Lecture 1 Exercise 1

1

- Calculate by hand the speed of the vehicle after 100 seconds assuming a vehicle mass of 1000 kg and an applied force of 100 N
- Use basic Simulink blocks to make the same calculation.
- Compare the vehicle speed using all three methods:
  - Longitudinal Vehicle Dynamics Block_______
  - Simulink Basic Blocks _____
  - Hand Calculations ____

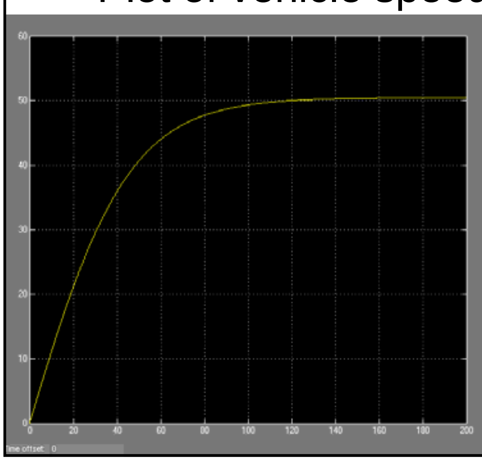
Demo__________

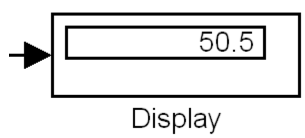
MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 1 Exercise 2

2

- System Testing
- Vehicle Terminal Velocity
- Plot of vehicle speed versus time.



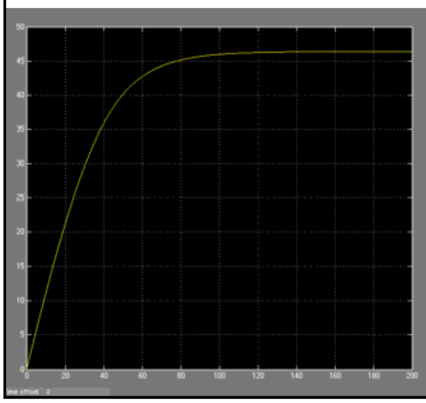


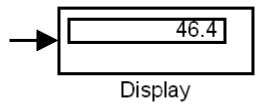
Demo__________

Lecture 1 Exercise 3

3

- You will need to sense the “motor” speed and convert it to rpm.
- You can do this using a 1-D lookup table.
- Plot the vehicle velocity and determine the vehicles velocity after 200 seconds.





Demo___________

Lecture 1 Exercise 4

4

- Show your completed Battery and Rear Diff and Body subsystems.
- Run a simulation that shows that your Battery:
  - Produces the correct output voltage for a given input current.
  - Calculates the correct battery state of charge for a given input current.

Demo___________

Lecture 2 Exercise 1

- The Simulation Runs!
- There appear to be some problems with our physical model.
- Demonstrate the operation of your model.
- The Speed Approaches 60 mph, but there are problems in the rpm signal.

Demo__________

Lecture 2 Exercise 2

- We would like our vehicle to be able to accelerate from 0 to 60 mph in 9 seconds.
- Determine:
  - Required motor torque________ (Nm)
  - Required battery current __________ (A)
  - The peak motor power __________ (kW)
- How does our model breakdown if the motor current is too large?

Demo__________

Lecture 3 Demo 1

7

- Demo of your vehicle running the AVL Drive Cycle

Demo___________

- Demo of your vehicle running the FU505 drive cycle.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 3 Exercise 1

8

- Part 1: Write an .m file that:
  - Clears all variables from the MATLAB workspace.
  - Asks the user to select an excel drive cycle and reads information in the file and stores the data with the same names as used when reading drive cycles with Excel.
  - Clears variables fn and pn from the workspace.
  - Saves the drive cycle variables in a .mat file with the same name as the excel file except with a .mat extension..

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 3 Exercise 1

- Part 2:
  - Create a new init file that is the same as the original init file except that the drive cycle is read as a .mat file rather than an excel file.
  - Using drive cycle "sch_fu505 ten times.xls", compare the time it takes MATLAB to complete each of your init files.
  - Use the tic and toc functions to see how long it haves to run each script file.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 4 Exercise 1

- The motor model has a problem in that the effective torque we request changes as the available torque goes down. The effectively changes the loop gain of our system and the motor rpm changes.
- We want to modify the model so that the torque request is always the maximum motor torque times the driver torque request. If the available motor torque is less than the torque request, then the available motor torque is used. If the available motor torque is greater than the torque request, then the torque requested is used.

Demo___________

Lecture 4 Exercise 2

11

- This motor has other problems:
  - What happens if the motor rpm is negative? Surely we want to use the vehicle in reverse.
  - What happens if the motor rpm exceeds the max rpm specified in the table?
- Fix the model so that the model works for negative values of rpm and that nothing catastrophic happens if the input rpm exceeds the max specified in the data file.
- You are not allowed to modify the data in the Excel file.

Demo__________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 4 Exercise 3

12

- In our plot, we see that the label for the electrical and mechanical power are not displayed in the Scope window.
- Fix this problem.

Demo__________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

13

Lecture 4 Exercise 4

- Demo of model working with motor efficiency and motor torque curve.

Demo__________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

14

Lecture 4 Exercise 5 Battery Model Improvements

- Different charge and discharge resistances.
- Resistance a function of battery SOC and temperature.
- Battery open circuit voltage is a function of battery SOC and temperature.
- Data contained in file “Battery Data.xls.”

Demo__________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

15

Lecture 5 Demo 1

- Engine demo at full throttle.

Demo___________

- Engine demo at zero throttle.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

16

Lecture 5 Exercise 1 Engine Model Improvements

- Add an “Engine on” signal to the engine model. When the engine is on, the fuel rate and the torque are determined by the lookup tables of the throttle cutoff.
- When the engine if off, the fuel rate is zero and the engine torque is a negative constant equal to – 15 Nm.
- Prove that your design works.
- Abrupt step changes in the output torque is not allowed.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

17

Lecture 5 Demo 2

- Demo of Stateflow controller charging the battery.

Demo__________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

18

Lecture 6 Exercise 1

Demo__________

- The generator appears to spin up the engine to the appropriate speed, the generator does not immediately start charging the battery. Instead there is a long delay before charging starts. This is an error.
- Fix the error so that charging starts as soon as the generators is up to speed.
- Your fixed model should have a plot as shown next.

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 6 Demo 1

- Demo the working controller.

Demo__________

Lecture 7 Demo 1

- Demo of System running the FU505 drive cycle five times

Demo__________

- Demo of model running the Consumer Reports drive cycle

Demo__________

- Demo of model running the Trip EPA Combined drive cycle.

Demo__________

Lecture 7 Exercise 1

- In the consumer reports drive cycle, we noticed large voltage spikes. The spikes we observed in the previous Consumer Reports slide are reduced because we used a large sample time and since the spikes were so fast.
- The next slide sets the Sample_Time to 0.01, and we see huge voltage spikes.
- Figure out the reason for the battery voltage spikes and update the model to prevent the problem, and show the drive cycle with the problem eliminated.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

22

Lecture 8 Exercise 1

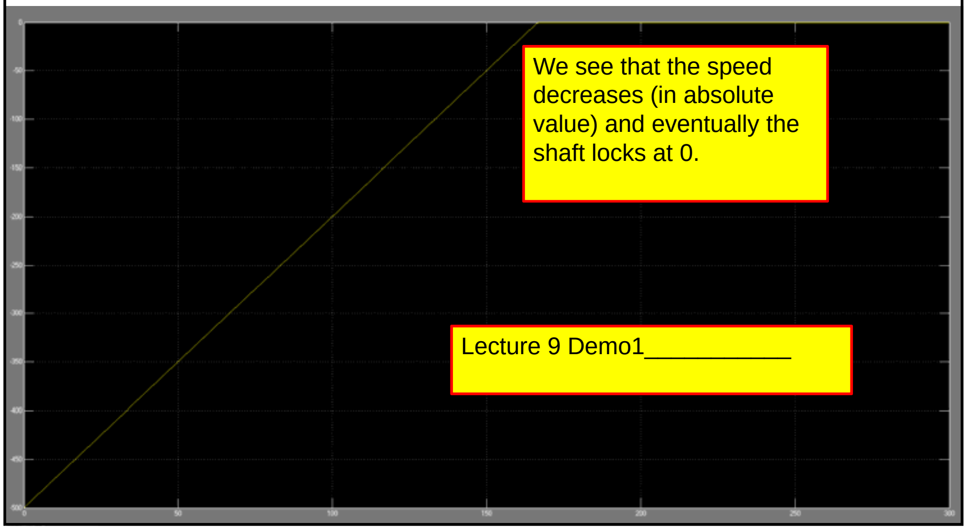
- Do the following:
  - Create an m-file that creates an equivalent plot to the one shown on the following slide. Use a legend to identify every trace, if necessary.
  - Name the m-file “post_Processing_Plot1.m”
  - Use the MATLAB commands
    - subplot
    - plot
    - xlabel
    - ylabel
    - title
    - axes
    - legend

Lecture 8 Exercise ___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

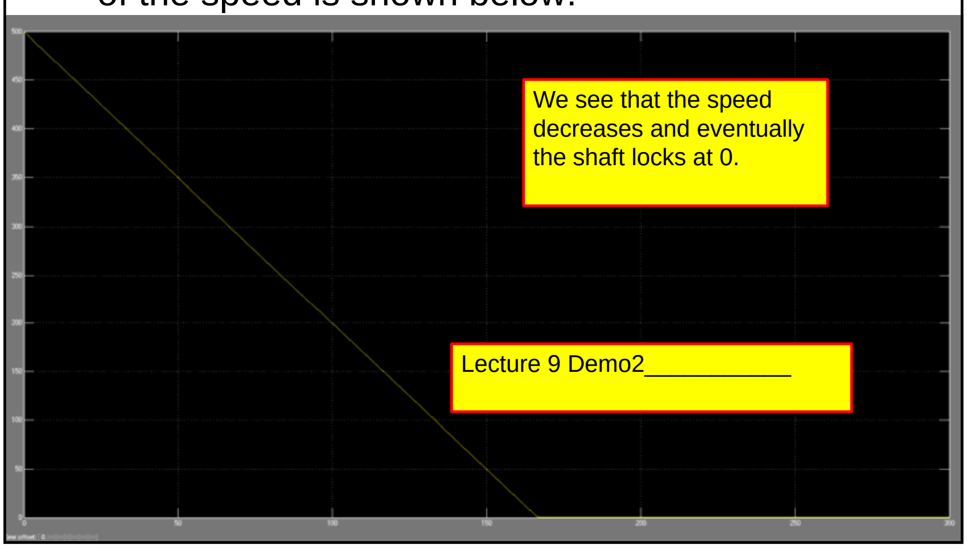
Brake Testing

- For an Initial condition of -1000 rad/sec, the plot of the speed is shown below:



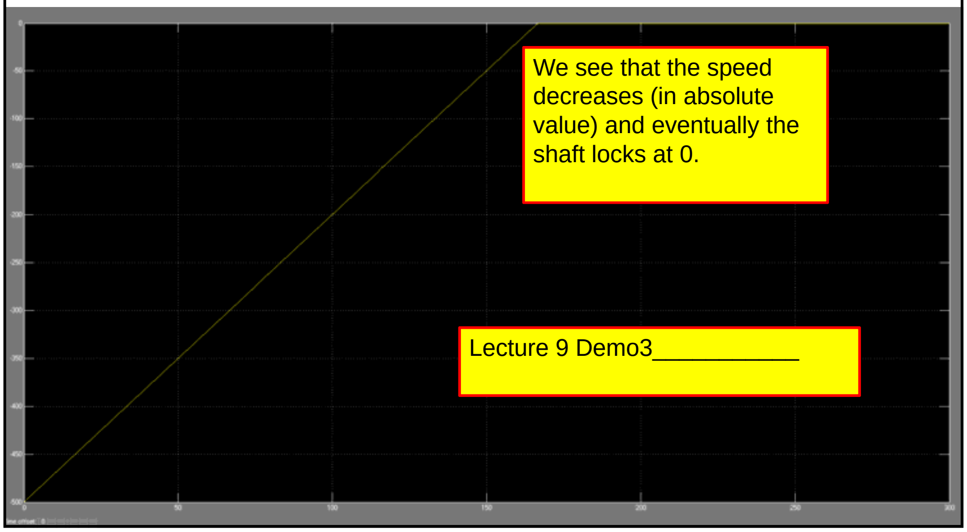
Brake Testing

- For an Initial condition of +1000 rad/sec, the plot of the speed is shown below:



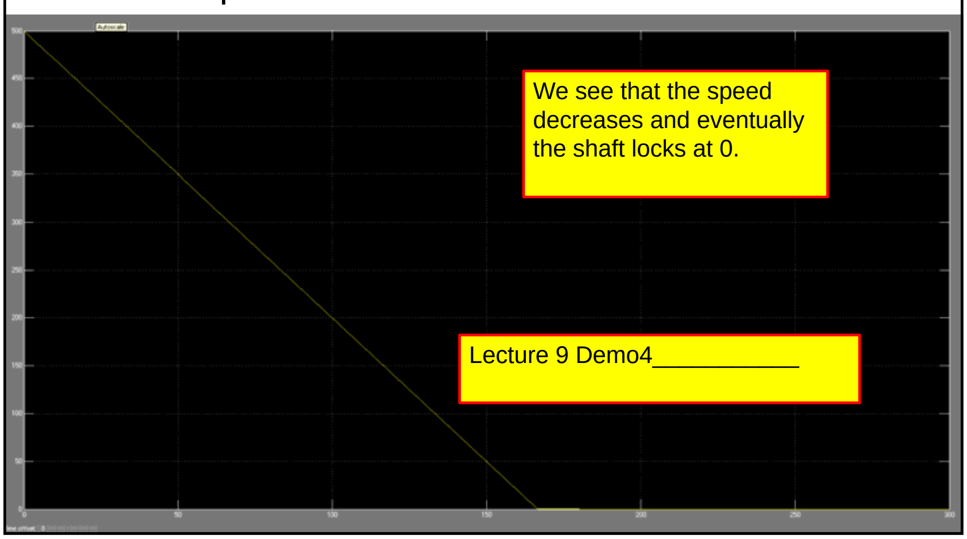
Brake Testing

- For an Initial condition of -1000 rad/sec, the plot of the speed is shown below:



Brake Testing

- For an Initial condition of +1000 rad/sec, the plot of the speed is shown below:



Lecture 10 Demo 1

Demo___________

Lecture 10 Exercise 1

- What is the “hash” that you are seeing in the previous slide?
- What is the cause of the problem?
- Determine a way to fix the problem and demo the Consumer Reposts City drive cycle showing that the problem has been eliminated.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 10 Exercise 2

29

- In Lecture 8 we calculated the fuel efficiency of a model that used only regen braking to slow the vehicle.
- In this lecture, we have now added foundation brakes, which can only reduce the efficiency of our vehicle.
- Compare the efficiency of your vehicle from lecture 8 to the efficiency of this vehicle using of the FU505 and Consumer Reports City drive cycles.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 10 Exercise 3

30

- Show that as the SOC is changed from 0 to 1, the total braking torque request from the driver (signal Foundation_Brake_Request plus Regen_Brake_Request) is unchanged.
- Set the Battery_SOC to a constant value and sweep the driver brake request from 0 to 1.
- Generate a plot and show that to total braking request is unchanged and independent of Battery_SOC.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

31

Lecture 10 Exercise 4

- Show that as the SOC is changed from 0 to 1 and the vehicle speed is changed from 0 to 10 mph, the total braking torque request from the driver (signal Foundation_Brake_Request plus Regen_Brake_Request) is unchanged.
- Set the Battery_SOC to a constant value and the vehicle speed to a constant value, and sweep the driver brake request from 0 to 1.
- Generate a plot and show that to total braking request is unchanged and independent of Battery_SOC and vehicle speed.

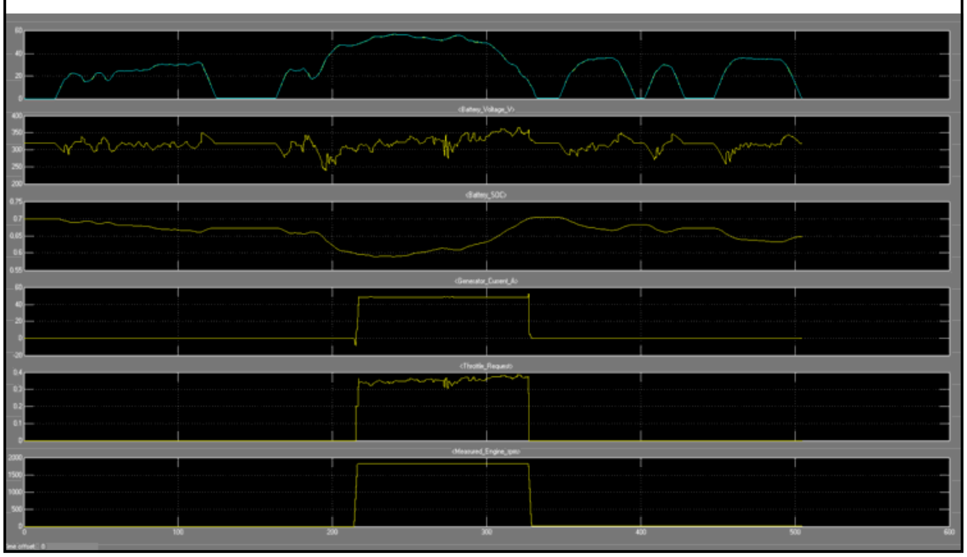
Demo__________

32

Lecture 11 Demo 1

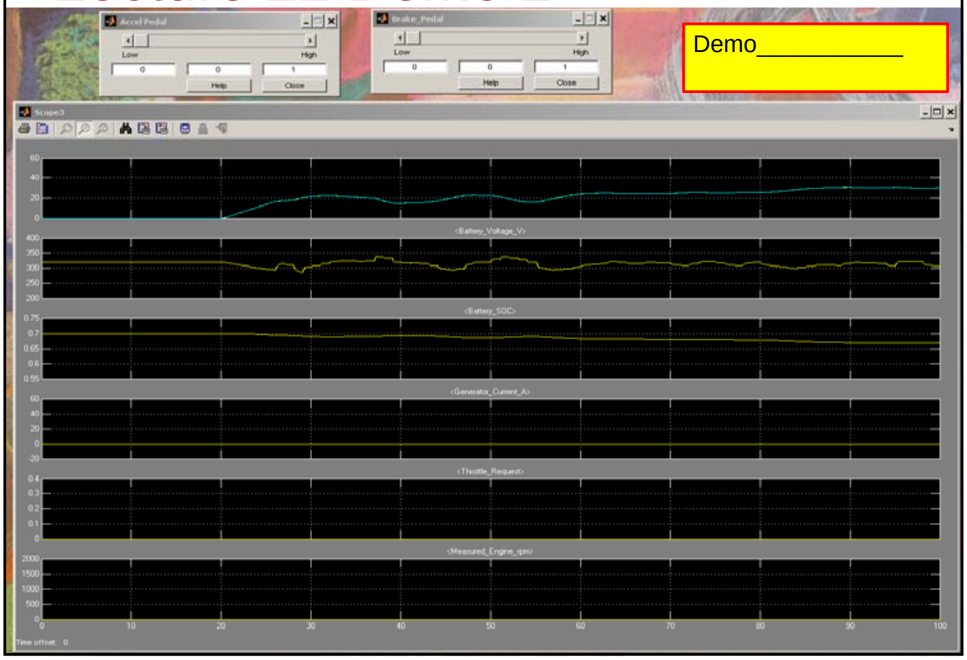
Demo__________

- Demo the working model of the rearranged system.



33

Lecture 11 Demo 2



Demo___________

34

Lecture12 – Exercise 1

- Demonstrate the operation of the Vehicle Key Switch and the Battery Connect command. Show the following:
  - Startup_and_Shifting chart as it walks through the startup procedure.
  - The battery voltage showing the operation of the contactor.
  - The battery status signal showing the various states.
  - Show a plot similar to the one shown on the next two slides.

Demo___________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

35

Lecture12 – Exercise 2

- Demonstrate the operation of the Vehicle Key Switch, Battery Connect, Motor Enable, and Generator Enable Commands. Show the following:
  - Startup_and_Shifting chart as it walks through the startup procedure.
  - The status signals showing the various states of each component.
  - Show a plot similar to the one shown on the next two slides.
  - Plots are shown on the next two slides

Demo__________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

36

Lecture12 – Exercise 3

- Demo of everything working.
- I will try to brake your model.

Demo__________

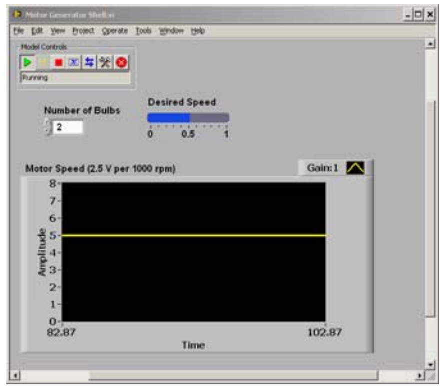
MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

37

Lecture 13 Demo1

- Demonstrate the working model running in real-time.

Demo___________



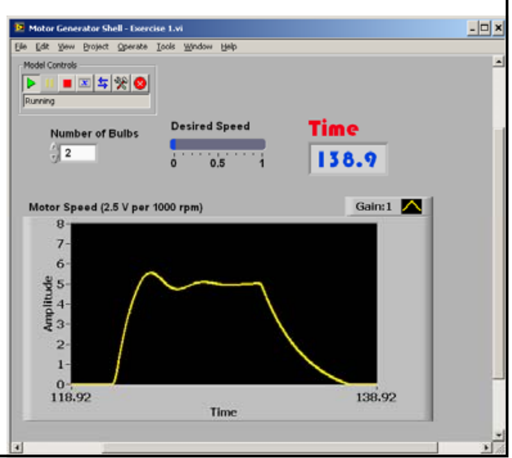
MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

38

Lecture 13 Exercise 1

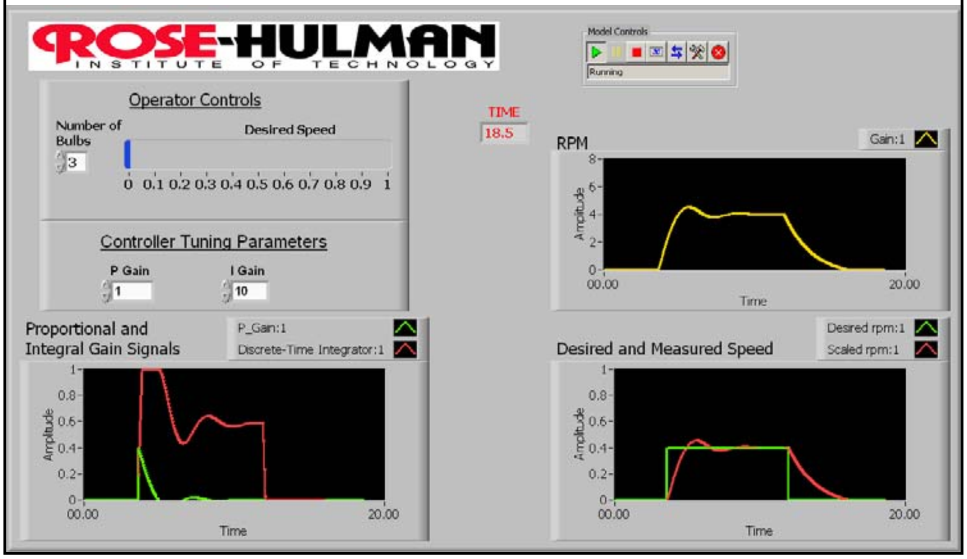
- Modify the front panel so that the current simulation time is displayed as shown. The time should display a total of 4 digits, one of which shows time to the tenth of a second. Note that Bauhaus font is being used.

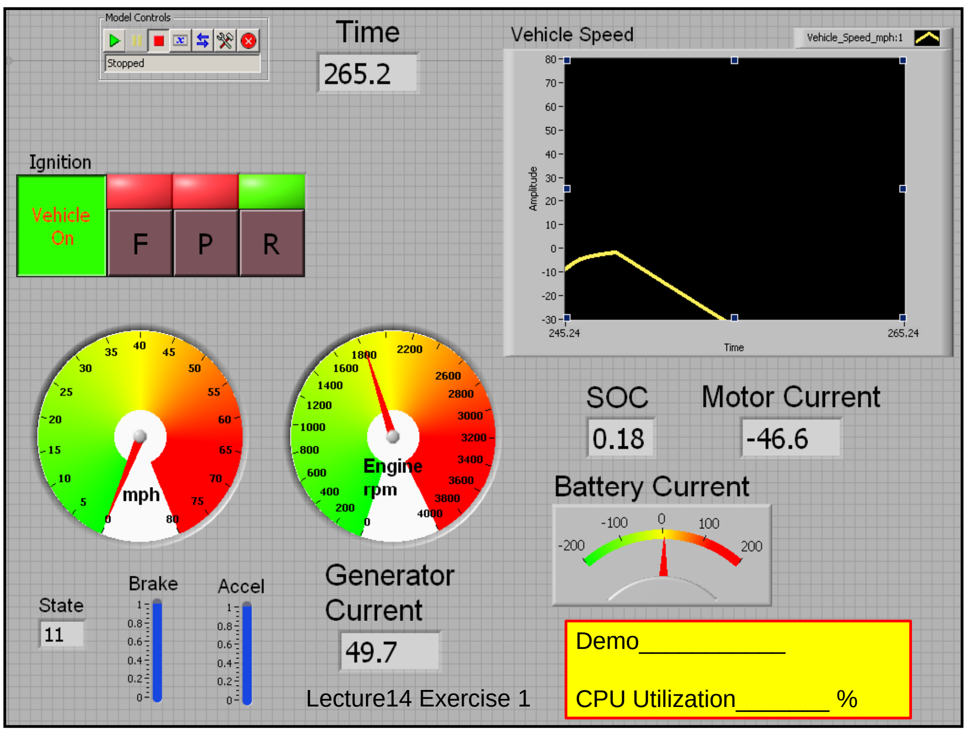
Demo___________



Lecture 13 Exercise 2

Demo___________

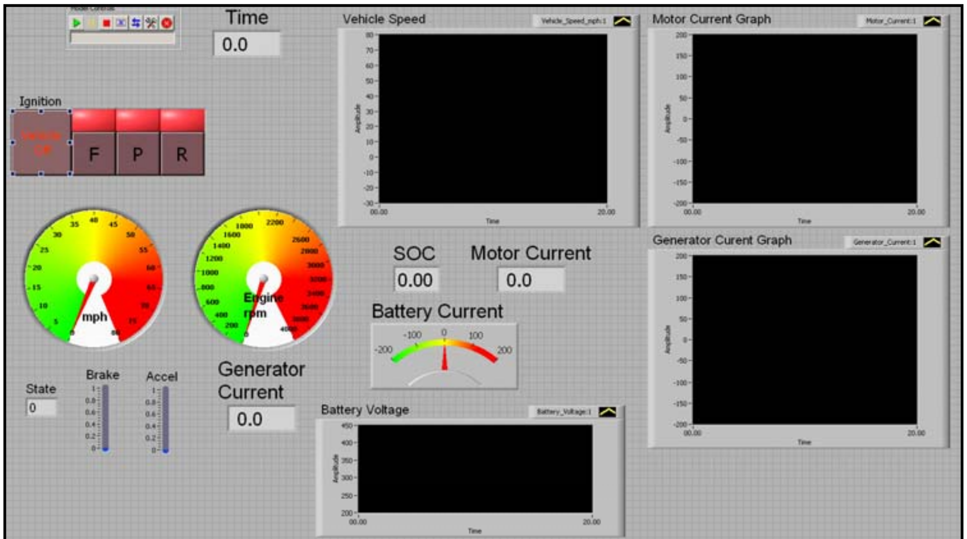




Lecture14 Exercise 1

Demo___________

CPU Utilization________ %



Lecture14 Exercise 2

Demo___________

CPU Utilization_______ %

Lecture 14 Exercise 3

- As a first fix, we will use the ODE14x solver and a time step of 0.001 seconds.
- The problem with this solution is that it may take too much CPU power to run the model.

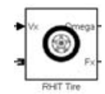
Demo___________

CPU Utilization_______ %

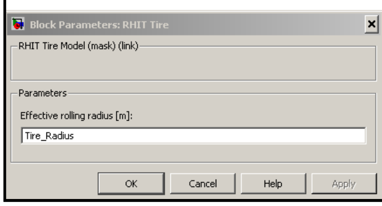
43

Lecture 14 Exercise 4a

- Create a subsystem for the new tire model.
- Create a mask for the subsystem that:
  – Specifies the tire radius as an input parameter to the model.
  – Displays the tire picture as shown.



  – Displays the name “RHIT Tire Model” rather than “Subsystem.”



Tire Masked Subsystem
____

44

Lecture 14 Exercise 4b

- With this new tire model, the model should behave well using a large step size (0.01 or larger) and the ODE14x solver is note needed.
- We will notice
  – Low processor utilization.
  – The model does not blow up any more.
  – The motor current now behaves.
- A screen capture of this model running in real-time is shown on the next slide.

Demo___________

CPU Utilization_______ %

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

45

Lecture 14 Exercise 5

- Modify the control algorithm as follows:
  - Under normal conditions, the generator will charge the battery at 50 A.
  - If the battery SOC goes below a value of 0.58, a new algorithm kicks in where the battery charges at the motor current plus 10% with some averaging. (What should happen if regen braking kicks in and the motor current flips?)
  - The minimum charging current in this mode is 50 A.
  - This method continues until the battery is charged back up to 0.7.
  - Once the battery is charged to 0.7, the normal charging algorithm kicks back in.

Demo___________

CPU Utilization_______ %

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

46

Lecture 14 Exercise 6

- One of the modifications we made to the model is that we reduce the braking torque at vehicle speeds below 3 mph.
- As we drive the vehicle in real-time, this becomes very annoying because the vehicle takes a long time to slow down below 3 mph.
- We made this modification because we had numerical problems with the brakes at low speed.
- With the new tire model, the braking problem may no longer be an issue.
- Modify the brakes so that we can apply full braking torque at speeds of 0.25 mph and higher.
- Verify your design and prove that it works.

Demo___________

CPU Utilization_______ %

47

Lecture 16 Demo 1

- Demo the Operation of the MotoTron ECU blinking lights. The CAN baud rate should be 500 k.

Demo___________

48

Lecture 17 Demo 1

- Demo of MotoTune with the Motor/generator system
  - MotoHawk Probes display measurements
  - MotoHawk override controls motor speed.

Demo___________

Lecture 17 Demo 2

49

- Demo of Motor/generator with the proportional feedback control system.

Demo___________

Lecture 17 Demo 3

50

- Demo of Motor/generator with the proportional feedback control system with the following
  - Foreground process set to a trigger rate of 1 ms
  - Modifying the feedback gain with MotoHawk calibrations.
  - Viewing the Error Signal

Demo___________

Lecture 17 Demo 4

51

- Demo of Motor/generator with the PI feedback controller.

Demo___________

Lecture 17 Demo 5

52

- Demo of Motor/generator with the PI feedback controller and constant voltage feedback.

Demo___________

Lecture 18 Demo ECU1

53

- ECU1: CAN Communication
  - Fred – ECU 1 Turns on LED when it receives value of -3127. Value sent with MotoHawk Probe.________
  - LED3 – Turn on and off an LED connected to ECU1. One bit signal sent by ECU2.________
  - Pulsewidth – Receive signal of 0 to 100 from ECU2. ECU1 Receives the signal and emits a PWM signal that controls the motor speed._________
  - Temperature – ECI1 Receive CAN signal from ECU2 and display value with probe.___________
  - Cooling FAN – Receive 10bit Signal from ECU2. Display with MotoHawk Probe. _________

Lecture 18 Demo ECU2

54

- ECU2: CAN Communication
  - Receive four sine waves from ECU1. Display values on a chart ._________
  - Potentiometer– Receive potentiometer signal from ECU1. Scale signal and emit a PWM signal that controls the motor speed._________
  - ECU2 receives signals for time, a ramp (shark tooth), and a sine wave over the CAN bus. The values will be displayed with probes and a chart. _________

Lecture 19 Exercise 1

- Demonstrate a working HIL system with the controller logic unchanged. You will need to:
  - Use MotoTune to debug and display many of the controller input and output signals.
  - Define some m-files for the missing CAN signals.
  - Wire the driver control board to your ECU.
  - Debug a lot of wrong connections and signal associations.
- You should be able to drive you vehicle with the driver controls.

Demo___________

Lecture 19 Exercise 2a

- Investigate an earlier model that we ran in Matlab.
- Add delay to the feedback loops to model the delay introduced by the periodicity of the CAN messages.
- Show that the control loops for maintaining constant engine rpm and constant oscillate when we add 20 ms delays to the incoming and outgoing signals.
- This should prove the theory that the reason the system is unstable is the added delay due to latency in the CAN network.

Demo___________

Lecture 19 Exercise 2b

57

- In the controller model running on the MotoTron ECU, add calibration blocks that allow us to change the feedback gains of the engine speed loop and the generator current loop.
- Determine the feedback gain of both loops necessary to obtain constant and stable charging currents.

Demo__________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY

Lecture 19 Exercise 3

58

- In Exercise 2b, we find that the proportional gains have to be reduce so much that the engine rpm and generator currents are quite far away from the desired values.
  - The loops are stable but we have a large error because the gains are so small.
- To fix this problem, add integrators to both loops and add calibration blocks so that we can tune both the proportional and integral gains of each loop separately.
- Show that the error goes to zero and that the system is stable. (A little bit of overshoot is acceptable.)
- You will need to build your own digital integrator and make sure that it saturates (or has limits on how big the value can grow).

Demo__________

MotoTron The MathWorks freescale semiconductor ROSE-HULMAN INSTITUTE OF TECHNOLOGY