Embedded system for short-term weather forecasting

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Abstract: *In this paper the specific solution is considered for the creation of embedded system by modulus principle for data acquisition, processing and visualization, related to temperature, atmospheric pressure, humidity, wind speed and direction, intended for giving of short-term weather forecast. The system reads and visualize on a display also the current time by means of built-in clock. The visualization is made with the help of seven-segment digital indicators and light emitting diodes (LEDs). The system is based on the one-chip microcontroller of type PIC16F877.*

Key words: *PIC 16F877, Weather forecast, Environment Sensors, Weather Station, Sensors Network.*

INTRODUCTION

For millennia people have tried to predict what the weather would be like a day or a season in advance. In this millennia history of weather forecasting the techniques used have changed significantly. Ancient methods of weather forecasting usually relied on experience to spot patterns of natural events. For example, they noticed that if the sunset gave a particularly red sky, then the following day brought fair weather. There are used also for this purpose primitive tools for indication of changes in the atmosphere. In the 20th century a great progress was made in the science of meteorology, which allowed understanding of atmospheric processes. With the invention of the mercury barometer it became possible to be changed the way through which the weather forecast was made. This leads to change in the former understandings for weather changes. The idea of numerical weather prediction (NWP) was presented by Lewis Fry Richardson in 1922 [1]. With this the beginning is put of a new method of approach for weather forecasting.

Today, weather forecasts are made by collecting as much data as possible about the current state of the atmosphere (particularly the temperature, humidity and wind) and using understanding of atmospheric processes (through meteorology) to determine how the atmosphere evolves in the future. However, the chaotic nature of the atmosphere and incomplete understanding of the processes mean that forecasts become less accurate as the range of the forecast increases (as time and location).

Weather forecasting (weather prediction) is the application of current technology and science to predict the state of the atmosphere for a future time and a given location.

Weather forecasts provide critical information about the weather to come. In severe weather situations, short-term forecasts and warnings can help save lives and protect property. It is vital that weather forecasts be as accurate as possible because so many people depend upon them.

Many methods are created for weather forecasting. Lately with the most applicable are five of them: Persistence Method, Trends Method, Climatology Method, Analogue Method and Numerical Weather Prediction Method [2]. They are taken under attention in the determination of the way of approach for a model creation, ensuring optimal input data for the system for short-term weather forecasting.

The designed system is intended to give short-term weather forecast, based on combination from pointed above methods for prediction. If the forecast is for time periods from 0 to 6 hours, this is determined as nowcasting.

WEATHER FORECASTING METHODS

The pointed above methods for weather prediction are characterized with some common features, and namely: Sensors data acquisition; Data assimilation; Processing of received data; Storing and post-processing of the results; Representation of obtained results and forecasts.

More detailed descriptions of the typical common features of discussed methods are:

Sensors data acquisition

In the information system there are both specialized sensors and sensor modules for collecting of data for typical meteorological parameters of the atmosphere. The information from the connected sensors into the system is collected from the microcontroller module by two ways:

- By using of standard serial communication interface I^2C – for atmospheric pressure, wind direction, temperature and real-time clock;
- By conversion of measured physical quantities into electrical signals with square waveform and variable frequency – humidity and wind speed.

Data assimilation

Including data processing with purpose to keep their authenticity and recovering of missing data. The keeping of the authenticity of the data is concluded in checking of previously defined boundaries for alteration. In the cases when for some reasons there is no received information from current measurement for one physical quantity, the system recovers missing data with such data from the nearest previous measurement.

Processing of received data

It is made with the help of previously created mathematical model by combination of thermodynamic equations which describe the state of the atmosphere in given location in any moment of time, and analysis of numerical statistical data (for temperature, pressure, humidity, level of illumination, wind speed and direction). In the nowadays meteorology this processing is the most complicated. It requires the use of supercomputers because the values are many and the systems of equations are very complex. This way of approach is in the base of numerical weather forecasting. Here are included the data from meteorological probes, balloons, satellites, Doppler and microwave radars and other. In the relation to the other mentioned methods for prediction, it is made statistical analysis and processing over the received data.

Storing and post-processing of the results

The storing and post-processing are used in the all methods with the purposes accumulation of statistics, filtration, systematization and verification.

Representation of obtained results and forecasts

Into every one of the methods, the obtained results and forecasts are represented in appropriate look to the end user. For example, by means of light emitting diodes with captions against them and matrixes from light emitting diodes, digital indicator elements, pointer indicators, LCD displays for texts and graphics, specialized LCD displays, monitors and others.

The purpose of the work is the designing of the embedded system, which supports the realization on methods for weather forecasting.

HARDWARE REALIZATION

After the review of the most used methods and their typical common features, there is chosen suitable set of sensors and modules for measurement of wind speed and direction and a real-time clock.

At the base of all this, it is designed a system tailored for short-term weather forecasting. The system consists of different modules. Block-diagram of this system is shown in Fig. 1.

The main modules of the system are:

1. Microcontroller PIC16F877

Module Microcontroller PIC16F877 from Microchip Company is designated to control the work of the all other modules. The main features of the microcontroller are: Work frequency – 20MHz; Flash Program memory (14-bit words) – 8K; RAM data memory (bytes) – 368; EEPROM data memory – 256; Programmable digital inputs/outputs;

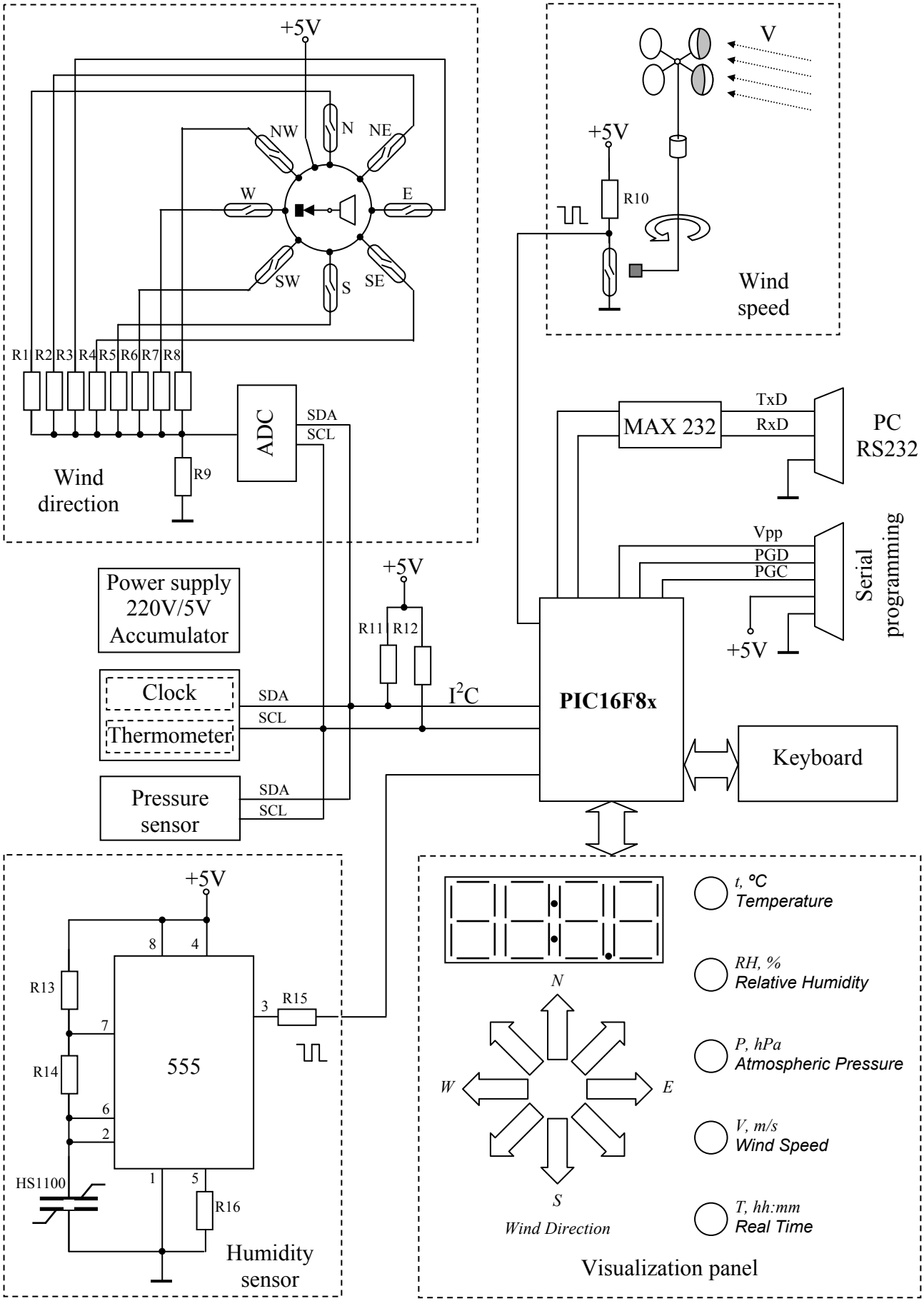

Fig. 1. Embedded system for weather forecasting

Serial communications - MSSP (I^2C), USART (RS232); Timers – 3; Watchdog timer; 40-pin package.

The choice of microcontroller type is made according to its technical features and abilities for the concrete application [3]. In the schematic solution there is a possibility for serial programming of the module "on-place" ("in-circuit").

2. Clock - Thermometer

The module Clock – Thermometer is realized with integrated circuit DS1629. It is 2-wire digital thermometer and real-time clock, integrated in small 8-pin SOIC package. The communication to the DS1629 is accomplished via a 2-wire interface I^2C [4]. The wide power supply range and minimal power requirement of the DS1629 allow for accurate time/temperature measurements in battery-powered applications.

The digital thermometer provides 9-bit temperature readings, which indicate the temperature of the device. No additional components are required; the device is truly a "temperature-to-digital" converter.

The clock/calendar provides seconds, minutes, hours, day, date of the month, day of the week, month, and year. The end of the month date is automatically adjusted for months with less than 31 days, including corrections for leap years. It operates in either a 12- or 24-hour format with AM/PM indicator in 12-hour mode [5].

3. Pressure sensor

The module Pressure sensor is represented by the integrated circuit SCP1000-D11, which consists of sensors for measurement of absolute pressure and temperature with built-in ADC for digital conversion of the measured analogue value from the sensors. The range for measurement of atmospheric pressure is from 300 mbar to 1200 mbar (30000 Pa to 120000 Pa). The scheme has ability for linearization and temperature compensation of measurements. The communication between SCP1000-D11 and the microcontroller module is based on serial interface I^2C. The sensor scheme supports 4 modes for measurement plus stand-by mode and low power mode. In the all modes of work the output word from pressure measurement is 19-bits, and from temperature measurement are 14-bits [6]. There is need of correction over pressure readings with -1% for every 80m altitude above the see level [7, 8].

4. Humidity sensor

The module Humidity sensor is realized by capacitive sensitive element for relative humidity type HS1100 and an integrated circuit timer TLC555 (Texas). Both form a capacity-to-frequency converter. The range for change of the humidity is from 1 to 99 % and the measurement error is +/-2%. The characteristic of the relation between the capacity in function from the humidity is comparatively linear. For the chosen scheme the range for variation of the frequency is from 7351Hz to 6033Hz (from 0% to 100%RH) [9].

5. Wind direction

Module Wind direction is built by 8 reed-relays uniformly placed radial in one plane around rotating spindle. The mounted on the spindle wing is pointing the wind direction, rotated by its force. On the same spindle is mounted a magnet and depend from its position, there are switched-on 1 or 2 adjacent reed-relays. The resistors form R1 to R8 are with thereby selected values that on the output of a divider with R9 are obtained 16 different levels of voltage in dependence from this, exactly who reed-relays are switched-on. The last is converted to digital form from an ADC type AD7992. The digital values from AD7992 are transferred over I^2C interface toward the microcontroller [10].

6. Wind speed (anemometer)

Module Wind speed is anemometer on the output of witch are received squire waveform impulses with variable frequency depending on the wind speed. The formed signals are passed to the microcontroller. There is need from correction over readings for wind speed with +5% for every 1 kilometer altitude above see level [11].

In the new versions of the wind speed sensor and the wind direction sensor, the reed-relays are replaced by electronic components.

7. Keyboard

Module Keyboard consists of four buttons, which are used for control of the device work. The functions of the buttons are:

1) Reset of the device;
2) Switching from mode 'Normal work' to mode 'Adjusting' and reverse;
3) When working in mode 'Adjusting' the adjusted values are chosen in the next sequence: year, month, day, hour, minutes, altitude; In mode 'Normal work' the values are chosen in the next sequence: year, month, day, hour, minutes, altitude – for checking of adjustments made;
4) In mode 'Adjusting' the value of the chosen quantity is changed unidirectional by increasing of its value. When the value reaches its maximum, then automatically the minimal value is set, and this is repeated cyclically; in mode 'Normal work' are visualized in the next sequence: temperature, relative humidity, atmospheric pressure, wind speed and real time.

The zeroing of the seconds of the clock is made when the device switches from mode 'Adjusting' to mode 'Normal work'.

8. Visualization panel

With the help of the visualization panel the current values of measured quantities are showed, and the showed value is pointed by the related light emitting diode. The wind direction is visualized in every moment when the system works. In the mode 'Adjusting' on the panel are visualized the adjustments made by the keyboard.

9. RS232 communication

RS232 communication is based on build in USART module into the PIC16F877. There is used level converter TTL/RS232 from type MAX232 of Maxim Integrated Products with needed external elements recommended by the manufacturer [12]. It is designated for serial communication with the personal computer. By previously chosen higher level protocol it is possible data transfer to the personal computer for further processing.

10. Power supply

Module Power Supply provides needed supply voltages for the work of all modules into the device. These voltages are obtained by the use of integral voltage regulator 7805 and a regulator for 3.3 V for supplying of module Pressure sensor.

For providing of partially autonomous work of the device against fallings and interruptions of the power supply in the electrical network, there is placed an accumulator for keeping uninterrupted the work of the system.

11. I^2C interface

I^2C interface is used between the microcontroller PIC16F877 and the integrated circuits DS1629, SCP1000-D11 and AD7992. Every module, connected to the I^2C-bus has its own address, by witch can be addressed in the communication.

It is possible to be connected up to 7 slave devices toward the microcontroller. There is used a built-in synchronous serial communication interface (MSSP) into the PIC16F877, which is configured according the I^2C specification [13].

ALGORITHM REALIZATION

The results from the algorithms realization and their working are subject of future work.

CONCLUSIONS AND FUTURE WORK

The work of the system is based on the combination from above pointed most used methods for forecasting. The algorithm realization of the system for short-term weather forecasting is obeyed on the constant verification of the model and taking under attention

in its designing the typical for the prediction methods common features.

The designed system cares out the measurement of current values for temperature, relative humidity, atmospheric pressure, wind speed and direction and real time. Based on juxtaposition of the collected statistical information with the current measured data, defined methods for weather forecasting and the determination of the correlation between processed meteorological quantities, there will be possible to realize an algorithm for short-term weather forecasting.

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