

LTC2975

4-Channel PMBus Power System Manager with $\pm 12\text{V}$ and $\pm 48\text{V}$ Power Supply Rails

DESCRIPTION

The DC2518A is a demonstration system for the **LTC[®]2975** Power System Manager that interfaces to various regulators. The board contains all the circuitry needed to use the LTC2975 in a power system and control four power supplies. The four power supplies include linear and switching regulators for the purpose of demonstrating a variety of methods to sense voltage and current. The demo board provides a sophisticated, digitally programmable 4-channel power supply system.

The LTC2975 is a 4-channel I²C/SMBus/PMBus Power System Manager that features accurate input current and energy measurement. The device monitors input current and input voltage to calculate input power and energy. The DC2518A demonstrates the ability of the LTC2975 to sequence, trim, margin, supervise, monitor, and log faults for four power supplies. The LTC2975 monitors each channel's output voltage and output current and also monitors each channel's external temperature sensor and its own internal die temperature.

The DC2518A board contains four independent power supply rails. The $+12\text{V}/-12\text{V}$ rails are based on LDO regulators, and the $+48\text{V}/-48\text{V}$ rails are based on DC/DC switching regulators. The board is pre-configured with these voltages and may be re-configured 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 DC2518A 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 DC2518A. Just plug and play!

Order pre-programmed devices from Linear Express[®] using LTpowerPlay.

The following items are required:

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

DC2518A Features

- Sequence, Trim, Margin, and Supervise Four Power Supplies
- Manage Faults, Monitor Telemetry, 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
- I²C/SMBus Serial Interface
- Powered from 9V to 14V

Design files for this circuit board are available at
<http://www.linear.com/demo/DC2518A>

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DEMO MANUAL DC2518A

PERFORMANCE SUMMARY

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

PARAMETER	CONDITIONS	VALUE
VPWR Supply Input Operating Range		9V to 15V
VDD33 Supply Input Operating Range		3.13V to 3.47V
ADC Total Unadjusted Error	$V_{IN} \geq 1\text{V}$	$\pm 0.25\%$
ADC Voltage Sensing Input Range		-0.1V to 6V
ADC Current Sensing Input Range	Differential Current Sense Voltage	-170mV to 170mV
ADC Voltage Sensing Resolution	$0\text{V} \leq V_{IN_ADC} \leq 6\text{V}$	122 μV /LSB
ADC Current Sense Resolution	$0\text{mV} < V_{IN_ADC} < 16\text{mV}$ $16\text{mV} < V_{IN_ADC} < 32\text{mV}$ $32\text{mV} < V_{IN_ADC} < 63.9\text{mV}$ $63.9\text{mV} < V_{IN_ADC} < 127.9\text{mV}$ $127.9\text{mV} < V_{IN_ADC} $	15.6 μV /LSB 31.25 μV /LSB 62.5 μV /LSB 125 μV /LSB 250 μV /LSB
DAC Resolution		10 Bits
DAC Full Scale Output Voltage	Buffer Gain Setting 0 Buffer Gain Setting 1	1.38V Typ. 2.65V Typ.
Temperature Sensor TUE		$\pm 1^\circ\text{C}$
Voltage Supervisor Input Voltage Range (Programmable)	$V_{SENSE[n]}$	0V to 6V (Low Resolution) 0V to 3.8V (High Resolution)
Voltage Supervisor Sensing Resolution	0V to 3.8V Range: 4.096/1024 0V to 6V Range: 8.192/1024	4mV/LSB 8mV/LSB
Voltage Supervisor Total Unadjusted Error (TUE)	$2\text{V} < V_{IN_VS} < 6\text{V}$, Low Resolution Mode $1.5\text{V} < V_{IN_VS} < 3.8\text{V}$, High Resolution Mode $0.8\text{V} < V_{IN_VS} < 1.5\text{V}$, High Resolution Mode	$\pm 1.25\%$ $\pm 1.0\%$ $\pm 1.5\%$
I ² C Serial Clock Frequency		10kHz to 400kHz

DEMO BOARD SYSTEM SPECIFICATIONS

	NOMINAL UNTRIMMED V_{OUT}	REGULATOR PART #	RESISTORS THAT SET UNTRIMMED V_{OUT}	RDAC	MARGIN RANGE
CH0	+12V $\pm 1\%$	LT3081	R3, R4		$\pm 10\%$
CH1	-12V $\pm 1\%$	LT3090	R17, R18	R31, R32	$\pm 10\%$
CH2	+48V $\pm 1\%$	LT8330	R34, R35	R40	$\pm 5\%$
CH3	-48V $\pm 1\%$	LT8580	R52	R58, R59	$\pm 5\%$

Notes:

- Keep load currents $< 100\text{mA}$ on $\pm 48\text{V}$ channels and $< 250\text{mA}$ on $\pm 12\text{V}$ channels.
- Output voltages can be margined by $\pm 10\%$ from nominal with the default resistor values. 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 – Nonvolatile 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 LTC2975 supervises.

Supervise – The act of quickly responding 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 by modifying: nominal output voltages, range and resolution of margining, sequencing, OV/UV limits, and OC limits.
- Create your own configuration: store in the LTC2975 EEPROM or save to a project file. Order pre-programmed parts.
- Test fault scenarios. Short outputs to ground, and observe system response and faults.

Demo System Hardware

Hardware Required:

1. DC2518A
2. PC + USB Cable
3. 12V, >1A Power Supply
4. USB to I²C/SMBus/PMBus Controller (DC1613)

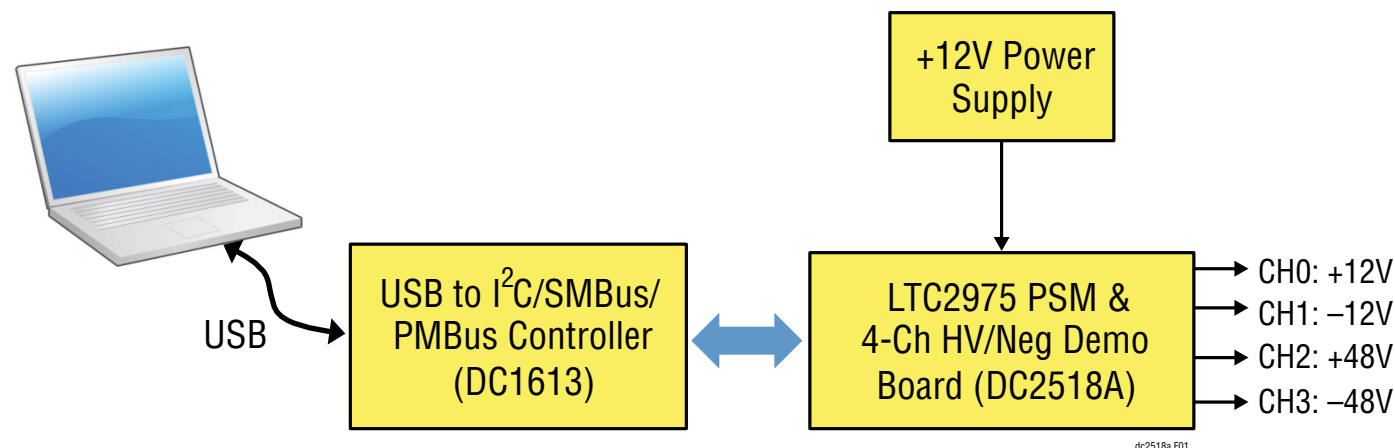


Figure 1. DC2518A Demo Setup

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 DC2518A 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:

www.linear.com/ltpowerplay

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

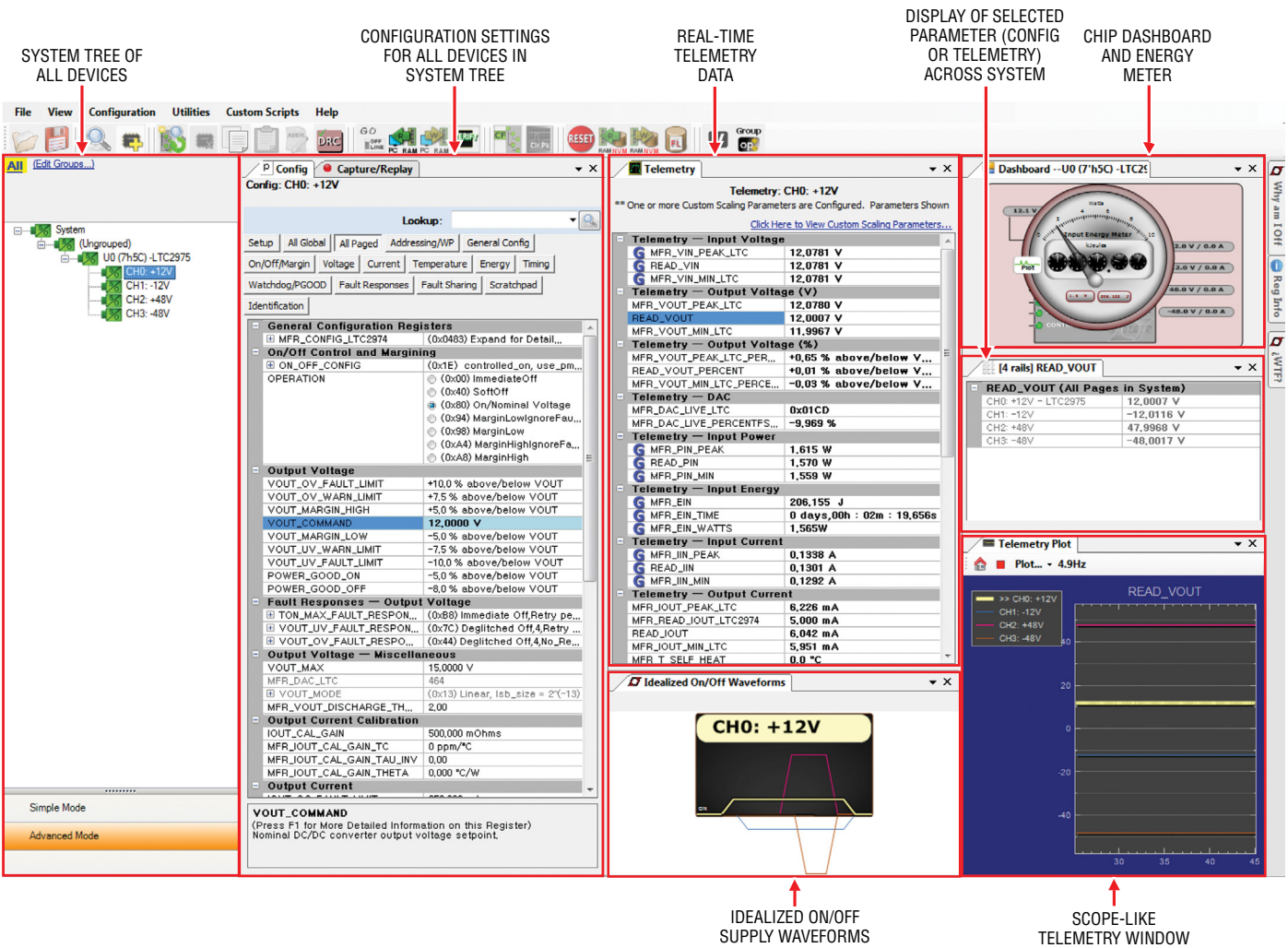


Figure 2. Screen Shot of the LTpowerPlay GUI

QUICK START PROCEDURE

The following procedure describes how to set up a DC2518A demo system.

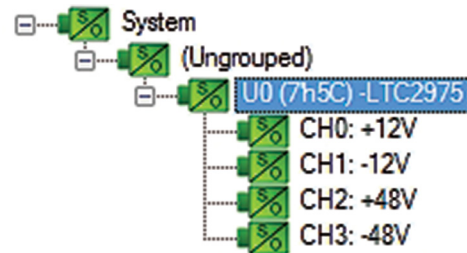
1. Download and install the LTpowerPlay GUI:

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 DC2518A board using the 12-pin ribbon cable.
3. Confirm that the RUN switch is set to its OFF position.
4. Plug the DC1613 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 to the V_{IN} input jack of the DC2518A board. The blue LEDs will illuminate indicating that DC jack power and input power to the LDOs is applied. Move the RUN switch to the ON position. The four outputs will power up and the green LEDs will illuminate.

6. Launch the LTpowerPlay GUI.

- a. The GUI automatically identifies the DC2518A 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 DC2518A is communicating.

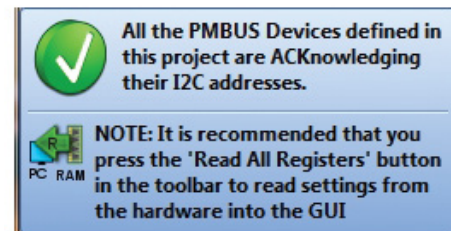
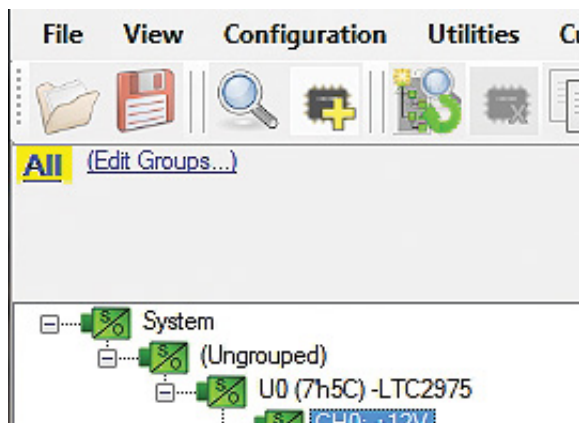


Figure 3. Connecting DC2518A and the DC1613 USB to I²C/SMBus/PMBus Controller

QUICK START PROCEDURE

- 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 pull-down item DEMO → DC2518A_Defaults. This writes the board defaults into the LTC2975's RAM and automatically to NVM as well.

7. The LTC2975 is configured to use the RUN switch to sequence on/off the four channels. Slide the switch to RUN to enable, OFF to disable all channels.

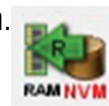
Loading a Configuration (*.proj) File with the GUI

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.



RAM



DC2518A DETAILS

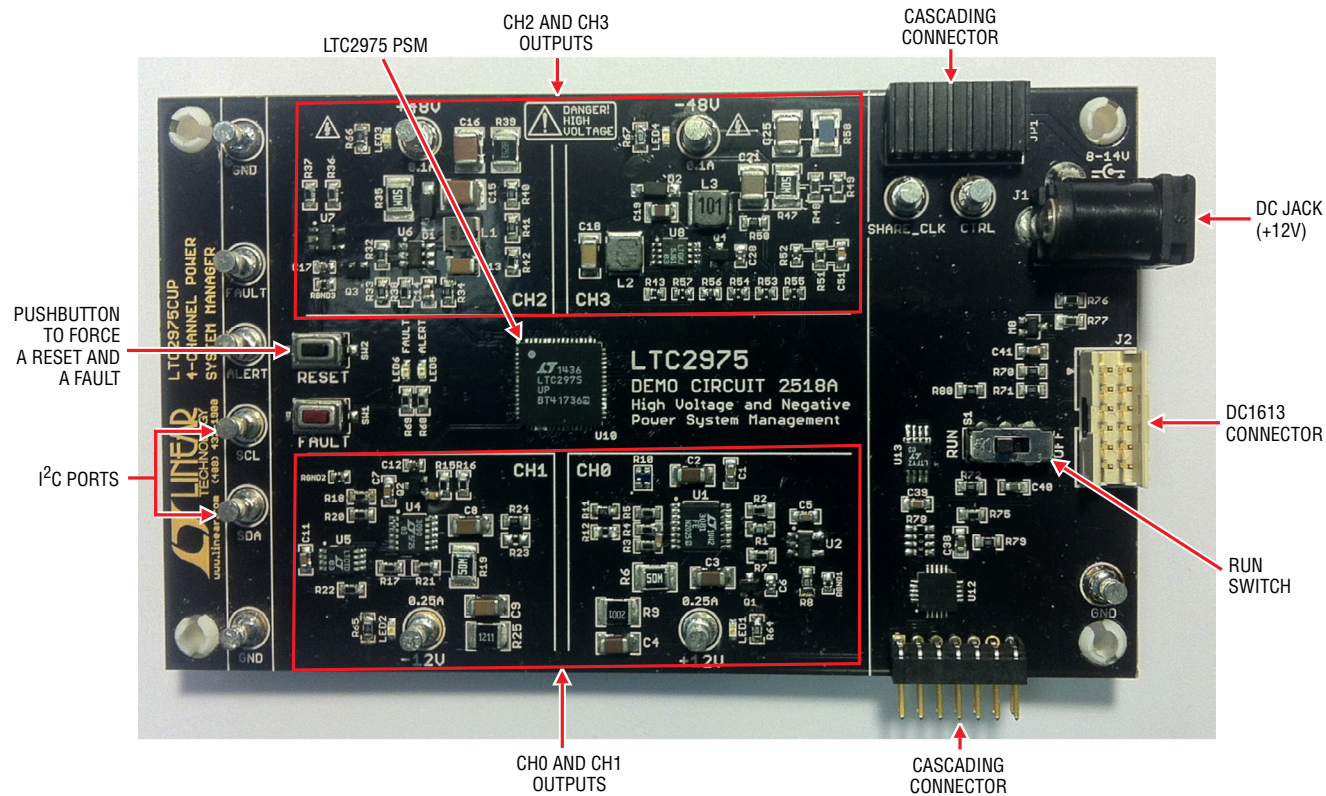


Figure 4. DC2518A Details

COMMON BOARD OPERATIONS

Overview

A simplified block diagram of the DC2518A is shown in Figure 5. The LTC2975 measures input current with a 10mΩ sense resistor. It also controls, monitors, and supervises all four outputs.

Powering the Board

The DC2518A board is powered from a wall-powered 12V supply. The supply must be capable of delivering > 1A. If the four channels are loaded with the maximum allowable current, the input current will be greater than 1A. The LTC2975 device is powered either from the DC1613's 3.3V power or jack power if V_{IN} is applied.

DC2518A LEDs

There are three blue LEDs near the power jack. These indicate that the DC jack has voltage and $\pm 15V$ switching regulator outputs are up and running. The LED labeled VDD33 illuminates when the LTC2975 is powered from either the USB controller or the external V_{IN} power. Each channel has its own green LED which indicates that the channel is enabled. The red LEDs on ALERTB and FAULTB indicate a warning or fault has occurred.

Reset the LTC2975

To reset the LTC2975 and reload the EEPROM contents into operating memory (RAM), press the pushbutton switch SW2 labeled RESET.

Preload the Outputs

Each of the outputs has preload resistors that provide 10mA of load. This ensures that the 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 all four channels on the DC2518A board are controlled by a single RUN switch.

The LTC2975 is pre-configured with different TON_DELAY values for each channel. The TON_DELAY parameter is applied to each of the channels relative to the CONTROL pin or Group operation command to turn all channels "on". Figure 6 shows an oscilloscope screen capture of the four output rails sequencing up.

The same applies to TOFF_DELAY values. When the Run switch is set to the OFF position, all rails will power down sequentially based on the TOFF_DELAY values.

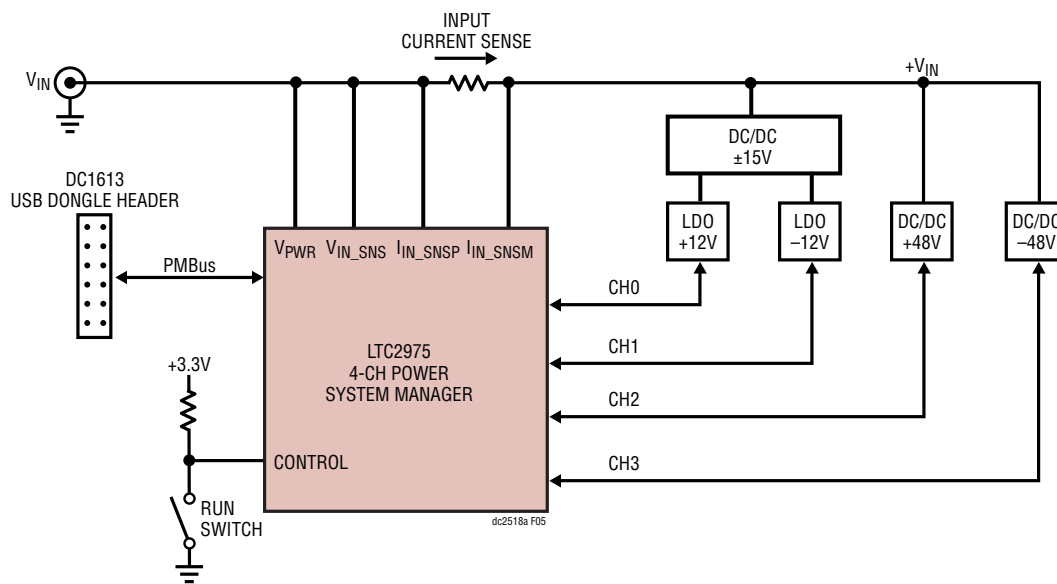


Figure 5. Simplified Block Diagram of the DC2518A

COMMON BOARD OPERATIONS

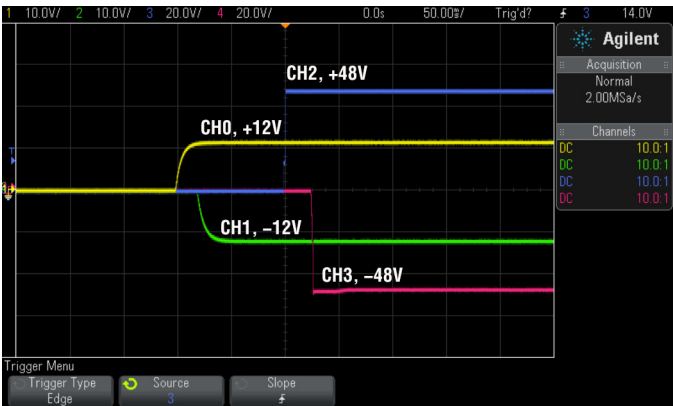


Figure 6. Sequencing Output Channels On/Off

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. The timings are intentionally skewed to show the rails ramp times more clearly.

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

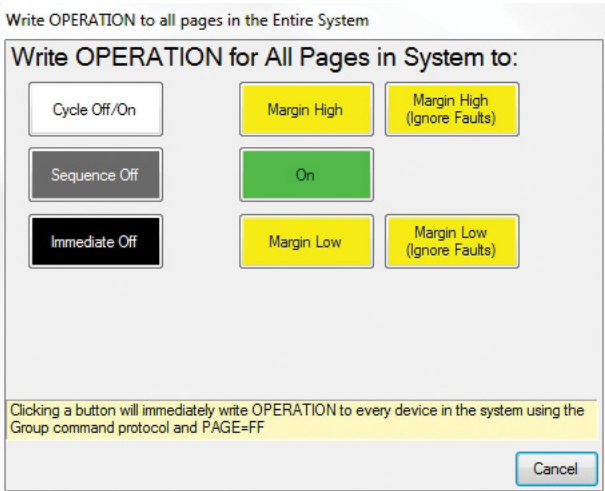
TON_DELAY (All Pages in System)		TOFF_DELAY (All Pages in System)	
U0:0 - LTC2975	0,000 ms	U0:0 - LTC2975	50,000 ms
U0:1	25,000 ms	U0:1	50,000 ms
U0:2	100,000 ms	U0:2	20,000 ms
U0:3	125,000 ms	U0:3	20,000 ms

Figure 7. TON_DELAY and TOFF_DELAY Settings

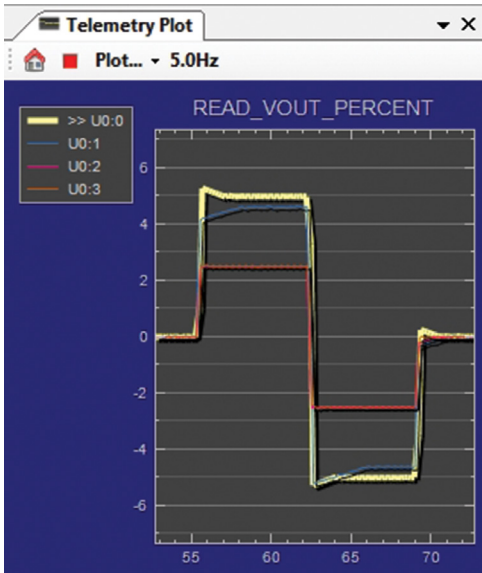
Margin All Rails

The LTC2975 Power System Manager on the DC2518A 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 and margin low operations. This screen shot is a telemetry plot of READ_VOUT_PERCENT showing all rails going from nominal set-points to margin high, margin low, and back to nominal voltages.

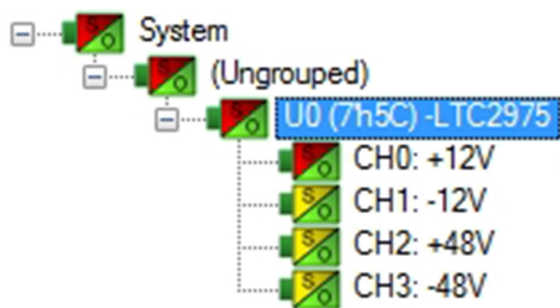


COMMON BOARD OPERATIONS

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 160ms.

Creating a Fault

There is a pushbutton on the DC2518A 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 Fault pushbutton creates a fault (shorts V_{SENSE} node to ground) on CH0, the +12V output (GUI channel U0:0). When faulted, all channels power down immediately and the GUI's system tree indicates the color red for the status portion of that channel. 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 hold the FAULT pushbutton indefinitely to demonstrate the fault behavior and retry timing.



Clearing a Fault

To clear a fault, you can click the CF icon in the GUI or simply push the RESET pushbutton (SW2) on the DC2518A 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 are 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.

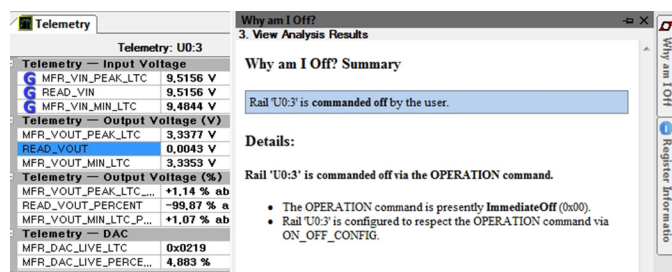


Figure 8. "Why Am I Off" tool in the LTpowerPlay GUI

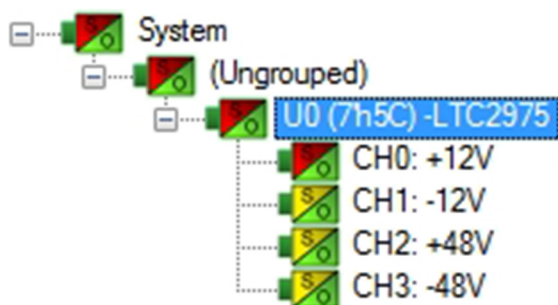
ADVANCED DEMO BOARD OPERATIONS

What is a Fault Log?

A fault log is a nonvolatile 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 DC2518A demo board.

Create a Fault Log

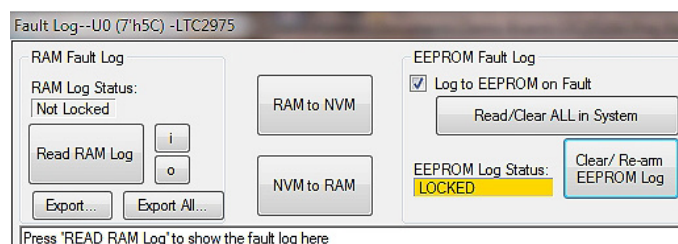
To create a fault log, check that the `fault_log_enable` bit is set in the `MFR_CONFIG_ALL` register. Then, create a fault, as described in the section “Creating A Fault”. If multiple boards are configured, select the appropriate device in the system tree by clicking on the appropriate LTC2975 chip.



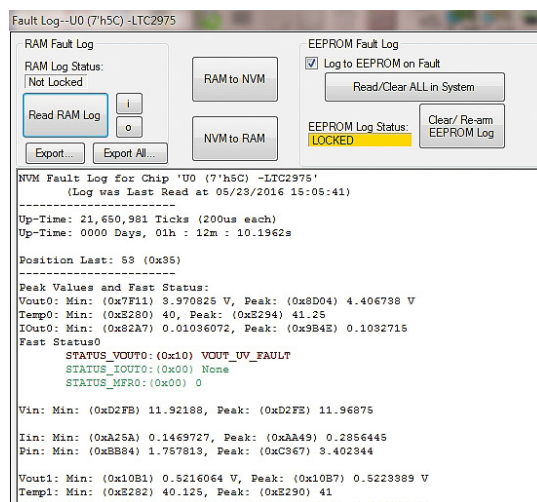
Working with the Fault Log



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 DC2518A boards are connected, be sure that the desired device is selected in the system tree. Notice that the EEPROM log is locked. The log will not change until it is cleared by the user.

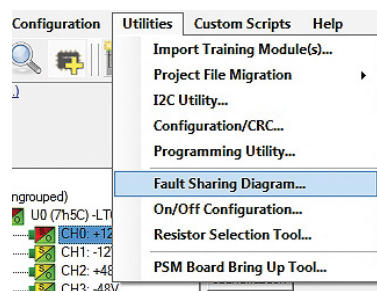


Reading the fault log is a 2-step process. First click the “NVM to RAM” button. At this point the RAM Log is locked. Click the “Read NVM Log” button. The fault log data will appear in the text box below.



The log contains timestamp, 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 U0:0 faulted due to a `VOUT_UV_FAULT` condition. On the previous telemetry loop, the channel voltage reading was a nominal value (+12V). 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.

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 9. All Respond 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.

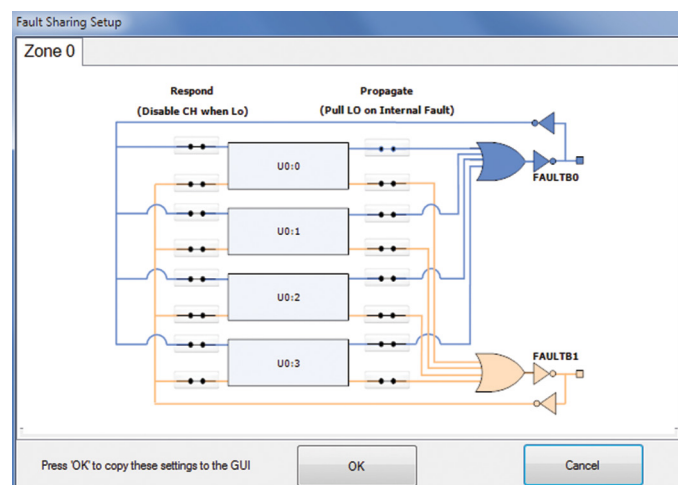


Figure 9. Fault Sharing Utility in LTpowerPlay GUI

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 bidirectional, meaning the device may drive its fault pin low (output) or may respond to the fault pin when another device drives it low (input). By default, the LTC2975 is configured to shut down all channels if the FAULT pin is low and to propagate its own fault to the other channels by driving both FAULT pins low. On the DC2518A, the two FAULT pins are tied together, which effectively creates one fault line. You can think of the “Respond” 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

Suppose we do not want channel CH0 (+12V rail) to propagate its fault to the other channels when it faults. And suppose we do not want channel CH1 (–12V 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 LTC2975.

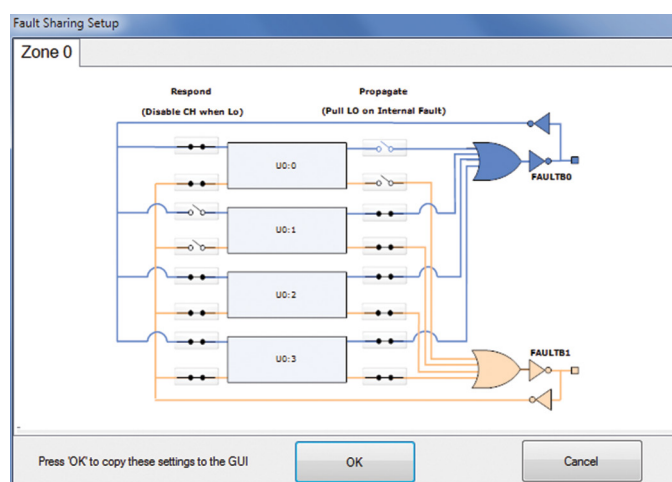


Figure 10. Updated Fault Sharing Configuration

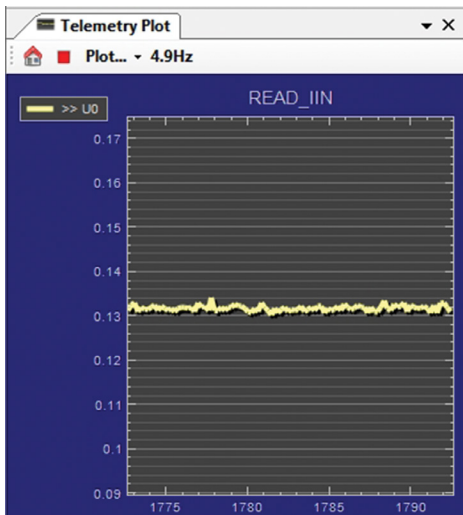
You can now create a fault on CH0 by pressing the FAULT pushbutton. This action does not directly short the +12V supply to GND but instead pulls the V_{SENSE} pin to GND. You will notice that the channel shuts off but the other channels remain powered up because its fault is not propagated to the other channels. After the retry period, channel CH0 will power back up. You can now observe the effect of changing the response setting on CH1. If you short the test point VSP3 to ground on CH3 (–48V rail), notice that all rails shut down except CH1. This is an example of a keep-alive channel that remains powered up independent of faults to other channels.

NOTE: It is not recommended to short the +48V or –48V power supplies directly to GND on this demo board as you may damage an output. Damage might occur if you change the fault response to “ignore”.

ADVANCED DEMO BOARD OPERATIONS

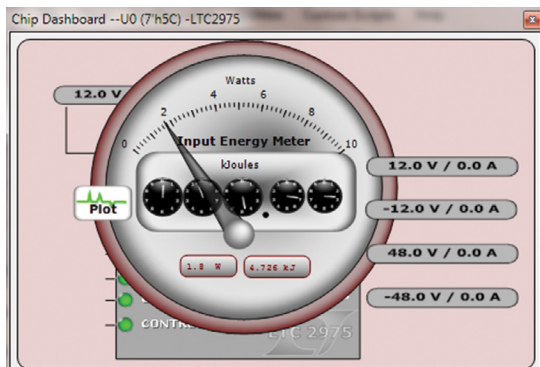
Energy Metering

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 ~130mA if all channels are enabled 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.



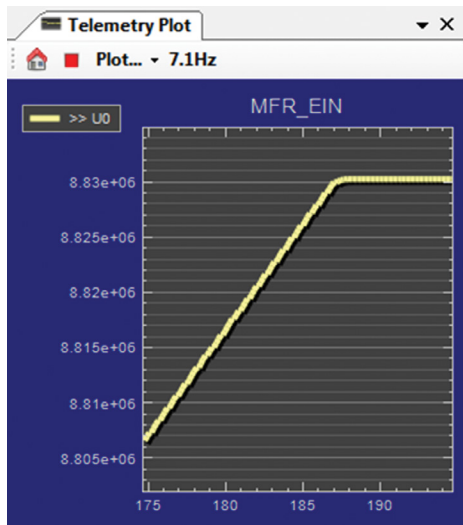
The DC2518A demo board has two power supplies that are capable of relatively high voltages, $\pm 48V$. Be careful when handling the board with these channels enabled since the voltage difference between the two is 96V.

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	1.619 W
READ_PIN	1.582 W
MFR_PIN_MIN	1.564 W
Telemetry — Input Energy	
MFR_EIN	172,053 J
MFR_EIN_TIME	0 days,00h : 01m : 47.9...
MFR_EIN_WATTS	1.589W
Telemetry — Input Current	
MFR_IIN_PEAK	0.1353 A
READ_IIN	0.1321 A
MFR_IIN_MIN	0.1306 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 milli Joules. 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 all channels by setting the RUN switch to the off position. You will notice that the slope has changed. The accumulated energy rate is the



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slope. Energy is still being accumulating but at a lower rate since channels 0 and 1 remain enabled. Note that the input current changed from about 130mA down to 0mA 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 $12V \cdot 130mA$ or 1.56W. 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.

Output Voltage Sensing Schemes

The voltage sensing schemes employed on the DC2518A are of three types. For positive voltage channels (CH0 and CH2), a voltage divider performs this function in a simple manner. It's inexpensive, takes up little board space, but introduces error in the voltage reading. For negative voltage channels (CH1 and CH3), two different sensing methods are used. One method uses a divider that is referenced to the REFP pin while the other method uses an op-amp that converts the sensed voltage to a positive single-ended divided-down voltage.

For the positive high voltage rails, a simple divider is used. The equation that relates divider resistors and the rail voltage is as follows:

$$V_{SNSP} = V_{RAIL} \cdot \left(\frac{R_{BOT}}{R_{TOP} + R_{BOT}} + I_{SNSP} \cdot R_{TOP} \parallel R_{BOT} \right)$$

The primary source of error is due to resistor tolerance. This is the reason 0.1% resistors are used. A secondary source of error comes from the I_{SENSE} pin current that is pulled from the divider into the LTC2975. The divider's IR drop is due to the product of the Thevenin equivalent resistance and the I_{SENSE} current. To minimize this error, the Thevenin resistance should be less than 2k.

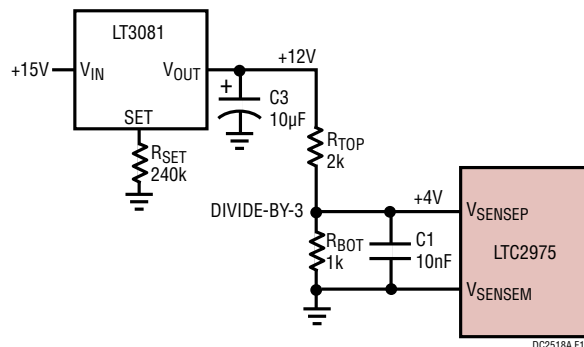


Figure 11. Output Voltage Sensing

The divider on CH2 (+48V) is 27k and 3k and the Thevenin equivalent resistance is 2.727k. The top resistor is comprised of two series resistors in order to keep the power dissipation within the limits of the 0603 case size which a 100mW rating. The divided voltage is 4.8V, and the pin current is 9µA. This information can be found in the Typical Operating Characteristics curve of the LTC2975 data sheet. The IR drop is ~24mV. This introduces approximately 0.5% error in the sensed voltage.

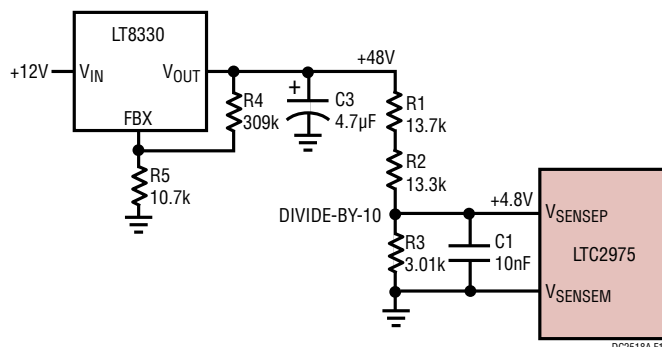


Figure 12. High Voltage Sensing

For the -12V channel (CH1), a divider is used; however, the V_{SENSE} pins must be kept above GND. To accomplish this, the V_{SENSEP} pin is tied to a positive voltage and the V_{SENSEM} pin to the divider. This arrangement not only divides the rail voltage down to a safe level but also provides an absolute value of the divided voltage. There are three sources of error in this case: the positive reference voltage that the top of the divider is connected to, the resistor tolerances, and the V_{SENSEM} pin current that is pushed into the divider node.

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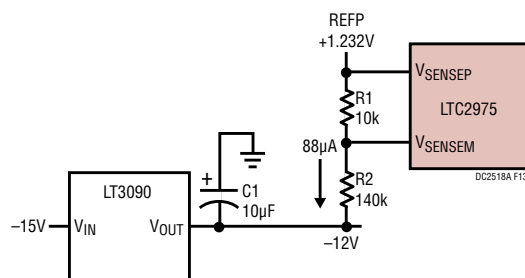


Figure 13. Negative Voltage Sensing

To minimize these errors, one can choose REFP as the positive reference supply and use 0.1% tolerance resistors. The reference is accurate to within a few millivolts of the nominal 1.232V value. To reduce the error introduced by the I_{SENSE} current, divider resistor values must be chosen to have a low Thevenin resistance while not drawing more than 100µA from the REFP pin. The divided down rail voltage is sensed across resistor R1. The resistors divide the -12V down by $10k/(10k+140k)$ or 15. This is reflected in the scale factor in the LTpowerPlay GUI.

To eliminate REFP and V_{SENSE} pin current errors, the -48V channel (CH3) uses a ground-referenced op-amp circuit to measure the negative rail voltage. See Figure 14. The LT6015 op-amp has input common mode range down to GND. Attaching a resistor from the negative supply to the inverting input and corresponding feedback resistor allows the circuit to “touch” highly negative nodes while providing a single-ended low impedance output to a V_{SENSE} input. Components R2/C2 set the low frequency anti-aliasing filter to 1.59kHz. The time constant 100µs establishes the response time to over- and under-voltage conditions on the -48V output.

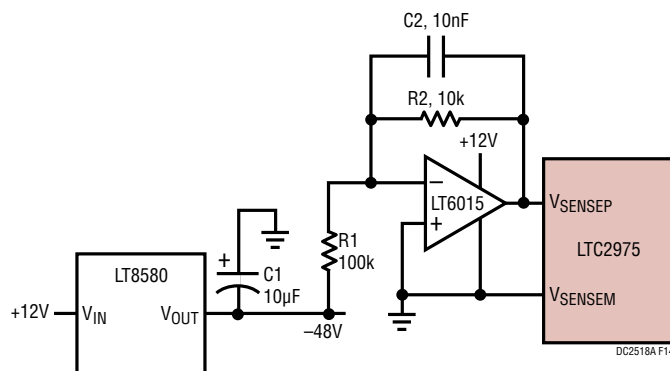


Figure 14. Output Voltage Sensing for Negative Rail

Output Current Sensing Schemes

The output current on each channel of the DC2518A demo board uses a 50mΩ sense resistor. This board uses a variety of sensing schemes: IMON, current sense amplifier, and op-amp with voltage-translating transistor. Each of the channels allows the user to try different sensing methods. Zero ohm jumpers select between one or the other method so that you can understand the trade-offs of cost versus accuracy.

Each channel's output has a pre-load resistor that is soldered in place. The primary reason for the pre-load is to quickly discharge the output when sequencing off/on.

The board comes with IOUT_OC_FAULT limits set to 0.4A for the +12V/-12V rails and 0.2A for the +48V/-48V rails. A deglitched fault response is set to mask OC when the channels start up.

The LTC6101 and LT6105 current sense amplifiers are used on the +12V (CH0), -12V (CH1), and +48V (CH2).

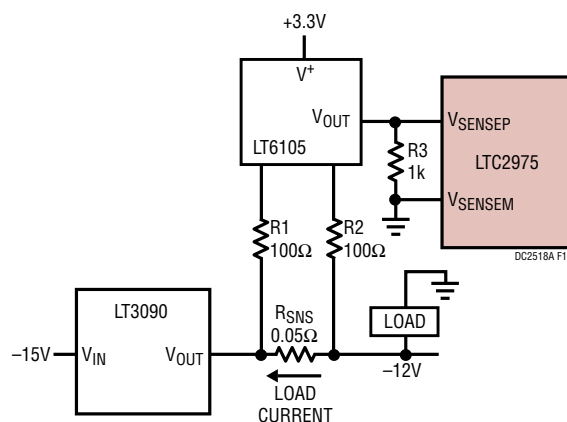


Figure 15. Output Current Sensing for Negative Rail

The LT6105 is a low side current sense amplifier and is able to tolerate voltages up to 36V. For the -48V rail, an alternative solution is needed. The -48V rail (CH3) uses an LTC2054 and NFET to provide the current sensing and level shift to a single-ended signal that drives the ISNSP and ISNSM pins. The circuit implemented on the DC2518 is that shown on the front page of the LTC2054 data sheet.

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Servo Circuits

A number of different servo circuits are utilized on the DC2518. The servo circuits control a regulator's SET pin, a feedback (FB) pin, and an FBX pin.

The +12V rail on CH0 is based on the LT3081 linear regulator. This device derives its output from a 50 μ A current source (SET pin) that connects to a single resistor tied to GND.

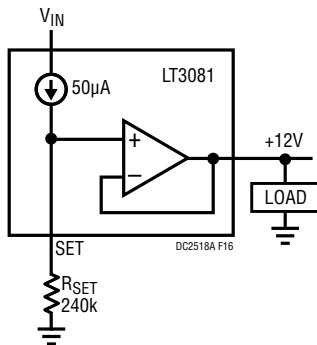


Figure 16. Regulator with SET Pin

The series resistors provide an equivalent 240k to GND. The 50 μ A current develops a nominal +12V on the SET pin which is buffered to the OUT pin. The output voltage may have some error due to SET current and external resistor tolerances. The LTC2975 can servo the output by accurately measuring the divided V_{OUT} and drives the SET resistor midpoint to make adjustments to V_{OUT} .

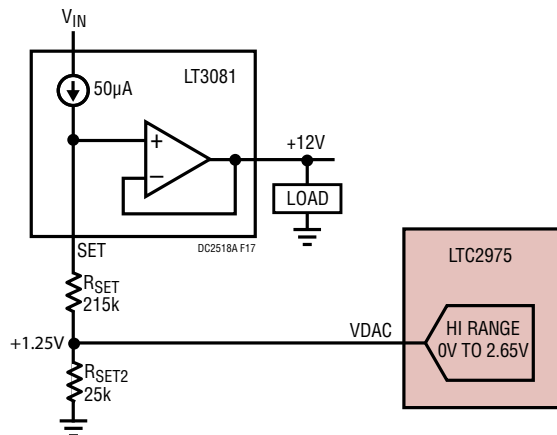


Figure 17. DAC Connects to SET Resistors

The LTC2975's DAC is connected directly to the midpoint of the two SET resistors. The R_{SET1} and R_{SET2} resistor values are chosen such that the midpoint is approximately 1.25V, a voltage that is half of the DAC's maximum output. After the DAC finds a suitable voltage, it is connected to the divider and controls this node, making it capable of changing V_{OUT} higher or lower by $\pm 1.2V$.

How to Servo a Negative LDO

A servo circuit that needs more thought is the LT3090 servo. The SET pin sinks 50 μ A and a 240k SET resistor develops 12V below GND.

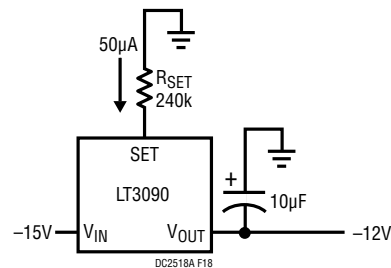


Figure 18. Negative LDO with SET Resistor

To add a servo circuit that translates a positive DAC voltage to a current pushing into a node that is below GND, a PNP transistor is used.

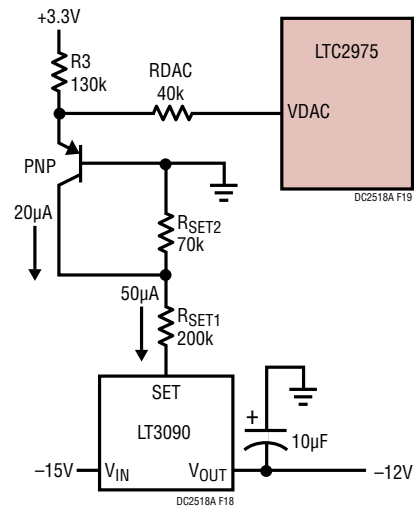


Figure 19. Negative LDO with Servo

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There are two SET resistors and the midpoint is fed with a $20\mu\text{A}$ pre-bias current that sets the floating voltage. The SET resistor $R_{\text{SET}1}$ always sees $50\mu\text{A}$ and $R_{\text{SET}2}$ sees $30\mu\text{A}$. This arrangement allows the DAC, via the PNP, to adjust the pre-bias current, thereby moving the resistor midpoint, and therefore the output voltage. The LTC2975 DAC can soft-connect to the emitter which sits $\sim 0.6\text{V}$ above GND.

With the DAC disconnected, the PNP emitter current is defined by R3. The collector pushes $20\mu\text{A}$ into the SET resistors. Once the DAC is soft-connected to Q5's emitter, the DAC resistor limits the current added or subtracted to the R3 current.

Enable/Disable

Not all regulators have a RUN, SHDN, or other “enable” pin that allows easy turn-on and shut-off. Additionally, there might be no way to ensure V_{OUT} goes to ground when the regulator is disabled. Buck regulators are straightforward in this regard. However, the regulator you choose for your design may require some thought.

The LT3081 linear regulator does not have any such pin, so an alternate method was devised to force V_{OUT} off. An external NFET is connected to the SET pin that when activated pulls the SET pin to GND, thereby bringing V_{OUT} to GND. When the channel is disabled, the VOUT_EN pin is low, thereby turning the PFET on which pulls the NFET gate high, activating the NFET which pulls the SET pin to GND. When the channel is enabled, the PFET gate pulls

high and the NFET is released, allowing the LT3081's $50\mu\text{A}$ current source to ramp the SET node via the R_{SET} resistor. The TON_RISE timer begins to count. Once the timer expires, the DAC starts its soft-connect operation.

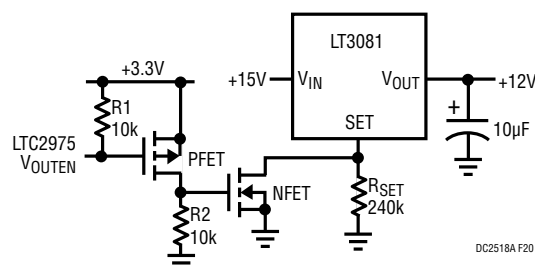


Figure 20. Disable Output with Input PFET

Another potential issue you may encounter is the proper disabling of a boost regulator. Look at the CH2: +48V supply. The LT8330 is configured as a boost topology which has a DC path (inductor and diode) from the input to output. There is an enable pin on the device. However when disabled, the output does not go to ground but rather only goes down to the input voltage. To solve this problem, a PFET was added in series with the input to disconnect V_{IN} , allowing the output to go to GND.

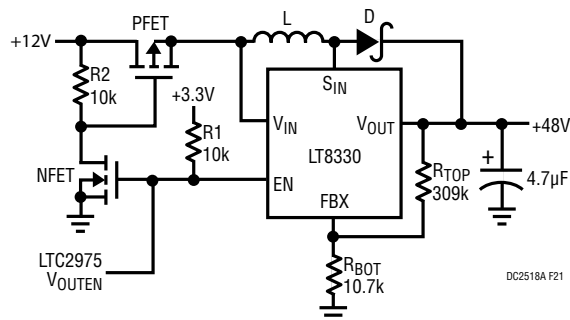


Figure 21. Disable Output with Input PFET

SETUP PROCEDURE FOR MULTI-BOARD ARRAYS

Multiple demo boards that have the 14-pin cascading connectors can be combined to control as many eight boards. Demo boards that can be cascaded include the DC2518, DC1962, DC2022, DC2023, DC2028, and DC2198. The number of boards is limited by an I/O expander chip that has three address pins, allowing 8 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 DC2518A board.
2. Ensure different slave address settings for each of the boards. The address of each DC2518A board is set by the DIP switch JP3 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 22. Only one +12V power source is allowed.

4. The USB-to-I²C/SMBus/PMBus Controller may be plugged into any board. If no demo boards show up in the GUI, click the magnifying glass icon to enumerate the I²C bus and find the addresses of the parts. Repeat steps #2-4 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.

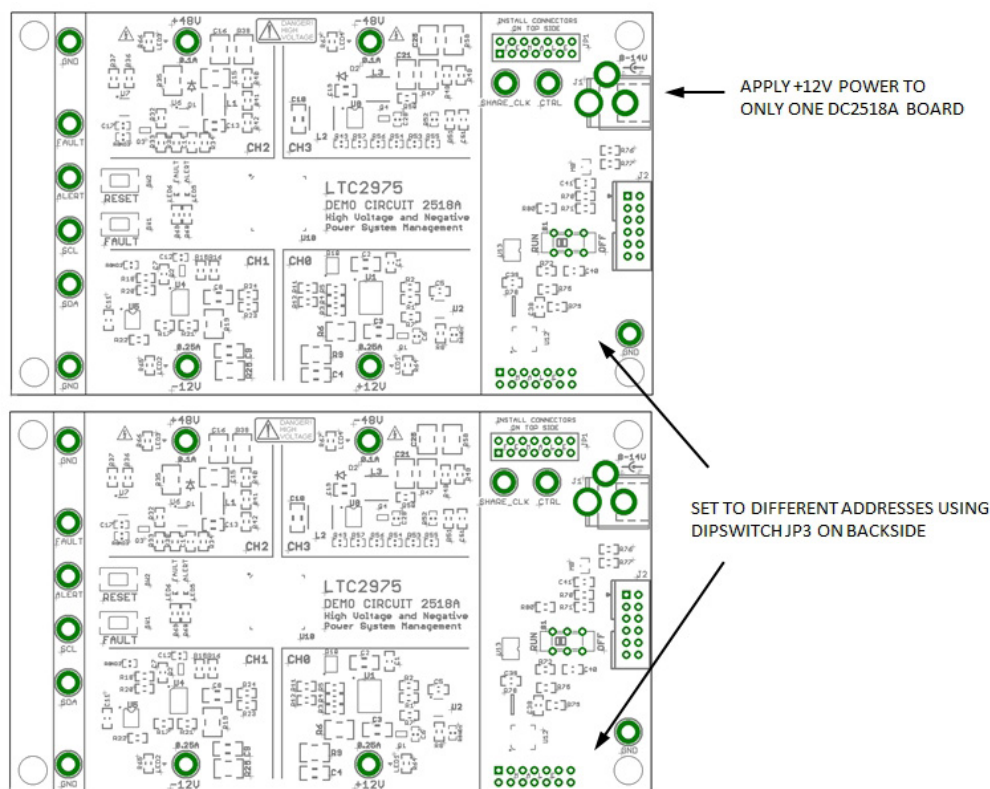


Figure 22. Array of Multiple Board Sets

SETUP PROCEDURE FOR MULTI-BOARD ARRAYS

Ensuring Slave Addresses Do Not Conflict

There is a small DIP switch on the backside of the DC2518A. 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.

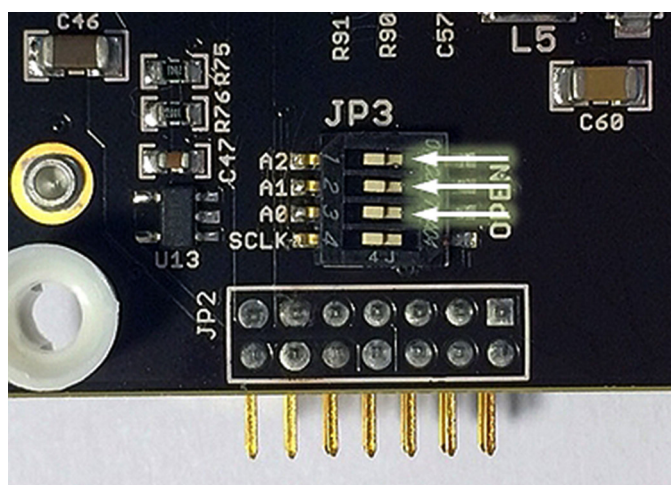


Figure 23. DIP Switch Set to All 0's

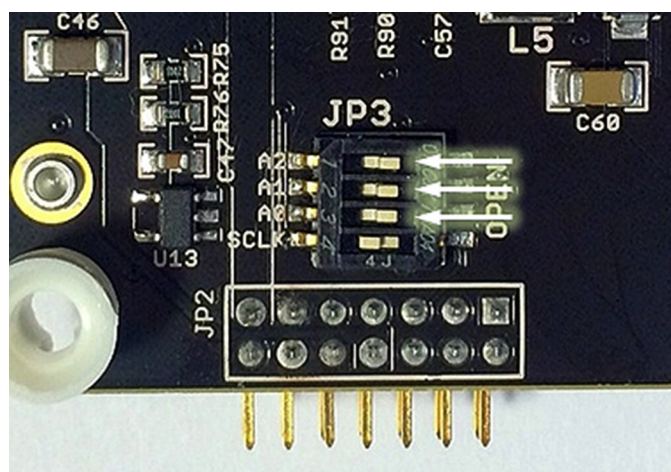
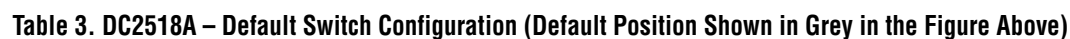


Figure 24. DIP Switch Set to All 1's

DC2518A DETAILS TOP

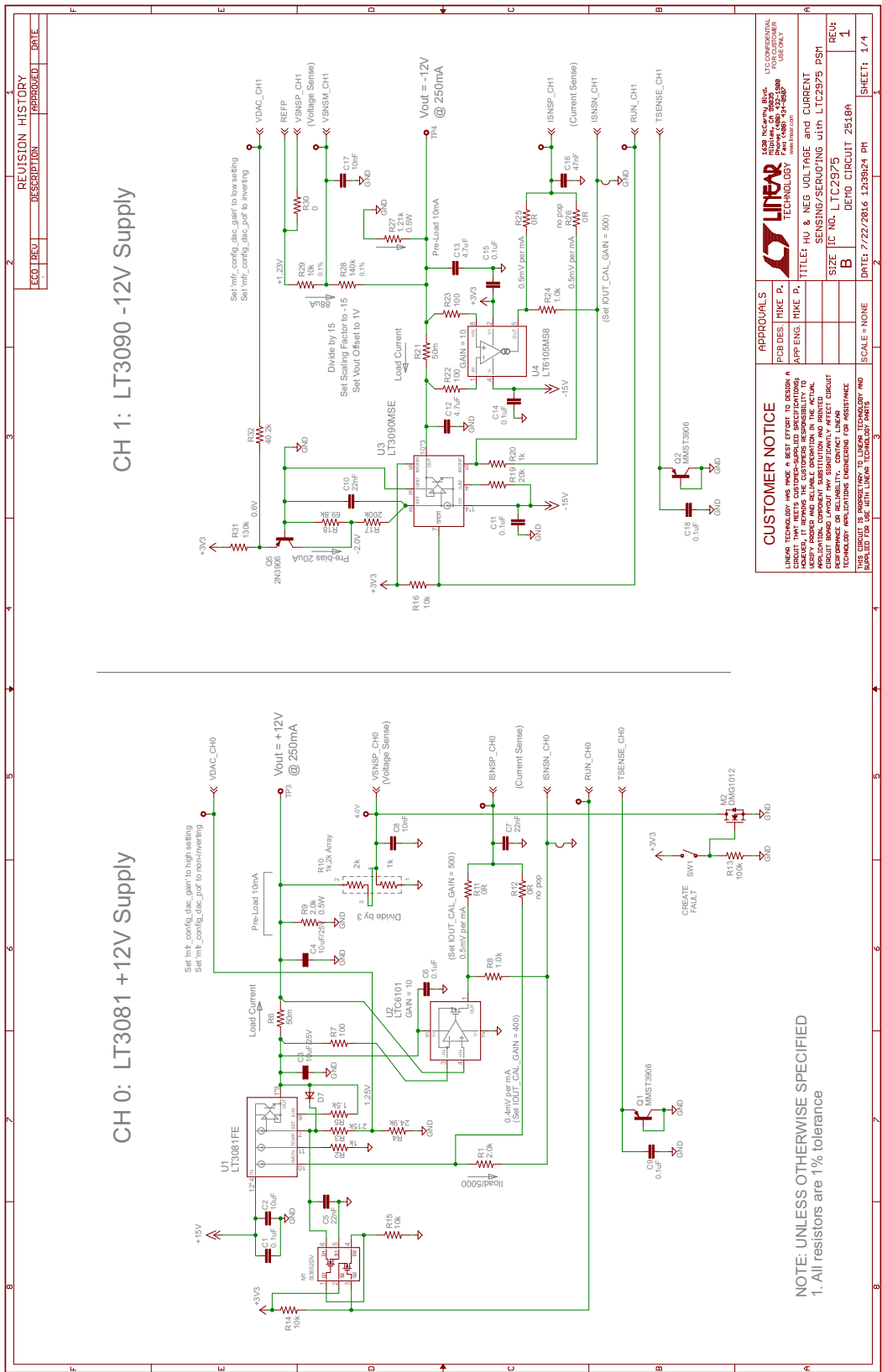


REFERENCE DESIGNATOR	SIGNAL NAME	USAGE	DEFAULT
JP3 (Bottom)	A0, A1, A2	DIP Switch Used to Set the Address Offset	OPEN
S1	CTRL	Switch Used to Enable/Disable Channels by Pulling the Control Input Pins High/Low of LTC2975	RUN

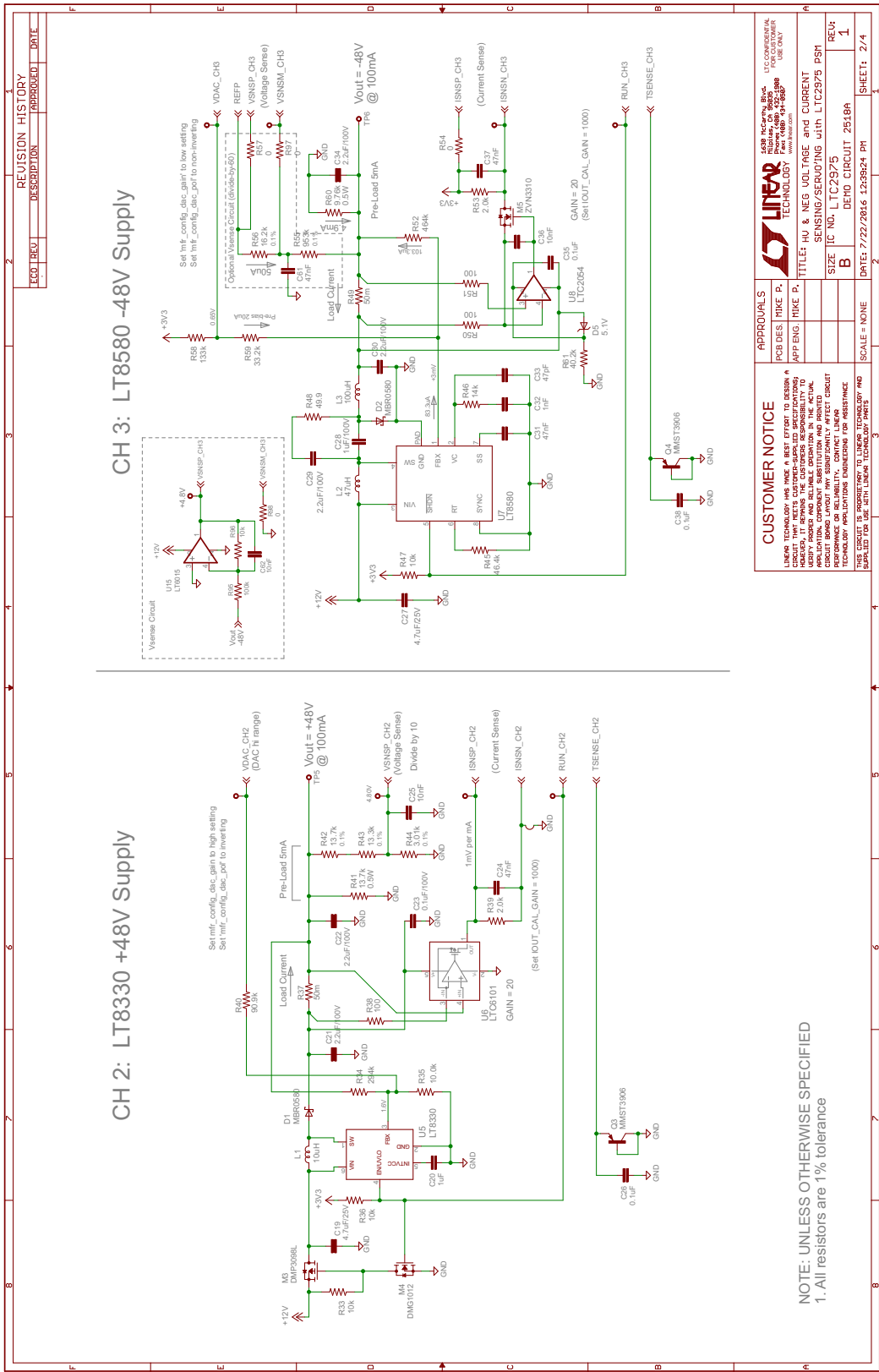


DEMO MANUAL DC2518A

DC2518A SCHEMATIC DIAGRAM



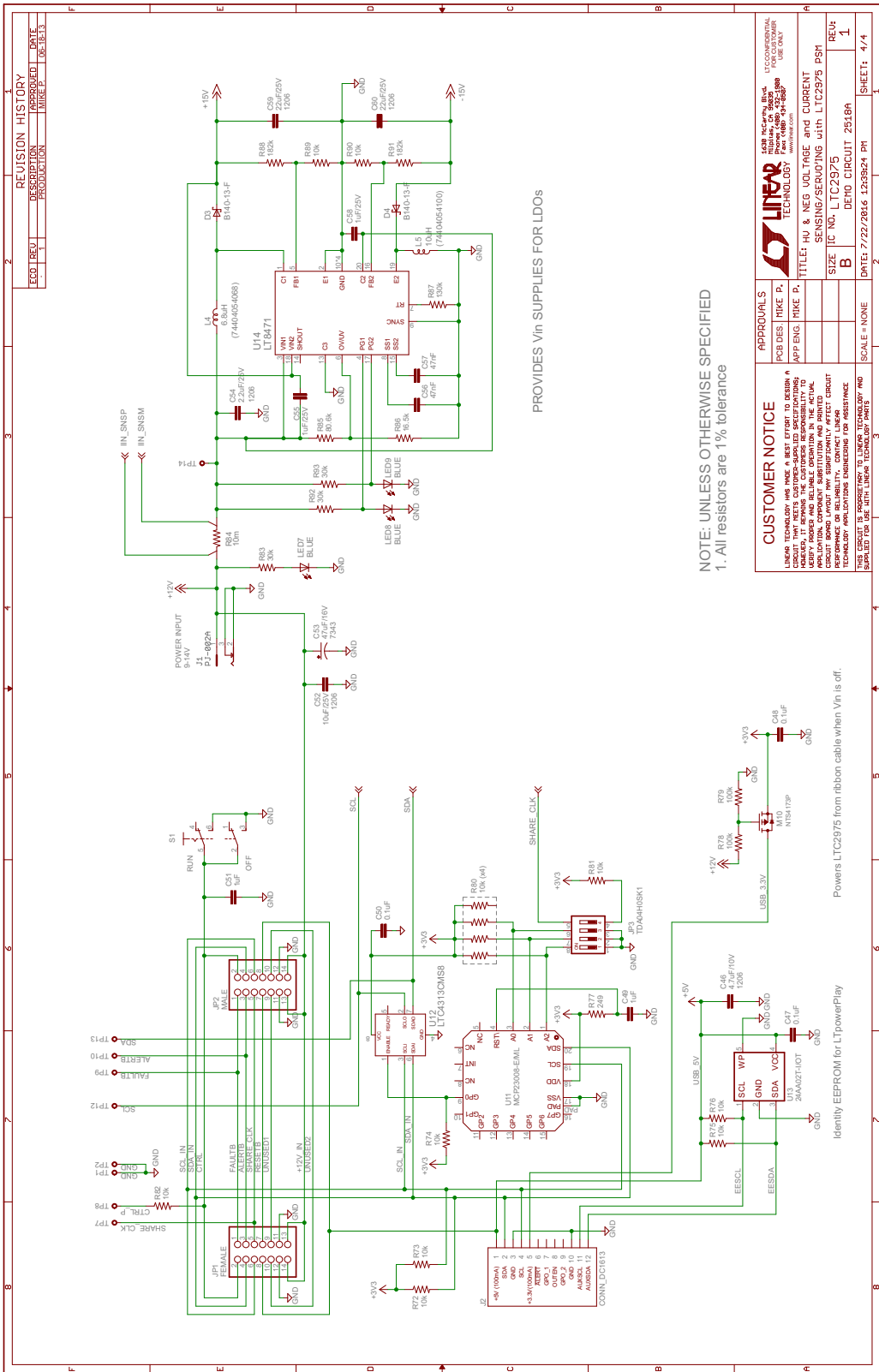
DC2518A SCHEMATIC DIAGRAM



DC2518A SCHEMATIC DIAGRAM



DC2518A SCHEMATIC DIAGRAM



DEMO MANUAL DC2518A

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