Physics based justification on C_p value ratification

(A presentation in support of draft 1.4 comments #115, #116 and #117)

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Supporters

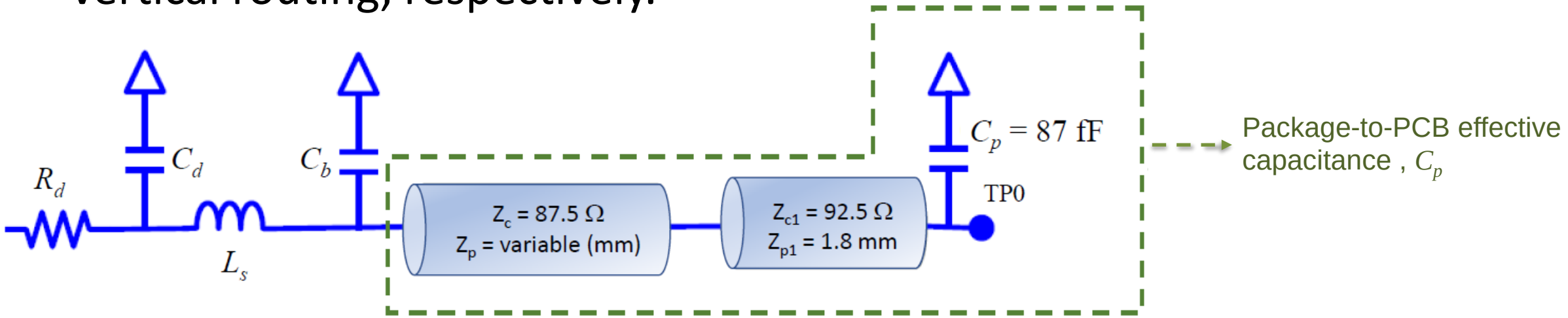
- Richard Mellitz, Samtech

Background and recommendation

- Individual workgroups for 400G have put the appropriate scrub on refining key parameters for PHY and PMD, e.g.
  - PHY equalization capability,
  - Connector optimization, and
  - Contribution of more realistic channel models representative of expected 400G designs.
- The COM reference package model has not received the same scrutiny from 200G to 400G.
- Principles of transmission line equivalent circuit theory indicate that the quantity C_p should be reduced from 87 fF to 60 fF.
- See comments #115, #116 and #117 proposing change for C_p.

Current topology for refence package

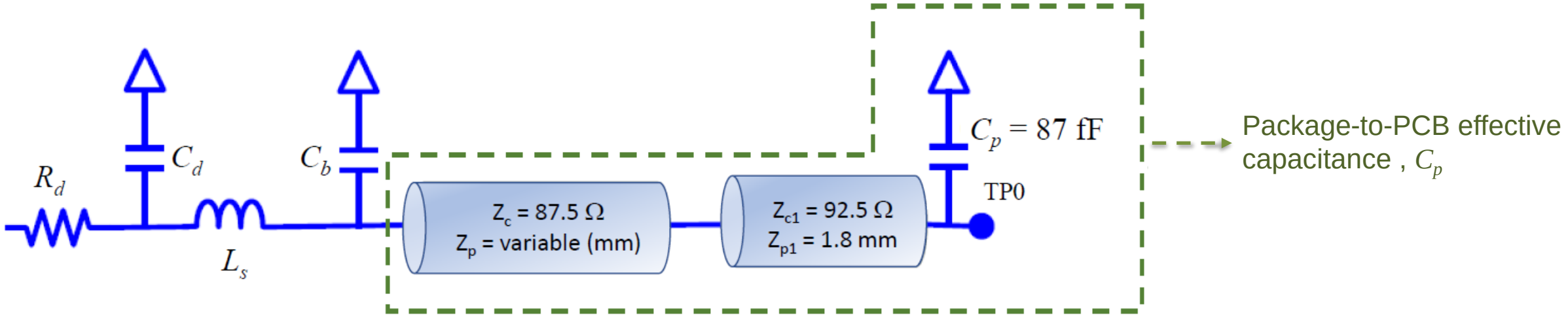
- R_s, C_d and L_s belong to the die.
- C_b is the die to package interface and includes the buildup vias.
- Series combination of two transmission lines for horizontal and vertical routing, respectively.



Mellitz, Richard, "COM 2.75 Update," IEEE 802.3 100 Gb/s, 200 Gb/s, and 400 Gb/s Electrical Interfaces Task Group Ad hoc, October 2 (2019)

Current topology for refence package (continued)

- The small effective transmission line section of the BGA is modeled using a shunt capacitor, C_p.
- Important note: modeling setup in 3D electromagnetic solvers will include a fraction of the PCB pad to BGA interface for port setup. Concatenated model overestimates the impact of the BGA region.



EM basics and basis for C_p change proposal

- BGA section is less than a quarter of a wavelength.
- Appropriate to approximate using a shunt capacitor relating characteristic impedance and equivalent capacitance by,
  - $Z_o = \frac{l}{v_p C} = \frac{l}{cC}$

    where c is the speed of light, l is the length of the transmission line, and C is the effective capacitance (F).
- Example:
  - BGA height once assembled, $l \approx 422$ μm.
  - Effective single ended impedance of the transmission line is only 16.1 Ω if $C_p = 87$fF; represents BGA ball and accompanying grounds.

EM basics and basis for C_p change proposal (continued)

- The capacitor approximation is valid for considered wavelength.
- The assignment of $C_p = 87$ fF equating to a corresponding 16.1 Ω single ended impedance (32.3 Ω differential) is too low.
- Contributions in other forums show that the value of C_p can be halved to $C_p = 43.5$ fF (presented at Q2 2020 OIF quarterly meeting, oif2020.224.01).
- Measurements from silicon vendors hint to a more conservative compromise of $C_p = 60$ fF, which was subsequently adopted in OIF 112G draft specifications; this allows for variability of substrate pad parasitic effect at BGA ball.

Summary

- As per comment for change request (#115, #116 and #117), C_p to be lowered to 60 fF.

- The proposed value translates to more accurate physical characteristic impedance of transmission line in the BGA field.

- The resulting impact of change: COM results for channel evaluation track more realistically physical implementation performance.