OCD EMULATOR

COMBINING BLACK-BOX AND WHITE-BOX MODELS TO EFFICIENTLY EMULATE AUDIO ANALOG CIRCUITRY IN REAL TIME

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FULLTONE OCD PEDAL

Overdrive pedal released by FullTone in 2004.

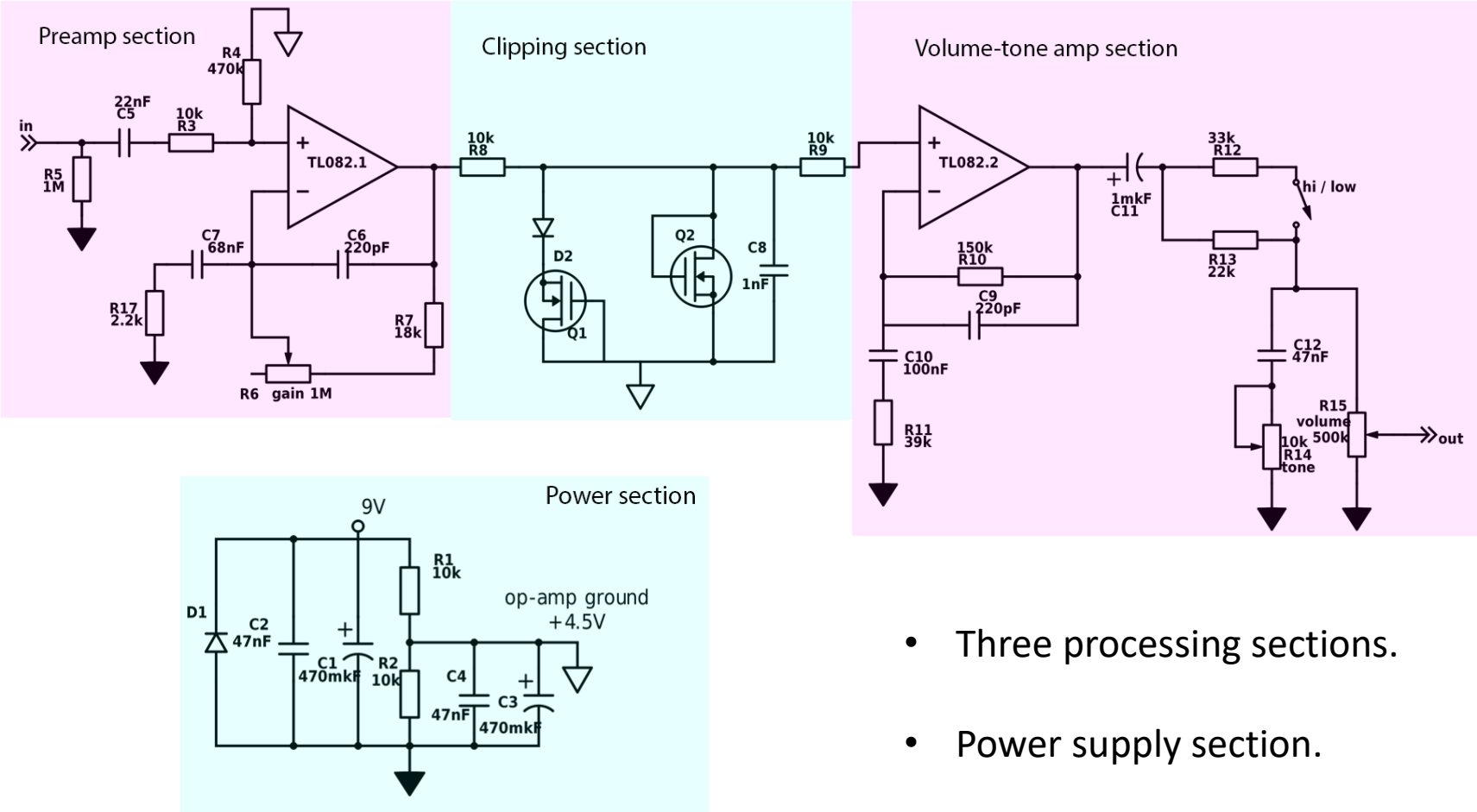
Three controllable knobs:

- Drive (preamplifying stage gain).
- Tone (tone control stage cutoff frequency).
- Volume (output stage level).

Two controllable switches:

- HP/LP (tone control stage cutoff frequency).
- Bypass (true bypass of the circuit).

FULL SCHEMATICS

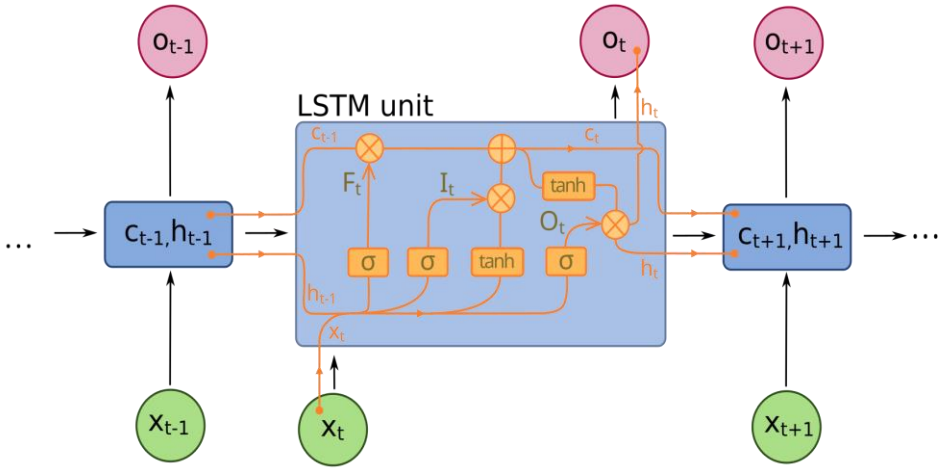


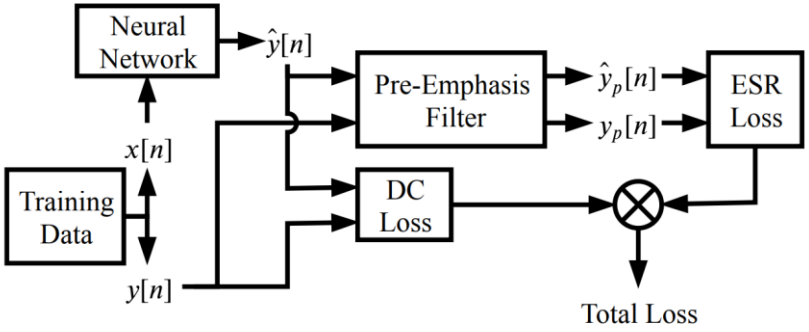
- Three processing sections.
- Power supply section.

RNN-BASED DISTORTION CIRCUIT

The circuit block that includes the preamp section and the clipping section is modelled with a RNN:

- Hidden size: 32.
- Unit type: LSTM.
- Training data prefiltering: high-pass.
- Initial learning rate: 0,005.
- Loss function: ESR and DC.
- Training epochs: 250.

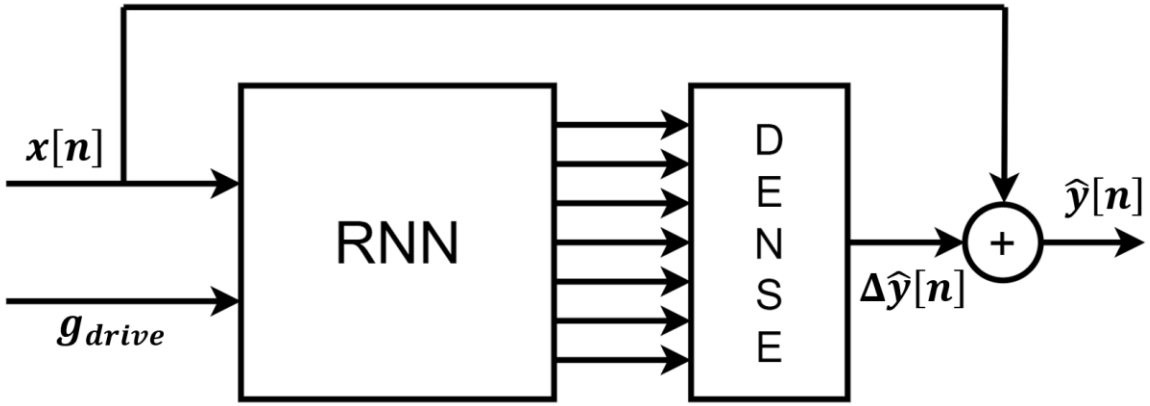




RNN-BASED DISTORTION CIRCUIT

The trained model of the distortion circuit behaves as follows:

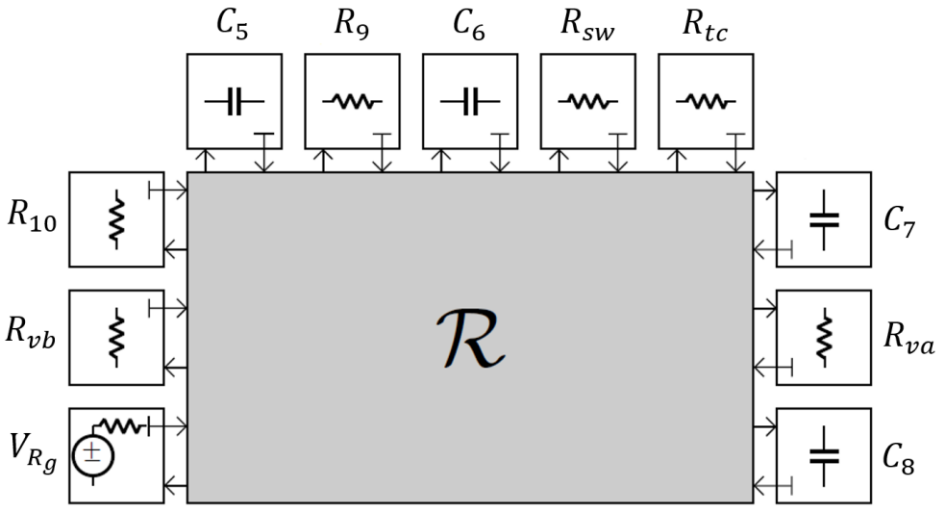
- The recurrent layer takes two inputs (clean sample + drive parameter).
- The final dense layer returns a single output (prediction difference).
- The clean sample must be added back to the prediction difference to obtain the distorted output.

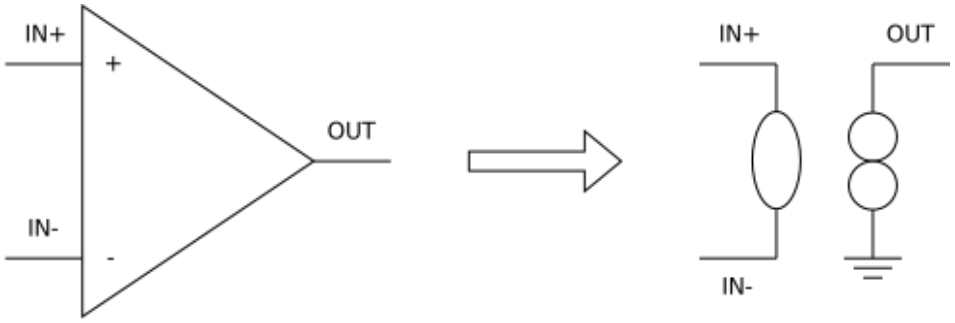


WDF-BASED TONE CONTROL

The volume-tone amp section is instead modelled with a single scattering junction WDF :

- The circuit is linear if the opamp can be considered ideal.
- The nullor-model then can be adopted.





- The ideal voltage source can be adapted with a tiny series resistance ($R_g = 1\ \mathrm{n\Omega}$).

WDF-BASED TONE CONTROL

All the elements in the circuit can be adapted and so the circuit can be discretized as a simple delay line:

- Resistive voltage sources become the actual input samples.
- Resistors become reflection free ends.
- Capacitors become unitary delays (all-pass filters).
- The scattering matrix (single junction) is constant as far as the sampling frequency remains constant.

$$\begin{cases} v[k] = \dfrac{a[k] + b[k]}{2} \\ i[k] = \dfrac{a[k] - b[k]}{2Z} \end{cases}$$

$$b_{V_{R_g}}[k] = V_g[k]$$

$$b_R[k] = 0$$

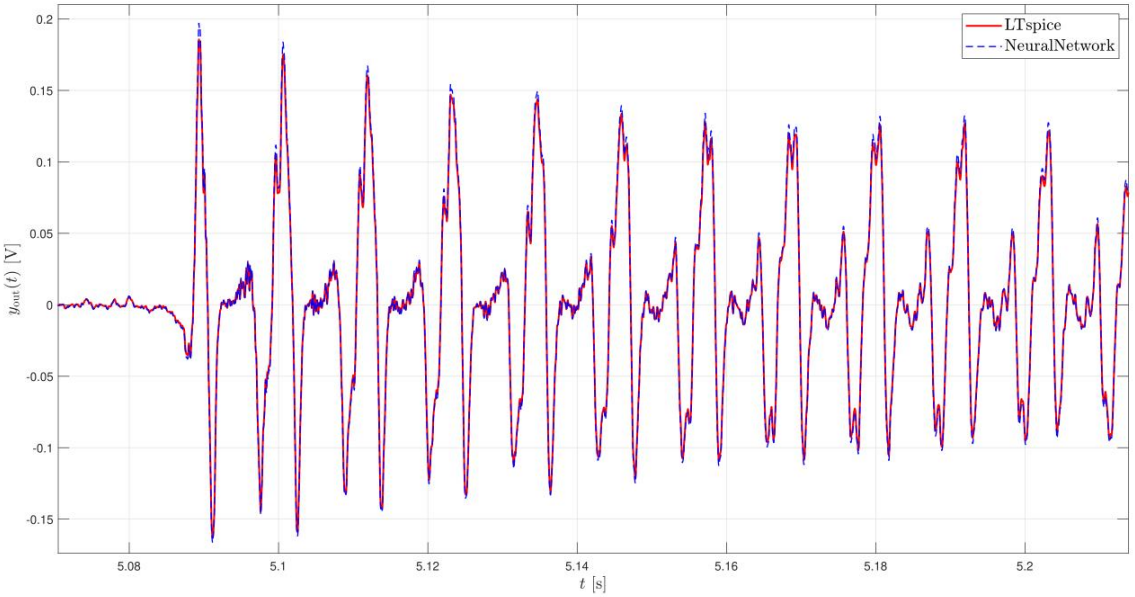
$$b_C[k] = a_C[k-1]$$

$$\mathbf{S} = \mathbf{I} - 2\mathbf{Z}\mathbf{B}_I^T(\mathbf{B}_V\mathbf{Z}\mathbf{B}_I^T)^{-1}\boldsymbol{B}_V$$

NEURAL NETWORK EVALUATION

Neural Network with respect to LTspice simulations of the distortion circuit:

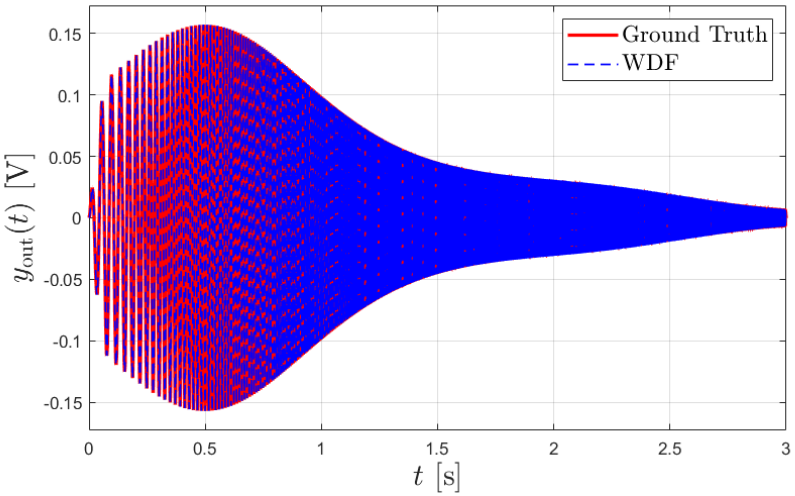
- Approximates really well the overdrive non-linearities.
- Gives an average absolute error around $5 \cdot 10^{-3}$ V.

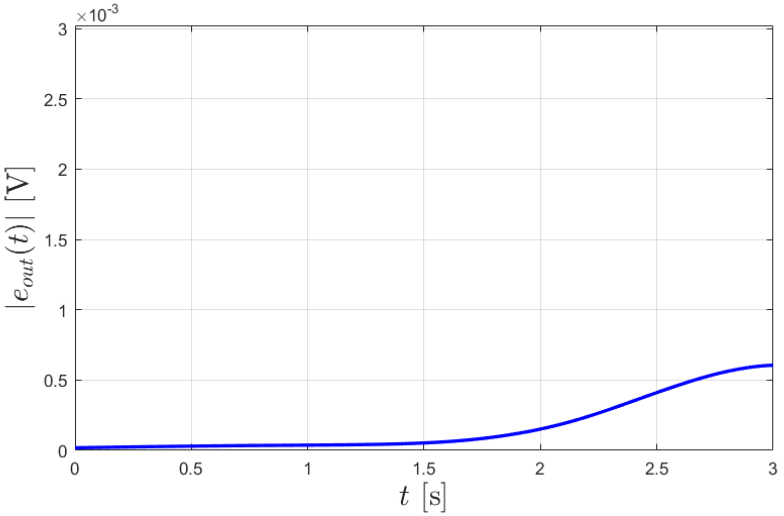


WAVE DIGITAL FILTER EVALUATION

Wave Digital Filter with respect to LTspice simulations of the tone control circuit:

- Approximates really well the behaviour over the entire audible frequency spectrum.
- Gives a maximum absolute error around $6 \cdot 10^{-4}$ V.





TECHNICAL/QUALITATIVE REMARKS

The software meets the following requirements:

- Usable in real-time applications.
- Only 0.9% resource usage (Cockos Reaper).
- Satisfactory simulation of the real overdrive effect (perceptual standpoint).
- Fully coded GUI (no binary data employed).
- Easy and intuitive to use.

GOALS ACCOMPLISHED

A “grey-box” approach facilitates virtual analog modelling:

- Fully virtualized procedure (no physical devices needed).
- Simulated datasets allow saving money (equipment) and time (recording).
- Partial black/white-box modelling reduce dataset size (training time).