

SAS-2 Transmitter/Receiver S-Parameter Measurement (07-012r1)

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S-Parameter Measurement





S11	S12	S13	S14
S21	S22	S23	S24
S31	S32	S33	S34
S41	S42	S43	S44

Four Port S-Parameter Table

Balanced S-Parameter Measurement





Sdd11	Sdd12	Sdc11	Sdc12
Sdd21	Sdd22	Sdc21	Sdc22
Scd11	Scd12	Scc11	Scc12
Scd21	Scd22	Scc21	Scc22

Two Port Balanced (differential) S-Parameter Table

S-Parameter Terminology



- For unbalanced terms the form is,
 - S_{<measured} port><injected port>
 - For example, S₃₂ is the response measured at port 3 from the signal injected into port 2
- For balanced terms the form is,
 - S_{<mode} of measured port><mode of injected port> <measured port><injected port>
 For example, S_{dc12} is the differential response measured at ports 1/3 from a common mode signal injected on both ports 2 and 4 (see balanced measurement diagram)
- Correctly interpreting the common mode to differential conversion measurement is difficult. More on that topic later.
- This presentation will focus on the various S_{11} terms

Balanced Port Values





Reflection Coefficient (Γ) and S_{11}

- How do the S₁₁ terms correlate to the reflection coefficient?
- The reflection coefficient (Γ) is the ratio of the amplitudes of the reflected wave to the incident wave
- It can be computed from the impedances of the incident media and termination
- The magnitude of Γ is ρ and the ${\rm S}_{11}$ magnitude is then

 $S_{11} = 20\log(\rho)$

$$\Gamma = \frac{V_{reflected}}{V_{incident}} = \frac{Z_t - Z_i}{Z_t + Z_i}$$
Incident Wave

Reflected Wave





- To verify the interpretation of the S₁₁ terms is correct, the following circuit was constructed with various termination values
- Both ${\rm S}_{11}$ and ρ where measured. ${\rm S}_{11}$ was then verified using the equations presented earlier





 In the following case the differential impedance matches the transmission line at 100Ω but the common mode impedance is 22.2Ω. Since the legs are mismatched a conversion is also introduced. We will introduce a common mode signal and analyze the conversion.



- Calculating the reflection coefficient *p* for the first leg we obtain is 0.143 and 0.200 for the second
- Also note that the results match very closely to the measured values
- For the reflected wave the first leg experiences a positive transitioning signal and the second leg a negative transitioning one



$$\rho = \frac{66.7 - 50}{66.7 + 50} = 0.143 \qquad \rho = \frac{33.3 - 50}{33.3 + 50} = -0.200$$

The reflected waves can be thought

- of as a signal injected into the instrumentation by the DUT. The same balanced port equations apply but in the opposite direction
- The reflected waves can be expressed as a ratio of the original signal injected into the termination network
- To determine S_{DC11} for the DUT, we merely need to interpret the reflected currents as differential mode signals

Balanced 1-port

Comparison of ρ and S_{11} Results





 The equation for differential mode currents presented earlier is (I_A - I_B)/2. Using the calculated values we obtain:

$$\frac{0.143 - (-0.200)}{2} = 0.172$$
$$S_{DC11} = 20\log(0.172) = -15.3$$

 Below 1 GHz, this value compares well with the actual measurement shown to the right





Full S_{DC11} Equation



• The equation used in the above comparison is:

$$20*\log(\frac{\rho_{pos_leg}-\rho_{neg_leg}}{2})$$

 Assuming identical impedance for both legs of the testing fixture we obtain



DUT Test Board

$$\frac{R_{pos_term} - Z_{fixture}}{R_{pos_term} + Z_{fixture}} - \frac{R_{neg_term} - Z_{fixture}}{R_{neg_term} + Z_{fixture}})$$

$$20*\log(\frac{R_{pos_term} + Z_{fixture}}{2})$$

What do S_{11} values mean?



 The fixture shown below can be used to demonstrate the relationship between \$11 and \$21



• The that S11 and S21 are the relative amplitude and not power





What do S_{11} values mean?



- For interfaces with impedance discontinuities, power is conserved. The sum of the reflected and transferred power is equal to the injected power – minus the power dissipated across the span of the discontinuity.
- Signal amplitude is determined by the reflection coefficient.
- S₁₁ is not a direct indicator of what S₂₁ is





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Vendor Samples

- To the right are S_{DD11} measurements of two test boards provided by two different PHY suppliers
- The measurements are made with power on and off
- Test board effects were not de-embedded from the measurements





Reference Material



- Agilent has two application notes with materials used in this presentation. Both are good for further reading on this topic.
 - 1. Characterization of balanced digital components and communication paths
 - 2. Advanced measurements and modeling of differential devices





i n v e n t

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