



Taming your old LPs From Analogue to Digital

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Gelato Project

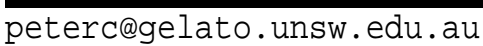
National ICT Australia

The University of New South Wales

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I have a lot of old LPs.



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The obvious solution is to digitise them.

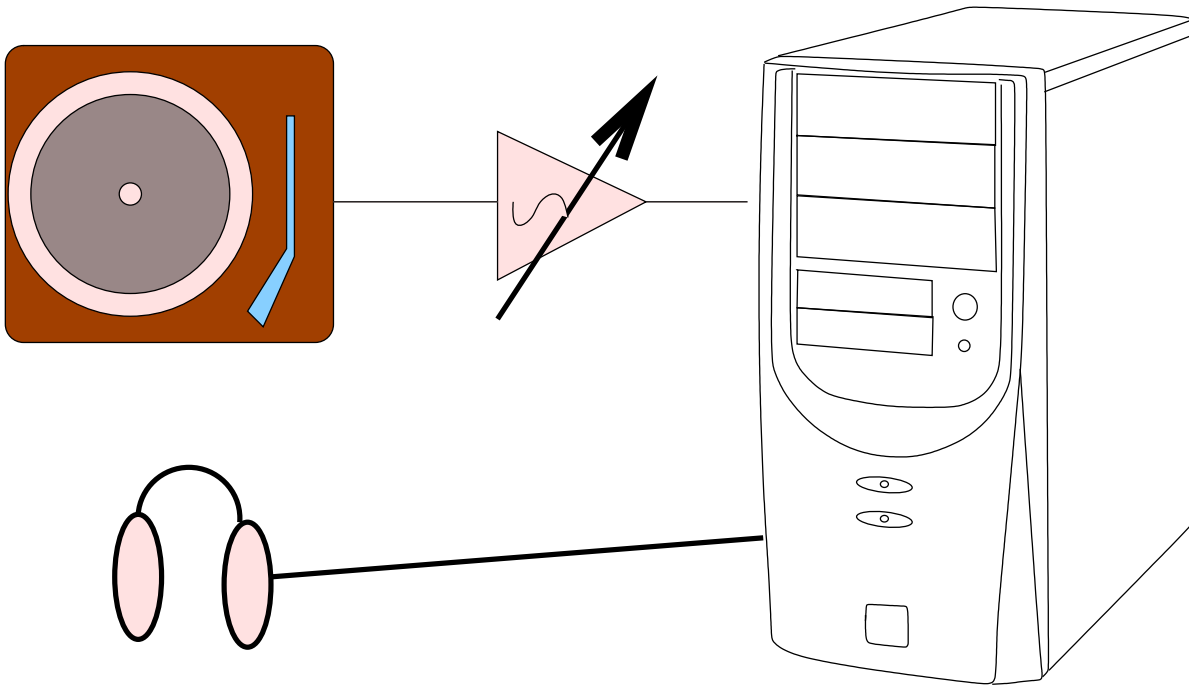
Copyright issues



- 70 years from death
 - of *everyone* involved in the recording!
- (except for deaths before 1954)
- or 25 years from first publication, whichever is later

Digitising your LPs is effectively copying them. And they're subject to copyright. This is a big can of worms; there may (or may not) be legislation in the pipeline to alleviate the situation, but at the moment it is illegal to copy most LPs.

LP to Digital: What you need



And lots of spare time

You need a turntable, tone-arm, cartridge and stylus, a preamp (preferably one with adjustable output levels) a halfway-decent sound card, and a computer with at least 256M memory, and 512M free disk space — preferably more. A CD or DVD burner is also quite useful.

Because you're going to want to be able to listen critically to the sounds, you either need to have a fan-free system, or a terminal in a quiet room with the computer somewhere else, or use a decent pair of headphones. *Don't* try to edit your files by listening to the sound from your typical PC speakers; after all, you're probably going to want to play your resulting CD through a HiFi system.

It takes around three quarters of an hour to record a single record side, then you need to spend time on top of that to postprocess the data and create your OGGs or CDs.

Record Players



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I'd love to have one of these, or a similar class turntable. This is a 'gyrodec': it retails at around \$2500, so I'm not going to get one any time soon.

Things to note are:

- The DC motor is acoustically isolated from the turntable and tone arm systems.
- The platter is heavy (high inertia), and has a separate suspension.
- There is a high impedance conductive mat on top of the platter, to remove static and to avoid scratches.
- The tone arm is sold separately; the mounting can be moved for optimum placement.

Record Players (II)



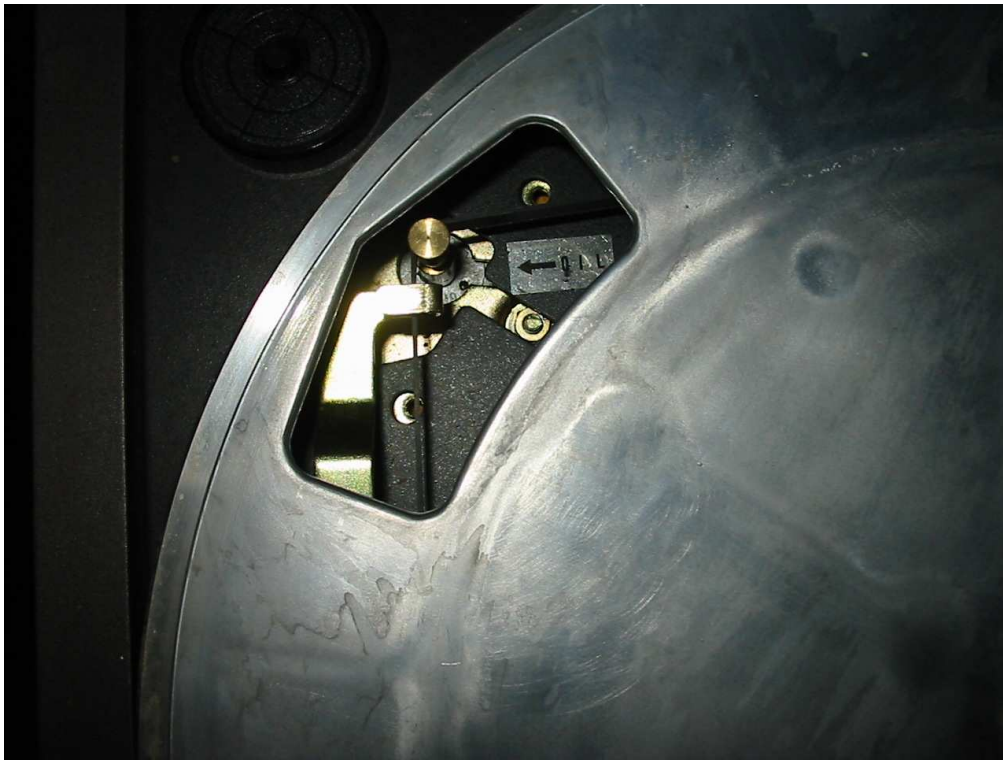
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Most of us have to settle for something more like this — a 1970s Sansui belt drive model. These can be perfectly adequate if well maintained.

Record Players: Belt Drive



If you take the mat off the platter you can see the belt under the platter though its balancing holes.

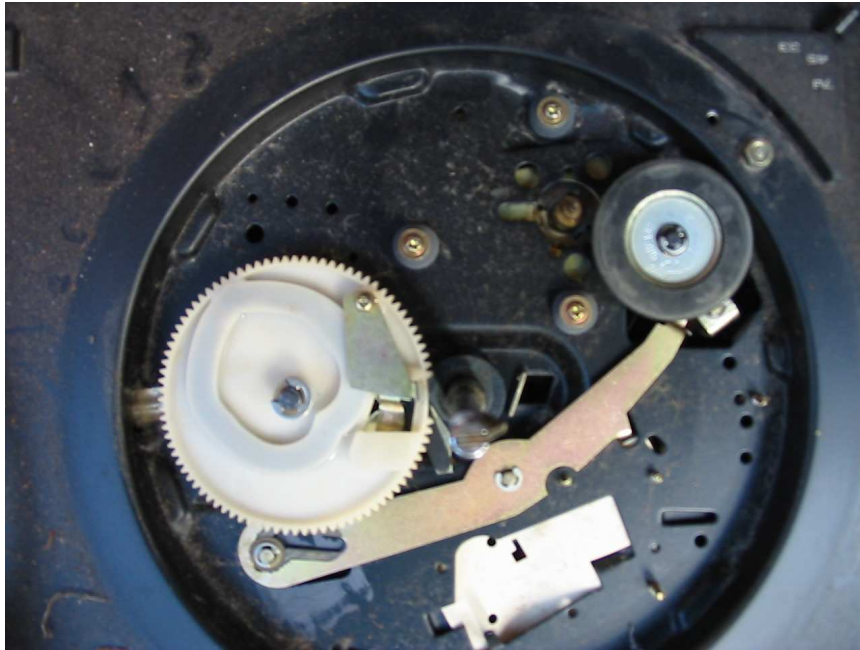
Record Players: Direct Drive



The other main type of turntable is the direct drive. These can be recognised by the speed adjustment knob on the front, and on removing the platter, there are no belts or balance wheels.

Direct drive platters tend to have less inertia than those for belt drive systems — a feed back loop in the circuitry ensures constant speed with load variations. Typically, a direct drive turntable will have a variable speed drive, with a stroboscopic arrangement for setting the speed.

Record Players: Avoid!



Cheap record players typically use an idler wheel that presses directly onto a capstan and the edge of the platter. Unfortunately the result is noisy.

I believe the Garrard transcription turntables used a belt driven idler wheel; they should be fine for your purposes.

Tone Arms, cartridges, styli...

- You probably have no choice
- High end turntables give choice
- 3 stylus shapes

If you've bought a high-end turntable, you'll have a choice of tone arms and cartridges. But if you've done that you should probably seek professional advice anyway (and probably have golden ears, so won't want to muck around with digital recordings anyway!)

There are three stylus geometries available. The simple spherical stylus is cheapest and most common. It can have difficulty tracking high frequencies, so elliptical styli have been developed that sit deeper into the record groove and can therefore pick up more details. The top-of-the-line styli are designed to be the same shape as the cutting tool on the lathe that cut the master disc. They are capable of the best tracking, but are also the most expensive.



Cartridges

- Ceramic/Crystal (High output (100mV), poor fidelity)
- Moving Coil (low output (0.5mV), very high fidelity)
 - (Usually do not have user-replaceable styli)
- Variable Reluctance (medium output (2-4mV), high fidelity)
 - (also called moving magnet)

Again, you may not have a choice. The main thing to make sure is that the cartridge is installed correctly such that the long access parallels the end of the tone arm, so that the stylus is precisely aligned at the two neutral points. Try to avoid the cheap ceramic cartridges, though, as they do colour the sound.

Mechanical Adjustments

- Decoupling
- Tracking weight
- Antiskating
 - Average the centrifugal force over the record surface.
 - Perfectly balance at the two neutral points (for an S tonearm) (around 66mm and 120mm)
 - Adjust with blank record

The cartridge is in effect a sensitive microphone that is suspended over a fast moving platter. It has to be decoupled acoustically from the noise sources around it — but it has to rest on the LP to do its job. This means that the turntable has to be acoustically decoupled via its bearings from the motor (by the belt drive) and from anything else around (via the plinth suspension). Unfortunately, rubber parts harden over time, and springs fatigue, meaning that if you have an old turntable it'll be less than ideal. A number of things can be done to improve the situation:

- Replace rubber parts
- Increase the inertia and damping of the platter with silicone gel (remember to adjust the balance afterwards!)

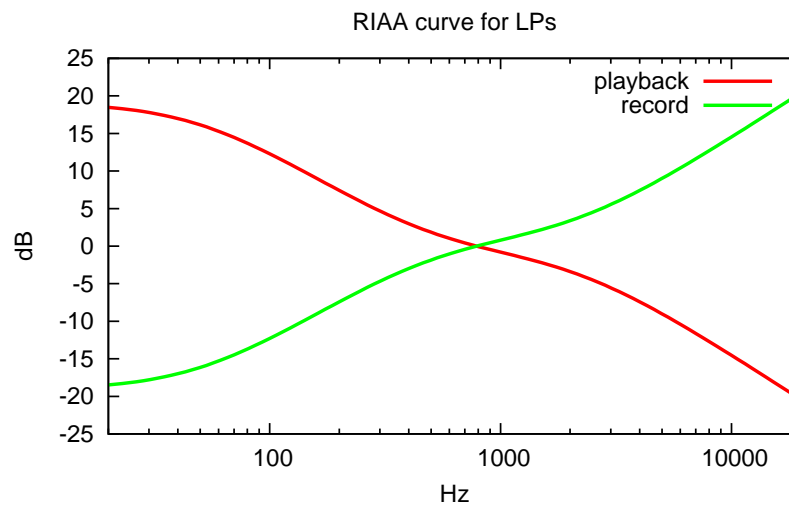
- Sit the turntable on springs on a rigid table on a concrete floor. Wooden floors tend to transmit footstep sounds.

Make sure that your tonearm is adjusted to give the proper tracking weight for your cartridge, and that the antiskating is adjusted so that if the tonearm is put onto a blank disc at either of the two neutral areas, it doesn't move either out or in. If you have a test disc, it'll have blank tracks at the two neutral areas; otherwise try to find a one-sided record. If you don't know the ideal neutral areas for your tonearm, you can guess at 66mm and 120mm from the centre.

Typical tracking weights are:

- Audiophile cartridges: 1–1.5g
- DJ cartridges: 1.5–2.5g
- 78s: 3g

The Preamp: 1, equalisation



(See <http://www.platenspeler.com/background/riaa/> for amp designs)

The friction of the stylus on the record surface produces high frequency sounds. Low frequencies cause major excursions of the wiggly groove, making it hard to track. The solution is to filter (preemphasize) the sound before recording, and to apply deemphasis afterwards. Since around 1960, almost all LPs used the RIAA preemphasis curve. Thus the output from your cartridge needs to be shaped before use.



The Preamp: 2, Amplification

- Sound card levels are 1Vrms.
 - Moving magnet cartridge needs 50dB gain
 - Moving coil magnet needs 60dB gain
- Variable is best.

Your cartridge produces a very low level signal — 0dB is a few millivolts. Your sound card's line level is either one or two volts for 0dB. Thus you need amplification.

An aside: Line levels

Sound Card 'Standard'

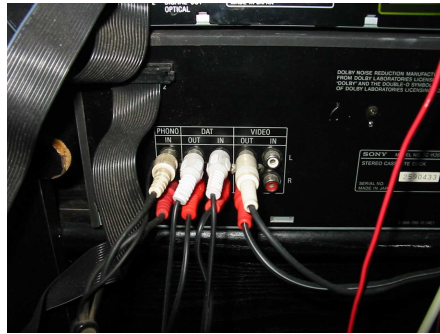
1-2V

'Standard'

600mV

DIN

200mV



Just a quick note: amplifiers that use RCA plugs *usually* use a 0dB line level of 600mV into 600 ohms. Amplifiers that use 5pin DIN plugs typically use 200mV into 1k. And your sound card wants 1V into 4.7k. Output from the RCA plugs is usually OK.

Sound Cards

- NOISE
- Dynamic range
- Connectors
- (rate not important: CD quality is 16 bits, 44.1kHz)

You'll need to experiment with sound cards. The main issues are noise, dynamic range and connectors.

Computers are very electrically noisy, and decoupling the sound card from that noise is a good thing. Getting a card that separates the audio analogue circuitry from the digital circuitry, or that puts almost everything outside your computer case and on a separate power supply are probably best. USB-powered devices aren't particularly good: I ended up buying a USB Creative Digital Music, and then having to buy a powered hub to use it (the USB power supply was too poor in quality).

Some sound cards have really awful preamplifiers in them. On one that I tried to use (an ESS1371 PCI card) I could find no

combination of preamp level and input level that would let me get a -3dB signal without distortion. Others, (e.g., an earlier ISA model from the same manufacturer) were fine.

3.5mm minijacks are notoriously bad; RCA plugs end up being much more reliable.



Monitoring

- Computers are noisy
- Use headphones.

When postprocessing your audio you'll need to be able to hear fine details in the music. Noise from fans, clicking typewriter keyboards, etc., get in the way — so unless you can isolate yourself and put your soundcard output into a hifi amp and speakers, use a decent pair of headphones.



Dynamic Range

- Double voltage \rightarrow 6dB gain
- 16 bits \rightarrow 96dB
- 24 bits \rightarrow 144 dB
 - Noise floor at around -100 dB, effective around 17bits.

(note) Open-reel tape with Dolby can record around 120dB; full symphony orchestra around 110dB; LP around 65–70dB.

decibels measure power ratio. The formula for difference in dB between two signals A and B is $10\log(A/B)$. A doubling of power is therefore $10\log 2$ dB — just over 3dB. Power goes as square of voltage ($P = E^2/R$), so a doubling of voltage is just over 6dB.

Each increase of one bit in the wordlength corresponds to a doubling of voltage — or a 6dB increase. Thus 16 bits can record from 0 down to -90 dB — and -96 dB is silence plus any noise that's present. 24 bits can record from 0dB down to -144 dB — except that with a noise floor of -100 dB, only the top 17 or so bits are useful for recording.

By comparison, a type II half-track open-reel tape running at 15ips using Dolby B for noise reduction can easily get 120dB of dynamic range; and a symphony orchestra runs about 110dB from a rest to everybody playing at once. Add in the bells and the cannons for Tchaikovsky's 1812 overture and you're talking 130dB or more.



Recording: Principles

- Keep it Clean!
 - Physical
 - Electrical
- Get the Levels right!

The main thing to do when recording is to try to get the cleanest possible signal into your AtoD converter. This means:

- Cleaning your LP to remove dust.
- Making sure that all electrical connections are clean.
- Avoiding distortion from overload.
- Keeping the signal levels well above the noise floor.



Surface Noise

- Small imperfections
- High-frequency friction noise (hiss)
- Dust is the main enemy.
- Static Electricity attracts dust to surfaces.
 - use an anti-static gun, or ioniser.
- wipe surface with anti-static solution *along the grooves* and allow to dry.
- Play the record once before converting it.

Small imperfections in the record surface come out as noise. These can be caused by any harsh treatment of the record, for example, over-heavy handed dropping of a stylus onto the record surface, or even lifting it off the surface; DJ 'scratch'; worn or chipped stylus; fingermarks; or even worse, scratches or cracks in the record itself.

The friction of even a well-adjusted stylus also provides high frequency white noise as it scrapes against the LP.

But most of the problem comes down to dust. A dust particle can be around the same size or a little bigger than the groove variation that the stylus is trying to track, giving thumps and crackles.

Dust is attracted to the vinyl used in modern LPs (older records didn't seem to have the problem quite so much). Especially, removing an LP from its plastic sleeve can generate a lot of static electricity; any dust in the air zips straight onto the record surface. Using an ioniser really

helps here — direct it into the sleeve as you remove the LP, to discharge the static as it builds up.



(Physical) Noise II

- Rumble
- Thumps and Bumps

A record player is a sensitive microphone suspended over a moving platform. If the cartridge is not effectively decoupled from everything else, it will pick up low frequency vibrations from the turntable itself, from the table it stands on, and from the ground as people walk past. Good turntable design will minimise this, but some vibrations will get through even the most sophisticated decoupling system.

Try to avoid thumping the table, or typing on the same table. Try to mount your turntable on its own heavy table preferably on a concrete floor.

Electrical Noise

- Cables are Antennas
 - so keep them short!
 - and avoid loops (plug all into the same adapter)
- Computers not optimised for good DC
 - use separate power supply for sound card
- Use a power supply filter.

Having reduced mechanical interference to the minimum, pay attention to electrical noise. Your cables are antennas, in that they provide magnetically-coupled loops and electrostatically-coupled wires. You can minimise pickup by keeping the wires as short as possible, and by running all the cables together (minimising loop area). You can get loops via the electrical mains, so try to run all the cables together to the same electrical outlet. Your turntable will almost always have a separate earth connection. Connect it to the preamp's ground voltage — which will not necessarily be the same as signal ground. Many preamps for record players use a balanced differential input to reject common-mode noise; connecting either side to earth will cause more noise than not.

If you have a sound card powered via the USB bus, consider buying a powered USB hub. At least on the computers I could test, the USB power was very dirty.

Taking a Recording

1. Clean the LP
and let it dry!!!
2. Record the LP looking for peaks
3. Record the LP 'for real'
4. Post-process the recording.

To clean an LP wipe it in the same direction as the grooves with a lint-free cloth with a few drops of anti-static solution. If you don't have anti-static solution, use distilled or deionised water. Allow the LP to dry thoroughly before attempting to play it, or you will wreck your LP (water in the grooves allows the stylus to bind to the vinyl, which can then tear away from the side of the groove).

Then play the LP, recording as you go. This run is primarily to allow the stylus to eject any more dust that might have missed your cleaning. It also allows you to check the recording levels.

Then wipe the LP again, and rerecord, this time 'for real' using the levels you've just worked out.

Put the LP away (or record the other side!) then you can archive then start postprocessing the recorded sound.



Record the LP

- (window 1) `alsamixer`
- (window 2) `brec -b 16 -r 44100 -s w xxxx.wav`

OR `arecord -f cd -v -v -t wav xxxx.wav`



Adjust Levels

- Adjust mixer to Peak at around -3dB (71%)
- In extreme cases, may need different levels per track
- Write the mixer settings down! (or save them)

I find it easiest to have a few windows open for this: a mixer in one, and the recording program in another. Or you can use a GUI tool. The aim is for the peak voltages in the recording not to overload any part of the audio chain. Depending on how you're monitoring, a visible (RMS) peak of -3dB corresponds to an actual peak of -1.5dB , which is very close to overloading the system. Unlike tape, digital media have no headroom, and overloads sound *appalling*.

If you use `gramofile` to do the recording it'll report the number of samples that are in the range 0.5–0.9 (-6 to -1dB) over 0.9. and clipped samples.

Try playing back the wav file you've recorded to make sure everything worked – you won't need to play everything.



Record for real

- Use mixer settings from previous run.
- Use `sox` to add the right headers

```
sox new.wav TRS6263-1.wav
```

Having got the levels right, you rerun the recording. Control-C the recorder when the record finishes. Then copy the recording using `sox` to add the headers, and save a copy of the resulting file somewhere. I use the record number as a key, with a -1 or -2 for the side number.



Postprocessing

- ARCHIVE it
- Remove noise
- Find tracks
- Generate OGG or CD.

Gnome Wavecleaner
cdrdao

After digitising your LP, save a copy of the WAV somewhere safe. It took you an hour or so to get, and some of the tools you'll want to use are 'in-place' tools with limited backup facility.

Then you'll need to remove the noise, snip off the leader and trailer, and then burn your CD or generate your OGG.



File formats

- .wav: Around 250–300M for a record side at 16bit, 44.1kHz
- All other common formats are lossy or larger.
 - Including Audio CDs!
- mp3 has patent issues
- But not many portable players grok OGG

Do archive your recordings as `.wav`, however. All the other formats are either larger or lossy — which means that several rounds of decoding, processing and reencoding will lose data. The best archival format I've found is recording as wav files onto CDs or DVDs. I don't know how long they'll last.

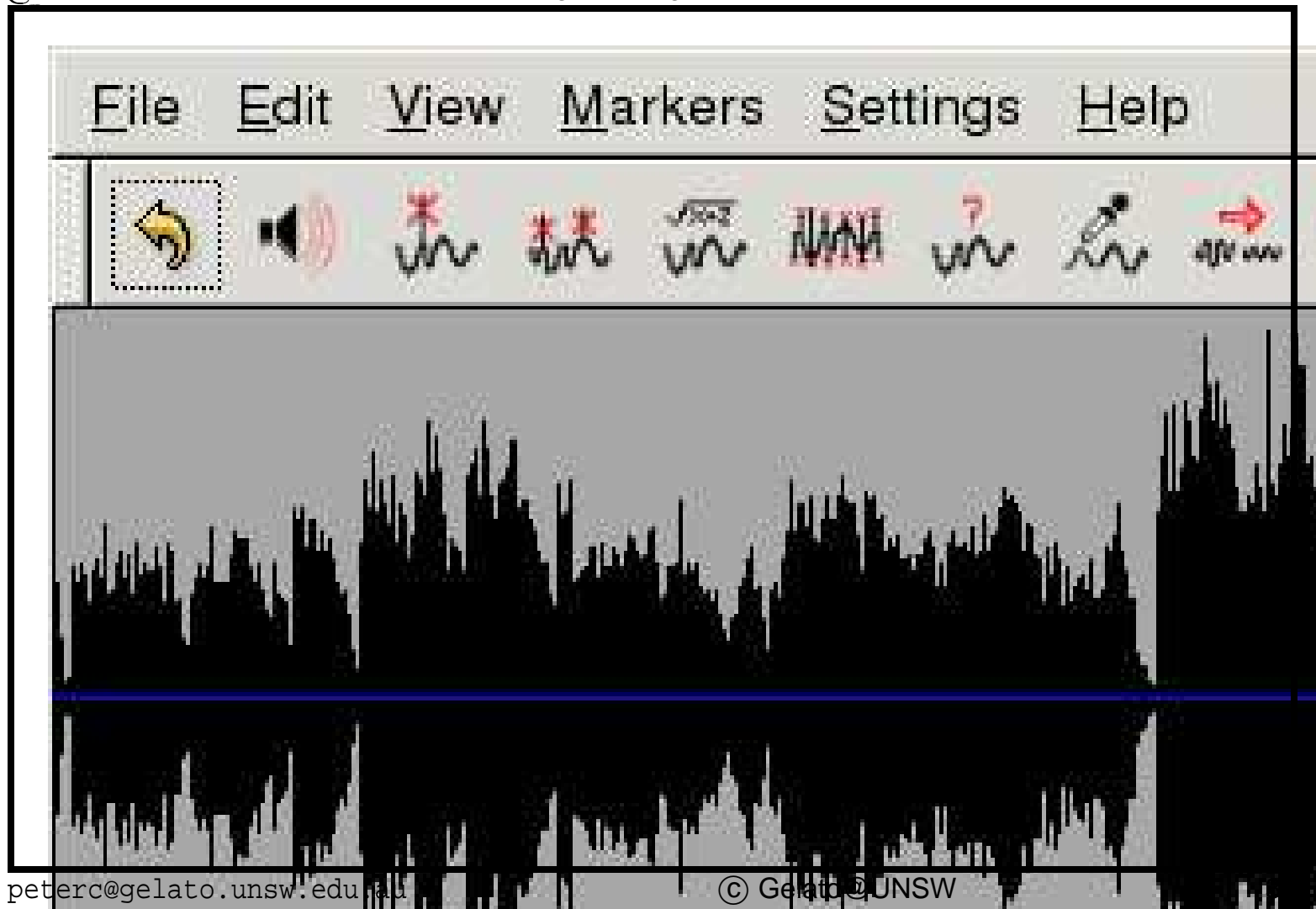


Gnome Wavecleaner

- Remove clicks and crackles
- Remove generic surface noise
- generate table-of-contents file
- GUI — requires manual operations

I used to use gramofile for all this; but gnome-wavecleaner does a much better job (although being a Gnome application it uses hundreds of megabytes of graphics libraries which you may not otherwise need on your system).





The default denoising settings from Debian are not the best; use the 'help' button to find some better ones.

I use the declick button once or twice to remove any egregious clicks, then the crackle button if it's needed (many of my recordings are sufficiently clean that it's *not* needed).

Then find a 'silent' spot (the intertrack gaps are best), zoom in and take a noise sample. Then select a minute or so of music, and denoise it, then play it. If you can't hear any degradation, undo and repeat for a different part of the music. When you're satisfied, undo everything, select the whole file and make yourself a cup of tea while the noise is removed.

Then trim the front and back of excess silence.

If there are one or two clipped samples you can 'fix' them by selecting the few samples (you'll need to zoom in a lot) then applying the

declicking algorithm. If you have only a few clipped samples, the result is to sound a bit 'buzzy' — like a kazoo.



Making the CD

- Split tracks, 2sec gap (gramofile)
- Create table-of-contents file, use cdrdao
- Or use a GUI if that takes your fancy

You can use `gramofile` to split a `wav` into one `wav` per track.

Or there's an option to locate tracks in the Gnome Wavecleaner 'Markers' menu. It looks for silences, so use it after denoising. I find it a little eager, and often have to move the markers by hand, removing many of them. Then select 'create `cdrdao` TOC file' from the 'file' menu, and fill in the names of all the tracks.

You can merge several `wavs` into a single CD by editing the TOC file yourself.

Gnome Wavecleaner is also very good at cleaning up tape hiss, if you want to digitise your tapes, too. But watch the dynamic range!

Once you're done, enjoy your music!