Design and Development of Micro Electro Mechanical System Based Industrial Pressure Measurement

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Abstract— The area of physical quantity processing in recent sensor applications demands for high accuracy, low distortion, fast response and low power consumption. The pressure processing is one of the most important issues for designers. There exist many problems, which have to be solved to measure relative and absolute pressure. Measuring the signal from sensor with low amplitude and to remove the noise is difficult process. This project deals with a custom based Integrated Measurement Unit (IMU), which serves as processing device for MEMS based pressure measurement. The IMU consists of the three elementary stages like measurement stage, processing stage and communication stage. The pressure measurement achieved with Micro Electro Mechanical Systems (MEMS) sensor. The sensor output is converted to digital signal using ADC and fed to the microcontroller unit. The microcontroller unit is interfaced to the computer; by this the sensor details accessed from microcontroller unit are updated to PC using Visual Basic (VB). A regulator circuit removes the ripples and also remains the same dc value even if the input dc voltage varies, or the load connected to the output dc voltage changes. This voltage regulation is usually obtained using one of the popular voltage regulator IC units.

Keywords- Pressure, Integrated Measurement Unit, Micro Electro Mechanical Systems, Sensor, Regulator.

I. INTRODUCTION

Usually the pressure is measured using capacitive principle. Basically there are two well-known possibilities of pressure measurement. First one is based on the utilization of AD 7745 chip from Analog Devices Inc., which is capacitance-to-digital number converter. The second is based on measurement using 555 timer/counter principles [1-3]. The new proposed method is uses band pass sigma-delta modulation for pressure measurement. The very important aim of the research was the definition of the signal measurement and processing routine. This procedure had to satisfy high demands for accuracy, sensitivity and protection against noise and other unwanted effects.

There also exists one method, which is relatively new. In this proposed method we use MEMS sensor for pressure measurement. The MEMS sensor is interfaced with the 8051 microcontroller via ADC. The value of the MEMS is converted and is transmitted to a PC via UART protocol. The visual basic used as a GUI to see the pressure values. The Figure.1 shows the proposed block diagram. The project deals with a custom based Integrated Measurement Unit (IMU), which serves as processing device for MEMS based pressure measurement. The IMU consists of the three elementary stages, measurement stage, processing stage and communication stage. For the pressure measurement the MEMS sensor is used. The sensor details are converted to digital signal using ADC and fed to the microcontroller unit. The microcontroller unit is interfaced to the personal computer. The sensor details accessed from microcontroller unit are updated to PC using VB.

The hardware is using the 8051 Microcontroller, ADC, MEMS pressure sensor and personal computer. The Keil C and Embedded C are used to develop the software code. The advantage of the proposed system was high reliability, low drift, low cost ceramic package. The operation range is -40°C to +125 °C and the standard pressure range is 15PSI, 100PSI, 200PSI. Micro Electro Mechanical Systems are systems based on a range of technologies whereby tiny mechanical elements, both sensors and actuators, can be implemented. It turns out that these elements have excellent system properties. The elements are often interfaced to microelectronic driving or sensing components (ICs) by appropriate packaging or on the same silicon wafer. The semiconductor silicon is not only good for making electronics but its material properties are extremely good.

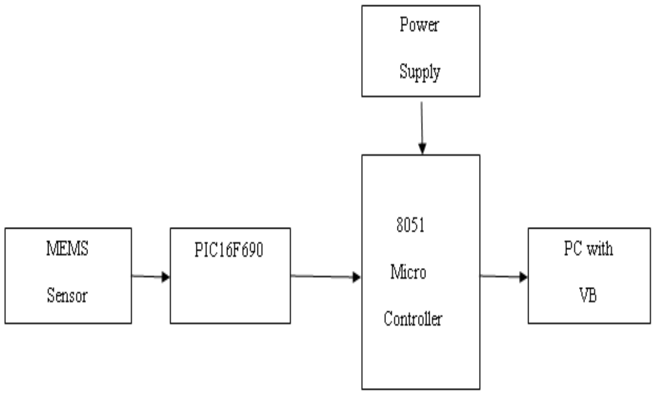

Figure 1. Proposed Block Diagram

The transmitter block is shown in Figure.2. The high frequency circuits will benefit considerably from the advent of the RF-MEMS technology. Electrical components such as inductors and tunable capacitors can be improved significantly compared to their integrated counterparts if they are made using MEMS and Nanotechnology. With the integration of such components, the performance of communication circuits will improve, while the total circuit area, power consumption and cost will be reduced [4-5].

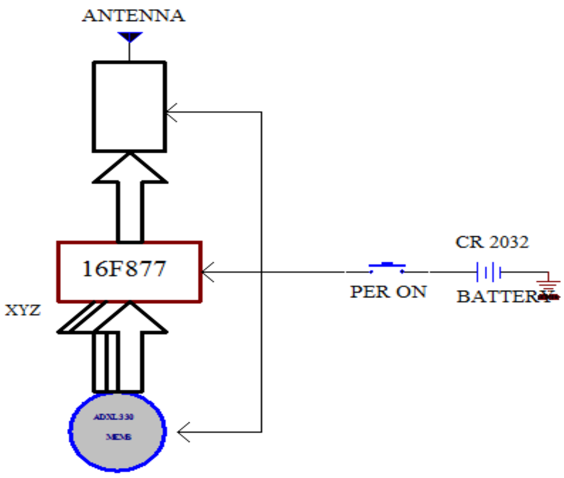

Figure 2. MEMS Transmitter

The Figure.3 shows the bock diagram of the receiver block. MEMS technology can be used to implement high quality switches, varactors (variable reactors), inductors, resonators, filters and phase shifters. Among the broad range of applications the MEMS technology gives a unique possibility to implement micromechanical resonators and filters with high performance regarding selectivity and Q-factors [6]. When combining these mechanical structures with microelectronics, central parts in wireless systems, RF systems (Radio Frequency systems) can be implemented [7].

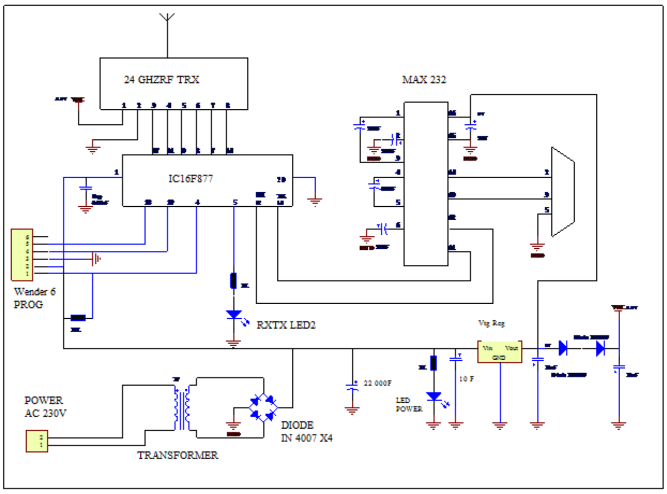

Figure 3. MEMS Receiver

II. CONTROLLER BLOCK

Microcontroller is a general purpose device, which integrates a number of the components on to single chip. It has inbuilt central processing unit, both read only memory and random access memory, parallel digital I/O peripherals to make it as a mini computer. Microcontrollers are available in different configurations, low cost and compact size with power saving mode and high operating speeds. This feature encourages implementing the proposed system using PIC microcontroller [8-9].

The significant part of embedded system development is the designing of hardware and software for the specific application. The PIC microcontroller has been used for this proposal. PIC microcontroller is the RISC based microcontroller fabricated in CMOS (complementary metal oxide semiconductor) that uses separate bus for instruction and data allowing simultaneous access of program and data memory. The main advantage of CMOS and RISC combination is low power consumption resulting in a very small chip size with a small pin count. The main advantage of CMOS is that it has immunity to noise than other fabrication techniques. Various microcontrollers offer different kinds of memories. EEPROM, EPROM, FLASH etc. are some of the memories of which FLASH is the most recently developed. The PIC16F96 is using the flash technology, so that data is retained even when the power is switched off. Easy Programming and Erasing are other features of PIC 16F96 [10].

In the present work 8-Bit microcontroller has been used to implement the control algorithm and having special features like 32K reprogramming flash memory, 512 bytes of internal RAM, 32 programmable I/O lines and eight interrupt sources. The microcontroller consists of a timer module and an analog to digital converter to accept analogue input for data processing. To make the data flow between controllers to other devices the serial I/O port is used. Microcontroller is a general purpose device, which integrates a number of the components of a microprocessor system on to single chip. It has inbuilt CPU, memory and peripherals to make it as a mini computer. A microcontroller combines on to the same microchip CPU core, Memory (both ROM and RAM), some parallel digital I/O.

Microcontroller manufacturers have been competing for a long time for attracting choose customers and every couple of days a new chip with a higher operating frequency, more memory and upgraded A/D converters appeared on the market. The main reason for their great success and popularity is a skilfully chosen configuration which satisfies different needs of a large number of users allowing at the same time constant expansions (refers to the new types of microcontrollers). Besides, the software has been developed in great extend in the meantime, and it simply was not profitable to change anything in the microcontroller’s basic core. This is the reason for having a great number of various microcontrollers which basically are solely upgraded versions of the 8051 family.

III. EXPERIMENTS CONDUCTED

The IMU consists of the three elementary stage measurement stage, processing stage and communication stage. They are implemented on the one single board. The measurement block has 16-bit resolution with 64 provided measurement ranges to satisfy appropriate accuracy. The power supply is 5 V, which allows to measure current with 238 nA step within 1 mA measurement range. The communication stage is based upon I2C standard. The core of the microcontroller is processing block in ATMEGA16. The measured data are displayed on the 16 characters, double-row, smart LCD display. The active mode of the display is controlled via microcontroller because of the power savings. There are two micro switches connected with microcontroller. They are used to set up the operating mode – measurement or data logging.

In the measurement stage current, which flows through the sensor, is measured by precise resistance shunt utilizing integrated circuit (IC) INA138. This IC serves as current to voltage converter. This voltage is connected to next stage, 16bits sigma-delta AD converter (ADC) ADS1100. Since the output of the ADC is I2C bus, the structure of the IMU is based upon this bus. The IMU universality is achieved through the extended connection of the I2C bus. It allows user to connect the capacity to digit converter AD7745. The measurement stage consists of ICs with accurate current measurement and high input dynamic range. The measured current, which flows through the precise reference resistor, provides voltage drop. This voltage is relatively low, in order of tens of mV. That is why, it is amplified by means of accurate differential amplifier INA138. The amplifier output is connected with 16bits ADC – ADS1100. Since the 16-bits resolution is not sufficient within the whole measurement range, this range is spitted into the 64 independent ranges with the same resolution. This dynamic range is extended utilizing the switched shunt and the input programmable amplifier of the ADC, which provides 8 levels of gain. Let’s assume 5 V power supply voltage, it means we obtain the 1.192 μV sensitivity. It represents 238 nA sensitivity within 1 mA current range.

In the communication stage input/output signals of the IMU correspond to I2C standard. The user is able to measure four sensors simultaneously by means of four independent I2C connections. This option prevents from communication collision with simultaneous measurement in case, when the sensors from fabrication are assigned with the same identification data (addresses).The communication with advanced system (PC) is provided via USB bus. The communication matching between these two different systems is realized using IC FT232R, which is USB – USART converter.

The basic function of the measurement process of the IMU is data logging; the data are saved in the operational memory of the microcontroller until they are loaded for next processing. The size of the memory is 2 kB. It is possible to carry out up to 2000 measurements thanks to partial compression. It is trade-off between speed of measurement and the measurement time. Nevertheless in the standard measurements with 1 Hz sampling frequency, the maximum record time is 30 minutes. The other advantage of the IMU is the possibility to connect external data logging memory through the I2C bus. The external memory module is prepared in embedded software in microcontroller.

The practical measurement function of the IMU was tested with fabricated capacitance MEMS. The sensors are able to measure absolute pressure from 0.1 to 1.2 bar. The capacity ranges from 5.8 pF to 6.2 pF at maximum. First run was before temperature measurement and the second after that. It is clear that reproducibility is very high and the curve shape also corresponds with the proposal. Since the sensors are also prototypes there exists small deviation during temperature measurements.

IV. RESULT ANALYSIS

The Table.1 shows the integrated measurement unit for MEMS based pressure measurement output. The unit measure current from sensor with 16bits resolution in 64 independent ranges. The very high accuracy of the measurement is obtained. The core of the IMU is driven by means of ATMEGA16 microcontroller. The function of the IMU was tested on fabricated prototypes of absolute pressure MEMS sensors. We plan in future research to produce hybrid IC, which will integrate some of the blocks into the one complex Sol. The improvement of MEMS humidity independence is other task for future research.

TABLE I. RESULT ANALYSIS

Rating	Symbol	Value	Unit
Maximum Pressure (P1>P2)	P_{max}	200	kP_a
Storage Temperature	T_{stg}	-40^o to $+125^o$	^oC
Operating Temperature	T_a	-40^o to $+125^o$	^oC

V. CONCLUSION

The use of MEMS components and Thermo-Fused die-attach technologies produces a more stable, accurate pressure transducer for ultra-high-purity applications. Recalibration issues and case stress sensitivity are virtually eliminated. The new pressure transducers are capable of withstanding the extreme environmental conditions inherent in semiconductor manufacturing processes, without requiring the continuous maintenance needed by other designs.

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