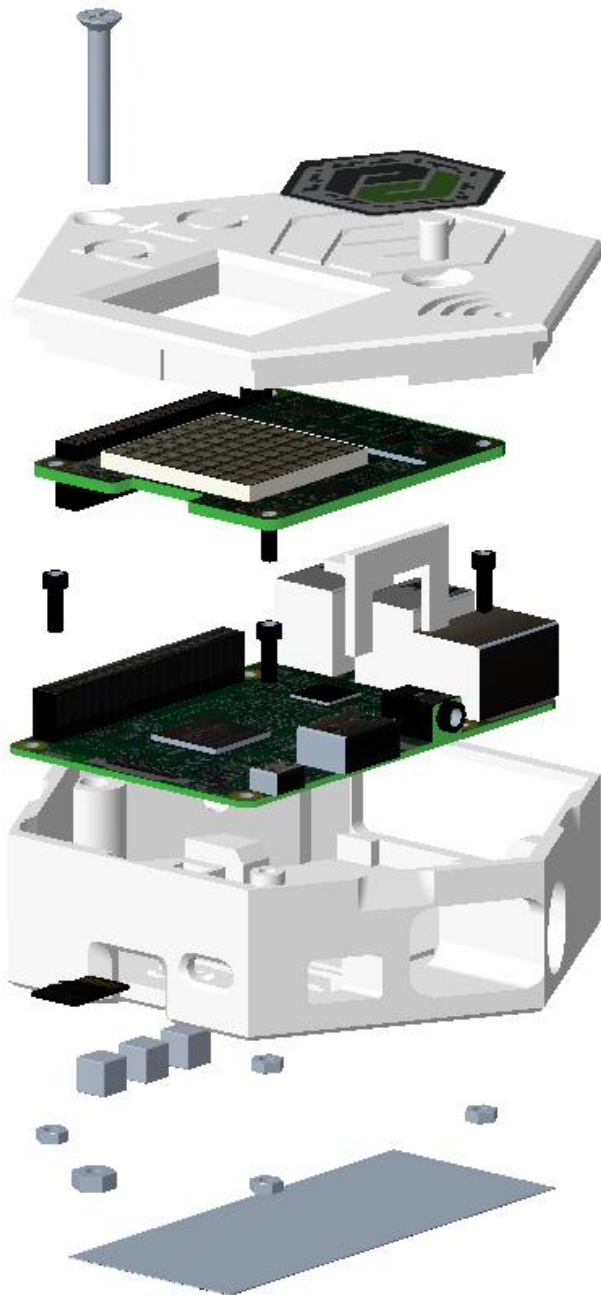




# BUILD A SIGMA TILE GUIDE

**Sigma Tile: V5**

05/07/2018

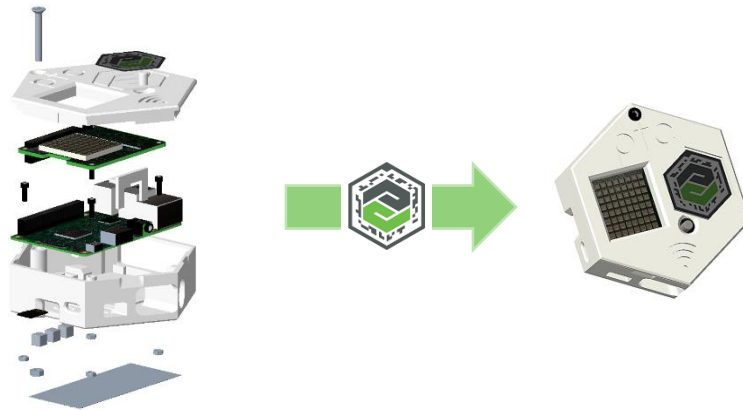


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## INTRODUCTION

In this guide you will learn how to build a Sigma Tile using simple, easy to procure, proven components such as a Raspberry Pi and a Sense Hat and by following simple instructions leveraging augmented reality for the mechanical assembly steps.



The PTC Sigma Tile runs on a Raspberry Pi with a Sense Hat using several Python programs. You will also learn how to install these programs on the Raspberry Pi of your Sigma Tile.

If you are new to the Sigma Tile and want to better understand what it is and intended application, go to Appendix A.

## REQUIREMENTS

In order to build your Sigma Tile, you will need a computer with the following programs and peripherals:

### Software Requirements

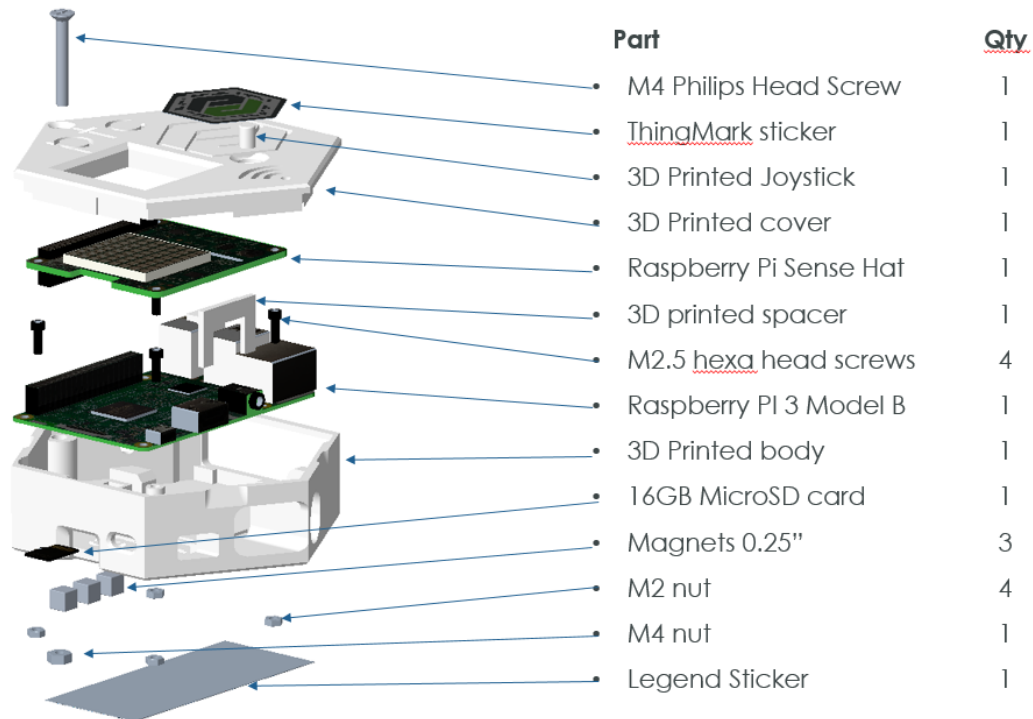
- [PuTTY terminal emulator](#) to remotely communicate with Raspberry-Pi.
- [7-Zip](#) for extracting archive files.
- [WinSCP](#) or other similar programs to transfer files between your computer and Raspberry Pi.
- [Win32 Disk Imager](#) for writing to a bootable USB drive or micro SD on a windows host.

## Helpful Peripherals

- USB mouse and keyboard
- Monitor with HDMI input
- Micro USB power supply (5V, 2.4A)

## STEP 1 – PROCURING COMPONENTS & MATERIALS

### 1. Review the key components of the Sigma Tile:



In order to build the Sigma Tile, you will need the following minimum required electronic components:

- Raspberry Pi 3 Model B
- Raspberry Pi Sense Hat
- 16GB MicroSD card
- MicroUSB cable

*Note: The Raspberry Pi Sense HAT is an add-on board for Raspberry Pi. It has an 8X8 RGB LED matrix, a five-button joystick and includes the following sensors:*

- Gyroscope
- Accelerometer
- Magnetometer
- Temperature Sensor
- Barometric Pressure Sensor
- Humidity Sensor

*It also comes with Python library.*

To create a complete experience with the Sigma Tile, you will need additional components. You will also need some basic tools.

The electronics components, fasteners and tools can be easily ordered online from various electronics and hardware suppliers. The enclosure can be 3d-printed using the STL file provided.

Below is the complete Bill of Materials for the Sigma Tile with estimated cost:

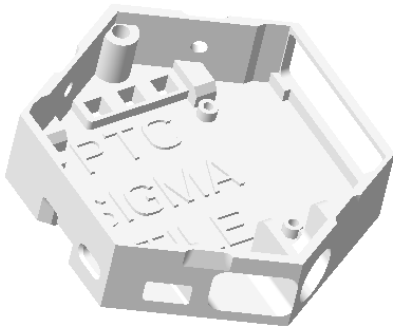



<b>Sigma Tile V5 BOM</b>			
	<b>Estimated Unit Cost</b>	<b>Qty</b>	<b>Estimated Cost</b>
<b>Electronic Components (minimum required)</b>			
Raspberry PI 3 Model B	\$ 39.95	1	\$ 39.95
Raspberry Pi Sense Hat	\$ 39.95	1	\$ 39.95
16GB MicroSD card	\$ 6.95	1	\$ 6.95
MicroUSB Cable	\$ 6.95	1	\$ 6.95
4GB USB Flash Drive	\$ 6.99	1	\$ 6.99
<b>Enclosure</b>			
3D printed cover	\$ 4.00	1	\$ 4.00
3D printed spacer	\$ 1.00	1	\$ 1.00
3D printed body	\$ 10.00	1	\$ 10.00
3D printed joystick	\$ 0.50	1	\$ 0.50
<b>Fasteners</b>			
M2.5-0.45 8mm Socket Hexagonal Head screws	\$ 0.22	4	\$ 0.88
Hex Nut M2.5-0.45	\$ 0.04	4	\$ 0.18
M4-0.7 30mm Phillips Flat-Head Machine Screw	\$ 0.45	1	\$ 0.45
Hex Nut M4-0.7	\$ 0.10	1	\$ 0.10
Magnets 0.25"	\$ 1.50	3	\$ 4.50
<b>Enclosure</b>			
ThingMark sticker (print)	\$ 0.50	1	\$ 0.50
Legend sticker (print)	\$ 0.50	1	\$ 0.50
<b>Estimated Total Cost</b>			<b>\$ 123.39</b>
<b>Tools / Accessories</b>			
Hex Key Short M2	\$ 0.45	1	\$ 0.45
Philips screwdriver	\$ 3.00	1	\$ 3.00
USB Keyboard and Mouse	\$ 24.00	1	\$ 24.00

## Tools

1. You will need a M2 Hex key and a Philips screwdriver

## STEP 2 – 3D PRINTING COMPONENTS

Using the provided [STL files](#) or the [Creo models](#), 3d-print the following parts:

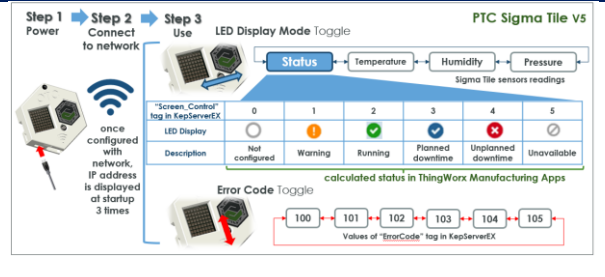
SigmaTile_Body_v5.stl	
SigmaTile_Cover.stl	
SigmaTile_Spacer.stl	
SigmaTile_Joystick.stl	

### STEP 3 – PRINTING STICKERS

Using the PDF files provided, print, on adhesive paper, and cut the following:

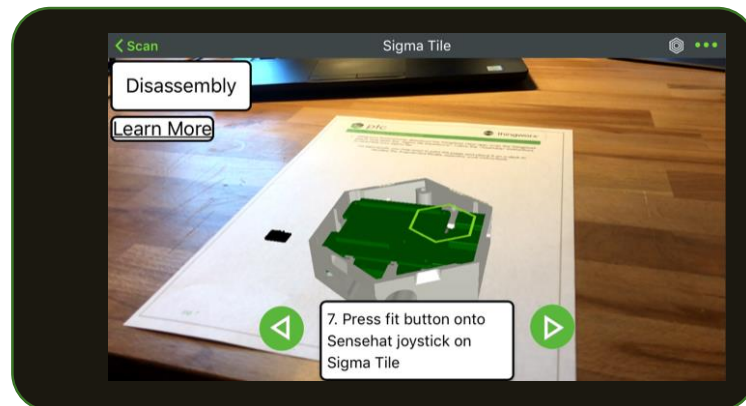
<a href="#">Sigma Tile ThingMark Print 1365-50.pdf</a>	
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[Sigma Tile Legend Sticker Print.pdf](#)



## STEP 4 – ASSEMBLING COMPONENTS

Using your smart phone or tablet, download the **ThingWorx View app**, scan the **ThingMark located in Appendix D** of this guide and follow the "Assembly" instructions to assemble your Sigma Tile.



**NOTE:** for best results, you may want to print Appendix D and place it on a desk to visualize the Augmented Reality assembly work instructions.

**CAUTION:** Raspberry Pi – Sense HAT is Electrostatic Sensitive Devices (ESD). Proper care must be observed protecting it from any damage. Best practices include using wrist straps and/or electrostatic grounding mat, keeping the electronic parts in protective bags, etc.

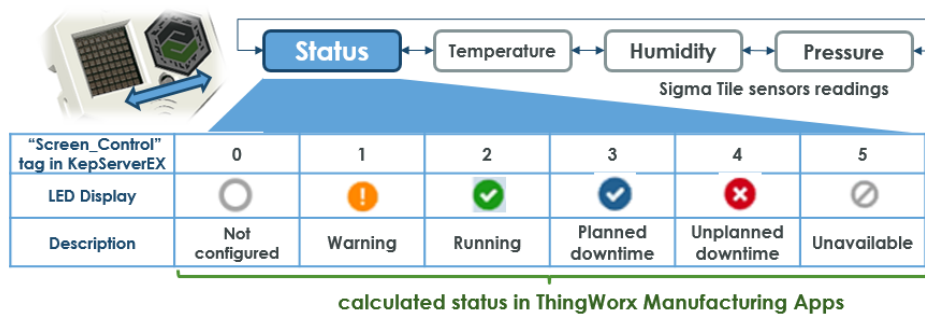


## STEP 5 – UNDERSTANDING THE SIGMA TILE PYTHON SCRIPT

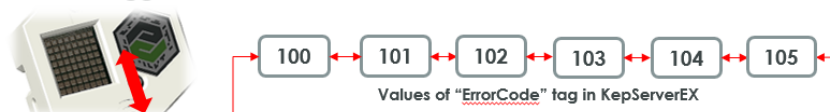
The heart of the Sigma Tile is the [SigmaTile\\_SenseHat\\_V5.py](#) Python script which can be found in the [ThingWorx Developer Portal](#). This script reads the Sense Hat sensors and uses the MODBUS protocol to communicate between Raspberry Pi and Kepware. Modbus is a serial communication protocol developed in 1979 for use in Programmable Logic Controllers (PLCs). You can find the details about this protocol at [modbus.org](http://modbus.org). Raspberry Pi will act as the server and Kepware will be a client. The python scripts will simply initialize the Modbus server and update the values from the Sense HAT when it receives the request from the client. We use pymodbus libraries, the details of which can be found at <https://github.com/bashwork/pymodbus>. Other libraries and protocols are available which are not in the scope of this documentation.

Other aspects of the code include the reading of the Sense HAT's joystick position to trigger various events: change of the LED Display mode and change of the Error Code values as illustrated in the picture below:

### LED Display Mode Toggle



### Error Code Toggle



For more details on the functional aspect of the Sigma Tile python script, please refer to the **Learn KepServerEX Using a Sigma Tile** guide and the **Learn ThingWorx Manufacturing Apps Using a Sigma Tile** guide.

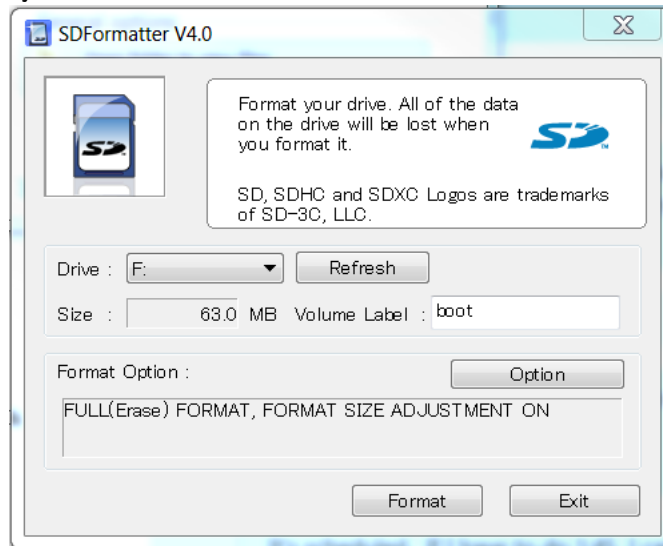
## STEP 6 - CREATING MICRO-SD CARD WITH SIGMA TILE SOFTWARE



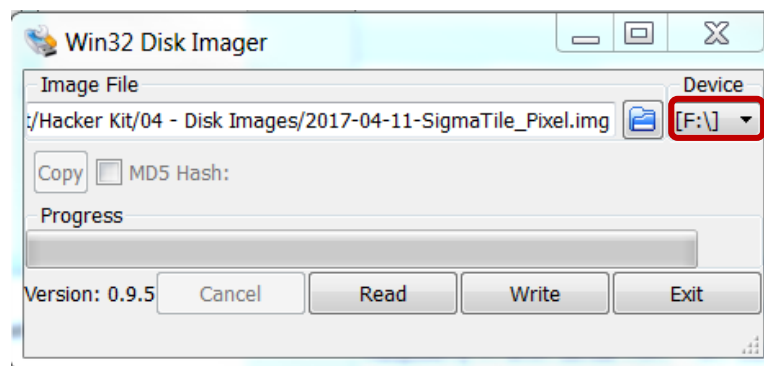
The easiest and fastest way to get your Sigma Tile running is for you to use our premade disk image of the Raspberry Pi software with the proper scripts and configuration. If you want to create your own image, see Appendix D.

### USING A PREMADE DISK IMAGE

1. Download the [Sigma Tile SD card disk image](#) for your Raspberry Pi. (Please note that this image is around 15GB)
2. Insert your microSD card, and format it using [SDFormatter](#).
  - a. Format Type: Full (erase)
  - b. Format Size Adjustment: On



3. Write the Sigma Tile disk image to the SD card using [Win32DiskImager](#).



4. Insert the microSD card into the Raspberry Pi

## STEP 7 – TESTING THE SIGMA TILE

1. Power your Sigma Tile with the Micro-USB cable. Within about 15 seconds a Wi-Fi symbol will be displayed on the LED display, indicating that the Sigma Tile is searching for a network.

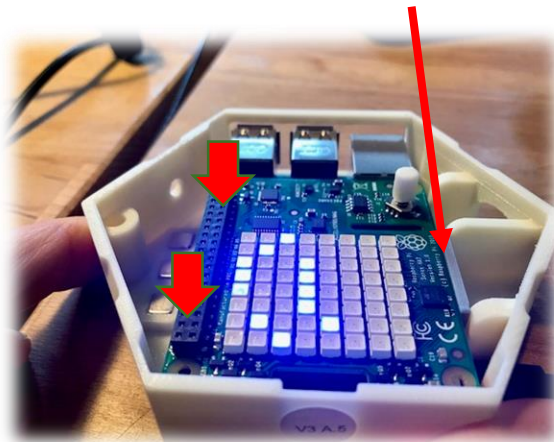


2. If you see the WIFI symbols: **Congratulations!** You have completed this guide and built your own Sigma Tile. The next step will be to connect your Sigma Tile to a network and to further connect it with Kepware KepServerEX. You will learn how to do that in the **Learn KepServerEX Using a Sigma Tile** guide.
3. If you did not see the WIFI symbols, continue to the troubleshooting section.

---

#### TROUBLESHOOTING:

1. If the LED Display shows a **rainbow** and stays on that image, try the following:
  - o Open the Sigma Tile Cover and try adjusting the SenseHat as the connection between the Raspberry Pi and the SenseHat may be improper with some possible Pins misalignments or false contacts
  - o Ensure that the Sense Hat is level with the Raspberry Pi and the SenseHat is fully placed on the lip of the Spacer.



2. If after waiting for over 1 minute, the LED Display still shows a **blank screen** after briefly showing a rainbow at started, the Python script may not have started properly. Using the USB keyboard, mouse and monitor, connect to your Sigma Tile and confirm that the Raspberry Pi Operating System has started properly. If not, you have a defective disk image. Try re-imaging your Micro-SD card with the latest image provided on the [ThingWorx Developer Portal](#). If the PI OS is running, in the command window, try running the Sigma Python script by typing the following command:

**`sudo python SigmaTile_SenseHat_V5.py`**

If the WIFI symbol now displays, it is an indication that the Python script did not start automatically. If so, follow these instructions:

1. Change to the directory that hosts all of the code to: **`cd mfg-tile/`**
  - a. Pull down the latest code from the repository: **`git pull`**
  - b. Ensure that the launcher is executable: **`chmod +x launcher.sh`**
  - c. Add the cron job to start the script on boot: **`crontab mycron.tab`**
2. Reboot the Raspberry Pi: **`sudo reboot now`**

## APPENDIX A: UNDERSTANDING THE SIGMA TILE

### WHAT IS A SIGMA TILE?

The **PTC Sigma Tile** is a **very low cost, ultra-portable** IoT device that you can **build yourself**. It is equipped with sensors and controls and can act as a **Smart Connected Product** or as the **Industrial Controller (PLC)** of a **production asset or line**. It is intended to be used for **IoT demonstration** and **IoT applications development and testing** purposes.



For a quick demo overview of the Sigma Tile in action, check out this video:



<https://vimeo.com/246388214>  
(2-minute video)

### GET STARTED

#### Step 1 – Learn Industrial Connectivity with KEPServerEX and a Sigma Tile



##### LearnKepServerEXUsingSigmaTileGuide.pdf

Install and configure the free trial edition of Kepware KEPServerEX to connect to the Sigma Tile and, in less than 10 minutes, stream real time readings from the Sigma Tile sensors: temperature, pressure, humidity... and control the Sigma Tile from KEPServerEX.

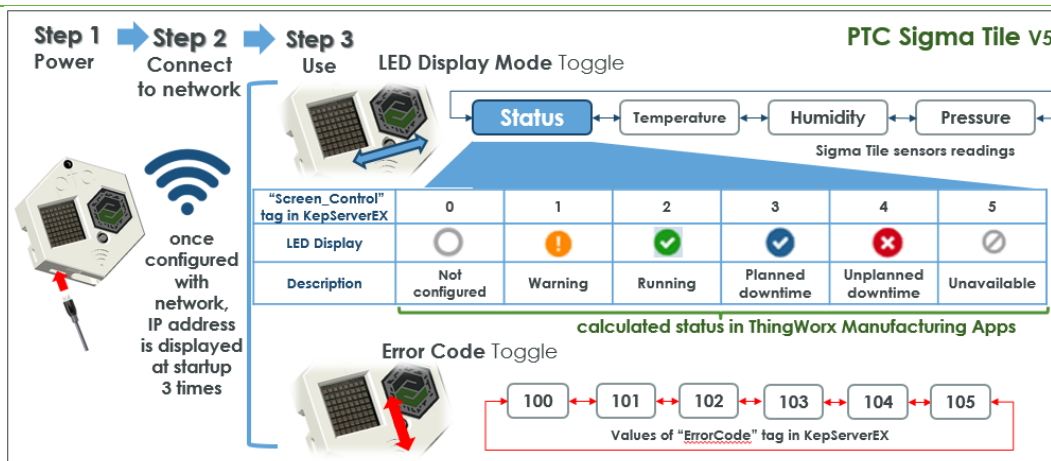
#### Step 2 – Learn ThingWorx Manufacturing Apps



##### LearnThingWorxMFGAppsUsingSigmaTileGuide.pdf

Download the ThingWorx Manufacturing Apps Free Trial and, in less than 60 minutes, experience the power of the Industrial IoT with your Sigma Tile acting as the PLC of a production asset or line.

### SIGMA TILE FUNCTIONAL REFERENCE GUIDE



---

## RESOURCES



- Sigma Tile related Guides – on ThingWorx Developer Portal (under **Additional Resources**):  
<https://developer.thingworx.com/apps/manufacturing>
- Kepware KepServerEX - Trial Edition:  
<https://my.kepware.com/mykepware/Landing.aspx>
- ThingWorx Manufacturing Apps Free Trial:  
<https://developer.thingworx.com/apps/manufacturing>

## APPENDIX B: TECHNICAL SUPPORT

If you have **any questions related to the Sigma Tile or this guide**, (installation, configuration, capabilities), we invite to check our ThingWorx User Community page at the link below:

- <https://community.ptc.com/t5/PTC-Sigma-Tile/gp-p/sigma-tile>.

You will be able to search and view posts from other users, from PTC Subject Matter Experts. You will be able to ask questions, share your lessons learned and provide feedback. You will need to create an account to be able to view or post to the community.

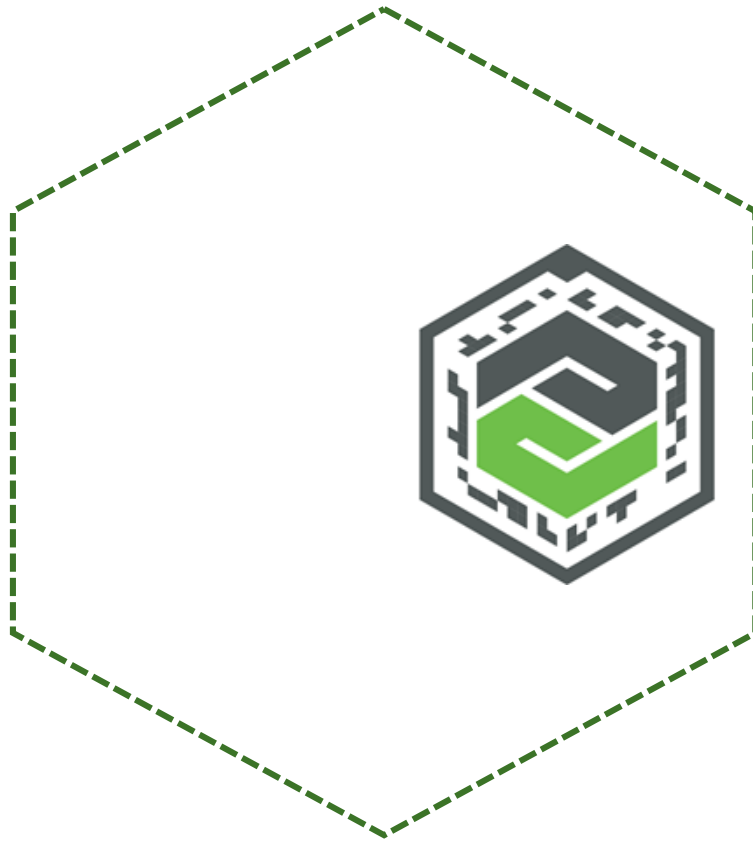
If you have **any questions related to the ThingWorx Manufacturing Apps**, check the following Community page:

- <https://community.ptc.com/t5/Manufacturing-Apps/bd-p/manufacturingapps>

If you have **any questions related to the KepServerEX**, check the Kepware Technical Support page:

- <https://www.kepware.com/en-us/support/technical-support/>

APPENDIX C: AUGMENTED REALITY ASSEMBLY TEMPLATE



*Note that the nuts and magnets are under the body of the Sigma Tile when viewing with ThingWorx View*

## APPENDIX D: CREATING YOUR OWN SIGMA TILE DISK IMAGE

In this Appendix you will learn how to create your own Sigma Tile disk image by installing all the necessary libraries and scripts on top of the standard Raspberry Pi Raspbian operating system. For more information about the Raspberry Pi OS, check <https://www.raspberrypi.org/>. The procedure is intended for experienced Raspberry Pi users. If you are new to the Raspberry Pi we recommend you use our pre-configure Sigma Tile SD Card disk image described in Step 6 above.

### PREREQUISITES

First you will need a Micro SD card with the following:

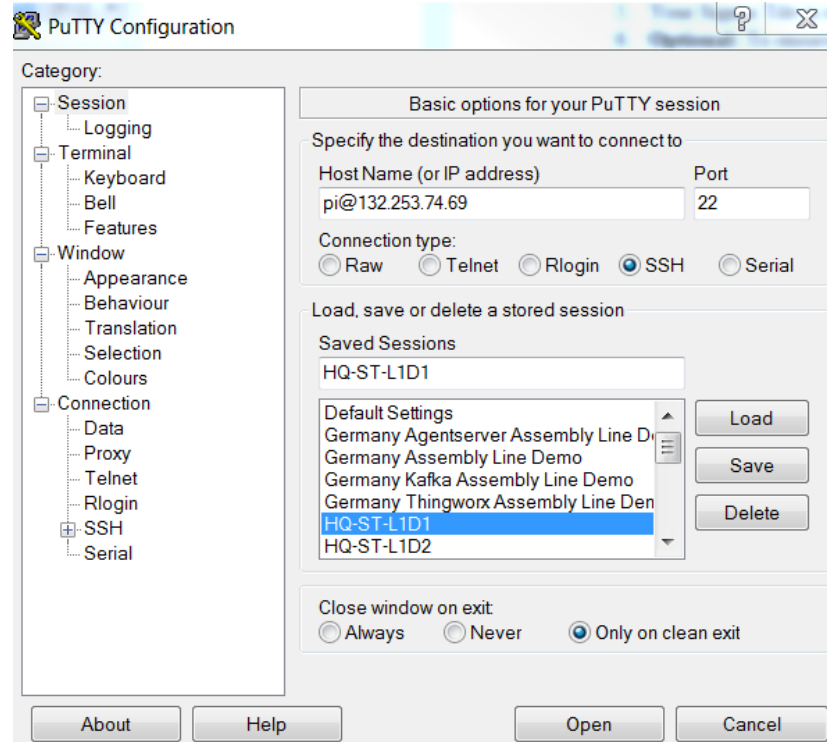
- NOOBS pre-installed Micro SD card (16GB minimum). Optionally, Raspbian can be installed on your own Micro SD card.



### INSTRUCTIONS

1. The first step is setting up the Raspberry Pi. In this step you need to make sure Raspbian is installed properly, network is configured either through network cable or Wi-Fi. The detailed instructions to setup Raspberry Pi is available at <https://www.raspberrypi.org/documentation/setup/>. Make sure to enable the SSH and I2C. The details for the same are provided in the Frequently Asked Questions section of this document. See Troubleshooting steps at the end of this Appendix for details.
2. The next step is to assemble Sense HAT onto Raspberry Pi. The Raspberry Pi should be powered off using the command **sudo halt**. Do use the Electrostatic Sensitive Devices precautions to avoid any damage to the hardware. The step by step installation instructions are provided at <https://www.raspberrypi.org/learning/astro-pi-guide/assemble.md>.
3. Use the IP address to SSH into the Pi.





or

Use the mouse and keyboard to access the command line of the Pi.

user: **pi**

password: **raspberrypi**

4. Open the terminal window using Putty or directly from Raspberry Pi. The first step is updating and upgrading the system. Run the following commands from the terminal windows:

```
sudo apt-get update  
sudo apt-get upgrade
```

Installing Python libraries

```
sudo apt-get install python-dev  
sudo apt-get install python-pip
```

With the latest version of pip, installing cryptography will render an error. Use the following four commands to resolve the error:

```
cd  
mkdir test  
cd test  
wget https://bootstrap.pypa.io/get-pip.py  
sudo python get-pip.py
```

the get-pip.py will install compatible pip verasudosudsiion.

```
sudo pip install pymodbus  
sudo pip install pycrypto  
sudo apt-get install libffi-dev  
sudo apt-get install libssl-dev  
sudo pip install cryptography
```

Then install Sense HAT Software packages.

```
sudo apt-get install sense-hat  
sudo reboot
```

After the reboot command, allow a few minutes for the system to reboot. We are ready to run our script and test now!

5. You will now install the necessary Sigma Tile scripts on your Raspberry Pi:

#### **Option 1: using Git-Hub**

- Open terminal window in Raspberry Pi. Execute the following commands.
- Make sure Git is installed by executing the command below.

```
sudo apt-get install git-core
```

- Copy the source code for this exercise from the git. Make sure to run from the home directory.

```
cd  
git clone https://github.com/PTCInc/mfg-tile
```

- You will find several files downloaded to mfg-tile directory





```
cd mfg-tile/  
ls -ltr
```

- You can execute the script using the command below:

```
sudo python SigmaTile_SenseHat_V5.py
```

#### **Option 2: copying Sigma Tile scripts manually**

- On the [ThingWorx Developer Portal](#), and using your computer, locate the Sigma Tile Raspberry Pi Scripts.

 get-pip.py	11/6/2016 2:30 PM	PY File	1,559 KB
 launcher.sh	2/13/2018 3:24 PM	SH File	1 KB
 mycron.tab	4/11/2017 9:16 AM	TAB File	1 KB
 SigmaTile_SenseHat_V5.py	2/13/2018 11:10 AM	PY File	12 KB

- Using WinSCP, open a session on your Raspberry Pi and follow these two steps:
  - Create a folder under root called **mfg-tile**
  - Copy the preceding files into the mfg-tile directory.
- From the command window on the Raspberry Pi, execute the script using the command below.

```
sudo python SigmaTile_SenseHat_V5.py
```

- Ensure that the launcher is executable:



```
chmod +x launcher.sh
```

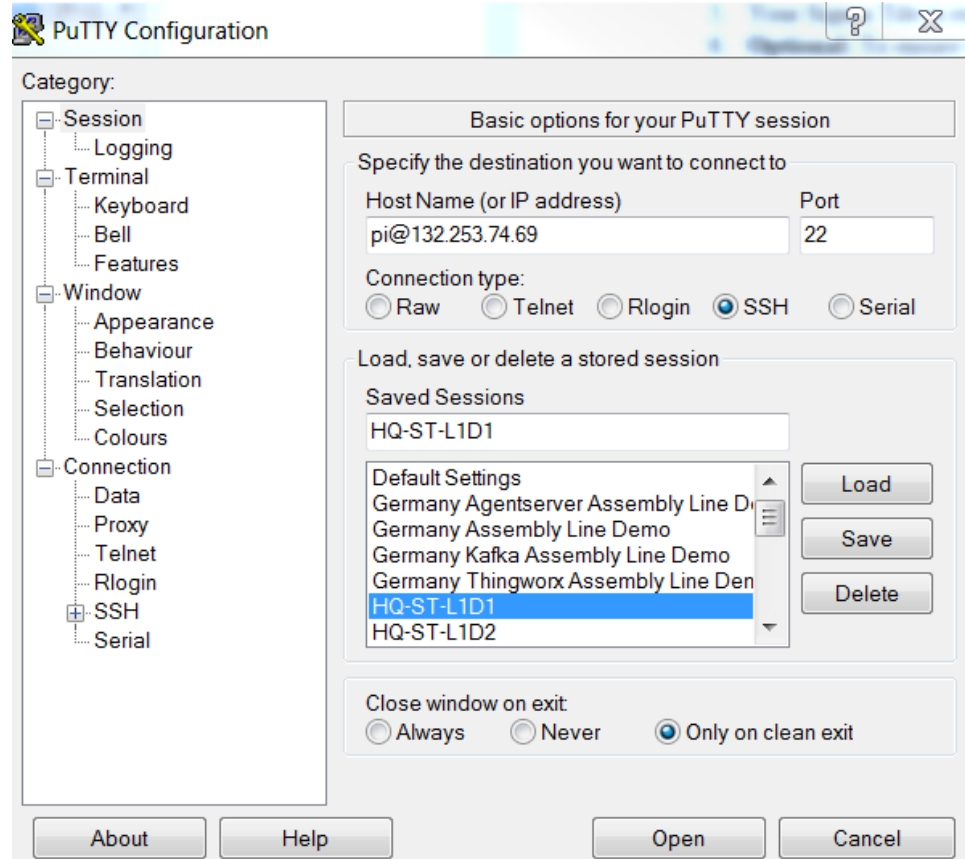
- Add the cron job to start the script on boot:

```
crontab mycron.tab
```

- Reboot the Raspberry Pi:

```
sudo reboot now
```

6. Within about 15 seconds a Wi-Fi symbol  or a white disk  will be displayed on the LED display, indicating that the Sigma Tile script is now running. You are now ready to start and follow the **Learn KEPServerEX using a Sigma Tile** guide.
7. **Optional:** To ensure you have the latest code, you can update the Raspberry Pi from the GitHub repository with these additional steps.
  - Use the IP address to SSH into the Pi.



or

Use the mouse and keyboard to access the command line of the Pi.

user: **pi**

password: **raspberrypi**

- In the Command terminal, change to the directory that hosts all of the code:

**`cd mfg-tile/`**

- Pull down the latest code from the repository:

**`git pull`**

- Ensure that the launcher is executable:

**`chmod +x launcher.sh`**

- Add the cron job to start the script on boot:

**`crontab mycron.tab`**

- Reboot the Raspberry Pi:

**`sudo reboot now`**

## Troubleshooting and FAQ:

1. **How do I find out the IP address of my Raspberry Pi?**

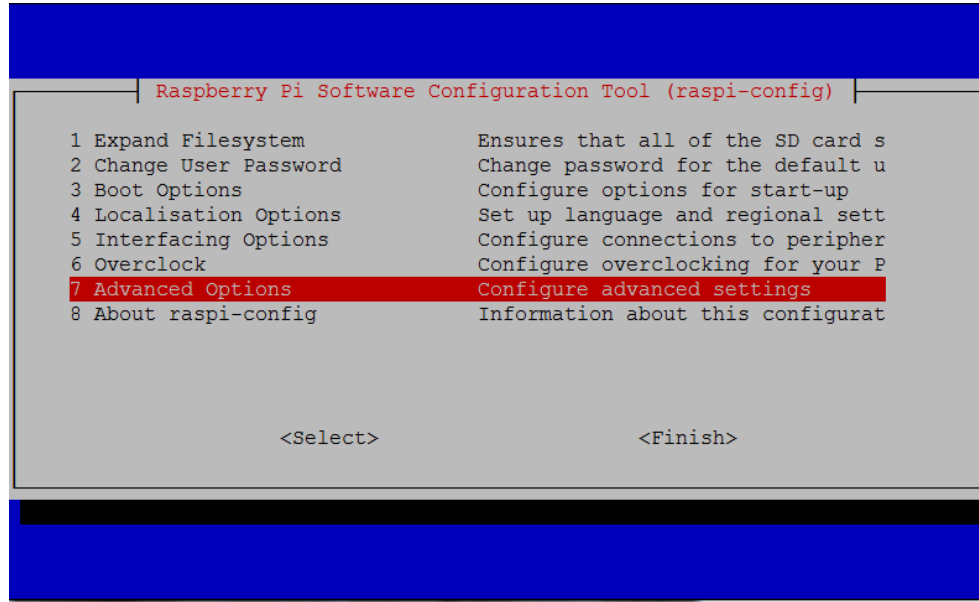
From the terminal window of Raspberry Pi, type **ifconfig**. It should provide the out as shown below.

Alternatively, if the user has access to router page, it can be found under connected devices. Refer to your router documentation for additional details.

## 2. How do I enable SSH Raspberry Pi?

SSH must be enabled to connect to Raspberry Pi from another device. From the terminal window of Raspberry Pi, type **raspi-config**. It will bring up a configuration window. Then follow the steps below.

- Select the Advanced Options



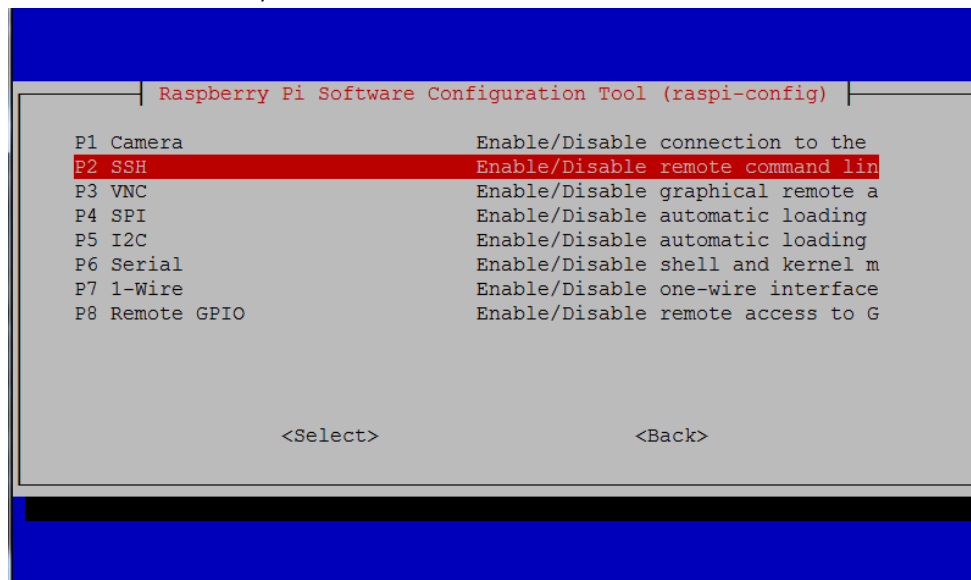
```

Raspberry Pi Software Configuration Tool (raspi-config)

1 Expand Filesystem          Ensures that all of the SD card s
2 Change User Password      Change password for the default u
3 Boot Options              Configure options for start-up
4 Localisation Options      Set up language and regional sett
5 Interfacing Options       Configure connections to peripher
6 Overclock                 Configure overclocking for your P
7 Advanced Options          Configure advanced settings
8 About raspi-config        Information about this configurat

<Select>                    <Finish>
  
```

- Select the P2 SSH Enable/Disable remote command line



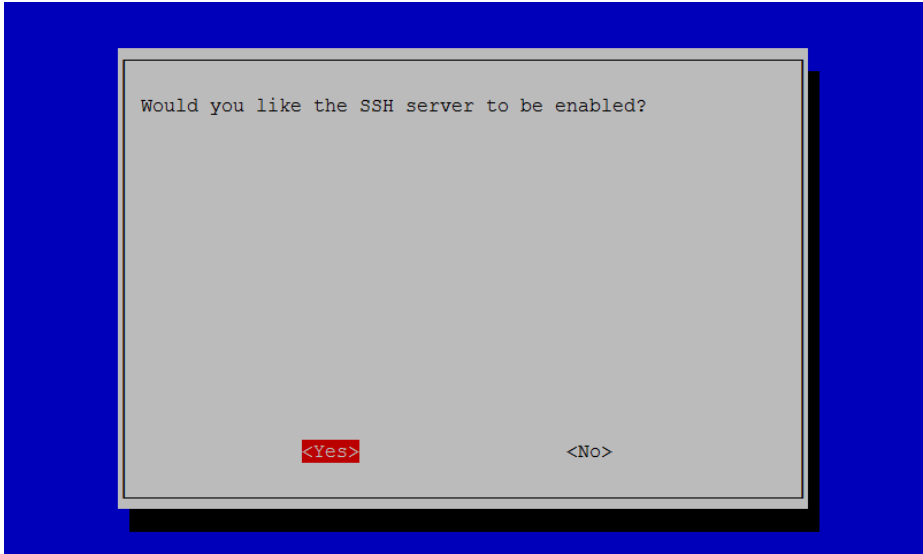
```

Raspberry Pi Software Configuration Tool (raspi-config)

P1 Camera                   Enable/Disable connection to the
P2 SSH                       Enable/Disable remote command lin
P3 VNC                       Enable/Disable graphical remote a
P4 SPI                       Enable/Disable automatic loading
P5 I2C                       Enable/Disable automatic loading
P6 Serial                    Enable/Disable shell and kernel m
P7 1-Wire                    Enable/Disable one-wire interface
P8 Remote GPIO               Enable/Disable remote access to G

<Select>                    <Back>
  
```

- Select the confirmation for Enable SSH to Yes

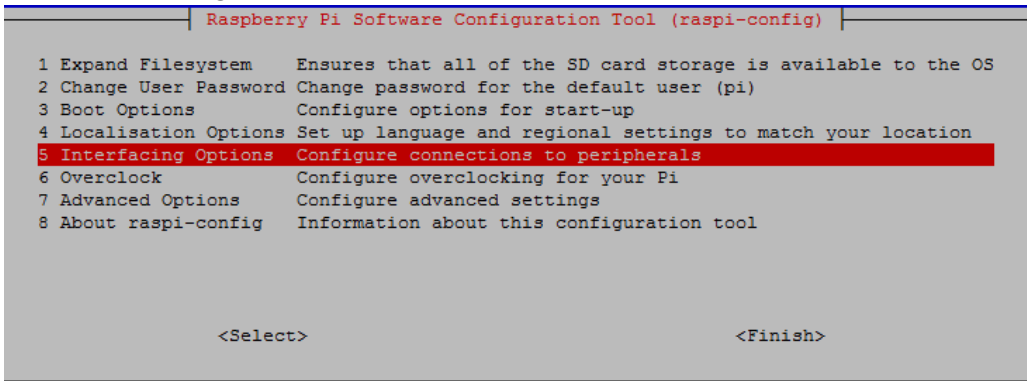


- Exit out of configuration window.
- Restart the Raspberry Pi using “sudo shutdown now -r” command
- After the restart, the user should able to perform a remote login from another system.

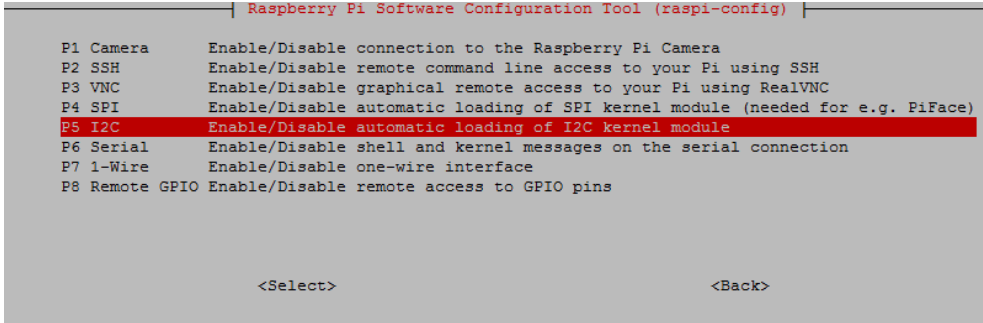
**3. How do I enable I2C interface in my Raspberry Pi?**

I2C must be enabled to connect the Raspberry Pi to Sense HAT. From the terminal window of Raspberry Pi, type raspi-config. It will bring up a configuration window. Then follow the steps below.

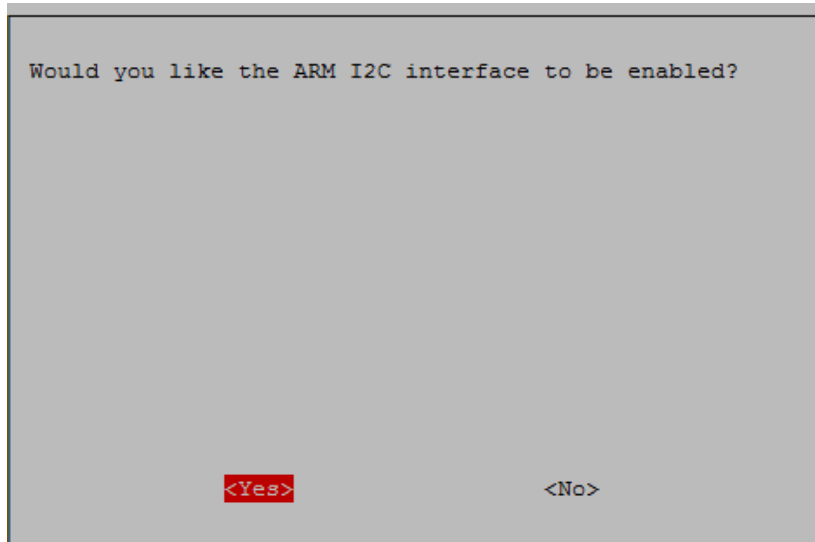
- Select **Interfacing Options**



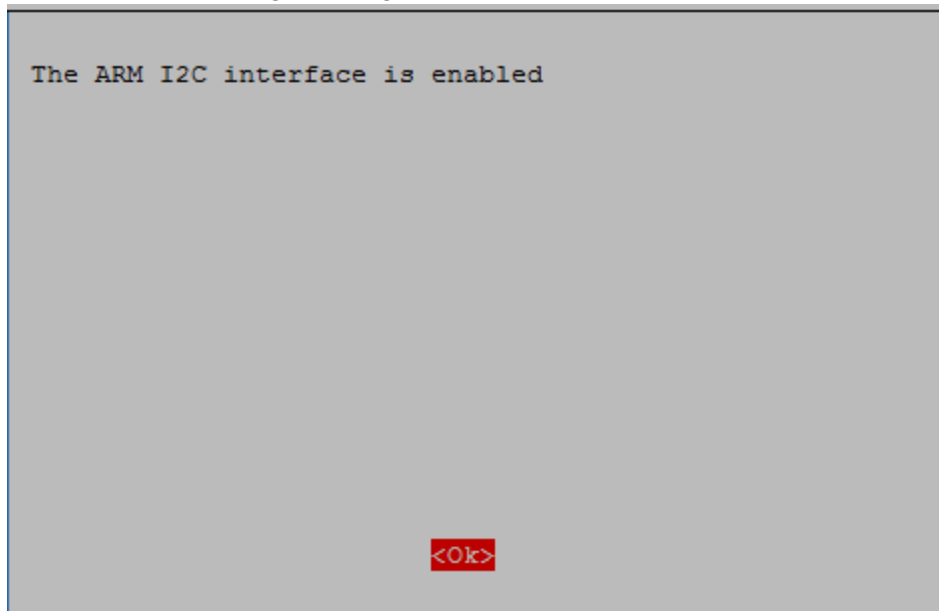
- Enable I2C by selecting options shown below



- Select **Yes**

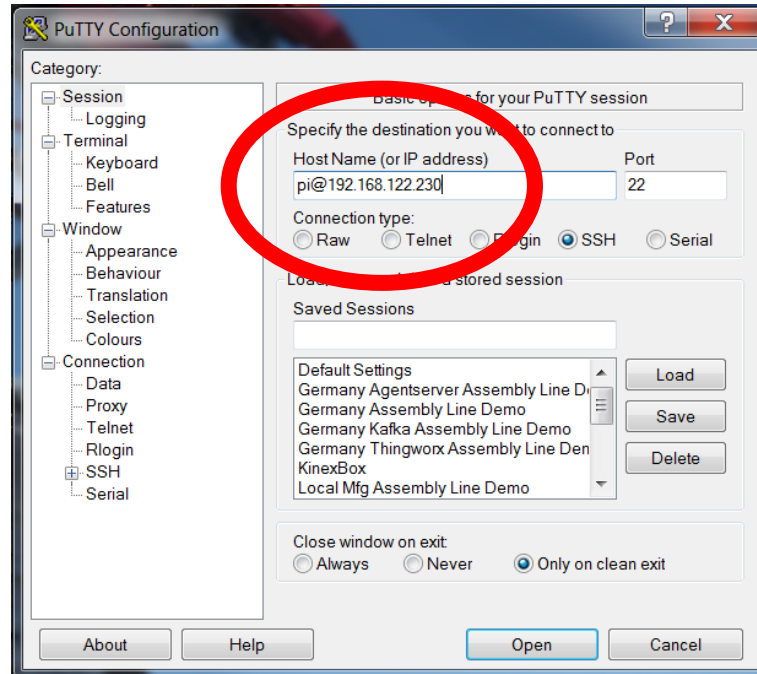


- The confirmation page stating I2C interface is enabled will be shown. Select **OK**.



#### 4. How do I connect to Raspberry Pi from my computer or laptop?

Putty is a handy tool for this. Following the link in the Bill of Materials section, download the software. You will need the IP address of the Raspberry Pi and SSH must be enabled on the Raspberry Pi. The following screen shot shows the rest.

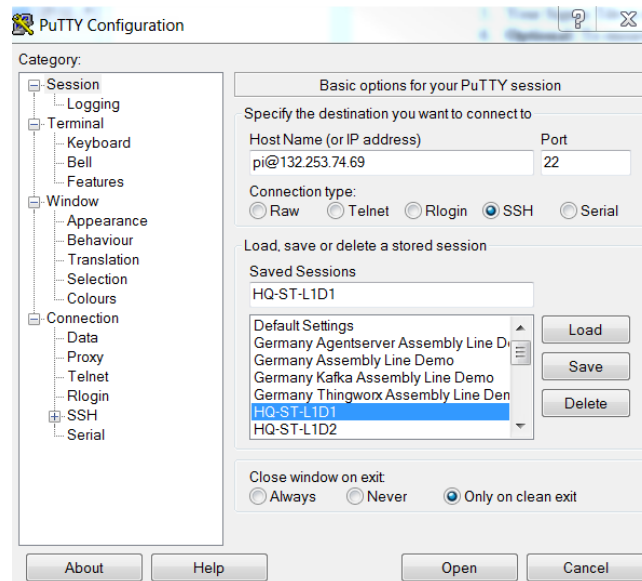




## APPENDIX E: UPDATING THE SIGMA TILE CODE FROM GITHUB

To ensure you have the latest code, you can update the Raspberry Pi from the GitHub repository with these additional steps.

- Use the IP address to SSH into the Pi.



or

Use the mouse and keyboard to access the command line of the Pi.

user: **pi**

password: **raspberry**

- In the Command terminal, change to the directory that hosts all of the code:  
**cd mfg-tile/**
- Pull down the latest code from the repository:

**git pull**

- Ensure that the launcher is executable:

**chmod +x launcher.sh**

- Add the cron job to start the script on boot:

**crontab mycron.tab**

- Reboot the Raspberry Pi:

**sudo reboot now**