Raspberry Pi Based LCD Clock

Introduction

This document describes the hardware and software for a Raspberry Pi (RPI) based clock that uses six 320x240 LCD displays (from Waveshare).

This document and the clock's software that runs on the RPi can be found here:
https://github.com/sgarrow/spiClock

List of Hardware Components

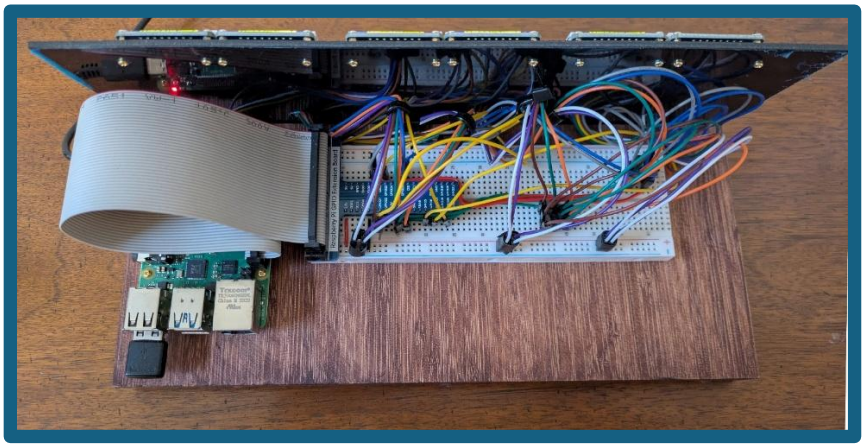
The major hardware components are (with Amazon links):

Raspberry Pi 4b (RPi):	RPi	~ $65
RPi SD card (OS):	OS	~ $15
RPi Power Supply:	PWR	~ $10
RPi micro-HDMI:	HDMI	~ $5
LCD Displays:	LCD	~ $15

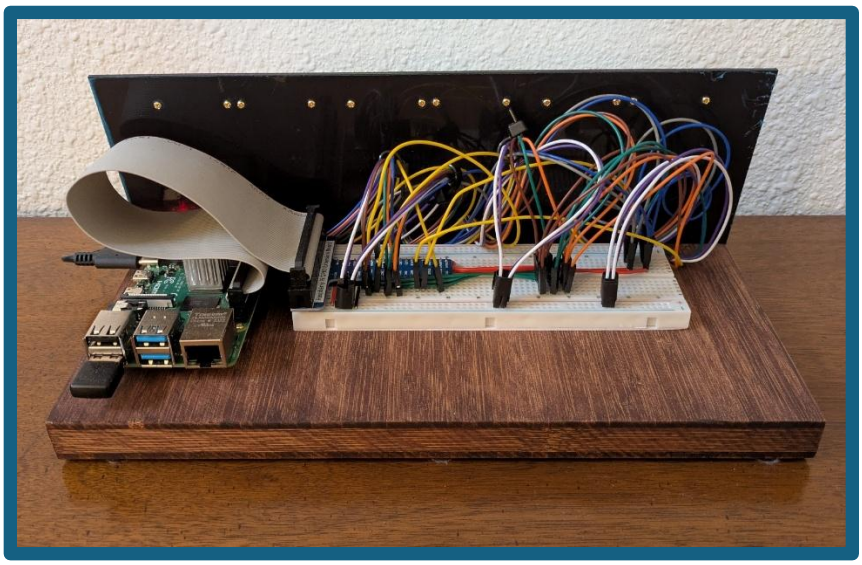
Additionally, there is a solderless bread board, a 40-pin ribbon cable and various jumper wires all of which come to about $30.

Photographs of Hardware Components

Photograph 1 – Front View



Photograph 2 – Back View 1



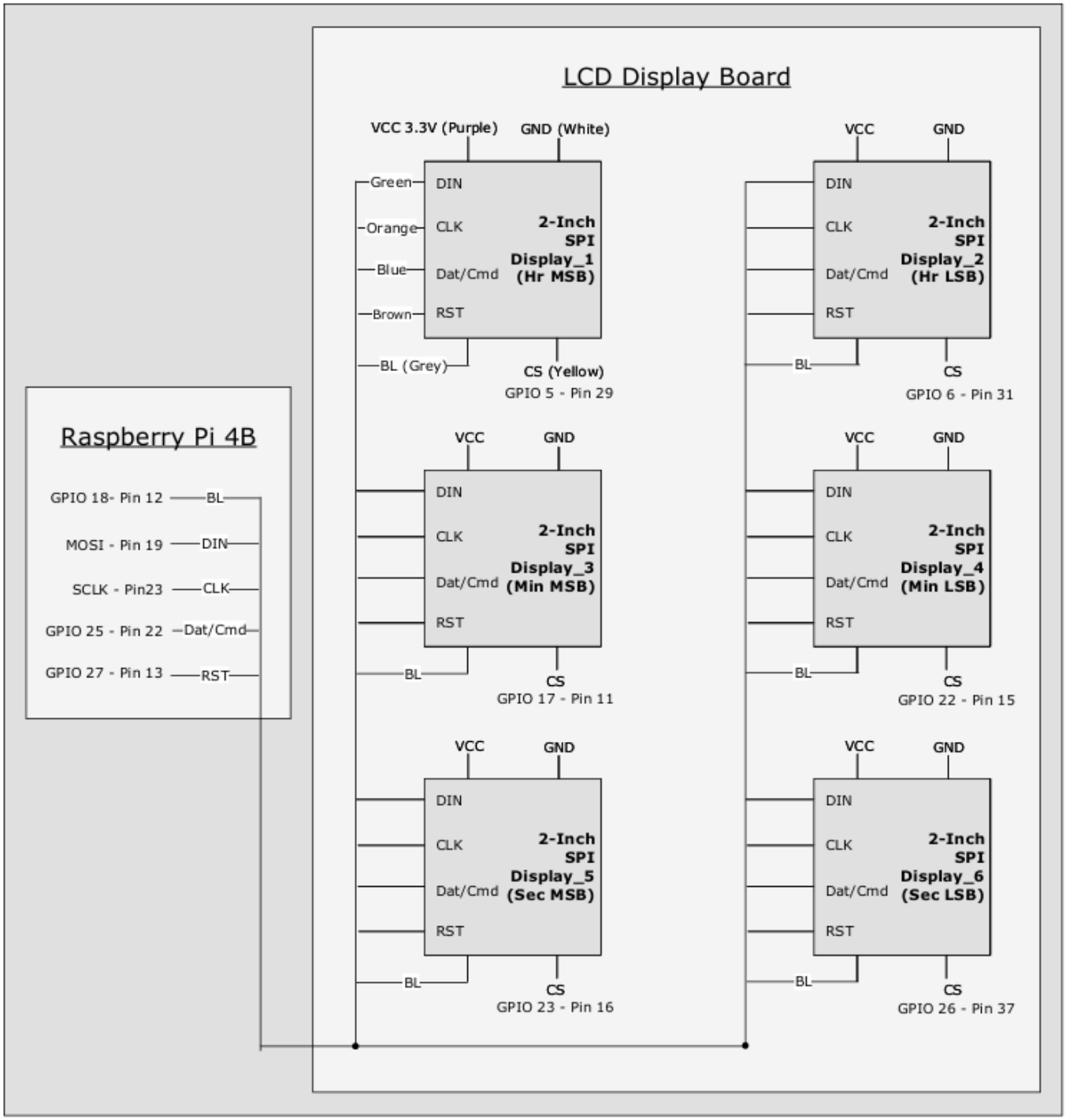
Photograph 2 – Back View 1

SPI Wiring

The RPi talks to the LCDs over an SPI interface – the wiring for which is provided below.

Note that each LCD has 8 connection points and that 7 of these are ALL common to each LCD. For example, pin 19 on the RPi (the Data In pin) is connected to all 8 LCDs. So, when the RPi is pumping out data on pin 19 it is going to ALL LCDs. That said, the only LCD that is "listening" is that LCD whose Chip Select pin (CS) is "low". The CS points are NOT all common. The RPi will only drive 1 of the 6 LCD CS signals low at a time.

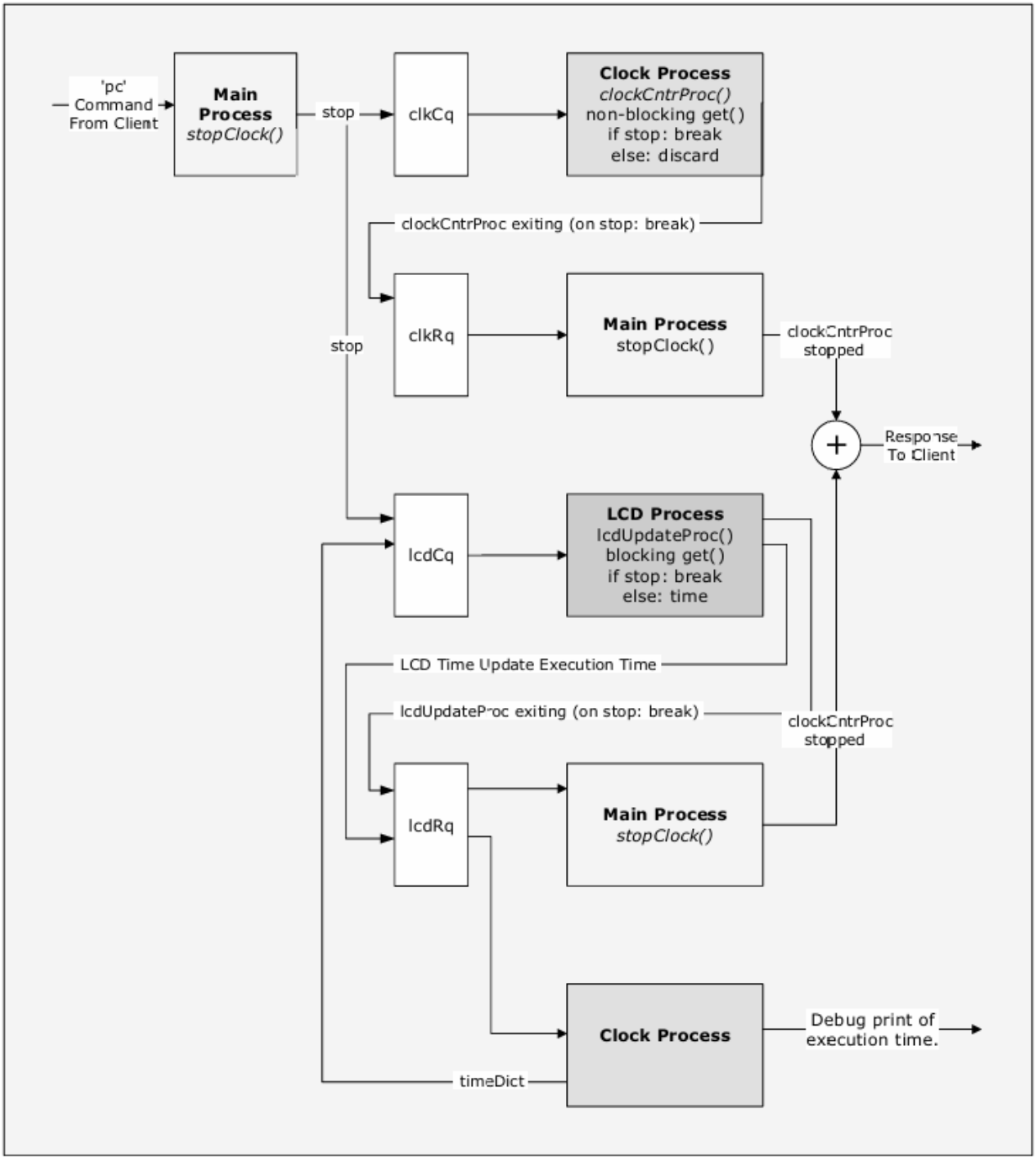
An introduction to SPI can be found here: https://en.wikipedia.org/wiki/Serial_Peripheral_Interface



Control of the clock is accomplished by running a python script (client.py) on a remote machine (PC, Phone). The clock on the Rpi runs within a server on the Rpi and the server will communicate with a remote machine running a client. Information on this client/server implementation can be found in Appendix 1:

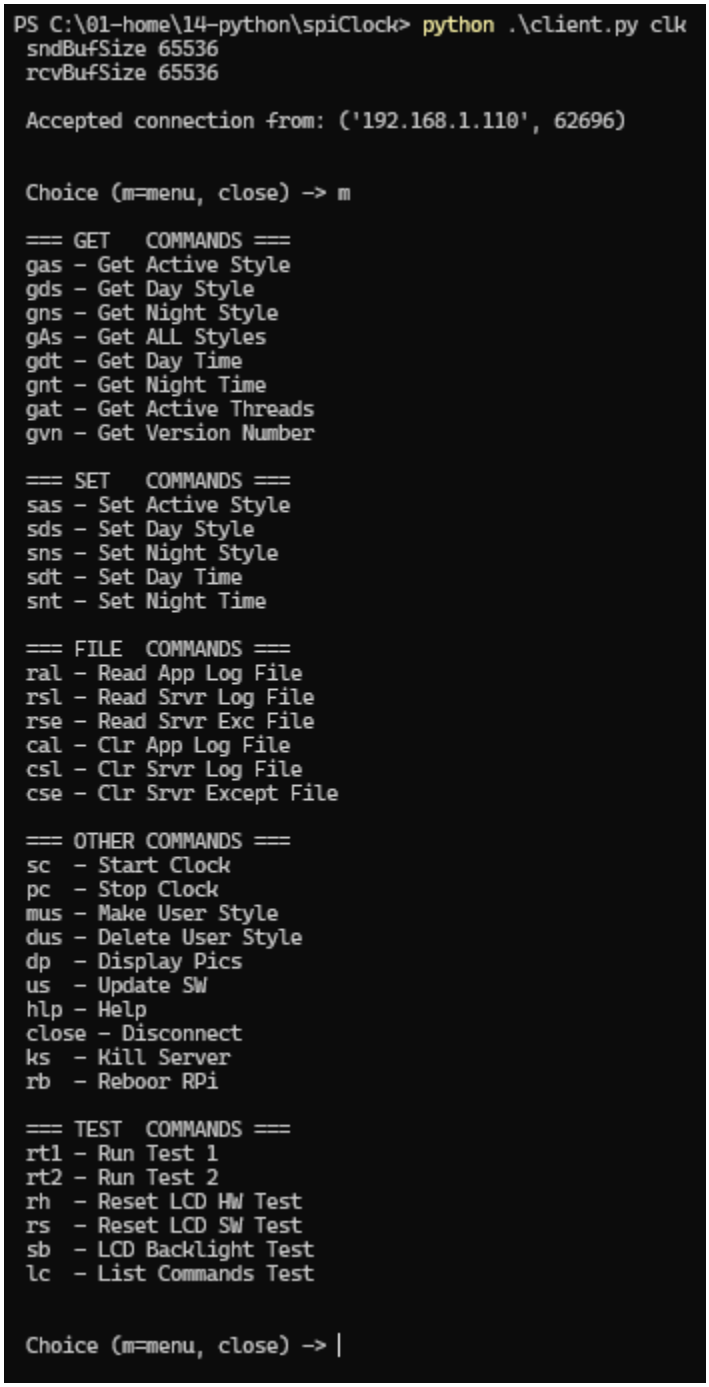
Communication Queues

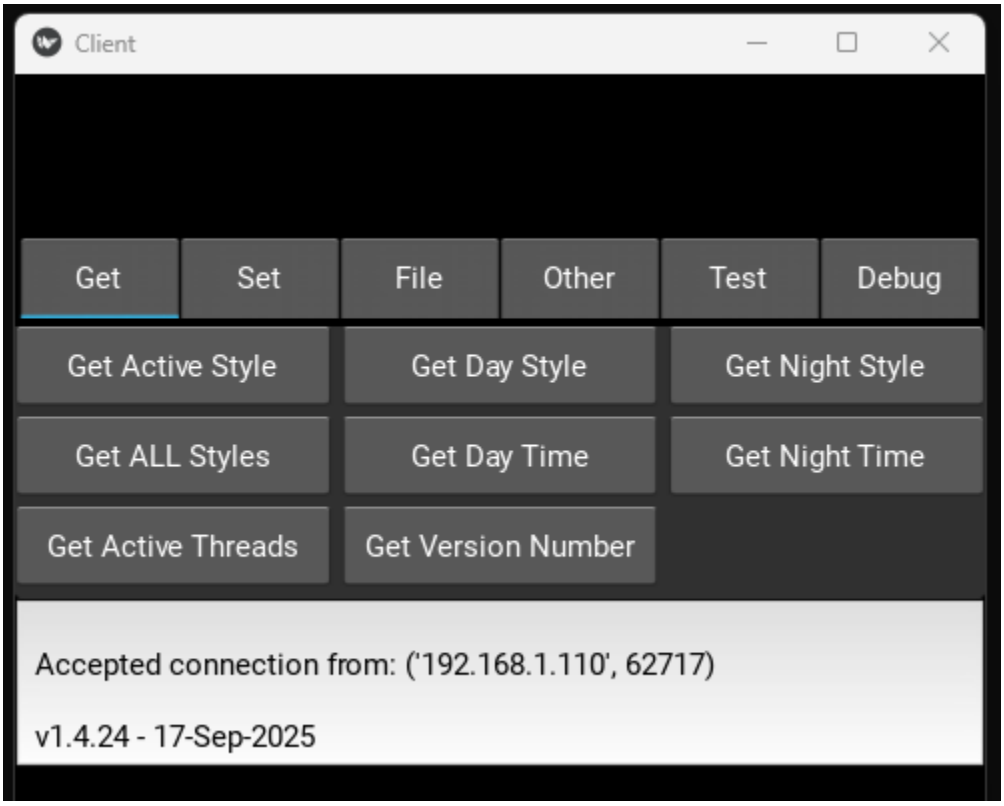
The clock runs on three separate cores, one core runs the server (Main Process), another runs the clock counter (Clock Process) and the third controls the displays (LCD Process). These three processes communicate with each other using four multiprocessing-communication-queues. Two queues are used for sending commands and the other two are used for receiving responses. A simplified communication diagram is presented below.



Running the client

When a client is started and a connection is accepted by the server a prompt is presented. When ‘m’ is entered at the prompt a list of available commands is presented as shown below.




Client
Get
Set
File
Other
Test
Debug
Get Active Style
Get Day Style
Get Night Style
Get ALL Styles
Get Day Time
Get Night Time
Get Active Threads
Get Version Number
Accepted connection from: ('192.168.1.110', 62717)
v1.4.24 - 17-Sep-2025

```
+--spiClock                    --+ ALL CODE RESIDES IN THIS ROOT DIRECTORY.
|    client.py                   | These 4 files are the only ones that need to be on
|    gui.py                      | the machine running the client, command line of gui.
|    cfg.py                      | The last 2 (cfg.*) also need to be on the machine
|    cfg.cfg                     | running the server (RPi). cfg.cfg, read by cfg.py,
|                                | contains IP addresses and passwords that need to be
|                                | shared between the client and the server. Files below
|                                | here only need to be on the RPi.
|                                |
|    server.py                   | Clients send commands via a socket to the server. The
|    cmdVectors.py               | The command is looked up in a table where the worker
|                                | function for that command is found and vectored to.
|                                |
|    startStopClock.py           | Worker functions for the Start Clock & Stop Clock
|      clockProcess.py           | commands reside in startStopClock.py. These worker
|      lcdProcess.py             | functions spawn/terminate two separate processes,
|                                | running concurrently on separate cores, that
|                                | increment the clock counter and push data out to
|                                | the LCDs respectively.
|                                |
|    makeScreen.py               | Screens pushed to the LCD need to be made before the
|    styleMgmtRoutines.py        | clock starts.  Making a screen results in a file.
|                                | When that file is loaded and pushed to an LCD it
|                                | results in, for example, a white "4" character being
|                                | displayed on a black background.  Management routines
|                                | allow for changing styles, choosing a nighttime style,
|                                | setting the times to automatically switch styles, etc.
|                                |
|    spiRoutines.py              | These files contain the worker functions for the
|    swUpdate.py                 | remaining commands and various helper routines.
|    utils.py                    |
|    cmds.py                     |
|    testRoutines.py             |
|    rpiShellCmds.py          --+
|
+----digitScreenStyles         --+ ALL SCREEN STYLES RESIDE IN THIS SUBDIRECTORY
|      blackOnWhite.pickle       | blackOnWhite is the default and cannot be deleted.
|      greyOnBlack.pickle        | All other styles can be deleted. New styles can be
|      orangeOnTurquoise.pickle  | created at will.  Each file contains an image for
|      turquoiseOnOrange.pickle  | all digits 1 through 9.
|      whiteOnBlack.pickle    --+
|
+----fonts                     --+ ALL FONTS RESIDE IN THIS SUBDIRECTORY
|      Font00.ttf             --+ This file contains the font that used for all digits.
|
+----pics                      --+ ALL PICTURES RESIDE IN THIS SUBDIRECTORY
|      240x320b.jpg              | Using the appropriate command the LCDs can be forced
|      240x320c.jpg              | to momentarily display a set of six 240x320 jpg
|      240x320d.jpg              | images.
|      240x320e.jpg              |
+      240x320f.jpg            --+
```

Appendix 1. A Python Implementation of a Client-Server Architecture

INTRODUCTION

This document describes a client-server architecture written in the Python programming language. A client-server architecture is a structure where multiple clients request services from a centralized server and separates user interaction from data processing.

To start the server type "python server.py" on the command line.
To connect a client to the server type "python client.py" on the command line.

A client can be run on the same machine as the server (in a different command window) or on a different machine entirely.

A WELL-KNOWN CLIENT SERVER RELATIONSHIP

Servers are things that respond to requests. Clients are things that make requests.

A web browser is a type of client that can connect to servers that "serve" web pages - like the Google server.

When a web browser (a client) connects to the Google Server and sends it a request (e.g., send me a web page containing a bunch of links related to "I'm searching this") the Google Server will respond to the request by sending back a web page.

Requests are sent in "packets" over connections called "sockets". Included in the request is the IP address of the client making it - that's how the server knows where to send the response back to. A given machine has one IP address, so if more than one instance of a web browser is open on a single machine how is it that the response ends up in the "right" web browser and not the other browser? Port number.

CLOSING A CLIENT AND STOPPING THE SERVER

Every client has a unique (IP, port) tuple. The server tracks every client by (IP, port). The server maintains a list of (IP, port) for all active clients.

Each client has two unique things associated with it - (1) a socket and (2) an instance (a thread) running the client's handling function

When a client issues a "close" command, its (IP, port) is removed from the list and as a result the handleClient’s infinite loop is exited thereby causing its socket to be closed and its thread to terminate.

When a client issues a "ks" (kill server) command, not only does that client terminate but all other clients terminate as well. Furthermore the "ks" command causes the server itself (it's still waiting for other clients to possibly connect) to terminate.

The worker functions associated with all commands are contained within file cmdWorkers.py with the exceptions of the close and ks commands. The work associated with the close and ks commands is performed in file server.py directly.

Upon receipt of the ks command the server (1) sends a message to all clients (including the one sent the command) indicating that the server is shutting down so that the client will exit gracefully, (2) terminates all clients and then finally (3) the server itself exits.

Additional details related to client connection types and to function calling sequences are provided in figures 1 and 2.

SERVER'S HANDLING OF UNEXPECTED EVENTS

If a user clicks the red X in the client window (closes the window) that client unexpectedly (from the server's viewpoint) terminates. This contrasts with the client issuing the close or ks command where the server is explicitly notified of the client's termination. An unexpected termination results in a sort of unattached thread and socket that may continue to exist even when the server exits. This situation is rectified by two try/except blocks in function handleClient. Two are needed because it was empirically determined the Window and Linux systems seem to block (waiting for a command from the associated client) in different places.

SOME ASSEMBLY REQUIRED

In file client.py on approximately lines 60 and 61 the following two lines of code are present:

```
connectDict={'s':'localhost','l':'00.00.00.00','i':'00.00.00.00'}
PORT =
```

Likewise in file server.py on approximately line 164 the following line of code is present:

```
port =
```

For all connection types (refer to Figure 1) a port number needs to be specified. The number used must be the same in both the client and the server files. Use a number greater than1024 – between 5,000 and 50,000 is safe.

For connection type 2, in addition to the port number, the IP of the server needs to be entered (value for key `'l'`) needs to be entered. The address can be found via the ipconfig command in a command window open on the machine that will be running the server.

For connection type 3, in addition to the port number, the external IP of the router needs to be entered (value for the key `'i'`) needs to be entered. The router's external IP address can be found using by going to the following web page on a browser.

https://whatismyipaddress.com/

The use of connection type 3 also requires port forwarding to be set up on the router. An example is shown below. The example shows forwarding port 1234 (substitute 1234 with whatever port number you entered client.py and server.py) to port 1234 for IP address 192.168.1.10. Substitute 192.168.1.10 with whatever the IP address of the machine running the server is. Again, this address can be obtained via use of the ipconfig command. Since only one port number needs to be forwarded the start and end port numbers are the same.

It seems weird that a port number needs to be forwarded to that same number, but it does.

Service Name	External Start Port	External End Port	Internal Start Port	Internal End Port	Internal IP address
My Service Name	1234	1234	1234	1234	192.168.1.10

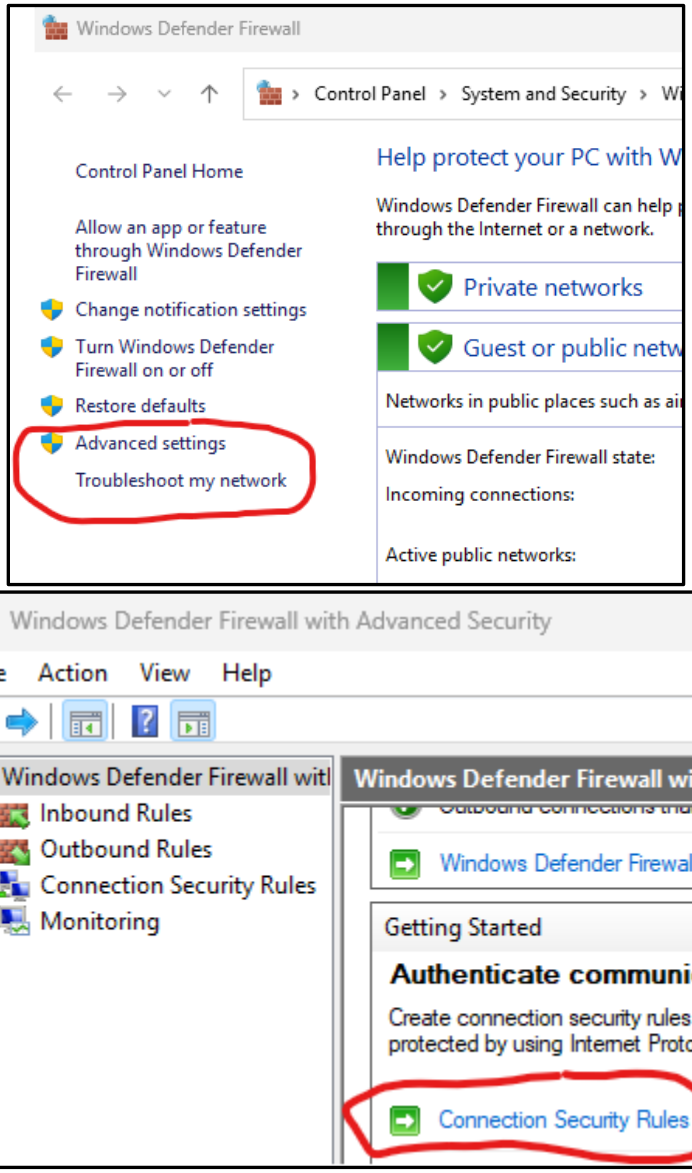
A POTENTIAL PITFALL – FIREWALL

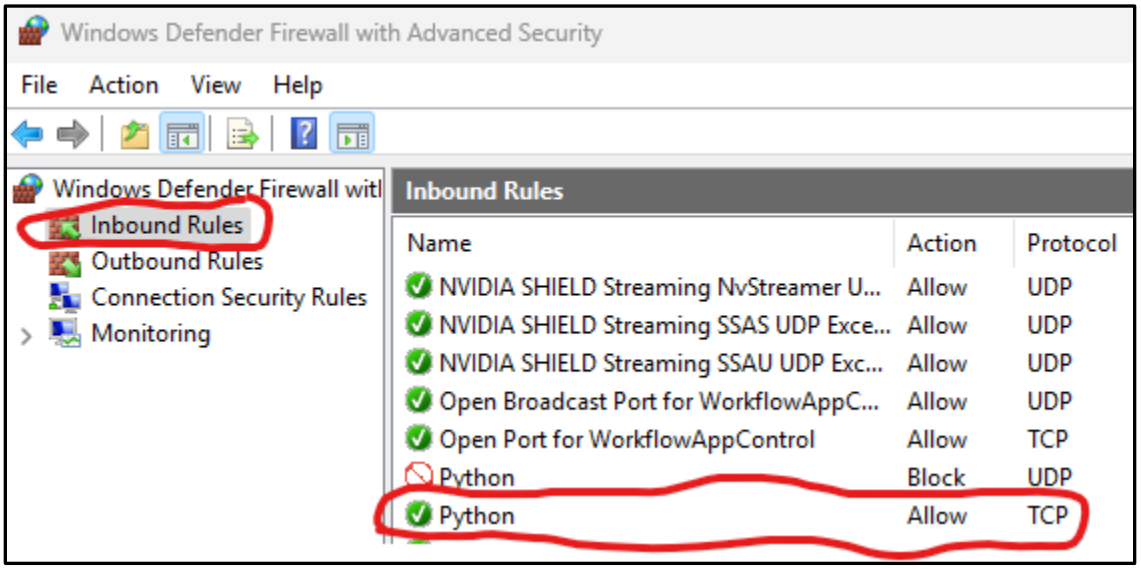
The above was all initially done with the server running on a Raspberry Pi. The Raspberry Pi runs Linux and by default its firewall is disabled. As such, all connection types worked only by performing the "SOME ASSEMBLY REQUIRED" steps outlined above.

On windows to get all connection types working, specifically connection type 3, the Windows firewall will need to be changed to allow incoming python TCP connections.

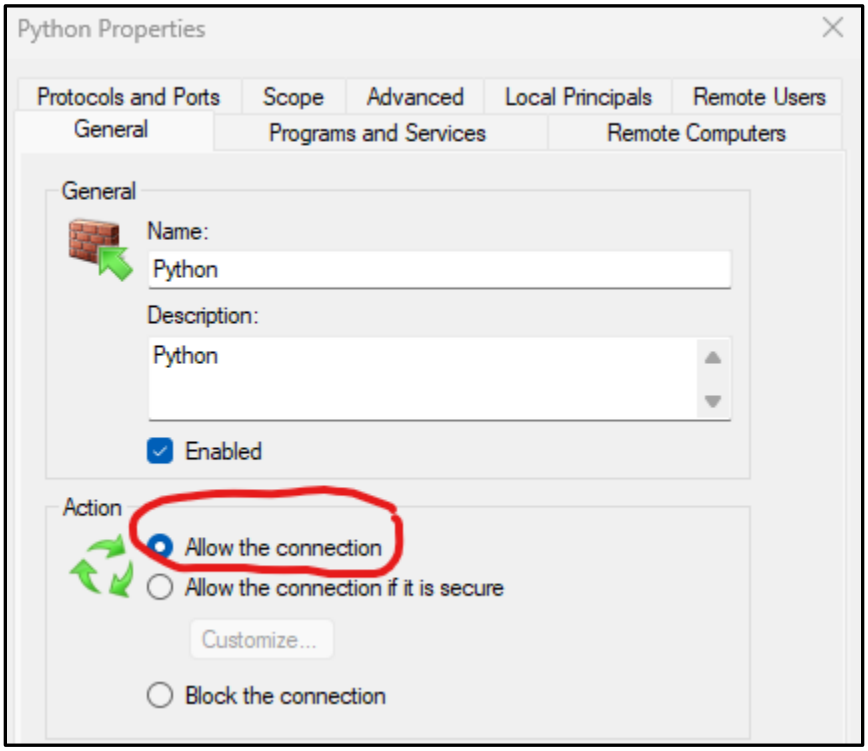
These are the basic steps:

Control Panel\System and Security\Windows Defender Firewall ---> Advanced settings ---> Connection Security Rules ---> Inbound Rules



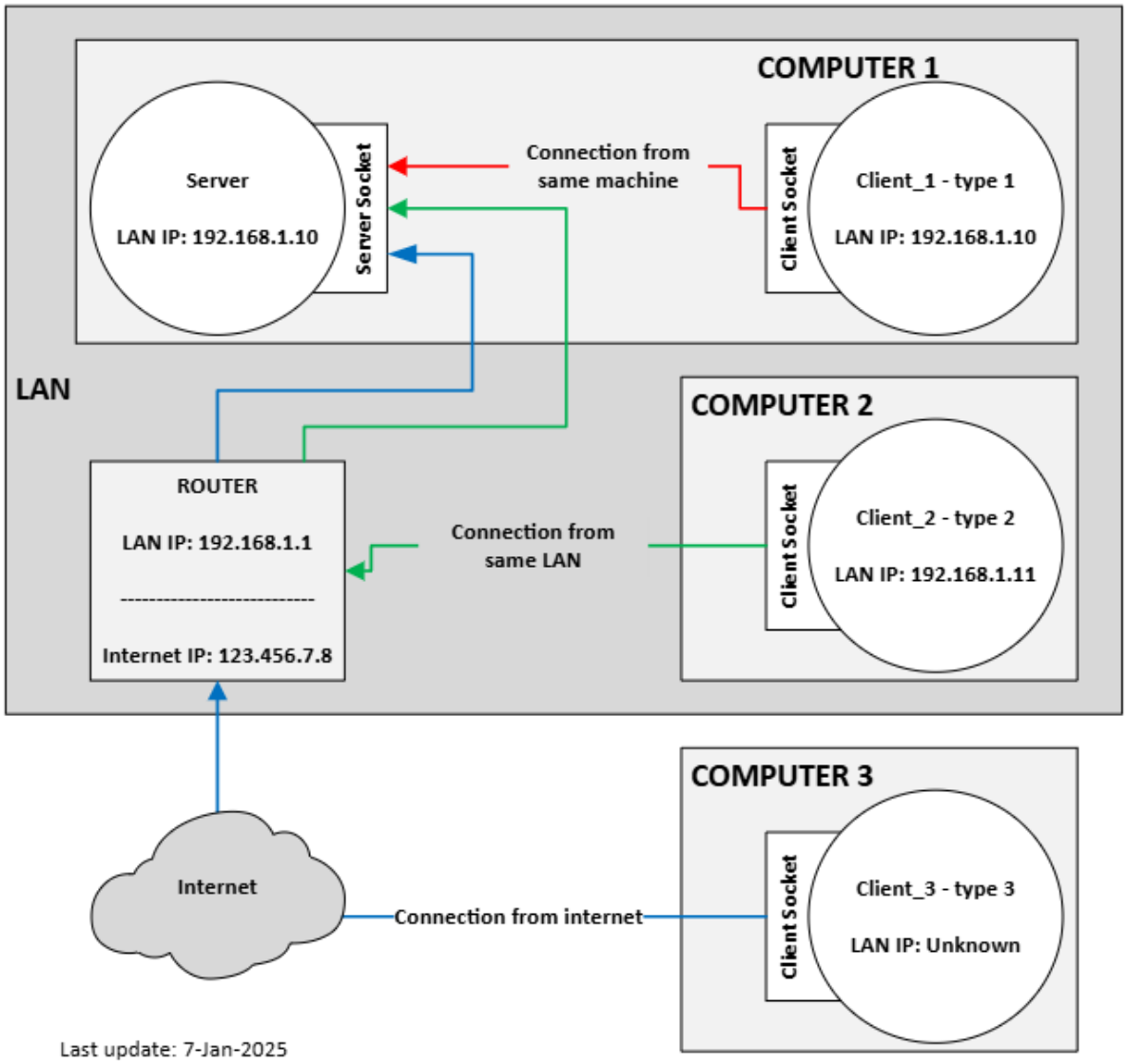


Right click on the Incoming Rule for Python TCP Protocol, select the General Tab and change to Allow the connection.



EXPLANATORY FIGURES

Figures 1 and 2 illustrate the various connection types and the functional call tree, respectably. This client-server architecture was used in the design of a Raspberry Pi sprinkler controller and a functional block diagram and a wiring diagram for that are provided in figures 3 and 4.



Last update: 7-Jan-2025

Computers 1 & 2 & the router are all on the same Local Area Network (LAN). Computer 3 in not on the same LAN but is connected to the **Internet** (an **Inter**connected set of Local Area **net**works).

When a client is started it prompts for the desired connection type and offers 3 choices: 's', 'l', 'i'.
s = same machine = type 1. l = same lan = type 2. i = internet = type 3.

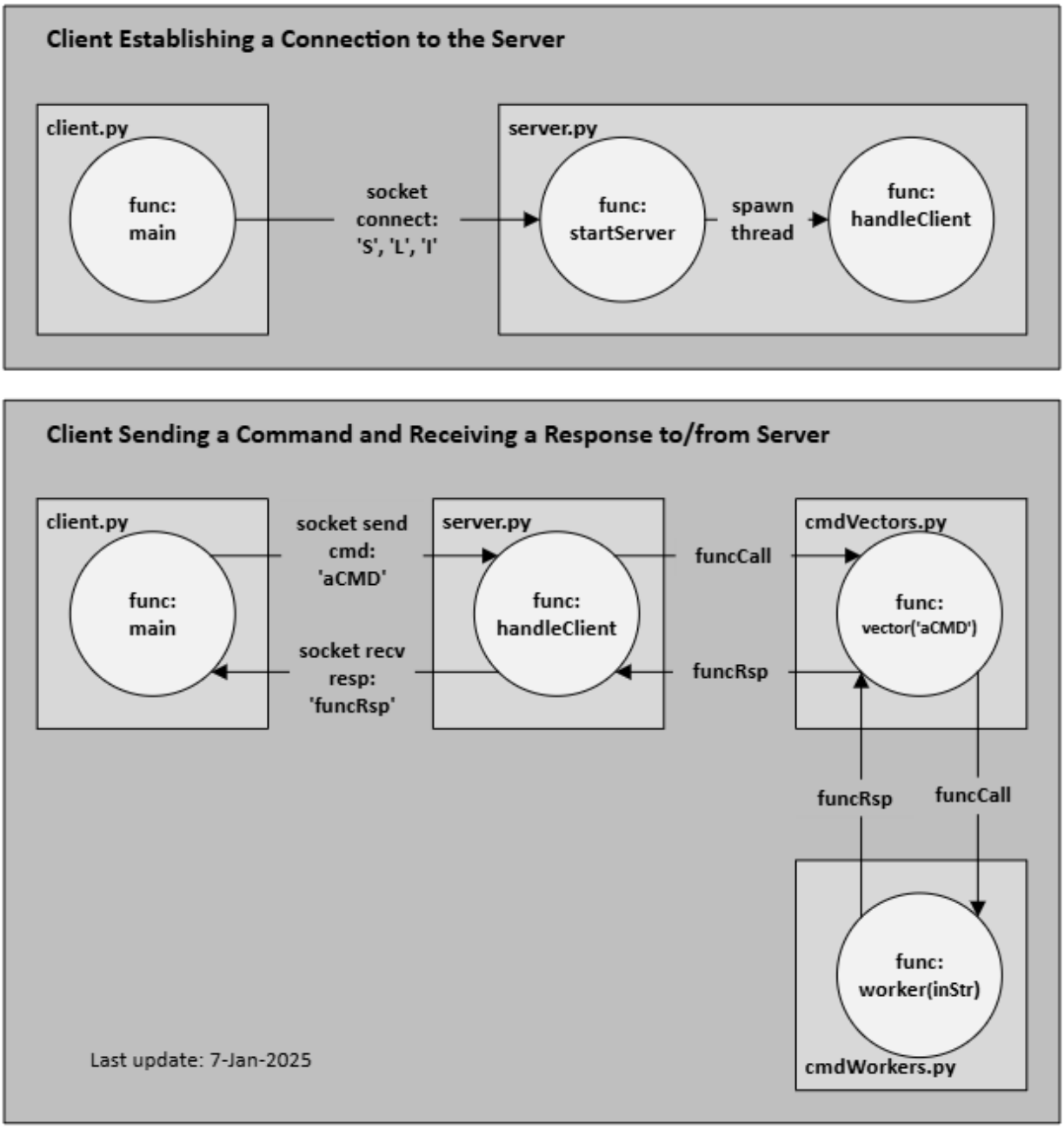
Computer 1 is running both the server and the client so the obvious connection type is type 1, as shown. However, computer 1 could also connect over the LAN or over the internet (neither shown).

Computer 2 is running only the client but is on the same LAN as the computer running the server so the obvious connection type is type 2, as shown. However, computer 2 could also connect over internet (not shown). Computer 2 can not connect to the server via a type 1 connection.

Computer 3 can only connect to the server via a type 3 connection.

The server can handle multiple connections of type 1,2 and 3 simultaneously.

Figure 1. Connection Types



A client's connection request gets transmitted to the server over a socket where it is recieved by function startServer. When the server accepts the connection it spawns a thread that runs function handleClient that is then dedicated to servicing commands recieved from that client.

A client's command (a text string) is recieved by function handleClient who in turn forwards it to function vector. Function vector looks up the worker function associated with the command and subsequently calls it. The worker function performs the associated processing and return the response (also a text string). The response is passes back up the call tree where it is eventually recieved by the client.

Figure 2. Function Call Tree

```
pi@rasp3:~ $ free --mega   # After Boot

              total        used        free      shared  buff/cache   available
Mem:            950         359         152          24         520         591
Swap:           536           0         536

pi@rasp3:~ $ free --mega   # After Starting Server

              total        used        free      shared  buff/cache   available
Mem:            950         389         100          24         542         560
Swap:           536           0         536

pi@rasp3:~ $ free --mega   # After Connecting Client

              total        used        free      shared  buff/cache   available
Mem:            950         387         102          24         542         562
Swap:           536           0         536

pi@rasp3:~ $ free --mega   # After Starting Clock

              total        used        free      shared  buff/cache   available
Mem:            950         410          76          24         545         539
Swap:           536           0         536

pi@rasp3:~ $
```