/

Learning Report – MBSE

Course Code: <CODE>



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| 2 | 23rd Sept 2020 | Amit Das | Arun U (99002594), Hemanth Kumar (99002592) | To be: Pagala Prithvi Shekhar,  Srinivas K | Included table of content and list of figures |
| 3 | 25th Sept 2020 | Amit Das | Arun U (99002594), Hemanth Kumar (99002592) | To be: Pagala Prithvi Shekhar,  Srinivas K | Added all required links and source code |
| 4 | 26th Sept 2020 | Amit Das |  | To be: Pagala Prithvi Shekhar,  Srinivas K | Edited to match the standard template |

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**PS Number: 99002591**

**Document History**

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# Activity 1: KNOWING MBSE: Case Study on MBSE at Gulfstream Aerospace

## Introduction

Gulfstream equipped its entire shop floor with CATIA V5 software, workstations and dual monitors. This allows the shop floor workforce to bring up the models and query necessary information in real time without having to wait for others. The 3D models reduce ambiguity in interpretation and avoid time delays. Separate electrical analysis to ensure that the critical signals are routed as designed. The team can trace any electrical signals throughout the airplane. Gulfstream extensively applies numerical controlled (NC) machining and precision manufacturing. Because of the 3D MBD data and precision manufacturing, the produced components are of much higher quality than before, which speeds up assembly time. For example, [Jeff Kreide](http://www.hpcuserforum.com/presentations/tuscon2013/GeneralDynamicsSalzman_OPK.pdf), vice president of Business Solutions with Gulfstream, pointed out that the barrel joining assembly used to take five people three and one-half days to complete. Now the components can be well aligned and assembled in just 15 minutes.

## Requirements

High Level Requirements

|  |  |
| --- | --- |
| ID | DESCRIPTION |
| HL\_01 | Fully electronic MBD system. |
| HL\_02 | Reusing old acquired data for newer models |
| HL\_03 | Reduction in cost of development |
| HL\_04 | Reduction in assembly time |
| HL\_05 | Lower paint job time. |

Low Level Requirements

|  |  |
| --- | --- |
| ID | DESCRIPTION |
| HL\_01\_LL\_01 | Identification of critical and non-critical mission parameters |
| HL\_01\_LL\_02 | Model everything including fasteners, hoses etc. CATIA V5 |
| HL\_02\_LL\_01 | Reuse MBD data of G450 to make G650 entirely on MBD approach. |
| HL\_03\_LL\_01 | Reduce standard part numbers by more than 50%. |
| Hl\_03\_ll\_01 | Applied numeric control machining. |
| HL\_03\_LL\_03 | Reduce number of outfitting clips and brackets from 450 to 6 |
| HL\_04\_LL\_01 | Reduce barrel joining assembly time to 15mins. |
| HL\_04\_LL\_02 | Use of ProjectWorks with multiple high-resolution laser projectors. |
| HL\_05\_LL\_01 | Use of 3D laser projection to prepare an aircraft for painting. |

## Testing and software used

1. CATIA V5

To provide a true 3D electronic representation of the aircraft every part on the aircraft was modelled as nominal geometries.

1. Project Works

Using this software along with multiple high resolution laser projectors, Gulfstream projects the fastener maps directly onto the airplane body. The projectors coordinate with each other to ensure that the projected image bends and reshapes onto the curved body of the plane.

1. Gulfstream Symmetry Flight Deck

Fully featured model based systems engineering tool with simulator support.

1. Matlab and Simulink

Simulink, Aerospace blockset and Simulink coder used to model the digital flight control system and flight dynamics.

1. MSC NASTRAN
2. HyperWorks Suite
3. Abaqus
4. Smarteam

MODEL IN LOOP

The actual model of the aircraft is designed to capture the most real world data readings during a simulation. Then the controlled is designed and modelled so that it can control the model of the aircraft as per requirement.

SOFTWARE IN LOOP

Once the model is verified in MIL, the next stage is Software in Loop, where the code is generated from the controller model and controller block is replaced with this code. This gives clarity on whether the controller logic is hardware implementable. In case the input output logs match with that of MIL, we move to the next step.

PROCESSOR IN LOOP

The controller model, i.e, the logic block in SIL is loaded onto an embedded processor and is run in a closed loop simulation with simulated model of aircraft and dynamics from the MIL.

HARDWARE IN LOOP

Once the above steps are successful a lab scale model of the actual hardware is built and tested while being controlled by the embedded processor from the PIL step.

# Activity 2: APPLIED LEARNING

## Logical Equation Modelling

Expression: ((a<b) && !(b>c)) || ((a==c) && !(b==2))

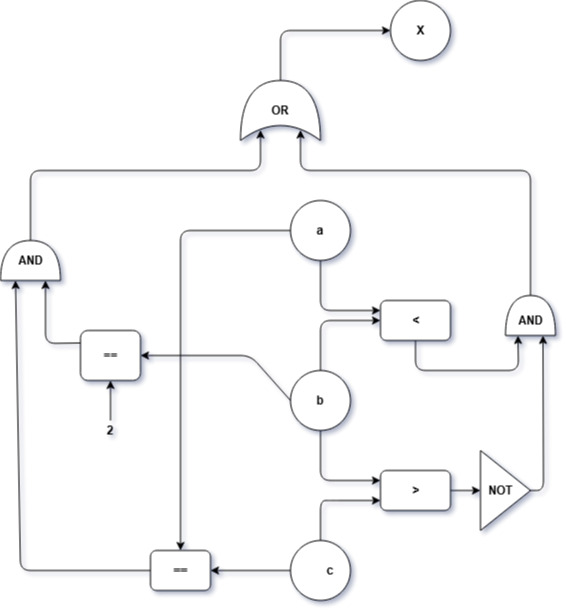


Figure 1: Logical equation model

## Second order differential Equation Modelling

Expression: R(di/dt) + L(d2i/dt2) + (1/C)I = (dV/dt)

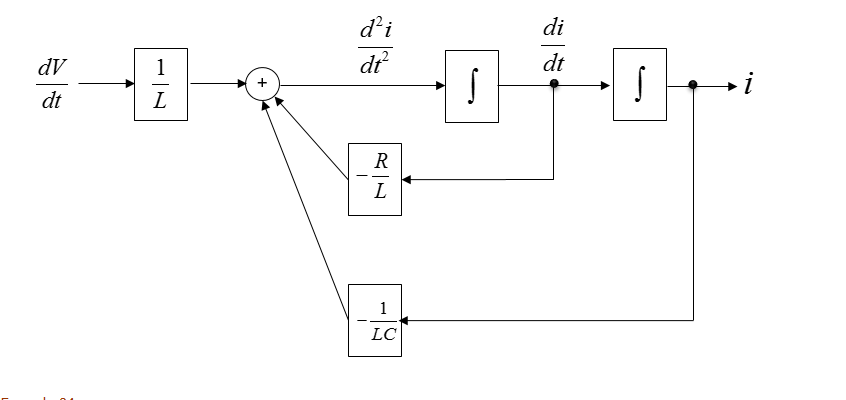


Figure 2: Second order differential equation model

## First order differential Equation Modelling

Expression: i(t) = (x(t) – y(t))/R = Cy’(t)

* RCy’(t) + y(t) = x(t)
* y’(t) = (1/RC)[x(t) – y(t)]

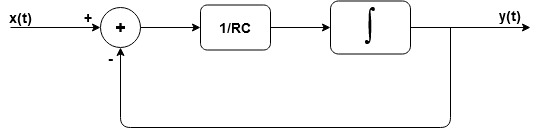


Figure 3: First order differential equation model

## Linear Difference Equation Modelling

Expression: y[n] = x[n] + 4y[n-1]

* x[n] = y[n] – 4y[n-1]

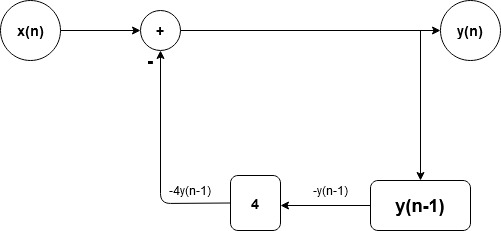


Figure 4: Linear differential equation model

# Activity 3: MATLAB

## Algorithm Development

##### Project Name: Ride Quality analyzer

##### REQUIREMENTS:

* HL\_01 : Develop an algorithm to analyze ride quality post the ride
* HL\_02 : The raw sensor data is captured through AndroSensor app on android phone
* HL\_03 : Sufficiently large dataset should be generated
* HL\_01\_LL\_01 : Taking into account the accelerometer data and sampling time, the instantaneous acceleration on all three axes are found out
* HL\_01\_LL\_02 : Vector sum of the acceleration gives us the acceleration vector in 3D
* HL\_01\_LL\_03 : Similar processes is followed for the gyroscope data
* HL\_01\_LL\_04 : Sensor fusion is done through a custom function (\*\*Filter has not been used)
* HL\_03\_LL\_01: Sampling time should be 0.001s

Documentation:

<https://lnttsgroup.sharepoint.com/:w:/r/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/_layouts/15/Doc.aspx?sourcedoc=%7BE36CC9DD-836A-4B42-98FB-9915E9226274%7D&file=ride_quality.doc&action=default&mobileredirect=true>

Code:

<https://lnttsgroup.sharepoint.com/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/Shared%20Documents/Forms/AllItems.aspx?originalPath=aHR0cHM6Ly9sbnR0c2dyb3VwLnNoYXJlcG9pbnQuY29tLzpmOi9zL0dFQS9HbG9iYWwlMjBFbmdpbmVlcmluZyUyMEFjYWRlbXkvR0VBJTIwSW5zaWdodHMvR2VuZXNpcy9FdF96am9MSF9qUk10Tl9LNFp2Xy1aOEJhTG03SDJNUXlWdTV5dnNUMGFBV1FRP3J0aW1lPW1rNnREaHRoMkVn&id=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FMatlab%2FA4%2DALGO%2Fride%5Fquality%2Em&parent=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FMatlab%2FA4%2DALGO>

Custom function:

<https://lnttsgroup.sharepoint.com/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/Shared%20Documents/Forms/AllItems.aspx?originalPath=aHR0cHM6Ly9sbnR0c2dyb3VwLnNoYXJlcG9pbnQuY29tLzpmOi9zL0dFQS9HbG9iYWwlMjBFbmdpbmVlcmluZyUyMEFjYWRlbXkvR0VBJTIwSW5zaWdodHMvR2VuZXNpcy9FdF96am9MSF9qUk10Tl9LNFp2Xy1aOEJhTG03SDJNUXlWdTV5dnNUMGFBV1FRP3J0aW1lPW1rNnREaHRoMkVn&id=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FMatlab%2FA4%2DALGO%2Fsensor%5Ffusion%2Em&parent=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FMatlab%2FA4%2DALGO>

Input data:

<https://lnttsgroup.sharepoint.com/:x:/r/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/_layouts/15/Doc.aspx?sourcedoc=%7B0B137B6F-58BB-4457-8834-BCF82A930EB0%7D&file=log.csv&action=default&mobileredirect=true>

Output log:

<https://lnttsgroup.sharepoint.com/:x:/r/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/_layouts/15/Doc.aspx?sourcedoc=%7B59BC1585-D7CA-4729-A57F-44FA3080ACBA%7D&file=ALL_DATA_LOGS.csv&action=default&mobileredirect=true>

Output of the algorithm

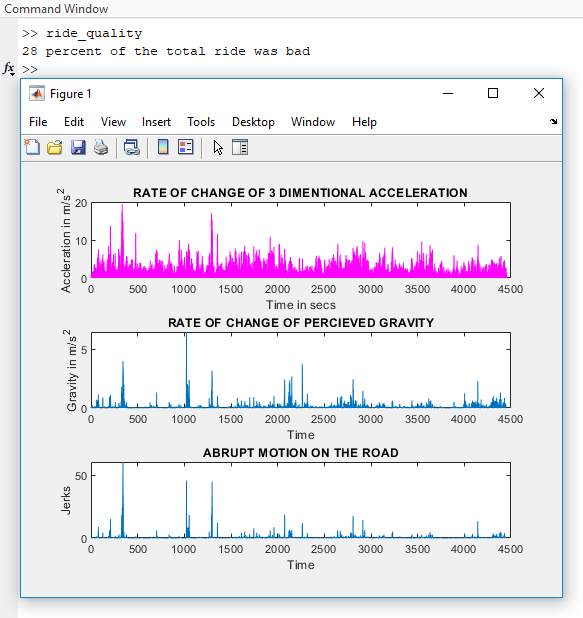


Figure 5 : Output of the program

## Automation Script

Documentation

<https://lnttsgroup.sharepoint.com/:w:/r/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/_layouts/15/Doc.aspx?sourcedoc=%7B82D3D939-E18F-40D2-A4AE-337DAB46DAD4%7D&file=script.doc&action=default&mobileredirect=true>

Code

<https://lnttsgroup.sharepoint.com/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/Shared%20Documents/Forms/AllItems.aspx?originalPath=aHR0cHM6Ly9sbnR0c2dyb3VwLnNoYXJlcG9pbnQuY29tLzpmOi9zL0dFQS9HbG9iYWwlMjBFbmdpbmVlcmluZyUyMEFjYWRlbXkvR0VBJTIwSW5zaWdodHMvR2VuZXNpcy9FdF96am9MSF9qUk10Tl9LNFp2Xy1aOEJhTG03SDJNUXlWdTV5dnNUMGFBV1FRP3J0aW1lPW1rNnREaHRoMkVn&id=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FMatlab%2FA5%2DAUTO%2Fscript%2Em&parent=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FMatlab%2FA5%2DAUTO>

Input file

<https://lnttsgroup.sharepoint.com/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/Shared%20Documents/Forms/AllItems.aspx?originalPath=aHR0cHM6Ly9sbnR0c2dyb3VwLnNoYXJlcG9pbnQuY29tLzpmOi9zL0dFQS9HbG9iYWwlMjBFbmdpbmVlcmluZyUyMEFjYWRlbXkvR0VBJTIwSW5zaWdodHMvR2VuZXNpcy9FdF96am9MSF9qUk10Tl9LNFp2Xy1aOEJhTG03SDJNUXlWdTV5dnNUMGFBV1FRP3J0aW1lPW1rNnREaHRoMkVn&id=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FMatlab%2FA5%2DAUTO%2Fltts%2Ehtml&parent=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FMatlab%2FA5%2DAUTO>

Output data

<https://lnttsgroup.sharepoint.com/:x:/r/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/_layouts/15/Doc.aspx?sourcedoc=%7B408A71B7-6547-4F71-9B69-FA1CE5CB5D6F%7D&file=ALL_DATA.xlsx&action=default&mobileredirect=true>

## Matlab Onramp Certification



Figure 6: Matlab Onramp certificate

# Activity 4: SIMULINK

## Simulink Models

Instruments Cluster

Instruments Cluster Test

Voltage to Kelvin

Voltage to Kelvin Test

Kelvin to Celsius

Kelvin to Celsius Test

Celsius to Fahrenheit

Celsius to Fahrenheit Test

Voltage to Kelvin to Celsius to Fahrenheit

Voltage to Kelvin to Celsius to Fahrenheit Test

Voltage to Speed (Voltage to m/s to km/hr)

Fuel gauge

Indicator

## Debugging methods in Simulink

Pausing Simulation:

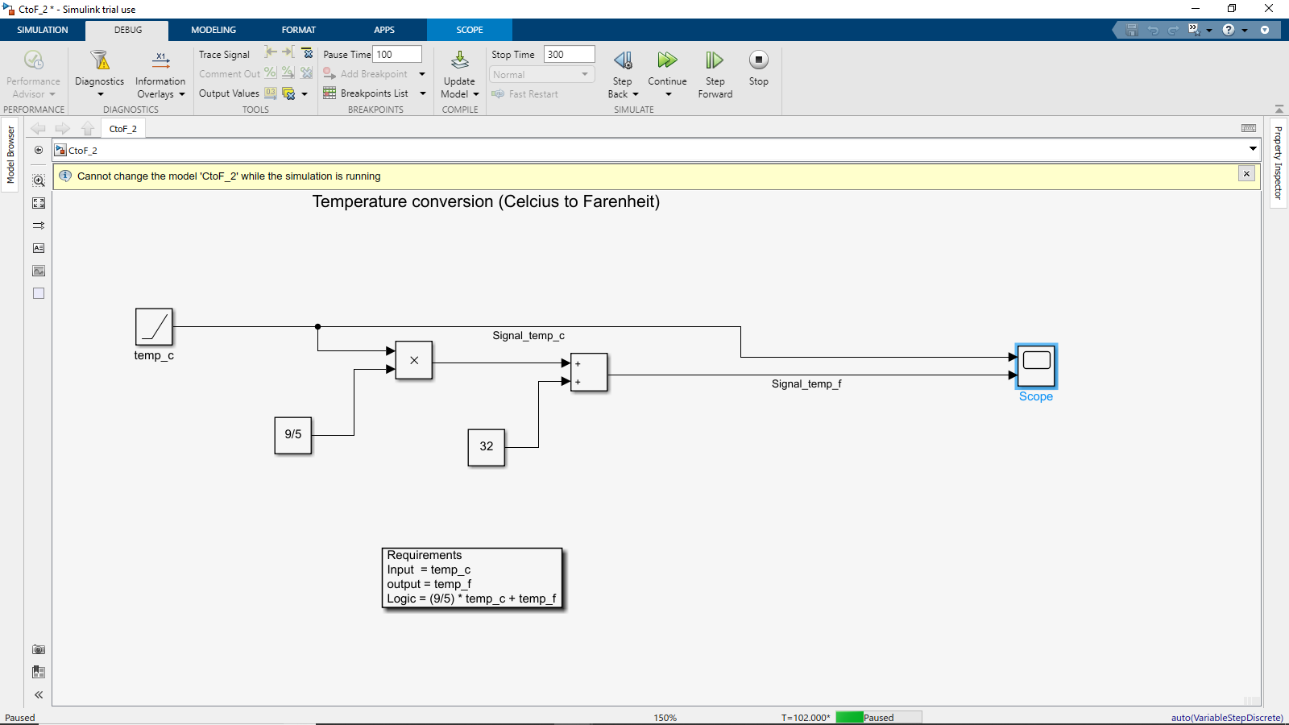


Figure 7: Pause time

Value label

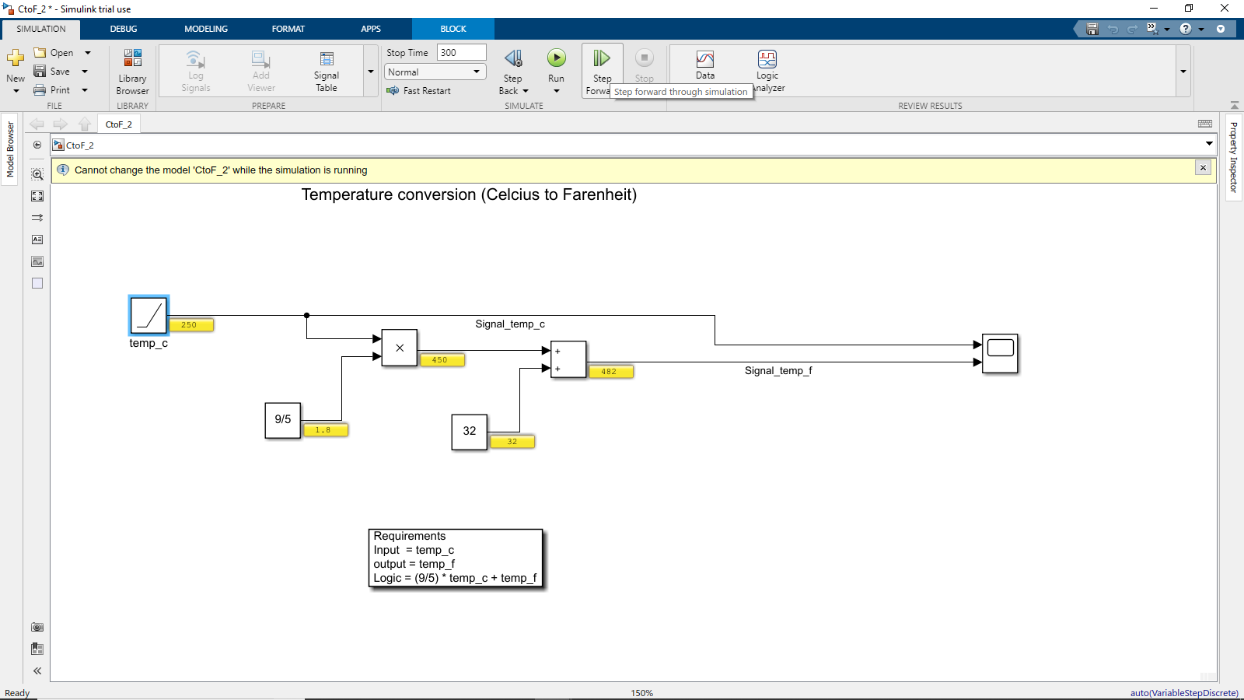


Figure 8: Value label

Breakpoint

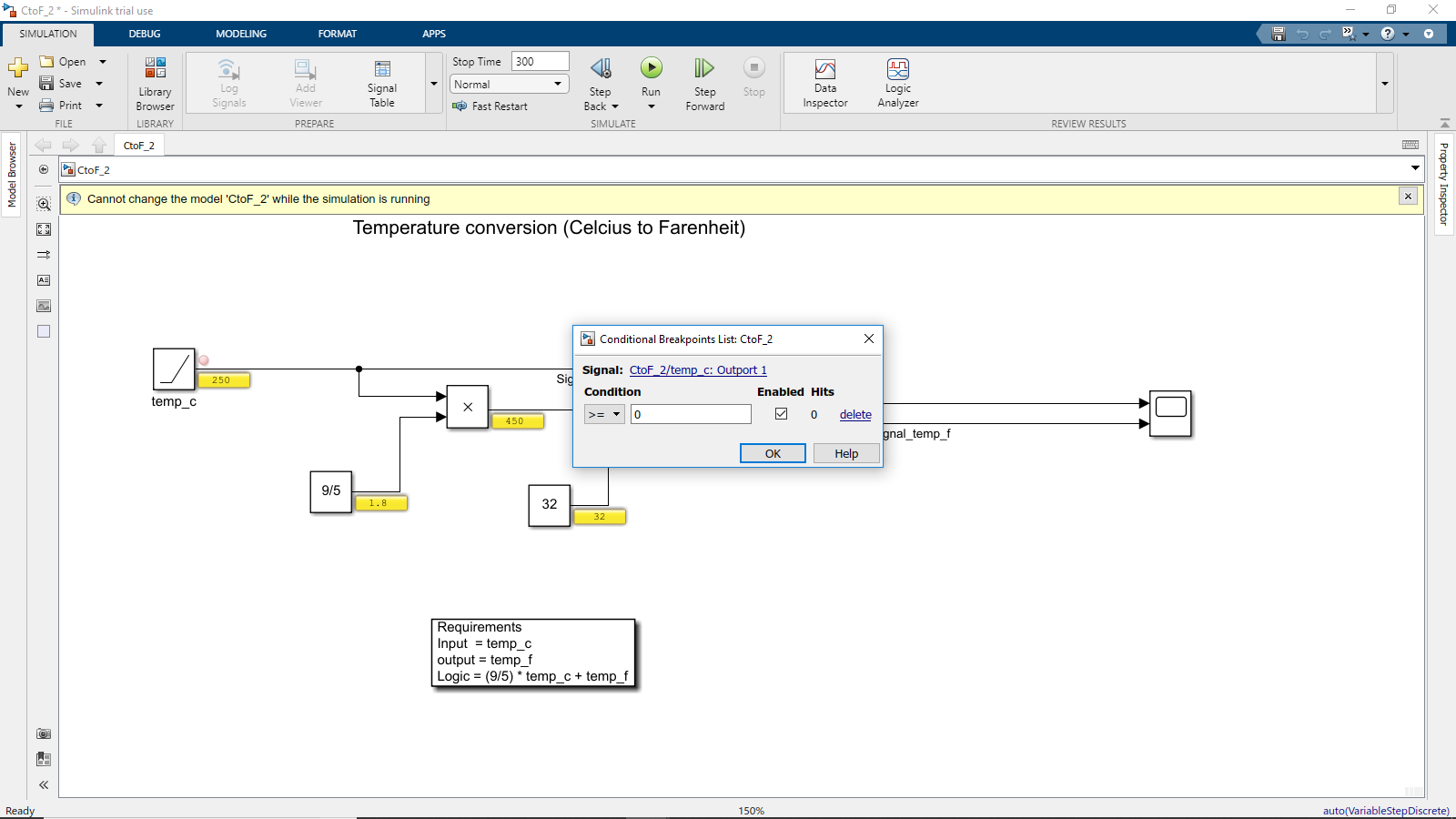


Figure 9: Breakpoint

Execution Order

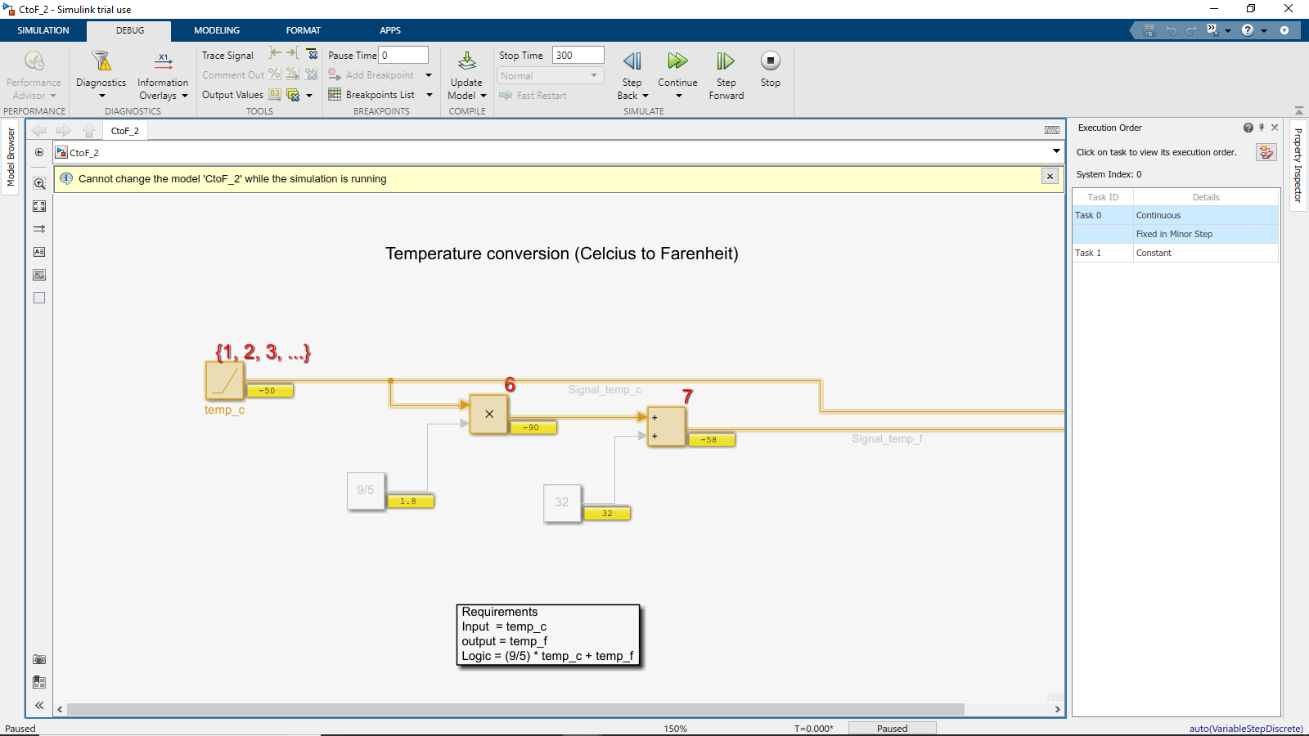


Figure 10:Execution order

Colored legend

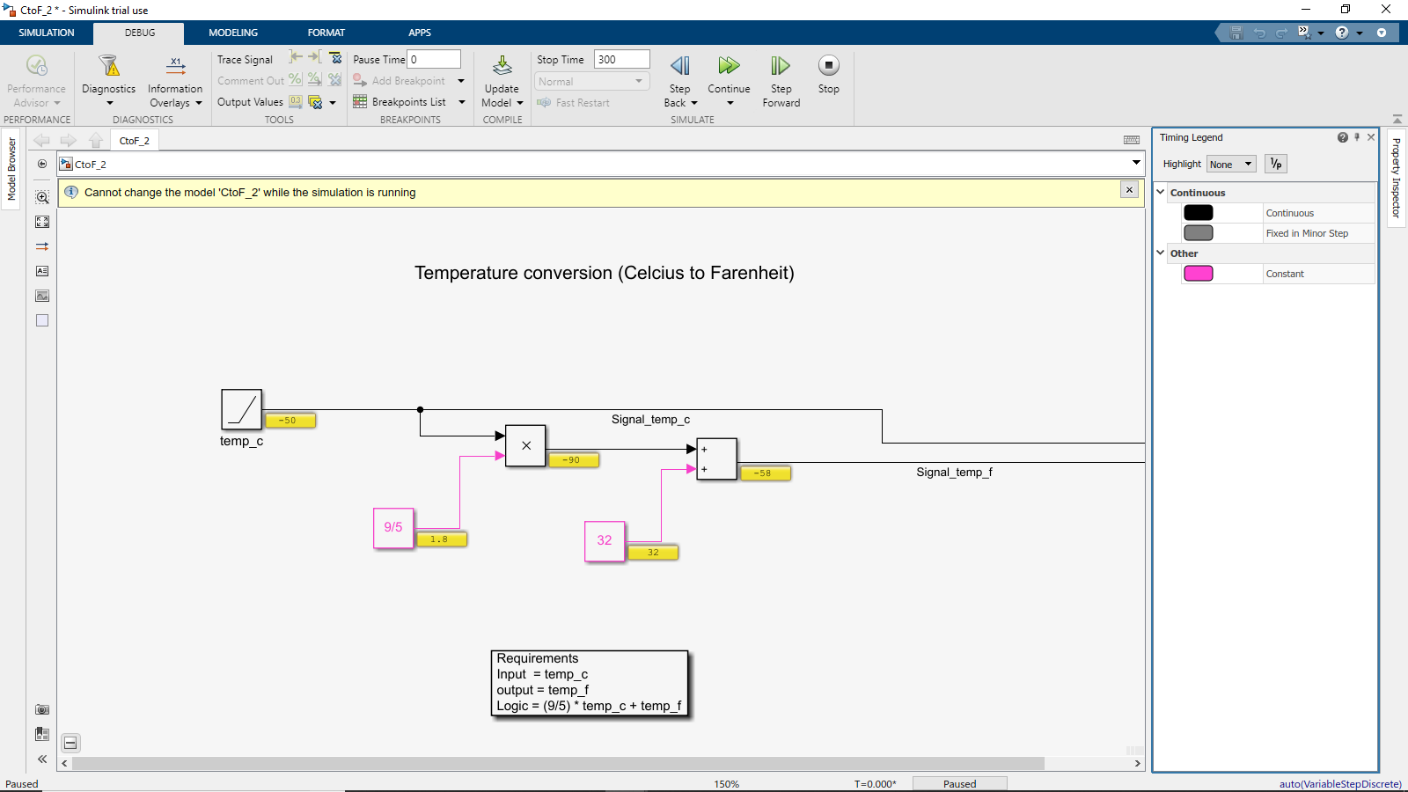


Figure 11: Colored legend

Logging

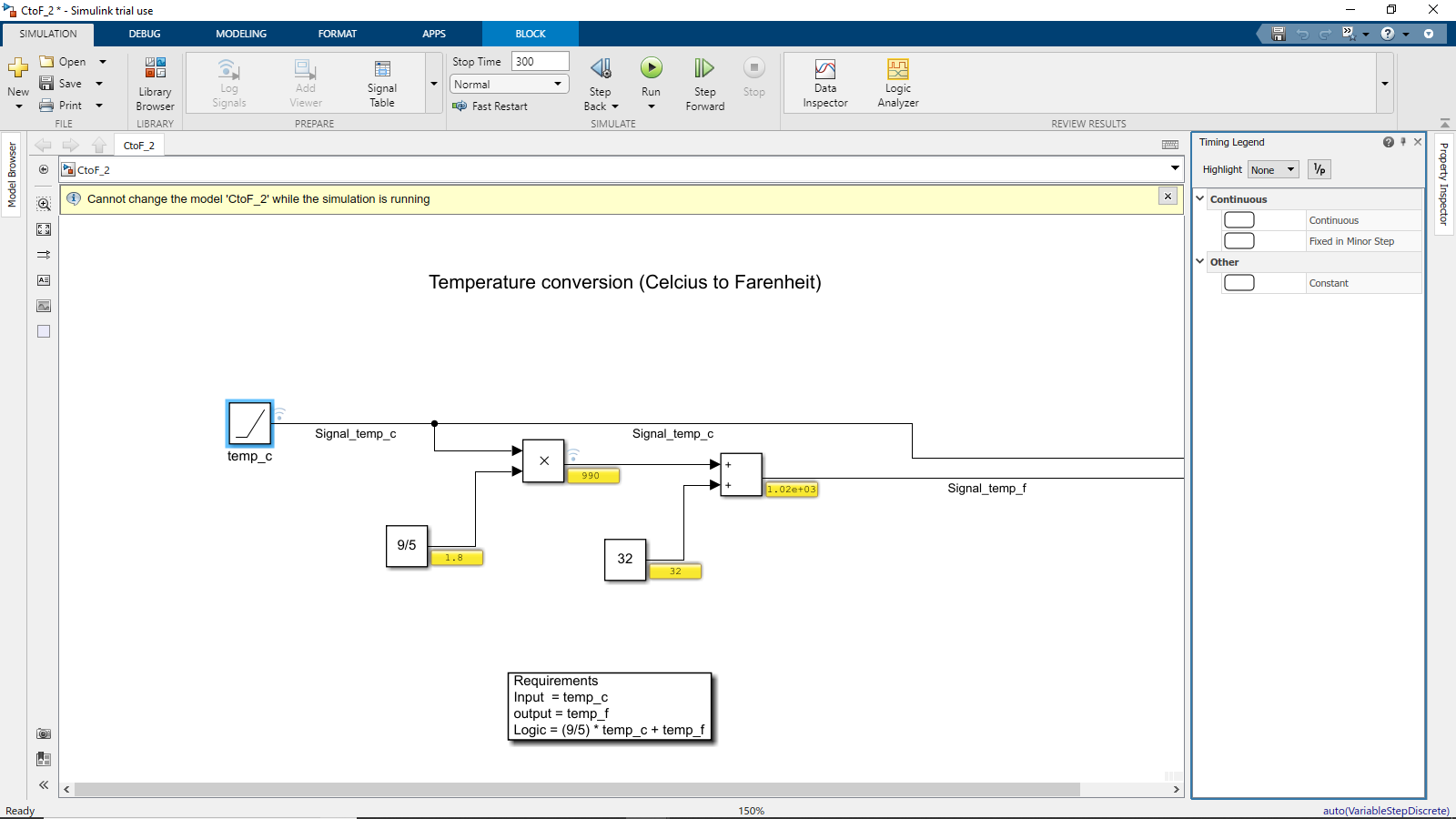


Figure 12: Signal logging

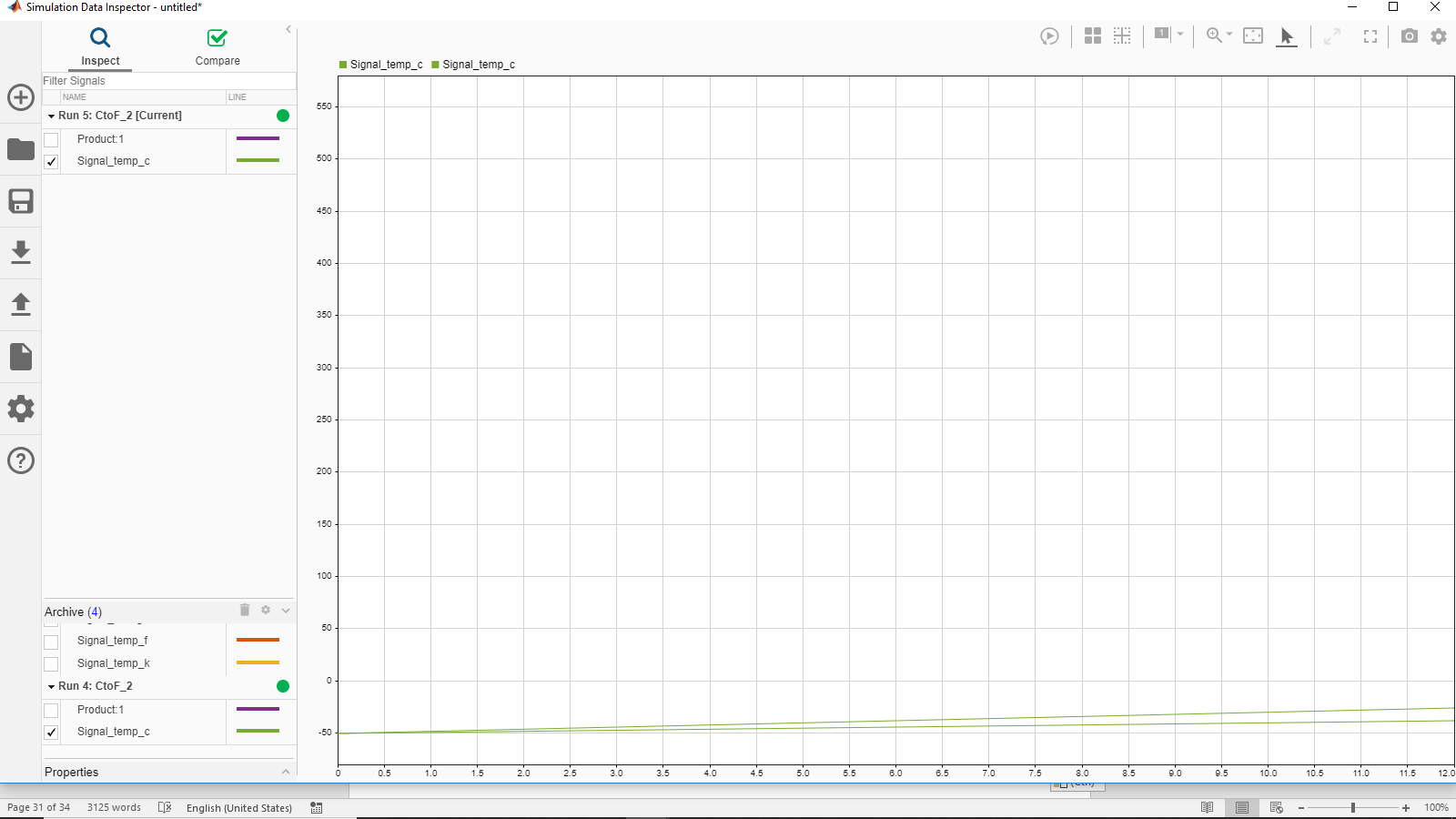


Figure 13: Comparison of two logged signals

Highlight to Source and Destination

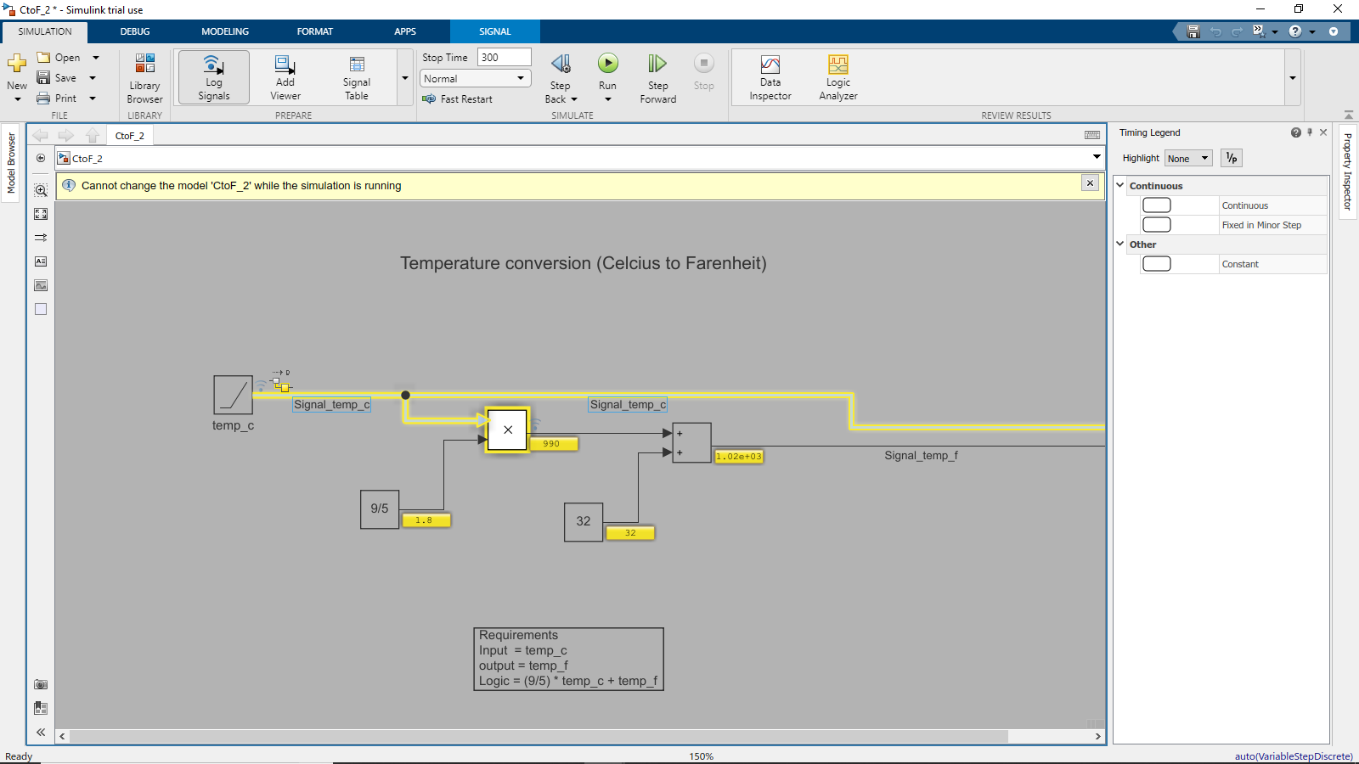


Figure 14: Highlight source to destination

## Subsystems in Simulink

Atomic

An atomic subsystem is a Subsystem block with the block parameter Treat as atomic unit selected. Non-atomic Virtual (or non-atomic) subsystems are simply a visual convenience, but Simulink treats the subsystems as if all the blocks existed at the same level.

Triggered

The Triggered Subsystem block is a Subsystem block preconfigured as a starting point for creating a subsystem that executes each time the control signal has a trigger value.

Enabled

The Enabled Subsystem block is a Subsystem block preconfigured as a starting point for creating a subsystem that executes when a control signal has a positive value.

Variant

A Variant Subsystem block contains two or more child subsystems where one child is active during model execution. The active child subsystem is referred to as the active variant. You can programmatically switch the active variant of the Variant Subsystem block by changing values of variables in the base workspace, or by manually overriding variant selection using the Variant Subsystem block dialog. The active variant is programmatically wired to the Input port and Output port blocks of the Variant Subsystem by Simulink during model compilation.

Reference

You can save a subsystem in an SLX file and reference it from a model. Such a modeling pattern helps re-usability. It really helps when a certain part of a model is needed to be reused. This way the system can be more modular and easier to build.

## Simulink onramp certification



Figure 15: Simulink onramp certificate

# Activity 5: Stateflow

## Model: HVAC with hysteresis

Link to model: <https://lnttsgroup.sharepoint.com/sites/GEA/Global%20Engineering%20Academy/GEA%20Insights/Genesis/Shared%20Documents/Forms/AllItems.aspx?originalPath=aHR0cHM6Ly9sbnR0c2dyb3VwLnNoYXJlcG9pbnQuY29tLzpmOi9zL0dFQS9HbG9iYWwlMjBFbmdpbmVlcmluZyUyMEFjYWRlbXkvR0VBJTIwSW5zaWdodHMvR2VuZXNpcy9FdF96am9MSF9qUk10Tl9LNFp2Xy1aOEJhTG03SDJNUXlWdTV5dnNUMGFBV1FRP3J0aW1lPW1rNnREaHRoMkVn&id=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FStateflow%2FHVAC%2Eslx&parent=%2Fsites%2FGEA%2FGlobal%20Engineering%20Academy%2FGEA%20Insights%2FGenesis%2FShared%20Documents%2FSubmission%2FMYSORE%2F2009MYSEMB%2FFoundation%2FMBSE%2F99002591%2FStateflow>

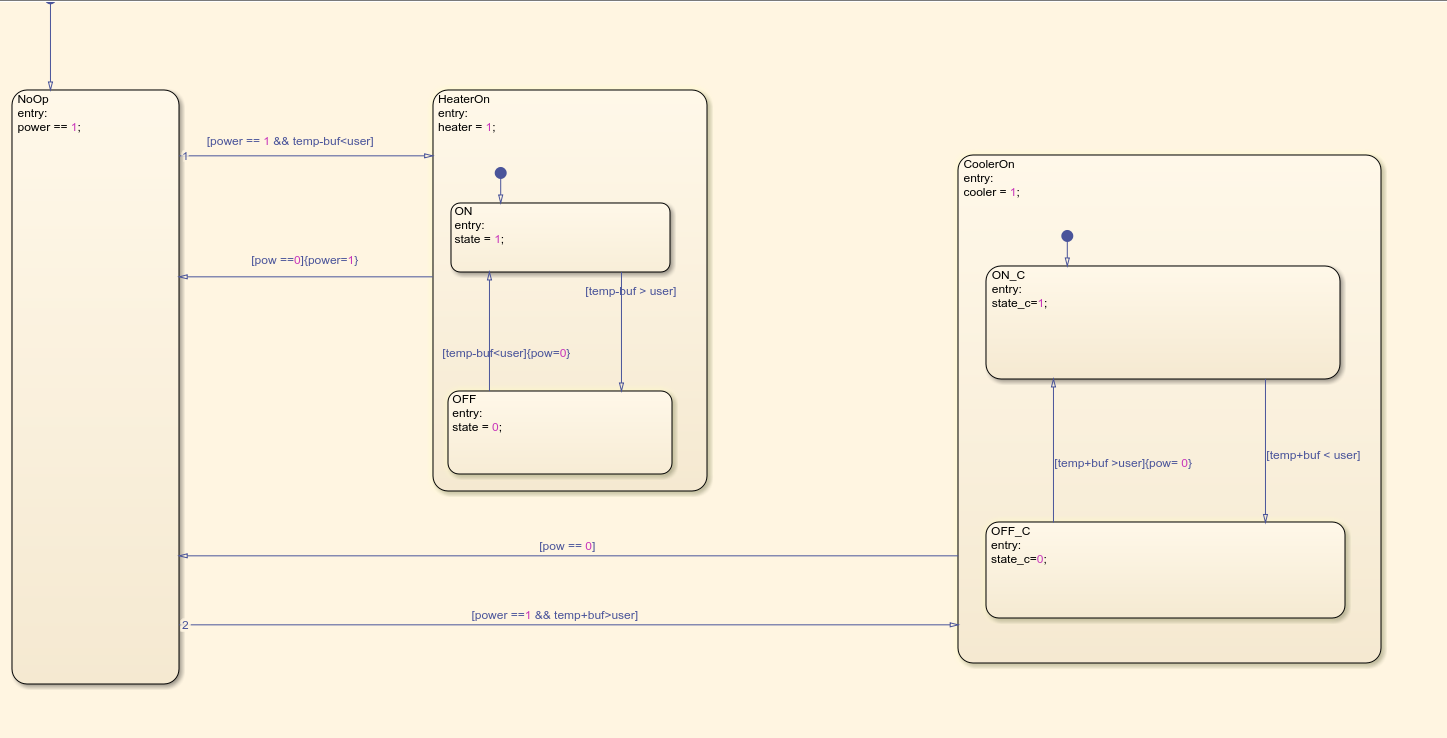


Figure 16: HVAC with hysteresis chart

## Debugging techniques in stateflow chart

Breakpoint

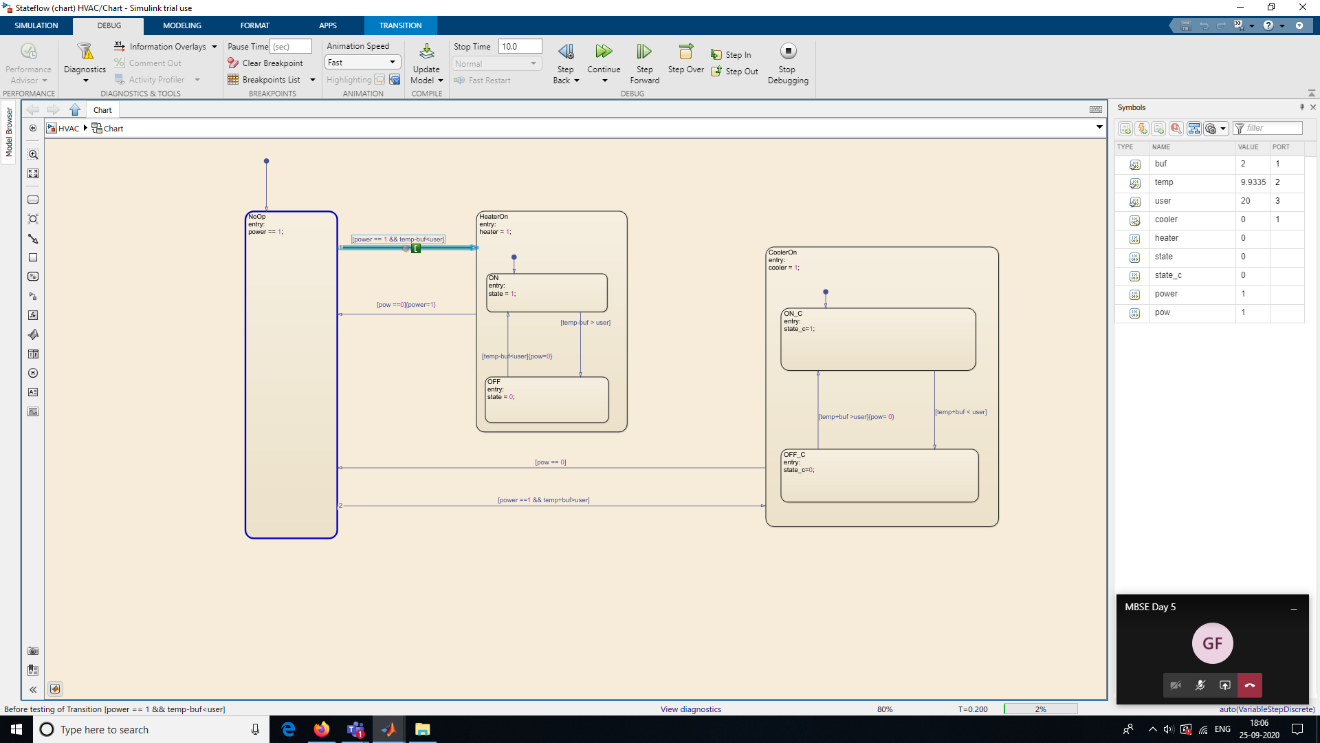


Figure 17: Breakpoint in stateflow chart

Pause time

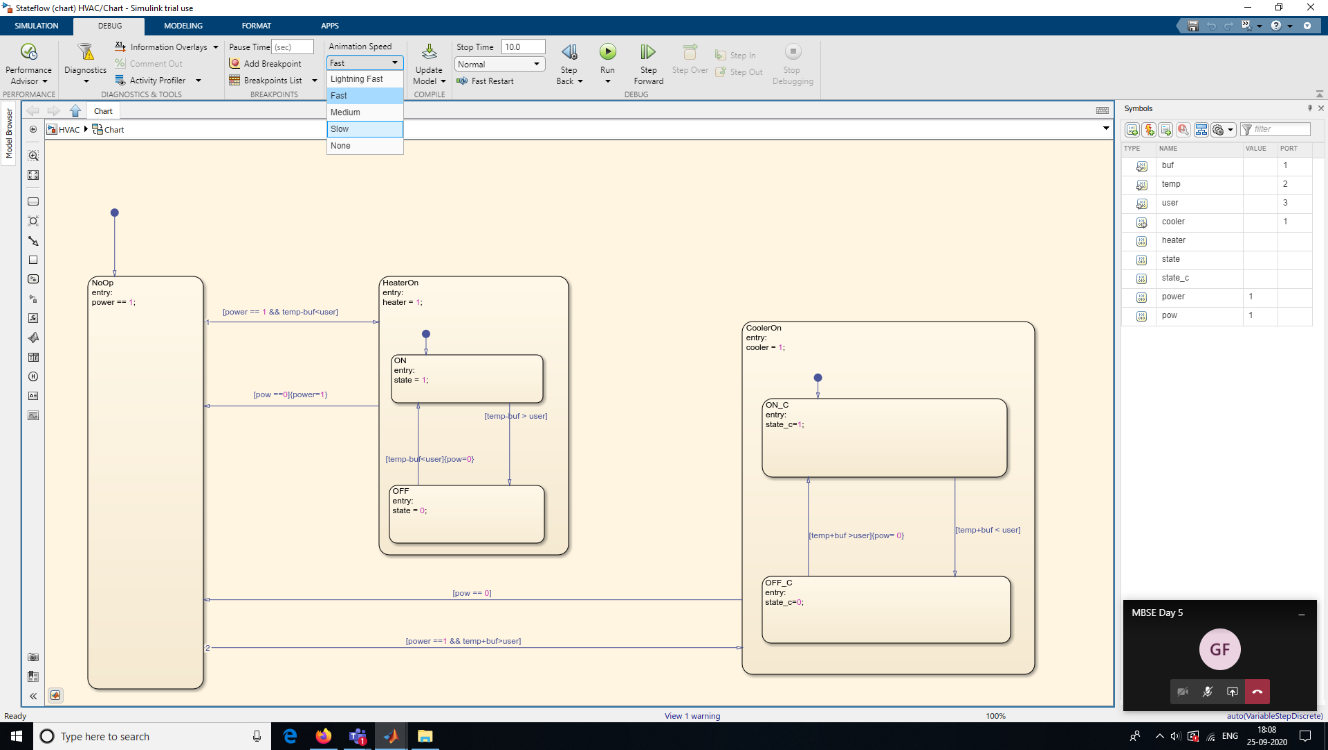


Figure 18: Pause time in stateflow chart

## Stateflow Onramp certification



Figure 19: Stateflow onramp certificate

# Appendix