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Implementation of a Low Cost Digital Electrocardiograph Machine

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ABSTRACT:
The main aim of this project is to design and implement biomedical monitoring system that efficiently and effectively monitors the pulse rate of a human being.
Traditional, electrocardiograph (ECG) machines are very costly with price of a basic ECG machine, commencing from Rs.25,000 reaching as high asRs.3,00,000.
Such high cost machines are unaffordable, especially in hospitals located in rural areas which lack in basic health monitoring systems even today, keeping them at the fringes of modern health. Heart rate has always been emphasised as the most important vital of cardiac and general health by the medical fraternity.
Thus, with this project we aim to design and implement a low cost ECG machine that measures the pulse rate or heart rate using non-invasive pulse oximeter circuit. Thereby, bringing technology to rural medical setups.

KEYWORDS: photodiode, microcontroller, interfacing, light emitting diode (LED), beats per minute (bpm)

1. STUDY AREA AND BACKGROUND

Traditionally an electrocardiogram (ECG) is used for monitoring the health of heart by measuring the pulse rate. Heart beat or pulse rate being has always been emphasised upon as one of vitals for good health. Hence, needs to be measured accurately. However, with a basic ECG machine having starting cost of Rs.25,000 going as high as Rs. 3,00,000 [1], they are incredibly difficult to afford especially for hospitals in rural areas which are not well equipped with efficient heart monitoring systems even today. We ought to change this by designing and implementing a low cost ECG machine which provides with high accuracy . Moreover, this is non –invasive in nature as pulse oximetry circuit is used for determining pulse rate thus, eliminating the need for electrodes traditionally pinned to chest for the same.

1.1. CARDIAC CYCLE:

The period of time that begins with contraction of the atria and ends with ventricular relaxation is known as the cardiac cycle. The period of contraction that the heart undergoes while it pumps blood into circulation is called systole. The period of relaxation that occurs as the chambers fill with blood is called diastole. Both the atria and ventricles undergo systole and diastole, and it is essential that these components be carefully regulated and coordinated to ensure blood is pumped efficiently to the body.

1.2.HEART RATE:

The resting heart rate of a newborn can be 120 beats per minute (bpm) and this gradually decreases until maturity and then gradually increases again with age. The adult resting heart rate ranges from 60 to 100 bpm. Exercise and fitness levels, age and basal metabolic rate can all affect the heart rate. An athlete's heart rate can be lower than 60bpm. During exercise the rate can be 150bpm with maximum rates reaching from 200 and 220 bpm.

1.3. IMPORTANCE OF MEASURING HEART RATE:

As your resting pulse rate is a key vital sign and an important indicator of good health, it is important to be aware of and track your resting pulse rate for the following reasons:

LONGEVITY:

At creation, each of us inherits a certain level of energy. How we manage that energy determines our lifespan. Those who have faster heart rates are using their heart beat allotment faster, therefore likely having a reduced lifespan.

1. **FASTER BEAT AND HEART ATTACK RISK:**

A faster heart beat rate is a key indicator for the risk of heart attack. Researchers have found that patients whose resting heart rate was above 70 beats per minute had significantly higher incidence of heart attacks.

2. **STRONG HEART:**

A slower heart beat generally indicates a stronger heart that works less hard to pump blood throughout the body.

3. **ENERGY LEVELS:**

A slower heart rate generally indicates a longer, higher and more enduring energy levels

4. **METABOLIC EFFICIENCY:**

A slower required heart beat is a general indicator of an efficient metabolism.

5. **ATHLETIC ENDURANCE FITNESS:**

A slower heart beat generally indicates aerobic fitness. Also, how quickly an athlete's heart beat recovers to lower beats per minute after vigorous exercise is an important indicator of aerobic fitness.

2. WORKING PRINCIPLE:

The principle of pulse oximetry is based on the red and infrared light absorption characteristics of oxygenated and deoxygenated hemoglobin. Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through. Deoxygenated (or reduced) hemoglobin absorbs more red light and allows more infrared light to pass through. Red light is in the 600-750 nm wavelength light band. Infrared light is in the 850-1000 nm wavelength light band.

(a) (b)

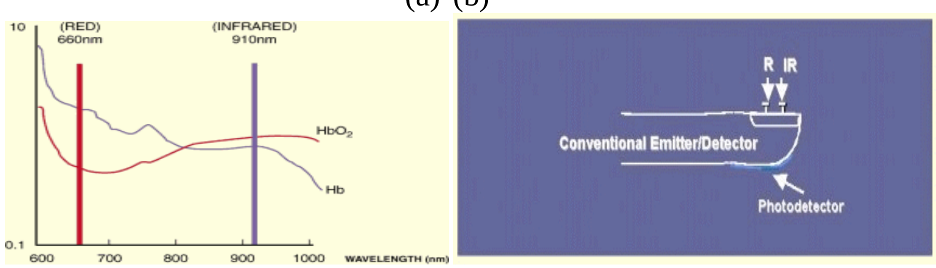

Fig.1 (a) wavelength sensitivity of pulse oximeter (b) emitter and detector of pulse oximeter

Pulse oximetry uses a light emitter with red and infrared LEDs that shines through a reasonably translucent site with good blood flow. Typical adult/pediatric sites are the finger, toe, pinna (top) or lobe of the ear. Infant sites are the foot or palm of the hand and the big toe or thumb. Opposite the emitter is a photo detector that receives the light that passes through the measuring site. At the measuring site there are constant light absorbers that are always present. They are skin, tissue, venous blood, and the arterial blood. However, with each heart beat the heart contracts and there is a surge of arterial blood, which momentarily increases arterial blood volume across the measuring site. This results in more light absorption during the surge. If light signals received at the photo detector are looked at 'as a waveform', there should be peaks with each heartbeat and troughs between heartbeats. If the light absorption at the trough (which should include all the constant absorbers) is subtracted from the light absorption at the peak then, in theory, the resultants are the absorption characteristics due to added volume of blood only; which is arterial. Since peaks occur with each heartbeat or pulse, the term "pulse oximetry" was coined. This solved many problems inherent to oximetry measurements in the past and is the method used today in conventional pulse oximetry.

3. HARDWARE DESCRIPTION:

3.1. MICROCONTROLLER (AT89S52):

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 pinout.

Features of AT89s52

1. Compatible with MCS®-51 Products
2. 8K Bytes of In-System Programmable (ISP) Flash Memory – Endurance: 10,000 Write/Erase Cycles
3. 4.0V to 5.5V Operating Range
4. Fully Static Operation: 0 Hz to 33 MHz
5. Three-level Program Memory Lock
6. 256 x 8-bit Internal RAM
7. 32 Programmable I/O Lines
8. Three 16-bit Timer/Counters
9. Eight Interrupt Sources • Fast Programming Times
10. Full Duplex UART Serial Channel

3.2.OPERATIONAL AMPLIFIER LM324 :

The LM324 series consists of four independent, high-gain, internally frequency compensated operational amplifiers designed to operate from a single power supply over a wide range of voltages. Operation from split-power supplies is also possible and the low-power supply current drain is independent of the magnitude of the power supply voltage.

(a) (b)

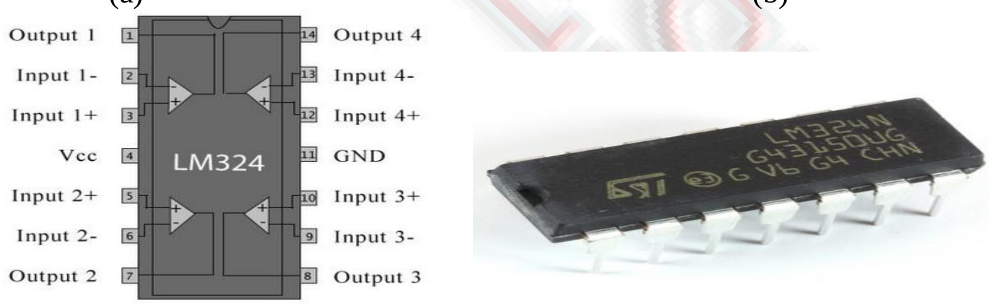

Fig 2. (a) pin description of LM324 (b) front view of LM324N

3.3.LIQUID CRYSTAL DISPLAY:

A liquid crystal display (LCD) is an electro-optical amplitude modulator realized as a thin, flat display device made up of any number of color or monochrome pixels arrayed in front of a light source or reflector. It is often utilized in battery-powered electronic devices because it uses very small amounts of electric power. Each pixel of an LCD typically consists of a layer of molecules aligned between two transparent electrodes, and two polarizing filters, the axes of transmission of which are (in most of the cases) perpendicular to each other.

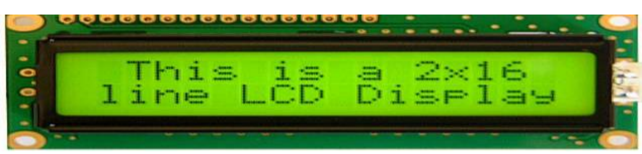

Fig.3. LCD screen

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3.4 POWER SUPPLY (IC7805 VOLTAGE REGULATOR):

A regulated power supply is very much essential for several electronic devices due to the semiconductor material employed in them have a fixed rate of current as well as voltage. The device may get damaged if there is any deviation from the fixed rate. The AC power supply gets converted into constant DC by this circuit. By the help of a voltage regulator DC, unregulated output will be fixed to a constant voltage.

(a) (b)

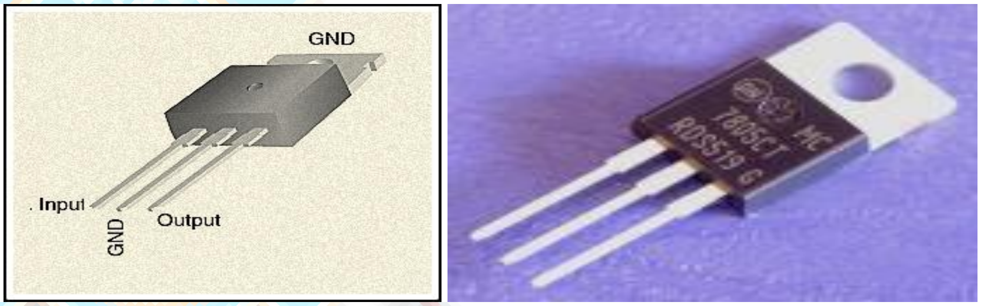

Fig.4. (a) voltage regulator pin description (b) front view of IC7805

3.5 STEP DOWN TRANSFORMER:

As a step-down unit, the transformer converts high-voltage, low-current power into low-voltage, high-current power. The larger-gauge wire used in the secondary winding is necessary due to the increase in current. The primary winding, which doesn't have to conduct as much current, may be made of smaller-gauge wire.

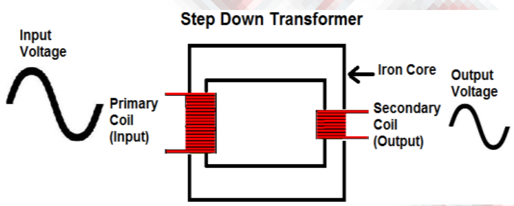

Fig.5. step down transformer

3.6 TIMER IC (NE555P):

These devices are precision timing circuits capable of producing accurate time delays or oscillation. In the time-delay or mono-stable mode of operation, the timed interval is controlled by a single external resistor and capacitor network. In the a-stable mode of operation, the frequency and duty cycle can be controlled independently with two external resistors and a single external capacitor.

(a) (b)

Fig.6. (a) pin description of 555 timer (b) front view of 555 timer

3.7 BRIDGE RECTIFIER:

A bridge rectifier makes use of four diodes in a bridge arrangement to achieve full-wave rectification. This is a widely used configuration, both with individual diodes wired as shown and with single component bridges where the diode bridge is wired internally.

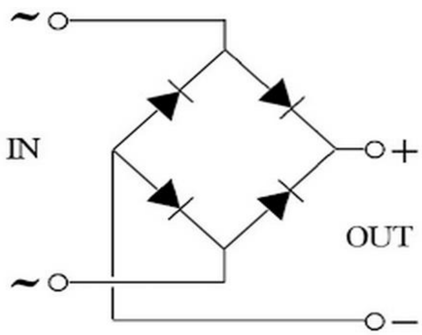

Fig.7. circuit diagram of bridge rectifier

3.8 LIGHT SENSORS:

In the light sensor we use one LDR. LDR is a light dependent resistor. Resistance of the LDR depends on the intensity of the light. As the light on the LDR is change, resistance of LDR is also change. Its resistance varies from 1k ohm to 500 k ohm. In full light resistance of the LDR is very low below then 1 k ohm and in no light resistance of the LDR is become very high above then 500k ohm.

In this project we use a LDR with only one 10k ohm variable resistor. This 10 k ohm resistor is connected to the positive voltage 5volt.

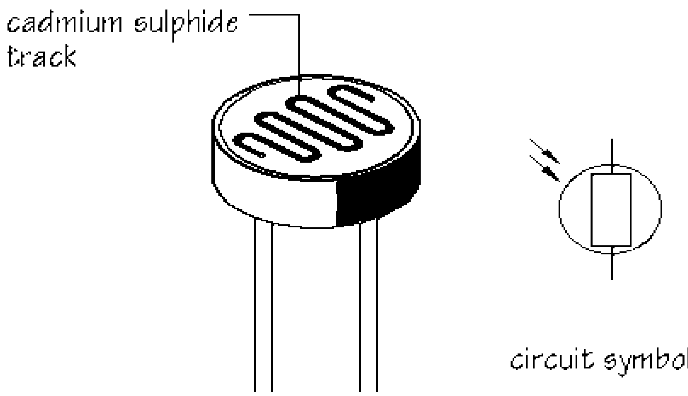

Fig.8. Light dependent resistor

3.9 LIGHT EMITTING DIODES:

When a light emitting diodes is forward biased (switched on), electrons are able to recombine with the hole and devices, releasing energy in the form of photons. this effect is called electroluminescence and the color of the light is determined by the energy gap of the semiconductor. An led is usually small in area(less than 1 mm sq.), and integrated optical components are used to shape it radiation and assist in reflection.

3. BLOCK DIAGRAM:

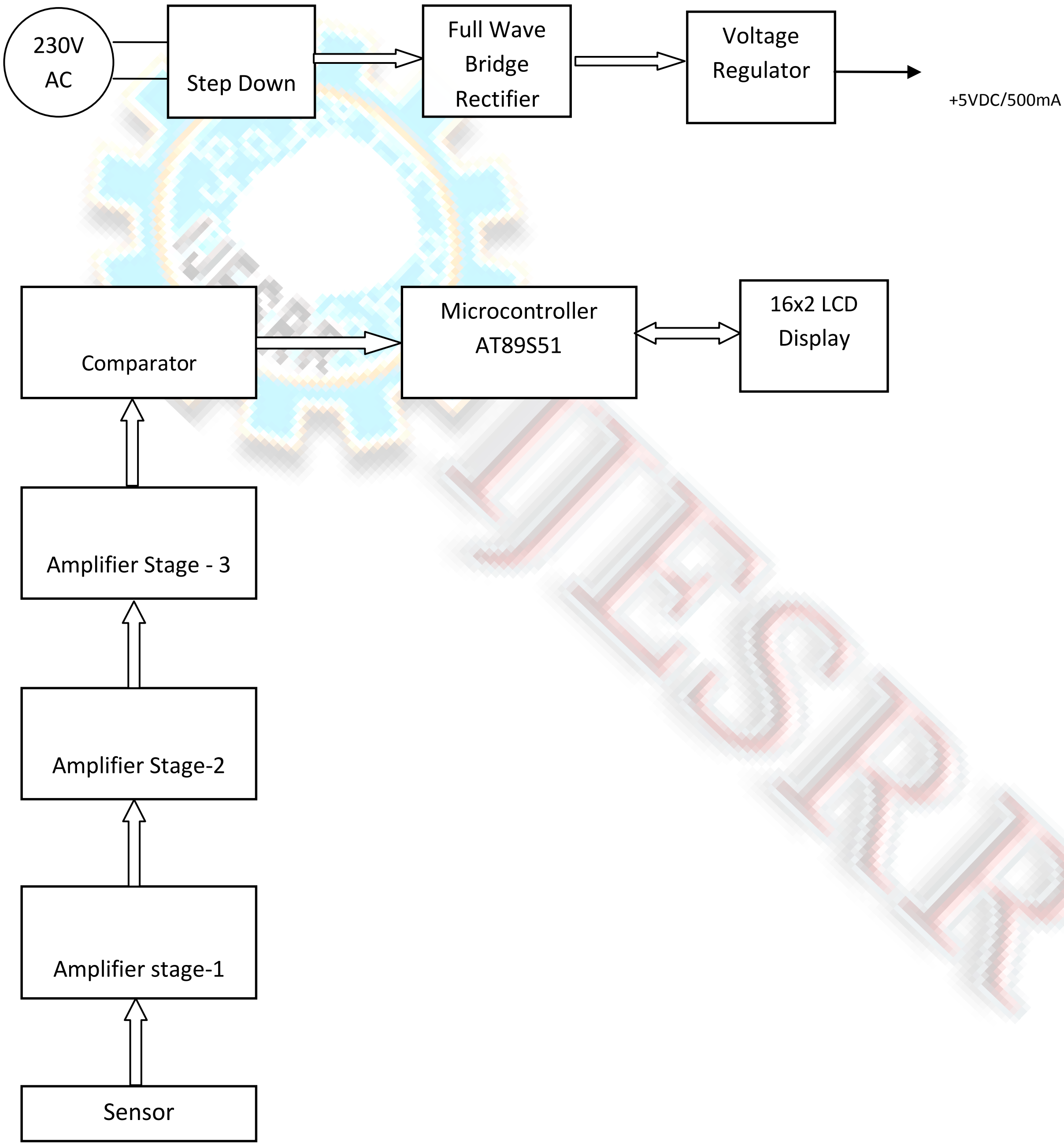

Fig.9 block diagram of low cost ECG machine

The electrical signals from cardiac musculature can be detected on the surface of skin. In theory one could grab the two leads of a standard volt meter, one with each hand, and see the voltage change as their heart beats, but the fluctuations are rapid and by the time these signals reach the skin they are extremely weak (a few millionths of a volt) and difficult to detect with simple devices. Therefore, amplification is needed. So instead of using electrodes, LED and a phototransistor are used for measuring the wavelength of blood fluctuations in the finger and converting this information into electrical signals.

Unfortunately, the heart is not the only source of voltage on the skin. Radiation from a variety of things (computers, cell phones, lights, and especially the wiring in your walls) is absorbed by our skin and is measured with the ECG, in many cases masking the ECG in a sea of electrical noise which is eliminated by using a low pass filter. A simple way to amplify the electrical difference between two points is to use an operational amplifier, otherwise known as an op-amp. The gain (multiplication factor) of an op-amp is controlled by varying the resistors attached to it, and an op-amp with a gain of 1000 will take a 1 millivolt signal and amplify it to 1 volt. We have used LM324N quad amplifier.

- STAGE 1: High gain amplifier. The input signals from either the ECG or pulse oximeter are fed into a chain of 3 opamp stages. The first is a preamplifier. The output is decoupled through a series capacitor to place it near VCC/2, and amplified greatly thanks to the 1.8Mohm negative feedback resistor. Changing this value changes initial gain.
- STAGE 2:Active low-pass filter. The 10kOhm variable resistor lets us adjust the frequency cutoff. The op-amp serves as a unity gain current source / voltage follower that has high input impedance when measuring the output of the low-pass filter and reproduces its voltage with a low impedance output. With the oximeter, virtually no noise gets through. Because the ECG signal is much smaller, this filter has to be less aggressive, and this noise is filtered-out by software.
- STAGE 3: Final amplifier with low-pass filter. It has a gain of ~20 (determined by the ratio of the 1.8kOhm to 100Ohm resistors) and lowpass filtering components are provided by the 22uF capacitor across the negative feedback resistor.

After amplification the resulting signal is fed to 8051 microcontroller, programmed in C language and interfaced to an LCD (Liquid Crystal Display) screen.

4. MONITORING SYSTEM

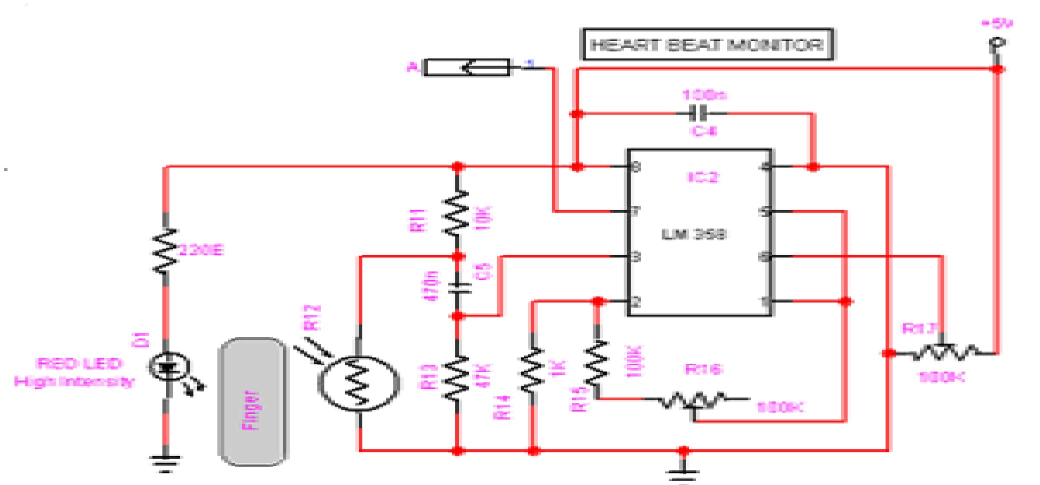

Fig.10. monitoring system consisting of all the components

In this project on two op-amps of IC LM 324 were used so in the circuit diagram above it is represented by IC LM 358 which has only two op-amps. As soon as the patient's finger is inserted between the LDR and the LED the pulse signal is transferred to the operational amplifier IC 358 or 324 after passing through various resistors. Now the data is processed in the IC as the first op-amp is the pre amplifier and the second is the final amplifier. The signal is successfully processed after passing through various amplification stages. We have also used a variable resistor to make the low pass filter function properly. The whole circuit is thus implemented according to the above circuit diagram.

5. DEVICE PROTOTYPE:

The concept is well implemented on the circuit interfaced with 8051 Controller. The output of the circuit is shown with the help of the diagrams below:

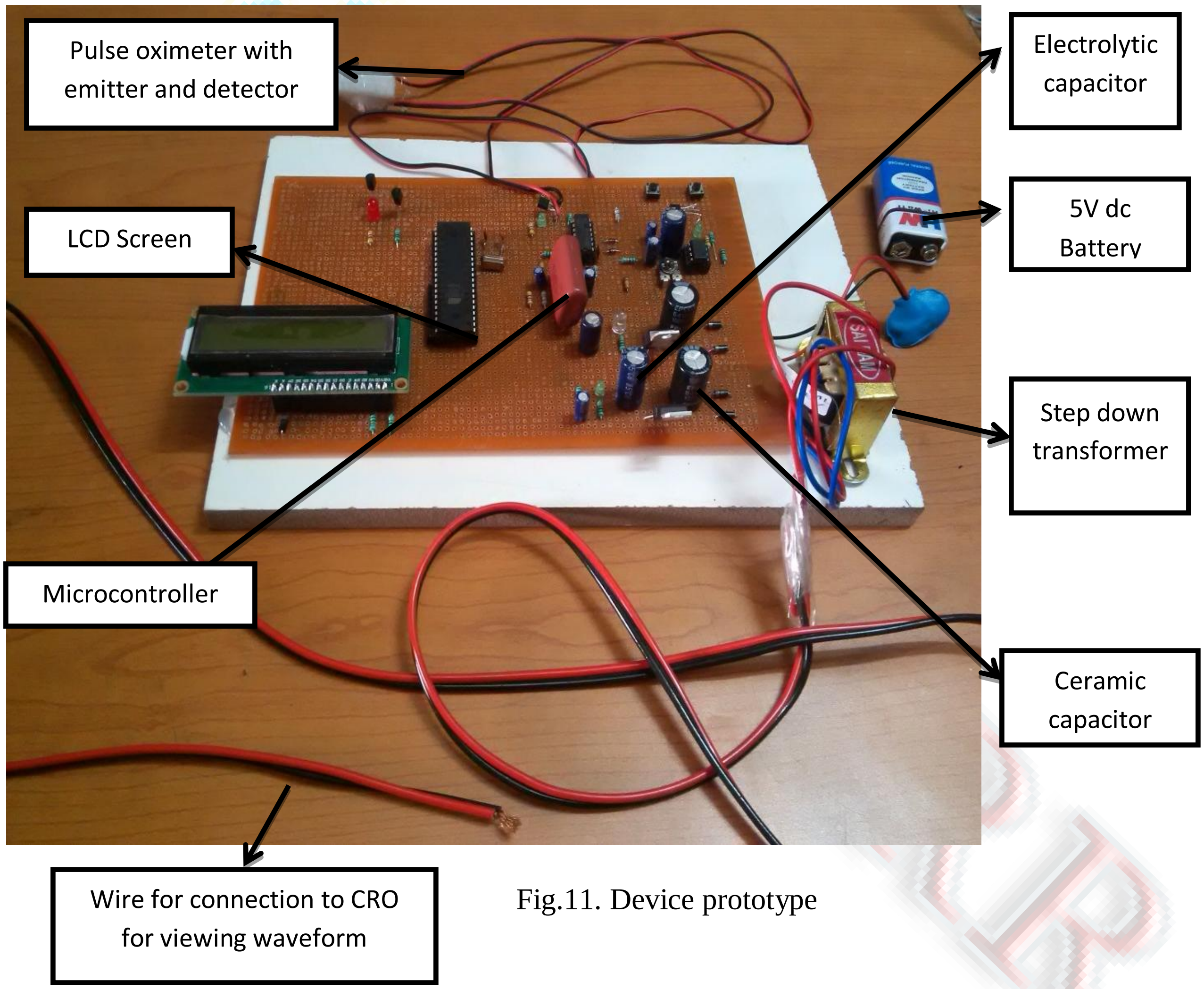

Fig.11. Device prototype

CONCLUSION:

Using the principles stated above we successfully designed a prototype which cost us Rs.300. The majority of India's population lives in rural areas with non-existent health infrastructure. These people shall be the primary beneficiaries of this project. The quality of life of these people shall improve as a result of this project as health care services will be available at their homes.

The primary customers of this system will be the Health Care Organizations and hospitals. They will be able to deploy this low cost and highly reliable machine in the areas where there is none at present. This would result in an increase in the quantity as well as quality of service of the overall health service being provided in the country. By taking advantage of this newly designed system based on technological revolutions, the government of India would be able to realize its vision of providing medical facilities to all of its citizens in a cost efficient manner. This would naturally lead to an improvement in the current catastrophic situation in the health sector.

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