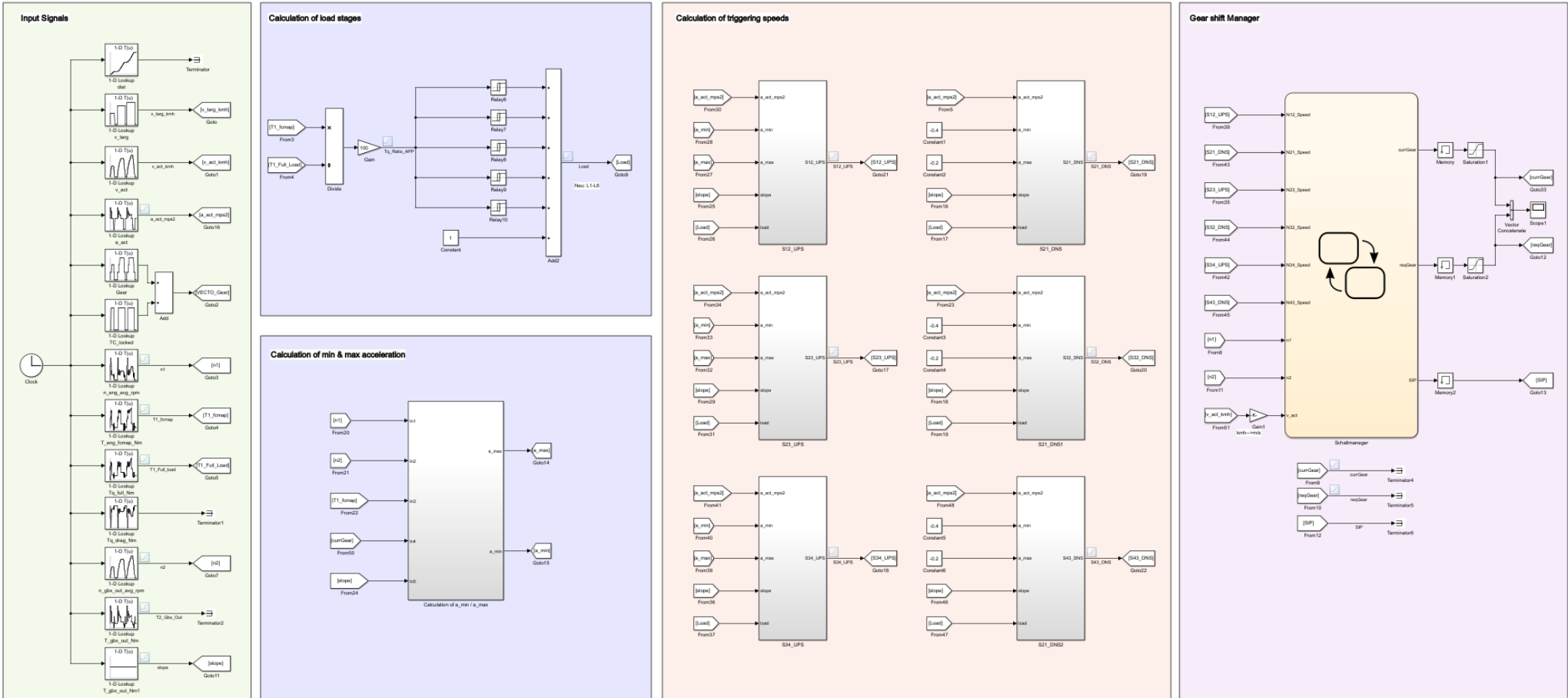


New gear shift logic for Vecto

Heidenheim | 2019-03-25 | confidential

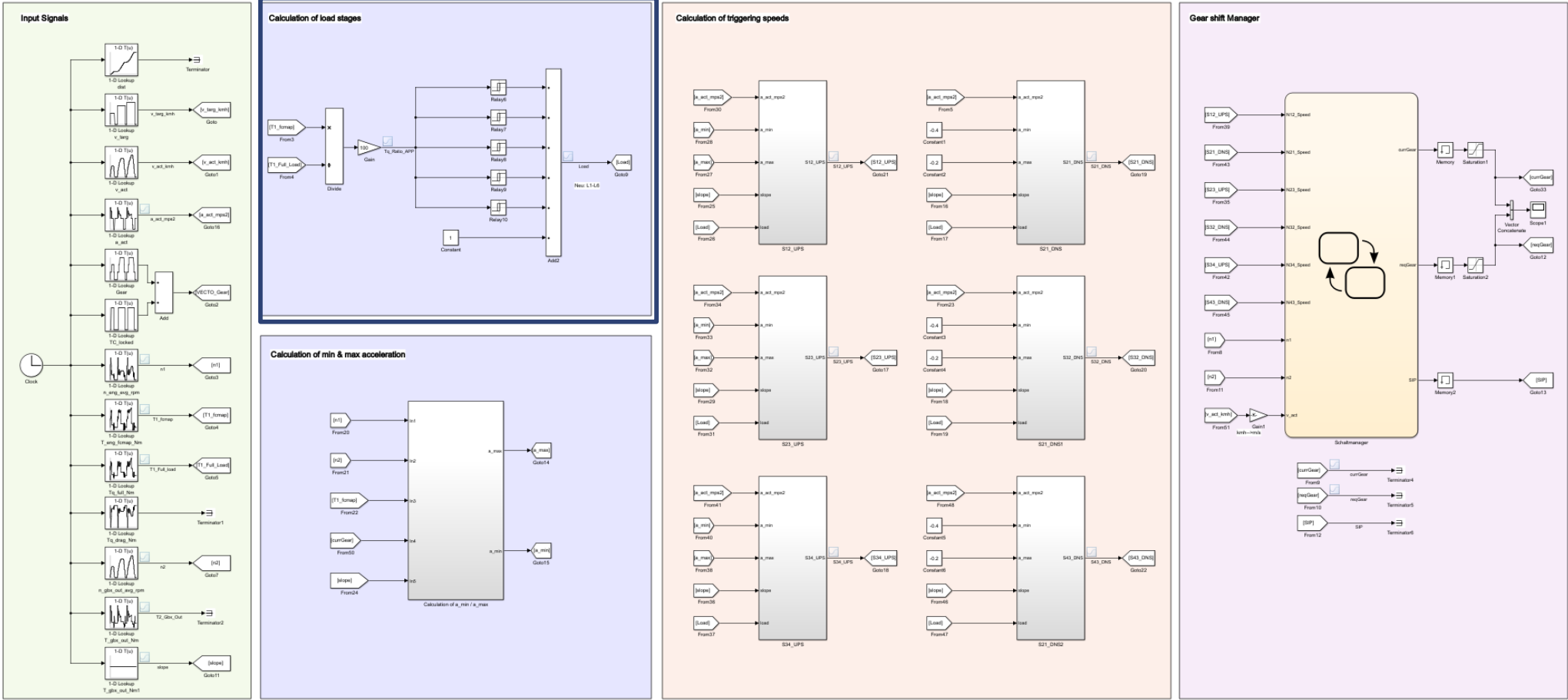


Overview



1. Get input signals for the simulation
2. Definition of load stages
3. Calculation of minimum and maximum acceleration
4. Calculation of triggering speeds
5. Determination of the gear shift through shift logic

Definition of load stages



Definition of load stages

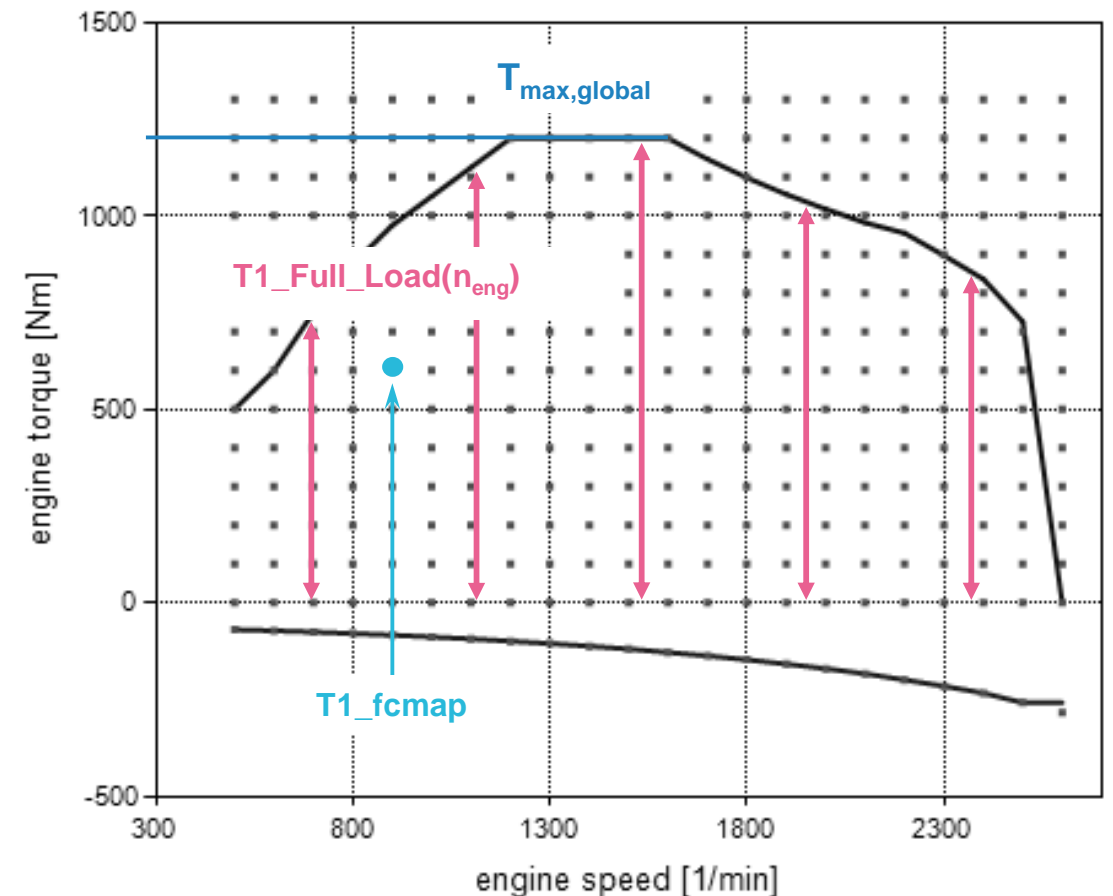
- Acceleration pedal position can be estimated from the torque ratio, which can be defined as below:

$$\text{Torque Ratio} = \frac{T1_{fcmap}}{T1_{Full_Load}} * 100$$

where,

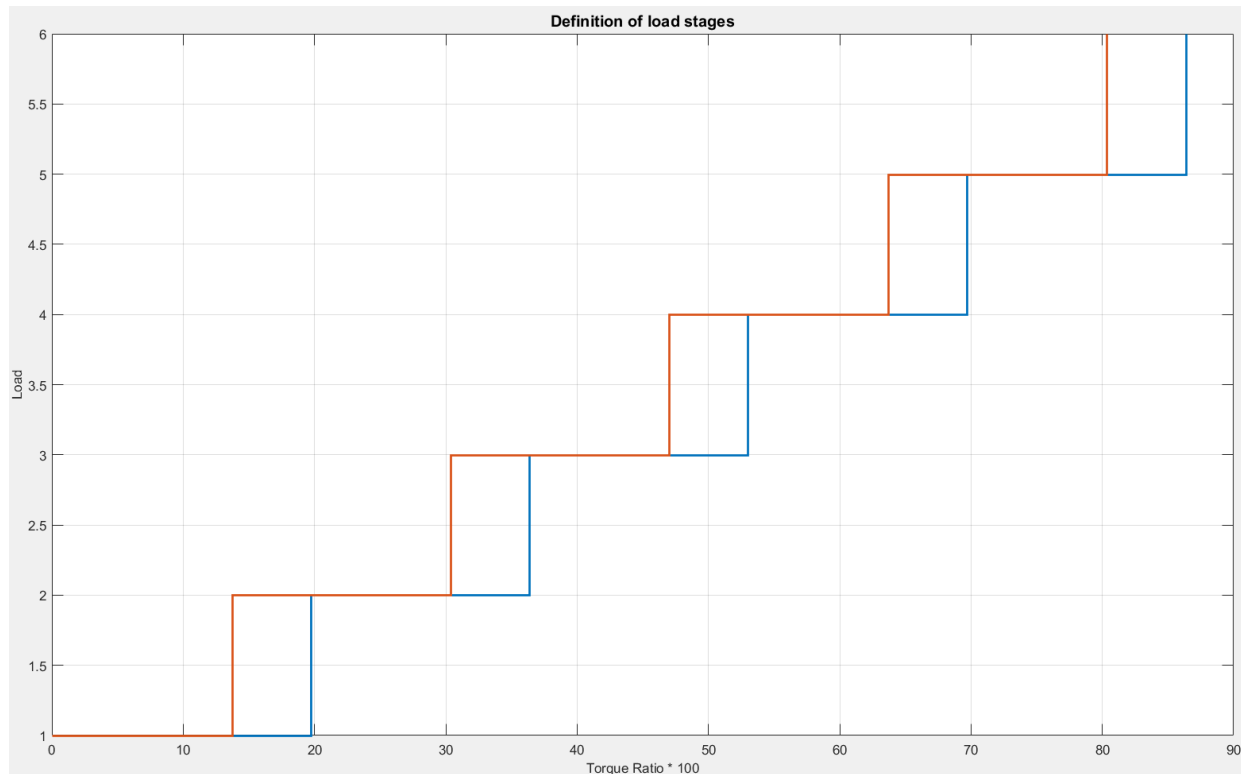
$T1_{Full_Load}$ is the maximum available torque for the given engine speed from the full load curve.

$T1_{fcmap}$ is the actual vehicle torque that is used to drive the vehicle.



Definition of load stages

- The variations of the torque ratio between 0-100 are equally divided in 1-6 load stages through an hysteresis as shown in the figure.



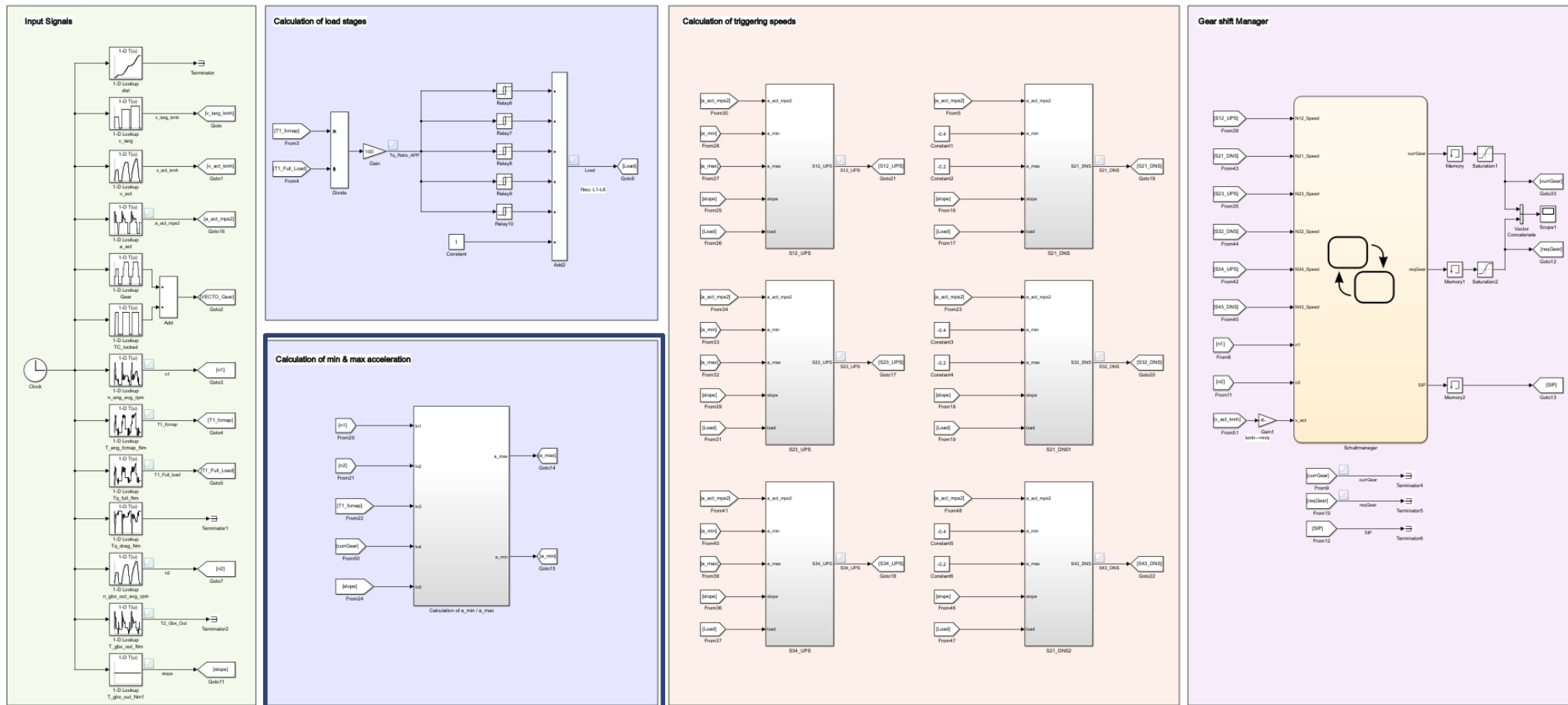
Torque Ratio [%] for Up

19.7	36.34	53.01	69.68	86.35
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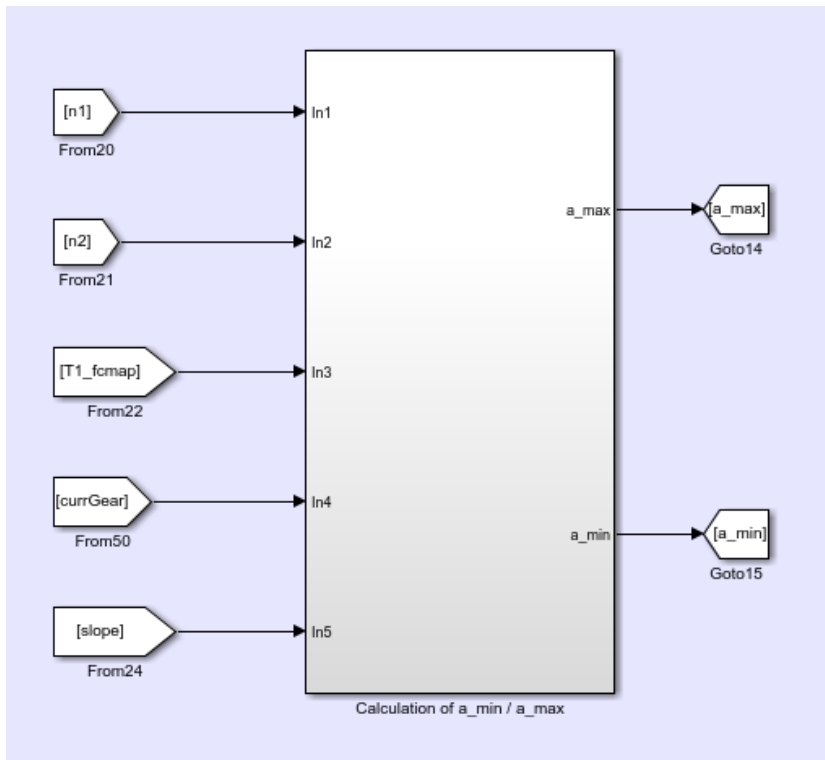
Torque Ratio [%] for Down

13.7	30.34	47.01	63.68	80.35
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Calculation of minimum & maximum acceleration



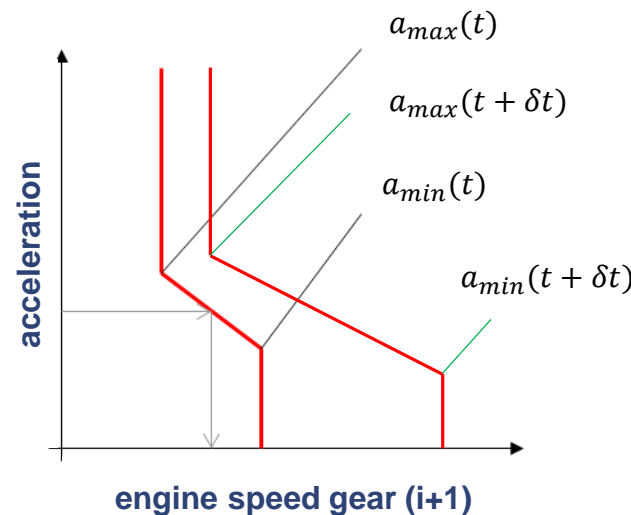
Calculation of minimum & maximum acceleration



$$a_{min} = \frac{F_z - F_w}{mVeh_{max}}$$

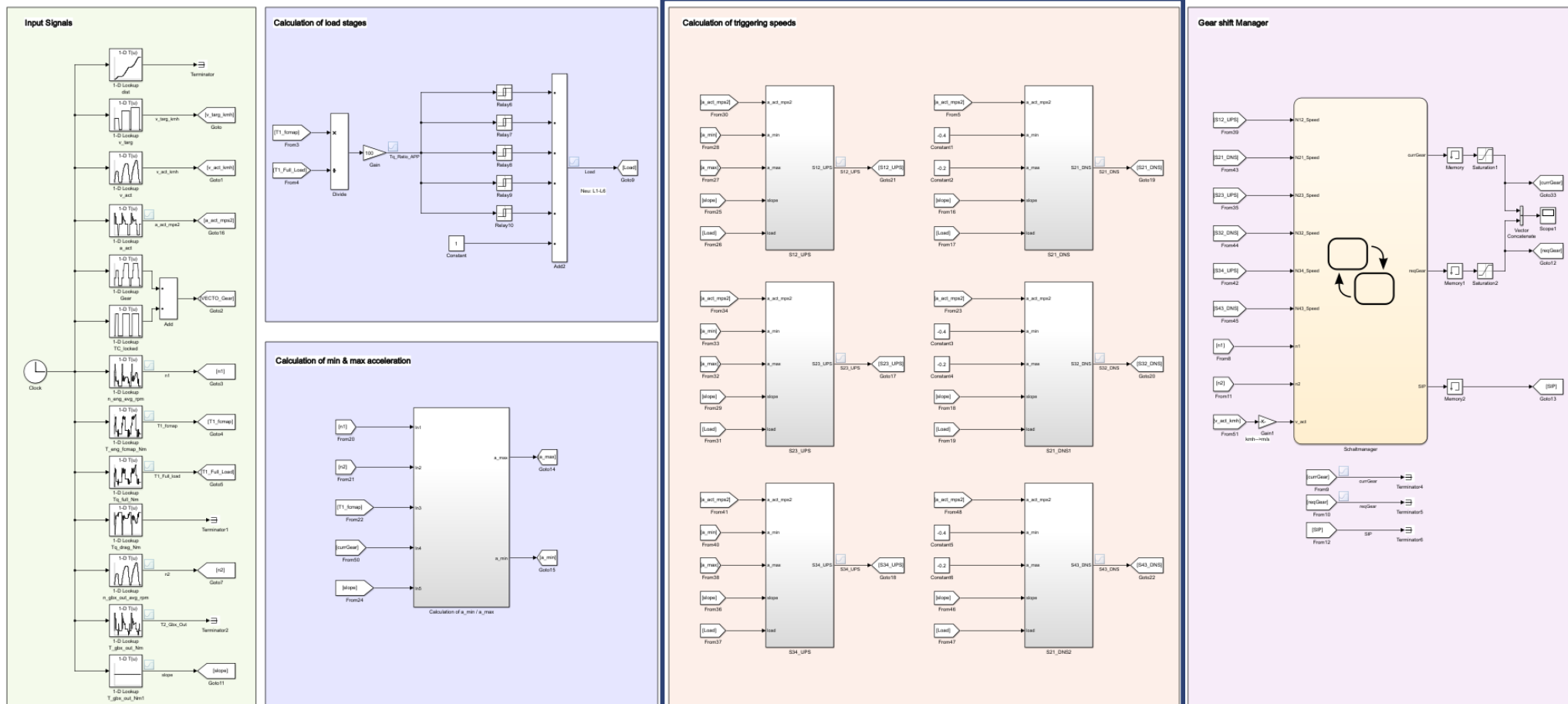
$$a_{max} = \frac{F_z - F_w}{mVeh_{min}}$$

a_{min}	Minimum vehicle acceleration
a_{max}	Maximum vehicle acceleration
F_z	Traction force
F_w	Driving resistance
$mFzg_{min}$	Minimum vehicle mass
$mFzg_{max}$	Maximum/Full vehicle mass



- The minimum and maximum values for vehicle acceleration are calculated for every time step.
- Hence, the new characteristic lines are created for each time step as well.

Calculation of triggering speeds



Load stages & shift points

- Shift points are defined for basic slope lines corresponding to the uphill (5%), downhill (-5%) and plain (0%)
- One example of the shift points table is shown below:

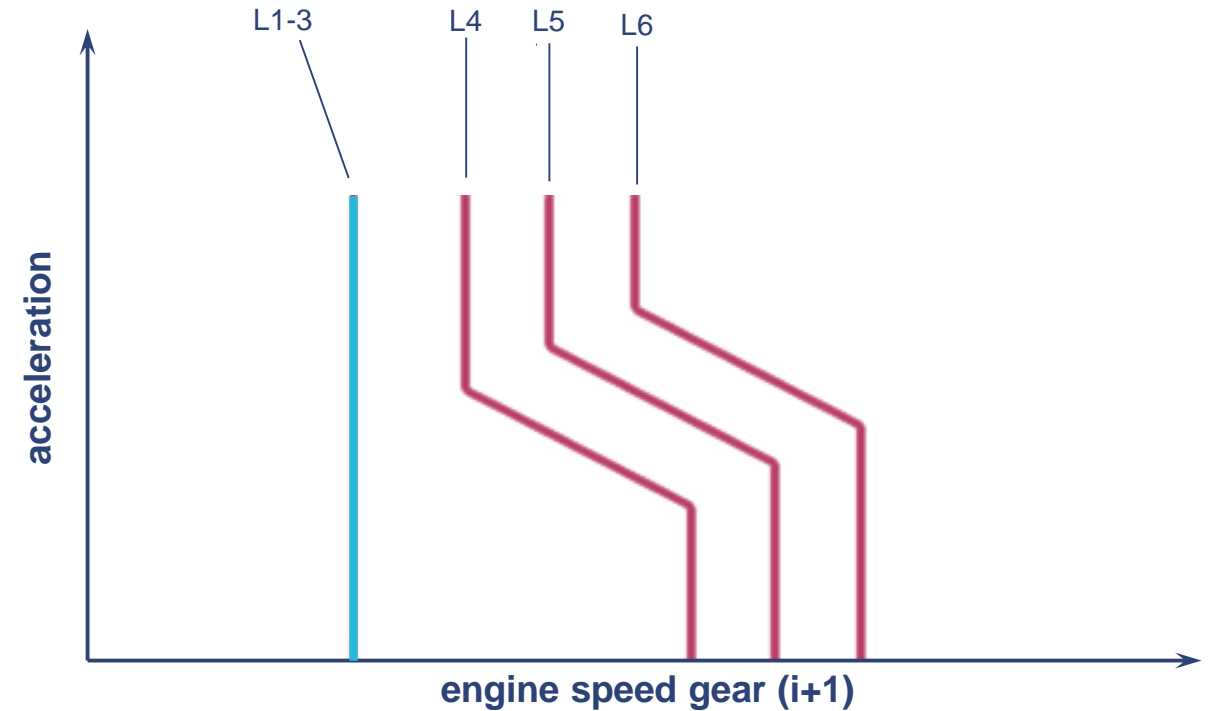
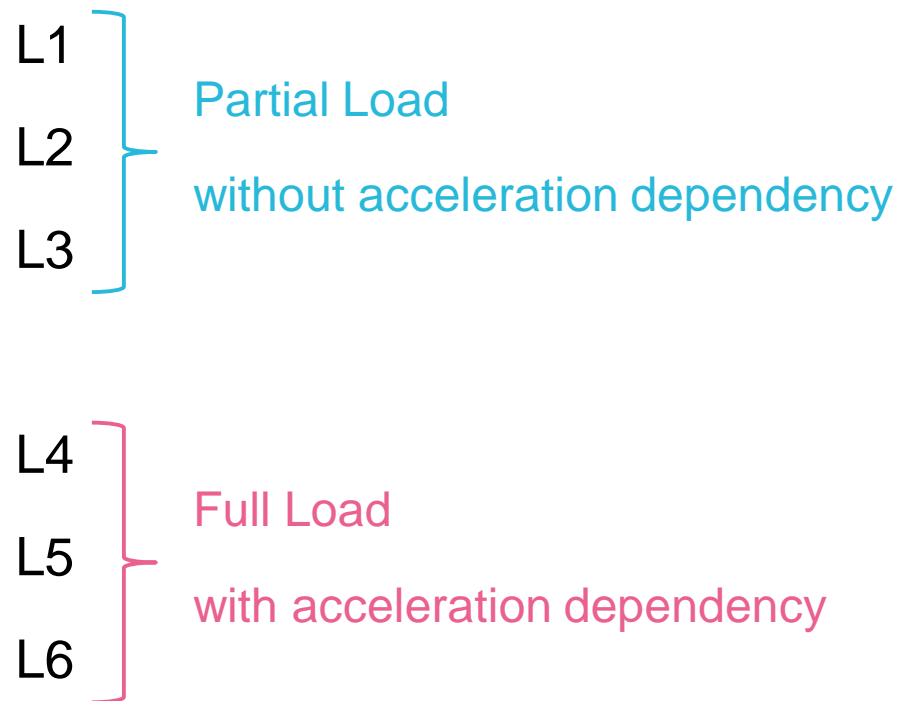
	Slope		
	-5%	0%	5%
1	650	680	700
2	650	680	725
3	675	700	725
4	700	725	745
5	725	750	750
6	750	775	800

Note:

The maximum & minimum values of the slope (5%, -5%) are just assumed values and can be changed as required.

Load stages and shift points

Load stages are divided in six parts: L1 – L6



Load stages and shift points

Calculation of shift points for partial load L1-L3

- The load stages L1-L3 are the partial load stages. They don't have acceleration dependency, but they do vary according to the current value of slope.

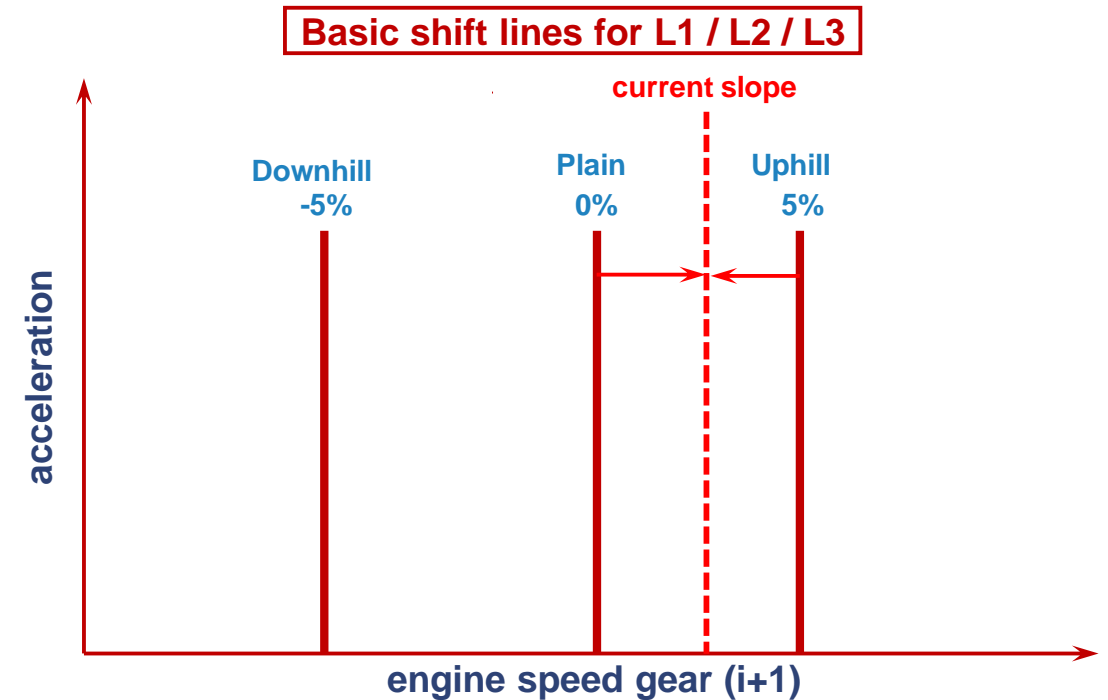
Slope			
	-5%	0%	5%
1	650	680	700
2	650	680	725
3	675	700	725
4	700	725	745
5	725	750	750
6	750	775	800

- The shift point for the 1st load stage L1 is read from the row number 1.
L1 → [650 680 700]
- The shift points for the 2nd & 3rd load stages L2 & L3 are read from the row number 2.
L2 = L3 → [650 680 725]

Load stages and shift points

Calculation of shift points for L1-L3

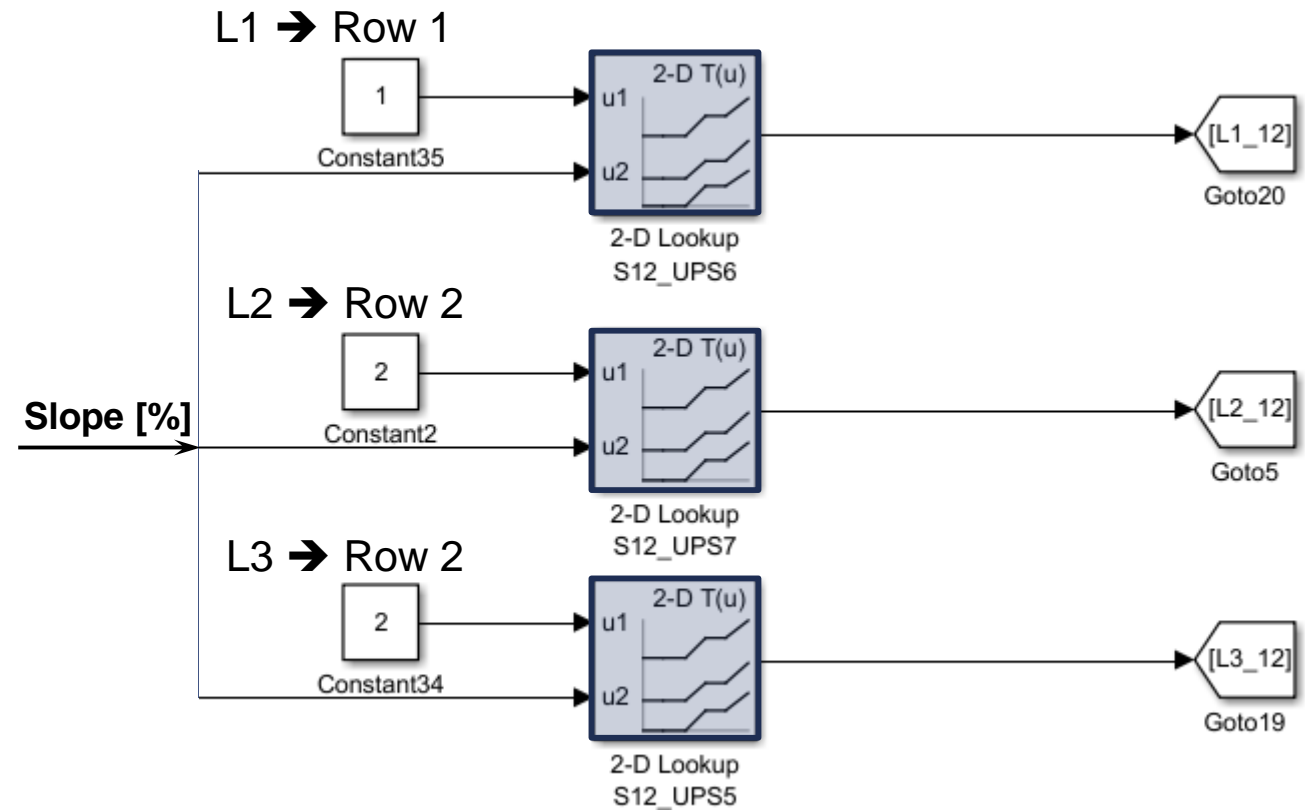
- In the end, the shift points are interpolated for the current value of the slope between downhill-plain & plain-uphill
- If the actual slope is more than 5% or less than -5%, then the corresponding shift points for 5% and -5% are taken, instead of extrapolating the values.



Load stages and shift points

Partial Load L1-L3 → Implementation in Simulink

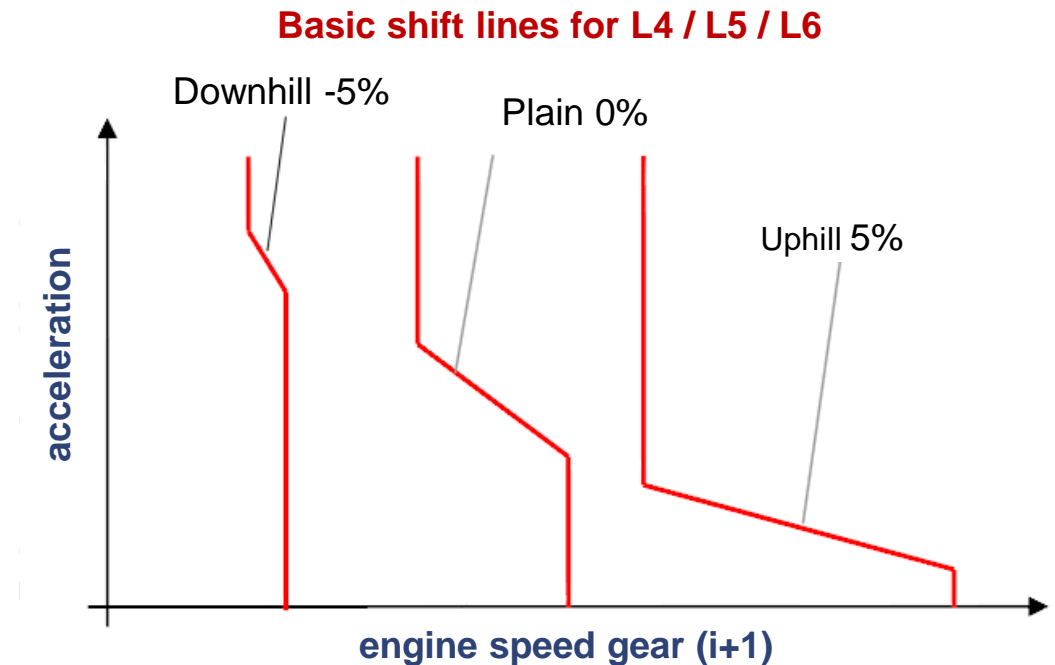
	Slope		
	-5%	0%	5%
1	650	680	700
2	650	680	725
3	675	700	725
4	700	725	745
5	725	750	750
6	750	775	800



Load stages and shift points

Calculation of shift points for full load L4-L6

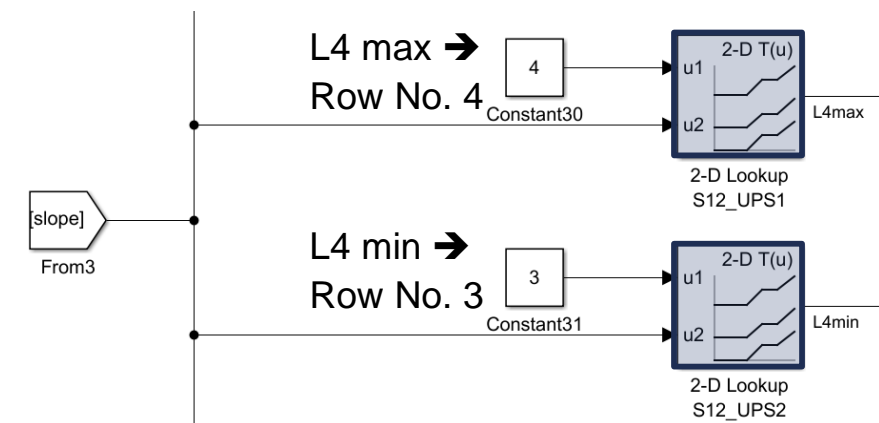
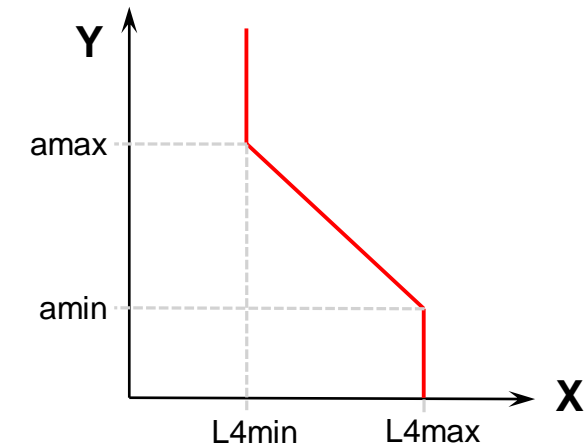
- The shift lines for full load vary with slope as well as vehicle acceleration and this is also evident from the figure.
- Following information is needed to calculate the shift lines:
 - min & max speed limits
 - min & maximum vehicle acceleration
- Based on the actual vehicle slope, the shift points are interpolated between Downhill-Plain & Plain-Uphill.



Load stages and shift points

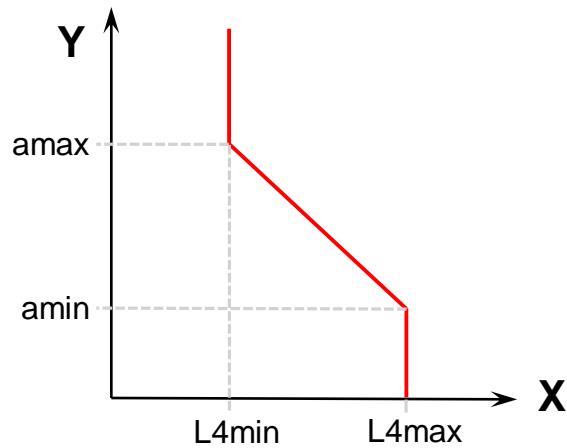
Calculation of shift points for full load L4

- In order to create the shift line for load stage 4, following values are required:
 - a_{\min} – minimum vehicle acceleration
 - a_{\max} – maximum vehicle acceleration
 - $L4_{\min}$ – minimum speed limit for L4
 - $L4_{\max}$ – maximum speed limit for L4
- The minimum & maximum vehicle acceleration are continuously determined from the block „Calculation of min & max acceleration“.
- Now, $L4_{\min}$ corresponds to the value of 3rd row from the shift table, whereas $L4_{\max}$ corresponds to the 4th row of the shift table

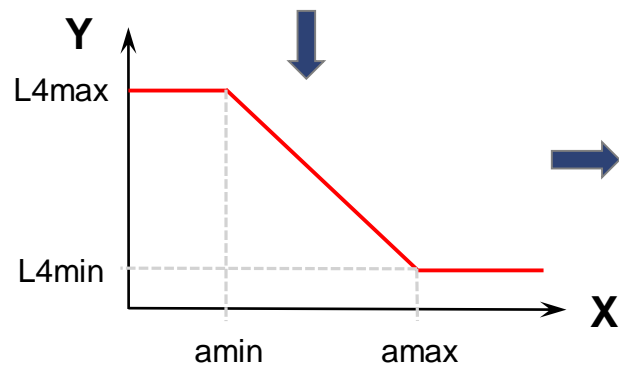


Load stages and shift points

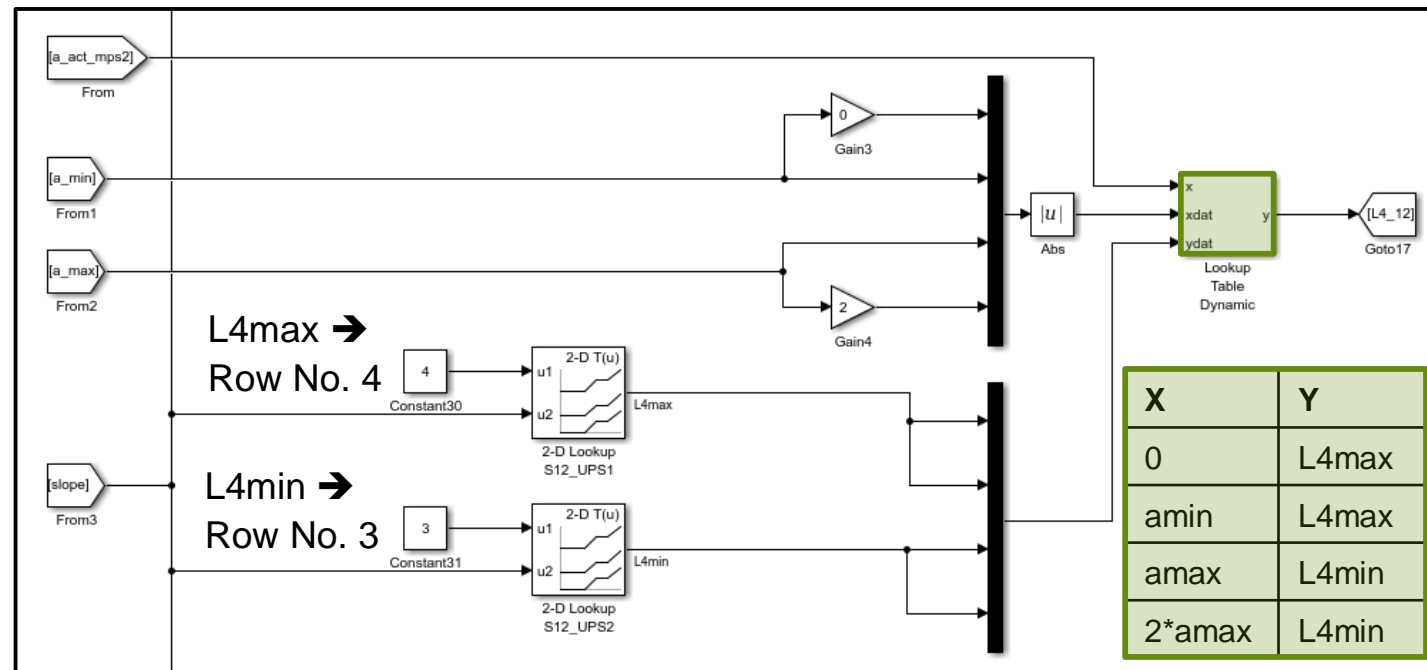
Calculation of shift points for full load L4 (For Acc.)



The shift line can be redefined as below:

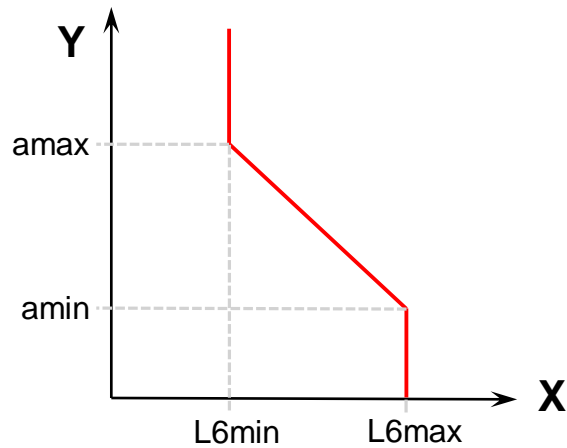


- Final value of the shift point is then interpolated for the current vehicle acceleration from the current shift line.
- Please note that the characteristic curve looks different for deceleration phase!!

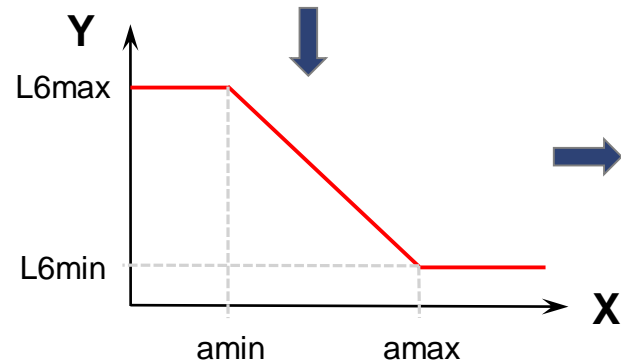


Load stages and shift points

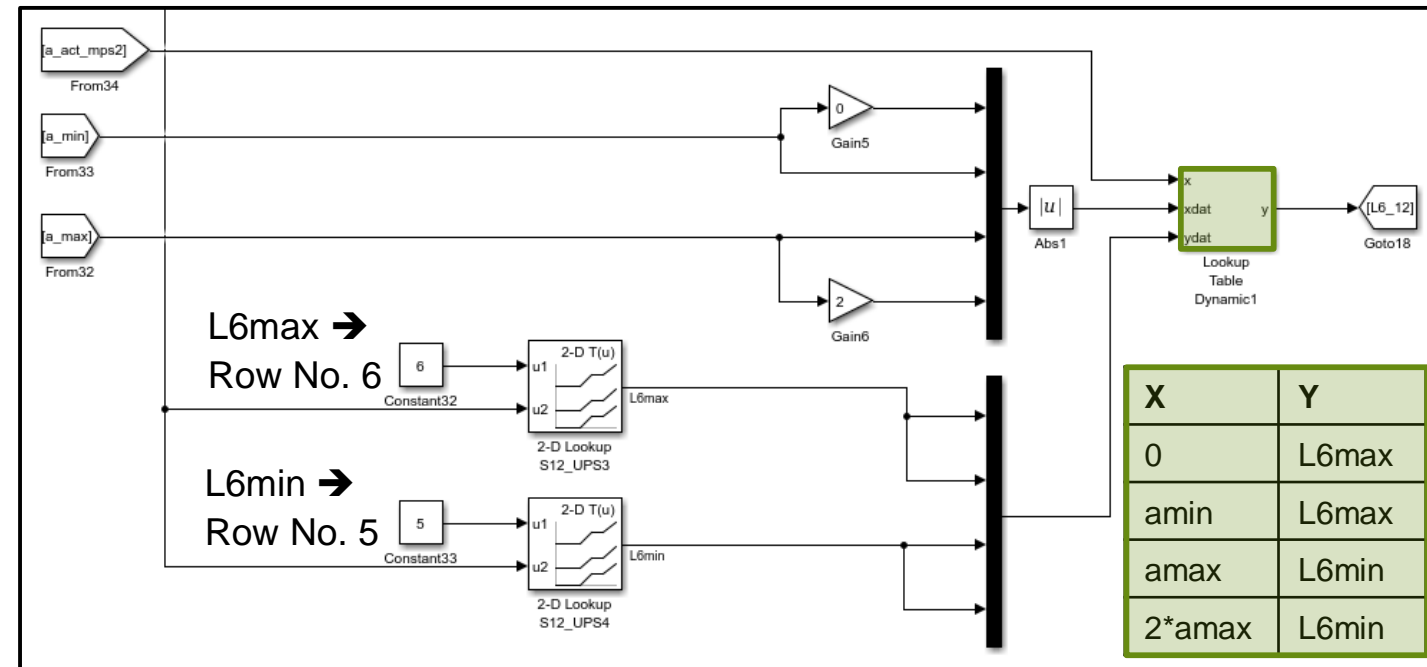
Calculation of shift points for full load L6 (For Acc.)



The shift line can be redefined as below:



- The similar calculation procedure follows for load stage 6 (L6) as the load stage 4 (L4).
- Please note that the characteristic curve looks different for deceleration phase!!



Load stages and shift points

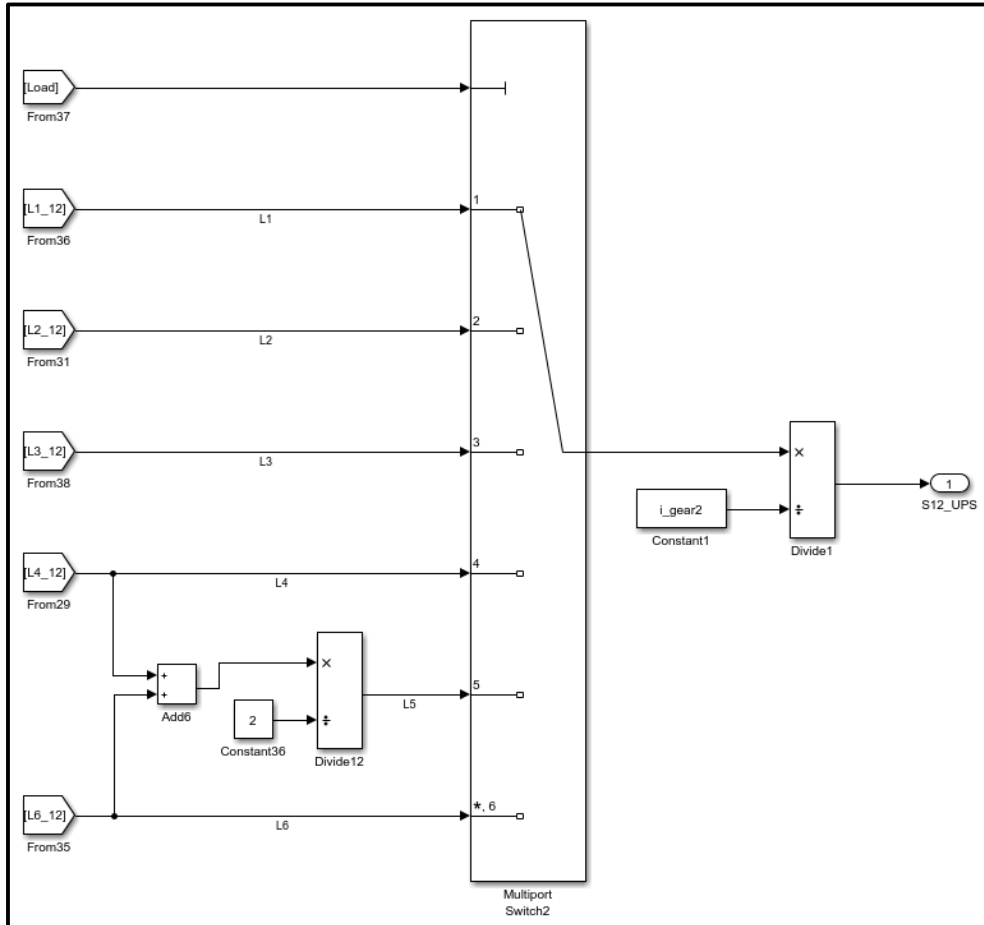
Calculation of shift points for full load L5

- The shift point for load stage 5 is an arithmetic mean of the shift points of load stages 4 and 6.

$$L5 = \frac{L4 + L6}{2}$$

Load stages and shift points

Calculation of triggering speed, Example: 1→2 Upshift



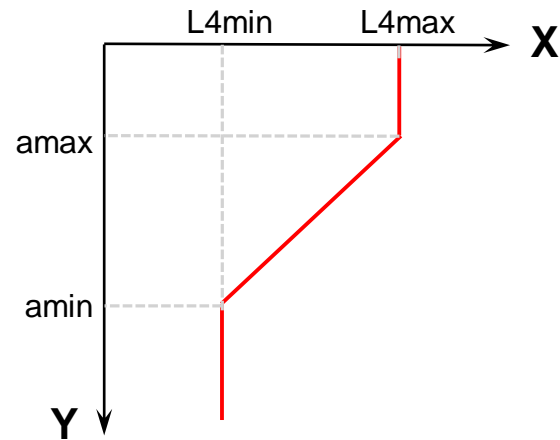
- For the current value of load, the shift points are continuously determined and the corresponding value is forwarded for further calculation through the multiport switch.
- the triggering speed is converted to the gearbox-output side. For example, the triggering speed for 1→2 upshift i will be calculated as (current gear = 1):

$$S12_{UPS} = \frac{\text{Shift point for } 1 \rightarrow 2 \text{ for current load}}{i_{gear2}}$$

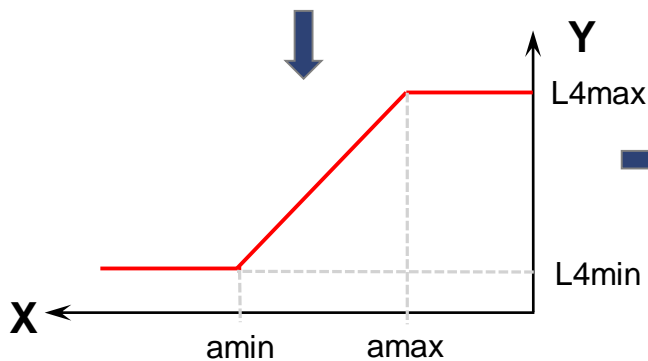
- Similarly, the triggering speeds for 2→3 and 3→4 upshift can also be determined.

Load stages and shift points

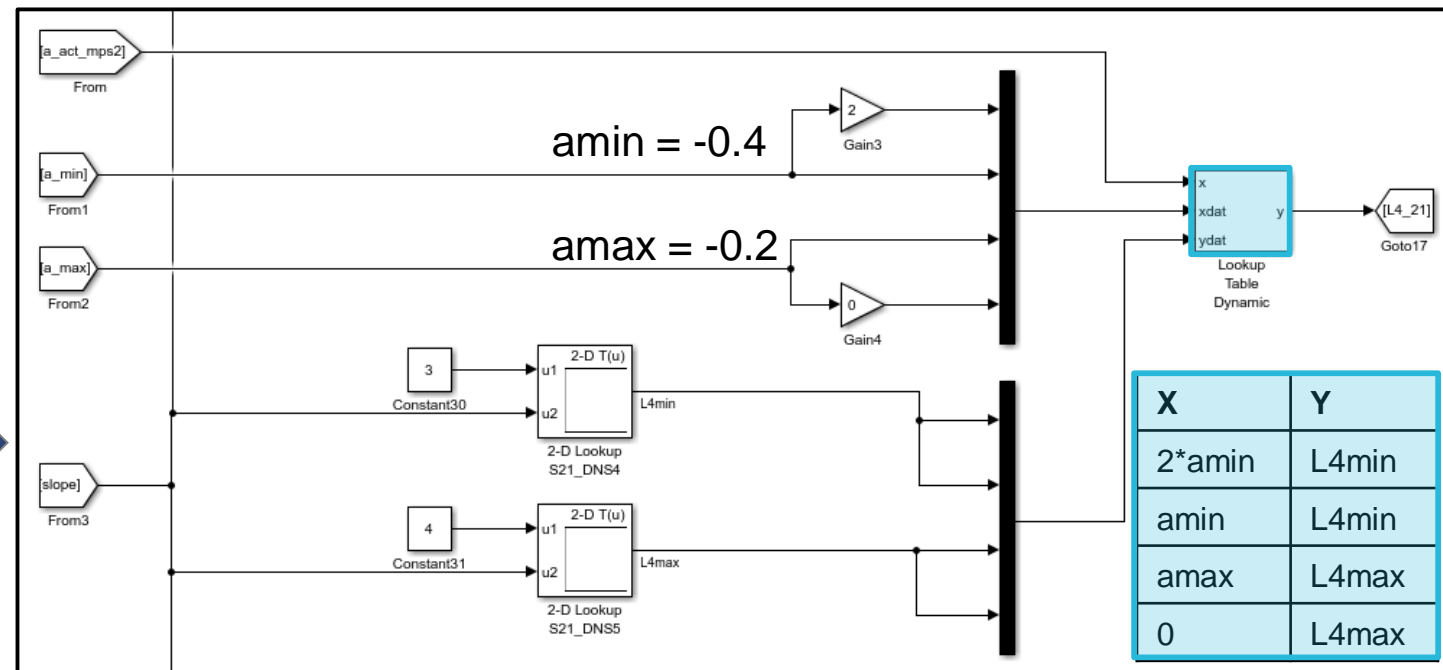
Calculation of shift points for full load L4 (for Dec.)



The shift line can be redefined as below:

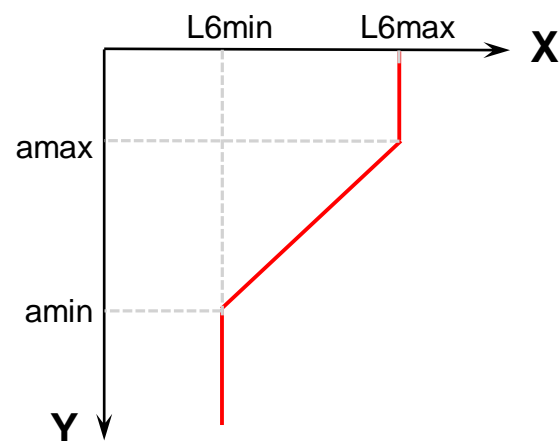


- For vehicle deceleration, the minimum and maximum deceleration points are considered to have constant values of -0.4 m/s^2 & -0.2 m/s^2 respectively.
- This is to ensure that the downshift happens as late as possible.

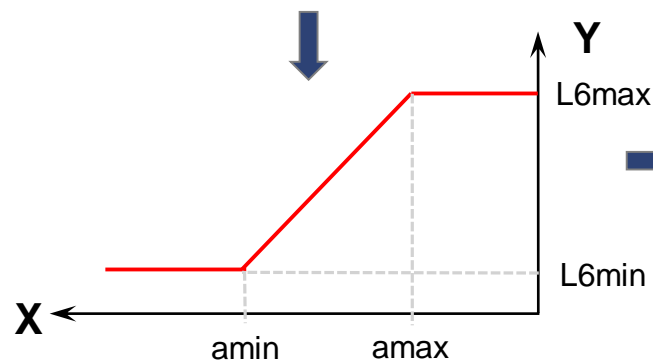


Load stages and shift points

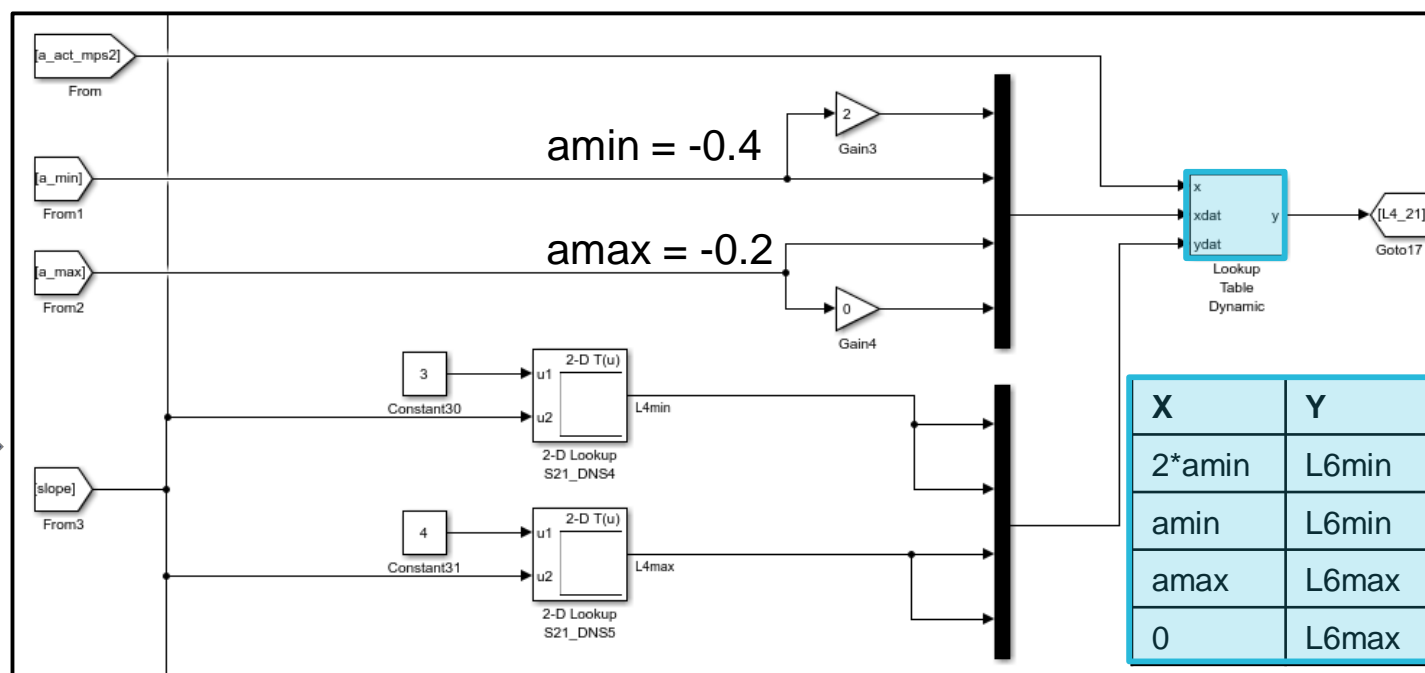
Calculation of shift points for full load L5 & L6 (for Dec.)



The shift line can be redefined as below:

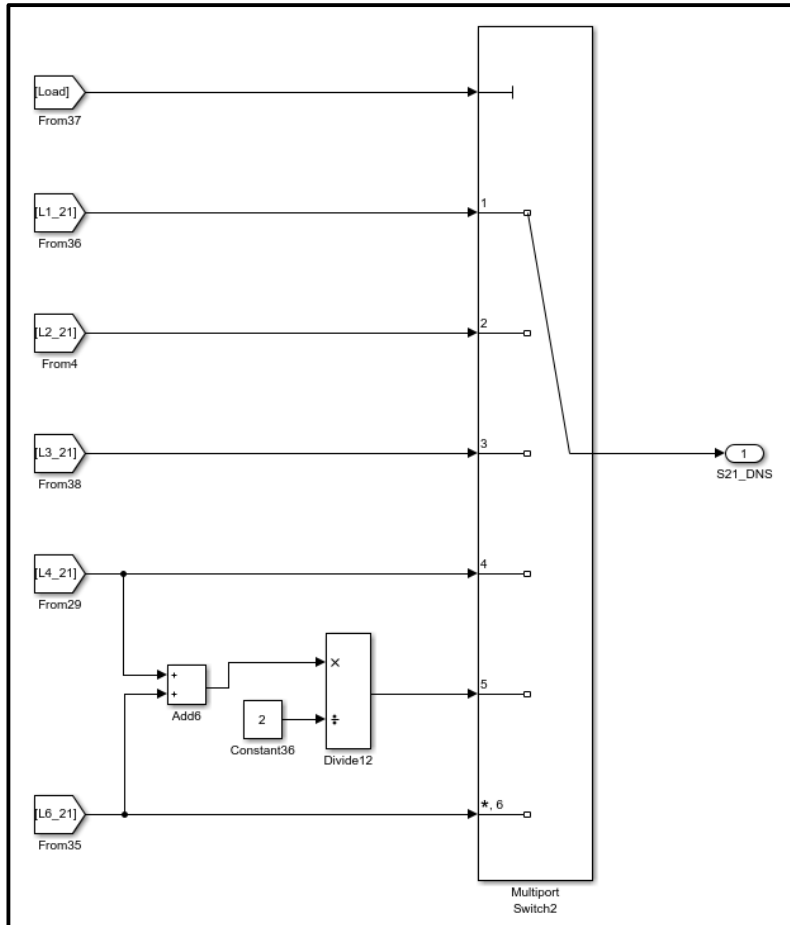


- The calculation of shift points for load stage 6 during deceleration phase is same as that of load stage 4.
- The shift point for load stage 5 is an arithmetic mean of the shift points from load stages 4 & 6.



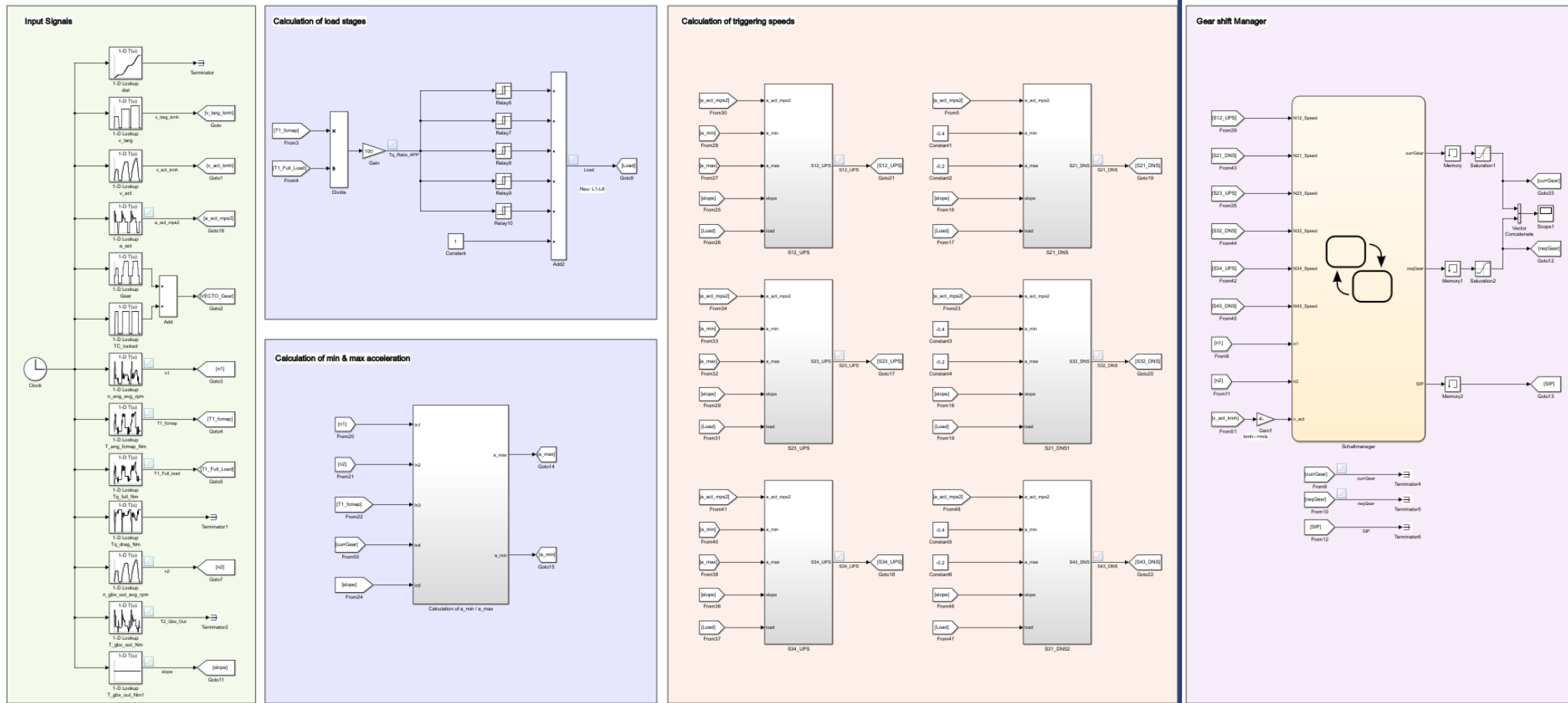
Load stages and shift points

Calculation of triggering speed, Example: 2→1 Downshift



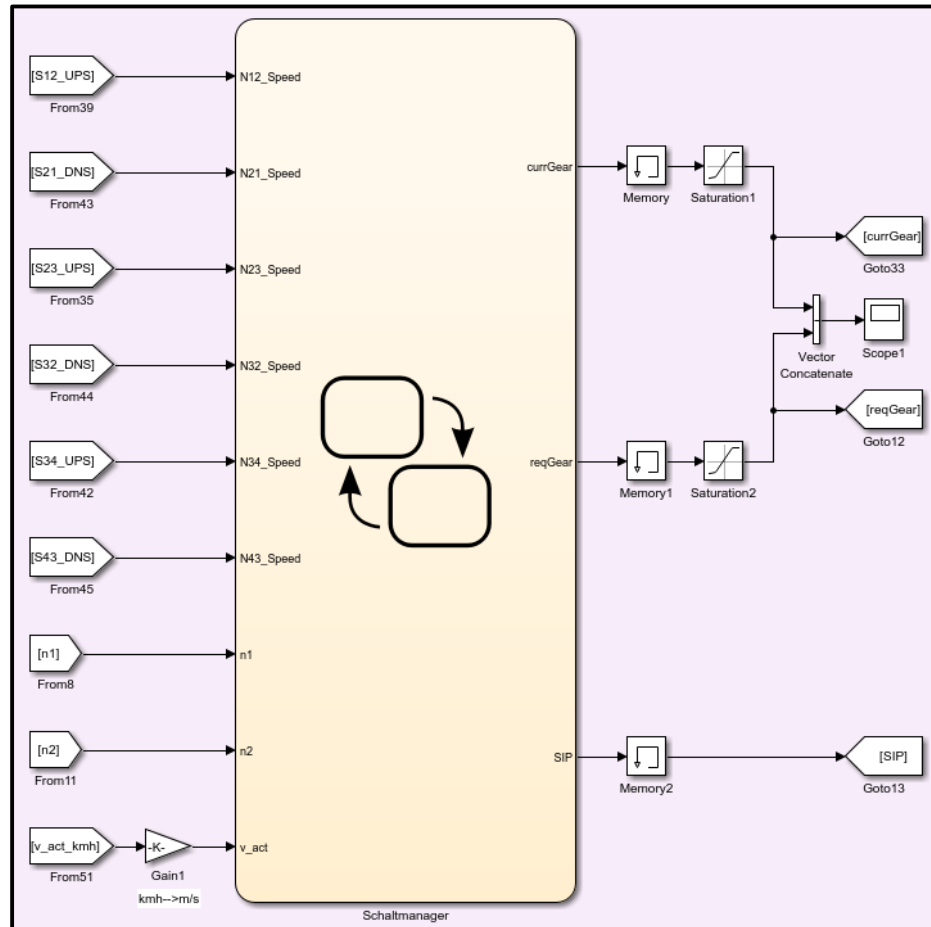
- Based on the current load, the shift points are determined for the calculation of shift logic.
- Unlike upshift triggering speeds, the downshift triggering speeds are not converted to the gearbox-output side.

Gear Shift Manager



Gear Shift Manager

Shift Logic



- At each time step, the triggering speeds are calculated for every possible upshifts as well as downshifts.
- The upshift will take place, when the gearbox output speed in the current gear is greater than the triggering speed.
- The downshift will take place, when the gearbox input speed (engine speed) in the current gear is smaller than the triggering speed
- Example: 2→3 upshift occurs when,

$$n_2 \geq S23_UPS$$

- 3→2 downshift occurs when,

$$n_1 \leq S32_DNS$$

Gear Shift Manager

Shift Logic

Reference: VECTO User Manual

Upshift rules

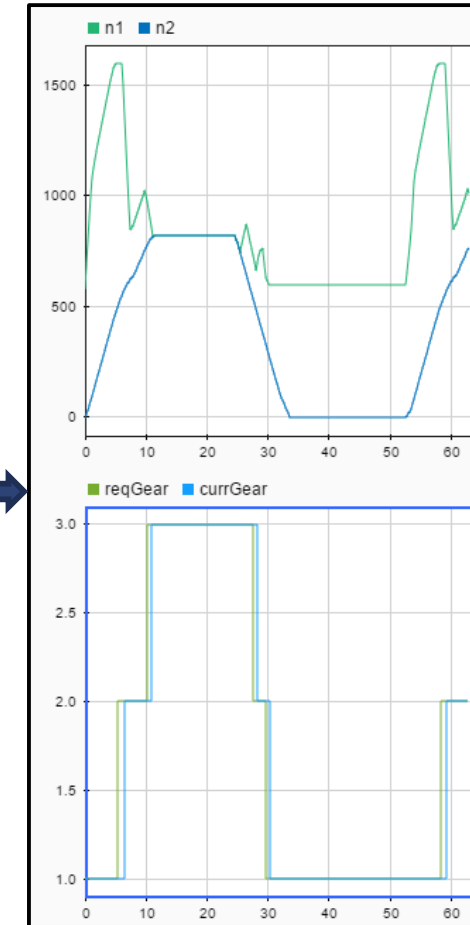
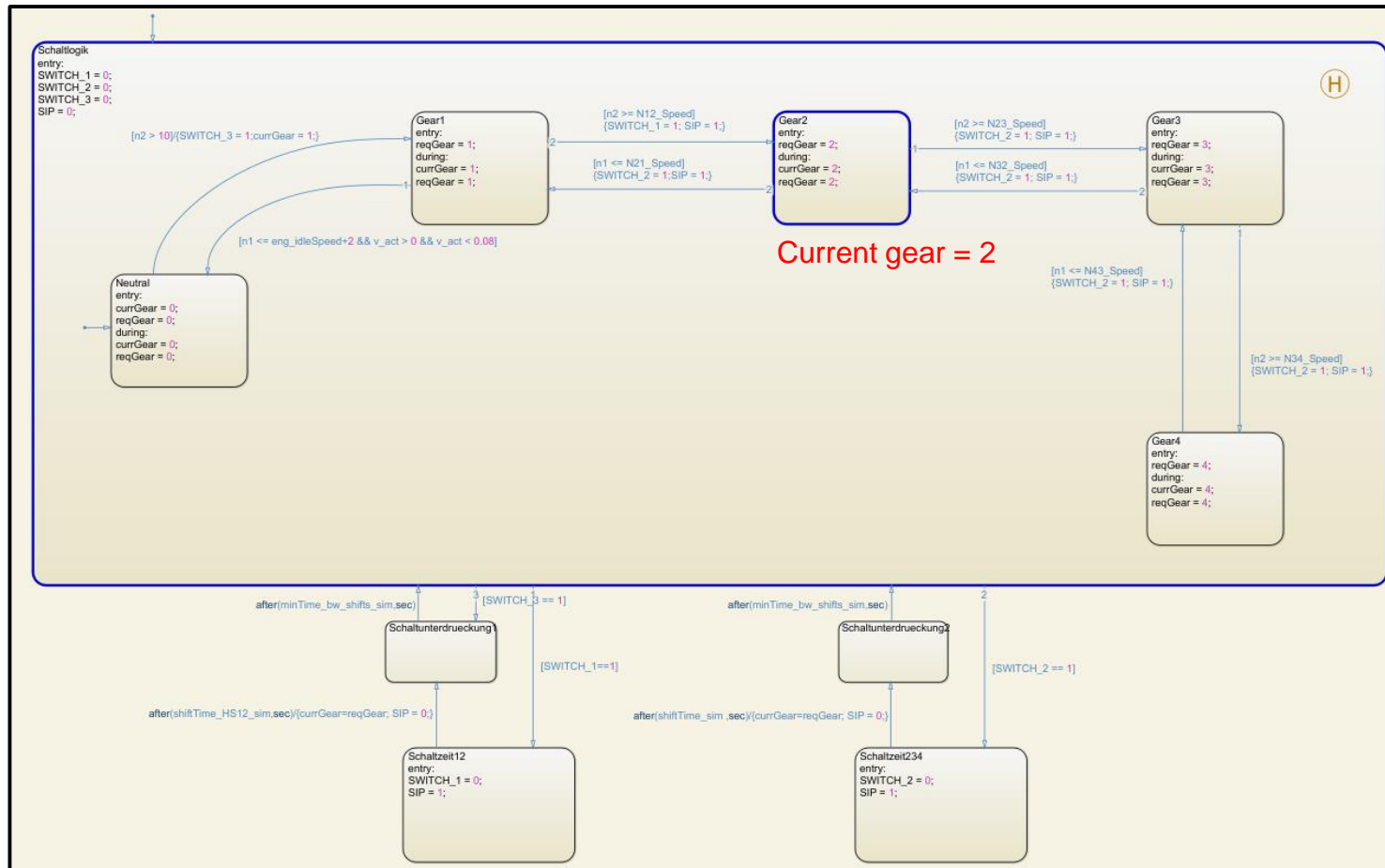
- If engine speed and engine torque in the *next gear* (see shift sequence) is above the upshift line AND
- the acceleration in the next gear is above a certain threshold if the driver is accelerating, i.e., $\text{acceleration_nextGear} > \min(\text{Min. acceleration threshold, Driver acceleration})$

Point for clarification:

As discussed before, the upshift happens, in our case, if the gearbox output speed is greater than the triggering speed. Does it also happen the same way (implementation) in Vecto ?!

Gear Shift Manager

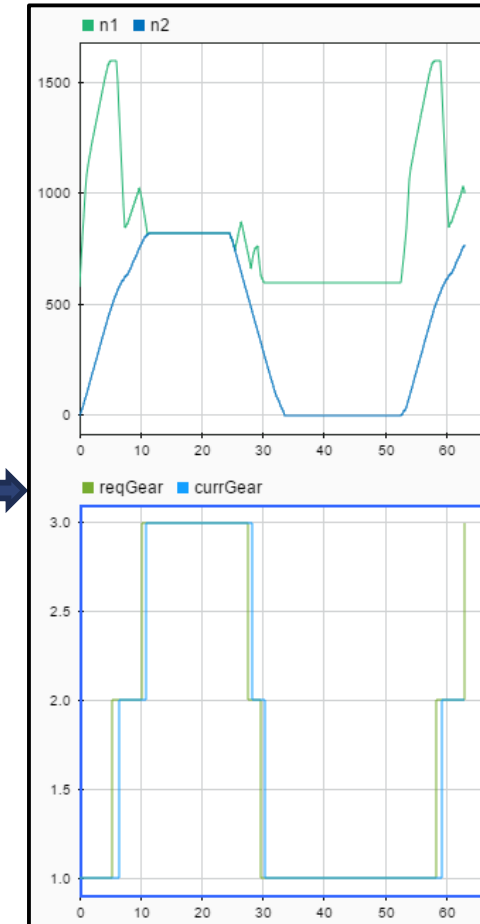
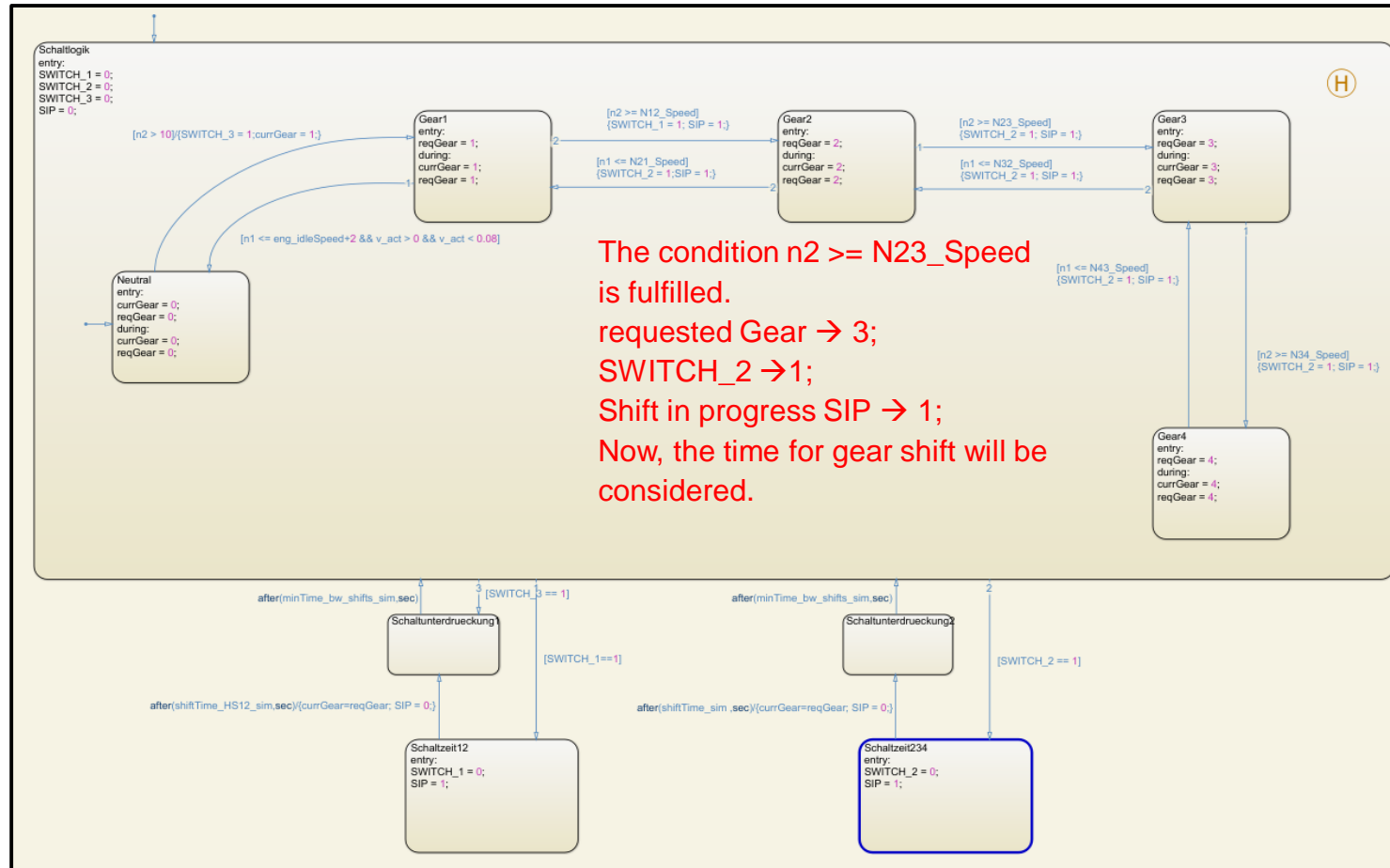
State Chart Example: 2→3 Upshift



t = 62.9 sec
requested Gear = 2
current gear = 2

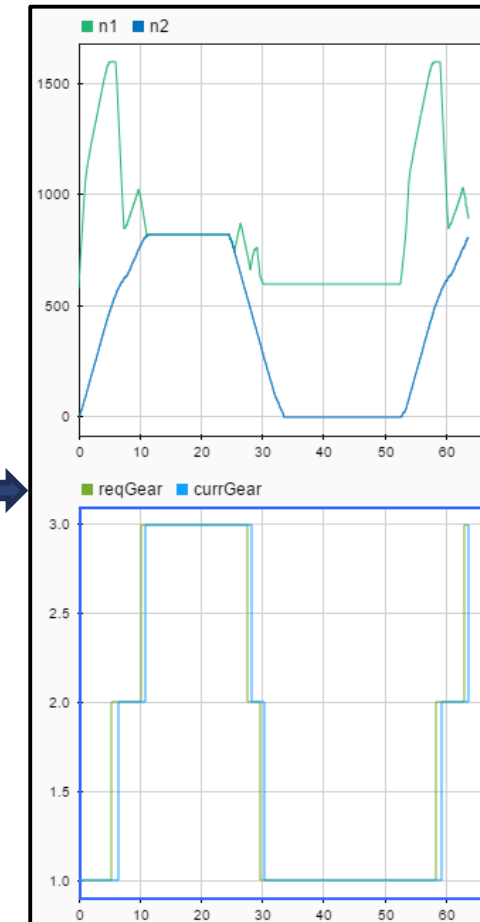
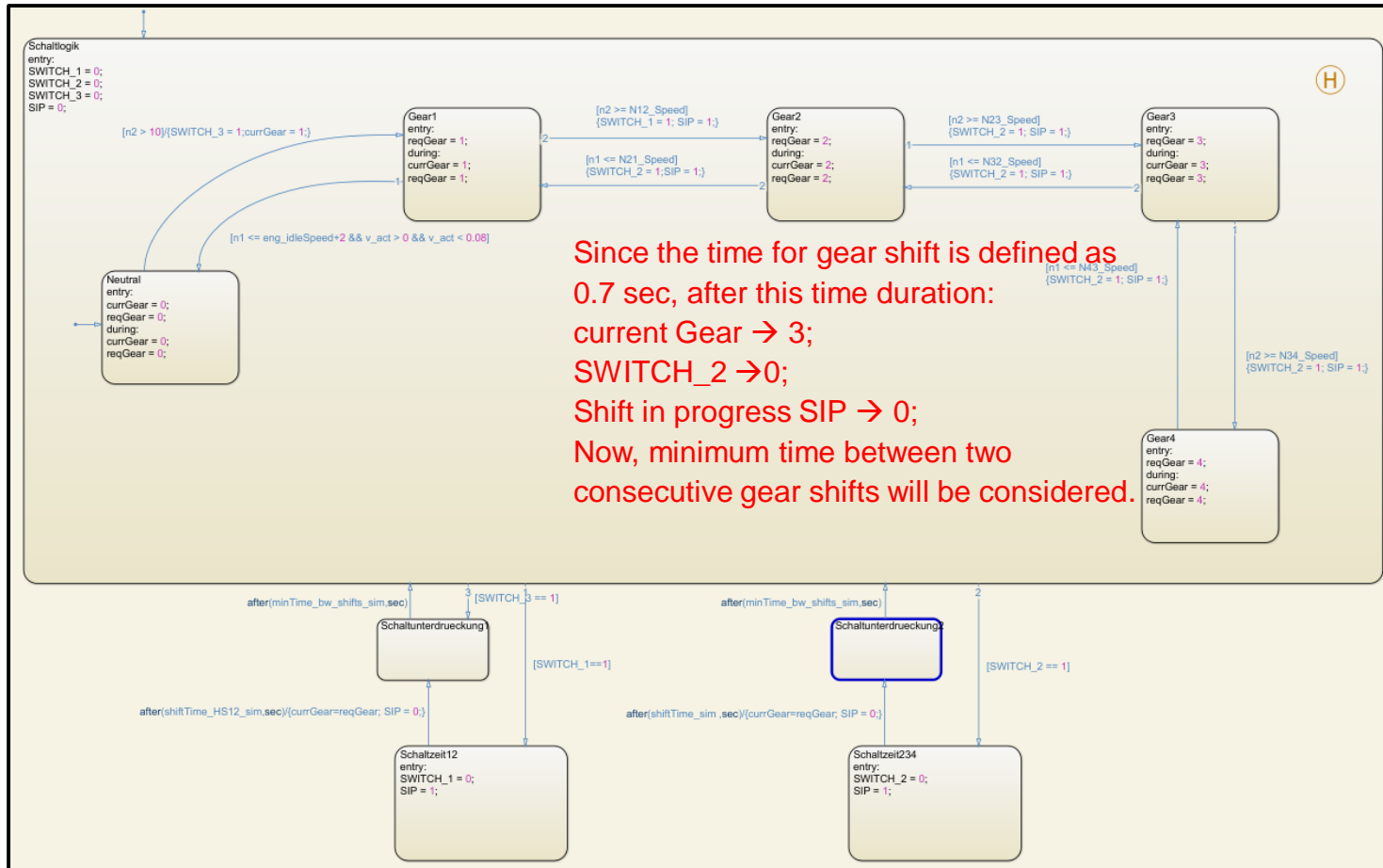
Gear Shift Manager

State Chart Example: 2→3 Upshift



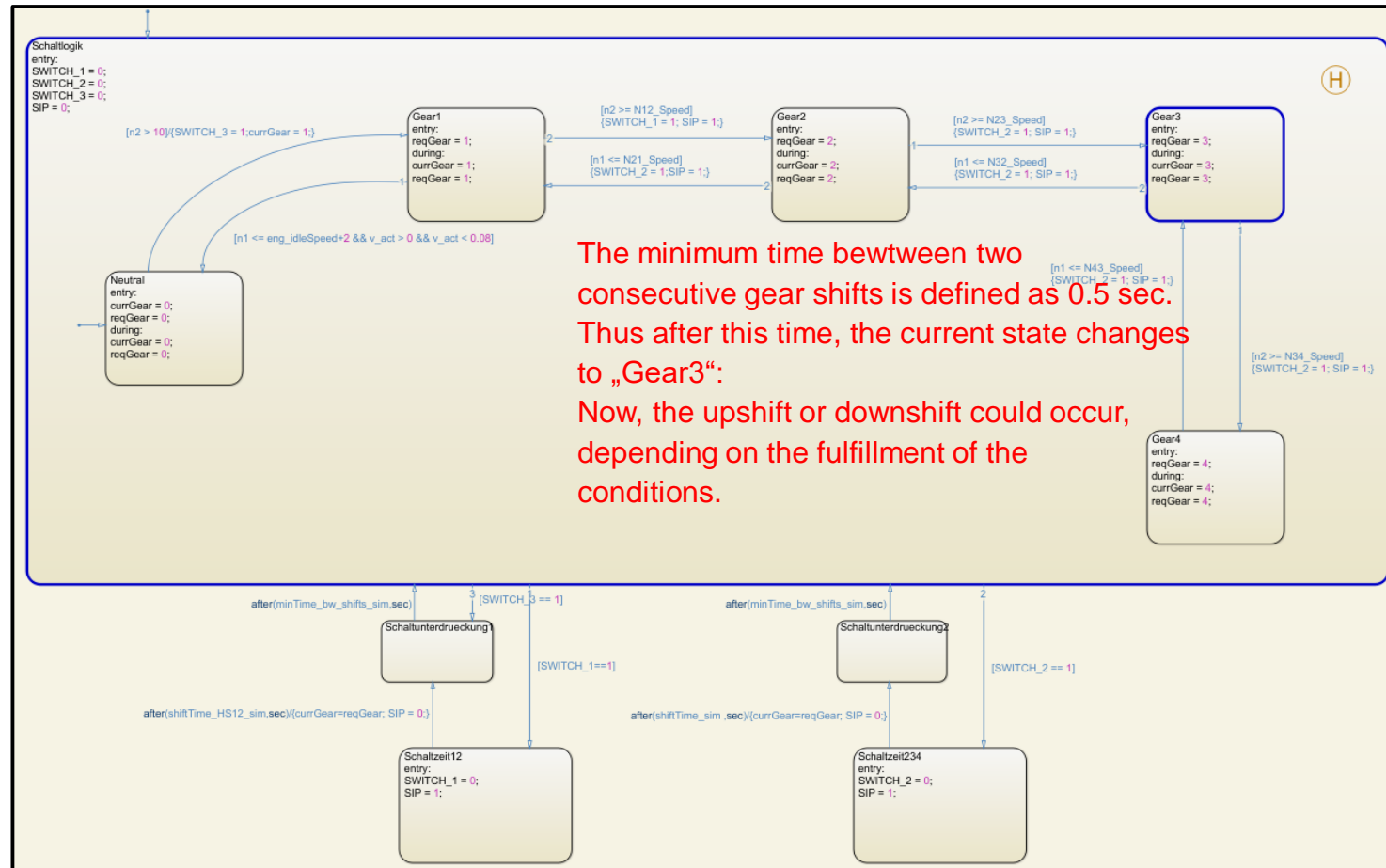
Gear Shift Manager

State Chart Example: 2→3 Upshift

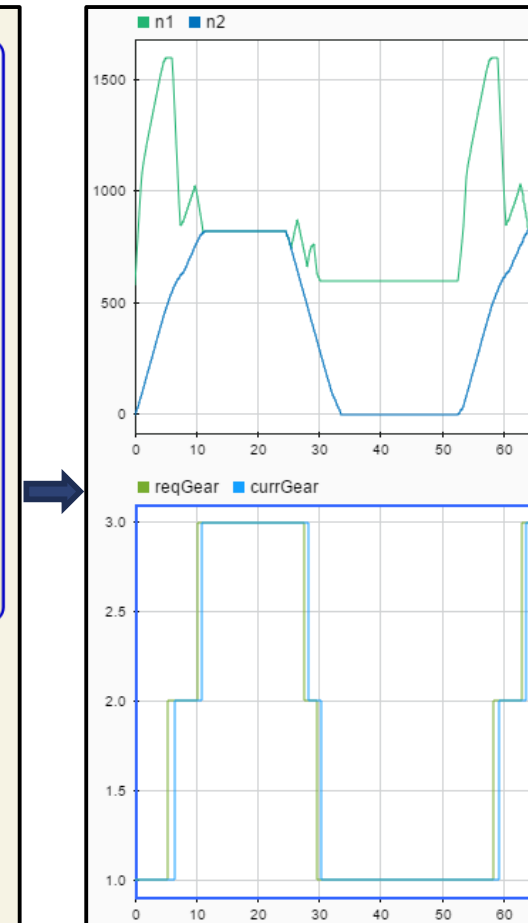


Gear Shift Manager

State Chart Example: 2→3 Upshift



The minimum time between two consecutive gear shifts is defined as 0.5 sec.
Thus after this time, the current state changes to „Gear3“:
Now, the upshift or downshift could occur, depending on the fulfillment of the conditions.



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