AUTOMATIC TRANSMISSION CONTROLLER

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1. INTRODUCTION:

Automatic Transmission Controller is a type of automotive ECU which is used to control electronic automatic transmission. It is also called as Transmission Control Unit (TCU), or Transmission Control Module (TCM), or Gearbox Control Unit (GCU). The modern automatic TCU uses signals from engine sensors, automatic transmission sensors and from other electronic controllers, to calculate how and when to change gears in the vehicle for optimum performance, fuel economy and shift quality. The modern TCU's are so complex in their design and make calculations based on so many parameters that there are an indefinite amount of possible shift behaviors. It uses information from sensors like Vehicle speed sensor (VSS), Wheel speed sensor (WSS), Throttle position sensor (TPS), Turbine speed sensor (TSS), Cruise control module, Brake light switch, Traction control system (TCS), etc.

2. MODELING:

In this project, the Automatic Transmission Controller follows the block diagram shown below. It is modeled using Simulink subsystems and Stateflow charts to represent engine, transmission, vehicle dynamics and shift logic block to control transmission ratio. The inputs to the model are 'throttle' (in percent) and 'brake torque' (in ft-lb), which are used to provide different driving conditions to the model. The outputs of the system are control of 'Engine RPM' and 'Vehicle speed' (in mph).

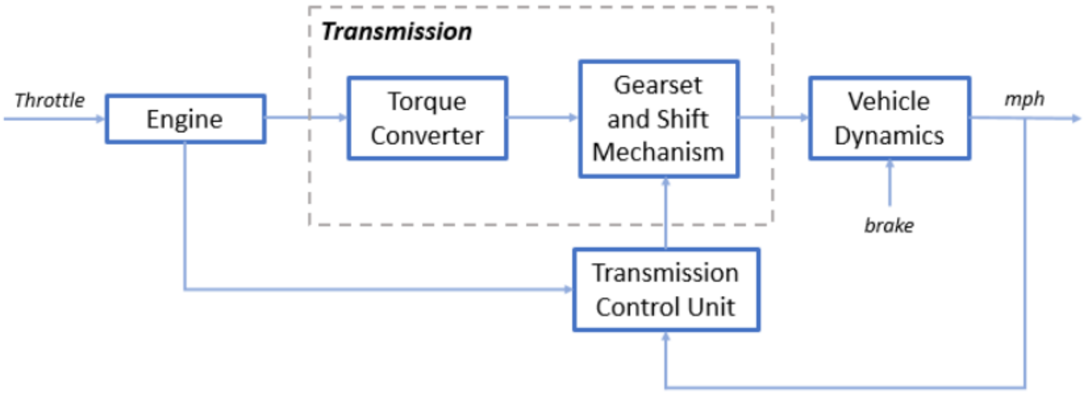

Fig1. Block diagram for Automatic transmission controller

Equations used:

- The 'throttle' is one of the inputs to the engine subsystem and its output is engine speed, which is connected to the torque converter. It is modeled using the following equation,

$$I_{ei}\frac{dN_e}{dt} = T_e - T_i$$

where, N_e = engine speed (RPM)

I_{ei} = moment of inertia of engine and impeller

T_e, Ti = engine and impeller torque

- The input-output characteristics of the torque converter can be expressed as functions of the engine speed and the turbine speed. It is modeled as per the equation below,

$$T_i = \frac{N_e^2}{K^2}$$

$$K = f_2 \frac{N_{in}}{N_e}$$

$$R_{TQ} = f_3 \frac{N_{in}}{N_e}$$

where, N_{in} = turbine speed = transmission input speed (RPM)
K = K-factor (capacity), R_{TQ} = torque ratio

- The equations for transmission ratio subsystem are,

$$R_{TR} = f_4(gear)$$

$$T_{out} = R_{TR} T_{in}$$

$$N_{in} = R_{TR} N_{out}$$

where, R_{TR} = transmission ratio
T_{in}, T_{out} = transmission input and output torque
N_{in}, N_{out} = transmission input and output speed (RPM)

- The vehicle dynamics are modeled using the equations below,

$$I_v \frac{dN_w}{dt} = R_{fd}(T_{out} - T_{load})$$

$$T_{load} = f_5(N_w)$$

$$T_{load} = sgn(mph)(R_{load0} + R_{load2} mph^2 + T_{brake})$$

where, I_v = vehicle inertia
N_w = wheel speed (RPM)
R_{fd} = final drive ratio
T_{load}, T_{brake} = load and brake torque
R_{load0}, R_{load2} = friction and aerodynamic drag coefficients

3. SKILLS DEMONSTRATED:

- Callback function:

Callbacks are commands that execute in response to a specific modeling action, such as opening a model, starting a simulation or stopping a simulation. They can be used to execute MATLAB codes.
In this project, the Callback function is used to load variables with values when the model is opened. To do so, a MATLAB script named “initialization.m” which consists of all the initial values of variables is define. It is then added to the ‘PreLoadFcn’ pane under Modelling – Model explorer – Callbacks.

- Simulation Data Inspector:

The data inspector in Simulink allows to log the required signals so that model input data or logged simulation data can be viewed, verified and inspected while iteratively modifying the model diagram, parameter values, or model configuration.
To do so, select a signal – right click on it – select the option ‘Log selected signal’. The data inspector app then logs all the selected signals. This way the status of signals over different runs can also be viewed and compared.

- MATLAB Function:

MATLAB Function block is used to implement MATLAB functions to Simulink models to deploy code and embed code in processors. In this block, the relation between input ‘u’ and output ‘y’ can be customized as a MATLAB function.
In this project, the MATLAB function block is used model the ‘Road Load’ output in the ‘Vehicle’ subsystem.

- Lookup Tables:

The Lookup table block maps inputs to an output value by looking up or interpolating a table of values defined with block parameters. The block supports flat (constant), linear (linear point-slope), Lagrange (linear Lagrange), nearest, cubic-spline, and Akima spline interpolation methods which can be applied to a table of any dimension from 1 to 30.
Here, a 2-D lookup table is used to compute engine torque and three 1-D lookup tables are used to compute K-factor, torque ratio and transmission gear ratio.

- Signal Builder:

The Signal Builder block allows to create interchangeable groups of piecewise linear signal sources and use them in a model. We can quickly switch the signal groups into and out of a model to facilitate testing.
The Signal builder is here used to provide four different drive conditions by changing the throttle and brake torque waveforms. The four drive conditions used to test the model are Passing maneuver, Gradual acceleration, Hard braking and Coasting.

- Solver Selection:

In order to sample the model output at regular intervals of time and to meet the required speed and accuracy, a Fixed-step solver is used. The model consists of continuous time states hence a discrete solver does not serve the purpose. Thus, an ode5 (Dormand Prince) solver with step-size of 0.005 is used. This combination of solver and step-size was found efficient than other solver options.

4. RESULTS:

- Output of the model for different test conditions.

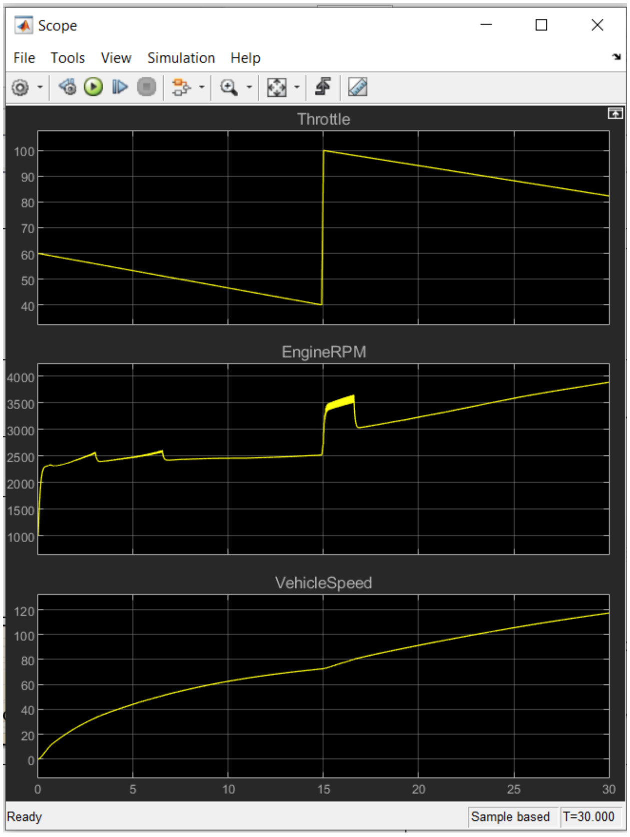

Fig2. Passing Maneuver

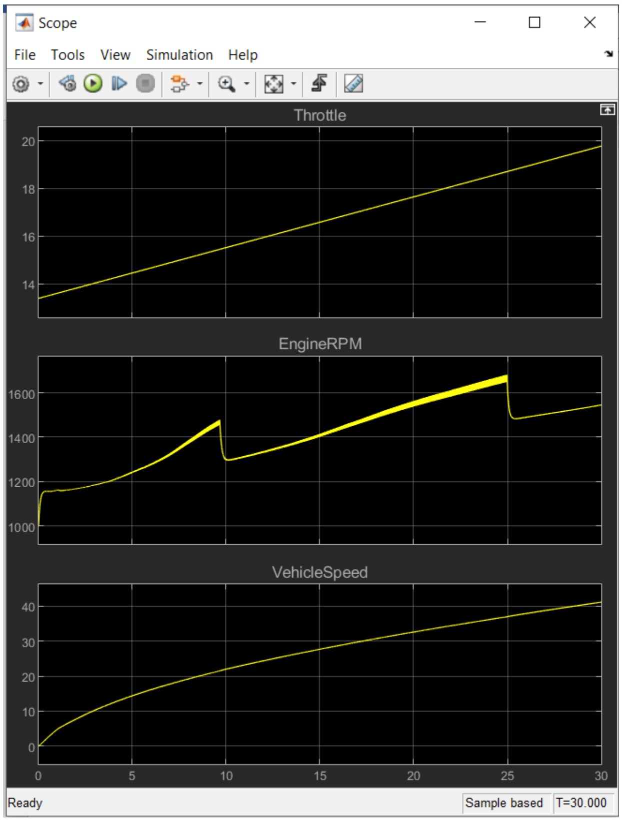

Fig3. Gradual Acceleration

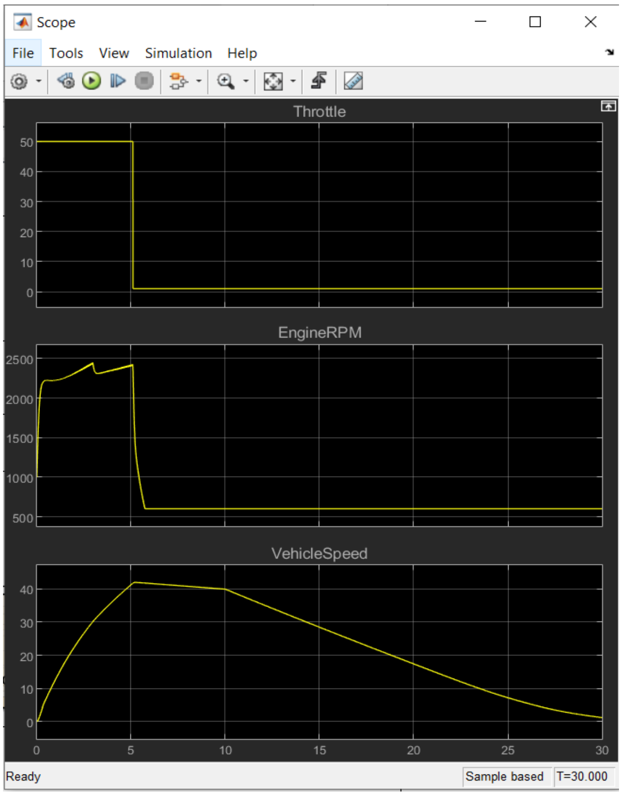

Fig4. Hard braking

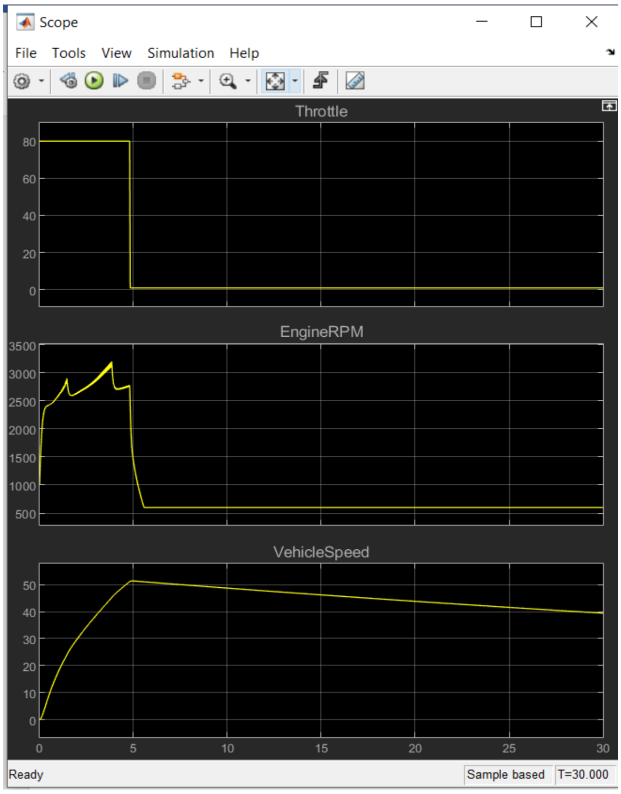

Fig5. Coasting

5. CONCLUSION:

The Automatic transmission controller is modeled using basic Simulink blocks and Stateflow chart. The model is also tested for various throttle and brake inputs to control the Engine speed and Vehicle speed.

REFERENCES:

- Transmission Controller Unit:
https://en.wikipedia.org/wiki/Transmission_control_unit

- Modelling an Automatic Transmission Controller:
https://www.mathworks.com/help/releases/R2020b/simulink/slref/modeling-an-automatic-transmission-controller.html

- Callback function:
https://in.mathworks.com/help/simulink/callback-functions.html

- Simulation Data Inspector:
https://www.mathworks.com/help/releases/R2020b/simulink/slref/simulationdatainspector.html

- MATLAB Function:
https://in.mathworks.com/help/simulink/what-is-a-matlab-function-block.html

- Lookup Table:
https://www.mathworks.com/help/releases/R2020b/simulink/slref/ndlookuptable.html

- Signal Builder:
https://www.mathworks.com/help/releases/R2020b/simulink/slref/signalbuilder.html

- Solver Selection:

https://in.mathworks.com/help/matlab/math/choose-an-ode-solver.html