



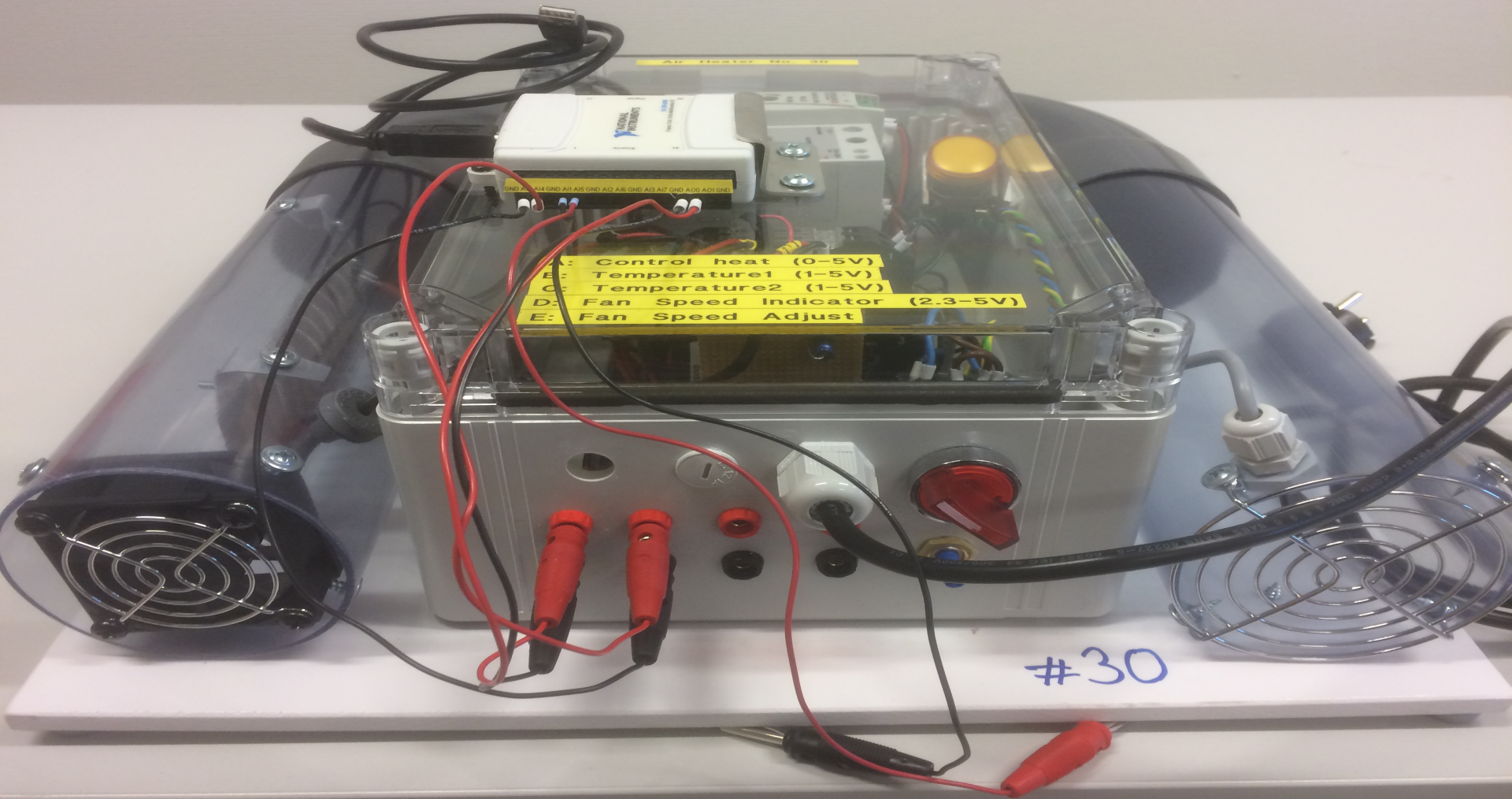
Air Heater Overview

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Introduction

The Air Heater is a small-scale Laboratory Process





A: Control heat (0-5V)
B: Temperature1 (1-5V)
C: Temperature2 (1-5V)
D: Fan Speed Indicator (2.3-5V)
E: Fan Speed Adjust

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Control System Example

PC with Control Application



PID

Control Signal

u

USB-6008 DAQ

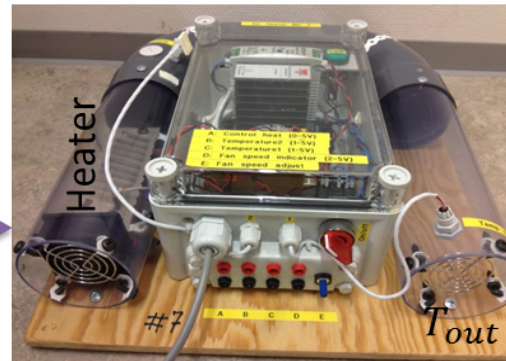


AO

0-5V

u

Air Heater Process



1 - 5V

T_{out}

y

Process Value

Digital Signal

AI

A/D



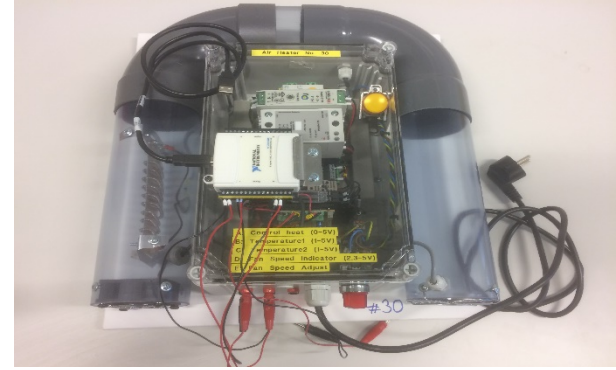
USB-6008 DAQ

Analog Measurement

Temperature

Air Heater

Mathematical Model



$$\dot{T}_{out} = \frac{1}{\theta_t} \{-T_{out} + [K_h u(t - \theta_d) + T_{env}]\}$$

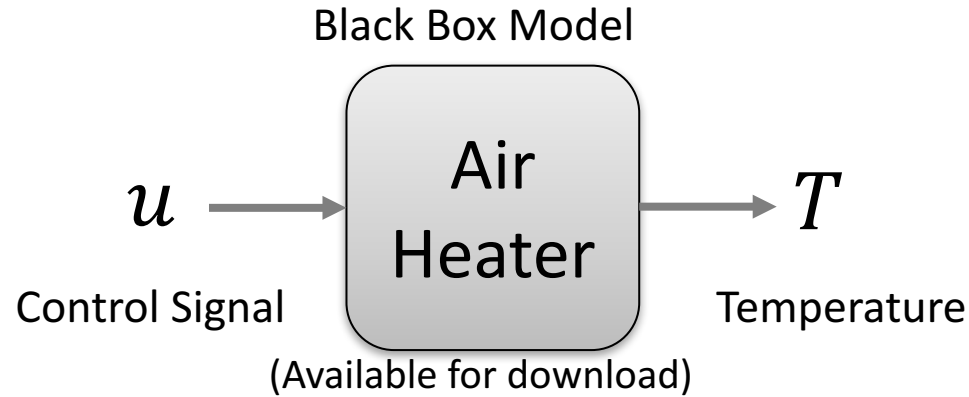
Where:

- T_{out} is the air temperature at the tube outlet
- $u [V]$ is the control signal to the heater
- $\theta_t [s]$ is the time-constant
- $K_h [deg C / V]$ is the heater gain
- $\theta_d [s]$ is the time-delay representing air transportation and sluggishness in the heater
- T_{env} is the environmental (room) temperature. It is the temperature in the outlet air of the air tube when the control signal to the heater has been set to zero for relatively long time (some minutes)

“Black Box Model”

- The Real Air Heater is only available in the Laboratory
- The Air Heater is also available as a “black box”. Actually, it is a LabVIEW SubVI where the Block Diagram and the Process Parameters are hidden.
- Useful when you are working outside the Laboratory

“Real Process” → “Black Box Simulator”



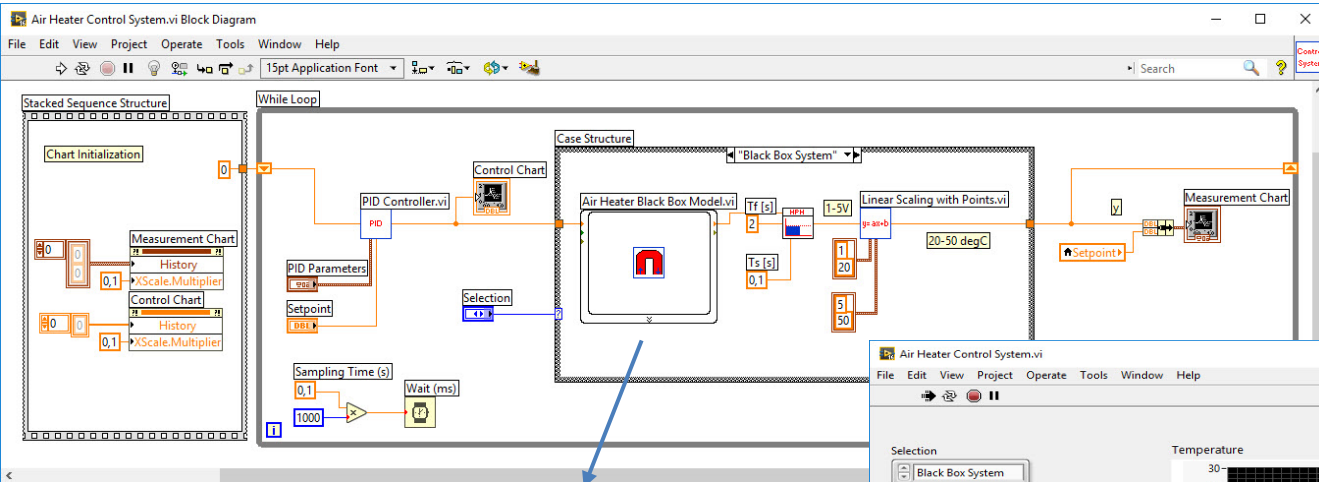
You can assume that the following model is a good representation of the “Black Box Model”:

$$\dot{T}_{out} = \frac{1}{\theta_t} \{-T_{out} + [K_h u(t - \theta_d) + T_{env}]\}$$

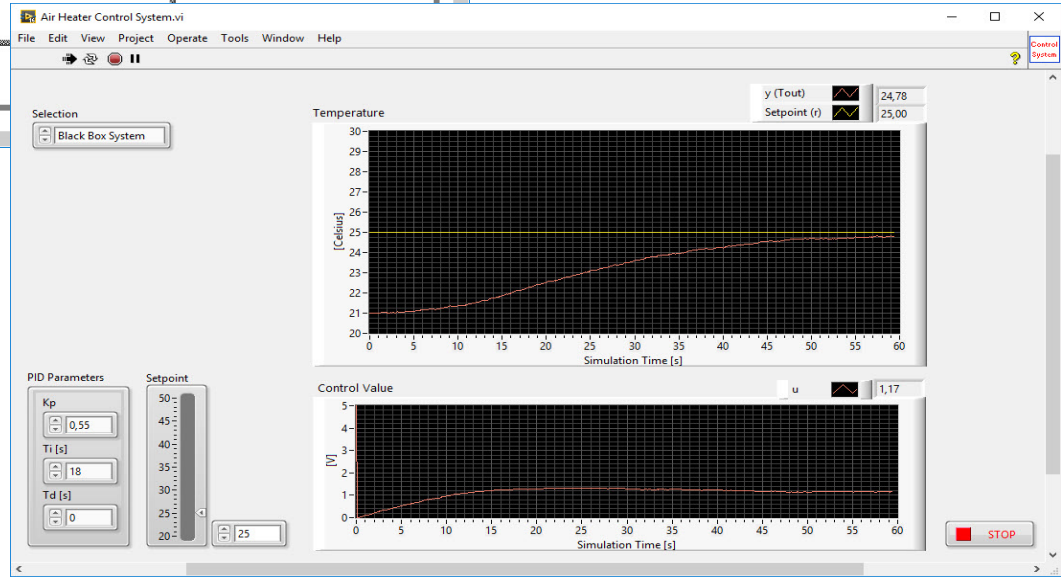
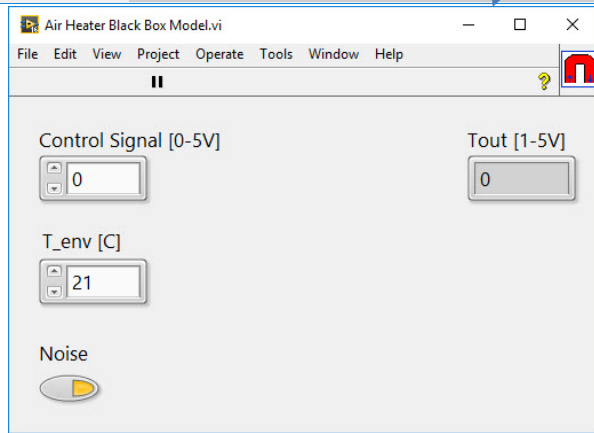
This means you need to need to find $\theta_t, K_h, \theta_d, T_{env}$

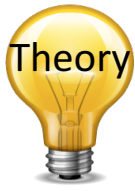
T_{env} is the temperature in the room

“Real Process” → “Black Box Model”

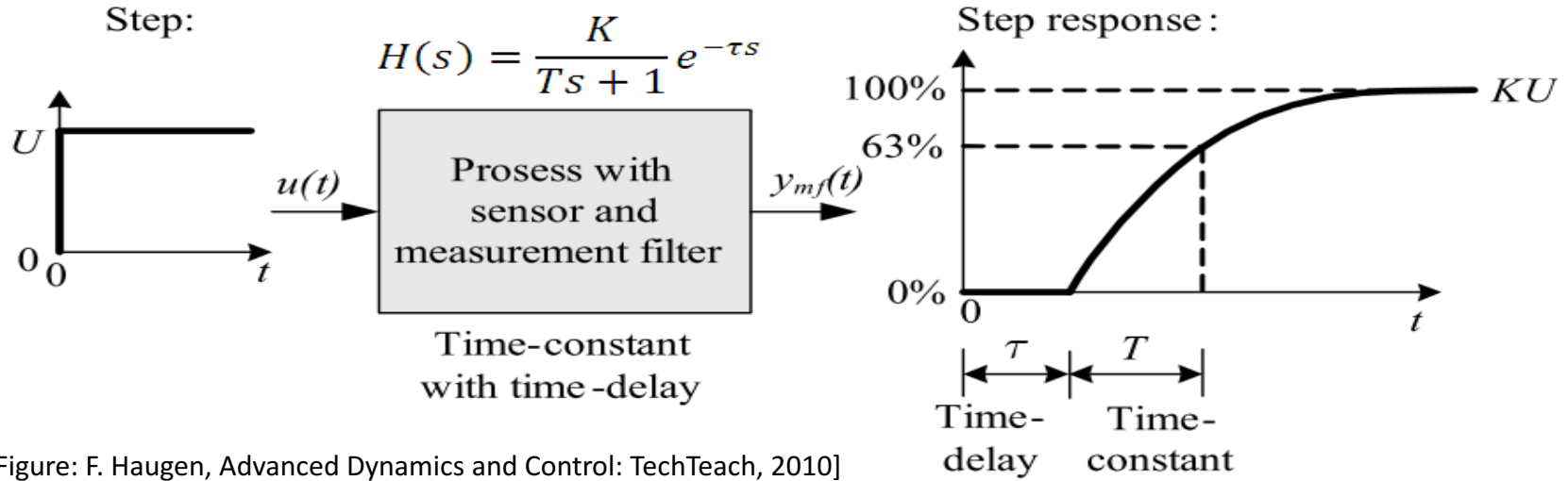


Here we see an example where we control the “Black Box” Model, which we “pretend” is the Real System





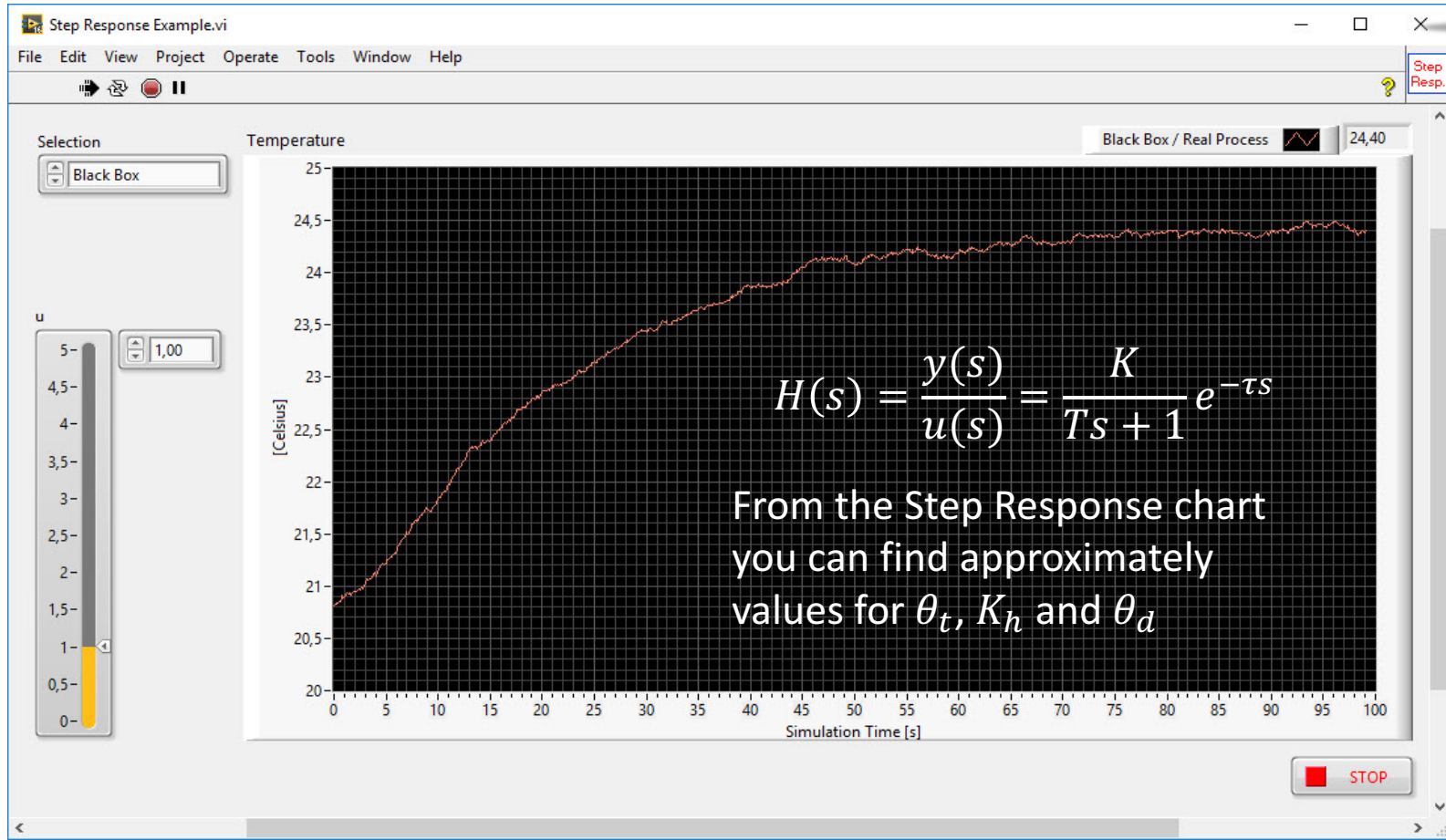
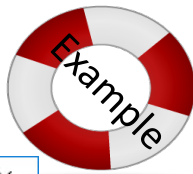
Step Response Method

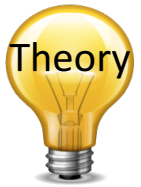


[Figure: F. Haugen, Advanced Dynamics and Control: TechTeach, 2010]

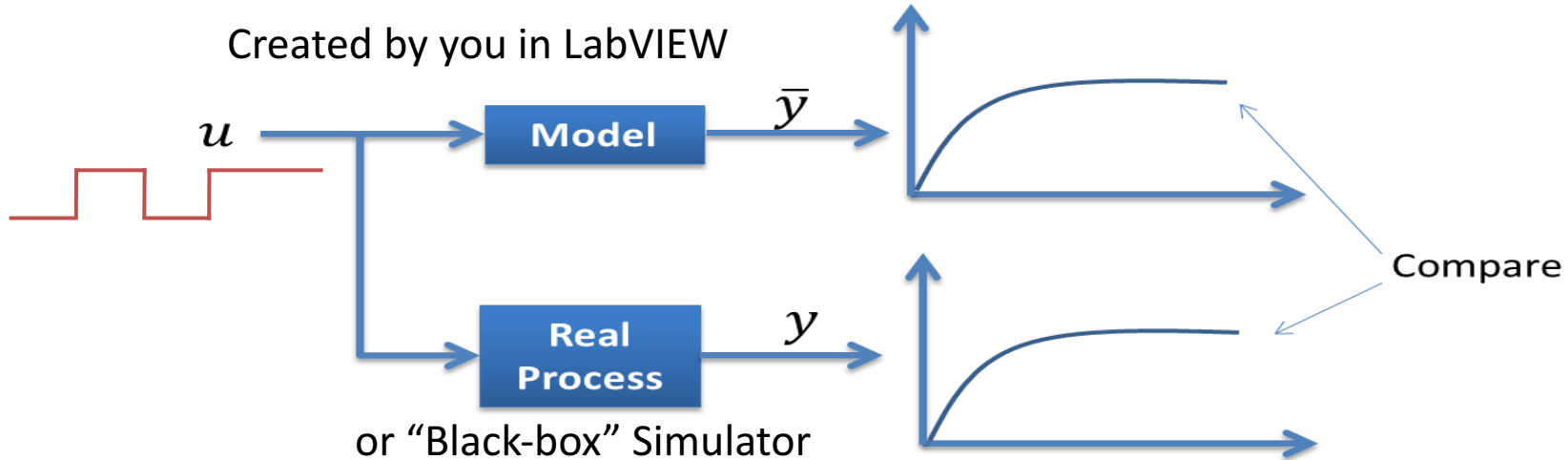
Assuming e.g. a 1.order model you can easily find the model parameters (Process Gain, Time constant and a Time delay if any) from the step response of the real system/or “Black-box” Simulator (plotting logged data)

Step Response Method



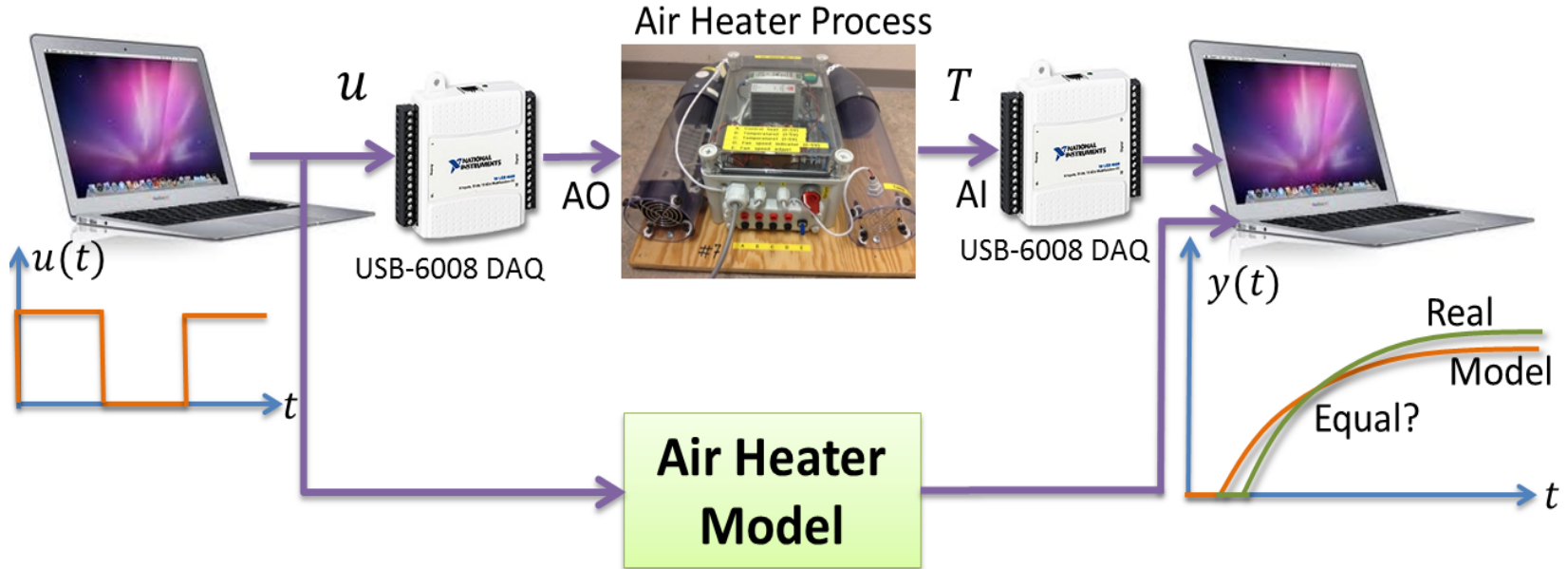


Trial & Error Method



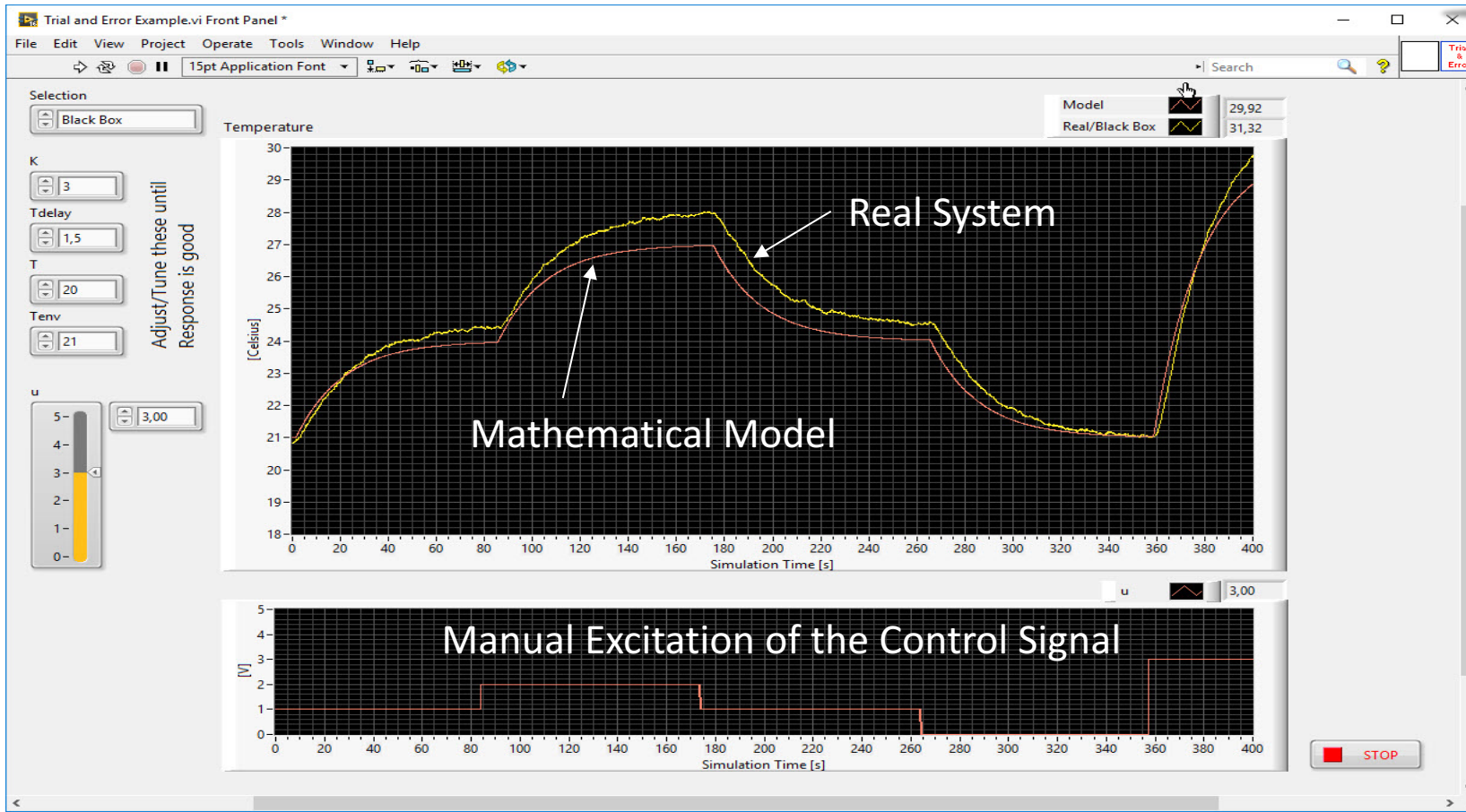
Adjust model parameters and then compare the response from the real system with the simulated model. If they are "equal", you have probably found a good model (at least in that working area)

Model Validation



You always validate the model by running the model in parallel with the real system, or test it against logged data from the real system.

Trial and Error and Model Validation



Air Heater Transfer function

The Air Heater process is a 1.order process with time-delay, so a transfer function on the following general form should be expected:

$$H(s) = \frac{y(s)}{u(s)} = \frac{K}{Ts + 1} e^{-\tau s}$$

Tip! Use **Laplace** transformation on the differential equation for the Air Heater and find the transfer function from $u(s)$ to $T_{out}(s)$.

$$H_{heater}(s) = \frac{T_{out}(s)}{u(s)} = ?$$

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