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K. V. Shivaram
Electrical And Electronics Engineering, Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Ettimadai, Coimbatore - 641105, kvs.in.eee@gmail.com

Design of a Personal Transporter with Electro-differential Drive

Shivaram K V, Sriram Sridhar, Ajay Kumar Menon, Ankit Sharma:
B.Tech IVth year, Electrical And Electronics Engineering, Amrita School of Engineering, Amrita Vishwa Vidyapeetham, Ettimadai, Coimbatore - 641105
Email: kvs.in.eee@gmail.com

Abstract*—The Personal Transporter (PeT) is an electric vehicle, with easy maneuverability and compactness, which finds its application in confined areas. It is designed to transport an individual with the aid of an intelligent system. The two main wheels are driven by separate dc motors, fed by a common battery source and aided with the power electronic drives for appropriate speed control. The directional control is a electro - differential system done using the H-bridge circuit. The speed control is done with the help of microcontroller by varying the duty ratio of pulse width modulation signals given to the mosfets in the H bridge circuit. Two castor wheels are placed in order to balance the vehicle. The vehicle is further embellished with an intelligent system that directs the person to his/her destination in the best possible manner. This is done through installing receivers and transmitters in the i-PeT, as well as the places around the specified range. The application of such a system will be very helpful in various places such as airports, hospitals, shopping centers and lounges.

I. *Introduction*

A. *Need for the Project*

Electric vehicles were introduced in the early nineteenth century when first electric vehicle was mentioned in the" popular mechanics" book in 1911. The fuel shortages in World War II prompted creative alternatives to locomotion. The invention of such vehicles was sporadic in many parts of the world during that period. The electric vehicles had striking advantages over its steam counter parts. They did not have the vibration, smell, and noise associated with gasoline cars. Changing gears on gasoline cars was the most difficult part of driving, while electric vehicles did not require gear changes. While steam-powered cars also had no gear shifting, they suffered from long start-up times of up to 45 minutes on cold mornings. The steam cars had less range before needing water than an electric's range on a single charge. The fact that the EV had a high initial cost; it was mostly restricted to the upper class society and did not adhere to the needs of the common man. The growing concerns of environmental pollution and advancement in technology have prompted many think tanks to re-introduce the electric vehicles, especially electric scooters that help a single or a couple of persons to travel for short distances. This will not only prevent using fuel vehicles for short distance travelling but also open a lot of scope in the area of sustainable development of resources

B. *About the Project*

. The prototype that we are designing is called the PERSONAL TRANSPORTER which will be a unique breed in this segment. The i-PET is a rare electric transporter that you can ride while standing. It is suitable for many applications both outdoor and indoor. Another striking feature of the i-PET is its intelligent system, which guides the user to reach his desired location by showing the appropriate path. The i-PET will have a database of specific number of routes covering a certain radius in the area which will constantly be updated according to the position of the vehicle. The system is governed by a set of transmitters and receivers located in various locations as well as the main frame system inside the i-PET. We have taken up this work as our final year engineering project.

The main project goals are :

- To develop a logical control system of the i-PeT using digital circuits.
- To simulate the logic using analog and digital devices.
- To design and develop power electronic drive for i-PeT
- To design and build a physical prototype of the i-PeT.
- Run prototype un-tethered using on board microcontroller.
- Implement an Intelligent communication system.

C. *Applications and Advantages*

The 'easy to carry' personal transporter attracts many event goers who will find it very convenient at outdoor events or for daily use. The manoeuvrability and ease of use makes it personal in every sense of the word and this prototype will lead to a new gateway in the research of personal vehicles. Our motivation is to implement the knowledge of engineering we gained through the course of study. A hardware project is interesting and challenging. This day and age, when energy conservation is high on priority, for all fields of engineering, an eco friendly vehicle comes handy. The vehicle can be used in small areas and allows easy manoeuvring unlike a scooter. Our campus, which covers a large area, is

lacking human transport system. Our prototype provides an easier, eco – friendly mode of transport in such areas. The manoeuvrability and ease of use makes it personal in every sense of the word and this prototype will lead to a new gateway in the research of personal vehicles.

II. *Specification Development*

A. Mechanical Design

All the basic dynamics and the kinematics of the vehicle are analysed with the appropriate use of its corresponding mathematical models. As the vehicle is a single person transporter, the maximum weight of the person standing must be chosen according to our requirements, that forms the basis of the whole system design. The motors, batteries and the wheel design are totally dependent on this factor apart from the other parameters such as friction and inertial mass which are inherent for any moving system. The chassis of the vehicle forms the base plate of the vehicle where the person will be standing and a handle bar is erected from the chassis which will help the user in balancing and controlling the vehicle. The base plate will house the two motors, one motor for each wheel and a common battery source which serves as the power source for the i-PET. The power electronic drives and controllers are also placed inside. The vehicle also consists of castor wheels that will be placed in the end section of the chassis, which will balance the system and aid during steering the vehicle. They will not be powered by the motor and thus solely used for system stability. The base platform over which the person stands, was mensurated based on the average foot size of a normal human being. The speed limit of the vehicle is designed to be above the walking speed of normal human being, which was found by practical experimentation.

A summary of the specifications of the i-Pet is presented below.

Maximum loading capacity
= 80kg

The maximum speed of i-PeT [Vmax]
= 2 m/s

The maximum acceleration of i-PeT
= 1 m/s^2

Main wheel diameter
= 25 cm

Based on the confirmed design the following parts have been acquired by the group for real time modelling, which is under progress.

- Two main wheels (25 cm diameter)
- Two castor wheels (10 cm diameter)

Based on the wheel diameter selected, the maximum rpm required to be provided by the motor can be calculated.

D = 25 cm
R = d/2 = 12.5 cm
V = (2πr × N) /60 m/s
V = 2 m/s (Calculated max speed)
Hence N = (2×60) / (2π×12.5) = 150 rpm.

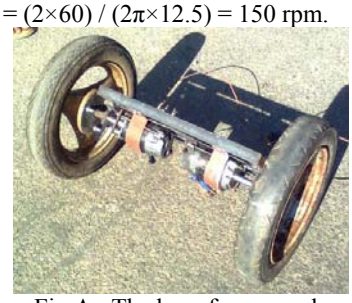


Fig A : The base frame work

B.

I. Electrical Design

It includes the selection of components, interconnection, technological analysis and fabrication. The selection of components, need to be done with a futuristic approach as it is what is driving the vehicle forward. The type and rating of the motors depend upon the weight of the person added up with the component weight of the vehicle. The size of the electrical components should be less, so that it can be placed easily in the vehicle chassis. The battery should be able to provide continuous supply of power to the system for a considerable amount of time. Economic feasibility and availability should also be taken into consideration. Several test were conducted to compare the speed of waking and running of a normal person and used as a reference to design our transporter based on those results. The analysis is thoroughly described in the sections below. The need of two motors , one for each wheel was essential for the design as it would aid in easy steering purposed and thus a differential system of steering could be easily adopted. The motor so designed are DC motors with a high starting torque capability and rated according to the design specification. We are moving steadily with the

electrical design in a positive manner. The battery under use is a 12V rechargeable battery with a rating of 15-20 Ah rating. The speed control is governed by the power electronic drives with the help of a double H-bridge circuit that allows a four quadrant operation in the vehicle. The use of the microcontroller enables proper generation of a PWM signal with desired duty ratio. This decides the current flow through the armature of the motors and thus deciding the speed of the rotor in both the wheels. This algorithm determines the steering action of the motor by adjusting the power generated in the wheels.

The details about the motors used are provided below.

Make: Toyota N1 Starter Motor.

Type: DC series actuator with Plunger and solenoid arrangement.

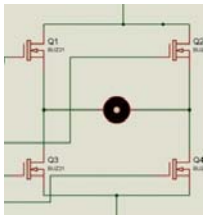
No of shaft outputs: 1.

No of poles: 4.

Fig B : Toyota N1 Starter Motor.

II. Electro-Differential Drive

The electronic design consists of the development of suitable driving mechanism of the i-PeT. The control logic should be less complicated to implement and also, the transporter should be user friendly. Considering all these factors, the control logic was developed. The control logic is developed using digital system blocks. It involves a digital logic with gates with four switches used for forward, backward, right and left turn respectively. These signals are the trigger pulses to the respective switching devices in the H-bridge. The basis of the control logic is the design of H-Bridge circuit for motor control. It consists of MOSFETs arranged in an H shape as shown in Fig 1.1. The MOSFETS are triggered by PWM signals.

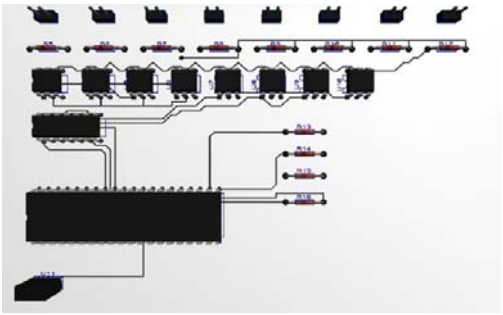


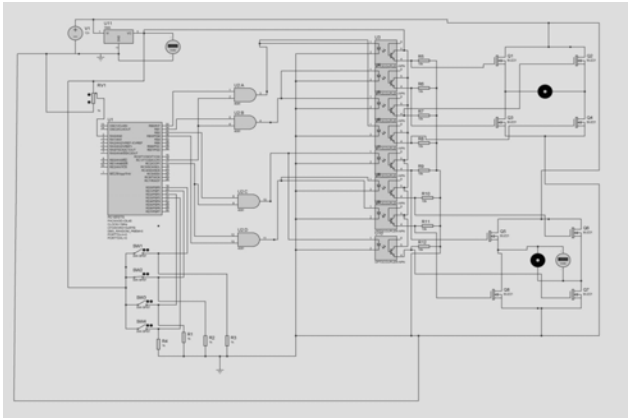
The digital circuit design is based on PWM signal generated by a microcontroller. The microcontroller also helps in controlling the direction of the motors based on the user input. The selection of microcontroller was done after considering various parameters which includes the platform requirement to develop the logic, cost, ease of use, reusability etc.

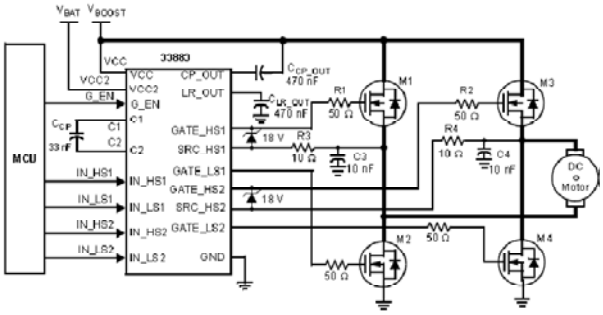
Basic requirements:

- 2 × PWM signals for motor control
- 1 × 16 bit ADC for accelerator
- 8 × I/O pins for motor control switches
- 8 × I/O pins for display system

PIC 16F877A is selected as the suitable one as it meets all the requirements. The complete logic is implemented with all the components in PROTEUS ISIS software platform. The simulated circuit diagram and PCB layout is provided below. The code is provided in the APPENDIX







The H – Bridge Driver IC is selected as MC33883 SOIC. It uses the control logic for controlling the speed and direction of motor control. The control logic is provided below. The datasheet link is provided in the references. Two of these ICs are to be used in the control board. The final pcb layout and hardware design is in the process of completion. Pins

IN1 and IN2 takes input from the microcontroller. IN1 is the PWM signal which varies with the accelerator. IN2 is the direction controller pin for changing the direction of the motor.

The motors are aligned in such a way that the direction of rotation of both the motors should be complimentary to each other in order to make the movement of the vehicle in forward/backward direction. The H – Bridge driver acts as switches which control the speed of the motors. The differential drive is incorporated in the motors at the microcontroller logic design.

C. Intelligence System

The electronic design is what is making i-PeT stand out from the other personal transporters available in the market. Pure imagination and creativity drove us into the concept of merging intelligence into the vehicle system. The transporter will provide personal assistance to the user, during his course of travel by notifying him with the various destination points he may prefer to go and also how to go as well. Multiple transmitter receiver system is the technology behind this intelligent system. It is designed and fabricated in such a way that the system is handy and useful.

III. Conclusion

This prototype is designed as a basic model of a personal transporter in order to understand the design issues of an electric vehicle. The electrical equivalent of the differential drive is successfully designed using PIC microcontroller and H – Bridge MOS circuits. The practical implementation of this kind of a vehicle is the need of the hour. Further developments in the intelligent systems like speech recognition and automatic path tracking systems can be implemented. The mechanical design can be made more aesthetic and pleasing as well. A closed loop current control can be implemented along with the power electronic drive in order to reduce the ratings of FETs and wires and thereby reducing the size and cost further.

IV.Appendix :

C – code written in MPLAB IDE and compiled in HITEC C Compiler

```
#include<pic.h>
int main()
{
        unsigned char i = 0;
        TMR2 = 0;                   //pwm timer
(tmr2) selection
        TRISB = 0;
        TRISC = 0;                  //port c is made
output
        TRISA = 1;                  //port A is made
input
        TRISD = 1;                  //port d made
input
        PORTC = 0;                  // port c
cleared(PWM output pins)
        PORTD = 0b00000000;         //port d cleared
        PORTB = 0;

        CCP1CON = 0b00111100;
        //configuring left motor pwm
        CCP2CON = 0b00111100;
        //configuring right motor pwm
        CCPR1L = 0;                         //on time
of left motor pwm
        CCPR2L = 0;                 //on time of right
motor pwm

        T2CON = 0b00000111;         //timer 2 on and
pre scaler selection
        PR2 = 0b11001111;                   //total
time period of pwm (on time + off time)
```

```
        ADCON1 = 0B00001110; //ADC control
selection
        ADCON0 = 0B01000001;
        ADGO =1;                        //ADC
conversion started

for(i=0;i<5;i++);

while(1)
{
        if(ADGO == 0)                   //if adc
conversion is over then
        {
        CCPR1L = ADRESH;
        //transfer adc o/p to on time of pwm
        CCPR2L = ADRESH;
        ADGO=1;
        //adc conversion starts
        }
        if(PORTD==0B00000001)
        //forward
        {
        RB0=RB2=1;
        RB1=RB3=0;
        }
        else if(PORTD==0B00000010)
        //backward
        {
        RB1=RB3=1;
        RB0=RB2=0;
        }
        else if(PORTD==0B00000100)
        //forward left
        {
        RB0=1;
        RB1=RB2=RB3=0;
        }
        else if(PORTD==0B00001000)
        //forward right
        {
        RB2=1;
        RB0=RB1=RB3=0;
        }
        else if(RD1==1 && RD2==1)
        //backward left
        {
        RB1 = 1;
        RB0 = RB2 = RB3 =0;
        }
        else if(RD1==1 && RD3==1)
        //backward right
        {
        RB3 = 1;
        RB0=RB2=RB1=0;
        }
        else       // all switches are off
        {
        RB0=RB1=RB2=RB3=0;
        }
}
```

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