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Design of Piezoelectric Energy Harvester and Power Conditioning

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ABSTRACT

The existing system presents a novel approach called simultaneous wireless strain sensing and energy harvesting from multiple piezo-patches, which is intended for self-powered Structural Health Monitoring applications. The Energy Harvesting subsystem is mainly the self-powered extended synchronous electric charge extraction interface based on double cross-coupled rectifying structure and a single fly back transformer, which is able to harvest energy from multiple piezo-patches. In this proposed work, the DC power is generated using piezoelectric and MEMS. Then the Produced by DC energy is given to Ultra Low Power Converter Using with Micro controller then Ultra capacitor used to Highly Discharging in the DC power bank. The outputs of transducers are also given to micro controller. The obtained energy is boosted up using Booster Ultra Low Power Converter. The output of the Ultralow Power Converter is given to the Relay for the switching unit to store energy in a DC Power Bank and the stored energy is inverted to AC voltage

Keywords : Embedded System, DSP, Piezoelectric, Power Conditioning, Energy Harvesting

I. INTRODUCTION

An embedded system is a computer system with a dedicated function within a larger mechanical or electrical system, often with real-time computing constraints. It is embeddedas part of a complete device often including hardware and mechanical parts. Embedded systems control many devices in common use today. Examples of properties typical of embedded computers when compared with general-purpose ones are low power consumption, small size, rugged operating ranges, and low per-unit cost. This comes at the price of limited processing resources, which make them significantly more difficult to program and to interface with. However, by building intelligence mechanisms on the top of the hardware, taking advantage of possible existing sensors and the existence of a network of embedded units, one can both optimally manage available resources at the unit and network levels as well as provide augmented functionalities, well beyond those available. For example, intelligent techniques can be designed to manage power consumption of embedded systems.

Modern embedded systems are often based on microcontrollers (i.e. CPUs with integrated memory or peripheral interfaces) but ordinary microprocessors (using external chips for memory and peripheral interface circuits) are also still common, especially in more complex systems. In either case, the processor(s) used may be types ranging from general purpose to those specialized in certain class of computations or even custom designed for the applicationat hand. A common standard class of dedicated processors is the digital signalprocessor (DSP).Since the embedded system is dedicated to specific tasks, design engineers can optimize it to reduce the size and cost of the product and increase the reliability and performance.

Some embedded systems are mass-produced, benefiting from economies of scale.

Embedded systems range from portable devices such as digital watches and MP3 players, to large stationary installations like traffic lights, factory controllers, and largely complex systems like hybrid vehicles, MRI, and avionics. Complexity varies from low, with asingle microcontroller chip, to very high with multiple units, peripherals and networks mounted inside a large chassis or enclosure. The objective of the work is to harvest the renewable energy from piezoelectric, to provide self secured system and to increase the discharging time using ultra low power capacitor.

II. METHODS AND MATERIAL

The main aim of this work is to produce light out of the force or stress applied on the piezoelectric sensor [1]. This can solve many problems regarding the dependency on the replenishing sources of energy, by harvesting energy, since the world is in need of energy. This produced light could be the solution for growing need for renewable sources ofenergy, Reduce dependency on batterypower and Lights can be used in automobiles, footwear,etc.

Today, the energy harvesting from light, thermal, magnetic or mechanical energy in the ambient environment is an important research topic. With recent progresses in wireless, sensor systems are being popularly used in various areas, including human body care, bridge or engine early health monitoring etc. However, replacement of small power supplies and batteries in sensor systems would be a tedious task. Therefore, it is quite interesting to supply a small amount of power for sensor systems from environmental energy. In addition, because of the shortage in energy sources [2], people are also seeking environmental energy to replace part of the electric energy used in daily life. Therefore, another interesting application is to harvest the mechanical energy from highway or railway for generating electric energy, which may supply a small to medium amount of power for powering road lights or even electric motors if there are enough vehicles/trains running.

One of the most effective methods for power harvesting systems is to use piezoelectric materials to convert mechanical vibration or strain energy to electric energy based on the piezoelectric effect. During the past ten years, there has been an explosion of research in the area of harvesting energy from ambient vibrations by using the direct piezoelectric effect. Piezoelectric materials are very good prospects for mechanical energy conversion because they have a good electromechanical coupling effect. Piezoelectric energy harvesting devices are also much simpler than, for example electromagnetic or electrostatic devices. For these reasons, piezoelectric energy harvesting devices have attracted much attention. Conventional piezoelectric harvesting devices are based on a piezoelectric unimorph or bimorph cantilever configuration i.e., one or two piezoelectric elements laminated with one long elastic plate, and they are operated in bending mode. In general, piezoelectric cantilever type harvesters generate only a very small power output, and they cannot work under pressure. In 2004, Uchino's group at Pennsylvania State University [3] developed a piezoelectric cymbal transducer which operated in flex tensional mode for vibration energy harvesting, which could work well under a small force load.

2.1. Piezoelectric effect

There are certain materials that generate electric potential or voltage when mechanical strain is applied to them; they tend to change their dimensions. This is called piezo electriceffect.This effect was discovered in the year 1880 by Pierre and Jacques Curie. The piezoelectric transducers work on the principle of piezoelectric effect [4]. When mechanical stress or forces are applied to some materials along certain planes, they produce electric voltage. The voltage output obtained from these materials due to piezoelectric effect is proportional to the applied stress or force [5].

2.2. Piezoelectric material

The following material are used as piezoelectric materials

Naturally occurringcrystals:
Berlinite (AlPO4), Cane sugar, Quartz, Rochelle salt, Topaz, Tourmaline Group Minerals, and dry bone (apatitecrystals)

Man-madeceramics:
Barium titanate (BaTiO3), Lead titanate (PbTiO3), Lead zirconate titanate (Pb[ZrxTi1-x]O3 0<x<1) - More commonly known as PZT, Potassium niobate (KNbO3), Lithium niobate (LiNbO3), Lithium tantalate (LiTaO3), Sodium tungstate (NaxWO3), Ba2NaNb5O5, Pb2KNb5O15

Polymer:

Polyvinyledene fluoride (PVDF)

2.3. Need for Energy Harvesting

- Proposes several potentially inexpensive and highly effectivesolutions
- Reduce dependency on battery power
- Complexity of wiring
- Increased costs of wiring
- Reduced costs of embedded intelligence
- Increasing popularity of wireless networks
- Limitations of batteries
- Reduce environmental impact

III. EXISTING SYSTEM

This existing presents the performances of rainfall energy harvesting through the use of a piezoelectric transducer and an Arduino-based measuring system. Different studies agree on the possibility of generating electricity from rainfall, but to date, a study on measuring the quantity of energy produced during rainfall is still missing [6]. The present study begins with results obtained from laboratory researchers using piezoelectric transducers and oscilloscopes, finalized to measure the energy produced from a single raindrop, and concludes with an ad hoc Arduino-based measuring system, aimed to measure the actual amount of electrical energy produced by a piezoelectric transducer that is exposed to rainfall of variable durations.

3.1. Hardware Platform and Circuital Componenets

Arduino is a hardware platform used for the development of applications based on ATMEL microcontrollers. The model "Arduino UNO R3 SMD", which is used in the current study, is a standard commercial board entrusted to acquiring and recording inputs. In this study, the Arduino UNO board was connected to the Ethernet Shield, in order to allow data storage on a microSD card (Samsung EVO HC 32GB, class 10), which was inserted into the Ethernet Shield and used to record data. The detection of values only between 0 V and 5 V was the only limit of the Arduino platform regarding the proposed study. In order to solve this problem, an ad hoc electrical circuit was used to regulate the signal, so that once the oscillation was exhausted, it guaranteed the voltage trend at 2.50 V, as to provide, after an appropriate encoding of the obtained results, the entire transition from -2.5 V to +2.5 V.

3.2. Piezoelectric Transducers And Raindrop

The ability of piezoelectric materials to convert electrical energy into mechanical and vice versa depends on their crystalline structure. The required condition for the piezoelectric effect is the absence of a center of symmetry in the crystal, which is responsible for charge separation between positive and negative ions and the formation of the Weiss domains [7]. By applying an electric field to a piezoelectric material, the Weiss domains are proportionally aligned to the field. As a consequence, the size of the material changes, by increasing or decreasing if the direction of the Weiss domains is the same as or opposite to the electric field. Therefore, a stress (tensile or compressive) applied to a piezo-crystal will alter the separation between the positive and negative charge sites in each elementary cell, leading to a net polarization at the crystal surface. The piezoelectric effect verifies the first law of the thermodynamics (principle of conservation of energy). In this study, the energy harvester consists of a piezoelectric film on an epoxy cantilever sandwiched between electrodes that are used to collect the generated power. A water drop falling on the structure creates an impulsive force that brings the internal lattice structure of the piezoelectric element to deform, causing the loss of symmetry, and therefore the generation of small dipoles, which global effect is an impulsive voltage on electrodes. Mechanical vibrations follow the impact, stress is induced within the material, thus giving rise to an electrical source. A sheet of piezoelectric material has some limitations in the mechanical-electrical transduction for low frequency signals, since the effects of the induced electric field, generated in the hit region, are mitigated by the surrounding areas, and for large sheets effects are tenuous. The behavior of generated pulses depends on the state of locking of the piezoelectric fiill.

Hardware Components Used:

Arduino Mega Board 2560.

16 × 2 liquid crystal display.

BREADBOARD:

AC100-240V to DC 12V 2A Power adapter.

Male to female or female to female jumper wire.

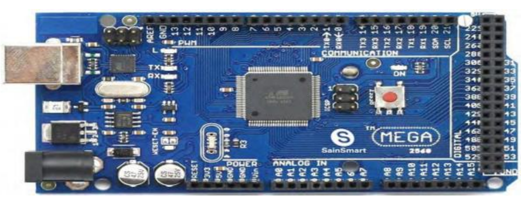

Figure 1. Arduino Mega 2560

LED: In this work three different color of LED. Red, green and yellow is used for sensor value high, normal and low respectively for each sensors (expect flow sensor). LEDs have cathode and anode pole which indicates either negative or positive.

Figure 2. 3MM LED

Liquid Crystal Display: A16×2liquid crystal display is interface with arduino mega to display the sensor values on screen. There are two rows and it can display 16 characters per row. So it will have (16×2=32)32characters in total and each character will be made of 5*8pixel dots.

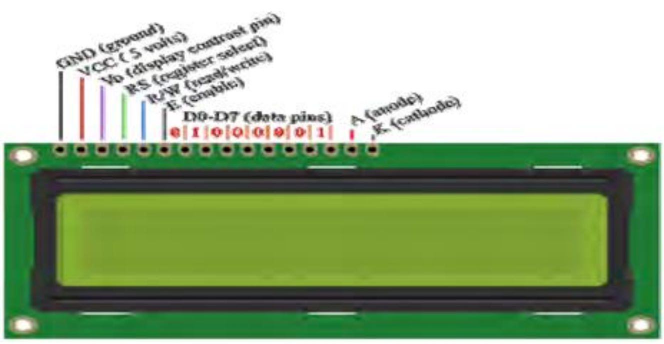

Figure 3. LCD Diplay

IV. PROPOSED SYSTEM

In this proposed work, the energy harvester consists of a piezoelectric film on an epoxy cantilever sandwiched between electrodes that are used to collect the generated power. A force on the structure creates an impulsive force that brings the internal lattice structure of the piezoelectric element to deform, causing the loss of symmetry, and therefore the generation of small dipoles, which global effect is an impulsive voltage on the electrodes. Mechanical vibrations follow the impact, stress is induced within the material, thus giving rise to an electrical source. The generated electrical energy is viewed on the LCD. The produced DC energy is fed to the ultra-low power convertor [8,9]. The ultra-low power capacitor reduces the discharging time; hence the battery time is longer. The output of the Ultra-Low Power Convertor is given to a DC Power Bank. The stored DC energy is converted to AC voltage and used for women safety equipment.

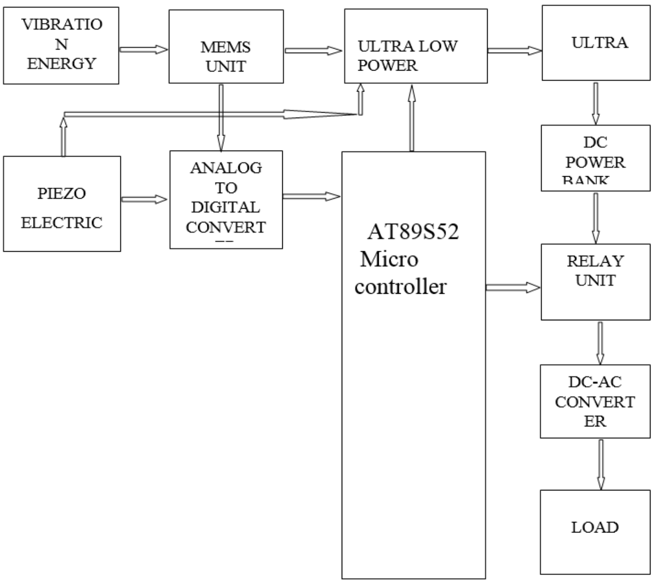

Figure 4. Block Diagram

The AT89S52 is a low-power, high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. The device is manufactured using Atmel's high-density nonvolatile memory technology and is compatible with the Industry-standard 80C51 instruction set and pin out. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly flexible and cost-effective solution to many embedded control applications. The AT89S52 provides the following standard features: 8K bytes of Flash, 256 bytes of RAM, 32 I/O lines, Watchdog timer, two data pointers, three 16-bit timer/counters, a six-vector two-level interrupt architecture, a full duplex serial port, on-chip oscillator, and clock circuitry.

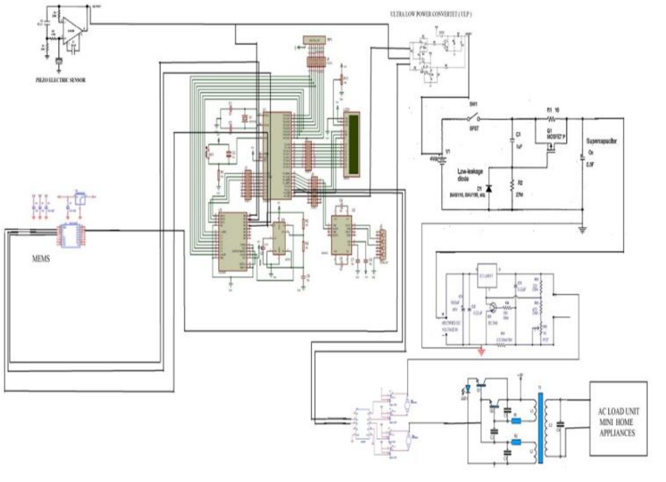

Figure 5. Circuit Diagram

In addition, the AT89S52 is designed with static logic for operation down to zero frequency and supports two software selectable power saving modes. The Idle Mode stops the CPU while allowing the RAM, timer/counters, serial port, and interrupt system to continue functioning. The Power-down mode saves the RAM contents but freezes the oscillator, disabling all other chip functions until the next interrupt or hardware reset.

V. RESULTS AND DISCUSSION

Software requirement

The main purpose of using the microcontroller in work is because high-performance CMOS 8-bit microcontroller with 8K bytes of in-system programmable Flash memory. By combining a versatile 8-bit CPU with in-system programmable Flash on a monolithic chip, the Atmel AT89S52 is a powerful microcontroller which provides a highly-flexible and cost-effective solution to many embedded control applications. The programs of the microcontroller have been written in Embedded C language and were compiled using KEIL, a compiler used for microcontroller programming. The communication between PC and the microcontroller was established MAX 232 standard and those programs were also done in C language.

The following programs are used at various stages for the mentioned functions. Serial communication In this program, the various special function registers of the microcontroller are set such that they can send and receive data from the PC. This program uses the serial library to communicate with the ports. The C programming language is a general-purpose, programming language that provides code efficiency, elements of structured programming, and a rich set of operators. C is not a *big* language and is not designed for any one particular area of application. Its generality combined with its absence of restrictions, makes C a convenient and effective programming solution for a wide variety of software tasks. Many applications can be solved more easily and efficiently with C than with other more specialized languages. The C*x*51 Optimizing C Compiler is a complete implementation of the American National Standards Institute (ANSI) standard for the C language. C*x*51 is not a universal C compiler adapted for the 8051 target. It is a ground-up implementation dedicated to generating extremely fast and compact code for the 8051 microprocessor. C*x*51 provides you the flexibility of programming in C and the code efficiency and speed of assembly language. Since C*x*51 is a cross compiler, some aspects of the C programming language and standard libraries are altered or enhanced to address the peculiarities of an embedded target processor.

Support for all 8051 Variants

The 8051 Family is one of the fastest growing Microcontroller Architectures. More than 400 device variants from various silicon vendors are today available. New extended 8051 Devices, like the Philips 80C51MX architecture are dedicated for large application with several Mbytes code and data space. For optimum support of these different 8051 variants, Keil provides the several development tools that are listed in the table below. A new output file format (OMF2) allows direct support of up to 16MB code and data space. The CX51 compiler is a variant of the C51 compiler that is design for the new Philips 80C51MX architecture.

Compiling with C*x*51

This explains how to use C*x*51 to compile C source files and discusses the control directives you may specify. These directives allow you to perform several functions. For example:

- Direct C*x*51 to generate a listing file
- Control the information included in the object file
- Specify code optimization and memory models

Running C*x*51 from the Command Prompt

To invoke the C51 or CX51 compiler, enter C51 or CX51 at the command prompt. On this command line, you must include the name of the C source file to be compiled, as well as any other necessary control directives required to compile your source file.

The format for the C*x*51 command line is shown below:

C51 source file _directives…_
CX51 source file _directives…_
Or:
C51 @command file
CX51 @command file
Where:
Source file is the name of the source program you want to compile.
*Directives*are the directives you want to use to control the function of the
Compiler.
Command file is the name of a command input file that may contain *source file*and *directives*. A *command file* is used, when the C*x*51 invocation line gets complex and exceeds the limits of the Windows command prompt.
The following command line example invokes C51, specifies the source file

SAMPLE.C, and uses the controls DEBUG, CODE, and PREPRINT.

C51 SAMPLE.C DEBUG CODE PREPRINT

The C*x*51 compiler displays the following information upon successful

Invocation and compilation.

C51 COMPILER V6.10

C51 COMPILATION COMPLETE. 0 WARNING(S), 0 ERROR(S)

8051 Derivatives

A number of 8051 derivatives are available that provide enhanced Performance while remaining compatible with the 8051 core. These derivatives provide additional data pointers, very fast math operations, and reduced instruction sets.

The C*x*51 compiler directly supports the enhanced features of the following 8051-based microcontrollers:

1. Atmel 89x8252 and variants (2 data pointers).
2. Dallas 80C320, 80C420, 80C520, 80C530, 80C550 an variants (2 data pointers).
3. Infineon C517, C517A, C509, and variants (high-speed 32-bit and 16-bit binary arithmetic operations, 8 data pointers).
4. Philips 8xC750, 8xC751, and 8xC752 (maximum code space of 2 KBytes, no LCALL or LJMP instructions, 64 bytes internal, no external data memory).
5. Philips and Temic support on several device variants 2 data pointers.

The C51 compiler provides you with support for these CPUs through the use of special libraries, library routines, and the MOD*xxx* command-line directives. These directives enable C51 to generate object code that takes advantage of the enhancements mentioned above.

Atmel 89x8252 and variants

The Atmel 89x8252 and variants provide 2 data pointers which can be used for memory access. Using multiple data pointers can improve the speed of library functions like memcpy, memmove, memcmp, strcpy, and strcmp. The MODA2 control directive instructs the C51 compiler to generate code that uses both data pointers in your program. The C51 compiler uses at least one data pointer in an interrupt function. If an interrupt function is compiled using the MODA2 directive, both data pointers are saved on the stack. This happens even if the interrupt function uses only one data pointer. To conserve stack space, you may compile interrupt functions with the NOMODA2 directive. The C51 compiler does not use the second data pointer when this directive is used.

VI. CONCLUSION

This work is successfully tested which is the best economical, affordable energy solution to common people. This can be used for many applications in city areas where want more power. Bangladesh is a developing country where energy management is a big challenge for huge population. By using this work we can drive D.C loads according to the force we applied on the piezo electric sensor. Although the theory developed in this report justifies the use of switching techniques in efficiently converting that energy to a usable form, there are obviously some practical limitations to the systems presented. The final prototype design does fulfil the objective of generating electricity from piezoelectric disk. Due to the low cost design of the piezoelectric system it is a practical product which could increase the operating period of most common products. The data collected is capable of extending the operational lifespan per charge of portable electronic devices. Although the theory developed in this report justifies the use of switching techniques in efficiently converting that energy to a usable form, there are obviously some practical limitations to the systems presented.

Measurements of source current into the primary and load current transferred from the secondary reveal that very little current gain truly occurs between the input and output ports of the switch in the forward converter hybrid. Further, similar results were encountered when one examines the energy transferred through the series switch and inductor in the buck converter. In addition, based on the results gathered in this investigation, the final prototype design does fulfil the objective of generating electricity from piezoelectric disk. Due to the low cost design of the piezoelectric system it is a practical product which could increase the operating period of most common products. The data collected is capable of extending the operational life span per charge of portable electronic devices.

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