OSEM

Paul J.M. van Kan
HAN University of Applied Sciences
Arnhem, The Netherlands

June 23, 2021

Contents

1 Introduction

This document presents the basic information for calculating a house model based on an RC network. This category of house models, analogous to electrical impedance networks, may have different numbers of R and C components, and may have various component topologies. For the specific model properties, references will be given.

2 Heat pump model

In heat transfer theory the basic thermal circuit contains thermal resistances. Heat transfer occurs via conduction, convection and radiation. In analogy with Ohm's Law for electricity, expressions can be derived for the heat transfer rate (analogous to electrical current) and the thermal resistances (analogous to ohmic resistances) in these three modes of heat transfer. The temperature difference plays a role analogous to the electrical voltage difference. These expressions are shown in Fig. 1.

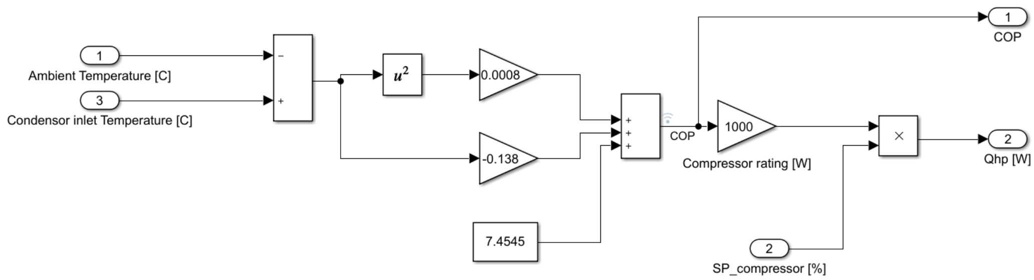


Figure 1: Heat pump model in Simulink [**GIGO**]

.

Listing 1: Heat pump model in Python

```
def HP_equation(T_amb, T_inlet_cond, P_compressor_kW, SP_compressor):
    p = Polynomial([7.4545, -0.138, 0.0008])
    cop = p(T_inlet_cond - T_amb)
    q_hp_W = cop * (P_compressor_kW * 1000) * SP_compressor
    return cop, q_hp_W
```

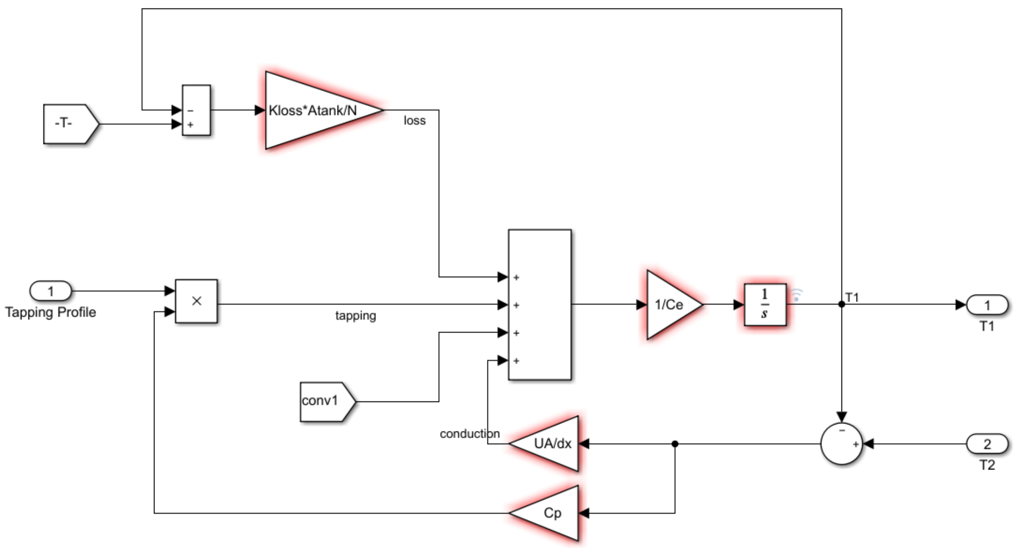


Figure 2: Storage tank layer model in Simulink

.

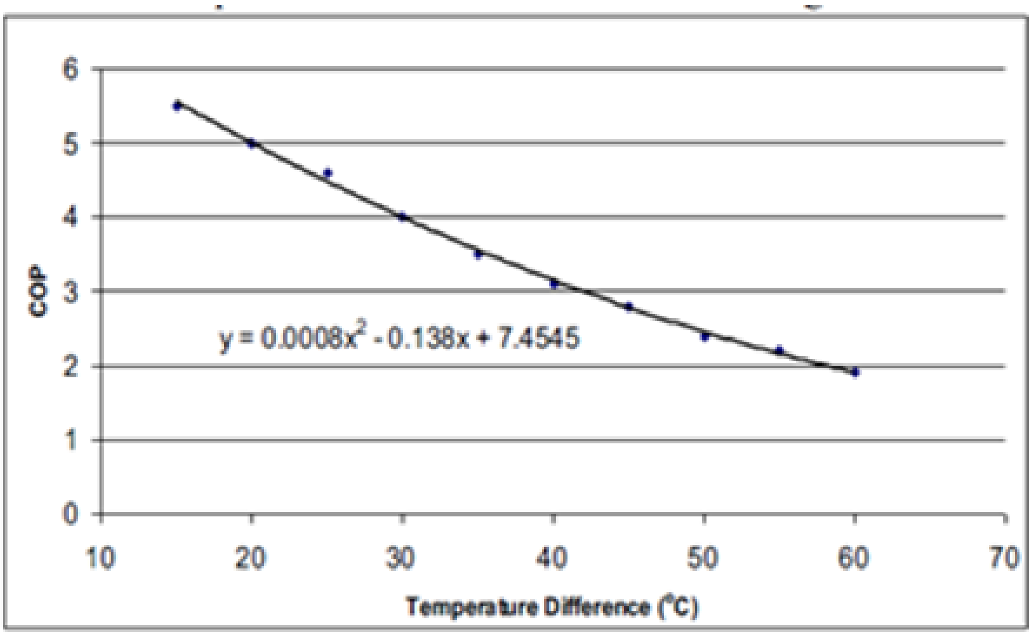


Figure 3: COP vs. Temperature difference between evaporator and condensor side [**GIGO**]

.

Heat transfer rate $\dot{Q}$ in $[W]$

$$c_{evap} \cdot \frac{dT_{a,out}}{dt} = \dot{m}_{air} \cdot c_{p,air}(T_{a,in} - T_{a,out}) - \dot{Q}_{evap} \tag{1}$$

Where $C_{evap}[J/K]$ is the heat capacity of the evaporator. $T_{a,in}$ and $T_{a,out}[K]$ are the temperatures of the air entering and leaving the evaporator, respectively. $\dot{m}_{air}$ $[kg/s]$ is the mass flow rate of the air through the evaporator. $\dot{Q}_{evap}[W]$ is the rate of thermal energy delivered by the evaporator. Note that the last term $\dot{Q}_{evap}$ can be rewritten as:

$$\dot{Q}_{evap} = P_{hp} \cdot (COP - 1) \tag{2}$$

Similarly, from the figure above, the heat balance of the condenser can be written as:

$$c_{cond} \cdot \frac{dT_{w,out}}{dt} = \dot{m}_w \cdot c_{p,w}(T_{w,in} - T_{w,out}) - P_{hp} \cdot COP \tag{3}$$

The set of equations presented above characterize the heat delivered by the heat pump as a function of the ambient temperature and the compressor power.

3 Storage tank model

The heat balance equation for one layer of the tank can be written as:

$$c_{layer} \cdot \frac{dT_{layer}}{dt} = \dot{Q}_{conduction} + \dot{Q}_{convection} + \dot{Q}_{tapwater} + \dot{Q}_{heating} + \dot{Q}_{heatloss} \tag{4}$$

3.1 Conduction

Thermal Law:

$$\dot{q} = -\lambda \cdot \frac{T_2 - T_1}{\Delta x} \tag{5}$$

$$\text{Heat flux } \dot{q} \text{ in } [W \cdot m^{-2}] \tag{6}$$

$$\lambda \text{ in } [\frac{W \cdot m}{m^{-2} \cdot K}] = [\frac{W}{m \cdot K}] \tag{7}$$

Thermal conductivity is a material property.

Conduction is the heat transfer between adjacent layers in the tank. This can be elaborated for layer 1 as:

$$\dot{Q}_1 = (\lambda_{water} \cdot A_{tank} + \lambda_{wall} \cdot A_{wall}) \cdot \frac{T_2 - T_1}{\Delta x} \tag{8}$$

Where $(\lambda_{water} \cdot A_{tank})/\Delta x$ is the thermal conductance through the interface with layer 2 in $[Wm/K]$. Δx is the length (height) of the layer $[m]$. For the layers 2 to 4:

$$\dot{Q}_n = (\lambda_w \cdot A_{tank} + \lambda_{wall} \cdot A_{wall}) \cdot \frac{T_{n-1} - 2T_n + T_{n+1}}{\Delta x} \tag{9}$$

And finally, for layer 5:

$$\dot{Q}_5 = (\lambda_{water} \cdot A_{tank} + \lambda_{wall} \cdot A_{wall}) \cdot \frac{T_4 - T_5}{\Delta x} \tag{10}$$

4 Setting up Raspberry Pi

A Raspberry Pi 4B was received from Contecto. This RPi contains a 16GB SD card with a standard RPi Debian image. Contecto tweaked the settings of the WiFi module, so that it forms an ad-hoc Wifi network with the TinyPico device.

4.1 Formation of the ad-hoc Wifi network between RPi and TinyPico

...to be written

4.2 Getting started with the RPi

The RPi as delivered is connected to:

- a computer screen with the included mini-HDMI to HDMI cable
- a USB keyboard
- a USB mouse
- a 230 V mains outlet socket. Use the included wall adapter with a USB-C interface to the RPi.

Keep the order of connecting things given above. The RPi will start up immediately upon connecting to the mains voltage.

The RPi comes with the standard device name: raspberrypi, the standard username pi and password-less logging in with complete (sudo) privileges. This is the easiest, but also the most unsafe way of operating a Linux system. Let's do something about it.

Under the Raspberry menu (default location: in the top left corner of the screen) go to Preferences → Raspberry Pi Configuration, and open the configuration program.

- on the System tab:
  - change the hostname to: osempi
  - disable the auto-login
  - disable the splash screen
  - Change Password to #Controller123
- on the Interfaces tab:
  - enable SSH
  - enable VNC
- Reboot (on prompt) and login as user pi with your new password

Then, a Linux operating system needs some maintenance. Open a *Terminal*. RPi Menu → Accessories → Terminal. Regularly, the following commands have to be carried out in this terminal window:

- sudo apt update
- sudo apt upgrade

These commands keep the Linux OS fresh and tidy. The sudo in front of the command shows that user pi wants to do an operation that needs system administrator privileges. User pi has these privileges by default, on every RPi in the world. That's why changing the password is the least you should do...

4.3 Building a network with the RPi

The RPi as delivered has a WiFi interface which is dedicated to the TinyPico device. The consequence is that the RPi has to connected to your home network with a RJ-45 ethernet cable. The IP address, given to the RPi by the DHCP server of your modem, can not be predicted, but after connecting the cable it can be found by the command:

- ifconfig
- find the IP address *e.g.* 192.168.178.30 under eth0:

Keep the hostname, username, password and IP address at hand for further use.

4.4 Connecting the RPi to your PC

The first time you log in to a new RPi, you have to connect a screen, mouse and keyboard. Once you have enabled the SSH server and VNC server on the RPi, you have three options:

- continue with screen, mouse and keyboard
- use a VNC client on your PC, which connects remotely to the desktop of the RPi. Go to `https://www.realvnc.com/en/connect/download/viewer/` and download VNC Viewer for Windows (OSX, Linux). Install VNC viewer and make a new connection with your RPi. You need the data kept at hand from the previous paragraph. You get the graphical desktop of the RPi as a window on your PC screen. Your PC mouse and keyboard operate on the RPi desktop as well.
- use a terminal connection via SSH. Go to `https://www.chiark.greenend.org.uk/~sgtatham/putty/` and download putty-64bit-0.xx-installer.msi. Install it and make a connection to the IP address of your RPi. Note that Putty will provide a RPi Linux Terminal only.

4.5 Connecting to the RPi from Matlab on your PC

When you have Matlab on your PC,and the right subscription license, there is an option to connect to the RPi from Matlab.

- Go to `https://nl.mathworks.com/help/supportpkg/raspberrypiio/ug/install-support-for-raspberry-pi-hardware.html`. The recipe given for installing the **MATLAB Support Package for Raspberry Pi Hardware** is given there. Do not carry out the setup option, offered during installation.
- Check the correct installation in Matlab: Add-Ons → Manage Add-Ons.
- In a similar way, install and check the installation of the **Simulink Support Package for Raspberry Pi Hardware**.

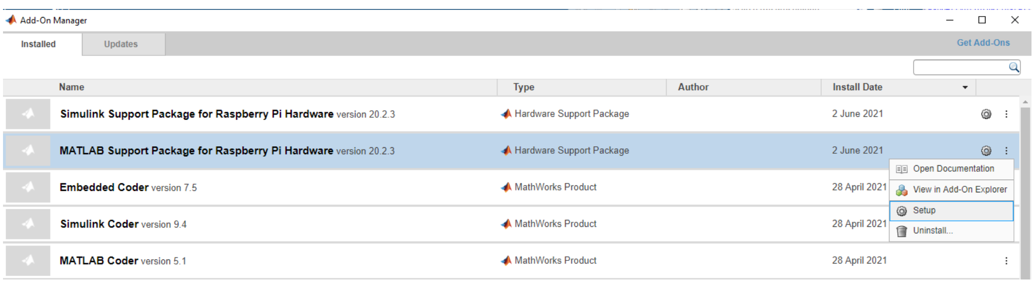
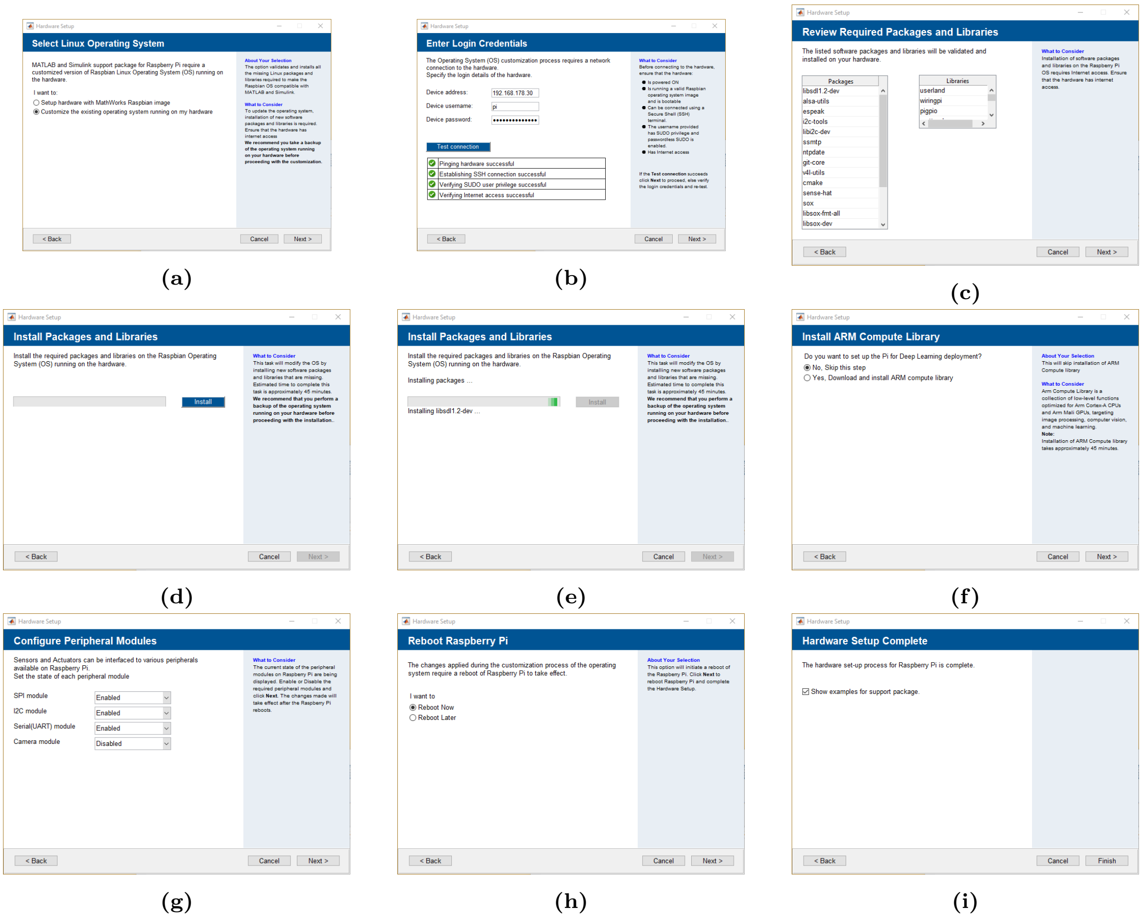


Figure 4

After the installation of the two Support Packages, keep the Add-On manager Window of Matlab open and click the Settings symbol (cogwheel) of the Matlab Support Package (see Fig. 4). In the setup procedure a connection with the RPi is established, and then a number of Linux packages will be installed on the RPi. (see



(a) (b) (c) (d) (e) (f) (g) (h) (i)

Figure 5: Setup of connection to Raspberry Pi in Matlab environment

Fig. 5) It is important to check "Customize..."in the dialog of Fig. 5a. Then the Matlab softwae is *added* to the SD card of the RPi, and this card is not overwritten, as will happen when the first option in Fig. 5a is chosen.

A similar procedure can be followed for the Simulink Support package. It may be that the setup for both Matlab and Simulink is identical. We will find out if the Simulink setup is necessary or not after the Matlab setup has been carried out already.

See also: [1–3] `https://nl.mathworks.com/videos/install-the-matlab-support-package-for-raspberry-pi-94266.html`

Note: after reboot following the setup dialog of the Support Package, the VNC server seems to be unreachable from the PC. Disabling the VNC server, reboot of the RPi, re-enabling the VNC server and rebooting the RPi again seems to remedy this Matlab mayhem. The connection on the PC in the VNC client has to be deleted, and a new connection to the RPi has to be created. Then the VNC connection works again.

4.6 Deployment of Open Source Controller on the Raspberry Pi

After installation of the Matlab and Simulink Support packages for the Raspberry Pi, a Matlab function can be "translated" into an executable (*.elf) program for the ARM processor of the RPi, downloaded to the RPi and executed (deployed) on the RPi. This can be done from the Windows Matlab environment, as shown in [4–6]:

`https://nl.mathworks.com/videos/deploy-matlab-algorithms-on-raspberry-pi-1591965724601.html`

4.6.1 Converting the OSEM Matlab MPC script into a function

... to be written

4.6.2 Deploying the OSEM MPC function on the RPi

... to be written

4.6.3 Running the MPC program on the RPi as an executable in the Linux terminal

...to be written

4.7 Adding MQTT communication from the RPi to the TinyPico

... to be written

References

[1] MatLab. *Raspberry Pi Support from MATLAB, Part 1: Getting Started with MATLAB Support Package for Raspberry Pi Hardware.* URL: https://nl.mathworks.com/videos/install-the-matlab-support-package-for-raspberry-pi-94266.html.

[2] Matlab. *Connecting to Raspberry Pi Hardware Board.* URL: https://nl.mathworks.com/help/supportpkg/raspberrypiio/ug/about-connecting-to-raspberry-pi-hardware.html.

[3] Matlab. *Getting Started with MATLAB Support Package for Raspberry Pi Hardware.* URL: https://nl.mathworks.com/help/supportpkg/raspberrypiio/ref/getting-started-with-matlab-support-package-for-raspberry-pi-hardware.html.

[4] Matlab. *Raspberry Pi Support from MATLAB, Part 2: Deploy MATLAB Algorithms on Raspberry Pi.* URL: https://nl.mathworks.com/videos/deploy-matlab-algorithms-on-raspberry-pi-1591965724601.html.

[5] Matlab. *Getting Started with Deploying a MATLAB Function on the Raspberry Pi Hardware.* URL: https://nl.mathworks.com/help/supportpkg/raspberrypiio/ref/getting-started-with-deploying-a-matlab-function-on-the-raspberry-pi-hardware.html.

[6] MatLab. *Create Hardware Configuration Object.* URL: https://nl.mathworks.com/help/supportpkg/raspberrypiio/ug/create-hardware-configuration-object.html.