ARM Based Research of Roots Flow Meter using Zigbee Technology

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Abstract: This paper introduces an intelligent roots flow meter based on ARM Cortex-M3 processor and μ C/OS-II embedded real-time operating system. ARM Cortex-M3 processor is an industry-leading 32-bit processor with lower power consumption and higher performance than other 8-bit or 16-bit processors. In roots flow meter gas flow, pressure of the flowing gas and temperature is sensed using corresponding sensors. Sensor continuously monitor at the effect of the different pressure of gas flow. Then the gas flow is expelled from the little space continuously Then the data is processed by the ARM processor at the instantaneous flow rate, temperature and integrated pressure is display on the LCD screen Using the μC/OS-II embedded real-time operating system, it will compensate the temperature and pressure of the roots flow meter more instantly. What's more, it makes communication and networking easier by using ZigBee technology.

Keywords: Cortex-M3; μ C/OS-II; ZigBee; low power; roots flow meter

I. INTRODUCTION

Gas flow has always been difficult to measure accurately in industrial engineering. Since the working condition is complex and variable, it is necessary for gas flow meter to compensate the temperature and pressure signal automatically in real-time. The flow meters were studied using a newly developed flow rig, designed for measurement of steady and pulsating air flow of mass flow rates and pulse frequencies typically found in the gas exchange system of cars and smaller trucks. Flow rates are up to about 200 g/s and pulsation frequencies from 0 Hz (i.e. steady flow) up to 80 Hz. The study included the following flow meters: hot-film mass flow meter, venturi flow meter, Pitot tube, vortex flow meter and turbine flow meter. The performance of these meters was evaluated at both steady and pulsating conditions. With ARM processor and embedded software system the intelligent roots flow meter of this paper introduced can achieve the requirements of gas flow meter and have such advantages like low power consumption, real-time, diagnosis, automatic compensation, etc.

Existing System:

In the earlier days there are lots of system and technology are implemented to measure and process the parameters of the gas flow. But there is no system is there to implement with integration of all of this within a system. And with advantages like low power consumption, real-time, diagnosis, automatic compensation, etc. so we move for a new system.

Proposed System:

In roots flow meter gas flow, pressure of the flowing gas and temperature is sensed using corresponding sensors. Sensor continuously monitor at the effect of the different pressure of gas flow. Then the gas flow is expelled from the little space continuously. The sensor signal goes into the microcontroller measuring system after being converted to digital by ADC. Then the data is processed by the ARM processor at the instantaneous flow rate, temperature and integrated pressure is display on the LCD screen. Temperature sensor and Pressure sensor collects the temperature signal and pressure signal respectively and send it to the ARM processor. The processor processes the data and sends it through Zigbee to PC which has a data base.

II. LITERATURE REVIEW

2.1 Studies on Roots Flow Meter

A flow meter is an instrument for determining the flow rate of a fluid in some sort of conduit, for instance natural gas and oil in pipelines, domestic water supply, intake air to a combustion engines etc. The necessity of accurate flow rate measurement of a fluid is as important today as it has been in the ancient history. Industrial flow measurements include measuring of flow rate of solids, liquids and gases. There are two basic ways of measuring flow; one on volumetric basis and the other on weight basis. Solid materials are measured in terms of either weight per unit time or mass per unit time. Very rarely solid quantity is measured in terms of volume. Liquids are measured either in volume rate or in weight rate. Gases are normally measured in volume rate.

2.2 Working Principle of Roots Flow Meter

The roots flow meter is one kind of waist wheel low meters. There is a fixed large space internal and a group of revolvers (waist wheel) break the large space into several small spaces which are known volumes. Waist wheel turns continuously at the effect of the different pressure of gas flow. Then the gas flow is expelled from the little space continuously. The speed of waist wheel is converted to corresponding frequency electrical impulses by the impulse. Pulse signal goes into the microcontroller measuring system after being magnified by the magnifier. Then throw the counts and accumulative counts of electrical impulses and temperature and pressure compensation, we can work out the instantaneous flow rate and integrated flow and display on the LCD screen.

2.3. Temperature and Pressure Compensation Mathematical Mode

In general the gas can be seen as ideal gas when its pressure is little but temperature is high. In gas flow measurement, the time that gas flows through a flow meter is very short, so there is no time for the gas to exchange heat with the world outside (The excite heat by friction is not considered in this condition), thus, the change processes of the state of gas can approximatively be seen as Reversible adiabatic process or Isentropic procedure. So the state equation of adiabatic process can be used to compute specific volume or density under different state. But in Engineering, the density is usually calculated based on the perfect gas equation Boyle Charles Equation (pV=nRT) that is

$$\rho = \rho_x \frac{p\,T_x}{p_x T}$$

Where.

ρ = The destiny of gas under working state

ρ_x = The density of gas under standard conditions

P= The pressure of gas under working state

p_x = The pressure of gas under standard conditions

T= The temperature of gas under working state

T_x = The temperature of gas under standard conditions

In order to illustrate the extent of differences between the working gas and ideal gas, we definite parameter Z as Coefficient of Compressibility to measure the extent of proximity between real gas and ideal gas:

$$Z = PV/nRT$$

The Coefficient of Compressibility of gas is (Z=1) when it is ideal gas, that is,

$$\rho = \rho_x \frac{p\,T_x\,Z_x}{p_x T\,Z}$$

Where..

Z_x = The Coefficient of Compressibility of gas under standard condition;

Z = The Coefficient of Compressibility of gas under working state.

But the state change of gas will not abide by the rules of state equation of ideal gas when the pressure and temperature is high and the operation conditions changes a lot. Especially under high pressure and near the saturation curve, The Coefficient of Compressibility of working gas Z is not equal to the Coefficient of Compressibility of gas under standard condition *Zx*.

III. HARDWARE DESIGN

For implementing hardware for the application needs fallowing requirements, those are listed below

- **ARM Processor**
- **Temperature Sensor**
- **Pressure sensor**
- **Zigbee**
- **LCD**
- **Flow sensor**
- **Mechanism**

Now let see the block diagram for implementing this application. Here the application block diagram consists of two sections

1. Receving Section and

2. Monitoring Section

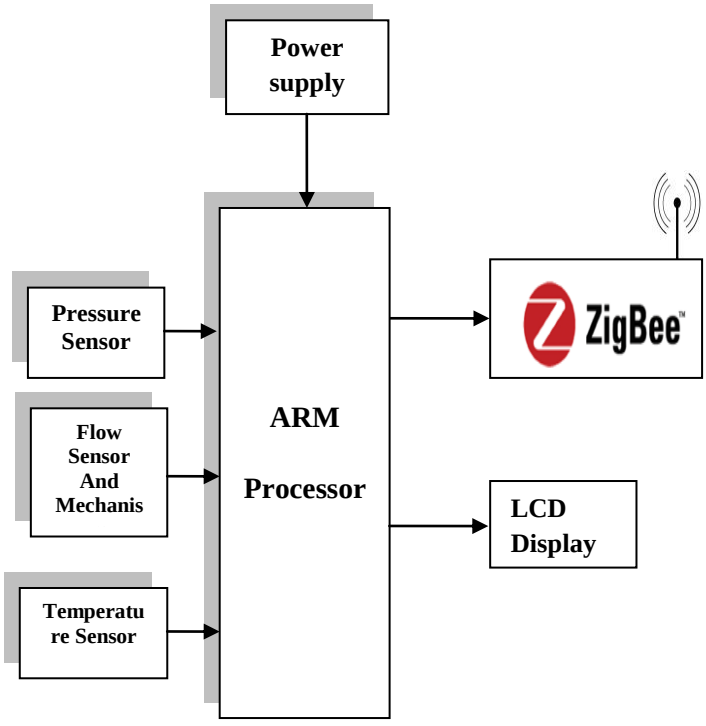

Figure 1. Receiving Section

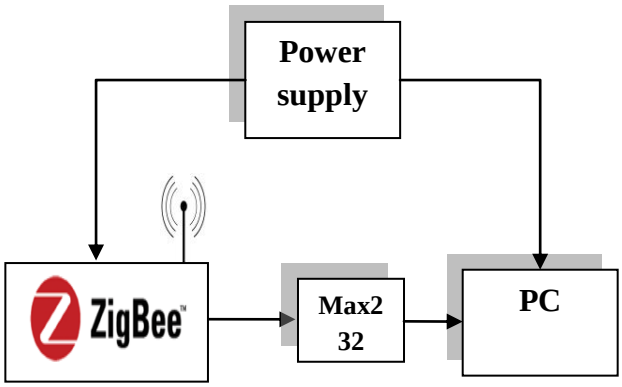

Figure 2: Monitoring Section

The above figure 1 and 2 shows the receiving section and monitoring section diagrams of the hardware design. Now we will see how the individual modules will work.

1. Controller Module

The functions needed to be done by the controller are responsible for snake movement and sensor value transmission in real time. These two functions requires two controllers because robot continuously sends the sensed values to one controller and at the same time it has to control the robot so two ARM 7 are used in the design.

It is a 32 bit controller with program memory 512kb and data memory of 32kb. It has 64 pins divided as two ports each with 32 pins. Each pin can be configured with four main registers IO direction register, pin select register, IO set and IO clear registers. Every pin is multi functional and selection is done by special function registers.

It has the following features in-system programmability, USB 2.0 compliant device controller, 10 bit ADC channels total 14 are available, one ten bit DAC channel with variable analog output and several communication methods are supported like I2c, SSI, and SPI which in built to the board.

2. Communication network

ZigBee is a low-cost, low-power, wireless mesh networking proprietary standard. The low cost allows the technology to be widely deployed in wireless control and monitoring applications, the low power-usage allows longer life with smaller batteries, and the mesh networking provides high reliability and larger range.

ZigBee is a wireless technology developed as an open global standard to address the unique needs of low-cost, low-power, wireless sensor networks. The standard takes full advantage of the IEEE 802.15.4 physical radio specification and operates in unlicensed bands worldwide at the following frequencies: 2.400–2.484 GHz, 902-928 MHz and 868.0–868.6 MHz

1. The power levels (down from 5v to 3.3v) to power the zigbee module.
2. The communication lines (TX, RX, DIN and DOUT) to the appropriate voltages.

The ZigBee Alliance, the standards body that defines ZigBee, also publishes application profiles that allow multiple OEM vendors to create interoperable products. The current list of application profiles either published or in the works are:

- Home Automation
- ZigBee Smart Energy
- Commercial Building Automation
- Telecommunication Applications
- Personal, Home, and Hospital Care
- Toys

The relationship between IEEE 802.15.4 and ZigBee is similar to that between IEEE 802.11 and the Wi-Fi Alliance. The ZigBee 1.0 specification was ratified on 14 December 2004 and is available to members of the ZigBee Alliance. Most recently, the ZigBee 2007 specification was posted on 30 October 2007. The first ZigBee Application Profile, Home Automation, was announced 2 November 2007.

3. Description of Sensors

In this application development we are using three sensors namely pressure sensor, flow sensor and Temperature sensor

- **Temperature sensor:** The LM35 is an integrated circuit sensor that can be used to measure temperature with an electrical output proportional to the temperature (in ^{o} C) .The LM35 - An Integrated Circuit Temperature Sensor. Why Use LM35s To Measure Temperature?
  - You can measure temperature more accurately than a using a thermistor..
  - The sensor circuitry is sealed and not subject to oxidation, etc.
  - The LM35 generates a higher output voltage than thermocouples and may not require that the output voltage be amplified.
- **Pressure sensor:** Many techniques have been developed for the measurement of pressure and vacuum. Instruments used to measure pressure are called pressure gauges or vacuum gauges. A 'manometer' is an instrument that uses a column of liquid to measure pressure, although the term is often used nowadays to mean any pressure measuring instrument.

IV. SOFTWARE DESIGN

During the design of the software platform, adopting the embedded real-time operating system to schedule and manage the task of system can meet the requirements about real-time and expansibility. Also, by using μC/OS-II real-time operating system kernel, it makes application system design simple and the whole system structure easily to be operated.

For implementing the software for required application we need to use three platforms, those are.

- **Embedded C**
- **Keil C Compiler**
- **Visual Basics**

A. Main Function

The main function mainly realizes the initialization of system hardware and operating system. The hardware initialization includes interruption, keyboard, display, etc. The initialization of operating system includes task control block and event control block. Before startup to schedule multi tasks, the operating system must create a startup task at least, which mainly responsible for the initialization and start-up of clock , interruption startup, the initialization of communications tasks module, and tasks division, etc. Main program flowchart is illustrated in "Fig. 3".

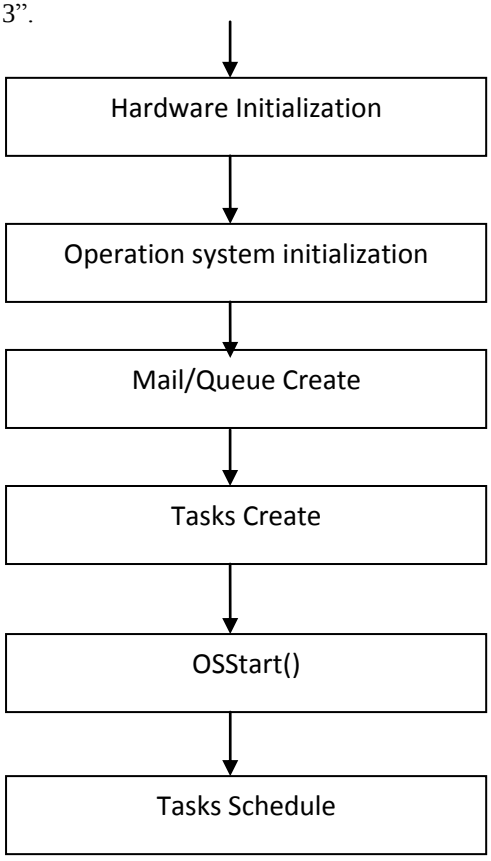

Figure 3: Main Program Flowchart

B. Task Division

To realize the real-time multitasking about all sorts of functions, it is necessary to divide the tasks. According to the importance and the real-time property of tasks, the tasks are divided into 9 different priorities as follows.

1) **The first priority**: Pulse signal collection.

2)**The second priority**: Temperature signal collection.

3) **The third priority**: Pressure signal collection.

4) **The fourth first priority**: Data processing.

5) **The fifth priority**: Zigbee communication.

6) **The sixth priority**: RS485 communication.

7) **The seventh priority**: LCD display.

8) **The eighth priority**: Keyboard input.

9) **The ninth priority**: System monitoring.

C. Synchronization and Scheduling of Tasks

Tasks' functions of the multi-tasking operating system are often different from general function, because they are an infinite loop and have no return values. If there is no higher priority task in a ready state, current task will not give up the right of use CPU. In order to realize operating system synchronization of failure-free operation and events concerning, flags of different tasks communication and events must be treated properly

V. EXPERIMENTAL DATA ANALYSIS

The calculation of systematic uncertainty: The inaccuracy of pressure sensor is ±0.5%. The inaccuracy of temperature sensor is ±0.7%, meter error is 0.8%, and then the system uncertainty is:

$$\delta_{\max} = \pm\sqrt{(0.5\%)^2 + (0.7\%)^2 + (0.8\%)^2} = \pm 1.17\%$$

TABLE I. EXPERIMENTAL DATAS

Flow rate	T(°C)	P(kPa)	Tested Meter K	Standard meter K=5843.9Er%
656.6	6.94	-0.46	5866.9	0.47%
256.9	7.44	-0.09	5819.5	-0.42%
129.5	7.55	-0.04	5816.7	-0.47%

Conclusion can be drawn from the table 1, the roots flow meter completely accords with system target (1.17%).

VI. CONCLUSION

The roots flow meter of this paper introduces in a low cost, low power and real-time spirit, is based on the ARM Cortex-M3 hardware platform and μC/OS-II operating system. It effectively solves the real time problems in the aspect of pressure and temperature compensation during the process of flow meter working. Both Zigbee technology and RS485 data transmission are applied to ensure the communication between flow meter with the host computer real time and accuracy. At the same time, Software system is former and more reliable because of the multi-tasking real time operating system.

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