EEE4119F – practical 2

Student names: Student numbers:

A quick note: there are many ways of doing each question – you're given hints but you can do what you want. Just try to make sure you understand what each question is trying to teach you.

Question 1

You have been given the task of modelling an absolute pressure sensor (16 bit) (look for an ADC block) to observe its effects on your flight computer. The sensor has the following properties:

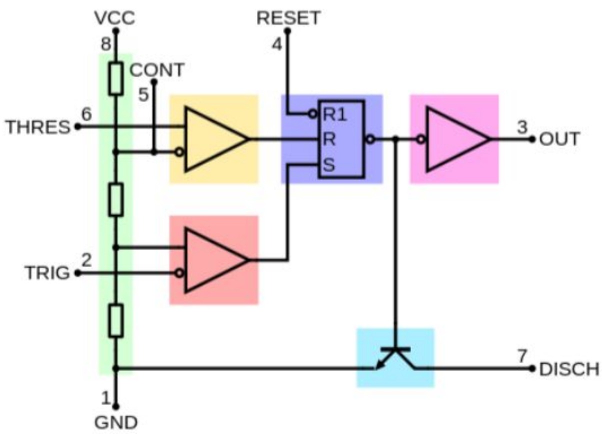
- Range of 115kPa to -15kPa
- Std. deviation noise (0.5 kPa)
- Sensitivity of 45.9 mV/kPa
- Assume a 5V supply voltage and sampling time of 0.02s (50Hz)
- Sensor lag of 0.5s

1. Model the system in Simulink. To model the lag effects, have a look at the Transfer Function Block in the Continuous library.
2. You would also like to observe the effect of sensor failure on your flight computer. Modify your sensor model so that it outputs zero after 5s
3. Apply a mask to the model so that the sensor can be easily/neatly used as a subsystem in a larger system (drag a box around the model > create subsystem)

TIP: you may find it useful to scope the signal at various points. Be aware that scaling issues may make a signal look like it's zero, when it's actually just much smaller than another signal on the same plot. Also, "right click on a plot > configuration properties > show legend" may be helpful

Question 2

A 555 timer works by pulling the output pin high when the trigger pin (pin 2) falls below 1/3 of the supply voltage. It is then pulled low if the threshold pin (6) falls below 2/3 of the supply voltage. We can create a simple model for this device in Simulink consisting of these two inputs and an output.



Before you try the question, brush up on how the 555 timer works, if you forgot. This will be unnecessarily hard otherwise

Also, this question is not about recreating the circuit using eg Simscape. For example, you can use "compare to constant" instead of "op-amp"

a) The output pin is controlled by an RS Flip Flop. Create an S-R Flip flop model in Simulink. *Hints: Check out the Combinatorial Logic block, also have a look at the Memory Block. I wrote some extra documentation for the Combinatorial Logic block at the end of this prac paper*

b) Using your RS Flip Flop, create a simple 555 Timer model block. Test it by feeding in various input values.

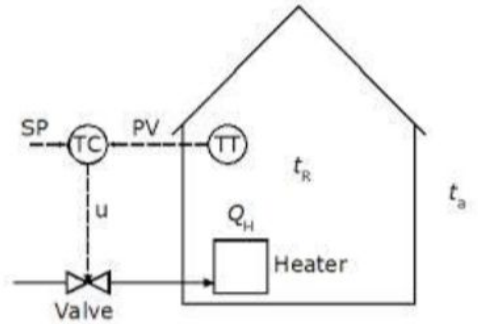
c) Create an astable vibrator by feeding back the output of the 555 timer into the Trigger and Threshold pins. To simulate a resistor-capacitor circuit charging/discharging use a Transfer Function block with $T(s) = \frac{5}{s+1}$

Question 3

You have been tasked with designing a simple temperature controller for a house.

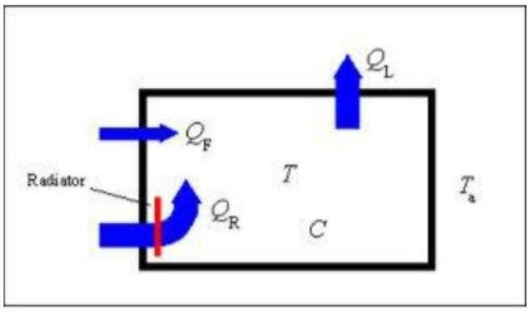
In this figure,

- SP = "Set Point" for the temperature, +25°C
- PV = "Process Variable" measured
- e = "error" = SP - PV
- TT = Temperature sensor and transmitter
- TC = Temperature controller



The control task is to control the heat output from the radiator until the room temperature is close to comfort temperature, i.e. +25°C - whatever might happen to heat losses and heat input from sun shine through windows etc.

The function is as follows: The temperature sensor measures the temperature in the room. Send the temperature to the controller (TC). The controller sends the control value, u, to the valve. The valve controls the energy flow (hot water, electricity, natural gas) to the heater/radiator.



The energy balance of the house is shown below:

$$Q_R + Q_F - Q_L = C_R \frac{dT}{dt}$$

Also,

$$Q_L = K(T - T_a)$$

Where,

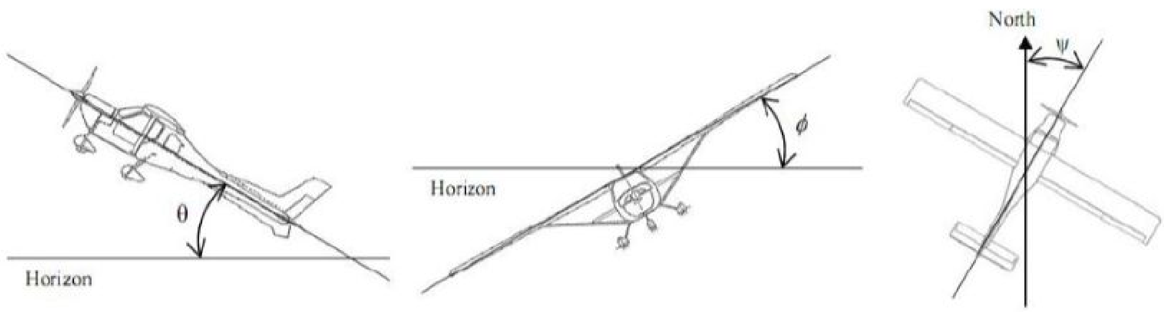
- T = Room temperature [5°C initially]
- C_R = Heat capacity of the room [100000 J/K]
- Q_R = Heat flow from room heater (radiator) [1500 W]
- Q_F = Free heat flow, eg. from sun radiation [1000 W]
- Q_L = Heat flow loss [W]
- T_a = Ambient temperature [0 °C]
- K = Coefficient of heat loss [100 W/°C]

a) Your first task to create a model for the house and simulate it for six hours. Assume that the sun energy is added 2 hours into the simulation. Use a Matlab script to make your system more configurable. It should save variables to your workspace, which your Simulink model can use. *[hint: you may want to increase the solver step size]*

b) Add an On-Off controller to your radiator. This controller will try and regulate the temperature to 25 °C. You can use a Relay Block to implement the switching with a hysteresis of +/- 1°C. Also add a sensor lag (3s) to your feedback loop. Also increase the radiator heat flow to 2500W. *Hint: Check out the Transfer Function with Initial Output Block*

Question 4

Aircraft attitude can be measure by three Euler angles (roll, pitch and yaw respectively) as shown in the following figure:



Most aircraft are equipped with MEMs gyro, which are capable of measuring the rotation rate of the aircraft in its three body axes. The Euler angles can be obtained by the following differential equation:

$$\begin{bmatrix} \dot{\Phi} \\ \dot{\Theta} \\ \dot{\Psi} \end{bmatrix} = \begin{bmatrix} 1 & \sin\Phi\tan\Theta & \cos\Phi\tan\Theta \\ 0 & \cos\Phi & -\sin\Phi \\ 0 & \sin\Phi\sec\Theta & \cos\Phi\sec\Theta \end{bmatrix} \begin{bmatrix} P \\ Q \\ R \end{bmatrix}$$

Note that P, Q and R are the gyro (roll, pitch, yaw) rates in the aircraft axes

a) Using a MATLAB Function block in Simulink create a model to simulate this system.

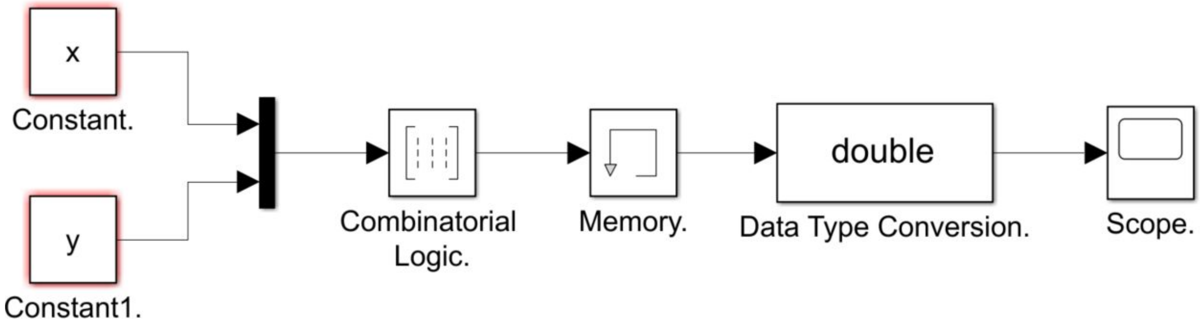
b) What would the effect be if the roll rate gyro has 0.1 rad/s white noise as well as a constant bias of 0.01 rad/s?

Extra combinatorial logic block documentation for question 2

The combinatorial logic block is essentially a truth table. As a reminder, a truth table can represent an XOR gate using the following table:

```
x y | z
-------
0 0 | 0
0 1 | 1
1 0 | 1
1 1 | 0
```

Since it is a single-input block, you have to combine multiple inputs using a MUX block, as follows:



You'd represent an XOR gate in the combinatorial logic block using the following array: `[0; 1; 1; 0]`. In this way 3 inputs with 2^3 = 8 possible arrangements would require an array of length 8 which looks something like `[0; 1; 1; 0; 1; 1; 0; 0]`

Next, you need a "memory" block (which feeds back into the MUX and then combinatorial block) to complete your S-R flip flop.

Finally, since the combinatorial logic block outputs a boolean value, you may need to use a "Data Type Conversion" block to get things back to doubles so that you can display them, pass them through transfer functions, etc. I suggest making a small model (as in the picture of the model above) and playing around until you're comfortable with how it works.

As an aside, some blocks have a "Signal Attributes" tab that can be used to adjust the block's output data type. You'll find this on the "constant" block, which may be helpful if you're testing your combinatorial logic block.