Constructing an Infrasound Monitor

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Abstract

Here are instructions for constructing a research quality high resolution infrasound monitoring station capable of detecting atmospheric infrasound down to 0.01Hz. Data and plots are automatically uploaded via the web and the system may be left running for months or years unattended. It employs a modern digital, I^2C enabled differential pressure sensor - unlike the older analog devices commonly used. Python software automatically uploads plots whilst data is stored in standard *.mseed* format for further analysis. Very open-ended with lots of opportunities to recode and test replacement components. This is real science, in a little studied area. The station is relatively cheap to build and offers many opportunities for students to build and refine a sensing system of research quality.

1 Introduction

To view plots and other information see
www.starfishprime.co.uk/projects/infrasound/infrasound.html

Opensource Code may be downloaded from
https://www.starfishprime.co.uk/downloads/downloads.html

2 Materials

For a full system you will need.

- DLVRF50D1NDCNI3F Amphenol All Sensors differential pressure sensor
- A Raspberry PI.
- A 5V Raspberry Pi psu.

- Hammond Case1551RFLGY
- Hammond Case1590B3OR or similar
- 30G hypodermic needle 0.3x13mm
- 50cm of 2mm breather tube
- 2mm barbed brass connector
- 3mm barbed brass connector
- Approx 3m of 3mm plastic tubing
- Foam pond filter block or 10-20m of porous hose (optional wind filter)

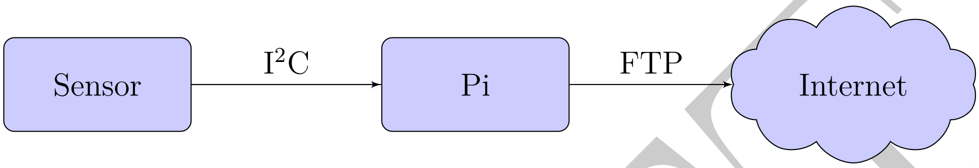


Figure 1: System Overview

3 Stabilised Power Supply

A simple double-regulated power supply constructed on veroboard may be used to provide a stable voltage to the Raspberry Pi. The sensor itself may be powered from the 3.3V output on the Pi. Over the past two years however I have found that powering the Pi from a standard mains adapter works fine. The sensor is powered directly from the Pi.

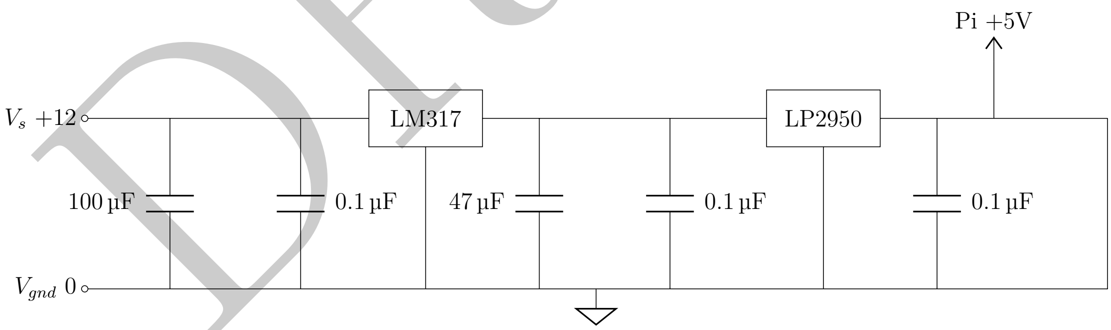


Figure 2: Stabilised Power Supply

4 The Sensor Unit

The sensor unit is housed separately from the Pi whilst not essential this eases maintenance. An aluminium enclosure such as the Hammond 1590B3 gives sufficient room to curve tubing. With some thought a much smaller enclosure could be used.

A hole approx 7mm in diameter is drilled in one side for the power and data cables to the Pi and other 3mm hole to take a double headed 3mm diameter brass barbed connector. This connects externally to a 3mm tube running to the windfilter and internally to a 2mm tube leading to the mems sensor. Inside this case sits the mems sensor and the backing volume. For mechanical convenience the sensor is mounted on a small piece of stripboard.

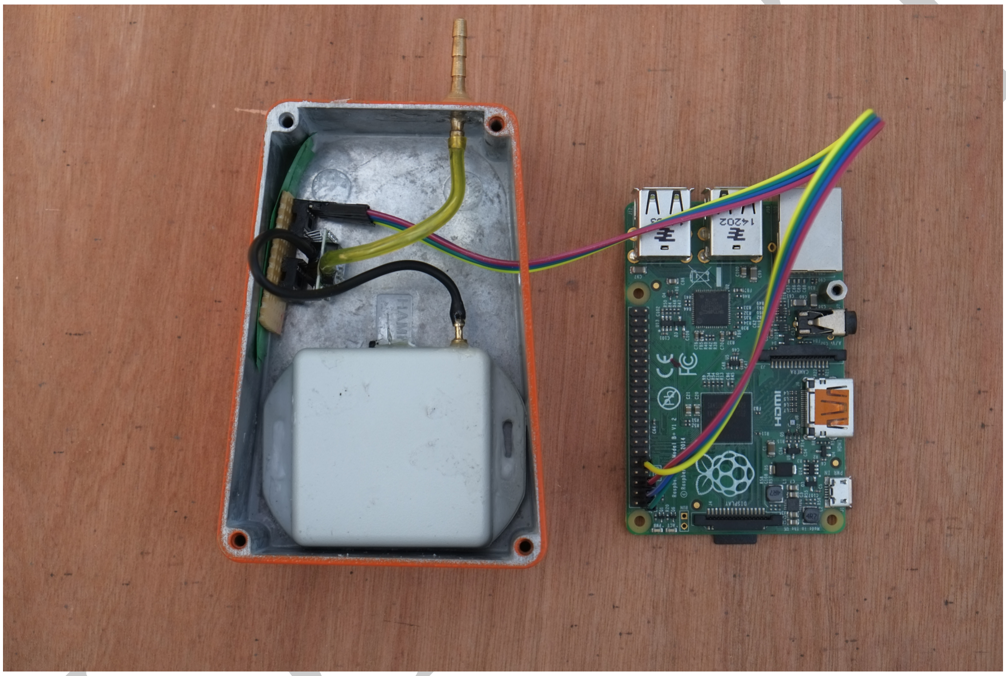


Figure 3: Complete rig no 3

4.1 Wiring the pressure sensor

Pretty simple. After some experimentation we found the DIL packaged sensor the easiest to work with.
Two DIL-8 sockets were soldered onto veroboard. The copper tracks underneath between the two sockets are cut to isolation pins 1-4 from 5-8. This provide

mechanical rigidity and allows for easy connection of the leads from the PI which attached to the unused DIL connects (see fig 5).

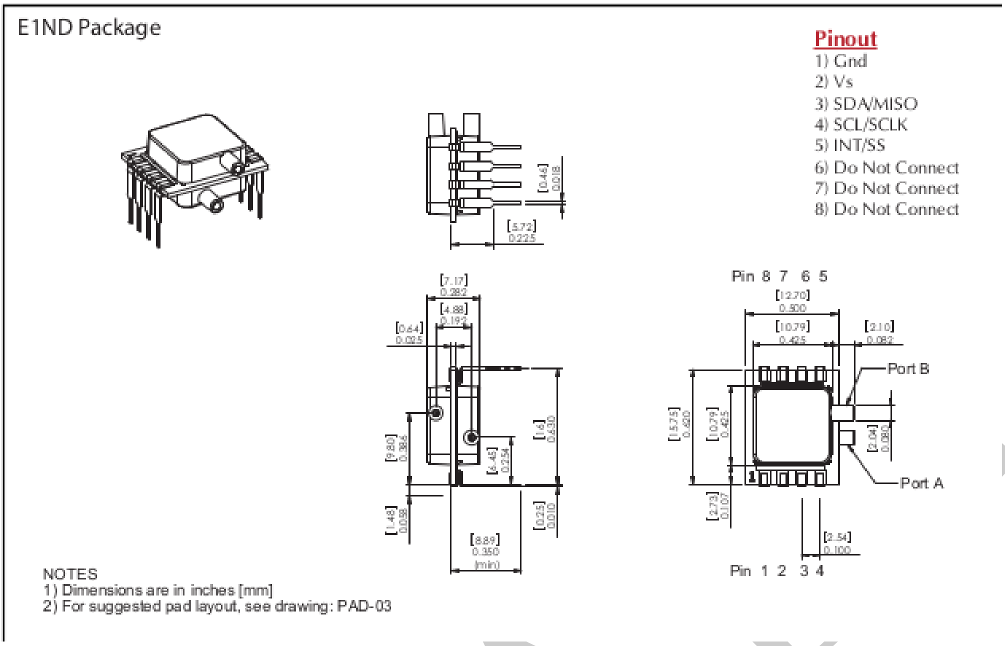
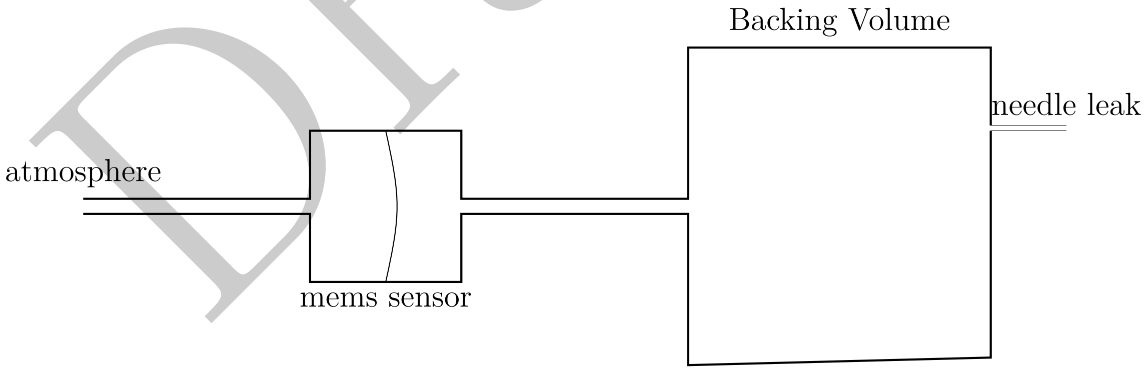


Figure 4: Pinout - only pins 1-4 required

Four leads then run out to the Pi GPIO header. Sensor Pin 1 to Pi Gnd, P2 to Pi 3.3V, P3 to Pi SDA, pin 4 to Pi SDL. Thats it!

4.2 The Backing Volume



A differential pressure transducer measures difference in pressure between its two ports, one connected to the atmosphere, the other to a sealed container generally known as the backing volume. This backing volume needs a slight, calibrated leak acting to protect the sensor and as a pneumatic filter. Too great a pressure

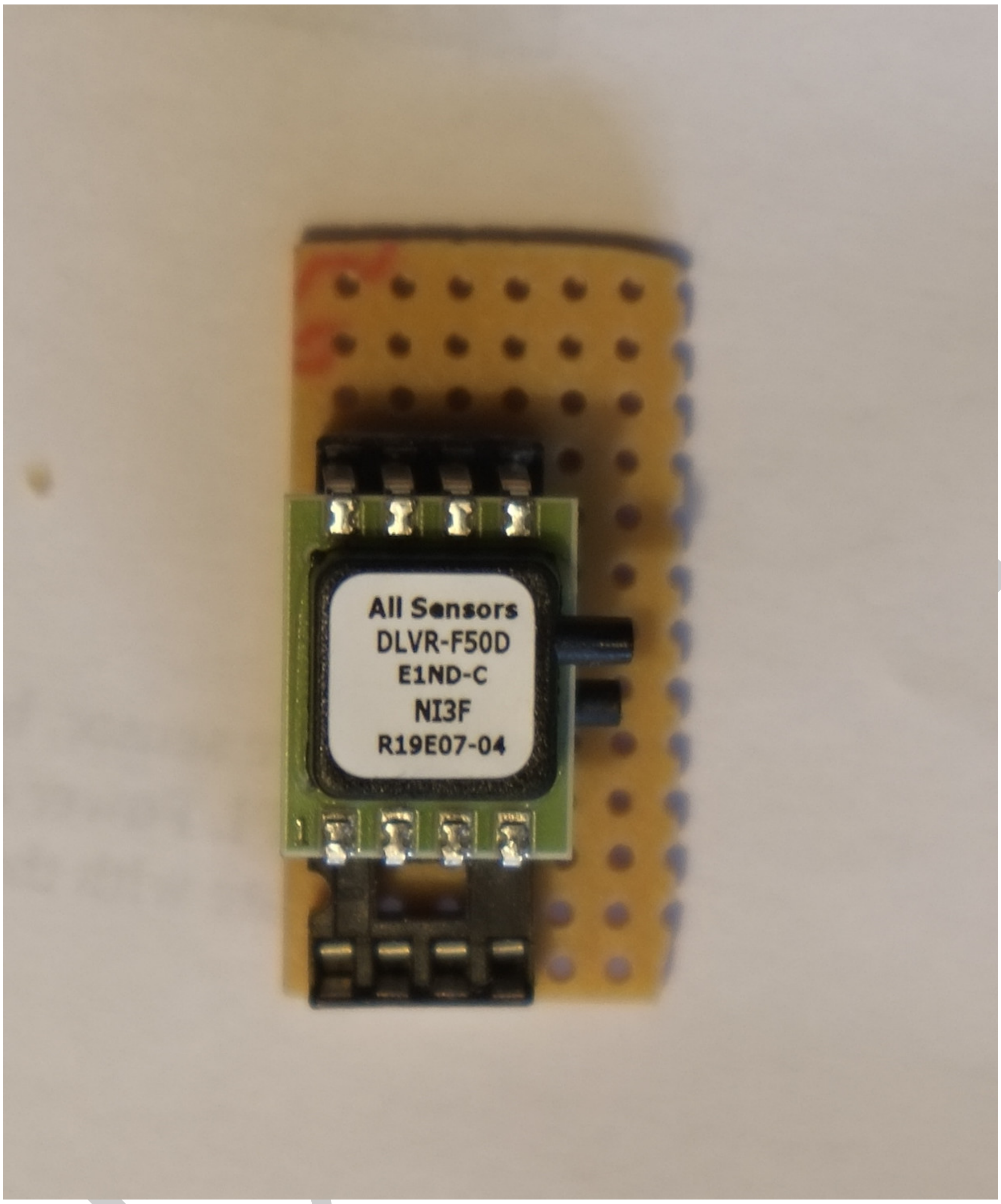


Figure 5: Sensor mounted into stripboard

difference due to weather changes may damage the sensor. As the ambient air pressure gradually changes pressure within the backing volume equalises with this via the leak - effectively zeroing the sensor. The leak thus acts as a pneumatic filter, removing very low frequency signals, less than 0.01 Hz caused by atmospheric pressure variation. The aim here being to measure infrasound rather than barometric variation due to the weather. Precision capillary tubing may be prohibitively expensive. A fine hypodermic needle (30G, 0.3x13mm), readily available online, glued into a pre-drilled hole in a Hammond 1551RFLGY plastic enclosure has been shown to exhibit a suitable time-constant of 100-150s.

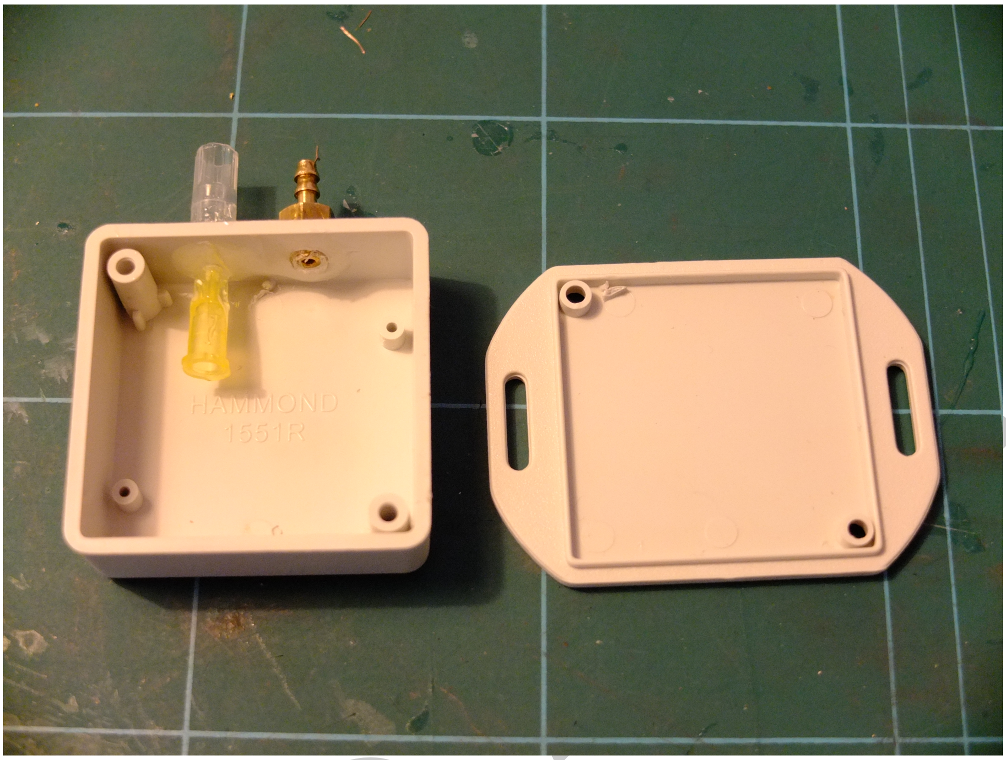


Figure 6: Pneumatic Filter ‘Backing Volume’

4.3 Wind Filter

There is considerable opportunity for experiment and improvisation here. // A filter is required of the sensor if installed outside though not if installed in a loft-space or similar. This prevent ingress of water and reduces wind turbulence.. Three configurations have been used successfully by the authors.

1. No Filter
2. A hard foam block
3. A 10m spiral of porous hose

4.3.1 No Filter

A loft-space appears to act as rather an effective filter averaging out local turbulence across its area.

4.3.2 Foam Block

Serendipitously a 30cm outdoor foam pond filter was found to work well with no adaptation.. The one purchased already had a removable core cylinder. Into this cavity runs the tube from the sensor block ending in a small funnel pointing downwards to prevent water entering the tube. This has been sited outdoors for a couple of years without problems.

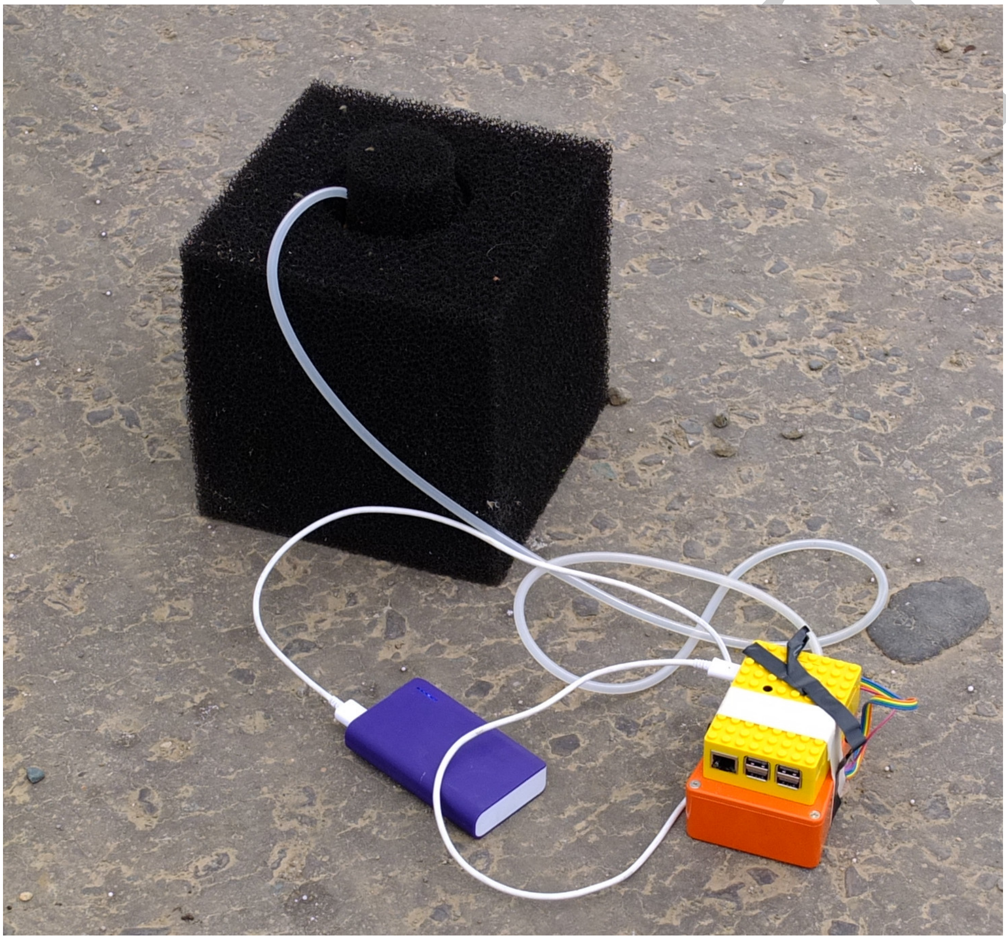


Figure 7: 30cm pond filter noise-filter

4.3.3 Porous Hose

This is used by many professional rigs. A 20m length of porous hose is closed at one end. The cap at the other end is drilled to take the hose from the sensor. This does an admiral job of minimising extreme wind noise for mobile readings such as at beaches and near turbines. When spread out in a spiral the hose averages pressure variations across its length thus cancelling local turbulence.

Figure 8: Pond filter tested alongside spiral hose

5 Setting Up The Pi

5.1 Installing an Operating System

Right – this can be involved but we learn a lot about computing here. We are going to use a Raspberry PI to record the pressure, save data, plot graphs and upload to your website. Since it only draws about 8W is can be left running 24/7

There are two ways we can 'talk' to the PI – either using a screen, keyboard and mouse – like a conventional computer or from a PC over a network – a.k.a 'headless mode'. A monitor and keyboard is handy in a schools lab but for a proper network install we are better with headless.

So the first thing to do is get the PI running. Firstly you will need to install the operating system. This will likely be Raspian – a version of Linux.

Grab Raspbian Buster Lite from :-
`https://www.raspberrypi.org/downloads/raspbian/`

Headless installation Instructions at:-
`https://hackernoon.com/raspberry-pi-headless-install-462ccabd75d0`

Hopefully you now have a working PI.

5.2 Installing ObsPy

Next we need to install Obspy, a suite of seismic analysis software To use the MiniSeed data format format, the best way is to use a library made for this: ObsPy. So we must first install it. You can use a notepad editor in root, e.g. from terminal, as long as you have an Internet connection on your Raspberry Pi. sudo nano /etc/apt/sources.list Add the following to the end of this sources file (the repository to the ObsPy Libraries) deb http://deb.obspy.org buster main

5.3 Installing Required Software

Using a terminal run each of the following commands

```
sudo raspi-config        (enable i2c)
sudo apt-get install python3
wget --quiet -O - https://raw.github.com/obspy/obspy/master/misc/
          debian/public.key| sudo apt-key add -
sudo apt-get update
sudo apt-get install python3-obspy
sudo apt-get install python3-smbus
sudo apt-get install python3-serial
sudo apt-get install python3-matplotlib  (used to plot the daily graphs)
```

Ensure that the PI knows the correct time

5.4 Install ntp time

```
sudo apt-get install ntpdate
sudo timedatectl set-ntp True
```

If you set the Time Zone in raspi-config the Raspberry Pi will automatically update the time on boot, if connected to the internet.

```
sudo raspi-config
Select Internationalisation (Localisation) Options
Select I2 Change Timezone
Select your Geographical Area
Select your nearest City
Select Finish
Select Yes to reboot now
```

5.5 CronTab

Set Up CronTab to automatically start the Infrasound Monitor on reboot
crontab -e (If given a choice of editors I would select 2- nano)
copy the following to the bottom of the file

```
# m h  dom mon dow   command
*/60 * * * * /home/pi/InfraSound/uploadHourly.sh 2>
      /home/pi/InfraSound/errorHourly.txt
05 0 * * * /home/pi/InfraSound/uploadDaily.sh  2>
      /home/pi/InfraSound/errorDaily.txt
@reboot python3 /home/pi/InfraSound/InfraSoundMonitor.py 2>
      /home/pi/InfraSound/errors.txt &
```

Replacing InfraSound/InfraSoundMonitor.py with the name of the directory containing the monitor program.

Exit with CRTL o then CTRL x

Install FTP to upload plots to your web-server sudo apt-get install ftp

5.6 Adding a real Time Clock

In normal use the PI gets its time signal from Internet. It lacks an internal clock so cannot add correct time to a trace if it is not connected to the internet. Adding a precise clock module is thus desirable only if you intend to use the sensor away from an Internet connection.

I use the DS3231 Precision R.T.C. from AdaFruit following instructions at https://pimylifeup.com/raspberry-pi-rtc/

6 Uploading to your Website

Grab the file uploadhourly.sh from this site or create a file with the same name in the infrasound monitor directory on the PI (assumed to be /home/pi/Infrasound)

```
#!/bin/bash
HOST='yourwebsite.co.uk'
USER='your_webserver_ftp_username'
PASSWD='yourPassword'
ftp -p -n -v $HOST << EOT
ascii
user $USER $PASSWD
prompt
cd  xxx/Infrasound/plots    (***remote directory for
↪ files***)
ls -la
put /home/pi/Infrasound/Plots/Today.png Today.png
            (***transfer the current day's plot***)
bye
EOT
```

6.1 Logging Software

Software has been written in Python which interrogates the mems sensor approximately 40 times per second. These pressure readings are stored every few minutes until midnight when the cumulative day's readings are saved and a new day's recording begun. At intervals (15 minutes in the case of my own systems) two plots , one of raw pressure and one of acoustic power are generated and saved to disc (see: https://www.starfishprime.co.uk/projects/infrasound/infrasound.html). These are uploaded to a remote website hourly by a separate crontab script via ftp. The entire system draws about 8 watts and has been left running unattended now for over 2 years. Data is viewed and downloaded for detailed analysis over the Internet.

Data is stored as *.mseed* files, a standard geophysics format. Files may be read using Obs-Py [1], an opensource suite of programs used to plot and analyse seismic data. Obs-py is an excellent introduction to python programming, producing publication quality plots and signal processing techniques such as F.F.T. A general purpose Python program has been developed to give students a start on this, figs 9 & 10 .

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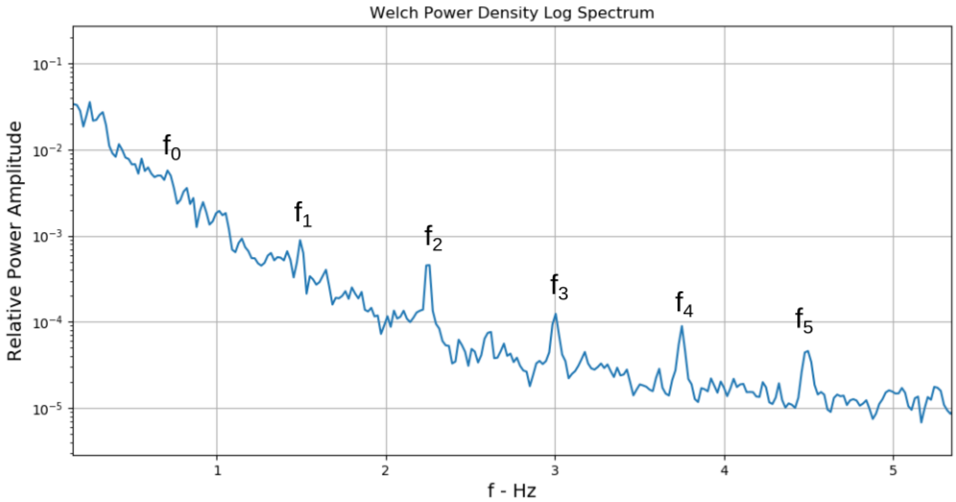

Figure 9: Wind Turbine: f.f.t. showing fundamental and harmonics

7 Further Analysis Software on a PC

8 Ideas for Student Projects

I suggest a team approach. One team building and testing the power supply, one the sensor unit and another the Pi. Later students could look at building a suitable website and then conducting longer-term data analysis.

9 Further Development

- Adding a wireless interface.
- Add a GPS module to the PI for mobile use and more precise timestamps.
- Experimenting with different wind filters.
- Comparing signals from multiple sensors some km apart.
- Making observations near wind-farms, airfields and quarries.

10 In Summary

This project has provoked considerable interest in students with electronics, programming and the possibility of investigating a relatively novel area of geophysics.

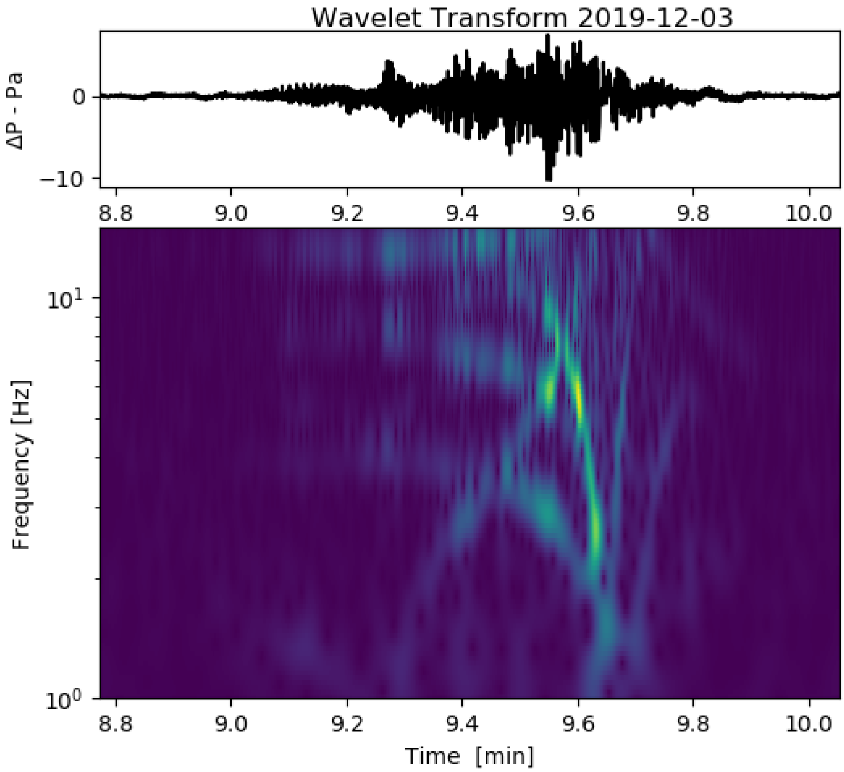

Figure 10: Wavelet transform (f.f.t.) of helicopter approx 200m overhead at 10-12 min and 23-27 min

It has been developed over 2 years and works. It has been simplified to minimise cost and allow for easy upgrading and further development. Veroboard and through hole-components allow the hardware to be assembled by primary age students. Whilst aimed at younger students this could form the basis of an undergraduate proect. It is a device of unusual sensitivity and capable of further refinement, particularly regarding analysis of the data. For less than £100 a school or home scientist can have an ongoing 'real science' project delivering data 24/7 and displaying data on their website.

11 Authors

Ian Robinson has taught physics and computing in Sixth Form Colleges for over 20 years whilst periodically running electronics/coding projects in primary & secondary schools. He recently completed a Ph.D in Computational Physics involving the Monte Carlo simulation of lattice gases. Outside of teaching he is developing a number of low-cost educational projects in geophysics sensing.

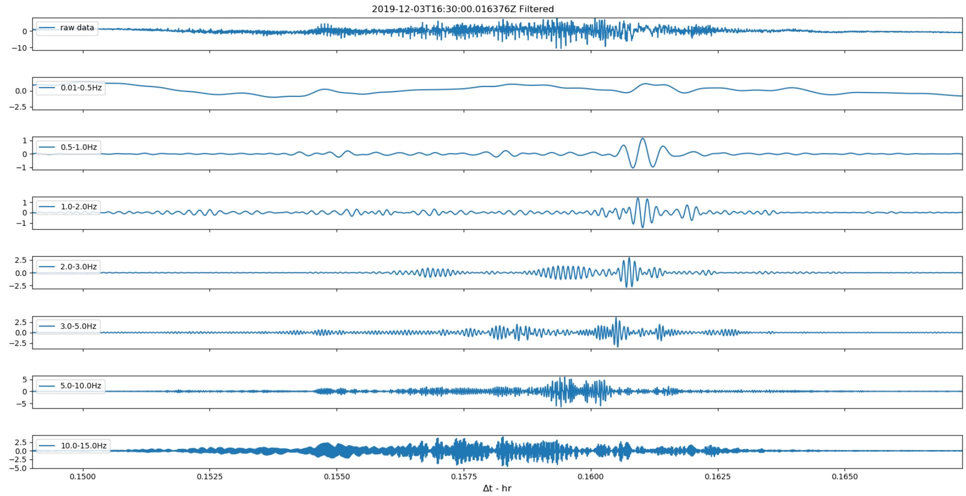

Figure 11: Helicopter Infrasound Power bands

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