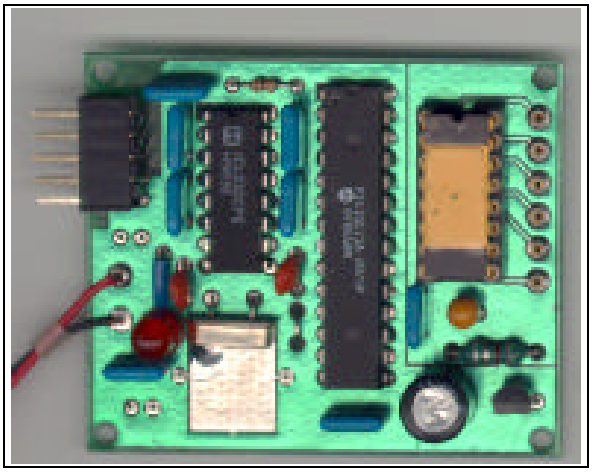
A temperature measurement system for legal applications



Introduction

Nowadays there is a great variety of sensors for temperature measurements. The Pt100 is well known as one of the transducers with excellent precision and linearity. The only problem is the need of a high gain precision instrumentation amplifier which greatly increases the cost of the system.

One of the ways to reduce the overall system cost without decreasing its precision is the Universal Transducer Interface (UTI). It greatly simplifies the hardware interface between the sensor and the microcontroller. The UTI converts the analogue signal in pulse sequence with logic levels directly compatible with microcomputers inputs. The achieved 14 bit accuracy satisfies almost all applications and illiminates the need of expensive instrumentation amplifiers and other analogue circuitry including the ADC.

Moreover in legal applications special measures are needed to guarantee the proper functioning of the system. In the proposed circuitry the Pt100 sensor is measured in 4-wire mode thus eliminating all parasitic thermocouples, lead resistance and other sources of systematic errors. In the same time a "control" resistor with a well known value of 100 Ohm is measured in 3-wire mode. In that way the program algorithm can easily distinguish if the system is working properly or not.

The sensors

A standard Pt100 sensor is used as a temperature transducer. The reference and "control" should be with excellent temperature and long time stability.

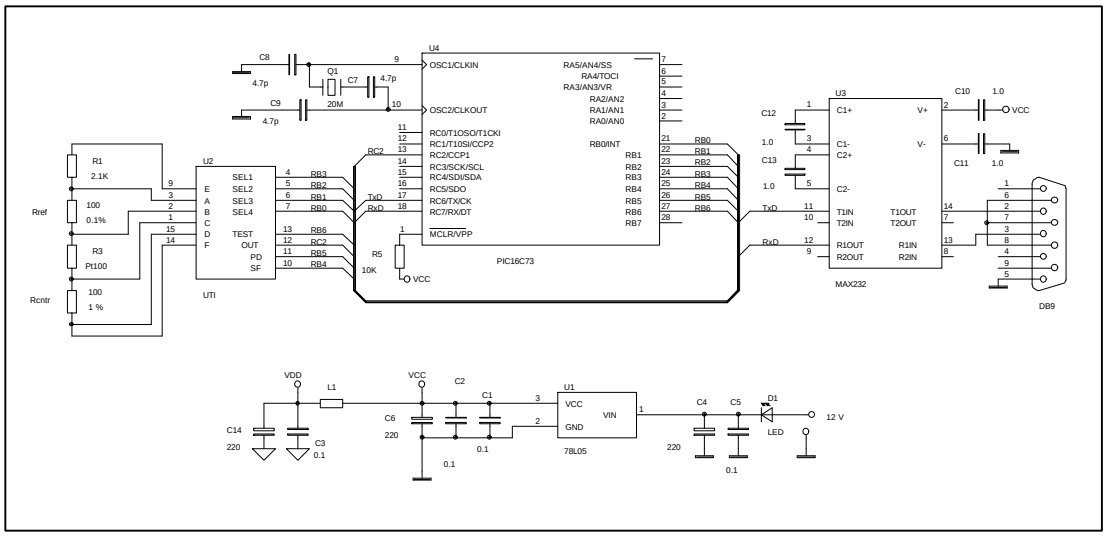
Function

The board shown in figure 1 is designed to provide temperature measurement for legal applications. The temperature is measured in 4-wire mode and a "control" resistor is measured in 3-wire mode. The results are sent to the host computer by a 3-wire RS232 interface. Slow or fast measurement mode of the UTI can be used.

Detailed circuit description

The supply Voltage

The supply voltage for the system can be in the range from 8 V up to 30 V. It is stabilised by a MC78L05 fixed voltage regulator in order to give the necessary 5V power supply for the digital part of the system. The +5V analogue power supply is provided by filtering the digital supply. The overall system consumption is less then 20 mA.



The analogue part

The analogue condition of the transducer signal and analogue to digital conversion are done by the UTI. The R1 limits the current passing thrue Pt100 sensor. It is well known that the bigger the current is the better sensitivity is achieved. On the other way the passing current gives effect of a self-heating of the sensor thus degrading system precision. That's why a compromise should be made between bigger signal and self-heating. The temperature error due to self-heating for a thermal resistance of 200K/W (still air) at 0°C and 2mA is about 80mK. This is 2 times better then initial accuracy of a class A Pt100. With a 5V power supply the R1 equals 2.1 kOhm for 2mA sensing current. The non linearity of the UTI is reported to be better then 150ppm in this mode.

The digital part

The Microchip's PIC16C73 single chip microcontroller is used as a core of the measurement system operating at 20MHz clock. The very low cost and small package make it very attractive for such a system. It has an incorporated Input capture timer function which greatly simplifies the measurement of the pulse sequences from the UTI output. This gives the resolution of 200 ns in pulse width measurement. The other control signals for the UTI are provided by a general purpose digital outputs of the microcontroller.

RS232 interface

The RS232 interface is based on the hardware SCI subsystem of the microcontroller. The 0-5V to RS232 levels translation is done by a single supply MAX232 interface chip. The standard non-return to zero standard is used, transmission rate is 19200 Baud, no parity, one stop bit.

Elimination of EMC problems

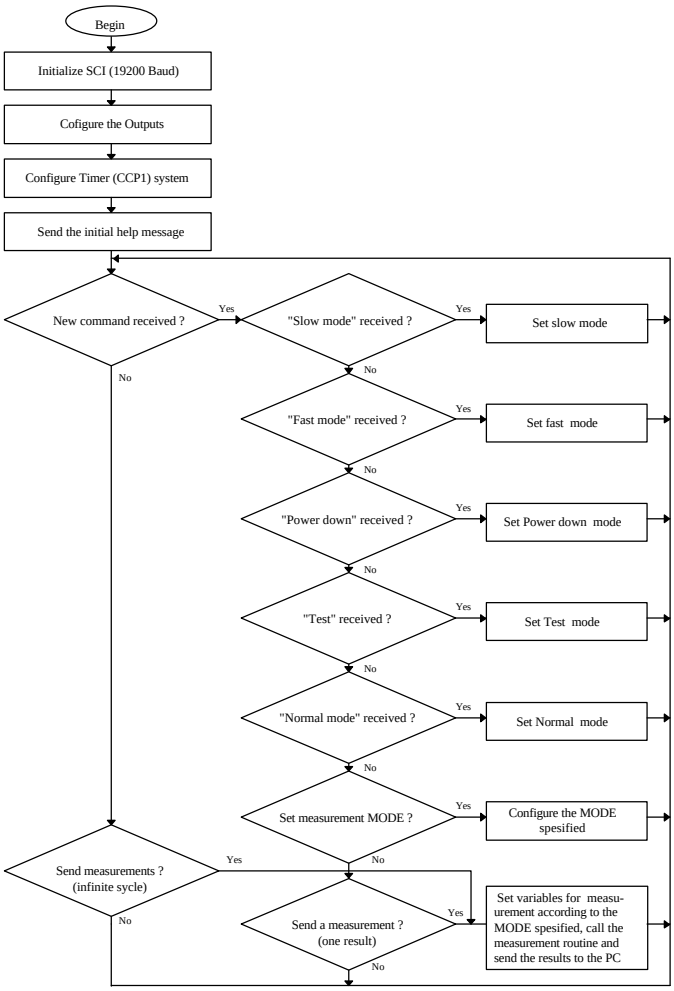
The low power consumption itself contributes to the EMC. The suppression of interference on the supply lines is done by blocking capacitors. Further reduction can be achieved by putting ferrite coil on the supply wires. Analogue power supply is divided from the digital one by a low-pass filters.

All the lines on the PCBoard are kept as short as possible thus reducing the antenna effect. A solid ground layer prevents the currents loops.

The highest frequencies are found in the clock generator. That's why the crystal oscillator is situated as close as possible to the microprocessor clock pins. Further reduction of the electromagnetic emission is achieved by surrounding the clock wires with ground layer.

Program algorithm

The flow-chart of the system software is shown on the figure:



The program can be divided in two major parts - PC communication routines and Measurement routines.

PC communication routines: that part of the program is responsible for the communication with the Personal Computer trough RS232 interface. No interrupt connected with the SCI is enabled.

Measurement routines: the measurement of the different phases of the UTI is based on the Input Capture function of the PIC16C73. On the rising edge of the signal the value of the 16-bit timer is "captured" in hardware in the 16-bit capture register and later is read by the program from that register. On every Overflow interrupt of the 16-bit timer another 8-bit sell in incremented in software thus creating a 24-bit counter. A dedicated software logic is implemented in order to eliminate the problem of eventually changing this sell between reading the hardware Capture register and this "Most significant byte" of the timer.

The Timer overflow interrupt is enabled and its only function is to increment the "Most significant byte" sell in order to have a 24 bit timer system.

System performance

Error due to the quantisation process:

- Fast mode: the lowest number is approximately 6 500, which means more then 12 bit quantisation precision (5MHz clock).
- Slow mode: the lowest number is approximately 50 000, which means more then 15 bit quantisation precision (5MHz clock).

The standard deviation in fast mode is 0,014% and 0,003% in slow mode (100 measurements).

Conclusion

The use of UTI gives the possibility for precision temperature measurement and in the same time precision measurement of a "control" resistor with a well known value. This gives the possibility to use it in legal applications. The UTI greatly simplifies the interfacing of a sensor with the microcontroller. It reduces the total system cost by eliminating the expensive analogue components without degrading the sensor precision.

PC Board layout