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A Portable ECG Monitor Based On Embedded System Technology.

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ABSTRACT

Electrocardiogram is an invaluable tool in detecting a problem associated with the heart. There are various methods to diagnose heart disease, such as electrocardiogram, ultrasound, MRI, CT and so on. Among these methods, ECG diagnosis has the advantage of convenience and low cost so that it can be used in wide area. This device is capable of measuring ECG signal and displaying it in beats per minute. Moreover most of the cardiac deaths occur outside the hospital. ECG is the best way to measure and diagnose abnormal rhythms of the heart. This project aims at the design of the hardware circuit for ECG acquisition and converting the ECG signal into pulses, so that beats per minute is displayed. From the analysis of various persons ECG signal, the mean value was taken to be the range, if the limit of the range is exceeded or degraded then the abnormality is displayed, else it is displayed as normal signal. The converted pulses is given as input to the microcontroller, it has an inbuilt analog to digital converter. The converted digital value is stored in a register. The signal and the pulse rate are analyzed. If there is any abnormality in the signal then LCD displays abnormal and it is sent as message to the mobile with the help of microcontroller.

Keywords: electrocardiogram, PIC microcontroller, trachycardia, bradycardia.

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INTRODUCTION

Heart disease is the main cause of early disability and premature death in most countries. Moreover, because of the ageing of the population, the number of cardiac deaths is steadily increasing. In modern medicine, there are various methods to diagnose heart disease, such as electrocardiogram (ECG), ultrasound, MRI, CT and so on. Among these methods, ECG diagnosis has the advantages of convenience and low cost so that it can be used in a wide area. Moreover, most of the cardiac deaths occur outside the hospital. For that reason the time before treatment is reduced. A portable ECG monitoring device which can monitor sporadically occurring symptoms will be very useful.

An ECG can be used to assess if the patient has had a heart attack or evidence of a previous heart attack. It depends on what is being measured. Usually, an ECG is taken while the patient is resting, but if there is concern that a patient's symptoms may be caused by coronary artery disease the test is done while the patient is on an exercise bike or treadmill. The electrocardiogram does not assess the contractility of the heart. However, it can give a rough indication of increased or decreased contractility.

Electrical impulses in the heart originate in the sinoatrial node [1] and travel through the heart muscle where they impart electrical initiation of systole or contraction of the heart. The electrical waves can be measured at selectively placed electrodes (electrical contacts) on the skin. Electrodes on different sides of the heart measure the activity of different parts of the heart muscle. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle.

ECG is the best way to measure and diagnose abnormal rhythms of the heart, particularly abnormal rhythms caused by damage to the conductive tissue that carries electrical signals, or abnormal rhythms caused by levels of dissolved salts (electrolytes), such as potassium, that are too high or low. In myocardial infarction (MI), the ECG[5] can identify damaged heart muscle. But it can only identify damage to muscle in certain areas, so it can't rule out damage in other areas. The ECG cannot reliably measure the pumping ability of the heart for which ultrasound-based (echocardiography) or nuclear medicine tests are used.

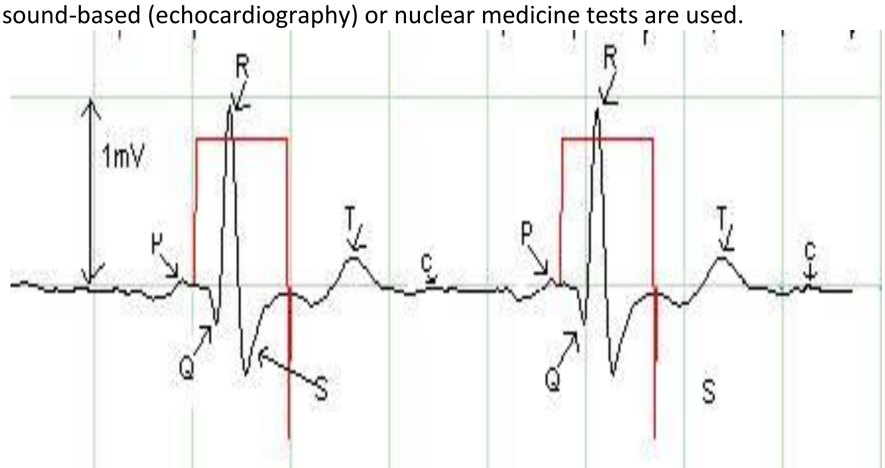

Figure 1: The normal electrocardiogram

The “P” wave represents the electrical impulse traveling across the atria of the heart. Abnormalities of the P wave, therefore, reflect abnormalities of the right and/or left atrium.

P wave = atrial depolarization

The QRS complex represents the electrical impulse as it travels across the ventricles. Abnormalities of the QRS are often seen when there has been prior damage to the ventricular muscle, such as in a prior myocardial infarction (heart attack).

QRS complex = ventricular depolarization

The "T" wave represents the recovery period of the ventricular muscle after it has been stimulated. T wave = ventricular repolarization

The portion of the ECG between the QRS complex and the T wave is called the ST[5] segment. Abnormalities of the ST segment and the T waves are often seen when the heart muscle is ischemic that is, when it is not getting enough oxygen, usually because there is a blockage in a coronary artery.

The normal duration of the QRS is 0.08-0.09 s. The P-wave follows the QRS-complex after about 0.2s as amplitude of about 0.1 mV and the duration of 0.1 s is reached as shown in Fig 1. The T-wave can be differentiated from the P-wave[2] by observing the T-wave.

SYSTEM OVERVIEW

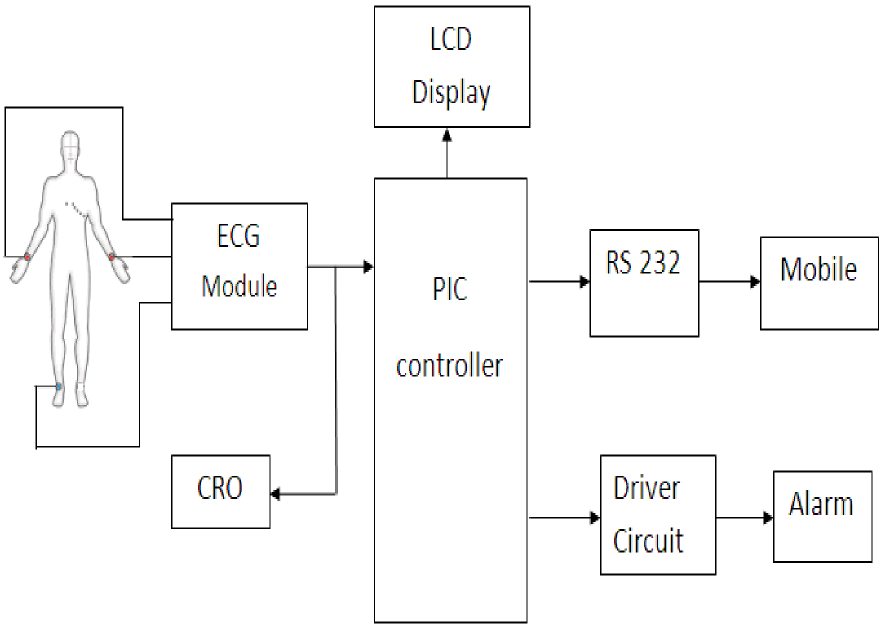

Figure 2: Block Diagram

There are two forms of circuits for measuring the ECG signals. One is to use amplifier ICs, resistors and capacitors to design a circuit board. The other is to use ASIC to achieve the measuring, in which A/D converter and serial communication ports were integrated. Any method can be used. In this design, the first method was chosen.

There are lots of microcontrollers that can be used for ECG monitoring, from 8-bit to 32-bit microcontroller, as well as DSPs. In this design, PIC based microcontroller called PIC16F877 is used. The LCD display is used to display the ECG level and pulse rate, when it exceeds beyond the particular set limit the microcontroller activates the Buzzer. This project is useful in all hospitals. This project can be easily fixed in the home. So manually the ECG level of every person can be checked.

METHODOLOGY

Placing the electrode leads on the right arm (-), left arm (+) and the right leg (ground) will acquire the patient's ECG signal. The acquired signal will be then passed on to instrumentation amplifier for amplification. The amplified signal will be then filtered out and then passed on to the pulse width modulator for modulation of the frequency.

This modulated signal is sent into the isolation circuit to isolate the patient from the bio medical instrument, to avoid electrical shock to the patient. This signal is demodulated in the pulse width demodulator to recover the information from the carrier wave of the signal. Then a notch filter is used to filter the signal within the required ECG frequency range.

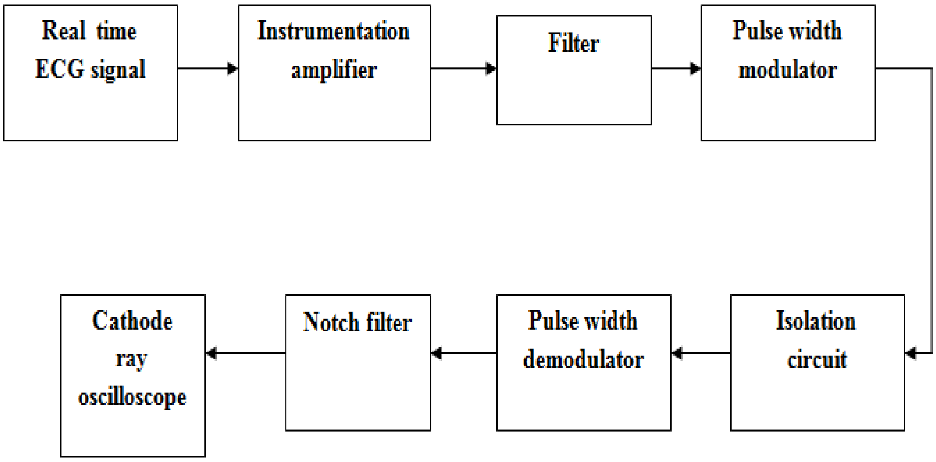

Figure 3: General block diagram of ECG hardware

Instrumentation Amplifier

In this circuit there are three electrodes is used to measure the ECG waves in which two electrodes is fixed with left and right hand another one electrode is fixed in the right leg which acts as reference ground electrode. Electrode 1 and Electrode 2 pick up the ECG waves from both the hands. Then the ECG waves are given to instrumentation amplifier section.

The instrumentation amplifier is constructed by the TL072 operational amplifier. The TL072 are high speed J-FET input dual operational amplifier incorporating well matched, high voltage J-FET and bipolar transistors in a monolithic integrated circuit [3]. The devices feature high slew rates, low input bias and offset current and low offset voltage temperature coefficient. The instrumentation amplifier amplifies the differential signal from the both electrode.

- The output of the ECG circuit will be in the range of 1mV to 5mV,but the microcontroller will be enabled only when (1-5)V is given as input.
- So the gain of the ECG circuit should be 1000 to get the desired output.
- The advantage of instrumentation amplifier is that by varying a single resistor Rg, gain can be altered.

Filter

This amplified ECG waves contains the line frequency, high frequency and low frequency noise signals. So the ECG wave is fed to filter section. The filter section consists of high pass filter and low pass filter which is used to remove the high frequency and low frequency noise signal.

Pulse width modulator

After the filtration the ECG wave is given to pulse width modulation unit. In this section the ECG wave is converted into pulse format in order to perform the isolation. PWM circuit produces pulses according to the time amplitude of the signal.

Isolation Circuit

The isolation is constructed by the opto-coupler[3]. The isolation is necessary to isolate the human body and monitoring equipment such as CRO, PC etc. The pulses are given as input to the isolation circuit, it consists of led and transistor. Each time when high pulse is obtained led glows and the transistor will conduct.

Pulse width demodulator

The aim of pulse modulation method is to transfer a narrowband analog signal, as a bit stream over another digital transmission system. Then the ECG pulse format wave is given to PWM demodulation unit in which the pulse format is reconstructed to the original wave.

Demodulation is the act of extracting the original information-bearing signal from a modulated carrier wave. A demodulator is an electronic circuit used to recover the information content from the modulated carrier wave.

Notch filter

Then the wave is fed to notch filter section in order to remove the line frequency noise signal. A notch filter is a band-stop filter with a narrow stop band (high Q factor). Notch filters are used in live sound reproduction (Public Address systems, also known as PA systems).And instrumentation amplifier are (especially amplifiers or preamplifiers for acoustic instruments such as acoustic guitar, mandolin, bass instrument amplifier, etc.) to reduce or prevent feedback, while having little noticeable effect on the rest of the frequency spectrum. Other names include 'band limit filter', 'T-notch filter', 'band-elimination filter', and 'band-rejection filter'. Typically, the width of the stop band is less than 1 to 2 decades (that is, the highest frequency attenuated is less than 10 to 100 times the lowest frequency attenuated). In the audio band, a notch filter uses high and low frequencies that may be only semitones apart. Here the notch filter is constructed by the operational amplifier TL074.

Amplifier

Finally noise free ECG wave is given to amplifier[7]. Then the amplified signal is given to monitoring devices such as CRO, PC etc. Since the signal from the notch filter is very low we give it to non-inverting amplifier.

Converting ECG signal into pulse

ECG signal from the final amplifier is given to the comparator circuit .The comparator signal which compares the signal voltage applied at one input of an op-amp with a known reference voltage at the other input .Here the reference voltage is set as 0.8v, hence if the ECG signal is greater than reference voltage, the output signal switches ON the transistor which produces a high signal to the microcontroller.

PIC microcontroller

PIC 16F877 is a 40-pin 8-Bit CMOS FLASH Microcontroller from Microchip. The core architecture is high-performance RISC CPU with only 35 single word1 instructions. Since it follows the RISC architecture, all single cycle instructions take only one instruction cycle except for program branches which take two cycles [4]. 16F877 comes with 3 operating speeds with 4, 8, or 20 MHz clock input. Since each instruction cycle takes four operating clock cycles, each instruction takes 0.2 µs when 20MHz oscillator is used. It has two types of internal memories: program memory and data memory. Program memory is provided by 8K words (or 8K*14 bits) of FLASH Memory, and data memory has two sources.

ECG signal is connected to port RA0. ECG pulse is connected to port RC3. RC7 and RC6 acts as the transmitter and receiver. The output for the alarm circuit is taken from port RB0.LCD is interfaced to the PORTD [4].

Peripheral communication

To allow compatibility among data communication equipments made by various manufacturers, an interfacing standard called RS232 was set by the Electronics Industries Association (EIA) in 1960. RS232 is the most widely used serial I/O interfacing standard. This standard is used in PCs and numerous types of equipments. Its input and output voltage levels are not TTL compatible. For this reason, to connect any RS232 to a microcontroller system we must use voltage converters such as MAX232 to convert the TTL logic levels to the RS232 voltage levels, and vice versa.

SYSTEM DESIGN

Normal signal

Sinus rhythm is a term used in medicine to describe the normal beating of the heart, as measured by an electrocardiogram (ECG)[6]. It has certain generic features that serve as hallmarks for comparison with normal ECG.

Figure 4: Normal signal displayed in CRO

There are typically five distinct waves (identified by the letters P, Q, R, S, and T) in a single beat of the heart in sinus rhythm, and they occur in a specific order, over specific periods of time, with specific relative sizes. While there is a significant range within which variations in rhythm are considered normal, anything that deviates from sinus rhythm by more than a certain amount may be indicative of heart disease.

Sinus rhythm is characterized by a usual rate of anywhere between 60-100 bpm. Every QRS complex is preceded by a P wave and every P wave must be followed by a QRS (the opposite occurs if there is second or third degree AV block). The P wave morphology and axis must be normal and the PR interval will usually be 120 ms to 200 ms. In normal sinus rhythm[6], electrical impulses from the SA node travel to the AV node with successful contraction of the two atria. The electrical impulses from the AV node successfully contract the ventricles. On the ECG, there are normal PQRST elements with no evidence of arrhythmia, tachycardia, or bradycardia.

Trachycardia

The heart normally beats at a rate of about 60 to 100 beats per minute at rest. A rate faster than 100 beats a minute in an adult is called tachycardia. Most people experience transient rapid heartbeats, called sinus tachycardia, as a normal response to excitement, anxiety, stress, or exercise. If tachycardia occurs at rest or without a logical cause, however, it is considered abnormal. The word tachycardia comes from the Greek words tachys (*rapid* or *accelerated*) and kardia (*of the heart*). Tachycardia typically refers to a heart rate that exceeds the normal range for a resting heart rate (heart rate in an inactive or sleeping individual). In humans, this rate is usually based upon age, sometimes it can be very dangerous depending on how hard the heart is working and the activity:

- 1-2 days: >159 beats per minute (bpm)
- 3-6 days: >166 bpm
- 1-3 weeks: >182 bpm
- 1-2 months: >179 bpm
- 3-5 months: >186 bpm
- 6-11 months: >169 bpm
- 1-2 years: >151 bpm
- 3-4 years: >137 bpm
- 5-7 years: >133 bpm
- 8-11 years: >130 bpm
- 12-15 years: >119 bpm
- >15 years - adult: >100 bpm

Tachycardia's may also occur in the course of a heart attack (or myocardial infarction).

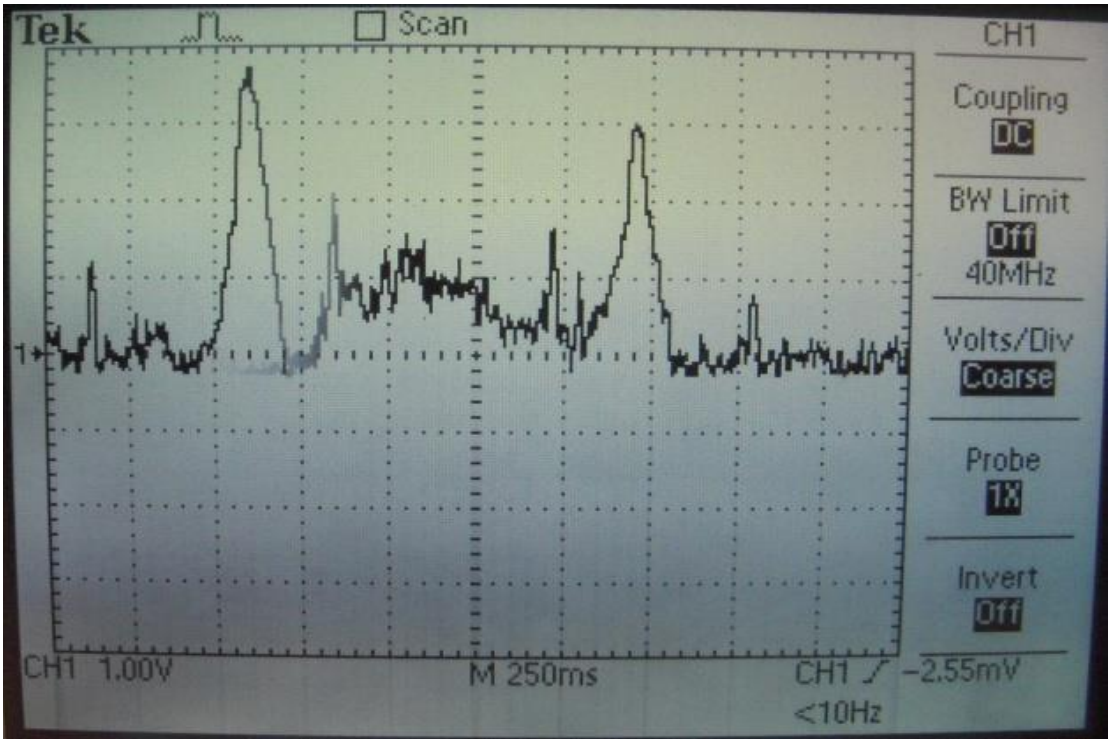

Figure 5: Abnormal signal displayed in CRO

Bradycardia

Bradycardia is a general term that describes a number of conditions in which the heart beats at an unusually slow rate (fewer than 50 to 60 beats per minute). Electrical impulses[7] travel through a complex network of cells and fibers making up the heart's circuitry, triggering a steady heartbeat. However, these impulses may be slowed, delayed or blocked altogether, resulting in bradycardia. This may be due to aging, medications, metabolic disturbances or pre-existing heart disease. The adult heart (at rest) beats at about 60 to 80 beats per minute. Fifty-five to 60 beats per minute would be considered bradycardia for an adult. Infants, however, have a much higher at rest heart rate (110 to l30 beats per minute), thus; bradycardia in infants would be a rate below 100 beats per minute. Slower than average heart rates are normal in people who are physically fit and people who are sleeping. Many athletes who train regularly have resting heart rates of 40 to 60 beats per minute. Severe bradycardia (fewer than 30 beats per minute) can be an emergency situation, leading to brain oxygen deprivation and convulsions. Death may result unless immediate medical measures are taken to increase the heart rate.

RESULT

The ECG signal taken through the electrodes from the human body is amplified and given to the PIC 16F877 microcontroller. The same amplified signal is converted into pulses and is also fed to the microcontroller. The microcontroller is programmed in such a way that it compares the ECG signal and the pulses to obtain the required output. If the obtained value is in between the required range, normal signal is displayed in the LCD. If it exceeds the limit then abnormal signal is displayed in the LCD, at this condition a message is sent to the mobile and the buzzer is activated.

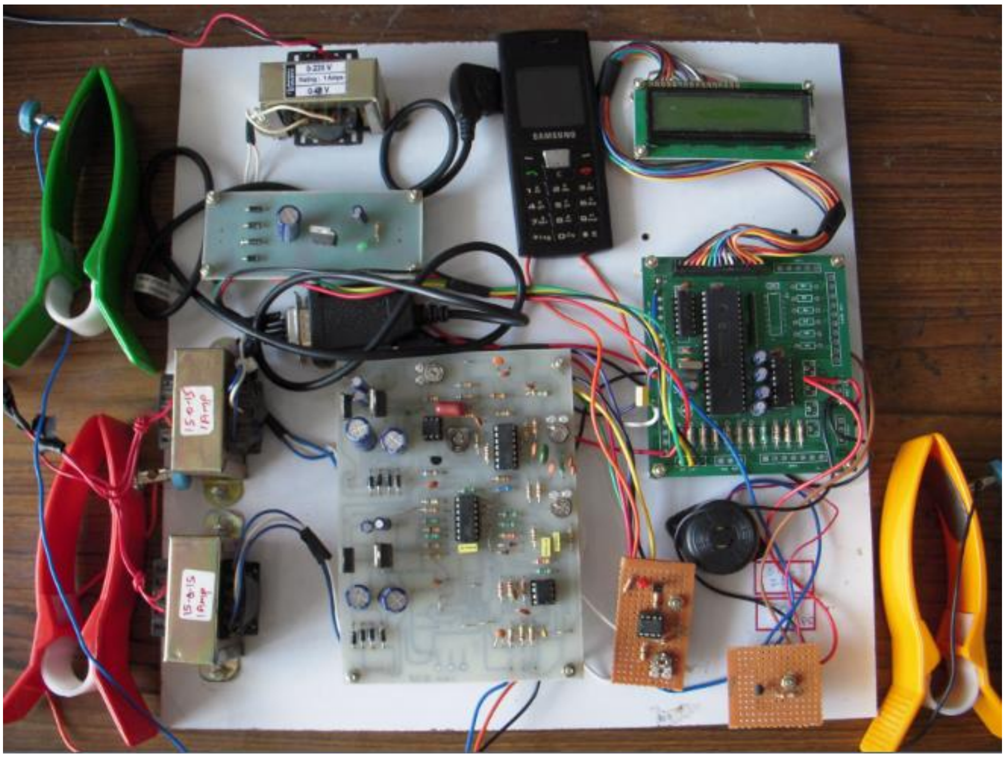

Figure 6: Hardware model

Conclusion and Future enhancement

In conclusion ECG circuit was designed, then the acquired ECG signal was given to the microcontroller. To have a legible output, ECG signal is converted into pulses and given to the microcontroller, which is displayed in LCD in beats per minute. The voltage of the signal has a minimum limit of 0.8V which is the reference given to the comparator. If there is any abnormality in the signal it is displayed in the LCD, alarm is enabled and text message is sent to the mobile else normal signal is displayed in LCD. In the abnormal condition time before treatment can be reduced, because a message is sent to a person nearby, who will lead him to the doctor.

The work presented in this project represents the in-sight into the analysis of detection of abnormality in ECG signal .In this project we can use power batteries instead of supplying 230Volts though the pin connector to the circuit, since it is a portable one. As a further development of this project it can be extended to detect various diseases such as heart attack, tachycardia, bradycardia and so on Such a development might be particularly useful for finding the heart disease of a person. Thus it paves way for the people to get the treatment at lesser cost. Progression can be made by replacing circuit with CHEFRAN chip.

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