

Corner Considerations

Bob Ross, Teraspeed Labs

bob@teraspeedlabs.com

Asian IBIS Summit

Shanghai, China

November 14, 2014

(Given by Anders Ekholm, Ericsson)



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, “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 V6.0

- 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_min, 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 “Corner” and “Language”)

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” is used to be distinct from the multiple meanings of 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

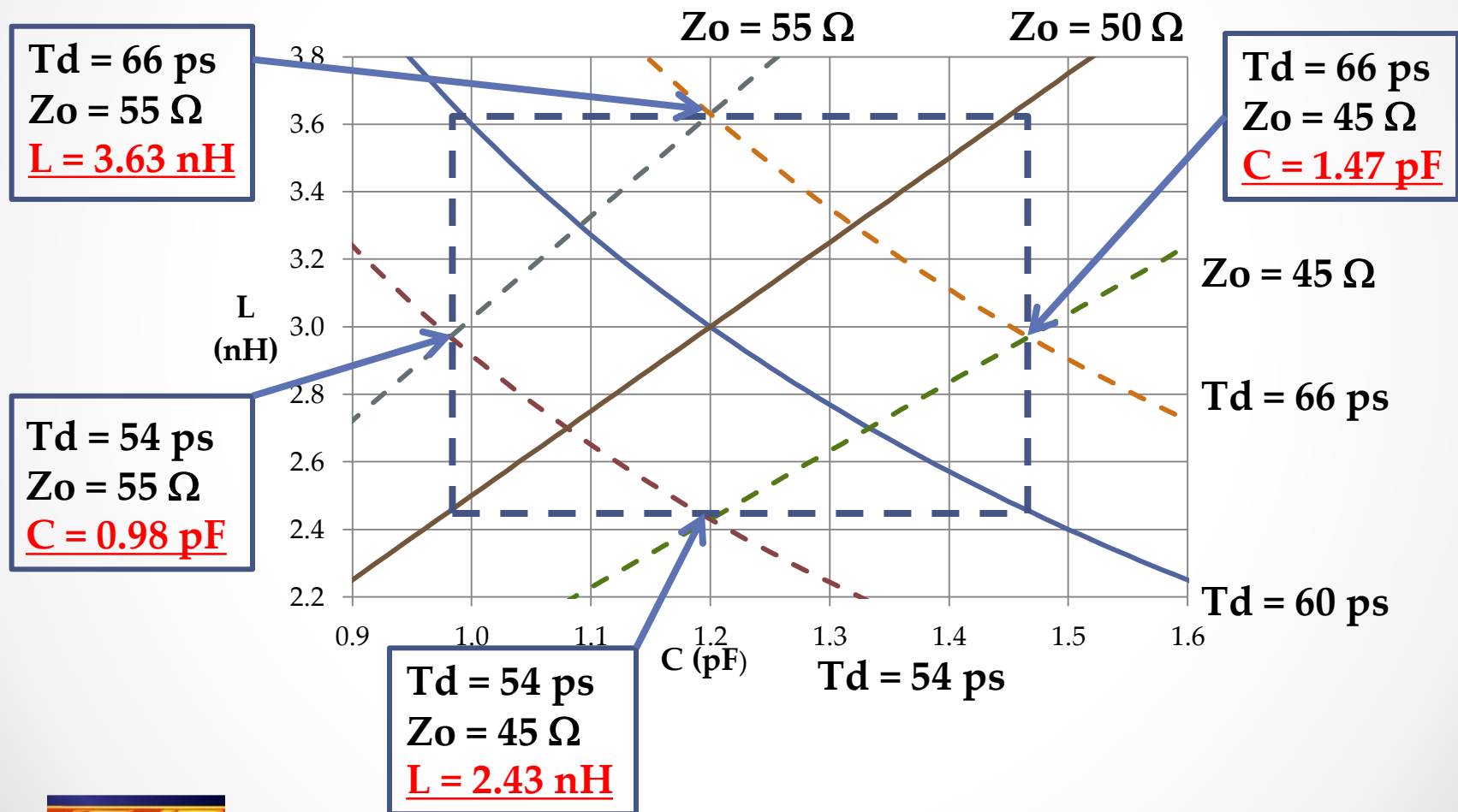


Equations to Plot L versus C as a Function of Td, Zo

- Transmission line to/from package transformations:
 - Td = Time delay
 - Zo = Reference impedance
 - L = Inductance
 - C = Capacitance
 - $Td = \text{Sqrt}(LC)$, $Zo = \text{Sqrt}(L/C)$ or
 - $L = TdZo$, $C = Td/Zo \quad \rightarrow \quad \underline{L = Td^2/C}, \underline{L = Zo^2C}$

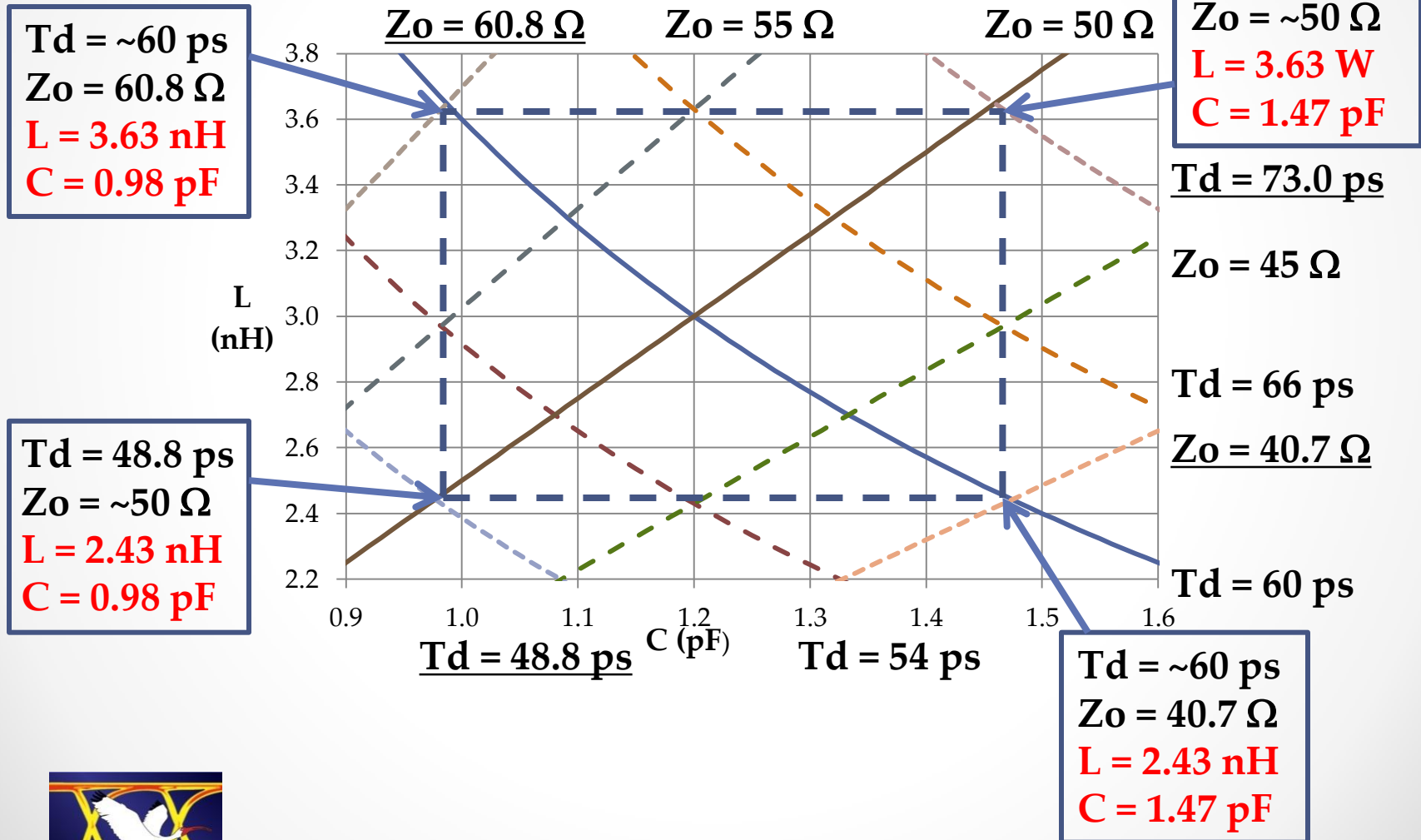


L, C Min/Max Values from Example Td, Zo Corners



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

