IBIS-AMI Modeling Using Scripts and Spice Models

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Agenda:

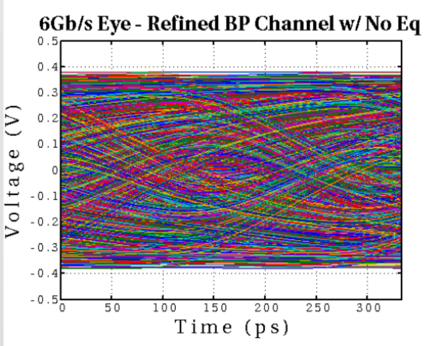
- Motivation
- Background
- IBIS-AMI Modeling Flow
- Modeling with Scripts
- Modeling with Spice models
- Summary
- Q & A

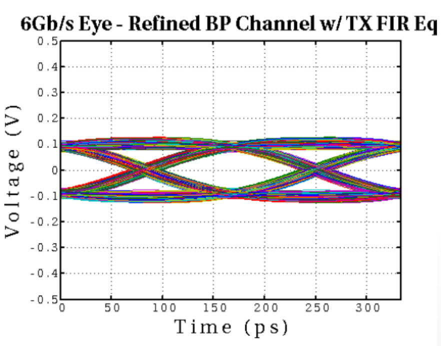
Motivation

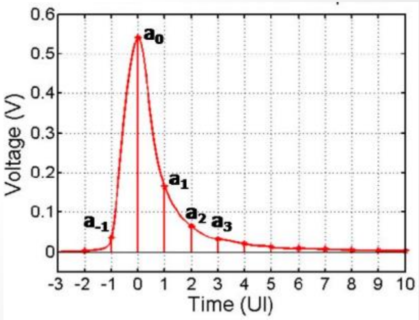
- Channel analysis usually requires IBIS-AMI:
  - For internal analysis and/or external model release
- AMI Modeling is technically challenging
  - Requires cross domain expertise
  - Take longer to ramp-up and develop comparing to IBIS
- Can we lower the AMI modeling barriers?
  - Use scripting languages
  - Use existing spice models

Background 1/3

- Channel analysis: [1]
  - Mostly have stages beyond traditional IBIS (e.g. Tx/Rx EQ)
  - Analyis methodologies [2]
    - Statistical: for LTI (Linear Time Invariant) circuit, using superposition
    - Time-domain: for NLTV (Non-Linear, Time Variant) circuit, using convolution

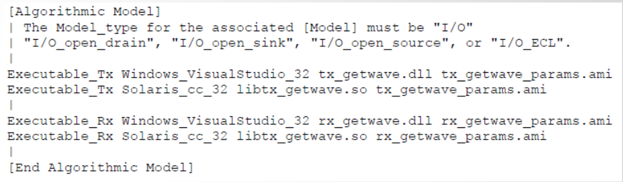




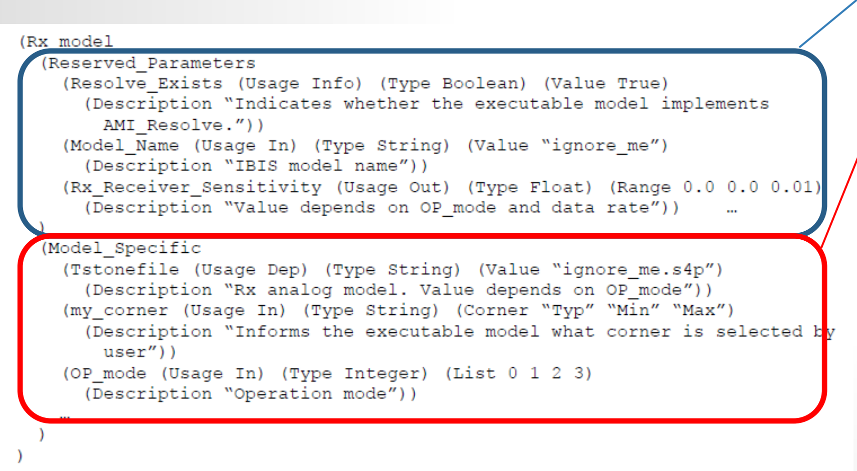


Background 2/3

- AMI Model: [3]
  - Includes an .ibs, .ami and .dll/.so files
  - .ibs specifies .ami and .dll/.so files
  - .ami is a plain text file



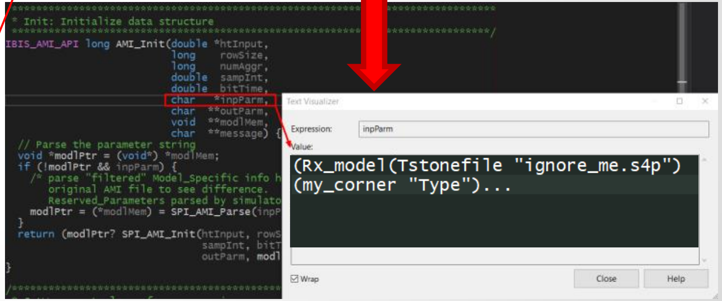
```
[Algorithmic Model]
| The Model_type for the associated [Model] must be "I/O"
| "I/O_open_drain", "I/O_open_sink", "I/O_open_source", or "I/O_ECL".
|
Executable_Tx Windows_VisualStudio_32 tx_getwave.dll tx_getwave_params.ami
Executable_Tx Solaris_cc_32 libtx_getwave.so tx_getwave_params.ami
|
Executable_Rx Windows_VisualStudio_32 rx_getwave.dll rx_getwave_params.ami
Executable_Rx Solaris_cc_32 libtx_getwave.so rx_getwave_params.ami
|
[End Algorithmic Model]
```



```
(Rx_model
  (Reserved_Parameters
    (Resolve_Exists (Usage Info) (Type Boolean) (Value True)
      (Description “Indicates whether the executable model implements
        AMI_Resolve.”))
    (Model_Name (Usage In) (Type String) (Value “ignore_me”)
      (Description “IBIS model name”))
    (Rx_Receiver_Sensitivity (Usage Out) (Type Float) (Range 0.0 0.0 0.01)
      (Description “Value depends on OP_mode and data rate”))    …
  )
  (Model_Specific
    (Tstonefile (Usage Dep) (Type String) (Value “ignore_me.s4p”)
      (Description “Rx analog model. Value depends on OP_mode”))
    (my_corner (Usage In) (Type String) (Corner “Typ” “Min” “Max”)
      (Description “Informs the executable model what corner is selected by
        user”))
    (OP_mode (Usage In) (Type Integer) (List 0 1 2 3)
      (Description “Operation mode”))
    …
  )
)
```

This part is for simulator

This part is for AMI model, passed into .dll/.so as name-value pairs

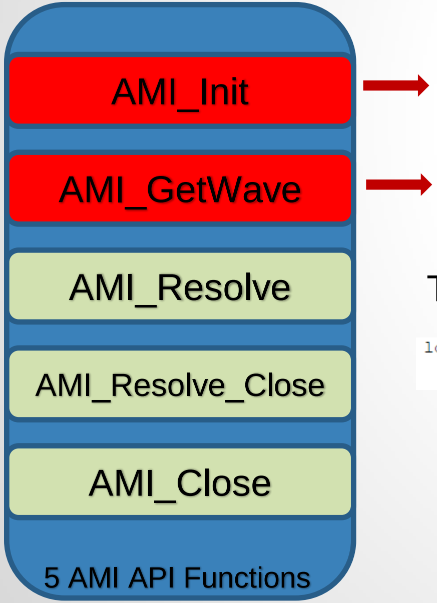


```
*******************************************************************************
 * Init: Initialize data structure
 ******************************************************************************/
IBIS_AMI_API long AMI_Init(double *htInput,
                           long    rowSize,
                           long    numAggr,
                           double  sampInt,
                           double  bitTime,
                           char    *inpParm,
                           char   **outParm,
                           void   **modlMem,
                           char   **message) {
  // Parse the parameter string
  void *modlPtr = (void*) *modlMem;
  if (!modlPtr && inpParm) {
    /* parse "filtered" Model_Specific info h
       original AMI file to see difference.
       Reserved_Parameters parsed by simulato
    modlPtr = (*modlMem) = SPI_AMI_Parse(inpP
  }
  return (modlPtr? SPI_AMI_Init(htInput, rowS
                               sampInt, bitT
                               outParm, modl
}
/*****************************************
```

```
(Rx_model(Tstonefile "ignore_me.s4p")
(my_corner "Type")...
```

Background 3/3

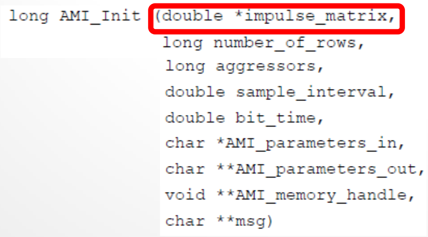
- AMI Model:
  - .dll/.so may implements these API functions



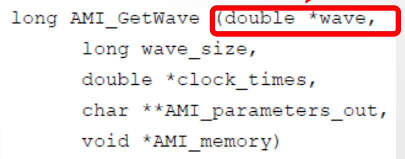
For LTI processing, when AMI_GetWave does not exist

For LTI or NLTV processing, when AMI_GetWave does exist

These arrays serve as both waveform data input and output!



```
long AMI_Init (double *impulse_matrix,
               long number_of_rows,
               long aggressors,
               double sample_interval,
               double bit_time,
               char *AMI_parameters_in,
               char **AMI_parameters_out,
               void **AMI_memory_handle,
               char **msg)
```



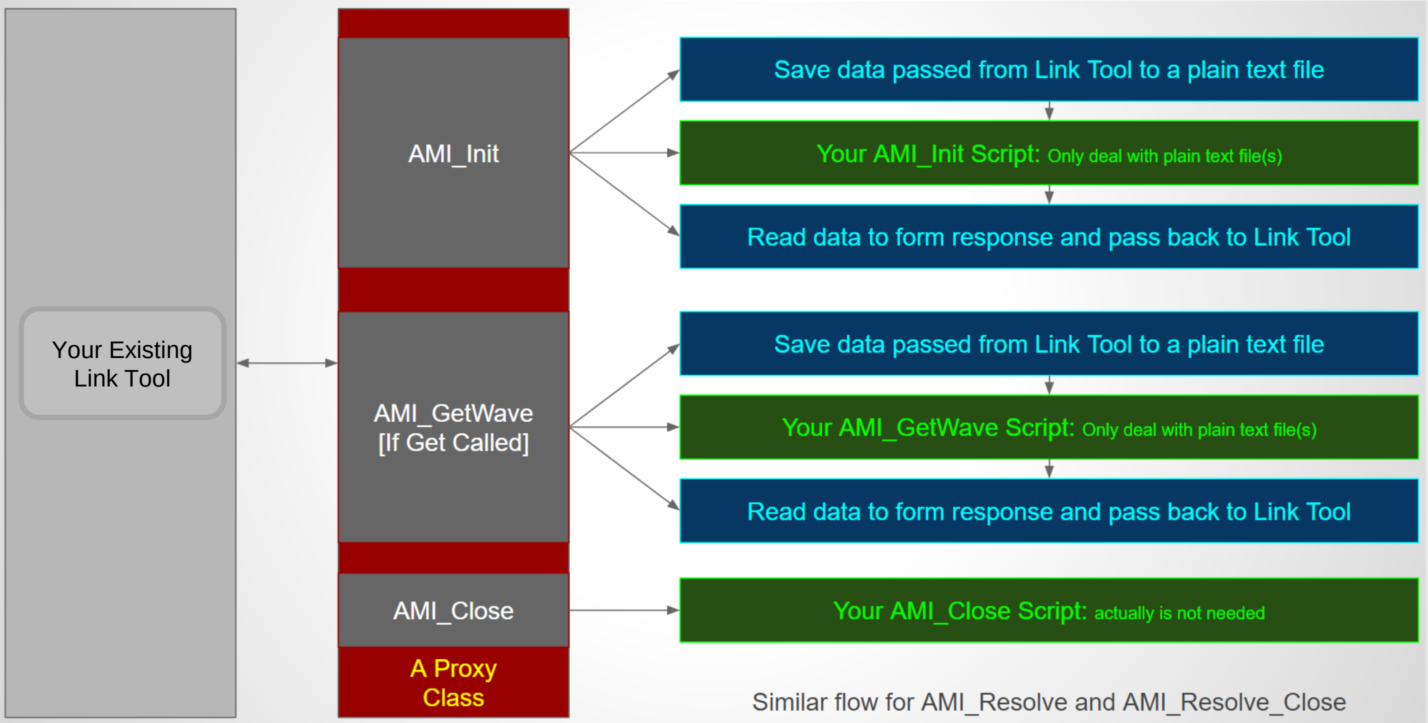
```
long AMI_GetWave (double *wave,
         long wave_size,
         double *clock_times,
         char **AMI_parameters_out,
         void *AMI_memory)
```

AMI Modeling Flow

- Identify model behavior(s)
  - From mathematical equation, simulation or measurements
- Code the behaviors and IBIS-AMI API
  - API implemented MUST follow IBIS spec. and in C
  - Core processing can be in written other languages
- Compile and link as .dll or .so
  - Check library dependencies, different OS bits & linux distros

With Script and/or Spice models for core processing, this AMI model is very reuseable!

Modeling with Scripts: Flow



Your Existing Link Tool

AMI_Init

AMI_GetWave [If Get Called]

AMI_Close

A Proxy Class

Save data passed from Link Tool to a plain text file

Your AMI_Init Script: Only deal with plain text file(s)

Read data to form response and pass back to Link Tool

Save data passed from Link Tool to a plain text file

Your AMI_GetWave Script: Only deal with plain text file(s)

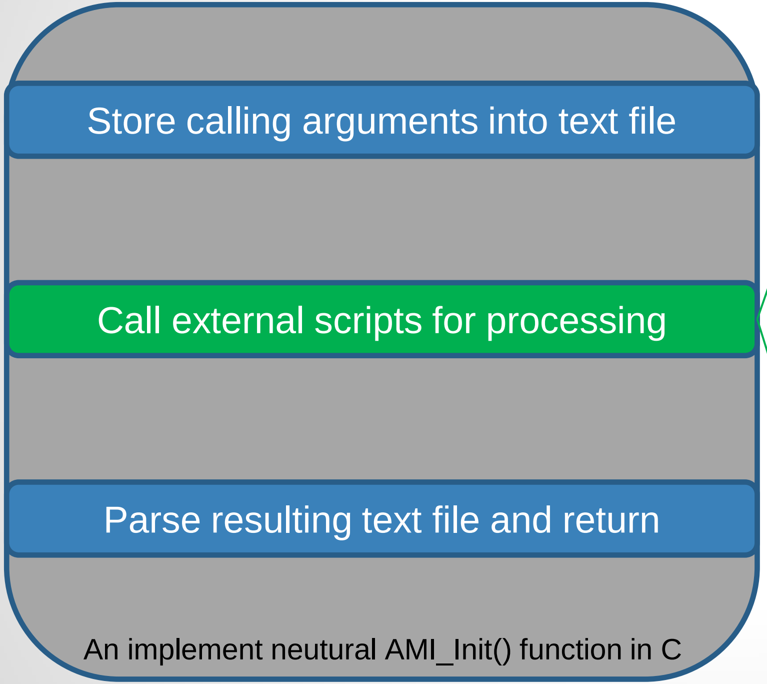
Read data to form response and pass back to Link Tool

Your AMI_Close Script: actually is not needed

Similar flow for AMI_Resolve and AMI_Resolve_Close [4]

Script path and arguments are passed via .ami file

Modeling with Scripts: Example

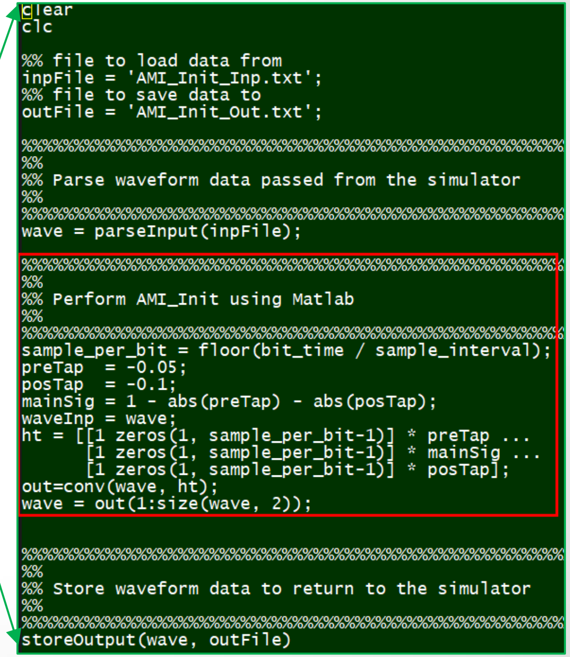


Store calling arguments into text file

Call external scripts for processing

Parse resulting text file and return

An implement neutural AMI_Init() function in C



```
clear
clc

%% file to load data from
inpFile = 'AMI_Init_Inp.txt';
%% file to save data to
outFile = 'AMI_Init_Out.txt';

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
%% Parse waveform data passed from the simulator
%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
wave = parseInput(inpFile);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
%% Perform AMI_Init using Matlab
%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
sample_per_bit = floor(bit_time / sample_interval);
preTap  = -0.05;
posTap  = -0.1;
mainSig = 1 - abs(preTap) - abs(posTap);
waveInp = wave;
ht = [[1 zeros(1, sample_per_bit-1)] * preTap ...
      [1 zeros(1, sample_per_bit-1)] * mainSig ...
      [1 zeros(1, sample_per_bit-1)] * posTap];
out=conv(wave, ht);
wave = out(1:size(wave, 2));


%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
%%
%% Store waveform data to return to the simulator
%%
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
storeOutput(wave, outFile)
```

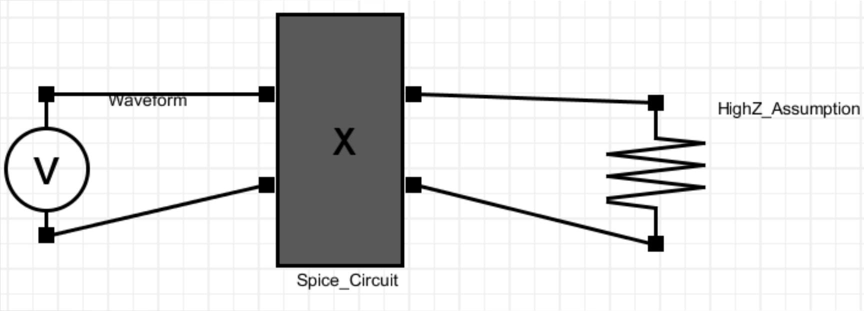
Modeling with Scripts: Consideration

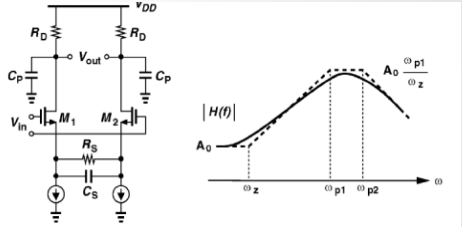
- Performance and distribuability:
  - Intepretor performance.
  - Redistributable (license)?
  - Does it require model user to install intrepreter?

- Consider Python! [5]
  - SciPy, NumPy etc for numerical analysis.
  - Embedded python: a single zip file together with AMI models.
  - Performance and extendability.

Modeling with Spice: Concept

- Dynamically generated PWL inputs:
  - High-Z assumption
  - Simulate
    - Circuit may need to provide GND.
  - Retrieve waveform and return





$$H(s) = \frac{g_m}{C_p} \frac{s + \frac{1}{R_S C_S}}{\left(s + \frac{1 + g_m R_S/2}{R_S C_S}\right)\left(s + \frac{1}{R_D C_p}\right)}$$

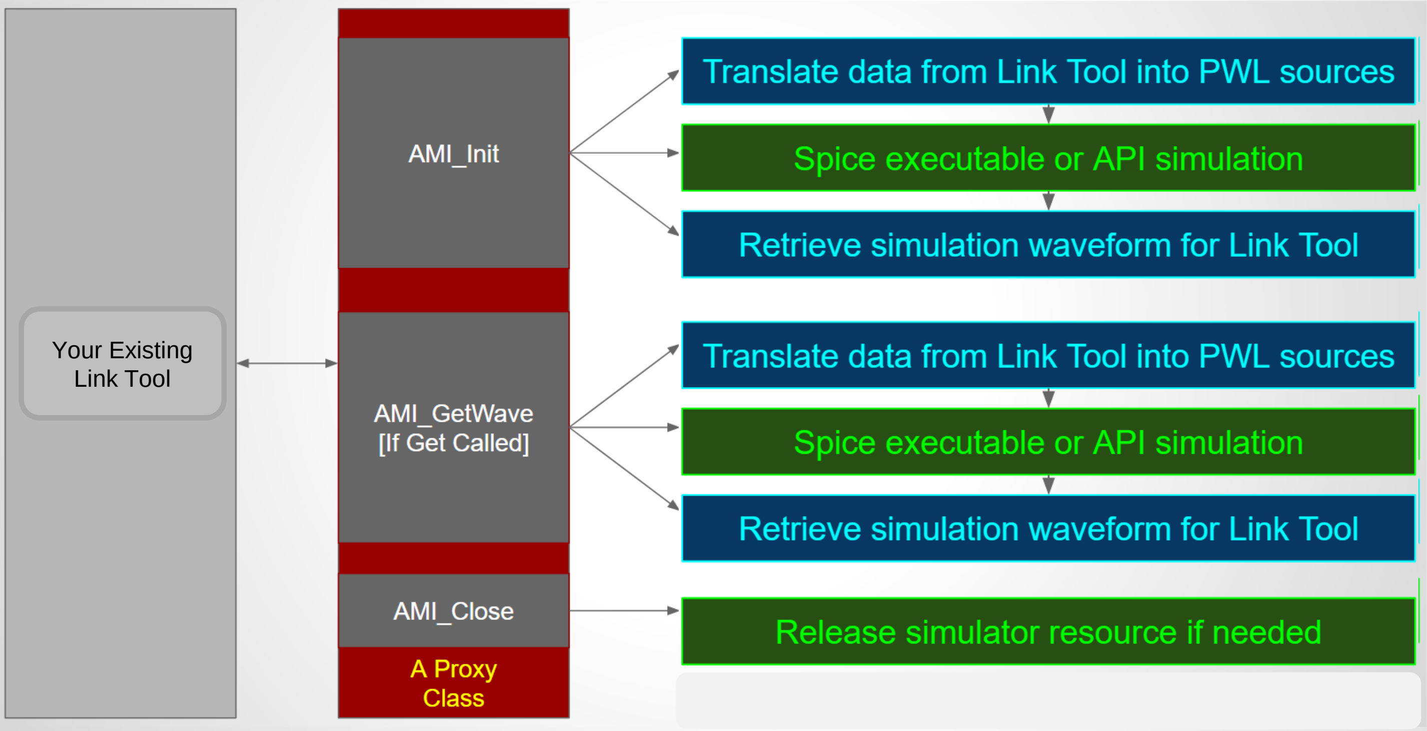
$$\omega_z = \frac{1}{R_S C_S}, \quad \omega_{\mathrm{p1}} = \frac{1 + g_m R_S/2}{R_S C_S}, \quad \omega_{\mathrm{p2}} = \frac{1}{R_D C_p}$$

$$\textbf{DC gain} = \frac{g_m R_D}{1 + g_m R_S/2}, \quad \textbf{Ideal peak gain} = g_m R_D$$

$$\textbf{Ideal Peaking} = \frac{\textbf{Ideal peak gain}}{\textbf{DC gain}} = \frac{\omega_{p1}}{\omega_z} = 1 + g_m R_S/2$$

No need to code circuit behavior!

Modeling with Spice: Flow



Your Existing Link Tool

AMI_Init

AMI_GetWave [If Get Called]

AMI_Close

A Proxy Class

Translate data from Link Tool into PWL sources

Spice executable or API simulation

Retrieve simulation waveform for Link Tool

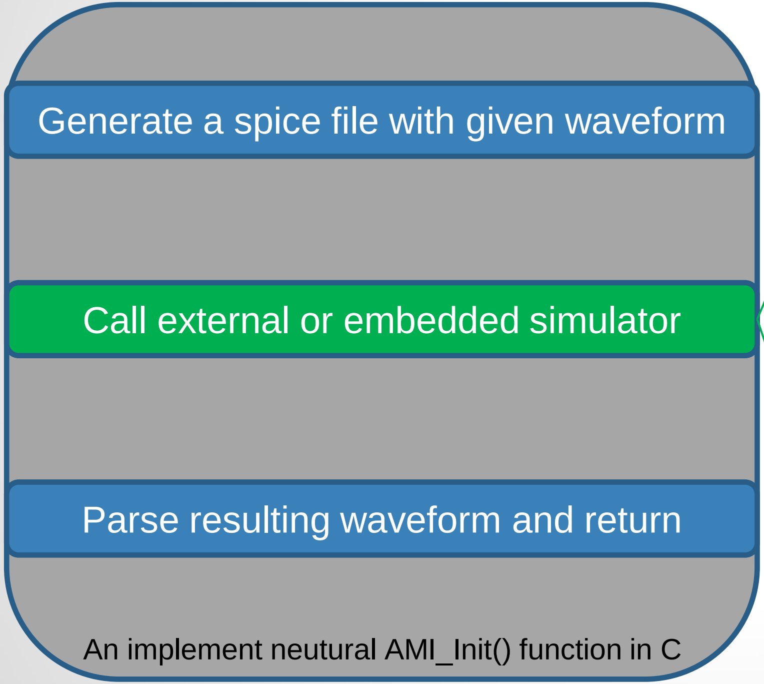
Translate data from Link Tool into PWL sources

Spice executable or API simulation

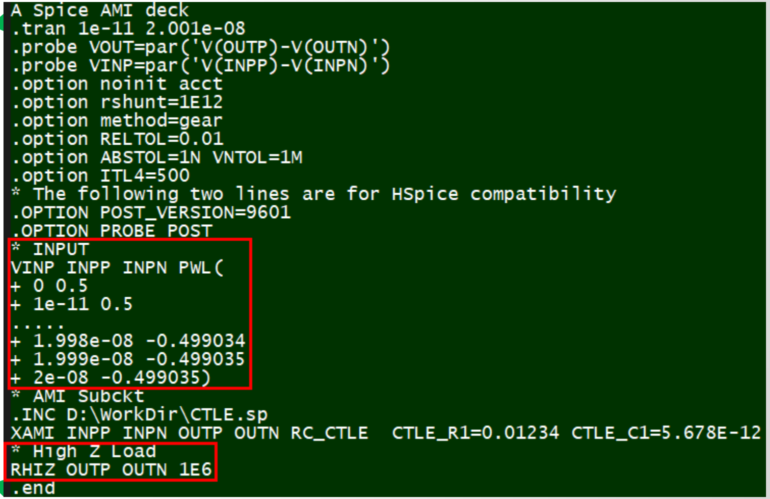
Retrieve simulation waveform for Link Tool

Release simulator resource if needed

Modeling with Spice: Example



Generate a spice file with given waveform
Call external or embedded simulator
Parse resulting waveform and return
An implement neutural AMI_Init() function in C



```
A Spice AMI deck
.tran 1e-11 2.001e-08
.probe VOUT=par('V(OUTP)-V(OUTN)')
.probe VINP=par('V(INPP)-V(INPN)')
.option noinit acct
.option rshunt=1E12
.option method=gear
.option RELTOL=0.01
.option ABSTOL=1N VNTOL=1M
.option ITL4=500
* The following two lines are for HSpice compatibility
.OPTION POST_VERSION=9601
.OPTION PROBE POST
* INPUT
VINP INPP INPN PWL(
+ 0 0.5
+ 1e-11 0.5
.....
+ 1.998e-08 -0.499034
+ 1.999e-08 -0.499035
+ 2e-08 -0.499035)
* AMI Subckt
.INC D:\WorkDir\CTLE.sp
XAMI INPP INPN OUTP OUTN RC_CTLE  CTLE_R1=0.01234 CTLE_C1=5.678E-12
* High Z Load
RHIZ OUTP OUTN 1E6
.end
```

Modeling with Spice: Consideration

- Performance and distribuability:
  - Availability of device models?
  - Redistributable (license)?
  - Does model user need specific simulator?

- Consider open source simulator!
  - NgSpice, QUCS etc all supports API/Shared library [6]
  - The AMI model is basically a circuit simulator
    - Implement once, use many times!
  - Performance vs Accuracy

Summary:

- AMI model using scripts and spice circuit:
  - Doable! (Has been implemented! Example included.)
  - Can reduce AMI modeling time significantly
  - Can serve as an intermediate step toward full C/C++ implementation.

- Considerations:
  - Performance:
    - Not a concern if only AMI_Init is needed (called only once)
  - Model release:
    - Can the model be distributed and used easily?
  - A simple wrapper IBIS-AMI model is needed as a proxy.

References:

1. High-speed Links Circuits and Systems http://www.ece.tamu.edu/~spalermo/ecen720.html
2. Simulating High-Speed Serial Channels with IBIS-AMI Models http://literature.cdn.keysight.com/litweb/pdf/5990-9111EN.pdf?id=2095655
3. IBIS V6.1 Spec. Section 10 http://ibis.org/ver6.1/
4. AMI Analysis Using a Proxy Class http://ibis.org/summits/feb17/
5. Embedding python in another application https://docs.python.org/3/extending/embedding.html
6. NgSPice as a shared library http://ngspice.sourceforge.net/shared.html

Q & A

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