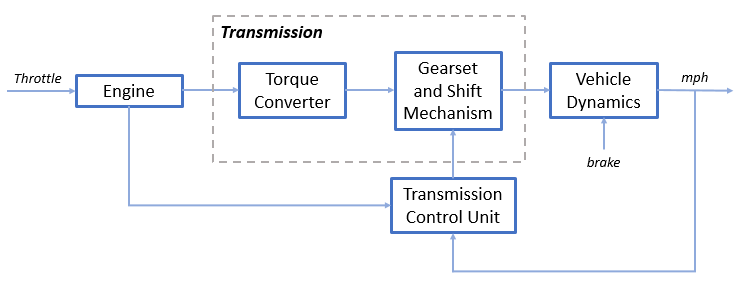
**Modeling an Automatic Transmission Controller**

In this project, Stateflow shows its strength by performing the function of gear selection in an automatic transmission. This function is combined with the drivetrain dynamics in a natural and intuitive manner by incorporating a Stateflow block in the Simulink block diagram.

### Analysis and Physics

The figure below shows the power flow in a typical automotive drivetrain. Nonlinear ordinary differential equations model the engine, four-speed automatic transmission, and vehicle. The model directly implements the blocks from this figure as modular Simulink subsystems. On the other hand, the logic and decisions made in the Transmission Control Unit (TCU) do not lend themselves to well-formulated equations. TCU is better suited for a Stateflow representation. Stateflow monitors the events which correspond to important relationships within the system and takes the appropriate action as they occur.

### Equations used in the project

**Equation 1**

$$I_{ei} \dot{N}_e = T_e -T_i $$

$$ N_e = \mbox{ engine speed (RPM)}$$

$$I_{ei} = \mbox{ moment of inertia of the engine and the impeller}$$

$$T_e, T_i = \mbox{ engine and impeller torque}$$

**Equation 2**

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

$$K= f_2 \frac{N_{in}}{N_e} = \mbox{ K-factor (capacity)}$$

$$N_{in} = \mbox{ speed of turbine (torque converter output) = transmission input speed (RPM)}$$

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

**Equation 3**

$$R_{TR} = f_4(gear) = \mbox{ transmission ratio}$$

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

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

$$T_{in}, T_{out} = \mbox{ transmission input and output torques}$$

$$N_{in}, N_{out} = \mbox{ transmission input and output speed (RPM)}$$

**Equation 4**

$$ I_v \dot{N}_w = R_{fd}(T_{out}-T_{load})$$

$$I_v = \mbox{ vehicle inertia}$$

$$N_w = \mbox{ wheel speed (RPM)}$$

$$R_{fd} = \mbox{ final drive ratio}$$

$$T_{load} = f_5(N_w) = \mbox{ load torque}$$

**Equation 5**

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

$$ R_{load0}, R_{load2} = \mbox{ friction and aerodynamic drag coefficients} $$

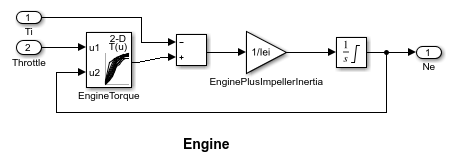
$$ T_{load}, T_{brake} = \mbox{ load and brake torques} $$

$$ mph = \mbox{ vehicle linear velocity}$$

### Modeling

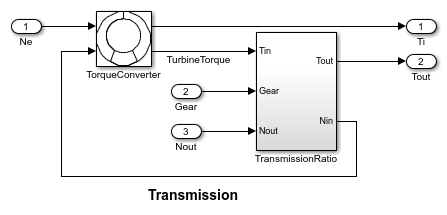
**Engine:**

The Engine subsystem consists of a two-dimensional **lookup table** that interpolates engine torque versus throttle and engine speed. The figure below shows the composite Engine subsystem.



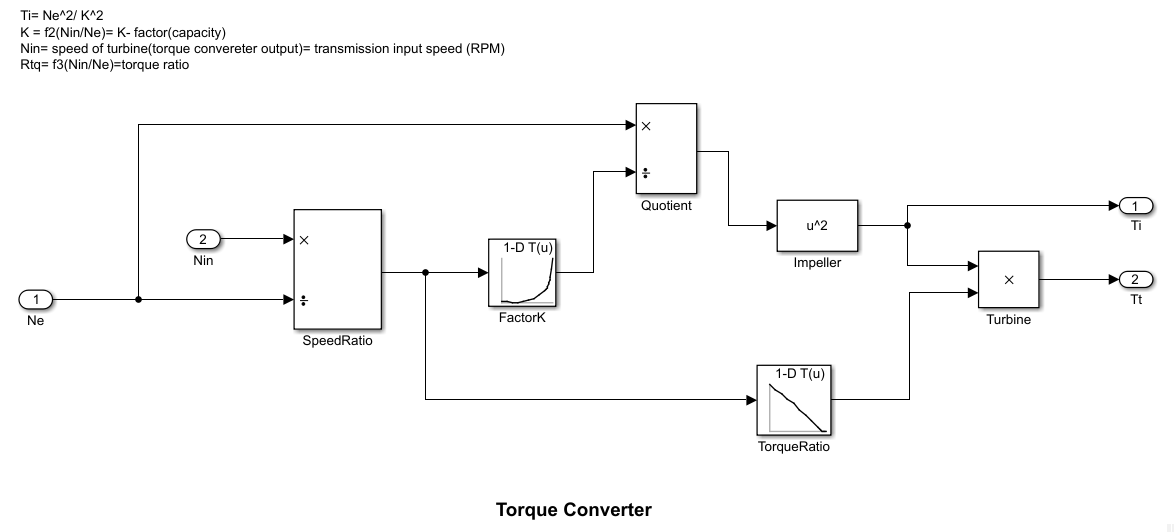
**Transmission:**

The TorqueConverter and the TransmissionRatio blocks make up the Transmission subsystem, as shown in the figure below.



**TorqueConverter:**

The TorqueConverter is a masked subsystem, which implements Equation 2. The mask requires a vector of speed ratios (Nin/Ne) and vectors of K-factor (f2) and torque ratio (f3). These vectors are passed through 1-D **lookup table** as shown. This figure shows the implementation of the TorqueConverter subsystem.



**Transmission Gear Ratio:**

The transmission ratio block determines the ratio shown in Table 1 and computes the transmission output torque and input speed with the help of a 1-D **lookup table**, as indicated in Equation 3. The figure that follows shows the block diagram for the subsystem that realizes this ratio in torque and speed.

**Table 1:** Transmission gear ratios

Gear Rtr = Nin/Ne

1 2.393

2 1.450

3 1.000

4 0.677

