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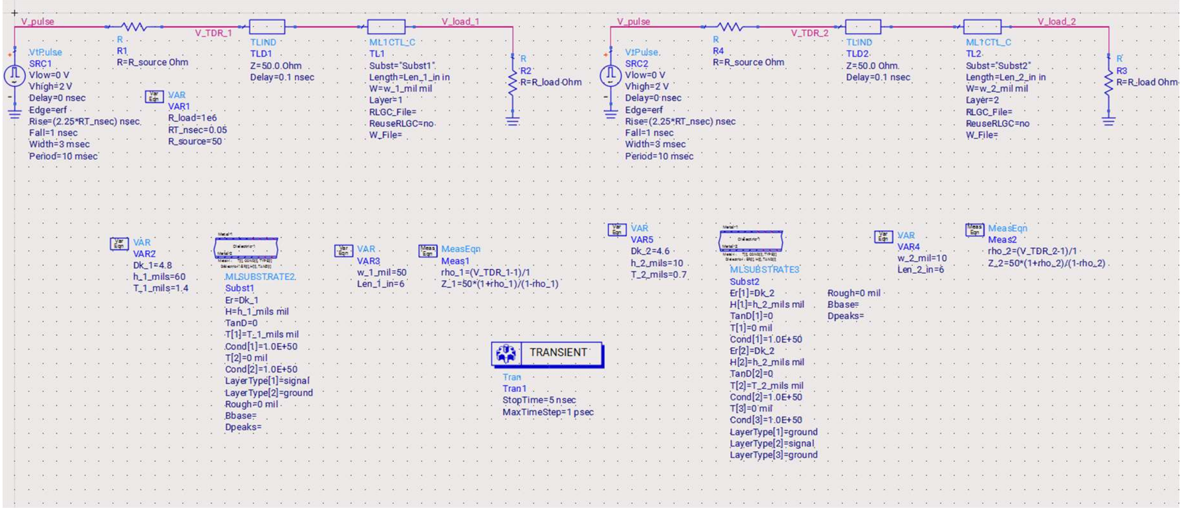
Week 6 Labs
2026-02-16

Lab 1:

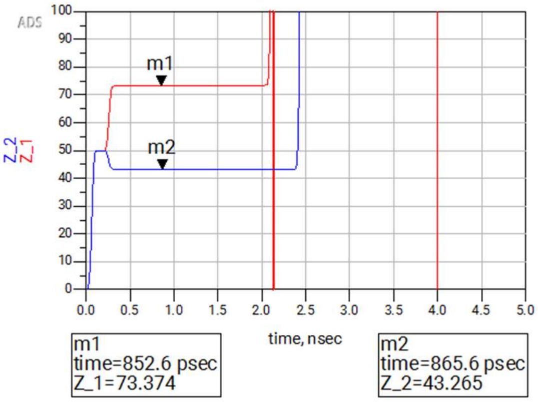
The purpose of this lab is to learn how to use the field solver in ADS and use that to judge the accuracy of approximating calculators like PCB Toolkit from Saturn PCB and the online tool from Sierra Circuits.

Two step responses were tested. In both configurations, the source voltage was 2V, the source impedance was 50 Ohm, the load was an open, and the 10-90 rise time of the step was 50 psec. In the first configuration, a microstrip was tested with a height of 60 mils, a line width of 50 mils, a pour thickness of 1.4 mils (1 oz pour), and a substrate dielectric constant of 4.8. The second configuration was a symmetrical stripline with a height of 10 mils, a line width of 10 mils, a pour thickness of 0.7 mils (0.5 oz pour), and a dielectric constant of 4.6.



```
VtPulse
SRC1
Vlow=0 V
Vhigh=2 V
Delay=0 nsec
Edge=erf
Rise=(2.25*RT_nsec) nsec
Fall=1 nsec
Width=3 msec
Period=10 msec

R
R1
R=R_source Ohm

VAR
VAR1
R_load=1e6
RT_nsec=0.05
R_source=50

TLIND
TLD1
Z=50.0 Ohm
Delay=0.1 nsec

ML1CTL_C
TL1
Subst="Subst1"
Length=Len_1_in in
W=w_1_mil mil
Layer=1
RLGC_File=
ReuseRLGC=no
W_File=

R
R2
R=R_load Ohm

VtPulse
SRC2
Vlow=0 V
Vhigh=2 V
Delay=0 nsec
Edge=erf
Rise=(2.25*RT_nsec) nsec
Fall=1 nsec
Width=3 msec
Period=10 msec

R
R4
R=R_source Ohm

TLIND
TLD2
Z=50.0 Ohm
Delay=0.1 nsec

ML1CTL_C
TL2
Subst="Subst2"
Length=Len_2_in in
W=w_2_mil mil
Layer=2
RLGC_File=
ReuseRLGC=no
W_File=

R
R3
R=R_load Ohm

VAR
VAR2
Dk_1=4.8
h_1_mils=60
T_1_mils=1.4

MLSUBSTRATE2
Subst1
Er=Dk_1
H=h_1_mils mil
TanD=0
T[1]=T_1_mils mil
Cond[1]=1.0E+50
T[2]=0 mil
Cond[2]=1.0E+50
LayerType[1]=signal
LayerType[2]=ground
Rough=0 mil
Bbase=
Dpeaks=

VAR
VAR3
w_1_mil=50
Len_1_in=6

MeasEqn
Meas1
rho_1=(V_TDR_1-1)/1
Z_1=50*(1+rho_1)/(1-rho_1)

Tran
Tran1
StopTime=5 nsec
MaxTimeStep=1 psec

VAR
VAR5
Dk_2=4.6
h_2_mils=10
T_2_mils=0.7

MLSUBSTRATE3
Subst2
Er[1]=Dk_2
H[1]=h_2_mils mil
TanD[1]=0
T[1]=0 mil
Cond[1]=1.0E+50
Er[2]=Dk_2
H[2]=h_2_mils mil
TanD[2]=0
T[2]=T_2_mils mil
Cond[2]=1.0E+50
T[3]=0 mil
Cond[3]=1.0E+50
LayerType[1]=ground
LayerType[2]=signal
LayerType[3]=ground
Rough=0 mil
Bbase=
Dpeaks=

VAR
VAR4
w_2_mil=10
Len_2_in=6

MeasEqn
Meas2
rho_2=(V_TDR_2-1)/1
Z_2=50*(1+rho_2)/(1-rho_2)
```

Figure 1: ADS schematic for testing the integrated 2D field solvers.

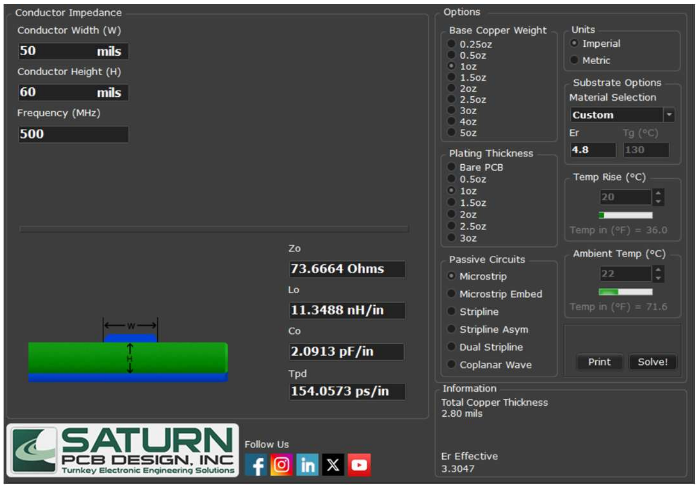


m1
time=852.6 psec
Z_1=73.374

m2
time=865.6 psec
Z_2=43.265

Figure 2: Simulated TDR for the transmission lines defined by the ADS 2D field solver. (Red=microstrip, blue=stripline).

These results show that the instantaneous impedance Z_0 is ~73.4Ω for the microstrip and ~43.3Ω for the stripline.


Conductor Impedance
Conductor Width (W)
50 mils
Conductor Height (H)
60 mils
Frequency (MHz)
500

Zo
73.6664 Ohms
Lo
11.3488 nH/in
Co
2.0913 pF/in
Tpd
154.0573 ps/in

Options
Base Copper Weight
○ 0.25oz
○ 0.5oz
● 1oz
○ 1.5oz
○ 2oz
○ 2.5oz
○ 3oz
○ 4oz
○ 5oz

Units
● Imperial
○ Metric

Substrate Options
Material Selection
Custom
Er 4.8
Tg (°C) 130

Plating Thickness
○ Bare PCB
○ 0.5oz
● 1oz
○ 1.5oz
○ 2oz
○ 2.5oz
○ 3oz

Temp Rise (°C)
20
Temp in (°F) = 36.0

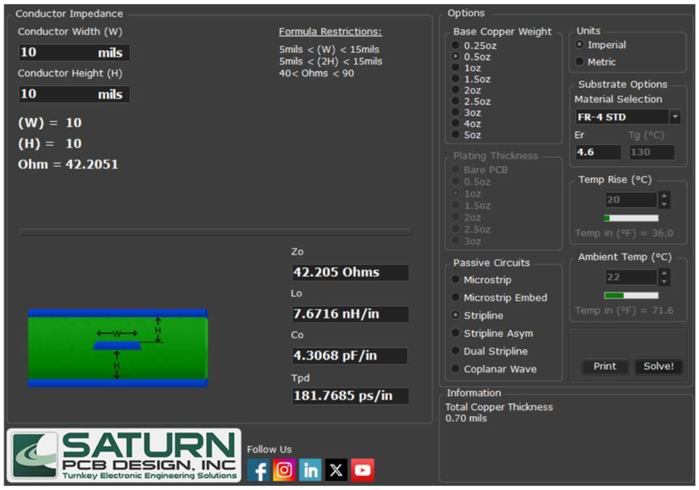
Passive Circuits
● Microstrip
○ Microstrip Embed
○ Stripline
○ Stripline Asym
○ Dual Stripline
○ Coplanar Wave

Ambient Temp (°C)
22
Temp in (°F) = 71.6

Information
Total Copper Thickness
2.80 mils

Er Effective
3.3047

Figure 3: Saturn results for microstrip.


Conductor Impedance
Conductor Width (W)
10 mils
Conductor Height (H)
10 mils

Formula Restrictions:
5mils < (W) < 15mils
5mils < (2H) < 15mils
40< Ohms < 90

(W) = 10
(H) = 10
Ohm = 42.2051

Zo
42.205 Ohms
Lo
7.6716 nH/in
Co
4.3068 pF/in
Tpd
181.7685 ps/in

Options
Base Copper Weight
○ 0.25oz
● 0.5oz
○ 1oz
○ 1.5oz
○ 2oz
○ 2.5oz
○ 3oz
○ 4oz
○ 5oz

Units
● Imperial
○ Metric

Substrate Options
Material Selection
FR-4 STD
Er 4.6
Tg (°C) 130

Plating Thickness
○ Bare PCB
○ 0.5oz
● 1oz
○ 1.5oz
○ 2oz
○ 2.5oz
○ 3oz

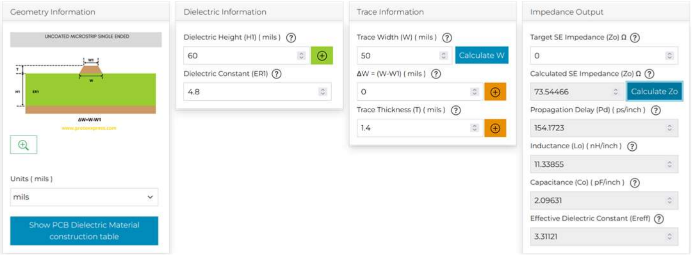
Temp Rise (°C)
20
Temp in (°F) = 36.0

Passive Circuits
○ Microstrip
○ Microstrip Embed
● Stripline
○ Stripline Asym
○ Dual Stripline
○ Coplanar Wave

Ambient Temp (°C)
22
Temp in (°F) = 71.6

Information
Total Copper Thickness
0.70 mils

Figure 4: Saturn results for stripline.

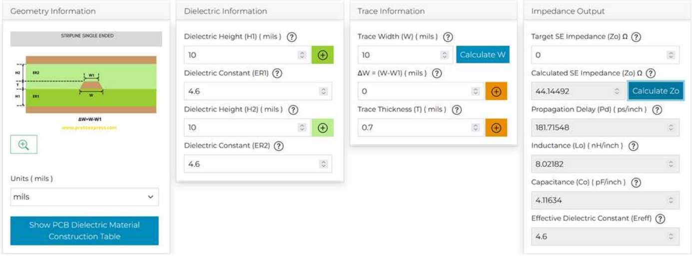

Geometry Information
UNCOATED MICROSTRIP SINGLE ENDED
Units (mils)
mils

Dielectric Information
Dielectric Height (H1) (mils)
60
Dielectric Constant (ER1)
4.8

Trace Information
Trace Width (W) (mils)
50
ΔW = (W-W1) (mils)
0
Trace Thickness (T) (mils)
1.4

Impedance Output
Target SE Impedance (Zo) Ω
0
Calculated SE Impedance (Zo) Ω
73.54466
Propagation Delay (Pd) (ps/inch)
154.1723
Inductance (Lo) (nH/inch)
11.33855
Capacitance (Co) (pF/inch)
2.09631
Effective Dielectric Constant (Ereff)
3.31121

Figure 5: Sierra results for microstrip.


Geometry Information
STRIPLINE SINGLE ENDED
Units (mils)
mils

Dielectric Information
Dielectric Height (H1) (mils)
10
Dielectric Constant (ER1)
4.6
Dielectric Height (H2) (mils)
10
Dielectric Constant (ER2)
4.6

Trace Information
Trace Width (W) (mils)
10
ΔW = (W-W1) (mils)
0
Trace Thickness (T) (mils)
0.7

Impedance Output
Target SE Impedance (Zo) Ω
0
Calculated SE Impedance (Zo) Ω
44.14492
Propagation Delay (Pd) (ps/inch)
181.71548
Inductance (Lo) (nH/inch)
8.02182
Capacitance (Co) (pF/inch)
4.11634
Effective Dielectric Constant (Ereff)
4.6

Figure 6: Sierra results for stripline.

Solver	**Microstrip Z_0 (Ω)**	**Stripline Z_0 (Ω)**
ADS	73.4	43.3
Saturn	73.7	42.2
Sierra	73.5	44.1

Table 1: Tabulated characteristic impedance results.

<u>So what:</u>

Based on the results in table 1, the estimator tools prove fairly accurate, but they do work better for the microstrip than for the stripline. I assume that this is because the equations get more complicated and harder to approximate when there are more layers.

Since using the ADS solver was so easy, I will not have much resistance to using it to get more accurate characteristic impedances. However, I do still need to build a circuit and simulate, so I will continue using the solvers when I need a quick answer or when the characteristic impedance isn't super important. If I don't have access to ADS, the results from the free estimators are close enough that I would feel comfortable using them for personal use cases.

Lab 2:

The purpose of this lab is to explore the impact of various termination strategies to mitigate reflections. The RX is open, the transmission line characteristics are common, and the voltage source is constant.

Three sources were tested (a clock, a step, and a single-bit response (SBR)) in conjunction with four termination strategies (no termination, source-series terminated, far-end ground terminated, and far-end Vtt terminated) for a total of 12 combinations.

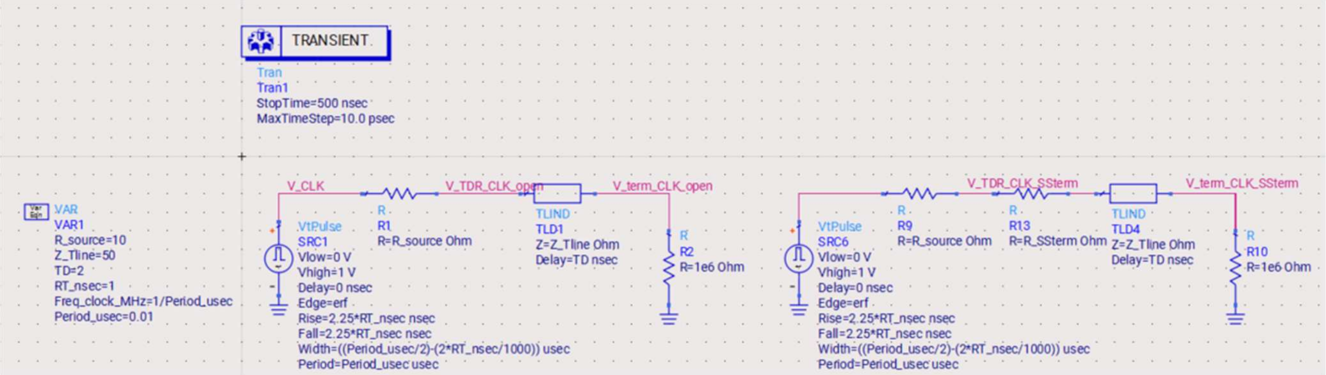


Figure 1: Portion of the ADS schematic for simulating the clock signal with no termination strategy and with source-series termination strategy. These termination strategies are copied onto other signal sources.

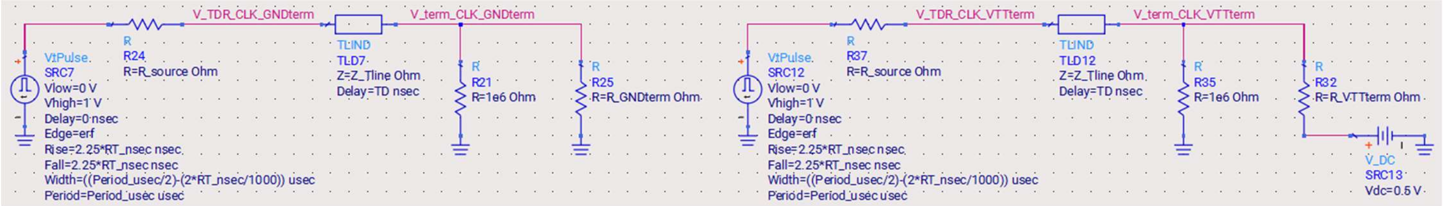


Figure 2: Portion of the ADS schematic for simulating the clock signal with far-end ground termination strategy and with far-end V_{tt} termination strategy. These termination strategies are copied onto other signal sources.

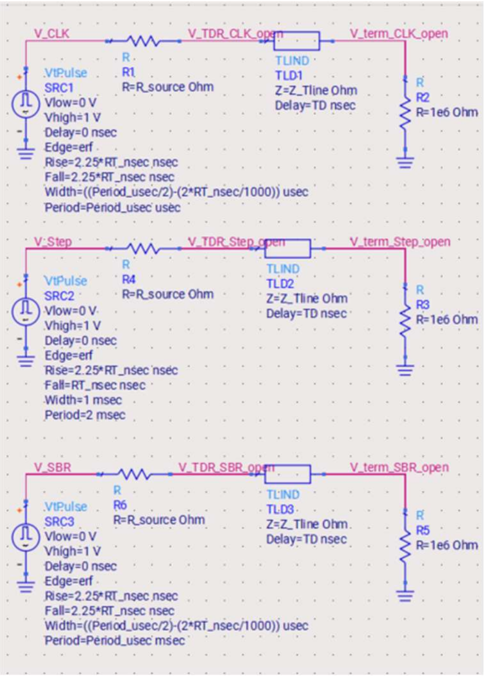


Figure 3: Portion of the ADS schematic showing the various sources without any termination strategy. The sources were copied for each termination strategy.

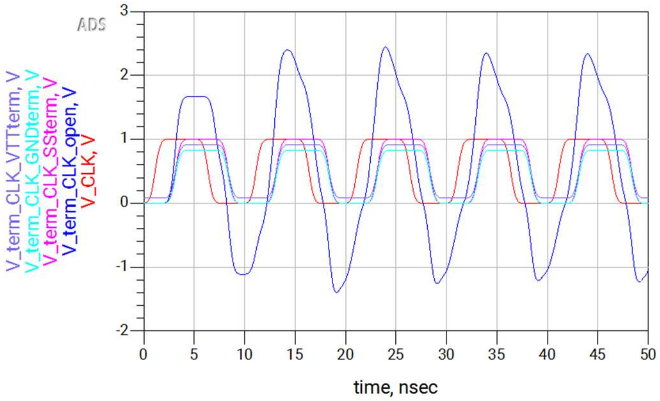


Figure 3: Termination results for the clock source.

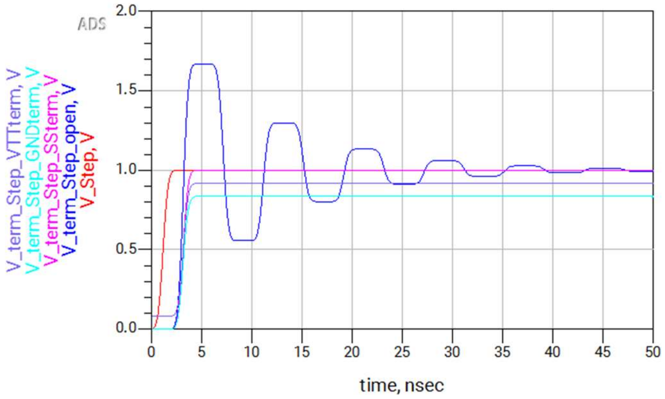


Figure 4: Termination results for the step source.

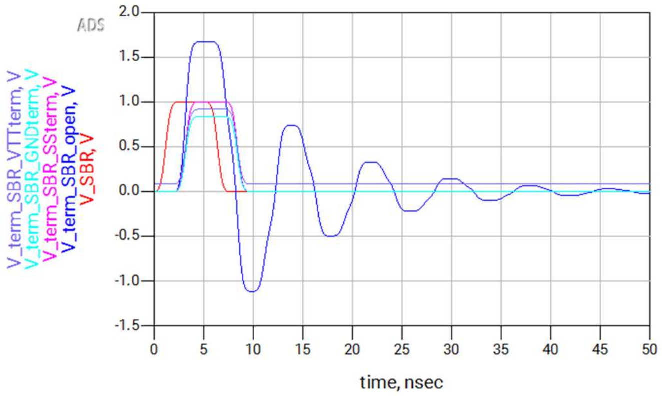


Figure 5: Termination results for the SBR source.

Based on the step, the response for an unterminated line takes ~30 nsec to settle, meaning it would create noise affecting the next two bits. This is an estimate and would vary depending on the margin of the RX.

All termination strategies show that they work to eliminate reflections at the RX end, though they all have different receiver voltage ranges. The source-series termination shows no voltage degradation due to the reflection at the RX. The far-end ground termination drops the high voltage by $V_{\text{source}} * \frac{Z_{tline} - R_{source}}{Z_{tline} + R_{source}} * 2 = 0.8\text{V}$. The far-end V_{tt} termination affects the low and high voltage. By setting $V_{tt} = 0.5 * V_{CC}$, the high voltage is 0.9V and the low voltage is 0.1V.

<u>So what:</u>

All of these termination strategies are valid. If having a reflection sent back through the transmission line to the source doesn't matter, I would prefer a source-series termination since it doesn't affect voltages at the receiving end. I like how the far-end V_{tt} termination can shift the voltages at the termination up or down so that the received voltage can be within the voltage range. I like the far-end ground termination because it is simple and doesn't require creating a V_{tt} source.