# DDSP Guitar Amp: Interpretable Guitar Amplifier Modeling

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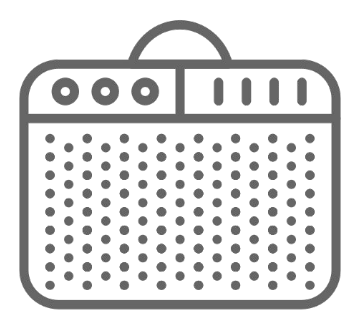
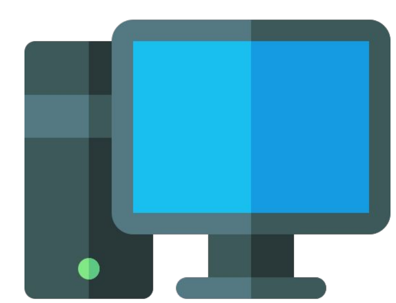
# Introduction

# Guitar amplifier modeling

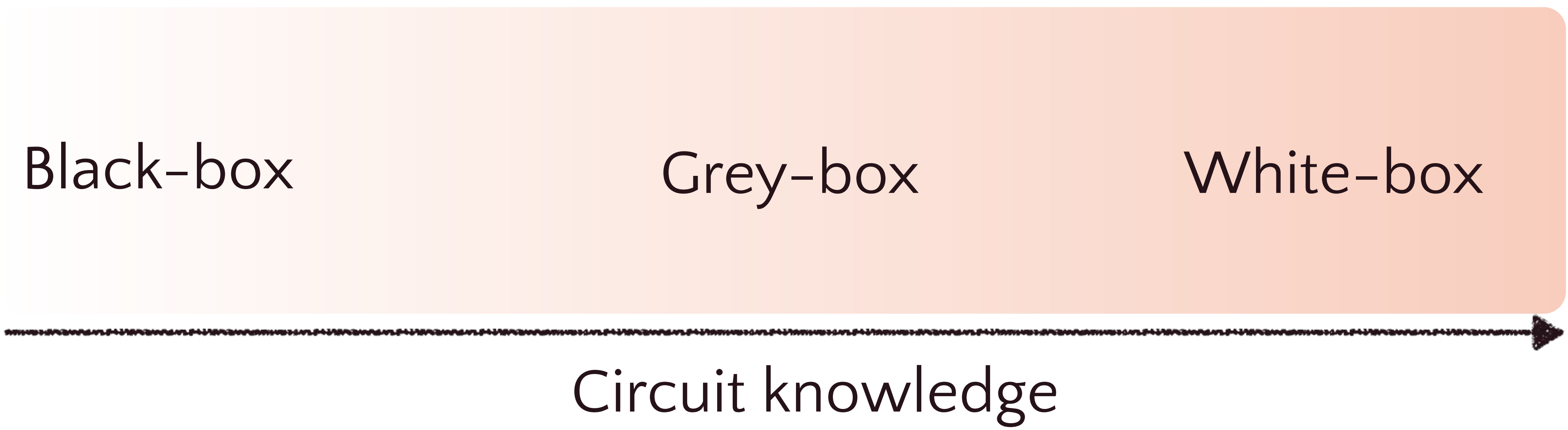
- Emulate the exact behavior of guitar amp in digital world





# Typical methods

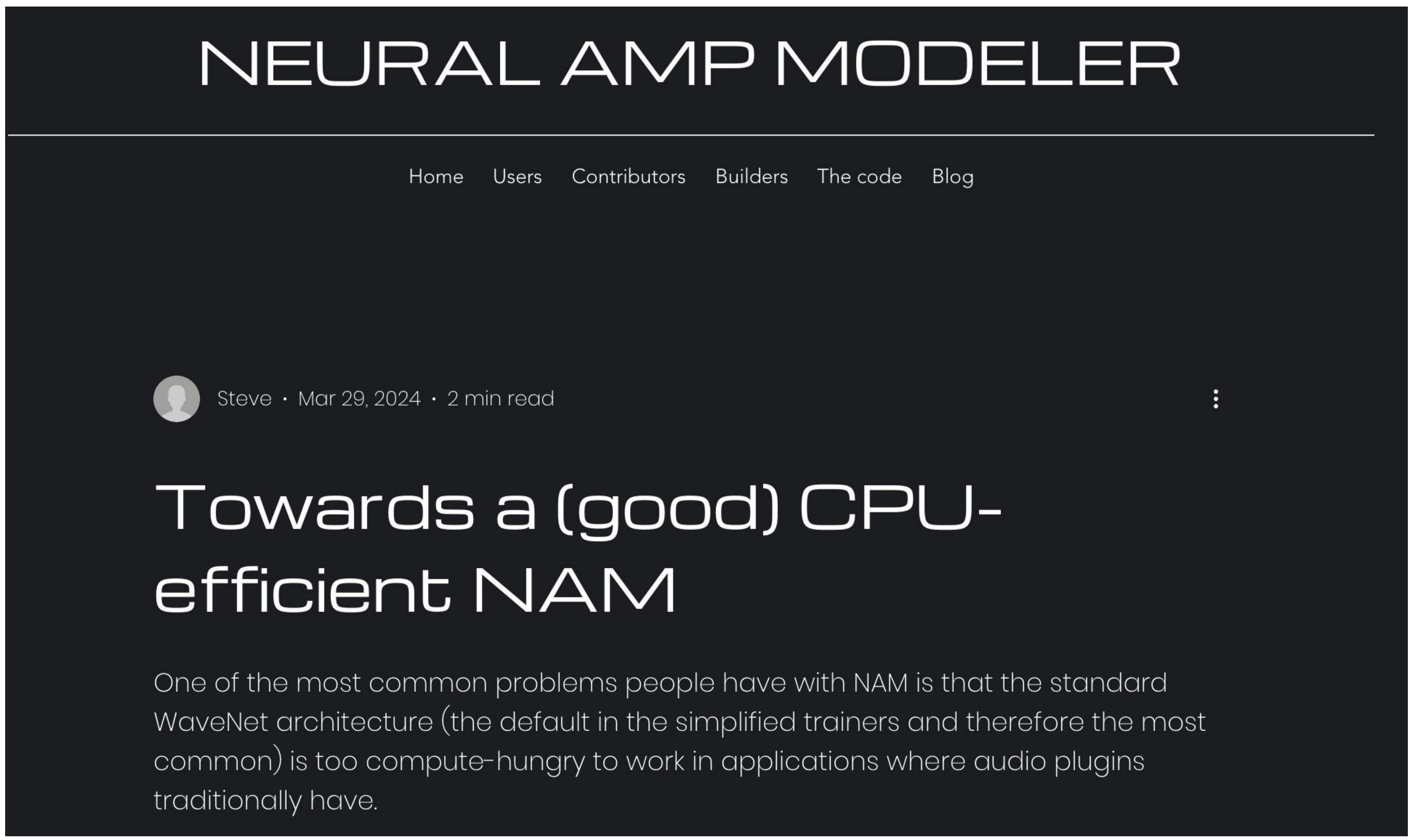
- Typical methods:




- In recent years, black-box (neural network-based) models have shown success in modeling guitar amplifier

# Challenges

- High Computation Cost




from Neural Amp Modeler: https://www.neuralampmodeler.com/post/towards-a-good-cpu-efficient-nam

- Non-interpretable
  - Hard to tune the sonic sound characteristics
  - Hard to understand the tone

# In this work

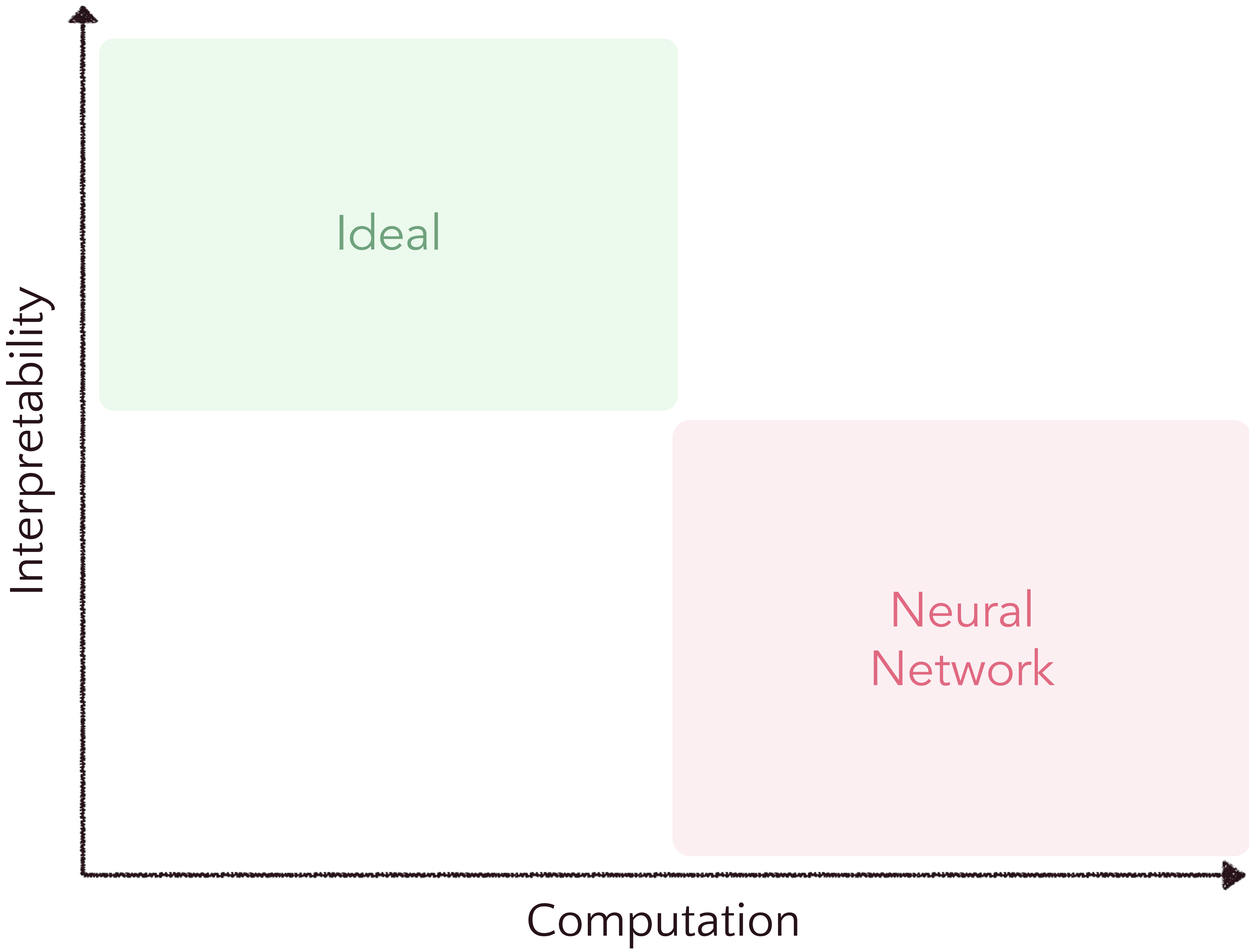
- Goal: Low-computation cost & interpretable guitar amplifier modeling model

Low-computation

Interpretable

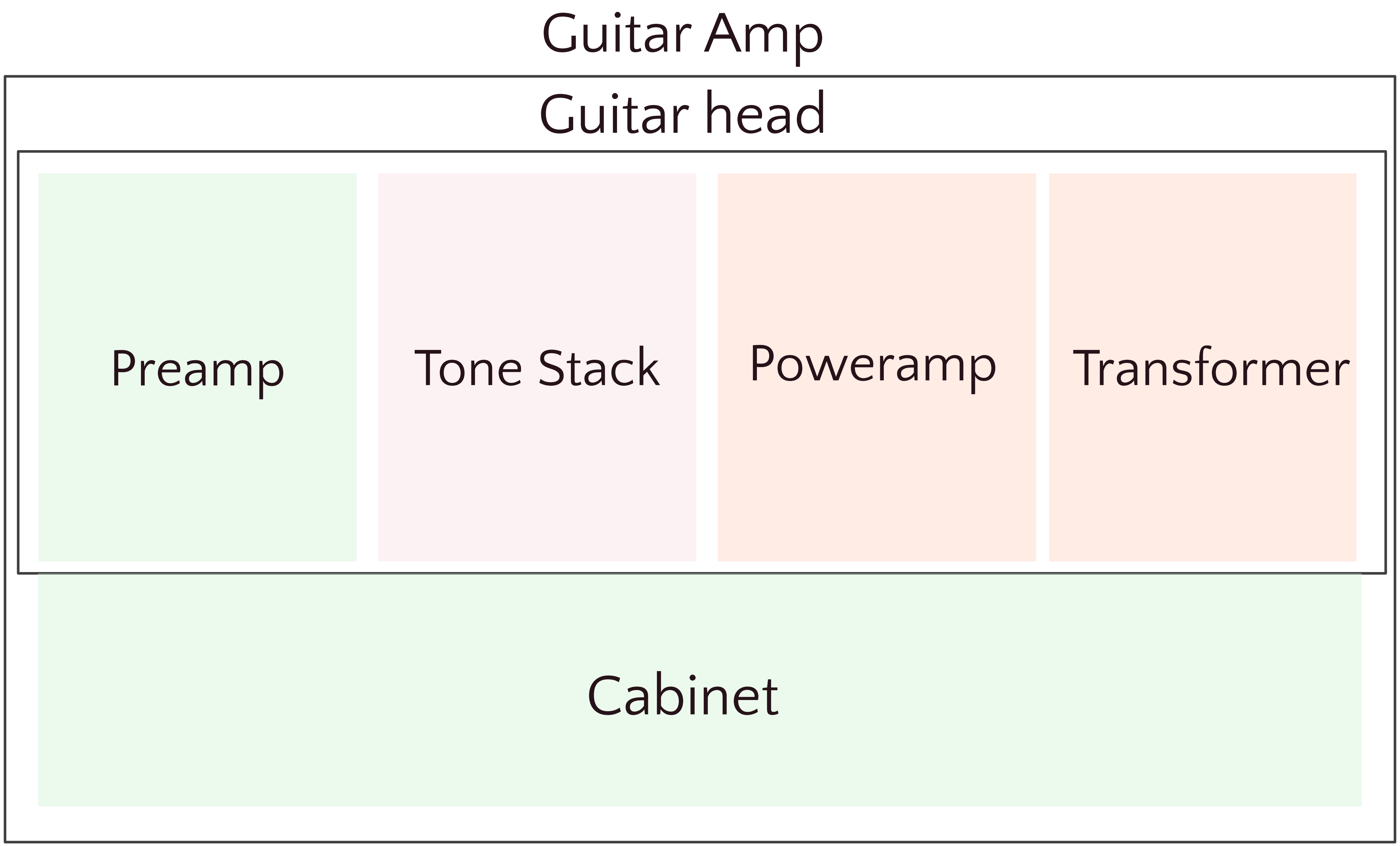
- We named it: **DDSP Guitar Amp**

# Comparison with NN



# Background

# Delve into physical guitar amp



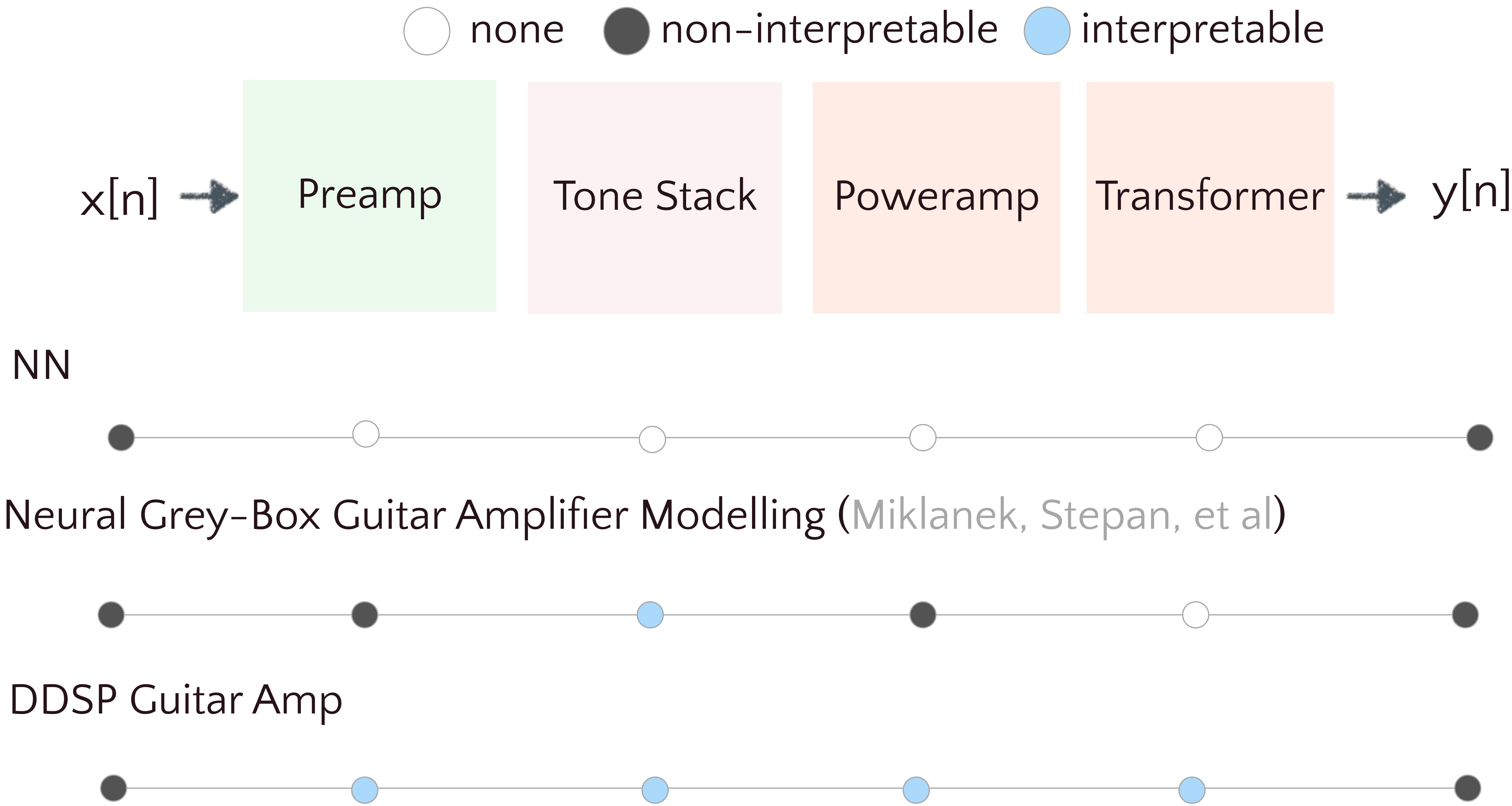


- We only focus on guitar head in this work

# Guitar head

| | |
|---|---|
| Preamp | Determines the primary tone of the amp |
| Tone Stack | Alter the frequency response |
| Poweramp | Tone enhancement |
| Transformer | Dynamics control and further coloring |

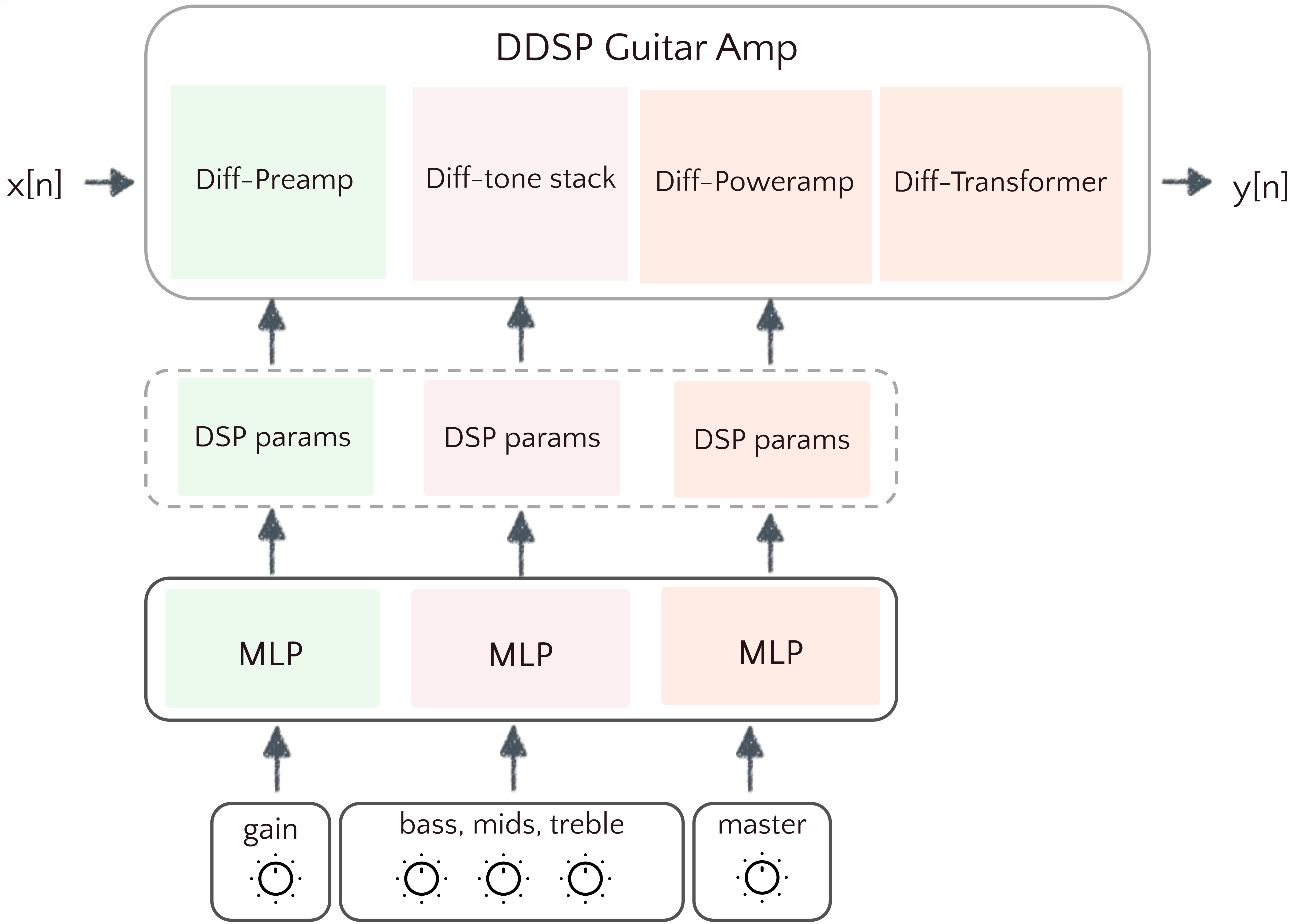
# Guitar head emulation




Miklanek, Stepan, et al. "Neural grey-box guitar amplifier modelling with limited data." *International Conference on Digital Audio Effects*. Aalborg University, 2023.

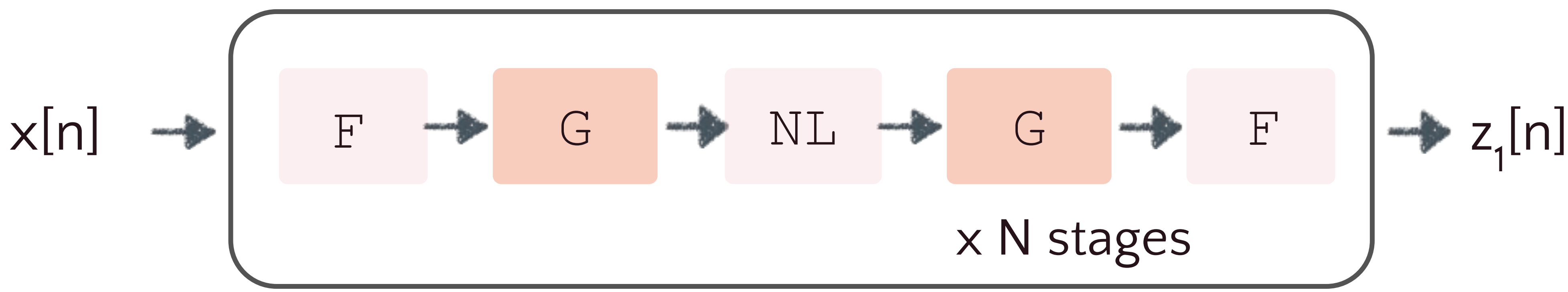
# Proposed Model

# Overview


DDSP Guitar Amp
x[n]
Diff-Preamp
Diff-tone stack
Diff-Poweramp
Diff-Transformer
y[n]
DSP params
DSP params
DSP params
MLP
MLP
MLP
gain
bass, mids, treble
master

# Diff-Preamp

- Wiener HammerStein with multiple stages




- In-series

| | | |
|---|---|---|
| F | Filter | : Determines the amount of distortion per frequency |
| G | Pre-Gain | : Determines the level of the distortion |
| NL | Nonlinear | : Introduce the nonlinearity |
| G | Post-Gain | : Adjust output level without altering distortion characteristics |
| F | Filter | : Alter the frequency after nonlinear function |

# Nonlinear Function

- TanH v.s. GRU with hidden size 1

| TanH | Ours |
|---|---|
| Static | Dynamic |
| Symmetric | Asymmetric |
| Non-Learnable | Learnable |

# Diff-Tone stack

- Low-shelf + peak + high-shelf filter

$z_1[n] \rightarrow \boxed{\mathtt{L}} \rightarrow \boxed{\mathtt{P}} \rightarrow \boxed{\mathtt{H}} \rightarrow z_2[n]$

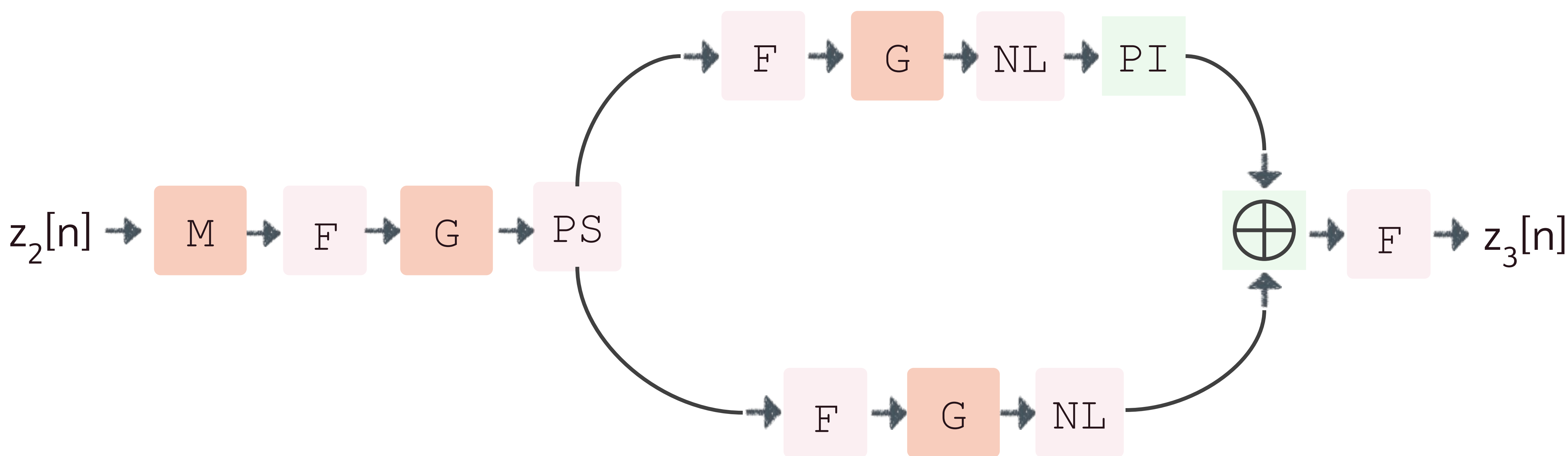
$\boxed{\mathtt{L}}$ : Control "bass" frequency responses (low)

$\boxed{\mathtt{P}}$ : Control "mids" frequency responses (mid)

$\boxed{\mathtt{H}}$ : Control "treble" frequency responses (high)

# Diff-Poweramp

- Phase Splitter (nonlinear) + Phase Inversion
- Wiener HammerStein with single stage
- Master Volume + Filter (emulate feedback)




PS Phase Splitter : Split into two identical signal that are 180 degrees out of phase with each other

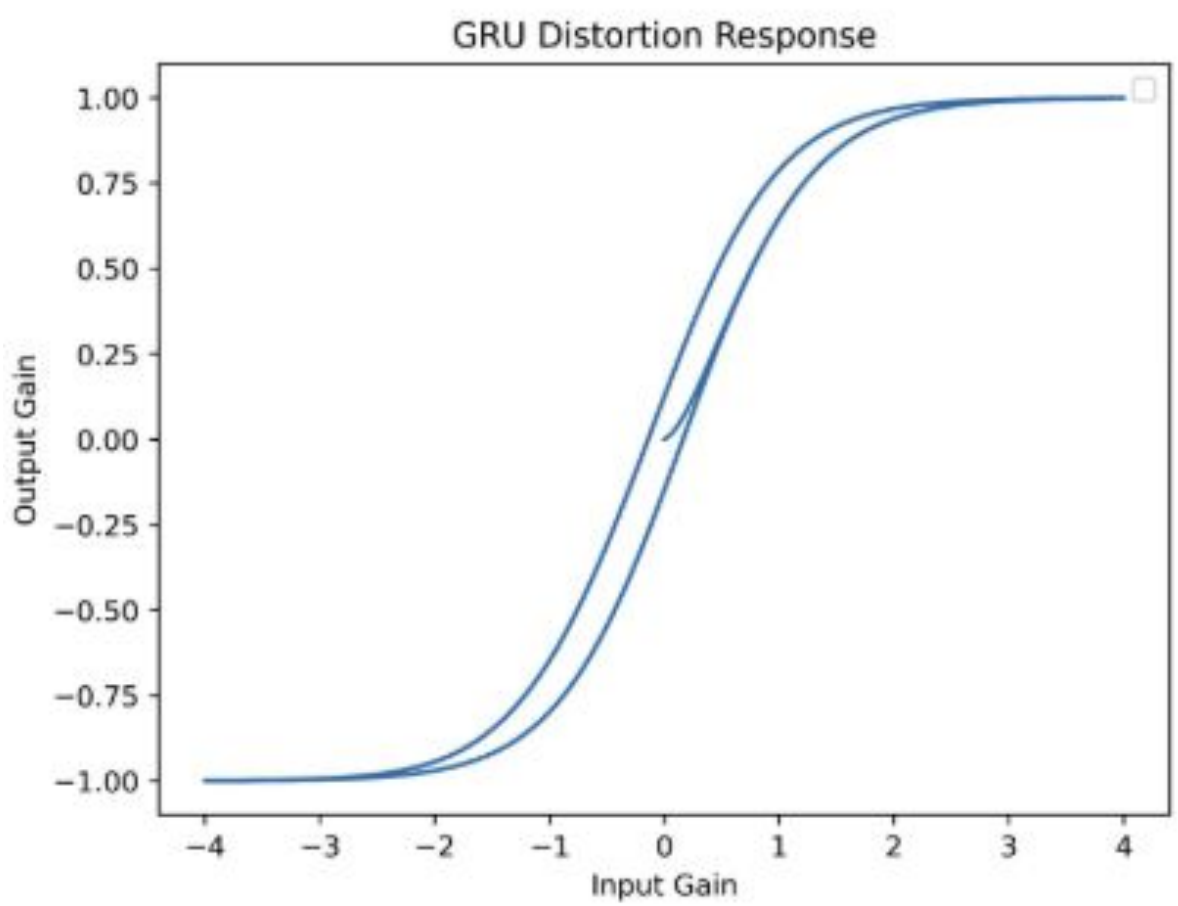
PI Phase Inv. : Inverse phase back

M Master : Increase level

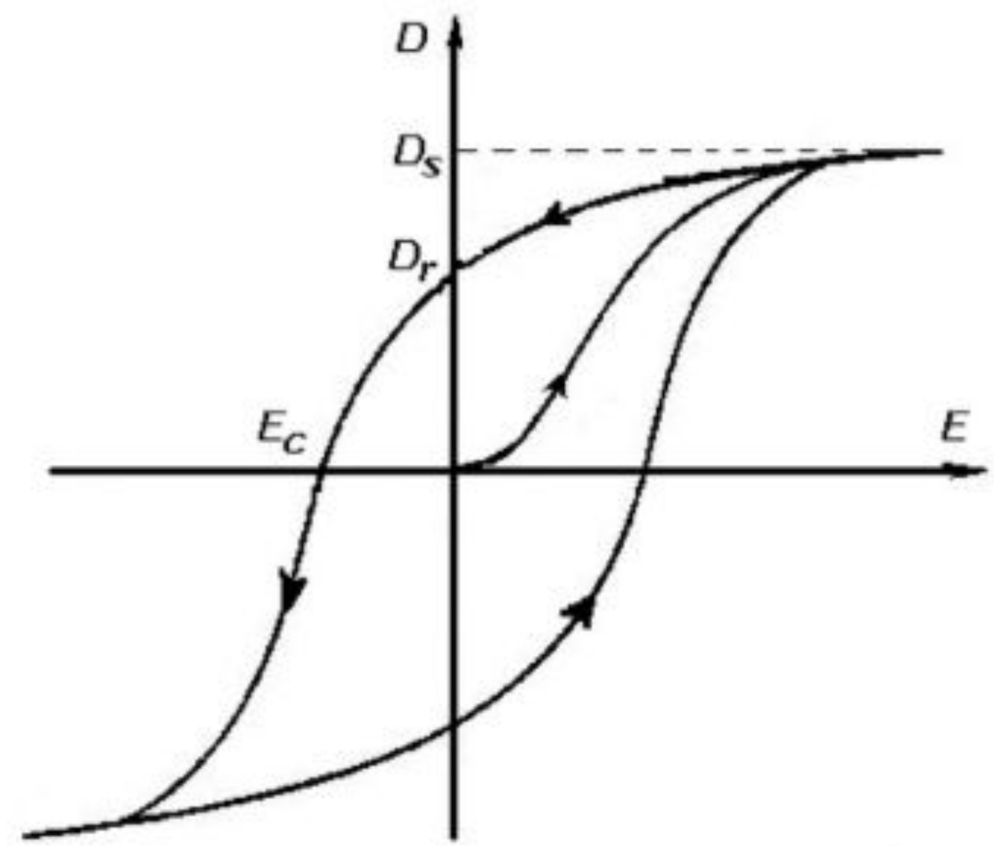
# Diff-Transformer

- Hysteresis behavior by GRU with hidden size 1

$z_3[n] \rightarrow$ G $\rightarrow$ NL $\rightarrow$ F $\rightarrow y[n]$

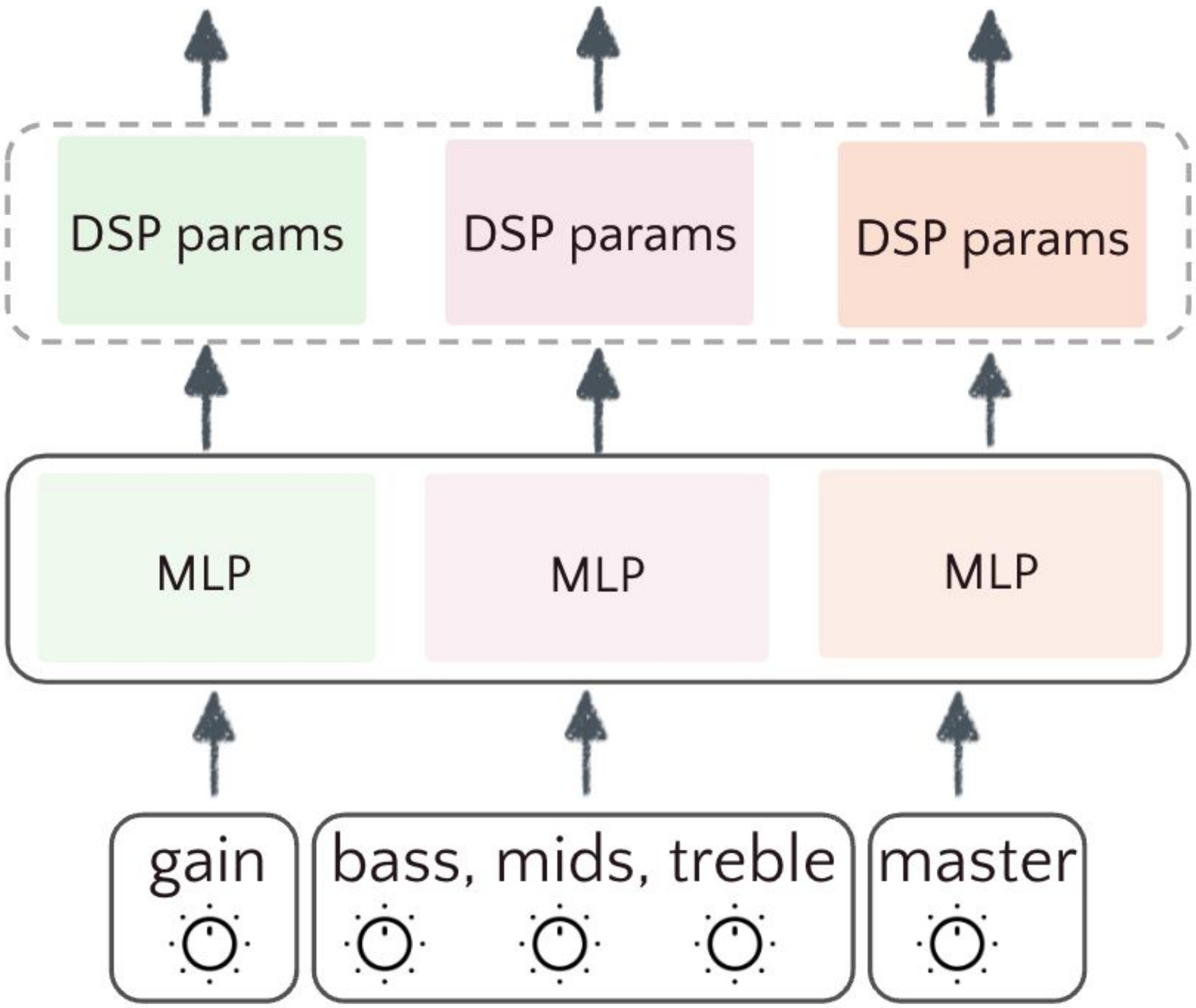



Distortion Curve from trained GRU
(the transformer part in our model)



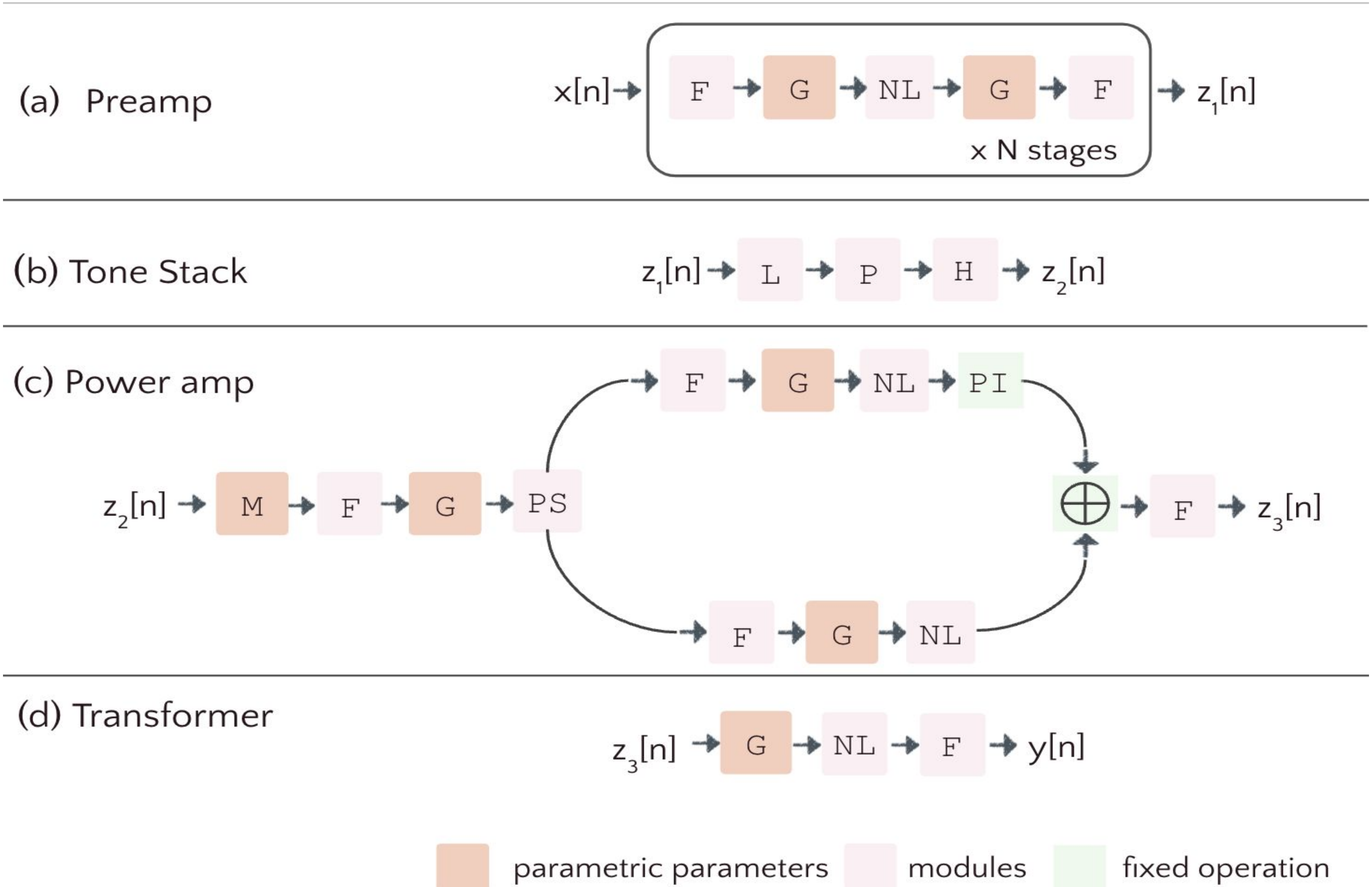

Standard Hysteresis Curve

# Knob Controller




Core idea: The mapping relationship between knob and dsp parameters is nonlinear

# Recap



(a) Preamp
x[n]
F
G
NL
G
F
x N stages
z1[n]
(b) Tone Stack
z1[n]
L
P
H
z2[n]
(c) Power amp
z2[n]
M
F
G
PS
F
G
NL
PI
F
G
NL
F
z3[n]
(d) Transformer
z3[n]
G
NL
F
y[n]
parametric parameters
modules
fixed operation

# Experiments

- Datasets: Marshall JVM 410H from (Miklanek, Stepan, et al)
- Loss Func: L1 Loss + Multi-resolution STFT Loss
- Baselines:
  - Small GRU (hidden size 8)
  - Big GRU (hidden size 48)
- Ablation studies:
  - WH only (Wiener Hammerstein model only)
  - WH + LPH + WH (Replace poweramp arch. with WH)
  - WH + LPH + POW (Ours proposed model w/o transformer)
  - WH + LPH + POW + TRANS (Ours full proposed model)

Miklanek, Stepan, et al. "Neural grey-box guitar amplifier modelling with limited data." *International Conference on Digital Audio Effects*. Aalborg University, 2023.

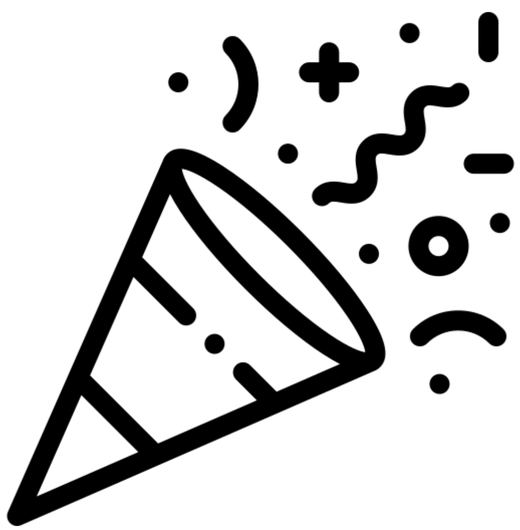
# Results

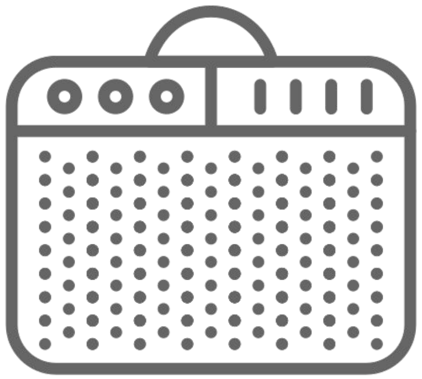
| Model | Seen knob conditions | | Unseen knob conditions | | Ops/sample | Params |
|---|---|---|---|---|---|---|
| | MAE ↓ | MR-STFT ↓ | MAE ↓ | MR-STFT ↓ | | |
| *A*. Small Concat-GRU-8 | 0.057 | 4.302 | 0.075 | 5.762 | 1,344 | 369 |
| *B*. Big Concat-GRU-48 | 0.013 | 1.214 | 0.023 | 1.851 | 19,872 | 7,969 |
| *C*. WH Only | 0.317 | 2.552 | 0.189 | 4.675 | 736 | 4,462 |
| *D*. WH+LPH+WH | 0.063 | 5.098 | 0.066 | 5.803 | 995 | 10,213 |
| *E*. WH+LPH+POW | 0.034 | 2.979 | 0.057 | 4.825 | 1,243 | 8,200 |
| *F*. WH+LPH+POW+TRANS | 0.024 | 2.161 | 0.043 | 3.972 | 1,352 | 10,126 |

**Table 1**. Evaluation results of (*A*–*B*) black-box baselines and (*F*) the proposed DDSP model and (*C*–*E*) its ablations.

# Conclusion

DDSP Guitar Amp can achieve competitive result with low computation, parametric, interpretable properties.





Low-computation

Interpretable

Demo page

Paper

Demo page: https://ytsrt66589.github.io/ddspGuitarAmp_Demo/

Paper: https://arxiv.org/abs/2408.11405