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Design & Development of E-bicycle Controller

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Abstract: This project deals with design and fabrication of a low-cost portable electric bicycle controller, which can be mounted on existing bicycle. It has two modes of drive; one is by pedaling and other one is by using electric motor. The developed controller and electric bicycle kit consists of 250W DC motor which is powered by 24V lead acid battery. E- bikes use rechargeable batteries and lead acid ones can travel up to 30km/hr and some electric bicycles speed can do excess of 30km/hr. There are two types of Electric Bicycle; one has a smaller motor to assist the rider's pedal power. The other one is more powerful E-bicycles which are closer to moped style functionality, but however all retain the ability to be pedaled by the rider. Major drawback of traditional bicycle is it increases rider fatigue on long distance travel. Thus implementing an external drive (electric motor), which can be switched between pedaling and electric drive and this will help to increase the range of travel, better riding experience and reduces rider fatigue. Expected range of E-bicycle is around 20-40 km on a single charge. E-bicycle can travel at a speed of 20 km/hr.

I. Introduction

The world's car usage is booming. Cars are polluting the world's cities, dumping increasing amounts of carbon dioxide and other climate-altering greenhouse gasses into the atmosphere, and consuming vast quantity petroleum. The alarming reality is that the automobile usage is growing at a much faster rate than the human population, with saturation nowhere in sight. Nowadays, the price of oil keeps on increasing. People want to use electricity instead of oil to operate transport. In India, the industry of electric bikes has grown rapidly in these 10 years. The design of electric bikes trends to more environmentally friendly. The energy from the sun can be used to run electronic devices. In this project, a electric powered bicycle controller is designed. The materials used are more environmentally friendly and the cost is much lower than the existing electric bicycle controller. The maximum speed of the bicycle achievable is 20km/hr.

Today, millions of people depend on automobiles as their main source of transportation. Automobiles are the most efficient and convenient way to travel when compared to other modes of transportation. Unfortunately, most of the automobiles use fossil fuel and it is very expensive to maintain in the present situation. So, an E-bike which is very similar to a normal bike with an externally fitted electric motor which is substitute for your pedaling efforts. In some cases, the motor will be activated by activating accelerator. It gives a smoother drive by eliminating many of the obstacles like steep hills and it makes rider less tired. E- bikes are mostly the alternative for both conventional bicycles and automobiles. E-bikes have risen in popularly due to restriction of gasoline motorcycles, extensive bicycle infrastructure, and increased car and public transit congestion. However, the rise in e- bikes has not spread to the rest of Asia. In fact, few cities in other Asian countries have any presence of e-bikes. In countries with dominant gasoline two-wheeler mode split, replacing those vehicles with electric bicycle could improve air quality and reduce greenhouse gases.

II. Necessity

1. Speed control- In any electric Bi-cycle its main entity to control the speed of vehicle.
2. Open loop speed control- At a time of riding according to road condition rider decides the speed acceleration of a vehicle that's why controlling is open loop in nature. For that Hall Effect acceleration technique is used. So According to rider action controller maintain the speed.

III. Objective & Scope

The main purpose of this research is to review the current situation and effectiveness of electric bicycle researched by various researchers. In order to approach this purpose, following objectives are specified:

1. To design electric bicycle controller.

2. To test performance of the controller on selected PMDC motor.

IV. HARDWARE IMPLEMENTATION

For the E-bicycle controller we need the motor whose working voltage is 24V/250W and working current is 10A.So, we used BLDC motor for this controller.

To run this motor, we required the MOSFET whose motor voltage is greater than three times working voltage (Vm>3Vw) and motor current is greater than two times working current (Im>2Iw). So, we used IRF250P MOSFET which is easily available in market.

The electric bicycle speed controller sends signals to the bicycle's motor hub in various voltages. These signals detect the direction of a rotor relative to the starter coil. The proper function of a speed control depends on the employment of various mechanisms. In a purpose-built electric bicycle, Hall effect sensors help detect the orientation of the rotor.

Then we used Arduino UNO in which the board contains 6 PWM pins. PWM stands for Pulse Width Modulation, using this process we can control the speed of the BLDC motor, DC motor, and brightness of the LED.There are 6 analogue pins integrated on the board. These pins can read the analogue sensor and can convert it into a digital signal.The UNO board supports a micro-SD card that allows the board to store more information. This pin is used to supply 5V power to your projects. The voltage regulator controls the voltage that goes into the board.

We used MCT2E IC which is used to provide electrical isolation between two circuits, one part of the circuit is connected to the IR LED and the other to Photo-transistor. The digital signal given to the IR LED will be reflected on the transistor but there will be no hard electrical connection between the two.

An e-bicycle throttle functions similar to a motorcycle. The throttle controls are usually found on the handlebar. To engage the throttle, you simply twist the handlebar, and the bicycle will accelerate. Let go of the throttle, and the bicycle will stop.

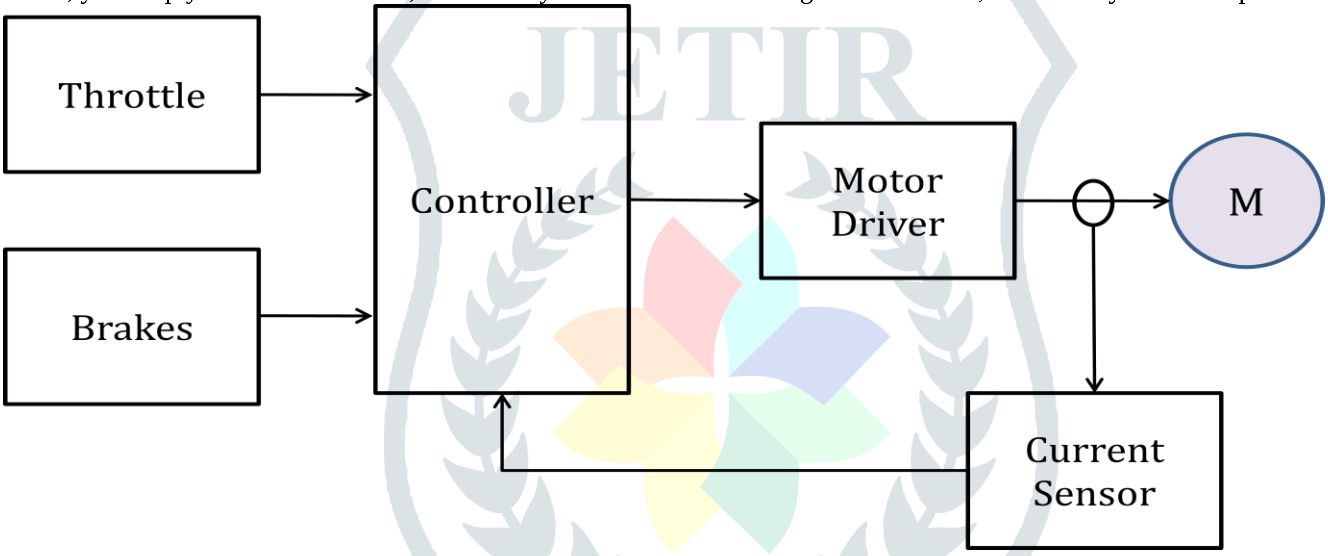

Fig.1.Block Diagram

3.1. Hardware Calculation:

DC-DC converters are also known as Choppers. Here we will have a look at the step-down Chopper or Buck converter which reduces the input DC voltage to a specified DC output voltage.
A typical Buck converter is shown in figure

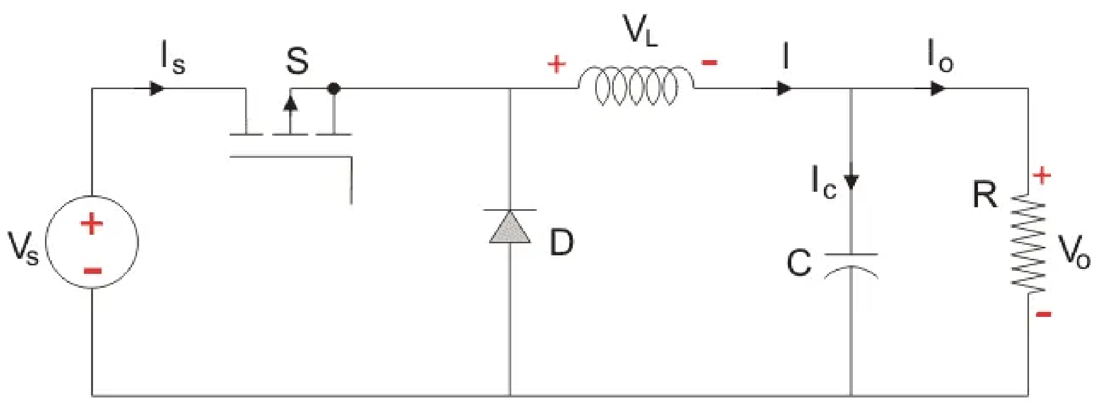

Figure 2: DC – DC Buck Converter

The input voltage source is connected to a controllable solid-state device which operates as a switch. The solid-state device can be a Power MOSFET or IGBT. Thyristors are not used generally for DC-DC converters because to turn off a Thyristor in a DC-DC circuit requires another commutation which involves using another Thyristor, whereas Power MOSFET and IGBT can be turned off by simply having the voltage between the GATE and SOURCE terminals of a Power MOSFET, or, the GATE and COLLECTOR terminals of the IGBT go to zero.The second switch used is a diode.

The switch and the diode are connected to a low-pass LC filter which is appropriately designed to reduce the current and voltage ripples. The load is a purely resistive load. The input voltage is constant and the current through load is also constant. The load can be seen as current source.

The controlled switch is turned on and off by using Pulse Width Modulation (PWM). PWM can be time based or frequency based. Frequency based modulation has disadvantages like a wide range of frequencies to achieve the desired control of the switch which in turn will give the desired output voltage. This leads to a complicated design for the low-pass LC filter which would be required to handle a large range of frequencies.

Time based Modulation is mostly used for DC-DC converters. It is simple to construct and use. The frequency remains constant in this type of PWM modulation. The Buckconverter has two modes of operation. The first mode is when the switch is on and conducting.

Mode I: Switch is ON, Diode is OFF

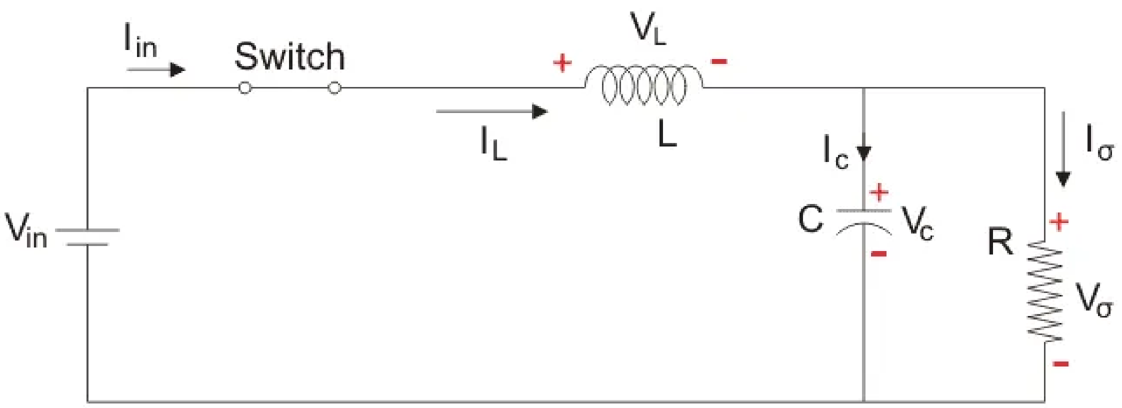

Figure 3: Mode – I of operation

The voltage across the capacitance in steady state is equal to the output voltage.

Let us say the switch is on for a time T_{ON} and is off for a time T_{OFF}. We define the time period, T, as

$$T = T_{ON} + T_{OFF}$$

and the switching frequency,

$$f_{switching} = \frac{1}{T}$$

Let us now define another term, the duty cycle,

$$D = \frac{T_{ON}}{T}$$

Let us analyse the Buck converter in steady state operation for this mode using KVL.

$$\therefore V_{in} = V_L + V_o$$

$$\therefore V_L = L\frac{di_L}{dt} = V_{in} - V_o$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{V_{in} - V_o}{L}$$

Since the switch is closed for a time T_{ON} = DT we can say that Δt = DT.

$$(\Delta i_L)_{closed} = \left(\frac{V_{in} - V_o}{L}\right) DT$$

While performing the analysis of the Buck converter, we have to keep in mind that

- The inductor current is continuous and, this is made possible by selecting an appropriate value of L.
- The inductor current in steady state rises from a value with a positive slope to a maximum value during the ON state and then drops back down to the initial value with a negative slope.
- Therefore the net change of the inductor current over anyone complete cycle is zero.

Mode II: Switch is OFF, Diode is ON

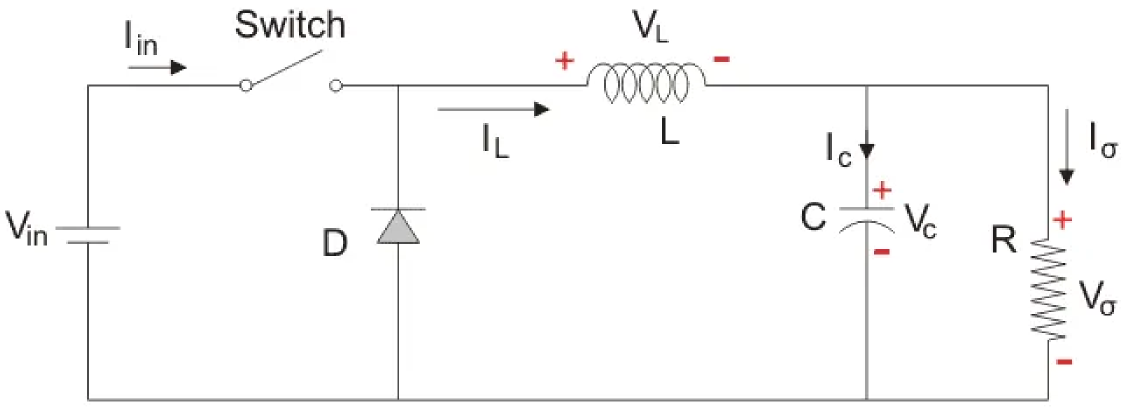

Figure 4: Mode II of buck converter

Here, the energy stored in the inductor is released and is ultimately dissipated in the load resistance, and this helps to maintain the flow of current through the load. But for analysis we keep the original conventions to analyses the circuit using KVL.
Let us now analyses the Buck converter in steady state operation for Mode II using KVL.

$$0 = V_L + V_o$$

$$\therefore V_L = L\frac{di_L}{dt} = -V_o$$

$$\frac{di_L}{dt} = \frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{(1-D)T} = \frac{-V_o}{L}$$

Since the switch is open for a time

$$T_{OFF} = T - T_{ON} = T - DT = T(1-D)$$

we can say that

$$\Delta t = T(1-D)$$

$$(\Delta i_L)_{OPEN} = \left(\frac{-V_o}{L}\right)(1-D)T$$

It is already established that the net change of the inductor current over anyone complete cycle is zero

$$(\Delta i_L)_{closed} + (\Delta i_L)_{open} = 0$$

$$\left(\frac{V_{in} - V_o}{L}\right)DT + \left(\frac{-V_o}{L}\right)(1-D)T = 0$$

$$\frac{V_o}{L} = D$$

3.2 Arduino Programming

```
int throttle = A1;
int brake = A0;
int motor = 11;
int l = 10;
int m = 9;

int i = 0;
int j = 0;

int a, b, c;

void setup()
{
  // put your setup code here, to run once:
  pinMode(motor, OUTPUT);
  pinMode(l, OUTPUT);
  pinMode(m, OUTPUT);
  Serial.begin(9600);
  a = analogRead(throttle);
  delay(1000);

}

void loop()
{
```

```
// put your main code here, to run repeatedly:
i = analogRead(throttle);
if(i>850)
{
  i = 850;
}
i = map(i, a, 850, 0, 255);
Serial.print("Throttle = ");
Serial.println(i);
j = analogRead(brake);
Serial.print("brake = ");
Serial.println(j);

if (j < 100)
{
  analog Write(l, i);
  analog Write(m, 0);
  analog Write(motor, i);
}

if (j > 100)
{
  analogWrite(l, 0);
  analogWrite(m, 255);
  analogWrite(motor, 0);
}

delay(10)
```

3.3 Flow of Simulation Model

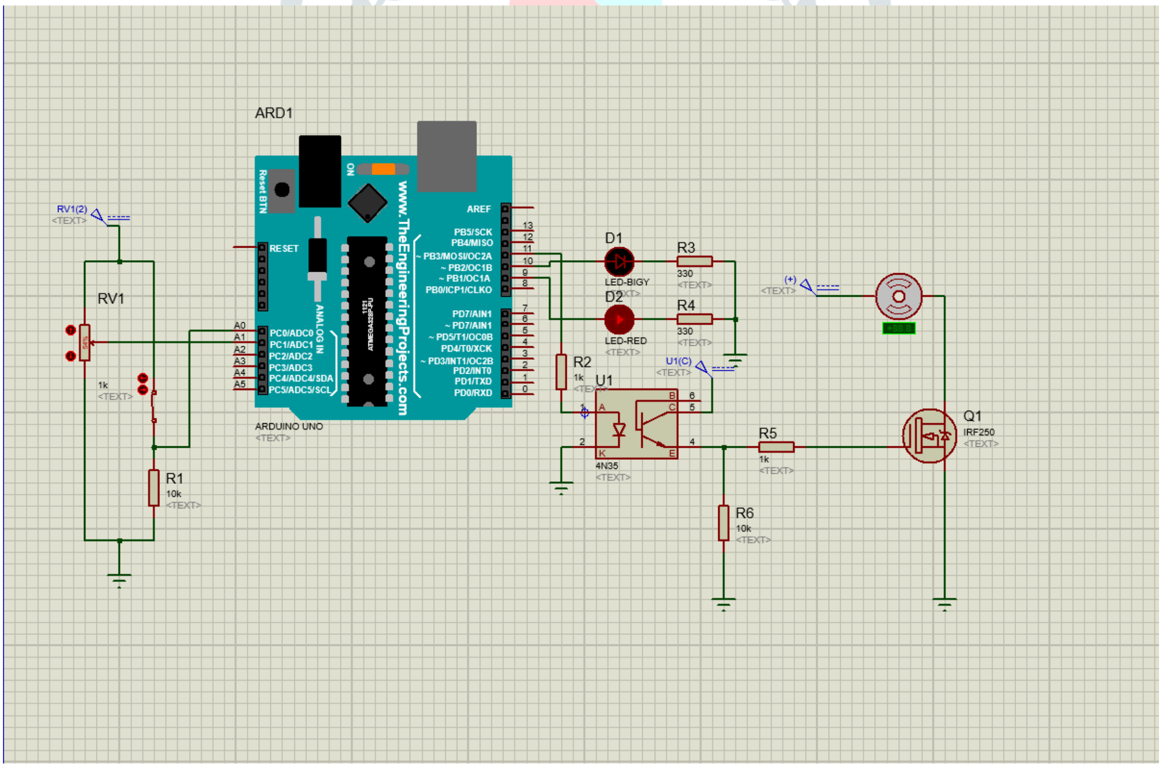

Fig.5.Simulation Circuit

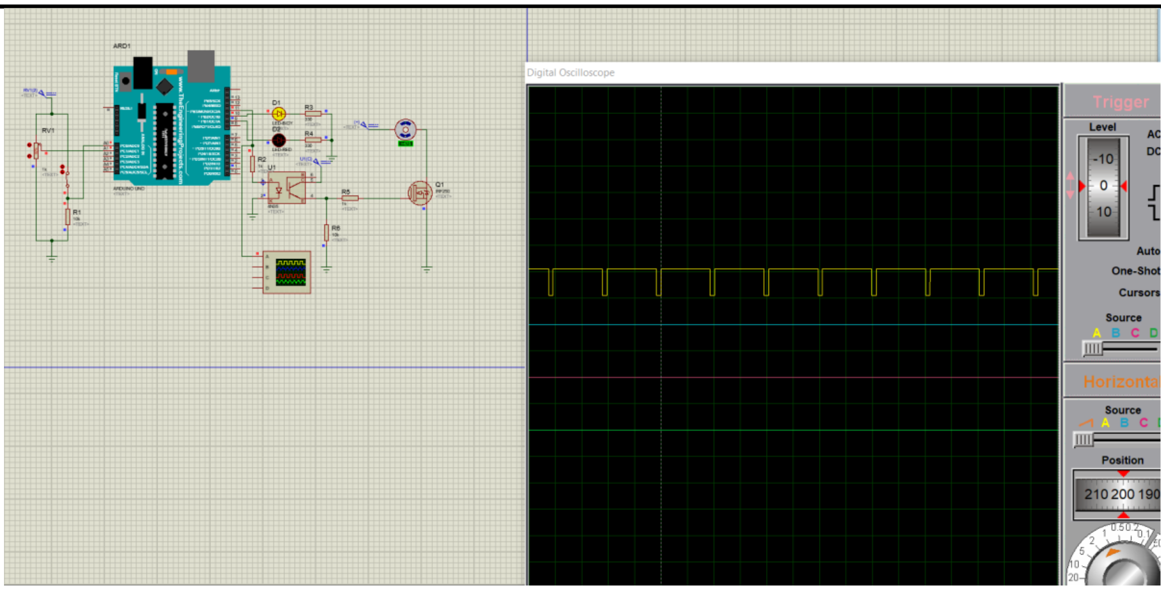

Fig.6. PWM is directly proportional to accelerator if pot value is less then duty cycle value is also less.

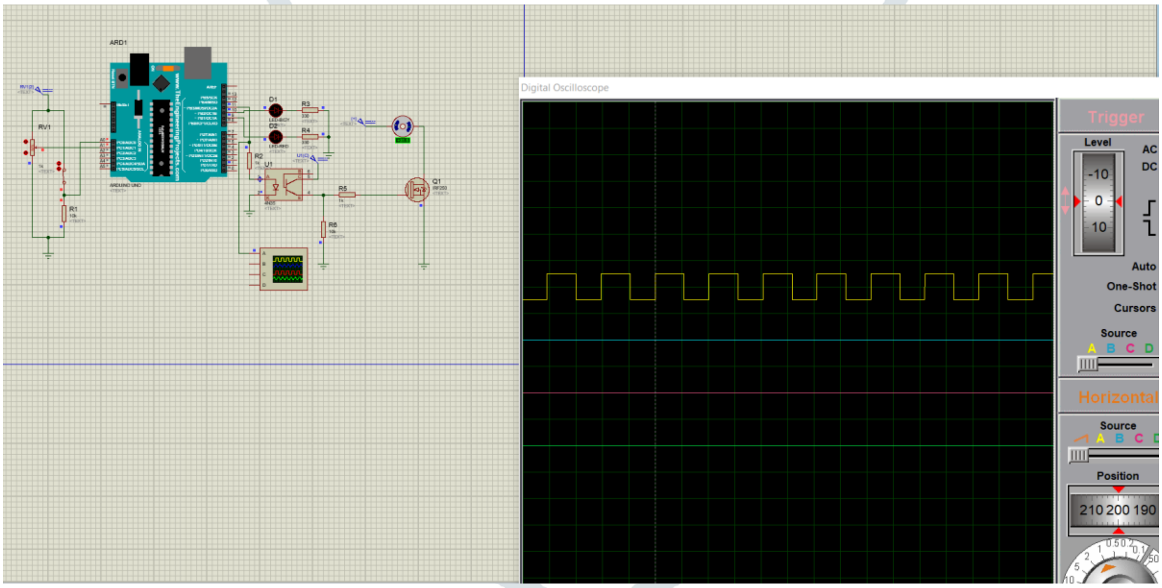

Fig.7.In DC Motor speed is directly proportional to voltage.

V. Conclusion

A low-cost solution for development of electric bicycle controller is presented in this project report. The developed controller is capable of driving 24V, 250W DC motor for electric bicycle. The PWM control is implemented for motor speed control through DC – DC converter. The PWM control gives smooth speed control.

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