Corner Considerations

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DesignCon IBIS Summit
Santa Clara, CA
January 30, 2015

(Given previously November 14, 17, 20, 2014)

Outline

- Overview
- Corner Review
- Parameter Passing Corners in IBIS Version 6.0
- Upcoming Interconnect Modeling Corners
- Td, Zo to/from L, C Conversions
- Concluding Comments

Overview

- Corners in this presentation mean the assignment of Typ, Min, Max (or Typ, Slow, Fast) entries
- Different areas of IBIS have different corner definitions
- IBIS supports passing parameter values into IBIS-ISS (an HSPICE subset) sub-circuits
- The parameter descriptions can also contain corners
- Purpose of this presentation is to show different methods and provide some advice

Corner Review

- [Model] Corners
- [External Model] Corners
- [External Circuit] Corners
- [Package] Corners
- IBIS-AMI Corners

[Model] Corners

- Typ: Typical process and conditions
- Min: Slow, Weak process and conditions (low voltage and high temperature for CMOS)
- Max: Fast, Strong process and conditions (high voltage and low temperature for CMOS)
- [Model Spec] corners are aligned with [Model]
- C_comp corners are by magnitude and represent the range of values
- [External Model] Corner lines track [Model] corners (shown next)

[External Model] Corners

```
[External Model] Buffer
Language IBIS-ISS
|
| Corner corner_name file_name     .subckt_name
Corner   Typ         buffer.iss    typ_typ
Corner   Min         buffer.iss    slow_min
Corner   Max         buffer.iss    fast_max
```

- [External Model] is under [Model]
- [Model] corner selection determines which Corner line to use

[External Circuit] Corners

```
[External Circuit] Circuit
Language IBIS-ISS
|
| Corner corner_name file_name      .subckt_name
Corner   Typ         circuit.iss    typ_typ
Corner   Min         circuit.iss    slow_min
Corner   Max         circuit.iss    fast_max
```

- User or EDA tool selects Corner line:
  - For buffer, set same as [Model] setting
  - For on-die interconnect, Corner can be used for range of values or aligned with connected [External Circuit] buffer

[Package] Corners

- **Default corners show range of values:**

```
[Package] | Corners by magnitude value give range
L_pkg  <Typ_val>  <Min_val>  <Max_val>
C_pkg  <Typ_val>  <Min_val>  <Max_val>
R_pkg  <Typ_val>  <Min_val>  <Max_val>
```

- **Most IBIS models have pin-specific detail that overrides [Package] setting:**
  - **L_pin, C_pin, R_pin**
  - **[Package Model] with [Define Package Model]**

IBIS-AMI Corners

- **AMI File, For example:**

```
(<parameter_name> (Usage Info) (Type Float)
                        (Corner <Typ val> <Slow val> <Fast val>))
```

- **Typ, Slow, Fast entries**
- **Slow, Fast entries not clear for some parameters such as Zo for reference impedance**
- **(Beyond Corners, IBIS-AMI allows these choices: List, Range, Steps, Increment, Value)**
- **User or EDA tool makes Corner selection**
- **Corners used for speed entry or range of values**

Parameter Passing Corners in IBIS Version 6.0 Note

- **Note, "parameter" used in several ways**
  - **"parameter" name variable in IBIS-AMI**
  - **"Parameter definition file" (an AMI file)**
  - **"Parameters" line assignment for [External Model] or [External Circuit]**
  - **"parameter" value passed into IBIS-ISS sub-circuit**
  - **"Parameter file (a non-AMI file for storing parameter names and assignments)**

Parameter Passing Corners in IBIS Version 6.0

- Used with [External Model] or [External Circuit]
- Actual corner selections stored in an IBIS-AMI file or a separate parameter file with any extension
- Parameter values passed into IBIS-ISS sub-circuits
- User selects which Parameter line corner to use
- Example shown next with transmission line Td (delay), Zo (reference impedance) parameters

[External Circuit] with Parameters Corner

```
Parameters Td=<name>.ami(<root>(Model_Specific(Td)))
Parameters Zo=<name>.ami(<root>(Model_Specific(Zo)))
....
[External Circuit] Interconnect-ISS
Language IBIS-ISS
|
| Corner corner_name file_name     .subckt_name
Corner   Typ         t-line.iss    typ_typ
Corner   Min         t-line.iss    slow_min
Corner   Max         t-line.iss    fast_max
```

- **Assume Parameters corners used in ALL Corner lines**
- **Td, Zo parameter values passed into the typ_typ, slow_min, fast_max sub-circuits**

[External Circuit] Parameters Using IBIS-AMI Example

- **Parameters to pass into IBIS-ISS:**

```
Parameters Td=<name>.ami(<root>(Model_Specific(Td)))
Parameters Zo=<name>.ami(<root>(Model_Specific(Zo)))
```

- **AMI File, (Model_Specific section):**

```
(Td (Usage Info) (Type Float)
                        (Corner 60e-12  66e-12  54e-12))
(Zo (Usage Info) (Type Float)      (Corner 50 55 45))
```

- **(Zo corner is ambiguous – larger value is selected as slow, (weaker) corner**

[External Circuit] Parameter Example Comments

- **Not clear whether the Parameters Lines should be aligned with the Typ, Min, Max corners or used as a range of values for each of the Corner lines**
- **Helpful solutions: use specific assignment:**
  - **Assign parameters directly in each IBIS-ISS sub-circuit**
  - **Or use separate parameter names; for example, Td_typ, Td_min, Td_max for individual range of values**
  - **Or use direct parameter Value assignment**
- **Minimize complication by minimizing user selections, where possible**

Upcoming Interconnect Modeling Corners

- **Attaches IBIS-ISS or Touchstone descriptions to buffers, die interfaces or pin interfaces**
- **Focus here is on IBIS-ISS applications**
- **Syntax is similar to [External Circuit] connection syntax ("File_ISS" replaces both "Corner" and "Language IBIS-ISS")**

```
| file_type   corner_name file_name    .subckt name
File_ISS      Typ         net.iss      netlist_typ
File_ISS      Min         net.iss      netlist_min
File_ISS      Max         net.iss      netlist_max
```

Param Line in Upcoming Interconnect Modeling Proposal

- **Supports parameter passing to IBIS-ISS ("Param" name is chosen to be distinct from the multiple meanings of the word "parameter")**

```
Param  <Name>  <Typ>  <Min>  <Max>
```

- **Min: Slow, Weak (where possible)**
- **Max: Fast, Strong (where possible)**
- **Mixing Min, Max possible for uncorrelated ranges**
- **All Min, All Max should be one option**

Adding Param Line Example:

```
| Param    Name      Typ       Min      Max
Param      Td        60ps      66ps     54ps
Param      Zo        50        55       45
|
| file_type  corner_name file_name    .subckt name
File_ISS     Typ          net.iss      netlist_typ
File_ISS     Min          net.iss      netlist_min
File_ISS     Max          net.iss      netlist_max
```

Interconnect Proposal Advice

- Similar to [External Circuit] advice
- Minimize or avoid parameter passing, where possible
- Be specific with parameter corner names
- Embed parameter values in sub-circuits
- Otherwise, parameters might be treated as a range of values

Td, Zo to/from L, C Conversions

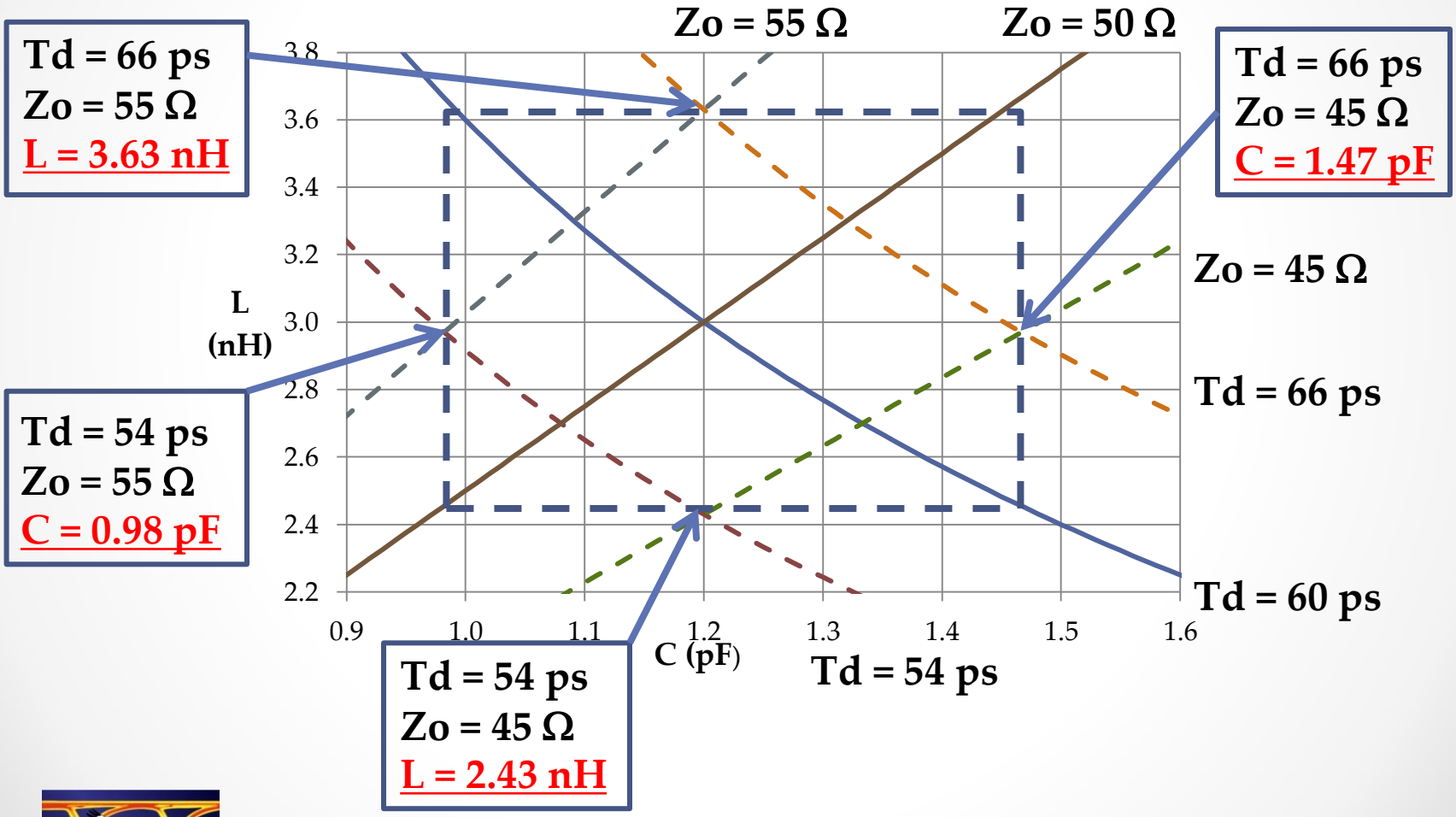
- Interconnect or package values may be extracted from TDR measurement in terms of ideal transmission line Td (delay) and Zo (reference impedance) values
- These values can be used directly, or might be converted to L, C representations for package models or for parameters in Interconnect Models
- L, C representation of corners give different "effective" ranges than the original Td, Zo corners

Equations to Plot L versus C as a Function of Td, Zo

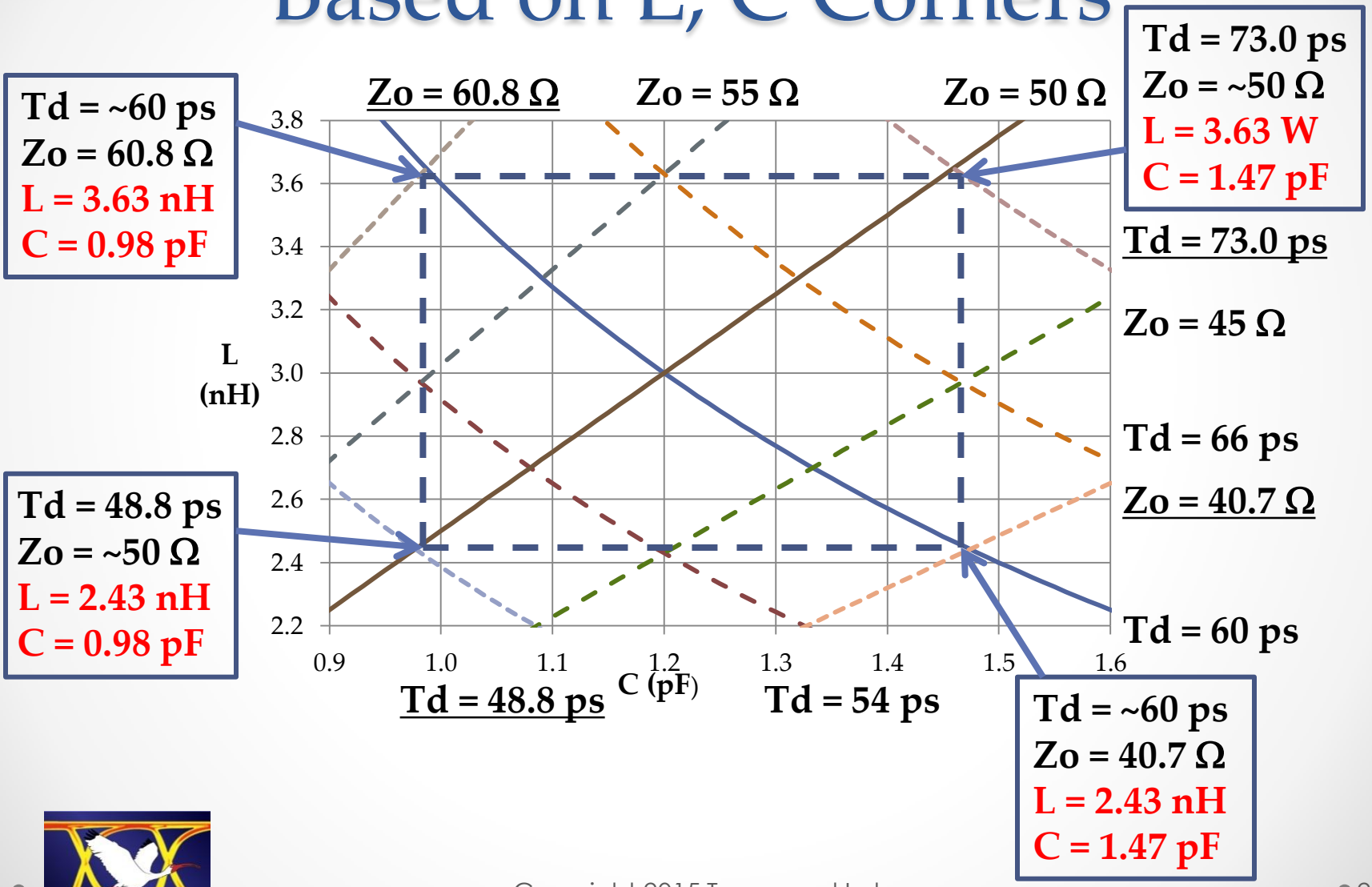
- **Transmission line to/from package transformations:**
  - **Td = Time delay**
  - **Zo = Reference impedance**
  - **L = Inductance**
  - **C = Capacitance**

  - **Td = Sqrt(LC), Zo = Sqrt(L/C) or**
  - **L = TdZo, C = Td/Zo → $\underline{L = Td^2/C}$, $\underline{L = Zo^2C}$**

L, C Min/Max Values from Example Td, Zo Corners



Wider "Effective" Td, Zo Based on L, C Corners



Wider "Effective" Td, Zo Based on L, C Corner Analysis

|Param	Name	Typ	Min	Max	| Original
Param	Zo	50	55	45	
Param	Td	60ps	66ps	54ps	

|Param	Name	Typ	Min	Max	L, C
Param	L	3.00nH	3.63nH	2.43nH	parameter
Param	C	1.20pF	1.47pF	0.98pF	corners

- **Combinations of L, C parameter do NOT give the original ranges, as shown in previous slide:**
  - **Td range = 48.8 ps to 73.0 ps**
  - **Zo range = 40.7 Ω to 60.8 Ω**

Concluding Comments

- IBIS contains several methods to describe corners and to assign and pass parameters
- Minimize parameter passing with corners because of different possible interpretations
- EDA tool should be capable of mixing or matching Typ, Min, Max conditions
- L, C corner values derived from Td, Zo corners can give different "effective" ranges