

VinyltoCD-RRecording ATutorial

Ganymede Test&Measurement

Summary

This tutorial describes the transfer of vinyl records to CD-R. It is divided into three sections as follows:

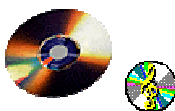
Part 1 deals with playing vinyl records with particular emphasis on the special requirements for digital re-mastering.

Part 2 explains how to make digital recordings on a multimedia PC using its built-in sound card to capture an analogue source.

Part 3 describes the audio restoration of vinyl recordings using Ganymede Test & Measurement's *WaveCorrector* program.

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Part1.PlayingVinylRecordsforDigitalRe-Mastering

Introduction

Playingvinylfordigitalre-masteringisalittledifferentfromplayingfornormallistening. You willwanttoensureabsoluteoptimumqualitybecauseanyimperfectionsatthisstagewillbe permanentlyincorporatedintoyourCD-Rcopy. Youmay,forexample,decidetoplayusinga slightlyhigherthannormaltrackingforcesincetheadditionalweartothevinylisoutweighedby theimprovednoiseanddistortioncharacteristicsattained.

Equipmentneeded

Thefollowingequipmentwillbeneededtoproduceasignalcapableofdrivingatypical multimediaPCsoundcard.

- Aturntableandpickuparmfittedwithagoodqualitycartridgeandstylus
- APre-AmplifierwithRIAAequalisation.
- Interconnectingcables

Turntable/PickupArm

Beforeembarkingonarecordingssession,youmustensurethattheturntableandpickupare correctlysetup. Thismeansthattheturntablemustbepositionedonasolidlevelsurfacefree fromvibration. Thepickuparmshouldbeinspectedtoensurethatthecartridgeiscorrectly installedforminimumhorizontaltrackingerrorandthecorrectplayingweight. Thecartridge manufacturerwillspecifyarangeofplayingweights. Formastering,itisadvisabletosethis adjustmentnearthemaximumrecommendedvalue. Havingsettheplayingweight,youshould thenensurethatthesidetrust(anti-skating)adjustmentiscorrectlyset. Thearmmanufacturer willhaveprovidedinstructionsformakingtheseadjustments.

PickupCartridge

Therearemanytypesofpickupcartridgeincludingcrystal/ceramicandvariousmagnetic types-movingcoil,movingironandmovingmagnet. Yourpickuparmwillprobablyhavebeen suppliedwithacartridgetosuitthecharacteristicsofthe arm. Ifyouchoosetochangethe cartridge,itisimportanttoensurethatthecomplianceofthereplacementcartridgematches the arm. Otherwiseunwantedresonancescanseverelycompromisequality. Ifalowcompliance cartridgeisfittedtoahighcompliancearmthenthe trackingperformancewillbeimpaired, particularlyduringloudsectionsofmusic. Conversely,ahighcompliancecartridgefittedtoa lowcompliancearmwillresultinmis-trackingiftherecordisnotperfectlyflat. Additionally,a largesub-audiosignalwillbegeneratedduetotheundulatingmotionofthecartridgeoveranon-flatrecord.

Mostmovingcoilcartridgeshaveaverylowoutputvoltage(~200microvolts)andaresupplied withastep-uptransformeroralownoiseamplifiertomatchthelevel(~10millivolts)ofa typicalmagneticcartridge. Somemodernmovingcoilcartridgesaresocalled‘highoutput’ and donotneedatransformeroramplifier.

A very small number of magnetic cartridges (eg Decca FFs) should not be used with a ferrous turntable because the strong magnetic field of the cartridge will be attracted downward causing serious damage to the cartridge.

Crystal/ceramic cartridges require special equalisation and will not produce the high quality output obtainable from a typical magnetic cartridge. For these reasons they are not recommended.

Stylus Maintenance

One of the most common causes of audio distortion when playing vinyl is contamination of the stylus. The contamination occurs when surface dust gradually accumulates on the stylus during play causing the distortion to get progressively worse.

Before playing each side of a record, always clean the stylus using a fine (camel hair) brush soaked in alcohol (IPA). Gently blow it dry before use. Only move brush from back to front (ie in the direction of record movement), **NEVER from front to back or from side to side**. High compliance cartridges, in particular, are very easily damaged so extreme care should be taken when cleaning your stylus.

When the side has finished playing, inspect the stylus for contamination. If the contamination is significant, you should consider re-recording part or all of the side. Only in this way will optimum results be maintained.

Your stylus should be regularly checked for wear as a worn stylus will permanently damage your records.

Record Cleaning

A vinyl record must be as clean as possible to achieve optimum audio quality. The main reason for cleaning a record before each play is to remove surface dust which would otherwise accumulate on the stylus and impair the sound. The recommended cleaning method is to use a carbon fibre brush such as the 'Decca Record Brush'. This also helps to reduce static and reduces the further accumulation of surface dust.

If your records have not been played for some years, dirt may have become ingrained in the grooves. In such cases, the records should be played at least once before re-recording. This will help remove dirt remaining in the groove and allow you to inspect the stylus to confirm the absence of contamination. If playing the record reveals high levels of background noise, or if the stylus becomes repeatedly clogged with dirt after playing, the records should be deep cleaned.

Deep cleaning involves covering the surface of the record with a mixture of alcohol and distilled water and then scrubbing and vacuum drying to remove all traces of residue. This task is accomplished using a 'Keith Monks' or similar specialist machine. A number of record/hifi shops will provide this service for a small charge. The results are usually dramatic.

Pre-Amplifier

Apre-amplifiermustbeusedtoamplifythe lowlevelsignalfromthepickuptoasuitablelevel (~1 volt)foramultimediaPCsoundcard. Also,thepre-amplifiermustprovidethecorrect equalisation(RIAA)toensureaflatfrequencyresponsefromtherecord.

Somehi-fi systemsintegrate thepre-andpoweramplifiersintoasingleunit.Inthiscase,itwill usuallybepossibletoutilisetheoutputintendedfortaperecordingtofeedthesoundcard.

ItisveryimportantnottodrivetoohighasignallevelintothePCsoundcard.Otherwise, clippingdistortionwilloccur.Forthisreason,yourpre-amplifiershouldideallyhavean adjustableoutputlevel.Ifyouroutputlevelisfixed,thenyouwillneedtousethegaincontrolin theWindowsmixerapplettoadjustyourrecordinglevel.SeePart2ofthetutorialfora descriptionofsettingtherecordinglevelcorrectly.

Interconnecting Equipment

MostPCsoundcardsutilisea3.5mmjackasthe lineinputconnector.Conversely,mosthi-fi equipmentuseseitherphonoorDINconnectors.Youwillthereforeneedtofabricateorpurchase aconnectingleadwhichconvertsbetweenthe twoconnectorstandards.

Ensurethatallconnectorsareofgoodqualityandthattheyallareseatedcorrectly.Poorlyfitting connectorsareafrequent sourceofnoiseandsometimeshum.

Evenwheneverthingisinterconnectedproperly,itisstillpossibleforlowlevelsofhumtobe presentduetopoorearthingormultipleearthpaths.Duringinitialauditioning,youshouldsatisfy yourselfthatyourrecordingsetupisnotintroducinganyhum.Ifyoufindthereissomehum present,thenyouwillneedtocarefullycheckallconnectors.Ifthisdoesnotcuretheproblem, youmayfindremovingthepowersupplyearthfromoneorotheritemiseffective.Note,ifyou dothis,youshouldensurethatyourpersonalsafetyisnotcompromised.

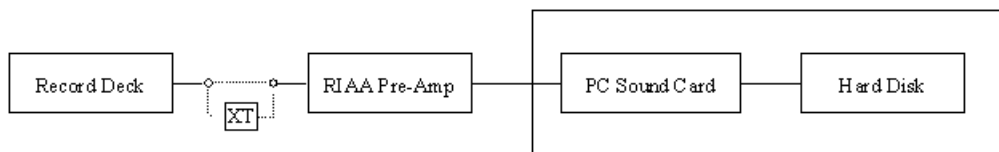
Part2.DigitalRecordingusingaMultimediaPC

Test Recordings

Because theCD-Risa 'writeonce' medium,it isveryimportantthatyouensurethe integrityof yourrecordingprocessbeforecommittingyourcollectionofLP's totheCD-Rburner! Throughoutthissection,youwillbeadvisedatseveralpointstomaketestrecordingstoverify audioquality.Inthisway,youcanbesurethatyourresultswillbeasgoodaspossible.This is particularlyimportantifyouaregoingtouseaudiorestorationsoftwaretoprocessyour recordings.Audiorestorationsoftwaredependsondetailintheoriginalrecordingtodifferentiate musicfromunwantednoise.Thebetterthequalityoftheoriginalrecording,themoreaccurate willberesultoftherestorationprocess.

In some cases, you can make a test recording to your hard disk, for example to verify that the sound card is not being driven too hard and causing overload distortion. In other cases however, you will need to actually burn a CD in order to verify that all is well. For example, this is necessary to ensure that your left and right channels are not reversed. For these test recordings it is very useful to be able to use CD-R/W's rather than CD-R's. Unfortunately, CD-R/W's will not play on the majority of audio CD Players. Therefore, if you use CD-R/W's you may be restricted to auditioning the end results using the speakers system attached to your PC. In most cases this will be adequate but if your speakers are not of a good enough quality, you should consider using a pair of good quality headphones for these pre-mastering tests.

The Recording Chain



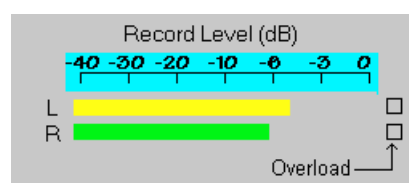
A/D Conversion

Digital recordings of an analogue source are made by sampling the analogue waveform and converting each sample to a numerical value. This process is known as analogue to digital (A/D) conversion. Note, the quality of the end result is determined by the number of bits used to express each sample value, and also by the rate at which the samples are taken. The CD audio standard specifies 16 bits per sample and a sampling rate of 44100 samples per second. 16 bits allow for a range of 2^{16} (65536) possible amplitude values and each sample has to be assigned to one of these 65536 steps.

Because the A/D converter only uses a finite number of steps, it is important that the analogue signal is presented at an appropriate amplitude if optimum results are to be achieved. If the signal is too small, the higher order bits will never be turned on and thus you may end up with only a 12 or 13 bit recording. Conversely, if the signal is too large, the A/D converter will be unable to assign a value to some samples because they are outside its range of possible values. In this case digital clipping occurs which is a severe form of distortion.

Setting the Record Level

To assist you in setting an appropriate level, most sound recording software provides you with a form of level meter which monitors the signal at the A/D converter input. WaveCorrector's Level Meter is illustrated below. By convention, 0 (zero) level is the level at which digital clipping occurs; and signal levels are expressed in decibels (dB) relative to that level.



Usually when recording, the sound level should be adjusted so that the loudest sections peak in the -3 to 0 section of the bargraphs. However, some sound cards with poor analogue front ends have a tendency to exhibit audio distortion at levels somewhat below this. In such cases, it is best to record at a lower level and then to digitally adjust the level after recording. (this is known as 'normalising') The best way to ensure an optimum recording level is to do some test recordings before burning any CD-R's. In this way, you can discover the appropriate recording level for your particular hardware components.

With most sound cards, you can adjust the recording level using the Windows 'Volume Control' (mixer) applet or any replacement applet which may be supplied with the card. The applet controls digital attenuators and switches which are built into your sound card. Note that some sound cards do not have the hardware to support all features and you may find that some controls are inoperative.

If your hardware pre-amplifier incorporates an output level control, you should use this in preference to the Windows applet control. In this case, set the applet control to maximum and adjust the recording level using the control on your pre-amplifier.

The Windows applet is selected by double clicking on the 'Volume' icon in the system tray. If the icon is not there, select Programs/Accessories/Entertainment/Volume Control. Having opened the applet, select Options/Properties and then select 'Adjust Volume For - Recording'. Then make sure that the 'Line' checkbox is checked. This enables a volume control for the sound card Line Input. Now check the 'select' checkbox under the 'Line' volume slider. If necessary, you can use the slider to set the recording level.

Now, open your recording program and adjust your recording level to a suitable level as indicated on the program's level meters.

Channel Alignment

In the process of interconnecting the various components in the recording chain, it is very easy for the left and right channels to become reversed. It is also the case that some CD-R burning software introduces a reversal of the audio channels if it is processing wave files recorded by incompatible sound recording software. To verify that your channels are correctly aligned, make a test recording to CD-R/W before committing your first recording to CD-R.

Track Splitting

Having recorded a vinyl album, you will probably want to split the resulting long wave file into separate files representing the individual tracks on the album. This will enable you to burn a CD such that the CD player can identify the start of each track.

Generally speaking, any wave editor program should be capable of performing the splitting function. However, there is a problem if you wish to burn the tracks without the 2 sec inter-track silence which is mandated in the red book standard. Some record companies ignore the standard and allow one track to follow on seamlessly from the previous track. This is particularly

important when the recording is of a live concert where you want the ambience to persist during the inter-track gaps. Most CD burning software also allows you to do this using the so-called 'Disc-at-Once' recording mode. However, because CD tracks are laid down in 588 sample packets, it is necessary to ensure that track lengths are an integer multiple of 588 samples. Otherwise the last packet of a track will either be truncated or padded out with zero (silent) samples and you will probably hear a glitch as the track changes.

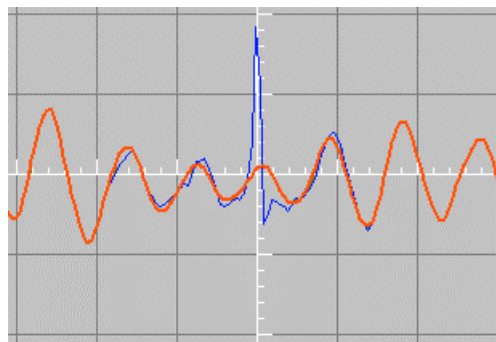
Ganymede's *WaveCorrector* is one of a number of programs which will perform the track splitting function whilst maintaining the 588 multiple requirement. As well as allowing you to split a wave file at arbitrary user-defined points, *WaveCorrector* also gives you the option of automatically splitting the file at points where the level falls below an adjustable 'silence' threshold.

Part3.VinylAudioRestorationusingWaveCorrector

OverviewofAudioRestoration

Vinyl is a relatively delicate medium which is easily damaged by the presence of dust and grit which becomes embedded in the record groove during normal play. A disc can also become damaged by the careless lowering of the stylus or by other hard objects. All these types of damage cause so-called 'impulsive noise' disturbances which produce sounds ranging from tiny high frequency ticks to loud unpleasant clicks and plops. Particularly annoying are the repeating clicks which occur when the damage has spanned several adjacent record grooves and which consequently repeat once per revolution of the record.

Audio restoration is the name given to the process of removing these disturbances and reconstituting the original waveform. The following illustration shows a typical click (in blue) overlaid by the restored waveform.



Audio restoration is a two-stage process. Initially the wave file is scanned using an algorithm which discriminates between wanted musical content and unwanted noise. This is a far from trivial task because some musical instruments, especially low frequency brass and reed instruments, have waveforms remarkably similar to typical clicks. The waveform can be analysed in either the time domain, the frequency domain, or a combination of the two. Generally speaking, the goal is to identify instantaneous deviations in the data which are statistically significant. These 'outlier' events are usually indicative of an impulsive noise spike.

The second stage involves excising the unwanted portion of the wave and replacing it with

approximation of the pre-damaged waveform. Generating the replacement waveform is another difficult procedure. If the noise spike is very short and only spans a few samples, then linear or bezier interpolation may provide a sufficiently accurate replacement. However, in the case of longer duration impulses, a more sophisticated approach is necessary if the noise is to be effectively masked. The techniques used to mask these longer impulses include:

- muting.
- inserting a combination of frequencies which the ear finds difficult to recognise.
- generating a waveform based on the frequencies present in the surrounding wave.

WaveCorrector uses the third of these options. The example illustrated above shows how the corrected wave matches up with the surrounding wave and blends naturally with it.

Mis-Operation of Audio Restoration Software

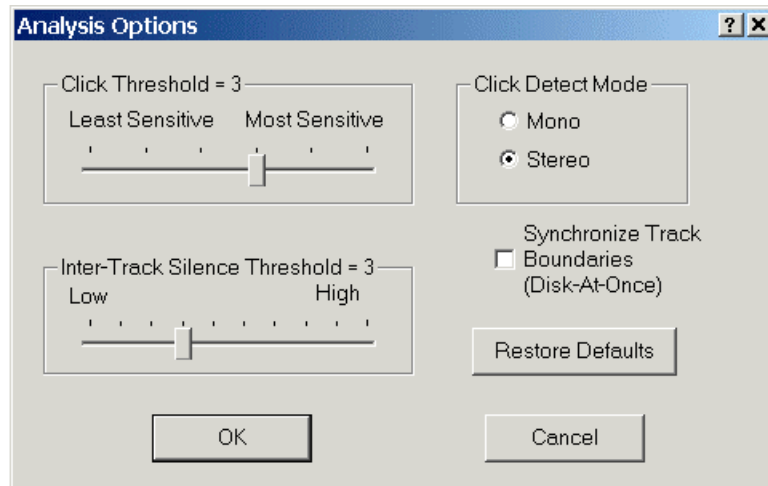
Because click detection is an imprecise process, it is quite common for audio restoration software to produce imperfect results. This is because the software must balance the conflicting requirements of detecting as many clicks as possible whilst at the same time not being triggered by musical forms resembling clicks. When this balance is incorrect, the result is:

- false negatives - the failure to detect and correct a click even though it is audible to the human ear.
- false positives - detecting and adversely modifying parts of the music where the ear does not perceive any clicks.
- a combination of both the above.

Ganymede's *WaveCorrector* software provides a number of features which allow the user to minimise these adverse effects. These features include the ability to re-scan selected blocks of the wave file as well as the facility to insert, delete and adjust individual click corrections. By these means, most of the problems usually associated with audio restoration can be overcome.

WaveCorrector User Options

WaveCorrector provides a minimalist set of user options for click detection. The *WaveCorrector* Options dialog shown below allows the user to set just sensitivity and detection mode. (Note, the other two settings affect track detection and are not covered in this tutorial.)



ClickThreshold

The click threshold can take values from 1 to 5 with a default value of '3'.

Note, you can also set the click threshold to '0'. This turns off click detection completely and allows you to use *WaveCorrector* simply for its track splitting functions.

The default setting (3) should be suitable in the majority of cases and novice users should use this setting whilst they gain experience of using *WaveCorrector*.

Settings 1 and 2 are the least sensitive settings and may occasionally be required if the source material is such that you need to globally reduce the number of 'false positives' being detected.

Settings 4 and 5 should only be used with care. If your source recording is exceptionally noisy with a very large number of clicks, then these settings will sometimes yield an improved result. However, this will be very dependent on the musical content. These settings reduce the *WaveCorrector*'s ability to discriminate between music and noise and therefore will only be useful if the musical content itself is relatively un-noise-like in its characteristics. Piano, strings and human voice can all be safely scanned at settings 4 and 5. However, if the music contains low frequency reed or brass instruments, cymbals or similar percussion instruments then these settings should be avoided.

In many cases it will be better to scan at setting 3 and then 'super-scan' those parts of the wave file which are still noisy. 'Super-scan' is one of *WaveCorrector*'s advanced features designed to allow the audiophile to enjoy better results than a purely automatic process is able to achieve.

Subsequent sections describe these advanced features in more detail.

ClickDetectMode

The default Click detect mode is 'Stereo'. In this mode each channel of the stereo pair is scanned independently and clicks on either channel will trigger a correction to be generated.

WaveCorrector also provides its so-called 'Mono' detect mode. This is only usable if the vinyl source is a **mono record** and if a **stereo cartridge** was used to create the digital recording. In such circumstances, it is possible to use the stereo difference channel (left minus right) to enhance the discrimination between music and noise. This is because a mono record should produce no difference channel signal and therefore *all* the difference signal is theoretically due to noise. It is recommended that you only experiment using this mode once you are confident using *WaveCorrector*'s default 'Stereo' mode.

WaveCorrector Advanced Features

On occasions, it is possible that *WaveCorrector* will over-correct or under-correct particular sections of the Wave File.

Over-corrected sections will exhibit distortion introduced by the correction process itself. Usually this will be manifested as the leading edges being taken off percussion instruments making their attack sound slightly duller than it should. Under-corrected sections will still have unwanted noise present after the file has been scanned.

With *WaveCorrector*, you can manually intervene to rectify these sub-optimal sections. The simplest method is to mark a block and then to either re-scan or delete the corrections in that block. At a more detailed level, you can insert, delete or adjust individual corrections. In order to carry out these actions, you need to navigate to the particular part of the wave file which requires manual intervention.

Navigation and Auditioning in WaveCorrector

WaveCorrector uses a slightly unconventional means of navigation which is described here.

To move directly to an arbitrary new location, single click with the left mouse button over a point in the Overview window. This will re-centre the main display on that point. Note, if there is an existing correction in the vicinity of the point clicked, the program will centre the display on that correction; otherwise it will centre on the point itself.

If the location you want to move to is already visible in the main window, you can double click over the point in the Main window to re-centre the display. As before, if a correction already exists in the vicinity of the point double clicked, that correction will be selected.

You can also click on any correction in the Correction List to immediately centre the display on that correction.

Use the horizontal scale control (or the numeric keypad cursor 'left' and 'right' keys) and the vertical scale control (or the numeric keypad cursor 'up' and 'down' keys) to zoom in and out to a suitable viewing scale.

By means of these navigation controls, you can quickly and easily move around the wave file to audition or edit the *WaveCorrector* output.

Use the audition controls to audition whatever is visible in the Main window. Note, if the Main window is zoomed in such that less than 2 seconds of waveform is visible, then the audition commands default to playing a 2 second clip centred on the main window.

You can also audition using the 'Play' controls. In this case, the entire current track is played, ie whatever is visible in the Overview window. During play, you can move to an arbitrary new location in the track by clicking over it in the Overview Window. When the end of the track is reached, play loops back to the beginning and repeats endlessly until the 'Cancel' button is pressed.

By means of these navigation and audition controls, you can quickly and easily move around the wave file to locate sections which might require manual intervention.

Block Operations

Block operations allow you to mark a block of the wave file and then to re-scan or delete corrections in the block.

To select a block, drag with the mouse in the Main window whilst holding down the left mouse button. The selected block is highlighted in blue.

NB, do **NOT** attempt to select a block whilst the mouse cursor is displayed as an E-Warrior. This form of the mouse cursor indicates that the mouse is hovering over the edge of a correction and if you press the mouse button at this point then 'Correction Adjust' mode is entered instead of 'Block Select' mode.

Having selected the block, you can now perform one of three actions:

- delete corrections - this deletes all corrections in the block and restores the original waveform.
- re-scan - this deletes all the existing corrections in the block and re-scans using a new click threshold. Thus you can selectively re-scan the block at a higher or lower sensitivity than the global setting for the entire file.
- super-scan - this leaves all the existing corrections in place and re-scans the corrected block to mop up any remaining clicks. Again, there-scan can be done at a higher or lower sensitivity than the global setting for the file.

Using these block operations, it is possible to quickly fine-tune the operation of

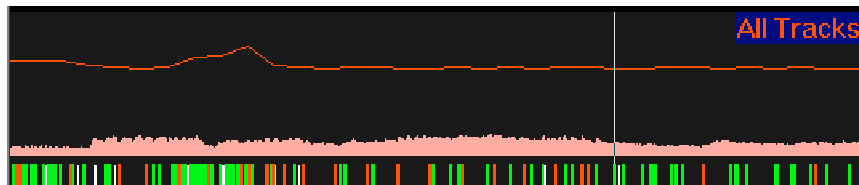
WaveCorrector

to accommodate sections of music which are particularly difficult to correct.

Finding False Positives

One of the main uses of the block operations is to remove the 'false positive' corrections which the program has applied to particular sections of a wave file music where the music is difficult to distinguish from noise. Sometimes these mis-corrections are difficult to locate since the audible effect is very often minimal. You may say that in such cases the mis-corrections might as well be ignored but if you are a perfectionist *WaveCorrector* provides a useful option called the 'corrections signature' to help you find them. To activate the corrections signature, select 'Signature' from the View menu.

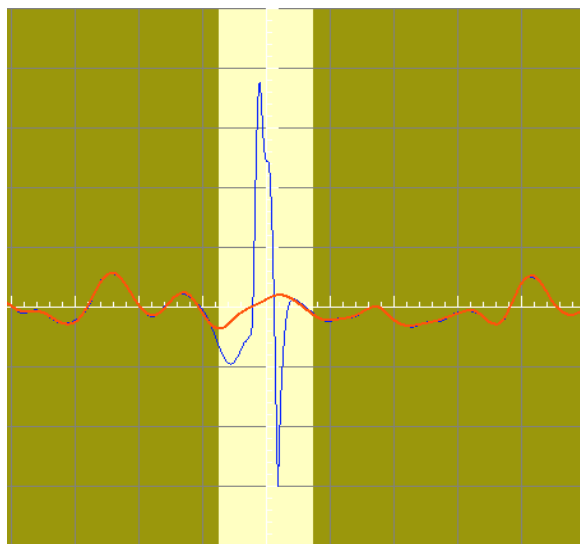
The signature is a thin red line which rises and falls to indicate the rate at which *WaveCorrector* is making corrections during the course of the wave file. A high correction rate during medium to high amplitude music is probably indicative of the false positives. Such areas should be auditioned and false corrections removed if necessary.



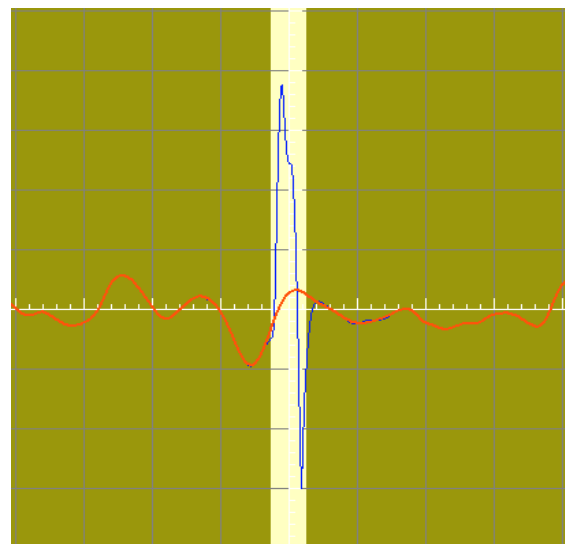
Adjusting Individual Corrections

At a finer level, it is also possible to manually adjust individual corrections. Adjusting a correction enables you to alter the shape of the corrected wave and hence to affect its audibility.

WaveCorrector automatically generates corrections based on its estimates of the precise position and width of each click. The *WaveCorrector* display indicates these click parameters by means of a light yellow band. By adjusting the position and width of the yellow band, you can alter the corrected wave. The display below shows an example of this. The left-hand image shows the corrected wave (in red) as automatically determined by *WaveCorrector*. The right-hand image shows the same wave after it has been manually adjusted. You can see that by manually adjusting the correction, you can obtain a better match of the underlying wave.



Before Adjustment



After Adjustment

To adjust the correction which is currently active, select the 'correction adjust' command either from the Corrections menu or by clicking its toolbar button. As a shortcut, you can also enter correction adjust mode by clicking the left mouse button over the edge of the click.

To adjust the width of the correction drag the correctionedgewhilst holding down the left mouse button or use the cursor up/down keys. To adjust its position, use the cursor left/right keys.

During Correction adjust mode, the screen background colour changes to blue-green and a confirmation box is displayed to enable you to accept or reject your adjustments.

Finding Critical Corrections

Wave Corrector categorises corrections according to the estimated severity of the underlying click. Generally speaking, only the most severe corrections are likely to require user adjustment. These are highlighted in red in the Correction List. Medium severity corrections are highlighted in yellow, and the least severe ones are highlighted in green.

You can jump immediately to the next or previous 'red' correction using toolbar buttons provided for the purpose. This enables you to quickly audition the critical correction to decide whether any manual intervention is necessary.

Deleting and Inserting Individual Corrections

It is also possible to manually delete and insert individual corrections.

To delete the currently active correction, select the Delete Correction command or use the keyboard shortcut (Delete Key). A confirmation dialogue asks you to confirm the deletion.

To insert a correction, select the Insert Correction command or use the keyboard shortcut (Insert Key). Then click with the left mouse button in the Main window over the point where you want the correction inserted. Once inserted, you can adjust the correction using the adjustment procedure described above.

Such manual corrections are highlighted in blue in the Correction list.

It is also possible to insert corrections 'on the fly' during track playback. To do this, simply hit the Space Bar at each instant you want a correction inserted. When you have finished playing the track, you will need to go back and adjust these manually inserted corrections to position them exactly over the clicks you want to correct. Before adjustment, these 'cued' corrections are highlighted in white in the Correction List. They are initially set to zero width and hence do not have any effect until they are manually adjusted.

END

Link to Internet Resources

Visit our linkspage at <http://www.ganymede.hemscott.net/links.htm> to find other tutorials and further information relating to the transfer of vinyl to CD-R.