USB3.0 IBIS-AMI Model Construction based on Measurement and Neural Network

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Outline

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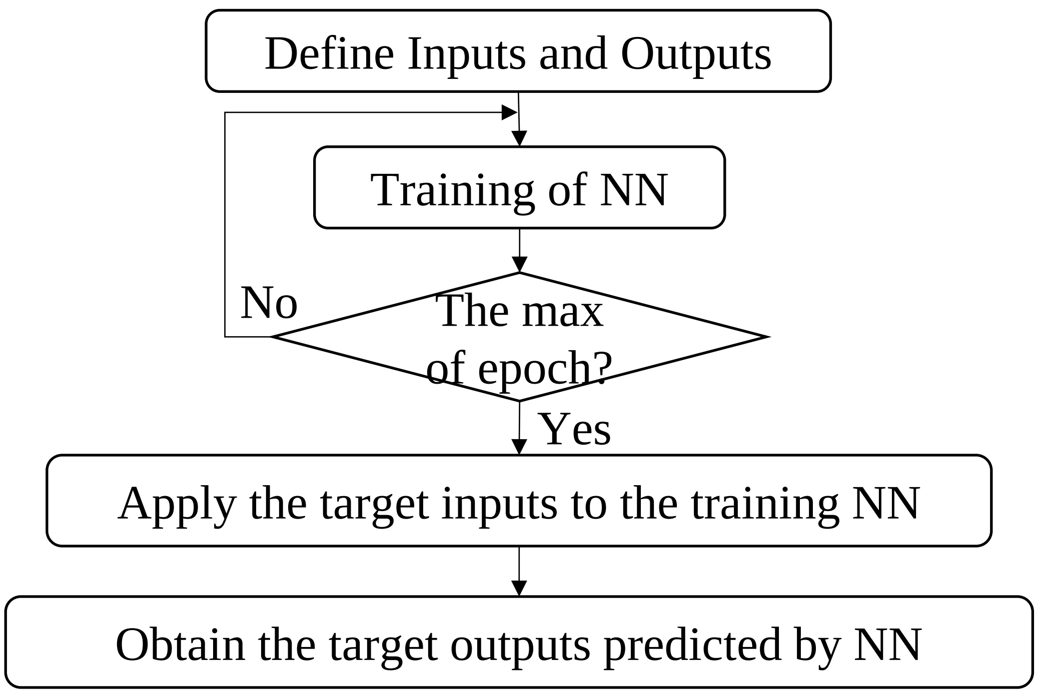
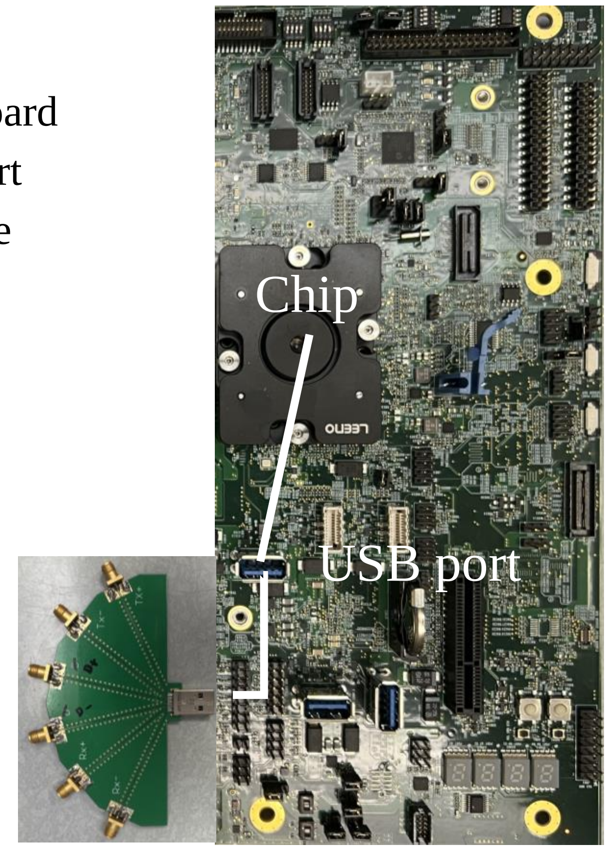
Motivation

- The signal integrity of data transfer in the Superspeed USB (USB3.0) standard is important to be simulated and analyzed.
  - ➢ What if the model of USB3.0 Tx is not provided by the manufacturer?
- The model construction for USB3.0 can be built by the measured output signal waveforms.
  - ➢ What if the chip is assembled on the motherboard? The measurement locations and conditions are limited.

Motivation

- In this work, we proposed a method to construct a digital output model for the USB3.0 Tx based on the measurement.
  - ➢ Device under test (DUT)
    - The digital output from the chip assembled on motherboard
    - The output signal through a PCB channel and a USB port
    - The output signal is measured using a USB-SMA fixture
  - ➢ Neural Network (NN)





IBIS-AMI Model on USB 3.0 Tx

IBIS-AMI model is commonly used in SuperSpeed USB instead of IBIS model. In this work, an IBIS-AMI model is constructed for the USB3.0 transmitter.

AMI Parameters:
FFE

AMI Parameters:
DFE / CTLE / CDR

The IBIS-AMI model construction focused on FFE taps values in AMI models and voltage level in IBIS models.

For example:

In IBIS file: [Voltage Range] 1.0 0.8 1.5

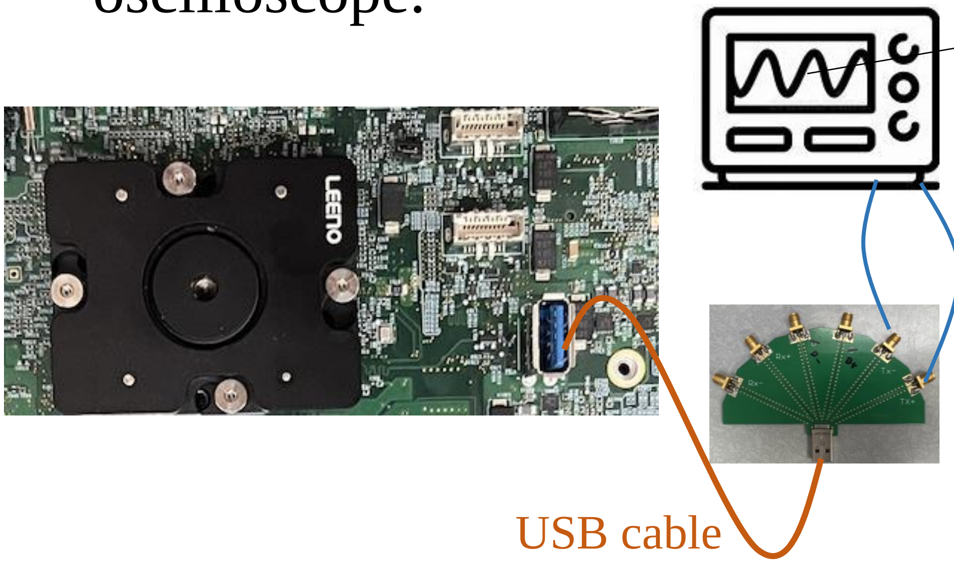
In AMI file: FFE defined in Model_Specific, [tap0 tap1 tap2]

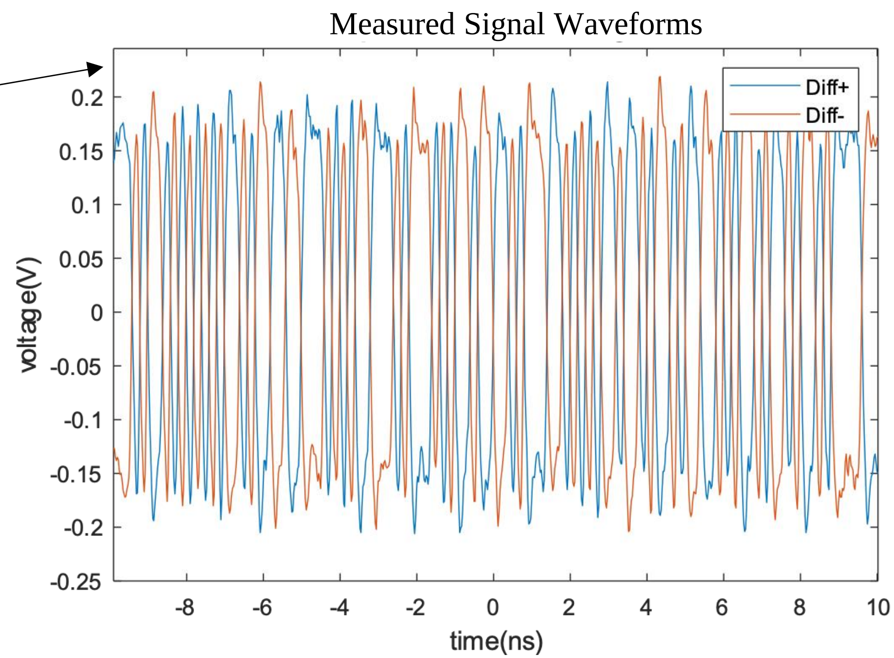
Where, $|tap0| + |tap1| + |tap2| = 1$

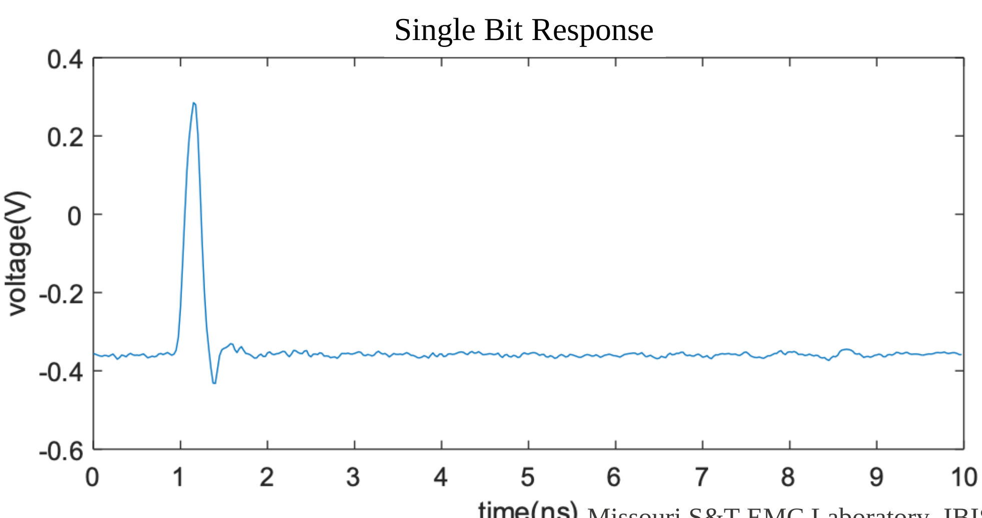
```
(Model_Specific
    (FFE
        (0 (Usage In) (Type Tap) (Format Value 0) (Description "FFE 0"))
        (1 (Usage In) (Type Tap) (Format Value 0.75) (Description "FFE 1"))
        (2 (Usage In) (Type Tap) (Format Value -0.25) (Description "FFE 2"))
    )
)
```

Measurement on USB3.0 Tx

- The 5Gbps PRBS signal from USB3.0 port is measured by the oscilloscope.



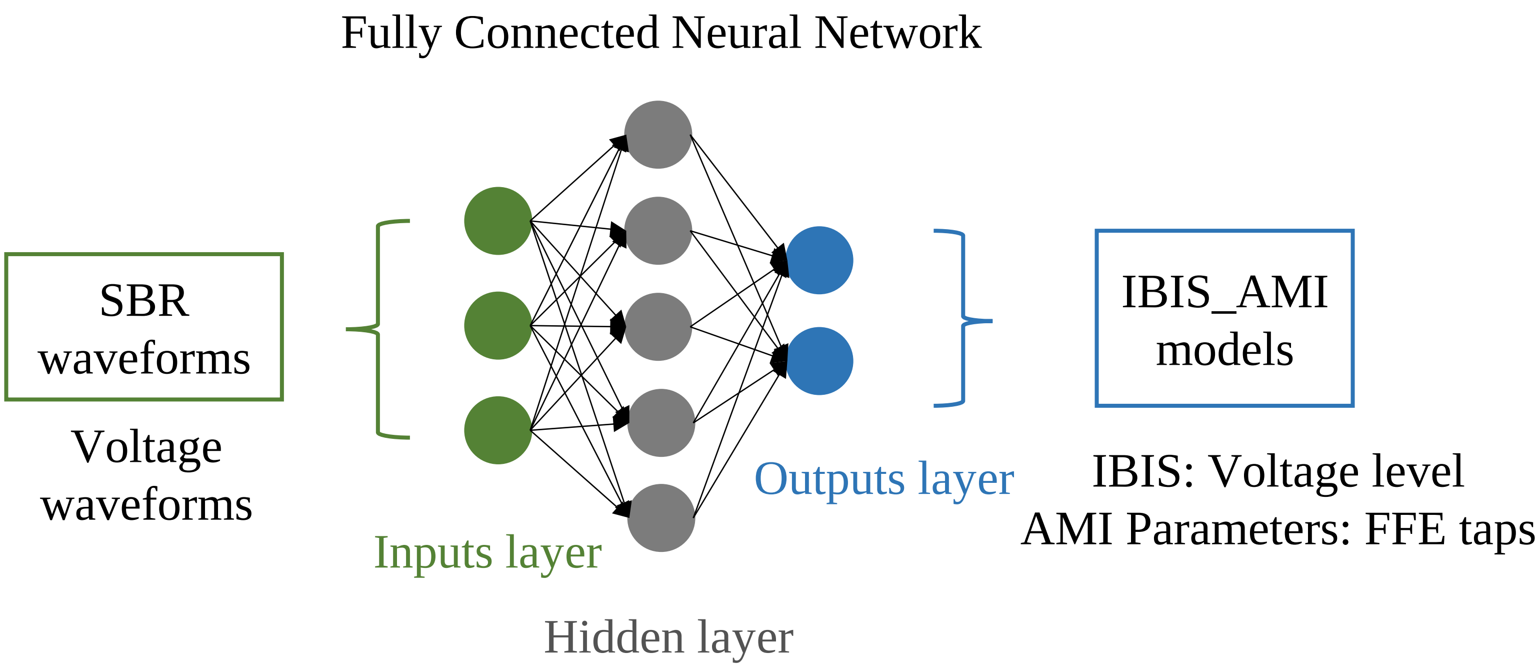




The differential single bit response is extracted from the measured waveform.

Neural Network Training

- Fully connected neural network (NN) is used in this work. NN was trained with single bit response (SBR) waveform as inputs and IBIS-AMI model parameters as outputs.



Dataset for NN training

- The dataset contains around 1000 sets of IBIS-AMI models and output SBR waveforms.

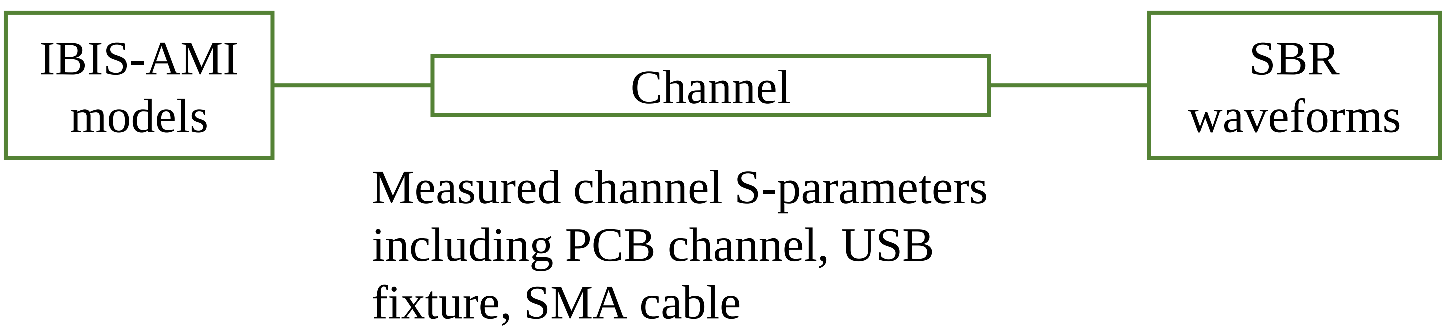
  – IBIS-AMI models:

Generated large number of IBIS-AMI models by sweeping voltage level and 2 FFE tap values (*tap0* and *tap2*) in a reasonable range.

  – SBR waveforms:

SBR waveforms are simulated in an EDA tool.

Several points on the waveforms are extracted to present SBR waveforms.



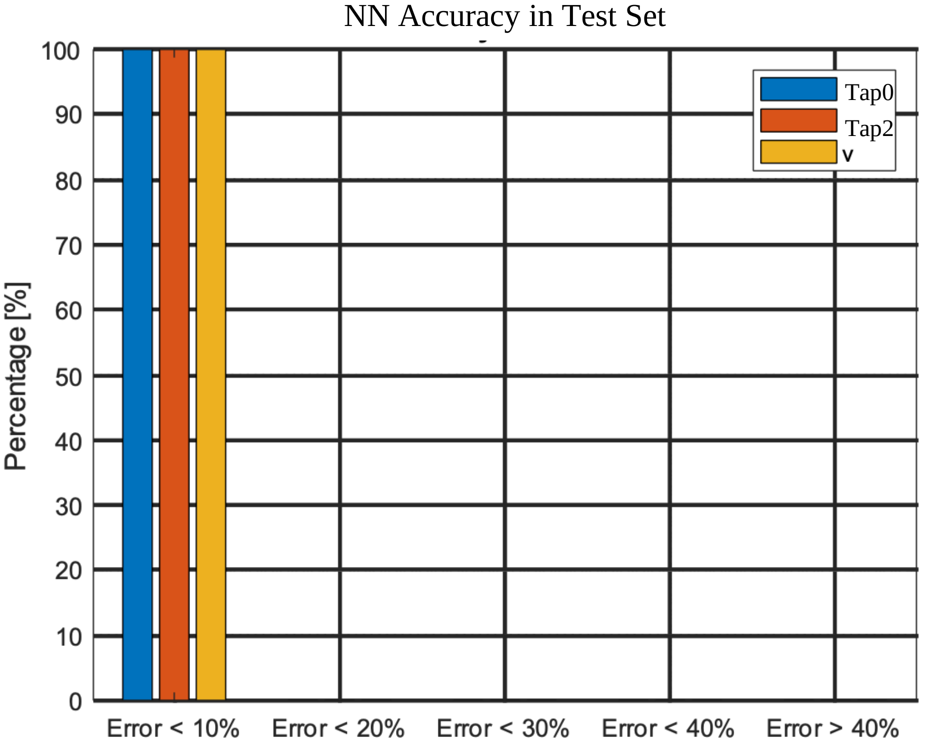
Neural Network Training Performance

- Training Accuracy
  - 90% datasets used as NN training
  - 10% datasets used as NN testing

- Neural Network training results shows a good correlation between SBR waveforms and IBIS-AMI models parameters

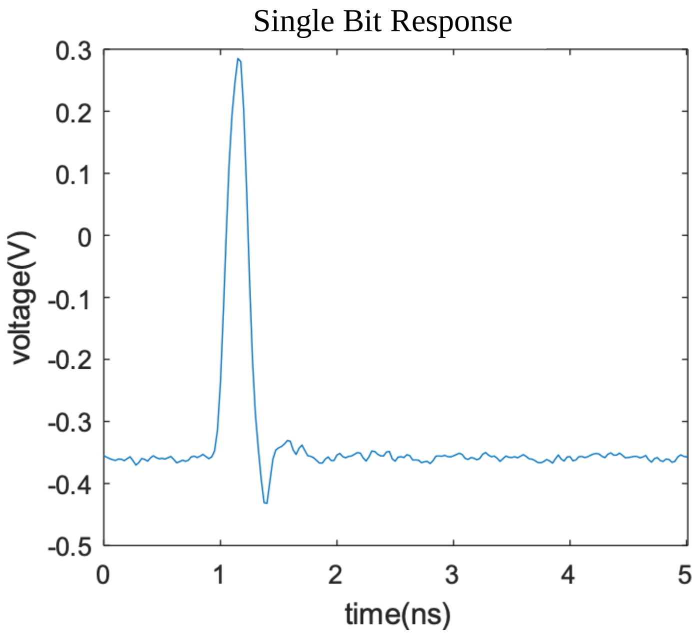
- Training efficiency:

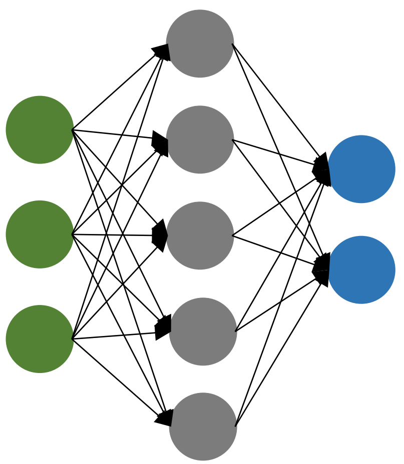
For epoch of 500, the training takes around 1 hour.



IBIS-AMI model construction

- With a well-trained NN, the NN is recalled with inputs → the SBR extracted from measured waveform.
- The NN gives the outputs → IBIS-AMI models parameters





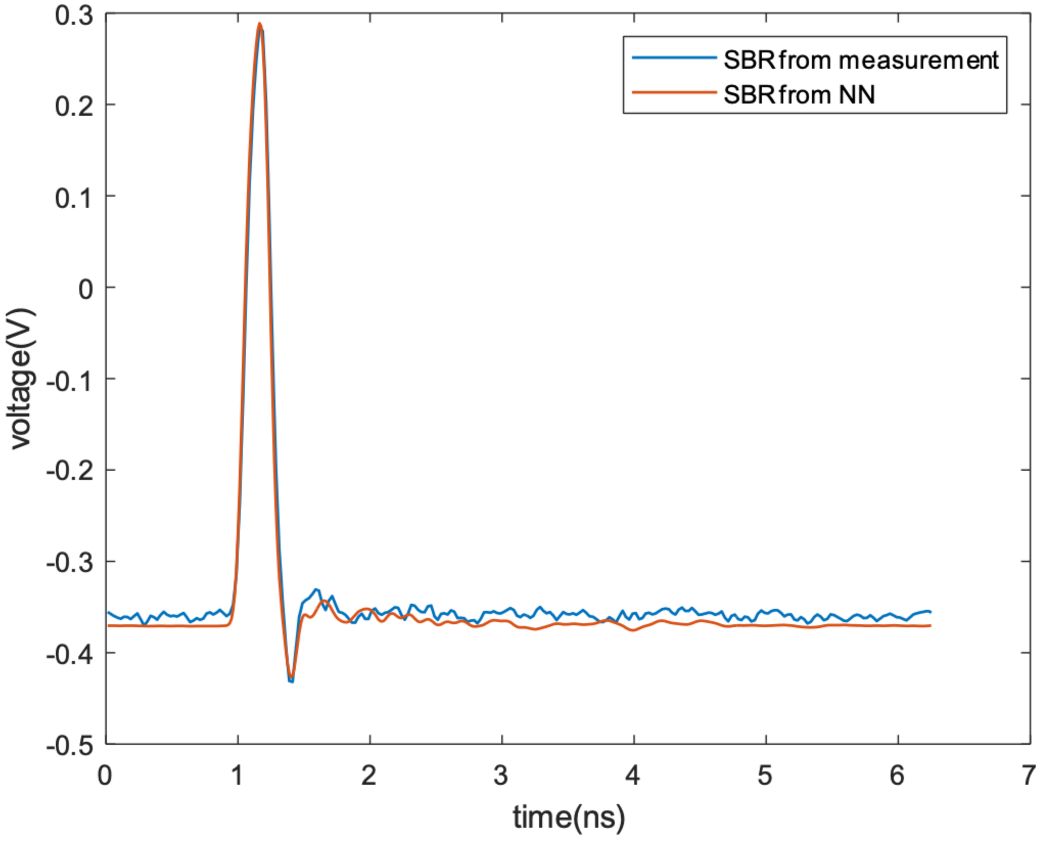
Predicted:

- Voltage level: 1.3V
- FFE:
  - Tap0: 0
  - Tap1: 0.8
  - Tap2: -0.2

The IBIS-AMI model for the USB Tx digital outputs is constructed with predicted parameters.
(Attached in appendix)

Constructed IBIS-AMI model validation

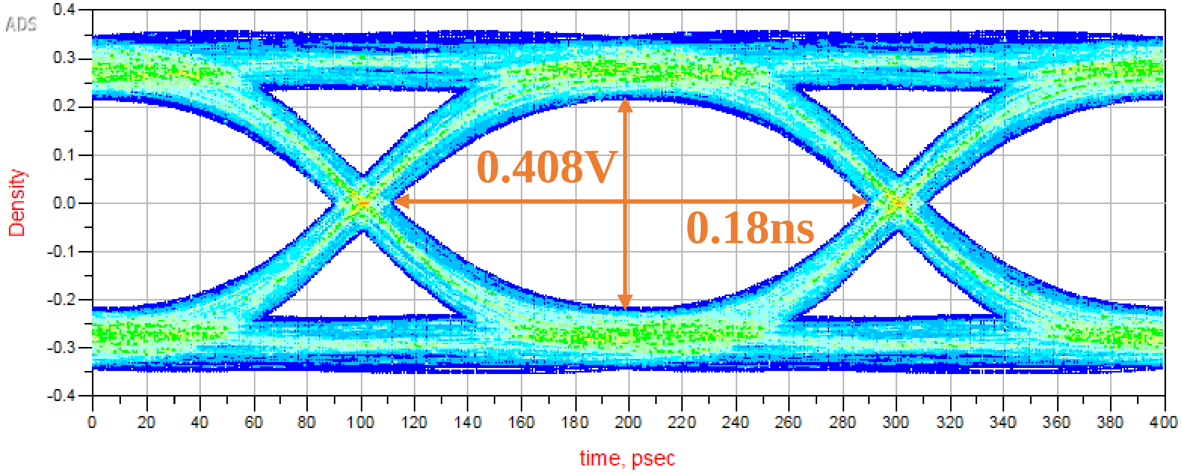
- The constructed IBIS-AMI model is simulated in the EDA tool for validation. The SBR waveforms from measurement and IBIS-AMI model constructed by NN are compared.



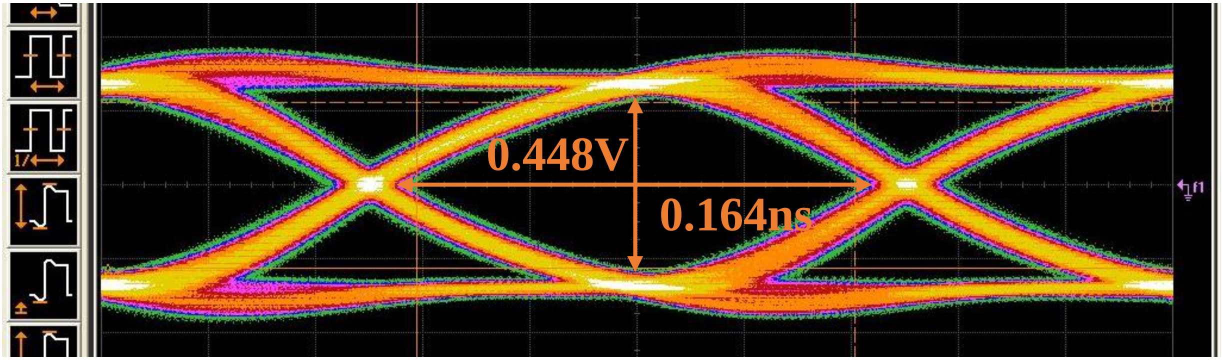
The waveform from the constructed model matches well with measurement.

Constructed IBIS-AMI model validation

- The eye-diagrams are also compared.



Constructed IBIS-AMI model



Measurement on Oscilloscope

The eye-diagrams have slight difference.

Conclusion

- Using neural network is an efficient method on the IBIS-AMI model construction for USB3.0 based on the measurement.

- The predicted output model from Neural Network shows a good correlation with the measurement.

- The method can be applied on the other digital outputs with higher speed and propagating in different channels.

Thank you!

Q&A

Appendix 1

- IBIS file

```
[IBIS Ver]     5.1
[File Name]    tx.ibs
[File Rev]     1.0
[Component]    tx
[Manufacturer] My Company

[Package]
R_pkg  0.0    NA      NA
L_pkg  0.0    NA      NA
C_pkg  0.0    NA      NA

[Pin]    signal_name             model_name        R_pin L_pin  C_pin
1p       tx_p          tx
1n       tx_n          tx

[Diff_Pin] inv_pin vdiff tdelay_typ tdelay_min tdelay_max
1p       1n           NA    NA    NA    NA

[Model] tx
Model_type Output

C_comp 0p 0p 0p
Cref = 0
Vref = 0.5
Rref = 50
Vmeas = 0.5

[Temperature_Range] 25 125 0

[Voltage Range] 1.3 0.8 1.5

[Algorithmic Model]
Executable Windows_cl19.35.32215_64 tx_x64.dll tx.ami
[End Algorithmic Model]
```

```
[Pulldown]
-6.6      -0.132     -0.132     -0.132
 0.0       0.0        0.0        0.0
 6.6       0.132      0.132      0.132

[Pullup]
-6.6       0.132      0.132      0.132
 0.0       0.0        0.0        0.0
 6.6      -0.132     -0.132     -0.132

[GND Clamp]
-6.6       0.0        0.0        0.0
 0.0       0.0        0.0        0.0
 6.6       0.0        0.0        0.0

[Power Clamp]
-6.6       0.0        0.0        0.0
 0.0       0.0        0.0        0.0
 6.6       0.0        0.0        0.0

[Ramp]
dV/dt_r 0.3/1.5p 0.3/1.5p 0.3/1.5p
dV/dt_f 0.3/1.5p 0.3/1.5p 0.3/1.5p

[END]
```

Appendix 2

- AMI file

```
(tx
   (Reserved_Parameters
      (AMI_Version (Usage Info) (Type String) (Default "5.1") (Description "Valid for AMI Version 5.1 and above"))
      (Init_Returns_Impulse (Usage Info) (Type Boolean) (Default True) (Description "Init_Returns_Impulse True"))
      (GetWave_Exists (Usage Info) (Type Boolean) (Default False) (Description "GetWave_Exists False"))
      (Max_Init_Aggressors (Usage Info) (Type Integer) (Default 2147483646) (Description "Max_Init_Aggressors 2147483646"))
   )
   (Model_Specific
      (FFE
         (0 (Usage In) (Type Tap) (Format Value 0) (Description "FFE 0"))
         (1 (Usage In) (Type Tap) (Format Value 0.8) (Description "FFE 1"))
         (2 (Usage In) (Type Tap) (Format Value -0.2) (Description "FFE 2"))      )    ))
```