

SECTION 7

HARDWARE MONITORING

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INTRODUCTION

Today's computers require that hardware as well as software operate properly, in spite of the many things that can cause a system crash or lockup. The purpose of hardware monitoring is to monitor the critical items in a computing system and take corrective action should problems occur.

Microprocessor supply voltage and temperature are two critical parameters. If the supply voltage drops below a specified minimum level, further operations should be halted until the voltage returns to acceptable levels. In some cases, it is desirable to reset the microprocessor under "brownout" conditions. It is also common practice to reset the microprocessor on power-up or power-down. Switching to a battery backup may be required if the supply voltage is low.

Under low voltage conditions it is mandatory to inhibit the microprocessor from writing to external CMOS memory by inhibiting the Chip Enable signal to the external memory.

Many microprocessors can be programmed to periodically output a "watchdog" signal. Monitoring this signal gives an indication that the processor and its software are functioning properly and that the processor is not stuck in an endless loop.

The need for hardware monitoring has resulted in a number of ICs, traditionally called "microprocessor supervisory products," which perform some or all of the above functions. These devices range from simple manual reset generators (with debouncing) to complete microcontroller-based monitoring sub-systems with on-chip temperature sensors and ADCs.

The ADM8691-series (see Figures 7.1 and 7.2) are examples of traditional microprocessor supervisory circuits. Comparator accuracy and glitch immunity is key to the circuit's operation. The ADM8691-series provides the following functionality: (1) Power-on reset output during power-up, power-down, and brownout conditions. Circuitry remains operational with V_{CC} as low as 1V. (2) Battery backup switching for CMOS RAM, CMOS microprocessor, or other low power logic. (3) A reset pulse is generated by the optional watchdog timer if the watchdog input has not been toggled within a specified time. (4) A 1.25V threshold detector for power fail warning, low battery detection, or to monitor a supply other than +5V.

An application of the ADM8691 is shown in Figure 7.3. Resistors R1 and R2 divide the regulator input voltage down and provide a Power Fail Indication when the voltage at the POWER FAIL INPUT falls below 1.25V.

HARDWARE MONITORING

The nominal low supply voltage threshold is set internally to 4.65V (ADM8691 and ADM800L) or 4.4V (ADM8693 and ADM800M). If V_{CC} falls below these values, RESET will be asserted.

MICROPROCESSOR SUPERVISORY FUNCTIONS - ADM8691 - SERIES

- Low Microprocessor Supply Voltage (4.65V or 4.4V)
- Battery Backup Steering Switch
- Power Failure Monitor (Low Line Voltage at Regulator Input)
- Power-On/Power-Down/Brownout Reset
- Watchdog Timer
- Inhibit Chip Enable to CMOS Memory (Prevents out-of-tolerance Microprocessor Addressing Memory)

Figure 7.1

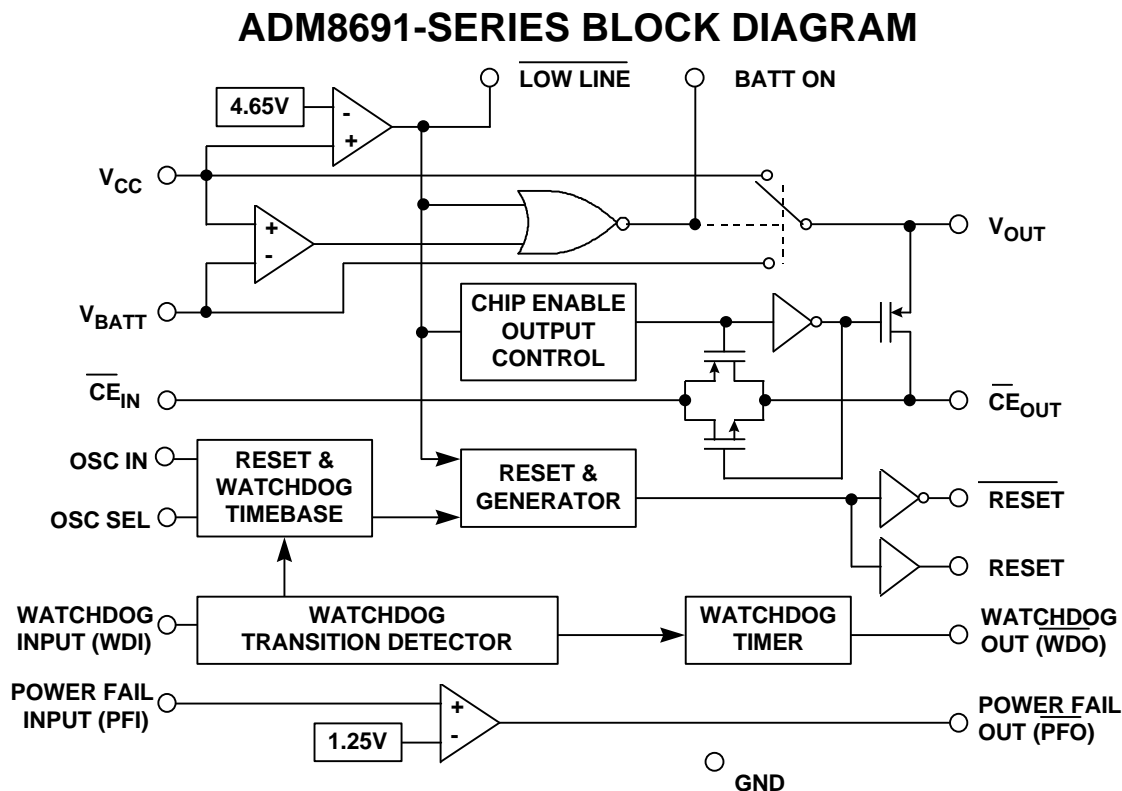


Figure 7.2

APPLICATION OF ADM8691 SERIES

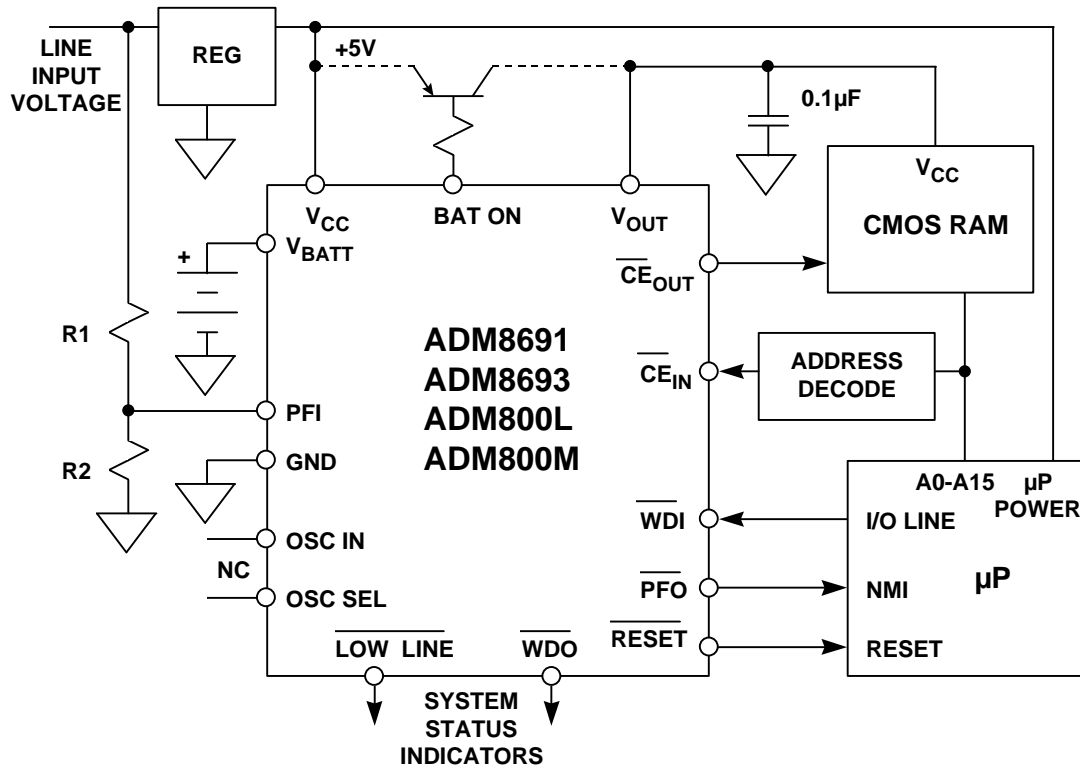


Figure 7.3

Several other actions occur when V_{CC} falls below its threshold value. The battery backup (V_{BATT}) is connected to the CMOS RAM power supply input via the V_{OUT} pin. Under normal operation, V_{CC} is connected to V_{OUT} , and the CMOS RAM receives its power from the V_{CC} input of the chip. The switch resistance from V_{CC} to V_{OUT} is 0.8Ω , and 12Ω from V_{BATT} to V_{OUT} . BATT ON goes high when V_{OUT} is internally switched to the V_{BATT} input. It goes low when V_{OUT} is internally switched to V_{CC} . The BATT ON output may also be used to drive the base (via a resistor) of an external PNP transistor to increase the output current above the 250mA rating of V_{OUT} .

The Chip Enable output (\overline{CE}_{OUT}) goes low only when \overline{CE}_{IN} is low and V_{CC} is above the reset threshold. If \overline{CE}_{IN} is low when reset is asserted, \overline{CE}_{OUT} will remain low for $15\mu s$ or until \overline{CE}_{IN} goes high, whichever occurs first.

The watchdog input, \overline{WDI} , is a three level input. If \overline{WDI} remains either high or low for longer than the watchdog timeout period, \overline{RESET} pulses low, and \overline{WDO} goes low. The internal timer resets with each transition on the \overline{WDI} line. The Watchdog Timer is disabled when \overline{WDI} is left floating or driven to midsupply.

With OSC SEL high or floating, the internal oscillator is enabled and sets the reset delay and the watchdog timeout period. Connecting OSC IN low selects 100ms while leaving it floating selects 1.6sec. With OSC SEL low, OSC IN can be driven by an external clock signal or an external capacitor can be connected between OSC IN and

HARDWARE MONITORING

GND. This capacitor then sets both the reset active pulse timing and the watchdog timeout period.

The ADM8691-series supervisory circuit contains a high degree of functionality. There are many applications, however, where all these features are not required. Figure 7.4 lists some popular supervisory products and the various functions available in each.

TYPICAL SUPERVISORY PRODUCTS

	Batt Switch	CE Gate	Power Fail Monitor	Low Line Monitor	Watch-dog Timer	Vcc Monitor, Reset Gen.	Manual Reset
ADM869x	X	X	X	X	X	X	
ADM1232					X	X	X
ADM707			X		X	X	X
ADM809/810						X	
ADM811/812						X	X

Figure 7.4

The ADM9261 is a triple power supply monitor IC which allows simultaneous monitoring of a 9V and two 3.3V supplies and is designed primarily for pager systems. An error signal is generated if any of the supply voltages falls below an acceptable minimum value. Limits are set at 4V for the 9V supply (SU1 input), 3.0V for the SU2 3.3V input, and 2.8V for the SU3 3.3V input. Power supplies greater than V_{CC} can be monitored because the ADM9261 has on-chip thin film resistor input attenuators. Key features of the design are the comparator hysteresis (3%) and glitch immunity (100mV, 20 μ s). Glitch immunity minimizes the possibility of spurious triggering by noise spikes on the supplies being monitored. A block diagram of the device is shown in Figure 7.5, key features in Figure 7.6, and a pager application circuit in Figure 7.7.

ADM9261 TRIPLE COMPARATOR AND REFERENCE

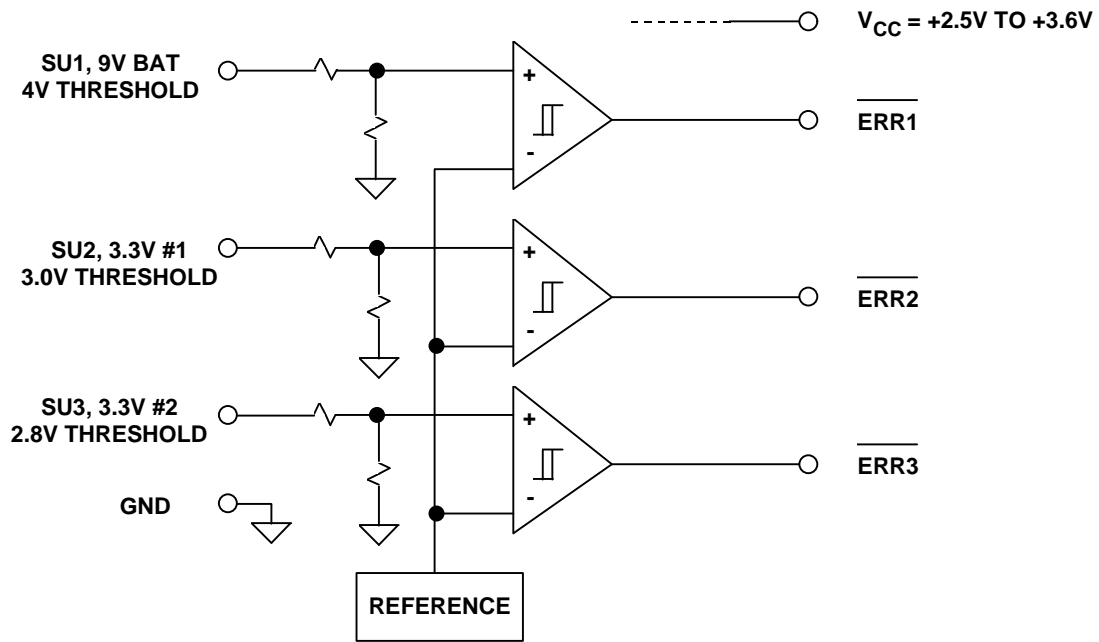
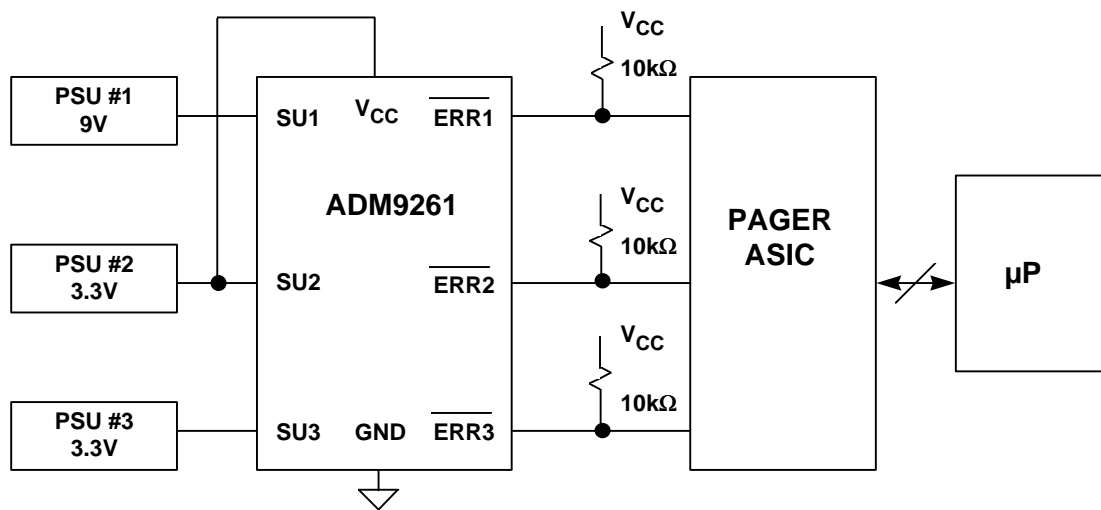


Figure 7.5

ADM9261 KEY SPECIFICATIONS

- Simultaneous Monitoring of 9V, and two 3.3V Supplies
- Limits set at 4V for SU1 9V Input, 3.0V for SU2 3.3V Input, and 2.8V for SU3 3.3V Input
- V_{CC} : 2.5V to 3.6V
- Low Power: 10 μ A Typical
- Internal Comparator Hysteresis: 3%
- Power Supply Glitch Immunity: 20 μ s, 100mV on V_{CC} or SU1-SU3
- Guaranteed from -10°C to +60°C
- No External Components Required
- 8-pin Micro SOIC Package

Figure 7.6

ADM9261 PAGER POWER SYSTEM APPLICATION CIRCUIT**Figure 7.7**

The ADM9264 is a quad power supply monitor IC which simultaneously monitors four separate supply voltage and outputs error signals if any of the supply voltages go above or below preset limits. It is designed for desktop PC supply monitoring but can be used in any system where multiple power supplies require monitoring. Each power supply monitor circuit uses a proprietary window comparator design whereby a three resistor network is used in conjunction with two comparators and a single precision reference to check if the supply is within its required operating tolerance. An added feature of this design is that the power supply voltages being monitored can be higher than the power supply voltage to the ADM9264. The allowable tolerance on the monitored voltages are as follows: $12V \pm 1V$, $5V \pm 0.5V$, $3.3V \pm 0.3V$, $2.8V \pm 0.2V$.

The error output signals are available individually and are also gated into a common output, PWROK. Auxiliary inputs ERRX, ERRY are provided which are also gated into the main PWROK signal. Signals other than power supplies can be accommodated as inputs to the ADM9264, such as temperature sensors.

A block diagram of the ADM9264 is shown in Figure 7.8, key specifications in Figure 7.9, and an application circuit in Figure 7.10.

ADM9264 QUAD SUPPLY VOLTAGE MONITOR

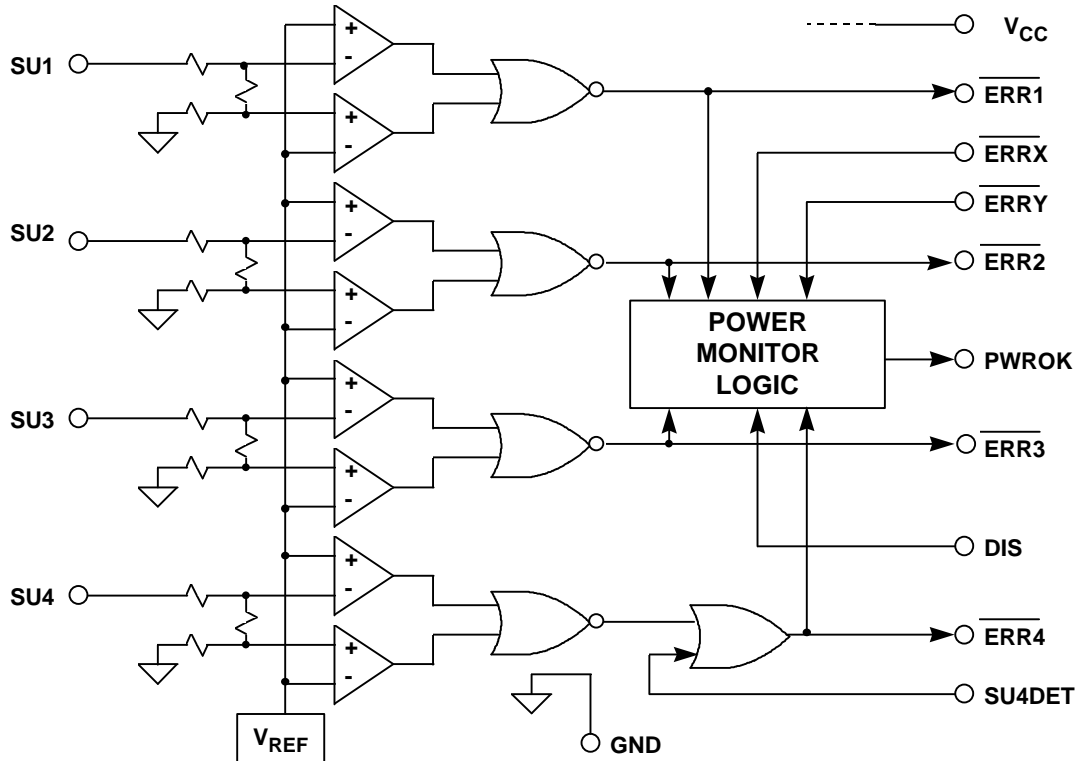


Figure 7.8

ADM9264 KEY SPECIFICATIONS

- Simultaneous Monitoring of 12V, 5V, 3.3V, and 2.8V for Desktop PCs
- Limits Set at 12V ± 1V, 5V ± 0.5V, 3.3V ± 0.3V, and 2.8V ± 0.2V
- Auxiliary Sensor Inputs
- Low Power: 25µA Typical
- Internal Comparator Hysteresis:
 - ◆ 320mV for 12V, 130mV for 5V, 90mV for 3.3V, and 80mV for 2.8V
- Power Supply Glitch Immunity: 100mV, 10µs on V_{CC} or SU1- SU4
- V_{CC}: 2.5V to 6V
- Guaranteed: -40°C to +85°C
- No External Components Required
- 16-pin Narrow SOIC Package (150mil wide)

Figure 7.9

ADM9264 APPLICATION CIRCUIT

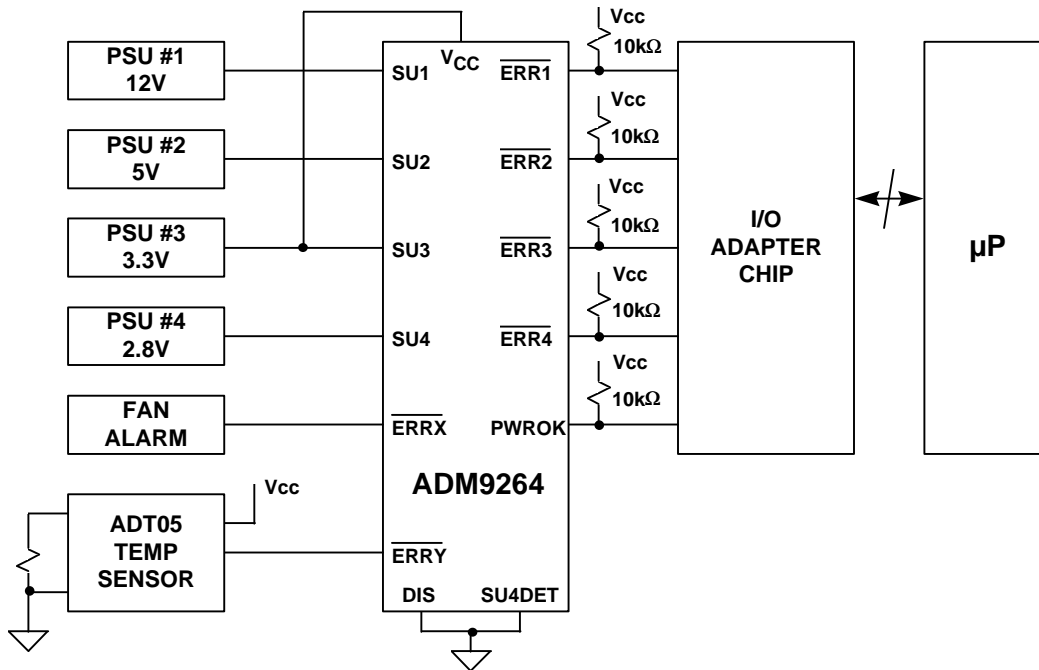


Figure 7.10

The ADM9268 (block diagram not shown) is similar to the ADM9264 but monitors six power supplies in a desktop PC and outputs the status information on an industry standard two-wire I²C-compatible serial interface. One input of the ADM9268 is designed to monitor the CPU core voltage of a Pentium II processor. The range of CPU voltage options is from 1.3V to 3.5V and is set by a 5-bit VID code which is inputted via the serial I²C-compatible interface. This makes the ADM9268 compatible with all the CPUs currently available in the marketplace. Key specifications for the ADM9268 are summarized in Figure 7.11.

ADM9268 HEX VOLTAGE MONITOR

- **Monitors All Six Desktop PC Power Supplies Simultaneously with Hex Window Comparators**
- **Monitors 12V (±6%), 5V (±7%), 3.3V (±7%), 2.5V or 3.3V (±7%), 1.5V (±7%), and CPU Core Voltage (±5%)**
- **5-bit VID Code Sets Core Monitor Voltage: 1.3V to 3.5V**
- **Standard two-wire I²C-Compatible Serial Interface**
- **Operates on V_{CC} from 2.5V to 6V**
- **16-pin Narrow (150mil) SOIC Package**

Figure 7.11

The ADM9240 (see Figure 7.12) is a complete high-level system hardware monitor for microprocessor based systems, providing measurement and limit comparison of up to four power supplies and two processor core voltages, plus temperature, fan speed, and chassis intrusion. Measured values can be read out via an I²C-compatible serial interface, and values for limit comparisons can be programmed over the same serial bus. The high-speed 10-bit ADC allows frequent sampling of all analog channels to ensure a fast interrupt response to any out-of-limit measurement. Key specifications for the ADM9240 are summarized in Figure 7.13.

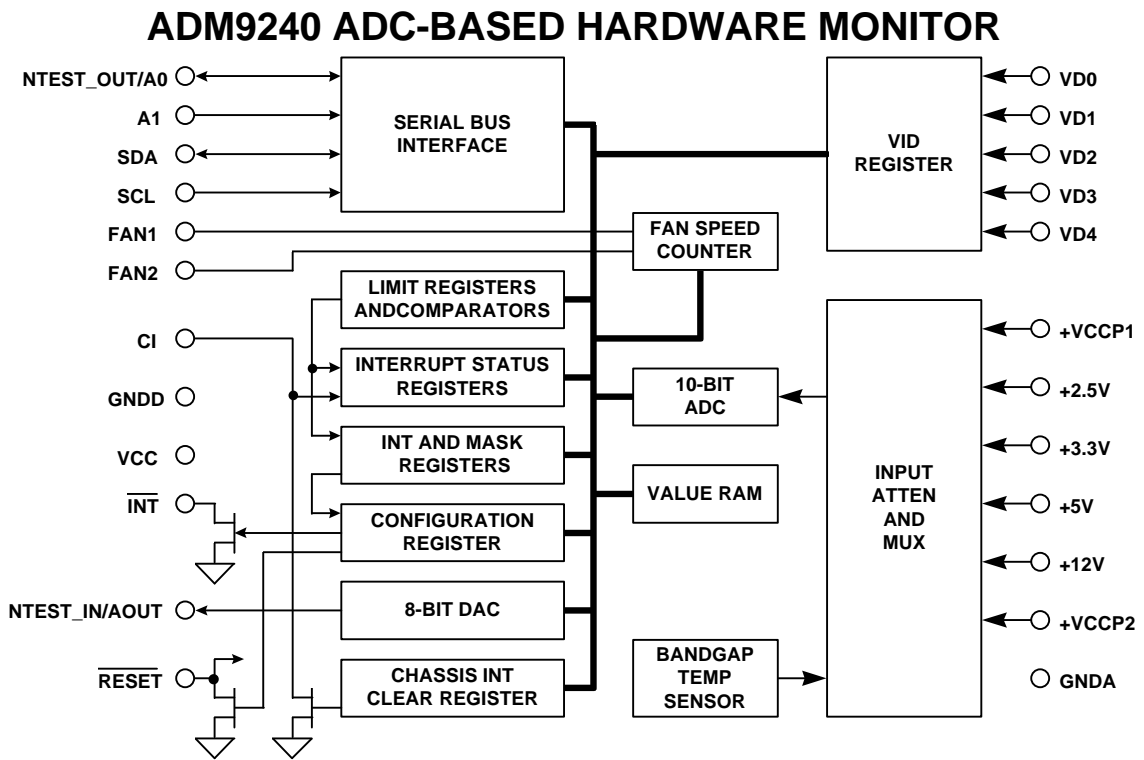


Figure 7.12

ADM9240 KEY SPECIFICATIONS

- **6 Direct Voltage Measurement Inputs (Including 2 Processor Core Voltages) with On-Chip Attenuators**
- **On-Chip 10-bit ADC and 8-bit DAC**
- **5 Digital Voltage Identification (VID) Inputs**
- **2 Fan Speed Monitoring Inputs**
- **I²C-Compatible System Management Bus**
- **Chassis Intrusion Detect**
- **On-Chip Temperature Sensor**
- **V_{CC}: 2.85V to 5.75V**
- **1.2mA Typical Supply Current, 10μA in Shutdown**
- **24-pin SOIC Package**

Figure 7.13

Figure 7.14 shows a generic application circuit using the AD9240. The analog inputs are connected to the power supplies and processor core voltage. VID inputs are connected to the processor Voltage ID pins. There are two inputs from fans, and the analog output is controlling the speed of a third fan. A chassis intrusion latch with a phototransistor as the sensor is connected to the CI input. In an actual application, every input and output may not be used, in which case unused analog and digital inputs should be tied to analog or digital ground as appropriate.

The chassis intrusion circuit could use a microswitch that opens or closes when the cover is removed, a reed switch operated by a magnet fixed to the cover, a Hall-effect switch operated by a magnet fixed to the cover, or a phototransistor that detects light when the cover is removed. In the circuit shown in Figure 7.14, light falling on the phototransistor when the PC cover is removed will cause it to turn on and pull up the input of N1, thus setting the latch N2/N3. After the cover is replaced, a low reset on the ADM9240 CI output will pull down the input of N3, thus resetting the latch.

ADM9240 APPLICATION CIRCUIT

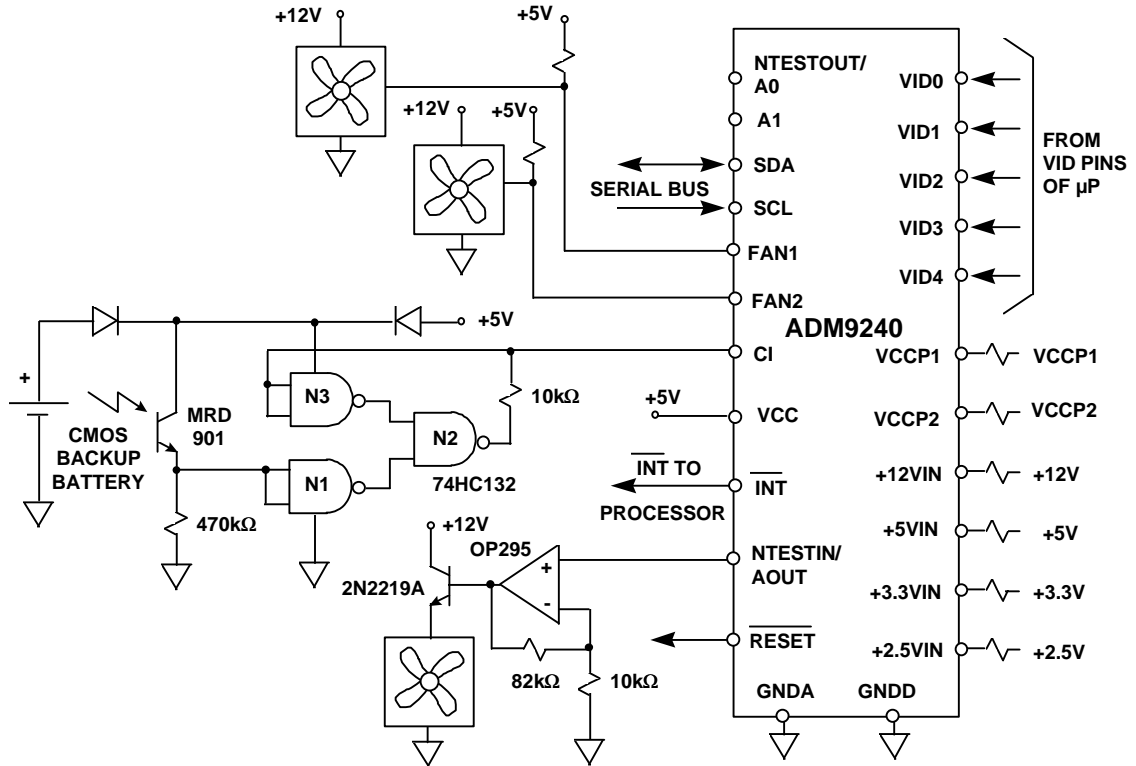


Figure 7.14

In hardware monitoring circuits it is often desirable to use a high-resolution low-cost measurement ADC, for tasks such as monitoring battery voltages during charging. The AD7705 is a 16-bit sigma-delta ADC with a two-channel multiplexed input as shown in Figure 7.15. Key specifications are given in Figure 7.16. The AD7705 has a programmable gain amplifier which can be set for a gain of 1 to 128. The inputs and outputs are handled with a three-wire serial interface. The device has an on-chip digital filter and a programmable output rate from 20Hz to 500Hz.

An application of the AD7705 as a cell monitor in a battery charging circuit is shown in Figure 7.17.

AD7705 16-BIT ADC BATTERY MONITOR

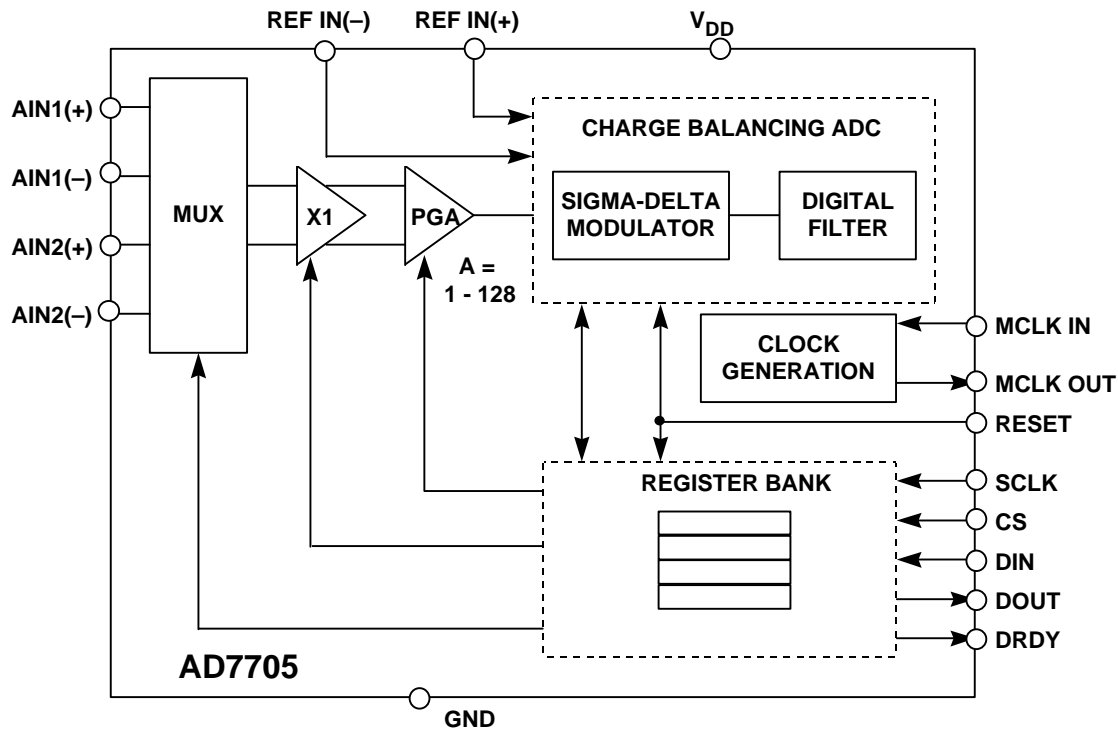


Figure 7.15

AD7705 ADC KEY SPECIFICATIONS

- 2 Channel Charge-Balancing ADC
 - ◆ 16-bits, No Missing Codes
 - ◆ 0.012% Nonlinearity
- Programmable Front End
 - ◆ Binary Gains from 1 to 128
 - ◆ Differential Input Capability
- 3 Wire Serial Interface
- Ability to Buffer Analog Input
- 3V or 5V Single Supply Operation
- Low Power: <math><450\mu\text{A}</math> @ 3V
- Programmable Low-Pass Digital Filter with Programmable Output Rate (20Hz to 500Hz)
- 16-pin DIP, SOIC, and TSSOP

Figure 7.16

AD7705 BATTERY MONITORING APPLICATION

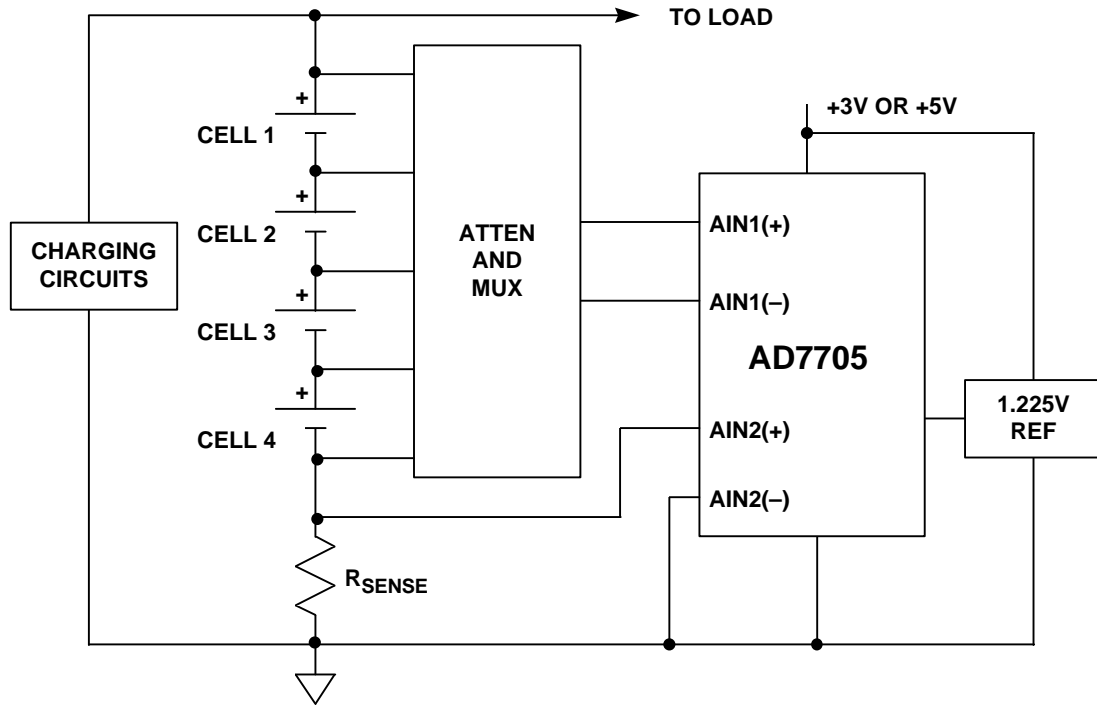


Figure 7.17

Complex hardware monitoring circuits often interface with a microcontroller (such as the 8051) which performs various operations based on the sensor and monitor outputs. The ADu810PC is a MicroConverter™ (combination ADC and microcontroller) based on the standard 8051 core. In addition to the microcontroller core, the device has a 10-bit, 2 μ s ADC with SHA and a 16-channel analog input multiplexer. The chip also contains a temperature sensor and bandgap voltage reference as well as two 8-bit DACs with voltage output buffers. MicroConverters such as these allow sophisticated monitoring and control functions such as power supply monitoring and watchdog timeout to be performed in a single chip.

ADuC810PC (MicroConverter™)

- Complete Hardware Monitor System with on-chip microcontroller (Standard 8051-based Core)
- Calibrated 10-bit, 2 microsecond ADC with SHA and DMA Mode
- 16 Channel Analog Multiplexer
- On-Chip Temperature Sensor and Bandgap Voltage Reference
- 2 DACs (8-bits) with Voltage Output Buffers
- 3V or 5V Single Supply Operation

- 64 Digital I/O for Address, Data, Interrupts, LEDs, LCDs
- UART and I²C-Compatible / SPI Serial Interfaces
- 3 x 16-bit Timers / Counters, 2 Muxed for 4-Channel Fans
- Independent Watchdog / Clock and Supply Monitor
- Power Management of Peripherals and I/O

Figure 7.18

ADuC810PC PROCESSOR

- DC TO 16MHz Static Industry-Standard (8051) MCU for up to 1MIP Operation
- 48k Bytes Flash Program Memory
- 2k Bytes Flash/EEPROM Lockable User Data Memory
- 1k Bytes Data RAM
- 64k Bytes External Program and Data Memory Space
- Enhanced Hooks™ Emulation and Debugging Tools
- Resident Loader and Debugger
- Simplified I/O through Special Function Registers
- Multi-Level, Maskable Interrupts
- 100-pin PQFP 14x14mm Package

Figure 7.19

REFERENCE

Bill Schweber, *Supervisory ICs Establish System Boundaries*,
EDN, Sept. 28, 1995, p. 71.