

# W.A.R.S. Workshop Notes

April 2023

## Digital Signal Processing – Part 1 (Capturing Input Signal)

Version 1.4

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### 1.0 Introduction

The objective of this workshop is to create and configure a device to capture an incoming analog signal, convert it to digital form, display the digital data as an oscilloscope type display and store the data for later processing. We will examine the effect of different sample rates, different input waveforms and different frequencies of the incoming signal.

The bulk of the hardware including IoT (Raspberry pi) boards and sound cards will be supplied by the Waverley club but it will be necessary for participants to prepare their own equipment in advance. We will ask participants to make a contribution of \$15 to cover the cost of the parts supplied for the workshop. If you wish to use one of the club's available MicroSD 16GB cards you should add \$5 to the contribution.

## 2.0 Before you come to the Workshop

### 2.1 Your smartphone Hotspot

These hardware boards have no direct connection to screen, keyboard etc. They will require you to connect to your own laptop using WiFi. This connection can pose some challenges. The best solution is to use your own smartphone as a WiFi Access Point (hotspot). Most phones can do that these days so get yours set up. Note the Access Point SSID and password for later use. If you do not have such an access point available we will indicate some workarounds.

### 2.2 MicroSD Card

Acquire a MicroSD flash card of 16 GB or larger capacity. The contents of this card will be erased so make sure it is not valuable. If you wish the club to supply the SD card contact Raffy, VK2RF (raffy@raffy.net). Plug the SD card into your laptop. If your laptop does not have an SD card socket you can get a USB based SD card reader/writer from your friendly computer dealer. You may borrow one from a fellow club member.

Now you need to install the "imager" software on your computer. It is available from <https://www.raspberrypi.com/software/> in forms which can run on Linux, Windows, MacOS and even a Raspberry pi itself. Get the latest version of the imager (which as of March 2023 is v1.7.4) and install it by running the downloaded .exe file.

Now start up the imager. Click on "Select the OS"; choose the first option (Raspberry pi OS (32 bit)). Exit the OS Selector. Click on "Storage". You should see a list of available writing devices including your SD card writer. Select your SD card and exit. Now click on the cunningly unlabelled cogwheel icon that has appeared in the bottom right of the imager window. A "Configuration" window will open. Set the "hostname" to something unique – like your name or callsign etc. Select "Enable SSH" and "Use password authentication". Enter a username and password (and write them down somewhere!). Click on "Configure Wireless LAN". Enter the SSID and PSK (password) for your smartphone hotspot. If you do not have a smartphone hotspot available then enter the SSID: vk2w and the password: vk2bv-147025  
This will make life a bit more difficult later but it will work and we will fix it later.

Then click "SAVE" and in the main imager window click on "Write". The OS image will be downloaded (if it hasn't already been cached on your laptop), written to the SD card and verified. This could take half an hour or so.

When the imager has finished, eject the SD card, label it with with your callsign or id using a “Sharpie” with an ultra fine point, put it in a safe place and bring it to the workshop.

## 2.3 Install Extra Software on your Laptop

### 2.3.1 WiFi monitoring

Go to

[https://www.nirsoft.net/utils/wireless\\_network\\_watcher.html](https://www.nirsoft.net/utils/wireless_network_watcher.html)

Do not click on any buttons labelled “Install” or “Download” you will just get advertising spam. Instead scroll way down to the bottom of the page and click on the text link:

“Download wireless network watcher with full install/uninstall support”

Then execute the downloaded file: `wnetwatcher_setup.exe`

Linux users will probably be aware that they can use `nmap` to do network watching.

### 2.3.2 VNC client/viewer

Go to

<https://www.realvnc.com/en/connect/download/viewer/>

Make sure your correct OS is selected (it will probably be by default) and click on “Download VNC Viewer”. Do not “Create an Account” or purchase a license or a free trial of a server. Just wait and the Viewer installer will download. It is called VNC-Viewer-7.0.1-Windows.exe (if you are using Windows). Double click the .exe file, accept all the defaults, license conditions etc and wait for the install. When you first start the VNC viewer it will offer options about signing in to the Cloud etc. Ignore this and click on “Use VNC viewer without signing in”. It will ask you for an IP address to connect to. That comes later; – just close up, the install is complete.

### 2.3.3 SSH Terminal

You will need an SSH connection to a command line shell. If you are using Linux this comes as standard. If you are using Windows you can use “Putty” if you are already using it or install a “Terminal”. Go to

<https://mobaxterm.mobatek.net/download.html>

Focus on the “Free” version and click on “Download Now”. Select “Home Edition (Installer edition)”. When this .zip file is downloaded extract the files from the .zip package, change to the extracted folder and double click the .msi file. Accept the defaults.

## 2.4 Power Connections

W.A.R.S. is supplying a number of IoT boards which emulate the Raspberry Pi Model 3B. These need 5V power to operate. The club will supply a power cable with “Dupont” connectors on the end. These Dupont connectors do not tolerate much movement so you cannot “jiggle” the board while in use.

If you want to build your own cable with a more stable standard header connector on the end you can do that before the workshop. Put a USB-A connector on one end of a cable and a standard (0.1 inch spacing) female header connector on the other end (either single or double row header). The +5 goes to pin 4 and the ground to pin 6. No other connections are required so a very small header connector can be used. The USB-A connectors are commonly available (such as Adafruit Part 1387 – from Core Electronics for example). The board connection is shown at Fig. 1.

## **2.5 What to bring to the workshop**

Now you are ready to go to the workshop. Bring the laptop, phone and the prepared MicroSD card. You will also need headphones with a 3.5mm stereo plug. A soldering iron will be helpful. If you have assembled the TwinTee oscillator from the March workshop bring that along too.

## **3.0 At the Workshop**

### **3.1 Startup**

Create an input cable with a 3.5 mm plug on one end and sufficient length to reach to the demonstration audio signal cable set up by the club. Plug the input cable into the “Mic” input socket of the sound card and your headphones into the phone socket then plug the supplied sound card into a USB port of the IoT board.

Put your SD card in the supplied IoT board, turn on your smartphone WiFi hotspot and plug in the 5V power cable WITH CORRECT POLARITY. We haven’t tested these boards for tolerance to reversed power.

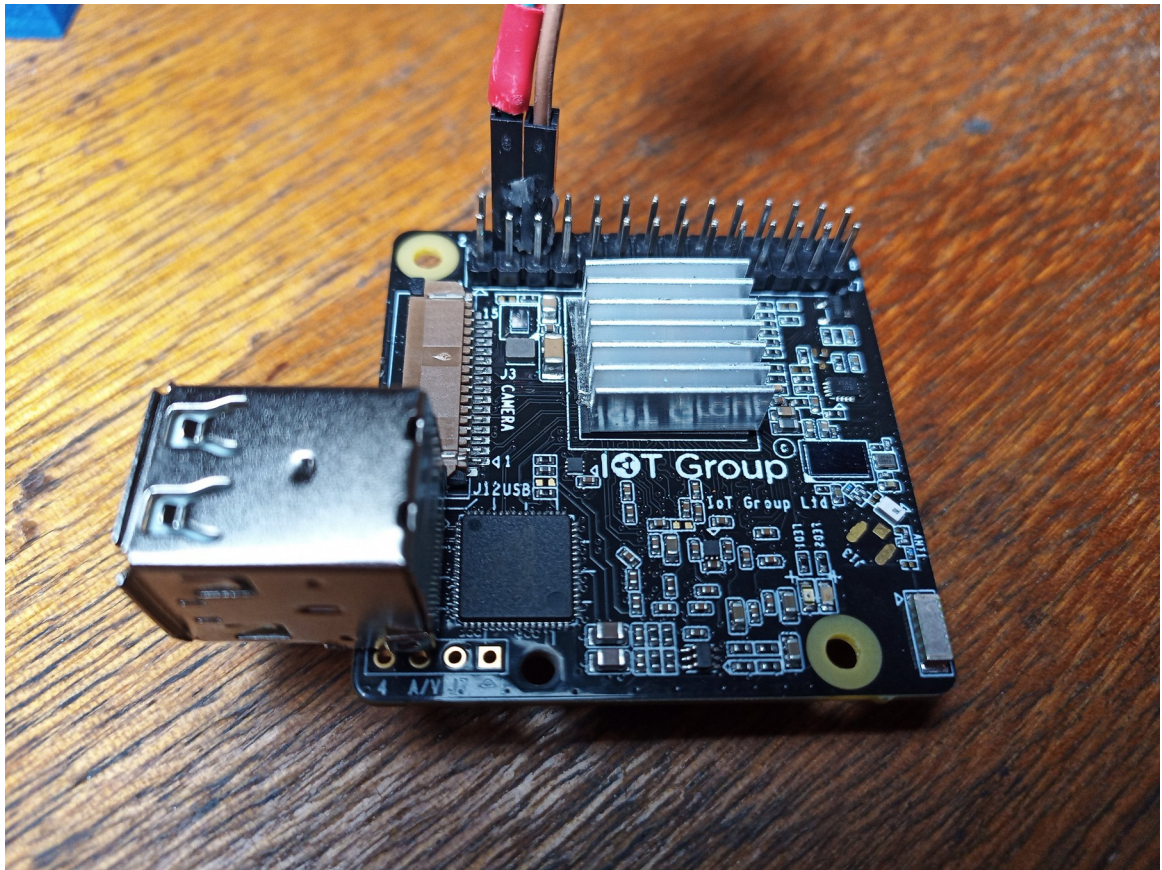


Fig. 1 Power connection to IoT board

### 3.2 Connect your laptop to the IoT board

Now start up your laptop wireless network watcher from NirSoft (“watcher”). The laptop has to be logged into the WiFi that the board is expected to use. If you are using your own hotspot connect the laptop to it, if not connect the laptop to the vk2w router using the password you were given in Section 2.2 when you setup the SD card. Watch the wireless network for your IoT board to connect. The MAC address of the board is on a label on the board so you can distinguish it from everybody else's board. There will be some dedicated “watchers” at the workshop so you can check the connections to the vk2w and the Club Rose Bay WiFi networks.

Once you see your board connected to a network you can connect to it using SSH, Putty, MobaXterm or your preferred SSH terminal device. You will be asked for your username and password (you did write it down back at the beginning didn't you). If you can't find the password that can be fixed with a lot of fiddling (see the workshop convenors).

Assuming you have logged on to the board you can type “ls” and list out the home files to confirm you are connected. You need to make some changes to the “plain vanilla” version. If you are not used to editing files and navigating Linux see Appendix B.

### 3.3 Configure the IoT software for the workshop

Edit the file: `/boot/config.txt` Add the line (after the `#dtoverlays`)  
`avoid_warnings=1`  
Save the file.

If you are not using your phone WiFi hotspot you will have to jump back and forth between two different WiFi networks and this will require extra work now (see Appendix A). If you use your phone you can continue without this fiddling.

Make sure you are connected to an “internet available” WiFi network and then in the terminal shell window do this:

```
sudo apt update
sudo apt upgrade
sudo apt remove pulseaudio lxplug-ptbatt
sudo apt install xoscope
```

Now there is no further requirement for the internet connection so you can switch back to a different WiFi if you need to.

In a terminal window type:  
`cat /proc/asound/cards`

You should get a listing of the available sound cards on the board. One of them should mention GeneralPlus USB Audio Device. Note the device number. This is the device we will be using.

Edit the file `/etc/asound.conf`  
Add the lines (assuming the device number noted above is 1):

```
defaults.pcm.card 1
defaults.ctl.card 1
```

Save the file

In a terminal window type:  
`sudo raspi-config`

In the `raspi-config` window select Display Options

```
| VNC Resolution
| 1280 x 720
| Select
|OK
```

```
select Interface Options | VNC | Enable Yes | OK
```

```
Then Finish | Reboot Yes
```

Make sure your laptop is on the same WiFi as the rebooted IoT board and check the Network Watcher to confirm its IP address.

Start up the VNC Viewer on your laptop

It will ask for the IP address of the IoT board, then the login name and password.

When the GUI interface opens you can click on the black “Terminal” icon (with the `>_` symbol) on the top taskbar and get a shell window. Type `ls` to check it is working.

Click on the Raspberry icon in the top left corner and in the window that opens move down to “Preferences” | Appearance Settings (it is slow)

Then select “Defaults” | For small screens – Set defaults

Then OK.

### 3.4 Configure for Sound Play/Record

Now in a terminal window – presumably in your home directory:

```
amixer sset Speaker 100% unmute
```

```
amixer sset Mic 50% unmute cap
```

```
cp /usr/share/sounds/alsa/Noise.wav .
```

 (Notice the dot on the end of the command)

```
aplay ./Noise.wav
```

You should hear the rushing noise sound in your headphones.

We will apply a test sine wave to the demonstration signal line (approx 1 kHz and 200 mv P-P).

You should hear that in the headphones.

### 3.5 Capturing an input signal

Now we can change to a square wave.

To record the input signal for processing type:

```
arecord -t raw /tmp/snd1
```

after a second or so hit Ctrl-C to stop the recording.

To play back the file you have just recorded

```
aplay /tmp/snd1
```

Now have a look at the data file you have captured.

```
od -t d1 /tmp/snd1 | more
```

(Will show you a bunch of numbers representing the digital conversion of the incoming sound you have recorded.)

We will be processing this sort of data in a later session to demonstrate spectrum analysis, filtering etc. In the meantime let's look at the waveform display of the converted data when we switch back to a sine wave.

## 3.6 Viewing with the xoscope (oscilloscope)

Open a terminal window and enter  
alsamixer

This will give you some sliders to change volume settings. Hit F5 to get all the sliders available.

In another terminal window type:  
xoscope

Select File | Device ALSA

You should see your applied input signal displayed. Fiddle with the volume slider settings to see the trace

Scope |Plot Mode | Step  
Trigger |Rising

Scope Change the "Time Base" to get a few cycles of input signal displayed.

Notice that the signal is not smooth but like a staircase. The smoothing that you often see is a trick of the computer processing.

Change the Scope | Sample Rate.

You may have to turn off the Triggering for a while.

Notice that as the sampling rate falls the actual signal sampling is a very coarse approximation of the actual sine input. Keep dropping the sample rate as low as it will go ( 8 K samples per second)

## 3.7 Input Frequency Limits

Now we can raise the frequency of the input waveform. Watch the effect on the sampled waveform displayed on the screen. At some frequency the displayed waveform will completely disappear. What frequency is that? This is the Nyquist frequency. You have just seen a practical demonstration of the Nyquist-Shannon sampling theorem which is the fundamental theorem of digital sampling. Now put the sampling rate back up to 44 K.

### 3.8 Input Bit Depth

At the top of the screen you will see the incoming "volume levels" showing max, min and peak to peak. As you turn up the incoming signal amplitude you will see "clipping" at the point where the hardware can no longer cope with the excursions of the signal. Now the peak-peak value will be 255. This is the maximum number that can be represented by an 8 bit digital value. This sound system is doing a 8 bit input conversion.



## Appendix A ---- Using multiple WiFi networks

If you don't have a smartphone WiFi hotspot you will have to do some juggling of your connections. There are at least two WiFi networks available for the workshop; the Club Rose Bay WiFi and a Waverley router WiFi. The Club Rose Bay network is a standard sort of connection to the internet but it is very overloaded, slow and unreliable. The Waverley router seems to be able to handle the necessary traffic but it is not connected to the internet. You will need different features at different times. Here is how to cope.

Your first connection as described in the OS installer setup instructions will be to the Waverley WiFi. Both your laptop and the IoT board will have to connect to the Waverley setup so connect to the vk2w WiFi, enter the vk2w details as shown in Section 2.2 into your laptop and make sure it connects OK when requested. Check the wireless network watcher to see your IoT board when it boots. Check the MAC address on the board label with the displayed MAC on the watcher. Then connect the laptop session using Mobaxterm or putty etc. to get the setup underway.

You will need to enter some details about the Club Rose Bay system to the IoT board. If you are new to Unix you may need to refer to Appendix B. Using the terminal session on your laptop connection edit the file `/etc/wpa_supplicant/wpa_supplicant.conf` so it looks like this:

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1

network={
    ssid="vk2w"
    scan_ssid=1
    psk="vk2bv-147025"
    priority= 94
}

network={
    ssid="CRB"
    scan_ssid=1
    psk="We will tell you this psk at the time of the workshop"
    priority=92
}
```

```
network={
    ssid="Your home WiFi if you want to use it"
    scan_ssid=1
    psk="Your home password"
    priority=80
}
```

Now after a reboot you will have at least two networks available. The IoT board will normally boot up and connect to the vk2w network to allow you to get underway. When you want to change networks it is a bit of a fiddle.

1. Click on the Wireless icon on the top taskbar. You will see a list of available WiFi networks. Make sure the net you want to change to is showing and that you know the correct password for that net.
2. Open a Terminal window and type in  
`sudo sh -c 'sleep 60; dhclient wlan0'`

After you hit Enter you will have 60 seconds to change the network. Click on the wireless icon, change to the desired network, untick the "hide characters", enter the password and click on OK. As soon as you hit OK you will lose contact with the IoT board because it is changing over to the other network which will take a minute or so. You will have to check the relevant network watcher to see the board come up on the new network. Meanwhile you have to switch your laptop over to the new network as well. Once the IoT board is showing on the new network you can connect your VNC session or SSH session to the new IP address and carry on.

## Appendix B – Unix Primer

For those new to Unix and not used to a command line interface here are a few simple commands to get you started.

- 1) `ls` (This will list out all the files in the current working directory (folder))
- 2) `ls -l` (This will give a file list with more detail)
  
- 3) `cd` (This will change the current working directory to your home directory)
- 4) `pwd` (This will print the current directory name on the screen)
- 5) `cd betty` (Change the current working directory to betty – a child of the current directory)
- 6) `cd /usr/local/betty` (Change the current directory to betty – a child of directory `/usr/local/`)
- 7) `cd ../` (Change to the directory which is the parent of the current directory)
  
- 8) `cat xyz` (This will put on the screen the contents of file xyz (in the current directory) – even if it is gibberish)
- 9) `mv xyz abc` (This will rename (move) the file xyz to the new name abc)
- 10) `cp jack jill` (This will copy the file jack to a file called jill – in the current directory)
  
- 11) `nano mary` (This will start up the simple text editor called nano to edit the file mary)

### Using Nano

If you named an input file when you started nano it will show on the screen. If not the screen will be blank. You can just type on the screen as you wish using arrow keys, backspace and delete key to create the text you want.

Some simple commands are shown at the bottom of the screen. For example the phrase `^X` means “hold down the Control Key and press the X key.

When you are satisfied with your changes do `^O` (This is a letter O not the number 0). This will save your changes. You will be asked what to call the saved file. If you don't enter a new filename it will be saved as the same name it started with (overwrite the input file). If you enter a new filename you will wind up with two files (the old one unchanged --- and the new one with the changes). If you get all mixed up you can just exit without saving any of the changes.

When you are finished the editing hit `^X` to exit.

