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Solar rechargable *pocket defibrillator with ECG display*

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Abstract— several hospitals and clinics, in the World are poor in resources. They cannot afford lif saving defibrillators as these are expensive. Furthermore, lack of reliable power as well as availability of appropriate batteries, hinders maintenance of these defibrillators, if they can be obtained. Furthermore, Automatic external defibrillators (AED) are inappropriate for these applications as they use expensive-disposable electrodes as well as, equally, expensive batteries and are not designed for repeated use. It is a well-known fact that one out of four AEDs fails to shock because of depleted batteries or expired electrodes. We have developed a defibrillator with low cost, small (pocket) size, solar recharger and also with an ECG display. This, affordable, defibrillator uses paddles and will not require batteries or disposable electrodes. The circuitry, in the defibrillator, has been designed, using commonly available components that are used in consumer electronics, to ensure robustness and enhance affordability. The ECG display in this device is only for reference purposes.

Keywords— Affordable Defibrillator; Cardiac defibrillation; pocket defibrillators, Sudden cardiac arrest (SCA), Electrocardiogram (ECG), Automated External Defibrillator (AED).

I. INTRODUCTION

A. The defibrillator and its use in treating Cardiac arrests:

The uncoordinated movement of the ventricle walls of the heart due to ventricular fibrillation from asynchronous contraction of heart muscles; this may results from coronary conclusion, from electric shocks or from abnormalities of body chemistry. Because of this irregular contraction of the muscle fibers, the ventricles simply quiver rather than pumping the blood effectively. This results in a steep fall of cardiac output and can prove fatal if adequate steps are not taken promptly. In fibrillation, the main problem is that the heart muscle fibers are continuously stimulated by adjacent cells so that there is no synchronized succession of events that the follow the heart action consequently, control over the normal sequence of cell action cannot be captured by ordinary stimuli.. Possibly, the fibers may then respond to normal physiological pace making pulses. The instrument for administering the shock is called as defibrillator.

Fig. 1 Normal heart Rhythms

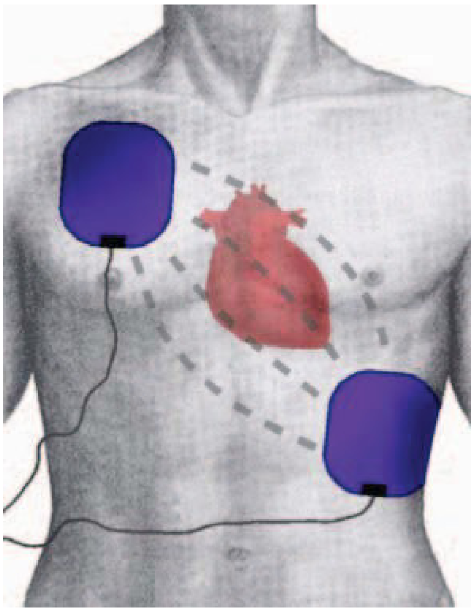

Fig. 2 Placement of electrodes/paddles for a defibrillator

B. Statement of Problem:

Defibrillators are unaffordable in resource poor settings. Cost of acquisition as well as maintenance of these devices is prohibitive in these areas. Furthermore, mains power is unreliable, or unavailable, in these settings and replacement- batteries are expensive. Some of these defibrillators use disposable electrodes that are also expensive. For example in India, SCA occurs in 324 out of 100,000 patients. Even in urban hospitals, in India, there is one defibrillator for every 50 beds. The availability of an affordable defibrillator, that is hand-cranked, can significantly, reduce SCA, in low and middle income countries (LMIC). Many ambulances in LMICs are not equipped with defibrillators. Furthermore, during disaster-relief; there may be unavailability of mains- power and replacement batteries.

C. Objective of theProject:

Our objective was to design a solar rechargeable pocket sized, affordable defibrillator with an ECG display. The attributes of this defibrillator are:

1) Ability to charge a High voltage capacitor to 200J in less than 12 seconds.
2) Ability to safely operate using multi-cell battery rechargeable with solar and main supply.
3) Acquire ECG signals from paddles or an ECG- cable; display these, as well as convert them to audio, to discern shakable rhythms, easily.
4) Discharge the capacitor into a patient by selecting energy levels of 150-200J, for an adult and around 50J for pediatric patients.
5) Ability to deliver over 30 shocks, reliably, over the life of the defibrillator.
6) Sustain vagaries of severe environments such as high storage temperatures, humidity, shock and vibration
7) Adhere to the IEC and AAMI standards that govern defibrillators.
8) Reusable, paddle, electrodes.
9) The defibrillator is a FDA Class II device, unlike an AED which is a Class III device. Substantial equivalence with other Class II defibrillators is sufficient to prove efficacy of such a device. This device has been designed to comply with the AAMI DF80 standard. One of the Authors (SD) is a member of the committee that writes this standard.
10) Storage temperature between $-20^0 – 70^0$C

11) Low cost of acquisition as well as cost of ownership.

II. DESIGN OF DEFIBRILLATORS

A. Performance goals:

Before The performance metrics of the defibrillator, for critical parameters, are listed in Table I

TABLE I. CRITICAL PERFORMANCE GOALS

Metric	Value
Charging time to400J	< 15 s
HV Capacitor	120 μF
EKG sensitivity	0.1-5mV
EKG Bandwidth	0.05-40Hz
Chord recharging time	<30 min
Patient impedance	25-175 ohm
Solar recharging time	<30 min
Defibrillator-Life	> 3000 shocks
Storage Temperature	$-20^0 – 70^0$ C

B. Architecture of Defibrillator

The followings are the important sub-systems of defibrillator:

1. *Voltage booster circuit:* This circuit uses a centre tapped transformer with the ratio of 1:100 and a MOSFET for switching operations, thus it boosts 3v to 500v AC which powers the Cockcroft Walton's Voltage multiplier.
2. *Voltage multiplier circuit*: It is actually the Cock-craft Walton's Voltage multiplier circuit which is used to convert the 500 V from the transformer circuit up to 2KV.
3. *Charging circuit and transformer*: It consists of isolated coupled-inductors which enable the low voltage from the inputs to be transformed to voltages up to 500V.
4. *Capacitor*: A high voltage capacitor is connected parallel to the voltage multiplier in order to gain 400J.
5. *Inductor:* An Inductor connected in series with the paddle which acts as a filter and slows down the charges from the capacitor to the human body
6. *Paddles:* For controlling and delivery therapy for patients, which passes the shock energy about 200 – 360 J. In this pads usually conducting gel is used because the electric shock through the pads may cause injury in order to avoid this, conducting gels are used.

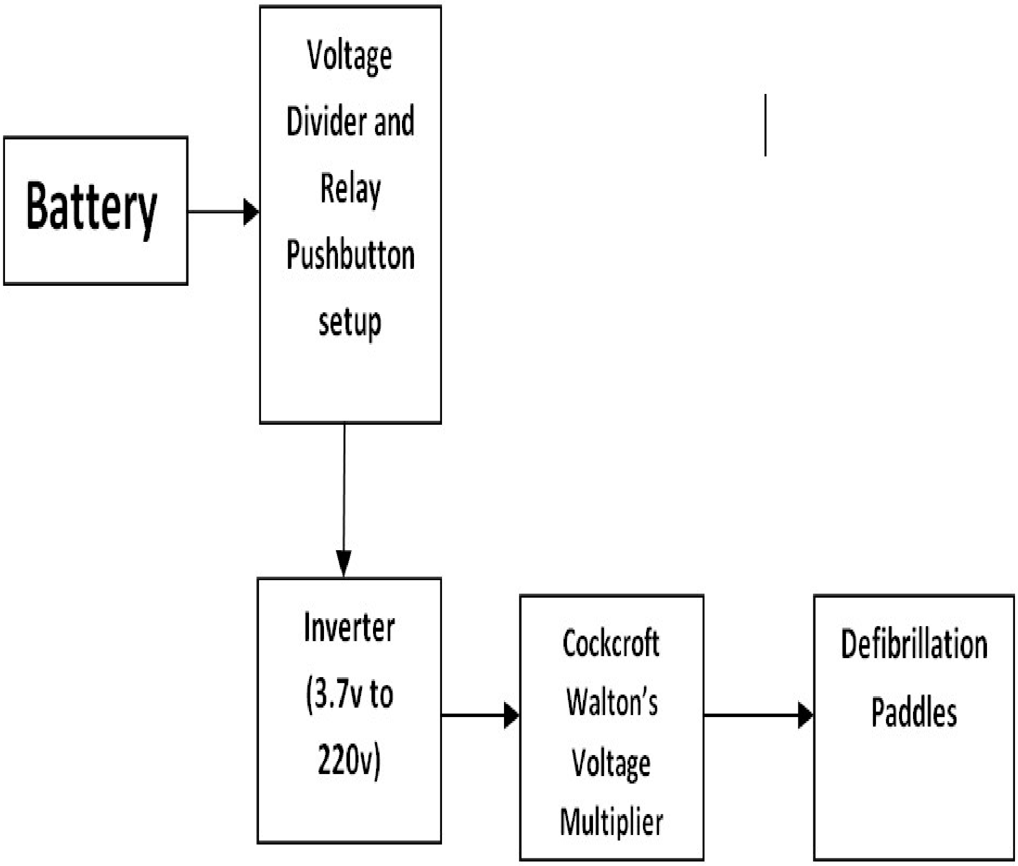

Fig 3 Schematic diagram of defibrillator

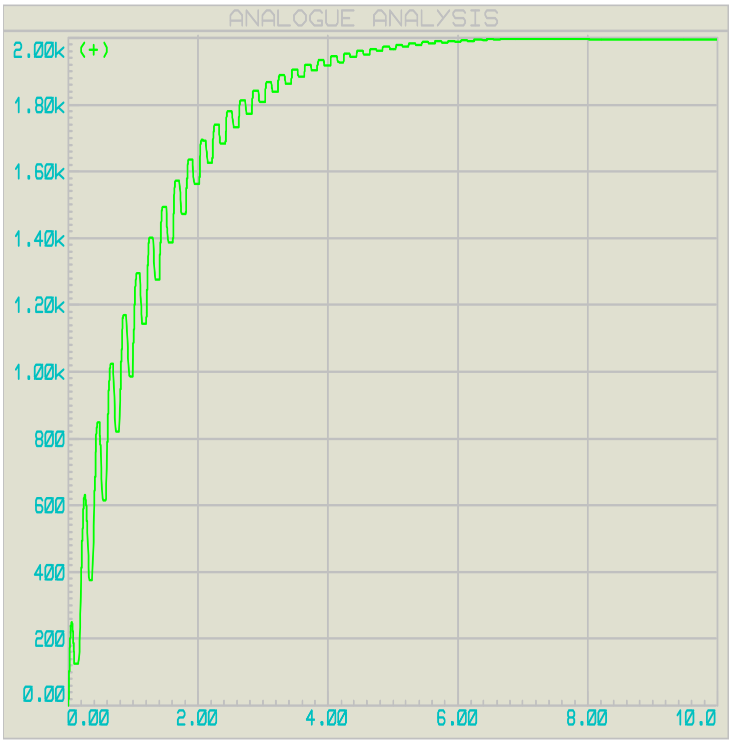

Fig 4 Output Voltage Characteristics

III. DESIGN OF ECG DISPLAY

A. *OLED display:* An organic light-emitting diode (OLED) is a light-emitting diode (LED) in which the emissive electroluminescent layer is a film of organic compound that emits light in response to an electric current. This device used to display the pulse rate in BPM(Beats per minute) and the sinus rhythm.This OLED device acts as a slave and an inbuilt I2C chip acts as a Master , the signals from the heart pulse sensor is processed in the arduino nano and it is given to the I2C master chip. This I2C master chip takes the SCL and SDA signal from the anrduino nano and gives to the OLED display due to the program in the arduino and with the help of the Adafruit ssd8601 and GFX library the sinus rhytm and the BPM will be shown in the OLED display.

B. *Arduino Nano:* Arduino is an open-source hardware and software company, project and user community that designs and manufactures single-board microcontrollers and microcontroller kits for building digital devices and interactive objects that can sense and control both physically and digitally.Arduino boards are available commercially in preassembled form or as do-it-yourself (DIY) kits.Arduino Nano is used instaed of its very small size In this device The signal from the heart pulse sensor is given to the pin A0 (digital I/O), this signal is processed in the arduino and given to the I2C OLED display via pin A4 and A5 which are the SCL and SDA pin required for the I2C OLED display.

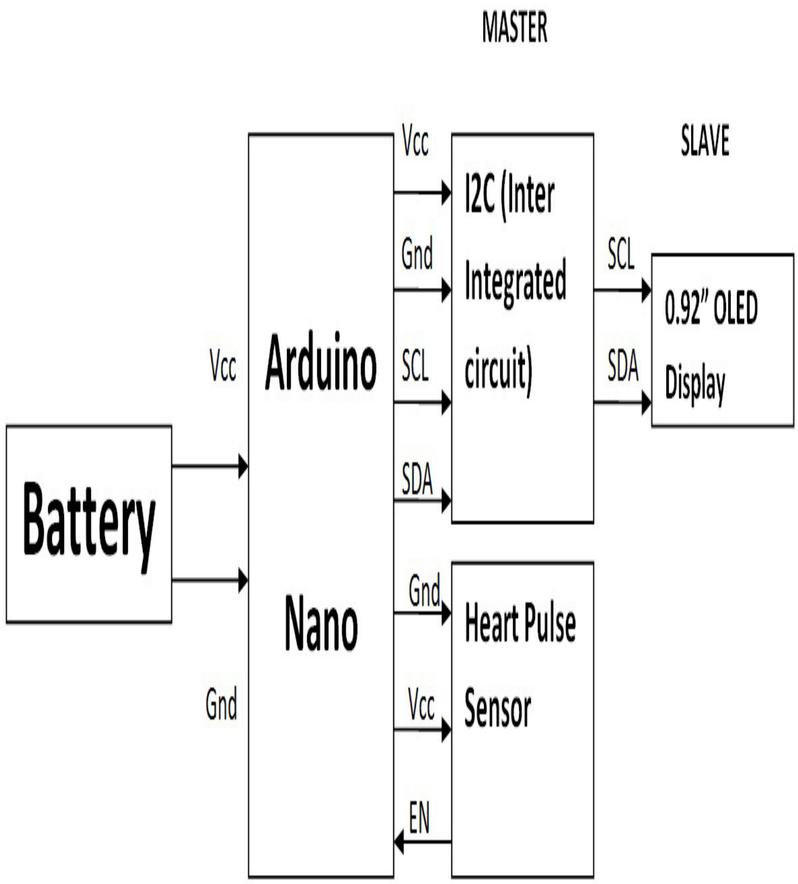

Fig 5 ECG Display Block Diagram

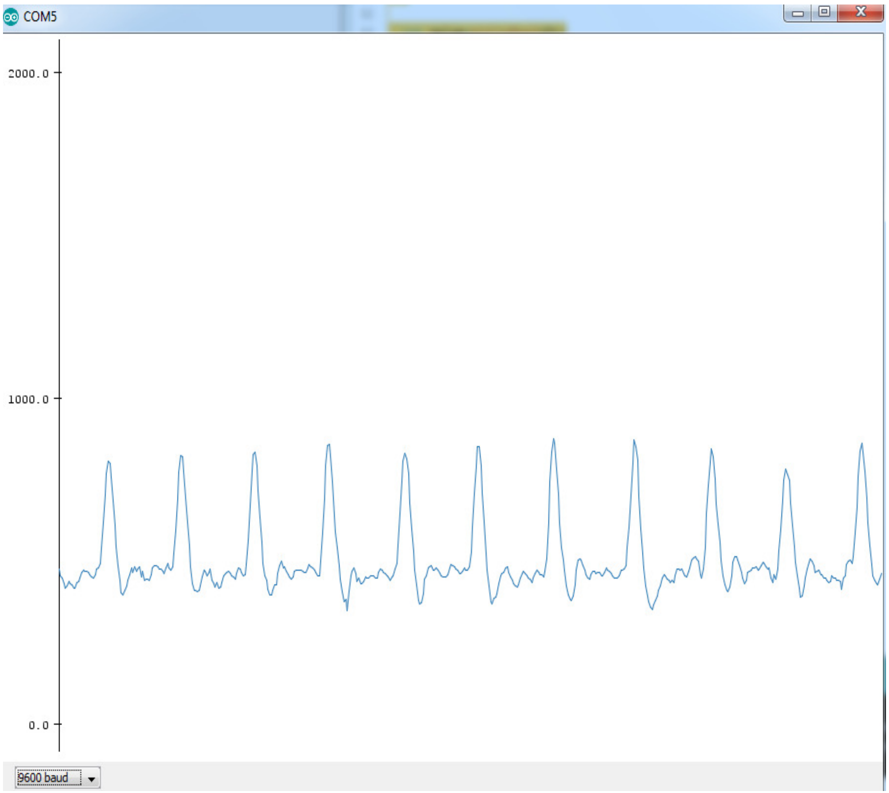

Fig 6 ECG output from the serial plotter using Arduino

C. Heart pulse sensor:

It is a sensor which senses the blood pumped by the heart using the IR sensors which is placed in the tip of the finger. When the heart pumps the blood it reaches every end of the blood capillaries and returns to the heart. When the blood flows through the capillaries it makes a stimulus while giving pressure to the finger tip thus the IR sensor senses the stimuli and the data is given to the arduino nano through the pin A0 which is the digital I/O pin.

IV. DESIGN OF CHARGING CIRCUIT

The following circuits are used for charging the batteries:

A. USB charging circuit:

In this device the charging is done by mobile phone USB charger because nowadays people changed to smart phones they use USB chargers everywhere in order to make it simple USB chargers are used to charge the batteries we have used a NiCad battery which is cheap and easily available. We have used the TP4056 micro USB module for charger circuit. It is compatible with micro USB cable.

B. Solar charger:

We have installed a solar charger with the 6V solar panel as a backup device for charging the battery. The ultimate aim of this charger is to make this device available at remote place where even the electricity is not available. This circuit use 5V voltage regulator with the capacitor arrangements

V. CALCULATIONS

A. *Energy calculation required for defibrillation shock:*

$$E = 1\backslash 2\ C\ (V)\ ^\wedge 2$$

C – Equivalent Capacitance of the circuit
V – Voltage across the capacitor
This formula is derived from the kinetic energy

B. *Inverter output calculation:*

From turns ratio,

$$N2\backslash N1 = V2\backslash V1$$
$$V2 = (I2\backslash I1) * V1$$

V1 – input voltage to the transformer
V2 – output voltage from the transformer
N1 – number of turns in the primary winding
N2 – number of turns in the secondary winding

VI. CONCLUSION

Although these devices (AED's) are easily available as an emergency kit in foreign, they are not easily available in India due to its high cost. Hence this device could be available at low cost only as an emergency device with solar charger and a cord charger in order to provide Defibrillation at any place and any situation.

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