Application Report

SLUA426A – July 2007 – Revised November 2007

Expanded System Monitoring Functions With UCD9080

Ed Walker

PMP Systems Power

ABSTRACT

In contemporary electronic systems, many supply voltage rails must be sequenced properly and monitored for proper voltage regulation. Sequencing can be done in many ways, often requiring several components. Reporting of improper voltage regulation has been reduced to a single bit, either good or bad, without providing details. To this extent, the UCD9080 8-Channel Power Supply Sequencer and Monitor has been developed by Texas Instruments. The ability of a device like this, however, goes beyond monitoring, sequencing, and reporting of power supply rails. This application report expands on the added uses of the UCD9080 for system monitoring.

Contents

List of Figures

List of Tables

1 UCD9080 Operation

1.1 Basic Functions

The UCD9080 has three main functions:

- Control outputs that use the Enable (EN1-EN8) and general-purpose (GPO1-GPO4) signals for enabling, disabling, and sequencing an external circuit, derived from the monitored inputs.
- Voltage monitoring with the MON1-MON8 inputs.
- Communication that uses the I^2C for writing operational configurations, plus reading status and error events.

The UCD9080 supports both configuration and monitoring using its I^2C slave interface. For monitoring of the sequencer, an I^2C memory map is used that allows an I^2C host to perform memory-mapped reads (and in some cases writes) that reports status information from the UCD9080. For instance, all inputs can report their voltage through the I^2C memory map. For information on which parameters are available via the I^2C memory map, see the *Monitoring the UCD9080* section located in the UCD9080 data sheet (SLVS692). To change configuration parameters of the sequencer, a different mechanism is used. The entire set of configuration parameters must be written at one time to the device as one large transaction over the I^2C interface. This ensures that the configuration of the device is consistent at any given time. The process for configuring the UCD9080 is described in the *Configuring the UCD9080* section of the data sheet (SLVS692).

1.2 Typical Application

A typical application might involve the monitoring, sequencing, and controlling multiple DC-to-DC converters in a multipower rail system. Figure 1 illustrates a typical power supply sequencing configuration. Power Supply 1 and Power Supply X require active-low enables while Power Supply 2 and Power Supply 3 require active-high enables. V_{OUT1} and V_{OUT3} exceed the selected A/D reference voltage; so, their outputs are divided before being sampled by the MON1 and MON3 inputs. V_{OUT2} and V_{OUTX} are within the selected A/D reference voltage; so, their outputs can be sampled directly by the MON2 and MON7 inputs. Figure 1 also illustrates the use of the GPO digital output pins to provide status and power on reset to other system devices.

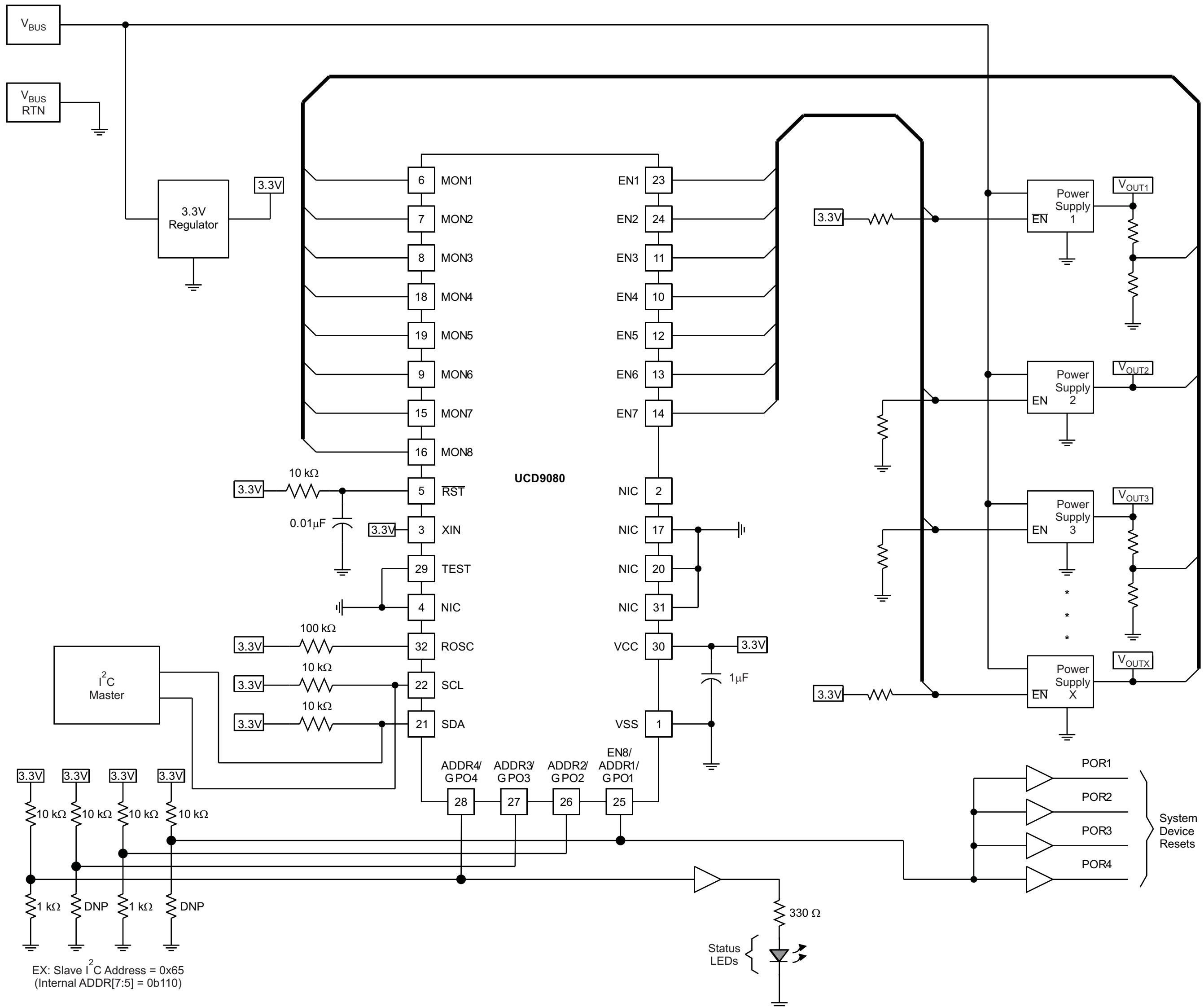

Figure 1. Typical DC-DC Converter Application

When the user considers that this operation consists of monitoring an analog input, making a decision derived from device configuration, and asserting a control output accordingly, it becomes apparent that a wide range of analog signals can be monitored and a wide range of external circuits can be controlled.

1.3 UCD9080 Inputs and Registers

The fundamental elements of voltage monitoring are:

1. MONx analog-to-digital converter input range. This is 0 V to 2.5 V when configured to use the UCD9080 internal reference, 0-V_{CC} when configured to use V_{CC} as the reference. This is the input for the voltage the user wants to monitor.
2. Define the overvoltage and undervoltage trip thresholds.

$$V_{raw} = \frac{1024 \times V_{RAILOV}}{V_{REF}} \quad (1)$$

$$V_{raw} = \frac{1024 \times V_{RAILUV}}{V_{REF}} \quad (2)$$

3. The internal registers of the UCD9080 are used to read the MONx voltage from the RAIL register. Each of the eight voltage rails that the UCD9080 supports has two registers that contain the rolling average voltage for the associated rail as measured by the device. This average voltage is maintained in real-time by the UCD9080 and is calculated as the output of a 4-TAP FIR filter. Each voltage rail has two registers. One holds the least-significant 8 bits of the voltage and the other the most-significant 2 bits of the voltage. The following formulas can be used to calculate the actual measured rail voltage.

   Without external voltage divider:

$$V_{RAILn} = \frac{RAILVn}{1024} \times V_{REF} \tag{3}$$

   With external voltage divider:

$$V_{RAILn} = \frac{RAILVn}{1024} \times V_{REF} \times \frac{R_{PULLDOWN} + R_{PULLUP}}{R_{PULLDOWN}} \tag{4}$$

1.4 *UCD9080 Error Logging*

Error conditions, OV/UV error flags, are accessible by periodic polling of the ERROR registers in the UCD9080. To determine when an error has occurred, the STATUS register must be read on a periodic basis. The RAIL error bit is set to alert the user to an issue with one of the voltage rails. When this bit is set, the user is advised to then query the RAILSTATUS register to further ascertain which RAIL input(s) have an issue. The user can then query the ERROR registers to get further information about the nature of the error condition. The ERROR register is 6 bytes located at hexadecimal address 0x20–0x25; see the *ERROR* subsection of the *Monitoring the UCD9080* section of the data sheet (SLVS692) for details. This register reports Error Code, Rail (MON1–MON8), error data, and time of error.

Figure 2 shows the ERROR register address and bit assignments.

0x20								0x21							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Error Code			RAIL			Data (dependent on error code)									
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

RAIL	**Meaning**
	Rail #(n) - 1, RAIL = 0 through 7

Error Codes	**Meaning**	**Data**
0 0 0	Null Alarm	0x0000
0 0 1	Supply did not start	Average voltage on Rail
0 1 0	Sustained overvoltage detected	Average voltage on Rail
0 1 1	Sustained undervoltage detected	Average voltage on Rail
1 0 0	Overvoltage glitch detected	Glitch voltage level on Rail
1 0 1	Undervoltage glitch detected	Glitch voltage level on Rail
1 1 0	Reserved	Reserved
1 1 1	Reserved	Reserved

NOTE: When Error Code = 'Null Alarm' then the Hours, Minutes, Seconds, and Milliseconds fields are zero.

0x23								0x22							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Hour								Minutes							
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

0x25								0x24							
7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
Seconds						Milliseconds									
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Figure 2. UCD9080 ERROR Registers

1.5 System Interrupt

The Enable outputs can be used to generate a system interrupt on an error condition. ENx can be configured to change state based on the conditions of a monitored rail. This is normally used for power supply sequencing, turning on subsequent output rails once another rail is within its tolerance. The ENx can be configured to be a 0 or a 1 when a monitored rail is within its operating window; however, this also means that ENx changes state when the monitored rail goes outside of its operating window. Therefore, this provides an independent signal, separate from the ERROR registers, to indicate an error condition.

2 Example 1: Temperature Monitoring

2.1 Temperature Circuit

In a digital system, a common requirement is to monitor the system temperature. If the system gets too hot, due to blocked airflow or a high, ambient air temperature, this can be reported using the UCD9080 on the I^2C bus.

Figure 3 shows the simple thermal monitor circuit using a low-cost 103AT-2 10K@25C negative temperature coefficient thermistor. Vin is derived from the UCD9080 3.3-V Vcc supply. The mathematical equation for the circuit is Equation 5.

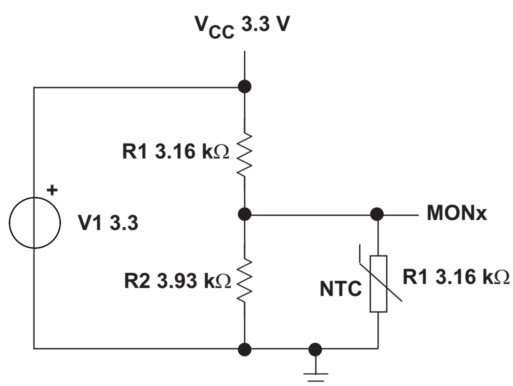

Figure 3. Temperature-Sensing Circuit

$$M_{ONx} = \frac{R_3 \times R_2}{R_2 \times R_1 + R_3 \times R_1 + R_3 \times R_2} \times V_1 \tag{5}$$

2.2 Design Parameters

By choosing the temperature-sensing design parameters to be cold alarm 10°C, hot alarm 85°C, the resultant modeled temperature sense voltages, with resistance and V_{CC} tolerances, are shown in Table 1.

Table 1. Temperature Sense Tolerance

Parameter	Specification	Calc Min	Calc Max
Vin	3.3 V	3.267 V	3.333 V
Res Tol 1.0%			
Temp Sense Res (Ω)		17960	1451
Cold Trip Temp	10°C	–1.8°C	18.7°C
Cold Trip Voltage	1.65 V	1.593 V	1.708 V
Hot Trip Temp	85°C	82.4°C	87.4°C
Hot Trip Voltage	0.825 V	0.807 V	0.844 V

2.3 Thermistor Curves

The thermistor impedance versus temperature curve is shown in Figure 4; the voltage output of the TS circuit versus temperature is shown in Figure 5 and will input to the UCD9080 MON8 analog input. The blue lines indicate the cold temperature tolerance; red lines indicate the hot temperature tolerance. If real-time reporting of the temperature is desired, a lookup table in the system RAM, corresponding to the voltage data, is required.

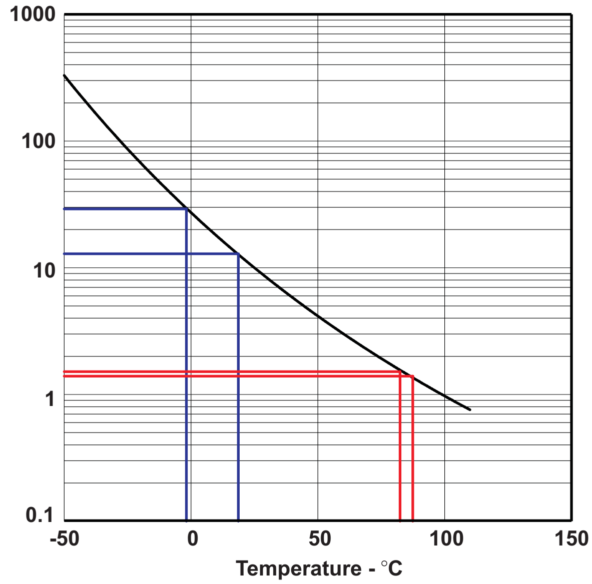

Figure 4. Thermistor Impedance vs Temperature

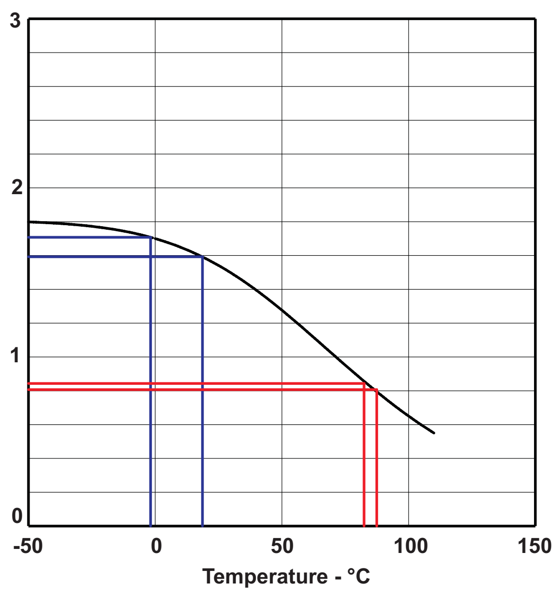

Figure 5. MON8 Input Voltage vs Temperature

2.4 UCD9080 Configuration

The monitor input is designed for 1.65-V COLD temperature alarm (10°C), 0.825-V HOT temperature alarm (85°C), and reports the range in between. The alarms use the overvoltage and undervoltage functions and the internal 2.5-V reference.

Following the equations in the UCD9080 data sheet:

$$V_{raw} = \frac{1024 \times V_{RAILOV}}{V_{REF}} \quad (6)$$

$$V_{raw} = \frac{1024 \times V_{RAILUV}}{V_{REF}} \quad (7)$$

Vrailov= 1.65 V, Vrailuv= 0.825 V, Vref=2.5 V
Vrawov = cold alarm = 675.84
Vrawuv = hot alarm = 337.92

These are the values to program into the OverVoltage UnderVoltage Threshold registers and generate an ERROR condition, accessible by reading the ERROR registers.

Real-time monitoring of the temperature requires reading the RAIL8H RAIL8L 10-bit binary registers.

When the ERROR data registers or the RAIL registers are read, they can be converted back into a corresponding voltage by the following formula and compared to the lookup table to extrapolate the temperature.

$$V_{RAILn} = \frac{RAILVn}{1024} \times V_{REF} \quad (8)$$

2.5 Actions Taken for Temperature Errors

Finally, several actions can be taken by reading the real-time temperature, error information, or a system interrupt created by an ENx transition.

1. Data collection for average, maximum, and minimum temperature. This can be used for reliability and to indicate gradual blockage of the airflow.
2. Alert the system software or maintenance management of an overtemperature condition.
3. Adjust the system cooling fans using other ENx or GPIO outputs.
4. Power down some portions of the system

3 Example 2: Monitoring a Negative Voltage

Negative voltages are in many systems, either supply rails or analog sources. A rather simple method of monitoring a negative voltage can be implemented, by reversing the interpretation of overvoltage and undervoltage, and the addition of a voltage divider providing a positive offset.

In a positive voltage-sensing application, the sensed voltage is in the range of VCC to ground. By implementing the resistor divider shown in Figure 6, the negative voltage is offset to a positive value. The resistors are selected to place the MONx voltage between 0 V and 2.5 V.

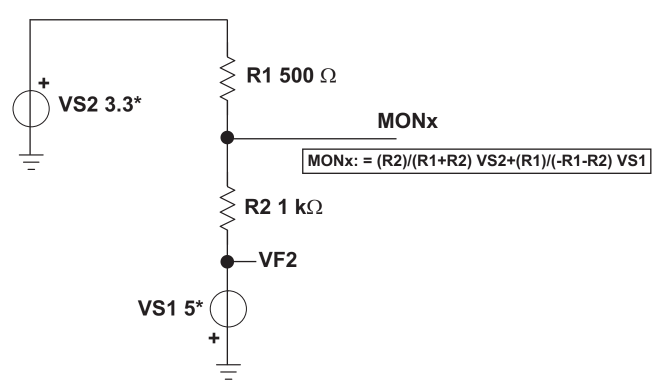

Figure 6. Negative Voltage Monitor

Equation 9 provides the formula for calculating the MONx voltage.

$$M_{ONx} = \frac{R_2}{R_1 + R_2} \times V_{S2} + \frac{R_1}{-R_1 - R_2} \times V_{S1} \quad (9)$$

Figure 7 illustrates a SPICE-modeled tolerance analysis of MONx obtained when a ±5% variation is allowed for the 3.3-V and –5-V rails. Note that 730 mV is obtained when V_{CC} is at 3.3 + 5% (3.47 V), –5 V is at –5% (–4.75 V), and is loaded into the OverVoltage threshold register to alert when the –5-V rail is too low. The UnderVoltage threshold register is set to 343 mV to alert when the –5 V is too high, above +5% (–5.25 V).

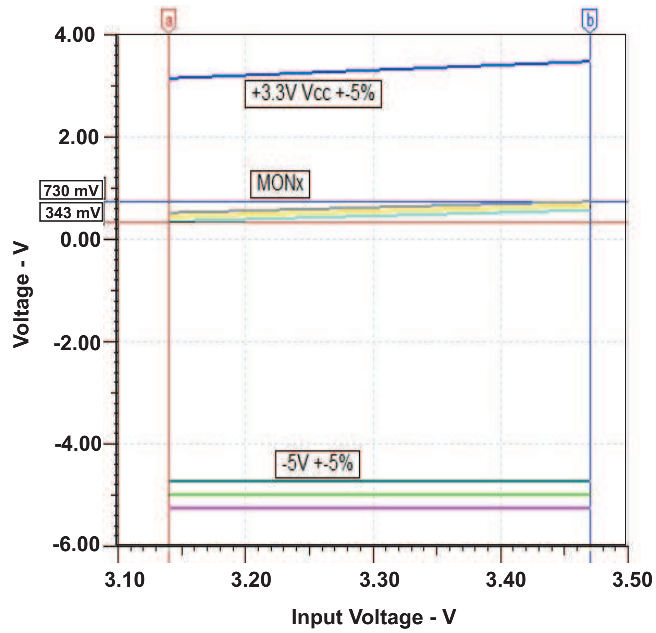

Figure 7. TINA-TI SPICE-Modeled Tolerance

A negative undervoltage alarm would use the OverVoltage threshold register, an overvoltage alarm would use the UnderVoltage threshold register. Error conditions are available in the ERROR register, as previously explained.

4 Example 3: Power Bus Current Measurement

A current-monitoring method can be added to the schematic in Figure 1 to measure the total input current to all the modules. In this manner, the total system power is monitored and overload conditions can be detected. Further, this can be modified to sense individual rail currents.

Figure 8 demonstrates a 12-V input source for multiple converters, a 5-mΩ current-sense element, and the INA194 current shunt monitor. The voltage output of the current monitored input is illustrated in Figure 9. The INA194 output is connected to one of the MONx inputs of the UCD9080.

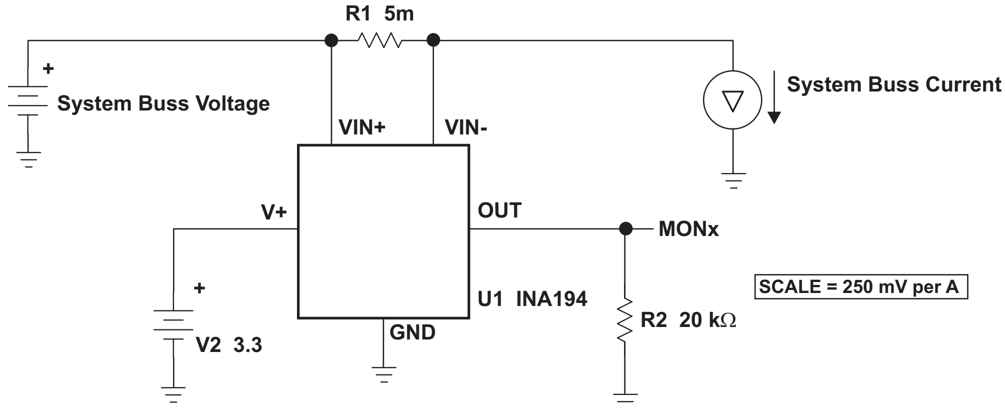

Figure 8. INA194 Input Bus Current Monitor

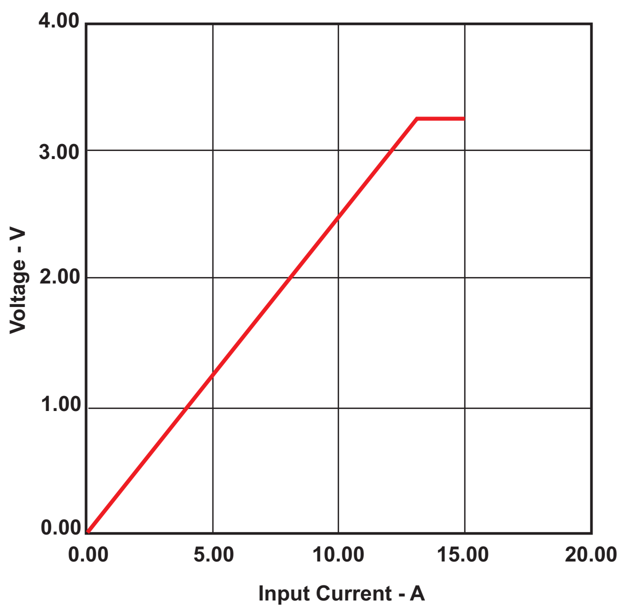

Figure 9. MONx Input vs Bus current

An overcurrent alarm would use the OverVoltage threshold register; an undercurrent alarm would use the UnderVoltage threshold register. Error conditions are available in the ERROR register, as previously explained in Section 1.4 UCD9080 Error Logging.

5 Conclusion

The monitoring of negative voltage rails, temperature, and input bus current demonstrates the expanded system-monitoring functions. The UCD9080's multiple analog inputs, configuration flexibility, and data extraction from the registers using digital communication, make this device an integral part of a digital system.

6 References

1. *UCD9080, 8-Channel Power Supply Sequencer and Monitor* data sheet (SLVS692).
2. TINA-TI SPICE-Based Analog Simulation Program (TINA)
3. INA194 Voltage Output High Side Current Shunt Monitor (INA194)

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Telephony	www.ti.com/telephony
Low Power Wireless	www.ti.com/lpw	Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265