4. Discussion and Conclusions

In order to calculate solar azimuth and zenith angles using an electronic system, equations (1) and (2) should be implemented on it and there are about 40 other equations that should be solved before feeding data to those equations.Implementation of such a lengthy calculation inside a microcontroller is not practical due to the limitation of program memory and the processing power. Therefore pre-calculation of solar angles using a computer and having them in a lookup table stored in a SD memory can be considered as anefficient alternative method. Angle data for one hour can be stored in one data array of 512 bytes of the memory card with one minute time intervals. Therefore, the memory requirement for one day is 13 kB and only 5 MB is needed for the storage of data for one year. Hence, solar angle data for a long period can be stored in a memory with small capacity.

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Evaluation of temperature dependence of oscillating frequency of an internal RC oscillator of a microcontroller as a temperature sensor

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Abstract

A novel, low cost and reliable method of using a microcontroller has been tested and evaluated for measuring temperature. Most of the microcontrollers come with a Watch Dog Timer (WDT) which is clocked by an internal Resistor Capacitor (RC) oscillator. The oscillating frequency of the RC oscillator depends on the temperature. The time-out periods (in counts) of WDT of Microchip PIC16F877A microcontroller were measured at different temperatures by means of a LM35 sensor from National Semiconductor Inc. It is found to give a good linear relationship (correlation coefficient R^2=0.997) between time-

out period and the temperature with a scale factor of 6 counts per 1 °C and an accuracy of 0.8 °C for the range ,5 °C to 60 °C when the microcontroller runs by a 4 MHz crystal oscillator. The response time is found to be 48 s with the water sealing material. There was no hysteresis effect found on these measurements and for the same series microcontroller the measurements lie within the given accuracy. The microcontroller is programmed to produce the reading in RS232 protocol and it can easily be software altered to any other standard protocol.

1. Introduction

Temperature is an important physical parameter which is a measure of average kinetic energy of the particles in a system [1]. Temperature of a system gives some understanding about the system and measuring of temperature is of a crucial importance. A large number of methods have been developed to measure temperature indirectly by measuring a physical property of a material which is temperature dependent. Mercury column thermometer is a well-known good example for such a measuring device. A large number of temperature sensors have been developed for automated applications by making use of temperature dependent physical properties which can electrically be coupled. Thermocouples, thermistors and resistance temperature detectors (RTD) are the most popular temperature transducers [2]. Also, there are a large number of monolithic temperature sensors that have been developed using different temperature dependent properties capable of coupling electrically. Interfacing a dedicated function temperature sensor to a microcontroller is the usual practice, but it may case several digital or analogue input/output (I/O) pins of the microcontroller. The objective of this study is to evaluate the performance of a temperature measuring capability of a microcontroller by making use of the temperature dependence of the internal oscillator of the WDT of a Microchip PIC16 series microcontroller.

2. Materials and metho

Watch Dog Timer

The WDT is an 8-bit timer with an 8-bit pre-scalar option, driven from a free running on-chip RC oscillator. This oscillator is completely independent of pins OSC1/CLKIN, OSC2/CLKOUT, and the INTRC oscillator. As with any RC oscillator, variances in temperature will affect the frequency of the circuit. Cumulative effects will therefore, show up as a change in the time-out period of the WDT.

Measuring the time out period of WDT vs. temperature

In this experiment, a Microchip PIC16F877A was chosen to evaluate and it is sealed for water with other components and in such a way that it can be immersed in a water bath for heating. Initially it was heated from 6 °C to 60 °C in order to get the relationship between number of counts (WDT time-out period in counts of another counter) and temperature.

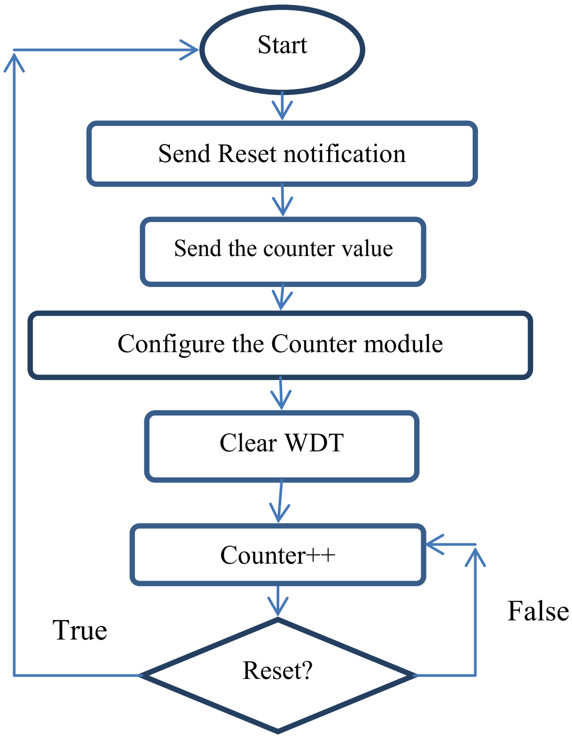

Figure 3: Flow chart of the program runs on the microcontroller

Figure 1 shows the process flow of the program runs on the microcontroller. Initially counter module is configured and then WDT timer is cleared, once the WDT timer module is cleared counter module will keep on counting until the time out period. Once the time out period is reached, microcontroller will get reset and rest event is noticed to the second microcontroller which measure the corresponding temperature using industry calibrated National Semiconductor LM35 (an accuracy of 0.1 °C) temperature sensor. Since the counter is an external module in the microcontroller reset won't change the data stored in it. As next step, microcontroller will send the value of the counter through serially to the computer.

3. Results and Discussion

Figure 2 shows the relationship between WDT time out periods (in counts) and temperature. For the range of 5 °C to 60°C, it shows a strong linear correlation (correlation coefficient R^2=0.997 and scale factor of 6 counts per 1 °C). The experiment was repeated for heating and cooling for several times to check the hysteresis effect. It is observed that there is a slight deviation between heating and cooling graph but there is no any significant evidence which shows hysteresis property. The residual error of the linear fit and the actual dataset is found to be normally distributed (with mean = 0 and σ =5) and the accuracy is found to be 0.8 °C.

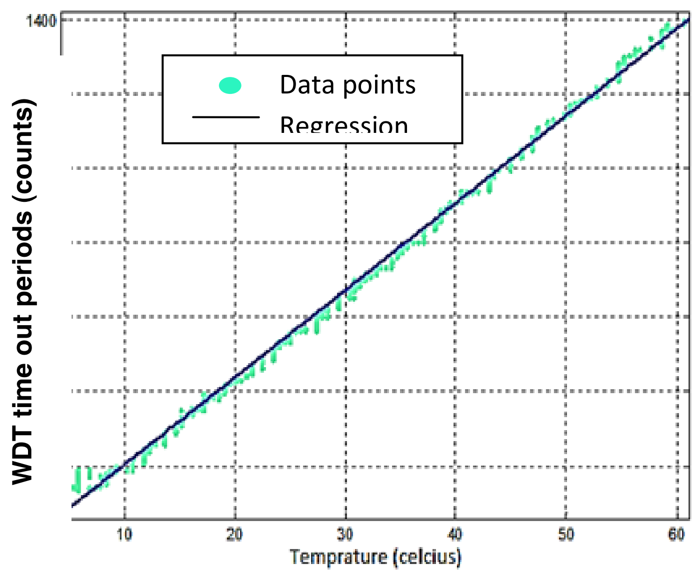

Figure 4: Variation of the WDT time out periods (in counts) when temperature is changed

The response time with the water sealed material was evaluated by keeping the sensor in 5 °C water bath until it reaches to steady state and then suddenly immersing it in 27 °C water bath. Time constant was calculated as the two by three time taken to reach it to the maximum value and it is found to be 48 s (see Figure 3).

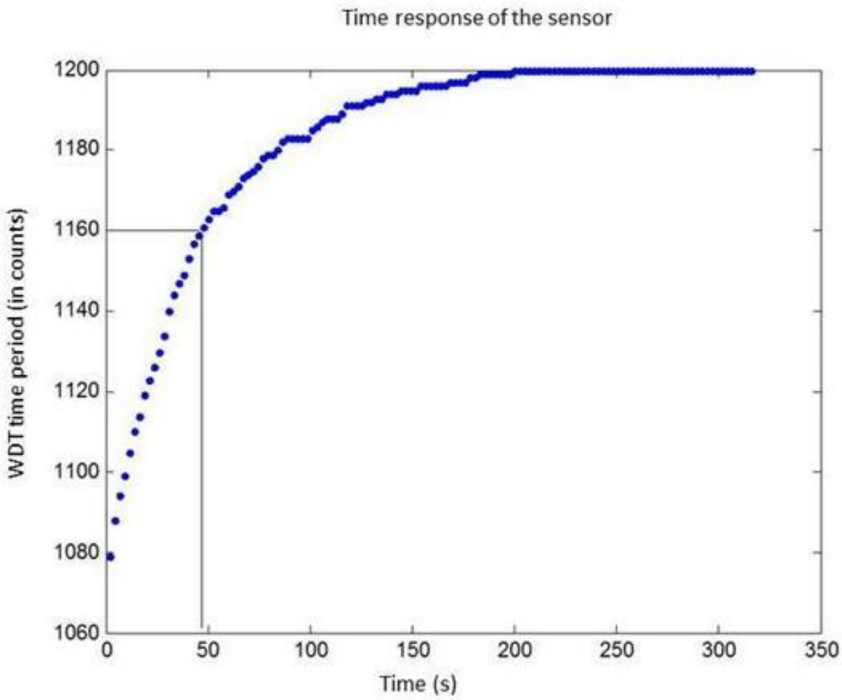

Figure 5: Time response of the sensor when suddenly change the temperature from 5°C to 27 °C using two water-baths at those temperatures

4. Conclusions

The built-in WDT of Microchip PIC16F877A series microcontrollers can be used for measuring temperature in the range of 5 °C to 60 °C within an accuracy of 0.8 °C. The microcontroller can be used an external temperature sensor (or sensor network) for master controller or microcontroller itself can be used to measure temperature without any external temperature sensor.

Acknowledgement: Assistance from the International Science Programs (ISP), Uppsala University, Sweden is acknowledged.

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[2] Practical Temperature Measurements: Agillent application note 290