Palestine Polytechnic University

College of Engineering

Design and Implementation of Defibrillator analyzer

By

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Submitted to the College of Engineering In partial fulfillment of the requirements for the Bachelor degree in Biomedical Engineering June 2021

الاهداء

من لله عزوجل مكانة و كرامة ..لمن علمني العطاء دون إنتظار ..لمن أحمل اسمه بفخر كبير ..أسأل الله أن يطيل حياتك لترى الثمار التي أتى حصادها بعد فترة طويلة ..انتظر و ستبقى كلماتك نجوما تهديهم اليوم و غدا و الى الأبد **.. والدي العزيز**

إلى ملاكي في الحياة ..لمعنى الحب ..لمعنى الرقة والتفاني ..الى ابتسامة الحياة وسر الوجود ..لمن كان دعاءها سر نجاحي وحنانها شفاء جراحي ..الى أغلى حبيبة **..امي الحبيبة**

لمن هم اكبروعليهم يعتمد .. على شمعه مشتعلة تنير ظلام حياتي ..لأولئك الذين أكتسب معهم القوة والحب بلا حدود .. لمن عرفت معهم معنى الحياة **.**

كلمة شكرأرسلها إلى أساتذتي الأجلاء الذين ضحوا بوقتهم وجهدهم وراحتهم وأغدقوا بعطائهم الوافر والمتواصل لتكويننا وصقل مهاراتنا وتزويدنا بالمعارف والمهارات التي ستجعل منا حتما مهندسين في المستوى المطلوب ونسمو بتعليمنا ونرقى به إلى مصاف الدول المتقدمة و لم لا ونحن تكونا على يد أساتذة ومهندسين يعجز لساني عن وصف جديتهم وتفانيهم في عملهم (أساتذة تخصص الاجهزة الطبية).

منك تعلمنا، أن للنجاح أسرار، ومنك تعلمنا أن المستحيل ممكن أن يتحقق ، ومنك تعلمنا أن الأفكار الملهمة تحتاج إلى من يغرسها بعقولنا فلك منا كل أنواع التقدير والشكر... **مشرفتنا المهندسة فداء الجعافره**

كلمة شكر وثناء أسجل بها امتناني وشكري الخالص و أخص بالذكر المهندس **علي عمرو** لتوجيهاته ونصائحه وجهوده معنا.

والشكر لكلا المهندسين **وضاح سلطان** و **محمد القيسي** لجهودهما الفاضلة معنا.

Abstract

Defibrillator analyzer is one of the most important calibration devices that is specified to test quality and functionality of defibrillators, in order to avoid injuries that may occur to patient thus to a higher or a lower dose of DC shock that has been obtained initially from defibrillator device. This project aims to design a low cost defibrillator analyzer, that depends on the received joule which is delivered by defibrillator, and attenuating the voltage to a sensible ratio that will be conditioned and programmed as an energy value that will be compared to the received energy from defibrillator in order to test the quality of the defibrillator for any need for calibration or maintenance.

ملخص المشروع

جهاز إختبار أجهزة الصدمات الكهربائية أحد اهم أجهزة المعايرة الطبية،يختص باختبار كفاءة جهاز الصدمة الكهربائية تفادياً للأضرارالتي قد تلحق بالمريض نتيجة لوصول قيمة جول زائدة أو قيمة أقل من القيمة التي تم ضبطها في جهاز الصدمة الكهربائية.

يهدف هذا المشروع إلى تصميم قليل التكلفة لجهاز إختبار أجهزة الصدمات الكهربائية،حيث يعتمد أساساً على إستقبال الجول القادم من جهاز الصدمة الكهربائية وتخفيض الجهد الواصل بنسبة مناسبة ،يتم معالجتها وإخراجها كقيمة جول ، ثم يتم مقارنتها مع قيمة الجول المدخل للحكم بصلاحية وكفاءة الجهاز أو حاجة الجهاز للصيانة .

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Chapter one

Introduction

Patient Safety is a health care priority that is emerged with the developed complex health care systems and the resulting rise of patient risks in health care facilities. It aims to prevent and reduce risks, errors and any type of harm that may occur to patients during the process of health care. A cornerstone of health care safety discipline is a continuous check on medical devices that are used in medical diagnostic and therapeutic aspects .

Medical equipment calibration is performed to ensure the overall functionality of the equipment, if it is accurate and reliable. Manufacturing equipment, medical equipment is prone to drifting and damage over time which impacts its performance. In order to retain medical equipment's effectiveness, calibration needs to be completed on a regular basis. By applying this safety criteria, equipment's will have minimal performance risks and ensure minimal uncertainties. Accuracy of medical equipment is especially important because it affects the overall output, relating to both quality and profitability.

Defibrillator analyzer ensures that the delivered energy to human body is delivered properly. In addition to guarantee the efficiency of the most important component of a defibrillator –Capacitor. Also, testing the efficiency of defibrillator battery.

1.1 Project motivation.

Defibrillator analyzer is a must-have tool in hospitals and therapeutic centers, that their absence would lead to many consequences, such that not enough DC shock dose to patient, or a higher dose of electric shock that may lead to death, tissue damage and heart failure. In addition, in case of an uncharged battery inefficient capacitor would lead to low accuracy of the output.

1.2 Project aims.

- Design and Implement defibrillator analyzer.
- Validation of DC-Shock (Energy).

1.3 Project Importance.

Lowering the percentage of accidents accruing in ICU rooms and in ambulance thus to medical device inefficiency. That we ensure proper operation of defibrillator, guarantee accurate amount of shock to patient. Validate that, Battery and Capacitor are working properly.

1.4 Time schedule of the semester.

Table1.1 Time schedual of the semester.

Week / Activities	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Finding Project Idea															
Proposal															
Collecting data															
Documentation															
Preparing for presentation															
Print documentation															

1.5 List of Abbreviations.

Abbreviations	Full word
SA	Sinoatrial ode
Bpm	beats per minute
AV	Atrioventricular
ECG	Electrocardiography
SCD	Sudden Cardiac Death

VF	Ventricular Fibrilla
AED	Automated external defibrillator
PAD	Public Access Defibrillators
VT	Ventricular Tachycardia
PEA	Pulseless Electrical Activity
SVT	Supraventricular Tachycardia
CPR	Cardiopulmonary Resuscitation
ICD	Implantable cardioverter defibrillators
DFT	Defibrillation Threshold
ILCOR	International Liaison Committee on Resuscitation
LCD	Liquid Crystal Display

1.6 Literature review

No.	Year	Study title	Details
1.	1974	DEFIBRILLATOR TESTING DEVICE	Generating a current portional to E^2 with a diode network and then integrating the current in a capacitor thus indirectly measuring the true energy.[1]
2.	2000	5 Building a Defibrillator Tester	Construct a device that tests the output of a defibrillator to ensure that it can deliver a sufficient shock to restart a heart.[2]
3.	2003	Energy levels for biphasic defibrillation	With the increasing availability of biphasic

			defibrillators for use in both the manual and hock advisory modes, considerable confusion has developed as to the appropriate energy levels to be used with these devices.[3]
4.	2013	Design and construction the low - Cost defibrillator analyze	This research has adopted the principle of voltage divider and standard calibration curves of the relationship between the set of standard output energy, the standard maximum voltage and the standard maximum current versus the digital output of them.[4] .
5.	2014	Automatic System to Test Semiautomatic External Defibrillators for Sensitivity and Specificity	Test different defibrillators on their reliability to recognize arrythmia requiring defibrillation and to recognize when there is no need for a shock.[5]
6.	2016	A discharging system for a defibrillator	The system comprises at least one high-voltage capacitor adapted to store predetermined energy, a plurality of modules, connected to a high-voltage capacitor, comprising of a

			floating power supply module which balances a plurality of semiconductor switches.[6]
7.	2017	A Study on Performance and Safety Tests of Defibrillator Equipment	Indicate a need for new regulations on periodic performance verifications and medical equipment quality control program for high risk instruments. It is necessary to provide training courses.[7]
8.	2017	Implementation of a defibrillator calibrator for working standard	There are two basic methods of measuring the energy in a defibrillator pulse. the first method is the calorimetric method, the second method is sampling method.[8]
9.	2018	DEFIBRILLATOR TESTER-AlMughtaribeen University	Design the defibrillator tester with lower coast and high accuracy to ensure a save usage of high dosage electrical devise. And encourage local production of defibrillator tester devise instead of buying from aboard.[9]

Chapter Two

Anatomy and Physiology of Cardiovascular

2.1 Anatomy and Physiology

The heart is placed under the rib cage, to the left of the breastbone and between the lungs and has about the size of a fist. It consists of four layers: The pericardium, the outmost layers the thin bag (membrane) that surrounds the heart. The next layer is the outer skin of the heart called epicardia. The myocardium is the layer of interest to us, as it is the muscular wall which contracts and relaxes, because of the electrical signals described in this chapter. The inner layer is the heart's inner skin also called endocardia, which is smooth to reduce the resistance for the blood-current.[10]

2.2 Circulatory System

As shown in Figure 2.1 the heart has four chambers through which blood is pumped. The upper two are the right and left atrium. The left atrium is responsible for receiving deoxygenated blood from the veins leading to the heart. When it contracts or depolarizes, blood is pumped into the lower left chamber called ventricle, which then pumps the blood into the lungs. The right atrium receives the oxygen rich blood from the lungs and pumps it into the right ventricle. This is the strongest muscle as it must force the blood through the aorta into the systemic circuit of the blood vessels in order to bring oxygen to the tissue cells throughout the body and even pushes the blood back to the heart again.[10]

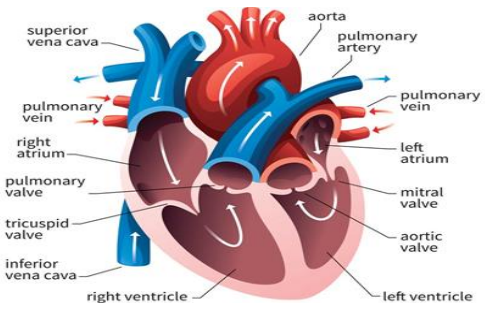

Figure2.1 The circulatory system of the heart. [11]

Between these chambers there are four valves, tricuspid, mitral, pulmonary, and aortic valve open and close to let blood flow in only one direction when the heart beats.

Blood flow occurs only when there is a difference in pressure across the valves, which causes them to open.

2.3 Electric Activation.

Electrical signals cause heart's chamber to contract and relax. The chamber contracts, when a signal passes through a chamber wall. As soon as the signal has moved out of the wall, the chamber relaxes . In a healthy heart, the chambers contract and relax in a synchronized way called the sinus rhythm. Any kind of abnormal disrupted rhythm or heart rate is called an arrhythmia which are described in detail in Section 2.4.2.[12]

The coordinated depolarization and contraction of the myocardium is carried out through the hearts conducting system, which consists of the sinoatrial node, atrioventricular node and the bundle of His and the Purkinje fibers shown in Figure 2.2.[12]

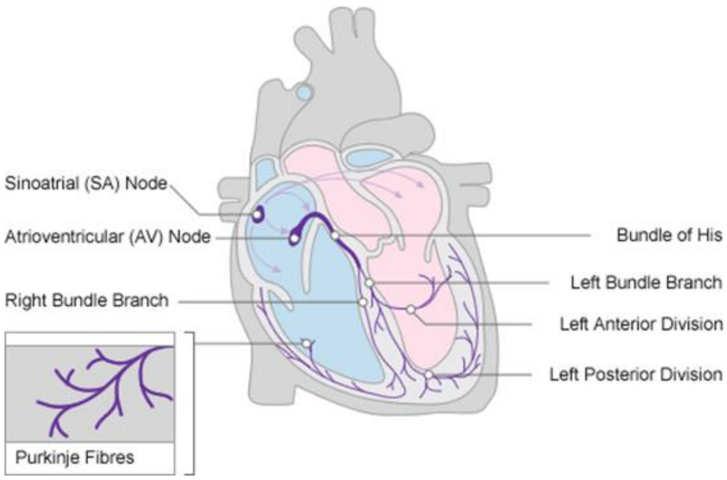

Figure 2.2 The conduction system of the heart [13]

2.3.1 The Sinoatrial Node.

The heart's natural pacemaker, the sinoatrial (SA) node is a bundle of specialized cells in the right atrium. The SA node cells create the electrical pulses which make the heart beat and control the heart rate, usually at 60-100 beats per minute (bpm).[14]

2.3.2. The Atrioventricular Node.

The atrioventricular (AV) node is the bridge that allows electrical impulses to pass from the atria to the ventricles. Like the SA node, the AV node is a bundle of specialized cells, which are the only ones allowing electricity to pass through between the atria and the ventricles. Furthermore, the cells slow down the electrical signal so that the delay gives the atria time to contract and relax before the ventricles do.[14]

2.3.3 The His-Purkinje System.

The His-Purkinje system is placed in the ventricles and consists of a pathway of fibers sending the electric impulses to the muscular walls of the ventricles, causing them to contract. The parts of the His-Purkinje system include:

- His Bundle or Common Bundle: the start of the His-Purkinje system.
- Right and left bundle branch.
- Purkinje fibers: the end of the system.[14]

2.4 Electrocardiogram

The electric activity of heart can be recorded and visualized by measuring ,at the surface of the body using an ECG. This is achieved by connecting various leads to the torso and/or extremities in order for a voltmeter to measure the electrical signal.[15]

2.4.1 Sinus Rhythm

Three major waves of electric signals appear on the ECG. Each one shows a different part of heartbeat. The normal range for sinus rhythm is between 60 and 100 bpm. In Figure 2.3ECG signal relation to the heart’s conducting system described in the previous subsection as shown. The meanings of each waveform are explained in the next subsection.[15]

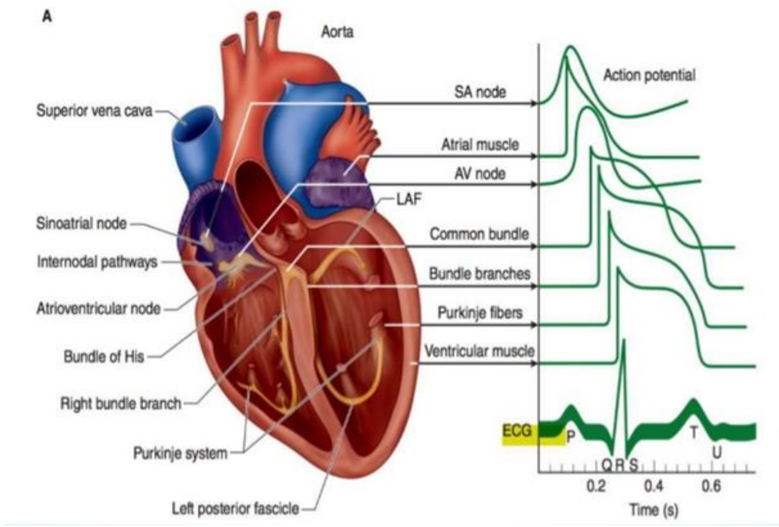

Figure 2.3 Electrophysiology of the heart.[16]

The typical ECG shown at the bottom of Figure 2.3, is composed of Einthoven waves which are called P, Q, R, S, T, and U. The first wave is called the P wave. It records the electrical activity of the heart's atria. Next part of tracing is a short downward section connected to a tall upward section called the QRS complex. This complex indicates that the ventricles are contracting to pump out blood. The QRS complex also ends the PQ interval which represents delay in AV node. The flat part from downward S peak to the upward T wave is called the ST segment. The ST segment indicates the amount of time from the end of the contraction of the ventricles to the beginning of the rest period before the ventricles begin to contract for the next beat. The last upward curve called T wave, records the heart's return to resting state.[17]

2.4.2. Arrhythmias

Arrhythmias or dysrhythmias are abnormal heart rhythms. They can cause the heart to pump in a lower efficiency which is called cardiac arrest. The main reasons for cardiac arrest are.[17]

1. Sudden Cardiac Death

The field of applications of external defibrillators can be summarized by the term Sudden Cardiac Death (SCD). According to American Heart Association (AHA), SCD, also called sudden death, occurs when the heart stops abruptly (cardiac arrest). The victim may or may not have a diagnosed heart disease. The time and mode of death are unexpected. It can occur within minutes after symptoms appear, or there may be no symptoms before collapse. The most common underlying reason that patients suddenly die from cardiac arrest is coronary heart disease. The most common arrhythmias are described in detail in the next sections.[17]

2. Ventricular Fibrillation

VF is a chaotic, disorganized electrical storm, which, if left untreated, will result in an unsalvageable patient. The only effective treatment for VF is immediate defibrillation. The most important predictor of outcome is the rapidity with which a patient who is in VF is defibrillated. The survival from VF decreases approximately by 10% for each minute of delay in defibrillation therapy. As a result, the assumption of VF in an arrested patient, the goal is to make an early defibrillation, has become a priority. Technology at this point allowed for a developed AEDs, which now are widely used as Public Access Defibrillators (PAD).[18]See figure 2.4

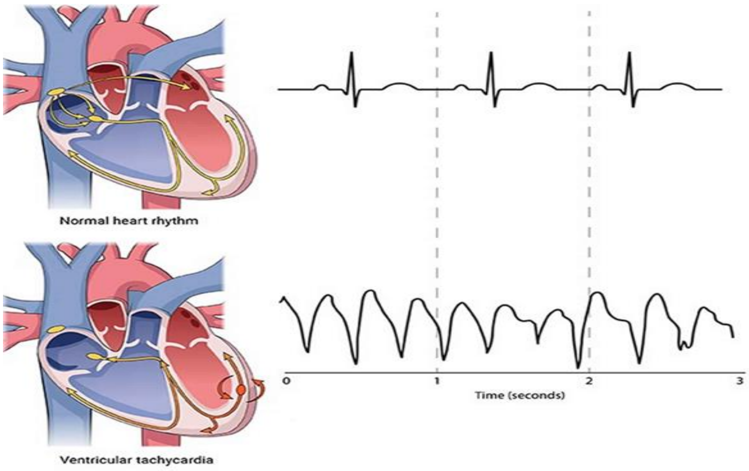

Figure 2.4 Ventricular Fibrillation.[18]

3. Ventricular Tachycardia

VT occurs when electrical impulses cause rapid ventricular depolarization (140-250 bpm). Since the impulse originates from the ventricles, the QRS complexes are wide and bizarre (see Figure 2.5) VT often occur due to some form of heart disease and can occur rarely in response to exercise or anxiety. In this case, the electrical impulses and rhythmic beats are similar to the normal beat, but at a much faster rate. During VT pumping, blood is less efficient because the rapid ventricular contractions prevent the ventricles from filling adequately with blood. As a result, less blood is pumped through the body. The reduced blood flow to the body causes weakness, dizziness, and fainting. If left untreated, VT may lead to a more life-threatening condition.[17]

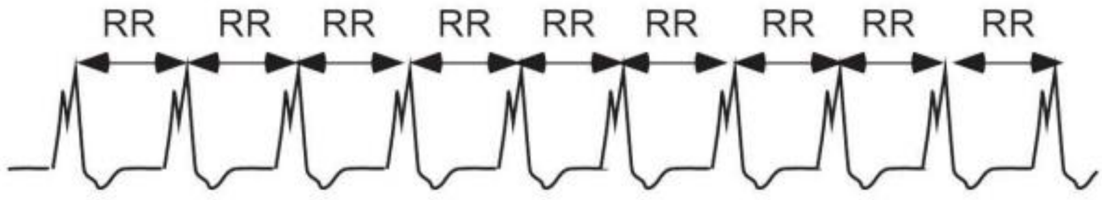

Figure 2.5 Ventricular Tachycardia.[18]

4. Asystole

Asystole stands for the heart showing no electrical activation and ECG signal shows only a straight line. In case of asystole no shock is advised. Only advanced care and drugs are capable of reviving the heart back to the normal sinus rhythm.[17]

5. Pulseless Electrical Activity

PEA means that the heart creates electrical signals but the Myocardium is not contracting, resulting in the patient having no pulse and blood pressure.[17]

6. Sinus Bradycardia

When heart's electrical activity is slower than 60 bpm is called a sinus bradycardia. This is observed especially with younger people or sportsmen during rest or sleep, ECG pattern may be normal but slow. But on the other hand heartbeat constantly below 40 bpm constitutes a life threatening heart disease which may eventually leads to asystole (see figure 2.6). In this case, shock is not advised and advanced care and drugs are required to revive the heart.

Figure 2.6 Bradycardia.[11]

7. Supraventricular Tachycardia

Supraventricular Tachycardia (SVT) includes various kinds of arrhythmias like atria tachycardia and sinus tachycardia, which can not be treated with defibrillation. Like VT the heart beat of SVT is rapid (140-250 bpm) caused by heart tissues in the region above the ventricular. The resulted ECG signal is similar to the VT signal.[17]

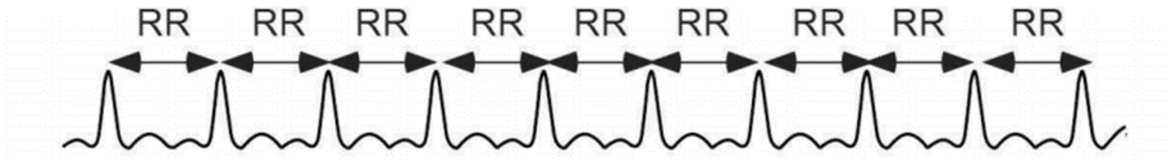

Figure 2.7 Supraventricular Paroxysmal Tachycardia[17]

Chapter Three

Theoretical Background

This chapter includes the theoretical background of Defibrillator and Defibrillator Analyzer.

3.1 Introduction

Heart diseases is a leading cause of death. An increased risk of death occur from sudden cardiac arrest (SCA). Initial rhythm of SCA is most commonly a malignant ventricular arrhythmia, either ventricular fibrillation (VF) or pulseless ventricular tachycardia (pVT), it's the occurrence of which inhibits activity of the natural pacemakers of the heart, causing a cardiac cessation. Treatment key for VF and pVT is defibrillation, supported by good cardiopulmonary resuscitation (CPR). Therefore, defibrillation and CPR remain as a cornerstone of both basic and advanced cardiac life support. When delivered early, they confer significant survival benefits.[19]

Defibrillator device shown in figure3.1, is the a very important medical instrument which is used in helping patients who have a serious heartbeat disorders that is called ventricular fibrillation. The general principles for this instrument is taking charge stored in the capacitor and discharge the stored electric energy through the electrodes and patient’s chest. This instrument can stimulate the cardiac muscle to be back in normal. Success operation rate depends on the value of the activation energy or electric current can transmitted through the chest to the cardiac muscle. As for the energy level, originated from defibrillator, shock efficiency is different for each patient because the patients have different of chest resistance.[20]

Figure 3.1 Defibrillator.[20]

3.2 Principles of Defibrillator

A typical defibrillator includes a power supply, capacitor, inductor, variable transformer and a rectifier. Figure3.2 shows a simple circuit of defibrillator. The power source can be generated from battery or the main supply. Capacitor is the most important component of defibrillator that t stores a large amount of electrical charge, then releases it over a short period of time in a patient's heart. Effective defibrillation depends on released energy at the heart. The current and charge are delivered by a discharging capacitor decay rapidly in an exponential function. Delivered current must be maintained in several milliseconds for a succeeded defibrillation. As for the inductor, it minimizes the rapid decay of current flow (delivered energy), it prolongs the duration of current flow to allow for optimum time. An adjustable transformer is used to convert the mains voltage of 240 V AC to 5000 V AC. By a rectifier, this is then converted to 5000 V DC. In practice, a variable voltage step-up transformer for selecting different amounts of adequate charge is used by specialist.[21]

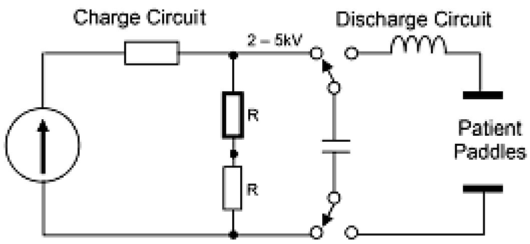

Figure3.2 Simple Circuit of Defibrillator.[21]

3.3 Types of Defibrillators

Several types of defibrillators are used to deliver electric currents to the heart muscles and correct abnormal and life threatening heart rhythms.

1. **Automated external defibrillator (AED)**

AEDs are easy to operate units, that may be used by the lay person or healthcare personnel who only have basic training. These devices analyze the cardiac rhythm and either instruct the delivery of shocks when required or deliver them automatically. As well as recommending that a shock is needed, so the system can advise on the extent of the shock what amount of shock should be delivered. The drawbacks of this technology are that the AED systems can only be used to treat ventricular fibrillation and ventricular tachycardia and not other forms of cardiac arrhythmia. In addition, the machines can take around 10 to 20 seconds to diagnose the rhythm, a gap in time that can be by-passed by a trained healthcare provider using a manual unit. Furthermore, in order to allow the machine time to analyze the cardiac rhythm, chest compressions usually need to be stopped.[22]

Figure 3.3 Automated external defibrillator.[22]

2. **Implantable cardioverter defibrillators (ICDs)**

   These units are placed directly into patients chest who are at high risk of sudden death, a medical conditions is known and diagnosed that put them at risk, or for patients who have already experienced ventricular fibrillation or ventricular tachycardia.[23]

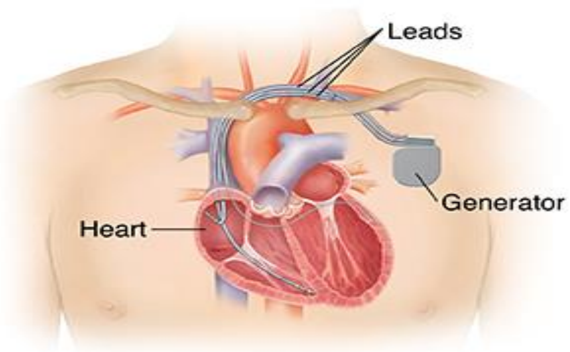

Figure3.4 Implantable cardioverter defibrillators.[23]

3. **Manual external defibrillator**

These defibrillators require more experience and training, to effectively handle them. Hence, they are only common in hospitals and a few ambulances where capable hands are present. In conjunction with an ECG, the trained provider determines the cardiac rhythm and then manually determines the voltage and timing of the shock—through external paddles—to the patient’s chest.[23]

Figure 3.5 Manual external defibrillator.[23]

4. **Manual internal defibrillator.**

   The manual internal defibrillators use internal paddles to send the electric shock directly to the heart. They are used in an open chests operations, so they are only common in the operating room.[23]

Figure 3.6 Manual internal defibrillator.[23]

5. **Wearable cardiac defibrillator.**

Further research was done on the AICD to bring forth the wearable cardiac defibrillator, which is a portable external defibrillator generally indicated for patients who are not in an immediate need for an AICD. This device is capable of monitoring the patient 24-hours-a-day. It is only functional when it is worn and sends a shock to the heart whenever it is needed. However, it is stored in the market today.[28]

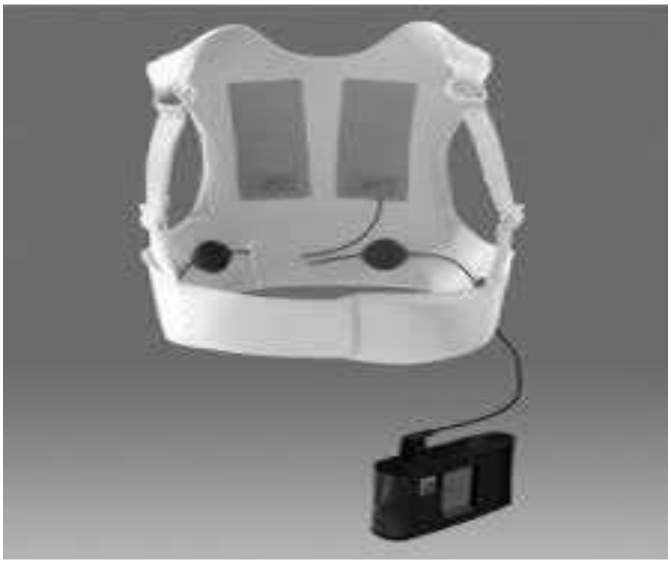

Figure 3.7 Wearable cardiac defibrillator.[23]

3.4 Waveforms and its importance

Energy-based defibrillators can deliver energy in a variety of waveforms, broadly characterized as monophasic, biphasic or triphasic.

1) **Monophasic waveform.**

Defibrillators with this type of waveform deliver current in one polarity and these were the first to be introduced. They can be further categorized by the rate at which the current pulse decreases to zero. If the monophasic waveform falls to zero gradually, the term damped sinusoidal is used. If the waveform falls instantaneously, the term truncated exponential is used (figure3.8). The damped sinusoidal monophasic waveforms have been the mainstay of external defibrillation for over three decades.[24]

2) Biphasic waveform.

This type of waveform was developed later. The delivered current flows in a positive direction for a specified time and then reverses and flows in a negative direction for the remaining duration of the electrical discharge (figure*3.8*). With biphasic waveforms there is a lower defibrillation threshold (DFT) that allows reductions of the energy levels administrated and may cause less myocardial damage. The use of biphasic waveforms permits a reduction in the size and weight of AEDs.[24]

3) Triphasic waveform.

It is said to be superior to biphasic waveform shocks for transthoracic defibrillation. It's a wave form in which acts in depolarizing the cells by application of a first electrical pulse or shock followed by a second electrical pulse having a polarity opposite to the first pulse. Finally, a third pulse having the same polarity as the first pulse is applied to the cells. There are no human studies that support the use of multiphasic waveforms over biphasic. Investigation in animals suggests that the benefits of biphasic waveform could be harnessed through the use of a triphasic waveform in which the second phase has the larger strength to lower the DFT and the third phase the lower strength, to minimize damage (figure3.8).[24]

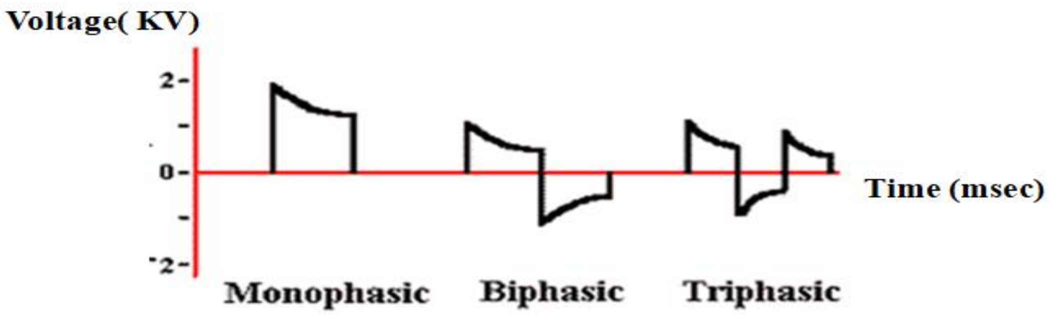

Figure3.8 Waveforms for external defibrillation.[24]

3.5 Defibrillation Energy

Most defibrillators are energy-based, meaning that the device charges a capacitor to a selected voltage and then delivers a prespecified amount of energy in joules as the equation (3.1).

$E = 0.5CV^2$…………………………..(3.1)

Where:

*E:*is the electric charge which has a measure in Joule

*C:*is capacitance value of capacitor which has measure in Farad

*V:*is the electric potential that charged in the capacitor which has measure in Volt

Modern defibrillators, deliver energy or current in waveforms. Energy levels vary with the type of device and waveform type. Several types of monophasic waveforms have been used in modern defibrillators. In this waveform, there is no ability to adjust patient impedance, and it is generally recommended that all monophasic defibrillators deliver 360J of energy in adult patients to insure maximum current is delivered in the face of an inability of patient impedance detection . Biphasic waveforms have recently been developed and approved for marketing and clinical use. They are rapidly replacing defibrillators that deliver monophasic waveforms by lower energy biphasic shocks which causes less myocardial injury and subsequent post-resuscitation myocardial dysfunction which improves potential for likelihood of survival. Recommendations of the International Liaison Committee on Resuscitation (ILCOR) state that biphasic energies less than or equal to 200 joules as efficacious as escalating higher energy monophasic shocks.[25]

Defibrillator devices have several manufacturers and each manufacturer differs in its device specifications. Table3.1 show table of defibrillator specifications for some companies.

Table3.1 Defibrillator Specifications.[26][27][28][29]

Defibrillator Type	Waveform Type	Maximum Energy	Capacitor Value	Maximum Voltage
Philips	Biphasic	200J	105uF	$2.1KV_{DC}$
Nihon Kohden	Monophasic	360J	40uF	$4.9KV_{DC}$
ZOLL	Biphasic	200J	45uF	$4.6KV_{DC}$
Hewlett Packard(HP)	Monophasic	360J	45uF	$4.3KV_{DC}$

3.6 Defibrillator Analyzer

One factor which is the main component for maintenance of medical instrument is testing and calibration for medical devices to ensure that the accuracy and precision are standard in the measurement at all time.

If the amount of energy applied to the patient is lower than the pre-set value, it will not be enough to restore normal heart rhythm. Alternatively, if the amount of energy applied to the patient is higher than the pre-set value, hazardous effects may result. So defibrillator analyzer is important to solve th problems.[30]

Figure 3.9 Defibrillator Analyzer[30]

3.7 Principle of Defibrillator Analyzer

Normally there are two basic methods for measuring the energy in a defibrillator pulse. The first method is the calorimetric method. The electrical pulse discharged into a coil of copper wire immersed in a water tank and is determined by observing the temperature changes of the coil as a function of time. The second method is the sampling method. An ordinary load and measuring the voltage and current applied, as functions of time from which the energy delivered could be calculated from these sampled signals.[30]

For the sampling method, the defibrillator calibrator is designed to measure the energy of the discharged pulse delivered by a defibrillator. The energy contained in a pulse of arbitrary wave shape, can be calculated by:

$$E = \int_0^T v(t).\, i(t)dt \qquad (3.2)$$

Where:

E :is the energy of the discharge pulse.

v(t): is the voltage as a function of time.

i(t): is the current as a function of time.

T: time duration of the pulse.

According to Ohm's law, when the voltage is applied across a fixed resistance, the energy dissipated in the resistance is described by:

$$E = \frac{\int_0^T [v(t)]^2 dt}{R} \qquad (3.3)$$

Where:

R: is the resistance of the load.

When the energy reached to the patient, it will be reduced by the equation (3.4)

$$\text{Edelivered} = E\{\frac{\text{Rpatient}}{\text{Rpatient+Rplates}}\} \qquad (3.4)$$

E: is the energy that has stored in the capacitor which has a measure in joule.
Edelivered: is the energy that comes to the patient which has a measure in joule.
Rpatient: is the patient's chest resistance (RL) which has a measure in ohm.
Rplates: is the plates resistance (L) which has a measure in ohm.

The output pulse of a defibrillator is applied across two paddles of the calibrator, with an internal load R (usually 50Ω). The voltage developed across the load is given to a squaring circuit and an integrator circuit. The pulse integrator circuit integrates the squared pulses. The integrated value divided by the resistance of the load is the energy of the pulse. From Equation (3.3), it shows that the power supplied by the defibrillator is proportional to the square of the potential difference across the resistor with a constant value.[30]

Chapter Four

System Design

This chapter includes the hardware and software stages that are required for design. The following block diagram shown in figure 4.1 demonstrates the implementation of the proposed project. The block diagram is divided into a sub-blocks to briefly illustrate the function of each stage separately.

Defibrillator tester is used to calibrate external defibrillator; by receiving energy from the defibrillator and discharge it across contact surface. The energy from it includes high voltages that is attenuated by attenuator circuit to pass it through following stages. A protection circuit receives signal and passes it to buffer circuit, which used to protect from danger.

The signal is then pass to Arduino for signal integration, energy calculation and display it in joules by LCD.

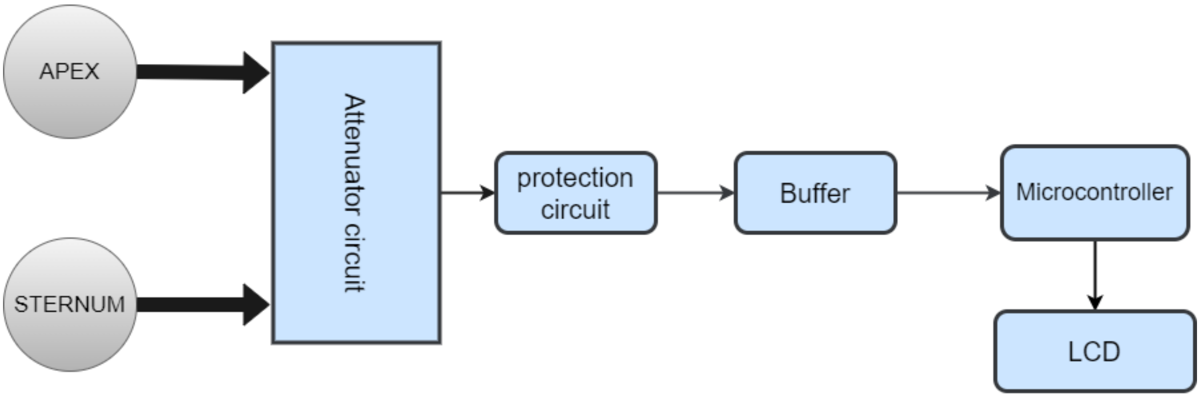

Figure4.1 Main block diagram for the system

Components of each stage will be described in more details in the following sections.

4.1 Contact Surface

Also called large defibrillator plates or paddle electrodes as illustrate in figure 4.2, receptacle for receiving the energy from defibrillator and pass through to the signal conditioning part.

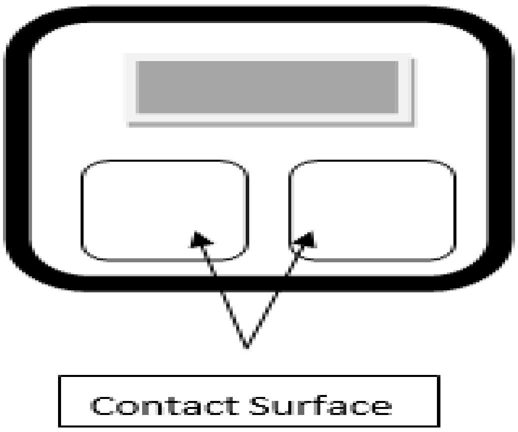

Figure4.2 Contact Surface

Normally, applying defibrillation into patients body requires holding the Paddles against the chest of a patient. Discharging operation consist of a flexible metal “paddle, a layer of conductive gel, and an adhesive ring that holds them in place on the patient’s chest.

In this project Paddles are applied to these contact surface as it is patient's chest, where Apex and Sternum are put on large defibrillator plates for discharging process. Noting that the resistance exhibited of a human body is configured as 50 **Ω**[31] in the circuit design .

For a functional discharging, these contact surfaces are made of an electrically conductive material, stainless steal with its 4.72*10^-7 Ohm resistance and it does not affect any energy loss. same material used in apex and sternum paddles, insures best conductivity.[32]

Due to differences in physical size, different electrode configurations are required when defibrillators are used with adults and children. Contact surface size suits all types of defibrillator paddles, Standard paddles size is withing 8 cm diameter to 12 cm.

The period in which should a paddle be applied to the contact surface range required in case of monophasic is within (3-12) ms, and in case of biphasic is within (1-10) ms.[32]

In addition, Voltage received from defibrillator ranges from 1000- 6000 volts, as for entered current, whenτ=0, current = 100 A within the shown equation.

$I = \frac{V}{R} e^{-t/\tau}$ ……………………..4.1

$$I = \frac{5000}{50} e^{-0} = 100 \text{ A}$$

where:

I: discharging Current(A).

V: defibrillator voltage applied(Volt).

R: Human body resistance (Ω).

τ = RC

An important notice to be corresponded is that the value of current at zero time equals 100 A as shown. But when put into patient body –Surface contact in our case, current -even with proper placement of paddles- only 4% to 25% of delivered current actually passes through patient's body.[33]

So in case of $\tau = 1$

$I = \frac{V}{R} e^{-t/\tau} \rightarrow I = \frac{5000}{50} e^{-1} = 36.78 \text{ A}$

Which is sensible to be understood by circuit elements.

4.2 Attenuator Circuit

Second stage design, voltage attenuator has been used thus to the enormous amount of voltage applied to the circuit. pointing out that these type of attenuators are used to lower voltage, dissipate power, and to improve impedance matching to enable measurements, or to protect the measuring device from signal levels that might damage it.

In general, In an external defibrillator, Voltage ratings range from 1000 Vdc to 6,000 Vdc with capacitance values covering ranges from 32 to 500 μF. [34]

The goal is to scale down a very high voltage so that it can be measured, in this stage, resistors were mainly used and attenuation sufficiently accurate if made only of resistors.

This is a multistage attenuating voltage process. As a circuit designer, a specified amount of attenuation is calculated as desired, using attenuator resistor shapes and certified tables specialized for attenuation with special measurements. Attenuator has many configurations shown in figure4.3. [35]

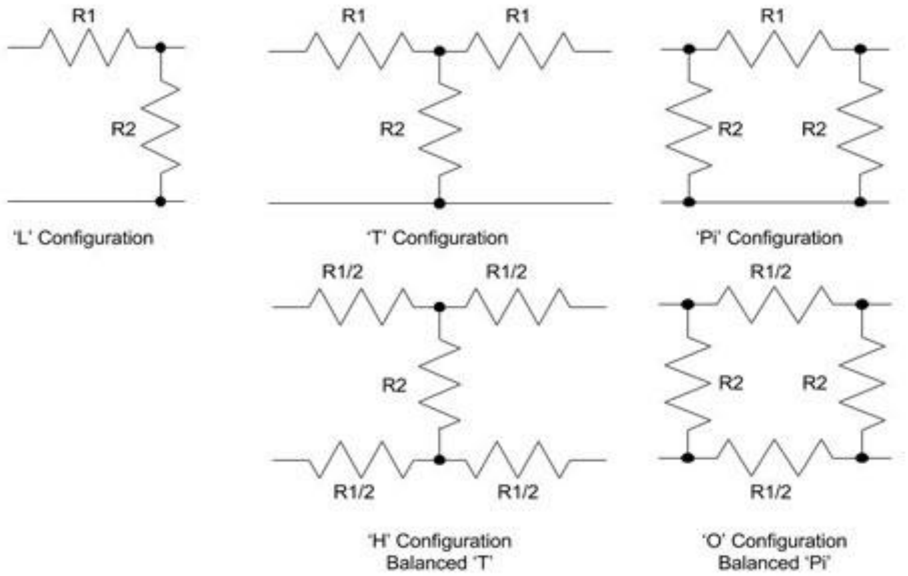

Figure4.3 Attenuator Configurations[35]

In this design T – Configuration has been used. Voltage ratios are used in the design of attenuators, are often expressed in terms of decibels. The voltage ratio must be derived from the attenuation in decibels.

The "T" configuration established layouts already have set equations and resistor values that can be used to yield the characteristic impedance (Z0), thus calculation were based on attenuator tables certified and tested and is shown in Table 4.1. [36]

Table 4.1 Resistors for T-section

Resistors for T-section			
Z = 50			
Attenuation			
dB	K=Vi/Vo	R1	R2
1.0	1.12	2.88	433.34
2.0	1.26	5.73	215.24
3.0	1.41	8.55	141.93
4.0	1.58	11.31	104.83
6.0	2.00	16.61	66.93
10.0	3.16	25.97	35.14
20.0	10.00	40.91	10.10

Formulas for T-section attenuator resistors, given K, the voltage attenuation ratio, and ZI = ZO = 50 Ω.

The T-Attenuator show in figure4.4:

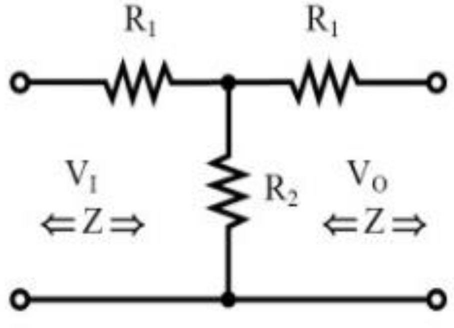

Figure 4.4 T-Attenuator [37]

To calculate R1 value, equation 4.2 is used:

$$R1 = Z(\frac{K-1}{K+1}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad 4.2$$

To calculate R2 value, equation 4.3 is used:

$$R2 = Z(\frac{2K}{K^2-1}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots 4.3$$

To calculate K, equation 4.4 is used:

$$k = \frac{Vin}{Vout} = 10^{dB/20} \ldots\ldots\ldots\ldots\ldots \quad 4.4$$

Where:

dB: attenuation in decibels.

Z: load impedance (resistive)

Using the 20 db:

$K = 10^{\frac{20}{20}} = 10$; attenuation ratio.

Attenuation circuit shown in figure4.5 is designed in this project into three stages, each stage is attenuated in the ratio of 10 as calculated earlier.

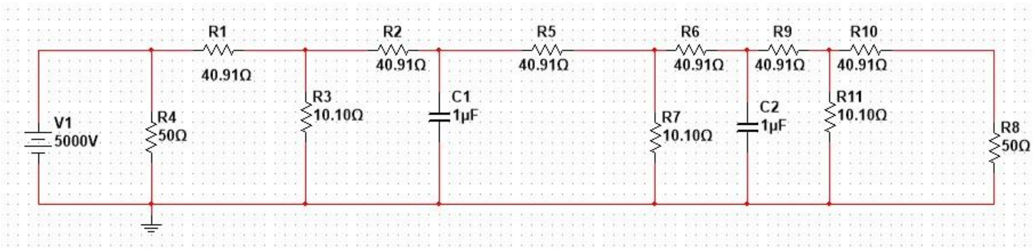

Figure4.5 Attenuator circuit Design

4.2.1 Voltage Calculations

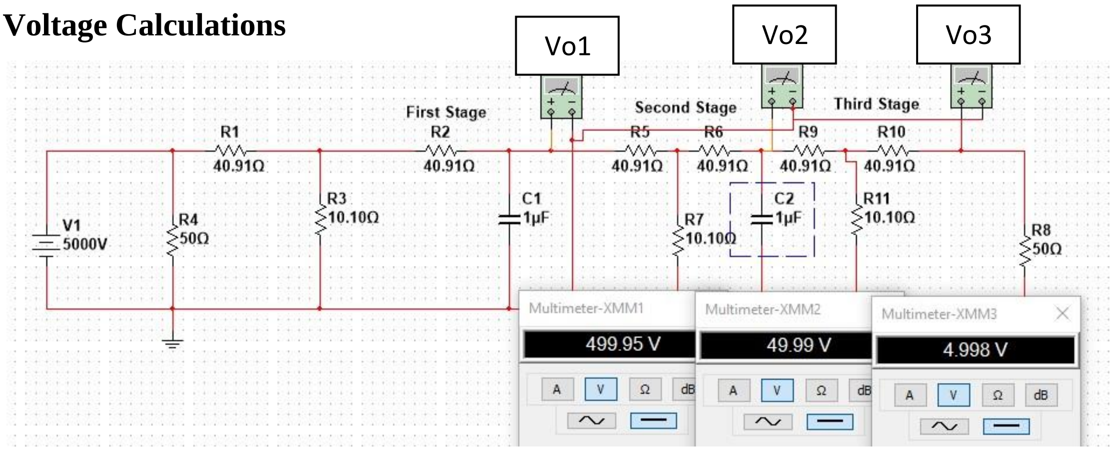

Figure4.6 Voltage Attenuator stages

- Let Vin from Dc – shock equals v = 5000 volts. Where k =10 for first stage:

$Vo1 = \frac{Vin}{K} \rightarrow \ Vo1 = \frac{5000}{10}$ =500 v.

- Second stage attenuation; Vin = 500 volt, k=10:

$Vo2 = \frac{Vin}{K} \rightarrow Vo1 = \frac{500}{10} = 50v.$

- Third stage attenuation Vin = 50 volt, k=10:

$Vo3 = \frac{Vin}{K} \rightarrow Vo1 = \frac{50}{10} = 5v.$

Capacitors were added to make signal delay.

4.2.2 Resistor Calculations

Next Step is Calculating T configuration resistance as configured in figure4.7:

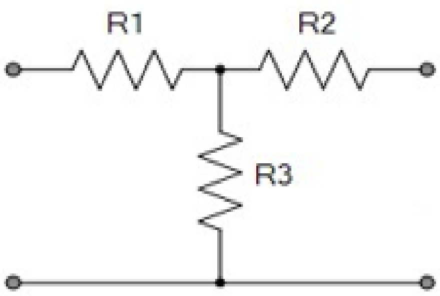

Figure4.7 T-configuration resistance.[37]

$R1 = z\ (\frac{K-1}{K+1})$→ R2=R1

$R3 = z\ (\frac{2k}{k^2+1})$

Z: load impedance (50Ω)

$R1 = z\left(\frac{K-1}{K+1}\right) = R1 = 50\left(\frac{10-1}{10+1}\right) = 40.9.9\Omega$

$R3 = 50\left(\frac{2*10}{10^2+1}\right) = 10.10\Omega$

After calculation the values of resistance, voltage values shown in figure4.8:

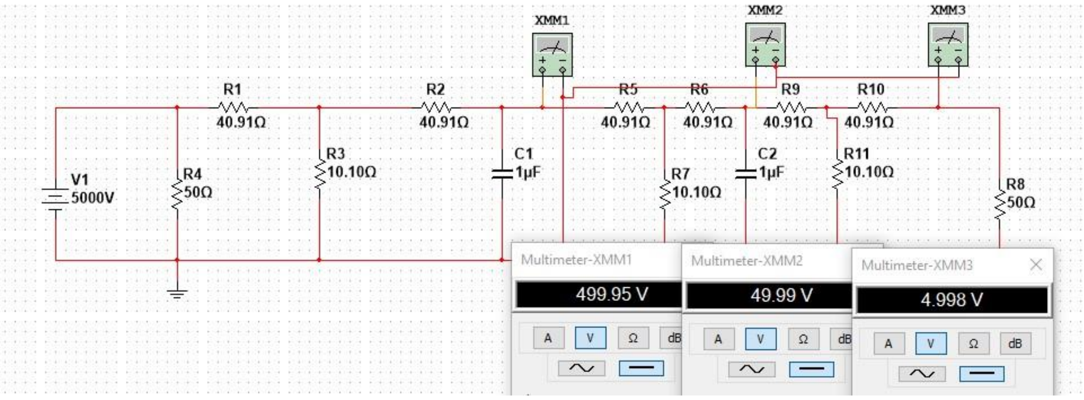

Figure4.8 voltage attenuated values and resistor values.

4.2.3 Current Calculations

Current is first introduced in defibrillator, equaled 100 A before reaching human body.

As calculated in first stage, the current which reaches human body is calculated using this equation:

$I = \frac{V}{R}e^{-\tau}$ *where* τ *equals V/RC*

On the other hand, Current in circuit shown in figure4.9 was found using nodal analysis:

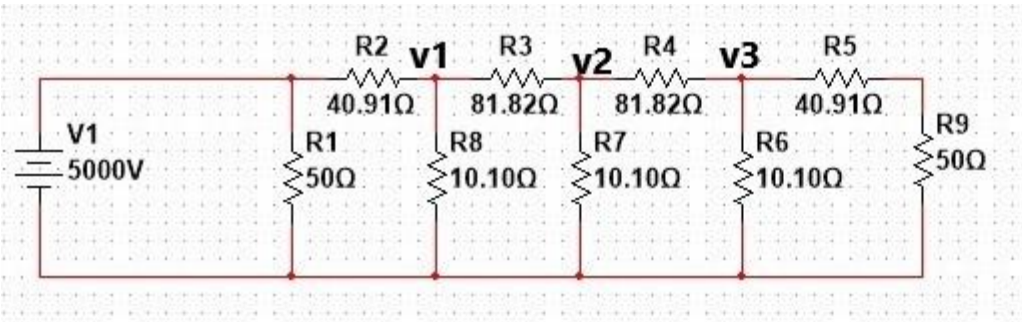

Figure4.9 Nodal Analysis for designed circuit

∑Iin=∑Iout

- At nodal V1 :

$\frac{5kv-V1}{40.91} = \frac{V1}{10.10} + \frac{V1-V2}{81.82}$ …….. (1)

- At nodal V2 :

$\frac{V1-V2}{81.82} = \frac{V2}{10.10} + \frac{V2-V3}{81.82}$ …….. (2)

- At nodal V3 :

$\frac{V2-V3}{81.82} = \frac{V3}{10.10} + \frac{V3-0}{90.9}$ …….. (3)

After compensation:

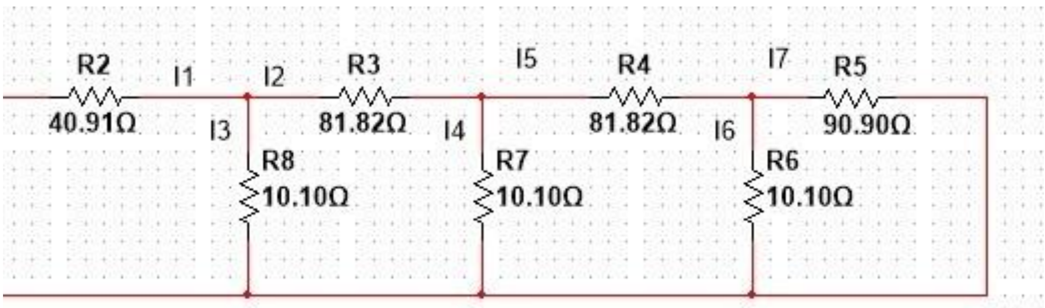

Figure4.10 Current distribution using nodal analysis

$$I1 = \frac{5kv - 909.7597}{40.91} = 99.98 = 100A$$

$$I3 = \frac{909.7597}{10.10} = 90.075A$$

$$I2 = \frac{909.7597 - 98.862}{81.82} = 9.9107A$$

$$I4 = \frac{98.862}{10.10} = 9.788A$$

$$I5 = \frac{98.862 - 9.884}{81.82} = 1.33A$$

$$I6 = \frac{9.884}{10.10} = 0.9786A$$

$$I7 = \frac{9.884}{90.90} = 0.108\text{A}$$

Measuring voltage, resistor values and currents has acquired for a succeeded attenuator circuit in which voltage has been attenuated to protect full circuit and compensate it to next step of design, with a rational value of current to enter next stage.

4.3 Protection Circuit

Protection circuit are used to protect any electronic appliance or circuit from any sudden mis-happening.

Overvoltage protection is a power supply features which cutoffs the supply whenever input voltage exceeds the preset value.

Overvoltage protection is built using Zener diode and PNP transistor. This circuit disconnects the output when the voltage exceeds the preset level. The preset value is the rated value of the Zener diode connected to the circuit. The circuit as shown in figure 4.11 is titled as " Protection circuit ".[40]

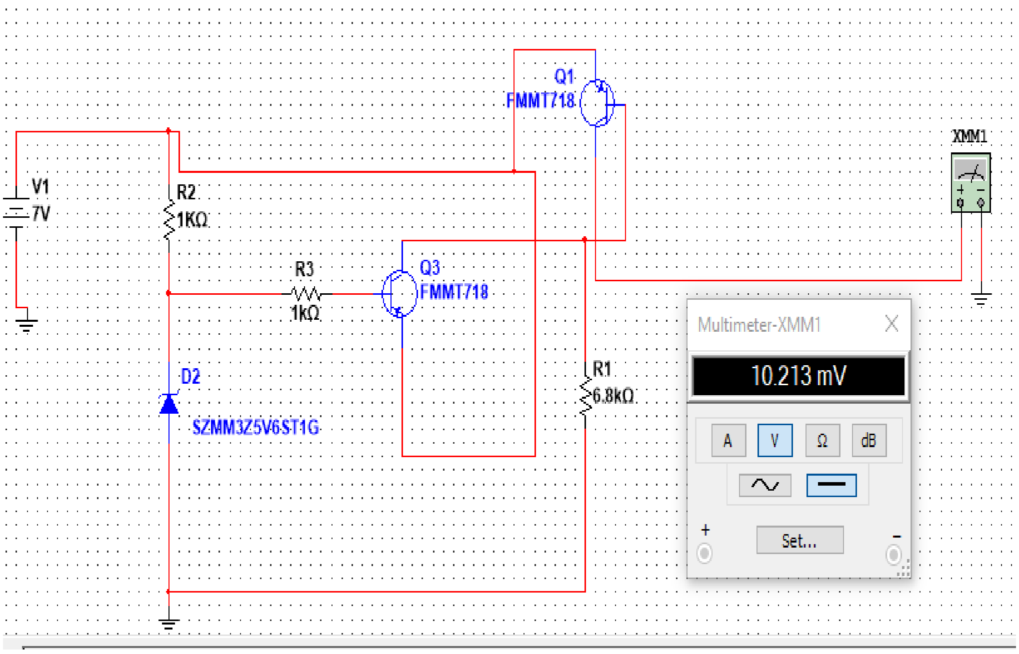

Figure 4.11 Protection Circuit

The protection circuit designed to pass input voltage less than 5.1V, and cutoff voltage exceed preset value, to protect our design from high voltage.

Zener diode (Model_SMM325V6STIG) was used, with two condition achieved:

1. In reverse bias mode.
2. Obtain suitable current value to operate it.

To calculate R2:

From datasheet Iz=5mA

$$R2 = \frac{V}{Iz} = \frac{5.1}{5mA} = 1\ K\Omega$$

Transistors used FMMT718 PNP transistor which exhibit very low VCE saturation value, due to this the voltage drop across transistors is low, and act as switch.

4.4 Buffer

A buffer as shown in figure4.12 is a unity gain amplifier packaged in an integrated circuit. Its function is to provide sufficient capability to pass signals or data bits along to a succeeding stage. Voltage buffers increase available current for low impedance inputs while retaining the voltage level. [38]

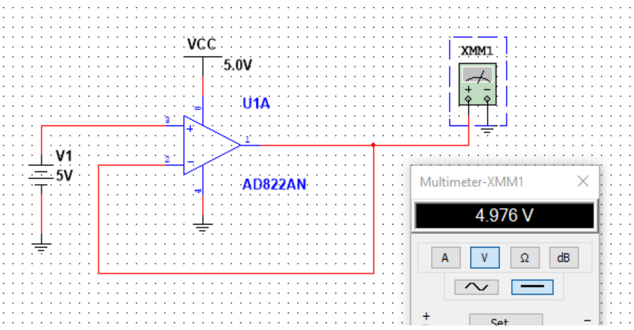

Figure4.12 Buffer

The input impedance of the op-amp buffer is very high, close to infinity. And the output impedance is very low, resulting in a gain that equals one. This means we can use buffers to help chain together sub-circuits in stages without worrying about impedance problems. Buffer has an output that exactly mirrors the input.

AD822 has been used through designing, and has these specifies features.[39]:

- Low noise
- Good dc performance
- Output swings rail-to-rail
- High load drive
- Single Supply

4.5 Power Supply

The system intended to operate using rechargeable (5Volt) battery to power the Arduino and other systems. because system is portable, we need a battery that has the following characteristics:

- Has relatively long life and have 91.2 mAh (see Table 4.2)
- Provide needed power
- Small and not heavy
- Rechargeable battery

Table 4.2 Current Consumption

Battery consumption time (Our battery 5V):

Item	Number	Quiescent Current
SZMM3Z5V6ST1G	1	5mA
Arduino	1	19 mA
AD822AN	1	1.6mA
FMMT718	2	10mA
Total current =		45.6 mA

mAh=Current(mA)*Time(h)

mAh= 45.6mA*2= 91.2 mAh

4.6 Arduino Interfacing

Arduino is an open-source prototyping platform used for building electronics projects. It consists of both a physical programmable circuit board and a software, or IDE (Integrated Development Environment) that runs on your computer, where you can write and upload the computer code to the physical board. The Arduino Nano as illustrate in figure 4.13, can be powered via 12V. The power source is automatically selected to the highest voltage source, each of the 14 digital pins on the Nano can be used as an input or output., they operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull up resistor (disconnected by default) of (20-50) K Ohms.[47]

The Arduino is used to receive a value of attenuating voltage and convert it to joules that will appear on the screen via energyequation.

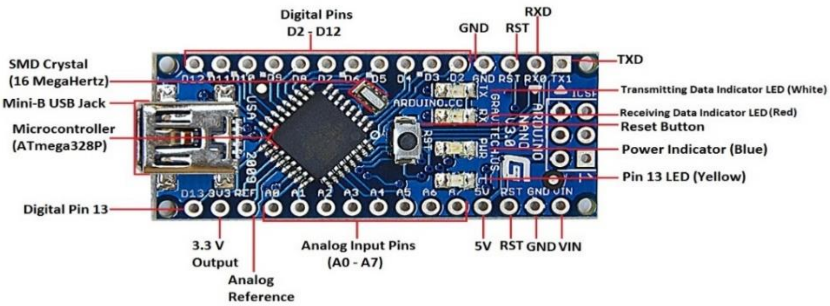

Figure 4.13 Arduino Nano.[47]

4.7 LCD

liquid crystal display or LCD (shown in figure14.14) draws its definition from its name itself. It is a combination of two states of matter, solid and the liquid. LCD uses a liquid crystal to produce a visible image, it used to display final energy in joule.[49]

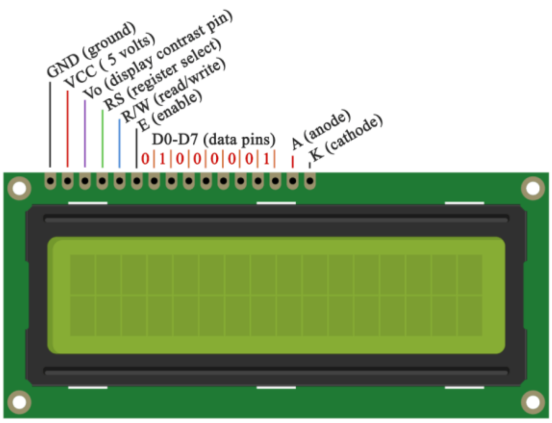

Figure4.14 LCD[49]

4.8 Flow Chart

As a start, voltage enters the Arduino, Arduino code is programmed to give us a vin which equals Vo*1000 , also using code in Arduino energy is calculated eternally and then displayed on screen.

The following figure 4.15 shown the flow chart of system.

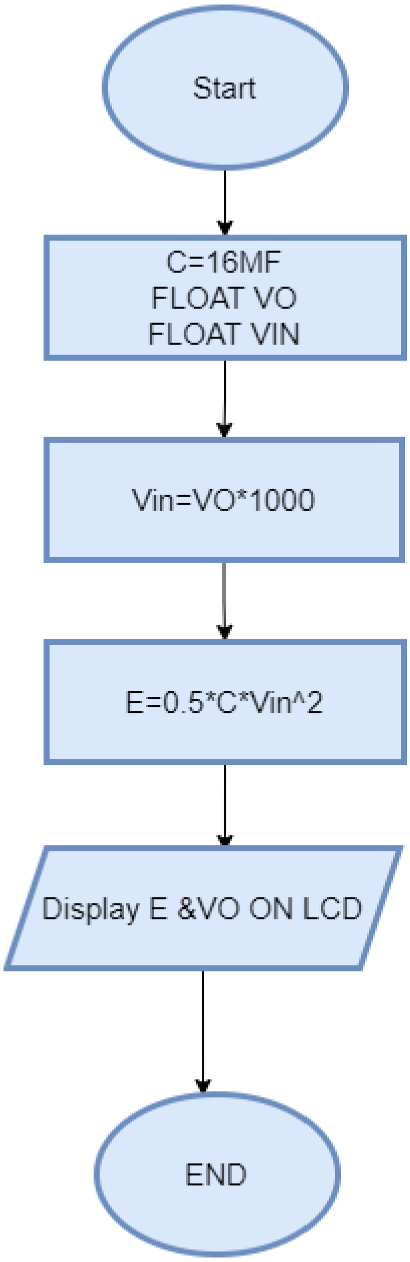

Figure4.15 System Flowchart

Chapter Five

Test and Implementation

Throughout this chapter the implementation process will be discussed and test procedure is occurred .

The principle of implementation and testing is implementing and testing each stage individually.

5.1 Contact Surface

In order to receive the energy from defibrillator and pass through to the signal conditioning circuits. In order to have a functional discharging, these contact surfaces are made of an electrically conductive material, stainless steal with its 4.72*10^-7 Ohm resistance.

Contact surface size suits all types of defibrillator paddles, Standard paddles size is within 8 cm diameter to 12 cm. Fig 5.1.a illustrates stainless steal paddles.

Fig.5.1.a Contact Surface

To attach the contact surfaces, stainless steel screws were used with 3 m diameter as in figure 5.1.b.

Fig.5.1.b Stainless Steel Screws

5.2 Attenuator Circuit

Second stage design, voltage attenuator has been implemented thus to the enormous amount of voltage applied to the circuit. Fig 5.2 shows full attenuator circuit.

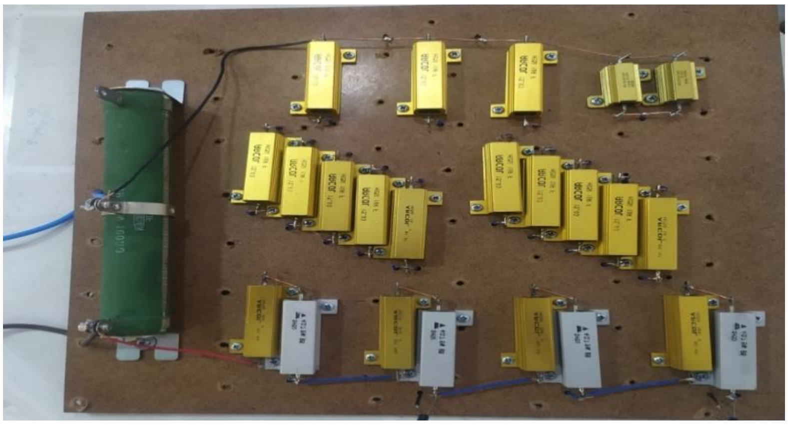

Fig 5.2 Attenuator Circuit.

As for the following process implemented Starting with a 50 ohm resistance "human body resistance" that receives the shock initially. noting that this resistance has been adjusted from 50 Ω to 100 Ω. This resistor is called Dynamic thermal resistor with a 120 watt and 50 Ωresistance and Fig5.2.1 Shows it.

Fig.5.2.1 Dynamic Thermal Resistor

And for the other resistors that have been used, have been connected together to attenuate voltage and have the following properties in table 5.1.

Table 5.1 Main Resistors and Energy Value

Resistor No.	Module Name	Resistance (Ω)	Energy (watt)	Number of Resistor
1	SH50	4.7	50w	4
2	ARCOL HS50	36	50w	4
3	Vishey Dale Resistor NH	100	25w	2
4	ARCOL HS50	10	50w	11
5	ARCOL HS50	1	50w	2

These resistors have similar properties, main properties is that they can be used under harsh conditions, heat sink, good mechanical protection and from 10 w to 50 watt range.

Fig 5.2.2 shows resistor No. 1

Fig.5.2.2 SH50

Fig 5.2.3 shows resistor No. 2.

Fig.5.2.3. ARCOL HS50 Resistor

Fig 5.2.4 shows resistor No. 3**.**

Fig.5.2.4 Vishey Dale Resistor

Fig 5.2.5 shows resistor No. 4**.**

Fig5.2.5 ARCOL 10R

Fig 5.2.6 shows resistor No. 5**.**

Fig5.2.6 ARCOL 1R

In addition, this stage was tested in Palestine polytechnic University labs as illustrated in Fig 5.2.7

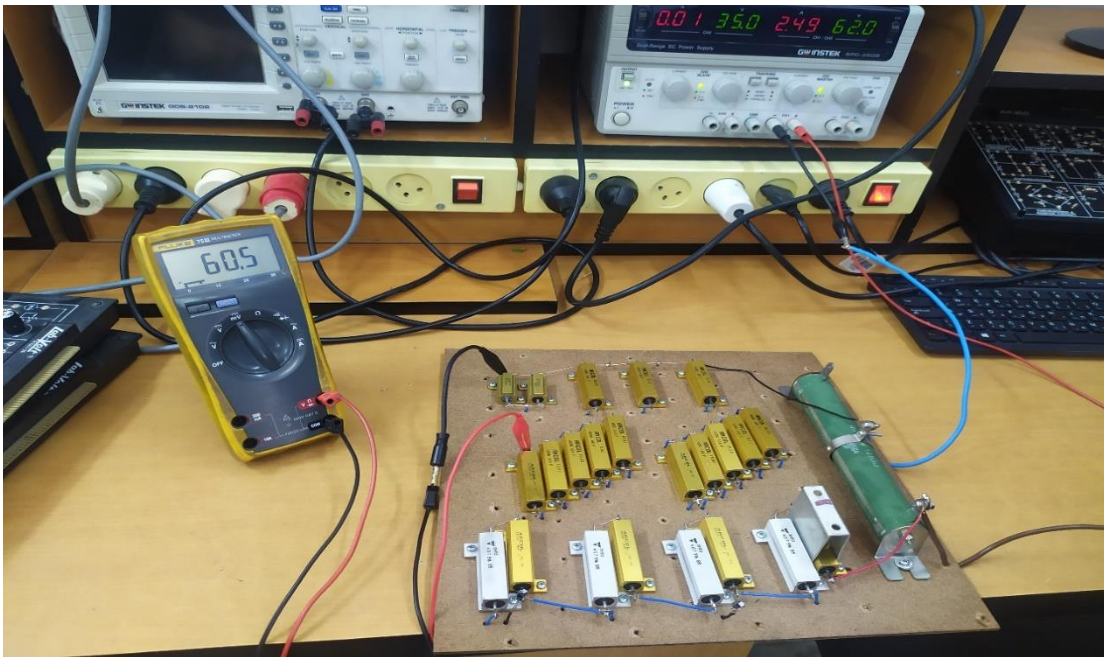

Fig5.2.7 Attenuator Circuit

5.3 Protection Circuit and Buffer Circuit

Overvoltage Protection Circuit using Zener Diode, In this method of overvoltage protection, whenever input voltage exceeds the preset level it **disconnects the output part or load** from the circuit. Fig5.3 illustrates Protection Circuit with buffer circuit.

A buffer can measure the voltage of a sensitive, low current (high impedance source) circuit without disturbing it's function, then copy that voltage and give the same voltage to a high-current circuit (low impedance load) that would disturb it if connected directly. It illustrates at Fig 5.3 with protection circuit.

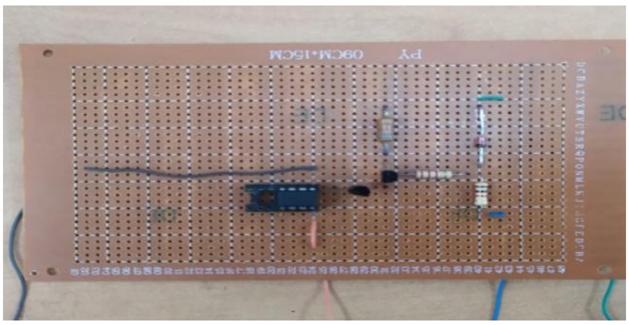

Fig5.3 Protection Circuit with buffer Circuit.

In addition, this stage was tested in Palestine polytechnic University labs as illustrated in Fig 5.3.1.

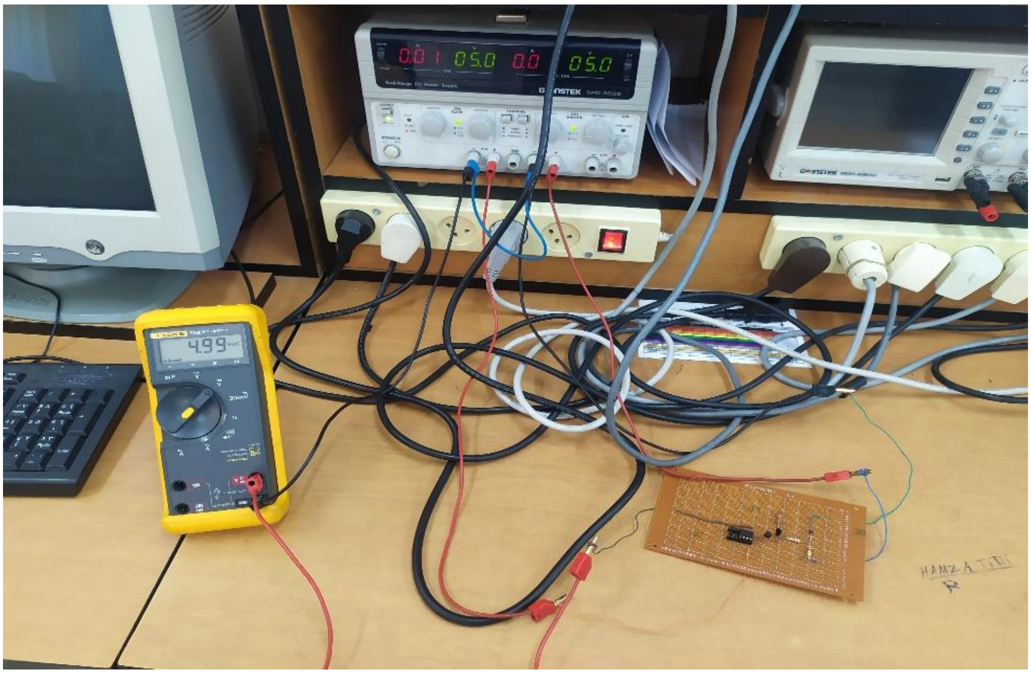

Fig.5.3.1 Protection Circuit with buffer circuit

5.4 Arduino Interfacing

The Arduino was used as a stage in which voltage enters will be used for internal calculations using energy law, and it will be multiplied by 1000 (attenuation percent) and finally the result will appear on the LCD screen**.** Fig 5.4 shown Arduino.

Fig5.4 Arduino

5.5 LCD

LCD screen shown in fig5.5 was used to show the of energy and voltage values.

Fig5.5 LCD

5.6 Box

A box shown in fig5.6 which designed to collect circuit design.

Fig 5.6 Box

Chapter Six

Results

This chapter includes results within each stage individually and final whole project results. In addition, studies, questioner, experiment results, challenges and Recommendations.

6.1: Design testing process

This part of chapter includes results obtained from experimental testing for stages independently and full design results.

6.1.1 Attenuator Circuit results

After implementing first stage, it has been tested after connecting it to the contact surface. Palestine Polytechnic University labs were used and started with the highest voltage can be produced by voltage suppliers which equals 60 volt.

Table 6.1 illustrates results of entering varied voltage values and attenuator voltage values in volts.

Table 6.1 Attenuator Circuit Results

Trial No.	Voltage	Attenuator voltage
1	60	0.057
2	50	0.048
3	40	0.038
4	30	0.032
5	20	0.018
6	10	0.009

These Results indicates the success of attenuation process with a percent error of about 4%.

In which actual value of attenuation for voltage diving it by thousand, before entering next stage.

Fig6.1 illustrates results from first stage testing in trial No.4 when V=30v.

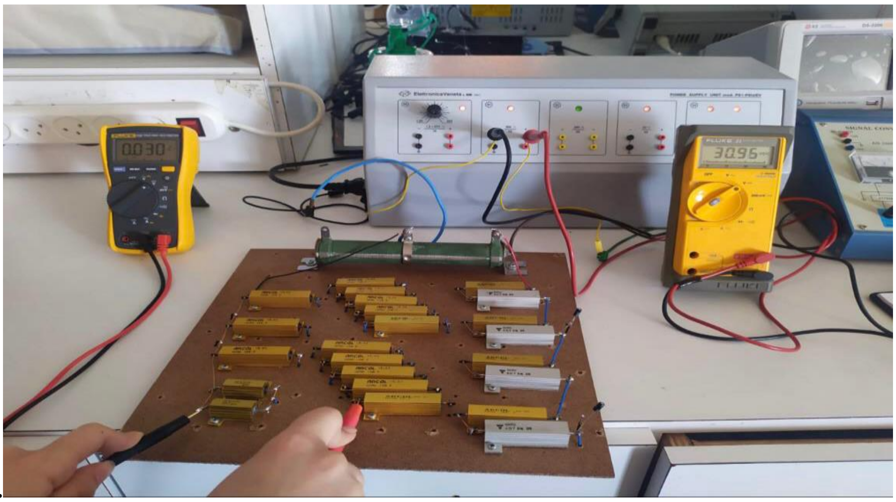

Fig 6.1 Attenuator Stage

6.1.2 Protection Circuit Results

Protection has been tested using varied amount of voltages, the main purpose is to have similar input incase of 1 to 5 volts and if higher, disconnecting the output.

Table 6.2 illustrates table results of input values to next stage in volts.

Table 6.2 Protection Circuit Results

Trial No.	Voltage	Output Voltage
1	8	13.67Mv
2	7	11.89mV
3	6	10.2mV
4	5	4.99V
5	4	4.09V
6	3	3.04V
7	2	2.072V
8	1	1.07V

As the results show, this stage is implemented and tested successfully.

Fig 6.2 illustrates protection circuit tested when 5 volts enters.

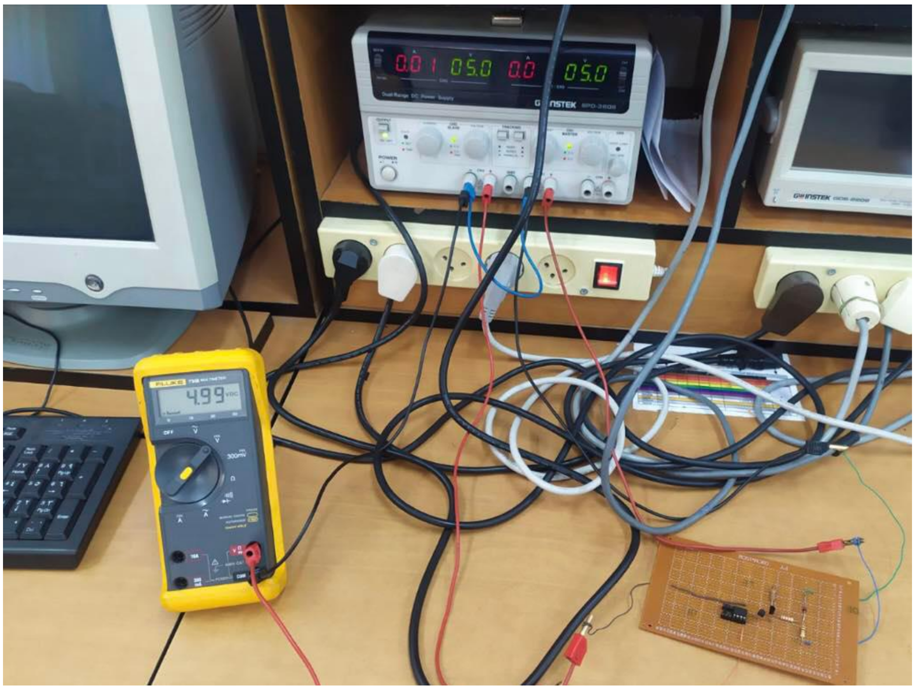

Fig6.2 Protection circuit testing

6.1.3 Arduino Interfacing and full circuit Results

Table 6.3 show final result shown on lcd, actual calculated value and error percent.

Table 6.3 Full Circuit Result

Trial No.	Voltage	Actual Energy	Experimental Energy	Error
1	60	28.8mJ	24.5Mj	4.3
2	50	20mJ	14.82m	5.18
3	40	12.8mJ	7.569MmJ	5.23
4	30	7.2mJ	1.9mJ	5.3

Fig6.3 Indicates Trial No.1 on LCD screen.

Fig6.3 LCD Screen

Programming Code

joull | Arduino 1.8.12

File Edit Sketch Tools Help

joull

```
#include <Wire.h>
#include <LiquidCrystal_I2C.h>

LiquidCrystal_I2C lcd(0x27,20,4);

void setup() {
  // put your setup code here, to run once:
lcd.init();                          // initialize the lcd
  lcd.init();
  // Print a message to the LCD.
  lcd.backlight();
  lcd.setCursor(0,0);
  lcd.print("Ene.");

   lcd.setCursor(6,0);
  lcd.print("Vi");

   lcd.setCursor(12,0);
  lcd.print("Vo");

}


float Vo, Vi, J;
void loop() {
  // put your main code here, to run repeatedly:
Vo = analogRead(A0)*(5.0/1023);
Vi = Vo*1000*1.258;
J = 0.5*0.000016*1000*Vi *Vi;
```

Done compiling.

joull | Arduino 1.8.12

File Edit Sketch Tools Help

joull

```
  lcd.print("Vi");

   lcd.setCursor(12,0);
  lcd.print("Vo");

}


float Vo, Vi, J;
void loop() {
  // put your main code here, to run repeatedly:
Vo = analogRead(A0)*(5.0/1023);
Vi = Vo*1000*1.258;
J = 0.5*0.000016*1000*Vi *Vi;

lcd.setCursor(0,1);
  lcd.print(J);

  lcd.setCursor(6,1);
  lcd.print(Vi);

  lcd.setCursor(12,1);
  lcd.print(Vo);



}
```

6.2 Questioner and experimental studies

This part contains studies and results acquired by this group project. In which questionnaire, theoretically and practically testing has been occurred. The main purpose is to make comparison, quality testing and understanding practical and theoretical standards of a qualified calibration device.

6.2.1 Questionnaire Results

Defibrillator devices are very important to maintain patient's life, the need for calibration is necessary and achieved by defibrillator tester. The absence of this calibration device would lead to many serious consequences and no risks should be taken, as a result, this study has been made in Hebron city hospitals. A statistical analysis data has been resulted as shown in figure5.1. This study also contains numbers of defibrillator, defibrillator testers and their period of calibration.

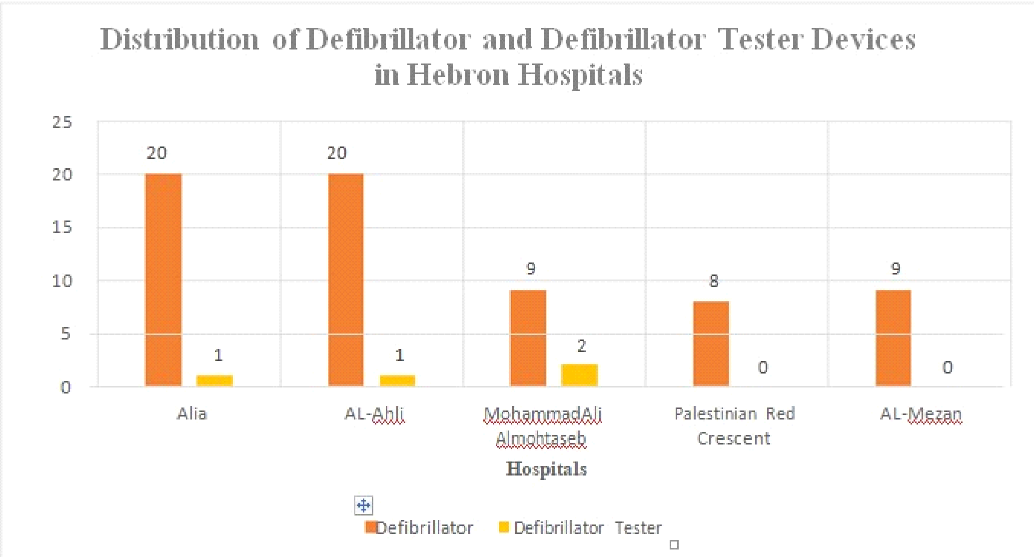

Fig6.2.2 Flowchart Distribution of Defibrillator and Defibrillator Tester Devices in Hebron Hospitals.

The numbers of defibrillator and defibrillator tester devices in Hebron hospitals and a period of calibration for both devices shown in Table6.4.

Table 6.4 Numbers of Defibrillator and Defibrillator Tester in Hebron Hospitals and Period of Calibration.

Hospitals	Number of External Defibrillator Devices	Calibration period of External Defibrillator Device	Number of Defibrillator Analyzer Device	Calibration Period of Defibrillator Analyzer
Alia Hospital	20	Every Six Months	1	Not performed
Al-Ahli Hospital	20	Weakly	1	Yearly
Mohammad Ali Mohtasib Hospital	9	Every Two Years	2	Every Two years By Agent
Palestinian Red Crescent Hospital	8	Yearly	0	Not performed
Al-Mezan Hospital	9	Not performed	0	Not performed

Questionnaire study have shown that many hospitals do not have defibrillator tester devices, such a serious problem, thus to the need of such calibrating device. This result has shown the importance of this project, of designing a low cost defibrillator tester.

6.2.2Testing Results

Energy testing results has been originated, using two types of testers implemented practically in AL-Ahli hospital. One of them is originally from Palestine Polytechnic University. Practical testing has been applied to different types of defibrillator companies. The purpose is to observe numerical comparison between the two testing devices and measuring these parameters for testing the quality and maintenance of defibrillators in hospital, in addition to the practical usage of such calibrating device and method of measuring and testing. However, percentage error has also been calculated.

- Defibrillator Tester(BIO-TEK INSTRUMENT QED-4)
- Defibrillator(NHON KHODEN Cardio life)

Table6.5 BIO-TEK Defibrillator Tester Testing Results for NHON KHODEN Cardio Life Defibrillator

Applied Energy (Joules)	Reading (Joules)	Error (Joules)	Uncertainty (± Joules)
50J	48J	2J	4%
100J	96J	4J	4%
150J	145J	5J	3.33%
200J	194J	6J	3%

- Defibrillator Tester(Electronics Unlimited DT-650)
- Defibrillator(NHON KHODEN Cardio life)

Table6.6 Electronics Unlimited DT-650 Tester Testing Results for NHON KHODEN Cardio Life Defibrillator

Applied Energy (Joules)	Reading (Joules)	Error (Joules)	Uncertainty (± Joules)
50J	48J	2J	4%
100J	98J	2J	2%
150J	147J	3J	2%
200J	194J	6J	3%

- Defibrillator Tester(BIO-TEK INSTRUMENT QED-4)
- Defibrillator(Agilent Heart Stream)

Table6.7 BIO-TEK Defibrillator Tester Testing Results for Agilent Heart Stream Defibrillator

Applied Energy (Joules)	Reading (Joules)	Error (Joules)	Uncertainty (± Joules)
50J	49J	1J	2%
100J	99J	1J	1%
150J	147J	3J	2%
200J	197J	3J	1.5%

- Defibrillator Tester(Electronics Unlimited DT-650)
- Defibrillator(Agilent Heart Stream)

Table6.8 Electronics Unlimited DT-650 Tester Testing Results for Agilent Heart Stream Defibrillator

Applied Energy (Joules)	Reading (Joules)	Error (Joules)	Uncertainty (± Joules)
50J	50J	0	0
100J	99J	1J	1%
150J	148J	2J	1.33%
200J	200J	0	0

- Defibrillator Tester(BIO-TEK INSTRUMENT QED-4)
- Defibrillator(Burdick Medic 5)

Table6.9 BIO-TEK Defibrillator Tester Testing Results for Burdick Medic 5 Defibrillator

Applied Energy (Joules)	Reading (Joules)	Error (Joules)	Uncertainty (± Joules)
50J	48J	2J	4%
100J	96J	4J	4%
150J	147J	3J	2%
200J	194J	6J	3%
360J	344J	16J	4.44%

- Defibrillator Tester(Electronics Unlimited DT-650)
- Defibrillator(Burdick Medic 5)

Table6.10 Electronics Unlimited DT-650 Tester Testing Results for Burdick Medic 5 Defibrillator

Applied Energy (Joules)	Reading (Joules)	Error (Joules)	Uncertainty (± Joules)
50J	49J	1J	2%
100J	97J	3J	3%
150J	148J	2J	1.33%
200J	195J	5J	2.5%
360J	354J	6J	1.67%

Chapter Seven

Conclusion

7.1 Conclusion

Graduation project design was implemented and tested successfully. Project goals were indicated and succeeded in steps individually and as a whole. In which each stage was carefully tested using universities supplies and all results were satisfying and compared with the values that were initially resulted from simulation and calculated to the practical side of project.

Error percent is acceptable, attenuator circuit have attenuated voltage to a suitable value of voltage in order to enter next stage, entering protection circuit guarantees a valid desired amount of input voltage equals output voltage in case of allowed value to next stage and in case it's higher, it will be disconnected from output. Buffer has an output that exactly mirrors the input and Arduino is processed using a special code to calculate energy, and shows result on lcd screen.

7.2 Challenges

Throughout the journey of implementing project design , a lot of challenges have stopped the project design from moving forward , the main challenge was to be able to supply all needed components from the local market that Palestine has a limited electronic supplies ,specially that this project is dependent on Thermal dynamic resistors and heat sinked resistors that are rare to find in the local market, and with the covid 19 situation has gone worse that we were not able to buy or get some of the main supplies also could not go to college and use main supplies for testing . . second challenge was to find protection circuit that does not drain the voltage because we need to use it's value for calculations.

7.3 Recommendations

This project needs a voltage supplier that exceeds the suppliers that were found in testing labs, so it's recommended to supply suppliers that produce a large value of voltage.

In addition, the microprocessor of this project has a noticed error percentage for reading, after studying the situation, this error can be generally decreased by using a 12 bit microprocessor.

Also, it's very important to have a modern Digital multimeters that are able to read voltage within a short time interval .

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Appendix

CMT6

ELECTRICAL CHARACTERISTICS (T_A = 25°C Unless otherwise noted)

	PARAMETER	MIN	TYP	MAX	UNITS	TEST CONDITION
Input	Forward Voltage (V_F)			1.50	V	I_F = 20mA
	Reverse Voltage (V_R)	3			V	I_R = 10μA
	Reverse Current (I_R)			10	μA	V_R = 3V
Output	Collector-emitter Breakdown (BV_{CEO})	30			V	I_C = 1mA (note 2)
	Emitter-collector Breakdown (BV_{ECO})	6			V	I_E = 100μA
	Collector-emitter Dark Current (I_{CEO})			100	nA	V_{CE} = 10V
Coupled	Current Transfer Ratio (CTR) (Note 2)					
	MCT6	20			%	10mA I_F, 10V V_{CE}
	MCT61	50			%	5mA I_F, 5V V_{CE}
	MCT62	100			%	5mA I_F, 5V V_{CE}
	MCT66	6			%	10mA I_F, 10V V_{CE}
	Collector-emitter Saturation Voltage V_{CESAT}					
	MCT6,61,62			0.4	V	16mA I_F, 2mA Ic
	MCT66			0.4	V	40mA I_F, 2mA Ic
	Input to Output Isolation Voltage V_{ISO}	5300			V_{RMS}	See note 1
	Input to Output Isolation Voltage V_{ISO}	7500			V_{PK}	See note 1
	Input-output Isolation Resistance R_{ISO}	5x10^10			Ω	V_{IO} = 500V (note 1)
	Output Rise Time, Fall Time tr , tf		2.4		μs	I_C = 2mA, Vcc = 10V, R_L = 100Ω (Fig. 1)
	Output Rise Time, Fall Time tr , tf		15		μs	I_C = 2mA, Vcc = 10V, R_L = 1kΩ (Fig. 2)

Note 1 Measured with input leads shorted together and output leads shorted together.
Note 2 Special Selections are available on request. Please consult the factory.

AD633

Table 1.

Parameter	Conditions	AD633J, AD633A Min	Typ	Max	Unit
TRANSFER FUNCTION		$W = \frac{(X1 - X2)(Y1 - Y2)}{10\ V} + Z$			
MULTIPLIER PERFORMANCE					
Total Error	−10 V ≤ X, Y ≤ +10 V		±1	±2[1]	% full scale
T_{MIN} to T_{MAX}			±3		% full scale
Scale Voltage Error	SF = 10.00 V nominal		±0.25%		% full scale
Supply Rejection	V_S = ±14 V to ±16 V		±0.01		% full scale
Nonlinearity, X	X = ±10 V, Y = +10 V		±0.4	±1[1]	% full scale
Nonlinearity, Y	Y = ±10 V, X = +10 V		±0.1	±0.4[1]	% full scale
X Feedthrough	Y nulled, X = ±10 V		±0.3	±1[1]	% full scale
Y Feedthrough	X nulled, Y = ±10 V		±0.1	±0.4[1]	% full scale
Output Offset Voltage[2]			±5	±50[1]	mV
DYNAMICS					
Small Signal Bandwidth	V_O = 0.1 V rms		1		MHz
Slew Rate	V_O = 20 V p-p		20		V/μs
Settling Time to 1%	ΔV_O = 20 V		2		μs
OUTPUT NOISE					
Spectral Density			0.8		μV/√Hz
Wideband Noise	f = 10 Hz to 5 MHz		1		mV rms
	f = 10 Hz to 10 kHz		90		μV rms
OUTPUT					
Output Voltage Swing		±11[1]			V
Short Circuit Current	R_L = 0 Ω		30	40[1]	mA
INPUT AMPLIFIERS					
Signal Voltage Range	Differential	±10[1]			V
	Common mode	±10[1]			V
Offset Voltage (X, Y)			±5	±30[1]	mV
CMRR (X, Y)	V_{CM} = ±10 V, f = 50 Hz	60[1]	80		dB
Bias Current (X, Y, Z)			0.8	2.0[1]	μA
Differential Resistance			10		MΩ
POWER SUPPLY					
Supply Voltage					
Rated Performance			±15		V
Operating Range		±8[1]		±18[1]	V
Supply Current	Quiescent		4	6[1]	mA

LM016L·LM016XMBL

- 16 character x 2 lines
- Controller LSI HD44780 is built-in (See page 79).
- +5V single power supply
- Display color: LM016L : Gray
  LM016XMBL : New-gray

MECHANICAL DATA (Nominal dimensions)

Module size .... 84W x 44H x 10.5T (max.) mm
Effective display area .... 61W x 15.8H mm
Character size (5 x 7 dots) .... 2.96W x 4.86H mm
Character pitch .... 3.55 mm
Dot size .... 0.56W x 0.66H mm
Weight .... about 35 g

ABSOLUTE MAXIMUM RATINGS

	min.	max.
Power supply for logic ($V_{DD}-V_{SS}$)	0	6.5 V
Power supply for LCD drive ($V_{DD}-V_O$)	0	6.5 V
Input voltage (V_i)	V_{SS}	V_{DD} V
Operating temperature (Ta)	0	50 40* °C
Storage temperature (Tstg)	−20	70 60* °C

* Shows the value of type LM016XMBL.

ELECTRICAL CHARACTERISTICS

Ta = 25°C, V_{DD} = 5.0 V ± 0.25 V

Input "high" voltage (V_{IH}) .... 2.2 V min.
Input "low" voltage (V_{IL}) .... 0.6 V max.
Output "high" voltage (V_{OH}) ($-I_{OH}$ = 0.2 mA) .... 2.4 V min.
Output "low" voltage (V_{OL}) (I_{OL} = 1.2 mA) .... 0.4 V max.
Power supply current (I_{DD}) (V_{DD} = 5.0 V) .... 1.0 mA typ.
3.0 mA max.

POWER SUPPLY FOR LCD DRIVE (Recommended) ($V_{DD}-V_O$)

Duty = 1/16

Range of $V_{DD}-V_O$ .... 1.5~5.25 V
Ta = 0°C .... 4.6 V typ.
Ta = 25°C .... 4.4 V typ.
Ta = 50°C .... 4.2 V typ.

OPTICAL DATA .... See page 7

INTERNAL PIN CONNECTION

Pin No.	Symbol	Level	Function	
1	V_{SS}	–	0V	Power supply
2	V_{DD}	–	+5V	
3	V_O	–	–	
4	RS	H/L	L: Instruction code input H: Data input	
5	R/W	H/L	H: Data read (LCD module→MPU) L: Data write (LCD module←MPU)	
6	E	H, H→L	Enable signal	
7	DB0	H/L	Data bus line Note (1), (2)	
8	DB1	H/L		
9	DB2	H/L		
10	DB3	H/L		
11	DB4	H/L		
12	DB5	H/L		
13	DB6	H/L		
14	DB7	H/L		

Notes:

In the HD44780, the data can be sent in either 4-bit 2-operation or 8-bit 1-operation so that it can interface to both 4 and 8 bit MPU's.

(1) When interface data is 4 bits long, data is transferred using only 4 buses of DB_4-DB_7, and DB_0-DB_3 are not used. Data transfer between the HD44780 and the MPU completes when 4-bit data is transferred twice. Data of the higher order 4 bits (contents of DB_4-DB_7 when interface data is 8 bits long) is transferred first and then lower order 4 bits (contents of DB_0-DB_3 when interface data is 8 bits long).

(2) When interface data is 8 bits long, data is transferred using 8 data buses of DB_0-DB_7.

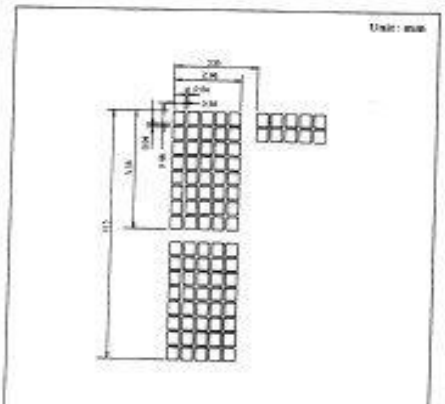


Fig. 1 Display pattern

Arduino

Arduino Uno

Arduino Uno R3 Front

Arduino Uno R3 Back

Arduino Uno R2 Front

Arduino Uno SMD

Arduino Uno Front

Arduino Uno Back

Overview

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.
The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.
Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.
Revision 3 of the board has the following new features:

- 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

DIODES INCORPORATED

Lead-free Green

FMMT718

20V PNP SILICON LOW SATURATION TRANSISTOR IN SOT2

Features

- BV_{CEO} > -20V
- I_C = -1.5A Continuous Collector Current
- I_{CM} = -6A Peak Pulse Current
- Low Saturation Voltage $V_{CE(sat)}$ < -200mV @ -1A
- $R_{CE(SAT)}$ = 97mΩ for a low equivalent on-resistance
- 625mW power dissipation
- h_{FE} characterized up to -6A for high current gain hold-up
- Complementary NPN Type: FMMT618
- **Totally Lead-Free & Fully RoHS compliant (Notes 1 & 2)**
- **Halogen- and Antimony-Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**
- **An Automotive-Compliant Part Is Available Under Separate Datasheet (FMMT718Q)**

Mechanical Data

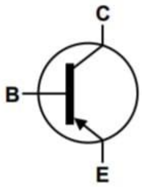
- Case: SOT23
- Case Material: molded plastic, "Green" molding compound
- UL Flammability Classification Rating 94V-0
- Moisture Sensitivity: Level 1 per J-STD-020
- Terminals: Finish – Matte Tin Plated Leads, Solderable per MIL-STD-202, Method 208 e3
- Weight 0.008 grams (Approximate)

Applications

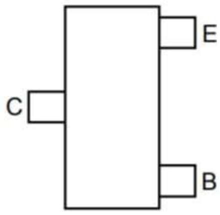
- Gate Driving MOSFETs and IGBTs
- DC-DC Converters
- Charging circuit
- Power switches

SOT23

Top View



Device Symbol



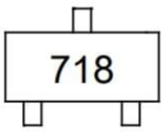
Top View
Pin-Out

Ordering Information (Note 4)

Product	Compliance	Marking	Reel size (inches)	Tape width (mm)	Quantity per reel
FMMT718TA	Standard	718	7	8	3,000
FMMT718TC	Standard	718	13	8	10,000

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.
4. For packaging details, go to our website at https://www.diodes.com/design/support/packaging/diodes-packaging/.

Marking Information



718 = Product Type Marking Code

Absolute Maximum Ratings (@ T_A = +25°C, unless otherwise specified.)

Characteristic	Symbol	Value	Unit
Collector-Base Voltage	V_{CBO}	-20	V
Collector-Emitter Voltage	V_{CEO}	-20	V
Emitter-Base Voltage	V_{EBO}	-7	V
Continuous Collector Current	I_C	-1.5	A
Peak Pulse Current	I_{CM}	-6	A
Base Current	I_B	-500	mA

Thermal Characteristics (@ T_A = +25°C, unless otherwise specified.)

Characteristic	Symbol	Value	Unit
Power Dissipation (Note 5)	P_D	625	mW
Power Dissipation (Note 6)	P_D	806	mW
Thermal Resistance, Junction to Ambient (Note 5)	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Ambient (Note 6)	$R_{\theta JA}$	155	°C/W
Thermal Resistance, Junction to Leads (Note 7)	$R_{\theta JL}$	194	°C/W
Operating and Storage Temperature Range	T_J, T_{STG}	-55 to +150	°C

ESD Ratings (Note 8)

Characteristic	Symbol	Value	Unit	JEDEC Class
Electrostatic Discharge - Human Body Model	ESD HBM	4,000	V	3A
Electrostatic Discharge - Machine Model	ESD MM	≥ 400	V	C

Notes:
5. For a device surface mounted on 25mm x 25mm FR4 PCB with high coverage of single sided 1 oz copper, in still air conditions; the device is measured when operating in a steady-state condition.
6. Same as note 5, except the device is measured at t ≤ 5 sec.
7. Thermal resistance from junction to solder-point (at the end of the collector lead).
8. Refer to JEDEC specification JESD22-A114 and JESD22-A115.

SZMM3ZST1G

MM3ZxxxST1G Series, SZMM3ZxxxST1G Series

Zener Voltage Regulators

300 mW SOD−323 Surface Mount Tight Tolerance Portfolio

This series of Zener diodes is packaged in a SOD−323 surface mount package that has a power dissipation of 300 mW. They are designed to provide voltage regulation protection and are especially attractive in situations where space is at a premium. They are well suited for applications such as cellular phones, hand−held portables, and high density PC boards.

Specification Features

- Standard Zener Breakdown Voltage Range − 3.3 V to 36 V
- Steady State Power Rating of 300 mW
- Small Body Outline Dimensions: − 0.067″ x 0.049″ (1.7 mm x 1.25 mm)
- Low Body Height: 0.035″ (0.9 mm)
- Package Weight: 4.507 mg/unit
- ESD Rating of Class 3 (> 16 kV) per Human Body Model
- Tight Tolerance V_Z
- SZ Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC−Q101 Qualified and PPAP Capable
- These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant*

Mechanical Characteristics:

CASE: Void-free, transfer-molded plastic
FINISH: All external surfaces are corrosion resistant
MAXIMUM CASE TEMPERATURE FOR SOLDERING PURPOSES: 260°C for 10 Seconds
LEADS: Plated with Pb−Sn or Sn only (Pb−Free)
POLARITY: Cathode indicated by polarity band
FLAMMABILITY RATING: UL 94 V−0
MOUNTING POSITION: Any

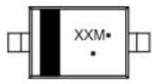
*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

ON Semiconductor®

http://onsemi.com

SOD−323
CASE 477
STYLE 1

MARKING DIAGRAM



XX = Specific Device Code
M = Date Code*
• = Pb−Free Package

(Note: Microdot may be in either location)

*Date Code orientation may vary depending upon manufacturing location.

ORDERING INFORMATION

Device	Package	Shipping†
MM3ZxxxST1G	SOD−323 (Pb−Free)	3,000 / Tape & Reel
SZMM3ZxxxST1G	SOD−323 (Pb−Free)	3,000 / Tape & Reel
MM3ZxxxST3G	SOD−323 (Pb−Free)	10,000 / Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

DEVICE MARKING INFORMATION

See specific marking information in the device marking column of the Electrical Characteristics table on page 3 of this data sheet.

January, 2014 − Rev. 22
1
Publication Order Number:
MM3Z2V4ST1/D

ELECTRICAL CHARACTERISTICS (V_F = 0.9 Max @ I_F = 10 mA for all types)

Device*	Device Marking	Test Current Izt mA	Zener Voltage VZ		Z_{ZK} I_Z = 0.5 mA Ω Max	Z_{ZT} I_Z = IZT @ 10% Mod Ω Max	Max IR @ VR		d_{VZ}/dt (mV/k) @ I_{ZT1} = 5 mA		C pF Max @ V_R = 0 f = 1 MHz
			Min	Max			μA	V	Min	Max	
MM3Z3V0ST1G	T4	5.0	2.90	3.11	1000	100	10	1.0	−3.5	0	450
MM3Z3V3ST1G	T5	5.0	3.32	3.53	1000	95	5.0	1.0	−3.5	0	450
MM3Z3V9ST1G	T7	5.0	3.89	4.16	1000	90	3.0	1.0	−3.5	−2.5	450
MM3Z4V3ST1G	T8	5.0	4.17	4.43	1000	90	3.0	1.0	−3.5	0	450
MM3Z4V7ST1G	T9	5.0	4.55	4.75	800	80	3.0	2.0	−3.5	0.2	260
MM3Z5V1ST1G	TA	5.0	4.98	5.2	500	60	2.0	2.0	−2.7	1.2	225
MM3Z5V6ST1G	TC	5.0	5.49	5.73	200	40	1.0	2.0	−2.0	2.5	200
MM3Z6V2ST1G	TE	5.0	6.06	6.33	100	10	3.0	4.0	0.4	3.7	185
MM3Z6V8ST1G	TF	5.0	6.65	6.93	160	15	2.0	4.0	1.2	4.5	155
MM3Z7V5ST1G	TG	5.0	7.28	7.6	160	15	1.0	5.0	2.5	5.3	140
MM3Z8V2ST1G	TH	5.0	8.02	8.36	160	15	0.7	5.0	3.2	6.2	135
MM3Z9V1ST1G	TK	5.0	8.85	9.23	160	15	0.5	6.0	3.8	7.0	130
MM3Z10VST1G	WB	5.0	9.80	10.20	160	15	0.5	6.0	4.5	8.0	130
MM3Z12VST1G	TN	5.0	11.74	12.24	80	25	0.1	8.0	6.0	10	130
MM3Z13VST1G	TQ	5.0	12.91	13.49	160	30	0.1	8.0	7.0	11	120
MM3Z15VST1G	TP	5.0	14.34	14.98	80	40	0.1	11	8.8	12.7	130
MM3Z16VST1G	TU	5.0	15.85	16.51	80	40	0.05	11.2	10.4	14	105
MM3Z18VST1G	TW	5.0	17.56	18.35	80	45	0.05	12.6	12.4	16	100
MM3Z22VST1G	WP	5.0	21.54	22.47	100	55	0.05	15.4	16.4	20	85
MM3Z24VST1G	WT	5.0	23.72	24.78	120	70	0.05	16.8	18.4	22	80
MM3Z27VST1G	WQ	5.0	26.19	27.53	300	80	0.05	18.9	21.4	25.3	70
MM3Z30VST1G	WV	5.0	29.19	30.69	300	80	0.05	21.0	24.4	29.4	70
MM3Z33VST1G	WR	5.0	32.15	33.79	300	80	0.05	23.2	27.4	33.4	70
MM3Z36VST1G	WU	5.0	35.07	36.87	500	90	0.05	25.2	30.4	37.4	70
MM3Z39VST1G	WN	2.0	38.22	39.78	500	130	0.05	27.3	33.4	41.2	45

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.
*Include SZ-prefix devices where applicable.

SH50

VISHAY. www.vishay.com **SH** Vishay Sfernice

Heatsink Encased Wirewound Power Resistors Industrial Applications

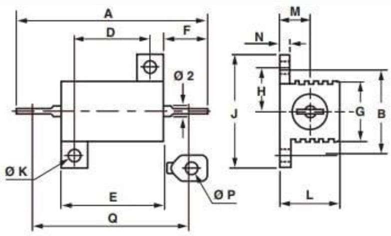
FEATURES

- ≤ 50 W at + 25 °C
- High power characteristics
- Utilize heatsink capability
- Good mechanical protection
- Industrialized product
- Material categorization: For definitions of compliance please see www.vishay.com/doc?99912

RoHS COMPLIANT

Built for high power dissipation applications, these components have very good overall characteristics for industrial use under harsh environmental conditions.

DIMENSIONS in millimeters



SERIES	A	B ± 0.2	D ± 0.2	E ± 0.5	F	G ± 1	H ± 0.7	J ± 0.5	Ø K ± 0.1	L MAX.	M ± 0.5	N ± 0.3	Ø P MIN.	Q	WEIGHT g
SH5	28.5 ± 1.5	12.5	11.3	16.3	6.8 ± 1.5	8.5	6.2	16.4	2.4	8.9	4.3	1.6	2.1	25.3 ± 1.5	3
SH10	35.5 ± 1.5	15.9	14	19	7.9 ± 1.5	11	7.9	20.6	2.4	11	5.6	2	2.1	30.6 ± 1.5	8.8
SH25	49 ± 1.3	19.8	18.3	28	11.1 ± 1.5	14	9.9	27.5	3.2	15	8	2.4	2.1	44.6 ± 1.3	16.5
SH50	70.2 ± 1.4	21.4	39.7	50	11 ± 1.2	15.5	10.7	29.4	3.2	15	8	2.4	2.1	66.5 ± 1.4	30.8

STANDARD ELECTRICAL SPECIFICATIONS

MODEL	RESISTANCE RANGE Ω	RATED POWER $P_{25\,°C}$ W	LIMITING ELEMENT VOLTAGE V	TOLERANCE ± %
SH5	0.1 to 3.3K	10	160	5
SH10	0.1 to 15K	12.5	250	5
SH25	0.1 to 33K	25	550	5
SH50	0.1 to 51K	50	1285	5

TECHNICAL SPECIFICATIONS

VISHAY SFERNICE SERIES		SH5	SH10	SH25	SH50
Power Rating Chassis mounted resistors: 413 cm² for SH5 and SH10, 536 cm² for SH25 and SH50	at 25 °C	10 W	12.5 W	25 W	50 W
	at 70 °C	8 W	10 W	20 W	40 W
Unmounted resistors	at 25 °C	4 W	6 W	9 W	12 W
	at 70 °C	3.2 W	4.8 W	7.2 W	9.6 W
Dielectric Strength V_{RMS}		800 V	1000 V	2000 V	2000 V
Insulation Resistance		> 10^4 MΩ		> 3 x 10^4 MΩ	
Temperature Coefficient		± 50 ppm/°C R_n > 50 Ω			
Climatic Category		55/200/56			
Temperature Limits		- 55 °C + 200 °C			

Revision: 05-Aug-13 1 Document Number: 50014

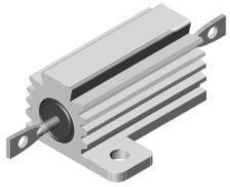
For technical questions, contact: sferfixedresistors@vishay.com

Vishey Dale

RH, NH

Vishay Dale

Wirewound Resistors, Military, MIL-PRF-18546 Qualified, Type RE, Aluminum Housed, Chassis Mount



FEATURES

- Molded construction for total environmental protection
- Complete welded construction
- Meets applicable requirements of MIL-PRF-18546
- Available in non-inductive styles (type NH) with Aryton-Perry winding for lowest reactive components
- Mounts on chassis to utilize heat-sink effect
- Excellent stability in operation

STANDARD ELECTRICAL SPECIFICATIONS

MODEL	MIL-PRF-18546 TYPE	POWER RATING $P_{25°C}$ W		RESISTANCE RANGE MIL. RANGE SHOWN IN BOLD FACE Ω				WEIGHT (Typical)
		DALE	MILITARY	±0.05%, ±0.1%	±0.25%	±0.5%	±1%, ±3%, ±5%	g
RH-5	— **RE60G**	7.5 (5)	**5**	0.5 - 6.75k —	0.1 - 8.6k —	0.05 - 8.6k —	0.02 - 24.5k **0.10 - 3.32k**	3
NH-5	— **RE60N**	7.5 (5)	**5**	0.5 - 2.32k —	0.1 - 3.27k —	0.05 - 3.27k —	0.05 - 12.75k **1.0 - 1.65k**	3.3
RH-10	— **RE65G**	12.5 (10)	**10**	0.5 - 12.7k —	0.1 - 16.69k —	0.05 - 16.69k —	0.01 - 47.1k **0.10 - 5.62k**	6
NH-10	— **RE65N**	12.5 (10)	**10**	0.5 - 4.45k —	0.1 - 5.54k —	0.05 - 5.54k —	0.05 - 23.5k **1.0 - 2.8k**	8.8
RH-25	— **RE70G**	25	**20**	0.5 - 25.7k —	0.1 - 32.99k —	0.05 - 32.99k —	0.01 - 95.2k **0.10 - 12.1k**	13
NH-25	— **RE70N**	25	**20**	0.5 - 9.09k —	0.1 - 12.8k —	0.05 - 12.8k —	0.05 - 47.6k **1.0 - 6.04k**	16.5
RH-50	— **RE75G**	50	**30**	0.5 - 73.4k —	0.1 - 96k —	0.05 - 96k —	0.01 - 273k **0 .10 - 39.2k**	28
NH-50	— **RE75N**	50	**30**	0.5 - 26k —	0.1 - 36.7k —	0.05 - 36.7k —	0.05 - 136k **1.0 - 19.6k**	35
RH-100	— **RE77G**	100	**75**	0.5 - 90k —	0.1 - 90k —	0.05 - 90k —	0.05 - 90k **0.05 - 29.4k**	350
NH-100	— **RE77N**	100	**75**	0.5 - 37.5k —	0.1 - 37.5k —	0.05 - 37.5k —	0.05 - 37.5k **1.0 - 14.7k**	385
RH-250	— **RE80G**	250	**120**	0.5 - 116k —	0.1 - 116k —	0.05 - 116k —	0.05 - 116k **0.10 - 35.7k**	630
NH-250	— **RE80N**	250	**120**	0.5 - 48.5k —	0.1 - 48.5k —	0.05 - 48.5k —	0.05 - 48.5k **1.0 - 17.4k**	690

NOTE: Figures in parentheses on RH-5 and RH-10 indicate wattage printed on parts, new construction allows these resistors to be rated at higher wattage but will **only** be printed with the higher wattage on customer request.

ORDERING INFORMATION

RH-50	**10Ω**	**1.0%**
MODEL	RESISTANCE Ω	TOLERANCE ± %

ARCOL

HS Aluminium Housed Resistors

ARCOL

Manufactured in line with the requirements of MIL 18546 and IEC 115, designed for direct heatsink mounting with thermal compound to achieve maximum performance.

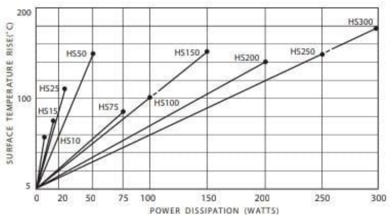
- High Power to volume
- Wound to maximise High Pulse Capability
- Values from R005 to 100K
- Custom designs welcome
- RoHS Compliant

Characteristics

Tolerance (Code):	Standard ±5% (J) and ±10% (K). Also available ±1% (F), ±2% (G) and ±3% (H)
Tolerance for low Ω values:	Typically ≥ R05 ±5% ≤ R047 ±10%
Temperature coefficients:	Typical values < 1K 100ppm Std. > 1K 25ppm Std. For lower TCR's please contact Arcol
Insulation resistance (Dry):	10,000 MΩ minimum
Power dissipation:	At high ambient temperature dissipation derates linearly to zero at 200°C
Ohmic values:	From R005 to 100K depending on wattage size
Low inductive (NHS):	Specify by adding N before HS Series code, e.g. NHS50
NHS ohmic value:	Divide standard HS maximum value by 4
NHS working volts:	Divide standard HS maximum working voltage by 1.414

Temp. Rise & Power Dissipation

Surface temperature of resistor related to power dissipation. The resistor is standard heatsink mounted using a proprietary heatsink compound.



Heat Dissipation

Heat dissipation: Whilst the use of proprietary heat sinks with lower thermal resistances is acceptable, uprating is not recommended. For maximum heat transfer it is recommended that a heat sink compound be applied between the resistor base and heat sink chassis mounting surface. It is essential that the maximum hot spot temperature of 200°C is not exceeded, therefore, the resistor must be mounted on a heat sink of correct thermal resistance for the power being dissipated.

Ordering Procedure

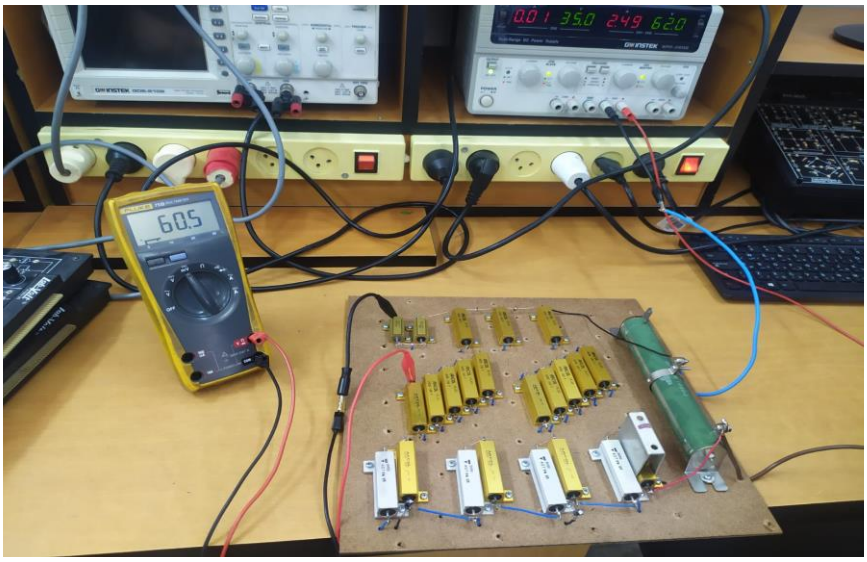
Standard Resistor. To specify standard: Series, Watts, Ohmic Value, Tolerance Code, e.g.: HS25 2R2 J
Non Inductive Resistor. To specify add N, e.g.: NHS100 10R J

ARCOL UK Limited,
Threemilestone Ind. Estate,
Truro, Cornwall, TR4 9LG, UK.
T +44 (0) 1872 277431
F +44 (0) 1872 222002
E sales@arcolresistors.com

For more information and ordering, please consult
www.arcolresistors.com

Page 1 of 2 12/14.08 OHMITE

Attenuator Results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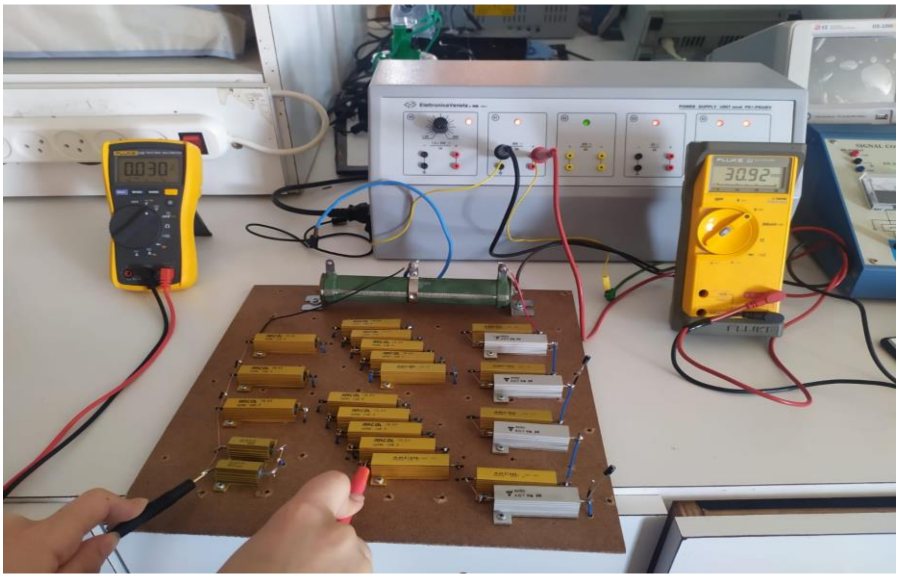
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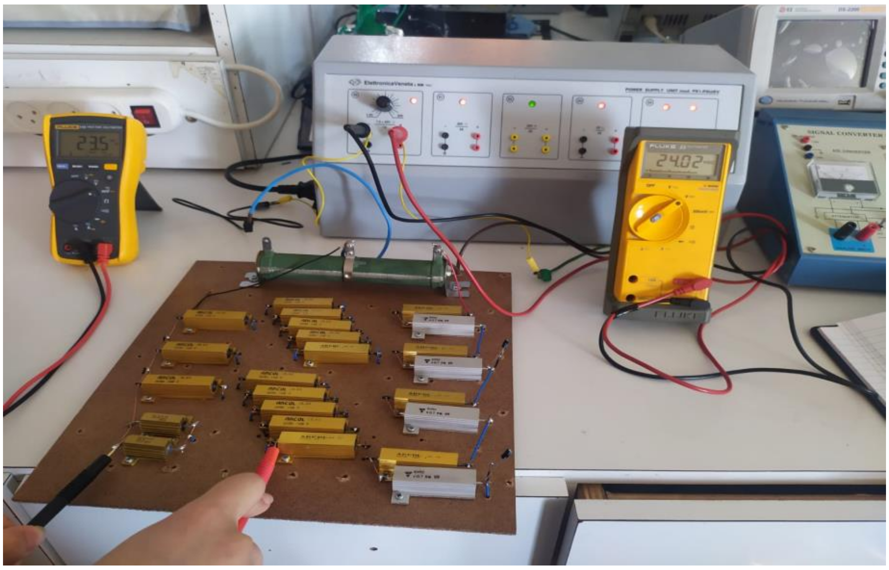
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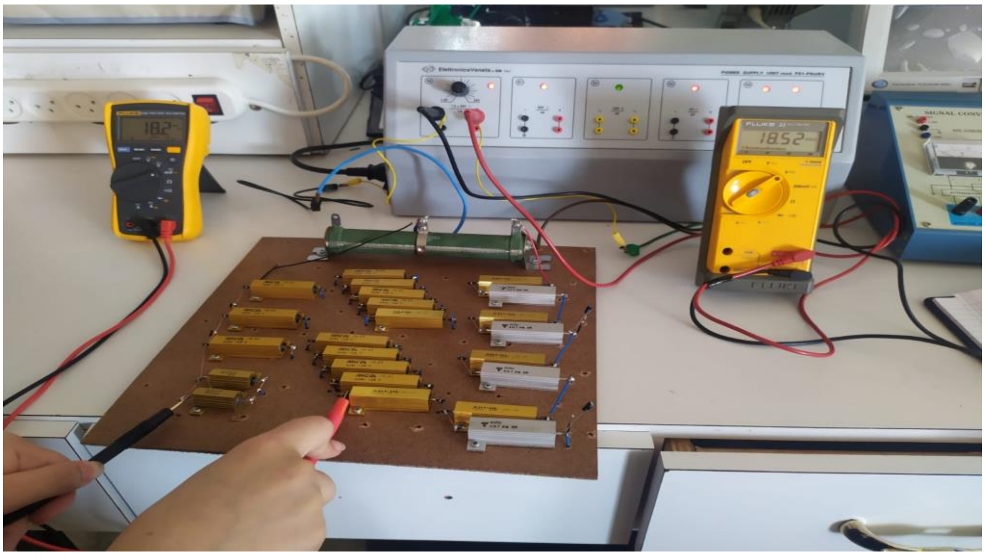
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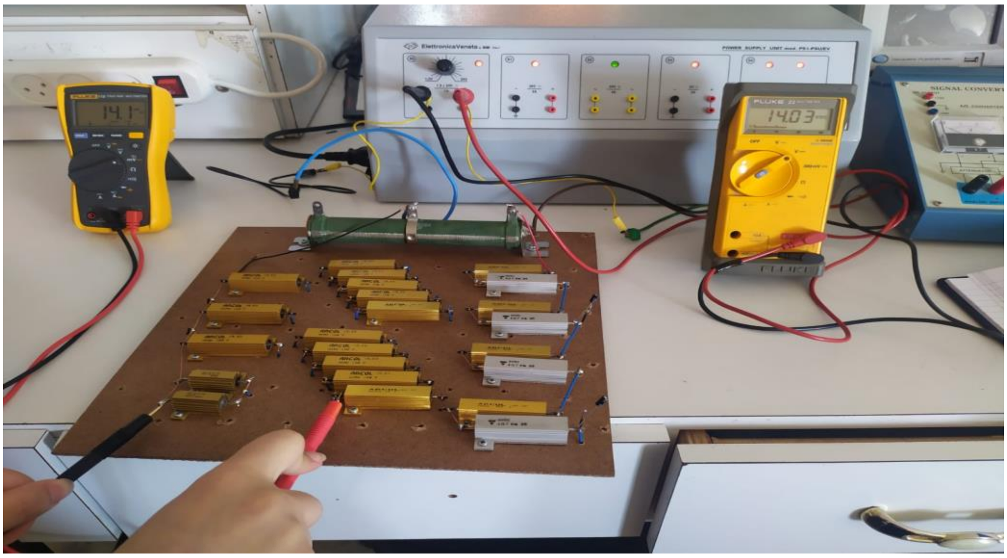
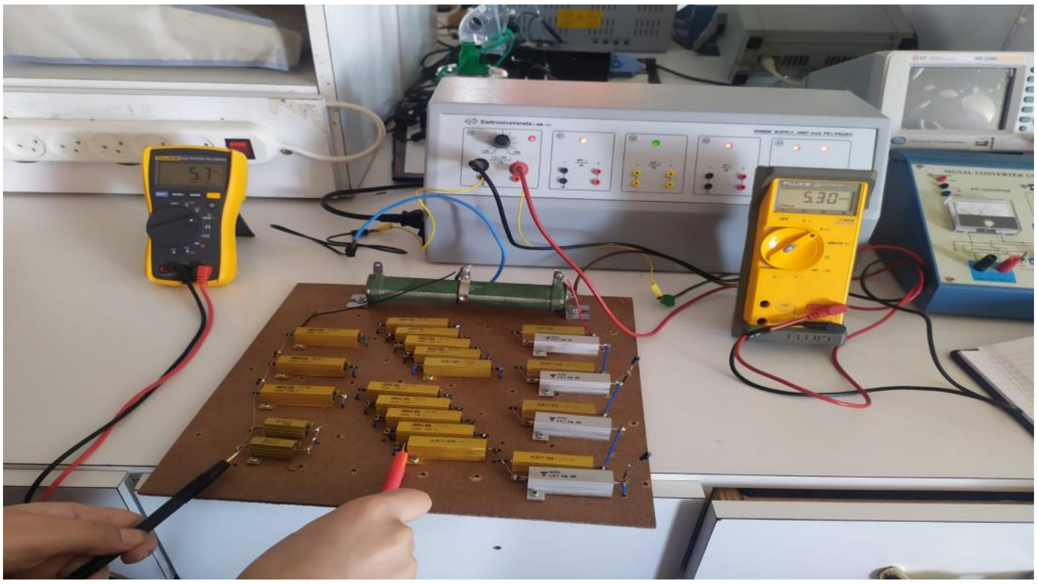
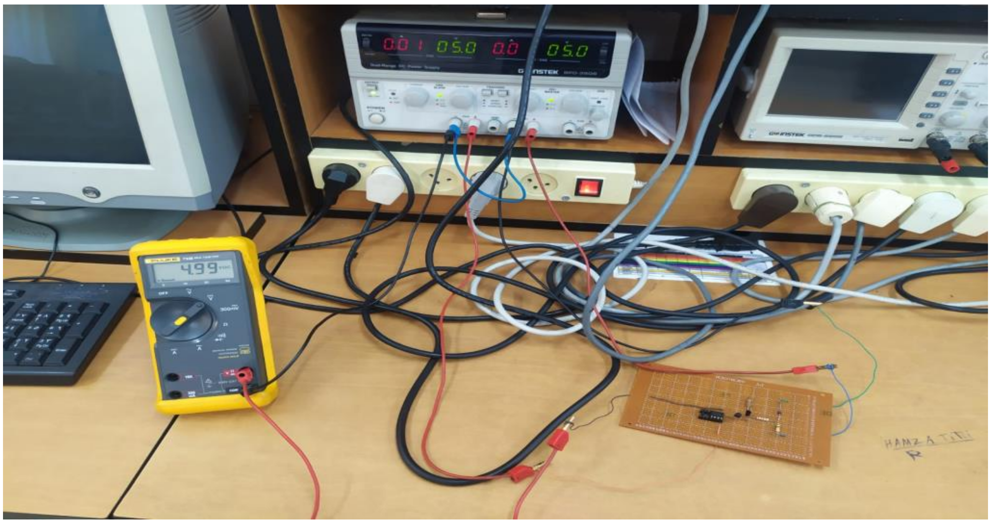
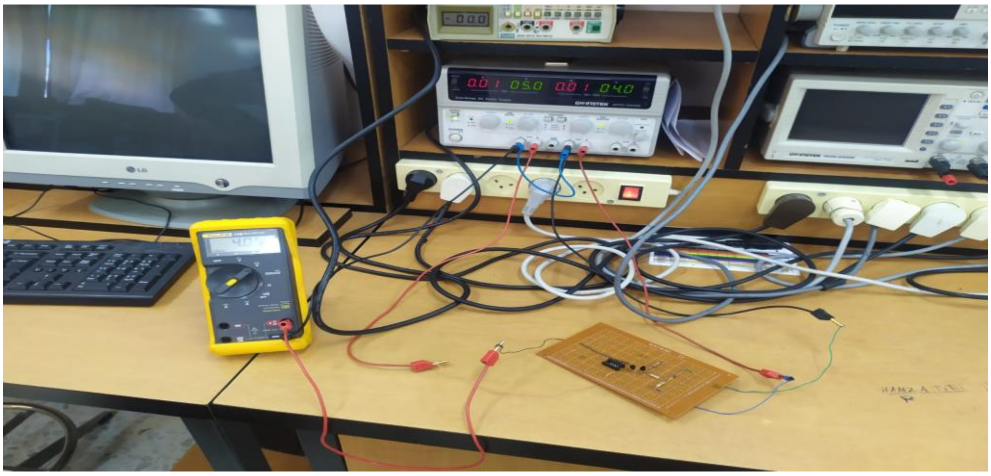

14.03

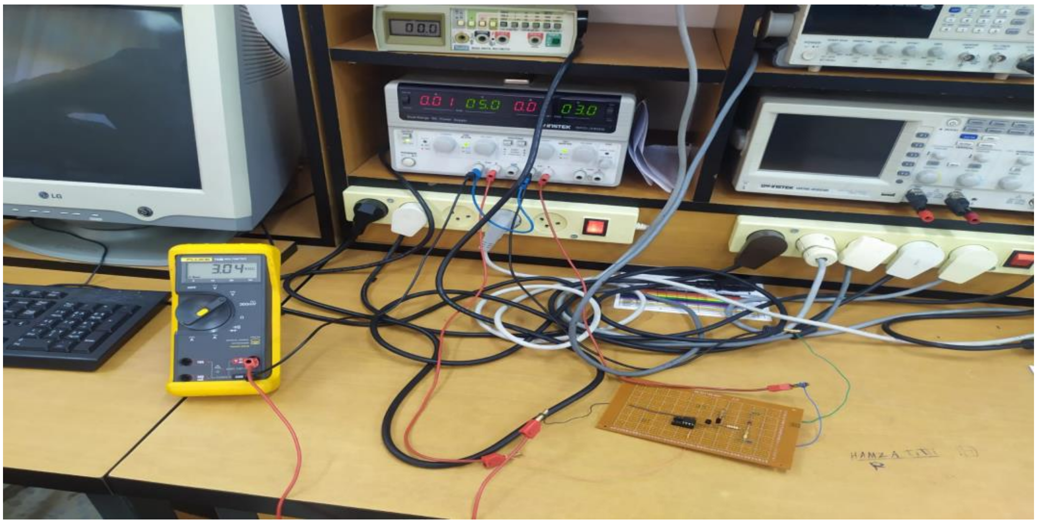
11.20



Protection Result



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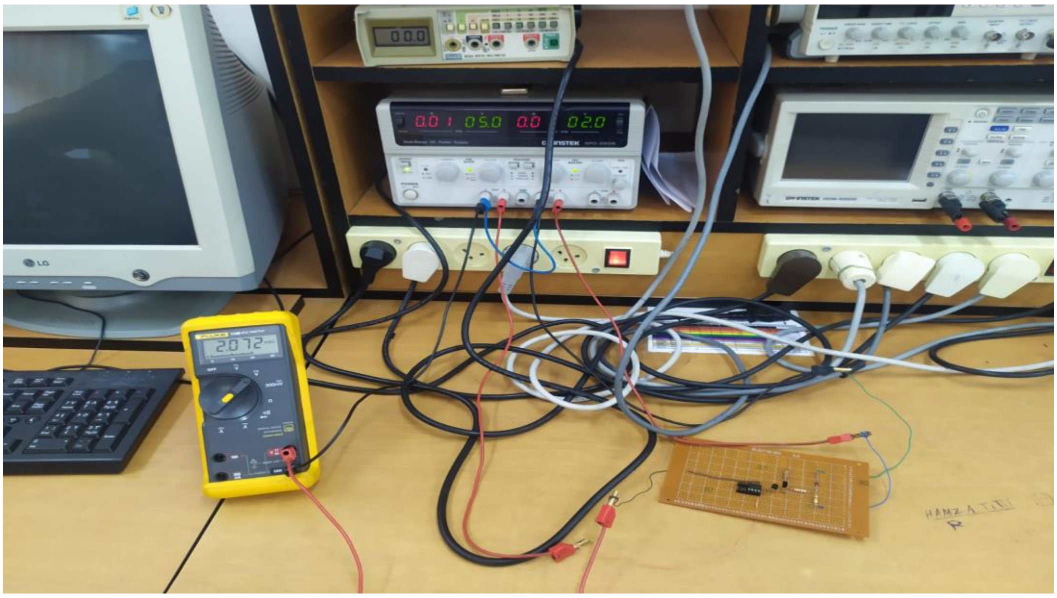
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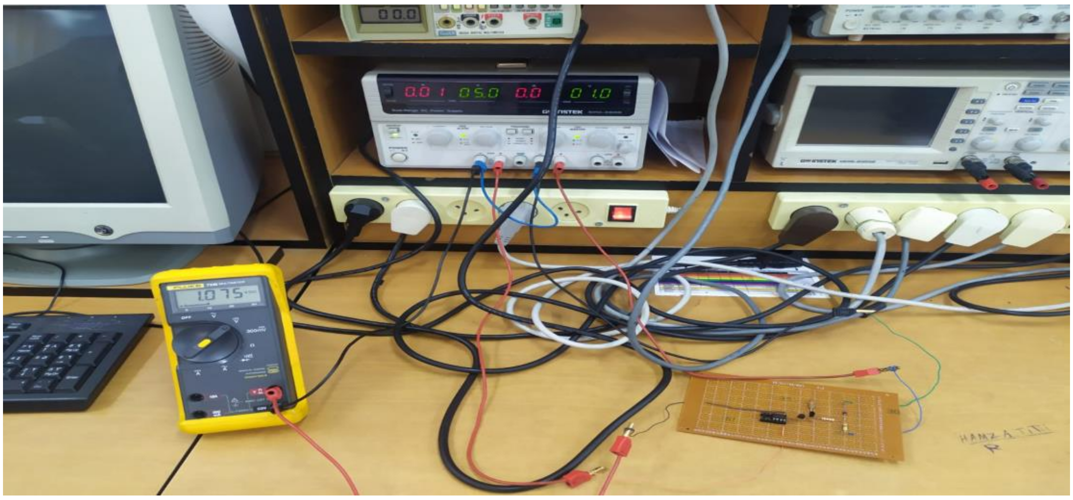
1.075