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A Novel Approach for Building Low Cost Automatic Gear Shifter

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Abstract— ***in this study, a gear shifting mechanism was designed and applied to make the shifting process faster and less difficult for the driver. This device provides a solution towards the difficulty in operating gears in manual transmission cars. This system incorporates an electromechanical system which can be attached to the existing gear shifter without altering the existing system and also provides an option to use the existing manual shifting as such according to the desire of the driver. The system consists of an efficient control system using Arduino Mega microcontroller which controls the motion of the existing gear sticks and clutch position. It uses a Grove electromagnet to adjust the gear lever position with the change in speed along with a DC motor arrangement to control the motion of the clutch pedal. The system also includes a PID control mechanism to determine the gear stick motion and also to optimise the performance of the car at varying driving conditions.***

Keywords—Grove Electromagnet, DC motor, Arduino Mega, PID control, Gear shift.

I. INTRODUCTION

At present because of the extended difficulties in manual operations for gear shifting, the technology has shifted from manual to automatic transmission in vehicles. There are many advantages because of this latest development in technology. Major notable advantages are that they provide stress and tension free driving in the heavy traffic conditions, improved performance to the vehicles and finally turns out to be a common feature of the automobile sector which was once considered an ultra luxury in automobiles. Despite these advantages, there are certain disadvantages some of which are directly and indirectly linked to the changing technology trends. When looking forward to the direct factors, one of the major disadvantage of the modern automatic transmission vehicles are related to their cost. The difference in the cost between the automatic and manual transmission variants of the same model of vehicle ranges between lakhs of rupees, where the cost of automatic transmission variant lies on the higher side. Another main drawback is that driver can't switch back to the normal H pattern shift when he desires even though many Automatic Manual Transmission systems are available in the market. Moreover, the fuel efficiency of automatic transmission vehicles also remains a big question, which is not clearly answered by the automobile manufacturers. An indirect disadvantage of these systems is that users are disposing of their old used vehicles to taste the changing trends in the automation technology without waiting for their product lifespan to end. This creates a huge amount of waste which cannot be tolerated in today's environmental conditions.

The major cause of the above-mentioned problems is due to the lack of adaptive technologies which can be incorporated into the existing technologies. This paper provides a solution with respect to this problem. The main idea behind the low-cost automatic gear shifter is that the system can be embedded in the existing gearboxes without altering the existing mechanical system. The gear shifting stick is moved using an electromagnet which is controlled over by an Arduino microcontroller. The major control variable is the vehicle velocity which is obtained using an accelerometer. Parallel

operation is done on the clutch motion, where the mechanical motion of the clutch is done using a DC motor with a shaft attached to it. An OLED display is used to indicate the measured variables and also displays the instructions to the driver.

II. EXISTING SYSTEM.

A. Manual Transmission

Manual transmissions are the simplest and oldest type of transmission systems. This gearbox uses a friction clutch which is adjusted by the driver's foot in order to transmit the engine's rotational energy via gears. From there, a fixed set of gears is engaged using gear selector fork connected to the shifter which is operated by the driver's right or left hand. Through years the variety of technical updates happened from manual, stick shift, standard, three, four, five, or six speed. In spite of the dull future, the manual transmissions have a lot of advantages over the newer and more complicated systems. The main advantage of stick shifts is that they are prone to have less maintenance and are easy operate. This technology proved its capability through decades with its use ranging from sports cars to ultra luxury vehicles. In recent years, the manual system has been kept in a shadow by the Dual-Clutch or semi-auto transmission in most high-end performance cars. However, these manual transmission systems are enhanced by performance when comparing with other systems and even CVTs. When dealing with the fuel economy the manually operated cars proved their efficiency when comparing with other technologies. Keeping aside the simplicity, performance, efficiency and other factors, the driving experience of manually operated cars are considered as the special attraction for the driving enthusiasts.

B. Automatic Transmission

It combines the use of complex torque converters and vehicular embedded systems in order to convert the engines rotational energy to vehicular motion through the use of planetary gear sets and clutches. The working of these systems is considered to be very complicated, and driver only needs to select from P-R-N-D-L choices present on the gear selector. The advantage is that it provides an easy driving experience. When looking forward to excellent driving experience the user needs to compromise the factors relating to the maintenance cost installation cost. Most automatics can't match the performance of manual transmissions but newer technologies are closer when compared to the old systems.

C. Continuously Variable Transmission

The CVT's provide the driving experience similar to that of automatic transmissions. But with a different mechanism. It uses a system of belts and pulleys to produce an infinite range of ratios without using gears and clutches. It is the car's embedded computer system which decides the adjustment pulleys to create the optimal ratio for the particular driving situation. The main merits of these technologies are that they provide more fuel efficiency and are less prone to failures and damages. The biggest drawback of these systems is that they provide the worst driving experience.

D. Semi-Automatic and Dual-Clutch Transmissions

They are a hybrid between the fully automatic and hybrid systems. It uses a similar layout to the traditional systems but uses a system of pneumatics and actuators to the change gears. The Dual-Clutch Transmission (DCT) consists of separate clutches for both odd and even gears, which enables faster shifts. These gearboxes can generally operate in a fully automatic mode, or manually shifted using paddle shifts or gear sticks. Semi-Auto and DCT transmissions offer high-end performance and lightening fast gear changes which are difficult to perform using manual systems. Currently, they are common in the racing cars and ultra-luxury vehicles. The drawback of these systems is that they are prone to heavy mechanical repairing costs.

III. HARDWARE DESIGN

A. Arduino Mega 2560

The Arduino Mega 2560 is a microcontroller board which is based on ATmega2560. It consists of fifty-four digital input output pins among which 15 can be used as the PWM outputs. The main parts include 16 analog inputs, 4 UARTs, 16 MHz crystal oscillator, USB connection, power jack and a reset button. The Arduino mega provides an integrated development platform where the microcontroller is programmed using embedded C. It is pretty much easy to program the operations which are to be performed by the microcontroller. The user only needs to connect the input-output pins and

upload the program using an integrated development environment. The unit is powered using a 5V DC supply. The Arduino supports an input voltage of 12 V DC.

B. Grove-Electromagnet

An electromagnet is a type of magnet which produces the magnetic field when an electric current is passed through it. In order to concentrate the magnetic field in an electromagnet, the wire is wound to form a coil with many turns of wire kept side by side. The magnetic field of all the coils passes through the centre of the coil, thus creating a strong magnetic field. The Grove-Electromagnet works with the same principle. It can suck 1 Kg of weight and hold on it. The working voltage of the Grove-Electromagnet is 5V DC, with a low standby current of 200uA and working current of 400mA.

Fig. 1: Grove-Electromagnet

C. Grove-3axis Digital Accelerometer

The velocity of the moving vehicle is measured using a Grove-3axis Digital accelerometer. This is a high precision digital accelerometer which provides a maximum 3.9mg/LSB resolution and large ±16g measurement range. It is based on an advanced 3-axis IC ADXL345. It is very robust and can survive up to 10,000g shock. The accelerometers are ideal for low accuracy velocity measurements.

Fig. 2: Grove-3axis Digital Accelerometer

*D. Grove OLED Display 128*64*

Grove OLED display module is an OLED monochrome 128*64 dot matrix display module with grove 4 pin I2C interface. When comparing with the LCD's, OLED screens are more competitive with a large number of advantages. The main advantages are high brightness, high contrast ratio, with thin outline along with wide viewing angles, operating temperature range and very low power consumption.

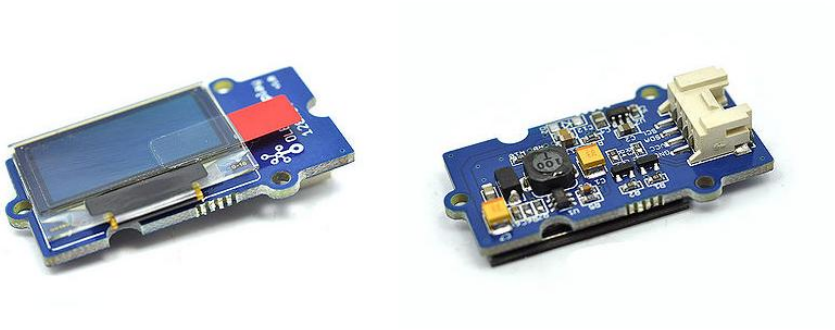

Fig. 3: Grove OLED Display

E. DC Motor

The motor used here is a 12V gear motor with 90:1 gearbox and an integrated quadrature encoder that provides a resolution of 64 counts per revolution of the motor shaft. The operating voltage is 5V with a stall torque of 38 kg.com. These motors are considered to be ideal for robotic applications.

F. A4950K Full bridge DMOS PWM Motor Driver

These are used for the pulse width modulation control of servo and DC motors. A4950K is an automotive grade device and is tested across extended temperature and voltage ranges to ensure compliance in automotive or industrial applications. The speed and direction of the motor are controlled using PWM signals at the input terminals. An internal circuit protection includes over-current protection, thermal shutdown with hysteresis, under voltage monitoring of VBB and cross over current protection.

IV. SYSTEM DESIGN

The system works on mainly two modes (1). Automatic and (2). Manual
In the manual mode, the shifting takes place in the normal manner which is done by the user. In the automatic mode, the gear motion, as well as the clutch motion, is handled by the microcontroller. The automatic gear shift by the microcontroller can be explained by dividing the whole system into four parts

- Velocity Measurement
- The gear-selector
- Auto-Clutch
- PID Optimiser

The basic logic flow of the automatic gear shift is shown in the figure 4.

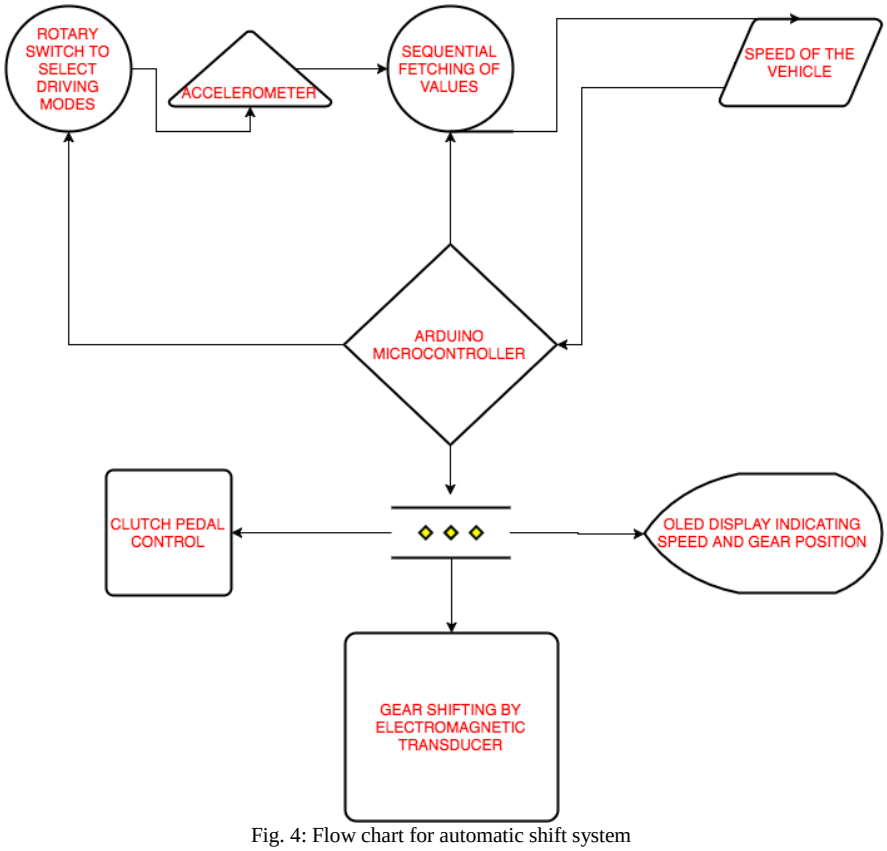

Fig. 4: Flow chart for automatic shift system

The system is designed in such a manner that proper gears are engaged at particular speeds. The speed is obtained using an accelerometer. Accelerometers are used for the velocity measurements where large accuracy is not required. Here a grove 3 axis digital accelerometer is used for the measurement of velocity. The accelerometer, measures both physical acceleration of the sensor and the contribution of the normal forces that prevent the accelerometer from accelerating toward the centre of the earth. In order to measure the physical acceleration, normal forces are removed. For the three axis accelerometer the measurement vector a_m can be modelled as

$$\mathbf{a}_m = \mathbf{a}_B - R_I^B \begin{pmatrix} 0 \\ 0 \\ g \end{pmatrix},$$

Where $\mathbf{a_B}$ is the actual body-frame acceleration. In this model the cross-axis alignment, scale factor, bias errors during the measurement are assumed to be zero.

$$\mathbf{a}_I = R_B^I \mathbf{a}_m + \begin{pmatrix} 0 \\ 0 \\ g \end{pmatrix}.$$

Thus the velocity can be extracted from the accelerometer using the following formula.

$$\mathbf{v}_I = \int \mathbf{a}_I,$$

The motion of gear stick follows the conventional H-pattern shift, through a groove. The gear is engaged at particular positions using grove electromagnet. The grove electromagnet is placed at various positions in the H-groove as marked in figure 5. Different gears are engaged based on the energization of different pairs of the electromagnet. For example, the first gear is engaged from the neutral position by the activation of the GEMC1 for a particular time followed by the activation of GEM1.The gear is shifted from 1st to 2nd by the deactivation of GEM1 followed by the activation of GEMC1 and GEM2 for a particular time. Similarly, the gear is moved through different positions through the activation and deactivation of different electromagnets at different times. The up shift procedure from neutral to 4th and then reverse gear is shown in table 1. In the table, A denotes activation and D denote deactivation. The timing and order for particular activation and deactivation are programmed in the microcontroller.

TABLE I
UPSHIFT ACTIVATION AND DEACTIVATION PATTERN OF ELECTROMAGNETS

Gear Position	**GEMC1**	**GEM1**	**GEM2**	**GEM3**	**GEM4**	**GEMC2**	**GEMR**	**GEMC3**
1st	A	A						
2nd	A	D	A					
3rd	A		D	A				
4th				D	A			
Reverse				A	D	A	A	A

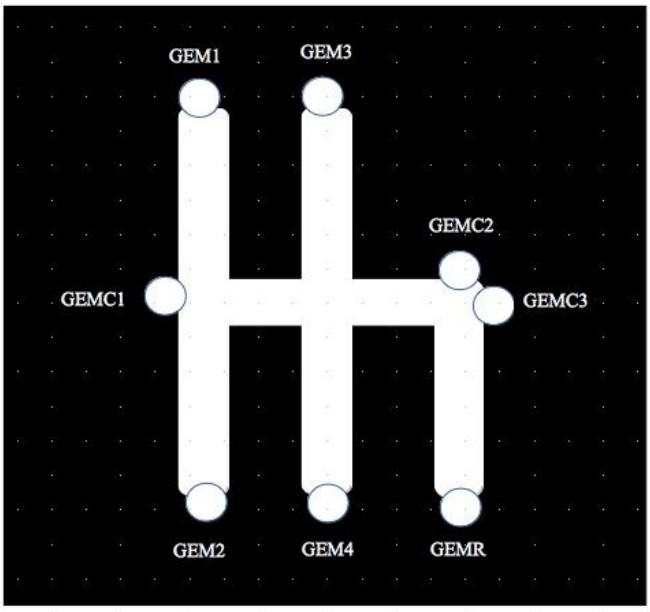

Fig. 5: Positions of Grove Electromagnet

Fig. 6: Gear shifter experimental setup

The gear shift is programmed in the microcontroller in such a way that particular gears are shifted at particular velocities. The 1st gear is engaged as soon the rotary switch is pushed to automatic mode with the clutch engaged. The vehicle moves as soon as the accelerator pedal is pressed with the disengagement of the clutch. The velocity is measured sequentially by the microcontroller. The set-point velocity for each gear is programmed in the microcontroller. The obtained velocity is compared with the set point velocity. The error between the two is recorded. Similarly, error value for five samples is taken for five different consecutive instances. The error value for each instance is averaged and the consecutive instances with minimum average error value are noted and control action is taken by the microcontroller.
A PID controller is used here to optimise the controller according to the driving pattern. The controller notes down the error values at different instants along with the gear shift patterns. Whenever the controller notes the change in the velocity pattern from the error values, it adapts itself to the driving pattern by changing the set points. Here the PID controller acts as the set point tracking controller. This gives the driver to stick on to one's own driving patterns without adapting to the preconfigured shifting patterns. Thus the tuning of the PID controller is very important in order to achieve good tracking and fast disturbance rejection at the same time. So the driver having good driving skills will train the automatic gear shifter more efficiently and economically. The system also enables the driver to change the driving pattern as and when required without any difficulty. The control variable u(t) for a PID controller is given as,

$$u(t) = K_{\mathrm{p}} e(t) + K_{\mathrm{i}} \int_0^t e(\tau)\,d\tau + K_{\mathrm{d}} \frac{de(t)}{dt},$$

The motion of the clutch is controlled automatically by the microcontroller using a dc motor arrangement, The clutch pedal gets engaged as soon as the gear is pulled on by the electromagnet, then slowly disengages through the motor action. The clutch pedal is attached to the dc motor through two level arrangements which convert rotational motion of the DC motor to linear motion of the clutch pedal which is shown in figure 7.

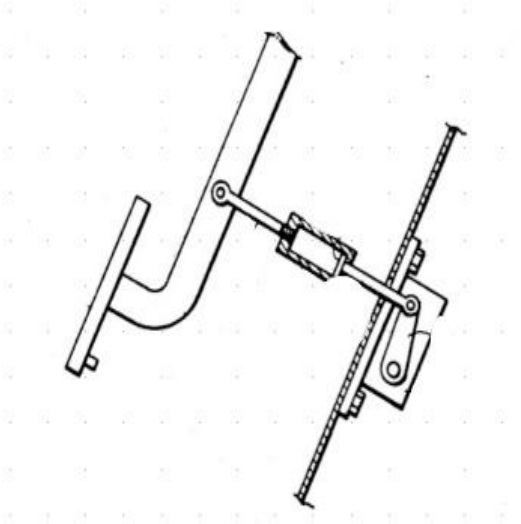

Fig. 7: Schematic drawing of clutch pedal motion

Fig. 8: Auto-clutch experimental setup

An OLED display is used to indicate the current gear position and varying velocities as measured by the microcontroller. Figure 8 shows the experimental setup involving the control of the clutch pedal. The schematic of the entire system is shown in figure 9. The circuit consists of eight Grove Electromagnet which is attached to the digital pins of the Arduino mega. A 2-way rotary switch is attached to the microcontroller which is programmed to select between manual and automatic driving modes. The whole system can be powered from the vehicle power supply since the maximum input

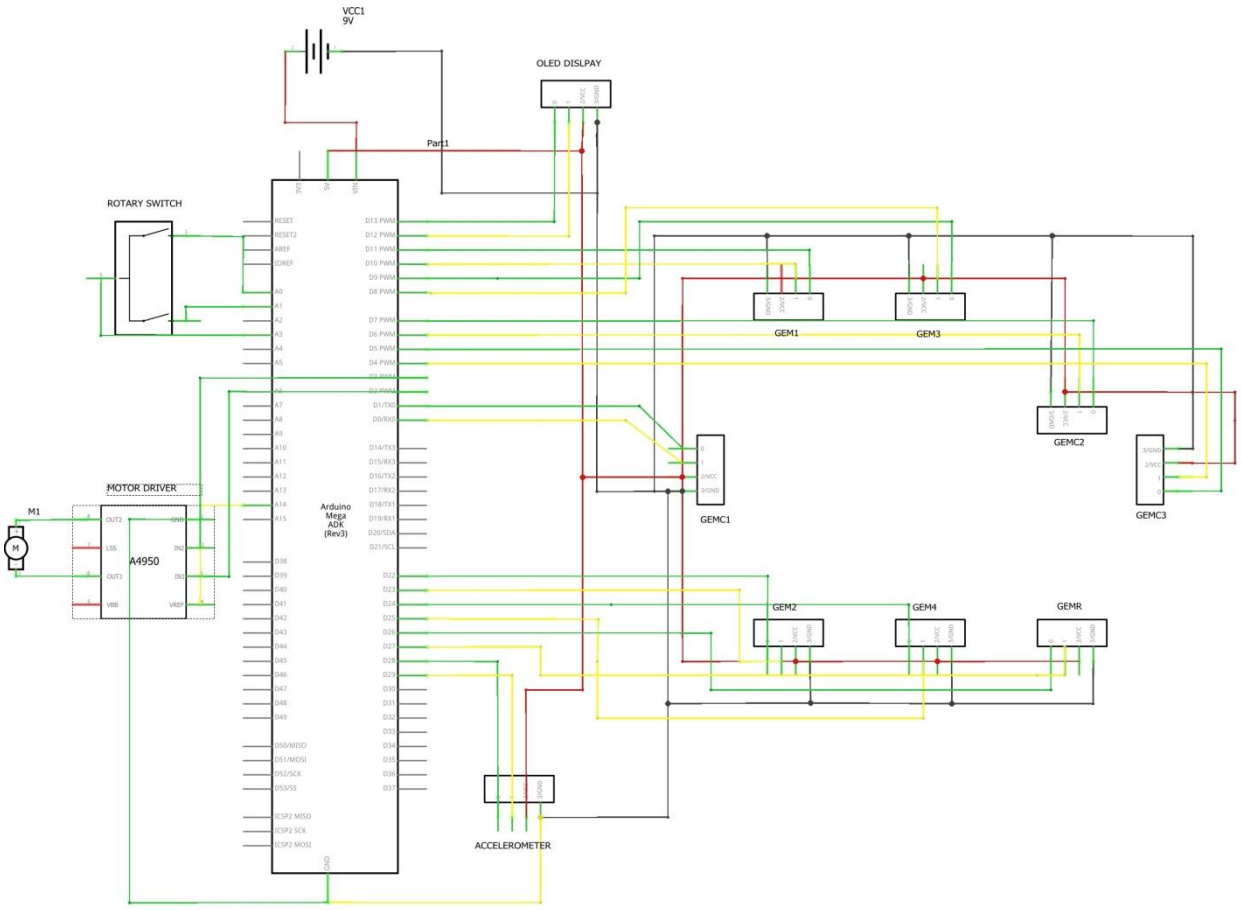

Fig 9: Schematic diagram

Voltage that the microcontroller can handle is 12 V DC. The green and yellow wires attached to the grove transducers represent the control lines where the power lines are denoted using red and black colours.

CONCLUSION

The system was implemented on the four-speed gear box of a Maruti 800. It worked perfectly even though a small process lag was observed. The engagement and disengagement of the gear was performed without any difficulty. The prototype proved its efficiency in different traffic conditions and got adapted to different traffic densities. More improved features can be added to the system through efficient learning algorithms such a neural networks or fuzzy algorithms. From the obtained results, it was observed that the proposed system can be incorporated in any type vehicles using conventional H-pattern shift at a very low cost. Through this approach the vehicles can be converted to automatic shift with ease. Thus the novel approach, towards the development of an automatic gear shift mechanism makes the driving more comfortable at a very low cost.

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