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MODELLING A HEATING SYSTEM OF A CAR

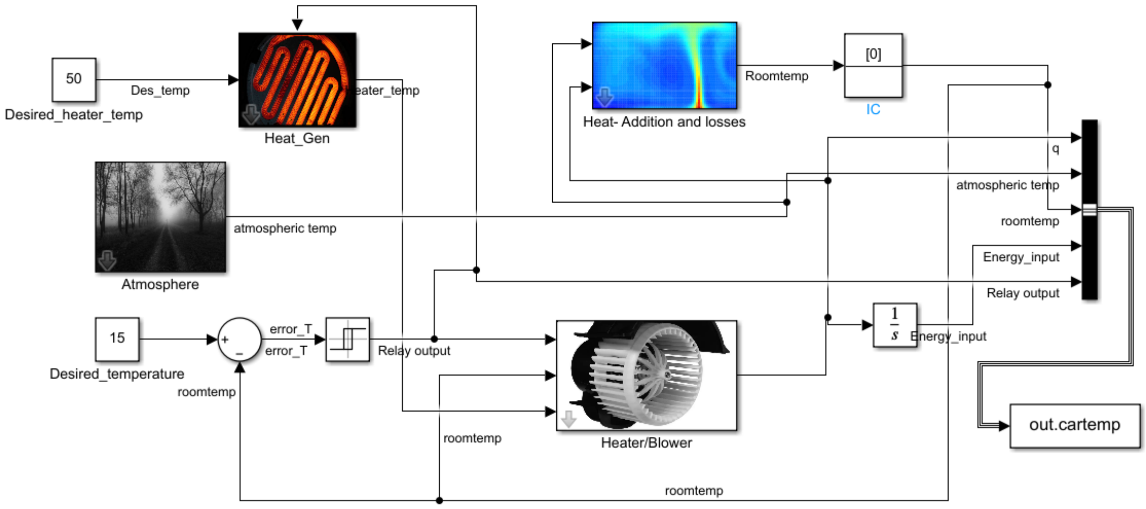
MATLAB SIMULINK

Let us suppose, one takes a car ride from Ladakh to Srinagar. The entire journey takes about 10 hours and distance to be travelled is 420 kilometers. If the trip is made in winter, one would surely require a heating system inside their car to keep them cozy and comfortable and help them battle the near zero temperatures outside.

Taking into considerations of the factors that would increase or decrease the temperature inside a car, a Simulink model is developed to get an estimation of how much energy one would require to complete the trip in a comfortable environment.

The atmospheric or the ambient temperature is considered to be 0°C and the desired temperature, 15°C. A heater coil is to be heat the incoming air from the atmosphere and through a blower the air heats up the interior of the car. The relay system switches on or off the system according to the error in temperature.

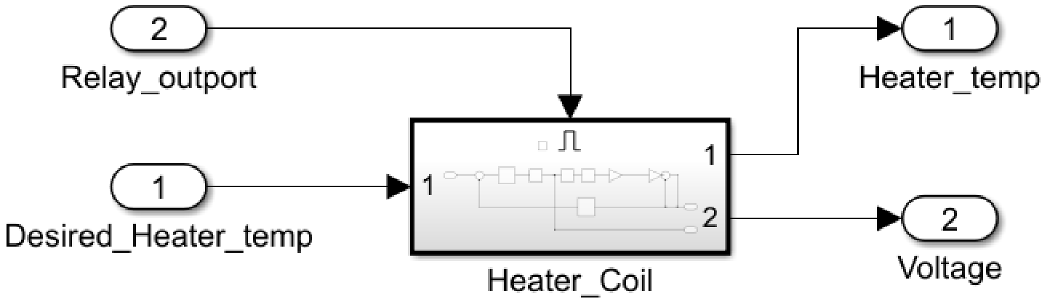
MODEL



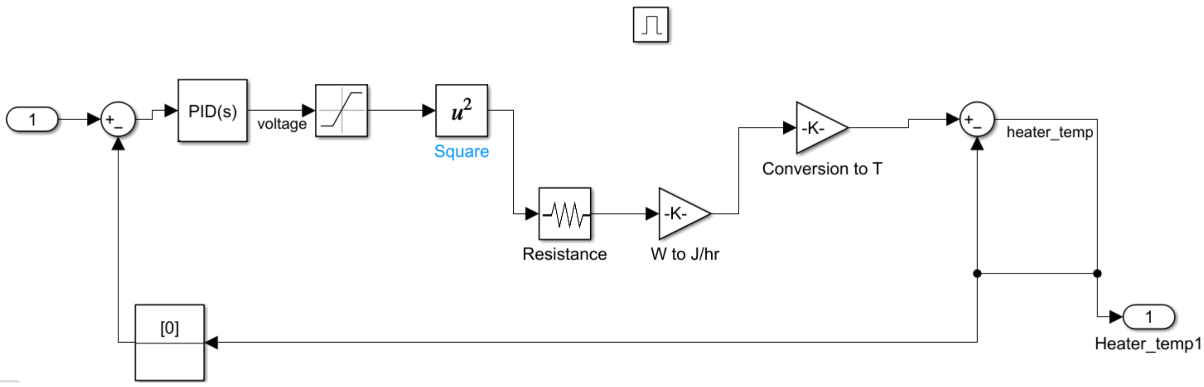
The entire model is divided into multiple subsystems: Heat generator, Heater/Blower, Atmosphere and the heat exchange area, i.e., the cabin space in the car. The difference between the room temperature and the desired temperature is fed to a relay and this determines whether the heat will be transferred to the car interior or not. The relay has a limit of ± 1°C.

The entire model is run taking hours as the unit of time.

Heat Generator:



Inside the heater coil:



A desired temperature of 50°C is set for the coil and initially the coils are at 0°C. When the power is passed to the coils, it takes some time for the coil to heat up to the desired temperature. Thus, a PID controller is used to speed up the process. Multiple times the model was run to get the optimum parameter values for the controller.

The entire subsystem is classified under an enabled subsystem, meaning that the heat will be generated only when the relay output is true, when it is off the power switches off. Reset option is enabled in the enabled subsystem.

From Joule's heating effect, the heat generated is equal to

$$\dot{Q} = \frac{V^2}{R}$$

$$where, \quad V\ is\ the\ voltage$$
$$R\ is\ the\ resistance = 100\ \Omega$$

While the temperature change is

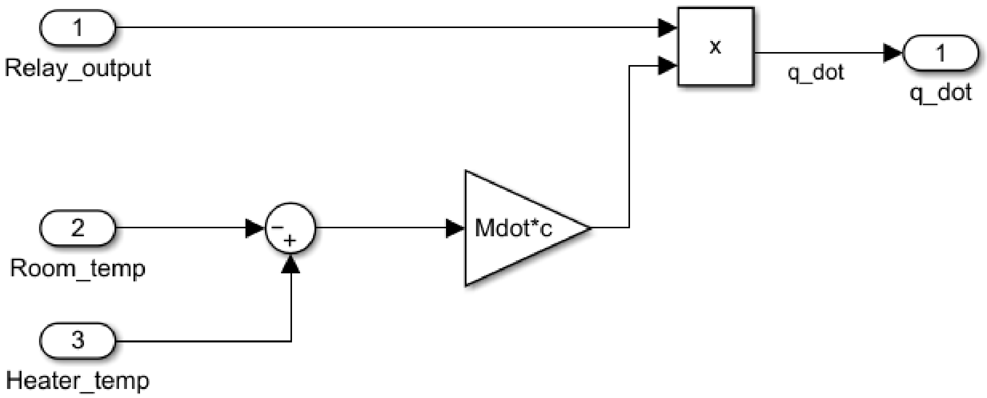
$$\Delta T = \frac{\dot{Q}}{\dot{m}C}$$

$$where, \qquad \dot{m} \ \ is\ the\ air\ flow\ rate = 10 \quad kg/hr$$

$$C\ is\ the\ specific\ heat\ capacity\ of\ air = 1005 \quad J/kg°C$$

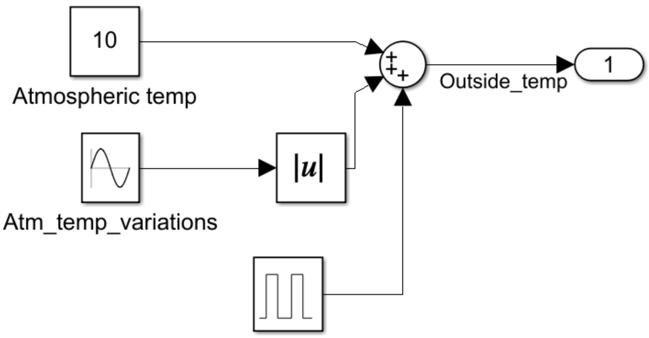
The heater temp. is fed as the input to the next subsystem heater/blower. Note that the heater coils take some time to heat up to the desired level.

Heater/Blower:

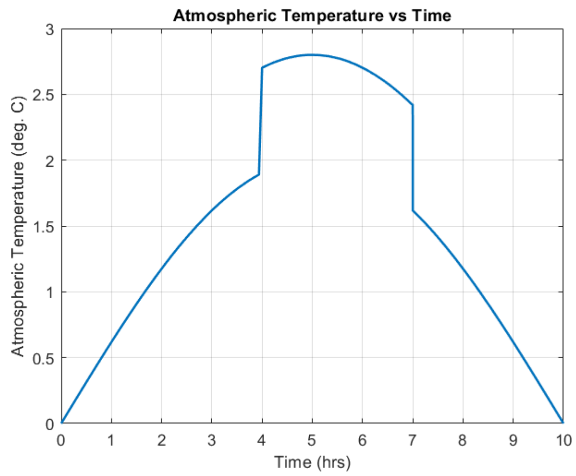


The heat ouptput is fed to the heat exchange subsystem.

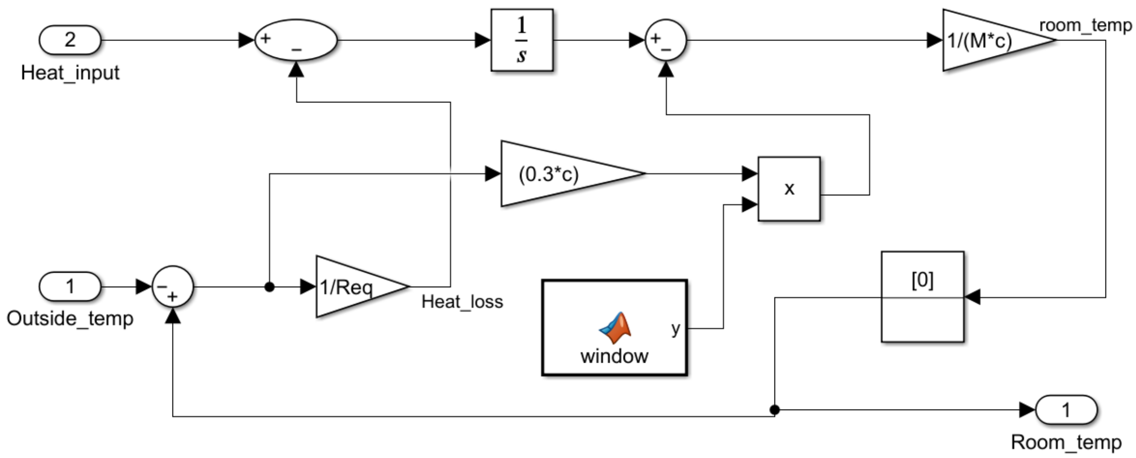
Atmosphere:



Here the atmospheric temperature is modelled with some variations as the temperature is never constant.



Heat exchanger – Addition and losses:



The temperature of the car interior will be increased by the air flow from the blower, while heat conduction through the car doors and the opening and closing of the door and windows will cause a temperature drop inside the car. The heat addition and heat losses are subtracted and the resulting room temperature is calculated. This value is fed to the to relay and the loop continues.

$$\dot{Q}_{losses_{atm}} = \frac{\Delta T}{Req}$$

$$Q_{losses_{windows}} = m_{air} C \Delta T$$

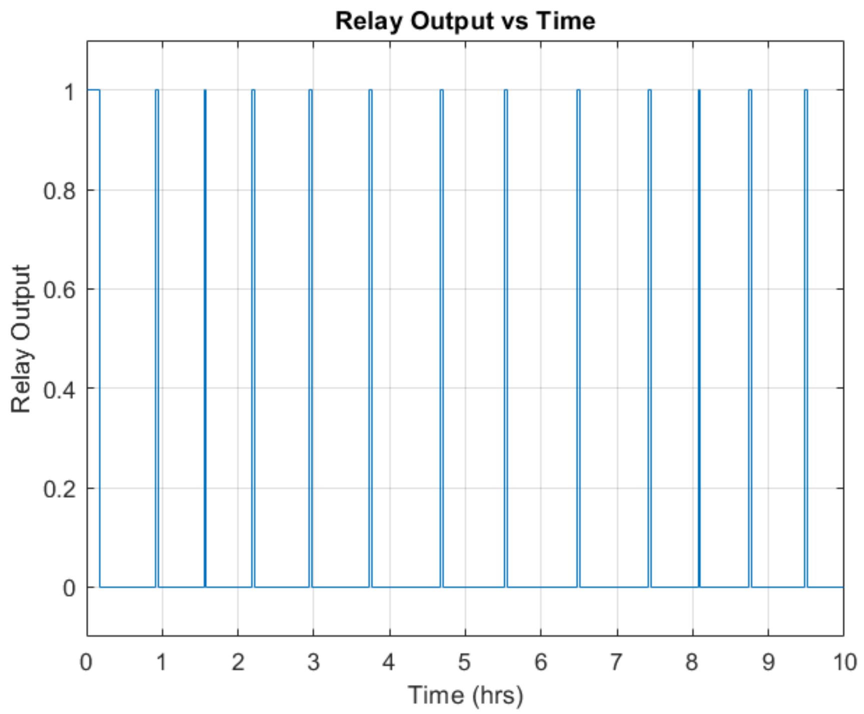
$$Room\,Temp, \qquad T = \frac{1}{MC}\left(\int (\dot{Q} - \dot{Q}_{losses_{atm}})dt \; - Q_{losses_{windows}}\right)$$

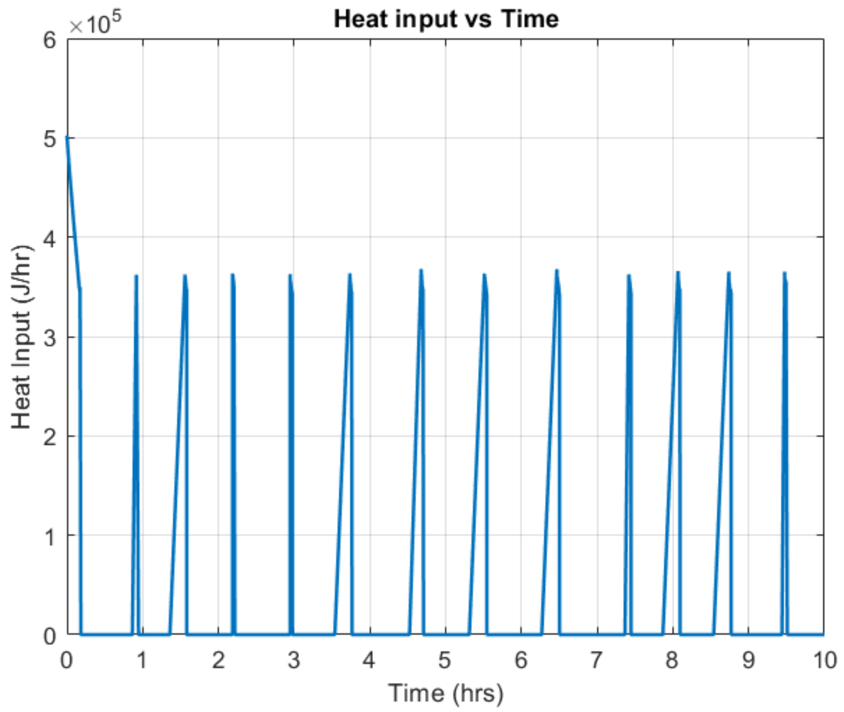
$where,\;\; Req\ is\ the\ equivalent\ thermal\ resistance\ of\ a\ car = 0.001\ \ ^{\circ}C\,(J/hr)^{-1}$

$m_{air}\ is\ the\ mass\ of\ incoming\ air\ when\ windows\ are\ open = 0.3\ kg$

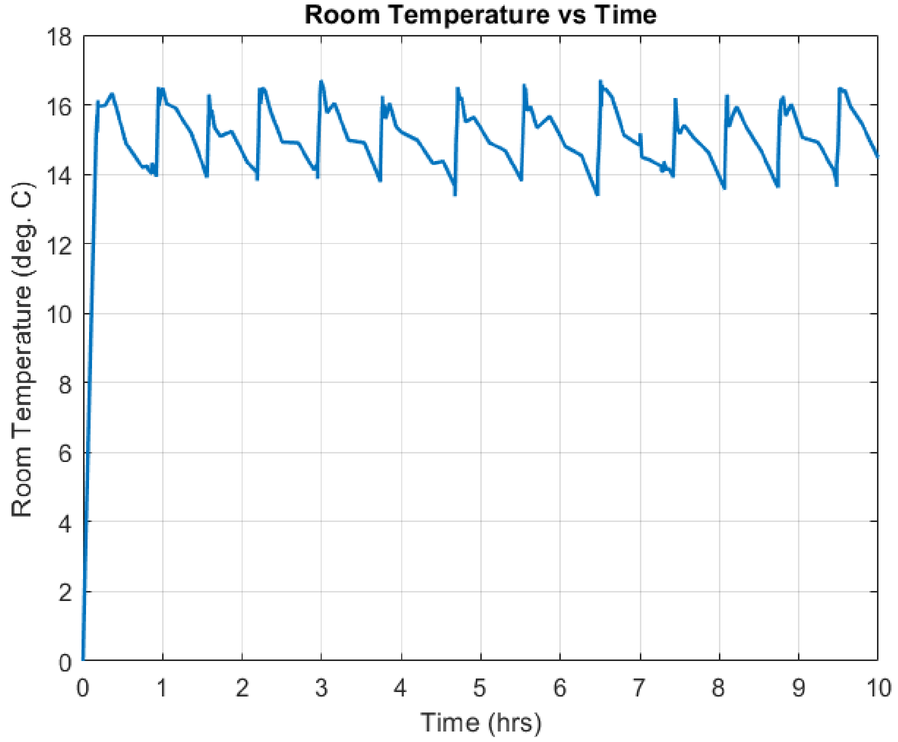
$M\ is\ the\ mass\ of\ air\ inside\ the\ car \qquad = 4.375\ kg$

RESULTS

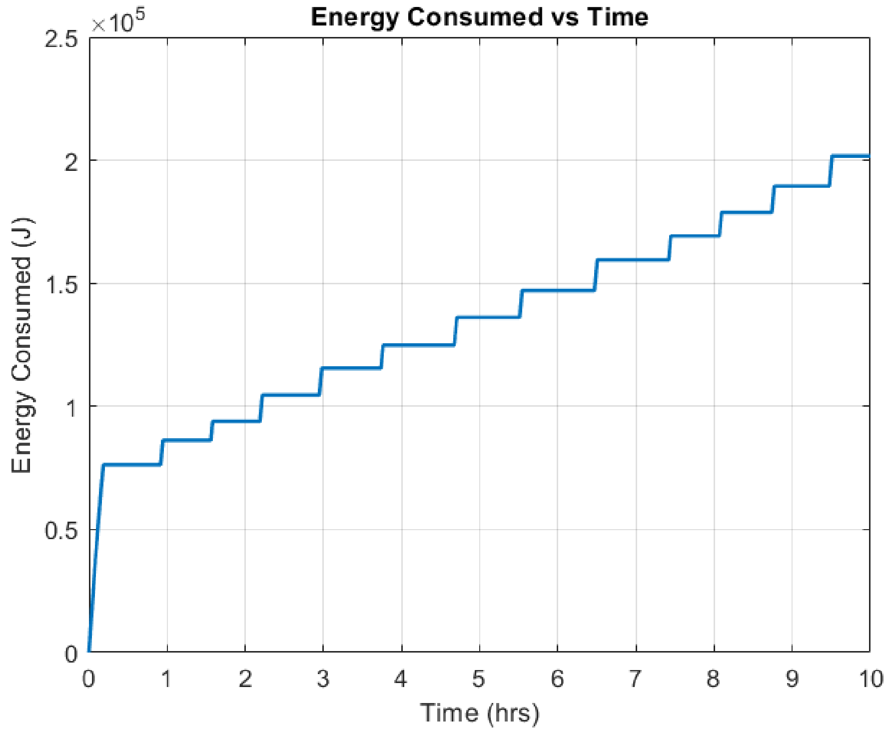




From the relay and heat input graphs we can see that whenever the relay is switched on heat is transferred to the air cabin. Initially the heat input is very high because the cabin temperature is at 0 deg. C intially.



The variation of air cabin temperature throughout the journey is plotted above. The room temperature oscillates between 14 and 16 as the tolerance limit was ± 1°C.



The total energy consumed is plotted above.