

PORTABLE MULTISENSOR ACQUISITION AND CONTROL SYSTEM

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Abstract

A modern user oriented approach to designing complete data acquisition and control system is described in this paper. The system is based on the 18F4550 Microchip MCU and the recent digital sensors of nonelectrical quantities as temperature, pressure, humidity and ambient light. Graphical user interface is designed by Delphi 7 integrated development environment. Dot matrix LCD module is added to USB acquisition interface so the system control hardware can displays all of nonelectrical quantities in the stand alone mode. Besides the direct measurements, the suggested system calculates altitude and dew point. The control of some nonelectrical quantities as temperature is accomplished by feedback via PC and appropriate actuator.

Applied digital sensors guarantee by manufacturers specified measurement accuracy.

Keywords: MCU, temperature, humidity, pressure, altitude, ambient light, dew point.

INTRODUCTION

Personal computer (PC) has become a standard platform for the needs of various measurements and tests thanks to its standardization, performances and low cost. In construction, so called virtual or personal instrumentations [1, 2], its appliance enables development of a qualitatively new generation of devices. With its performances which are becoming higher and higher and with the increasing number of software applications, PC is widely accepted as an inevitable tool on the desks of engineers of various profiles.

All virtual instrumentation systems have the flexibility to be modified easily without the new hardware equipment need. It saves time and money since the virtual instruments are mainly based on the software.

Numerous dedicated software packages for virtual instrumentations development and realization are available today at the markets as *LabView* (USA) [2]. However, conventional graphical oriented programming environments can be successfully use for the same purposes also. The application software realized by mentioned software tools, the hardware platform and PC

makes the virtual instrument. Instrument control hardware is designed to be connected with personal computer as plug-in data acquisition board, GPIB instruments, serial interface etc [11]. The plug-in boards are ideal for high speed, direct control as well as slow speed monitoring applications. The serial communication between the PC and instrument control hardware is comparatively slower but doesn't need machine opening. It is important in cases of the notebook computer appliance. However, for many applications the main goals are utility, flexibility and cost, not speed.

Portable multisensor system, described in this paper, represents a modern virtual concept of the instrument for nonelectrical quantities acquisition and control on the base of USB communication. The base of the system makes microcontroller and digital sensors as well as appropriate graphical user interface. The system is portable and can be easily installed and connected to any IBM compatible PC via USB port.

SYSTEM ARCHITECTURE

The proposed system comprises PIC microcontroller based acquisition hardware with serial communication interface and PC with installed

graphical user interface. As the serial communication interface between the PC and the acquisition hardware is selected USB 2.0 port by reason of its widespread incorporating in PCs. Moreover, adopted interface gives the possibility of the hardware power supply during real time monitoring without outside sources.

The acquisition hardware is configured as HID (human interface device) device thanks to built-in USB module in the Microchip PIC18F4550 MCU [3]. Operating system Windows XP is equipped with HID based driver, so no need for driver development.

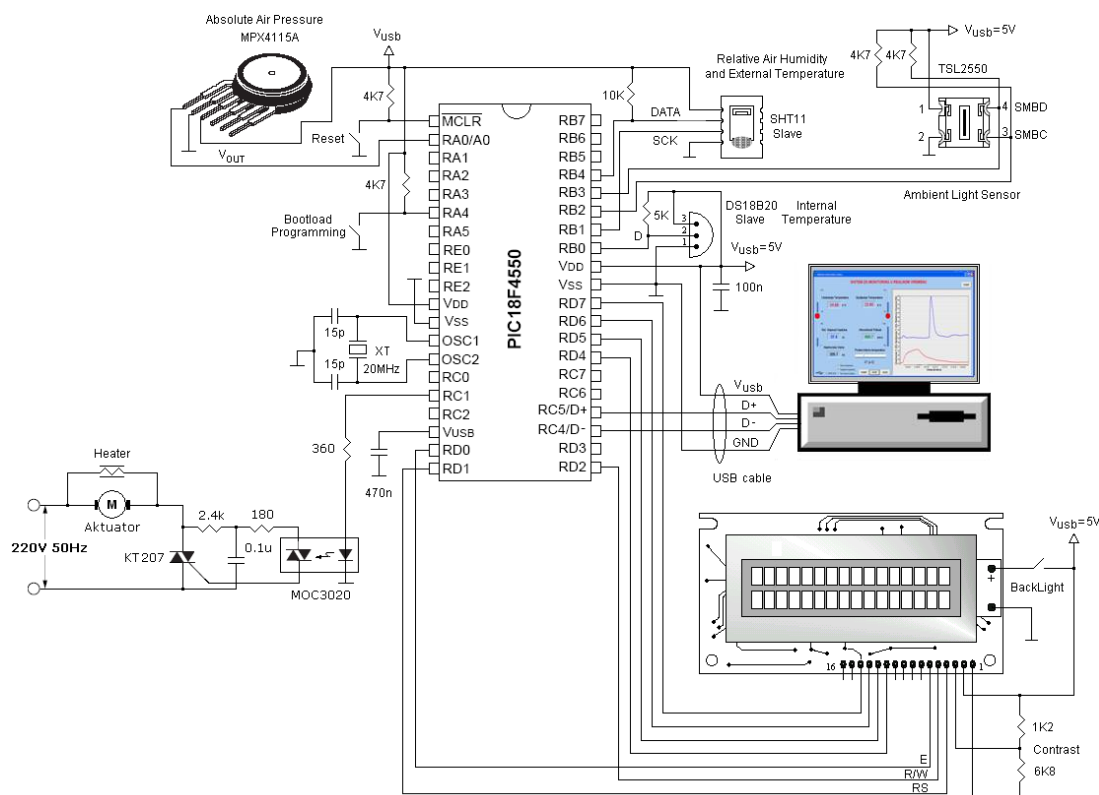


Fig. 1. The acquisition and control system outlook.

Sensors selection has been concentrated mainly to integrated digital sensors with built-in one-wire or two-wire SCI. Such selection enables simple sensors connection to MCU and their simple replacement.

Functional electronic scheme of the system is presented in Fig. 1. As can be show the heart of the system is microcontroller PIC18F4550 as well as PC. Ambient light-to-digital sensor TSL2550 (Texas) [4] is uses for light level monitoring. The device is designed for use with broad wavelength light source. One of the photodiodes is sensitive to visible and infrared light, while the second photodiode is sensitive primarily to infrared light. The ADC digital outputs of the two photodiodes are used to obtain a value that approximates the human eye response in the commonly used unit of Lux. The SMBus serial interface is optimized

for sensor readout. ADC data format is shown in Fig. 2. The sensor can discriminate the type of light (sunlight, fluorescent and incandescent light) More details can be found in datasheet [4, 10].

VALID	CHORD BITS			STEP BITS			
B7	B6	B5	B4	B3	B2	B1	B0
VALID	C2	C1	C0	S3	S2	S1	S0

Fig. 2. ADC data format for TSL2550.

The SHT11 [5] is a single chip relative humidity and temperature multi sensor module comprising a calibrated digital output. The device includes a capacitive polymer sensing element for relative humidity and a bandgap temperature sensor. Both are seamlessly coupled to a 14 bit ADC and a two wire serial interface circuit on the same chip. The two-wire serial interface is optimized for sensor readout and low power

consumption and is not compatible with standard I²C interface. The default measurement resolution of 14 bit (temperature) and 12 bit (humidity) can be reduced to 12 and 8 bit. By the manufacturer specifications [3] typical response time of the humidity sensor is 4s and for temperature sensor about 30s.

The DS18B20 digital thermometer [6] provides 9 or 12-bit programmable resolution temperature readings as shown in Fig. 3.

	BIT 7	BIT 6	BIT 5	BIT 4	BIT 3	BIT 2	BIT 1	BIT 0
LS BYTE	2 ⁷	2 ⁶	2 ⁵	2 ⁴	2 ³	2 ²	2 ¹	2 ⁰
	BIT 15	BIT 14	BIT 13	BIT 12	BIT 11	BIT 10	BIT 9	BIT 8
MS BYTE	S	S	S	S	S	2 ⁶	2 ⁵	2 ⁴

Fig. 3. 12-bit word format of the temperature.

The information interchange between a master and slave is done over a 1-wire communication interface so that only one wire needs to be connected from a master to a DS18B20. Because each DS18B20 contains a unique silicon serial number, multiple DS18B20 devices can exist on the same 1-wire bus. The DS18B20 resolves temperatures to 0.1°C in the range of temperatures from -55°C to 125°C. Typical temperature error curve of the DS18B20 is specified from the manufacturer [6].

The protocol for accessing the DS18B20 consists of four sequences: initialization, ROM function command, memory function command and transaction/data. Master should first provides one of five ROM function commands and then some of six memory function commands as 'Convert T', 'Read Scratchpad' etc. The DS18B20 requires strict protocols to insure data integrity and adequate timing procedures.

Main shortages of the DS18B20 thermometer are long temperature conversion time, up to 750ms, and narrow temperature range (-55°C to 125°C).

Motorola's MPX4115A silicon absolute pressure sensor [7] is only analogue sensor which integrates on chip bipolar op. amplifier circuitry and thin film resistor networks to provide high output signal and temperature compensation. Fig. 4 shows the sensor output signal relative to pressure input.

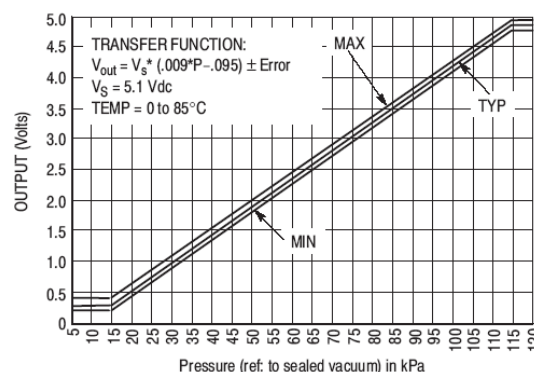


Fig. 4. Transfer characteristics of the MPX4115A.

Typical minimum and maximum output curves are shown for operation over 0°C to 85°C temperature range. The output will saturate outside of the rated pressure range.

Analog signal from pressure sensor is digitalized using built-in PIC ADC with 10-bits resolution. By oversampling technique the resolution is enlarged to 12 bits.

Opto-isolated triac, as shown in Fig. 1, serves for control some of nonelectrical quantities as temperature by driving appropriate actuator.

The complete microcontroller's firmware is written using CCS C compiler IDE ver. 4.057. Only USB descriptor header file has been changed so that the MCU can send and receive a packet up to 16 bytes.

GRAPHICAL USER INTERFACE

The user's software is realized under Windows operating system which ensures quality graphical environment, multitasking and interaction between graphical user's interface objects and appropriated subroutines (event-driven principle). GUI is designed under Borland Delphi 7 graphical programming environment.

Fig. 5. shows the GUI configuration. Six digital displays show instantaneous values of the following quantities: internal temperature, external temperature, relative air humidity, atmospheric pressure, ambient light level and altitude. GUI gets the raw data packet of 16 bytes from acquisition hardware, once per second strictly, see Table 1. GUI then reads and processes ten from sixteen received bytes from the packet and display calculated values. Digital equivalent of each of five nonelectrical quantities is presented with two bytes. Pressure altitude is arithmetic value which is obtained on

the base of the value of atmospheric pressure.
More details about conversion of sensors digital

words into physical values can be found in
datasheets [4, 5, 6, 7, 8, 10].

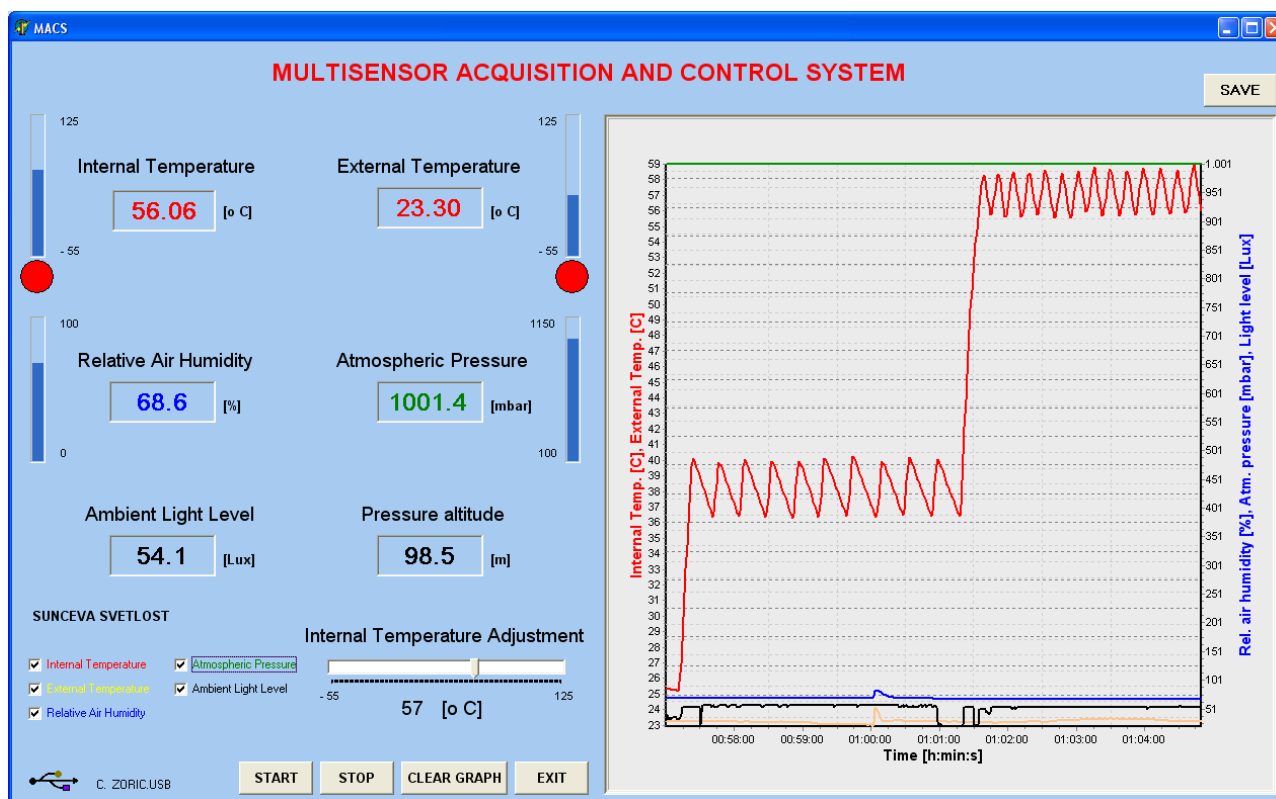


Fig. 5. GUI layout with recorded waveforms.

GUI is equipped with chart which shows curves of five quantities in the real time. In this way the continuous real time monitoring process is provided. User can starts and stops, acquisition process, clears chart and saves chart as bmp file. With five check boxes on the front panel of GUI, users can select or deselect appropriate curves in order to accomplish better visibility. Finally, GUI contains track bar for internal temperature adjustment. Namely, program continuously compares real value of internal temperature with set point value on the track bar. If the set point value is greater than real the PC sends one data byte via USB and acquisition hardware turn on the fan/heater. Otherwise, the PC sends different data byte and acquisition hardware turn off the fan/heater, see Table 1. In this way user can controls the internal temperature as shown in Fig. 5.

The template code for designed GUI is generated by EasyHID (Mecanique) Wizard [9]. EasyHID software is designed to be simple to use, generating code that enables a user to quickly implement bi-directional communication between an embedded device and a PC. It is not designed to exploit the full capability of the USB HID standard. However, the chosen designing approach reduces the complexity of the GUI code because of complex USB port configuration procedures. All functions to work with USB port are built into the system library mcHID.dll that is dynamically linked with the application.

The acquisition hardware of the system can works in the stand alone mode without communication with GUI and with power supply from USB port. In that case all values of nonelectrical quantities will be showed on LCD dot matrix module with two rows.

Table 1. Description of USB packet 16-bytes which HID sends to PC and vice versa.

Ordinal byte No.	Notation	HID -> PC	Notation	PC -> HID
		Description		Description
1.	T _{INTLOW}	Int. temp. low byte	B0	Byte for int. temp. actuator driving
2.	T _{INTHIGH}	Int. temp. high byte	B1	Reserved
3.	T _{EXTLOW}	Ext. temp. low byte	B2	Reserved
4.	T _{EXTHIGH}	Ext. temp. high byte	B3	Reserved
5.	RH _{LOW}	Rel. hum. low byte	B4	Reserved
6.	RH _{HIGH}	Rel. hum high byte	B5	Reserved
7.	AP _{LOW}	Atm. press. low byte	B6	Reserved
8.	AP _{HIGH}	Atm. press. high byte	B7	Reserved
9.	LL _{LOW}	Light lev. low byte	B8	Reserved
10.	LL _{HIGH}	Light lev. high byte	B9	Reserved
11.	-	0	B10	Reserved
12.	-	0	B11	Reserved
13.	-	0	B12	Reserved
14.	-	0	B13	Reserved
15.	-	0	B14	Reserved
16.	-	0	B15	Reserved

Described graphical user interface may be modified and upgraded easily by adding new functions in according with user requirements.

CONCLUSION

The realised multisensor system represents one approach to the virtual instrument developing. Special benefit presents the usage of recent digital sensors. Namely, owing to the precalibrated characteristics of the sensors, expensive system calibration procedures are avoided and thus reduced the costs of the system maintenance. Suggested system can be easily modified by modifying GUI and can be extended by adding more sensors.

Described system can be uses in the weather stations, aviation industrial controls and smart house applications.

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