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Design And Development Of An External Cardiac Defibrillator Using The Fly Back Transformer

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***Abstract*—Defibrillators are devices that are used to apply a large electric shock to the heart and restore a normal sinus rhythm to a heart which is still active but not contracting in a coordinated fashion. The use of a defibrillator on a patient following a heart attack is an emergency procedure, as the pumping action of the heart has to be restarted within a few minutes if the patient is to survive. A century has passed since the defibrillator has been invented. But it is matter of shame that yet this simple technology failed to reach all the class of people around the world which could save a lot of lives .This paper deals with the design a defibrillator by using flyback transformer and high voltage capacitor to generate the required triggering pulse. So,we model a defibrillators by preparing a circuit which costs much lower than the available one.**

Keywords—Defibrillator, Fly Back transformer, High voltage capacitor

1.Introduction

Defibrillator is used for the treatment of fibrillation (an arrhythmia of heart). The technology of defibrillation was invented more than a century ago and it's more than half a century since it's been used on human being. Almost all the industries and public places of the developed countries keep Automated External Defibrillators (AEDs). This technology has advanced to such a stage that wearable and implantable defibrillators are used at a frequent rate by the patient of the developed countries. But like many other inventions of science this invention also failed to reach all the people around the world. In the third world countries yet there are hospitals where there is not a single external defibrillator which could have saved a lot of lives.

Coronary Heart Disease Deaths in Bangladesh is 163,769 or 17.11% of total deaths (WHO, April 2011). This death rate ranks Bangladesh 25 in the world. Price of defibrillators imported to Bangladesh varies from 3 lakhs to 15 lakhs or more. So most often government hospitals and private clinics cannot afford to keep sufficient defibrillators. Again once these devices start malfunctioning they cannot be repaired locally. Sometimes device warranty also doesn't work out. People of the remote areas, attacked by fibrillation die long before reaching the town hospitals. Every minute passes, the chance of a patient attacked by
fibrillation coming back to life decreases. A defibrillator at the union health complex could have changed the picture.

1.1 Fly Back Transformer:

Fly back transformers are relatively used to Generate high voltage in high frequency. The design cost is comparably lower than other high voltage transformers. These types of transformers are very reliable and efficient to generate high voltage. It is used
extensively in switched mode power supplies for both low (3V)
and high voltage (over 10 kV) supplies.

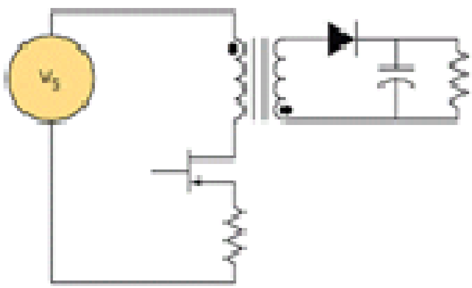


Figure 1.1: Flyback Transformer

Figure 1.2: A typical TV flyback transformer

Though we designed a flyback transformer, we found that if the FBTs available at the market for CRT display is used for the high voltage generation then the cost reduces to 80% for the flyback transformer. We selected two flyback transformers from the market. One was FBT-BSC-25-4813 which is used for color television & another one was FBT- SALSON 1245AL which is used for black & white television.

1.1.1 Calculation of number of joules required to charge the capacitor:

$$J = \frac{CV^2}{2}$$

$$J = \frac{54 * 10^{-6} * 4000^2}{2}$$

=432 joules (Let's consider 400J)

1.1.2 Calculation of number of charging pulses in the stated time:

Number of pulses (N) = 10 seconds * 1000 pulses per second

= 10,000 pulses

1.1.3 Calculation of energy required per charging pulse:

Energy per pulse (J) = $\frac{\text{Joules}}{\text{N}}$

$= \frac{400}{10000}$

=0.04 J/pulse

Joules from DC source = $\frac{\text{Joules per pulse}}{\text{Efficiency}}$

$= \frac{0.04\text{J}}{.8}$

=0.05 J/pulse

1.1.4 Calculation of current:

$L = \frac{E\partial t}{Ip}$ where, Ip=peak current

Or, $L = \frac{24 * 900\mu}{Ip}$

$$J = \frac{LIp^2}{2}$$

So,

$$L = \frac{2J}{Ip^2},$$

$$\text{or,} L = \frac{2 * .05}{Ip^2}$$

From the above equation , we can write,

$$\frac{24 * 900\mu}{Ip} = \frac{2 * .05}{Ip^2}$$

$$\frac{Ip^2}{Ip} = \frac{2 * .05}{24 * 900\mu}$$

$$Ip = \frac{2 * .05}{24 * 900\mu}$$

So, Ip = 4.63 Amp

$$L = \frac{Np^2\mu A}{l}\text{Henry}$$

From this equation, we can find the number of turns in primary, Np Besides,

Ns=n*Np

1.1.5 Calculation of inductance, L:

$L = \frac{2 * .05}{4.63 * 4.63}$

=4.665mH

2. Methodology

The circuit which is planned for the project is given below:

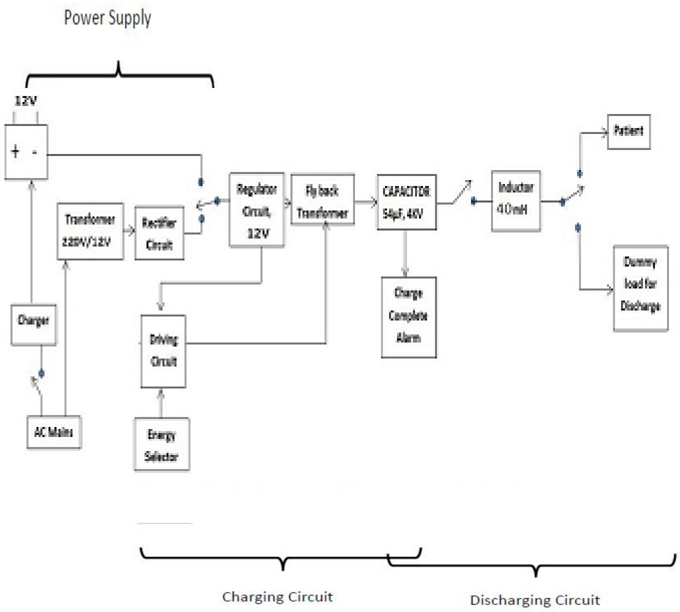


Figure 2.1: Block Diagram of the planned circuitry

Options for power supply from both the mains and battery is kept. In case of main line power failure or load-shedding the defibrillator might be used by the battery power supply. A driver circuit also powered by 12V drives the flyback transformer. Then the capacitor is charged. When the capacitor charge completes the charge complete alarm sounds. Pressing a button the operator can disconnect the capacitor from the charging circuit & connect it to the discharging circuit. Lately, if the button fitted on the defibrillator paddle is pressed then it discharges through patient's chest. If the energy is not needed to be discharged through the patient then another switch can discharge it through a dummy load or the defibrillator testing circuit. This planned circuit was tested in the lab on a dummy load, but the capacitor value was 10 µF, 2000 V & the inductor was designed as 20 mH and wound by hand on a silicon core.

2.1 Power supply:

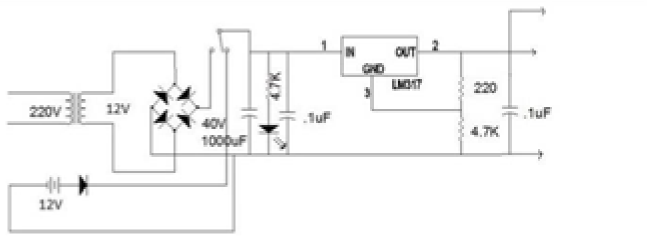
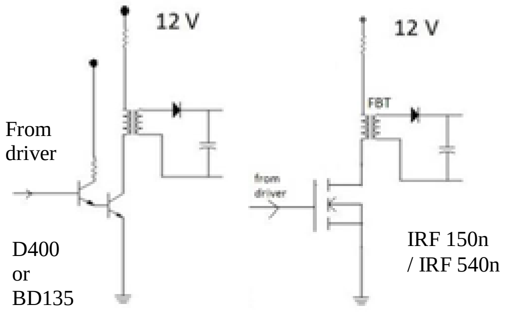


Figure 2.2: Power supply unit of the defibrillator

From AC mains, a 220/12V transformer steps down the voltage which is rectified by a bridge rectifier. A three way switch is used for the selection of the power source between mains and battery. LM317 is used for the regulation of constant 12V. An LED indicates the power availability. This 12V goes to the FBT & to the driver circuit for the FBT.

2.2 Charging circuit:

Firstly the switching of the flyback transformer was done
with BJT. BJT D400 was used for the amplification of current
to drive the BJT D2499. D2499 did the switching of the FBT.



Also BD135 was used in exchange of D400 as it was easier to use heat sink with BD135. This circuit was problematic to bias properly. Also charge storage effect of the BJTs was causing the distortion of the waveform as the switching was not working perfectly. For this reason MOSFET was chosen for switching. As the driver circuit supplies a small amount of current & MOSFET is voltage driven, there is no need to amplify the current &it is perfect for switching. IRF540n& IRF150n was used for the switching of the flyback transformer.

2.3 Discharge Circuit:

After charging the capacitor, it might be discharged in two ways. One is through the inductor to the patient body; another is through the defibrillator simulation circuit or a dummy load if it is not needed to discharge through patient. A switching mechanism is used to control this discharge path. The inductor is 40mH and the dummy load is 50ohms. The chest resistance of patient is typically 50 ohms.

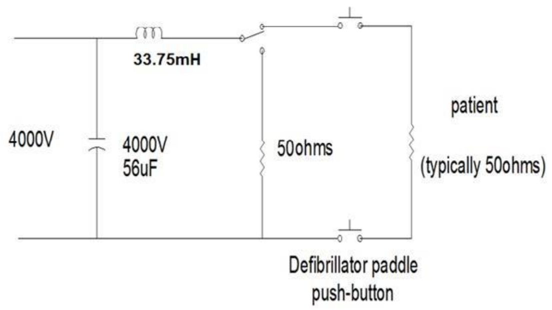


Figure 2.2: Discharge circuit

Driver Circuit:

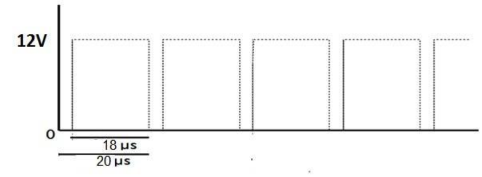


Figure 2.3: Pulse from Driver Circuit

Several driver circuits were made using op-amps and 555 timer & a potentiometer was used as regulator for changing the duty cycle. To vary the energy by varying the defibrillator energy regulator in an increasing or decreasing sequence, the output voltage of the FBT should also increase or decrease in a sequential way. Changing the driver PWM and keeping the frequency constant it can be done. But while changing the duty cycle of the astable multivibrators made by op-amps & 555 timers, the output voltage of the FBT was also changing because of frequency variation. But the problem with these circuits was that during changing the duty cycle the frequency could not be kept constant. For this reason the output voltage at the FBT was not increasing or decreasing in a sequence.

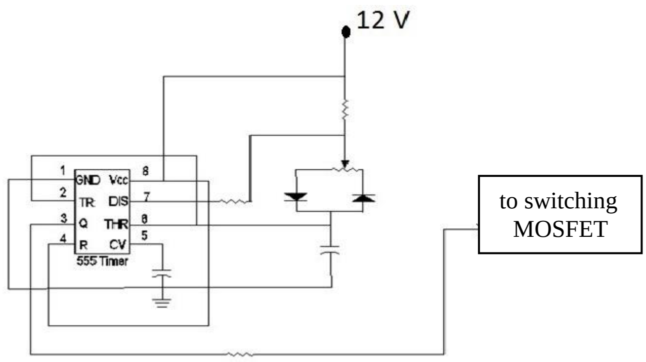


Figure 2.4: An astable multivibrator using 555 timer which ideally should not change frequency during PWM.

3.Simulation & Result:
The complete simulation circuit of this thesis work is shown in figure 3.1.

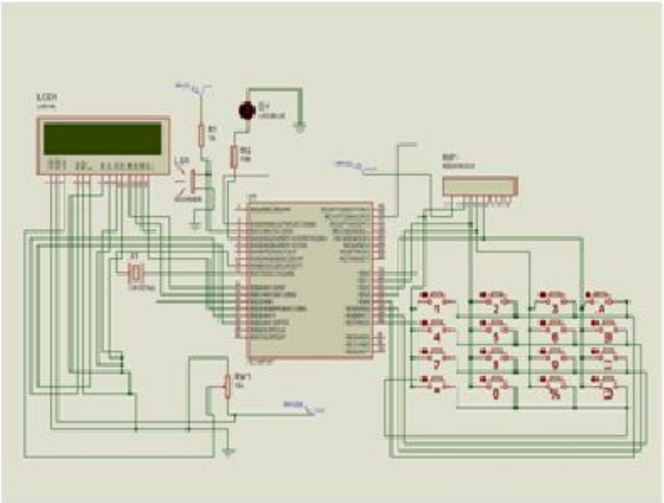
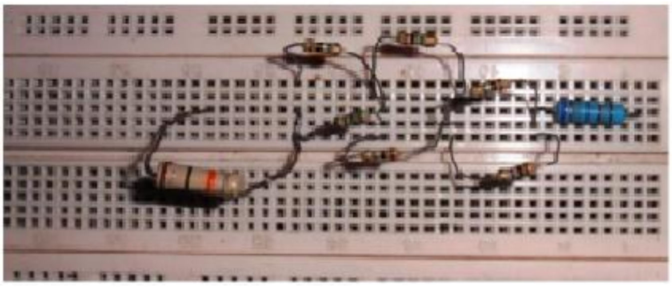


Figure 3.1:PWM & Charge complete signaling using PIC 16F887

3.2 Measurement of High Output Voltage of FBT:
The high output voltage was measured with the help of a resistance chain of 27MΩ. At the end of this resistance chain, across a 10K resistance the voltage was measured by an Oscilloscope. So the multiplier was 2700 to get the actual voltage from the measured Oscilloscope voltage.



3.3: Output voltage for different input voltage between different pins of the fly back transformers:

B&W TV FBT (SALSON 1245AL) (5V Input):

Input Pin Number	V_{out} (V)
Between 1&2	1525
Between 1&4	1525
Between 1&3	1906.25
Between 5&6	1525
Between 1&2	1525

B&W TV FBT (SALSON 1245AL) (15V Input):

Input Pin Number	V_{out} (V)
Between 1&2	7625
Between 1&3	6710
Between 1&4	6100

Color TV FBT (BSC-25-4813) (5V Input):

Input Pin Number	V_{out} (V)
Between 1&2	3050
Between 1&3	762.5
Between 1&4	305
Between 1&5	1067.5
Between 1&6	1525
Between 2&6	2287.5
Between 2&5	1525
Between 2&4	457.5
Between 2&3	1143.75
Between 7&8	3431.25

The output directly from the fly back transformer had ripples because of its inductive effect. But when the storage capacitor was added across it the ripple was reduced to almost zero.

3.4 Discharge pulse across dummy load:
As mentioned before a 10 µF capacitor was charged. Then the charged capacitor was discharged through a dummy load. Dummy loads of different values were used.

Figure 3.3: A picture from the last lab set up of the defibrillator circuit

The discharge pulses were captured with the help of a Digital Storage Oscilloscope. Then different values regarding the waveforms were calculated from the captured pulse.

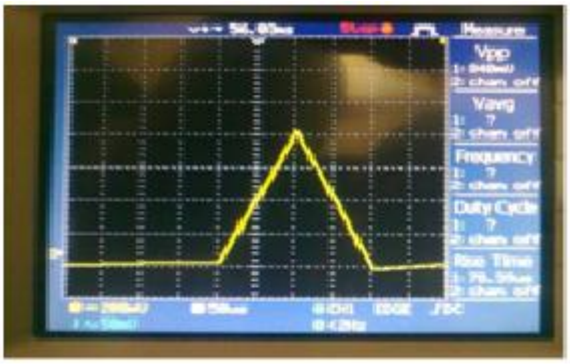


Figure 3.4: Discharge pulse through a 35 Ω load

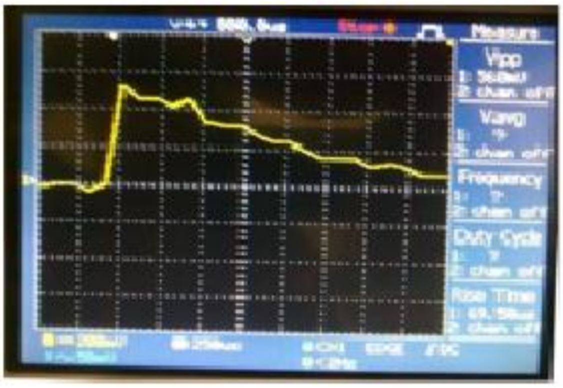


Figure 3.5: Discharge pulse through a 100 Ω load

4. Conclusion:

The final defibrillator circuit was made with 10mF, 2KV capacitor & 20mH inductor. But for making a useable one it has to be made with 54mF, 4KV capacitor & 40mH inductor. Recently we are working with this circuit. The electrodes have not been designed yet. It will be designed soon including the paddle switch with proper safety and insulation. After that the circuitry will be boxed in a proper way ensuring safety. The casing will be insulated and grounding will be done properly. The circuit will be tested by professionals and Bangladesh Institute for Biomedical Engineering & Appropriate Technology (BiBEAT) has ensured us to help in this work. This organization also wants to launch the product in the market without any profit if the circuit is proved to be an effective one after testing. We also want to make an AED in future which would be able to detect abnormal ECG and defibrillate the heart if necessary. We have a dream to reach this technology to everyone of the world.

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