31: Modeling tools

What’s the point of modeling?

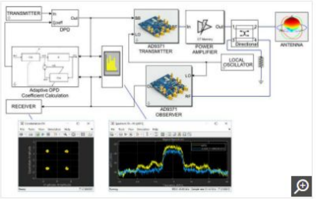
Simulation using models

- Run model through *specific* scenario(s)
  - **Not** a proof of system working in all possible scenarios
- Usually cheaper/faster/more flexible than running system for test
- May provide a bit more flexibility for some kinds of models

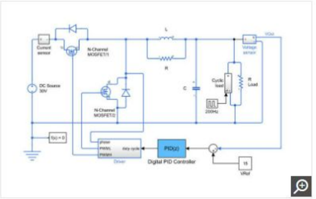
[image source](#)

Simulink (not an ad)

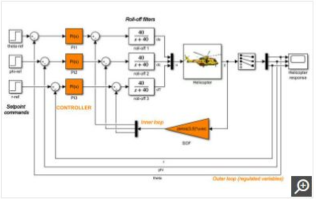
Simulink is for Every Project



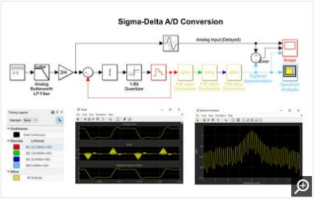
Wireless Communications



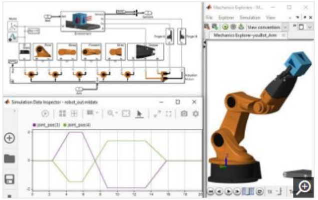
Electrification



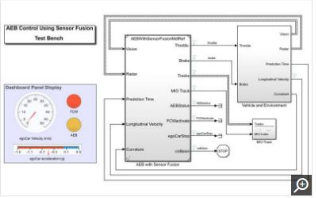
Control Systems



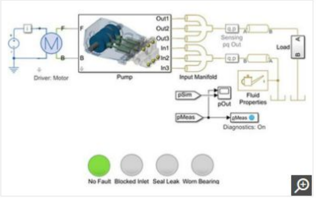
Signal Processing



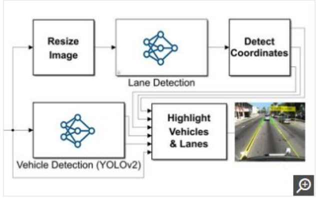
Autonomous Systems and Robotics



Advanced Driver Assistance Systems



Digital Twins



Artificial Intelligence

Automata

There are many ways to model/simulate a system, but automata (FSMs/ESMs/timed automata)...

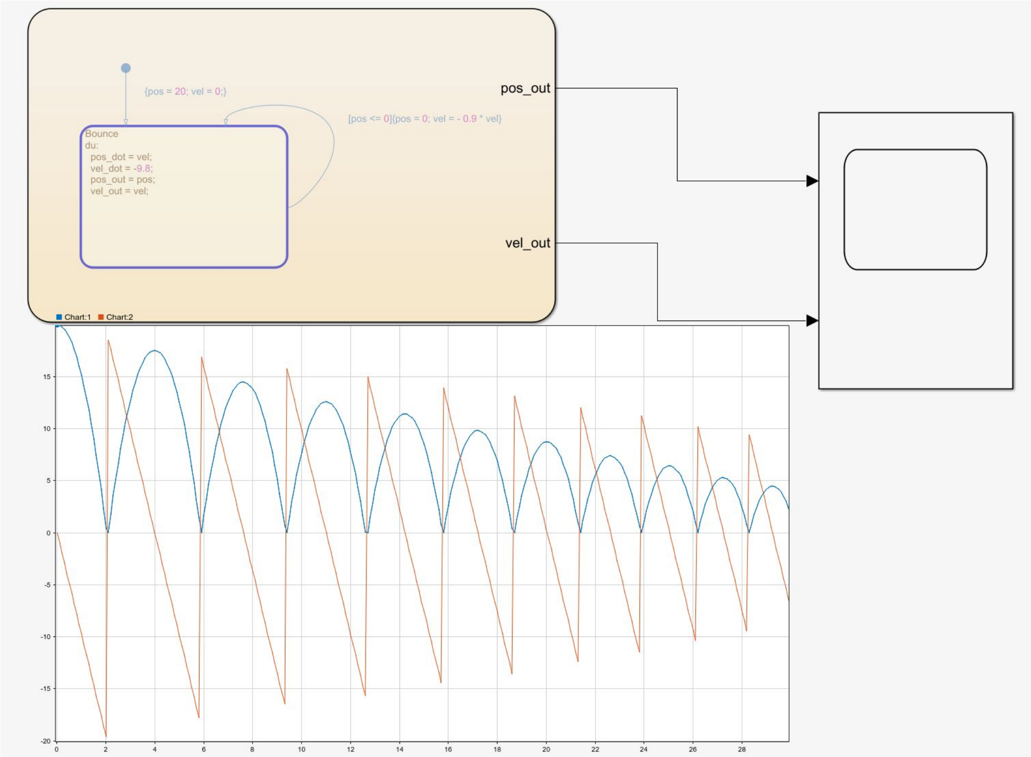
- Translate well to coding
- Translate well to proofs
- Are supported by many simulation tools

Stateflow

Simulink's automata simulator

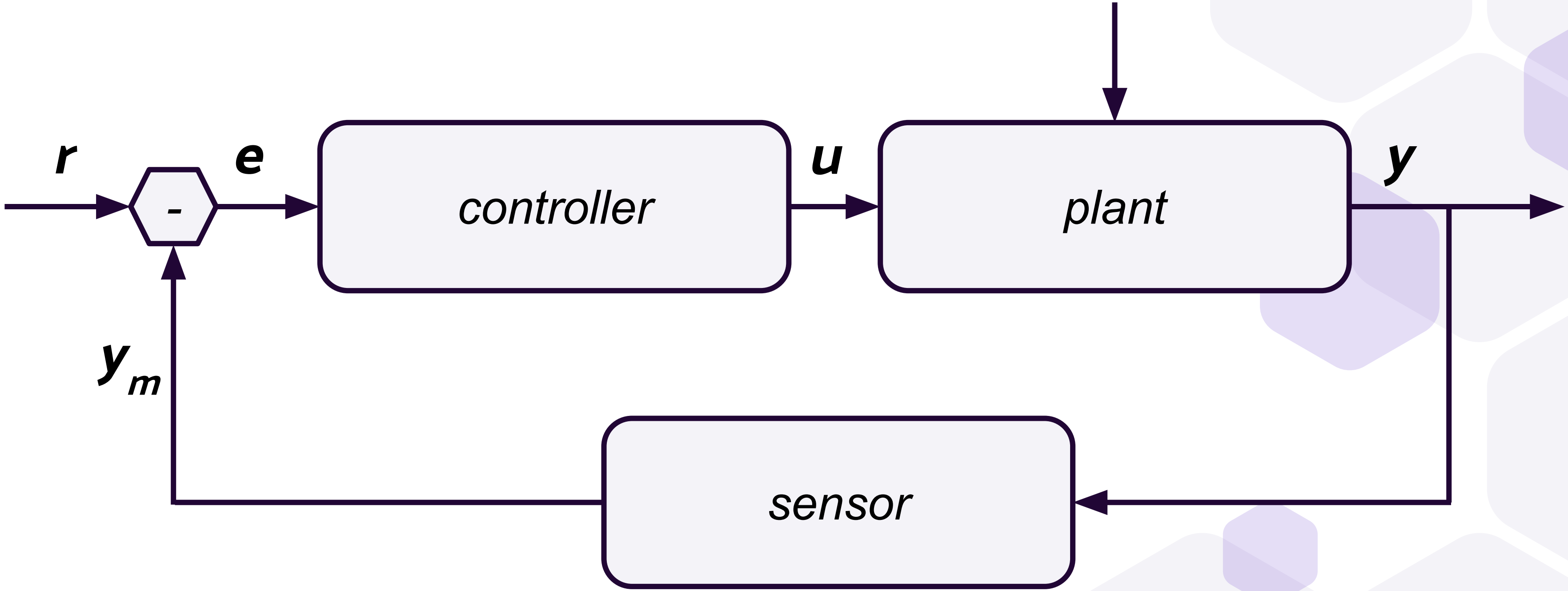
- Discrete and continuous behavior (+ variables)
- Discrete and continuous outputs
- "Zero-crossing" detection
- Deterministic only
  - Non mutually-exclusive transitions allowed (with prioritization)

Bouncing ball automata in simulink



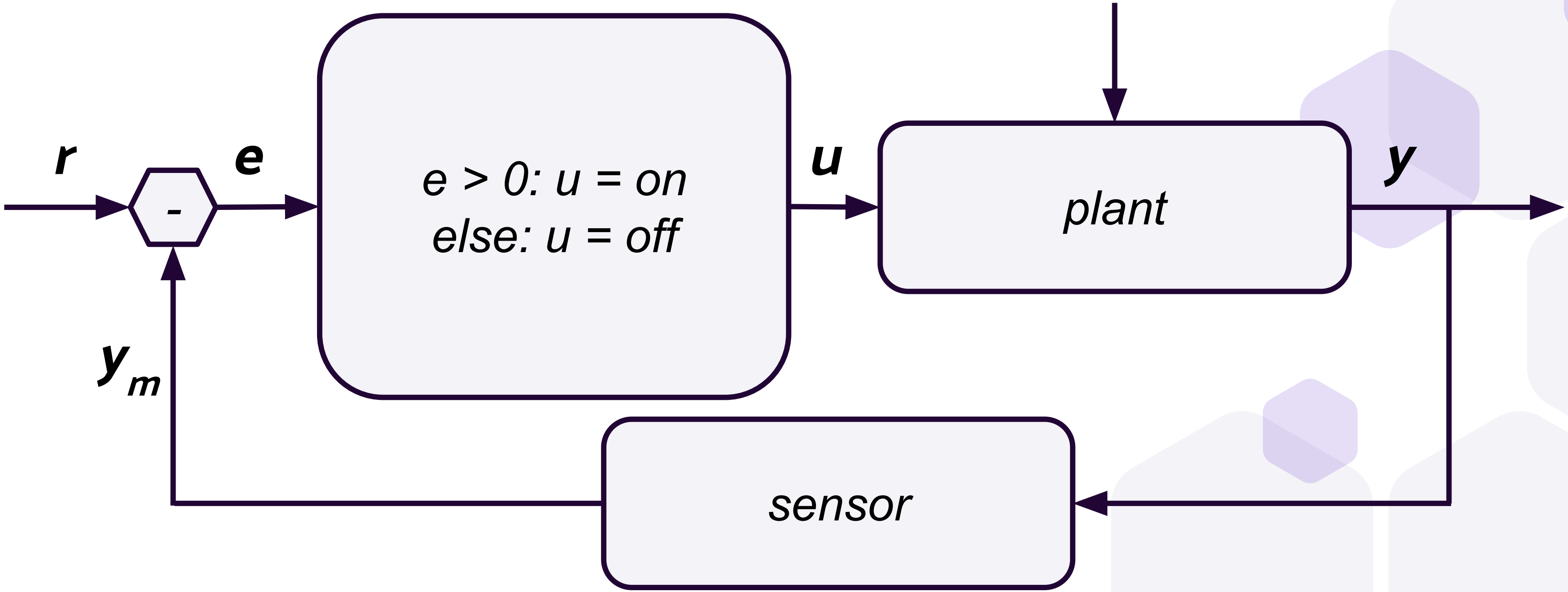
We want to control physical values (temperature, velocity, altitude, etc) but we only have voltage outputs. How do we achieve the desired values?

Feedback loops and control



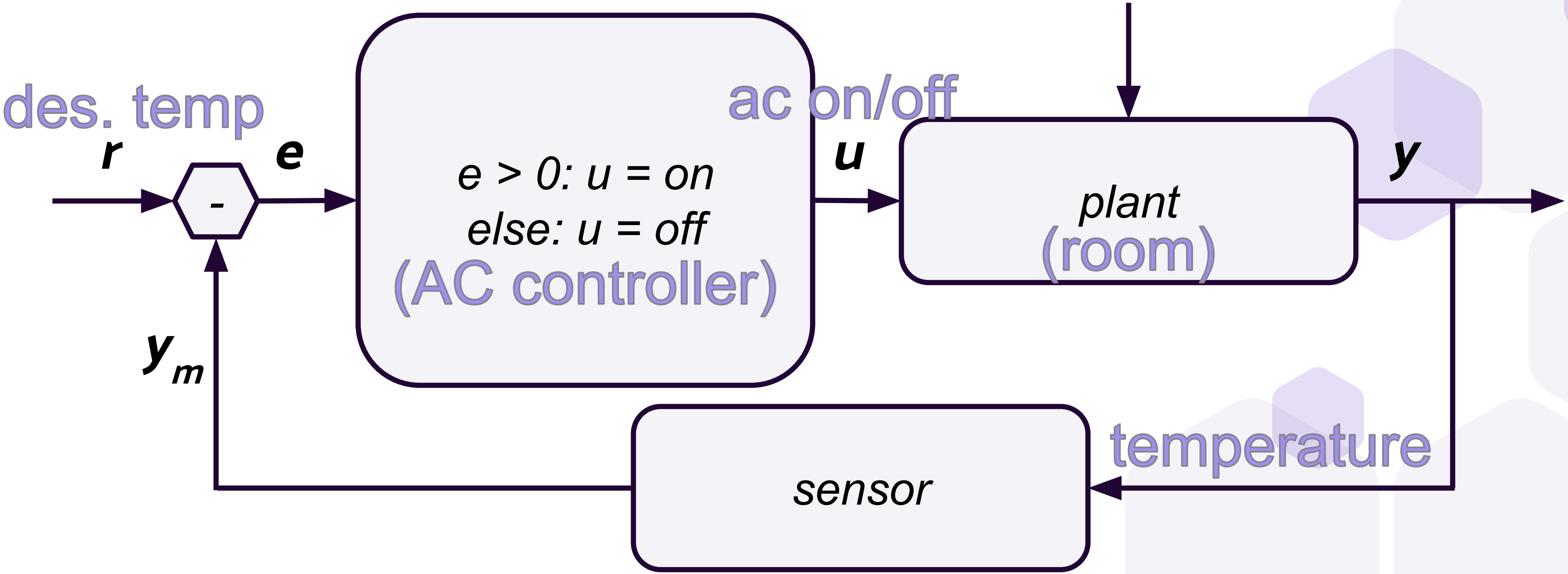
Bang-Bang controller

Controller output is 2-state ({on, off}, {up, down}, etc)

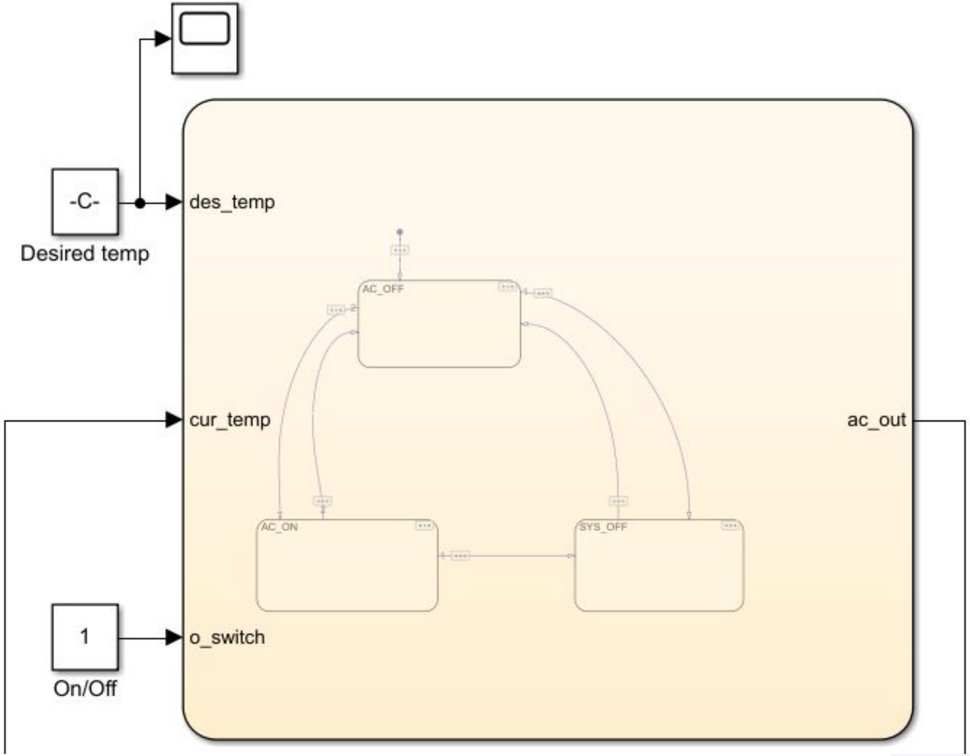


Bang-Bang controller

Controller output is 2-state ({on, off}, {up, down}, etc)



AC controller in simulink



Air conditioner temperature model

Dejvises, Jackravut, and Nutthaphong Tanthanuch. "A simplified air-conditioning systems model with energy management." *Procedia Computer Science* 86 (2016): 361-364.

The model can be described by the following equations

$$\frac{dQ}{dt} = \left(T_{in} - T_{aircon}\right) \cdot Mdot \cdot c \qquad (1)$$

$$\left(\frac{dQ}{dt}\right)_{losses} = \frac{T_{out} - T_{in}}{R_{eq}} \qquad (2)$$

$$\frac{dT_{in}}{dt} = \frac{1}{M_{air}.c}\left(\frac{dQ_{losses}}{dt} - \frac{dQ_{aircon}}{dt}\right) \qquad (3)$$

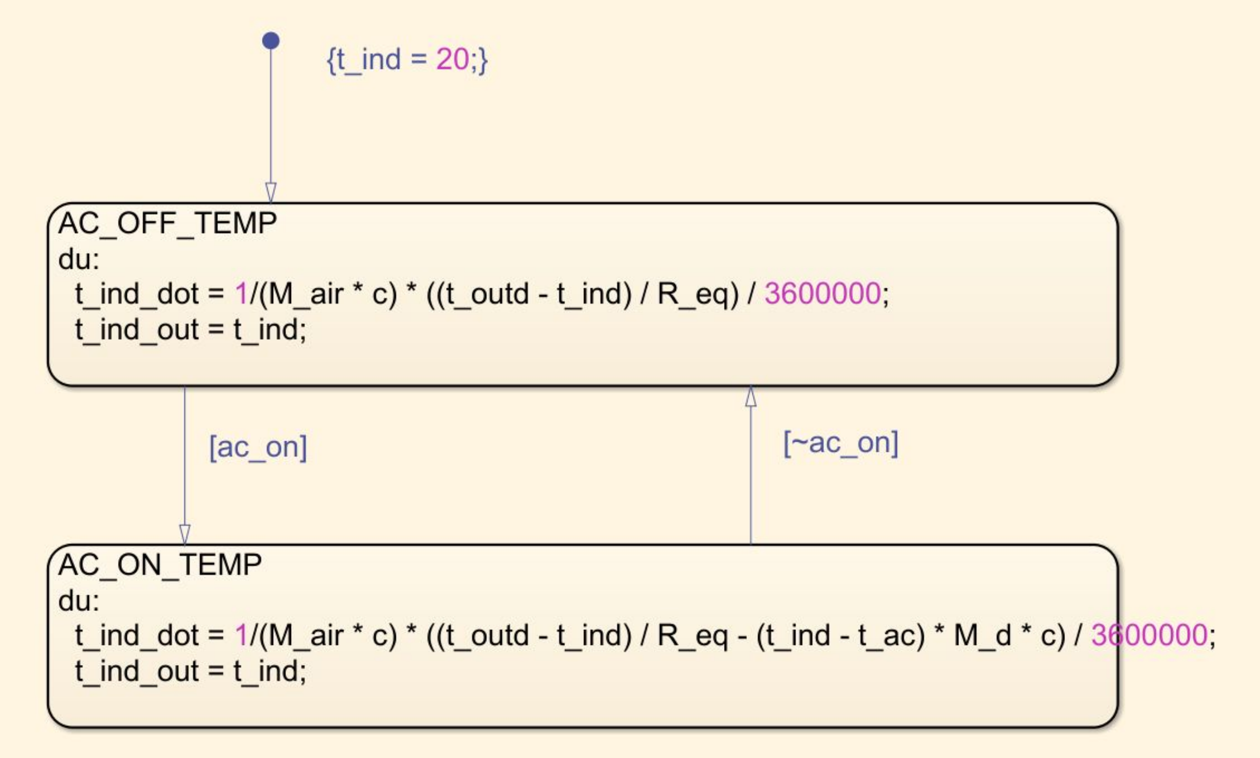
where

$\frac{dQ}{dt}$	heat flow from air-conditioner out of a room (J/h)	M_{air}	air mass inside the room (kg)
c	heat capacity of air at constant pressure (J/kg.K)	T_{in}	room temperature (°C)
$Mdot$	air mass flow rate through air-conditioner (kg/h)	T_{out}	outdoor temperature (°C)
T_{aircon}	temperature of cold air from air-conditioner (°C)	R_{eq}	equivalent thermal resistant of the room (K/W)

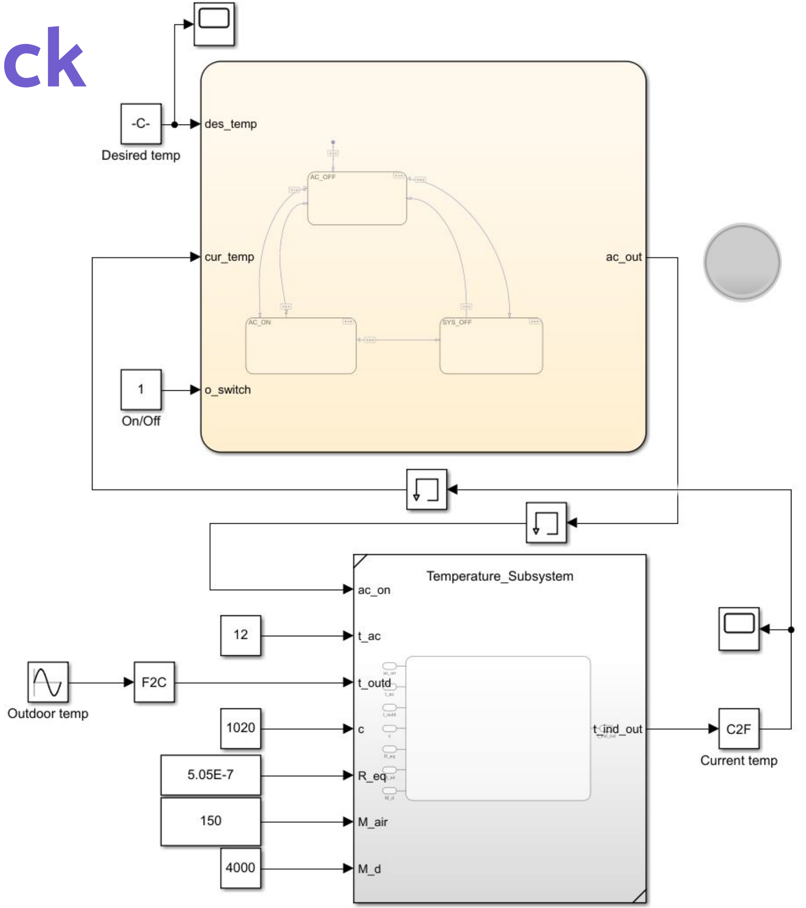
3. Experimental Results

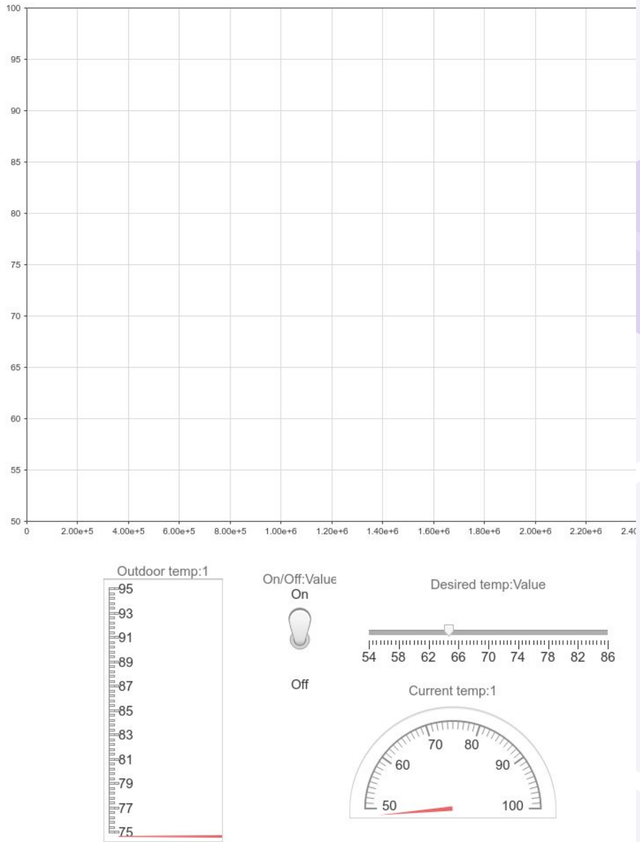
The experiments are performed in a room of which dimensions are 7.65m (W) × 7.69m (L) × 3.10m (H) as shown in fig.2. CENTRAL AIR brand air conditioner in the room has the cooling capacity of 7,500W or (25,590 BTU/h) as shown in fig.3. The rated electrical power consumption is 2,630 W. The model parameters have been estimated as followed. dQ/dt maximum at (25,590BTU/h * 1,055 J/BTU) J/h, c = 1020 J/kg.K, $Mdot$ = 2655 kg/h, T_{aircon} = 22.5°C, M_{air} = 182.37kg, R_{eq} = 5.05x10^{-8} K/W

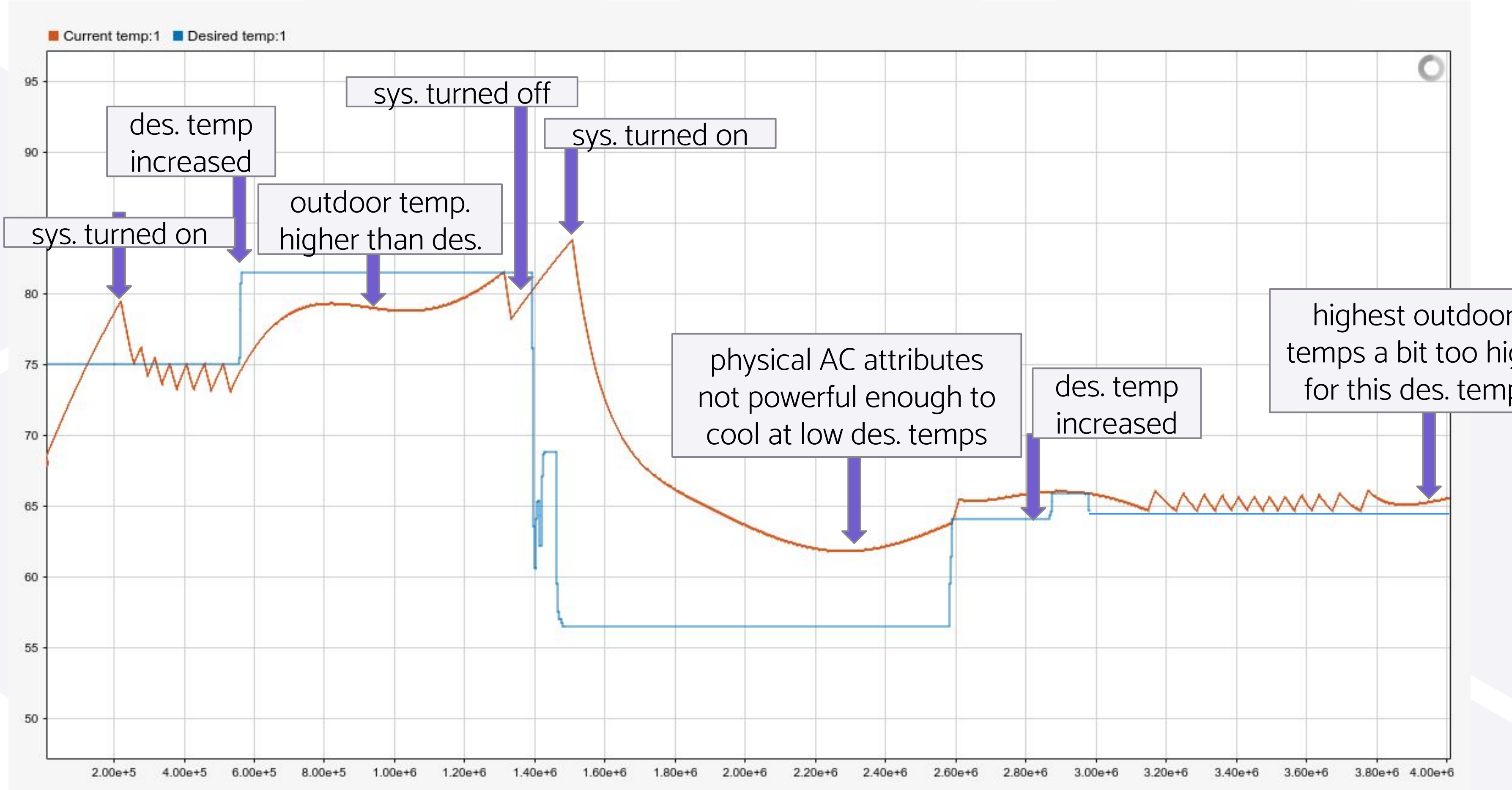
Temperature model in simulink based on paper



Feedback system model






Current temp:1
Desired temp:1
95
90
80
75
70
65
60
55
50
2.00e+5
4.00e+5
6.00e+5
8.00e+5
1.00e+6
1.20e+6
1.40e+6
1.60e+6
1.80e+6
2.00e+6
2.20e+6
2.40e+6
2.60e+6
2.80e+6
3.00e+6
3.20e+6
3.40e+6
3.60e+6
3.80e+6
4.00e+6
sys. turned on
des. temp increased
outdoor temp. higher than des.
sys. turned off
sys. turned on
physical AC attributes not powerful enough to cool at low des. temps
des. temp increased
highest outdoor temps a bit too hi for this des. tem

PID controller

For continuous controller outputs