CHAPTER 5

DESIGN OF ELECTRONIC CONTROL

5.1 ELECTRONIC PARTS / ASSEMBLY DESIGN

The main function of electronic system is to automate the braking force control based on the pillion load on the two-wheeler. In this work, a simple system is proposed to automate this work. The block diagram in Figure 5.1 shows the major parts required to vary the effective radius of the disc.

The main parts include:

- Load cell – Model No CZL_60
- Microprocessor controller unit - PIC16F877A, Coding Software - MikroC
- Stepper motor

![Figure 5.1 microcontroller setup](image-url)
5.2 LOAD CELL

The basic function of a load cell which is shown in Figure 5.2, is to measure the pillion load and send appropriate signals to controller unit based on various pillion loads on the two wheeler.

The load cell with the range up to 80 kg is used. The load cell is exactly placed rigidly under the load position of the motorcycle seat as shown in Figure 5.4. The schematic of load cell is shown in Figure 5.3.
The specifications of the load cell are listed in Table 5.1.

**Table 5.1 Load cell specification**

<table>
<thead>
<tr>
<th>Rated Load(kg)</th>
<th>Up to 120 kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision</td>
<td>C2 C3</td>
</tr>
<tr>
<td>Comprehensive Error(%F.S)</td>
<td>0.03 0.02</td>
</tr>
<tr>
<td>Rated output(mv/v)</td>
<td>2 ± 0.1</td>
</tr>
<tr>
<td>Non-linearity(%F.S)</td>
<td>0.03 0.017</td>
</tr>
<tr>
<td>Hysteresis(%F.S)</td>
<td>0.03 0.02</td>
</tr>
<tr>
<td>Repeatability(%F.S)</td>
<td>0.02 0.01</td>
</tr>
<tr>
<td>Creep (%F.S/30min)</td>
<td>0.02</td>
</tr>
<tr>
<td>Zero Balance (%F.S)</td>
<td>±1</td>
</tr>
<tr>
<td>Input Resistance (Ω)</td>
<td>405±6</td>
</tr>
<tr>
<td>Output Resistance (Ω)</td>
<td>350±3</td>
</tr>
<tr>
<td>Insulation Resistance(MΩ)</td>
<td>≥5000(100VDC)</td>
</tr>
<tr>
<td>Excitation Voltage</td>
<td>9〜12 (DC)</td>
</tr>
<tr>
<td>Compensated temp.Range (°C)</td>
<td>-10〜+40</td>
</tr>
<tr>
<td>Use Temp. Range (°C)</td>
<td>-35〜+65</td>
</tr>
<tr>
<td>Temp.Effect on Zero (%F.S/10 °C)</td>
<td>0.03 0.017</td>
</tr>
<tr>
<td>Temp.Effect on Span (%F.S/10 °C)</td>
<td>0.02 0.014</td>
</tr>
<tr>
<td>Safe Overload (%F.S)</td>
<td>120</td>
</tr>
<tr>
<td>Ultimate Overload (%F.S)</td>
<td>150</td>
</tr>
<tr>
<td>Defend Grade</td>
<td>IP65</td>
</tr>
<tr>
<td>Cable Length</td>
<td>0.42m</td>
</tr>
</tbody>
</table>

**Figure 5.4 Load cell mounting (Beam load cell)**
5.3 MICROCONTROLLER

The microcontroller unit is kept in a plastic box as shown in Figure 5.6 to control the stepper motor rotation for the various pillion loads measured by the load cell. It is programmed in such a way that the stepper motor gives precise rotation for the various signals of the load cell. The Caliper moves 1.5mm for a single rotation of stepper motor shaft. Hence the stepper motor rotation is calculated for the various pillion loads.

5.3.1 Block Diagram of Stepper Motor Controller

Figure 5.5 shows the block diagram of a typical controller for hybrid or variable reluctance stepper motor. It consists of the following blocks:

![Block Diagram of Stepper Motor Controller](image)

**Figure 5.5 Block diagram of a Typical stepper motor controller**

Logic Sequence generates programmed logic sequence required for the operation of a stepper motor. It is a finite sequential logic circuit which generates the particular logic sequence. The logic sequence is treated as a truth table, and is implemented with the help of flip-flops and logic gates. Power drivers are power switch circuits which ensure a fast rise of current through the phase windings which are to be turned on at a particular step in the logic sequence. The signals output by the logic sequence generate low level signals which are too weak to energize stepper motor windings.
Consequently, switching power amplifiers have to be used to raise the voltage, current, and power levels of the logic sequence sufficiently high to drive the rated currents through stepper motor circuits. Current suppression circuits needed fast decay of current through the winding when it is turned off.

5.3.2 Stepper Driver Logic

The stepper driver logic consists of buffer, opto-coupler, pre-driver and driver.

- Buffer interfaces 8255 with high-level circuits (such as metal oxide semi conductor (MOS - It is a transistor which is used for switching the circuits) for driving high current loads.)

- Opto-coupler consists of opto-emitter and phototransistor in which opto-emitter emits infra red radiation which in turn drives the phototransistor.

- The opto-coupler cannot directly couple to the TIP122 (NPN), since it requires large current for driving. The driver SL100 (Pre-driver) is used to boost the current level.

The main principle of the driver is to amplify the current. It amplifies the 50mA current to 2A, which is needed to drive the motor.

![Figure 5.6 Microcontroller assembly](image)
5.3.3 Buffer

A buffer amplifier (sometimes simply called a buffer) is one that provides electrical impedance transformation from one circuit to another. Two main types of buffer exist: the voltage buffer and the current buffer.

A voltage buffer amplifier is used to transfer a voltage from a first circuit, having a high output impedance level, to a second circuit with a low input impedance level. The interposed buffer amplifier prevents the second circuit from loading the first circuit unacceptably and interfering with its desired operation. Other properties of the ideal buffer are: perfect linearity, regardless of signal amplitudes, and instant output response, regardless of the speed of the input signal.

Typically a current buffer amplifier is used to transfer a current from a first circuit, having a low output impedance level, to a second circuit with a high input impedance level. The interposed buffer amplifier prevents the second circuit from loading the first circuit unacceptably and interfering with its desired operation. Again, other properties of the ideal buffer are: perfect linearity, regardless of signal amplitudes, and instant output response, regardless of the speed of the input signal.

It is the first stage of stepper driver logic unit. Its input is obtained from the output of programmable peripheral interface (PPI - It is used as both input and output interfacing circuit and meant for receiving the input signal from load cell and for sending the output signal to the stepper motor from the microcontroller respectively). Since the output current of PPI is very low, a buffer LS7406 (Hex inverter buffer) is used. It is a driver with open collector high voltage output. So it is used for interfacing with high level circuits (such
as MOS), or for driving high current loads (such as lamps or relays), and are also characterized for use as inverter buffers for driving transistor transistor logic (TTL) inputs. The buffer LS7406 has minimum breakdown voltages of 30 Volts, and maximum sink current of 40 mA.

The main advantages of this IC are

- Converts TTL voltage level to MOS level
- High sink current capability
- Input clamping diodes simplify system design
- Open collector driver for indicator lamps and relays
- Inputs fully compatible with most TTL circuits.

The sink current required for the driver unit is

\[ I_{\text{sink}} = \frac{\text{Volts}}{\text{Resistance}} = \frac{5000\text{mV}}{180\text{ohms}} = 27\text{mA}. \]

Since the IC has maximum sink current of 40 mA, it is very much suitable for this driver unit. 5000mV supply is given to the driver circuit from battery.

5.3.4 Opto Coupler

It consists of opto-emitter and Phototransistor. An opto coupler is essential to prevent the computer from hazardous conditions like voltage transients, back electro magnetic force (EMF), and high voltage spikes.

Normally when direct current (DC) is passed to a coil it will get electro magnetized. If the DC source is withdrawn from the coil it will not get demagnetized immediately. If it is not demagnetized, back EMF is produced
which can create kick back current (Current flow due to the back EMF) to the subsequent devices or associated circuitaries. To avoid these problems, a device is required which can isolate electrically and couple by other means.

Opto-emitters anode is connected to 5Volts supply (Logic1). Its cathode is connected to the buffers output. When the logic 1 is given to the input of the buffer LS7406 logic 0 gets as the output. Sink current of opto-emitter is lower than that of LS7406. Now this opto-emitter emits infra red (IR) rays. This drives the phototransistor whose collector is forced to 24Volts. When IR rays are emitted from the opto-emitter the phototransistor starts to conduct. The collector to emitter resistance becomes low. So the 24Volts will appear at emitter. It is given as input for the pre driver (CL100).

CNY 17-2 opto-coupler is used. It consists of Gallium Arsenide IR emitting diode optically coupled to a monolithic silicon photo transistor detector.

Advantages are:

- Closely matched current transfer ratio (CTR) that is less conversion losses.

- Guaranteed 70 volts (Br.) $I_{CEO}$ minimum. $I_{CEO^-}$ Collector to emitter leakage current (or) reverse saturation current is used to isolate the high power section from the low power section with minimum guaranteed voltage (Breakdown voltage) of 70Volts

Applications:

- Feed back control circuits.

- Feed back control circuit

- General purpose switching circuits.
- Interfacing and coupling systems of different potentials and references.

5.3.5 Pull Up/Down Resistor

Pull-up resistors are used in electronic logic circuits shown in Figure 5.7, to ensure that inputs to logic systems settle at expected logic levels if external devices are disconnected or high-impedance is introduced. They may also be used at the interface between two different types of logic devices, possibly operating at different power supply voltages.

![Figure 5.7 Circuit for pull-up resistor](image)

When the switch is open the voltage of the gate input is pulled up to the level of $V_{in}$. When the switch is closed, the input voltage at the gate goes to ground.

A pull-up resistor weakly "pulls" the voltage of the wire it is connected to towards its voltage source level when the other components on the line are inactive. When all other connections on the line are inactive, they are high-impedance and act like they are disconnected. Since the other
components act as though they are disconnected, the circuit acts as though it is disconnected, and the pull-up resistor brings the wire up to the high logic level. When another component on the line goes active, it will override the high logic level set by the pull-up resistor. The pull-up resistor ensures that the wire is at a defined logic level even if no active devices are connected to it.

A pull-down resistor works in the same way but is connected to ground. It holds the logic signal near zero volt. when no other active device is connected.

10 kohms resistor is used as pull down resistor. It is used to verify the input of pre driver stage being low. When the IR detector is not conducting, the collector to emitter voltage is high. Now the current input at pre driver (CL 100) may be high or low. But it should be low. To make it, pull down resistor is used.

5.3.6 Pre Driver

CL 100 power transistor is used. It is used to boost the current. It is an NPN transistor. When 24Volts supply is given from the opto coupler as an input to the base it starts conducting the output.

5.3.7 Driver

TIP 122 power transistor is used. A 24Volt supply is given to it through 47ohms resistor to its base. The logic 0 output from CL 100 is given to the base of TIP122. It is an NPN transistor and so output is low.

The maximum rating and characteristics of transistor TIP 122:

| Package | TOP66 |
Lead information  

\begin{align*}
\text{L32} \\
\text{Vcb max.} & \quad 100\text{Volts.} \\
\text{Vce max.} & \quad 100\text{Volts} \\
\text{Veb max.} & \quad 5\text{Volts} \\
\text{Ic max.} & \quad 5\text{A} \\
\text{Hfe} & \quad 1000 \\
\end{align*}

Where,

\begin{align*}
\text{Vce, max} & = \text{Maximum collector-emitter voltage} \\
\text{Vcb, max} & = \text{Maximum collector-base voltage} \\
\text{Veb, max} & = \text{Maximum emitter-base voltage} \\
\text{Ic, max} & = \text{Maximum collector current} \\
\text{H_{fe}} & = \text{DC current gain (Output current/Input current)} \\
\end{align*}

When the TIP 122 transistor has high input signal in its base, collector to emitter the resistance is relatively low. So it produces a low output signal. When the output signal is low the coil is energized. Now the motor can move forward or reverse as per the pattern given in the software routine.

A reverse biased diode is connected in parallel with the coil. When the coil is demagnetizing it produces high back EMF which can destroy TIP122 which is in the cut off state. This can be avoided by this diode.

\section*{5.4 STEPPER MOTOR}

Stepper motors uses a magnetic field to rotate a rotor. Stepping can be done in full step, half step or other fractional step increments. Voltage is applied to the poles around the rotor. The voltage changes the polarity of each
pole, and the resulting magnetic interaction between the poles and the rotor causes the rotor to move. Stepper motors provide precise positioning and ease of use, especially in low acceleration or static load applications.

Important performance specifications to consider when searching for stepper motors include shaft speed, terminal voltage, current per phase, continuous output power, and static or holding torque. Shaft speed is the no-load rotational speed of output shaft at rated terminal voltage. The terminal voltage is the design DC motor voltage. The current per phase is the maximum rated current or winding for a stepper motor. The continuous output power is the mechanical power provided by the motor output. Static or holding torque is the maximum torque a motor can develop to hold its rotor in a stationary position.

Motor types for stepper motors can be permanent magnet, variable reluctance, or hybrid. Permanent magnet (PM) motors use a permanent magnet on the rotor. Step angles range from 1.5 to 30 degrees. Permanent magnet motors are the most common and versatile stepper motors. This includes both unipolar (bifilar) and bipolar types.

Variable reluctance (VR) motors have a free-moving rotor; no residual torque is produced due to the lack of a permanent magnet. The rotor is composed of a soft iron metal. The rotor is also composed of its own very prominent poles, tending to stick out more than a rotor found on the PM version. The range of step angles is 7.5 to 30 degrees and a single power source is required (like a bifilar PM motor). This is the least expensive stepper motor. Hybrid motors consist of a heavily toothed PM rotor and toothed stators, plus prominent rotor poles like a VR rotor. They are capable of very fine step angles range 0.5 to 15 degrees and have a high-speed capability (less chance of a stall). There is a higher available torque than in PM or VR stepper motors. The hybrid motor is most effective but most
expensive stepper motor type. Stepper motor configurations can have different numbers of leads depending on the specific winding wiring. For example, bipolar PM motors can have 4, 5, or 6 leads, unipolar PM motors can commonly have 5 or 6 leads (two windings with two ends plus center taps, which may or may not be tied together), hybrid motors frequently contain 8 leads, and multiphase motors can have different lead configurations (for example, a motor wired for 5-phase power could have 5 or 10 leads).

In this research work, the main function of the Stepper motor is to receive the signal from controller and move the caliper accordingly. The caliper movement requires precise control for both up and down movement, also it has to stop at a particular angle of rotation, and hence the need of stepper motor is essential in this work.

Stepper motor which is shown in Figure 5.8 moves the caliper up and down along the “Y” axis (viewing the vehicle from the side). A normal stepper motor gives rotation only on its shaft axis and so a mechanism is required to convert the rotational movement of the motor shaft to linear movement of the caliper.

A mechanism that is taken into consideration is “simple bolt and nut mechanism”. In this mechanism, the motor threaded output shaft is attached with a nut which is fixed in the caliper mounted C-clamp, hence the rotation of thread is converted to linear movement of caliper by fixing stepper motor case with the vehicle frame.

Advantages of the proposed mechanism:

- It is very simple to manufacture and assemble.
- Less space required for mechanism (the space between caliper and wheel rim is very minimal)
• Direct pulling action
• No gear reduction, hence simple program to control linear movement based on weight
• Minimum over hanging of stepper motor.

5.5 STEPPER MOTOR TORQUE CALCULATION

Size of the thread is M12.

Diameter of caliper actuating shaft \((d_m)\) is 12mm.

Pitch of the threads \((P_t)\) = 1.75mm.

\[
\text{Helix angle} (\alpha_t), \tan \alpha_t = \frac{P_t}{\pi * d_m}
\]

\[= 0.046\]

\[\alpha_t = 2.66^\circ\]

\[\tan \phi_i = \mu_2\]  \hspace{1cm} (5.2)

Where, \(\phi_i\) = Friction angle between shaft and nut.

\[\mu_2 = \text{Coefficient of friction between shaft and nut.}\]

\[\mu_2 = 0.15 \text{ (Lubricated)}\]

\[\phi_i = 8.53^\circ\]

Required stepper motor torque \((T_m)\) is equal to \(= p_m * \frac{d_m}{2}\) \hspace{1cm} (5.3)

Where, \(p_m\) = Tangential force acting between shaft and nut.

\[p_m = w_c * \tan(\alpha_t + \phi_i)\] \hspace{1cm} (5.4)

Where, Caliper weight including ‘C’ clamp \((w_c)\) = 49 N

\[p_m = 9.69 \text{ N}\]
\[ T_m = 0.058 \text{ N-m} \]

Figure 5.8 Stepper motor assembly

5.6 SUMMARY

In this chapter, the constructional and working of electronic parts required for controlling braking force are discussed. A few electronic devices used in microcontroller are also presented.

5.7 CONCLUSION

A ‘simple bolt and nut mechanism’ is inefficient as the friction between them is high even when the friction surface is lubricated. Hence a new mechanism may be used to vary the position of the caliper with less energy consumption because of the battery being the energy source to operate the mechanism. So a new system may have the energy sources like hydraulic or pneumatic.