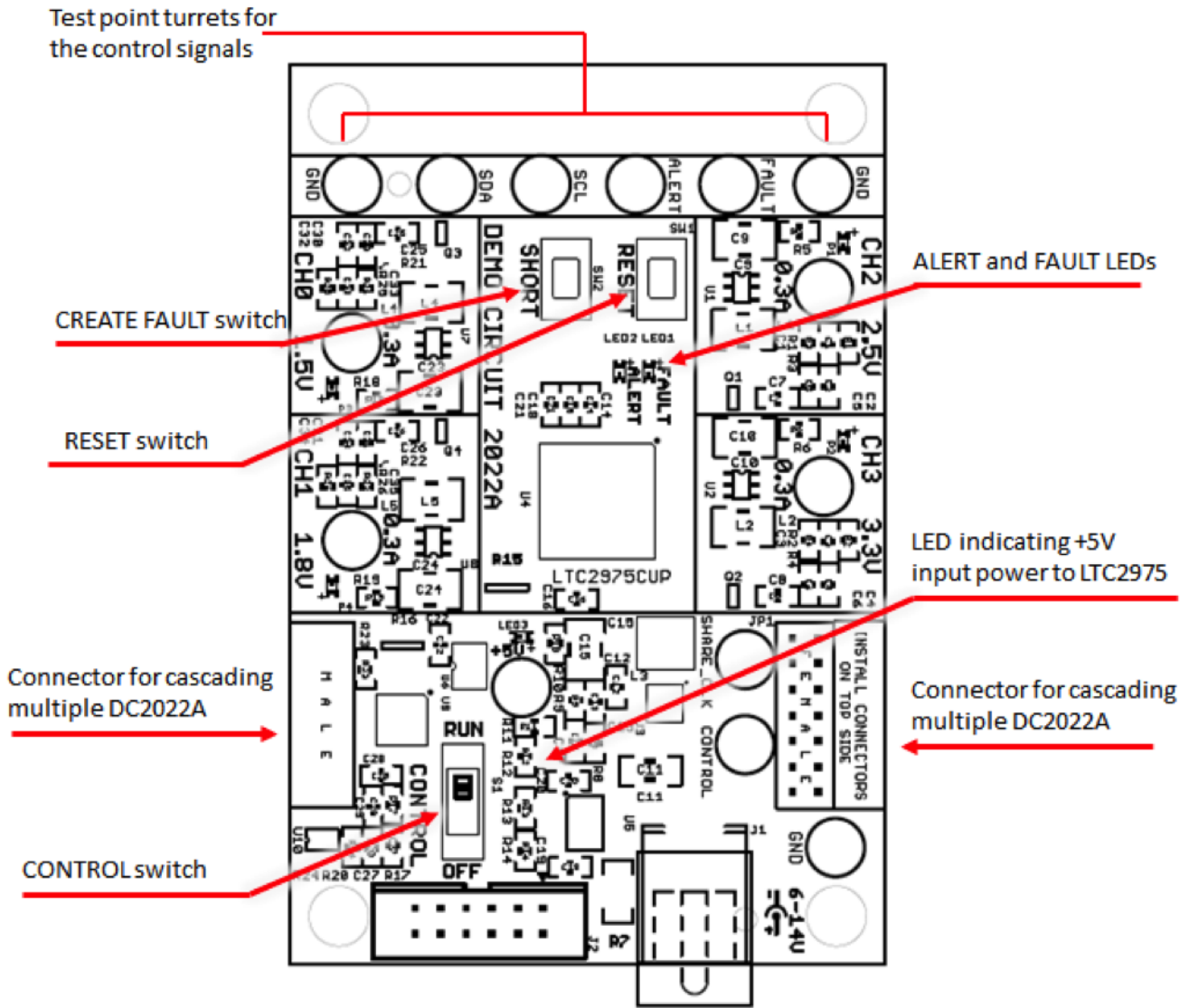
Table 1. DC2022A - Default Switch Configuration (Default Position Shown in Gray)

REFERENCE DESIGNATOR	SIGNAL NAME	USAGE	DEFAULT
JP3 (Bottom)	A0, A1, A2	DIP Switch Used to Set the Address Offset	OPEN
S1	CONTROL	Switch Used to Enable/Disable the CONTROL0 Input Pin of LTC2975	RUN

dc2022af

DC2022A DETAILS - BOTTOM

PARTS LIST

| ITEM	QTY	REFERENCE	PART DESCRIPTION	MANUFACTURER/PART NUMBER
Required Circuit Components				
1	1	U4	IC 4-CH POWER SYSTEM MANAGER 64QFN	Linear Technology: LTC2975CUP#PBF
Additional Demo Board Circuit Components				
2	4	C1, C3, C33, C35	CAP CER 220pF 50V 10% X7R 0603	AVX: 06035A221KAT2A
3	8	C2, C4, C5, C6, C30, C31, C32, C34	CAP CER 2200pF 50V 20% X7R 0603	Murata: GRM188R71H222MA01D
4	14	C7, C8, C12, C16, C18, C21, C22, C25, C26, C43, C44, C50, C54, C55	CAP CER 0.1µF 16V 10% X7R 0603	TDK Corp: C1608X7R1C104K
5	10	C9, C10, C15, C23, C24, C41, C42, C45, C56, C57	CAP CER 22µF 10V 10% X5R 1210	Murata: GRM32ER61A226KE20L
6	2	C11, C48	CAP CER 10µF 25V 10% X7R 1206	Kemet: C1206C106K3RACTU
7	2	C13, C53	CAP CER 68pF 50V 5% NPO 0603	Yageo: CC0603JRNPO9BN680
8	7	C14, C19, C20, C27, C28, C29, C46	CAP CER 1µF 16V 10% X7R 0603	Murata: GRM188R71C105KA12D
9	1	C17	CAP CER 47pF 50V 5% NPO 0603	Yageo: CC0603JRNPO9BN470
10	10	C36, C37, C38, C39, C49, C58, C59, C60, C61, C62	CAP CER 10000pF 25V 10% X7R 0603	Yageo: CC0603KRX7R8BB103
11	1	C40	CAP TANT 47µF 16V 20% 7343	Kemet: T520D476M016ATE035
12	2	C47, C51	CAP CER 4.7µF 16V 10% X5R 0603	TDK: C1608X5R1C475K
13	1	C52	CAP CER 4.7pF 50V NP0 0603	Murata: GRM1885C1H4R7CZ01D
14	1	D1	DUAL SCHOTTKY DIODE 30V CC SOT-323-3	STMicroelectronics: BAT30CWFILM
15	4	L1, L2, L4, L5	INDUCTOR SHLD POWER 4.7µH SMD	Abracon Corporation: ASPI-0315FS-4R7M-T2 Würth: 744029004 (Alternate)
16	1	L3	INDUCTOR POWER 2.2µH 2.85A SMD	Vishay: IHLP1616BZER2R2M11
17	2	LED1, LED2	LED RED HI BRT SS TYPE LO CUR SM	Panasonic: LNJ208R8ARA
18	5	LED3, P1, P2, P3, P4	LED GREEN HIGH BRIGHT ESS SMD	Panasonic: LNJ326W83RA
19	4	Q1, Q2, Q3, Q4	TRANS GP SS PNP 40V SOT323	ON Semiconductor: MMBT3906WT1G
20	5	Q5, Q6, Q7, Q8, Q9	MOSFET N-CH 30V 900MA SOT323-3	Diodes Inc.: DMG1012UW-7 Vishay/Siliconix: SI1304BDL-T1-E3 (alternate)
21	9	R1, R2, R25, R26, R29, R30, R43, R52, R53	RES 100K OHM 1/10W 1% 0603 SMD	Vishay: CRCW0603100KFKEA
22	1	R3	RES 47.5K OHM 1/10W 1% 0603 SMD	Vishay: CRCW060375K5FKEA
23	1	R4	RES 32.4K OHM 1/10W 1% 0603 SMD	Vishay: CRCW060332K4FKEA
24	5	R5, R6, R10, R18, R19	RES 3.01K OHM 1/10W 1% 0603 SMD	Yageo: RC0603FR-073K01L
25	1	R7	RES CURRENT SENSE .050 OHM 1W 1%	Ohmite: MCS1632R050FER
26	8	R8, R12, R20, R23, R24, R37, R39, R56	RES 10.0K OHM 1/10W 1% 0603 SMD	Vishay: CRCW060310K0FKEA
27	2	R9, R45	RES 73.2K OHM 1/10W 1% 0603 SMD	Yageo: RC0603FR-0773K2L
28	1	R11	RES 46.4K OHM 1/10W 1% 0603 SMD	NIC: NRC06F4642TRF
29	2	R13, R17	RES 249 OHM 1/10W 1% 0603 SMD	Yageo: RC0603FR-07249RL
30	1	R14	RES 1.00K OHM 1/10W 1% 0603 SMD	Yageo: RC0603FR-071KL
31	3	R15, R16, R38	RES ARRAY 10K OHM 4 RES 1206	Vishay/Dale: CRA06S08310K0JTA
32	1	R21	RES 115K OHM 1/10W 1% 0603 SMD	Vishay: CRCW0603115KFKEA
33	1	R22	RES 80.6K OHM 1/10W 1% 0603 SMD	Vishay: CRCW060380K6FKEA
34	4	R27, R28, R54, R55	RES 330 OHM 1/2W 1% 1210 SMD	Vishay Dale: CRCW1210330RFKEA
35	4	R31, R32, R50, R51	RES ARRAY 2.7K OHM 4 RES 1206	Vishay/Dale: CRA06S0832K70JTA

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36	4	R33, R35, R47, R49	RES 100 OHM 1/10W 1% 0603 SMD	NIC: NRC06F1000TRF
37	1	R34	RES 340K OHM 1/10W 1% 0603 SMD	Vishay: CRCW0603340KFKEA
38	1	R36	RES 402K OHM 1/10W 1% 0603 SMD	Vishay: CRCW0603402KFKEA
39	1	R40	RES 2.15K OHM 1/10W 1% 0603 SMD	Vishay: CRCW06032K49FKEA
40	1	R41 (OPT)	RES 10.0K OHM 1/10W 1% 0603 SMD	Vishay: CRCW060310K0FKEA
41	2	R42, R44	RES 698 OHM 1/10W 1% 0603 SMD	Yageo: RC0603FR-07698RL
42	1	R46	RES 158K OHM 1/10W 1% 0603 SMD	Vishay: CRCW0603158KFKEA
43	1	R48	RES 210K OHM 1/10W 1% 0603 SMD	Vishay: CRCW0603210KFKEA
44	4	U1, U2, U7, U8	IC BUCK SYNC ADJ 0.3A SOT23-6	Linear Technology: LTC3405AES6#TRMPBF
45	1	U3	IC BUCK SYNC 2.5A 16QFN	Linear Technology: LTC3604IUD#PBF
46	1	U5	IC DUAL 4A DIODES 16-MSOP	Linear Technology: LTC4415IMSE#PBF
47	1	U6	IC 2WIRE BUS BUFFER 8MSOP	Linear Technology: LTC4313CMS8-2#PBF
48	1	U9	IC I/O EXPANDER I2C 8B 20QFN	Microchip: MCP23008-E/ML
49	1	U10	IC EEPROM 2KBIT 400KHZ SOT23-5	Microchip Technology: 24AA02T-I/OT
50	1	U11	IC VREF SERIES PREC TSOT-23-6	Linear Technology: LT6654BHS6-1.25#TRMPBF
51	1	U12	IC BUFFER DUAL NON-INV SC706	TI: SN74LVC2G34DCKR
Hardware: For Demo Board Only				
52	1	J1	CONN PWR JACK 2.1X5.5MM HIGH CUR	CUI Inc: PJ-002AH
53	1	J2	CONN HEADER 12POS 2MM STR DL PCB	FCI: 98414-G06-12ULF
54	1	JP1	CONN RECEPT 2MM DUAL R/A 14POS	Sullins Connector Solutions: NPPN072FJFN-RC
55	1	JP2	CONN HEADER 14POS 2MM R/A GOLD	Molex Connector Corporation: 87760-1416
56	1	JP3	SWITCH DIP 4POS HALF PITCH SMD	C&K Components: TDA04H0SB1
57	4	MH1, MH2, MH3, MH4	SPACER STACKING #4 SCREW NYLON	Keystone: 8831
58	1	S1	SW SLIDE DPDT 6VDC 0.3A PCMNT	C&K Components: JS202011CQN
59	1	SW1	BLK SWITCH TACTILE SPST-NO 0.05A 12V	C&K Components: PTS635SL25SMTR LFS
60	1	SW2	RED SWITCH TACTILE SPST-NO 0.05A 12V	C&K Components: PTS635SK25SMTR LFS
61	14	TP1, TP2, TP3, TP4, TP5, TP6, TP7, TP12, TP13, TP14, TP19, TP20, TP21, TP22	TERM SOLDER TURRET .219" .078"L	MILL-MAX: 2501-2-00-80-00-00-07-0

SCHEMATIC DIAGRAM

dc2022af

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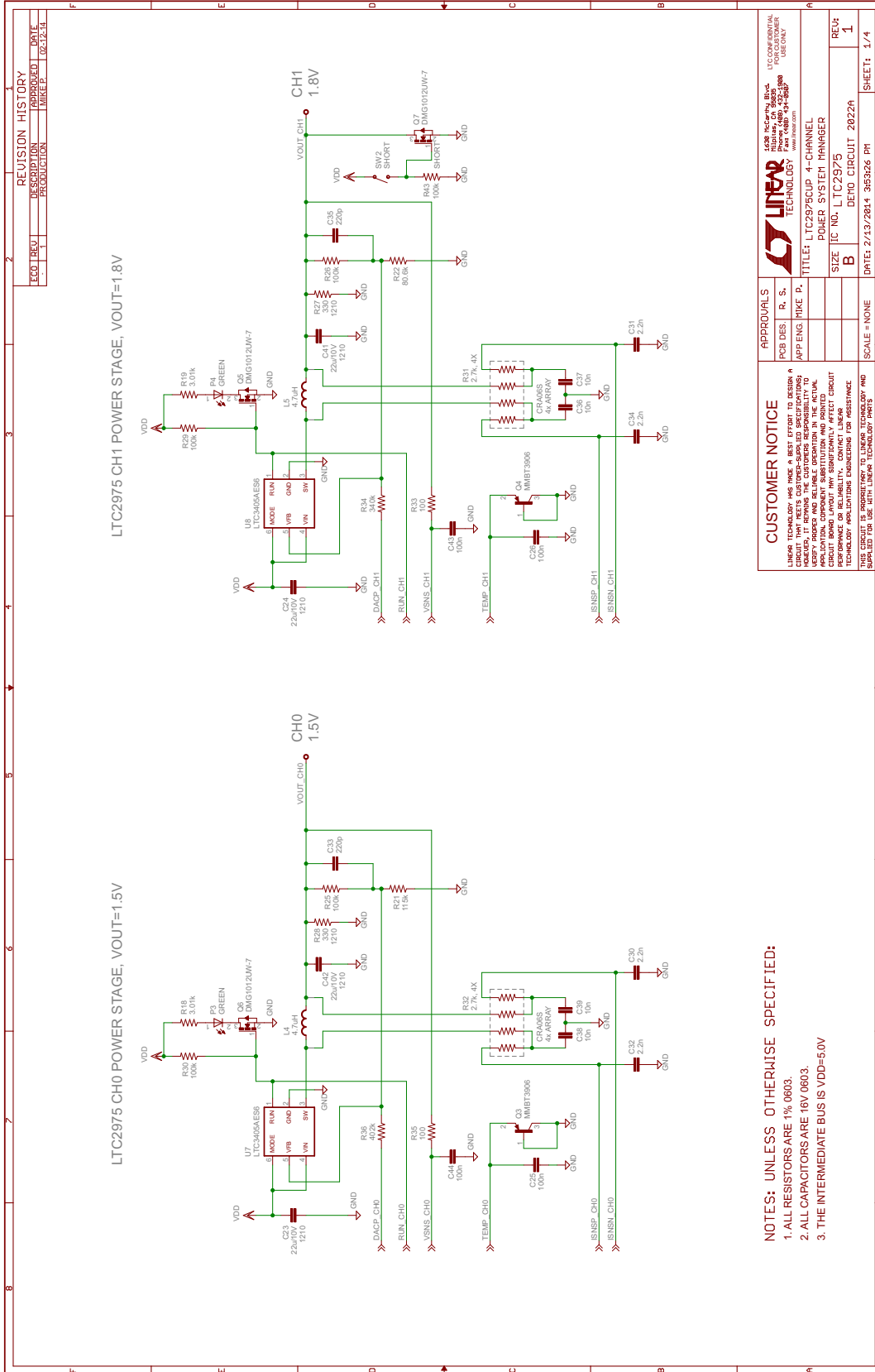
NOTES: UNLESS OTHERWISE SPECIFIED:
1. ALL RESISTORS ARE 1% 0603.
2. ALL CAPACITORS ARE 16V 0603.
3. THE INTERMEDIATE BUS IS VDD=5.0V

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