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International Sensor Development Project

Development of an indoor weather station

Metropolia University of ApplieScences

Electrical Engineering

Final report

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The indoor weather station project was a cooperation work between Metropolia UAS and University of Osnabruck which consists of six students from each Institution. The project focuses on measuring Temperature (indoor and outdoor), Humidity, Air pressure and other interesting measures.

Keywords	Development of an indoor weather station

Glossary

ISD - Indoor sensor development

OSU - outdoor sensor unit

ISU - Indoor sensor unit

CPU - Central processing unit

ET - Evapotranspiration

LCD - Liquid crystal display

LED - Light Emitting Diode

MCU - Microcontroller

CO_2 - Carbon dioxide

RISC - Reduced instruction set computing

GPS - Global positioning system

PDA - Personal digital assistant

LPMS - Low power mode system

EMF - Electromotive force

SCL - System clock line

SDA - Serial data line

I^2C - I-Squared –C serial interface

R\W - Read \ write

ACK - Acknowledgment

S - Start

P - Stop

RH - Relative humidity

T - Temperature

TI – Texas Instruments

MSB - Most significant bit

LSB - Least significant bit

Contents

1 Introduction

Weather station is a facility that is able to collect data related to environment and climate using different sensors. It may be called as weather centre, personal weather station, professional weather station, and weather forecaster.

Weather station sensors may occupy fields of temperature reader (Thermometer), atmospheric pressure measurement (Barometer); moreover, rain, humidity and other sensors. Because of modern technologies this station can express data's from simple analog to digital technology. It has many applications like providing necessary weather information to compute or analyse a specific data. Also it is used to predict weather forecast. Examples: It is used by farmers, weather buffs, gardeners, students, pilots, meteorologists, irrigation management through the process of evapotranspiration (ET) and etc. Manufacturers use various equipment to build weather station and the scope of the model differs according to its application used.

This project focuses on building an indoor weather sensor in cooperation with Osnabruck university of Germany. It aims at creating working device that is able and effective in measuring the needed measurements like temperature, humidity, pressure and other necessary measures. Additionally this project creates communication between group members. The system Includes indoor sensor unit, outdoor sensor unit, microcontrollers and central processing unit which coordinates each other for proper functioning.

2 Weather station

2.1 Overview

Weather station is a facility that enables us to determine atmospheric conditions which are necessary and helpful in determining weather forecast and to study issues related to climate and environment. Wind speed, Wind direction, precipitation, humidity, pressure and temperature amounts can be measured using this device. Maintenance of weather station requires professional personnel.
Weather Display is a method of using software in determining data from weather station using our computers.

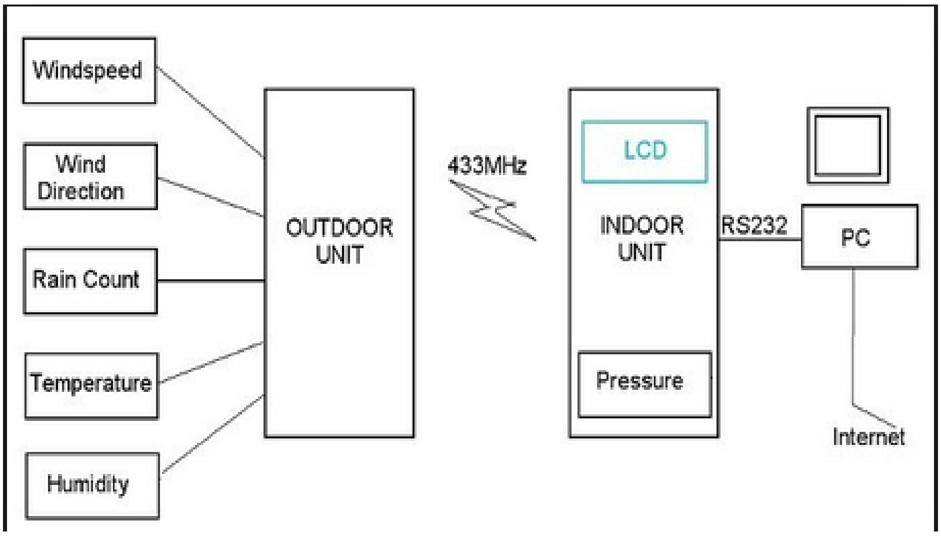

Figure 1. Weather station system including outdoor unit and indoor unit

Figure 1 shows outdoor measurements with outdoor unit and indoor unit interaction with a computer, which shows usage of weather station software in determining and reading measurement.

2.2 Area of Application

The weather impacts quite many areas of our life such as: agriculture and food production, transportation and communication, safety and health and the likes.
There are many application areas for weather stations. These application areas are discussed in detail in the following sections.

2.2.1 Agriculture

A weather data that is reliable is a very important aspect in the agricultural sector. Having a reliable data can optimize the overall production of the sector by giving us all the necessary information about change in temperature, humidity and CO_2 level. For this sector the important elements of weather are solar radiation, evapotranspiration, rain and precipitation, soil temperature, soil moisture, leaf wetness, wind speed and direction, relative humidity and air temperature

2.2.2 Hydrology

This sector is mainly concerned with prediction and solution for flood, draught, erosion and water pollution problems. This sector is interested in data about precipitation, water level (rivers, lakes, reservoirs, and wells), water temperature, snow depth, water flow, evaporation, soil moisture and ambient water quality.

2.2.3 Climatologic Meteorology

This sector deals with forecasting weather based on data collected overtime. In this sector we make use of air temperature, soil temperature, relative humidity, atmospheric, pressure at station level, wind speed and wind direction, precipitation, snow depth, visibility, sky cover, state of the sky, height of cloud base, and type of cloud solar radiation/sun duration.

2.2.4 Maritime and Costal Meteorology

This is mainly concerned about forecasts concerning sea weather and coastal areas. The main elements we are interested at when dealing with this sector are true wind speed and wind direction, atmospheric pressure, air temperature, relative humidity and dew point, water temperature and water level.

2.2.5 Urban Meteorology

Weather can affect the urban life in great deal. Heavy rain can cause flooding. Bad weather can cause power cut and disruption of transportation. Additionally industrialization also results in increasing level of pollution which we should keep an eye on. And knowing the weather data helps us make an informed decision about our day to day life.

3 Hard ware

3.1 Sensors

3.1.1 Digital relative humidity & temperature sensor RHT03

This is a humidity and temperature sensor which gives a calibrated digital output signal. Its sensing element is connected with 8-bit single-chip. As operation specification, power voltage should be 3.3 – 6 volts and one wire communication is used between MCU and RHT03. Sending a signal from MCU rapidly makes RHT03 to change its standby mode to running mode. When MCU is finished sending signal, RHT03 sends response message of 40 bit data which shows humidity and temperature to MCU. This shows that RTH03 cannot respond without MCU communication.

3.1.2 TGS 4161 - for the detection of Carbon Dioxide

Figaro TGS is a solid electrolyte CO_2 sensor that offers miniaturization and low power consumption. It has an ability to measure carbon dioxide level in a range of 350~10,000ppm which makes this sensor suitable for indoor applications. It is possible to measure the amount of CO_2 concentration by varying electromotive force (EMF) that is created between the two electrodes in CO_2 sensor which consists of a solid electro-lyte.

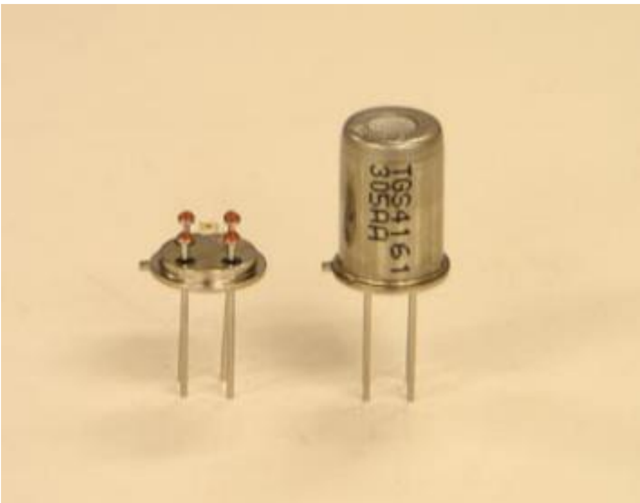

Figure 2. TGS 4161 - for the detection of Carbon Dioxide

The top cap has an absorbent substance called zeolite which decreases the interaction of other gases.

The TGS4161 sensor needs a heater voltage input and this voltage is going directly to the integrated heater to balance the sensing nature at a specific temperature. High impedance input of operational amplifier with a biased current (<1pA) is required to measure the electromotive force (EMF) of the sensor.

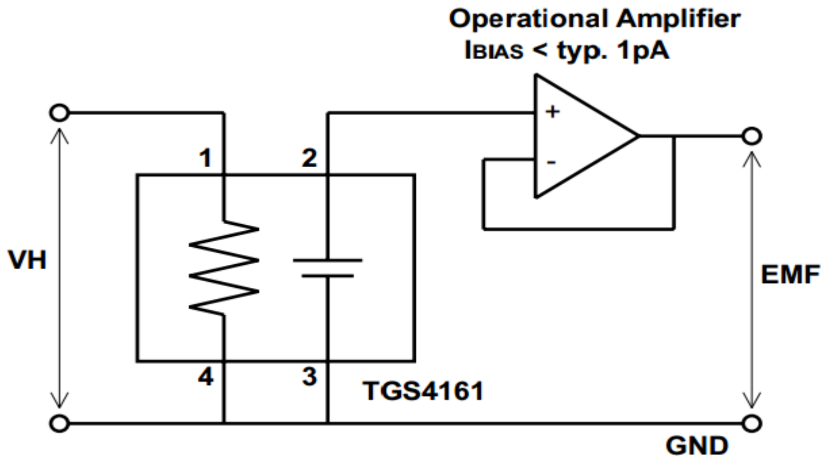

Figure 3. Circuit diagram for TGS 4161 Carbon Dioxide detector

3.1.3 Digital pressure sensor BMP085

Also called Bosch Sensortech, is a high resolution sensor for measuring atmospheric pressure and consists of analog to digital converter which is built inside. It is applicable in mobile, GPS, PAD_S and outdoor equipment because of its low power optimization.

The sensor has a temperature sensor built inside beside pressure sensor but for this project only the pressure sensor was used.

Figure 4. Digital pressure sensor BMP085

The BMP085 digital pressure sensor is functionally compatible to the existing Bosch sensortec SMD500 digital pressure sensor.

3.2 MSP430

This is 16 bit microcontroller of ultra-low power RISC mixed microprocessor from Texas Instruments which is able to use with portable applications. TI supplies all the necessary information like technical documents, training, tools and other software in working with this microcontroller. MSP430 has specific features which make them preferable:

1 - Flexible clocking system.
2 - Multiple low power modes.
3 - Ultra power optimization.
4 - Dramatically straighten battery life.

This feature shows the ability of enabling and disabling different clocks and oscillators for the sake of allowing low power signal (LPMS) to devices. In direct, this saves electrical current in our system.

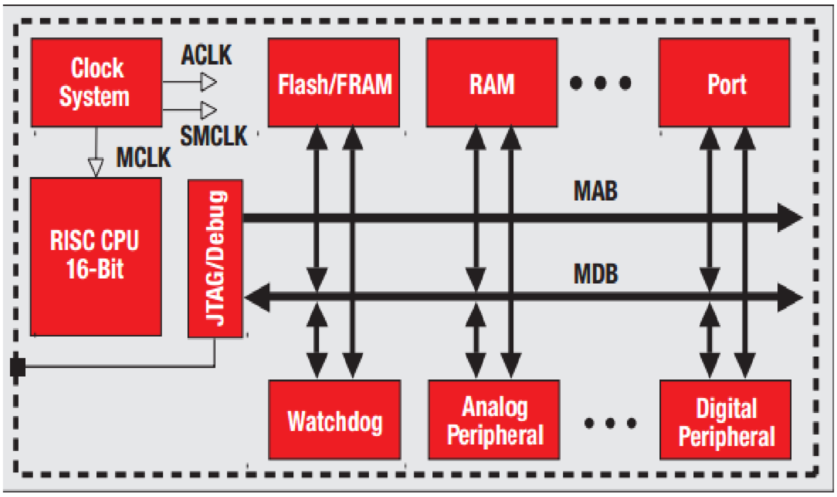

Figure 5. 16-Bit Orthogonal Architecture of MSP430 MCU

3.3 Assembly circuit board

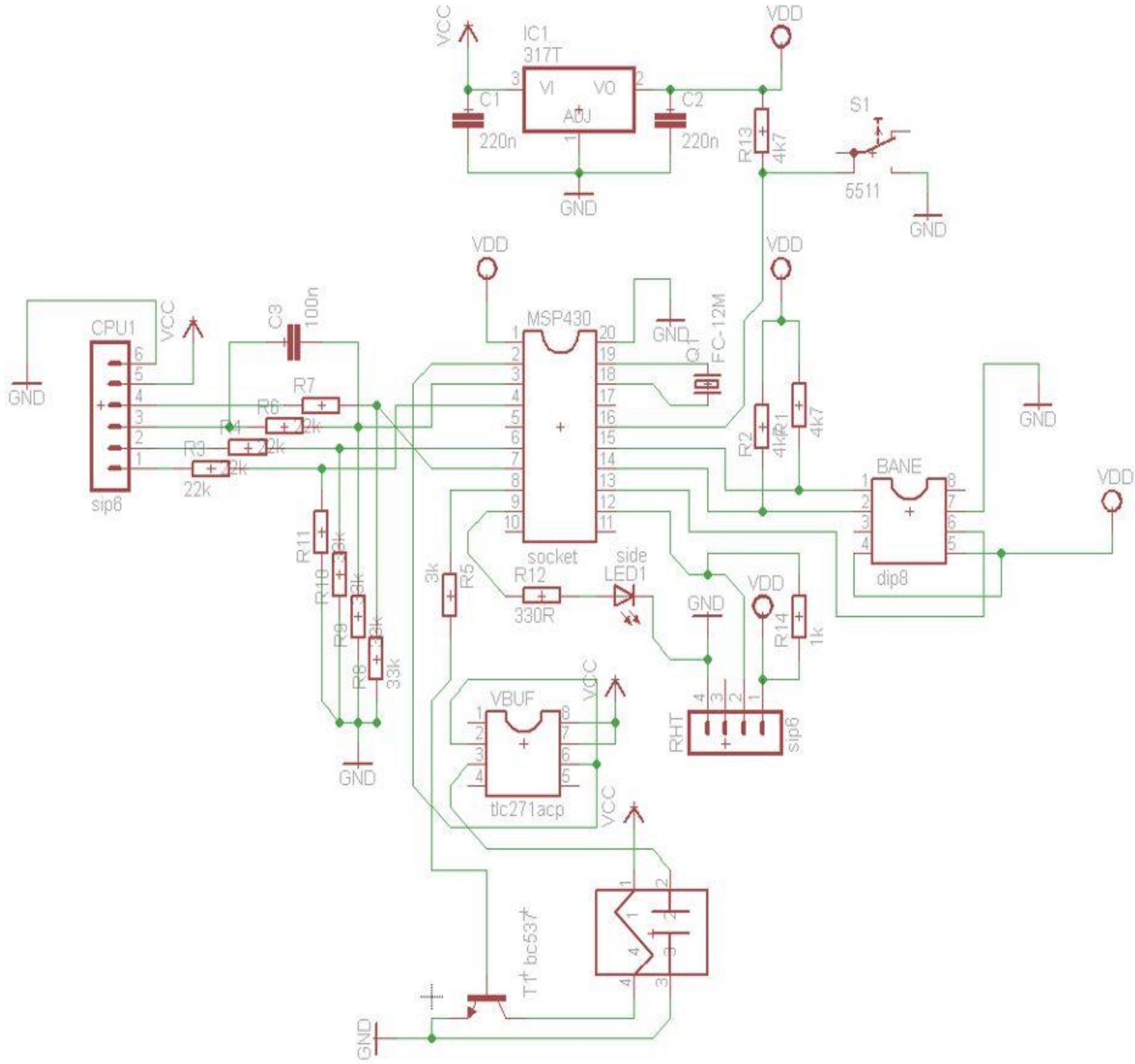

Figure 6. Logical design schematic of ISU

Circuit board design was made according to each main element (sensor, microcontroller) needs. Together, circuit components create necessary conditions for higher-level operation of the ISU. Most content of circuit except main elements are:

- Capacitors – are keeping operating voltages stable
- Resistors – setting constant voltage levels
- Voltage buffer (VBUF) – part of analogue sensing circuit (see Fig. 3)
- Switching voltage regulator – stable power source for the board

4 Soft ware

4.1 Communication inside ISU

4.1.1 Communication between CO_2 sensor and microcontroller

The Figaro CO_2 sensor is an analog sensor. The communication between microcontroller and this sensor was made as follows: First we take our analog data and fed it to the ADC of MCU. Then after the conversion is done we calculate the corresponding CO_2 value by using the relationship between the conversion and the voltage and the relationship between the voltage and actual CO_2 level.

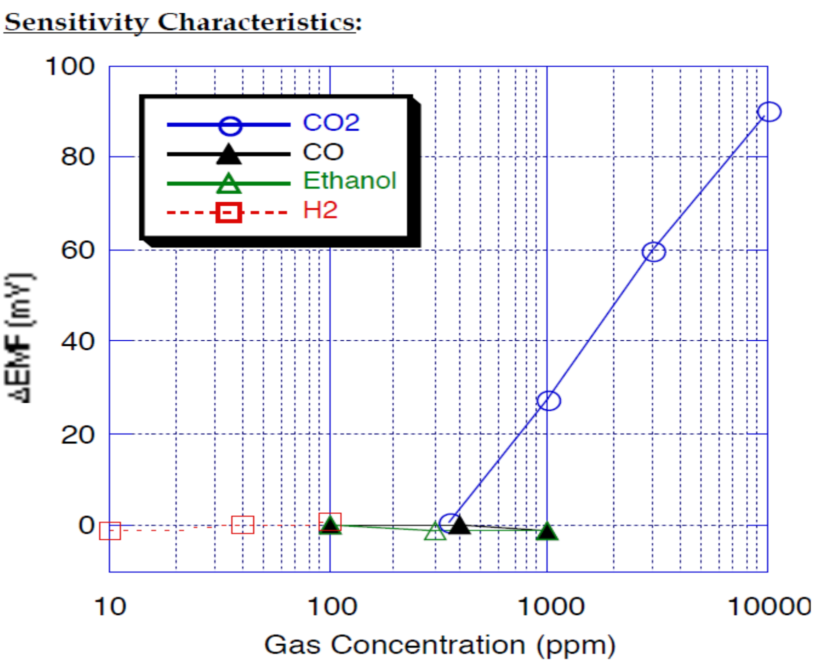

Figure 7. Characteristics graph of CO_2 Sensor

4.1.2 Communication between pressure sensor and micro controller

Since the pressure sensor is a digital sensor it generates a digital output. The communication between MCU and the pressure sensor was done by I^2C interfacing method.
To start transmission of data between sensor and MCU using I^2C the SCL should be high and the SDA should have a failing edge. Then the master MCU sends the slave address. After sending the 7 address bits direction control bit is sent selecting the read

or write operation. Then the slave sensor in this case recognizing its being addressed pulls SDA low in the ninth SCL cycle. To stop transmission SCL should be high when SDA has rising edge.

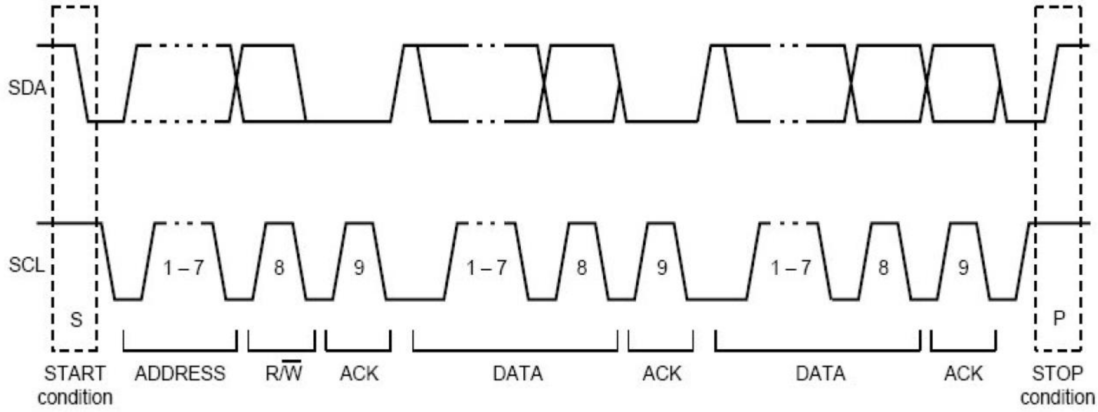

Figure 8. Timing diagram for transmission

4.1.3 Communication with humidity and temperature sensor

When communicating with the relative humidity and temperature sensor MAXDetect 1-Wire bus is used. The data that is sent out by the sensor consists of five 8 bit parts as shown below.

DATA = 8 bit MSB RH data + 8 bit LSB RH data + 8 bit MSB T data + 8 bit LSB T data + 8 bit check-sum.

If the data transmission is right the sum of the first four 8 bit parts should be equal to the 8bit check sum. Dividing the decimal value of the first 16 bits gives us the relative humidity percentage while dividing the decimal value of the second 16 bits gives us the temperature in degree Celsius. If the HSB of the temperature data is high it means the temperature is negative.

To start transmission the MCU first sends out a start signal and the sensor sends a response signal. Initially in the data-bus´s free state the voltage in the transmission line is high. To start the transmission the MCU pulls the data-bus low for about 1~10ms. Then the MCU pulls up and wait 20-40us and wait for response from sensor. When sensor detects signal it pulls low for 80us as response, then sensor pulls again up for 80us as preparation to send data.

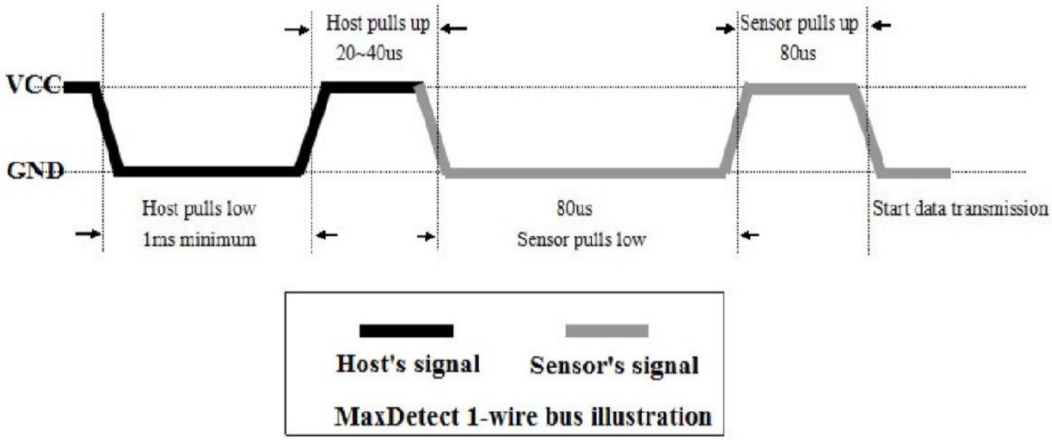

Figure 9. Starting transmission of data

After the start condition is completed sensor sends the actual 40bit data. Every bit´s transmission is preceded with a low voltage that lasts for 50us, the following high voltage level signal´s duration decides if the bit is a "1" or a "0".

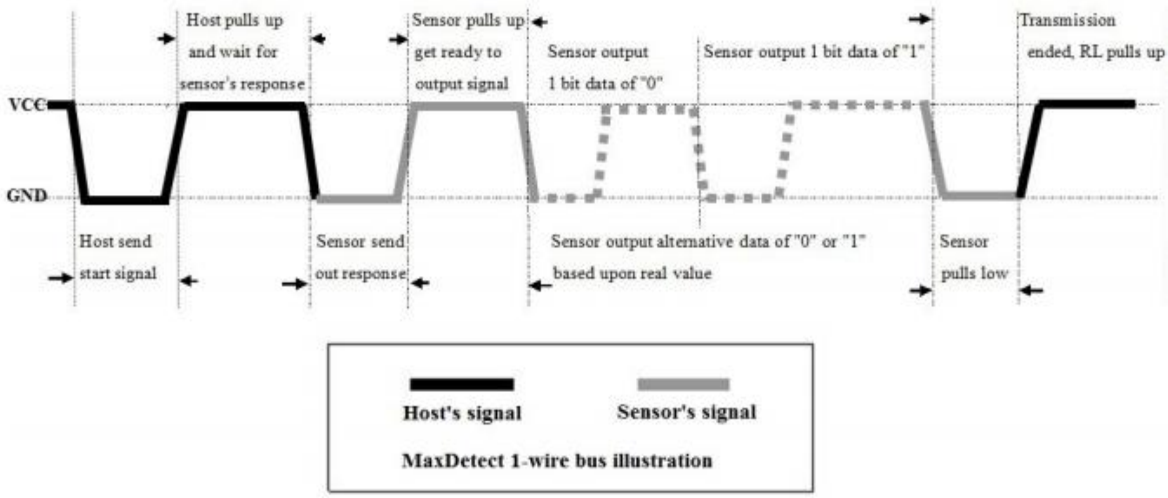

Figure 10. This figure shows overall communication process, the interval of whole process must above 2 seconds

4.2 MSP 430 Operation

In order to have all the measurements evenly time-distributed, MSP 430 is programmed to be a state machine. Processor clock operates on frequency of 16 MHz, and is switched off every time it is not needed. When peripheral timers A or B are triggering timing event, processor goes to measurement state, after which it goes to low power mode again. Processor wakes up as well in case of data transfer demand from CPU. In this case, right after answering to CPU, microcontroller low power mode is executed. Operation structure is given by while-loop based C program:

```
int main(void)
{
  clockset();                                   // setting up peripherals
  pinset();
  serialset();
  bane_calibration();                           // BMP085 calibration
  timerset(1);                                  // timer a (main delay) and b (adc delay) setup
  while(1){                                     // standby mode loop = continuous operation
     switch (state) {                           // main state machine
               case pressure: {
               timerset(0);                     // timer a stop
               bane(pres);                      // pressure measurement
               bane_math();
               timerset(2500);                  // timer a delay 2500 ms
               spi_sleep();                     // enable cpu transmission until timer wake up
               state = temp_hum;                // timer a wake up, go to next state
               break;
               }
               case temp_hum: {
               timerset(0);
               onewire();                       // temperature and humidity measurement
               timerset(2500);
               spi_sleep();
               state = pressure;
               break;
               }
     }
     if (wait > 0){
               wait = 0;
               adc++;
               switch (adc) {                   // auxiliary state machine, executed after main
                     case 2: {
                     heater(on);                // start heating up TGS 4161
                     co_sample(a);              // first adc measurement
                     adc++;
                     break;
                     }
                     case 3: {
                     co_sample (b);             // second adc measurement, delta calculation
                     heater(off);
                     adc = 0;                   // adc state reset
                     break;
                     }
                     default: break;
               }                                // repeat main loop
     }
  }
}
```

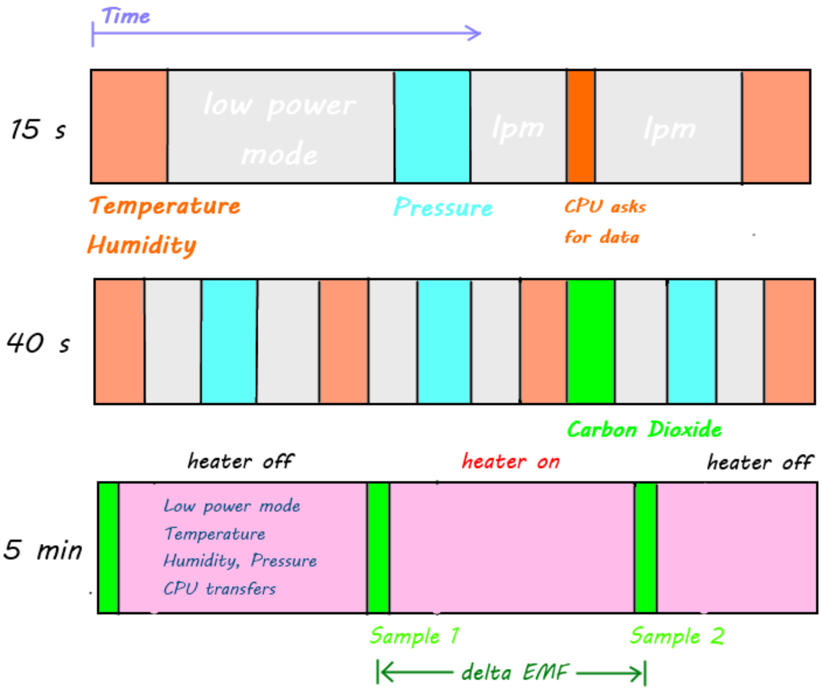

Figure 11. ISU State machine operation

4.3 Communication between ISU and CPU

Microcontroller connects to Central Processor Unit with SPI serial interface. SPI is a full duplex serial connection protocol which allows relatively big data transfer rates (up to 500 Kbit/s) in both directions at the same time.

In normal operation, Central Processor Unit is not sending any information to the ISU Microcontroller. In order to get bytes of data from it, CPU should send same amounts of zero bytes forward first, thus initializing connection as Master.

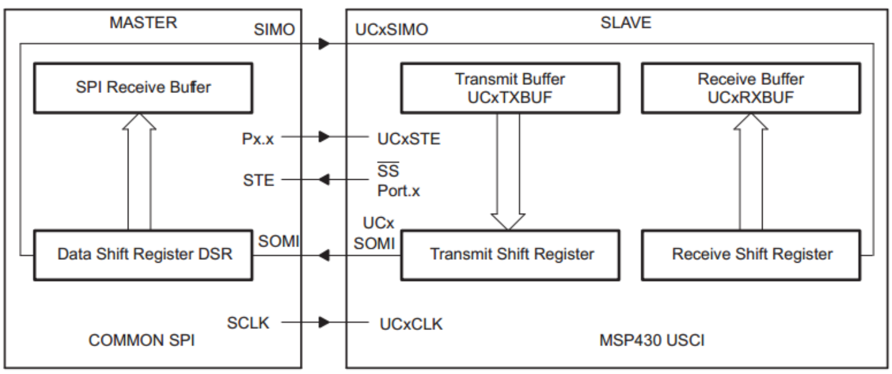

Figure 12. MSP430 SPI Slave operation

5 Conclusion

Experience has shown that creating a clustered device in teams requires a lot of collaboration and understanding among students. Various stages of completion need almost equal amount of distributed effort.

It figures that overall realization and “whole view” are key aspects for cutting down complex device like weather station to lower level parts. After separating whole to pieces, it is obviously necessary to structure them and think of ways for the parts to interconnect.

One not less significant detail of the device as abstract is discrete levels of its operation. Meaning physical level of stability for example, is achieved only when all the circuits of given device or sub-device are connected and voltage levels are behaving according to theoretical model. Higher level operation is achieved when expected logical feedback can be seen, and some part or even whole device (or sub-device) can be considered “working”. Even higher levels involve hierarchal structures with topologies, central and peripheral elements, or even networks of elements.

Using all these factors as “borders”, work can be distributed between project members. Milestones and different versions of the product are also divisible by these aspects.

Good to mention that operating in such variable environment needs a lot of agile management and communication between members. Putting effort into work by gathering together in laboratories yields most productive results. Mostly it reflects high compatibility between project members’ skills and knowledge, vision of situation, and motivational part of problem-solving as well. Good pointed goals and methods of autonomous tasks have proven themselves as effective. It is always good to be aware of what and why one is doing at the moment for the project to be completed in time.

All the project members have learned well, that most of problems arising in development of particular project internationally should be realised by oneself own experience. In other words, they should be understood personally. During project trip, team learned that it is impossible to be ready for all of the practical problems, except having open mind and right attitude instead.

6 References

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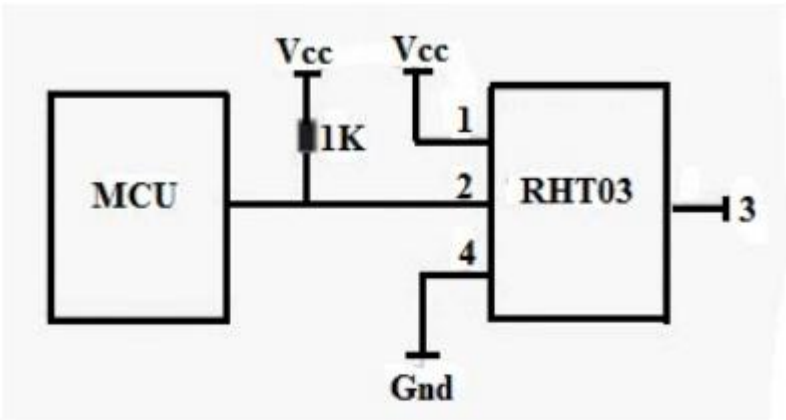
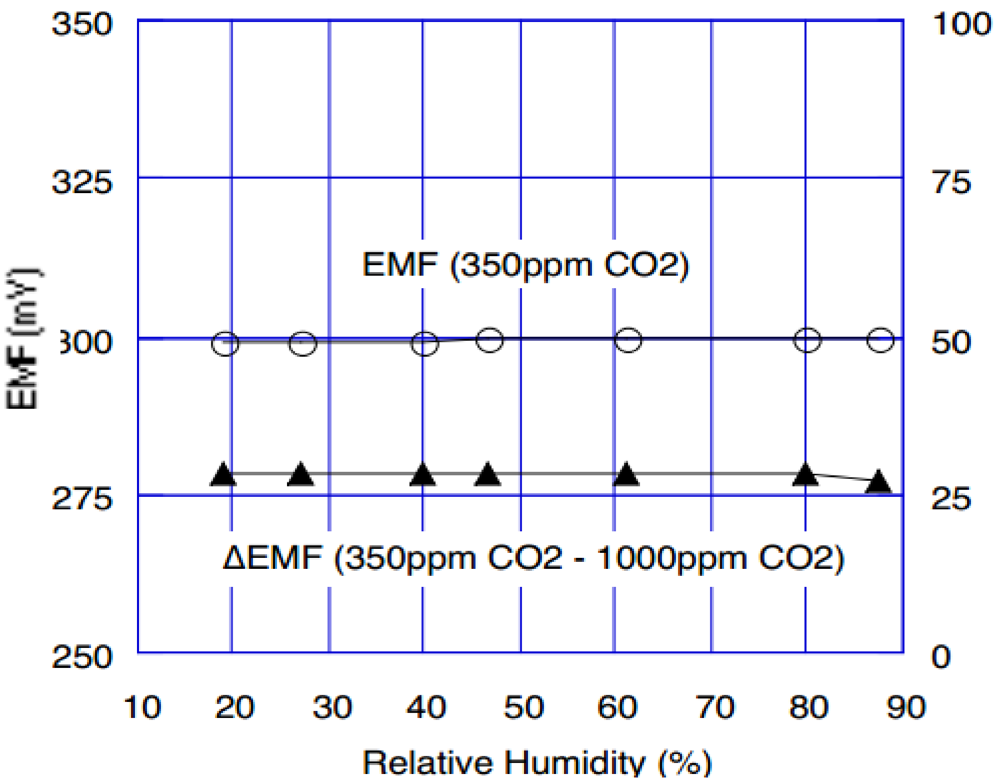
7 Appendices

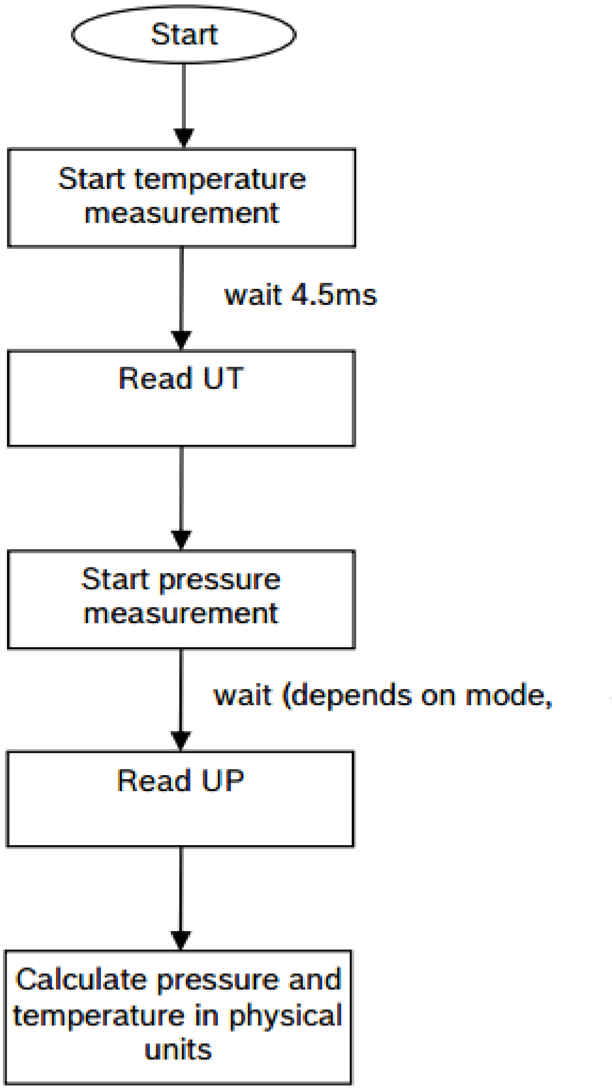
Digital relative humidity & temperature sensor RHT03 communication with microcontroller



TGS 4161 CO_2 sensor relationship with relative Humidity



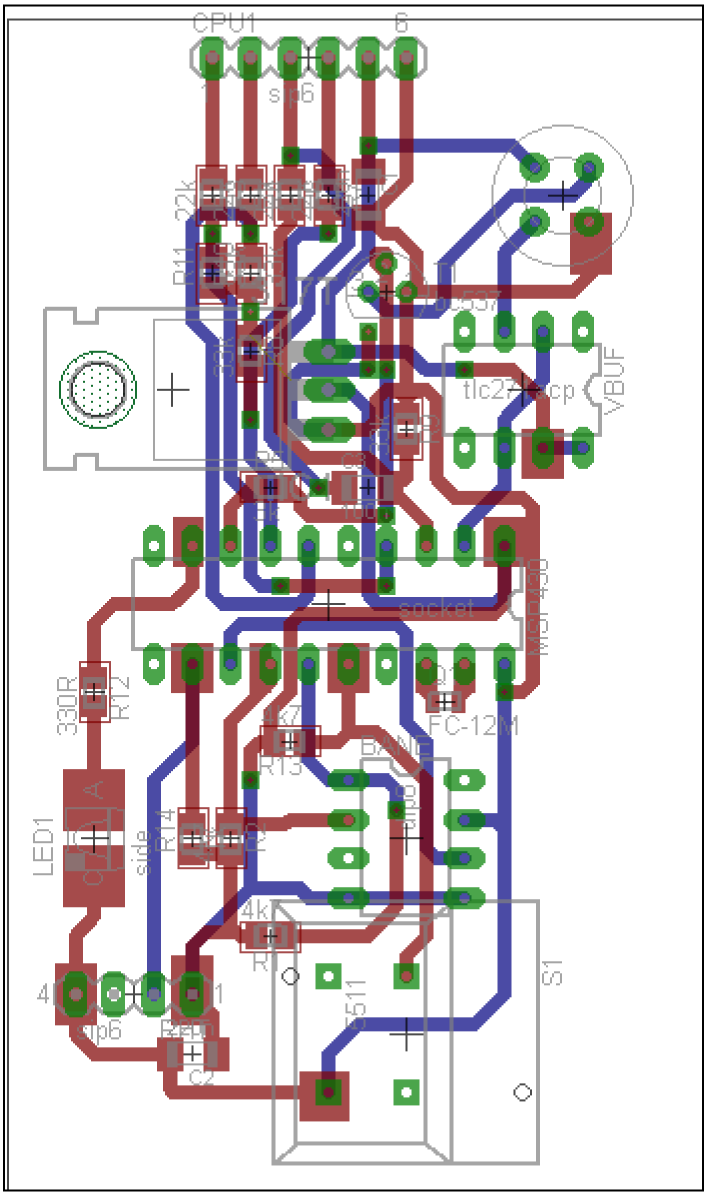
Measurement of Digital pressure sensor BMP085



Component description

PCB Component	Discription	Implementation
MSP430	MICROCONTROLLER	Texas Instruments MSP 430g2553
CPU	CENTRAL PROCESSING UNIT	SIP-connector (Cypress CY8C27x43_38)
Vcc	POWER SUPPLY	SIP-connector (From CPU board)
GND	GROUND	SIP-connector (From CPU board)
C	CAPACITOR	SMD package 1210 compatible type
R	RESISTOR	SMD package 1206 compatible type
LED	LIGHT EMITTING DIODE	Phillips Side LED SMD package
R3,R4,R6,R7,R8,R9,R10,R11	PULLUP RESISTORS, VOLTAGE DIVIDERS	Not Applicable
VBUFF	VOLTAGE BUFFER	Texas Instruments TLC271 Op. Amplifier
IC317T	VOLTAGE REGULATOR	National Instruments LM1117T-3.3
BANE	PRESSURE SENSOR	BOCSH Sensortec BMP085
RHT	HUMIDITY AND TEMPERATURE SENSOR	Maxdetect RHT-03

Printed Circut Board Layout



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