Voltage Monitor With a Timestamp Using a Low-Memory MSP430™ MCU

Introduction

Voltage monitoring is essential for battery- and bus-powered applications to save the system state through a power loss event. Often the real time should be saved as a timestamp to track the power loss event. The MSP430FR2000 microcontroller (MCU) can be used as a low-cost solution for this problem by making use of the internal enhanced comparator (eCOMP), real-time clock (RTC) counter, and internal ferroelectric random access memory (FRAM). By using the UART, the host can set the initial time in POSIX format, and it can interrogate the MSP430™ MCU over the UART to provide the current time in the same format. Additionally, the real time is saved as a timestamp in FRAM during the power loss. To get started, download project files and a code example demonstrating this functionality.

Implementation

This solution uses the internal comparator of the MSP430FR2000 MCU and external resistors to monitor the supply voltage. As the block diagram in Figure 1 shows, the supply voltage is divided by resistors R1 and R2, and the divided voltage (V_{in}) is connected to the comparator positive input channel. The voltage is calculated by Equation 1.

$$V_{in} = \frac{V_{supply} \times R1}{R1 + R2} = \frac{V_{supply}}{3} \quad (1)$$

The negative input of the comparator is connected to the 6-bit built-in digital-to-analog converter (DAC). The internal 1.5-V reference is selected as the DAC reference voltage. The DAC output voltage is defined by the macro COMPTHR in the firmware. V_{th} is the voltage threshold and is calculated from Equation 2.

$$V_{th} = \frac{COMPTHR \times 1.5V}{64} = \frac{43 \times 1.5V}{64} = 1V \quad (2)$$

The RTC module is used as an external RTC to provide the current real time in POSIX format. The host can set the initial time and then read the current time through a UART interface. An external 32768-Hz crystal is used as the clock source for the RTC and UART modules.

If the supply voltage falls below 3 V, V_{in} falls below 1 V, which is lower than V_{th}, and a comparator interrupt is triggered. In the comparator interrupt service routine, the current timestamp is stored in FRAM to record the power loss event. The eCOMP module supports programmable hysteresis settings, and this demo uses the 30-mV hysteresis mode to avoid false triggers. By changing the divider resistor and the macro COMPTHR, different voltage levels can be monitored based on application requirements.

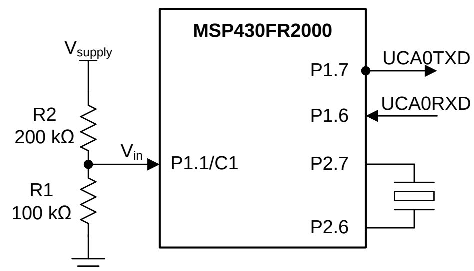

Figure 1. Voltage Monitor Block Diagram

The comparator input voltage (V_{in}) is set by the ratio of the two resistors in the divider. Keeping the ratio constant, there are tradeoffs to consider for selecting the actual resistor values. With higher resistances, the leakage current at the comparator input can affect the V_{in} voltage accuracy. With lower resistances, the current through the divider is increased. For information on how to select optimally-sized resistors, see *Optimizing Resistor Dividers at a Comparator*. Another scenario is having one MCU GPIO instead of ground connected to the R1 resistor. Setting the GPIO output low can replace the ground connected to the R1 resistor, and setting the GPIO output high can reduce the power consumption of the voltage divider.

The firmware implements the following communications protocol over UART:

READ/WRITE	D0	D1	D2	D3

Where READ = 00h, WRITE = 01h, and D0 to D3 are the data bytes to be written or the requested data as a response from the MSP430 MCU on appropriate commands.

WRITE TIME Command

01h	D0	D1	D2	D3

READ TIME Command

00h	D0	D1	D2	D3

(shaded) = Reponse

The timestamp is sent LSB first, so that the timestamp should be interpreted as D3D2D1D0h.

This UART communication protocol is simplified for lowest code size, fitting in a low-cost 0.5KB MSP430FR2000 MCU. The external RTC implementation is explained further in *External RTC With Backup Memory Using a Low-Memory MSP430™ MCU*. The MSP-TS430PW20 target development board was used for testing this solution. The MSP-FET or eZ-FET backchannel UART can be used to connect to a PC terminal program at 9600 baud for test.

Performance

In this solution, the comparator is used for voltage monitoring, and a timestamp is stored in FRAM when a power loss event is detected. By default, the FRAM is write-protected. The FRAM is only unprotected when a timestamp must be stored, and it is protected again after the write.

Different voltage thresholds can be easily set with internal 6-bit DAC. Voltages higher than MCU supply voltage can also be monitored with an external resistor voltage divider.

The RTC Counter module in the device updates the real time once per second. The host can request the current real time by using the READ TIME command. An example showing the setting of the initial RTC time and reading back is shown in Figure 2.

Observe that the WRITE TIME command was sent at 11:57:00 and set to 78563412h. 5 seconds later, at 11:57:05, the READ TIME command was sent, and the reply shows the current timestamp value is 78563417h. Therefore the timestamp has incremented 5 seconds.

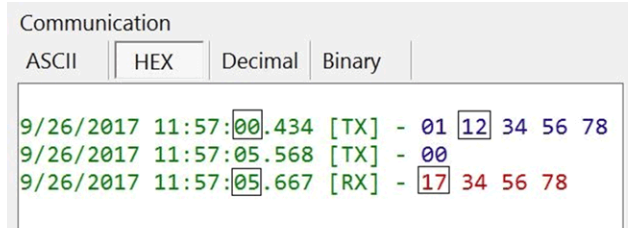

Figure 2. Write and Read RTC Example

This solution provides optimized software that fits in a 0.5KB MCU. Due to the limited code size the UART communication protocol is simplified and supports only two commands. The timestamp stored in FRAM can only be read out through JTAG interface using the current software, but it is quite easy to add one UART command to read out the timestamp in FRAM with a higher memory device.

Device Recommendations

The device used in this example is part of the MSP430 Value Line Sensing portfolio of low-cost MCUs, designed for sensing and measurement applications. This example can be used with the devices shown in Table 1 with minimal code changes. For more information on the entire Value Line Sensing MCU portfolio, visit www.ti.com/MSP430ValueLine.

Table 1. Device Recommendations

Part Number	Key Features
MSP430FR2000	0.5KB FRAM, 0.5KB RAM, eComp
MSP430FR2100	1KB FRAM, 0.5KB RAM, 10-bit ADC, eComp
MSP430FR2110	2KB FRAM, 1KB RAM, 10-bit ADC, eComp
MSP430FR2111	3.75KB FRAM, 1KB RAM, 10-bit ADC, eComp

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