

## **Two Wheeled Self balancing Robot**

Group No 8

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### **1) Introduction**

The project is aimed at making a two wheeled self balancing electric vehicle. A processor and electric motors in the base of the device keep the vehicle upright when powered on with balancing enabled . Users lean forward to go forward, lean back to go backward. Gyroscopic sensors are used to detect tilting of the device which indicates a departure from perfect balance. Motors driving the wheels are commanded as needed to bring the vehicle back into balance. The dynamics of the vehicle are identical to a classic control problem, the inverted pendulum. The vehicle has electric motors powered by lithium-polymer batteries. It balances with the help of a microcontroller , one tilt sensors, and one gyroscope. . The rider accelerates or decelerates by leaning forward or backwards in the direction he or she wishes to travel. Steering can be controlled by simply varying the speeds between the two motors, rotating the vehicle (a decrease in the speed of the left wheel would turn the vehicle to the left).

## 2) Design

The vehicle consists of :

- 1) Two 250W Brushless Dc Electric Motors
- 2) Two Tvs Scooty Wheels
- 3) Mechanical structure which consists of the motor mountings , a platform (for the person to stand ) and a vertical handle
- 4) Sensors comprising of a gyroscope and an accelerometer
- 5) A microcontroller for processing the data received from the sensors and giving the appropriate signal to the motors
- 6) Two motor drivers which amplify the signal received from the microcontroller and give it to the motor

### 2.1) Brushless Dc Motors

Two 250W brushless dc hub motors are used . They have been selected over normal Dc motors as they have a better power/weight ratio , greater efficiency and hence are more compact ,robust and reliable . The absence of a commutator and carbon brushes (which are subjected to mechanical wear and tear due to friction) enables this type of motor to have a longer life. The armature is the stationary part and has three coils , while the rotor is a permanent magnet. Each motor has three hall sensors used to detect the position of the rotor. The stator speed  $N_s$  and the rotor speed  $N_r$  are both the same at steady state as this is a synchronous motor . The rotor speed  $N_r$  is measured by taking feedback from the hall sensors while the stator speed  $N_s$  is the frequency at which you alternately switch the coils. By taking feedback  $N_r$  and  $N_s$  are kept the same . Hence the speed

of the rotor is directly proportional to the frequency of switching and the output torque is inversely proportional to the frequency of switching.

## 2.2) Wheels

Two Tvs Scooty ES wheels are used . The outer diameter of the motor almost matches the rim size and hence mounting the motor in these wheels is considerably easier. By using a circular 10mm thick plate of mild steel the motor is mounted between the wheels.

## 2.3)Mechanical structure

The entire structure is made of mild steel . After both the motors are individually connected to the wheels three rectangular sections are connected between them . They are welded at both the ends . A rectangular platform is fitted on these sections . A vertical rod is screwed on this platform with a rectangular rod welded at the top end . The rider stands on the platform and takes support from the vertical rod .

## 2.4)Sensors

Gyroscope – ADXRS610 a MEMS based angular rate sensor is used . The output signal, RATEOUT is a voltage proportional to angular rate about the axis normal to the top surface of the package . Integrating this signal we get the tilt angle , but when we integrate , the noise in each measurement also gets integrated and hence the angle we measure starts drifting. The analog signal is connected to the ADC input of the microcontroller.

Accelerometer – MMA7260QT a MEMS based accelerometer is used to measure the tilt angle . It measures all non contact forces and hence its reading is also affected by pseudo forces due to acceleration . The analog output is connected to the ADC input of the microcontroller .

To get the net tilt angle a complimentary filter , where the gyroscope reading is integrated (high passed) and the accelerometer reading is low-passed , is implemented . By assuming that over a sufficient interval the net acceleration is zero we can assume that the low passed accelerometer reading corresponds to the tilt angle . Hence by replacing the gyroscope angle with this reading we can get the tilt angle and compensate for the drift in the gyroscope reading. Here is the code to do it –

```
ang_gyro = ang_gyro + ((gyro_adc - bias) / 30.0) ;  
ang_acc_prev = ang_acc ;  
ang_acc = ((90*(acc_adc-87.0)) / 45.0) + 90.0 ;  
ang_acc = (ang_acc_prev * 0.95) + (ang_acc * 0.05) ;  
ang_gyro = ang_gyro + (0.15 *(ang_acc - ang_gyro)) ;
```

## 2.5) Microcontroller

AVR Atmel Atmega128 microcontroller is used . It is a 8-bit microcontroller and it can run at a maximum clock frequency of 16 MHZ . It has various timers analog to digital converts and supports various protocols of data transfer . I have developed a basic application board of this uc . In this board there are three basic parts – the first part has the power supply circuit where from any input voltage between 7 to 36 V is converted to 5V and given to the uc . To do this a switching regulator is used to convert the input to around 5.5V and then a low dropout regulator is used to convert 5.5V to regulated 5V . This method is used as it is more efficient and reliable . Only using a linear regulator is not efficient as all the the excess voltage is just dropped across the regulator and it gets heated up and may blow off when used for a long time . While a switching regulator switches the input and converts it to the desired voltage , it is about 85-90% efficient . But the ouput

of the switching regulator has frequency components and giving it directly to the uc may blow it off . Hence a low dropout regulator is used .

The second part includes the clock circuit , reset and programming circuit . An external crystal of 16Mhz is connected between the XTAL1 and XTAL2 pins and load capacitances of 22pf are connected from each pin to ground.

The reset pin is pulled up with an external resistor (1.5k) to 5V and also a capacitor(10uf) is connected from this pin to ground .

The uc is programmed using SPI(Serial Peripheral Interface) from an external programmer . For this the PDI , PDO , SCK , RESET pins are connected to the programming port.

The third part includes connecting the input , output pins to various connectors in the way they are going to be used . Various pins are given along with power supply for connecting the analog inputs . There are connectors where you can connect the motor drivers . Also various connectors are given for connecting the LCD and serial port which is used for debugging .

2.6) Motor drivers – They need an analog signal for speed control and a digital signal for direction control . These both are generated from the uc . A timer is used to generate a PWM and then a Low Pass Filter is implemented to generate a flat analog signal . Varying the duty cycle changes the value of the analog output .