

ELECTRIC TWO WHEELER

PROJECT REPORT

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**In partial fulfillment of the requirements for the
Award of the degree of BACHELOR OF ENGINEERING in
ELECTRICAL AND ELECTRONICS ENGINEERING Branch of
BHARATHIAR UNIVERSITY, COIMBATORE**

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

KUMARAGURU COLLEGE OF TECHNOLOGY

COIMBATORE - 641 006

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CERTIFICATE

This is to certify that the project report entitled

ELECTRIC TWO WHEELER

Is the bonafide work done by

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*in partial fulfillment of the requirements for the Award of the degree
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TO WHOMSOEVER IT MAY CONCERN

This is to certify that Mr. Rajagopalan (0027C0071), Mr. S. Ramesh Kumar (0027C0072), Mr. M. S. Srihari (0027C0084) & Mr. K. Vinaey Karthick (0027C0095), Final year B.E. - Electrical and Electronics co Engineering students of Kumaraguru College of Technology, Coimbatore have successfully completed their project work titled "ELECTRIC TWO WHEELER " at our concern in the period of July 2003 to March 2004.

During the period their character and conduct were found good.

We wish them success in all their future endeavors.

For UMS RADIO FACTORY Ltd.,

(Sarabeswaran V)
Engineer, R&D

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ABSTRACT

The project 'Electric Two Wheeler' aims at obtaining a fuelless alternative to gasoline powered transportation. It involves the complete design and implementation of variable speed drive, drive system and appropriate selection of motor. The permanent magnet DC motor used develops 260 watts of power and sufficient torque for propelling a 70 kg passenger with relative ease. The motor speed is controlled using a Peripheral Interface Controller. The pulsed output generated by the PIC using a proportional integral derivative process control algorithm drives a DC - DC chopper that serves to give the actuating signal to the motor. The speed variation module is available to the user in the form of a potentiometer that varies the set point from 0 - 100%. The vehicle is modeled based on the chassis of Bajaj Sunny, with the existing drive train replaced with a custom fabricated mounting plate on which the motor and drive system are mounted. The torque developed by the motor is transmitted to the rear wheel using a direct chain - sprocket drive system. The power supply used is a rechargeable lead acid battery pack. Such an electric two wheeler would prove to be extremely efficient considering the cost per kilometre for small distance commuting. Future improvements may concentrate upon the use of alternative supply source with the ability to deliver power for a long time with a low dead weight.

Chapter 1

1.1 INTRODUCTION:

With the continually increasing effects of pollution on the earth and the depleting nature of petroleum resources, many of the technically advanced nations are resorting to alternative fuelled vehicles. These include solar, chemical and electric powered vehicles. The recent trend in alternative fuel powered vehicles is the use of electric power to drive vehicles.

Robert Anderson of Scotland invented the first crude electric carriage. A small-scale electric car was designed by Professor Stratingh of Groningen, Holland, and built by his assistant Christopher Becker in 1835. Practical and more successful electric road vehicles were invented by both American Thomas Davenport and Scotsmen Robert Davidson around 1842. Both inventors were the first to use non-rechargeable electric cells. Frenchmen Gaston Plante invented a better storage battery in 1865 and his fellow countrymen Camille Faure improved the storage battery in 1881. This improved-capacity storage battery paved the way for electric vehicles to flourish.

1.2 ELECTRIC TWO WHEELER - AN OVERVIEW

Our project involves designing and constructing a two wheeler powered by an electric motor. The speed control is achieved by the use of a Peripheral Interface controller and final torque transmission by a chain - sprocket drive. The motor is powered by a rechargeable and efficient battery pack. The result is a highly efficient and economic means of commuting especially for the traffic infested modern day roads.

The vehicle can carry a payload of upto 80kg and requires recharging every 40 kilometers. Considering the cost of recharging, the overall economy adds upto Rs.12.5 for 60 kilometers. With a top speed of 40 kilometers per hour and good starting torque, the electric two - wheeler provides an ideal solution for short distance in - city commuting. Our electric vehicle also incorporates regenerative feedback and hence battery draining effect is less pronounced.

The 'electronic' aspect of the project comprises of designing and implementing a Peripheral Interface Controller and a two quadrant (forward motoring and regeneration) chopper for motor speed control.

The chassis of a Bajaj Sunny with the engine and drive train completely removed was used. A plate was designed and fabricated for mounting the motor and a simple chain - sprocket drive unit to use it in place of the original drive train. Appropriate fitments for mounting the battery and the passenger comfortably were also incorporated.

1.3 OBJECTIVES:

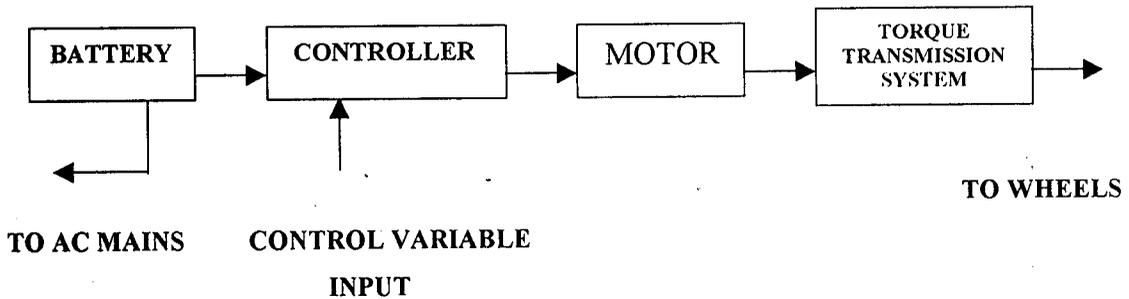
- To develop an environment friendly automobile for personal use.
- To design and implement a battery powered electric two - wheeler (scooter).
- To achieve a zero emission, zero noise alternative for gasoline powered transportation.
- To re design the chassis of a Bajaj Sunny to accommodate a single passenger, a battery pack and the motor.
- To design an effective speed control unit (Peripheral Interface Controller)

1.4 BACKGROUND STUDY:

1.4.1 Study on Existing System:

The modern electric two - wheeler comes in a compact form with permanent magnet DC motors or brushless DC motors. These motors are designed to have high current ratings. The power source is in the form a Lead-Acid battery with an ampere hour capacity of 30 - 50 and minimum weight. The most advanced in Electric Vehicle battery technology is the use of AGM (Absorbed Glass Mat) technology for battery construction. This reduces the battery charge drain rate and also has less recharging time. The basic block diagram of a typical existing system is shown:

BLOCK DIAGRAM OF EXISTING SYSTEM



The controller, in earlier versions used to be a simple IGBT or MOSFET drive fed by a Pulse Width Modulator input. The width of the pulse is dependant on the control input. The width of the pulse controls the duty cycle of the IGBT which offers the required switching characteristics to the motor, and hence a variation in voltage of 0 to rated voltage is achieved. This variation in voltage translates as a variation in motor and hence wheel speed.

More advanced versions of the electric vehicle use microprocessor based control units. The control action is achieved by assembly level language programming which can be modified for several operating modes. The controller develops a digital pulse waveform according to the program which is used to drive a power electronic device like an IGBT or MOSFET. The output of the power electronic device is used to provide a variable armature voltage required for varying the speed of the motor.

The torque transmission in many cases is provided by a chain sprocket or gearbox drive depending on the size of the vehicle.

Chapter 2:

2.1 AN OVERVIEW OF THE DESIGN PROBLEM:

Our primary concern was to design and fabricate an electric two wheeler. This first step in doing this was to identify and decide the modules involved in the project. We classified our project into the following modules:

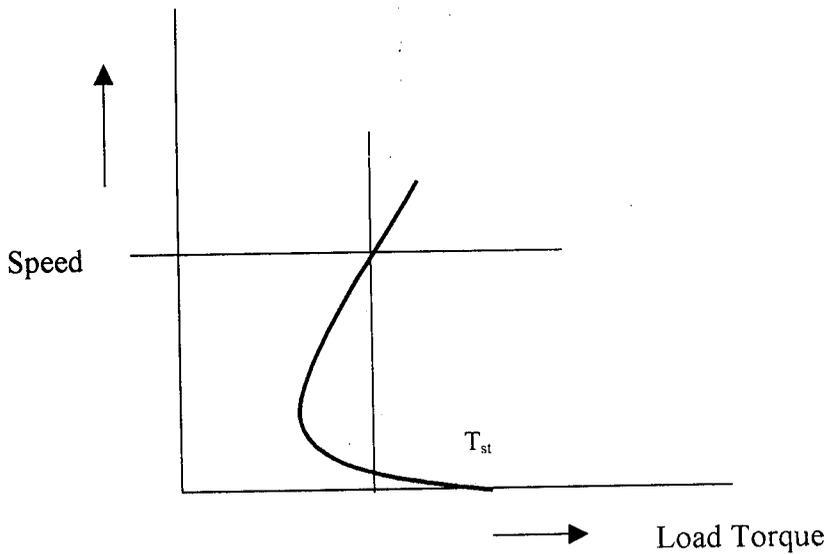
1. Motor - choice of type and design
2. Speed control system - design and fabrication.
3. Supply - Choice of battery type.
4. Chassis - Alterations on the chassis to facilitate mounting of the motor and drive system.
5. Torque transmission system - Choice, design and fabrication.

2.3 SOLUTIONS ADOPTED:

2.3.1 Choice of Motor:

A motor for such an application requires consideration of parameters like power, rpm, maximum current operating voltage and operating characteristics. We were in a position to choose from DC series motor, Permanent magnet DC motor and brushless DC motor. For our requirement we needed the motor to be able to give enough torque while starting and running so that the vehicle could be propelled forward. The motor should also be able to handle current surges and should be able to withstand varying voltages.

Though for most traction applications, the motors are rated based on intermittent duty with starting and braking for this traction application, the motor is rated based on continuous duty of operation.



We also needed the motor to be highly responsive in speed requirements. This is possible only with a permanent magnet motor. So we chose a permanent magnet DC motor (parameters detailed in Design section). The motor's temperature characteristics also posed a design issue as the motor was only air cooled.

2.2.2 Choice of Battery:

The battery is an important design aspect. Some of the parameters to be considered are:

1. Suitability for various applications.
2. Capacity in ampere hours.
3. Terminals configuration.
4. Voltage rating.
5. Charging current
6. Charging time.
7. Idling requirements.
8. Visual electrolyte checks
9. Maintenance and electrolyte change intervals.
10. Battery weight.
11. Percentage that can be recharged.
12. Cost.

For use in our case, we needed a 24V battery with a slow discharge rate. We selected such a battery pack with a recharging circuit that plugs into the AC mains. The selection was also based on the recharge time as referred to voltage to which the battery has been drained.

2.2.3 Choice of speed control system:

The speed control system provides a closed loop control using armature voltage control method. The drive is specifically chosen for the motor that is selected. A PWM based permanent magnet DC motor drive is used. Here a switching MOSFET acts as a power modulator. Variation of duty cycle of the MOSFET from 0 to 1 varies the output voltage from 0 to rated value. The gate drive circuitry employs a microcontroller that can generate PWM output based on the duty cycle written to one of its internal registers. A totem pole driver is employed to the gate of the MOSFET using two transistors.

The microcontroller chosen is peripheral interface controller which has built in PWM output and analog to digital conversion capabilities. A data acquisition system as well as a process control system can be developed using a single chip.

2.2.4 Torque Transmission System:

The torque transmission system is of utmost importance as this is what determines the amount of power transmitted effectively to the wheels from the motor. For such an application as an electric two wheeler, we thought it was best to use a simple chain - sprocket setup because it has the following advantages:

- Greater efficiency
- Gear ratios can be adjusted easily.
- It can withstand high loads.
- Easy installation and maintenance.
- Greater capacity to absorb shocks.

2.2.5 Chassis and frame elements:

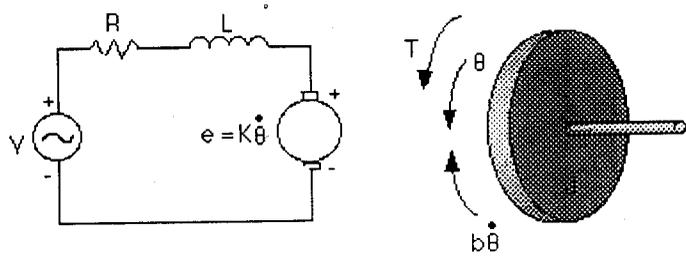
Our entire project was designed to be run on the chassis of a Bajaj Sunny. This required us to remove the existing drive system and internal combustion engine and strip the vehicle essentially to its basic frame elements and wheels. From here, we needed to design and fabricate a bed plate for mounting the motor and drive system sturdily. The plate would also have to be mounted effectively as in integral part of the chassis. The effective use of space is achieved by compactness of the motor and drive system mounting and also by the mounting of the battery under the seat.

Chapter 3:

3.1 ANALYSIS AND STUDY

The basic concept of the project rests on effective motor speed control. The speed control of a permanent magnet DC motor is analyzed using MATLAB by constructing the mathematical model of the system.

3.1.1 Physical setup of DC motor:



The motor torque, T , is related to the armature current, i , by a constant factor K_t . The back emf, e , is related to the rotational velocity by the following equations:

$$T = K_t i$$
$$e = K_e \frac{d\theta}{dt}$$

K_t (armature constant) is equal to K_e (motor constant).

This system is modeled by summing the torques acting on the rotor inertia and integrating the acceleration to give the velocity. Also, Kirchoff's laws will be applied to the armature circuit.

The integrals of the rotational acceleration and of the rate of change of armature current are modeled first.

$$\int \frac{d^2\theta}{dt^2} = \frac{d\theta}{dt}$$

$$\int \frac{di}{dt} = i$$

The system is then modeled using Newton's law and Kirchoff's law. These laws applied to the motor system give the following equations:

$$\begin{aligned} J \frac{d^2\theta}{dt^2} = T - b \frac{d\theta}{dt} &\implies \frac{d^2\theta}{dt^2} = \frac{1}{J} \left(K_t i - b \frac{d\theta}{dt} \right) \\ L \frac{di}{dt} = -Ri + V - e &\implies \frac{di}{dt} = \frac{1}{L} \left(-Ri + V - K_e \frac{d\theta}{dt} \right) \end{aligned}$$

Terminology:

Moment of inertia of the rotor (J) = kg.ms²s⁻².

Damping ratio of the mechanical system (b) = 0.1 Nms.

Electromotive force constant (K=K_e=K_t) = 0.01 Nm/Amp.

Electric resistance (R) = 1 ohm.

Electric inductance (L) = 0.5 H.

Input (V): Source Voltage.

Output (theta): position of shaft.

Using these equations, the MATLAB model is built. The following steps are involved:

- Insert an Integrator block (from the linear block library) and draw lines to and from its input and output terminals.
- Label the input line "d2/dt2(theta)" and the output line "d/dt(theta)" as shown below. To add such a label, double click in the empty space just above the line.
- Insert another Integrator block above the previous one and draw lines to and from its input and output terminals.
- Label the input line "d/dt(i)" and the output line "i".

- Insert two Gain blocks, (from the Linear block library) one attached to each of the integrators.
- Edit the gain block corresponding to angular acceleration by double-clicking it and changing its value to " $1/J$ ".
- Change the label of this Gain block to "inertia" by clicking on the word "Gain" underneath the block.
- Similarly, edit the other Gain's value to " $1/L$ " and it's label to Inductance.
- Insert two Sum blocks (from the Linear block library), one attached by a line to each of the Gain blocks.
- Edit the signs of the Sum block corresponding to rotation to "+-" since one term is positive and one is negative.
- Edit the signs of the other Sum block to "-+-" to represent the signs of the terms in Kirchoff's equation.
- Insert a gain block below the inertia block, select it by single-clicking on it, and select Flip from the Format menu (or type Ctrl-F) to flip it left-to-right.
- Set the gain value to "b" and rename this block to "damping".
- Tap a line (hold Ctrl while drawing) off the rotational integrator's output and connect it to the input of the damping gain block.
- Draw a line from the damping gain output to the negative input of the rotational Sum block.

Adding the torque from the armature:

- Insert a gain block attached to the positive input of the rotational Sum block with a line.
- Edit it's value to "K" to represent the motor constant and Label it "Kt".
- Continue drawing the line leading from the current integrator and connect it to the Kt gain block.

Adding the voltage terms which are represented in Kirchoff's equation (the voltage drop across the coil resistance):

- Insert a gain block above the inductance block, and flip it left-to-right.
- Set the gain value to "R" and rename this block to "Resistance".
- Tap a line (hold Ctrl while drawing) off the current integrator's output and connect it to the input of the resistance gain block.
- Draw a line from the resistance gain output to the upper negative input of the current equation Sum block.

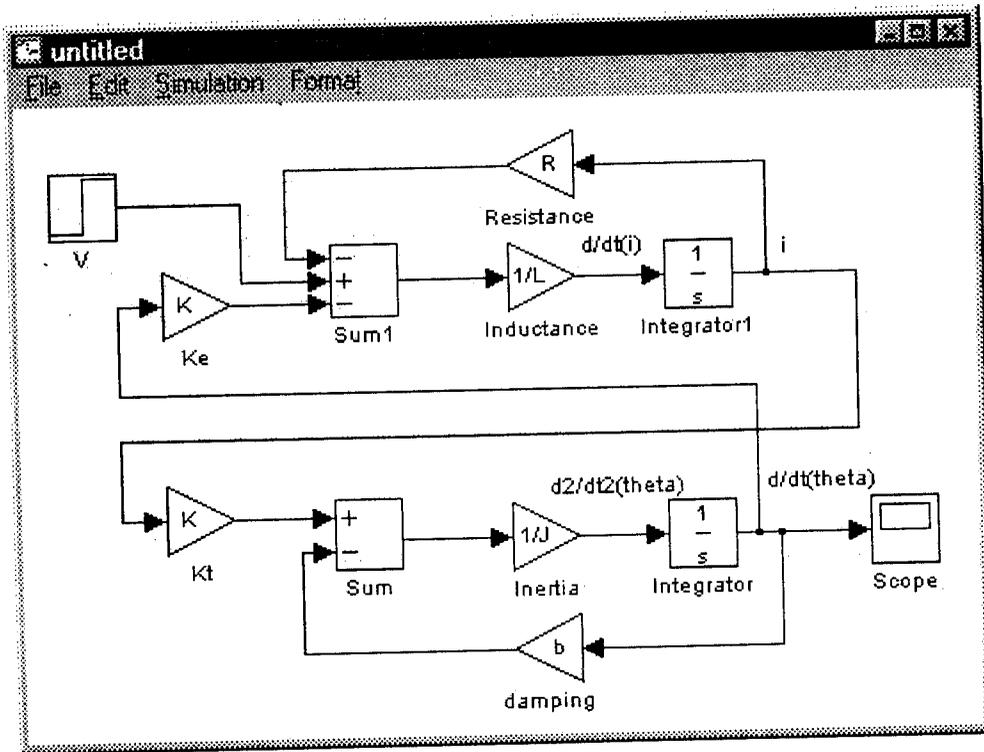
Adding the back emf from the motor:

- Insert a gain block attached to the other negative input of the current Sum block with a line.
- Edit it's value to "K" to represent the motor constant and Label it "Ke".
- Tap a line off the rotational integrator output and connect it to the Ke gain block

Applying V as a step input:

- Insert a Step block (from the Sources block library) and connect it with a line to the positive input of the current Sum block.
- To view the output speed, insert a Scope (from the Sinks block library) connected to the output of the rotational integrator.
- To provide a appropriate unit step input at $t=0$, double-click the Step block and set the Step Time to "0".

The completed block diagram in MATLAB Simulink looks like this:



For viewing the open loop response, assume the following values:

$$J=0.01;$$

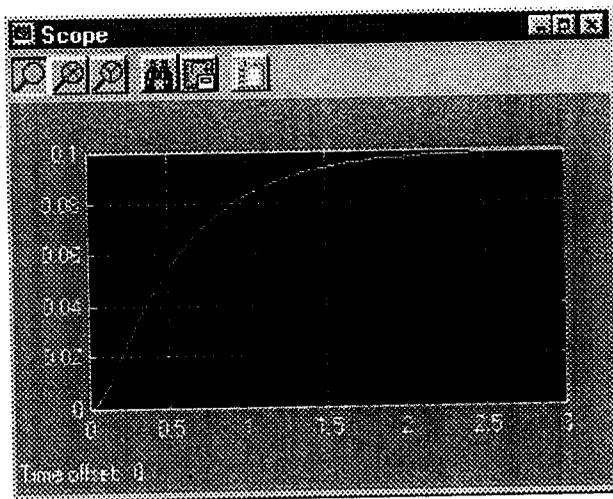
$$b=0.1;$$

$$K=0.01;$$

$$R=1;$$

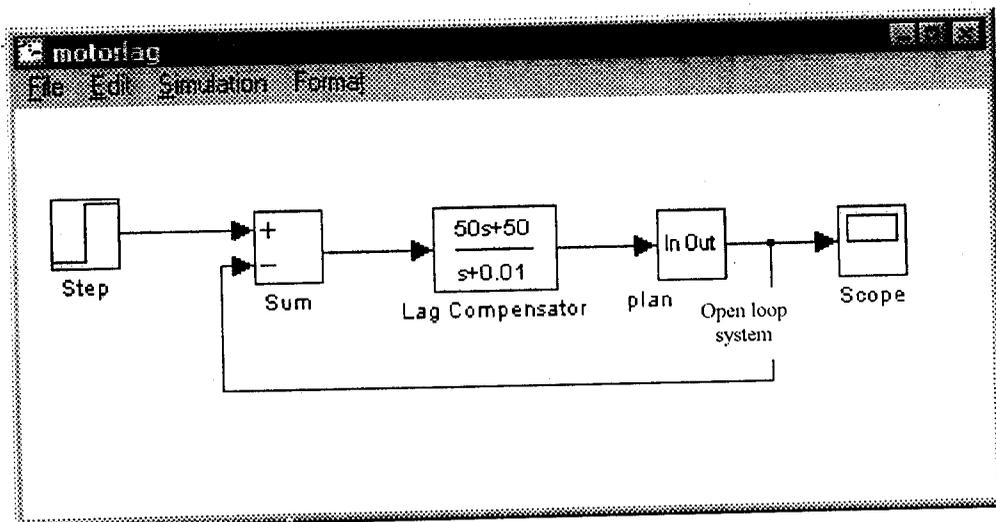
$$L=0.5;$$

The open loop response can be viewed by attaching a scope at the point where the required quantity is to be measured. On running the simulation, the following graph is obtained:



OPEN LOOP RESPONSE

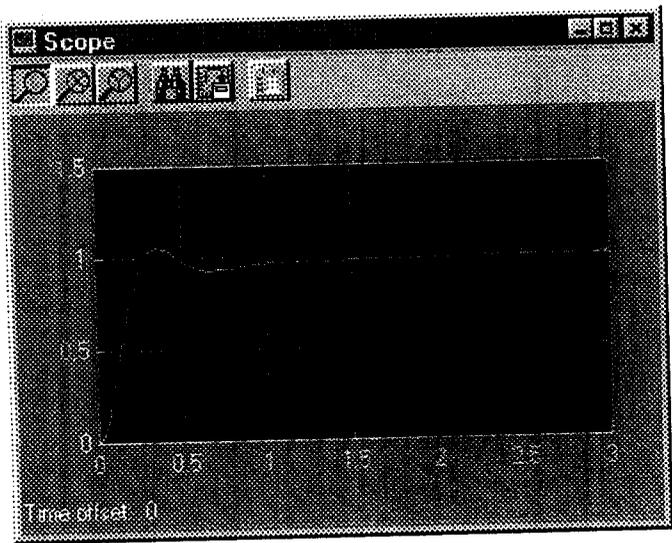
To obtain the closed loop response a lag compensator of default value is added in the loop as shown:



CLOSED LOOP MODEL

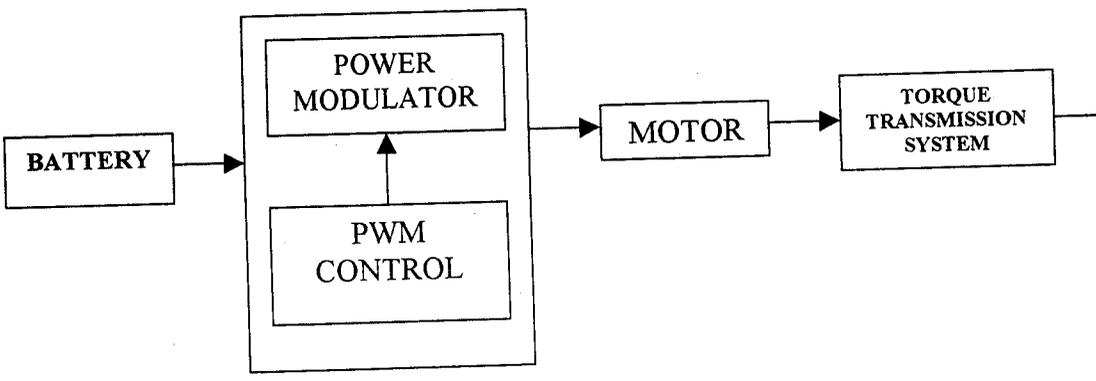
Where 'Open loop system' is the model constructed earlier.

By placing the scope on the 'out' line of the open loop model as shown, the closed loop response can be obtained. On running the closed loop simulation, the following graph is obtained:



Thus the open and closed loop response of a DC motor is analyzed.

3.2 GENERAL BLOCK DIAGRAM:



The power modulator circuit makes use of a switching power MOSFET. The PWM drive circuit isolation is provided by a totem pole connection of transistors. The permanent magnet DC motor has a constant field facilitating linear speed vs. voltage characteristics. The motor can also withstand a substantial amount of load. Overloading of the motor during starting is an important factor to be considered.

The battery provides a steady voltage output. The power modulator provides a variable output voltage across the motor terminals. The control of the voltage is made available to the user using a set point potentiometer that specifies the reference speed. The PWM output is generated by peripheral interface controller. The PWM output is varied depending upon the duty cycle written on one of its internal registers.

The torque transmission system used is a simple chain sprocket drive which effectively transmits the torque developed by the motor to the rear wheel with maximum efficiency and least slippage.

Chapter 4:

4. DESIGN:

Once the analysis of the system is complete, the design aspect is carried out. This comprises of the following parts:

- Basic Calculations
- Finalization of motor parameters
- Design of Controller
- Design of torque transmission system

The basic calculations comprise of primary design values like dead weight, acceleration and traction calculation. The motor parameters are then finalized based on the results of the values obtained from the basic calculations. The basic calculations provide a raw idea as to how much force is required to pull the vehicle and what is the top speed it can achieve. These values are interpreted as motor parameters. The design of controller comprises of design of power electronic circuit and simulation of the functioning of the peripheral interface controller. The final element incorporates the design of chain - sprocket system.

4.1 BASIC CALCULATIONS:

4.1.1 Dead weight and maximum payload:

This is the first among the basic calculations. The dead weight refers to the weight of the chassis, frame elements, motor, drive system, batteries and any other fitments. The maximum payload in our case was 60 to 70 kg as the vehicle is in a single seater configuration.

Weight of chassis with wheels - 45 kg.

Weight of batteries - 8 kg.

Weight of drive train and fitments - 12 kg.

Maximum payload - 85 kg.

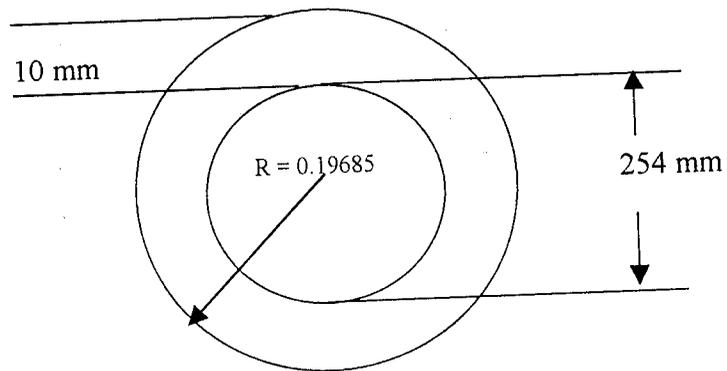
Total weight - 150 kg.

Ideally, this calculated weight can be used for design purposes. But in practicality, the vehicle is subject to gradients, aerodynamic resistance, rolling resistance and moment of inertia.

4.1.2 Top speed and acceleration:

Top speed:

The designed top speed of the vehicle is approximated to 40kmph. The dimensions of the wheel are measured:



From the above figure, the circumference is calculated as the product of diameter and the constant pi. The circumference is found as 1.2369m.

The top speed is 40 kmph, i.e., 40000 meters/hour.

Since the circumference is 1.2369 m, the wheel covers 1.2369 m in one revolution. Hence for 40000m, the number of revolutions is: $40000/1.2369 = 32338.911$.

The revolutions per minute is given by $32338.911 / 60 = 538.9$ rpm.

Starting acceleration:

This is one of the foremost design requirements. Only upon deciding this, the tractive effort and henceforth the motor parameters can be determined. The designed acceleration is 0 to 40 kmph (top speed) in 6 seconds.

→ 6 seconds - 0 - 40 kmph

→ Hence 1 sec - $40 / 6 = 6.6667$

This translates to $4.1667 \text{ mph/s} = 4.1667 / 21.95 \text{ ft/s}^2$

→ Acceleration = 0.18982 ft/s^2

4.1.3 Traction:

Tractive force is an important design parameter. It can be defined as the force required for propelling the vehicle forward when natural resistive forces are acting. This is given by:

$$F = F_a + F_h + F_r$$

Where:

F = Tractive force.

F_a = Acceleration force.

F_h = Gradient force.

F_r = Rolling resistance.

Acceleration force is defined by Newton's law as the product of mass and acceleration. It is given by:

$$F_a = C_i W a$$

Where

C_i = mass factor which represents the vehicle's rotating mass

W = weight in pounds

a = acceleration in mph/second.

F_h is defined as gradient overcoming force and is given by:

$$F_h = W \sin f$$

Where

W = weight of the vehicle in pounds.

f = angle of incline of gradient.

F_r - Rolling resistance is defined the impedance to motion of the vehicle offered by friction between the tires and the tarmac and is given by:

$$F_r = C_r W \cos f$$

Where

C_r = coefficient of friction.

W = weight of the vehicle in pounds.

Calculations:

Acceleration force:

$$\begin{aligned} F_a &= WaC_i \\ &= 330 \times 0.189 \times 1.04051 \\ &= 65.0765 \text{ pounds.} \end{aligned}$$

The value of C_i is calculated using the formula:

$$\begin{aligned} C_i &= 1.04 + 0.0025 (N_c)^2 \\ &= 1.04 + 0.0025 (0.45166)^2 \\ &= 1.04051. \end{aligned}$$

Where N_c = combined ratio of transmission and final drive.

Gradient effect:

$$F_h = W \sin f$$

$$= 330 \times \sin (1^{\circ}43') \text{ (assuming 3\% incline)}$$

$$= 9.8868 \text{ pounds.}$$

Rolling Resistance:

$$F_r = C_r W \cos f$$

$$= 0.018 \times 330 \text{ (for tarmac, } C_r = 0.018)$$

Since during starting, speed is zero, we have:

$$F = F_a + F_h + F_r$$

$$= 65.076 + 9.8868 + 5.94$$

$$\rightarrow \text{Total tractive force} = 80.9028 \text{ pounds}$$

During running, the force is given by:

$$\text{Force} = C_r W \cos f + (C_d A V^2 / 391) + C_w F_d$$

Where

C_r = rolling resistance coefficient.

W = weight of the vehicle in pounds.

C_d = coefficient of aerodynamic drag.

A = Effective area of chassis directly exposed to air flow.

V = maximum possible velocity of vehicle.

The value of aerodynamic drag force F_d is calculated from a chart relating drag and the maximum velocity of the vehicle which in this case is assumed to be 31.25mph.

$$\begin{aligned}
 \text{Force} &= \frac{5.94 + (1.98 \times 2 \times 31.25)^2 + 0.206 (9.74)}{391} \\
 &= 5.94 + 9.7406 + 2.007. \\
 &= 17.687 \text{ pounds.} \\
 &= 8.0395 \text{ kg.}
 \end{aligned}$$

The rated torque is calculated using the formula:

$$\begin{aligned}
 T_r &= \frac{\text{Force} \times \text{radius of wheel} \times \text{reduction ratio}}{\text{Transmission efficiency}} \\
 &= \frac{8.0395 \times 0.19685 \times 0.5}{0.95} \\
 &= 0.82761 \text{ Nm.}
 \end{aligned}$$

MOTOR TORQUE RATING = 0.82761 Nm

The rated maximum rpm of the motor is 3000 rpm.

Thus transmission ratio is given by:

$$\begin{aligned}
 \text{Ratio} &= \frac{\text{maximum designed rpm of rear wheel}}{\text{Rated rpm of the motor}} \\
 &= \frac{539.005}{3000} \\
 &= 0.17966.
 \end{aligned}$$

The ratio of the torques is also given by this value. Hence,

$$0.17966 = \frac{T_{\text{motor}}}{T_{\text{wheel}}}$$

Thus wheel torque is given by:

$$T_{\text{wheel}} = \frac{0.82761}{0.17966}$$

$$= 4.60653 \text{ Nm.}$$

Considering a transmission efficiency of 0.95, wheel torque is:

$$4.60653 \times 0.95$$
$$= 4.37620 \text{ Nm.}$$

At starting, the torque required at the wheel is:

$$T_{\text{starting}} = T_{\text{rated}} \times 1.65$$
$$= 4.37620 \times 1.65$$
$$= 7.2207 \text{ Nm.}$$

Similarly, the starting torque at the motor = $1.65 \times T_{\text{rated}}$ (motor)

$$= 1.65 \times 0.82761$$
$$= 1.36566 \text{ Nm.}$$

4.2 MOTOR:

The calculations performed above indicate in raw terms how much force or rather power is required to drive the vehicle. These values have to be interpreted as parameters of the motor as it is the machine responsible for driving the vehicle.

4.2.1 Finalization of motor parameters:

The motor used herein is rated at 24V which is indicative of the battery terminal voltage also.

$$\text{Voltage} = 24\text{V}$$

The power developed by the motor is an important parameter to understand whether the motor generates enough power to propel the vehicle forward.

$$\begin{aligned}\text{Power output} &= \frac{2p NT}{60} \\ &= \frac{2 \times 3.14 \times 3000 \times 0.82761}{60} \\ &= 260.\end{aligned}$$

$$\text{Power} = 260 \text{ W.}$$

As explained above, the torque required is calculated by finding out the tractive effort required to pull the vehicle against forces like rolling resistance, aerodynamic drag and its own weight.

$$\text{Rated torque} = 0.82761 \text{ Nm.}$$

Ideally, rated current is calculated as $I_{\text{rated}} = P / V$.

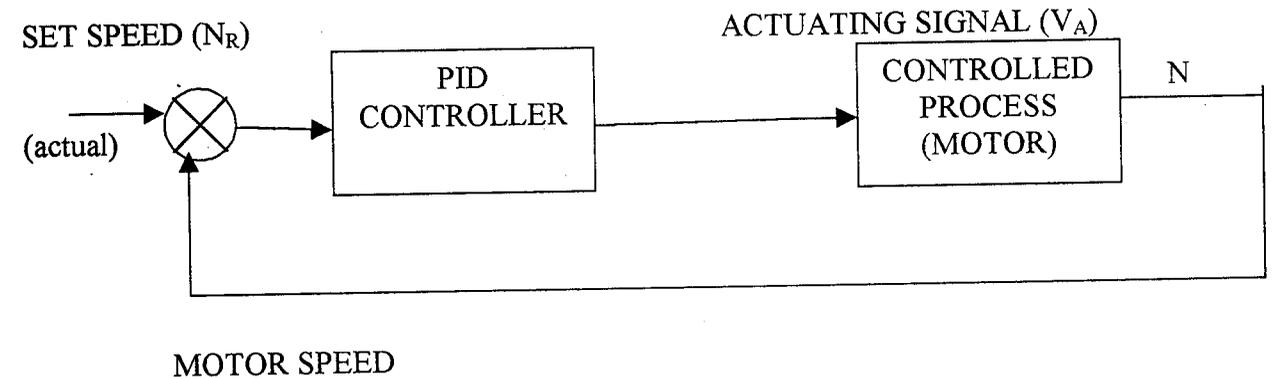
$$\text{Rated current} = 10.8333 \text{ A.}$$

The rated rpm of the motor is 3000.

4.3 DESIGN OF SPEED CONTROLLER:

The electric vehicle controller should perform the following functions:

- 1) Sense the set point or the base speed specified by the user.
- 2) Calculate the actual speed/current speed of the motor.
- 3) Sense the current continuously to provide current limit protection.
- 4) Output the PWM gate control waveform of the desired duty cycle to provide the necessary speed adjustment.



The electric vehicle controller has two main components:

- 1) The high voltage power electronic DC step down chopper circuit that provides a variable output voltage (V_a).
- 2) A micro controller based process control system that outputs a duty cycle based on a PID control algorithm.

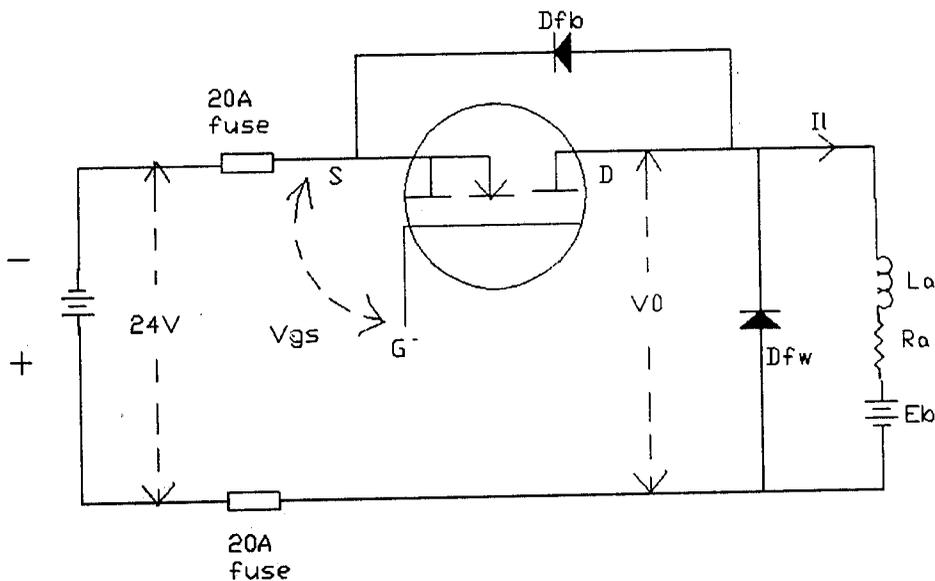
4.3.1 Design of power electronic circuit:

The design of DC chopper circuit involves the selection of high frequency switching transistor that chops off the supply voltage at regular time intervals. The two quadrant DC chopper requires a inverse parallel diode configuration to facilitate power flow in the opposite direction. A free wheeling diode must also be selected based on the load ratings.

The battery supply has negligible source inductance. Hence we can do away with the input filter. The output harmonics depend upon the duty cycle.

The power semiconductor devices must be rated based on the maximum values of the circuit variables. The maximum current in the circuit occurs during the starting of the electrical vehicle ($I_{st} = 17.87495 \text{ A}$). The MOSFET should safely withstand such a current or even above such a value for a brief duration of time. Current limit protection must be provided to all the power electronic components. The presence of a motor inductance results in a reverse blocking voltage that which may exceed the supply voltage of 24 V. The MOSFET should safely withstand such a voltage rise though a free wheeling diode is provided across the motor which will suppress such a rise.

The MOSFET chosen is IRF 3205 (data sheet included).



$$V_{DSS} = 55 \text{ V}$$

$$R_{DS} = 8 \text{ m ohm.}$$

$$I_D = 110 \text{ A}$$

The maximum drain to source voltage of the MOSFET is 55V. Under conduction state, the MOSFET has an on state resistance of $R_{DS(ON)} = 8 \text{ m ohm}$. The diode used is SemiKron P600A (50V, 60A).

GATE DRIVER CIRCUIT FOR MOSFET:

The gate drive for the MOSFET must have a low impedance voltage source capable of supplying the capacitive current. The PWM output from the port pin of the microcontroller should be suitably isolated from the power electronic circuit even though the gate drive voltage is very low. The drive should also offer appropriate rise and fall times for the PWM pulsed input. A standard totem pole configuration of two transistors is used.

The design of the gate drive circuit involves the consideration of the following:

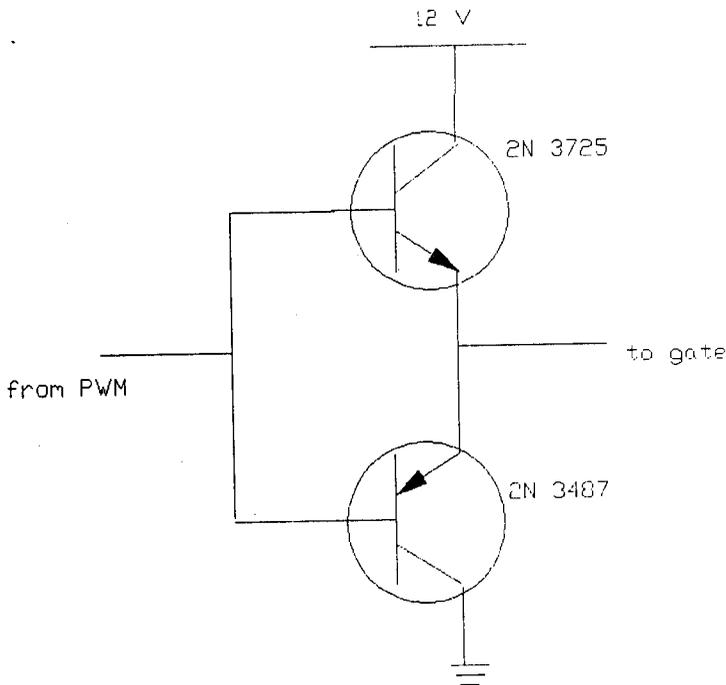
- 1) The total charge accumulated at the MOSFET's gate (specified in the datasheet)
- 2) Determination of gate voltage corresponding to the maximum operating drain current.
- 3) Calculation of gate capacitance using 1 and 2.
- 4) The calculation of gate current from the total gate capacitance and the ratings of the transistor used in the totem pole circuit.

From the data sheet of the MOSFET, for a drain current of approximately 30A, the required gate voltage is just greater than 5V (for $V_{ds} = 24V$, pulse width = 25 microseconds). Hence a traditional approach of using a 12V supply for the totem pole gate drive is used as shown below. The current is calculated from,

$$Q_{total} = 110 \text{ nC (from datasheet),}$$

$$\begin{aligned} C_{total} &= Q_{total} / V_G \\ &= 110\text{nC} / 12\text{V} \\ &= 9.166 \text{ nF.} \end{aligned}$$

$$\begin{aligned} \text{Hence } I_g &= V / X_C \\ &= 12 / 110\text{nC} = 8.29 \text{ mA} \end{aligned}$$



The transistors chosen for the gate drive circuit are 2N3487 and 2N3725 and they can safely handle a current of 8.29mA. There is no requirement for a limiting rate gate resistor which may affect the rise time of the gate pulse as the operation frequency is about 1KHz. The transistors are driven into saturation (ON) by the logic high of 5V from the port pin of the PIC. The totem pole configuration provides precise pulsed gate input to the MOSFET.

DESIGN OF DRIVE CONTROLLER:

The PIC microcontroller is used in the above process control application where

- a) It generates the PWM gate pulse of the desired duty cycle for the chopper circuit.
- b) It calculates the instantaneous duty cycle based on the PID control algorithm.
- c) It senses the instantaneous value of current, motor speed and the set point specified.
- d) Offers protection and drive control for the chopper circuit (microprocessor based gate firing - digital control).

The peripheral interface control is a natural choice as it has a built in PWM waveform generator of continuously variable duty cycle which can be calculated by a suitable process control software.

The PIC chip can be made completely operational by very few external components.

- 1) Regulated power supply (V_{CC} and ground)
- 2) 4MHz crystal clock generator.
- 3) Reference voltage (3V) for analog to digital converter.

The PIC IC chip is 'PIC 16C74' of MicroChip make.

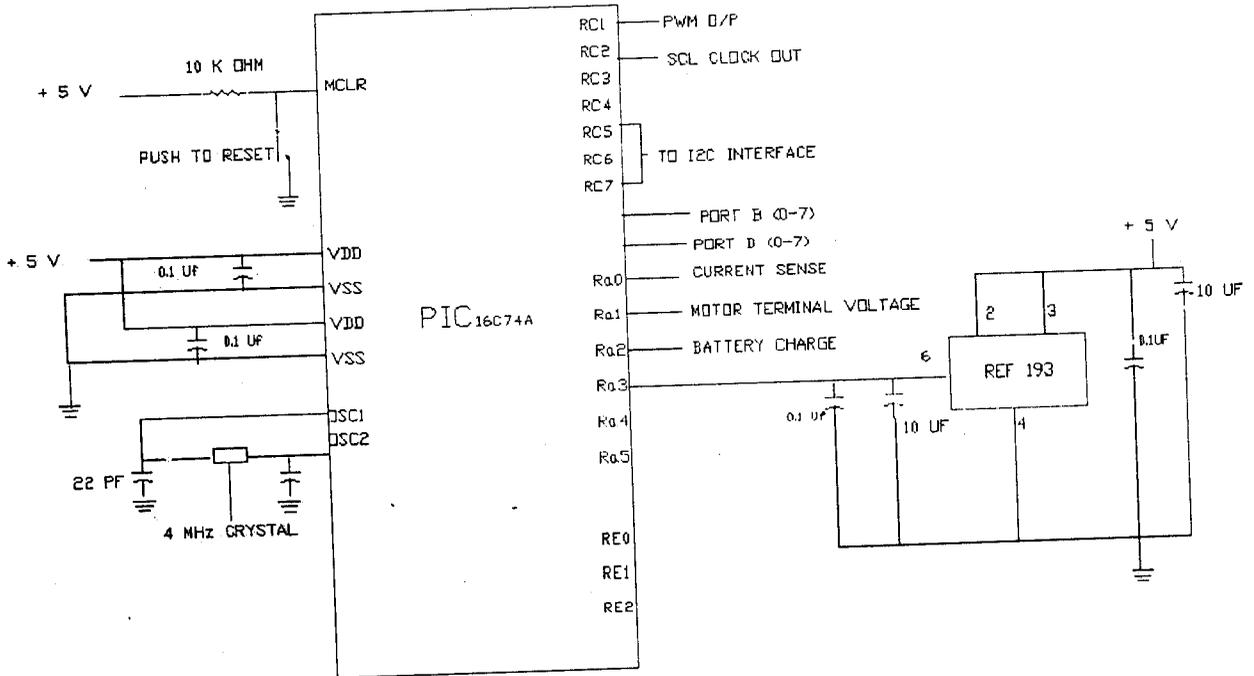
The two important modules of the PIC IC that find use in the above process control application are

- 1) Analog to digital converter module - for data acquisition.
- 2) Capture / Compare / PWM module for pulsed gate waveform generation.

Each CCP (Capture/Compare/PWM) module contains a 16-bit register which can operate as a 16-bit capture register, as a 16-bit compare register or as a PWM master/slave Duty Cycle register. Both the CCP1 and CCP2 modules are identical in operation, with the exception of the operation of the special event trigger.

Further, the accessed circuit variables can also be displayed using one of the slave ports $R_b 0-7$ or $R_d 0-7$ or the I²C pins of port C. The circuit schematic (hardware of the drive controller) is shown below. It shows the inputs / outputs interface of the PIC IC chip with the current, voltage and speed measuring components.

PERIPHERAL INTERFACE CONTROLLER



The 3V reference voltage supply provided to the pin R_{a3} of the PIC serves to act as the reference analog voltage input against whose value all the analog inputs are scaled down.

There are three analog inputs varying from 0 - 3V (full scale),

- a) Current input for measuring the chopper circuit current.
- b) Battery terminal voltage indicating charge.
- c) Motor terminal voltage for determination of speed.

For specifying the modes of operation of the PIC A/D the control registers TRISA, ADCON1 are initialized with appropriate values. The supply voltage ripples are bypassed through 22 micro farad capacitors to offer a steady 5V supply for the chip.

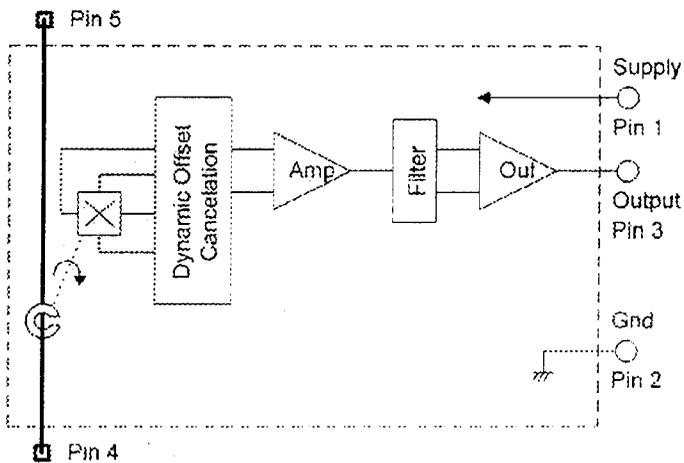
The data acquisition involves analog circuit design using operational amplifiers IC 741 for providing proportional analog inputs to the PIC chip, that which would vary with variations in circuit variables - current, voltage.

The circuits are shown below:

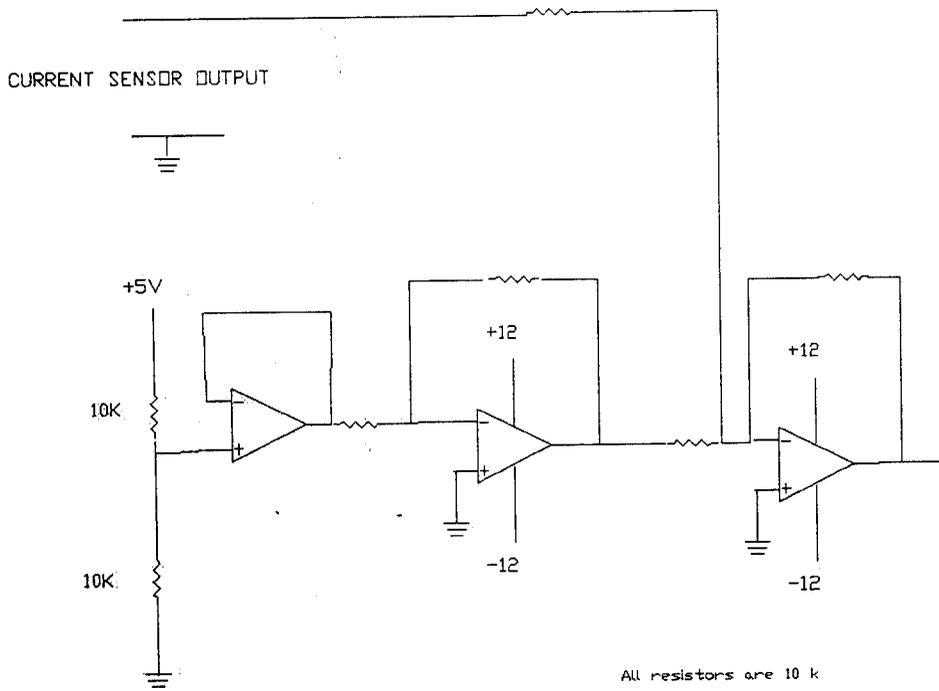
Current sensor:

The current sensor IC used is Allegro ACS750. The sensor consists of a precision linear Hall IC optimized to an internal magnetic circuit to increase device sensitivity. The combination of a precisely controlled self-aligning assembly process and the factory programmed precision of the linear Hall sensor result in high level performance and product uniformity.

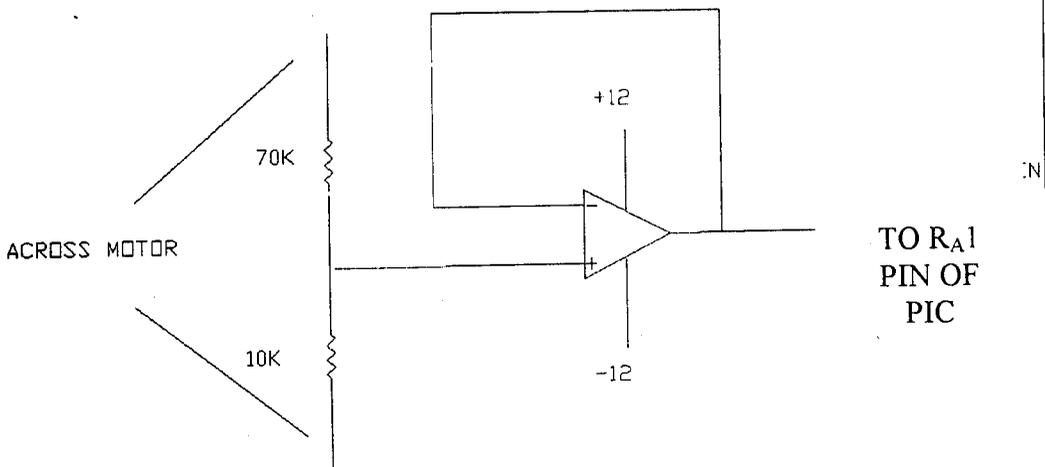
The primary conductor used for current sensing (terminals 4 and 5) is designed for extremely low power loss. The power terminals are also electrically isolated from the sensor leads (pins 1 – 3). This allows the ACS750 family of sensors to be used in applications requiring electrical isolation without the use of opto-isolators or other costly isolation techniques. The functional block diagram of the IC ACS750 is shown:



BLOCK DIAGRAM



Motor terminal voltage sensing circuit:



Software:

The process control software performs the following functions:

- a) Acquires data from the drive circuit and the motor and stores them in the internal register banks.

- b) Uses the above data and employs a PID algorithm based process control.
- c) The controlled variable is the speed of the motor and the actuating or control signal is the duty cycle (8 bit value) written to the CCPR1L register that changes the ON time of the PWM waveform keeping the frequency as constant.
- d) The period (frequency of waveform) is specified by the formula
$$\text{Period} = (\text{PR2} + 1) \times (\text{pre scaler value} / \text{OSC}) \times 4.$$
- e) The program is developed in the form of subroutines with each one performing specific tasks within a specific duration of time.

The PID control algorithm is shown below:

- Step 1: Calculate the difference between the set speed and actual speed. This constitutes the error value.
- Step 2: Multiply this error by a constant K_p . This is the proportional component.
- Step 3: Run the continuous average all the previous errors. Multiply it by K_i . This will be the integral component.
- Step 4: Calculate the difference between successive errors and multiply by K_d . This will be the differential error component.
- Step 5: Add all the three components and scale down to a value of 256 as reference to calculate the duty cycle.
- Step 6: Proper selection of K_p , K_i , and K_d will tune the system to the desired response.

4.4 DESIGN OF TORQUE TRANSMISSION SYSTEM:

The primary purpose of the torque transmission system is to effectively transmit the torque developed by the motor to the wheels. The system comprises of two sprockets - one connected to the motor called as the driver sprocket and one connected to the wheel termed driven sprocket. A chain runs between the two sprockets, effectively transmitting the torque. The design thus comprises of the following:

- Number of teeth on driver sprocket
- Number of teeth on driven sprocket
- Centre Distance - distance between the sprockets
- Chain length.
- Chain pitch.

According to the initial calculations, the designed wheel rpm at top speed is 539. The rated maximum rpm of the motor is 3000 rpm. This rpm is reduced to 900 in two stages within the motor itself. Thus the rpm has to be reduced from 900 to 539. As used earlier, the drive ratio is approximately 0.5 and hence the number of teeth in the driven sprocket is 18 -20 teeth. The centre distance is measured from the original drive train as 12.22 inches. The chain used for transmission is alternately linked 12 mm pitched chain.

The length of the chain used is calculated using the following procedure:

CD = Centre distance (distance between motor and wheel shaft) in inches

N = Number of teeth in wheel sprocket.

n = Number of teeth in motor sprocket.

P = Chain pitch in inches.

Procedure:

1. Calculate C, Where $C = CD - P$

$$C = 12.22 - 0.5$$

$$= 11.72$$

2. Calculate A, Where $A = N + n$

$$= 18 + 9$$

$$= 27.$$

3. Calculate S, Where $S = N - n$

$$= 18 - 9$$

$$= 9.$$

4. From the ST chart for standards in chain design, the value of T is 44.6

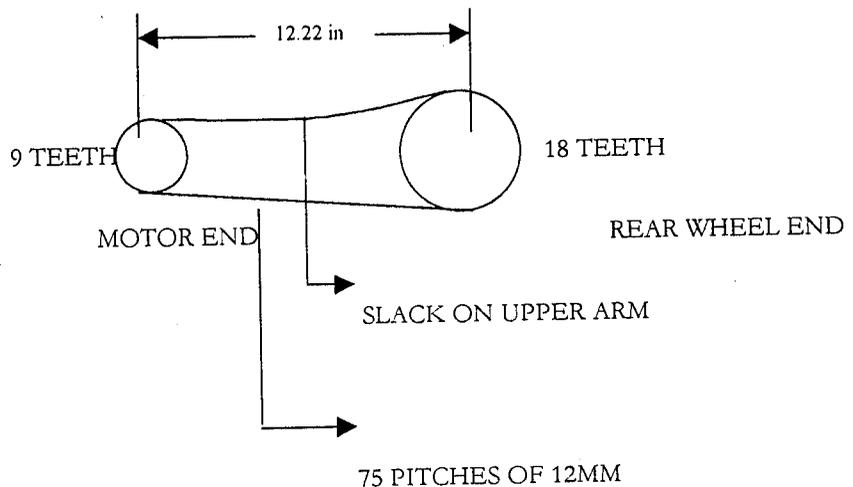
5. Chain Length (Pitches) $L = 2C + (A/2) + (10T/C)$.

$$= 2(11.27) + (27/2) + (10 \times 44.6 / 11.27)$$

$$= 74.8688 \text{ pitches.}$$

$$= 75 \text{ pitches.}$$

The length of the chain is calculated as the product of individual chain pitch length and number of pitches, i.e., $75 \times 12 = 900 \text{ mm}$. The drive system is so arranged that the extra length of the chain length falls as a slack on the upper arm of the chain for effective transmission. In the event of tooth biting or link locking, the drive system can be experimented with a couple of extra links and using an idler sprocket to maintain the tension in the chain.



4.5 FRAME AND CHASSIS ELEMENTS:

4.5.1 Design:

The chassis used is that of a Bajaj Sunny stripped down to its elemental form without the internal combustion engine and the drive train. This chassis modified to accommodate the motor and drive system. Since the original drive train and IC engine have been removed, a plate had to be fabricated with provisions for attaching it to the chassis at two points - swing arm and suspension tail.

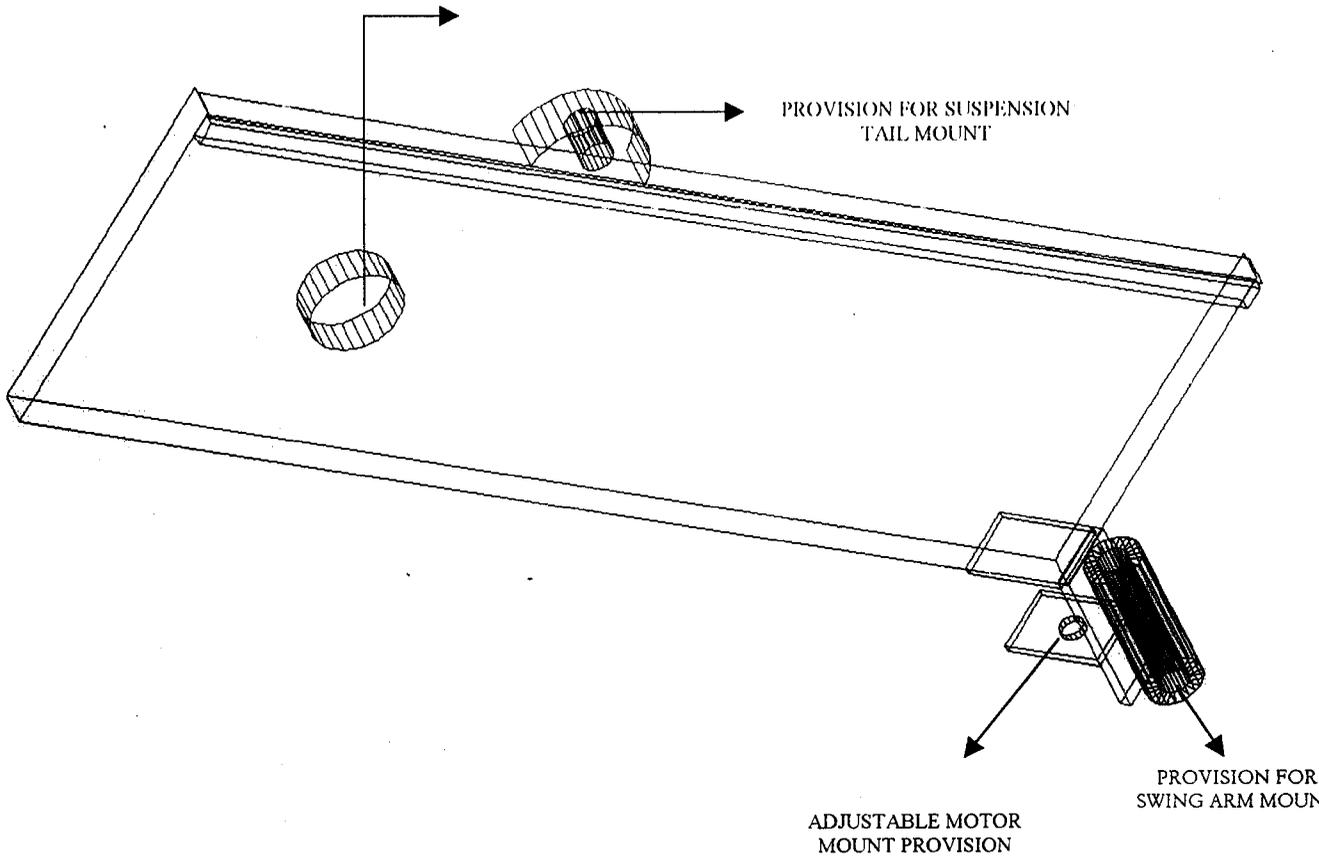
The isometric view of the plate is shown below. It comprises of a 4 mm thick plate bent at the top to form an 'L'. Another 4mm piece is bent in the form of an 'L' and is welded at the base of the bigger piece. A pipe is welded to the smaller 'L' plate into which stay bushes of the factory specifications are inserted. This provides mounting provision on the swing arm.

There is another semicircular piece welded to the plate as shown which has the factory specification suspension bush fitted into it. This provides the sole suspension mount on the vehicle. The plate also has a hole bored into it for housing the rear wheel drive which comprises of a ball bearing, housing and a shaft.

The motor is mounted on another small 'L' section welded to the section which houses the swing arm mount. This section is free bolted so that the distance between the motor position and the rear wheel can be slightly adjusted to satisfy centre distance needs for chain design.

The autocad model developed for the fabrication process is shown below:

BORE FOR BEARING
HOUSING AND SHAFT



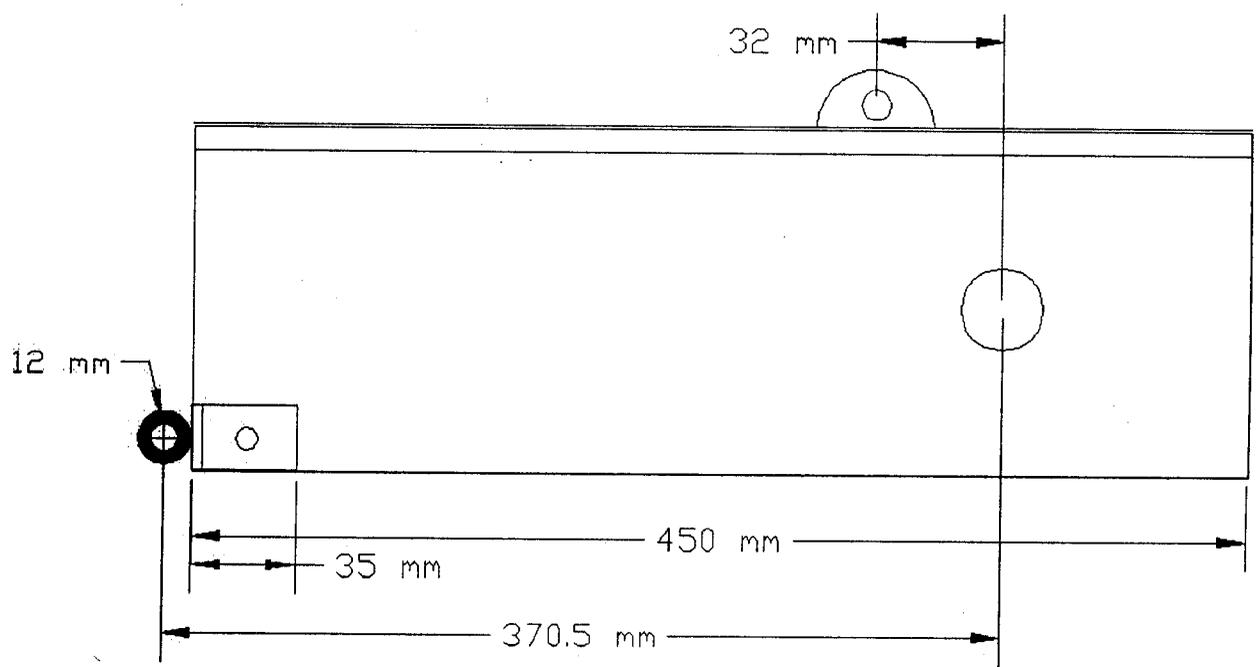
The hole provided in the far end of the plate for housing the bearing and rear wheel shaft shares the load with the suspension mount. But since this is not fool proof, another strip is rigidly bolted between the bed plate and the chassis. The battery box is strapped under the seat and the controller is clamped onto a chassis arm.

4.5.2 Fabrication:

The dimensions of the piece are shown in the engineering drawing. The fabrication basically comprises of bending the plates and strips at perfect right angles. Then the smaller 'L' strips are rigidly welded onto the parent plate as shown. The pipe which houses the swing arm mount is then welded onto the smaller 'L' strip as shown.

The mounting position of the suspension tail is located and a small section housing the suspension bush is welded onto the plate as shown. As this piece should take maximum load descending from the suspension, the welding process is done with extreme caution. The second 'L' strip which is used to mount the motor is then welded onto the longer 'L' strip. Holes for motor mounting and rear wheel shaft are bored.

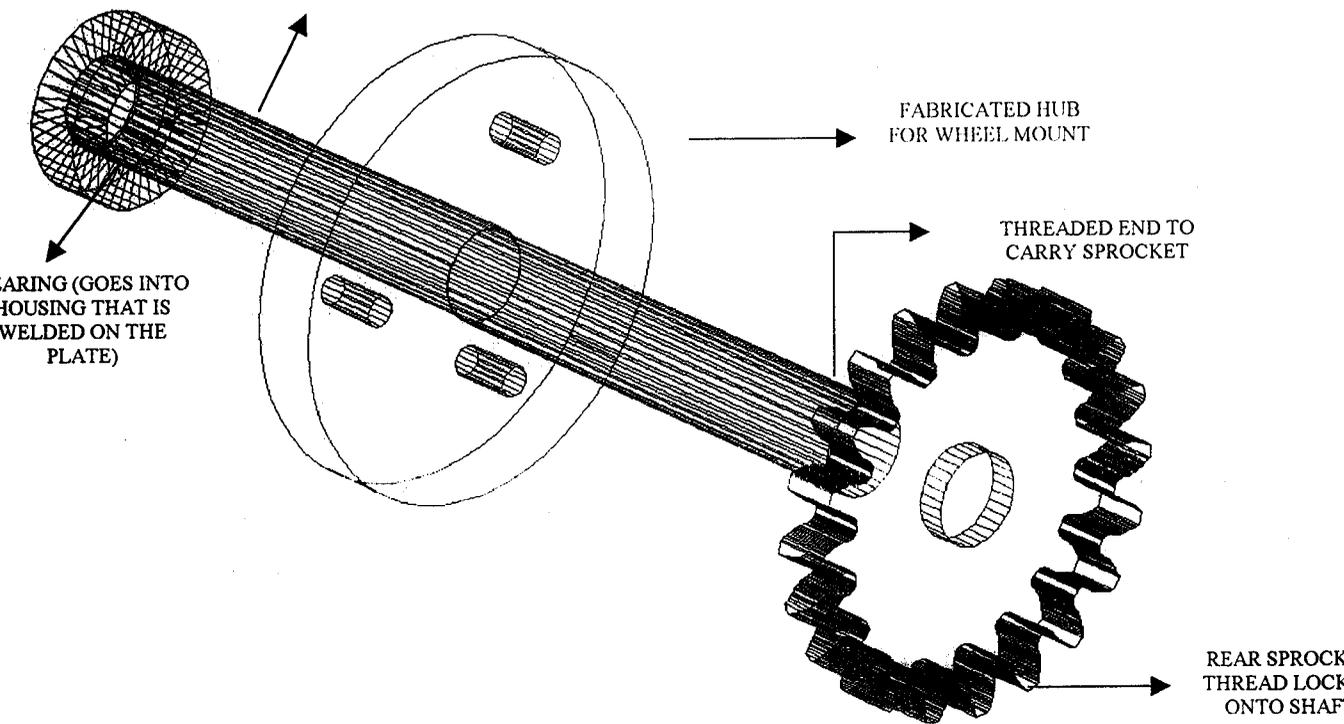
The linear dimensions of the plate are shown in the following diagram:



The rear wheel is sprocket driven. To provide this, a hub is bolted onto the rear wheel and the shaft is welded onto the hub. Passing through a sleeve and the hole drilled in the plate, the shaft terminates in a freely rotating ball bearing whose housing is mounted on the plate.

The bearing is locked tight on the housing so that free rotation is possible. The shaft is also machined so that it perfectly fits into the bearing. The other end of the shaft has to provide for the rear sprocket. For this purpose, the shaft is threaded so that the sprocket can be thread locked. The autocad model (exploded) developed for this element is shown below:

MACHINED END
TO FIT INTO
BEARING



As shown above, the shaft is first machined at one end and threaded at the other end. The machined end is made to fit tightly into the bearing so that the inner ring rotates freely against the outer ring that is fitted into the housing which is welded onto the plate. The hub is a circular piece of metal of thickness 10mm which is cut at the exact size of the wheel's central hub.

The centre point of the hub is located and a hole is drilled to insert the shaft. The shaft is centralized and welded at both sides of the plate to make the hub (and hence the wheel) as a single rotating body. Now that the rear wheel setup is completed, the next step is to provide drive to the shaft.

This is done by threading the rear sprocket on the shaft. By doing this, the rotation of the motor transmitted via the chain onto the sprocket is relayed as torque on the hub and hence the wheel. Some of the precautions exercised are snug fitting of the shaft into the bearing and the bearing into the housing. Additional support to the housing is provided to ensure better load handling capabilities. Additional support is provided to the shaft by enclosing it in a sleeve through which it passes freely.

Chapter 5:

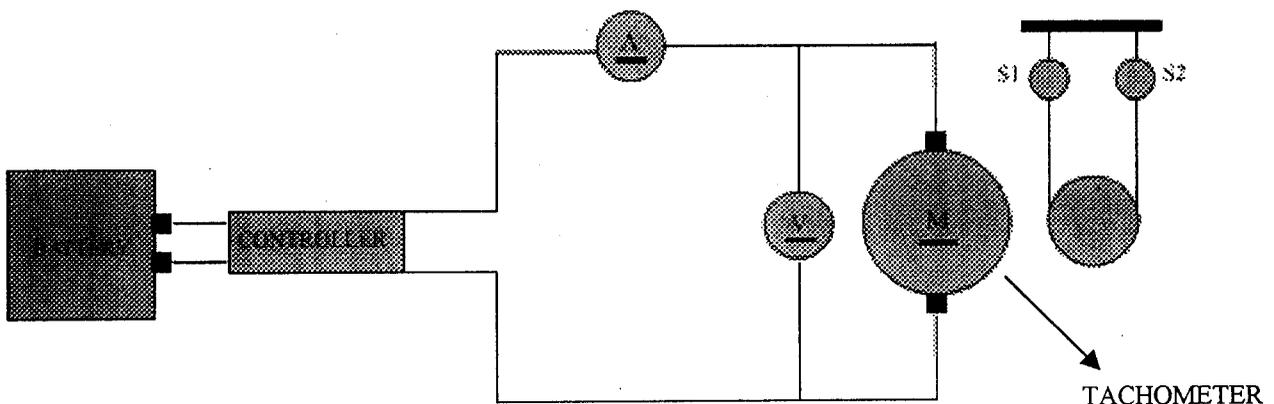
5.1 TESTING OF MOTOR:

The testing process for any machinery is inevitable if the particular machinery is designed for use in the practical life. The load testing is a vital test in the process of proving the capacity and the efficiency of the motor in carrying the load. The load test carried out here is a simple and direct test of finding out the maximum load up to which the motor can withstand. The very purpose of the load testing is to design the end value of the load using the specifications of the motor.

The load test not only finds out the load that motor can withstand, it also can determine the efficiency of the motor. This direct method is also highly efficient and economical. The load testing can also help in the better selection of the motor if the desired value is not achieved. The load test not only finds out the load that motor can withstand, it also can determine the efficiency of the motor.

5.1.1 Load test:

Load test is performed on the motor using brake drum loading. The following experimental setup is used.



In the above show experimental setup, the 24 V battery is connected to the motor via the controller which allows variation from 0 - 24 V to effect speed control. The ammeter measures motor current and the voltmeter measures the voltage. The motor speed is recorded using the tachometer.

Loading of the motor is done using brake drum loading mechanism, wherein the motor shaft is connected to a drum to which load can be applied using a belt. The amount of load applied is read from the two spring balance readings.

The power supply is switched on and using the controller, the maximum voltage of 24 volts is applied to the motor so that it reaches the rated speed of 3000 rpm noted in the tachometer. The values of current and voltage at no load are noted. Then the brake drum is loaded and the corresponding spring balance readings and ammeter and voltmeter readings are noted. This procedure is continued till the motor is loaded to 110% of its maximum loading capacity.

The observations are shown in the tabulation below:

S.no	Voltage (V)	Current (A)	S1 (kg)	S2 (kg)	S3 s1~ s2	Torque = 9.81R (S3) Nm	Speed (rpm)	Input power (W)	Output power (W)	Efficiency
1.	24	5.1	2.1	1.8	0.3	0.22586	3001	122.4	70.98	58
2.	24	7	2.3	1.7	0.5	0.38120	2988	168	119.28	71
3.	24	8.6	2.6	1.9	0.7	0.50935	2979	206.4	158.9	77
4.	24	10.2	3.1	2.2	0.9	0.65566	2958	244.8	203.1	83
5.	24	11	3.3	2.3	1	0.76316	2940	264	234.96	89
6.	24	11.8	3.5	2.4	1.1	0.84275	2920	283.2	257.7	91

FORMULAE USED:

Let,

S1= Reading on spring balance 1 in kg.

S2= Reading on spring balance 2 in kg.

S3 = S2~S1 kg.

The net weight applied to the motor= S3 *9.81 Newton.

Let,

R= Radius of the drum = 0.075 m.

N= Speed of the motor.

The shaft toque T_{sh} developed by the motor is given by:

$$T = 9.81 \times 0.075 \times S3$$

A motor is a machine that converts electrical energy into mechanical energy. Hence input power is give by the product of voltage and current.

$$\text{Power}_{\text{input}} = V_a I_a$$

The output power is given by the formula:

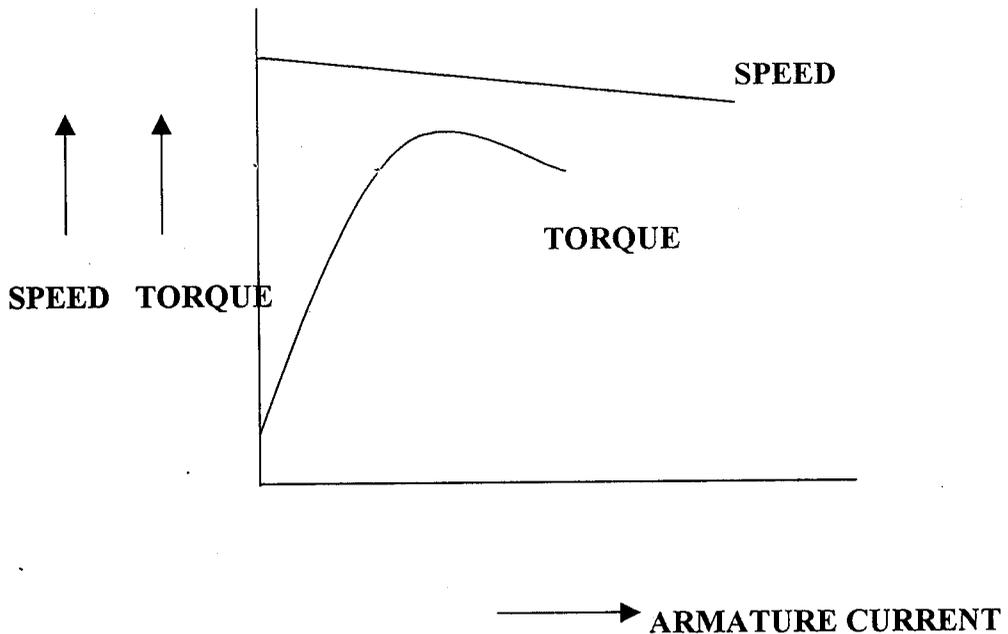
$$\text{Power}_{\text{output}} = \frac{2\pi NT}{60}$$

Efficiency is computed as the ratio between input and output power:

$$h = \frac{\text{Power}_{\text{output}}}{\text{Power}_{\text{input}}}$$

Assuming the flux to be almost constant, we can conclude that $T \propto I_a$.

Hence the graph between torque and current will be as shown below:

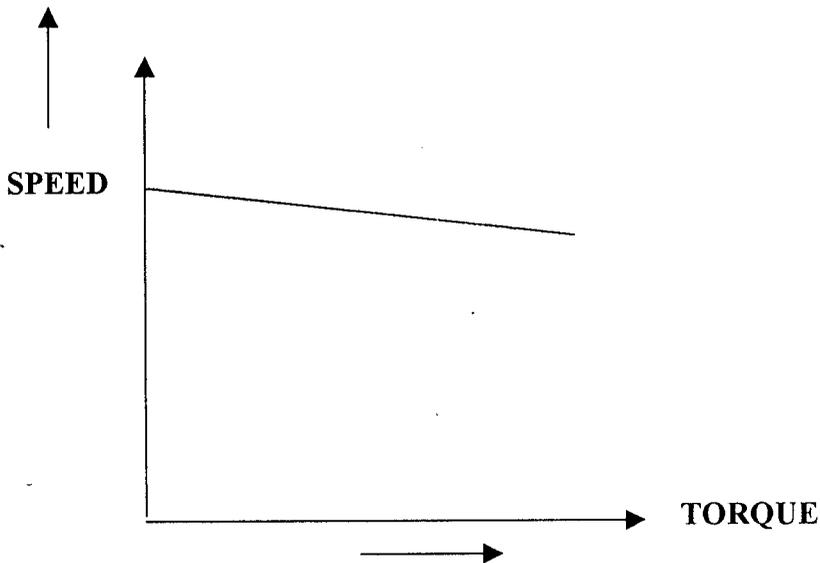


For a DC motor, the speed is proportional to the back emf. Hence $N \propto (V - I_a R_a) / f$

Since flux is assumed to be constant, $N \propto (V - I_a R_a)$.

From the above expression, it is evident that, as the armature current increases, the drop in $I_a R_a$ also increases. Thus $(V - I_a R_a)$ decreases and hence the speed N also decreases. The speed versus current characteristics is also shown in the above figure.

The two expressions $N \propto (V - I_a R_a)$ and $T \propto I_a$ are used for finding the relationship between speed and torque. The speed torque characteristics of the motor are shown below:



The other performance curves required for the analysis are armature current, efficiency, speed and torque versus the output power.

5.2 TESTING OF BATTERY:

The choice of battery for the electric vehicle depends on various factors like capacity in ampere hours, terminals configuration, voltage rating, charging current, charging time, idling requirements, visual electrolyte checks, maintenance and electrolyte change intervals, battery weight, percentage that can be recharged and cost, among which the following important factors are tested:

- Initial charge duration.
- Initial idle time.
- Initial charge time.
- Specific gravity specifications.

The initial charge duration is defined as the time taken for the battery to charge up to the rated maximum voltage. The initial charge is provided using the following procedure and then the time taken to reach the maximum voltage is observed.

- Fill in the battery with electrolyte of specific gravity specified by the manufacturer.
- Leave the battery idle for 12 hours.
- Charge the battery with 3.5 amperes at starting and 4.5 amperes after 4 hours.
- Note the time taken for the electrolyte to reach the full charge specific gravity level as specified by the manufacturer.

This is an important parameter and was observed to be 25 hrs. This process, though not used in everyday purposes, is important in cases like electrolyte gassing or contamination.

The initial idle time is defined as the time for which the battery should be left idle before it can accept charging. In our case, this was found to be 12 hours.

The specific gravity specifications issued by the manufacturer are - 1.210 and 1.240 for initial and final charges.

5.3 TESTING OF CONTROLLER:

The testing of the peripheral interface controller involves a simulation of the assembly level code which shows us the waveforms of the PWM output when the set point (throttle) is varied. This allows us to study the delay that occurs between the application of change in the throttle and the actual change in PWM output.

The simulation also allows us to study the effects of rapid throttling and sudden voltage surges. Using this data, it is possible to incorporate appropriate protection devices. Another important parameter is sensitivity which can be defined as the ratio between rate of change of throttle and the rate of change of PWM output.

5.4 TESTING OF CHASSIS ELEMENTS:

The primary objective for this is to observe which frame elements bear most loads and to provide support for these elements or direct the load to other elements. The main element that requires this test is the fabricated shaft and bed plate.

In the bed plate, the crucial areas to be tested are the suspension mount which takes the entire weight of the passenger and the chassis elements above it. On testing, the element shifted slightly first and then failed. To correct this, strong triangular pieces were welded on the mount's sides to prevent shifting. This also increases the strength of the suspension mount.

The next crucial loaded element is the joint between the bed plate and the swing arm mounting provision. In sprocket driven systems, there is a possibility of shocking of the chain and the sprocket. Due to this, the far end of the plate undergoes some travel, which is not encouraged.

To restrict this motion, a metal strip is bolted onto the plate and the other end is strain tightened onto an element on the chassis. This blocks the sideways motion of the wheel.

The shaft and bearing form another important testing aspect. The load actually falls on the wheel first through the suspension. The wheel, in turn is supported by the shaft and bearing. The bearing is tested with more than rated payload to check for travel within the housing or bearing failure.

The shaft is also tested for shear and bending when subject to 110% of rated load and drive is given. For strengthening purposes, the shaft is passed through a sleeve which is welded onto the inner side of the plate. The sleeve is machined to be slightly bigger than the shaft so that a greased keyway can be provided for the shaft.

5.5 TESTING OF TRANSMISSION:

This test involves the following:

- Testing if the sprockets are in line: This is of utmost importance in chain sprocket drives. On any case, with any amount of loading, the sprockets should always be in line. Washers are provided at the appropriate places to ensure this.
- Testing tautness of chain: This again is crucial for chain sprocket systems. The designed chain length should descend over the sprockets only with a maximum allowable slack. Any more slack should be checked using an idler. In our case, the designed chain length was under the allowable slack and hence the use of idler was unnecessary.
- Rear sprocket rotational travel: Though the rear sprocket is tread locked onto the rear wheel hub, under practical conditions, it is possible for it to slip, causing chain failure. To prevent this, a spring washer and an outer nut with a cotter pin is provided.

Chapter 6:

6.1 REPLACING EXISTING DRIVE WITH CUSTOM DRIVE:

The replacement procedure can be done by removing the two main chassis binds - swing arm and suspension. The wheel, which is mounted on a hub and sprocket in the existing drive system, is detached and the custom hub with shaft is attached.

The fabricated bed plate is rigidly mounted at the same two major chassis binds - suspension and swing arm. By the use of appropriate bushes, the swing arm bolt is lubricated and fitted through the provision provided. The suspension tail is then bolted through the suspension mount on the plate.

The wheel assembly with the hub and shaft is attached onto the bearing available on the plate. The sprocket is then thread - locked and nuts wherever required are terminated with cotter pins.

6.2 MOTOR MOUNTING:

The next process in assembly is mounting of motor. This is done in the slot provided between the two 'L' clamps. The 'L' clamp associated with the swing arm mount is ground slightly so that the motor fits snugly into the slot.

As explained above, the motor mount is adjustable for two reasons - to adjust motor position to ensure chain slack is below allowable maximum and to ensure that the driver and driven sprockets are in line. Once this position is determined, the motor is tightened.

6.3 MOUNTING OF BATTERY AND CONTROLLER:

The mounting of the battery is done in the space under the seat. The batter box is rigidly clamped and taped onto the horizontal arm. Pieces of foam are used as padding between the battery box and the chassis to prevent vibration.

The controller is enclosed in a plastic casing which is provided with drill holes to house a clamp. The clamp is bolted on the chassis in a safe location so that it receives least shock and also in close proximity to the motor and battery.

6.4 WIRING:

The wiring comprises of the following main leads:

- Battery to controller.
- Accelerator to controller.
- Controller to motor.

These wires are insulated properly and routed with clamps at regular intervals to ensure that they do not come loose. The wire terminals are soldered onto appropriate male and female sockets so that they are not only fault free but also removable.

Chapter 7:

7.1 HYBRID ELECTRIC VEHICLES (HEV)

The first opinion of anyone who drives an electric vehicle is that it lacks power. To overcome this researchers around the world are currently working on a system wherein the power of the internal combustion engine is coupled with the efficiency and economy of the electric motor to arrive at a system known as a hybrid electric vehicle.

Hybrid electric vehicles (HEVs) combine the internal combustion engine of a conventional vehicle with the battery and electric motor of an electric vehicle, resulting in twice the fuel economy of conventional vehicles. This combination offers the extended range and rapid refueling that consumers expect from a conventional vehicle, with a significant portion of the energy and environmental benefits of an electric vehicle. The practical benefits of HEVs include improved fuel economy and lower emissions compared to conventional vehicles. The inherent flexibility of HEVs will allow them to be used in a wide range of applications, from personal transportation to commercial hauling.

Hybrid power systems were conceived as a way to compensate for the shortfall in battery technology. Because batteries could supply only enough energy for short trips, an onboard generator, powered by an internal combustion engine, could be installed and used for longer trips. In the old days, we thought that by biasing the system toward battery-electric power and operating on wall-plug electricity as much as possible, efficiency and emissions would then be about as optimal as we could hope for until better batteries came along. The natural conclusion of this concept was that, with better batteries, we probably would not need hybrids at all. But after 20 years of study, it seems that hybrids are taking center stage and electric vehicles are only being used in niche market applications where fewer miles are traveled.

More efficient cars can make a big difference to society in terms of environmental benefits, and the serious deterioration of urban air has motivated regulators to require cleaner cars. Use of production HEVs will reduce smog-forming pollutants over the current national average. Hybrids will never be true zero-emission vehicles, however, because of their

internal combustion engine. But the first hybrids on the market will cut emissions of global-warming pollutants by a third to a half, and later models may cut emissions by even more.

HEVs have several advantages over conventional vehicles:

- Regenerative braking capability helps minimize energy loss and recover the energy used to slow down or stop a vehicle.
- Engines can be sized to accommodate average load, not peak load, which reduces the engine's weight.
- Fuel efficiency is greatly increased (hybrids consume significantly less fuel than vehicles powered by gasoline alone).
- Emissions are greatly decreased.
- HEVs can reduce dependency on fossil fuels because they can run on alternative fuels.
- Special lightweight materials are used to reduce the overall vehicle weight of HEVs.

The HEVs available for sale are very cost competitive with similar conventional vehicles.

Any cost premium that may be associated with HEVs of the future can be off-set by overall fuel savings and incentives.

Auto manufacturers are making these HEVs with comparable performance, safety, and cost because they know that these three elements are most important to consumers. And by combining gasoline with electric power, hybrids will have the same or greater range than traditional combustion engines. The HEV is able to operate approximately two times more efficiently than conventional vehicles. Honda's Insight can go 700 miles on a single tank of gas. The Honda Civic hybrid can go 650 miles on a tank of gas, and the Toyota Prius can go about 500 miles. For the driver, hybrids offer similar or better performance than conventional vehicles.

7.2 ALTERNATIVE SOURCES OF ENERGY:

This is another primary research area which deals with the use of energy sources like the sun or hydrogen to generate power. Two of such energy sources highly relevant in this area are - solar power and fuel cells.

A fuel cell is an electrochemical energy conversion device that converts hydrogen and oxygen into water, producing electricity and heat in the process. It is very much like a battery that can be recharged while you are drawing power from it. Instead of recharging using electricity, however, a fuel cell uses hydrogen and oxygen.

Combustion engines like the turbine and the gasoline engine burn fuels and use the pressure created by the expansion of the gases to do mechanical work. Batteries store electrical energy by converting it into chemical energy, which can be converted back into electrical energy when needed.

A fuel cell provides a DC (direct current) voltage that can be used to power motors, lights or any number of electrical appliances. There are several different types of fuel cells, each using a different chemistry. Fuel cells are usually classified by the type of electrolyte they use. Some types of fuel cells show promise for use in power generation plants. Others may be useful for small portable applications or for powering cars.

Solar Power:

This is the process of tapping the power of sun to generate electric power that can be used to run the vehicle. The main components in a solar cell are the photovoltaic cells that convert light energy incident on them into electric power by the principle of photovoltaic cell briefly explained below.

The "photovoltaic effect" is the basic physical process through which a PV cell converts sunlight into electricity. Sunlight is composed of photons, or particles of solar energy. These photons contain various amounts of energy corresponding to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they

may pass right through. Only the absorbed photons generate electricity. When this happens, the energy of the photon is transferred to an electron in an atom of the cell (which is actually a semiconductor).

With its newfound energy, the electron is able to escape from its normal position associated with that atom to become part of the current in an electrical circuit. By leaving this position, the electron causes a "hole" to form. Special electrical properties of the PV cell—a built-in electric field—provide the voltage needed to drive the current through an external load such as a motor.

7.3 BATTERY RELATED ISSUES:

The prime concern regarding the battery is its weight. Traditional batteries use Lead acid batteries which are cumbersome and heavy. They also have a mediocre ampere hour capacity and drain rate on the higher side. The recharging process is also time-consuming and voltage fluctuations are aplenty.

All batteries work according to the same basic principle. Two dissimilar materials serving as an anode and a cathode are linked by a third material that serves as the electrolyte. Many different materials can be used as an electrode and an electrolyte, which results in a wide variety of battery technologies. The choice of chemistries also influences the storage density and voltage output.

Traditionally, manufacturers have used nickel-cadmium batteries. However, newer technologies, such as nickel-metal hydride cells, offer users more powerful alternatives and are becoming more popular.

Nickel-cadmium batteries use cathodes made from nickel and anodes made from cadmium. They can withstand up to 1,000 charge and discharge cycles before deteriorating. Because of their reliable ability to provide large amounts of power on demand, nickel-cadmium batteries are still widely used for power tool applications.

The next stage in battery development came when it was realized that Cadmium poses an environmental hazard. As a result, nickel-cadmium cells are increasingly being replaced by other types of rechargeable batteries.

Battery manufacturers are now using nickel-metal hydride, a technology that has similar characteristics to nickel-cadmium, in that it accepts fast and continuous charging. Cells that use hydride cathodes carry over the nickel anodes from nickel-cadmium cell designs. These batteries have an electrolyte of a diluted-solution of potassium hydroxide, which is alkaline in nature.

Other battery technology may soon be available to users, such as lithium-ion, lithium-ion polymer, lithium-iron disulfide and zinc-air. Portable fuel cells are another power option that may be coming soon to a cordless tool near you. But, widespread application of these technologies is currently limited due to exorbitant costs. These batteries offer an excellent prospect to battery powered vehicles as they have minimal recharge time, slow drain rate and minimum weight.

CONCLUSION

Our main aim to design and fabricate a fully functional electric two wheeler was achieved and more importance was given to the proper assembly of the integral component parts. The drive system, though an aspect of automobile engineering, was a very important factor that had to be considered for stable operation of the vehicle.

The chosen motor was upto design expectations and the vehicle could withstand a considerable amount overload. There was a satisfactory response when considering the load torque withstanding capability of the motor and the vehicle. There was a need for further development to increase the top speed of the electric vehicle.

The control was sensitive and adequate response could be obtained as one can expect in a similar sized engine driven vehicle. The drive system was rugged enough and required least maintenance.

The noise free, pollution free automobile making use of the clean cheap electrical energy has a great future in modern day commuting.

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- 5) **PIC microcontroller Design Manual - Microchip Incorporate.**
- 6) **Power Electronics - Rashid.M**
- 7) **Build Your Own Electric Vehicle - Gregory.J.Bonann.**
- 8) **Gear Handbook - S.Rajasekar.**
- 9) **Exide Battery Selection Guide.**



MICROCHIP

PIC16C7X

8-Bit CMOS Microcontrollers with A/D Converter

Devices included in this data sheet:

- PIC16C72
- PIC16C73
- PIC16C73A
- PIC16C74
- PIC16C74A
- PIC16C76
- PIC16C77

PIC16C7X Microcontroller Core Features:

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
DC - 200 ns instruction cycle
- Up to 8K x 14 words of Program Memory, up to 368 x 8 bytes of Data Memory (RAM)
- Interrupt capability
- Eight level deep hardware stack
- Direct, indirect, and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code-protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low-power, high-speed CMOS EPROM technology
- Fully static design

- Wide operating voltage range: 2.5V to 6.0V
- High Sink/Source Current 25/25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
 - < 2 mA @ 5V, 4 MHz
 - 15 μ A typical @ 3V, 32 kHz
 - < 1 μ A typical standby current

PIC16C7X Peripheral Features:

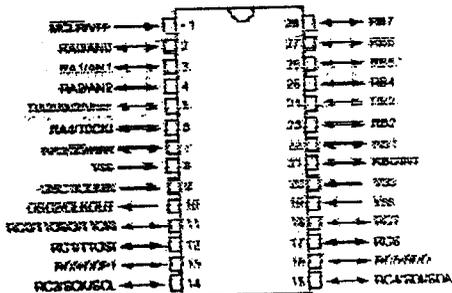
- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during sleep via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Capture, Compare, PWM module(s)
- Capture is 16-bit, max. resolution is 12.5 ns, Compare is 16-bit, max. resolution is 200 ns, PWM max. resolution is 10-bit
- 8-bit multichannel analog-to-digital converter
- Synchronous Serial Port (SSP) with SPI™ and I²C™
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI)
- Parallel Slave Port (PSP) 8-bits wide, with external RD, WR and CS controls
- Brown-out detection circuitry for Brown-out Reset (BOR)

PIC16C7X Features	72	73	73A	74	74A	76	77
Program Memory (EPROM) x 14	2K	4K	4K	4K	4K	8K	8K
Data Memory (Bytes) x 8	128	192	192	192	192	368	368
I/O Pins	22	22	22	33	33	22	33
Parallel Slave Port	—	—	—	Yes	Yes	—	Yes
Capture/Compare/PWM Modules	1	2	2	2	2	2	2
Timer Modules	3	3	3	3	3	3	3
A/D Channels	5	5	5	8	8	5	8
Serial Communication	SPI/I ² C	SPI/I ² C, USART					
In-Circuit Serial Programming	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Brown-out Reset	Yes	—	Yes	—	Yes	Yes	Yes
Interrupt Sources	8	11	11	12	12	11	12

PIC16C7X

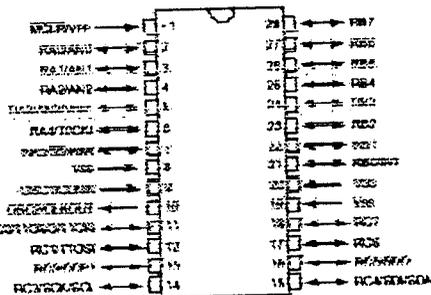
Pin Diagrams

SDIP, SOIC, Windowed Side Brazed Ceramic



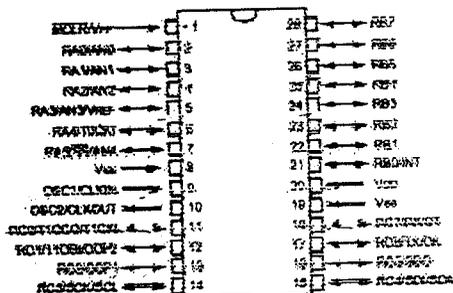
PIC16C72

SSOP



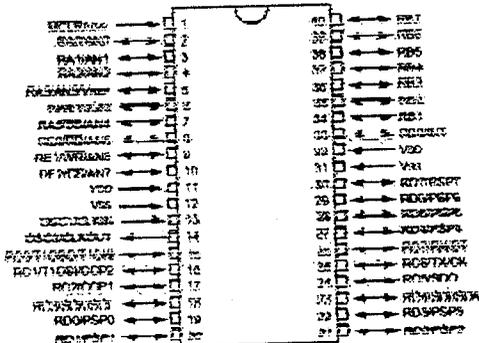
PIC16C72

SDIP, SOIC, Windowed Side Brazed Ceramic



PIC16C73
PIC16C73A
PIC16C78

PDIP, Windowed CERDIP



PIC16C74
PIC16C74A
PIC16C77

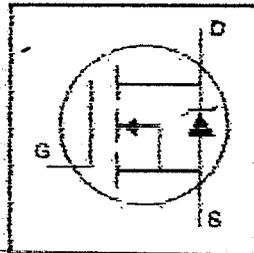
International IR Rectifier

PD-91279E

IRF3205

HEXFET® Power MOSFET

- Advanced Process Technology
- Ultra Low On-Resistance
- Dynamic dv/dt Rating
- 175°C Operating Temperature
- Fast Switching
- Fully Avalanche Rated



$V_{DSS} = 55V$
$R_{DS(on)} = 8.0m\Omega$
$I_D = 110A^{\text{①}}$

Description

Advanced HEXFET® Power MOSFETs from International Rectifier utilize advanced processing techniques to achieve extremely low on-resistance per silicon area. This benefit, combined with the fast switching speed and ruggedized device design that HEXFET power MOSFETs are well known for, provides the designer with an extremely efficient and reliable device for use in a wide variety of applications.

The TO-220 package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 watts. The low thermal resistance and low package cost of the TO-220 contribute to its wide acceptance throughout the industry.



Absolute Maximum Ratings

	Parameter	Max.	Units
$I_D @ T_C = 25^\circ C$	Continuous Drain Current, $V_{GS} @ 10V$	110 ②	A
$I_D @ T_C = 100^\circ C$	Continuous Drain Current, $V_{GS} @ 10V$	80	
I_{DM}	Pulsed Drain Current ①	390	
$P_D @ T_C = 25^\circ C$	Power Dissipation	200	W
	Linear Derating Factor	1.3	W/°C
V_{GS}	Gate-to-Source Voltage	± 20	V
I_{AR}	Avalanche Current ①	62	A
E_{AR}	Repetitive Avalanche Energy ①	20	mJ
dv/dt	Peak Diode Recovery dv/dt ③	5.8	V/ns
T_J	Operating Junction and	-55 to +175	°C
T_{STG}	Storage Temperature Range		
	Soldering Temperature, for 10 seconds	300 (1.8mm from case)	
	Mounting torque: G-32 or N20 screw	10 lbf-in (1.14-n)	

Thermal Resistance

	Parameter	Typ.	Max.	Units
$R_{\theta JC}$	Junction-to-Case	—	0.75	°C/W
$R_{\theta CS}$	Case-to-Sink, Flat, Greased Surface	0.50	—	
$R_{\theta JA}$	Junction-to-Ambient	—	62	

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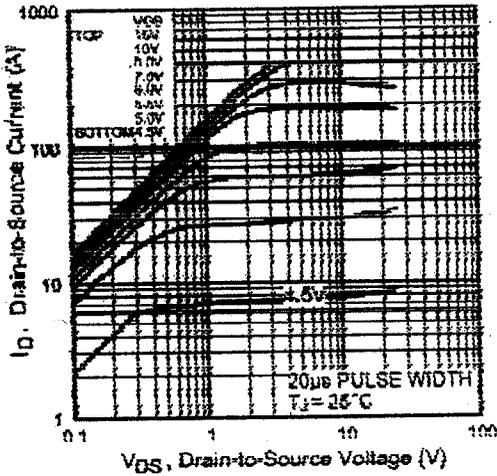


Fig 1. Typical Output Characteristics

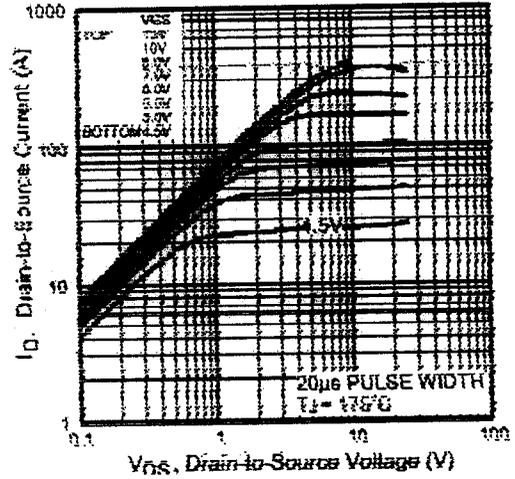


Fig 2. Typical Output Characteristics

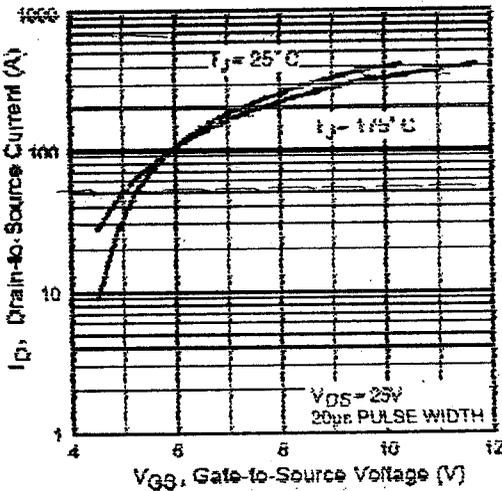


Fig 3. Typical Transfer Characteristics

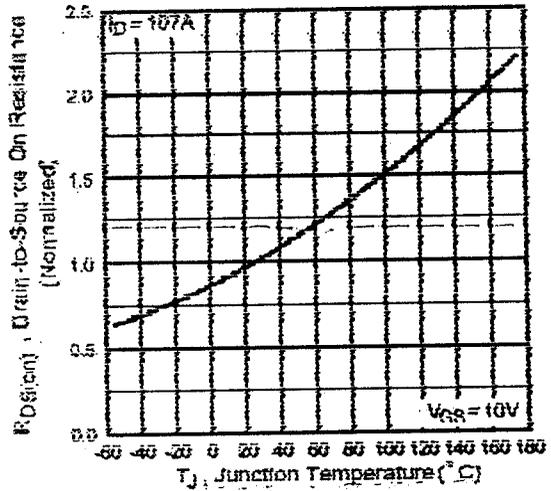


Fig 4. Normalized On-Resistance
Vs. Temperature