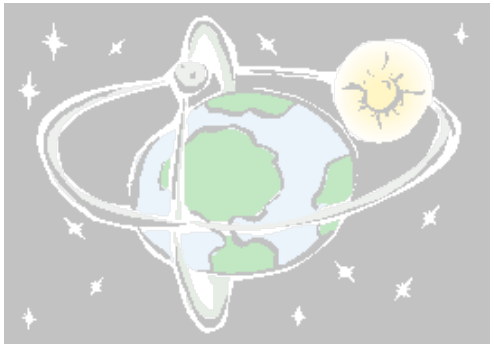
ELEN 503
Hardware-Software Co-Design

Homework #1
Models of Computation



Prof. Hoeseok Yang
Santa Clara University

Spring Quarter 2023

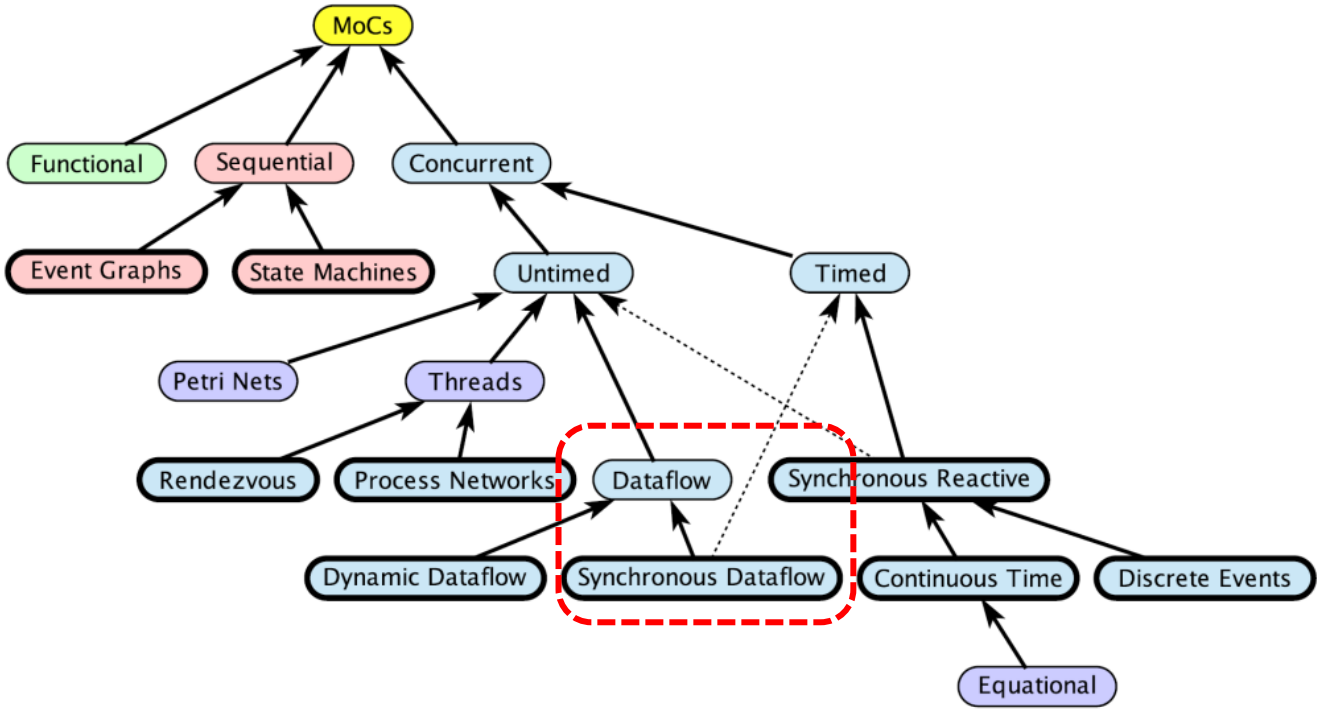
Homework #1 - Overview

- In this homework, you will practice modeling (specification) and simulation of cyber-physical systems using Ptolemy II.

- Tasks – 10 points + 2 extra points
  - Part 0 (warming-up): 2 points
    - Dataflow modeling of Fibonacci series
  - Part I: 3 points
    - Simulation of Heterogeneous models of computation
  - Part 2: 3 points
    - Dataflow modeling of noise filtering
  - Part 3 (extra): 2 points
    - FSM modeling of an enhanced controller
  - Report: 2 points

- Submission
  - Upload your report (in pdf) and specification files (in xml) to Camino
  - Due: May 11th, 11:59pm

Part 0: Dataflow Modeling of Fibonacci Series

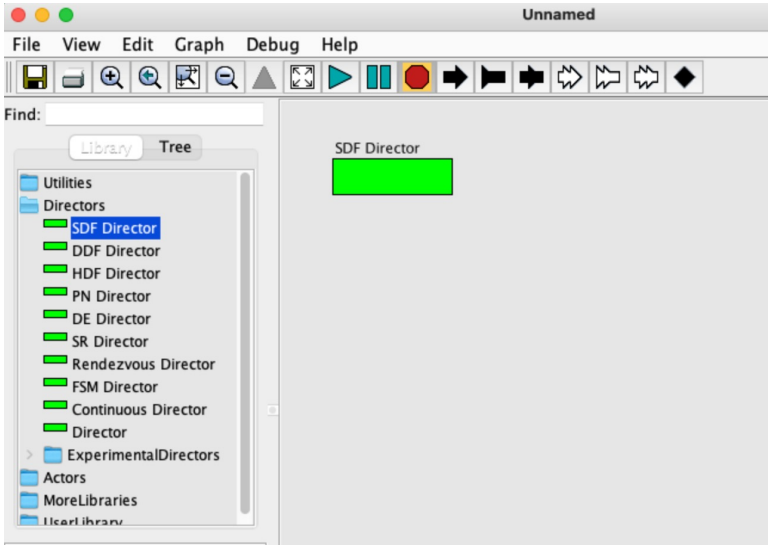


Part 0: Background Information

- What is Fibonacci series?
  - F(n) is defined to be
    - 0 , if $n = 0$
    - 1 , if $n = 1$
    - F(n-1) + F(n-2) , otherwise ($n > 1$)
  - 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, …
- Assume that the SDF model you specify in Ptolemy II outputs/prints a single element at each iteration
  - E.g., 1st iteration: 0, 2nd iteration: 1, 3rd iteration: 1, 4th iteration: 2, …
- How to access the old output?
  - For calculating F(n), you need two previous outputs, F(n-1) and F(n-2)
  - Use "initial tokens (delay)"

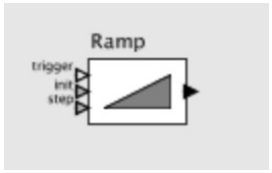
Part 0: Getting Started with Ptolemy II

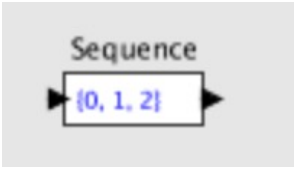
- Install Ptolemy II 11.0 (released in June, 2018)
- Make a new Dataflow model
  - Open a new Vergil (or Ptiny)
  - File → New → Graph Editor
  - Directors (left panel) → drag and drop "SDF Director"

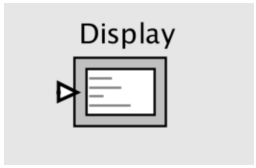


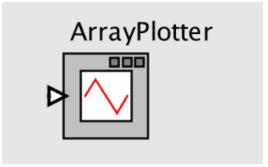
Useful Actors

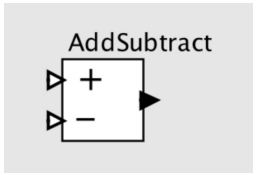
- Actors in the left panel
  - Sources (actors without incoming ports)
    - Generate input events/sequences
    - Const, Sequence, Sinewave, Ramp, Pulse, …
  - Sinks (actors without outgoing ports)
    - Print/Plot information
    - Display, ArrayPlotter, BarGraph, ArrayPlotterXY, XYPlotter, …
  - Math
    - Arithmetic data processing
    - AbsoluteValue, AddSubtract, Average, …
  - CompositeActor (in "Utilities")
    - Hierarchical design

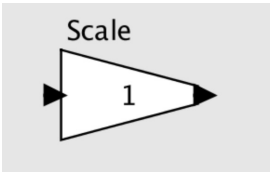


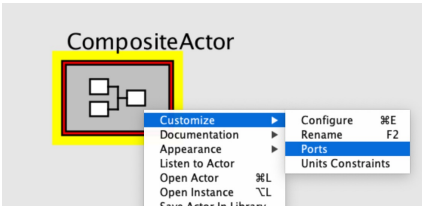






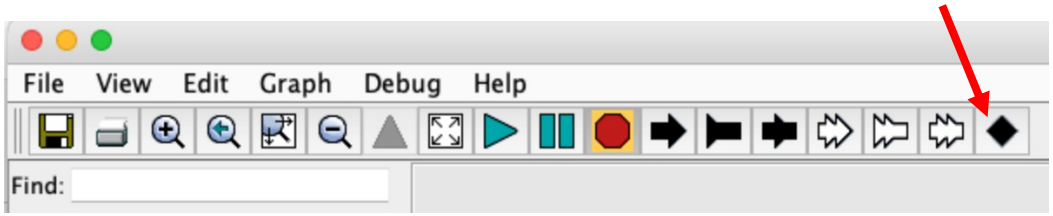


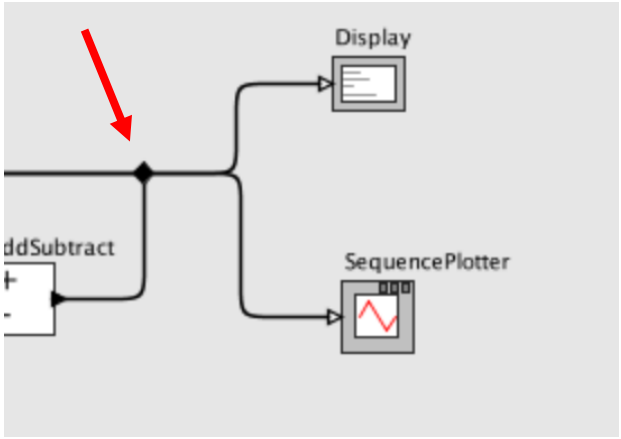




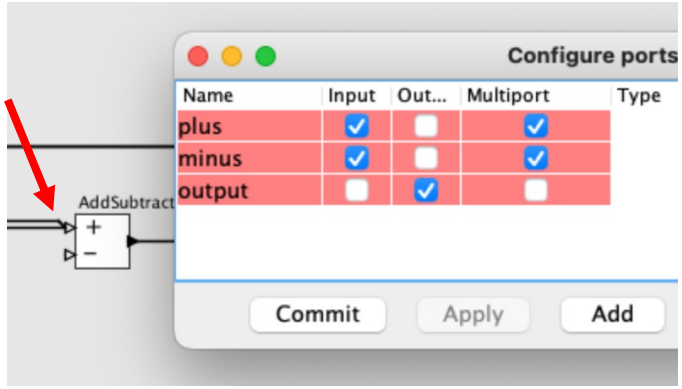
Relation (Fork) and Multi-Port

- In principle, all connections between actors are
  - Point-to-point and directed
  - In case you need to have 1-to-n connections
  - Use relation (fork)



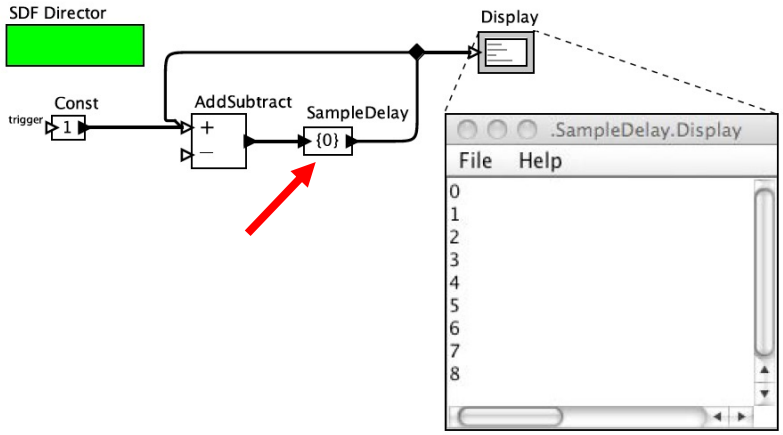


- Some ports support multiple connections
  - E.g., AddSubtract's input ports



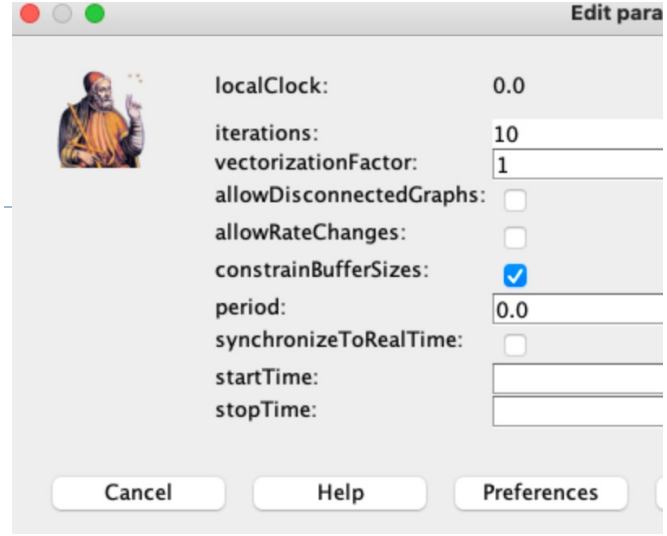
Initial Delay

- Sometimes, you would need to have a feedback loop in your dataflow modeling
  - Previous results fed back to input
  - This might result in a deadlock
- Use the initial delay actor
  - (FlowControl → SequenceControl → "SampleDelay")

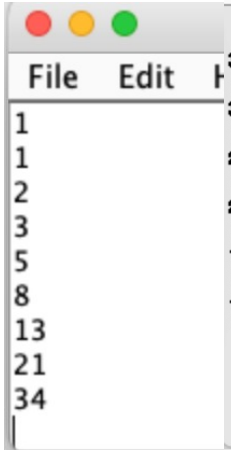


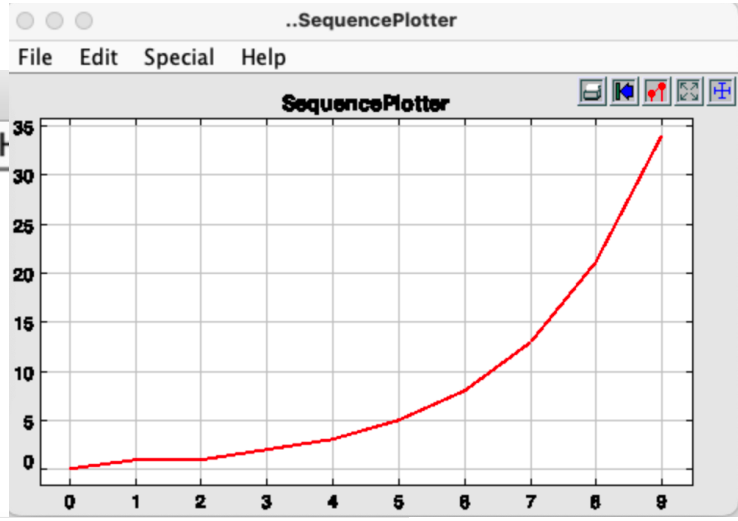
Expected Result

- Set the number of iterations to be simulated
  - Double click "SDF Director"
  - Enter the number of Iterations in the "iterations" field



- Use "Display" or "SequencePlotter" to print out your results
  - Library → Sinks → GenericSinks/SequenceSinks



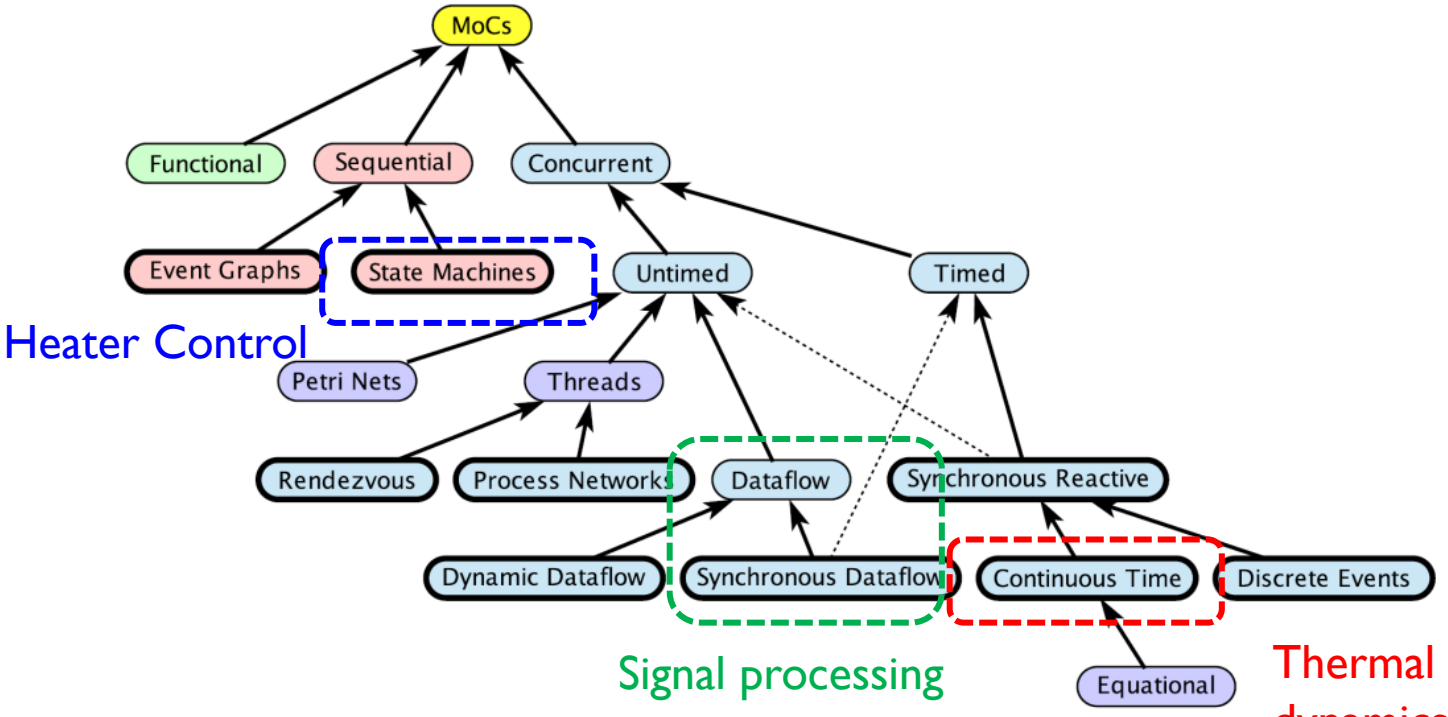


Part 0: Your Tasks

- Build your own SDF model for Fibonacci sequence
  - Include an SDF modeling in your report
  - Submit the export XML file of your model

- Report the results
  - Simulation screenshots should be included in your report

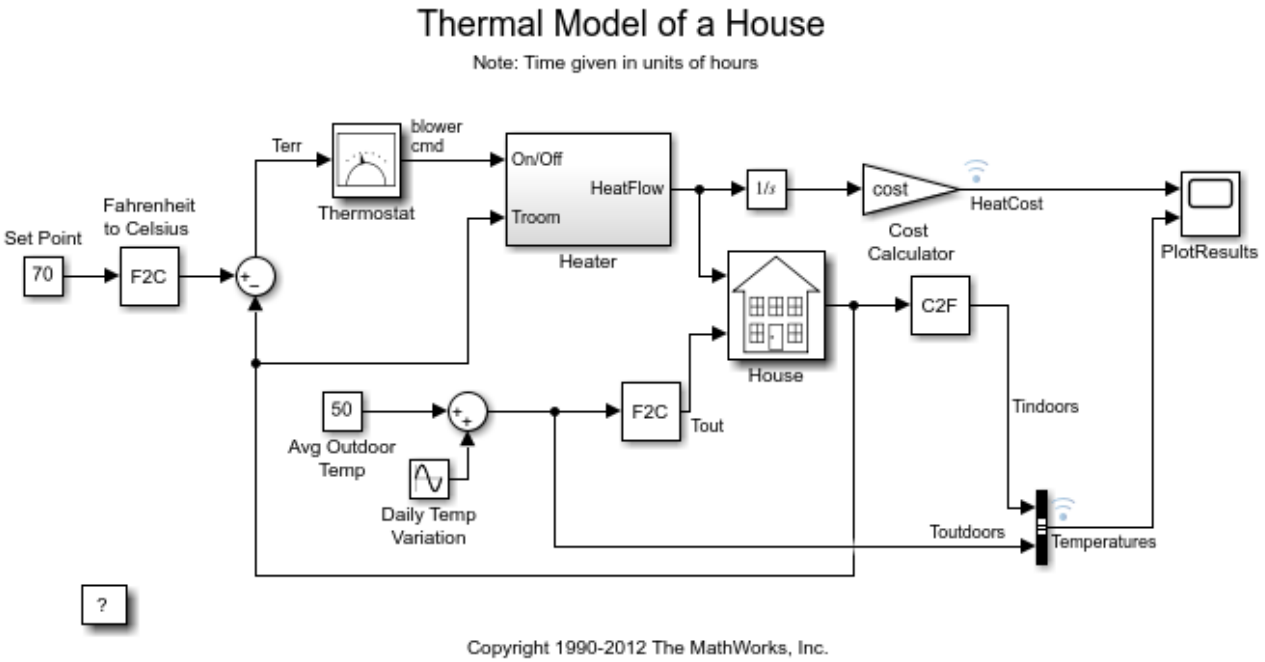
Part 1: Modeling/Simulation of House Heating System



Modeling of a House Heating System

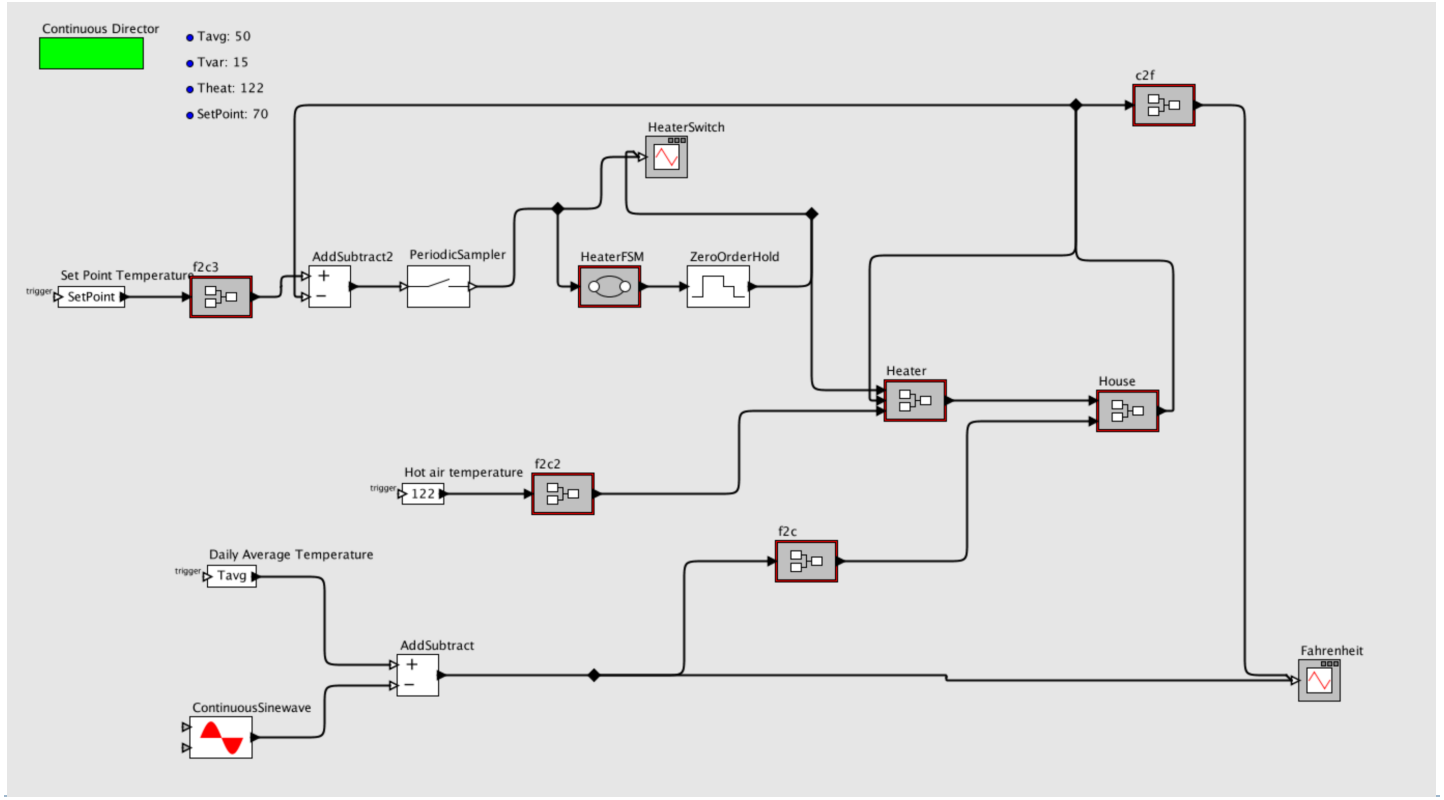
- This system is taken from a Matlab/Simulink demo
  - https://www.mathworks.com/help/simulink/slref/thermal-model-of-a-house.html

- To try this example in Matlab/Simulink
  - Type in "openExample('simulink_general/sldemo_househeatExample')" in your Matlab prompt



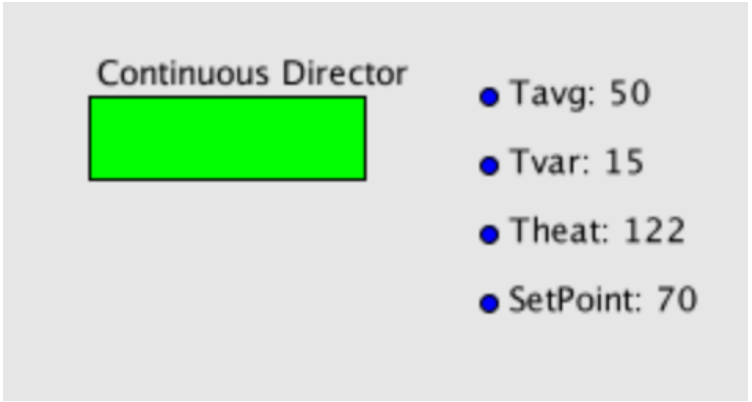
Part 1: Modeling the *Entire* House Heating System

- Not a *part* of your work
- Basic modeling is given to you: hw1.xml
  - File → Open File

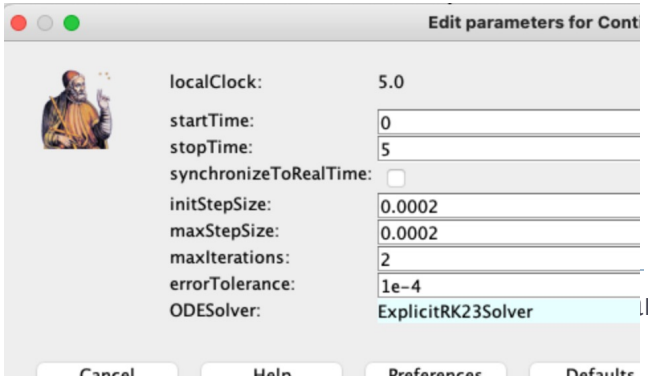


Part 1: Top-level schematic

- Parameters: System wide variables that you can configure (Utilities → Parameters → Parameter)
  - Right click → Rename
    - Tavg: 50F (daily average outdoor temperature)
    - Tvar: 15F (temperature variation: Tavg-Tvar < T < Tavg+Tvar)
    - Theat: 122F (hot air temperature)
    - setPoint: target indoor temperature

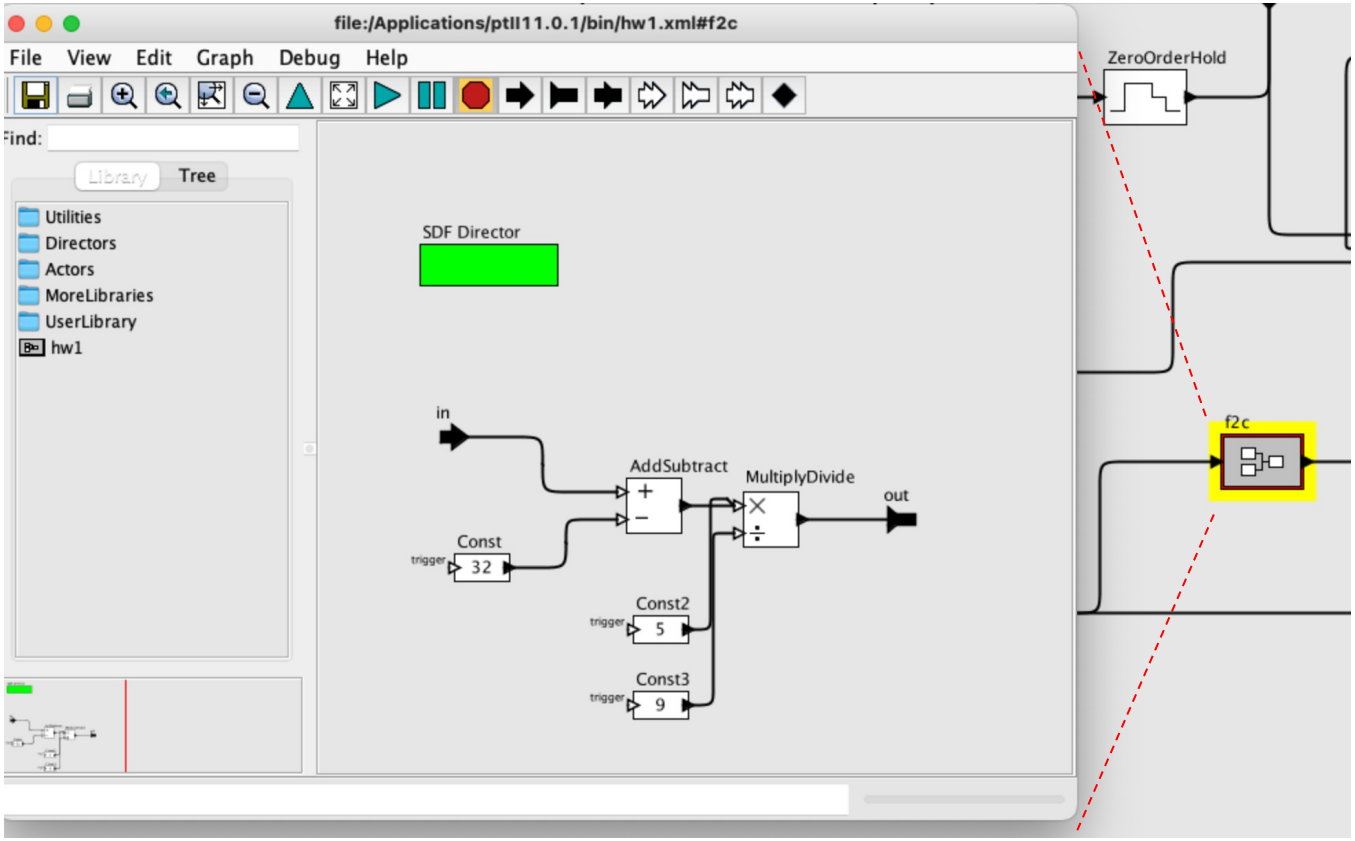


- Simulation time
  - Double-click on the director



Part 1: F2C or C2F

- CompositeActor (in "Utilities")
  - Right click → Open Actor



Part 1: Heater Subsystem

Equation 1

$$\frac{dQ}{dt} = (T_{heater} - T_{room}) \cdot Mdot \cdot c$$

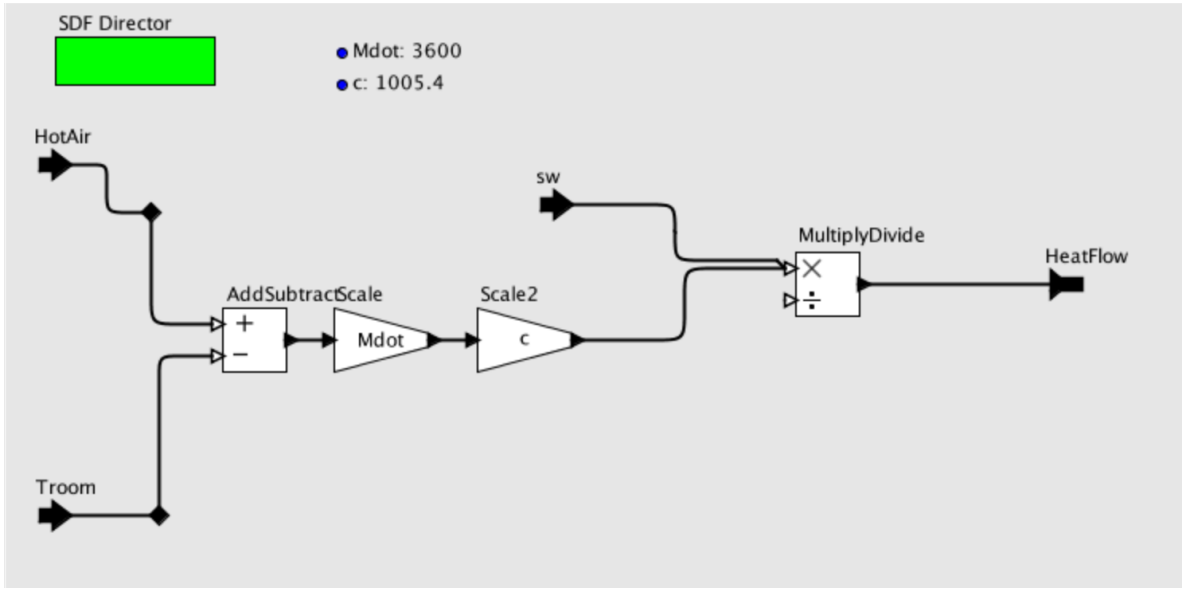
$\frac{dQ}{dt} =$ heat flow from the heater into the room

$c =$ heat capacity of air at constant pressure

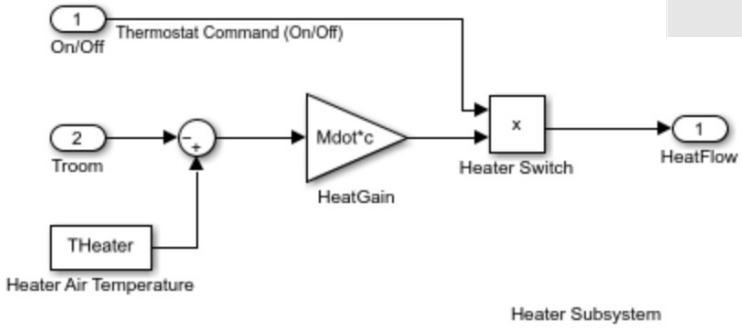
$Mdot =$ air mass flow rate through heater (kg/hr)

$T_{heater} =$ temperature of hot air from heater

$T_{room} =$ current room air temperature



Open the Heater subsystem.



Heater Subsystem

Part 1: House Subsystem

Equation 2

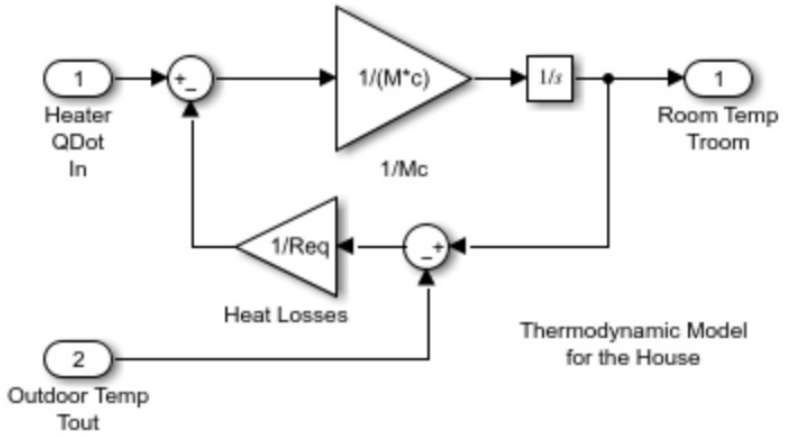
$$\left(\frac{dQ}{dt}\right)_{losses} = \frac{T_{room} - T_{out}}{R_{eq}}$$

$$\frac{dT_{room}}{dt} = \frac{1}{M_{air} \cdot c} \cdot \left(\frac{dQ_{heater}}{dt} - \frac{dQ_{losses}}{dt}\right)$$

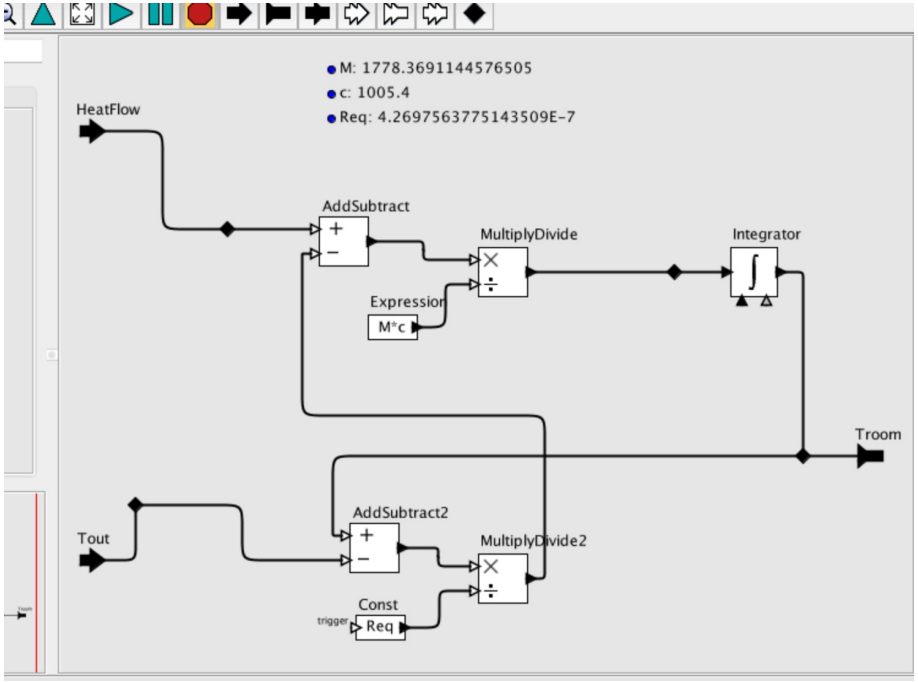
$M_{air} =$ mass of air inside the house

$R_{eq} =$ equivalent thermal resistance of the house

Open the House subsystem.

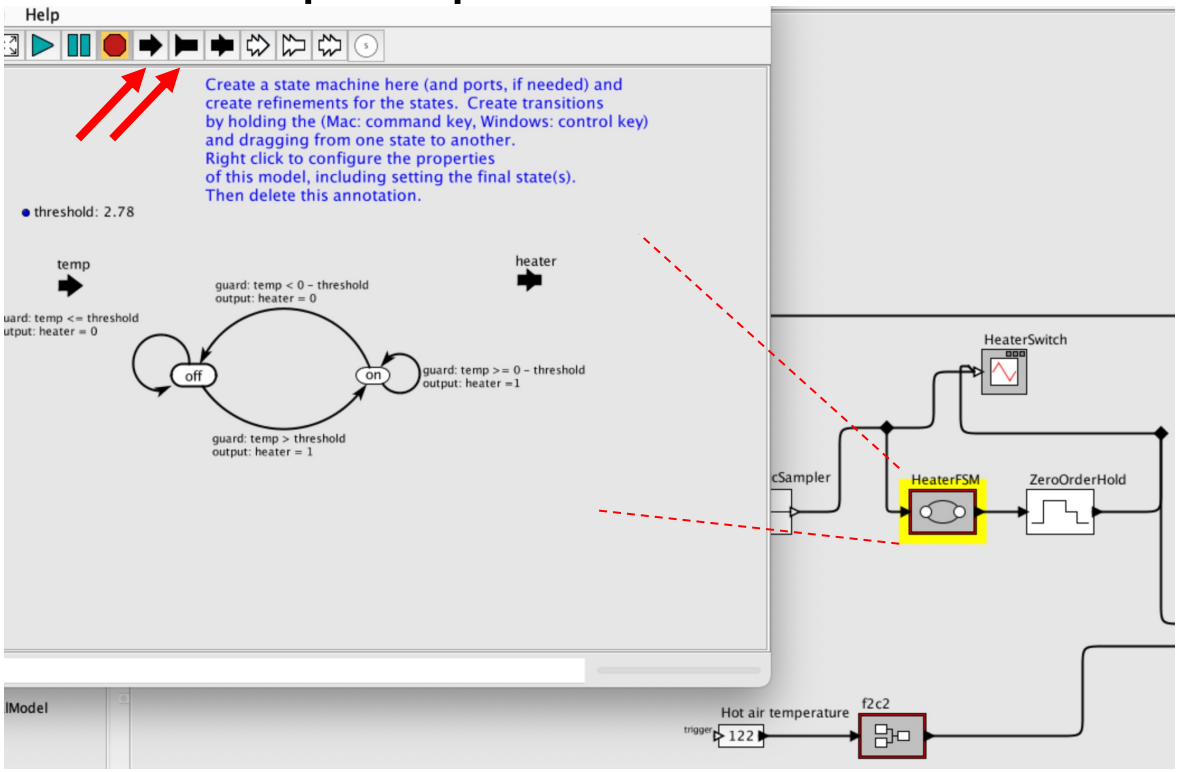


Where is a director?



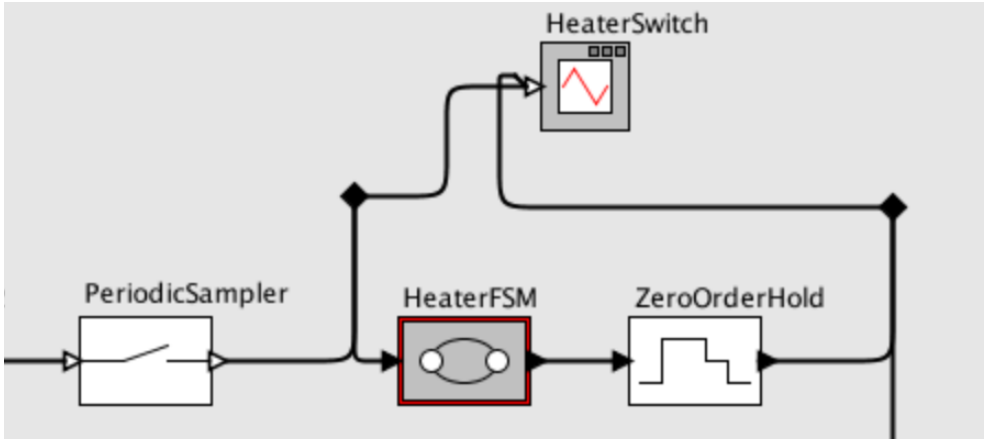
Part 1: Heater Control FSM

- Finite State Machine
  - Utilities → ModalModel
  - Open Actor → New output/input Port



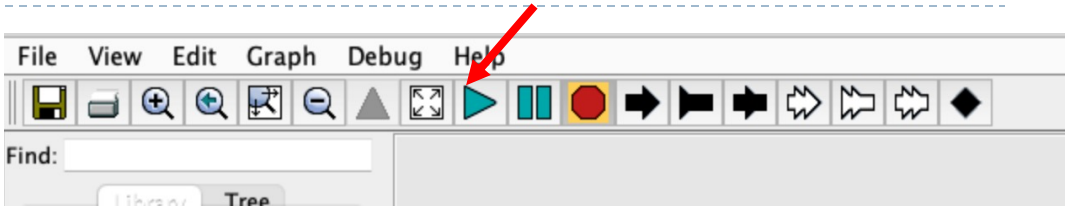
Part 1: Heater Control FSM (Interface)

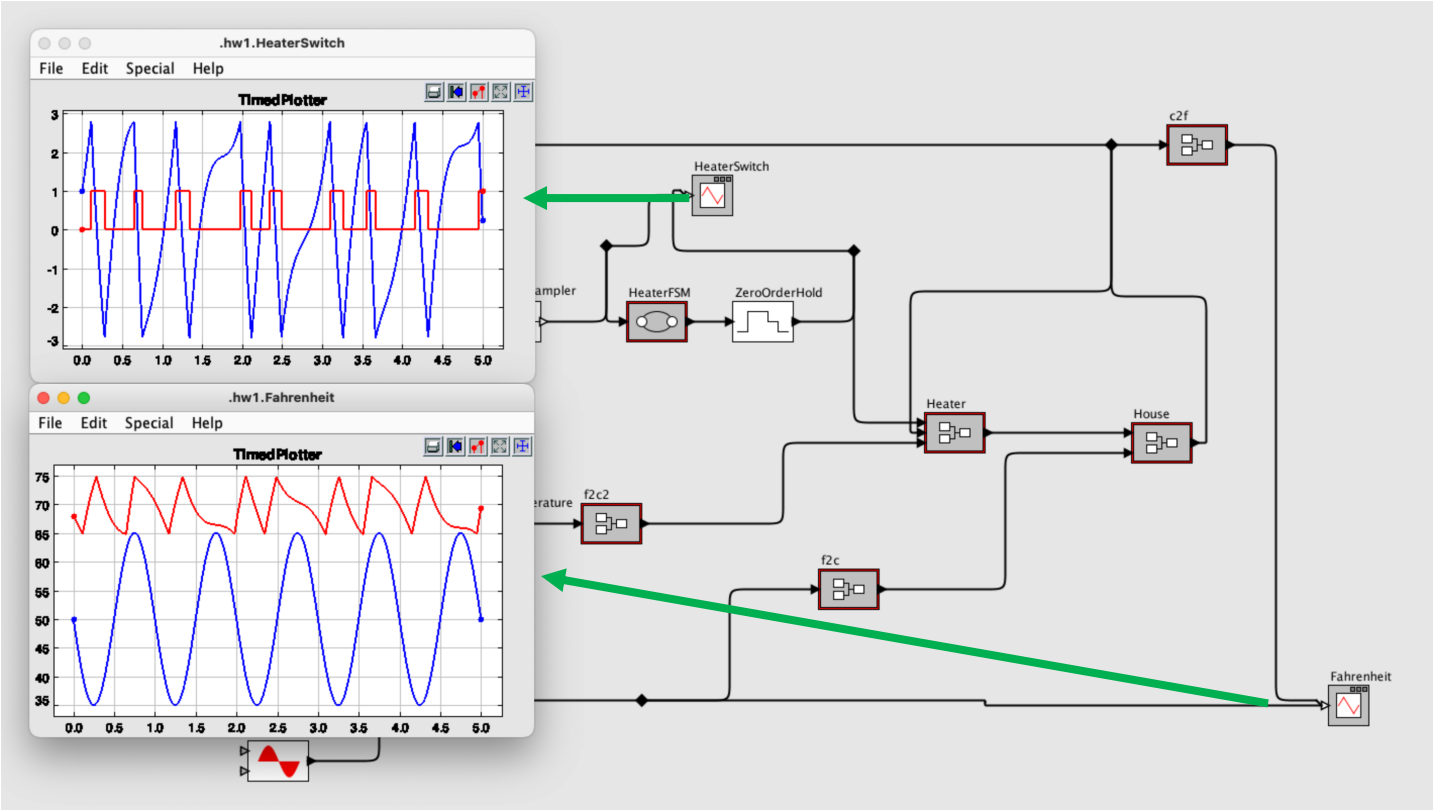
- Interface between Discrete Events and Continuous Time
  - Periodic Sampler
    - Actors → DomainSpecific → Continuous → Continuous to Discrete
  - ZeroOrderHold
    - Actors → DomainSpecific → Continuous → Discrete to Continuous



Part 1: Simulation Results

- Hit "Run"



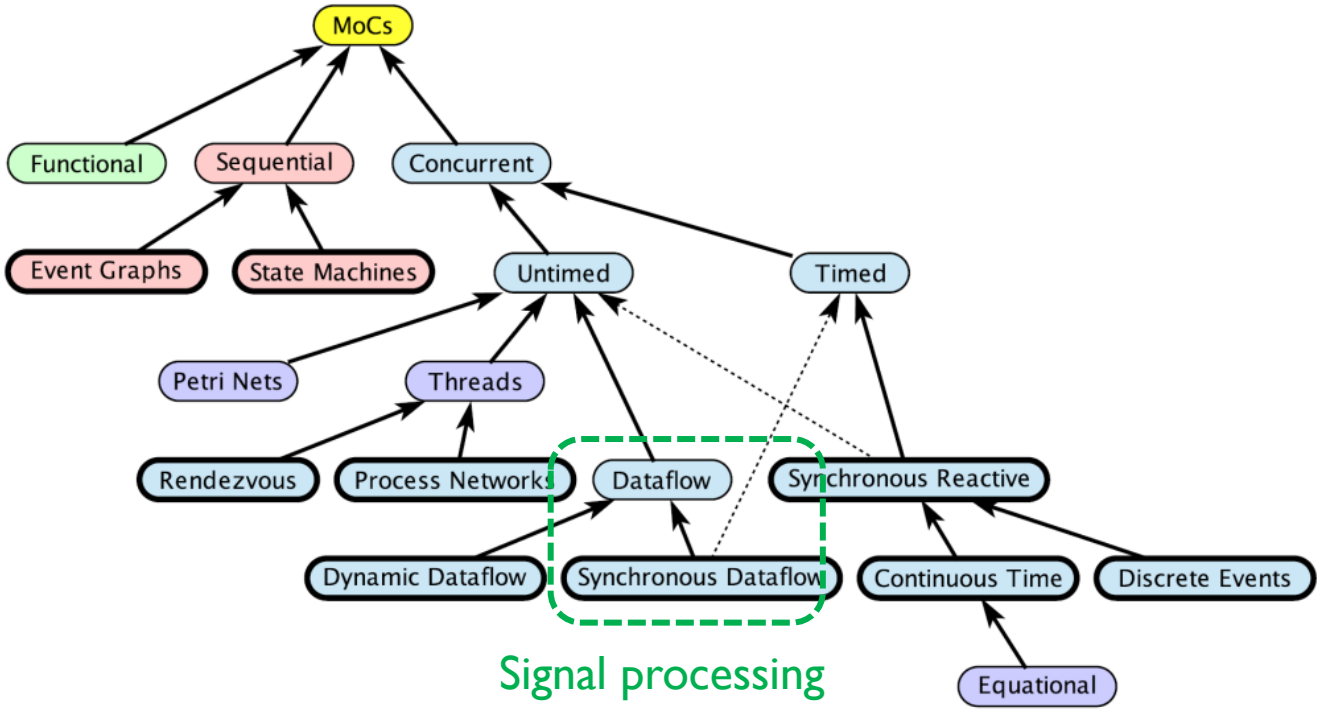


Part 1: Your Tasks

- Try multiple simulation runs with
  - different "parameters"
  - different timing granularity
    - Director: initStepSize and maxStepSize
    - PeriodicSampler: samplePeriod

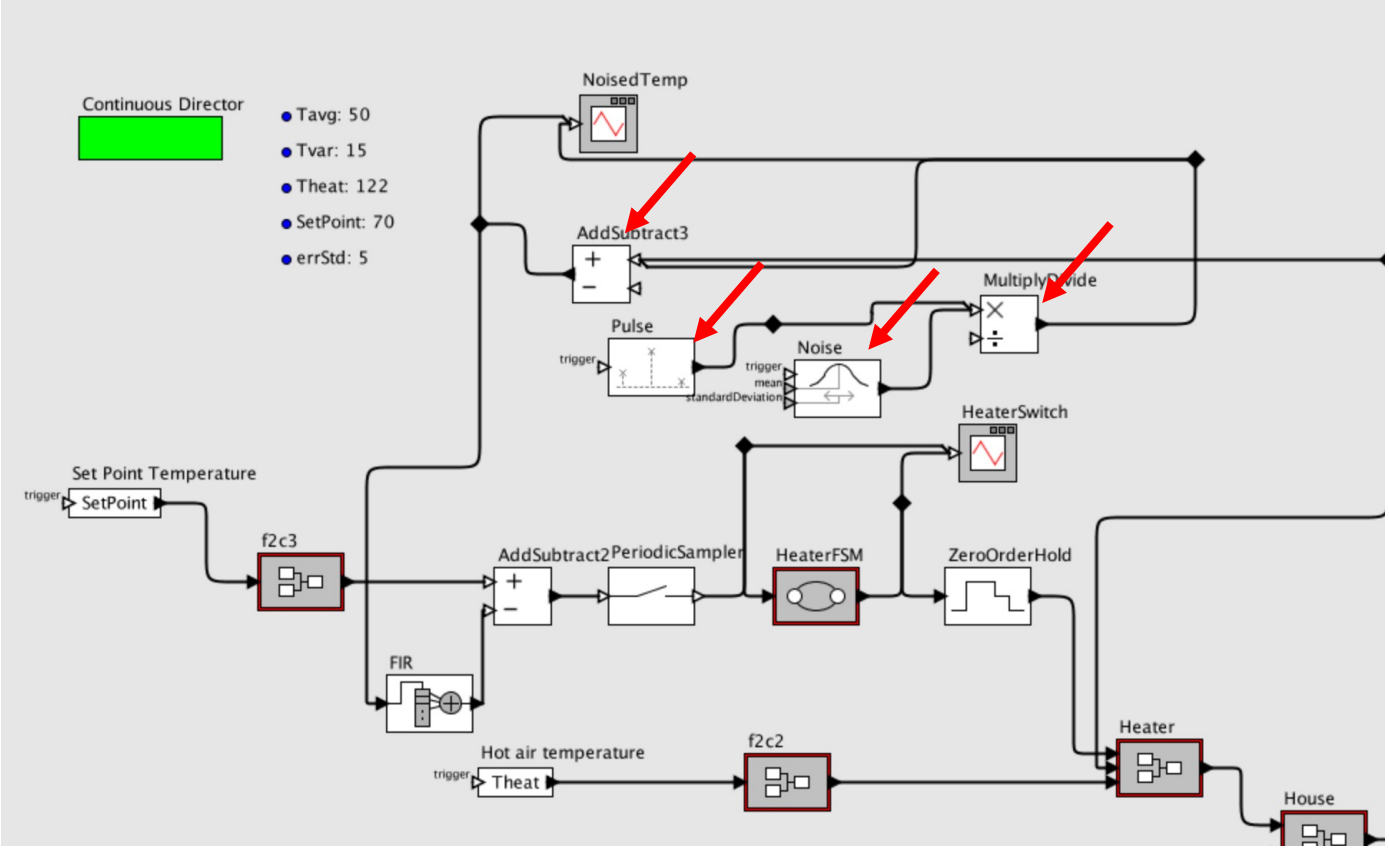
- Report the results
  - Screenshots should be included in your report

Part 2: Noise Filtering



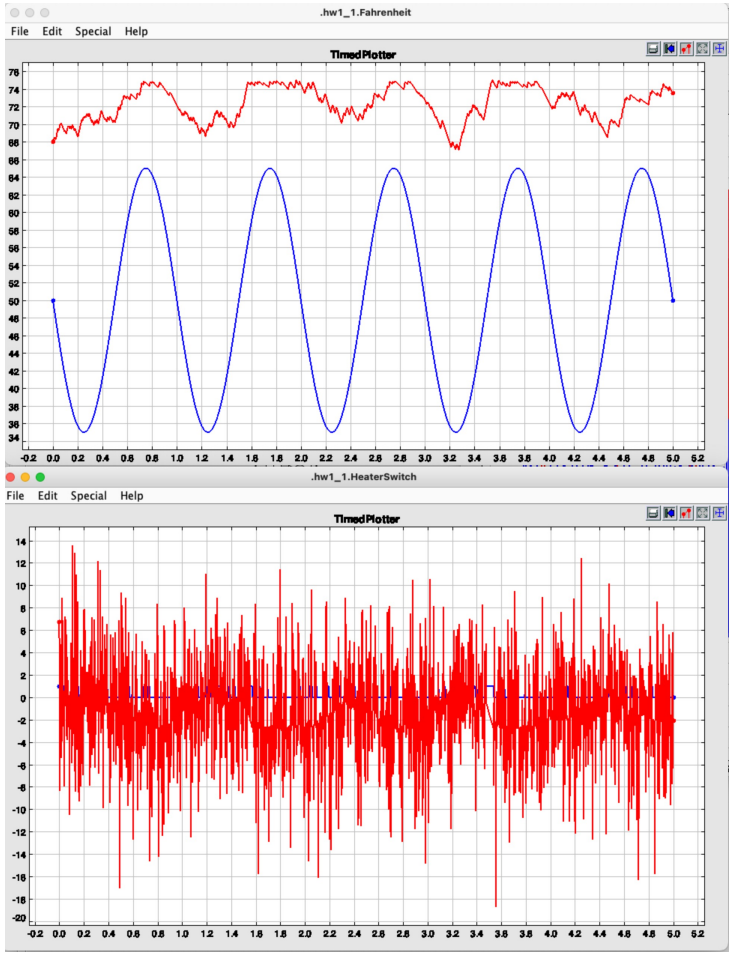
Part 2: Temperature Sensors are noisy!

- Temperature noises have been added
  - hw2.xml



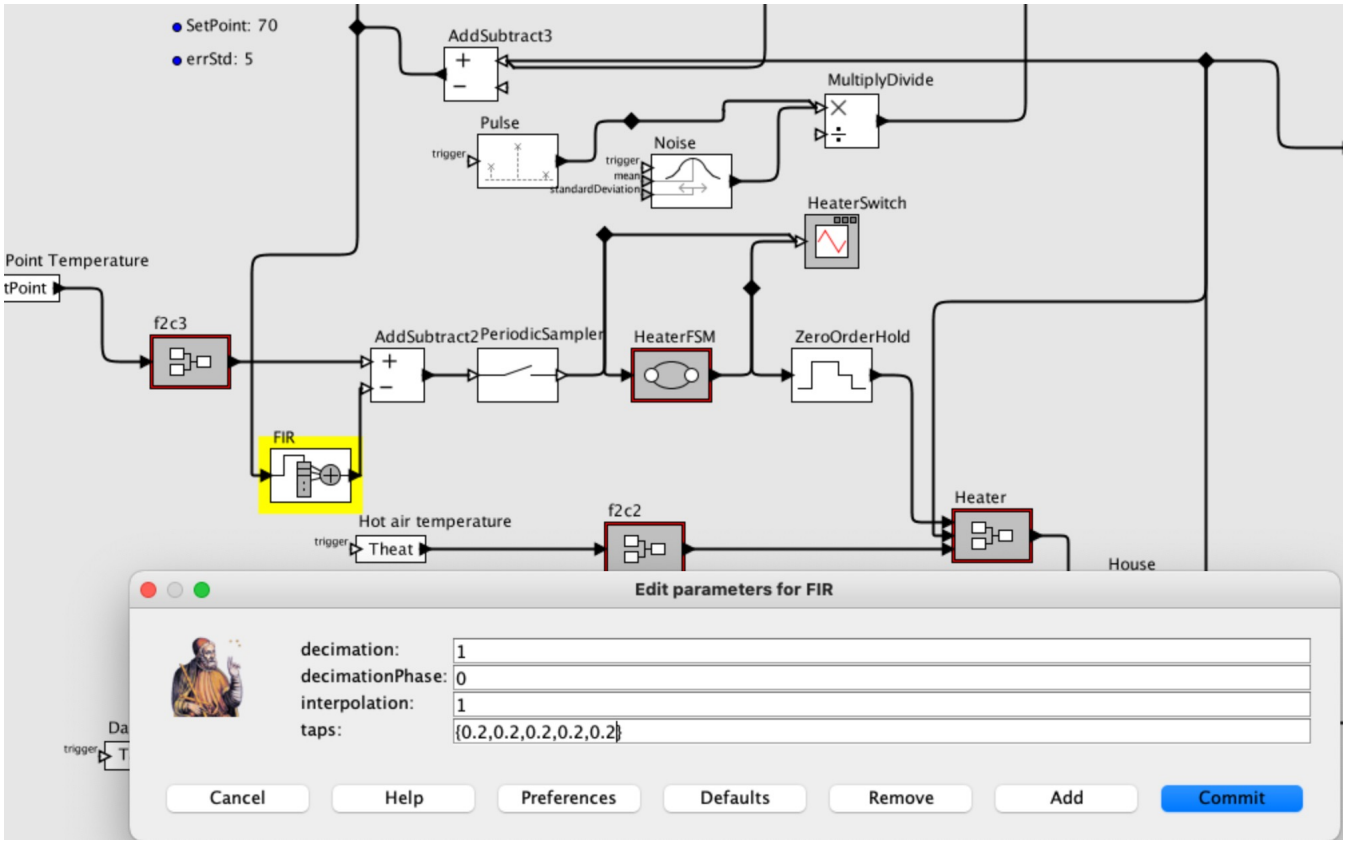
Part 2: Temperature Sensors are noisy! (cont'd)

- Simulation results without filtering



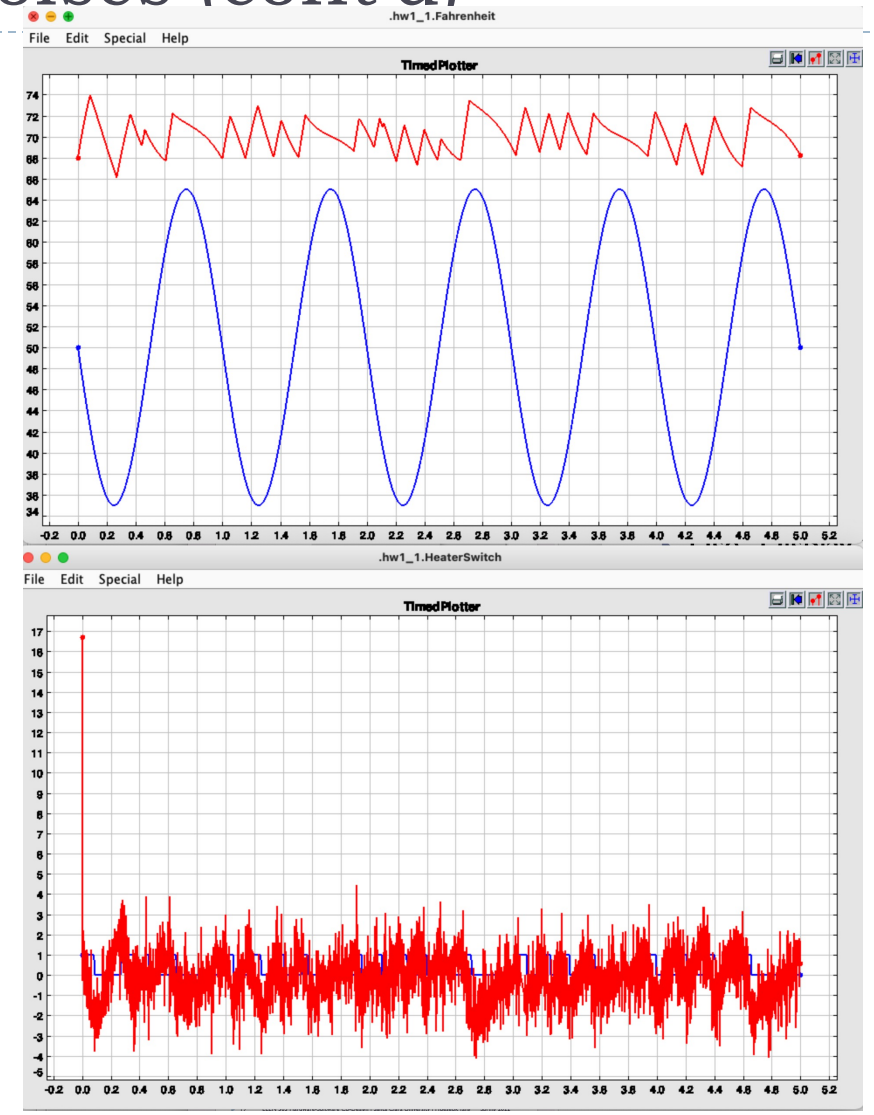
Part 2: Filtering out noises

- A common solution is to user an FIR filter



Part 2: Filtering out noises (cont'd)

- Simulation results with 5-tap FIR filter

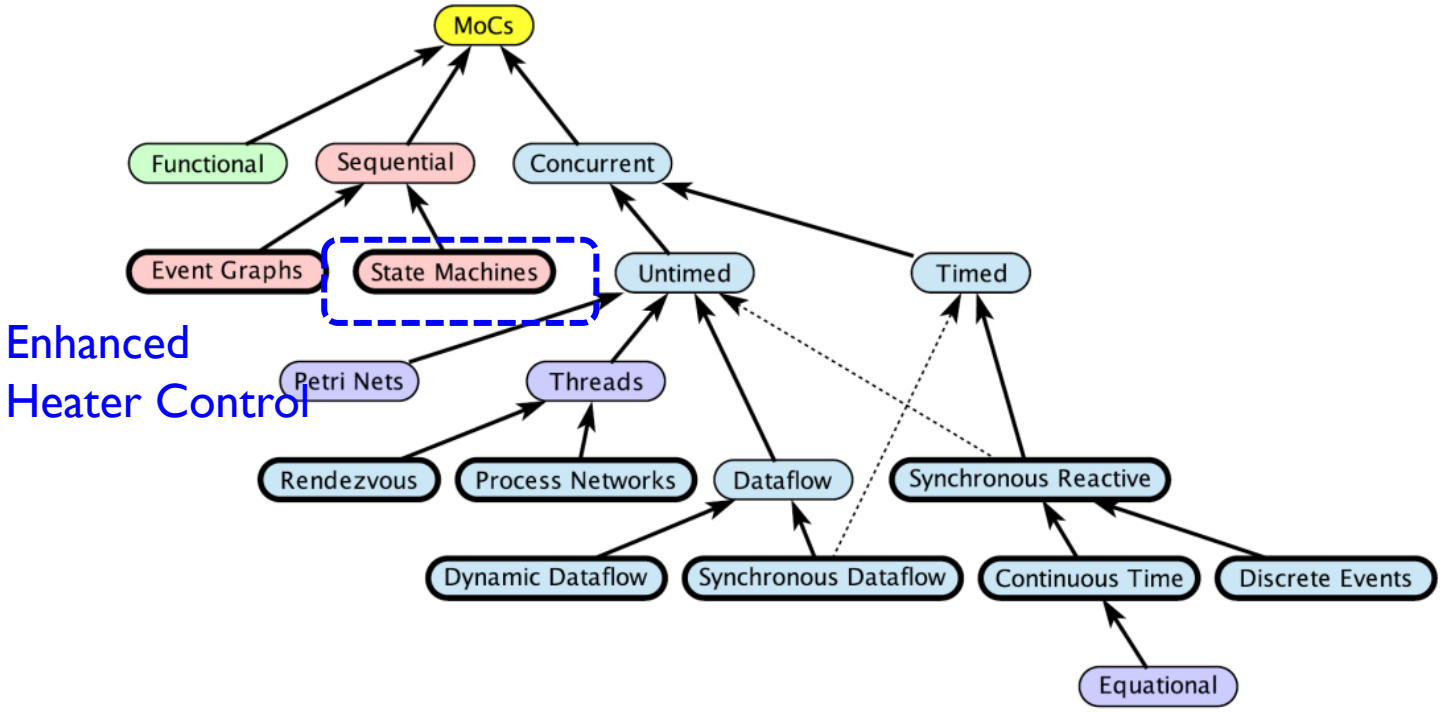


Part 2: Your Tasks

- Build your own SDF filter
  - Whatever filter you like to use
  - Replace the FIR filter in hw2.xml with your own composite actor
  - Include the SDF modeling in your report
  - Submit the export XML file of your actor

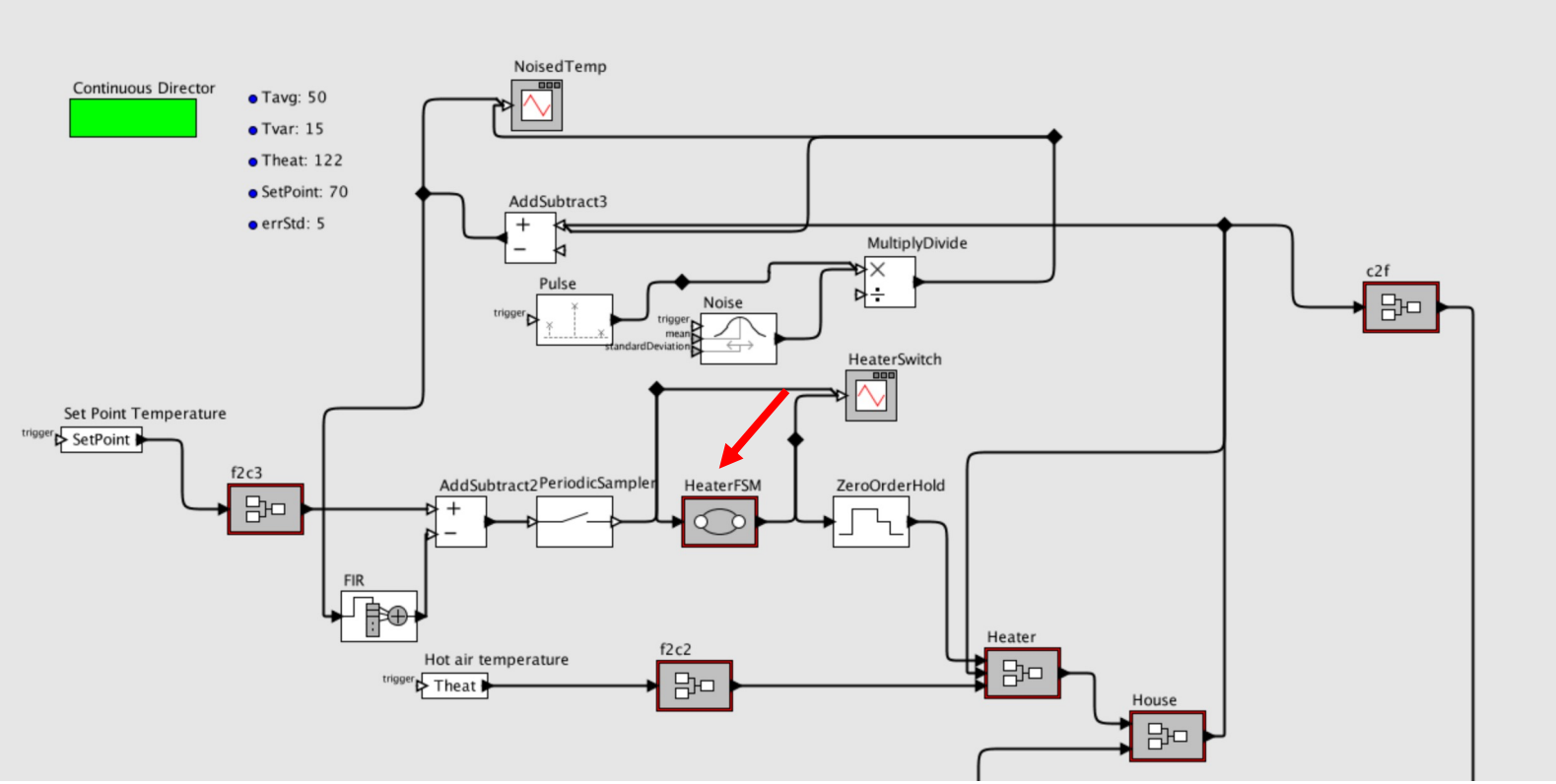
- Report the results
  - Simulation screenshots should be included in your report

(Extra) Part 3: Noise Filtering



Part 3: Enhanced Heater Controller

- Previously you only have on/off control
  - Enhance the heater controller with intermediate level
  - You may need to modify the topology of the top-level model



Part 3: Your Tasks

- Build your own ModalModel actor for Heater FSM
  - Replace the HeaterFSM actor in hw2.xml with your own composite actor
  - Include the FSM modeling in your report
  - Submit the export XML file of your actor

- Report the results
  - Simulation screenshots (that prove the enhanced control) should be included in your report

Need Help?

- Many, if not all, of you are not familiar with Ptolemy II
- You are welcomed to join (optional) Ptolemy II sessions (tentative schedules)
  - Please see Camino and sign up for one of the Ptolemy II office hours sessions if you wish to join