VENTRICULAR DEFIBRILLATOR

Group No: B03

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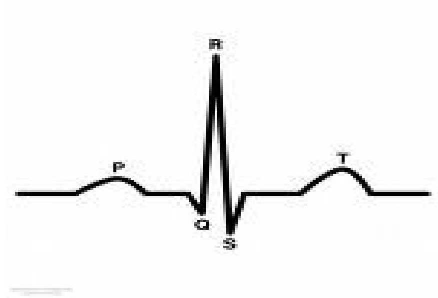
<u>ABSTRACT</u>:

The problem statement of our EDL is to design a ventricular defibrillator. In this design, we have processed the ECG signals, which are either taken directly from the body of the patient or are generated by using an arbitrary waveform generator. After processing of ECG signals, it is indicated whether the ECG is normal, ventricular fibrillated or having any other arrhythmia. In case of ventricular fibrillation, the user is prompted by the device to provide high voltage shocks to the patient in a controlled manner. This whole process is termed as "Ventricular Defibrillation".

1. <u>INTRODUCTION</u>:

The condition and proper functioning of heart are monitored by recording and studying the heart beat, by a process known as Electrocardiography (ECG), An ECG signal has several peculiar properties, thereby making their study and drawing conclusions from them very specific and reliable. A typical ECG waveform looks like as in the figure:



Some major properties of an ECG signal are:-

1. The shape of the waveform remains same for all healthy hearts, with amplitude varying amongst various persons.

2. For a normal, healthy heart beat (whose heart rate ~ 70-75 beats per minute), there is a PQ wave which lasts to around 0.3 to 0.4 s, a QRS peak, which is around 0.1-0.15 seconds long and an ST wave which is again about 0.3-0.4 seconds long.

3. The QRS peak is peculiar of a heart signal. It is a sharp peak with its peak height to be around 5-6 times higher than the maximum height in the whole signal.

Exploiting these properties of the ECG signals, one can process them and tell whether the signal corresponds to a normal human heart, or ventricular fibrillation (which corresponds to a highly distorted wave with much higher average derivative over a time period), or any other arrhythmia like tachycardia (higher heart rate than normal - >100 beats per minute), Bradycardia (lower heart rate than the normal - <50 beats per minute).

Now, in order to remove ventricular fibrillation, user has to provide a high voltage shock to the patient. This shock should last for maximum 0.5 seconds, and the amount of current flowing should be quite low, in order to prevent really fatal results

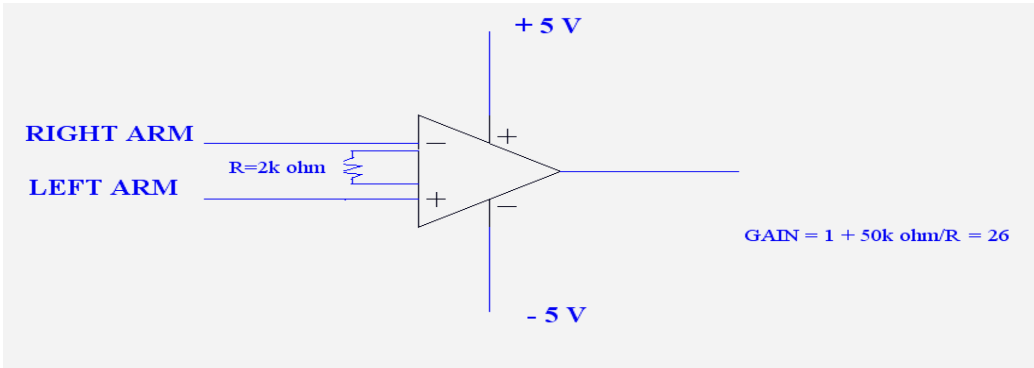
2. PRODUCT DESIGN:-

The design of a ventricular defibrillator mainly includes the following steps:

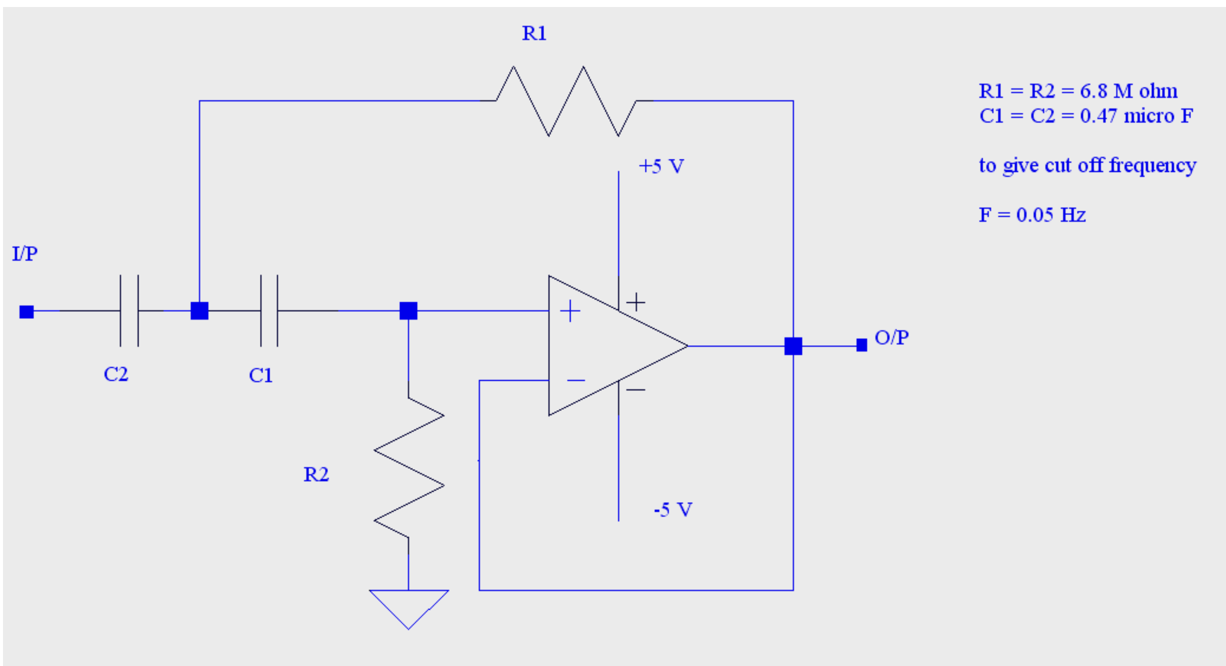
1. **ECG Signal Acquisition: -** We have used the most standard circuit in order to acquire ECG signals from our body. In this method, the signals from our body are recorded by means of 3 cables which are placed at right arm (RA), left arm (LA) and right leg (RL) of the body. This signal is then passed through the remaining circuit which includes :

   i. *Surface Electrodes*, which convert the bio-potentials into electric voltage, so that the signal can be processed electronically. These waves are sensed through a metallic button, made up of Ag-AgCl metal.

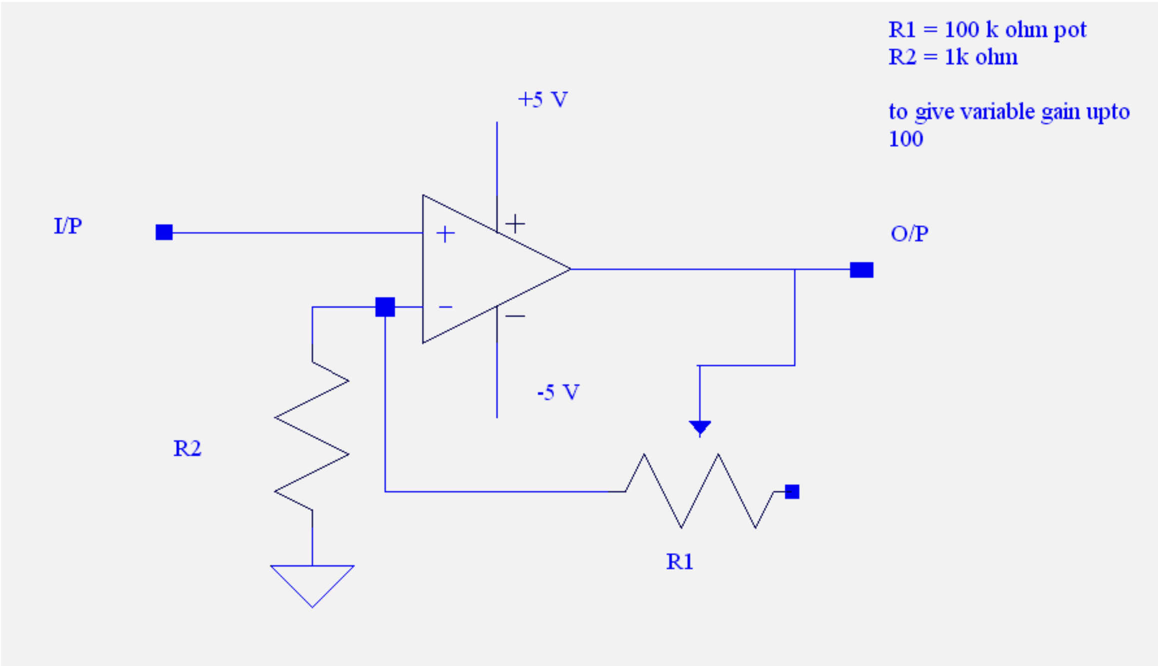
   ii. *Preamplifier*, which is an instrumentation amplifier with the signals from the 2 arms as its input. We have used AD 620 as our instrumentation amplifier. The circuit diagram is as follows :



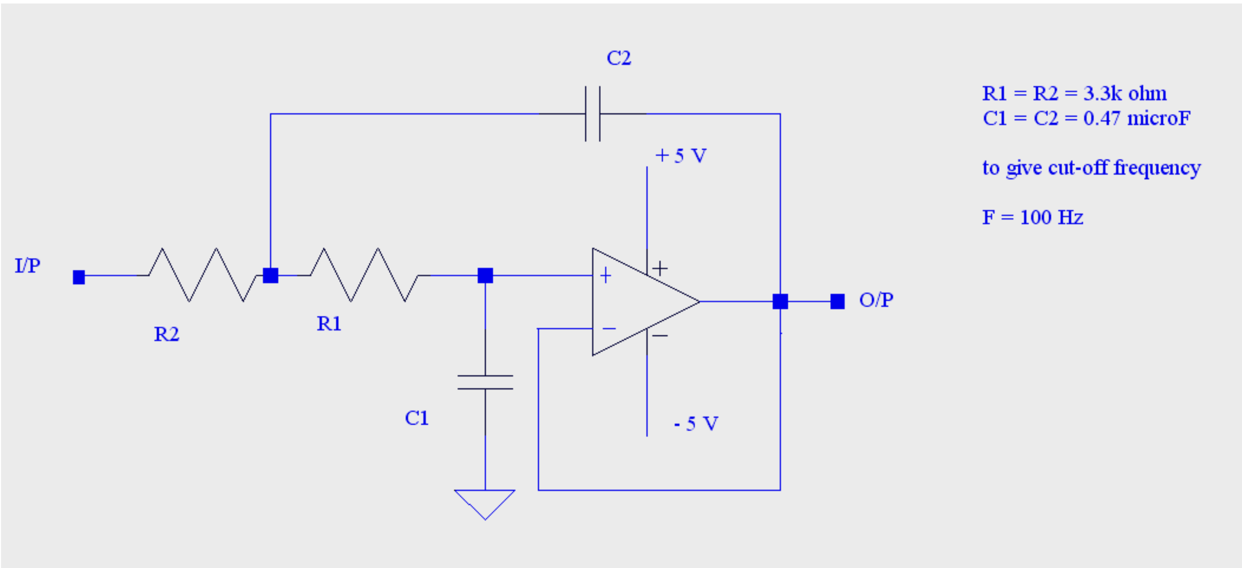
iii. *A High Pass Filter*, whose cut-off frequency = 0.05 Hz, in order to remove DC component, which gets added through our bodily contacts with electrodes. LF 412 has been used for this purpose. The circuit diagram is as follows :



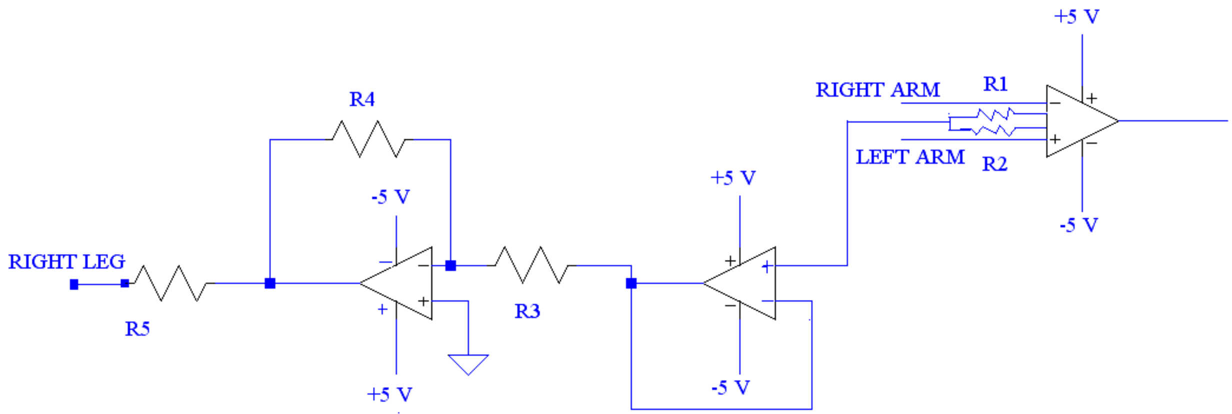
iv. *An Amplifier*, which is used to supplement the gain of the instrumentation amplifier, as the latter is not sufficient for proper reading of ECG signals. We have used LF 412 for this, and the gain is variable upto 100. The circuit diagram is as follows :



v. *A low pass filter,* which has a cutoff frequency of around 100 Hz. Even though the ECG signal has very low fundamental frequency, such larger bandwidth is chosen so as to retain high frequency components of the ECG signal (i.e., the QRS peak). LF 412 is used in the circuit. The circuit diagram is as follows :



vi. *Right Leg Drive Circuit,* in which the common mode voltage of the signal from the 2 arms is, first, inverted by the right-leg amplifier and then fed to the right leg of the patient. In order to minimize the current flow, this common mode voltage is fed to a voltage follower circuit instead of directly connecting to the inverting amplifier. This circuit acts as a feedback loop to reduce the common mode noise from the 2 arms. LF 412 and AD 620 have been used for this purpose. The circuit diagram is as follows :



2. ECG Signal Processing :-

This is the most important part of the whole project as it is all about reading the ECG signal and interpreting. For this purpose, ATMEGA-16L microcontroller, as it has a large RAM of 2k, which is used for saving large data samples of the ECG waveform, hence, making the conclusions more accurate and more reasonable.

The algorithm for ECG processing is as follows. First of all, we connect the ECG source to the microcontroller, which takes samples for 2 seconds (sample rate = 50 samples/sec). From these samples, it calculates the minimum and maximum values taken by the signal in one time period. Then it takes samples again for next 10 seconds and stores these 500 values in an array. A derivative array is also defined from the signal array as

Derive[i] = signal[i] – signal [i-1]

This array corresponds to the sampled values of derivative of the original signal. From the signal array, no. of QRS peaks and their position and height can be determined in the sample with the help of earlier determined maximum and minimum values. From the distance between 2 QRS peaks, heart rate is calculated. For heart rate < 60, *Bradycardia* is detected. For heart rate > 100, *tachycardia* is detected. For heart rate in between them, it is the case of a *normal human heart.* For no clear detection of QRS peaks or varying heart rates in the sample, it is the case of some arrhythmia.

For the detection of ventricular fibrillation, some quantities are defined as,

lowlimit = qrsheight/30

baselimit = qrsheight/8

highlimit = qrsheight/8

baseln = baseln + (signal[i] - baseline)/64

and the following algorithm is used,

```
if deriv(i) < lowlimit AND signal(i)-baseln(i) < baselimit
                horpoint =horpoint+1
if deriv(i) > highlimit
                 vertpoint=vertpoint+l
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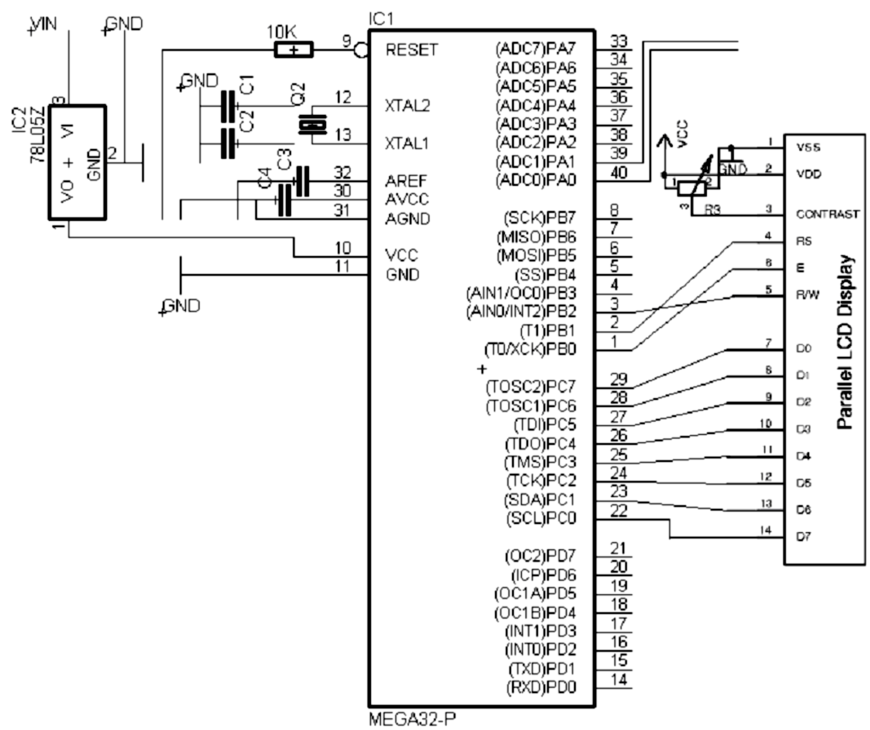
Now, for every 500 samples,

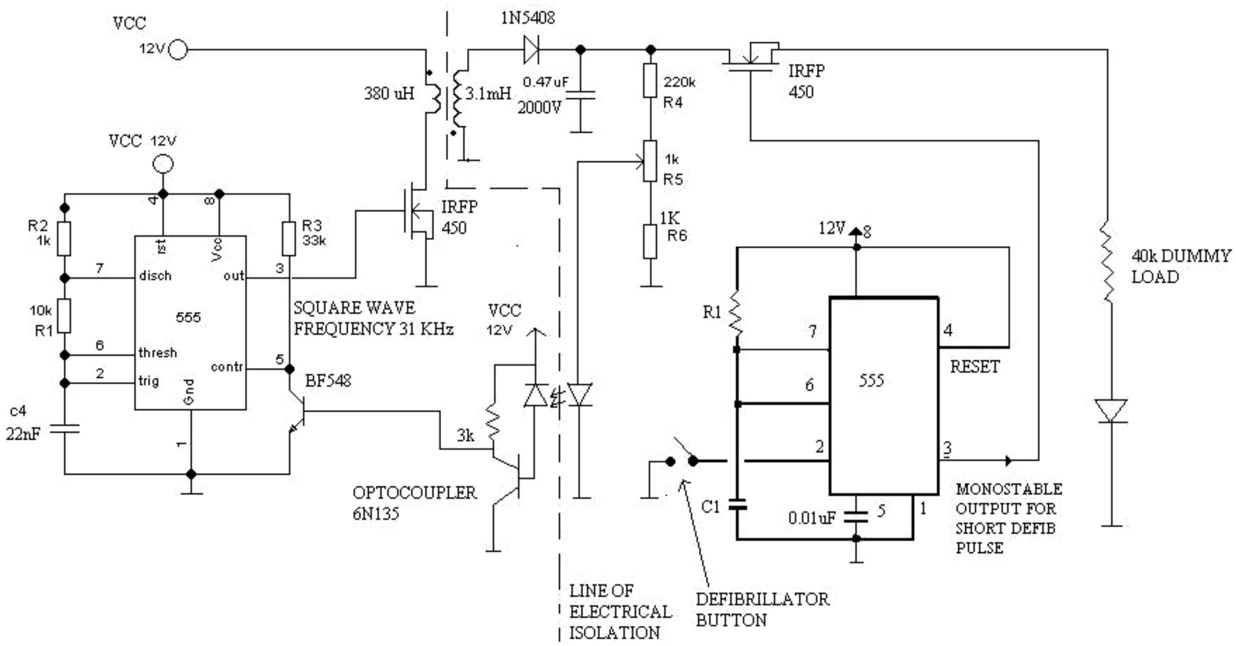
if horpoint < 35 AND vertpoint > 200

Ventricular Fibrillation is detected; otherwise there is some other arrhythmia.



CIRCUIT DIAGRAM FOR ECG PROCESSING

3. Defibrillator Circuit (High Voltage Shock Generator) :-



DEFIBRILLATOR CIRCUIT USING FLYBACK CONVERTER

A *Fly Back Converter* has been implemented in order to generate high voltage of around 400V from a battery of 12 V, in order to provide defibrillation. As soon as, ventricular fibrillation is detected by the ECG processing block, the user is prompted to switch ON the defibrillator circuit and give a high voltage shock to the patient. The construction and working of the defibrillator unit is as follows.

When the switch at the primary side of the transformer gets ON, current starts flowing into the primary side of the transformer. As a result, the secondary winding of the transformer gets energized and current starts flowing into the capacitor. Hence, the capacitor gets charged up and voltage across it goes on increasing. Now, when the switch at the primary side gets turned OFF, current ceases to flow into the primary side. As a result, the connection between the secondary and the capacitor goes off and the capacitor starts discharging through the load. This load gives feedback to the controller of the astable multivibrator on the primary side through an optocoupler in order to stabilize the output voltage. When a shock is required for the patient, the switch of the monostable multivibrator is pressed. The switch turns ON for stipulated time period, and shock is given to the patient. In this circuit, transformer and optocoupler are used to provide isolation to the patient from the voltage source.

4. **<u>ECG Waveform Simulator</u> :-**

Instead of acquiring ECG signals from the body, one can simulate several signals for testing. We have used ArbExpress software from Tektronix in order to sketch waveforms of several types and these waveforms can be generated using Arbitrary Waveform Generator (AWG). Waveforms with different shapes corresponding to normal and fibrillated signals can be applied at any frequency in order to test whether the ECG processing code is working well or not.

3. <u>TESTING PROCEDURE</u>:-

The testing procedure for the circuit is as follows:

1. In order to acquire ECG signal from the body, stick the surface electrodes to the body at the specified positions, i.e., one on the right arm and one on the left arm, both near the wrist, and one on the right leg between knee and ankle. Connect the probes from the circuit to the electrodes and switch ON the circuit and see the waveform on the Digital Signal Oscilloscope (DSO). As the frequency is quite low, CRO can't be used for viewing the ECG signal.

2. If the signal to the ECG processing microcontroller is generated through simulation, then first sketch the waveform on the ArbExpress software and get it generated using Arbitrary Waveform Generator (AWG). This waveform has shape and frequency as per the will of the user.

3. For testing the ECG processing block, connect the ECG source to the microcontroller, i.e., either the ECG acquired from the body or the signal from the AWG. Now, one can see the results of ECG processing on the LCD screen, i.e., maxima, minima, no. of QRS peaks, heart rate, horpoints, vertpoints and final verdict about the nature of the waveform (i.e., normal or fibrillated and so on). The user can verify these results by looking at the waveform and comparing its peak size and frequency with the results, like heart rate, maxima, minima etc.

4. If the result of the ECG processing block is "Fibrillated" waveform, then the user will be prompted to switch ON the defibrillator circuit.

5. As soon as the defibrillator circuit is switched ON, the voltage across the capacitor goes on building up, which can be seen by measuring the voltage across it. The final shock to be given to the patient can be verified as when the switch is pressed for

delivering the shock, an LED gets lightened up for the stipulated time interval (~ 1 sec.), which means that high voltage has been applied to the patient for that much time interval.

4. TEST RESULTS, PLOTS AND OBSERVATIONS DURING EXPERIMENTATION:-

While experimenting, a number of observations were made and a number of simulations were done. They have been recorded below for the user's reference:-

TESTS MADE WITH THE ECG PROCESSING BLOCK:-

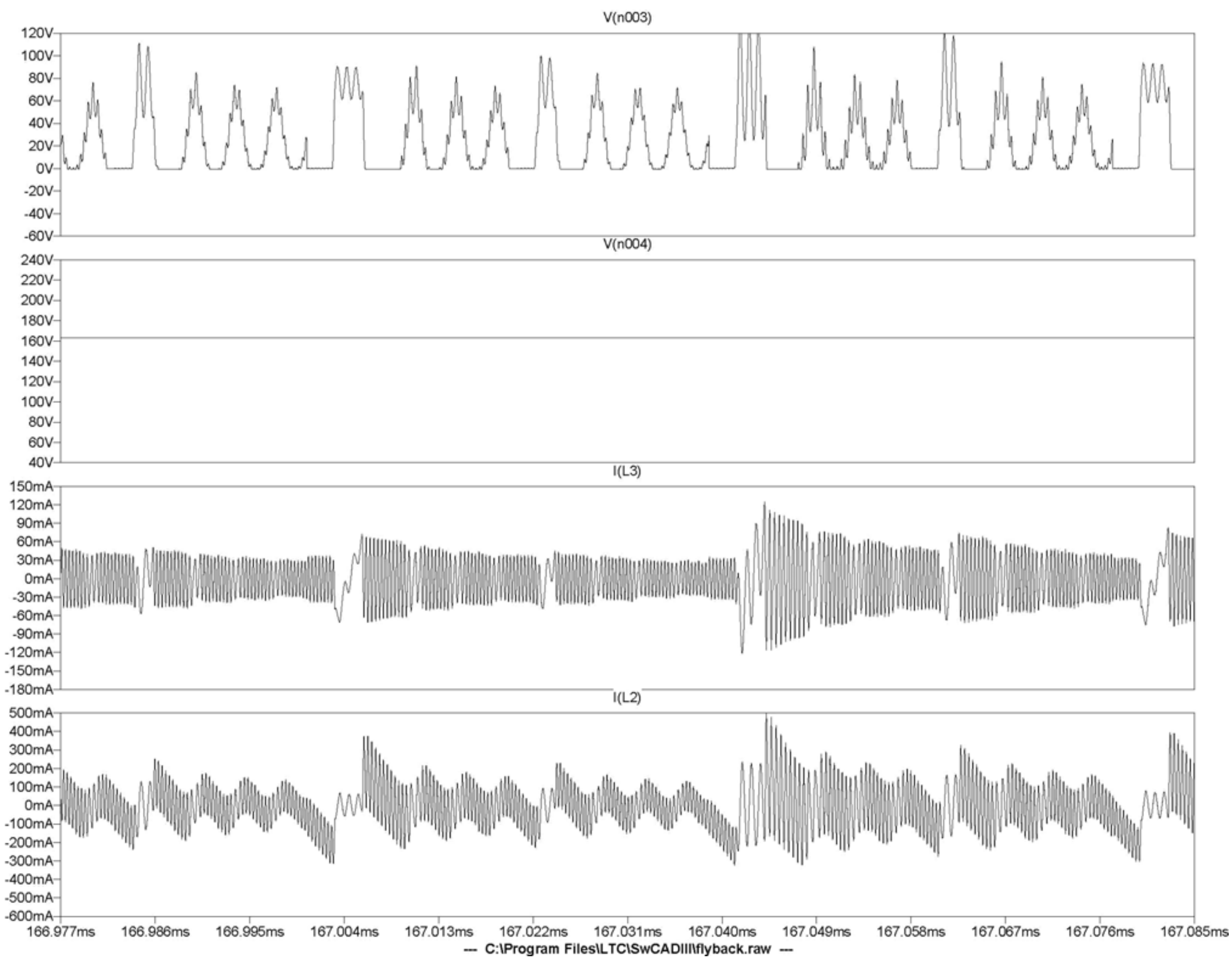
NORMAL HEART WAVEFORM GIVEN BY AFG				
SET FREQUENCY	HORPOINTS	VERPOINTS	NORMAL WAVEFORM (Y/N)	HEART RATE
0.6 Hz	130	176	N (BRADYCHARDIA)	38
1 Hz	120	180	Y	61
1.2 Hz	114	187	Y	72
1.5 Hz	108	192	Y	93
2 Hz	107	200	N (TACHYCHARDIA)	124
FIBRILLATED WAVEFORM GENERATED BY AFG				
SET FREQUENCY	HORPOINTS	VERPOINTS	NORMAL WAVEFORM (Y/N)	HEART RATE
1 Hz	13	221	N (FIBRILLATION)	-
2 Hz	8	226	N (FIBRILLATION)	-
3 Hz	3	229	N (FIBRILLATION)	-

TESTS MADE WITH DEFIBRILLATOR BLOCK

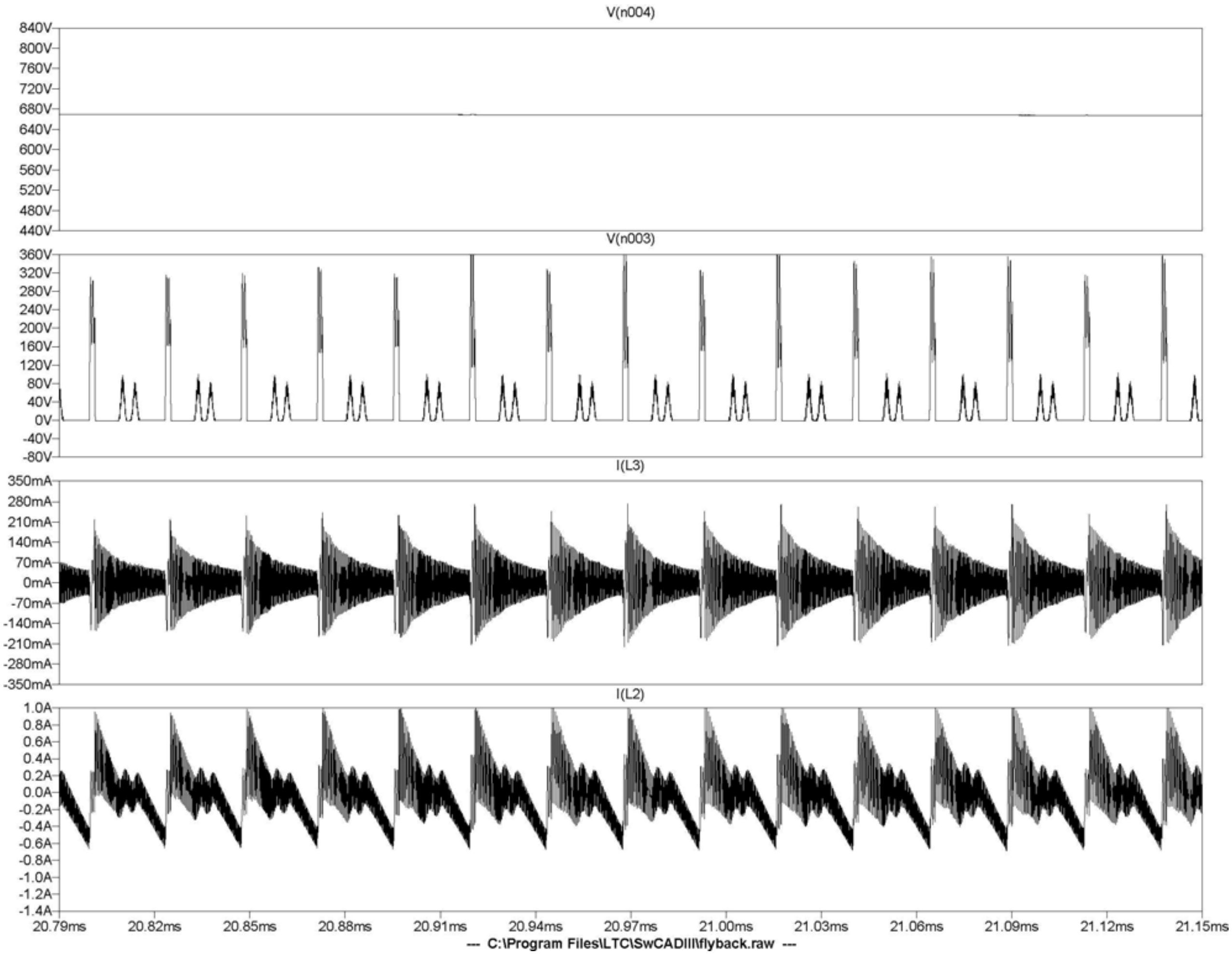
VOLTAGE OUTPUT OF FLYBACK CONVERTER	
POTENTIOMETER SETTING R4 = (ohms)	OUTPUT VOLTAGE
610	301
500	310
420	318
400	333
352	344
320	360
312	370

LTSPICE SIMULATIONS OF DEFIBRILLATOR BLOCK

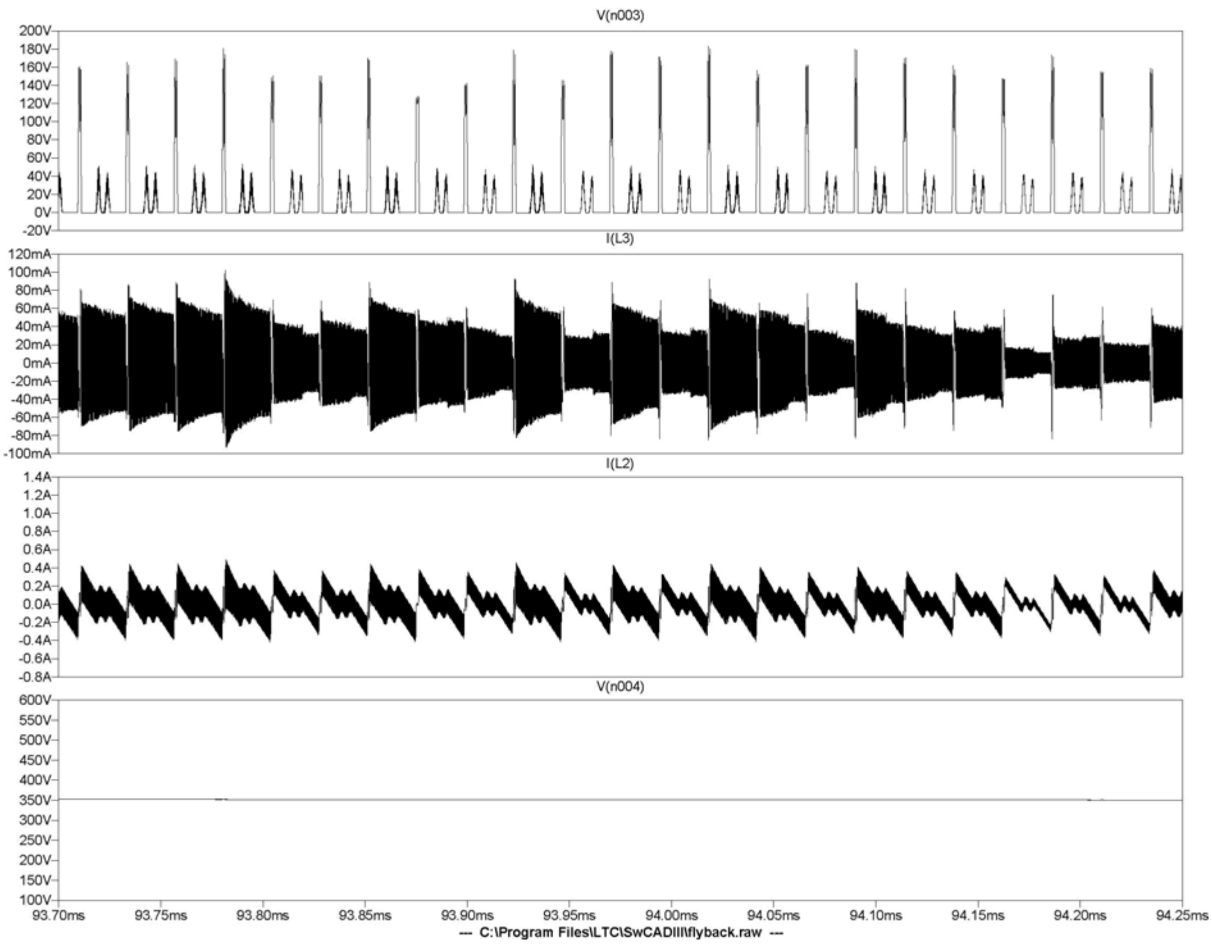
SIMULATION FOR OUTPUT VOLTAGE OF 160 V



SIMULATION FOR OUTPUT VOLTAGE OF 670 V



SIMULATION FOR OUTPUT VOLTAGE OF 350 V



5. DISCUSSION OF THE RESULTS AND SUGGESTIONS FOR FURTHER IMPROVEMENT:-

(i) ECG Acquisition block:-

Comments about the Result:-

The resulting ECG signal is carrying significant amount of noise. Hence, it is a bit risky to use these signals for further processing.

Suggestions:-

One can use more filters for cutting down noise of appropriate frequencies to bring down the noise. Also one can use effective envelope detector because the shape of the resulting signal resembles to that of actual ECG.

(ii) ECG Processing block:-

Comments about the result:-

The sample rate of the microprocessor is 50 sample/sec. This can be increased to make the results much more accurate.

Suggestions:-

A microcontroller with more RAM can be chosen or programming can be done in EEPROM in order to cope with higher data rate.

(iii) Defibrillator block:-

Comments about the result:-

Voltage has been multiplied many times but still is not equivalent to the voltage levels used for professional purposes. We were limited to reach such voltages due to ratings of the available devices. Isolation has been done by using transformer and optocoupler, so the patient's body is isolated from the main power supply

Suggestions:-

Higher rating devices can be used to reach higher voltage levels (similar to professional standards). A proper testing circuit can be made instead of using just an LED for laboratory demonstration.

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6. REFERENCES:-

1. "Embedded Web Server Based Data Acquisition System", a report by Sri Ranganadh Thatha under Prof. Vivek Agarwal, January 2003.
2. "EKG with Arrhythmia Detection" by Bob Schoonover under Prof. Gary Swenson, 2008.
3. L. PatomLki and M. Jkviluoto, "ALGORITHM FOR DETECTION OF VENTRICULAR FIBRILLATION ON LINE IN A CCU", University of Kuopio, Finland, 1990

7. USER MANUAL:-

This "VENTRICULAR DEFIBRILLATOR" is a complex device and unless the user has appropriate know how of usage of the device, it is a bit difficult and risky to handle. Therefore, to improve the user-friendliness of the product, we would like to lay down some guidelines for safe and smooth usage by laymen:

- First of all, the device needs to acquire the heart signals from the user. For this, the user has to attach the surface electrodes at appropriate positions on the body, i.e., one on right arm, one on left arm (both near the wrist) and one on right leg. After this, the user needs to connect the probe to the appropriate electrode. The initials of the desired position of the probes are scripted on them, viz., RA, LA and RL.
- After these connections, the user has to switch on the power supplies to the ECG Acquisition block. The output can be seen on a digital oscilloscope by choosing appropriate scales and positions by the user.

- Now this ECG signal goes to the ECG Processing block, which reads and processes the incoming ECG signal (While Lab demonstration, we can use simulated ECG signals for testing of the microcontroller but for common purposes, real ECG signals are to be used). The user has to press the switch for the activation of ECG processing block.

- After processing is complete, the user will get several information about his heart signals, like the heart rate, maxima, minima, horpoints, vertpoints, no. of QRS peaks and the final decision about the nature of the signal (i.e., normal, fibrillated or any other arrhythmia). Most of these information are not useful to the laymen but have been displayed only for lab demonstration.

- In case, the wave comes out to be fibrillated, the user will be prompted to use the defibrillator block. For this, the user needs to switch the defibrillator circuit and to deliver the shock, the switch at the output end needs to be switched on. The shock will be delivered for the stipulated time interval, as decided by the circuit.

<u>Precautions and Sources of Error</u>:-

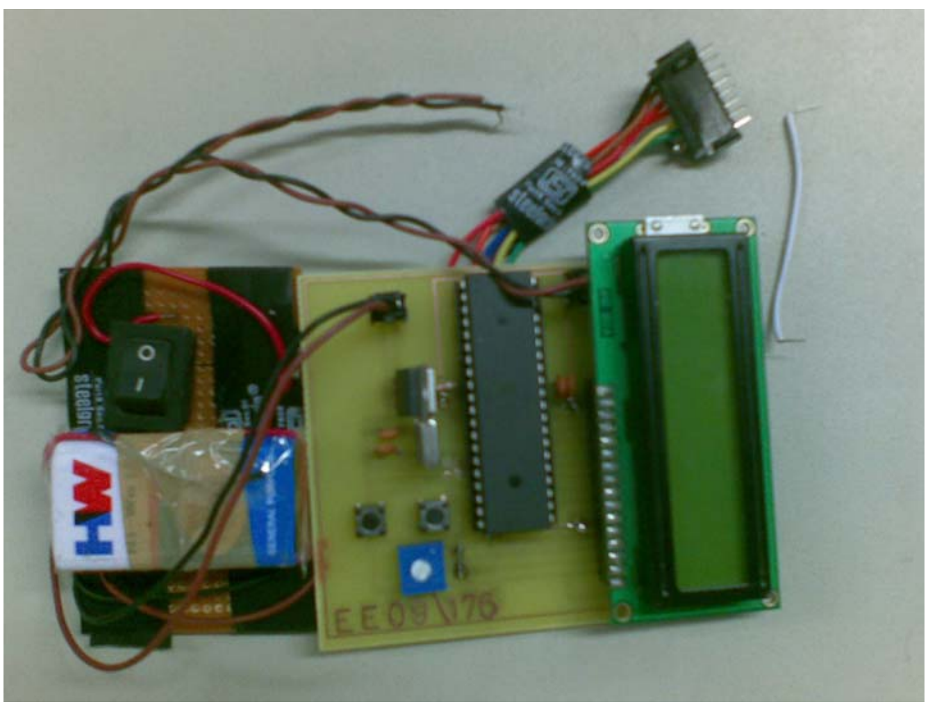
- The effect of motion of user can distort the ECG signal. Hence, the user needs to calm and at rest while ECG is being read.

- The distortion of ECG signal may lead to wrong sampling and hence wrong interpretation by the microcontroller.

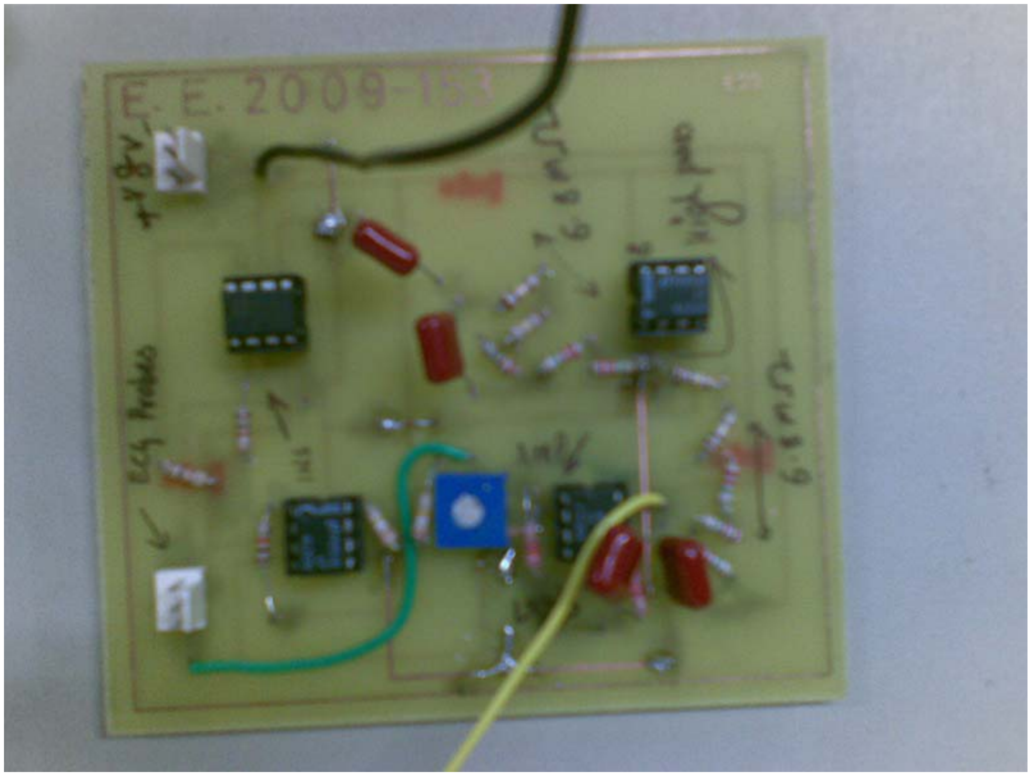
- The user needs to be precautionary and completely insulated while delivering the shock to prevent any injury.

SNAPSHOTS OF CIRCUITS AND COMPONENTS USED:-

DEFIBRILLATOR BLOCK



ECG SIGNAL PROCESSING BLOCK



ECG ACQUISITION BLOCK

ARBITRARY FUNCTION GENERATOR

NORMAL ECG WAVEFORM FED BY AFG

FEBRILLATED ECG WAVEFORM FED BY AFG