Golden Ears Double-Blind Tester from Dome Music Technologies

The Golden Ears Bundle from Dome Music Technologies provides you with the tools to experiment with bit-depth reduction in digital audio, and to perform ABX double-blind listening tests in the comfort of your own home.

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Introduction

I've always had my suspicions about digital audio. How could you accurately represent an analogue signal (continuous in time and voltage) with a digital number (quantised in time and voltage)? My doubts were very much calmed by this fascinating video by Monty Montgomery:

[D/A and A/D – Digital Show and Tell](#)

Unfortunately, I don't have access to the test equipment that Monty demonstrates, so I was unable to play about with experiments he performed. However, I thought it might be possible to create some modules for Voltage Modular which would let me try it for myself with full real-time control.

Overview

The Golden Ears Bundle allows you to hear the effects of reduced bit-depth resolution on any input signals. If you've ever wondered if CD quality is good enough for the distribution of mixed and mastered tracks, you can hear the effects for yourself within the Voltage Modular environment. You can hear the difference between dithering and truncation, and try different probability density functions in the dithering noise signal. Finally, you can use the ABX Tester module to run a series of double-blind listening tests by yourself to check if you really have audiophile-quality 'Golden Ears'!

Note that Golden Ears only allows you to hear the effects of different bit-depths. As Voltage Modular runs at a constant 48kHz sample rate, there is no way to compare the sounds of 48kHz vs higher-resolution formats such as 96kHz or 192 kHz.

Useful Additional Modules

One VST plug-in which I found ultra-useful is the [Voxengo SPAN spectrum analyser](#). It is completely free-of-charge, but is extremely professional in its facilities. See the effects of quantisation distortion, dithering and bit-depth reduction in real time!

[Waverley Instrument's AF Player](#) is a great way to import and play audio sound files within the VM environment. It will faithfully reproduce 24-bit WAV files, which you can then proceed to destroy using bit-depth reduction! AF Player is also completely free-of-charge.

Bit Reducer Module

The Bit Reducer Module quantises the stereo input signal in steps from 1-bit to 24-bits. There is a dither noise input and attenuator. Finally, there are three outputs which let you compare the original signal against the quantised one.

Inputs and Bit Depth Control

The Bit Reducer Module has stereo inputs and two independent (left / white and right / red) processing channels. It can also be used as a monoaural effect by selecting one channel and ignoring the other.

The Bit Depth knob selects how many bits of resolution the quantised output uses. The range available is from 1 bit up to 24 bits. The input signal is rounded to the nearest discrete voltage level available for that bit depth range. For example, if 4-bit quantisation is used, there are only 16 (2 to the power of 4) discrete voltage levels available to represent the continuous input signal. This leads to the generation of 'quantisation noise' at a level of -24dB, and 'harmonic quantisation distortion', which produces unwanted overtone frequencies.

The number of discrete voltage levels used for quantisation can be calculated by the formula:

Discrete levels = 2 ^ (bit depth) + 1

Due to the way the Bit Reducer Module works, there is actually one extra discrete level than standard analogue-to-digital converters (ADCs). Therefore, at 1-bit quantisation, there are three discrete voltage levels: one at -5V, one at 0V, and one at +5V. At 16-bit quantisation, there are 65537 voltage levels, equally spaced between -5V and +5V.

Dither Noise Input and Attenuator

Before quantisation is applied, you have the option to add dither noise to the input signal. The TPDF Noise Module is the ideal source for dither noise, but any input signal may be used instead. The attenuation slider allows you to set the dither level from 0 (fully left) to 2 Least Significant Bits (fully right). As the main bit depth control is increased in value, the relative amplitude of the dither noise will decrease automatically.

Outputs

The 'Processed' output is the signal which has been sent through the dithering and quantisation steps.

The 'Unprocessed' output is an exact copy of the input signal.

The 'Difference' output is the Unprocessed output minus the Processed output. As bit depth is increased, the difference signal decreases in amplitude. You can use the Null Tester Module to boost the difference signal when using large values of Bit Depth.

The TPDF Noise Module

The TPDF Noise Module provides sources of white and blue noise with selectable Probability Density Functions (PDFs). It was designed to be used as a source of Triangular Probability Density Function white noise for dithering purposes in the Bit Reducer Module. Uncorrelated stereo TPDF noise can be generated by running two instances of the module in parallel – one providing noise for the left channel and one for the right channel.

White Noise Output

The White noise output can be switched between Rectangular PDF (to the left), and Triangular PDF (to the right, default). White noise has a flat frequency response across the entire audio spectrum. If RPDF white noise is used as input to a Sample & Hold module, the random output voltages will have equal probability within the range -5V to +5V. If TPDF white noise is used instead, there is much higher probability that the random output voltages will be close to 0V, and lower probability of being close to the +/-5V extremes.

Blue Noise Output
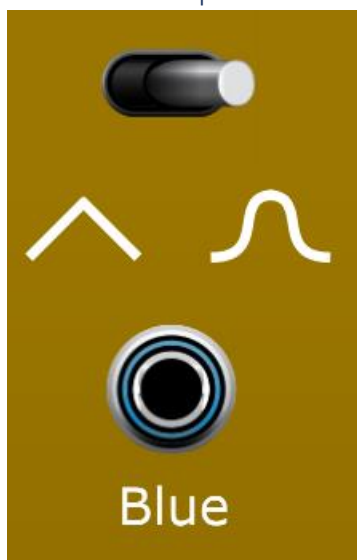
The Blue noise output can be switched between Triangular PDF (to the left), and Gaussian PDF (to the right, default). Blue noise has greater energy towards the upper end of the audio spectrum, and thus provides a rudimentary form of perceptual 'noise shaping' when used as a dithering source. Gaussian PDF noise has an even greater tendency towards 0V output than Triangular PDF, although there is still a finite probability of experiencing voltage outputs very close to +/-5V.

ABX Tester Module

The ABX Tester Module allows you to switch between two stereo inputs to determine if you can perceive any difference between them. For example, you could use the Processed and Unprocessed outputs of the Bit Reducer Module, and see if you can tell any difference between a double-precision floating point signal and one which has been quantised to 16 bits.

Input Selection Controls
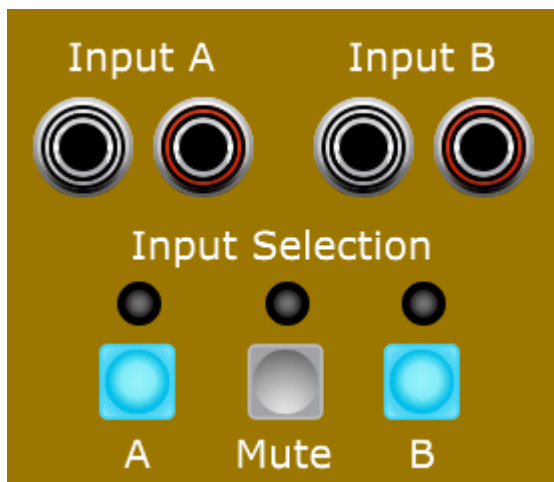
The module defaults to 'Monitor Mode', where you can audition the two input signals at will. There are two stereo inputs, A & B. You can select which signal is passed to the stereo Output jacks by pressing Input Selection button A or B. In Monitor Mode, an LED above each button shows which input channel is currently selected. You can also choose the "Mute" button, which silences the output.

The Test Start and Answer Controls
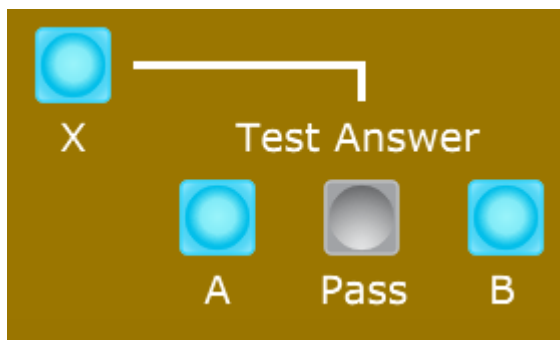
When you are satisfied that you can tell a difference between the two signals in Monitor Mode, you can switch to 'Test Mode' by pressing the 'X' button. This will select Input A or Input B at random and send the signal to the Output jacks. However, the Input Selection LEDs are blanked so that you cannot tell visually which channel is currently being heard. The Input Selection buttons are also disabled at this time. You must choose one of three options to return to Monitor Mode:

1. Press Test Answer A button if you believe that you are hearing Input A.
2. Press Test Answer B button if you believe that you are hearing Input B.
3. Press the Pass button if you are unable to tell which input you are hearing.

In all cases, the module will return to Monitor Mode and the Input Selection LEDs will indicate which input was heard during the previous test. If you made an explicit choice of Input A or Input B, your result will be tallied and displayed in the Test Results Panel. If you chose 'Pass' instead, then your result is not tallied and you simply return to Monitor Mode.

Test Results Panel
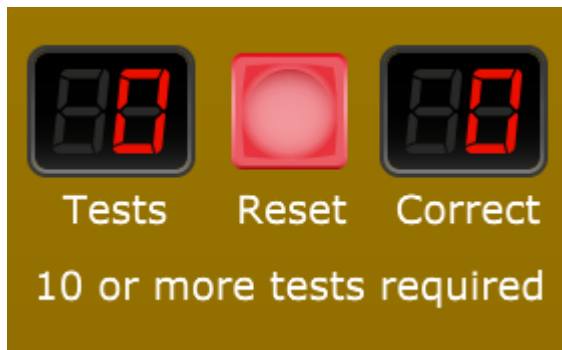
The Test Results Panel keeps track of the number of tests you have run and the number of correct answers you entered. The Tests and Correct seven-segment LED counter displays can record up to 99 each. The red Reset button in the middle resets both the Tests and Correct counts to zero and returns the module to Monitor Mode.

The test status text below the counter displays ("10 or more tests required") provides an indication of the statistical significance of the current test run. The module is configured to report a confidence value of >95% for runs of between 10 and 25 individual tests. Test scores necessary for this confidence value are shown in the table below:

Number of Tests	Min Correct Answers	Number of Tests	Min Correct Answers
10	9	18	13
11	9	19	14
12	10	20	15
13	10	21	15
14	11	22	16
15	12	23	16
16	12	24	17
17	13	25	18

If fewer than 10 tests have been executed, the message "10 or more tests required" is displayed in white.

If more than 25 tests have been executed, the message "25 tests are enough!" is displayed in magenta.

If you have recorded enough correct answers, the message "Confidence > 95% !" is displayed in green.
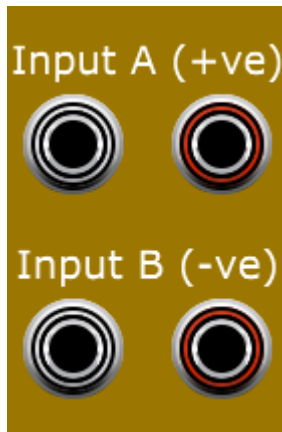
If you have recorded insufficient correct answers, the message "Confidence < 95%" is displayed in dark red.

Null Tester Module

The Null Tester Module calculates the difference signal of two stereo inputs and amplifies the resultant signal for monitoring on the Difference Output jacks.
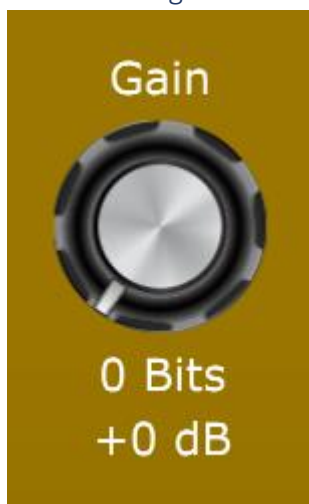
Differential Signal Inputs

The Null Tester Module has two stereo inputs:

Input A is the non-inverting input. If you want to use the Null Tester as a straightforward amplifier, connect your signal to Input A only, and leave Input B disconnected.

Input B is the inverting input. The signal at Input B is subtracted from the signal at Input A before being sent to the gain stage. If you want to use the Null Tester as an *inverting* amplifier, connect your signal to Input B only, and leave Input A disconnected.

The Gain Stage

The Null Tester can amplify the differential input signal from 0dB up to 144dB in 6dB steps. The Gain knob is calibrated in integer bits (from 0 to 24). Each bit of amplification represents a doubling in signal amplitude (equivalent to a gain of 6dB).

Bit Depth Attenuator
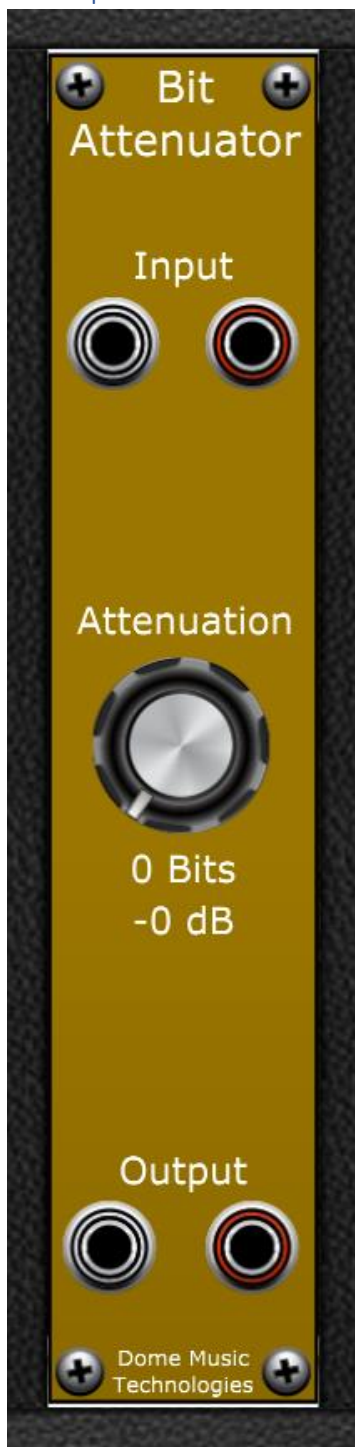
The Bit Depth Attenuator Module takes a stereo input and attenuates it from 0dB to -144dB in 6dB steps.

The Attenuation Stage
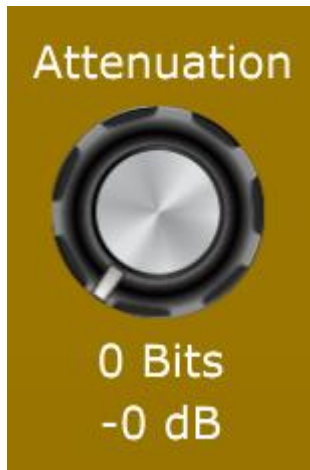
The Bit Depth Attenuator Module can attenuate the input signal from 0dB down to -144dB in 6dB steps. The Attenuation knob is calibrated in integer bits (from 0 to 24). Each bit of attenuation represents a halving of signal amplitude (equivalent to a gain of -6dB).

Further Information

Wikipedia has many good articles on digital audio, quantisation, dithering and ABX testing. Here are some good starting points:

Digital Audio

Quantization (Signal Processing)

Dither

Triangular Distribution

Null Hypothesis

Statistical Significance

Blinded Experiment

ABX Test

YouTube Videos:

D/A and A/D – Digital Show and Tell by Monty Montgomery

Sound By Numbers: The Rise of Digital Sound by Technology Connections

Nyquist-Shannon; The Backbone of Digital Sound by Technology Connections

If you would like to see some evidence-based reviews of 'audiophile' gear, and its manufacturers, I strongly recommend Amir Majidimehr's Audio Science Review Website and YouTube Channel:

Understanding FFT in Audio Measurements

Audio Blind Testing and Listener Training

Audio Blind Testing – You Are Doing It Wrong!

Understanding Audio Dynamic Range / SNR (Part 1)