



E210 Engineering Cyber-Physical Systems (Spring 2021)

# Raspberry Pi/UART Introduction

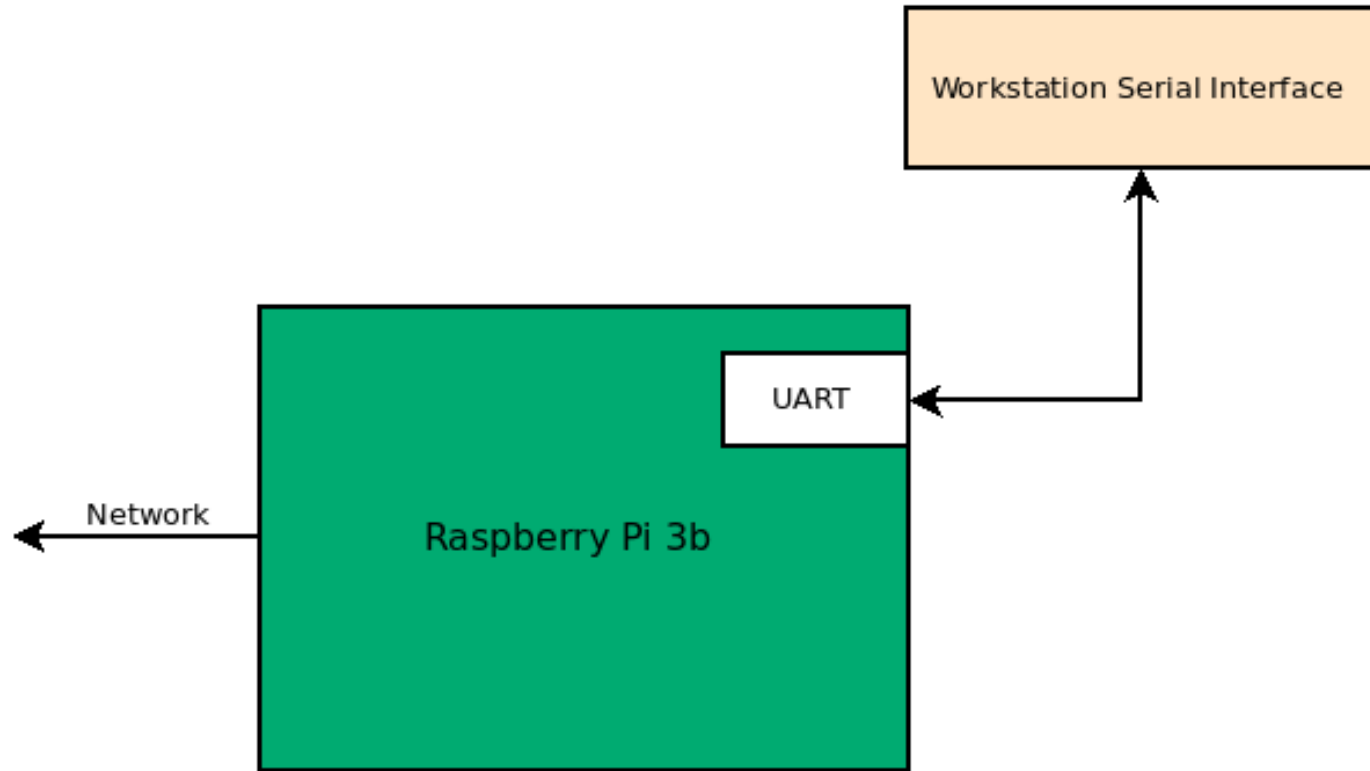
Bryce Himebaugh

Weekly Focus	Reading	Monday	Wed	Lab
CPS Intro/UART		1/10: CPS Introduction	1/12: Pi Intro/UART Bus	Project 0 Raspberry PI Setup
GPIO/Scope		1/17: MLK Day	1/19: Electronics/GPIO/LED	Project 1 UART Controlled LED
SPI Bus		1/24: I2C Bus Overview	1/26: Pressure Sensor	Project 2 I2C Pressure/Temperature Sensor
I2C Bus		1/31: SPI Bus Overview	2/2: Accelerometer	Project 3 Project 2 SPI Flash Memory
Networking		2/7: Networking Overview	2/9: Flask	Project 4 Flask Web Server
Web Server		2/14: Redis/matplotlib	2/16: CPS Wrapup	P5 Demultiplexer
Evaluation		2/21: Exam 1	2/23: CE Intro/ Logic	P6 ALU

<https://engr210.github.io/>

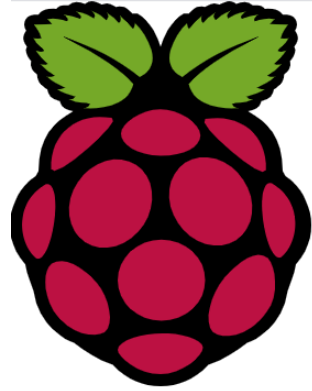
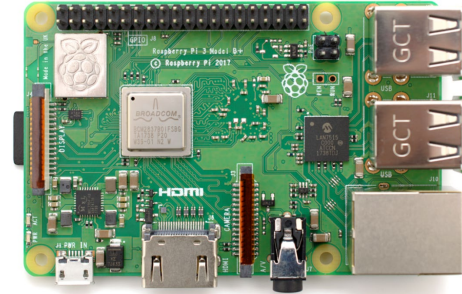


## Raspberry Pi/UART

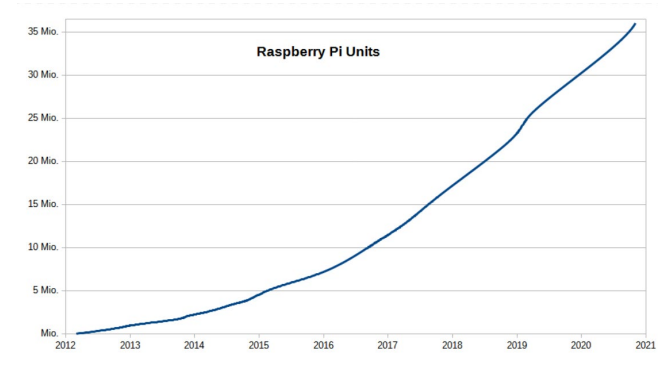


# Raspberry Pi Overview

# Raspberry Pi History



- Collaboration between University of Cambridge and Broadcom
- Released in 2012 to teach basic computer science in schools and developing countries.
- Managed by Raspberry Pi Foundation
- Original target application was robotics.
- 3B+ Costs \$35, 4B Costs \$75



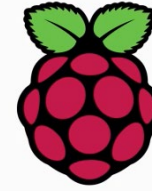
# Raspberry Pi Hardware



- Processor
  - Broadcom BCM2837B0 quad-core ARM A53
  - 64-bit 1.4Ghz
- GPU
  - Broadcom Videocore-IV
- 1GB LPDDR2 SDRAM
- Gigabit Ethernet, 2.4GHz and 5GHz 802.11b/g/n/ac Wi-Fi
- HDMI Video Output
- Audio Output
- 32GB SD Card Drive



# Raspberry Pi Software



Raspberry Pi OS

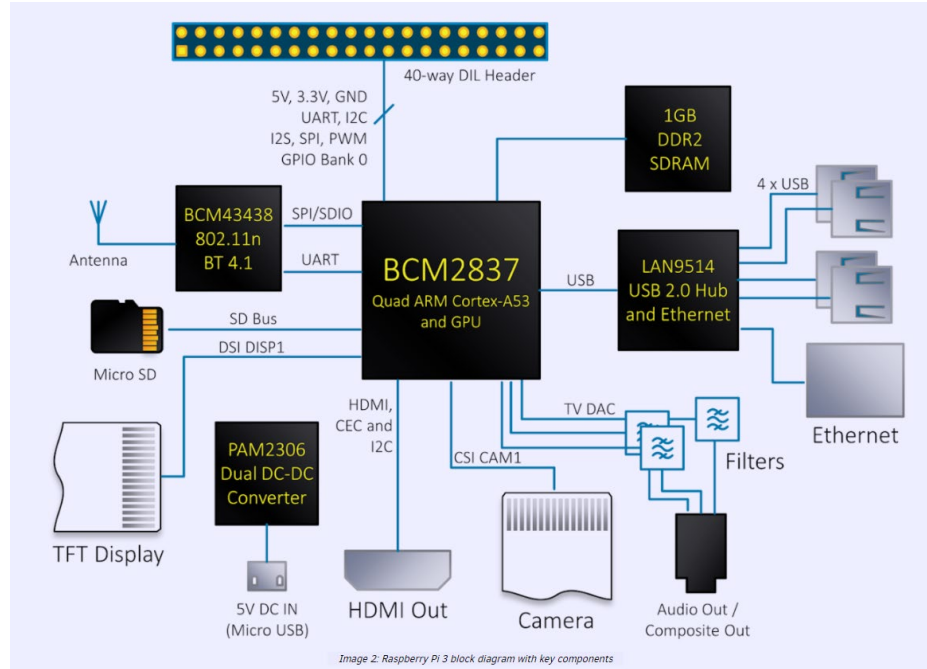
- Typically runs a variant of Linux
- Pi OS Linux
  - Formerly known as Raspian
  - Debian based
  - Created in 2012
  - Managed by the Raspberry Pi Foundation
  - Uses LXDE (lightweight X11 Desktop Environment) Desktop Environment by default
- Others
  - Ubuntu
  - LibreElec
  - RetroPie
  - TLXOS
- Possible to create “bare-metal” programs.
  - Documentation can be challenging



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

# Raspberry Pi Block Diagram



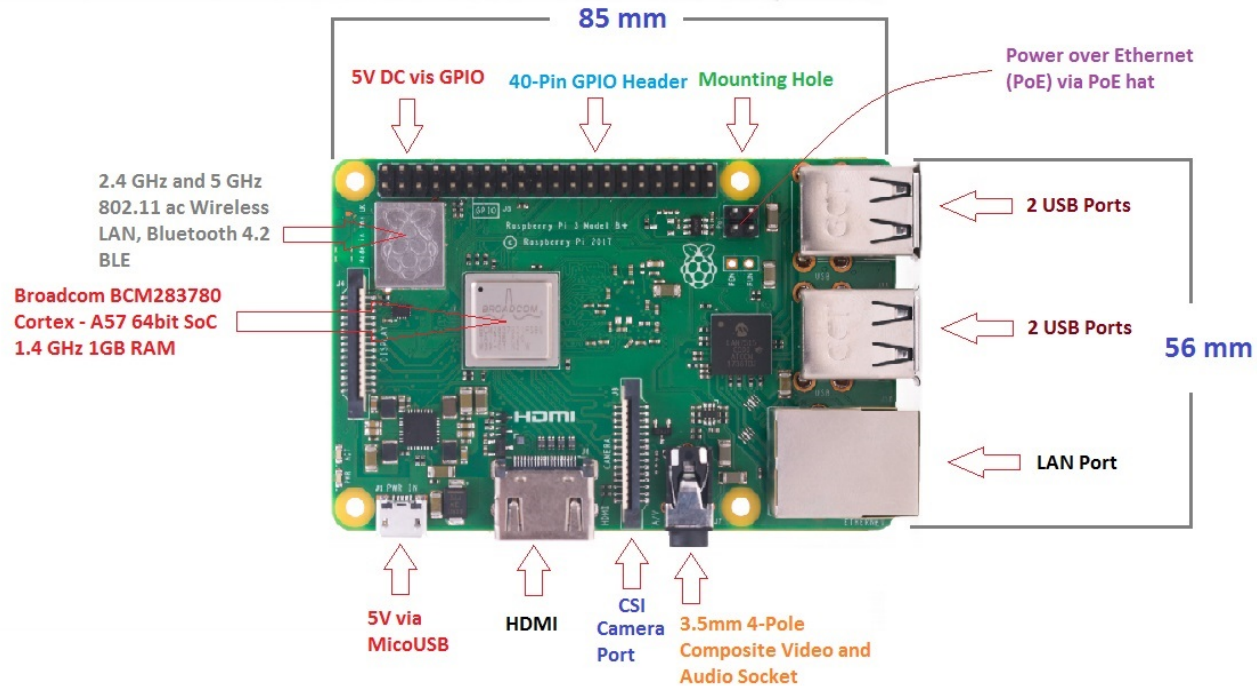
[https://xdevs.com/article/rpi3\\_oc/](https://xdevs.com/article/rpi3_oc/)



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**





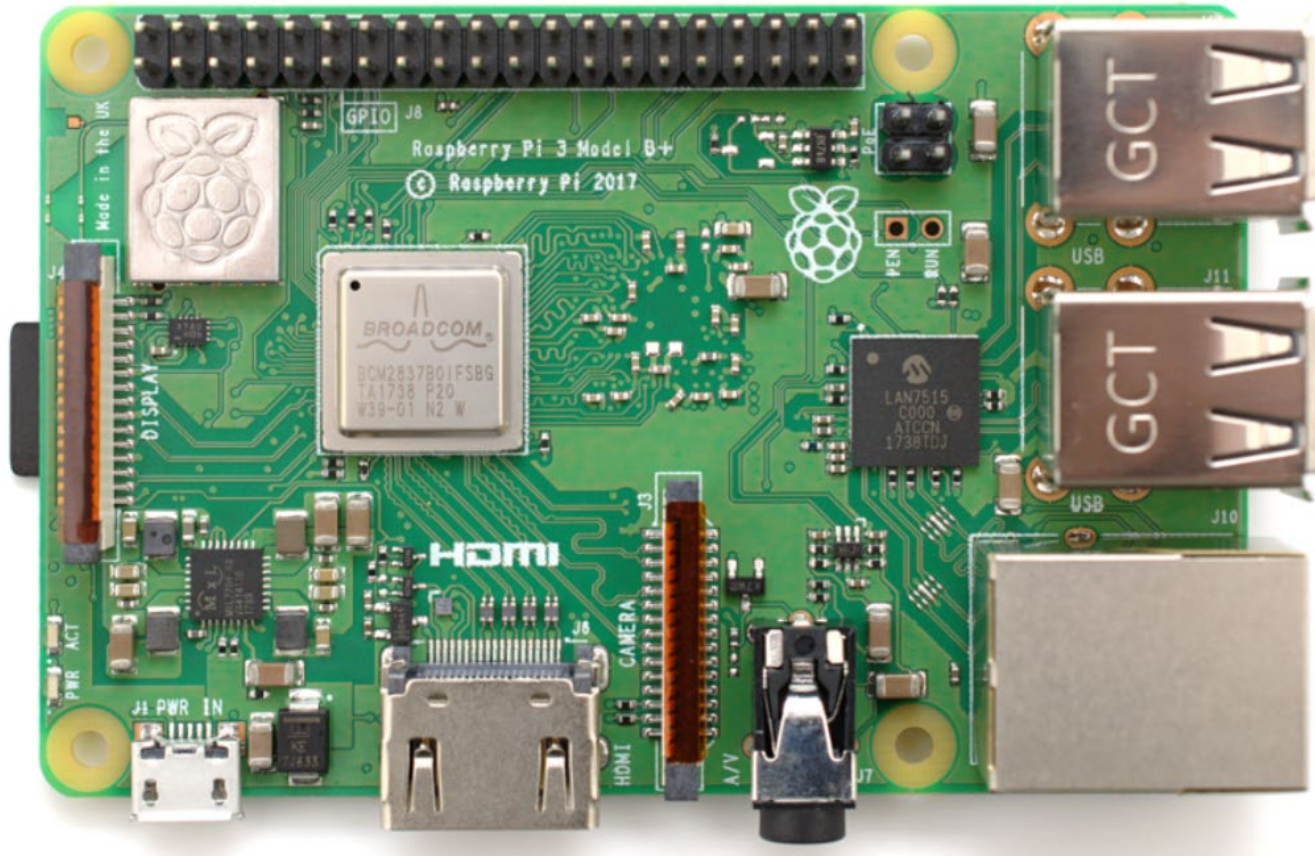
### Introduction to Raspberry Pi 3 B+

[www.TheEngineeringProjects.com](http://www.TheEngineeringProjects.com)



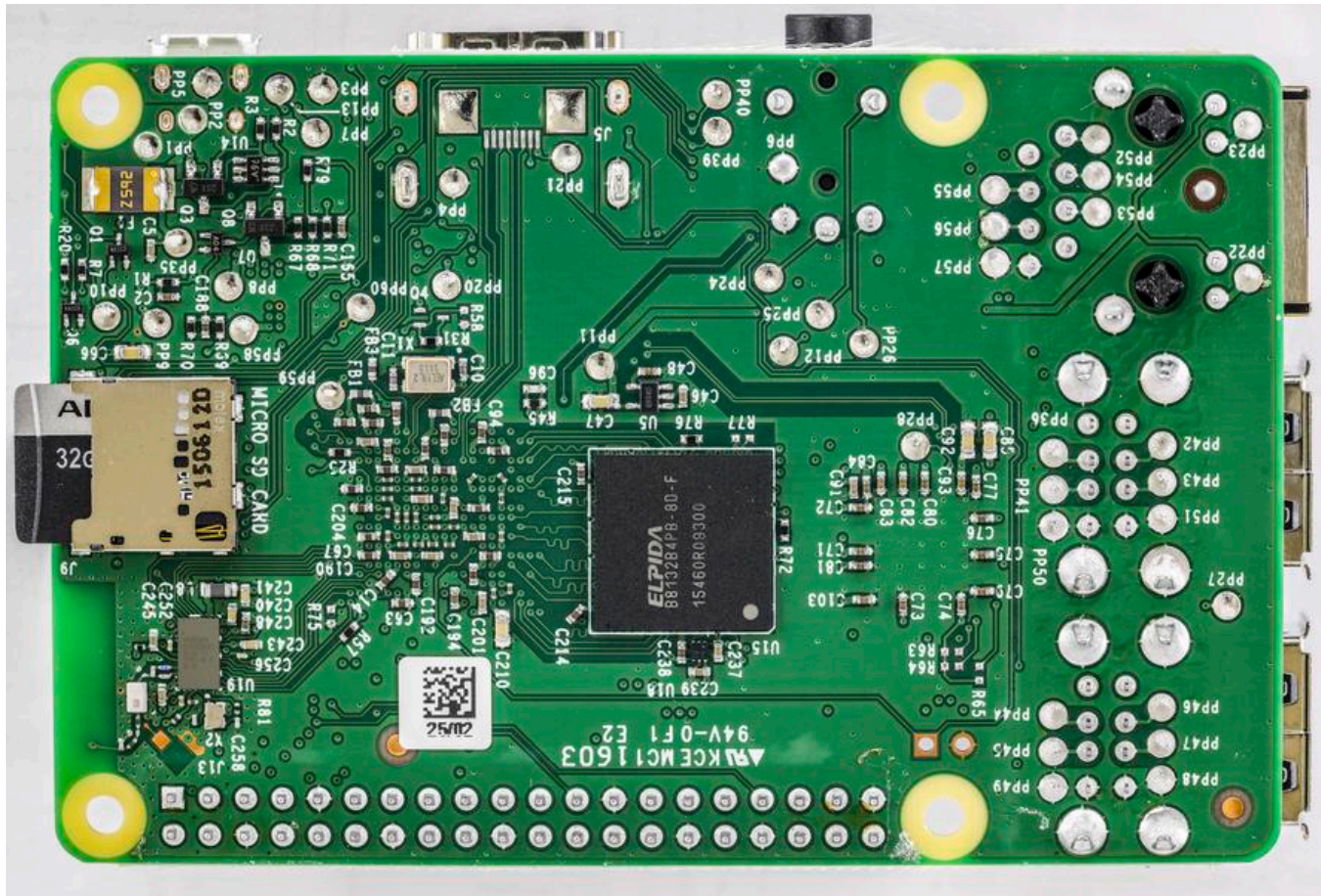
INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**





3.3v	5V
GPIO 2 Serial Data (I2C)	5V
GPIO3 Serial Clock (I2C)	Ground
GPIO 4	GPIO 14 (UART TX)
Ground	GPIO 15 (UART RX)
GPIO 17 Chip Enable-CE1 (SPI1)	GPIO 18 Chip Enable-CE0 (SPI1) [PWM]
GPIO 27	Ground
GPIO 22	GPIO 23
3.3v	GPIO 24
GPIO 10 MOSI (SPI 0)	Ground
GPIO 09 MISO (SPI 0)	GPIO 25
GPIO 11 SCLK (SPI 0)	GPIO 8 Chip Enable-CE0 (SPI0)
Ground	GPIO 7 Chip Enable-CE1(SPI0)
GPIO 0 EEPROM Serial DATA (I2C)	GPIO 1 EEPROM Serial Clock (I2C)
GPIO 5	Ground
GPIO 6	GPIO 12 (PWM)
GPIO 13 (PWM)	Ground
[PWM] GPIO 19 MISO (SPI 1)	GPIO 16 Chip Enable-CE2 (SPI 1)
GPIO 26	GPIO 20 MISO (SPI 1)
Ground	GPIO 21 SCLK (SPI 1)

# R-Pi 3 B+ Pinout

[www.eTechnophiles.com](http://www.eTechnophiles.com)



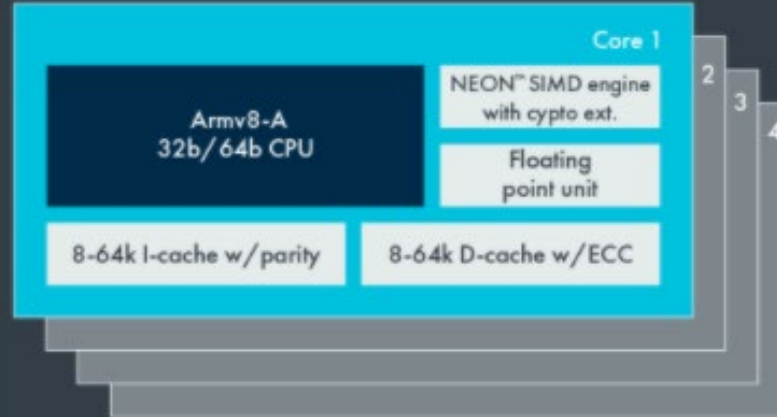
INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**



# arm CORTEX<sup>®</sup>-A53

CoreSight<sup>™</sup> multicore debug and trace



ACP

SCU

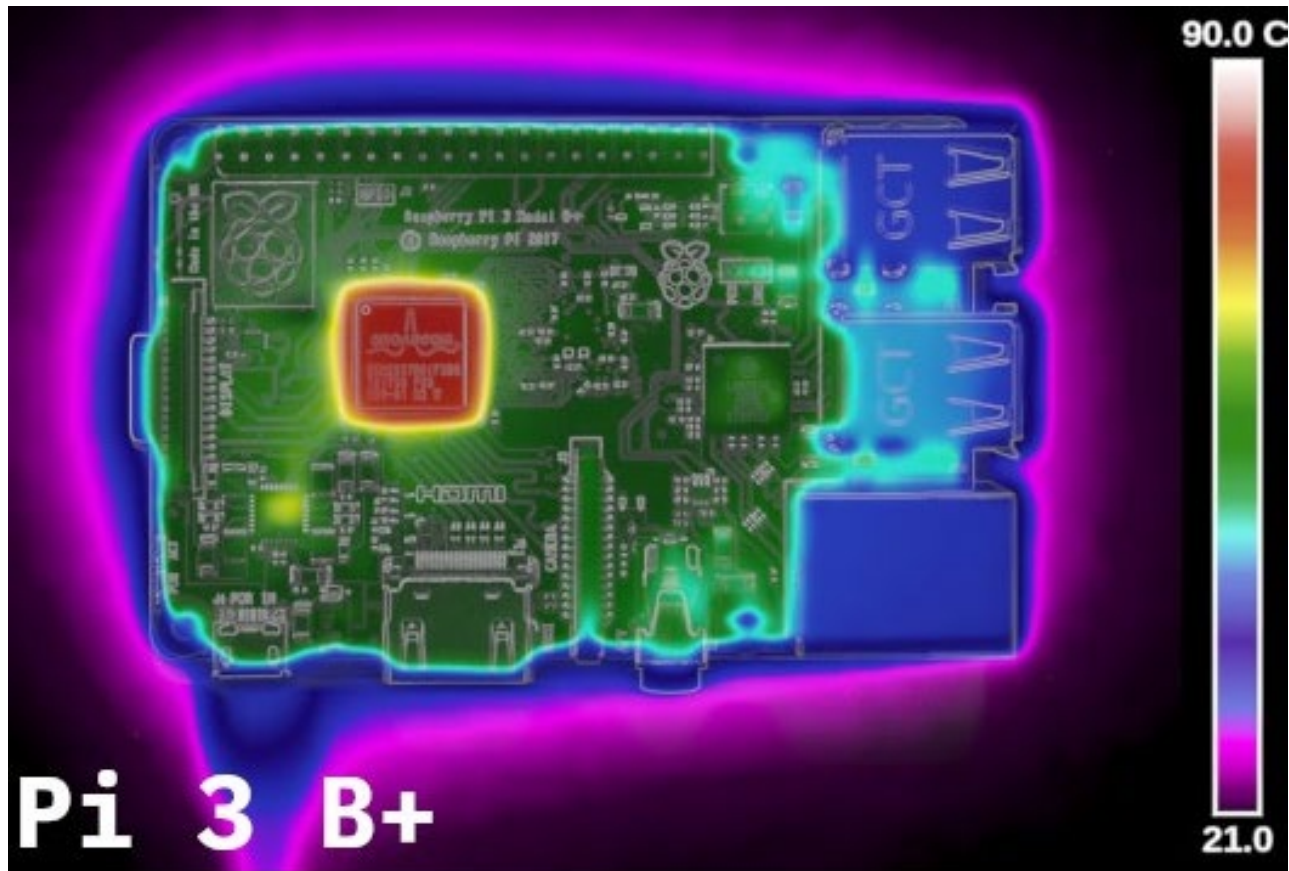
L2 w/ECC (128kB~2MB)

Configurable AMBA<sup>®</sup> 4 ACE or AMBA 5 CHI coherent bus interface



INDIANA UNIVERSITY

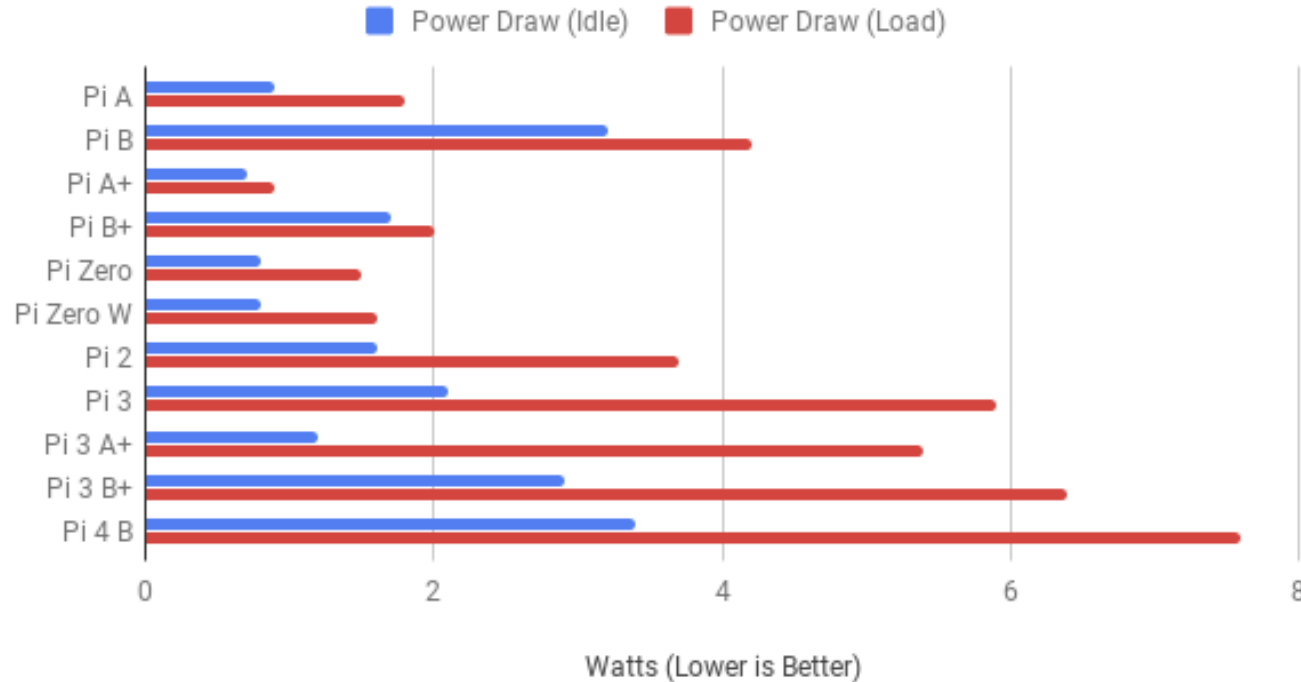
**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**



INDIANA UNIVERSITY

SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING

## Power Draw Benchmark



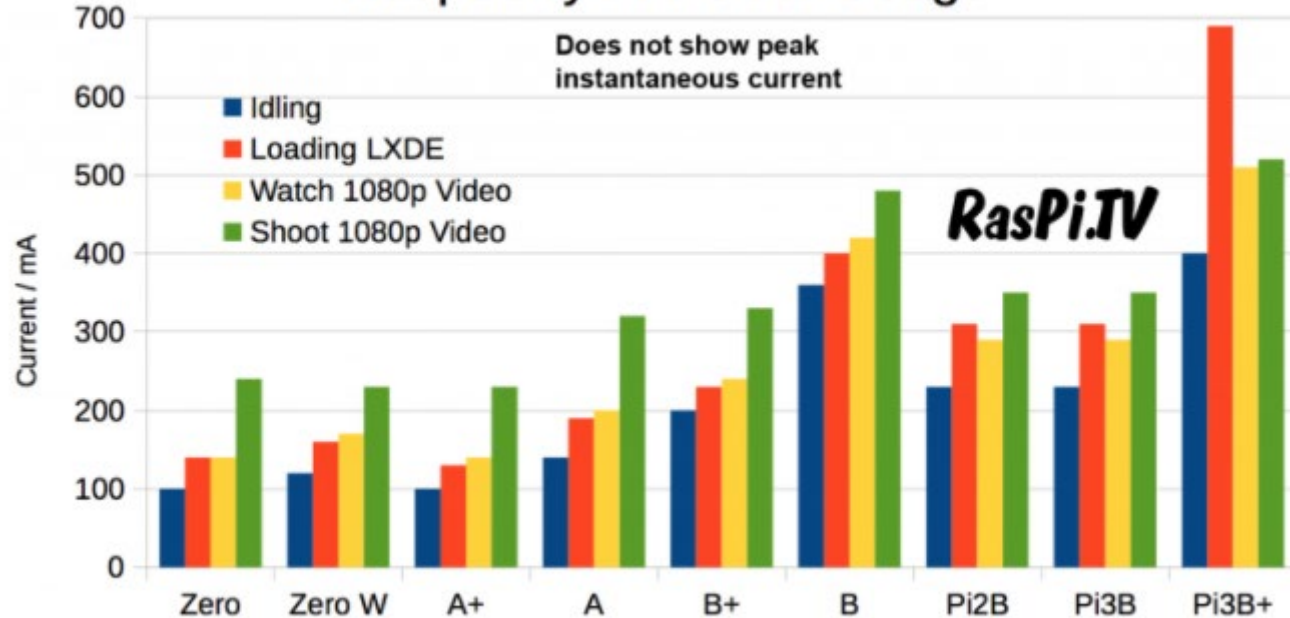
<https://medium.com/@ghalfacree/benchmarking-the-raspberry-pi-4-73e5afbcd54b>



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

# Raspberry Pi Power Usage



*Raspberry Pi power usage chart incorporating Pi 3B plus*

<https://raspi.tv/2018/how-much-power-does-raspberry-pi-3b-use-power-measurements>

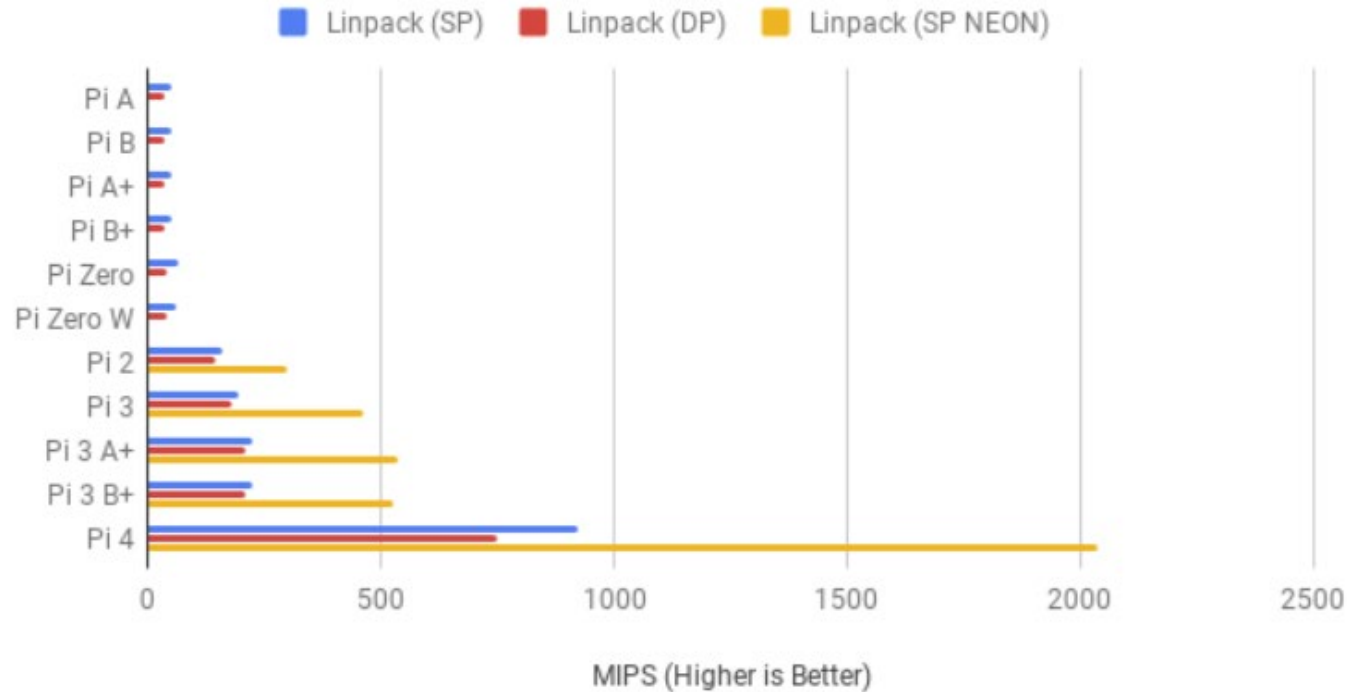


INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**



# Linpack Benchmark



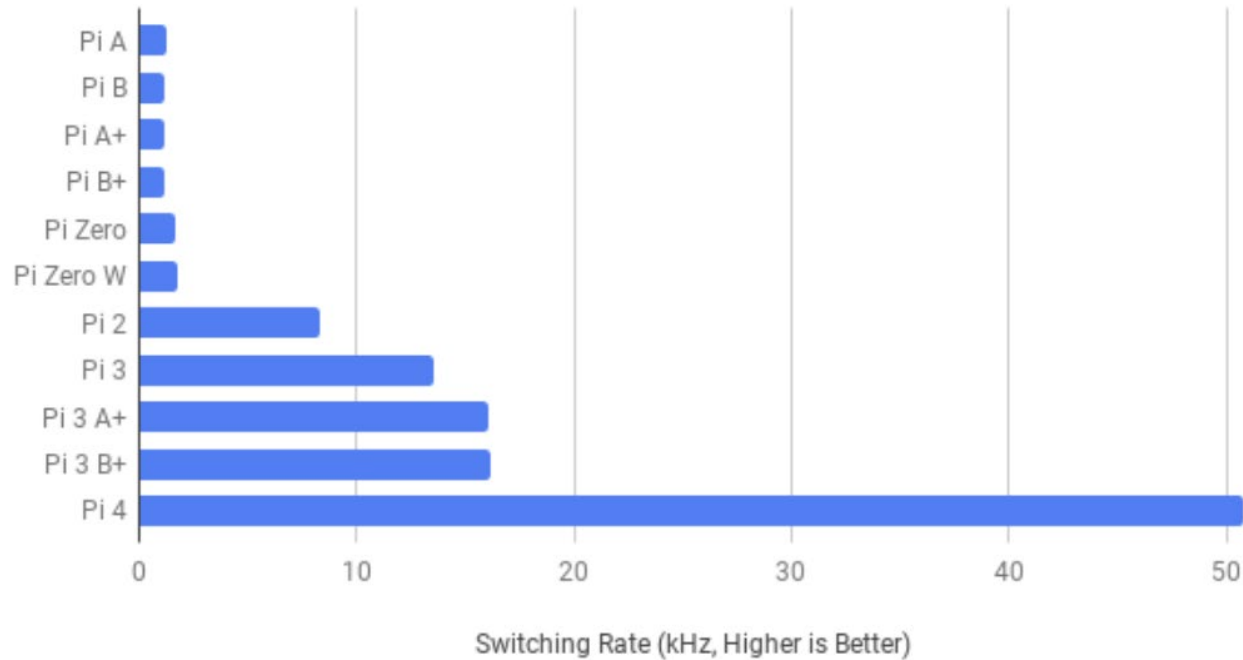
<https://medium.com/@ghalfacree/benchmarking-the-raspberry-pi-4-73e5afbcd54b>



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

## Gpiozero Benchmark



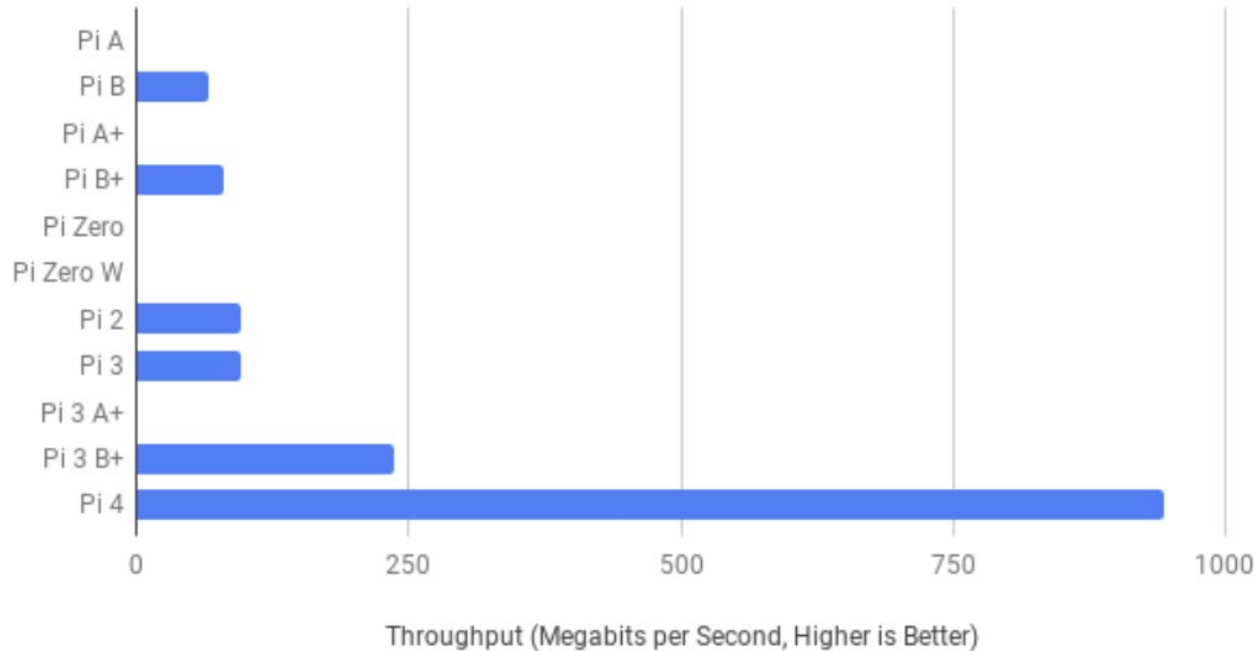
<https://medium.com/@ghalfacree/benchmarking-the-raspberry-pi-4-73e5afbcd54b>



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

## Ethernet Throughput Benchmark



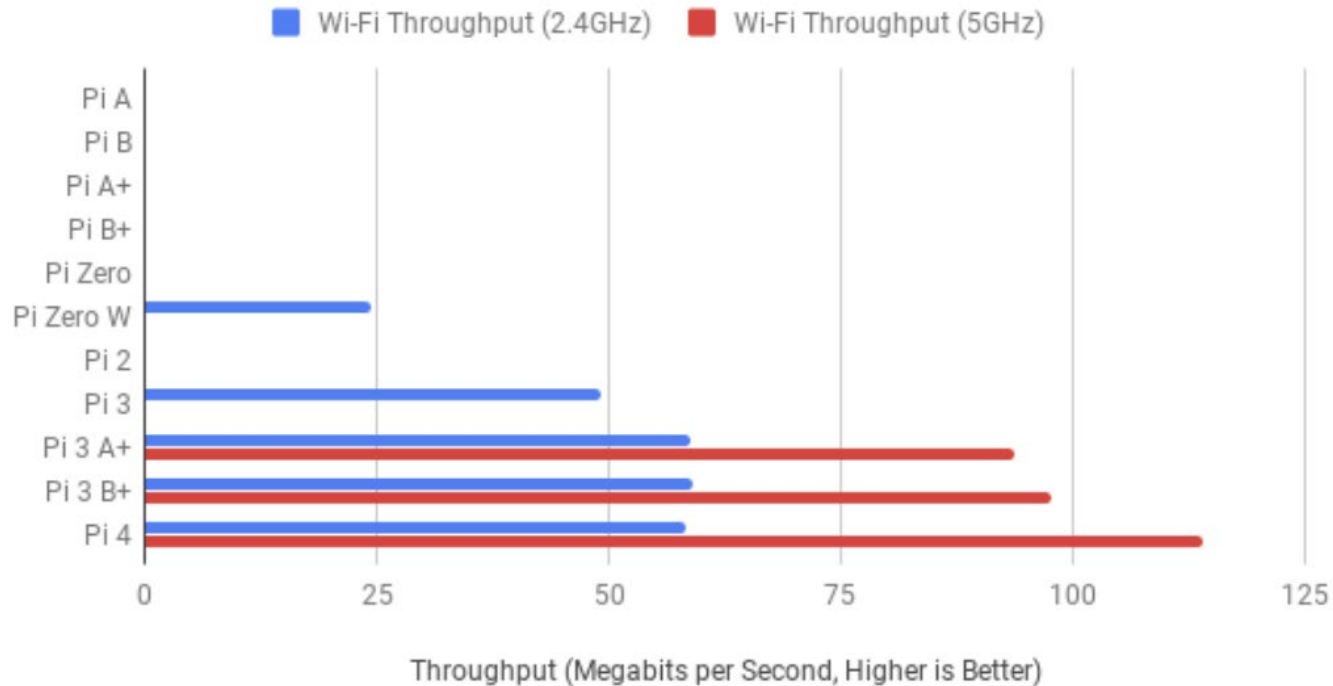
<https://medium.com/@ghalfacree/benchmarking-the-raspberry-pi-4-73e5afbcd54b>



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

## Wi-Fi Throughput Benchmark



<https://medium.com/@ghalfacree/benchmarking-the-raspberry-pi-4-73e5afbcd54b>



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

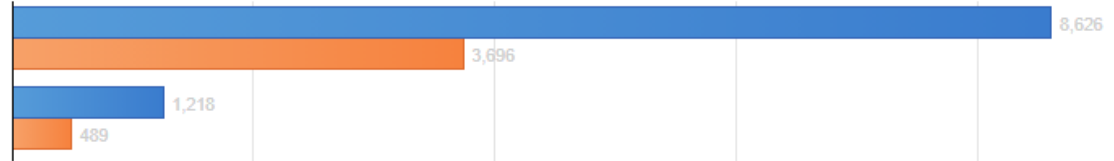
On Android 64-bit:



Intel Core i7-8565U #ad

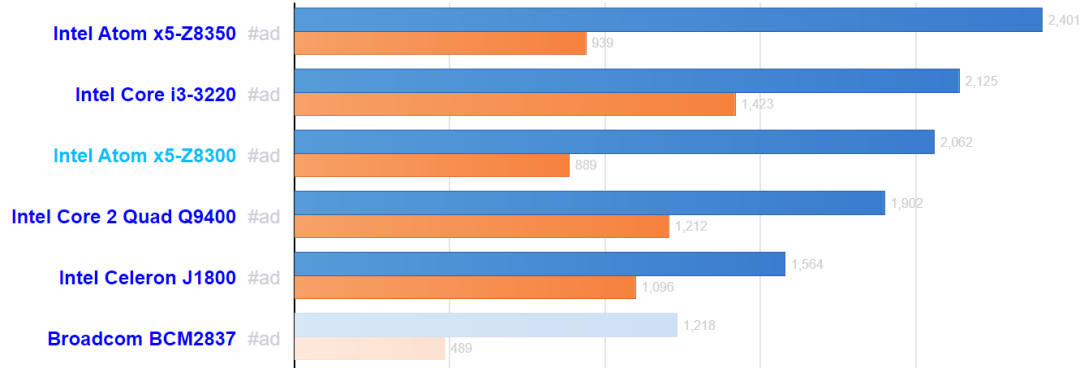
Broadcom BCM2837 #ad

Geekbench 4 - Multi-core & single core score - Android 64-bit



In single core, the difference is 656%. In multi-core, the differential gap is 608%.

Geekbench 4 - Multi-core & single core score - Android 64-bit



<https://gadgetversus.com/processor/intel-core-i7-8565u-vs-broadcom-bcm2837/>



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

# Wifi Connection to Pi

# Static IP Address when on the IU Network

1. Each Pi has the following:

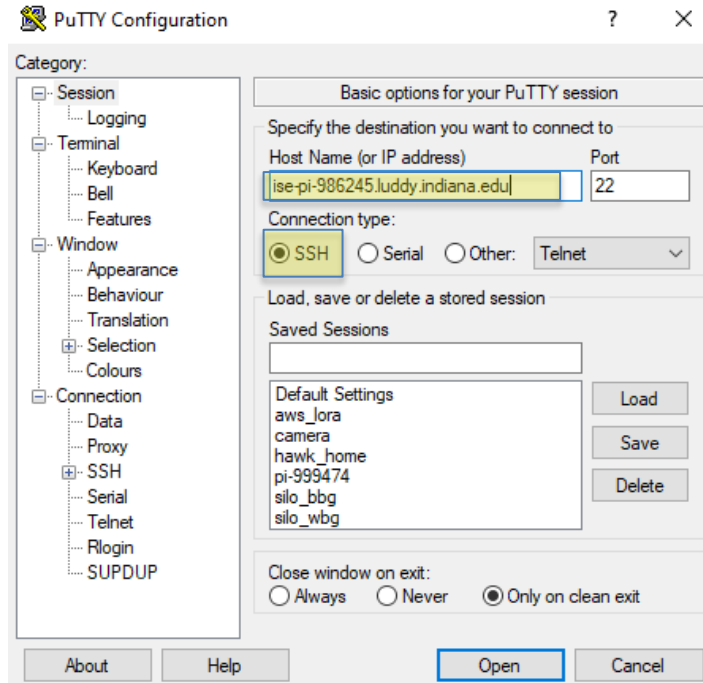
- Static IP Address
- DNS Name

2. The name will be:

- ise-pi-xxxxxx.luddy.Indiana.edu where xxxxxx is the 6-digit serial number on the white tag attached to the pi.



# Using Putty to ssh into Pi



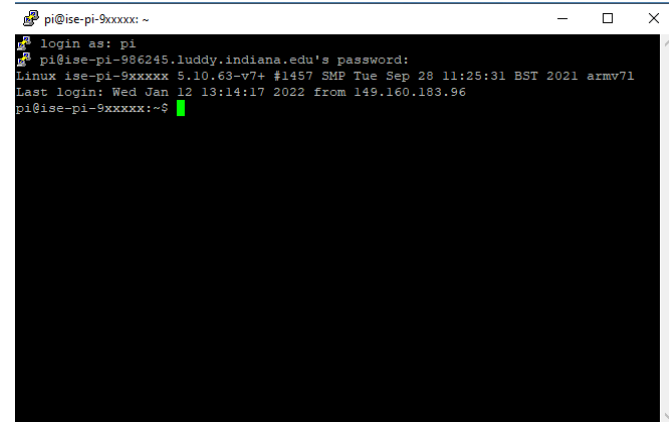


# After logging into the machine:

- Username: pi
- Password: e101class



A terminal window titled 'ise-pi-986245.luddy.indiana.edu - PuTTY'. The prompt is 'login as: pi'. The user has entered 'pi' and the prompt is now 'pi@ise-pi-986245.luddy.indiana.edu's password:'. A green cursor is visible at the end of the password prompt.



A terminal window titled 'pi@ise-pi-9xxxxx: ~'. The prompt is 'login as: pi'. The user has entered 'pi' and the prompt is now 'pi@ise-pi-986245.luddy.indiana.edu's password:'. The user has entered the password and the prompt is now 'pi@ise-pi-9xxxxx:~\$'. The terminal displays the following system information: 'Linux ise-pi-9xxxxx 5.10.63-v7+ #1457 SMP Tue Sep 28 11:25:31 BST 2021 armv71', 'Last login: Wed Jan 12 13:14:17 2022 from 149.160.183.96', and 'pi@ise-pi-9xxxxx:~\$'.



**Suppose there is a problem ...**

# UART can help diagnose the problem.

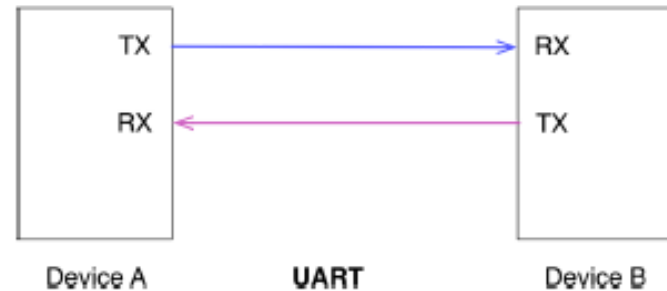
1. A UART-type console is available on most linux machines.
2. Enables debug of system where network does not come up properly



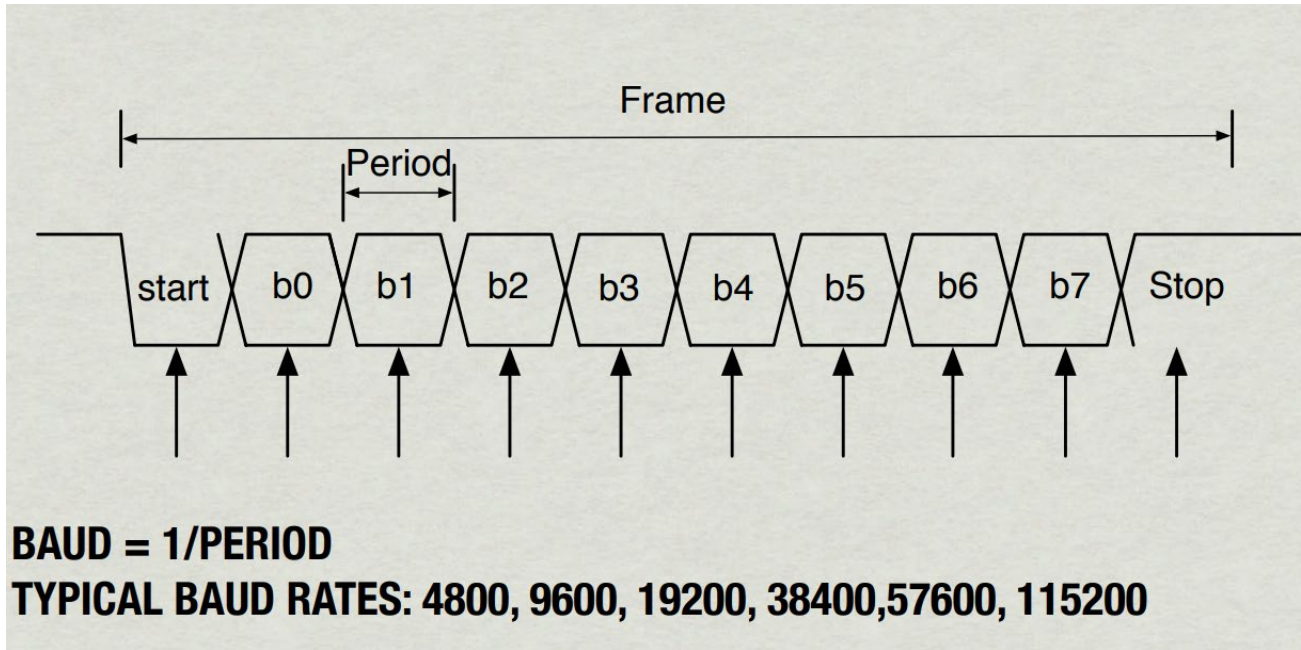
# UART Overview

# UART Overview

- Universal Asynchronous Receiver Transmitter
- Full-Duplex - Receive and Transmit Simultaneously
- Communication with systems using different clocks.



# Waveform



# Pins

- TX (output): Transmit Data
- RX (input): Receive Data
- Flow Control
  - nCTS: Clear to Send - prevents Pi from transmitting data when high.
  - nRTS: Ready to Send - indicates Pi is ready to receive data when low



# USB to Serial Converter



# Serial Connection to PI



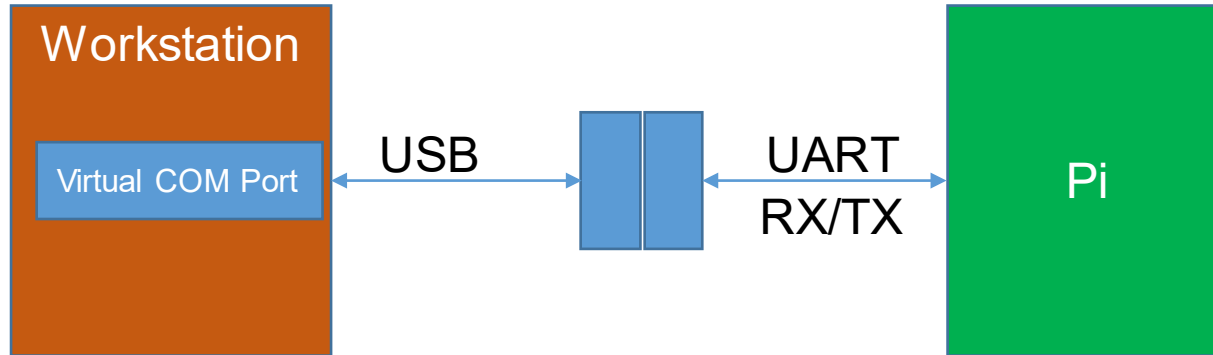
USB-to-Serial Adapter



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

## FTDI USB-UART Converter



## Future Technology Devices International Ltd. FT232BL/BQ USB UART IC



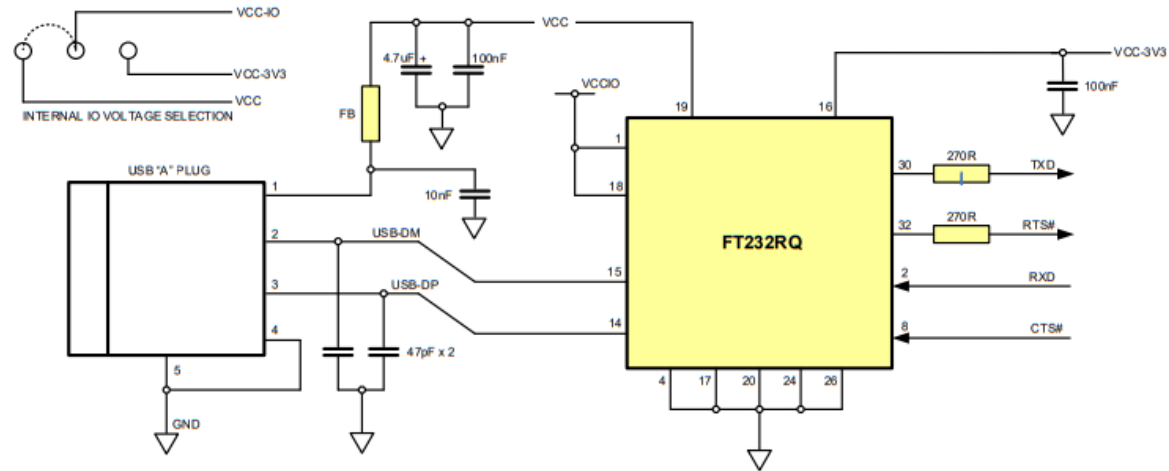
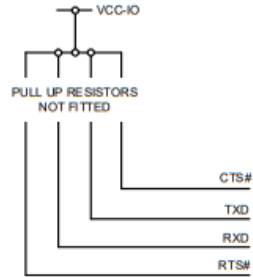
The FT232B is a USB to serial UART interface with the following advanced features:

- Single Chip USB to Asynchronous Serial Data Transfer
- Full Handshaking & Modem Interface Signals
- UART I/F Supports 7 / 8 Bit Data, 1 / 2 Stop Bits and Odd/Even/Mark/Space/No Parity
- Data rate 300 => 3M Baud (TTL)
- Data rate 300 => 1M Baud (RS232)
- Data rate 300 => 3M Baud (RS422/RS485)
- 384 Byte Receive Buffer / 128 Byte Transmit Buffer for high data throughput
- Adjustable RX buffer timeout
- Fully Assisted Hardware or X-On / X-Off Handshaking In-built support for event characters and line break condition
- Auto Transmit Buffer control for RS485
- Support for USB Suspend / Resume through SLEEP# and RI# pins
- 4.35V to 5.25V single supply operation
- Support for high power USB Bus powered devices through PWREN# pin
- Integrated level converter on UART and control signals for interfacing to 5V and 3.3V logic
- Integrated 3.3V regulator for USB IO
- Integrated Power-On-Reset circuit
- Integrated 6MHz – 48Mhz clock multiplier PLL
- UHCI / OHCI / EHCI host controller compatible
- USB 1.1 and USB 2.0 compatible
- USB VID, PID, Serial Number and Product Description strings in external EEPROM
- EEPROM programmable on-board via USB
- Available as a compact lead free RoHS compliant 32-LD LQFP package (FT232BL) or 32-LD QFN package (FT232BQ).



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

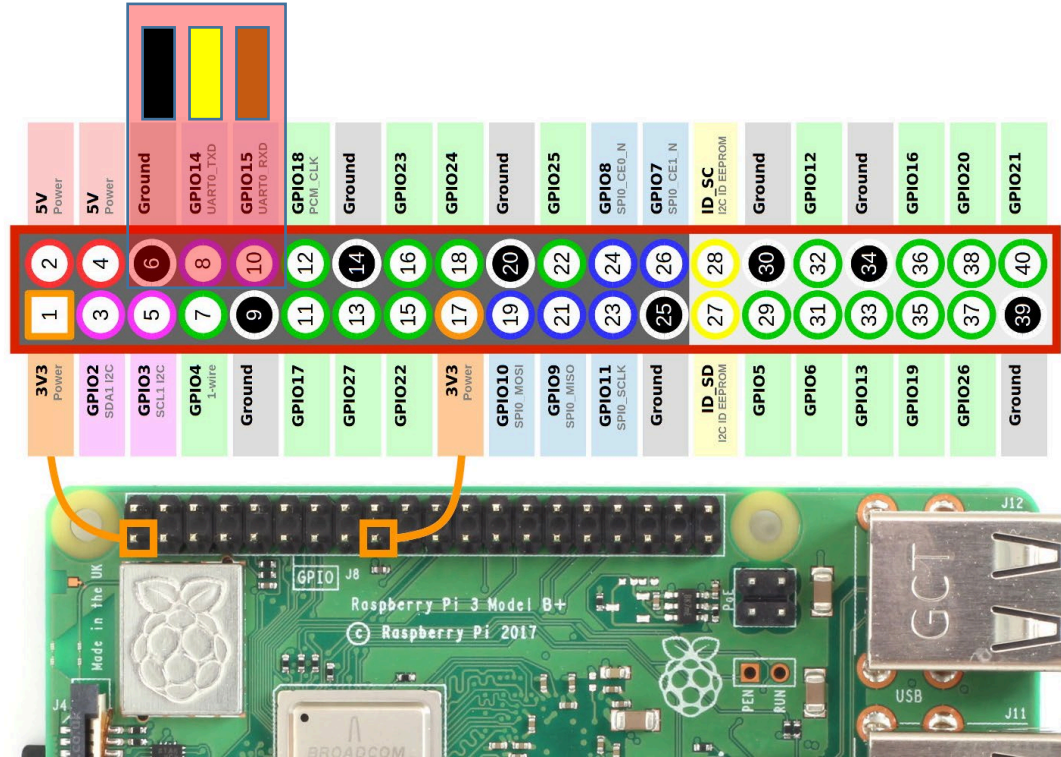
# Connecting the Pi

# Connecting with Putty

- Connect USB cable
- Determine the COM port of FTDI cable
- Connect to COM port using Putty

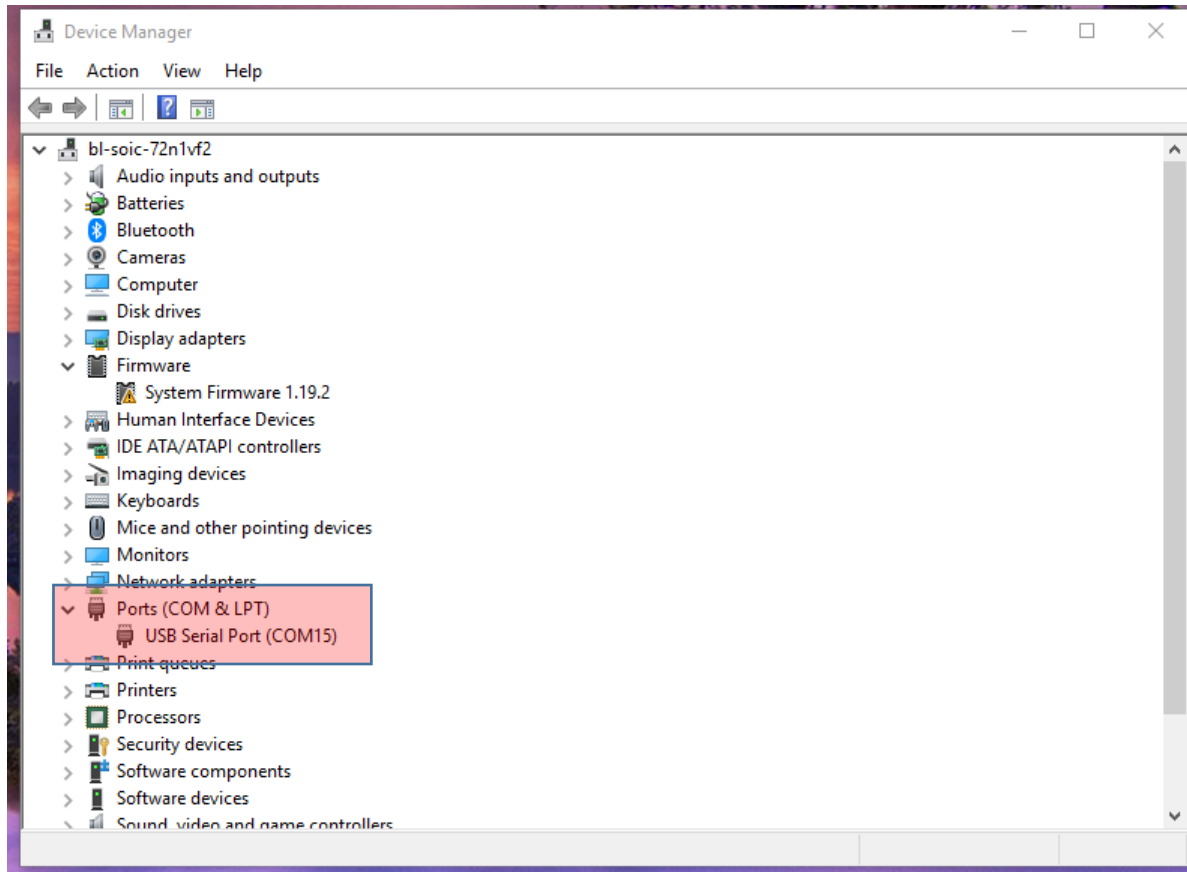


## Console Connections



INDIANA UNIVERSITY

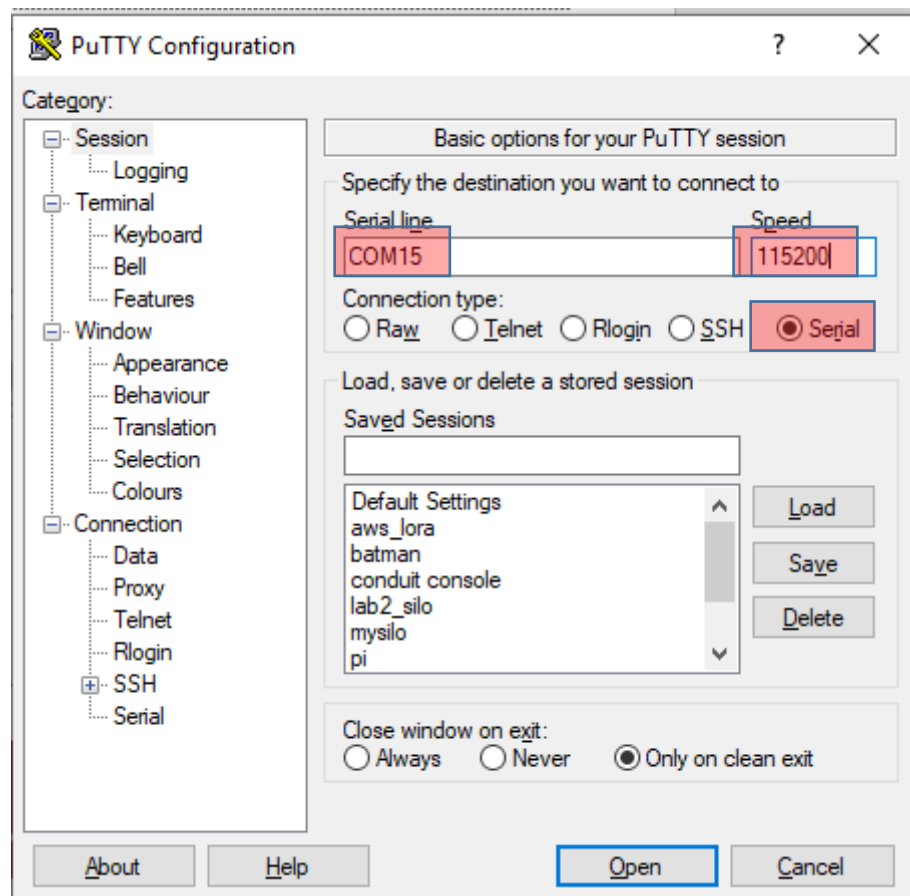
**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**



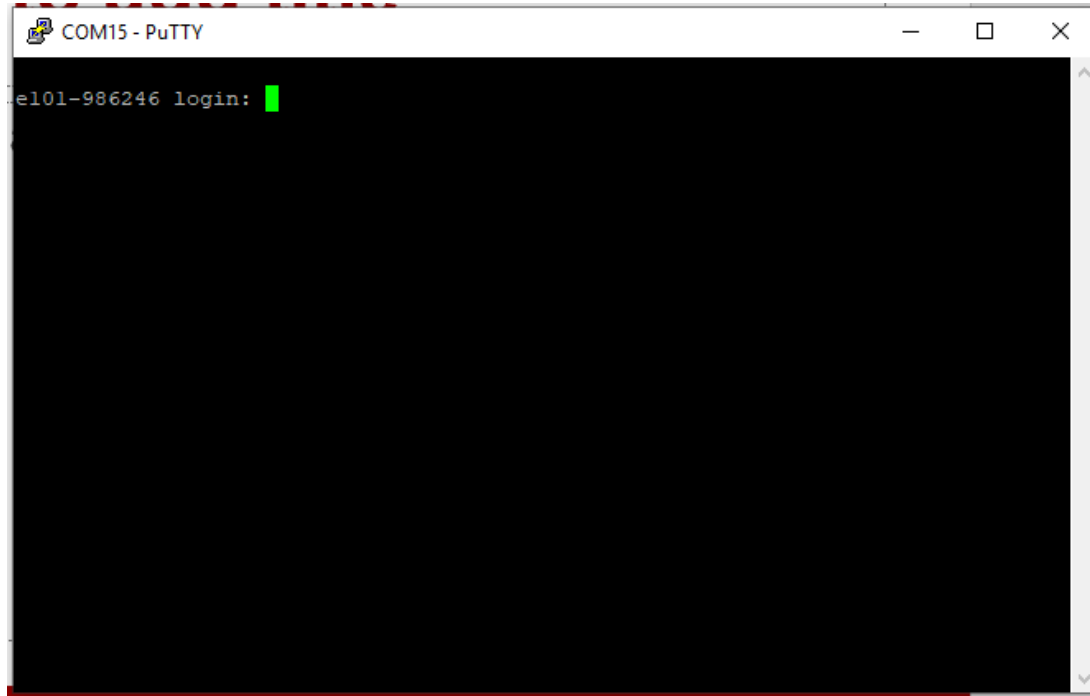
INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**





Might have to hit Enter a couple of times ...  
Username: pi  
Password: e101class



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

# Connecting with Mac/Linux

- Connect the USB/Serial Cable
- Look in the /dev directory to find name of device.
  - Linux: ttyUSBx where x is an integer starting at 0
  - MacOS: cu.x where x is likely something like usbserial
- Connect to the device using **screen** utility
- <https://pbxbook.com/other/mac-tty.html>

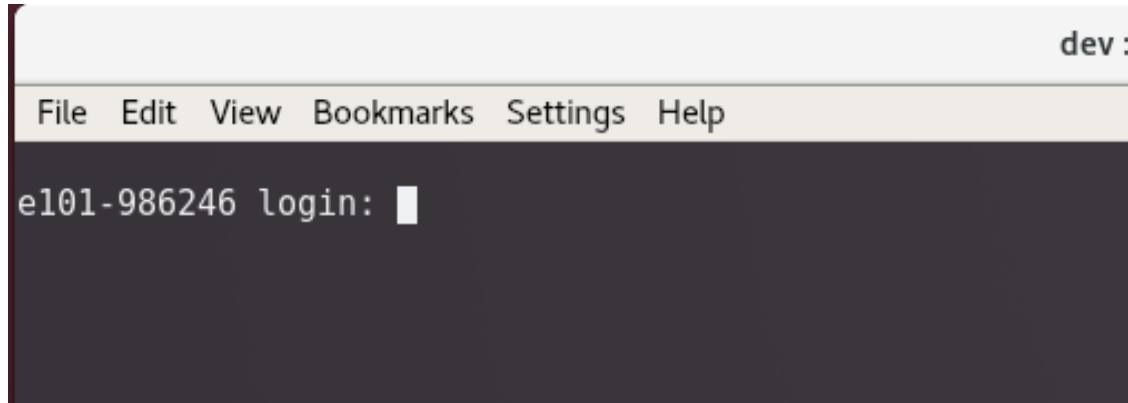


```
dev : bash — Konsole
File Edit View Bookmarks Settings Help
bhimebau@mercury:/dev$ ls
agpgart      hidraw0      loop20      ptmx         tty11        tty31        tty51        ttyS12       ttyS4        vcsa3
autofs       hpet         loop3       pts          tty12        tty32        tty52        ttyS13       ttyS5        vcsa4
block        hugepages    loop4       random       tty13        tty33        tty53        ttyS14       ttyS6        vcsa5
bsg          hwrng        loop5       rfkill       tty14        tty34        tty54        ttyS15       ttyS7        vcsa6
btrfs-control initctl      loop6       rtc          tty15        tty35        tty55        ttyS16       ttyS8        vcsa7
bus          input        loop7       rtc0         tty16        tty36        tty56        ttyS17       ttyS9        vfio
cdrom        kmsg         loop8       sda          tty17        tty37        tty57        ttyS18       ttyUSB0      vga_arbiter
cdrw         lightnvm     loop9       sda1         tty18        tty38        tty58        ttyS19       uhid         vhci
char         log          loop-control serial        tty19        tty39        tty59        ttyS2        uinput       vhost-net
console      loop0        mapper      sg0          tty2         tty4         tty6         ttyS20       urandom      vhost-vsock
core         loop1        mcelog      sg1          tty20        tty40        tty60        ttyS21       userio       vmci
cpu_dma_latency loop10       mem         shm          tty21        tty41        tty61        ttyS22       vcs          vsock
cuse         loop11       memory_bandwidth snapshot      tty22        tty42        tty62        ttyS23       vcs1         zero
disk         loop12       midi        snd          tty23        tty43        tty63        ttyS24       vcs2
dmideid      loop13       mqueue      sr0          tty24        tty44        tty7         ttyS25       vcs3
dri          loop14       net         stderr       tty25        tty45        tty8         ttyS26       vcs4
dvd          loop15       network_latency stdin         tty26        tty46        tty9         ttyS27       vcs5
ecryptfs     loop16       network_throughput stdout        tty27        tty47        ttyprintk    ttyS28       vcs6
fb0          loop17       null        tty          tty28        tty48        ttyS0        ttyS29       vcs7
fd           loop18       port        tty0         tty29        tty49        ttyS1        ttyS3        vcsa
full         loop19       ppp         tty1         tty3         tty5         ttyS10       ttyS30       vcsa1
fuse         loop2        psaux       tty10        tty30        tty50        ttyS11       ttyS31       vcsa2
bhimebau@mercury:/dev$
```



```
dev : bash — Konsole
File Edit View Bookmarks Settings Help
bhimebau@mercury:/dev$ screen /dev/ttyUSB0 115200
```



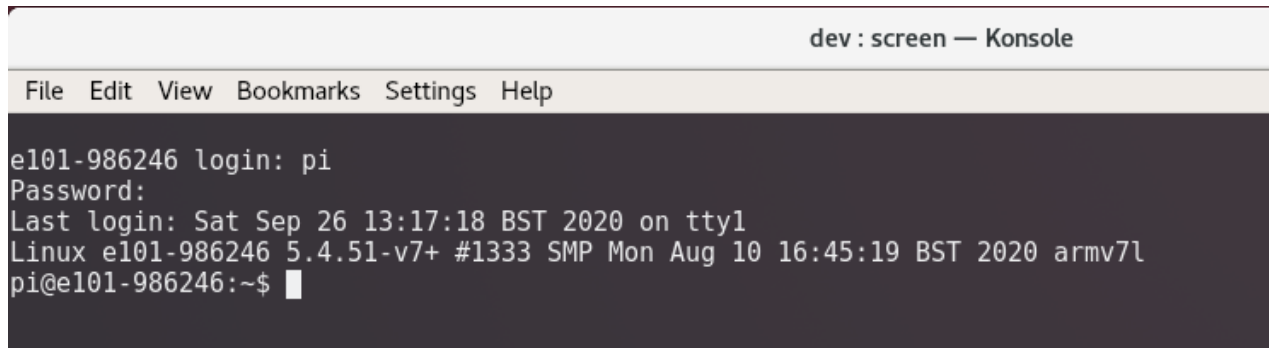


INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

# After logging into the machine:

- Username: pi
- Password: e101class



The screenshot shows a terminal window titled "dev : screen — Konsole". The terminal has a menu bar with "File", "Edit", "View", "Bookmarks", "Settings", and "Help". The output of the login process is as follows:

```
e101-986246 login: pi
Password:
Last login: Sat Sep 26 13:17:18 BST 2020 on tty1
Linux e101-986246 5.4.51-v7+ #1333 SMP Mon Aug 10 16:45:19 BST 2020 armv7l
pi@e101-986246:~$
```



# Determine IP Address

- If you are in Luddy, the PI will connect automatically to IU DeviceNet
- You should have an IP address that begins with 140.
- Use the command `ifconfig` to verify address of wlan0 interface





```
dev: screen — Konsole
File Edit View Bookmarks Settings Help

e101-986246 login: pi
Password:
Last login: Sat Sep 26 13:17:18 BST 2020 on tty1
Linux e101-986246 5.4.51-v7+ #1333 SMP Mon Aug 10 16:45:19 BST 2020 armv7l
pi@e101-986246:~$ ifconfig
eth0: flags=4099<UP,BROADCAST,MULTICAST> mtu 1500
    ether b8:27:eb:63:06:6f txqueuelen 1000 (Ethernet)
    RX packets 0 bytes 0 (0.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 0 bytes 0 (0.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

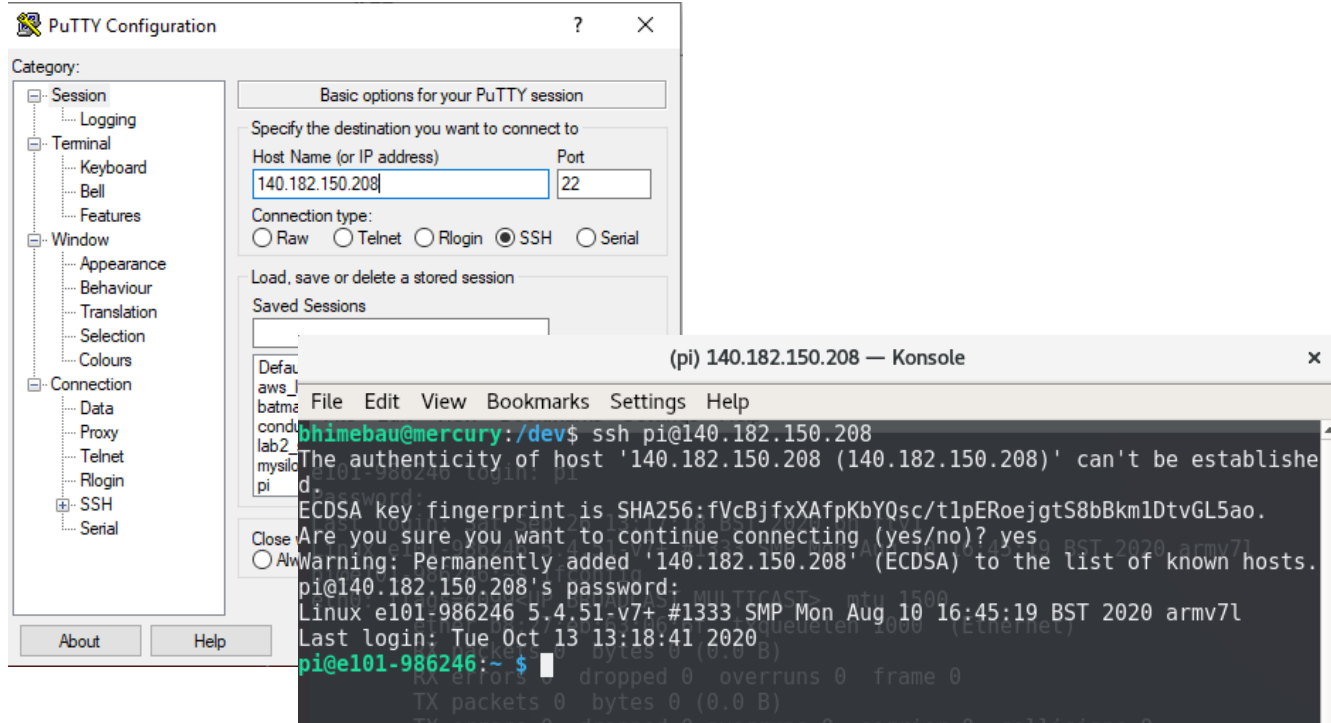
lo: flags=73<UP,LOOPBACK,RUNNING> mtu 65536
    inet 127.0.0.1 netmask 255.0.0.0
    inet6 ::1 prefixlen 128 scopeid 0x10<host>
    loop txqueuelen 1000 (Local Loopback)
    RX packets 12 bytes 720 (720.0 B)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 12 bytes 720 (720.0 B)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

wlan0: flags=4103<UP,BROADCAST,RUNNING,MULTICAST> mtu 1500
    inet 140.182.150.208 netmask 255.255.252.0 broadcast 140.182.151.255
    inet6 fe80::b327:4337:9e97:7089 prefixlen 64 scopeid 0x20<link>
    ether b8:27:eb:36:53:3a txqueuelen 1000 (Ethernet)
    RX packets 265 bytes 18023 (17.6 KiB)
    RX errors 0 dropped 0 overruns 0 frame 0
    TX packets 475 bytes 73637 (71.9 KiB)
    TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0

pi@e101-986246:~$
```



# SSH to this IP Address



# Not at Luddy ...

- Use the raspi-config utility to add the name and password of your wireless access point.
- Run the command using sudo. For Example:
  - “sudo raspi-config”



File Edit View Bookmarks Settings Help

pi@el01-986246:~\$ sudo raspi-config

dev : screen — Konsole

File Edit View Bookmarks Settings Help

Raspberry Pi 3 Model B Rev 1.2

| Raspberry Pi Software Configuration Tool (raspi-config) |

- |   |                        |   |
|---|------------------------|---|
| 1 | Change User Password   | Change password for the 'pi' user                   |
| 2 | <b>Network Options</b> | <b>Configure network settings</b>                   |
| 3 | Boot Options           | Configure options for start-up                      |
| 4 | Localisation Options   | Set up language and regional settings to match your |
| 5 | Interfacing Options    | Configure connections to peripherals                |
| 6 | Overclock              | Configure overclocking for your Pi                  |
| 7 | Advanced Options       | Configure advanced settings                         |
| 8 | Update                 | Update this tool to the latest version              |
| 9 | About raspi-config     | Information about this configuration tool           |

<Select>

<Finish>



INDIANA UNIVERSITY

**SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING**

## Raspberry Pi Software Configuration Tool (raspi-config)

- N1 Hostname Set the visible name for this Pi on a network
- N2 Wireless LAN Enter SSID and passphrase**
- N3 Network interface names Enable/Disable predictable network interface na
- N4 Network proxy settings Configure network proxy settings

&lt;Select&gt;

&lt;Back&gt;



