DESIGN OF SEMI-AUTOMATIC ELECTRONIC GEAR SHIFTING MECHANISM

Rahul Sharma[1]

Avichal Agarwal [2]

Udit Sharma[3]

Department of Mechanical Engineering,

College of Engineering Studies,

University of Petroleum and Energy Studies, Dehradun, INDIA.

Abstract
In an automobile, gears are used to manually control the power output of the engine and utilize it according to the requirement. In motorcycles, the sequential type of gearboxes are used which are operated by means of a foot pedal. Due to this mechanical linkage, the shifting of gears takes time and can be a deciding factor in a motor racing environment. Use of electronically actuated system can significantly reduce the gear changing time and address the issue. Many events like FSAE, BAJA and SUPRA are organized all over the world in order to provide Mechanical Engineering students a platform to showcase their talent and engineering skills. The University of Petroleum & Energy Studies has been a consistent performer in such events and has great recognition. The use of electronically actuated gear shifters can provide a significant edge over the rest of the field and may turn into a winning idea.

Keywords:FSAE, Go-Kart, RPM, actuation, sensor, torque.

1. Introduction
The old shifting system on the car was actuated by a lever mounted to the left of the driver. This lever was attached to a bar which ran the length of the car to the transmission. When a shift was needed, the driver would remove his or her left hand from the wheel, grab the lever, and push it forward. Pushing caused amovement of the gear lever in forward direction causing clockwise rotation of the gear shaft, causing anupshift. Pulling the lever backwards leads to rotation of gear shaft in anticlockwise direction, making the car downshift. The system was fully mechanical, but required the driver's left hand to be off the steering wheel. This was problematic in a few specific ways. The time taken between when the shift was needed to when it was actuated was somewhat slow due to the driver's need to move his or her hand. The lever also proved to be difficult to actuate at certain critical times. On a Formula SAE competition course with many turns, frequent shifting is required to maximize performance. If a shift was needed during a turn, the driver would have to make the turn with one hand on the steering wheel or simply wait until out of the turn and lose time while the engine was in a bad RPM range. As well, toward the end of a race the driver's arms would be tired from steering, causing increased difficulty in actuating the shift and longer delays between when the shift was needed and when it was actuated. Both situations would lead to a decrease in overall performance. The goal of this project was to install an electronic shifting system to address these issues and eliminate the detriment of the push-pull system to overall performance in a race. With electronic shifting, the driver would be able to actuate a shift without

removing his or her hand from the steering wheel, increasing control at every point in the race. As well, the amount of force required by the driver to actuate the shift is minimized to reduce the strain of a race. This would ideally lead to faster shift times, a decrease in weight, and reduction in part numbers by removing the long cable. The system is designed with increased performance, lighter weight, and simplicity as the driving parameters. When finalized, it would allow the driver to actuate a shift almost instantaneously without losing any control of the car.

2. Data Gathering and Component Selection:

In this phase of the project, the data required for the design of the shifting mechanism is gathered through experimentation and literature. This includes the amount of torque required for the gear shifting along with the angular travel of the gear selector shaft. It also deals with the selection of the engine and actuation mechanism to be designed for gear shifting by analysing various actuation methods on the basis of their merits-demerits.

2.1 Selection of Engine:

The Semi-Automatic Gear Box system would require the use of an Engine-Transmission assembly. In order to keep the budget of the project as low as possible, the choice of selection of the Engine-Transmission assembly was restricted to the available assemblies in the Automotive Chassis Laboratory of the University.

An extensive study was carried out on the powertrain complexities of the Baja 2012, Supra 2012 and the Go-Kart 2015 vehicles.

- The Supra 2012 vehicle features the use of a Maruti 800 model's Engine-Transmission assembly. This assembly, being a 4-wheeler's powertrain, features an H-Type gearbox. Since the Semi- Automatic Gearbox project requires the use of a sequential gearbox, the Supra 2012 powertrain was rejected.
- The Baja 2012 vehicle satisfies the requirement of a sequential gearbox. But further inspection revealed the use of a complex Engine Control Unit on the Baja. In order to design a mechanism that functions accurately with respect to the Engine's RPM, it was deducted that the said ECU of the Baja 2012 vehicle will have to be re-tuned, which greatly increases the cost and complexity involved in the Project.
- With the above observations, it was concluded that the Go-Kart 2015 car would be the ideal vehicle to implement the Semi-Automatic Gearbox mechanism. The Go-Kart 2015 vehicle is powered by a 125cc TVS Phoenix engine with a 4-speed sequential gearbox.

2.2Torque Requirement:

The TVS Phoenix is a 2-Wheeler that requires the rider to operate the gearbox with the use of his foot. During the selection of a gear, the driver initially depresses the clutch pedal and shifts his/her foot angularly so that the necessary torque is provided to the transmission shaft that projects out of the gearbox. The above said shaft is provided with grooves on its circumference which when rotated guide the Gearbox's selector fork to translate linearly from its initial position in order to engage the required gear. It is the rotation of this shaft with respect to the gearbox that provides the upshift or downshift of gears in this sequential gearbox.

The project requires the design of such a mechanism that would carry out the above process electronically instead of the driver applying the torque with his/her foot. The substitute for a driver's foot for the changing of a gear is an electric motor capable of producing an output torque equal to the torque provided by the driver by operating his/ her foot on the transmission shaft.

- Subsequent force analysis showed that 8 Nm of torque provided at the transmission shaft was sufficient to carry out the change of a gear in the TVS Phoenix transmission.
- Further study led to the conclusion that the utilization of an Electric Motor with an output torque characteristic of 10 Nm (after keeping a Factor of Safety of 1.25) would be sufficient for the execution of a gear change.

2.3 Selection of Actuating Mechanism:

The Actuating Mechanism in the Semi-Automatic Gear Shifting Mechanism would be one with sufficient output torque characteristics in order to carry out the gear changing process by trying to replicate the movement of driver foot.
Three kinds of actuators may be used-

Electric Solenoid Hydraulic Piston Cylinder mechanism Electric Motor

Extensive market research and comparative study revealed the following -

1. The Electric Solenoid gives the most accurate response in terms of reaction time from the initiation of the actuation to the end of the task. But high costs and the lack of availability in the Indian Market led to the rejection of the Solenoid actuator.
2. The Piston Cylinder mechanism provided appreciable torque. The downside of using this system is the use of extensive hydraulic lines and addition of pumps or compressed gas chambers in case of pneumatic shift. Any leakage of these lines would render the mechanism ineffective.
3. The Electric Motor provides an output torque and a response time similar to the Hydraulic Piston Cylinder system. Its low cost and high availability in the Indian Market made it a viable choice as the Actuating Mechanism for the Project.

The Electric Motor selected for Actuating Mechanism has the following specifications-

- 12 V power supply
- 60 RPM
- 9.8 N-m torque.

3. Design and Analysis:

3.1Design of Actuating Mechanism:

This section further describes the details of the Actuating Mechanism that would drive the Motor. The shifting of the gear from, say, neutral to first would be carried out by the driver pressing 'Upshift' button on the steering wheel of the Go-Kart vehicle. A similar button for 'Downshift' is also provided at the steering wheel. Both the 'Upshift' and 'Downshift' buttons have been placed at the right and left hand side of the steering wheel respective.

Figure 1: Mountings of Upshift (red) and Downshift (green) on the steering wheel.

1. The driver would operate either button by his left or right thumb, depending on the type of shift (up or down) he or she wishes to carry out.
2. This operation of the Upshift or Downshift button would send an electric signal to the Motor assembled to the transmission shaft.
3. The Electric signal to the said Motor would be provided by an Atmega 8 Microcontroller.
4. Further, the input to the said Microcontroller would be provided by an Infrared Sensor which enables the motor to rotate by the exact amount that is required for the change of a gear in the TVS Phoenix transmission.

The required rotation of the shaft for the change of a gear in the TVS Phoenix transmission was calculated to be 12 degrees. Thus the IR Sensor must be coded to limit the rotation of the motor to 12 degrees during either upshift or downshift of gears.

For this process, a Metallic Disc with exactly 30 slots was designed to be the reference point of the IR Sensor. The sensor was then coded to stop the motor after the encounter of the next tooth after initial movement. The mounting of the IR Sensor with respect to the Disc has been shown in Figures 3 and 4. The figure in the following page shows the drawing of the designed Disc.

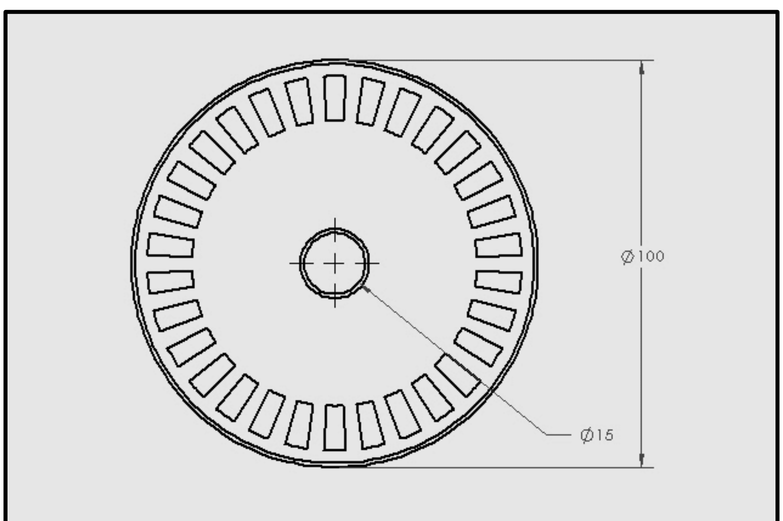

Figure 2: The Metallic Disc (SolidWorks 2014)

The figure below shows the exploded view of the individual components of the actuating mounted onto the transmission –

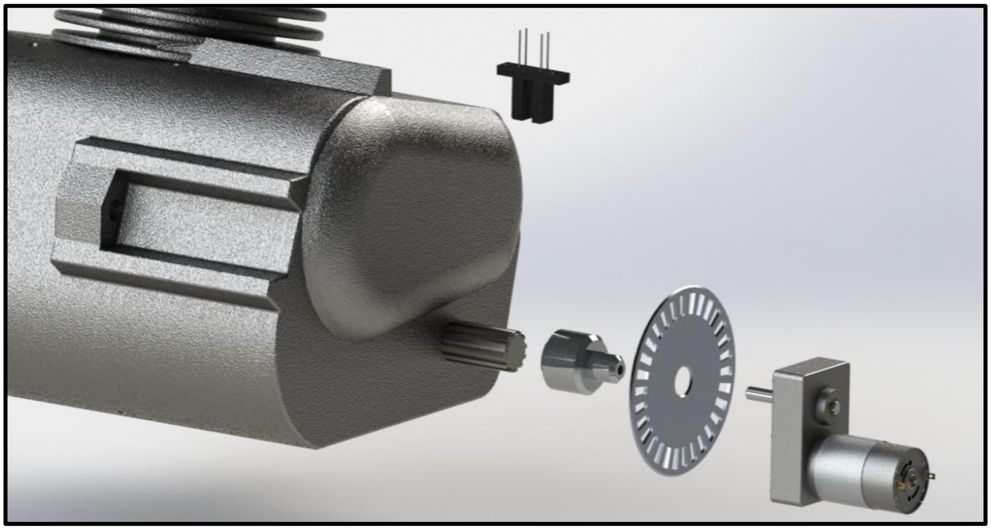

Figure 3: Actuating Mechanism Components exploded view (Solidworks 2014)

The individual components as shown the above figure are listed below,
Fromright to left-
- Electric Motor (12V, 60 RPM, 9.8 N-m torque output)
- Metallic Disc
- Coupler Shaft (Couples the Motor with the transmission shaft)
- (Above) H21A1 Infrared Sensor
    - Engine

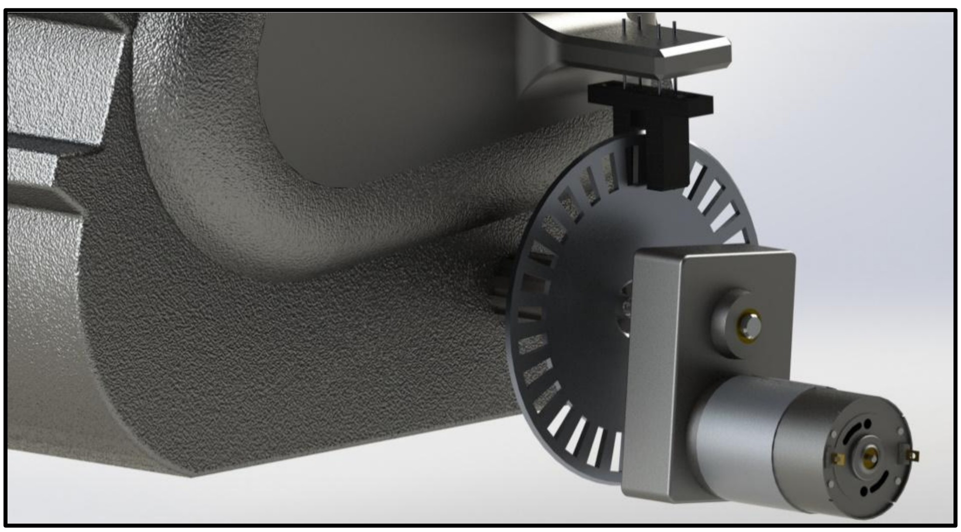

Figure 4: Actuating Mechanism assembled view (Solidworks 2014)

3.2 Micro-Controller Coding

A program was fed into the Atmega 8 Microcontroller which coordinated the Actuating Mechanism from the time the driver selected a gear shift (from the steering wheel) to the execution of the gear. The program written to carry out the above process has been shown in the following lines.

```
#include<avr/io.h>
#include<util/delay.h>
#include"lcd.h"
voidmotor_forward()
{
PORTB&=~(1<<PB0);
PORTB&=~(1<<PB1);
_delay_ms(10);
PORTB|=(1<<PB0);
}
voidmotor_backward()
{
PORTB&=~(1<<PB0);
PORTB&=~(1<<PB1);
_delay_ms(10);  PORTB|=(1<<PB1);
}
voidmotor_stop()
{
PORTB&=~(1<<PB0);
PORTB&=~(1<<PB1);
}
int main()
{
LCDInit(LS_NONE);
LCDWriteStringXY(0,0," Initiating...  ");
_delay_ms(1000);
LCDClear();
uint8_t gear=0;
uint8_t up=0;
uint8_t down=0;
//gear=eeprom_read(3);
//InitADC();
DDRB=0b00000011;
DDRC=0;
PORTC=255;
while(1)
{
if(bit_is_clear(PINC,PC0))
{
up=1;
}
else
{
up=0;
}
if(bit_is_clear(PINC,PC1))
{
down=1;
}
else
```

```
 {
down=0;
}
if(down==1 && gear>0)
 {
motor_forward();
while(bit_is_clear(PINB,PB2) );
while(!( bit_is_clear(PINB,PB2) ));
motor_stop();    motor_backward();
while(bit_is_clear(PINB,PB2) );
while(!( bit_is_clear(PINB,PB2) ));
motor_stop();
gear--;
 }

if(up==1 && gear<4)
 {
motor_backward();
while(bit_is_clear(PINB,PB2) );
while(!( bit_is_clear(PINB,PB2) ));
motor_stop();    motor_forward();
while(bit_is_clear(PINB,PB2) );
while(!( bit_is_clear(PINB,PB2) ));
motor_stop();
gear++;
        }
LCDWriteIntXY(0,0,gear,2);
 }}
```

4. Conclusion

Through this paper, we aimed to design a Semi-Automatic Paddle shifting mechanism which will be used in universities future race car projects. This will allow us to improve the cornering efficiency and minimize driver fatigue to further improve the overall performance of our vehicle. The designed mechanism was fabricated using the selected components and was incorporated into the university's go-kart. Testing was performed on the gear shifter and the positive results proved its efficiency and reliability.

References

1. Albakri, Ammar Alfaiz Bin Mustafa Design and Fabrication of Semi-Automatic Gear Shifting Mechanism for UTeM Formula Style Race Car ,UniversitiTeknikal Malaysia Melaka (2011)
2. Ajirogi, Andrew, Aldrin Ben, et al. Paddle Shifter, Team Raptor (2012)
3. Kiencke, Uwe, Nielsen Lars Automotive Control Systems, Springer, Berlin (2005)
4. Naunheimer, Harald, LechnerGisbert Automotive Transmissions, Springer, Berlin (1999)

Acknowledgements:

Rahul Sharmais pursuing his B. Tech in Automotive Design Engineering from University of Petroleum and Energy Studies Dehradun, India and has represented the University in various

national events like 'NGKC 2014' (AIR-10) and 'NKRC 2015' (AIR-1) as Technical Head. He has stood as vice-captain for 'EcoKart-2015' (AIR-4) and Design-Head for 'BAJA SAE INDIA 2016' virtuals.

Avichal Agarwalis pursuing his B. Tech in Automotive Design Engineering from University of Petroleum and Energy Studies Dehradun, India and has represented the University in QuadTorc 2015 and currently working as a member of Drive-train department in BAJA SAE India 2016. He also served as a member of Chassis department for the Quad-bike project.

Udit Sharma is pursuing his B. Tech in Automotive Design Engineering from University of Petroleum and Energy Studies Dehradun, India and has represented the University in the International event 'Formula Student United Kingdom' as the Technical Head of the University team 'Formula Racing UPES' in the year 2015.