IEEE802.3ap

Channel Model TP4-TP5

Analysis of AC Coupled Path

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Agilent Technologies

Analysis Outline

- Project Definition
- Equipment and Measurement Setup
- DUT Specifications
- Measured Data Frequency Spectrum
- Measured S-Parameters
- Measured Eye Dimensions
- Time Domain Simulation Setup and Results
- Conclusions

Project Definition

Is:

Measured 2 port S-Parameters of a various AC coupling capacitors and a 0ohm resistor to see frequency domain effects on transmission

Measured spectral response of PRBS data to highlight broadband nature of data

Measured eye diagrams at 10.3125Gbps to see broadband time domain effects of PRBS7

Simulated transient response of ideal AC coupling capacitors to see run length effects

Is Not:

TP4-TP5 definition for the following reasons

- laminate is Rogers 4350 vs. Nelco 4000-13
- trace is 25mil microstrip vs. 4-10mil stripline
- trace is single-ended vs. differentially coupled
- no vias or solder pads vs. 1-2 vias and 2 solder pads

Test Equipment and Setup

Agilent E8362B 10MHz-20GHz PNA

IEEE802.3ap Network Analyzer Setup

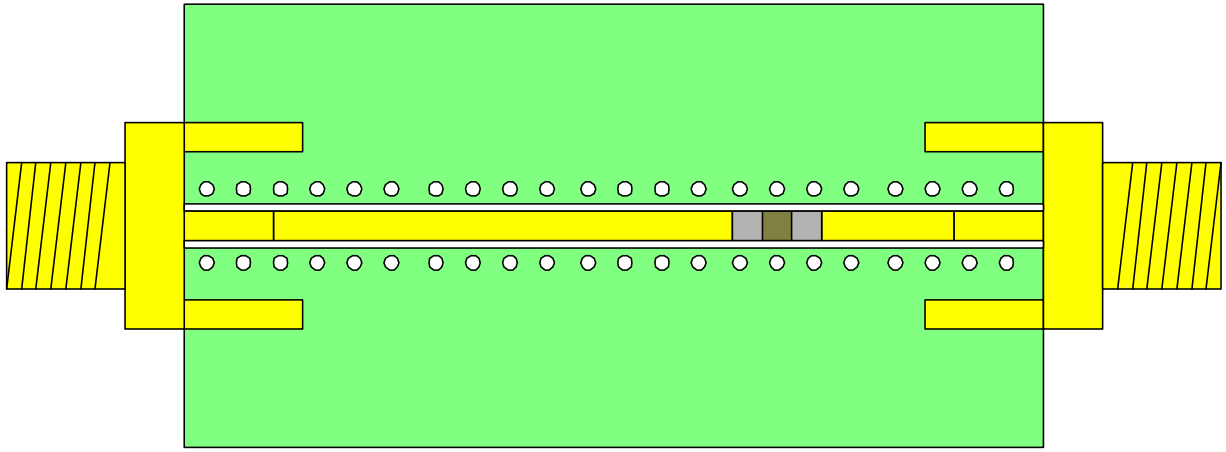
- **Frequency Span: 50MHz-15GHz**
- **IF: 300Hz**
- **Sweep: 10MHz interval, discrete steps, 5ms dwell**
- **Power: -0.5dB**
- **SOLT calibration to end of cables**

Agilent 86100C DCA-J

Agilent E4445A 3Hz-13.2GHz Spectrum Analyzer

Agilent N4901B 13.5Gbps BERT

PCB Detail



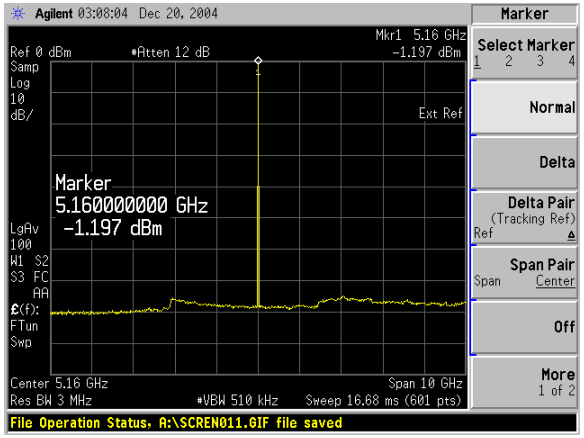
- **Laminate: 62mil thick Rogers 4350**
- **Transmission Line: 25mil x 1000mil, 50ohm, coplanar waveguide**
- **Connectors: edge launch SMA**
- **DUT: variety of SMT capacitors soldered in place and measured**

Devices Under Test

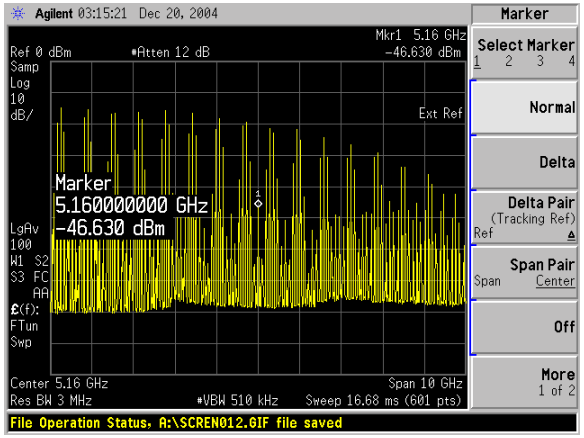
Value	Dielectric	SMT Size	Resonant Freq. (MHz)	ESL (nH)
0ohm	N/A	0402	N/A	N/A
55pF	C0G	0402	660	0.8
120pF	C0G	0402	550	0.5
860pF	???	0603	200	0.9
1.5nF	X7R	0402	120	1.1
4.7nF	X7R	0402	55	1.7
10nF	X7R	0402	40	1.9
100nF	X7R	0603	11	1.9
150nF	X7R	0603	9	2.0

10.3125Gbps Spectrum

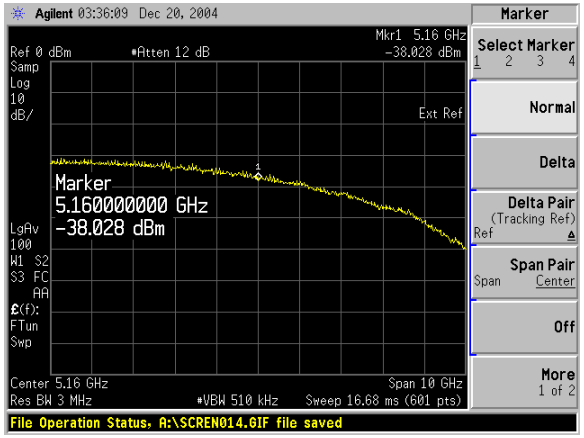
Comparison of SINE at Nyquist rate vs BERT generated PRBS at 10.3125Gbps



5.15625GHz SINE



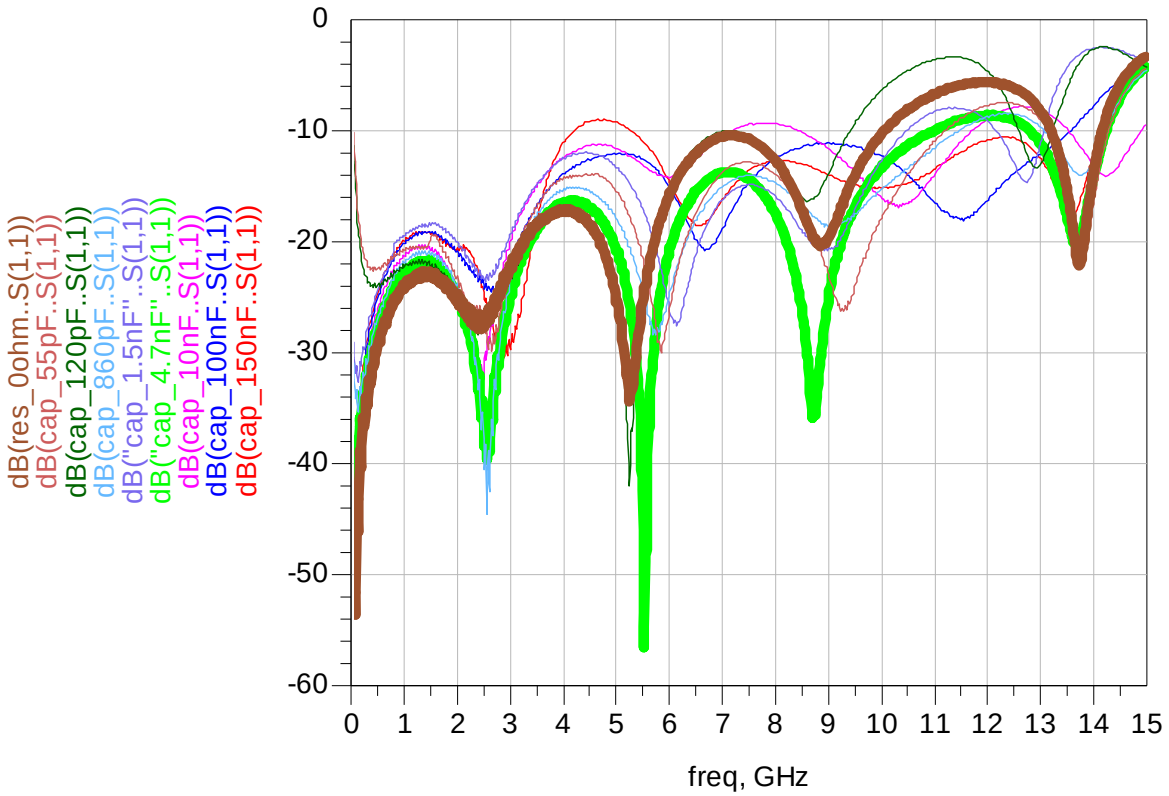
10.3125Gbps PRBS7



10.3125Gbps PRBS31

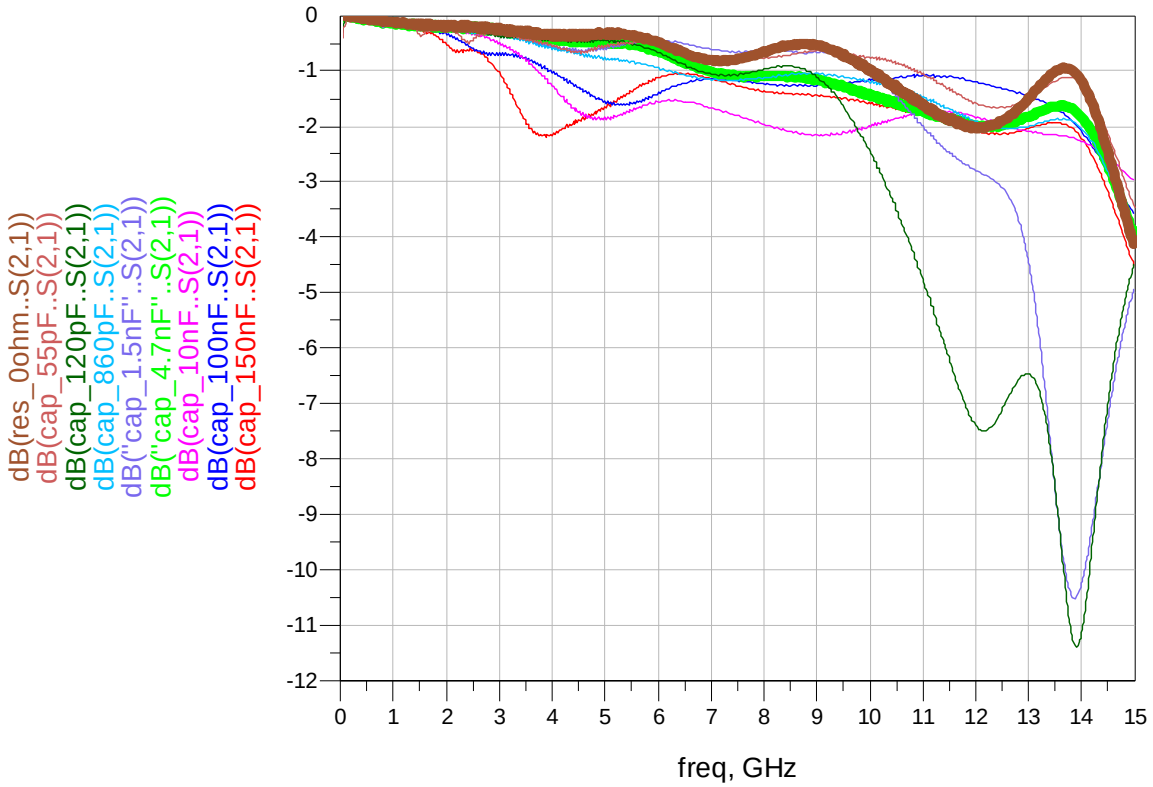
Spectral content of PRBS data is broadband and loses 30dB at 2*Nyquist rate

AC Coupled Path Return Loss



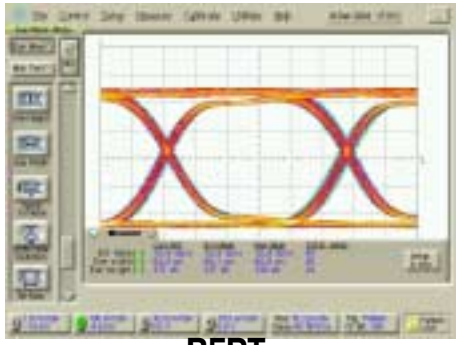
- **4.7nF cap (thick green) provides S11 comparable to DC coupling (thick brown)**
- **<860pF has worst impedance match below 500MHz**
- **other caps have much worse match across 3-6GHz range**

AC Coupled Path Insertion Loss

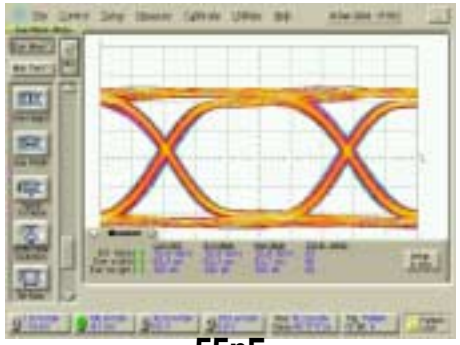


- **4.7nF cap (thick green) provides S21 comparable to DC coupling (thick brown)**
- **<860pF has worst loss <500MHz**
- **>4.7nF has worst loss >2GHz**

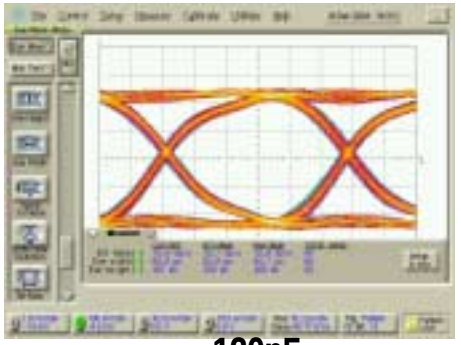
AC Coupled Eyes (PRBS7, 10.3125Gbps)



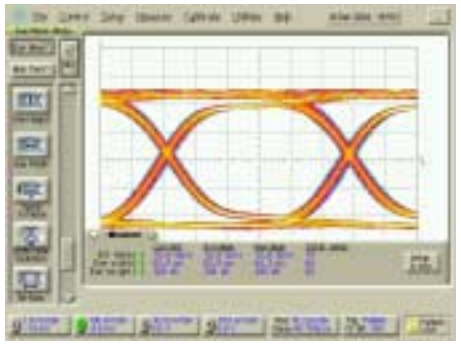
BERT



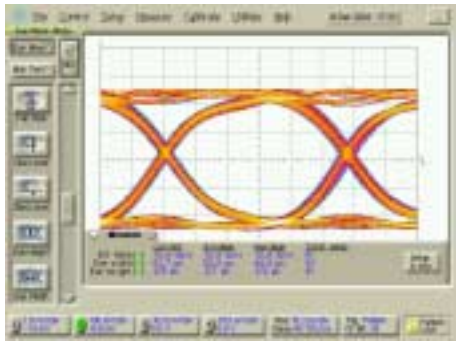
55pF



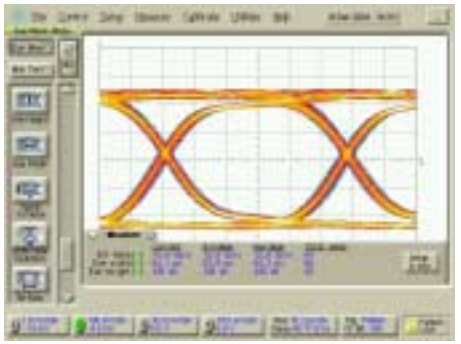
120pF



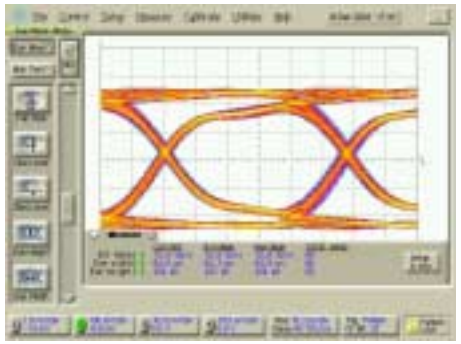
860pF



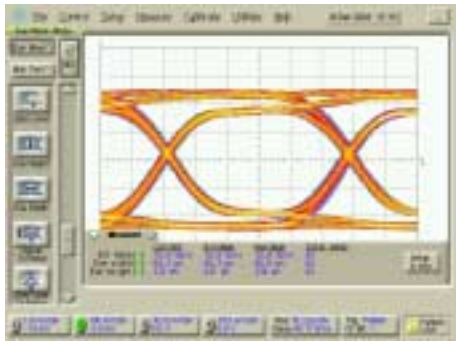
1.5nF



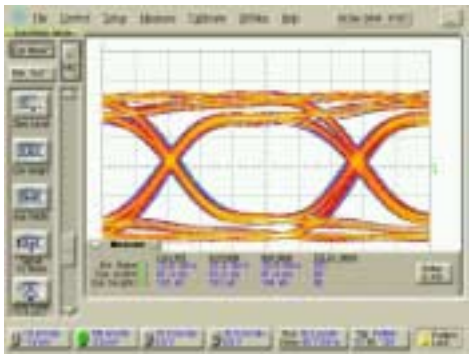
4.7nF



10nF



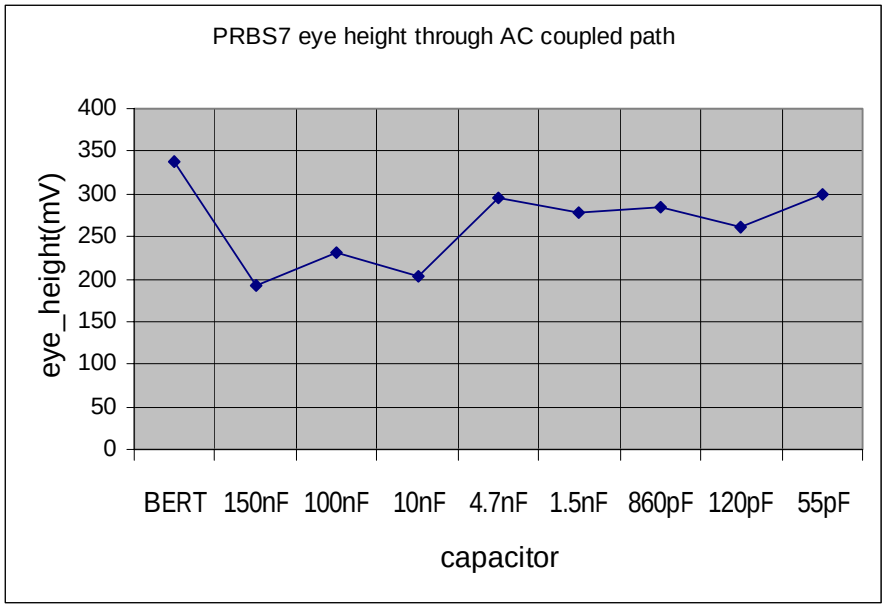
100nF

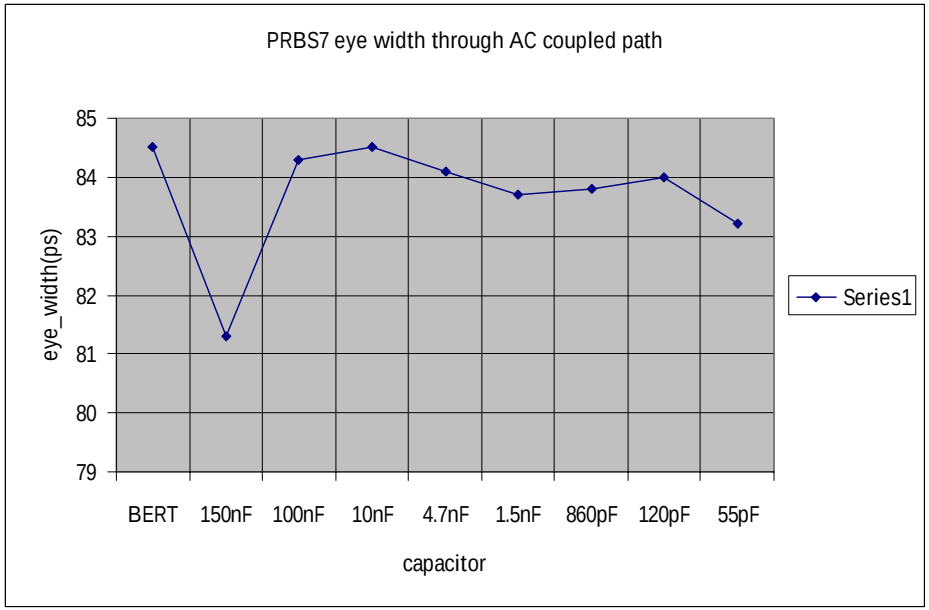


150nF

AC Coupled Eye Dimensions

Measurement Summary

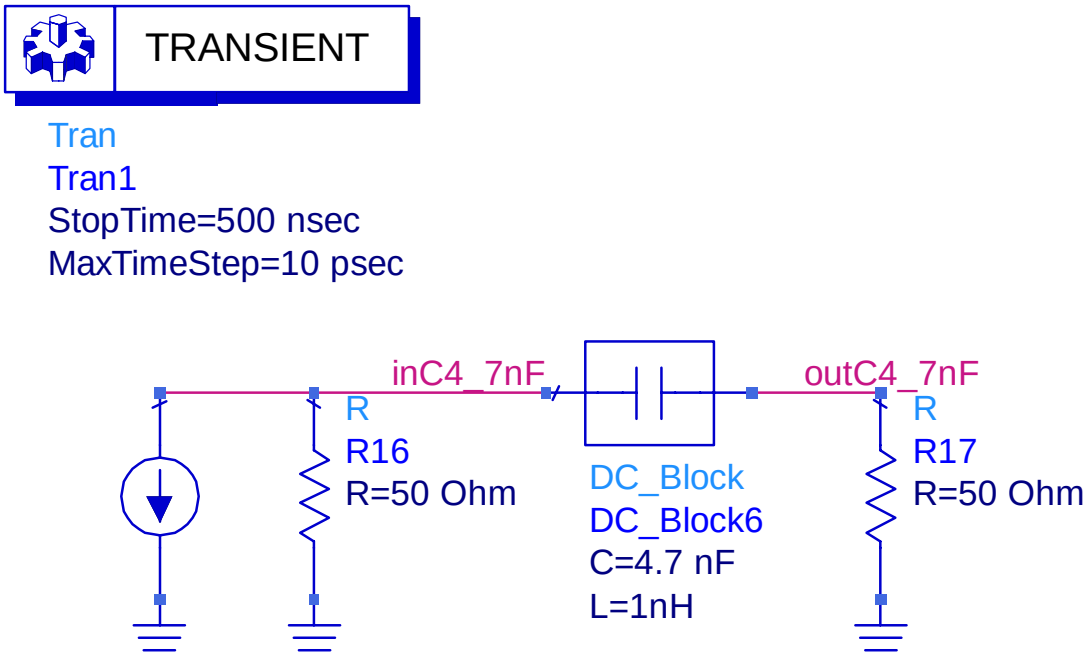




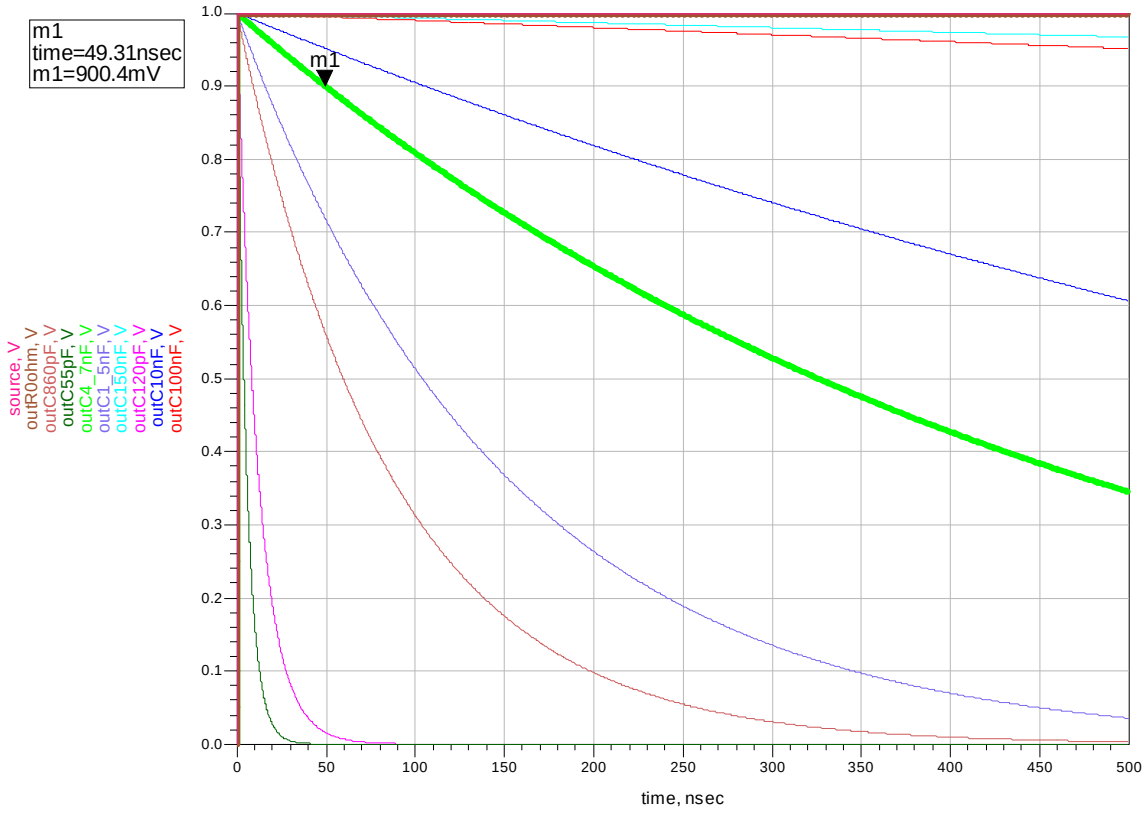
<10nF provides best eye height

100nF-4.7nF provides best eye width

Step Response Simulation Schematic



Transient Step Response



- **4.7nF cap holds 90% of input voltage for 508 bit times @10.3125Gbps**
- **This will provide adequate data run lengths**

Conclusions

- 10.3125Gbps PRBS data has broadband frequency spectrum that drops off ~10dB (DC-5GHz) and another ~20dB (5-10GHz) so a capacitor with minimal loss across this range would be preferable.
- S11 shows that caps <860pF have large reflection below 500MHz and caps >4.7nF have more reflection at 3-6GHz
- S21 shows that caps <860pF poor transmission below 500MHZ and caps >4.7nF have more loss and nulls >2GHz
- Eye height was maximized with <10nF
- Eye width was maximized with 4.7nF-100nF
- Run lengths of 100 bit times will produce no more than 10% droop for coupling capacitors >1nF
- 4.7nF capacitor with clean launch is best fit for 10.3125Gbps