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Design of Battery Charging Control System (Fast Charging) on Electric Vehicle based on Atmega32 Microcontroller

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Abstract. Electric Vehicles are vehicles that do not release toxic gases that can reduce environmental pollution caused by combustion. The electric vehicle requires a lithium ion battery as a replacement energy source of fuel oil so it needs charging a battery that can speed up charging safely. This research uses fast charging method through high current method and adjusts the current capacity needed by the battery in accordance with the result of circuit specification. This research uses rectifier circuit, buck converter, Atmega microcontroller. The results of this study are expected to increase current capacity and speed up the process of charging the battery.

1. Introduction

The development of automotive technology is growing rapidly around the world [1]. Automotive technology generally uses an internal combustion system or ICE (Internal Combustion Engine) as its prime mover, but the impact of this combustion system causes air pollution or exhaust fumes that disrupt human breath and damage the environment. Along with the development era of many scientists from various countries and manufacturers engaged in the field of automotive that has applied electric propulsion technology that is electric motors used for electric vehicles. On the continent of Europe already almost all transportation vehicles use electricity. Not less behind in Asia, especially Japan and China, the country has long ago developed this friendly environmental transportation technology and the State has been able to create the main driving force that is Electric Motors, Indonesia is also now - re-develop electric cars, one of them namely the electric car named Selo type of electric vehicle is a vehicle intended for high-speed.

Electric vehicles require lithium-ion batteries to store energy sources to drive electric motors. Lithium-ion batteries are rechargeable batteries and can be used many times. These batteries consist of positive electrodes containing LiCoO2 and negative electrodes made of carbon graphite (C6) and separator made of a thin layer of plastic that can be passed by ions. This type of battery is strongly recommended for storage of energy used electric vehicles, because Lithium is a highly reactive element, meaning that bias stores more energy in bonds atoms. Lithium-ion battery loses only 5% of its content every month meaning this battery is durable and very suitable for energy source of electric vehicle [2],[3].

In order to develop an electric car, the need for fast and safe battery charging, therefore in this study examined about the design of charging control system (fast charging) on electric vehicle based on Atmega32 microcontroller. The design of this battery charging design has two charging conditions that are at the time of normal charging condition and at the time of full charging condition by using high current (fast charging) [4]. This method can be achieved in a simple way without using complex mathematical calculations, by using a MOSFET control based on Atmega32 microcontroller [5]. Microcontroller will control high voltage and current through PWM buck converter when charging electric car battery.

2. Methods

2.1. Block diagram design of fast charging circuit

Figure 1 illustrates our design related to fast battery charging system. As shown in Figure 1, we utilized microcontroller, driver MOSFET, buck converter DC to DC, and voltage detector and current sensors for supporting the efficiency of our proposed design.

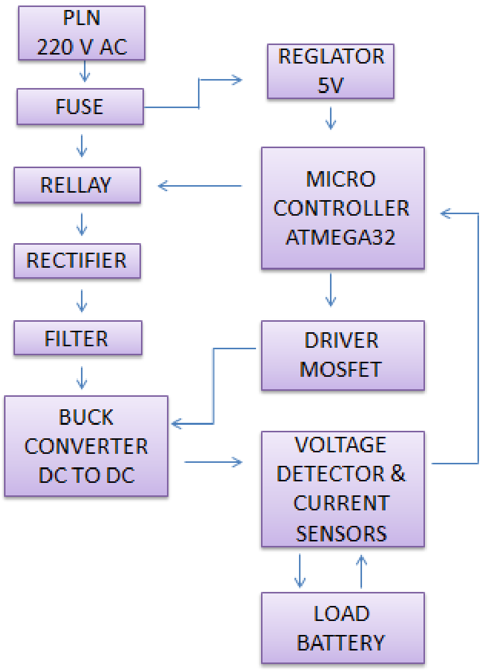

Figure 1. Design diagram of fast battery charging system.

2.2. Design of buck converter circuit

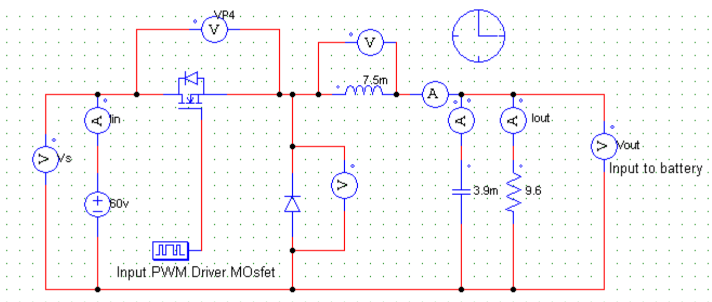

Figure 2. Schematic buck converter circuit.

The buck converter circuit on Figure 2 has functions to convert DC voltage into DC voltage which is variable. The working principle of Buck-Converter is by using a continuous switch (ON-OFF) known as PWM (Pulse Width Modulation) and Duty Cycle in controlling the speed of the switch's work.

Calculation duty cycle:

$$D = \frac{t_{on}}{t_{on} + t_{off}} = \frac{t_{on}}{T}$$
$$t_{on} = DT$$
$$t_{off} = (1 - D)T$$
$$L = \frac{V_S - V_R}{\Delta I} t_{on}$$

Calculation of inductor value:

$$L = \frac{V_S - D\,V_S}{\Delta I} t_{on} \leftrightarrow L = \frac{V_S\,(1 - D)\,D}{\Delta I\ f}$$

$$\Delta V = V_{\max} - V_{\max}\,(e^{-\frac{1}{RC}t_{off}})$$
$$= V_{\max}\,(1 - e^{-\frac{1}{RC}t_{off}})$$
$$= V_{\max}\left(\frac{t_{off}}{RC}\right)$$
$$\Delta V = V_{\max}\left(\frac{1 - DT}{RC}\right)$$
$$C = V_{max}\frac{1-D}{f\,R\,\Delta V} \qquad ; V_{\max} = V_R + \frac{\Delta V}{2}$$
$$C = \left(D\,V_S + \frac{\Delta V}{2}\right)\frac{1 - D}{f\,R\,\Delta V}$$

Calculation of capasitor value

$$\Delta V = V_{max} - V_{min}$$

$V_{\max} = V_R + \frac{\Delta V}{2}$ ...(1) Capacitor voltage when charging

$V_{\min} = V_R - \frac{\Delta V}{2}$ ...(2) Capacitor voltage when discharging

$$\Delta V = V_{\max} - V_{\max}\left(e^{-\frac{1}{RC}t_{off}}\right) \qquad ; V_{min} = V_{\max}\left(e^{-\frac{1}{RC}t_{off}}\right)$$
$$= V_{\max}\,(1 - e^{-\frac{1}{RC}t_{off}})$$
$$= V_{\max}\left(\frac{t_{off}}{RC}\right)$$
$$\Delta V = V_{\max}\left(\frac{1 - DT}{RC}\right)$$
$$C = V_{max}\frac{1 - D}{f\,R\,\Delta V}$$
$$C = \left(D\,V_S + \frac{\Delta V}{2}\right)\frac{1 - D}{f\,R\,\Delta V}$$

2.3. Designing MOSFET driver circuit

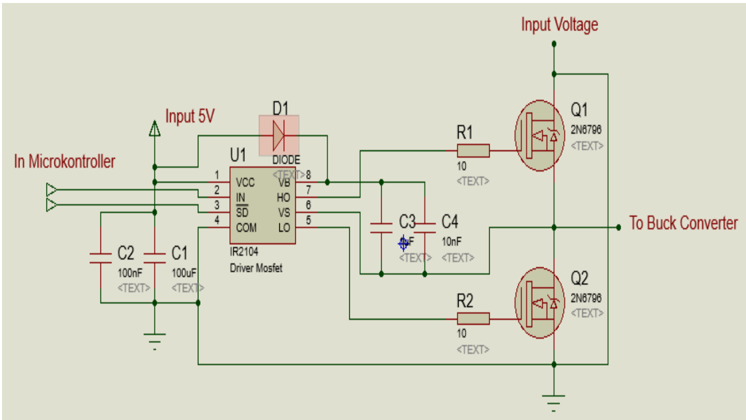

Figure 3. Schematic mosfet driver circuit.

This circuit depicted in Figure 3 serves as a liaison between the microcontroller with a buck converter and as a separator between power circuits with control circuit. The goal is to avoid damage to the microcontroller in case of voltage behind the buck converter.

2.4. Designing a series of relay modules

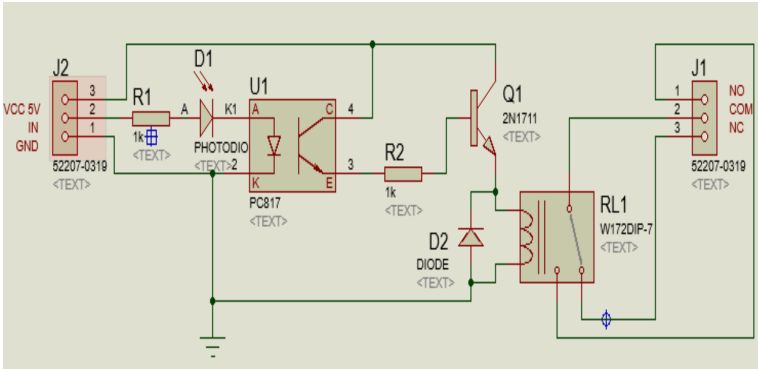

Figure 4. Schematic of relay modules.

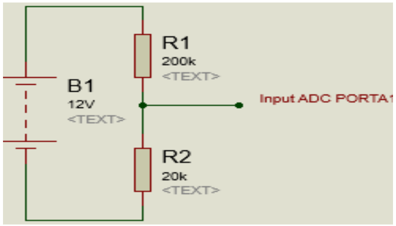

Figure 5. Schematic of voltage sensors circuit.

The relay circuit in Figure 4 serves to disconnect and connect the voltage from the voltage source to the battery fast charging circuit set by the microcontroller whose input adjusts from the voltage sensor and current sensor.

2.5. Design of voltage detector

This voltage divider circuit in Figure 5 works for voltage divider or voltage sensor circuit, because microcontroller system can not accept voltage more than 5 volts and the circuit can measure DC voltage of 48V – 54V to 0V – 5V.

2.6. Design of current sensor circuit

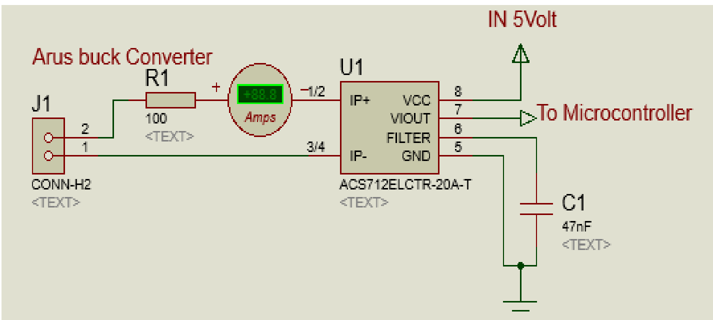

Figure 6. Schematic of current sensor circuit.

This series of current sensors serves as a safety and monitoring current that flows on the battery charging circuit.

2.7. System design of Atmega32A microcontroller

The design of the minimum system set of atmega32A functions as the brain of all battery charging devices. Microcontroller Atmega 32A consists of PORTA, PORTB, PORTC and PORTD, each PORT different function. And the schematic of microcontroller Atmega32 circuit is shown in Figure 7.

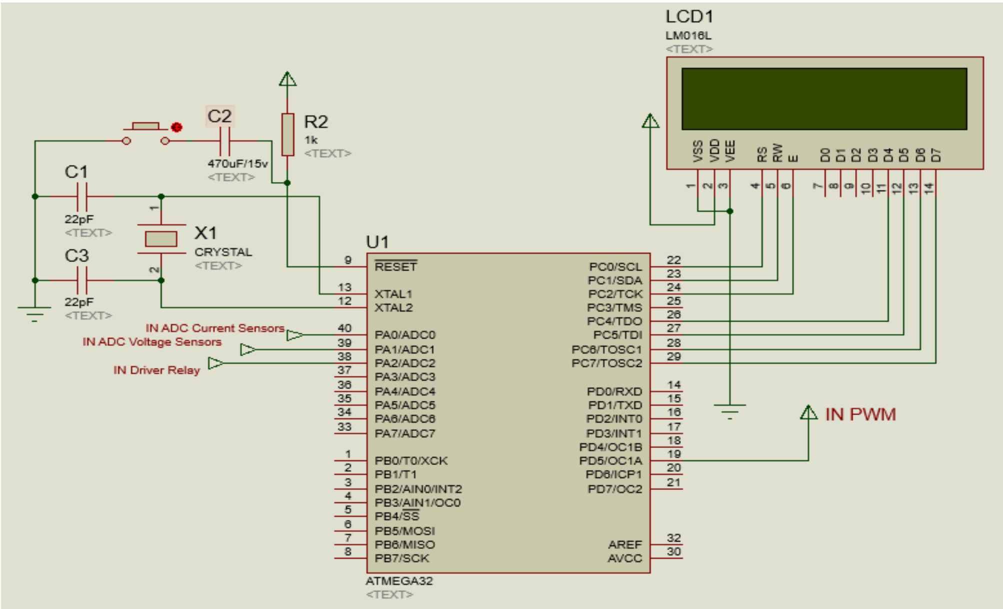

Figure 7. Schematic of microcontroller Atmega32 circuit.

3. Results and Discussion

Here is a quick battery charging device test that uses voltage changes through the buck converter set by frequency changes using the mosfet component. Current sensors and voltage sensors in the input to the system of this circuit device are to determine the condition of the battery. And the battery capacity is in full or empty and also the sensor as a safety at the time of charging the battery take place. All devices are in control using Atmega32 microcontroller. The real of our product design is shown in Figure 8.

Figure 8. Fast charging device.

Testing device tool is done by testing all parts of each series of simulation results and measurements of the circuit. Our experiments show the results in Figure 9 and Figure 10 which include:

3.1. *Rectifier and filter circuits*

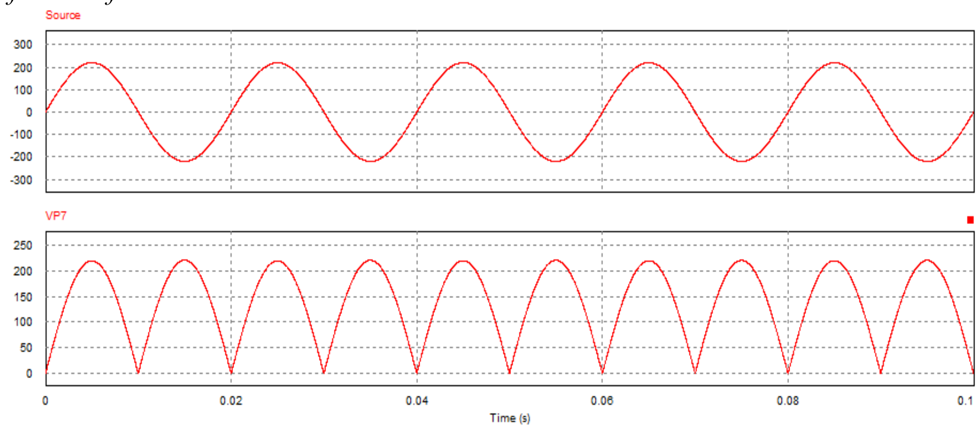

Figure 9. Wave simulation results.

This circuit uses a 2A bridge diode component, 220 AC input voltage and is converted to 220 DC. Figure 9 shows the input simulation of power line, while Figure 9 presents the signals after filtering. The output of regulator circuit is shown in Figure 10. The parameters for simulation are listed in Table 1.

3.2. *Regulator circuit*

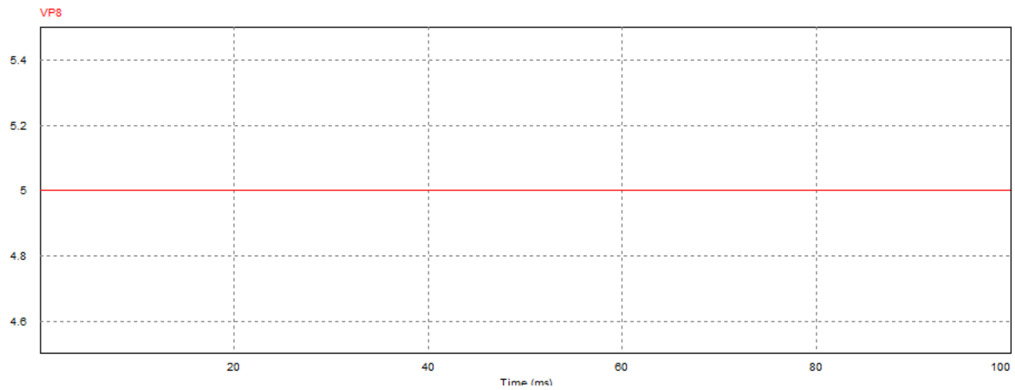

Figure 10. Output voltage waves.

3.3. *Buck converter*

Table 1. Main Circuit Parameter.

Parameter name	Symbol	Value
Input voltage	Vin	220 V
Output voltage	Vout	54 V
indutor	L	7.5mH
Capacitor	C	7.9uF
Freqency	F	50000
resistance	R	9.6 Ohm

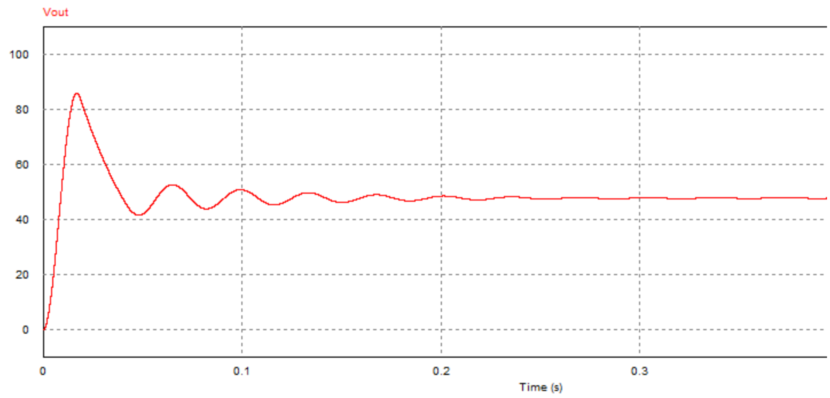

Figure 11. Voltage output buck converter.

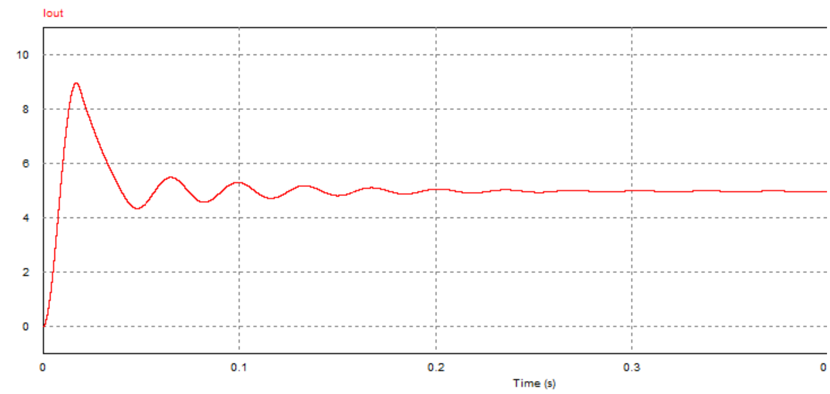

Figure 12. Current Output buck converter.

The above wave simulation is the result of the buck converter circuit with the value of the component that has been specified (Figure 11 and Figure 12).

3.4. Microcontroller Atmega32A

Table 2. Port-specific functions.

PORT	Function
VCC	IN + DC 5V
GND	IN – DC 5V
PORT A0	IN Current Sensors
PORT A1	IN Voltage Sensors
PORT B	Dwonloader Program
PORT C	Output LCD
PORT D0	Output Module Relay
PORT D1	Output High Driver Mosfet
PORT D2	Output Low Driver Mosfet

For testing microcontroller, systems need to unite all the sensor modules and all the driver modules that include: current sensor module, voltage sensor, MOSFET driver and relay driver. Relay works when receiving input I / O from sensors and in process by microcontroller using C language program using CV AVR software. Table 2 lists the functions of ports in microcontroller.

Figure 13 and 14 show the relation of voltage and current over time. While, using lithium-ion battery with 10 Ah and 5 Ah charger is compared as listed in Table 3.

Table 3. Battery charge measurement using 5A charging device.

Type Battery	Output Voltage	Output Current	Long battery charge time
Lithium –	46 V	4.88 A	0 Minute
Ion	47 V	4.88 A	12,5 Minute
10 Ah	48 V	4.88 A	25 Minute
	49 V	4.88 A	37,5 Minute
Charger	50 V	4.88 A	50 Minute
5A	51 V	4.88 A	62,5 Minute
	52 V	4.88 A	75 Minute
	53 V	4.88 A	87,5 Minute
	54 V	0.78 A	100 Minute
	54.28 V	0.66 A	112,5 Minute
	54.28 V	0.59 A	125 Minute
	54.28 V	0.51 A	137,25 Minute
	Times		2 Hour 12.5 Minute

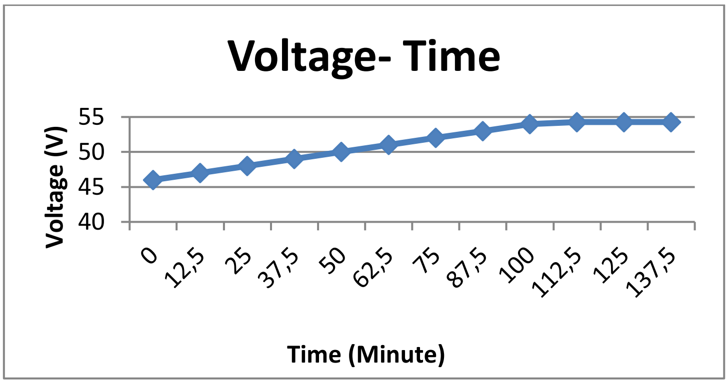

Figure 13. Chart of Voltage – Time.

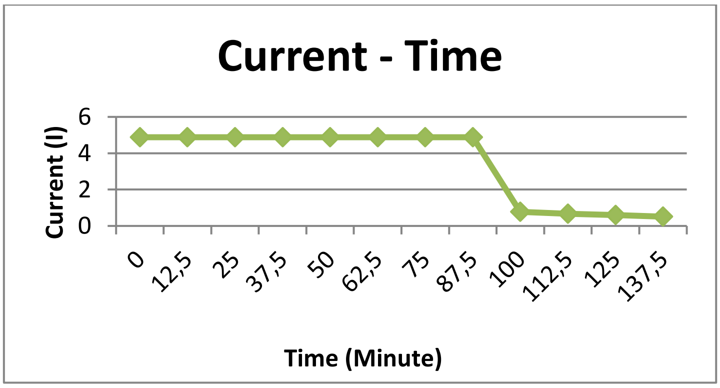

Figure 14. Chart of Current – Time.

4. Conclusions

The conclusion of the design is that the device is not maximal functioning properly because there is one circuit device that does not work properly, namely the power circuit. This circuit consists of various circuit-shaped circuit modules from the start of the sensor and driver circuit modules. Each circuit module and sensor system is tested one by one for the device until work properly. However, at the time of testing or simulation on the device, there are several circuit systems that do not match with the simulation in the software. Like MOSFET in buck converter circuit system is very susceptible to heat because of fast on-off switch for voltage. On this project, the voltages and currents are 48-54V and 4.88 - 0.51 A respectively of buck converter with a battery charging time spend around 2.5 hours from a blank status until the battery is full.

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