

# Design of DC Shock Simulator

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**Abstract**—Defibrillators are electronic devices that carry shock electrical signals (pulses) to the heart muscle to maintain myocardial depolarization that is undergoing cardiac fibrillation (ventricular fibrillation or atrial fibrillation) (Bronzino, 2000). There are several conditions that must be met for the occurrence of shock processes including shock time, energy to be provided, patient and operator safety. In this defibrillator, the use of selectors/energy selection is linear in the range 1-30 Joules with the use of tools at 10, 15, 20, 25, 30 Joules. The energy will then be discarded or given to the patient via a paddle when pressed the Discharge/shock button. The result of the signal given to the patient is monophasic. This study used a pre-experimental type with a One Group post-test design research design. Measurements were made 5 times the voltmeter at the test points determined by the compiler.

**Keywords**—Defibrillator; Monophasic; Atmega 328P; Condensator

## I. INTRODUCTION

Defibrillators are electronic devices that carry shock electrical signals (pulses) to the heart muscle to maintain myocardial depolarization that is undergoing cardiac fibrillation (ventricular fibrillation or atrial fibrillation). Cardiac fibrillation (cardiac fibrillation) is a condition in which myocardial cells contract asynchronously (out of sync). When fibrillation occurs in the ventricles, this causes cardiac output (CO) blood flow to drop dramatically and can cause death within a few minutes. Atrial CO fibrillation decreases but is not too fatal. Repetition of electroshock is no longer than 45 seconds after the heart stops. The external energy given is between 50 to 400 Joules. Internal energy is given maximum 1/10 External Position of the electrode (paddles): anterior - anterior (apex sternum) or anterior-posterior. Electrode diameter between 8-10 cm for adults. Energy regulation and energy supply are controlled by microcontrollers [1].

In fact, a defibrillator is a medical device that is part of Basic Life Support equipment that is most often used and needed in emergency treatment, so it is not uncommon for this equipment to not only be placed in places like the OK Room, ICU Room, IGD but also equipment. Which is needed in public places such as airports, cruises, and others for rapid handling of defibrillation that can occur at any time.

Because of its increasing use and rapid development, it also requires operators and technicians who have the competence to handle the defibrillator tool, this aims to obtain optimal benefits from the use of defibrillators. It is important for operators or technicians to have a thorough knowledge of the functions, performance of tools and security of tools for this purpose, and the interests of electromedical candidates are given understanding and debriefing on the basis of the working principle of defibrillator tools [2]. With this problem, the

author wants to make a learning tool and debriefing the defibrillator tool, "DC-Shock Simulation".

Basically, the working principle of a defibrillator is to provide electrical energy stimulus in units of joules produced from a defibrillator machine equipped with a battery. The energy is channeled through a paddle electrode (shaped like an iron). The user is affixed to the patient's chest. The paddle defibrillator is equipped with a charge button "filling" energy and a button to do a defibrillator or "release" the electrical energy. When a heart rhythm condition is chaotic, someone analyzes it by looking at the ECG chart on the monitor screen. Then determine some of the energy that will be used [3].

The AC defibrillator was the first defibrillator known since before 1960. This defibrillator uses an electric current of 5 to 6 amperes, with a frequency of 60 Hz which is attached to the patient's chest for 250 to 1000 ms [4]. The success rate of this AC defibrillator is slightly low, so it cannot handle atrial fibrillation properly. Even in reality, when trying to overcome atrial fibrillation with AC defibrillators often produce ventricular fibrillation which is a more serious arrhythmia.

This type of AC defibrillator uses a number of cycles of alternating current originating from the flow of the mesh through a step-up transformer to flow to the heart. The typical (typical) AC defibrillator circuit is shown in Figure 1. To achieve defibrillation, the internal electrode requires a voltage range of 80 to 300 Vrms; Whereas for external electrodes, it is required to be about twice the voltage range above. so to obtain the voltage value, a step-up transformer is needed to increase the voltage originating from the grid. The operator can choose the desired voltage through the selector switch. This transformer must be able to supply 4 to 6 amperes during the stimulus period. The transformer is equipped with a switch that can control the pulse time interval. The pulse time interval used

is usually in the order of 250ms. One of the disadvantages of an AC defibrillator is that it can cause ventricular fibrillation during the cardiac cycle.

Starting in 1960 several DC defibrillators were developed. This instrument stores DC electrical charges and is then given to patients. The main difference (principle) between a DC defibrillator and an AC defibrillator is the waveform and the electrical charge given to the patient. Typical waveforms are Lown, mono-pulse, delay-line and trapezoidal forms.

The advantages of DC defibrillators are:

1. Can reduce the effect of damage to the heart because it does not cause ventricular fibrillation as in AC pulses.
2. Can reduce the convulsive effect on skeletal muscle (skeletal muscle).
3. Can be used in the treatment of supraventricular (atrial) arrhythmias properly.

In 1962 Dr. Bernard Lown from Harvard University introduced a wave-form that uses its name called the Lown-wave form. Lown waves are shown in Figure 2, where the voltage and current applied to the top of the patient's chest are indicated by dashed lines. Very fast generated currents around 20A at a source voltage of around 3 kV (3000 volts). The resulting waveform will gradually drop to zero within 5 ms and then return a small negative pulse for 5ms[5].

In 2006 Shahrul from the Indonesian university's computer engineering department made a study of Defibrillators that discussed patient resistance, resistor capacity, and also the working principle of a defibrillator.

In May 2017 Irawan Sukma, Siddiq Wahyu Hidayat, and Wuwus Ardiana from the LIPI Testing Quality and Technology System Research Center conducted a study on The Effects of Inductor Resistance on Defibrillation Energy from the Electrocardiograph Endurance Test System.

In making the "DC-Shock simulation" tool the authors pay attention to several things, namely; the first is the phase form, in this case, the writer only uses one phase form that is monophasic phase, this is because in the making of the tool it is still in the initial design so that it has not designed for making biphasic signals, both sync and async modes, in this case, the authors limit just asynchronize mode because in making the "DC-Shock simulation" tool, restrictions are needed so that there is no propagation to other problems so that the writer can focus on the core problems, at the same time so that it can be used as a suggestion for further development.

As explained above, the authors hope that the "DC-Shock simulation" tool can be used as one of the learning facilities, especially learning in the life support laboratory, especially on DC Shock devices so that in the future students will be able and have good supplies to overcome trouble shooting that may occur in the field and carry out proper maintenance on the defibrillator.

## II. MATERIALS AND METHODS

### A. Experimental Setup

This study uses twenty-five measurements by comparing the value between the results of the voltage conversion to joule with the results of energy readings in the range of energy 10, 15, 20, 25, 30 with five times the measurement of each selector.

#### 1) Materials and Tool

This study uses paddles designed according to the concepts that have been made. A paddle is installed in the sternum and heart apex. Using comparator IC 741. Arduino Nano microcontroller is used to give commands to the control circuit. The control circuit consists of two series namely micro and macro circuits. Microcircuit functions to control settings from min-system to macro circuits, while macro circuits function to run each process on a device with large power. The generator circuit in high voltage step-up is rectified by a 10 Ampere rectifier.

#### 2) Experiment

In this study, after the design was completed, the energy yield of this device was tested using defibrillator analyzer with the results in accordance with the specifications of the energy that had been designed. In the calibration phase, the energy results are tested using simulated patients with reference-adjusted resistance. Each setting, the output is calculated and converted to validate the results of this study.

### B. The Diagram Block

When the main switch is pressed, the circuit will get a supply voltage from PLN. Press the ready button to start setting energy, after setting the Joule, then press Charge to be able to load the capacitor, the charge button and the discharge button will provide logic to the microcontroller which then instructs the charge and discharge process on the device, the TFT LCD will display the energy graph given to the patient, the alarm will give an indication of each process that takes place on the appliance, after the active charge process the capacitor will take place, the comparator will compare the value of the capacitor with the set, the comparator will disconnect when the capacitor matches the setting, the capacitor loop circuit interlock functions as a safety, after the energy is in accordance, the energy in the capacitor will be discharged to the paddle (patient) when the shock process takes place. In making the "DC-Shock simulation" tool the authors pay attention to several things, namely; the first is the phase form, in this case, the writer only uses one phase form that is monophasic phase, this is because in the making of the tool it is still in the initial design so that it has not designed for making biphasic signals, both sync and async modes, in this case, the authors limit just asynchronize mode because in making the "DC-Shock simulation" tool, restrictions are needed so that there is no propagation to other problems so that the writer can focus on the core problems, at the same time so that it can be used as a suggestion for further development.

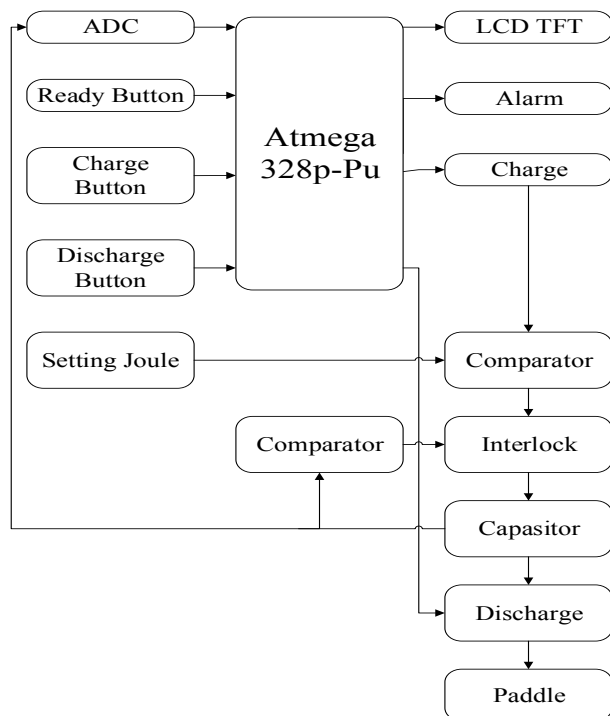


Fig. 1. The diagram block of the Simulator DC Shock

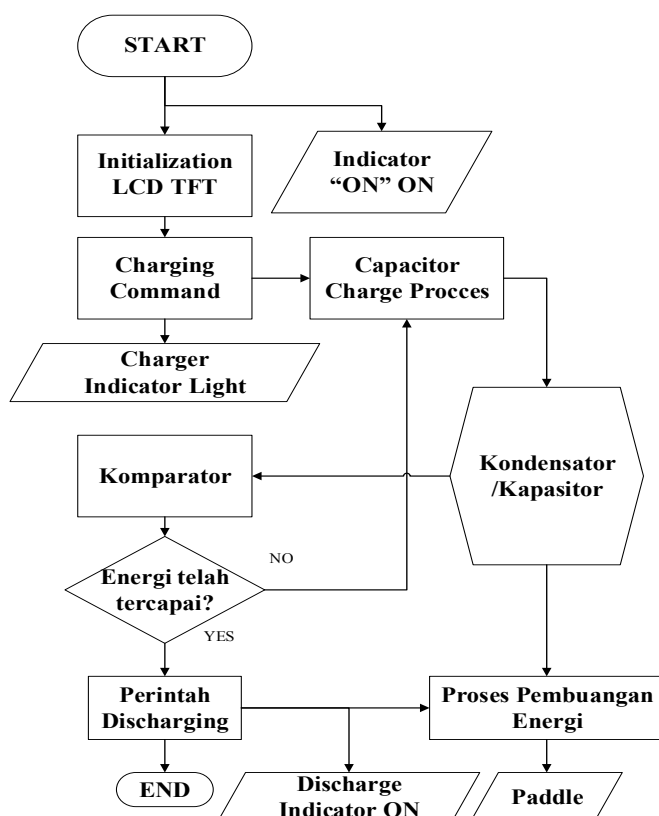


Fig. 2. The Flowchart of the Arduino Program

### C. The Flowchart

When the ready button is pressed the start tool is turned on when the LCD TFT display will display the joule value and the ON indicator is active. When the button charge is pressed the charge command will be active, the charge indicator will light up and a capacitor will be processed, the comparator will compare the capacitor value with the setting, when the capacitor contents have not reached the setting the capacitor will be filled again when the capacitor contents are suitable then disposal, when the button the discharge is pressed then the discharge command will be active and the discharge indicator will light up, then the disposal will be carried out through paddle, and end / reprocess process.

### D. The Analog Circuit

An important part of this development is the analog circuit that illustrates in Fig. 3 (control circuit), Fig. 4 (comparator circuit), Fig. 5 (capacitor charging circuit), and Fig. 6 (generator circuit).

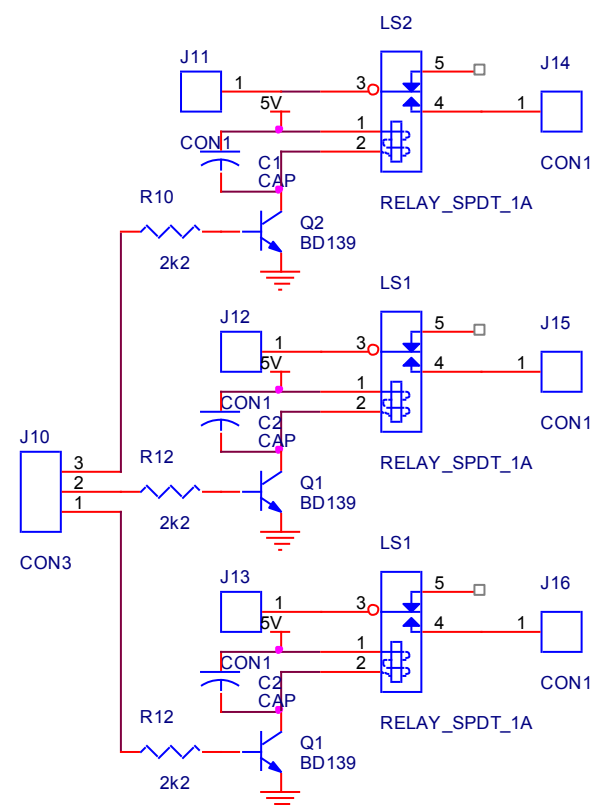


Fig. 3. Control Circuit

#### 1) Control Circuit

The control circuit which describes in Fig. 3. This circuit functions to control the relay driver, the input comes from the logic given by the minimum system circuit, if the Arduino pin gives a High logic then the transistor will saturate, when the

transistor is saturated the relay will contact which will then control the AC relay.

### 2) Comparator Circuit

This circuit serves to compare the voltage between the capacitor voltage which has been lowered by the setting/joule variable voltage, the output of the comparator goes into the driver relay circuit which in turn controls the charging of the capacitor.

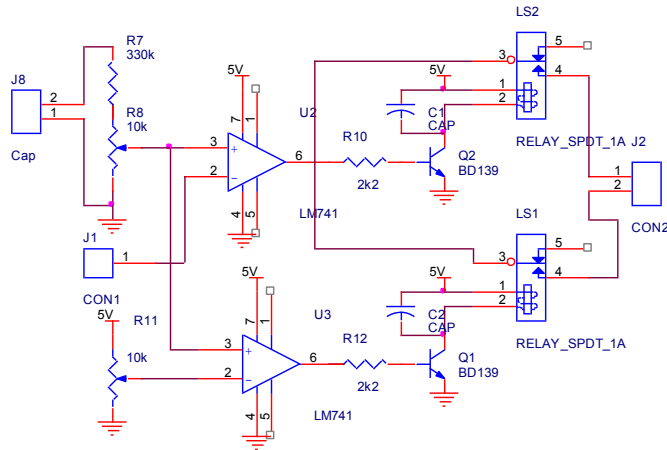


Fig. 4. Comparator Circuit

### 3) Capacitor Charging Circuit

The circuit consists of three pairs of AC relays that are used to contact when ready, charge and discharge conditions. The circuit input is obtained from the 220V PLN voltage. R3 functions as contact from R4, when pressed it will turn on the ready process. R5 functions as contact from R6, when pressed it will turn on the charging process. R7 functions as contact from R8, when pressed it will turn on the ready process. The capacitor will be filled and discarded according to the instrument concept. The capacitor Charging Circuit was designed as shown in Fig. 5.

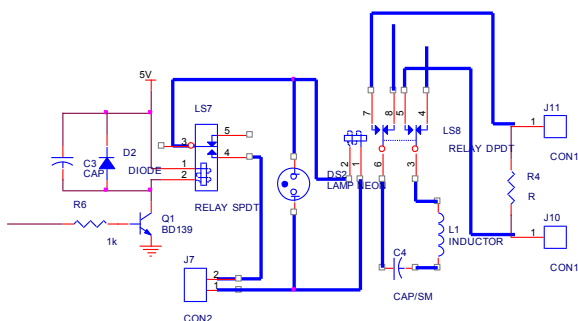


Fig. 5. Capacitor Charging Circuit.

### 4) High Voltage Generator Circuit

The input/step down primary transformer is given the voltage from PLN directly and produces a voltage value of 110 Volt. The first comparator input comparator comes from the

joule setting whose value is variable. The comparator input of the second comparator comes from a setting whose voltage value remains as a safety capacitor. The output of the comparator goes into the relay driver circuit. Comparator one as a setting and two comparators as safety and both are arranged in series. as shown in Fig. 6.

## III. RESULTS

In this study, the defibrillator was tested using analyzer defects and internal conversions on the device. The results show that Berberian dc shock is feasible because it produces the appropriate energy value.



Fig. 6. Value Defibrillator



Fig. 7. The Digital part of the Defibrillator

### 1) The Defibrillator Design

Defibrillator design Photographs of analog and digital parts of the Holter ECG are shown in Figure. 8 and Figure. 9, respectively. The comparator part consists of IC 741 (OP-AMP), BD139 transistor and relay to contact. There is also a series of energy settings that will be given. The digital part consists of an Arduino 328 microcontroller which is the main board of the device, a capacitor charging circuit and a high voltage generator circuit.

2) *The Listing Program for Arduino DC Shock Simulator*  
Listing program 1. Program Initialization

```
const int buttonPin1 = 2;
const int buttonPin2 = 3;
const int buttonPin3 = 4;
const int Pinready = 5;
const int Pincharge = 6;
const int Pindischarge = A0;
const int Alarm = A1;
const int komparator = 10;
const int LedIndikator = 13;

unsigned int dataadc;
unsigned int vcap;
unsigned int vcapkuadrat;
unsigned int energi;
unsigned int energi1;
//
boolean ready = false;
boolean charge = false;
boolean discharge = false;
// variables will change:
int buttonState1 = 0;
int buttonState2 = 0;
int buttonState3 = 0;
```

In initializing "int" is a numerical data type used when not dealing with fractions or decimals. Integer numbers also recognize positive and negative values, "unsigned int" has almost the same function as int variables, the difference is that unsigned numbers mean only positive values. "Const int" is an integer constant that refers to the Arduino pinboard, Boolean data type to hold the truth value (flag)

Listing Program 2. Setup Program

```
void setup() {
  Serial.begin(9600);
  pinMode(buttonPin1, INPUT);
  pinMode(buttonPin2, INPUT);
  pinMode(buttonPin3, INPUT);
  pinMode(Pinready, OUTPUT);
  pinMode(Pincharge, OUTPUT);
  pinMode(Pindischarge, OUTPUT);
  pinMode(LedIndikator, OUTPUT);
  pinMode(Alarm, OUTPUT);
  digitalWrite(Pinready, LOW);
  digitalWrite(Pincharge, LOW);
  digitalWrite(Pindischarge, LOW);
}
```

The program listing above is for setting up the setup tool, "Serial.begin" to set the data transmission speed, buttonPin1,

buttonPin2, buttonPin3 is set as input from the push button. Pinready, pin charge, discharge pin is used as an output to control the relay driver where the initial condition is LOW.

Listing Program 3. Control Program

```
void loop() {
  buttonState1 = digitalRead(buttonPin1);
  buttonState2 = digitalRead(buttonPin2);
  buttonState3 = digitalRead(buttonPin3);
  if (buttonState1 == HIGH)
  {
    digitalWrite(LedIndikator, HIGH);
    ready = true;
    digitalWrite(Pinready, HIGH);
    digitalWrite(Alarm, HIGH);
    delay(500);
    digitalWrite(LedIndikator, LOW);
    digitalWrite(Alarm, LOW);
    delay(300);
    digitalWrite(LedIndikator, HIGH);
    digitalWrite(Alarm, HIGH);
    delay(300);
    digitalWrite(LedIndikator, LOW);
    digitalWrite(Alarm, LOW);
  }
  if (ready == true) {
    digitalWrite(Pinready, HIGH);
  }

  if (buttonState2 == HIGH)
  {
    charge = true;
    digitalWrite(Pincharge, HIGH);
    digitalWrite(Pinready, HIGH);
  }
  if (charge == true)
  {
    digitalWrite(LedIndikator, HIGH);
    digitalWrite(Alarm, HIGH);
    delay(4000);
    digitalWrite(LedIndikator, LOW);
    digitalWrite(Alarm, LOW);
    delay(200);
    digitalWrite(LedIndikator, HIGH);
    digitalWrite(Alarm, HIGH);
    delay(500);
    digitalWrite(LedIndikator, LOW);
    digitalWrite(Alarm, LOW);
    delay(200);
    digitalWrite(LedIndikator, HIGH);
    digitalWrite(Alarm, HIGH);
    delay(500);
    digitalWrite(LedIndikator, LOW);
  }
```

```
digitalWrite(Alarm, LOW);
delay(200);
digitalWrite(LedIndikator, HIGH);
digitalWrite(Alarm, HIGH);
delay(500);
digitalWrite(LedIndikator, LOW);
digitalWrite(Alarm, LOW);
charge = false;
}
```

```
if (buttonState3 == HIGH)
{ digitalWrite(Pindischarge, HIGH);
  digitalWrite(Alarm, HIGH);
  digitalWrite(Pincharge, LOW);
  delay(300);
  digitalWrite(Pindischarge, LOW);
  digitalWrite(Alarm, LOW);
  digitalWrite(Pincharge, LOW);
  delay(500);
}
```

The above program explains that the user gives an instruction that button state1 represents the ready button when this button is pressed it will change the ready pin to HIGH to control the relay ready, the button state represents the button charge when the button charge is pressed it will change pin-charge to HIGH for control the relay charge, buttonstate3 represents the button discharge when the button discharge is pressed it will change the pin-discharge to HIGH to control the relay discharge, the Alarm condition and the led indicator are adjusted to the ongoing process.

#### Listing Program 4. Display Program

```
vcap = analogRead(A5) / 2.482;
vcapkuadrat = vcap * vcap;
energi = vcapkuadrat / 1111;
Serial.print("n0.val=");
Serial.print(vcap);
Serial.write(0xff);
Serial.write(0xff);
Serial.write(0xff);

Serial.print("n1.val=");
Serial.print(energi);
Serial.write(0xff);
Serial.write(0xff);
Serial.write(0xff);

{
  dataadc = analogRead(A5) / 3 ;
  String Tosend = "add "; //We send
the string "add "
  Tosend += 2; //send the id of
the block you want to add the value to
```

```
Tosend += ",";
Tosend += 0; //Channel of
taht id, in this case channel 0 of the waveform
Tosend += ",";
Tosend += dataadc; //Send the
value and 3 full bytes
Serial.print(Tosend);
Serial.write(0xff);
Serial.write(0xff);
Serial.write(0xff);
}
```

The above program explains that the user gives instructions to TFT Nextion with a customized id, and displays the conversion that the user uses to convert the voltage to joules by formula  $1 / 2 \times C \times V *$

#### 3) Value of energy discharge error

Validation of the Joule value shown in the energy display on the TFT screen compared to the set of settings that have been set. Errors are shown in Table I.

TABLE I. ERROR MEASUREMENT OF ENERGY PARAMETERS BETWEEN DESIGN AND CALIBRATOR.

ENERGY	Error(%)
10	0.15
15	0.06
20	0.23
25	0.64
30	0.47

TABLE II. ENERGY MEASUREMENT MISTAKE PARAMETERS BETWEEN DESIGN AND STANDARD UNITS (DEFIB ANALIZER).

No	setting	Error (%)
1	10	7.02
2	15	9.10
3	20	10.65
4	25	12.30
5	30	13.01

#### IV. DISCUSSION

After making the literature making and study process, planning, testing, testing tools and data collection or author measurements can be concluded on measurements with Volt meters, obtained for the measurement of voltage measurement

results at energy values 10, 15, 20, 25, 30 Joule the biggest error is obtained 2.5% and the smallest error is 0.4%. Whereas for the measurement of voltage in the comparison the biggest error value and the smallest error is 1%.

In the joule measurement, the greater the voltage setting in the comparator, the higher the voltage that enters the capacitor, so the higher the joules obtained, the higher the value of the capacitor, the higher the joules produced. In time measurement it is set at 300ms, adjusted for the RC formula. It can measure and condition the time of shock.

## **V. CONCLUSION**

This study has shown the development of a Defibrillator Simulation to monitor energy signals from subjects in real-time. This study was built based on the Arduino microcontroller and several control circuits and comparator comparators. This study has proven that its accuracy is appropriate for monitoring energy signals produced in real-time. In the future, this research can be made into 2 biphasic and monophasic signals. Then develop the tool by adding a patent selector and can measure and condition the time of shock.

## **REFERENCES**

- [1] W. Pairindra, "The Enhancement of Multilevel Converter for Coaxial Inductive Power Transfer in Low Voltage DC Power Distribution," in *2016 13th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, 2016.
- [2] T. R. Oliveira, "Design of a Low-Cost Residual Current Sensor for LVDC Power Distribution Application," *2018 13th IEEE Int. Conf. Ind. Appl.*, pp. 1313–1319, 2018.
- [3] J. Desember, F. A. Noor, H. Ananta, and S. Sunardiyo, "Pengaruh Penambahan Kapasitor Terhadap Tegangan , Arus , Faktor Daya , dan Daya Aktif," *Sci. J. Informatics UNNES*, vol. 9, no. 2, pp. 66–73, 2017.
- [4] P. Hsia, D. Mendoza, S. Gurunathan, S. Naik, and R. D. Jr, "Design of a Real-Time Ventricular Fibrillation Waveform Anailysis System for Improved Low Energy DC Defibrillation Shock Delivery," in *Computers in Cardiology*, 1996, pp. 349–352.
- [5] S. I. S. Enanv, H. Medical, S. Ab, and S. Bertling, "International Standard," vol. 2004, 2010.