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# Take the Easy Road to Digitally Managed Power

by Andy Gardner

## Introduction

Digital management of high availability power supplies holds great promise, but it often comes at the cost of complicated multichip circuit solutions. For example, an application with voltage-current monitoring and supply voltage margining can require a number of ICs, including a low-drift reference, a multichannel, differential input ADC with at least 12 bits of resolution, an 8-bit DAC, and a dedicated microcontroller. Add to this the considerable software development effort required for margining algorithms, voltage and current monitor functions, and the cost, complexity, spacious board real-estate

requirements and blossoming design-debug time can deter even the most dedicated power supply designer from trying digitally managed power.

The LTC2970 simplifies the design of digitally managed power supplies by incorporating important features into one easy-to-use device: a dual power supply monitor and controller. Figure 1 shows a block diagram of the LTC2970, highlighting the following features:

❑ A 14-bit, differential input,  $\Delta\Sigma$  ADC with a maximum total unadjusted error (TUE) of  $\pm 0.5\%$  over the industrial temperature range when using the on-chip reference.

❑ A 7-channel ADC multiplexer with four external differential inputs, a 12V input, a 5V  $V_{DD}$  input, and an input for the on-chip temperature sensor.

❑ Two continuous time, 8-bit, current output DACs with voltage buffered outputs. The outputs of the voltage buffers can be placed in a low leakage, high impedance state.

❑ A built-in, closed-loop servo algorithm that adjusts the point-of-load voltage of a DC/DC converter to the desired value. The range and resolution of the voltage servo is user adjust-

able with two external resistors.

❑ Extensive, user configurable overvoltage and undervoltage fault monitoring.

❑ An I<sup>2</sup>C and SMBus compliant 2-wire serial bus interface, two GPIO pins, and an  $\overline{\text{ALERT}}$  pin.

❑ An on-chip, 5V, linear regulator that allows the LTC2970 to operate from an external 8V to 15V voltage supply.

❑ Another part in the family, the LTC2970-1, adds a tracking algorithm that allows two or more power supplies to be ramped up and down in a controlled manner.

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LTC2970, continued from page 1

## Margining and Monitoring Application

Figure 2 shows a typical application circuit for monitoring and margining a DC/DC converter with external feedback resistors.

The LTC2970's  $V_{IN0\_A}$  differential inputs sense the voltage directly at the point-of-load while inputs  $V_{IN0\_B}$  monitor the voltage across sense resistor  $R_{50}$ . The DC/DC converter's output voltage can be margined to precise, user-programmable set points by a

linear search algorithm that compares the digitized point-of-load voltage against the target. The current being sourced by  $IDAC0$  is then adjusted as needed one LSB per servo iteration. This current develops a point-of-load ground referenced correction voltage across resistor  $R_{40}$  which is buffered to the  $V_{OUT0}$  pin. The resulting voltage differential between the  $V_{OUT0}$  pin and the converter's feedback node is multiplied by a factor of  $-R_{20}/R_{30}$  and added to the nominal output voltage of the DC/DC converter, thus closing

the servo loop. When voltage margining is disabled, the converter's feedback node can be isolated from the LTC2970 by placing the  $V_{OUT0}$  pin in a high impedance state.

Figure 3 shows the LTC2970 applied to a DC/DC converter with a TRIM pin. As in Figure 2, two external resistors are required:  $V_{OUT0}$  connects to the TRIM pin through resistor  $R_{30}$  and  $I_{OUT0}$  is terminated at the DC/DC converter's point-of-load ground by  $R_{40}$ . Following power-up, the  $V_{OUT0}$  pin defaults to a high impedance

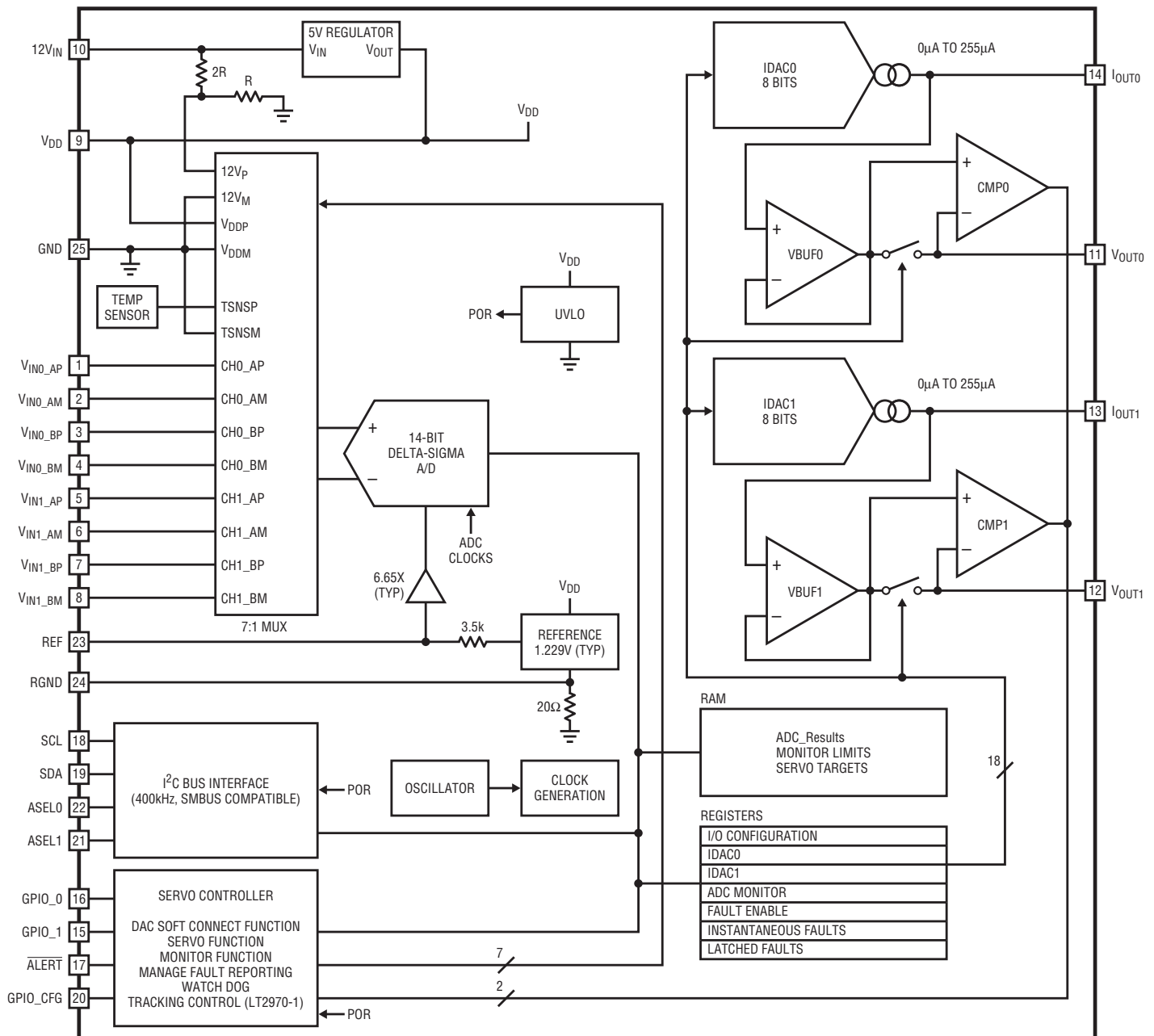


Figure 1. Block diagram of the LTC2970

state allowing the DC/DC converter to power-up to its nominal output voltage. After power-up, the LTC2970's soft-connect feature can be used to automatically find the IDAC code that most closely approximates the TRIM pin's open-circuit voltage before enabling  $V_{OUT0}$ .

Applications that need to be sequenced can be configured to hold off the DC/DC converter when the LTC2970 powers-up by tying the GPIO\_CFG pin high. This causes the GPIO\_0 pin to automatically pull the DC/DC converter's RUN pin low until the SMBus compatible I<sup>2</sup>C interface releases it.

The absolute accuracy of the LTC2970 is demonstrated in Figure 4. The LTC2970 is configured to servo one of the outputs of a LTC3728 DC/DC converter to 1V if the converter's voltage deviates by more than  $\pm 0.1\%$ . The LTC2970 is easily able to hold the output voltage to within  $\pm 1\text{mV}$  of 1V while both it and the DC/DC converter are heated from  $-50^\circ\text{C}$  to  $100^\circ\text{C}$ . When the LTC2970 is isolated from the LTC3728, the output voltage drifts between 1.002V and 1.0055V over the same temperature range.

## Features

The LTC2970's features offer several benefits that differentiate it from competitive solutions:

### Delta-Sigma ADC

The LTC2970's ADC is a second-order delta-sigma modulator followed by a sinc<sup>2</sup> digital filter that converts the modulator's serial data into a 14-bit word at a conversion rate of 30Hz. The ADC's TUE is less than  $\pm 0.5\%$  when using the on-chip reference.

One advantage delta-sigma ADCs offer over conventional ADCs is on-chip digital filtering. Combined with a large over-sampling ratio (OSR = 512), this feature makes the LTC2970 insensitive to the effects of noise when sampling power-supply voltages. The LTC2970's sinc<sup>2</sup> digital filter provides high rejection except at integer multiples of the modulator sampling frequency,  $f_s = 30.72\text{kHz}$ . Adding a simple RC low-pass filter at the input of the ADC

attenuates ripple components that have the potential to alias to DC.

The ADC's differential inputs can monitor supply voltages at the point of load and sense resistor voltages.

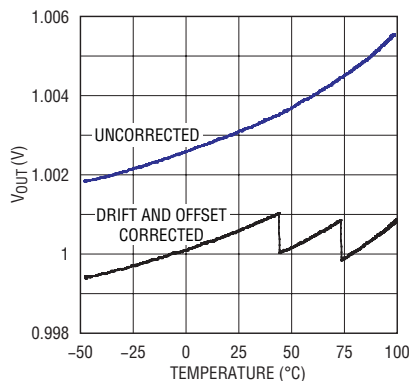


Figure 4. Corrected and uncorrected DC/DC converter output voltage vs temperature

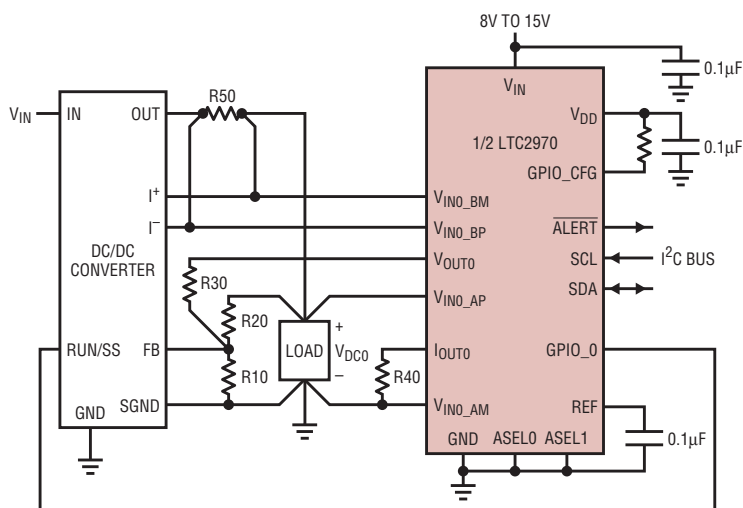


Figure 2. Application circuit for DC/DC converter with external feedback resistors

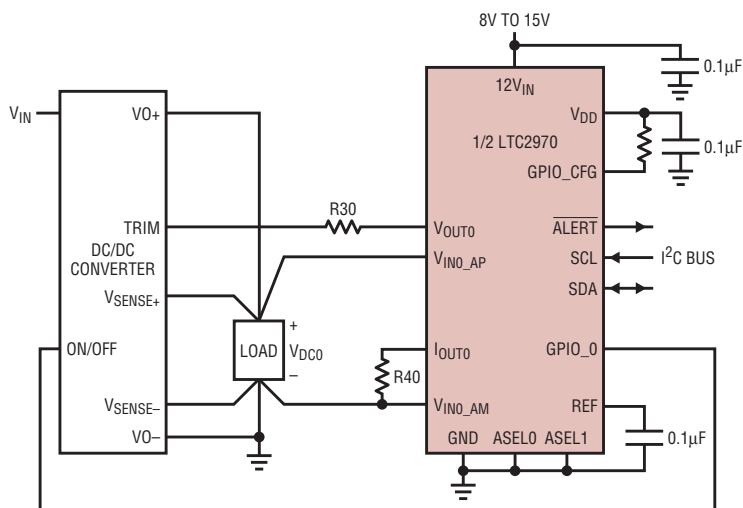


Figure 3. Application circuit for a DC/DC converter with a trim

The differential and common mode input ranges span  $-0.3\text{V}$  to  $6\text{V}$ . With its  $500\mu\text{V}/\text{LSB}$  resolution, the ADC can resolve voltages for a wide range of load current across sense resistor values of only a few milliohms. For

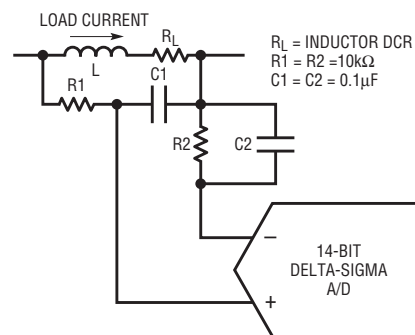
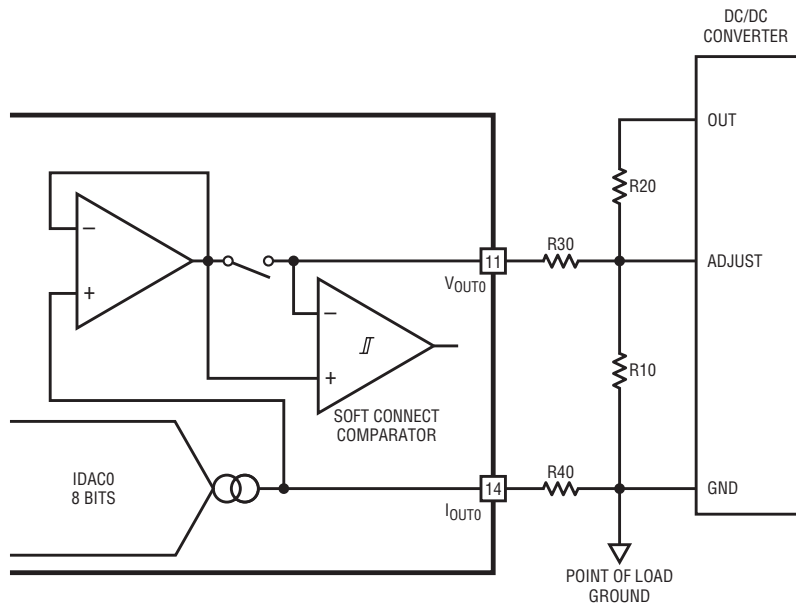


Figure 5. Network for sensing load current with inductor DCR



**Figure 6. DAC connections to DC/DC converter with an external feedback resistors**

switching power supply applications without sense resistors, measure the load current via the DC resistance of the inductor using the application circuit shown in Figure 5.

The ADC inputs are also isolated from the LTC2970's internal supply. So the user can measure differential and common mode input voltages that are greater than  $V_{DD}$  without turning on body diodes, and no special precautions need to be taken if the LTC2970 loses power while monitoring DC/DC converter voltages powered from a different supply.

## Voltage Buffered IDACs

Figure 6 illustrates how each of the LTC2970's continuous-time IDACs connects to a DC/DC converter with an external feedback network. The servo'd correction voltage is set by resistor  $R_{40}$ . Since  $R_{40}$  is terminated at the point-of-load ground, the correction voltage is insensitive to load induced ground bounce. The correction voltage is buffered to the  $V_{OUT0}$  pin by a unity-gain amplifier whose output can be placed in a low-leakage ( $<100\text{nA}$ ), high impedance state. Resistor  $R_{30}$  connects the  $V_{OUT0}$  pin to the feedback node of the DC/DC converter. The range and resolution over which the correction voltage can

move the converter's output is adjustable via resistor  $R_{30}$ .

A “soft-connect” feature allows the LTC2970 to automatically find the  $V_{OUT0}$  voltage that most closely approximates the DC/DC converter’s feedback node voltage before enabling the voltage buffer thus minimizing any

disturbance to the converter's output voltage.

There is no body diode from the  $V_{OUT0}$  pin to the LTC2970's  $V_{DD}$  supply, and the  $V_{OUT0}$  pin goes into a high impedance state when  $V_{DD}$  drops below the LTC2970's undervoltage lockout threshold. So no special precautions need to be taken in the event the DC/DC converter is still active when the LTC2970 powers down.

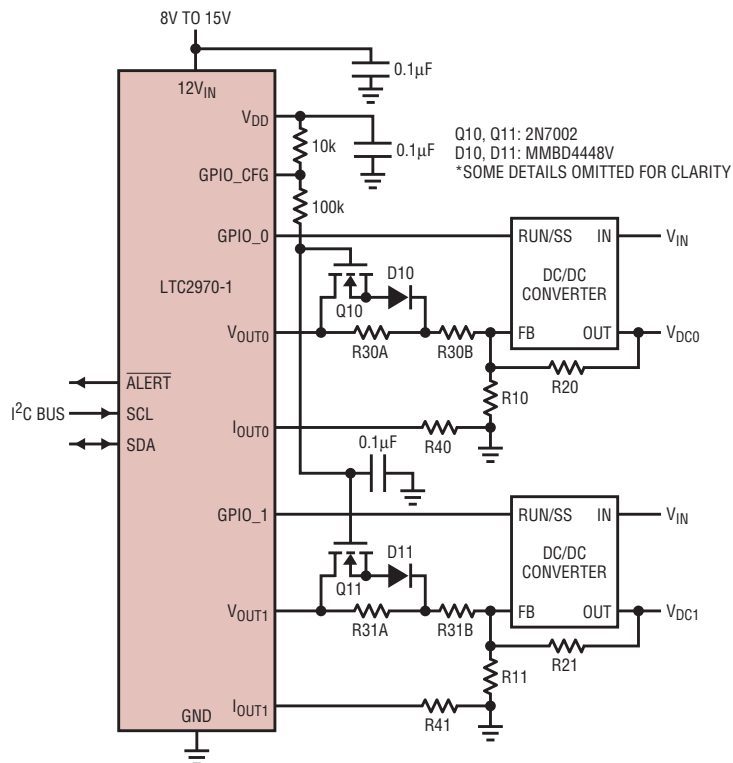
## Voltage Servo

The voltage servo feature can be configured to trigger on under voltage and/or over voltage events, run continuously, or run just once. The LTC2970 relies on a simple linear search algorithm to find the IDAC code that results in an ADC input voltage that most closely corresponds to the servo target. The polarity of the servo algorithm can be programmed as inverting (default) or noninverting.

## Voltage Monitor

The LTC2970 is able to perform ADC conversions on any combination of seven different input channels. Over-voltage and undervoltage threshold

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**Figure 7. The LTC2970-1 enables supply tracking**



# New Device Cameos

## Wide Dynamic Range RF/IF Log Detector

The LT5537 is a wide dynamic range RF/IF detector, which operates from below 10MHz to 1000MHz. The lower limit of the operating frequency range can be extended to near DC by the use of an external capacitor. The input dynamic range at 200MHz with  $\pm 3\text{dB}$  nonlinearity is 90dB (from  $-76\text{dBm}$  to  $14\text{dBm}$ , single-ended  $50\Omega$  input). The detector output voltage slope is nominally  $20\text{mV/dB}$ , and the typical temperature coefficient is  $0.01\text{dB}/^\circ\text{C}$  at 200MHz.

The LT5537 is available in a tiny 8-Lead (3mm  $\times$  2mm) DFN package.

## Dual Output Synchronous DC/DC Controller Draws Only 80 $\mu\text{A}$ Quiescent Current in an Automotive System

The LTC3827 is a low quiescent current, 2-phase dual output synchronous step-down DC/DC controller. The LTC3827 draws only  $80\mu\text{A}$  when one output is active and only  $115\mu\text{A}$

when both outputs are active, making it ideally suited for automotive applications, such as navigation systems, where one or more supplies remains active while the engine is off. The LTC3827's input supply range of 4V to 36V is wide enough both to protect against high input voltage transients and to continue to operate during automotive cold crank. The LTC3827 features a  $\pm 1\%$  internal reference and can provide output voltages from 0.8V up to 10V, making it perfect for the higher voltage supplies typically required for audio systems, analog tuners, and CD/DVD players in many automobiles. Each output can deliver up to 20A of current at efficiencies as high as 95%. The LTC3827 is rated for operation from  $-40^\circ\text{C}$  to  $85^\circ\text{C}$ , and has a maximum operating junction temperature of  $125^\circ\text{C}$ .

The LTC3827's constant frequency, current mode architecture provides excellent line and load regulation, and its 2-phase operation reduces input capacitance requirements. The LTC3827

smoothly ramps each output voltage during startup using separate adjustable soft-start and tracking input pins. It operates at a selectable frequency between 250kHz and 550kHz, and can be synchronized to an external clock from 140kHz to 650kHz using its phase-locked loop (PLL). Output overvoltage and overcurrent (short circuit) protection are provided internally. With both outputs shut down, the LTC3827 draws a mere  $8\mu\text{A}$ .

The LTC3827 is offered in two packages: a 28-lead SSOP (LTC3827-1) and a 32-pin 5mm  $\times$  5mm QFN (LTC3827).

**For further information on any of the devices mentioned in this issue of *Linear Technology*, use the reader service card or call the LTC literature service number:**

**1-800-4-LINEAR**

**Ask for the pertinent data sheets and Application Notes.**

*LTC2970, continued from page 5*

registers allow the user to define instantaneous and/or latched faults in the event one of the input voltages deviates outside an acceptable window. The GPIO\_0 and FAULT pins can be configured to assert if a fault occurs.

## Tracking Two or More Supplies with the LTC2970-1

The LTC2970-1 enables power supply tracking with the addition of a few external components. A special global address and synchronization command allow multiple LTC2970-1s to track and sequence multiple pairs of power supplies.

A typical LTC2970-1 tracking application circuit is shown in Figure 7. The GPIO\_0 and GPIO\_1 pins are tied directly to their respective DC/DC converter RUN/SS pins. When GPIO\_CFG is pulled-up to  $V_{DD}$ , the LTC2970-1 automatically holds off

the DC/DC converters after power-up. N-channel FETs Q10 and Q11 and diodes D10 and D11 form unidirectional range switches around R30A and R31A while GPIO\_CFG is high, which allow the  $V_{OUT0}$  and  $V_{OUT1}$  pins to drive the converter outputs all the way to/from ground through resistors R30B and R31B. When GPIO\_CFG pulls low, FETs Q10 and Q11 turn off. R30A and R31A then combine in series with R30B and R31B for normal margin operation. The  $100\text{k}\Omega/0.1\mu\text{F}$  lowpass filter in series with the gates of Q10 and Q11 minimizes charge injection into the feedback nodes of the DC/DC converters when GPIO\_CFG pulls low.

## Conclusion

The LTC2970 dual power supply monitor and controller combines the necessary features essential for digitally managed, high availability

power applications into one easy-to-use device. A multiplexed, differential input 14-bit delta-sigma and a low drift on-chip reference deliver less than  $\pm 0.5\%$  total unadjusted error. Two continuous-time, 8-bit, voltage-buffered IDACs can also be programmed through the I<sup>2</sup>C and SMBus compatible interface to servo power-supplies to the desired voltages. Extensive, user configurable fault monitoring and a built-in servo algorithm reduce the burden on system computing resources and shorten software development time. The LTC2970 and LTC2970-1 are available in a 24-lead QFN package.

