Energy Efficiency Enhancement of Electrical Vehicles

Anand M. Sharan, Mohammad Zamanlou

Abstract— **This work presents energy recovery in electrical form that is supplied by the batteries of the electric vehicles. In these vehicles, the batteries do not hold as much charge in the winter or cold months, thereby reducing the distance traveled per charge. This paper provides a method using a microcontroller to generate heat and regenerating the electrical charge in a blended form. The Musettes are controlled in such a way to blend the two processes – regenerating the charge and heating in an optimal manner depending upon the requirement.**

KEYWORDS: **Resistance braking; Dynamic braking; Regenerative braking; Electric Vehicles**

I. Introduction

The environmental pollutions due to the combustion of fossil fuels has propelled society to look for other options. One such option is to shift from the combustion of fossil fuels in cars to another form – electrically driven motor drive. But the challenge in the use of these alternate vehicles is in the range (distance) per charge, and of course the economy of using such vehicles. There are other advantages in the use of such vehicles, such as in noise abatement, fuel emissions, which cause illness in others – which is not measurable in dollars.

Another advantage in using these vehicles which are electrically driven is that the electricity can be obtained by converting solar energy into electricity and since the solar energy is distributed throughout the world, many countries do not need to spend hard currency to buy fossil fuels which are sold by few countries in the world [1-4].

The concept of regenerative braking is being used to increase the range in driving various kinds of modes of transportation such as in hybrid and electric vehicles, electric three-wheelers, electric bicycles, skateboards, and electric scooters [5-10]. There are To-day, far more people are traveling in two or three-wheelers or use scooters on roads than use electric cars. These electric vehicles are also being used at airports to transfer passengers within the terminals or also in golf courses or for material handling in warehouses. These two and three-wheelers are far more cost-effective in

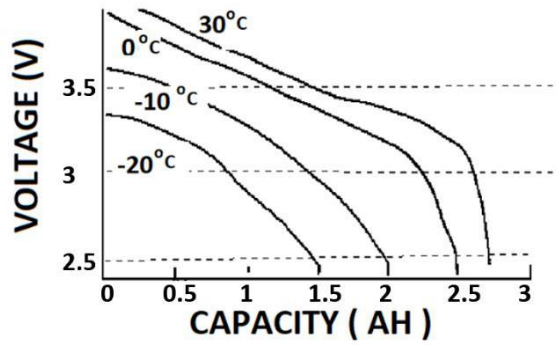


FIG. 1 BATTERY VOLTAGE VERSUS CAPACITY AT VARIOUS TEMPRATURES

terms of energy usage than electric cars. In this era of environmental pollution, more and more countries are encouraging this electricity to use transportation systems.

II. Electrical Circuitry in Various Modes of Motor in Electrical Vehicles (EV)

First of all, the energy in electrical form is obtained from batteries. These vehicles are used in all seasons – summer, fall, winter, etc. The charge holding capacity (energy storage) of batteries is temperature-dependent, and it can be seen in Fig. 1. In this figure, one can see that the same type of batteries can hold less charge in winter than in summer. In addition, the starting voltage is lower in winter; thus, the corresponding torque will be less and would require more current to drive the electric vehicle (EV) for specific vehicle speed. Not only this, but it will also result in less distance travel of the vehicle per charge.

Fig. 2 shows the modes needed for the motor in the use of EV. In the forward motion, MOSFETs Q1 and Q4 are closed, and Q2 and Q3 are open. However, when slowing down or braking - Q2 and Q3 are closed, and Q1 and Q4 are open when the vehicle is in the forward motion but decelerating. This action causes the motor to go into the regenerative mode where the battery gets recharged due to the current being in the opposite direction, but the recharging process is not as much efficient to charge the batteries as compared to the discharge process when the motor is in the forward motion – as far as the magnitude of the current is concerned. The charge recovery process is about 20 to 32 percent only [8].

In these vehicles, the total charge of the batteries is used up in driving, in illumination, and in heating the vehicle, etc. It is desirable to recover as much energy as possible. Therefore, it would be quite desirable to utilize a part of the reverse direction current in heating the batteries and the

Anand M. Sharan, Professor**,** Mechanical Engineering, Memorial University of Newfoundland, St. John’s, Newfoundland, Canada A1B 3X5

Mohammad Zamanlou, Graduate Student, M.Eng. Electrical Engineering, Faculty of Engineering & Applied Science, Memorial University of Newfoundland, St. John’s, NL, Canada.

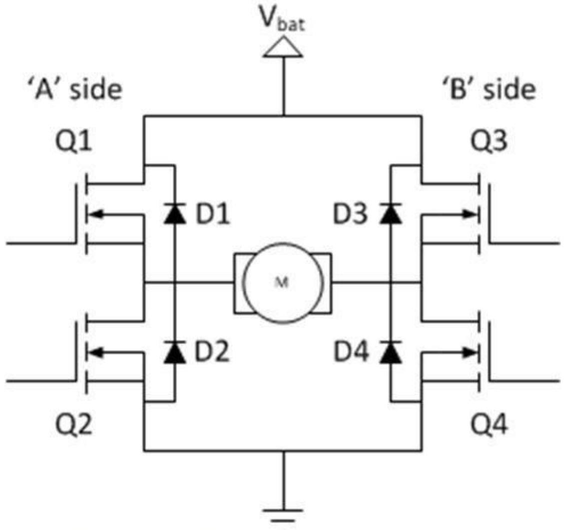


FIGURE 2. TYPICAL H-BRIDGE CIRCUITRY

vehicle in cold weather. This heat generation process is very efficient. Thus, any heat generation in the regenerative mode would be very desirable because we are able to use this reverse direction current for recharging the batteries and also heating.

The intent of this paper is to present a method to re-distribute the reverse current between the battery and a resistor connected in parallel to the battery (see Fig. 3). If α is a number less than or equal to 1, then (1- α) will be a remaining fraction of 1. Therefore, one can divide the current between the resistor in parallel with the battery in the ratio α I and (1- α) I. By using a potentiometer, one can vary α, thereby directing the current to these two – battery and the resistor.

In cold weather, one can recover the energy from the batteries to the maximum by charging the battery (smaller part of the current) and obtaining heat to raise the temperature of the batteries so that they maintain the maximum charge while slowing down the vehicle where the resistor serves to decelerate the vehicle while at the same time providing the heat to raise the temperature of the batteries and heating of the vehicle.

The circuit diagram to achieve this goal is shown in Fig.
3. In this figure, the four modes of the motor in both forward and reverse direction motion of the vehicle are shown on the right part of the figure, which we discussed earlier in Fig. 2. On the left half of this figure, the battery and a resistor in parallel are also shown. In the regenerative mode - the current going towards the battery is directed to the battery as well as to the resistor where there are Moffatts Q5 (two in number) are used for the flow of current to the battery whereas Q6 is used for the resistor. When Q5 is closed, then Q6 is open for α fraction of time, and the remaining fraction
- the Moffett in series with the resistor will be closed – all of this will happen only in the regenerative mode of the motor.

Table 1 shows the positions of various MOSFETs in the Forward, Forward-Regenerative, Backward-Regenerative, and Backward-Regenerative modes of the vehicle motion. This table also shows the position of the diodes and MOSFETs while the vehicle is stationary or Parked, which is considered as the 5th mode.

Another question arises as to what the driver of the vehicle will do to shift between the modes considered, as states in Fig. 4. Here. 'a' and 'b' are shown representing push button switches, which have two states – on and off. To go from the Forward to the Forward–Regenerative mode (slowing down or braking or decelerating), the driver will press switch 'a' once and when the slowing down is over and wants to accelerate then presses 'b' to accelerate. At the end of the journey, the driver will press 'a' again to go to the parked state. These switches 'a' and 'b' are shown in Fig. 5A, and it also shows its connections (D22, and D23) with the Arduino Micro Controller. This figure also shows the connections of potentiometers to control the speed of the vehicle and the selection of α. These selections are made through the pins A0 and A1. It should be noted that α is selected and kept fixed depending upon the requirements of generating the heat or braking versus charging the batteries. In the colder weather, it would be necessary to heat up the batteries to a specified temperature. Once the battery chamber temperature is attained, then α can be changed so that the battery is charged for more time.

It needs to be clarified that the vehicle should have independent hydraulic or mechanical brakes too. One can use resistance for braking and generating the heat. In the regeneration mode, the vehicles do get decelerated, but not to the extent that it would bring the vehicle to a stationary state. We would need the mechanical brake for sure. The resistance braking can increase the life of mechanical braking pads. If the vehicle is in Park state, then the driver can press 'b' to go to the Forward mode.

Fig 4 shows that the button 'b' is pushed in order to go from the Park to the Reverse or Backward mode. If there is a need to slow down the reverse direction speed, then again, the button 'b' is to be pushed. This figure also shows that one can obtain other states by following Fig. 4 [16,17].

Fig 5A also shows the connections of various Light Emitting Diodes (LEDs), which indicate the state in which the vehicle is. Therefore, the driver knows in which state he or she is – by observing the glow of the LEDs. Then to change the state, the driver has to follow Fig. 4.

Fig. 5B shows a detailed circuit for driving the MOSFETs (Q1, Q5, etc.) shown in Fig. 3. The Arduino output signals are at 5 Volts, whereas the MOSFETs are driven by voltages varying between 9 to 16 volts. The connections are Gnd, G1 to G6, and are shown in both figures, Fig 3 and Fig 5B. Some other details of the circuit can be seen in [18].

The vehicle driver has to continuously vary the potentiometer to vary the speed (Mosfette Q1 or Q2) . To slow down the speed depending upon the traffic condition – he or she has the choice of applying mechanical and or resistance brakes. If the situation permits, he or she can use the regeneration mode to slow down the vehicle.

Fig 6 shows the actual experimental setup. The theory developed here was checked using the circuitry shown in this photograph.

III. CONCLUSION

In this work, the importance of energy recovery to the maximum was discussed. The energy recovery is highly desired as all of the useful energy is stored in the batteries, which supply energy for the motion of the vehicle as well as for illumination and heating. In cold weather, the charge holding capacity of the batteries decreases, thereby reducing the range of the vehicle per charge.

One can regenerate a small fraction of the charge while decelerating by resorting to regenerative braking, but this process is at the most 32% efficient. In these vehicles, the entire heat is generated using the stored form of electrical energy. Thus, the energy left for driving gets substantially reduced. Considering that, the paper provides a choice of generating charge and heating while braking by blending the two - a very desirable feature of using a blend of the two.

IV. REFERENCES

[1] Sharan A. M., Zamanlou M., Rahman M H, and Al-Mehdi M.A.A., 2019, " Centralized Power Generation of Solar Parks using Wireless Controlling," International Journal of Current Engineering and Technology, Vol.9, No.3 (May/June 2019), pp 405-411

[2] Sharan A. M., Zamanlou M., 2019, "Accurate And Efficient Power Generation Of Photovoltaic Systems Using Wireless Technology", International Journal of Engineering and Applied Sciences (IJEAS), Volume-6, Issue-4, pp 2394-3661 April

[3] Sharan, A. M., and Prateek, M., 2006, "Automation of Minimum Torque Based Accurate Solar Tracking Systems Using Microprocessors "86, Sept – Oct., pp. 415 - 437 Journal of Indian Institute of Science

[4] Sharan, A. M., "Solar Tracking System "- U. S. A., Patent No. 5, 632,832, Issued, May 27, 1997

[5] Sharan, A. M., "Solar Energy Powered Electric Vehicle"- U. S. Patent No. 6, 021, 862 Dated Feb. 8, 2000

[6] Sharan, A. M., 2002, "Design of an Economical, and Mechanically Stable E-Cycle," NECEC St. John's, Canada

[7] Sharan. A. M., 2002, "Design of E-Bike and Controllers," NECEC St. John's, Canada

[8] "Regenerative braking: how it works and is it worth it in small EVs?", https://electrek.co/2018/04/24/regenerative-braking-how-it-works

[9] "Regenerative brake," https://en.wikipedia.org/wiki/Regenerative_brake

[10] "Dynamic braking," https://en.wikipedia.org/wiki/Dynamic_braking

[11] Kiddee K., and Khan-Ngern W., 2018," Performance Evaluation of Regenerative Braking System B Based on a HESS in Extended Range BEV, "Journal of Electrical Engineering and Technology, v 13, n 5, pp 1965-1977.

[12] Wang G., Xiao. H, Zhang J., and Wang F., 2012, "Energy Regenerative Braking ABS Control Research on Feedback Lockup Driving-Braking Integrated System for Electric Vehicles," Mechanika, v 18, n 3, pp 341-346.

[13] Kim D., Choi S., Kim, D., Zhang S., Park S., and Tak T., 2018, "Regenerative Braking Performance Evaluation and Dynamic Stability Analysis for Electric Bicycles," Transactions of the Korean Society of Mechanical Engineers, A, v 42, n 6, pp 565-573.

[14] Chen Q. , 2015, "Study on Stability Control of Electrical Vehicle Based on Regenerative Braking System0", SAE International Journal of Commercial Vehicles, v 8, n 1, pp 69-76.

[15] Liu Z. and Pu X., 2018, "An Experimental Study on Anti-lock Braking of Continuous Regenerative Braking System in Electric Vehicles," Quiche Gongcheng/Automotive Engineering, v 40, n 7, pp 804-811,

[16] "Finite State Machine (Finite Automata)" – YouTube, https://www.youtube.com/watch?v=Qa6csfkK7_

[17] "Finite State Machines" | Brilliant Math & Science Wiki, https://brilliant.org/wiki/finite-state-machines/

[18] "VO3120 product information" (DataSheet) | Vishay, https://www.vishay.com/ppg?81314

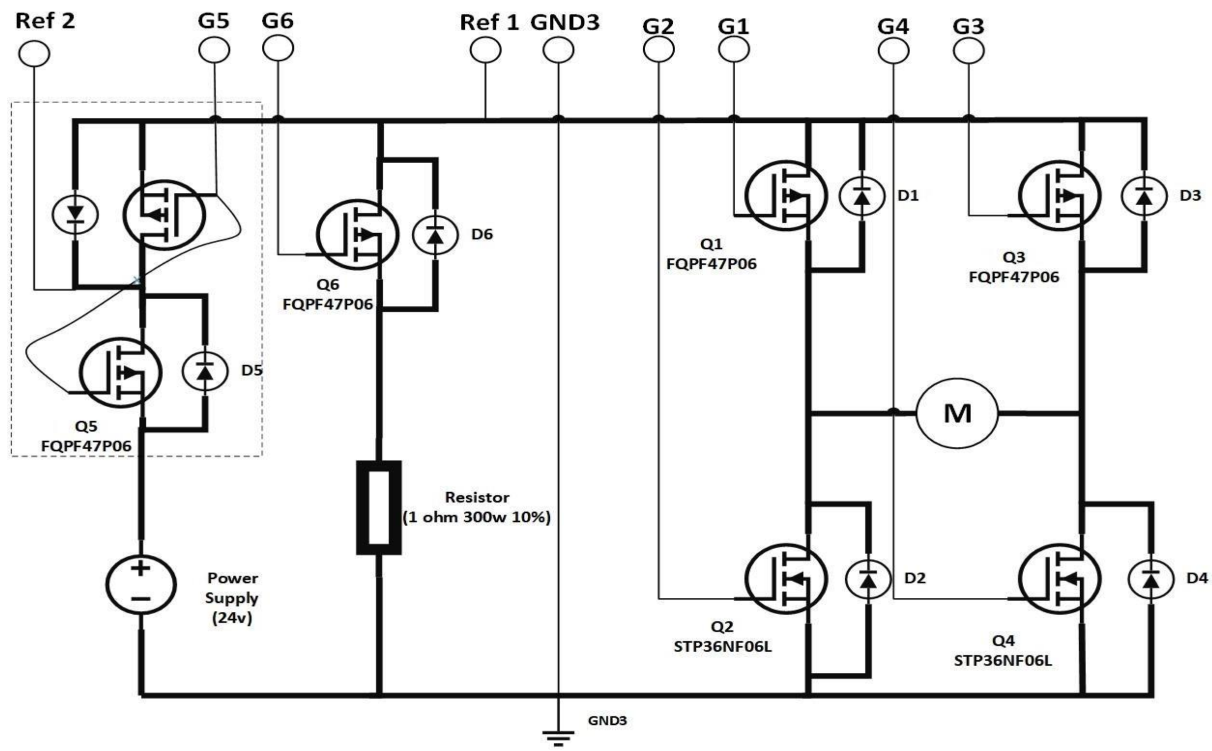


FIGURE 3. MAIN DEVELOPED CIRCUIT

TABLE 1. OPERATION CHART

Mode	Drive				Regenerative			
Forward	State A				State C			
	Q1	PWM (spd)	D1	off	Q1	off	D1	off
	Q2	off	D2	PWM (1-spd)	Q2	off	D2	on
	Q3	off	D3	off	Q3	off	D3	on
	Q4	on	D4	off	Q4	off	D4	off
	Q5	on	D5	off	Q5	PWM (alpha)	D5	off
	Q6	off	D6	off	Q6	PWM (1-alpha)	D6	off
Backward	State B				State D			
	Q1	off	D1	off	Q1	off	D1	on
	Q2	on	D2	off	Q2	off	D2	off
	Q3	PWM (spd)	D3	off	Q3	off	D3	off
	Q4	off	D4	PWM (1-spd)	Q4	off	D4	on
	Q5	on	D5	off	Q5	PWM (alpha)	D5	off
	Q6	off	D6	off	Q6	PWM (1-alpha)	D6	off
Park	State E							
	Q1	off			D1	off		
	Q2	off			D2	off		
	Q3	off			D3	off		
	Q4	off			D4	off		
	Q5	off			D5	off		
	Q6	on (Inverse Q5)			D6	off		

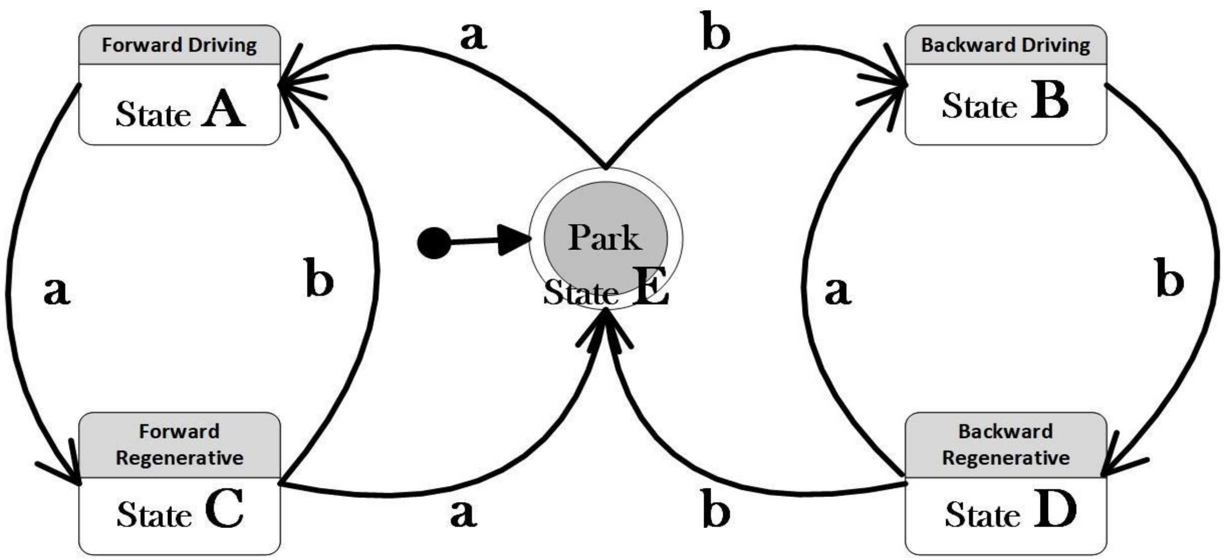


FIGURE 4. DIAGRAM OF TRANSITION BETWEEN DIFFERENT STATES

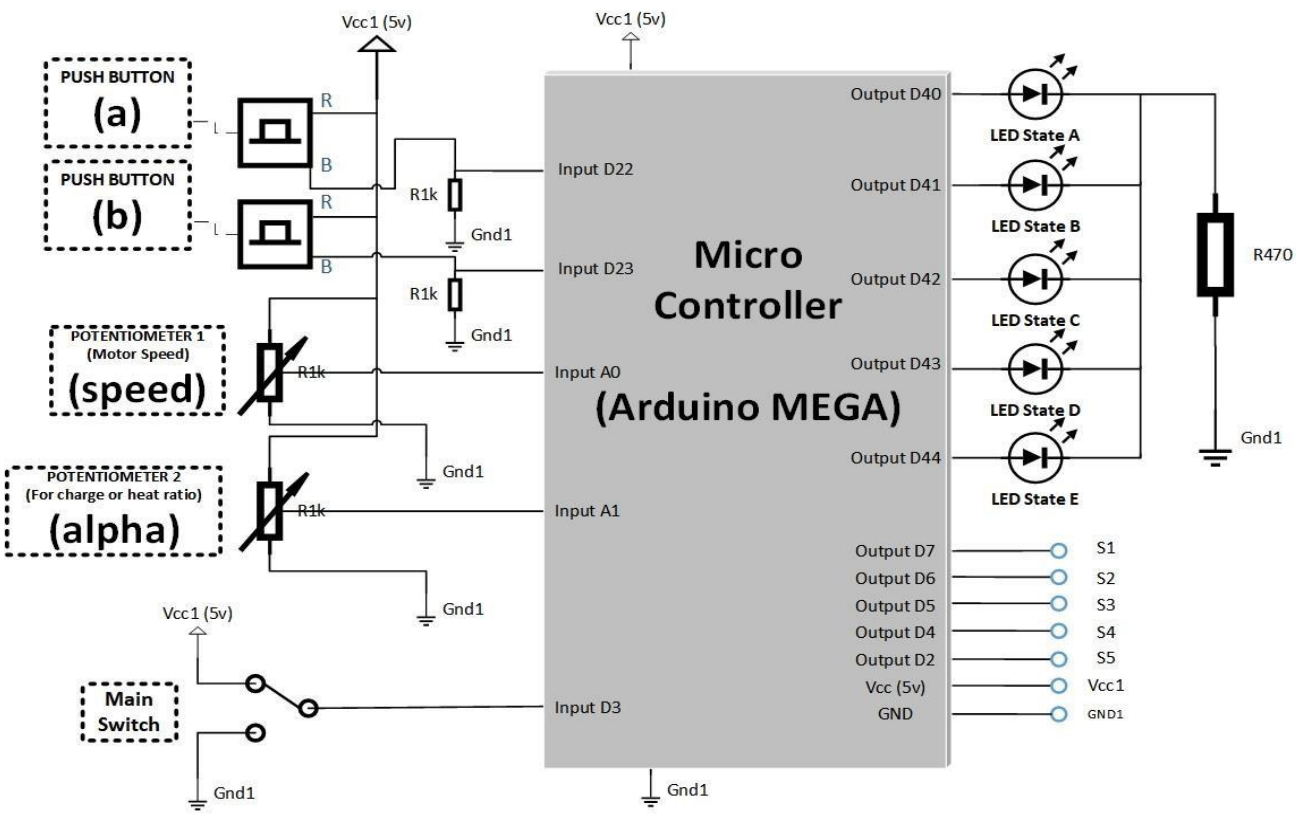


FIGURE 5A. DETAILED CONTROL CIRCUIT DIAGRAM

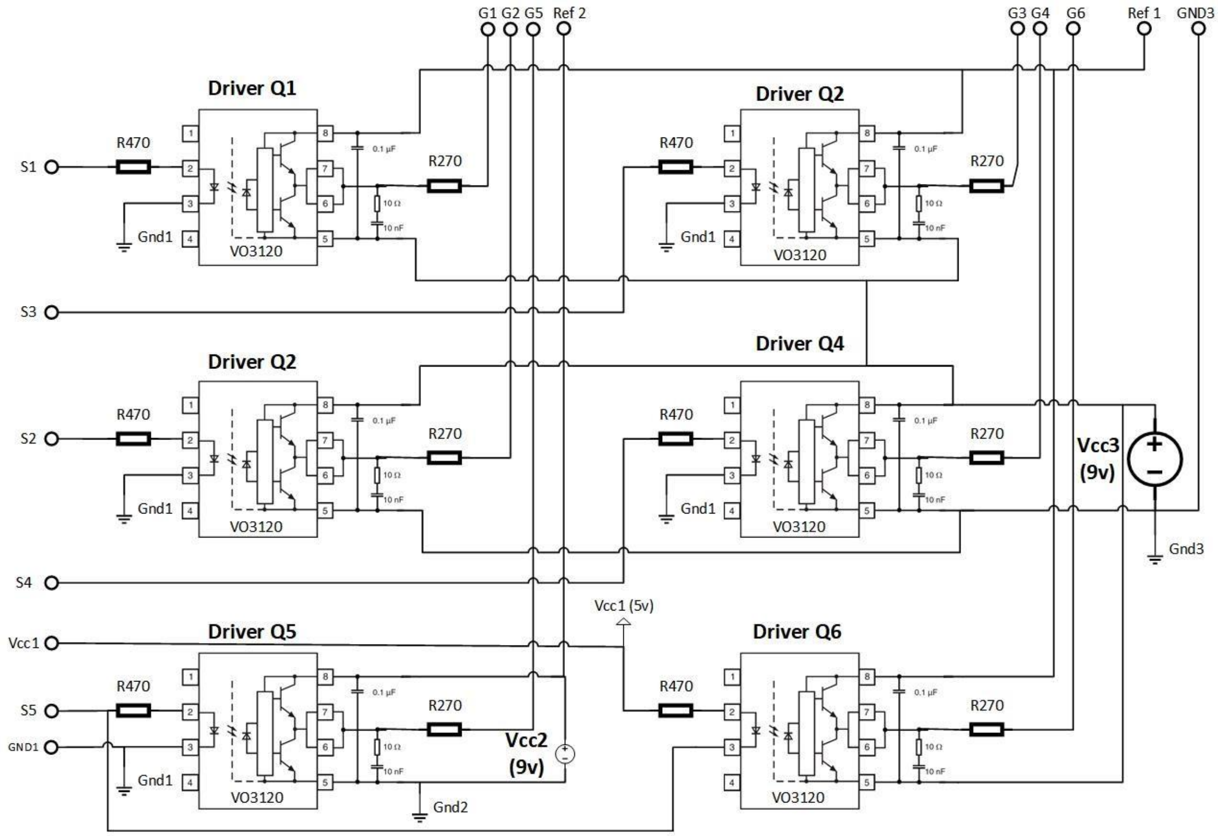
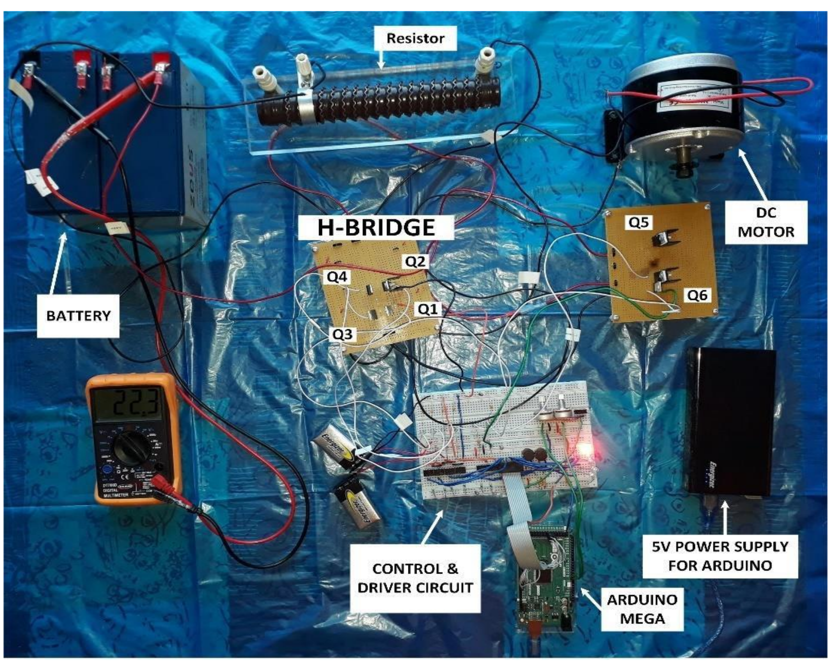


FIGURE 5B. DETAILED CIRCUIT FOR DRIVING MOSFETS



FIIGURE 6 - A VIEW OF THE EXPERIMENTAL SET UP