SMART SHIRT FOR MEASURING VITAL SIGNS MEASUREMENT WITH ENERGY HARVESTING MODULE

A.Tangadurai , K. N.Monisha , S.Keerthana , R.RadhaKrishnan

***Abstract*—** The growing demand for wearable devices is imposed by the ability to monitor in real-time critical situations in the different areas of the daily life. The heart rate and temperature are considered as important vital signs of elderly people and it is important to measure accurately. So we have aimed to develop a Smart Shirt for measuring these two parameters. The wearable smart device consist of embedded electrodes for heart rate measurement and circuit for the temperature measurement. In many cases power is the limiting factor for such devices. One aspect is the power supply with batteries that introduces issues due to weight, the overall dimensions and the disposal of batteries. A viable solution to overcome the limitations of the batteries as power source is to harvest ambient energy to power the devices directly. The energy harvesting module can be implemented to directly power the electronic circuit board by flexible solar panel. Hence, the availability of devices is capable of autonomously monitoring elderly subjects during daily life measuring the body's functions guarantees the first assistance and provides a response to the emergencies by the energy harvesting module.

***Keywords* --** Heart rate monitoring, instrumented T-shirt, power harvesting, temperature measurement, wearable system.

I. INTRODUCTION

A wearable system can be a viable solution for monitoring the vital signs of a person during daily activities for variety of applications in the medical, sport, and wellness fields. In the medical field, one of the most compelling problems is the care to the elderly population that is expected to grow in the next years, since it raises questions about the cost of the structures and assistance activities. In particular the availability of devices capable of autonomously monitoring elderly subjects during daily life measuring the body's primary functions guarantees the first assistance and provides a primary response to the emergencies. The main advantages are decrease in the health costs both for patient and for the medical corps, of the waiting time and of the overcrowding in the medical structures; on the other hand, increasing of the people independence and their autonomy improve their quality of life [1],[2]. Other interesting application fields are sports and wellness; in fact, wearable systems can constantly monitor the performance of the athlete and provide information in real time to improve constantly his/her physical activity. Therefore, it is expected that these devices can operate for an extended time where the activity is held, even outdoors. In this paper, an instrumented shirt is described; this smart shirt monitors the heart rate, the temperature. This smart-shirt is designed to monitor the physic status of the patient and to generate some alarms for potential physical problems.

A.Tangadurai , Department of Electronics & Instrumentation Engineering , K S Rangasamy college of technology Tiruchengode .
K. N.Monisha , Department of Electronics & Instrumentation Engineering , K S Rangasamy college of technology Tiruchengode .
S.Keerthana, Department of Electronics & Instrumentation Engineering , K S Rangasamy college of technology Tiruchengode .
R.RadhaKrishnan , Department of Electronics & Instrumentation Engineering , K S Rangasamy college of technology , Tiruchengode .

II. HARDWARE DESCRIPTION

The smart-shirt is composed by three main sensors: temperature sensor and electrodes for cardiac activity module.

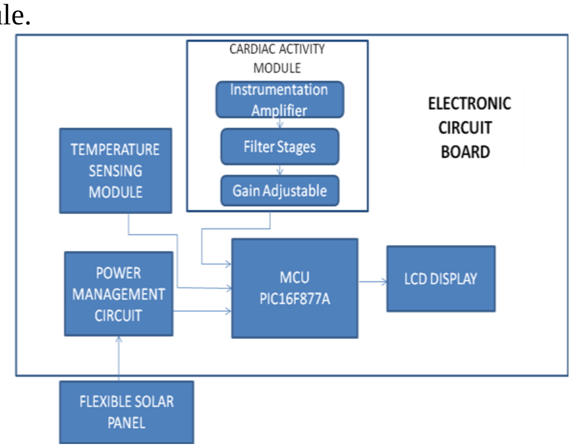


Figure 1. Block Diagram for the Wearable System

The block diagram for the proposed system is shown in fig. The proposed system can be divided into several blocks. One is T-shirt is made of single jersey cotton with Lycra for enhanced comfort and good body adherence. And the electronic circuit board including conditioning sensor circuits. The textile conductive sensors for measuring cardiac activities. The flexible solar panel used as energy harvesting system to supply the circuit board. Flexible solar panels of the PowerFilm Solar were investigated to the small dimensions and the flexibility that permits the wearability of the T-shirt. These devices are built by roll-to-roll manufacturing process realizing monolithically integrated solar panels on plastic obtaining a substrate of 0.025mm, and finished panels are encapsulated in materials appropriate for the application environment. The PT15-150 (PowerFilm WeatherPro Series) solar panel has been chosen as energy harvesting source, because it is perfect for permanent outdoor applications.

A. Flexible Solar Panel

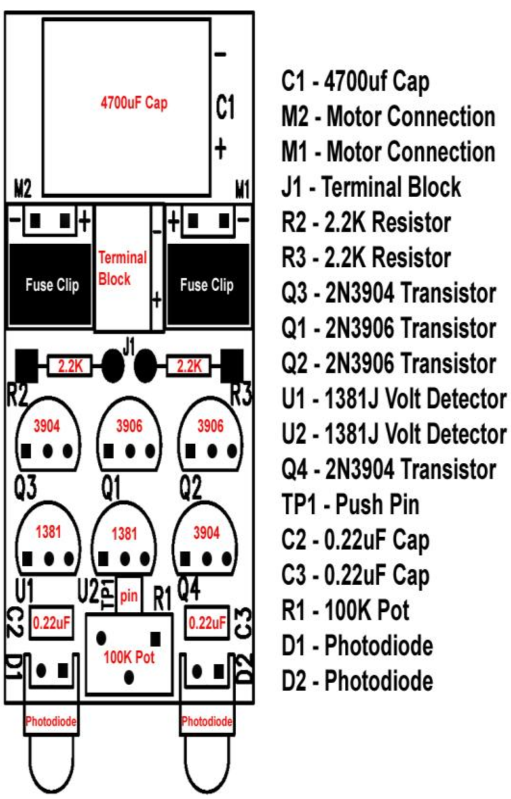
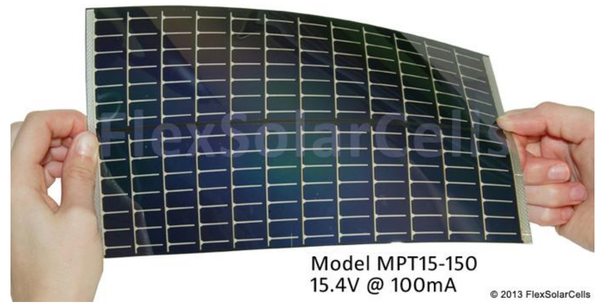


Figure 2. PT15-150 solar panel model

The flexible solar panel used as energy-harvesting system to supply the circuit board. Flexible solar panels of the PowerFilm Solar were investigated due to the small dimensions and the flexibility that permits the wearability of the T-shirt. The PT15-150 (PowerFilm WeatherPro Series) solar panel has been chosen as energy-harvesting source, because it is perfect for permanent outdoor applications. The PT15-150 solar panel has dimensions of 270mmX175mm and 56.4kg of weight and can produce 19V and 100 mA in open circuit and short circuit, respectively.



The especially rugged construction of these solar panel includes a UV-stabilized surface , extra edge seal for weather protection and tin-coated copper leads that extend from the module.

B. Power Management Circuit

Flexible solar panel is connected to a power management circuit to scale the voltage in input to the supply value of 3.3V. The TPS620102 has been chosen as a step-down buck converter because it is low power and has high efficiency.

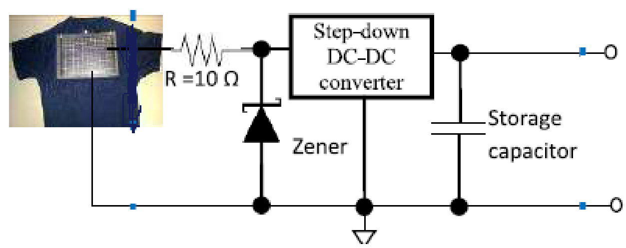


Figure 3. Proposed Solar Power Management Circuit

The power management circuit of our proposed system in figure 3. This device has a wide input range of 2.5-9 V, but the solar panel can generate up to 19V with full sun, and therefore, an 8.2V Zener diode has been added in the input to the step-down converter to limit the input voltage. A storage capacitor (supercapacitor) has been connected to store the energy in excess coming from the solar panel.

C. Cardiac Activity Electrodes

The measurement of the cardiac activity is made using two textile electrodes sewn directly on the T-shirt. The advantage of textile electrodes over the classical dry electrodes is that they are made of ordinary fabric, soft and flexible and they not cause skin irritation. Therefore they are appropriate for chronic long-time applications.

D. Cardiac Activity Module- Signal Conditioning

The two electrodes located inside the T-shirt on the right center and the left chest, which guarantees a maximal expression of the R complex and allows calculating the heart rate using the distance between the peaks of the signal.

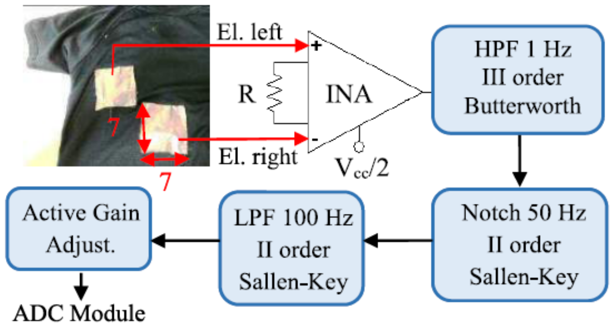


Figure 4. Conditioning circuit of the cardiac signal

The electrodes are realized using a conductive metalized nylon fabric (Nora Dell) of 7cmX7cm. This material is a light weight rip-stop fabric woven with nylon monofilament and has high strength and resistance to the normal conditions of use such as multiple deformations for wearable application. Furthermore, the conducting fabric can be washed due to the ability to resist temperature up to 150 degree Celsius. Conditioning circuit of the cardiac signal circuit is shown in figure 4. The cardiac signal conditioning circuit has a current consumption of 0.2mA.

E. Instrumentation Amplifier

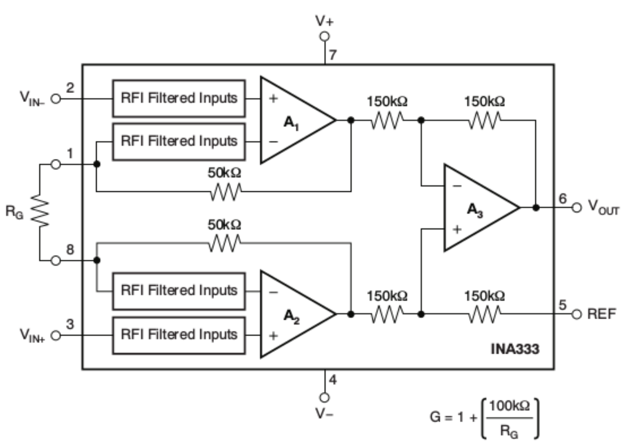


Figure 5 Instrumentation Amplifier circuit

The INA33 device is a low power, precision instrumentation amplifier offering excellent accuracy. The versatile 3-operational amplifier design, small size, and low power make it ideal for a wide range of portable applications. An instrumentation amplifier (INA), the low-power INA333 performs the difference between the signals coming from the two electrodes. This INA has high Common Mode Rejection Ratio(CMRR), 100 db, and extremely high input impedance, approximately 100Giga ohm. The circuit of the instrumentation amplifier is shown in figure 5.

F. Filter Stages

A third order Butterworth high pass filter, a selective second-order filter at 50Hz and a second-order low-pass filter in Sallen-Key configuration are implemented. Adopted passive components have tolerance less than 1% and very low temperature coefficients. The cardiac signal conditioning circuit has a current consumption of about 0.2mA. These filter outputs are given to the gain adjustable module and from there it is given to the ADC module of the microcontroller.

G. Temperature Sensor LM37

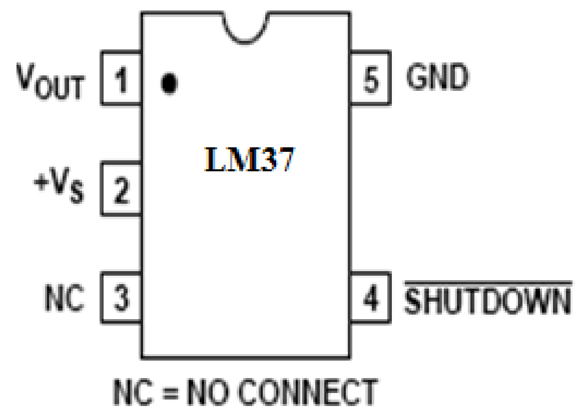


Figure 6. Pin Configuration LM37

The temperature changes depend upon the time to time and day to day. So its need to measure the temperature continuously. Pin Configuration of LM37 is shown in figure 6. The TMP37 is low voltage, precision centi-grade temperature sensors. They provide a voltage output that is linearly proportional to the Celsius (centigrade) temperature. The TMP37 do not require any external calibration to provide typical accuracies of ±1°C at +25°C and ±2°C over the −40°C to +125°C temperature range.

The low output impedance of the TMP37 and its linear output and precise calibration simplify interfacing to temperature control circuitry and ADCs. All three devices are intended for single-supply operation from 2.7 V to 5.5 V maxi-mum. The supply current runs well below 50 µA, providing very low self-heating—less than

0.1°C in still air. In addition, a shutdown function is provided to cut the supply current to less than 0.5 μA.

H. Features

- Calibrated Directly in Celsius (Centigrade)
- Linear + 10-mV/°C Scale Factor
- 0.5°C Ensured Accuracy (at 25°C) Rated for Full −55°C to 150°C Range
- Suitable for Remote Applications.

I. Temperature Ranges of Human

Category	Temperature Range (°C)
Hypothermia	<35.0
Normal	36.5 – 37.5
Hyperthermia	> 37.5 – 38.3
Stage 1 hypothermia	35-36
Stage 2 hypothermia	34 – 33
Stage 3 hypothermia	32
Hyperpyrexia	>=40.0 -41.5

Table 1. Classification on temperature range

J. PIC16F877A Microcontroller

Microcontroller PIC16F877A is one of the PIC Micro Family microcontroller which is Popular at this moment, start from beginner until all professionals. Because very easy using PIC16F877A and use FLASH memory technology so that can be write-erase until thousand times. The superiority this Risc Microcontroller compared to with other microcontroller 8-bit especially at constant speed maintenance and with its code compression. PIC16F877A have 40 pin by 32 path of I/O.

K. Pin Description

PIC16F877A is a Harvard computer model. It has separate memories for program and data each with its own buses. The major advantage with this architecture is that while an instruction is being executed the next one can be fetched. The execution speed is doubled the memory of this chip which was referred to earlier be its data memory. Its program has 14 bits in each location .All instructions fit in one program memory location An instruction is in other words completely defined with a number between 0x0000 and 0x3FF. Program memory data bus has 14 pins and address bus has 13 pins. Every instruction in PIC16F877A is represented by a 14 bit binary number. The PIC16F877A pin diagram is shown in figure 7.

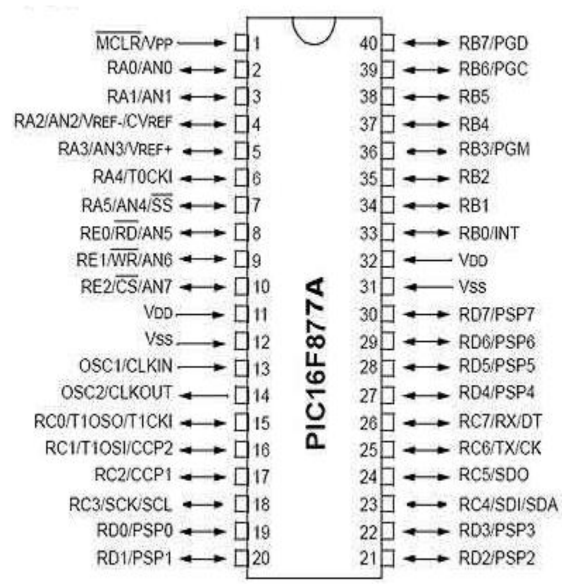


Figure 7. Pin Diagram of PIC16F877A

L. Features

- High-performance RISC CPU. This Processor has Lead-free RoHS-compliant Its Operating speed is 20 MHz, 200ns instruction cycle and Operates at a voltage of 4.0-5.5volts.It has 15 Interrupt sources and 35 single word instruction.
- Special Microcontroller Features includes Flash memory of 14.3KB(8192 words) It has an main configuration on Data SRAM of 368 bytes and Data EEPROM of 256 bytes.PIC16F877A is Self-reprogrammable under software control. Specially has Watchdog timer with on-chip RC oscillator.
- Peripheral Features include pin configurations like 33 I/O pins: 5 I/O ports. Timer0:8-bit timer/counter with 8-bit prescaler. Timer1:16-bit timer/counter with prescaler. Timer2:8-bit timer/counter with 8-bit period register, prescaler and post scale .It also accompanies USART/SCI with 9-bit address detection
- Analog Features includes 10-bit, 8-channel A/D converter, Brown-out reset, Analog comparable module, 25mA sink/source per I/O and Self Programming.

III. SOFTWARE DESCRIPTION

A. EAGLE for PCB Designing

EAGLE (Easily Applicable Graphical Layout Editor, German: Einfach anzuwendender grafischer Layout-Editor) is introduced by CadSoft Computer is a flexible, expandable and scriptable EDA application with schematic capture editor, PCB layout editor, auto-router and CAM and BOM tools developed by CadSoft Computer GmbH, Germany. We use this EAGLE software for the PCB designing of electronic circuit board capable to measure the heart rate and temperature.

B. Schematic Editor

EAGLE's easy-to-use schematic editor allows you to create an easy-to-read representation of your electronics design with zero complexity.

C. Features

- Better document your design with hierarchical schematic
- Define PCB rules in schematic with simple list-editing of rules and classes
- Multiple selection modes, incl. polygon-select, enable fast, flexible edits
- Intuitively edit multiple objects with advanced change/replace functions
- Real-time forward and backward synchronization keeps designs in sync
- Create crystal-clear documentation with multiple layers in schematic
- Execute multiple commands with a single click using the command line
- Bind command line operations to shortcuts, extending the editor
- Extend EAGLE schematic with EAGLE's powerful scripting interface.

D. Layout Editor

PCB Layout brings the designs from the symbolic world of schematic into the real world. EAGLE's PCB editor makes component placement, routing, validation and the interface to manufacturing simple and straightforward.

- Designed for the single user - UI consistent across schematic and PCB
- Manage multiple versions of a design with Assembly Variants
- Supports multiple package variants
- Snap to pad centers automatically to ensuring clean, consistent routing
- Route tracks with fixed 45/90 degree angles or rounded corners
- Mitering smooths corners - supports both straight and rounded angles
- Easy to use, efficient copper pour algorithms make editing fast!
- Build complex layer stack-ups with support for up to 16 signal layers
- Support high speed designs with:
  - Length-tuning of traces to match trace lengths
  - Support for differential pair routing
  - Native support for Blind and Buried vias
- Execute multiple commands with a single click using the command line
- Bind command line operations to shortcuts, extending the editor
- Extend EAGLE schematic with EAGLE's powerful scripting interface.

E. Autorouter

The EAGLE autorouter is a great way to get your simpler designs routed quickly and cleanly. The autorouter is used to route whole designs, start new designs, finish pre-routed designs, or even just to test how routable your component placement may be.

- Multi-Threaded

The autorouter can run multiple configurations simultaneously. The user is able to select the best outcome that accommodates the design. On computers with multiple core processors each thread can run on its own processor core. This optimizes EAGLE's use of the available hardware.

- TopRouter

The new autorouter includes the option to use our TopRouter. This intricate process will result in boards with significantly less points of transition compared to our previous algorithm. This means very cost effective boards that will need less manual interaction by the end user.

IV. CONCLUSION

Thus we have aimed to give, a novel autonomous instrumented T-shirt powered by an energy harvesting module. No batteries are used as power source. Low power circuits have implemented in the circuit board measuring heart rate and temperature. The instrumented T-shirt with the conductive textile electrodes and wires is washable. The electronic circuit board can be separated from the T-shirt by means of snap buttons and the solar energy panel is waterproof. The wearable shirt give the possibility of use the T-shirt in outdoors in sunny and shadow areas.

REFERENCES

[1] Aionisi,V.Pasqui,E.Sardini and M.Serpelloni "Instrumented shirt to evaluate classical human movements", in.proc.IEEEINT.symp.med.meas.appl, Lisbon,Portugal,jun-2014 pp.1-6.

[2] Cheng S Chin, William Atmodihardjo, Lok W Woo and Ehsan Mesbahi "Remote temperature monitoring device using a multiple patients-coordinator set design approach" Chin et al. ROBOMECH Journal (2015) .

[3] D. K. Kamat, Sanika Dadhi, Dr. P. M. Patil "A Heart Rate Measurement using Bio-impedance Signal Analysis" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 3, Issue 4, April 2014.

[4] Daniel Teichmann, Student Member, IEEE, J´erome Foussier, Jing Jia, "Noncontact Monitoring of Cardio respiratory Activity by Electromagnetic Coupling" IEEE transactions on biomedical engineering, VOL. 60, NO. 8, AUGUST 2013 .

[5] Faisal Ahmed1, Yannick Le Moullec1, Paul Annus1 "Energy Harvesting Technologies- Potential application to Wearable Health- Monitoring" IEEE sensors J.,vol 14, no 7,pp2299-2306,July 2014.

[6] Ji-er Hang, Kuo-Sheng Cheng and Cheau-Jane Peng "Temperature Compensated Bio impedance System for Estimating Body Composition" IEEE ENGINEERING IN MEDICINE AND BIOLOGY 0739-2000IEEE November/December 2000.

[7] Lijun Gao, Roger A. Dougal, Shengyi Liu,Albena P. Iotova. "Parallel-Connected PV System to Address Partial and Rapidly Fluctuating Shadow Conditions," IEEE Transactions on Industrial Electronics, Vol.56, No. 5,

[8] Mechanical and Industrial Engineering Department, University of Brescia, "Multi-parameters wireless shirt for physiological monitoring" 2011 IEEE.

[9] N. Ravi et al., "Activity Recognition from Accelerometer Data," Proc. 17th Conf. Innovative Applications of Artificial Intelligence, 2005, pp. 1541–1546.

[10] Naazneen M. G., Sumaya Fathima, Syeda Husna Mohammadi, Sarah Iram L. Indikar "Design and Implementation of ECG Monitoring and Heart Rate Measurement System" International Journal of Engineering Science and Innovative Technology (IJESIT) Volume 2, Issue 3, May 2013.

[11] O. Chipara et al., "Reliable Clinical Monitoring Using Wireless Sensor Networks: Experiences in a Step-Down Hospital Unit," Proc. 8th ACM Conf. Embedded Networked Sensor Systems, 2010, pp 155–168.

[12] O. Lara and M. Labrador, "A Survey on Human Activity Recognition Using Wearable Sensors," IEEE Comm. Surveys and Tutorials, vol. 15, no. 3, pp. 1192–1209, 2013.

[13] P. J. Xu, H. Zhang, X. M. Tao, "Textile-structured electrodes for electrocardiogram," Textile Progress, 40:4, pp. 183-213, 2008. pp. 1548-1556, May 2009.

[14] R. Vas, "Electronic device for physiological kinetic measurements and detection of extraneous bodies," IEEE Trans. Biomed. Eng., vol. BME-14, no. 1, pp. 2–6, Jan. 1967.

[15] Sara Khalifa, Mahbub Hassan, and Aruna Seneviratne, Sara Khalifa , "Energy-Harvesting Wearables for Activity-Aware Services" IEEE sensors J.,vol 14, no 7,pp2299-2306,July 2014.