ANN White Paper

What is ANN

ANN(Audio Neural Network) is the latest modeling technology from Sinco's research team.

As well known, the overwhelming majority methods of nonlinear modeling can be divided into two ways which is so called **White box** and **Black box**. Even the method based on **Neural Network(AI)** has been introduced into nonlinear modeling in the last decade. Each theories has its own advantages and disadvantages. The **ANN** take advantages of each theories' strengths, and it delivers more dynamic, deep, fully tonal feel.

White box

What is white box

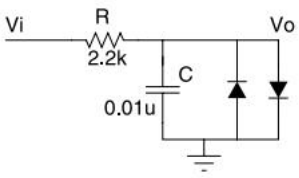
The **White box** explains a system by the detail '**Map**' of its inside, just like we run a maze with the help of its map. In practice, the details of pedal's component parameters will be all involved into mathematics modeling, then solving a series of integro-differential equations through **numerical methods**, like **runge-kutta**, under an extremely high sampling rate.

advantages

Accurate tonal details. Because of its highly mathematics modeling, all modeling errors come from its numerical calculation process, and it converges to white noise at a very low level, which is decided by sampling rate.

disadvantages

Mass-Computation. As an example, a simple diode circuit subsystem can be described



as :

$$V_o{}' = f(t, V_o) = \frac{V_i - V_o}{RC} - \frac{2I_s}{C}\sinh\left(\frac{V_o}{V_i}\right)$$

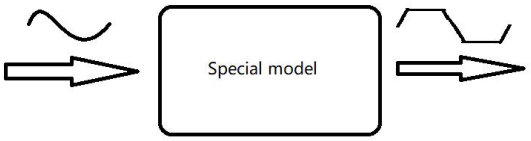
According to **runge-kutta** method, after highly sampling(like 48 * 256 KHz) the analog signal, we would calculate 4 times $f(t_{i,j}, V_o)|_{(i,j)=\{(0,0),\left(0,\frac{1}{2}\right),\left(\frac{1}{2},\frac{1}{2}\right),(1,1)\}}$ and weighted summed together to approximating $V_o{}'$, which is known as a differential term. As a result, this simple diode subsystem will contribute to nearly 1G mips cpu consumption. Although with the help of **parallel dsp** or **wave digital filter designing**, it's not easy to modeling a complex circuit on an embedded system.

Over-reliance on circuit diagram. As we can see above, **white box** must have all the details of circuit diagram, which limit it to give a general solution.

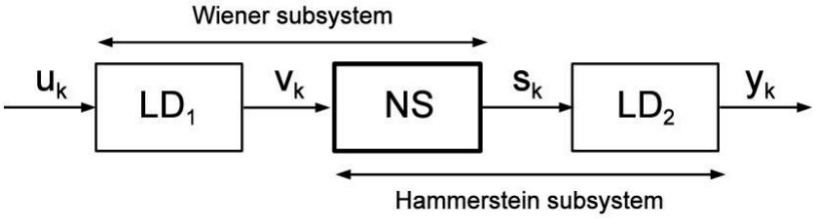
Black box

What is black box

Instead of researching into the circuit diagram, when modeling by **black box**, the target system will be automatic learned in terms of inputs and outputs, without any knowledge of internal workings. Just like we put a face towel on someone's face, the towel will slowly sink to the contours of his face under the power of gravity.



The most import part of **black box** is the selection of black box model, which decide the final tonal characteristic of the output signal. As well known, the mostly used is the **Wiener-Hammerstein** model shown below:



The front part of this model is called **wiener subsystem** and the end one is called **hammerstein subsystem**. These two components both have an independent linear system , LD_1 and LD_2, and share a nonlinear system NS. LD_1 or LD_2 can also be treated as so-called **EQ** and NS, the most important one, contributes to nonlinear transformations.

advantages

Automatic learning. Once the target signal and referring signal have been prepared,

the **wiener-Hammerstein** model can automatic adjust its internal parameters to fit the target signal.

Universal applicability to multiple devices. Outstanding NS model, especially with high degree of freedom, can better reflect the tonal characteristic in terms of frequency and phase.

disadvantages

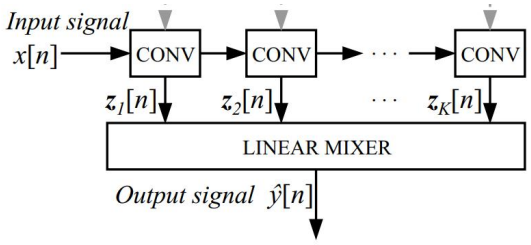
Model complexity. As we sayed above, we need high degree of freedom to enable the model to fit target devices. So how and where to add more correct mapping faction nodes in the whole NS system is complex. Maybe we can learning **BOSS** series well with model A, but it doesn't works with **JS** series. In order to be compatible with various series, the model A need be more and more complex.

Unable to perceive the variable circuit component. As example, we turn the knob to the middle and start our learning process. Once the model learning has finished, all the parameters internal can only fit this situation, and the learning process has to restart if we change the knob.

Neural Network(AI)

Neural Networks(AI) has got a rapid development and been used in many field in the recent decades. Because of its superb learning ability, naturally, some learning models, like **WaveNet-Style** and **Long Short-Term Memory (LSTM)**, have been introduced by researchers.

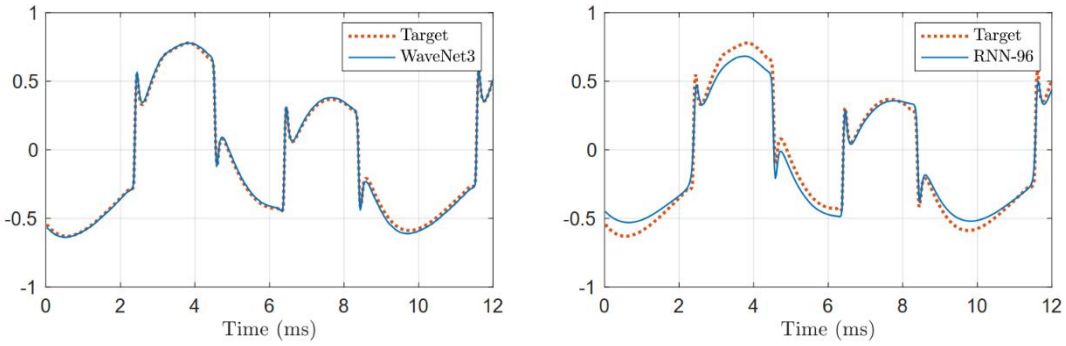
WaveNet-Style Model. It consists of a series of convolutional layers. The input signal is given to the first convolutional layer. The convolutional layers apply linear filtering and a nonlinear activation function to the signal.



It is worth noting that each convolutional layers will be dilated by 2 times from one to the other, which provides a wide receptive field. At the same time to some extent, this process can be seen as sub-band analysis which has more frequency resolution, so it is more possible to learning details of what the circuit happened internal.

Long Short-Term Memory (LSTM). It can also be seen as a RNN model**.** A key difference between **WaveNet-Style Model** and **LSTM** is that **LSTM** has a state. The state is used and updated at each time step. This means that the **LSTM** can operate with just a single sample as input at each time step, whilst still using information from previous time steps. Just like the difference between **fir** and **iir**. **LSTM** has less cpu assumption, but with less frequency

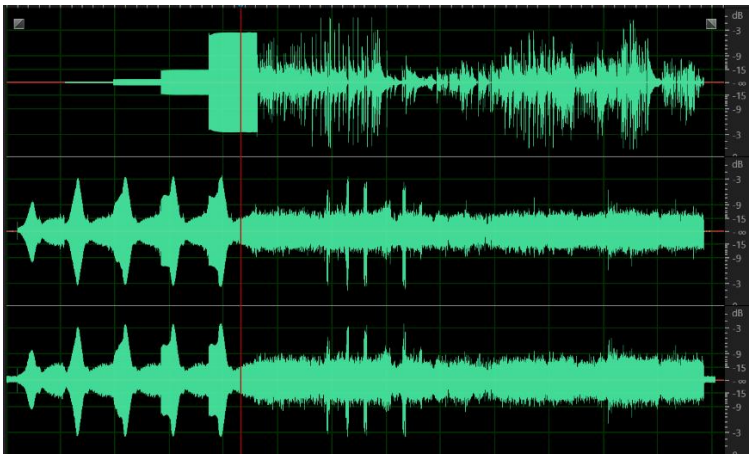
resolution.



Neural Networks(AI) seem to be very suitable for circuit modeling. But unfortunately, not matter **WaveNet-Style Model** either **LSTM**, because of the models' statistical properties and time-domain processing, the dynamic range controlling and high frequency harmonic component analysis of high distortion signal is still hard to handling.

ANN

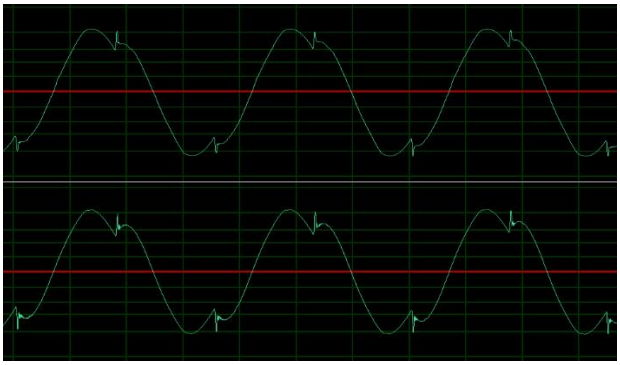
ANN(Audio Neural Network) take advantages of each theories' strengths. We introduce the Sinco in-house **Waveform Automatic Nonlinear Tracking(WANT)** algorithm to learn the dynamic range characteristic as precise as possible. We have tested the model ability on KPS 5150 AMP at high gain.



Top. Original signal Mid. Modeling signal Bot. Target signal

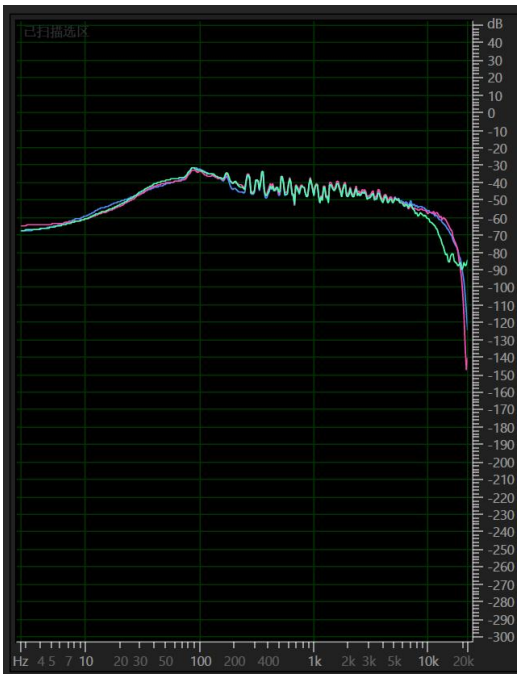
As the figure shown above, the dynamic range of first sweeping signal has highly fitted.

The time domain pointwise tracking ability of **ANN** is also be guaranteed by the using of simplified **WaveNet-Style** model. The figure shown below is the distortion at 62.5hz.



Top. Modeling signal Bot. Target signal

Lastly, in order to handling high frequency harmonic component, we introduce the Sinco in-house **High Harmonic Automatic Generation**(**HHAG**) algorithm to make signal to be well-stacked at high frequency area.



As the figure shown above, the target signal is marked as blue line, non-**HHAG** modeling signal marked as green and **HHAG** modeling signal marked as pink. It is obvious that **HHAG** has more high frequency harmonic response 11Khz(half the Nyquist Frequency) above and is more close to target signal in frequency domain. Despite the possibility of phase distortions caused by **HHAG**, we can just ignore these in perspective of human auditory sensation.