

## ECE 733 Project 2 – Spice Support

### Producing an Eye Diagram

The following code fragment will allow you to produce an eye diagram:

```
V1 EYE_X_AXIS 0 PULSE 0 'period*2' 'period*offset+fine_offset'  
'period*2-step' step 0.0n 'period*2'
```

You can also do this in the cadence calculator.

ADD ABOVE LINE INTO YOUR SP FILE;  
USE EYE\_X\_AXIS AS X\_AXIS, AND THE SIGNAL AS Y\_AXIS, THEN YOU WILL  
SEE THE EYE.

\* where period is the width of a bit; offset is from which bit you want to see EYE, say 1,2,3,... or whatever you want; fine\_offset is used to set the sampling point; step is used to set the resolution

\*Example: To see the EYE of a 5Gbps NRZ signal

\*Set the parameters to

\*period=200ps

\*offset=0

\*fineoffset=0ps

\*step=1p

\*You need to set your own offset, fine\_offset and step to get best EYE and reduced run time.

### **Single Sided Interconnect Circuit Model**

#### Interconnect Circuit

For a single sided transmission line, use the following W-model:

```
W1 N=1 TL_IN 0 TL_OUT 0 RLGCMODEL=ECE733 l=1.0
```

```
.MODEL ECE733 W MODELTYPE=RLGC N=1
```

```
+Lo=
```

```
+300e-9
```

```
+Co=
```

```
+120e-12
```

```
+Ro=
```

```
+0.54
```

```
+Rs=
```

```
+0.000462
```

+Gd=  
+1.4e-11

This is the W model (for microstrip line on PCB),  
TL Length is 100cm, Z0=50ohm, propagation speed is 1.67E+8m/s.  
The corresponding PCB trace is:

1. thickness of the top metal layer(copper): T is 2~2.5mil,
  2. width of the top metal layer: W=22mil,
  3. thickness of dilectric layer: H=12mil,
- The Hspice manuals provide more detail.

**W Model for differential TL:**

```
W1 N=2 TL_IN_POS TL_IN_NEG 0 TL_OUT_POS TL_OUT_NEG 0  
RLGCMODEL=ECE733 l=1.0
```

```
.MODEL ECE733 W MODELTYPE=RLGC N=2  
+Lo=  
+300e-9  
+60e-9 300e-9  
+Co=  
+120e-12  
+ -24e-12 120e-12  
+Ro=  
+0.54  
+0 0.54  
+Rs=  
+0.000462  
+0 0.000462  
+Gd=  
+1.4e-11  
+ -0.14e-11 1.4e-11
```

Explanation: **This is the model to use for your project.**

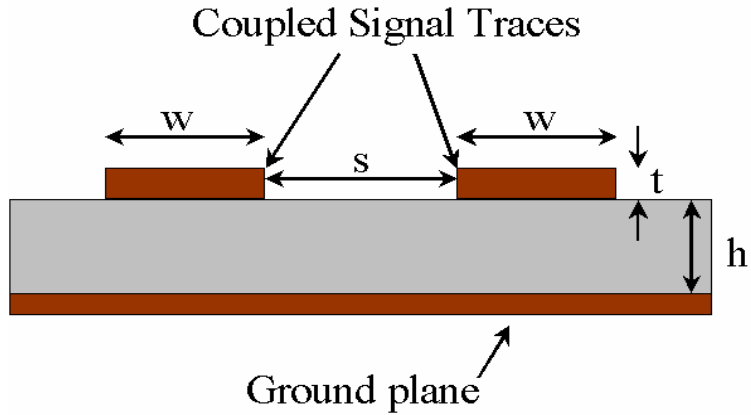


Fig.1 Actual Size

$w=22\text{mil}$ ,  $h=12\text{mil}$ ,  $t=2\sim 2.5\text{mil}$ ,  $s=5*w$ ,  $\epsilon_r=4.6$

1. Assume Coupled dielectric loss is 10% of the self dielectric loss, that is mutual  $G_d=1.4e-11*10\%=0.14e-11$ . This mutual  $G_d$  is enough, given the space of the coupled traces is not place very near:  $w=5*s$ .
2. Mutual capacitance and mutual inductance of the coupled differential TL is derived from the actual geometrical, see detail derivation in the matlab file. The result is shown in Fig2 and Fig3. Fig2 shows Odd mode impedance and Even mode impedance Vs.  $S/W$ . We don't need to consider Even mode impedance too much since the common mode voltage on TL is zero for ACCI. Fig.3 shows the coupling coefficient: for lines in homogeneous medium,  $K_m=K_c$ . For case of  $S=5*W$ ,  $K_m=K_c=0.2$ ,  $Z_{odd}=41\text{ohm}$ (that is Differential impedance is  $80\text{ohm}$ ).

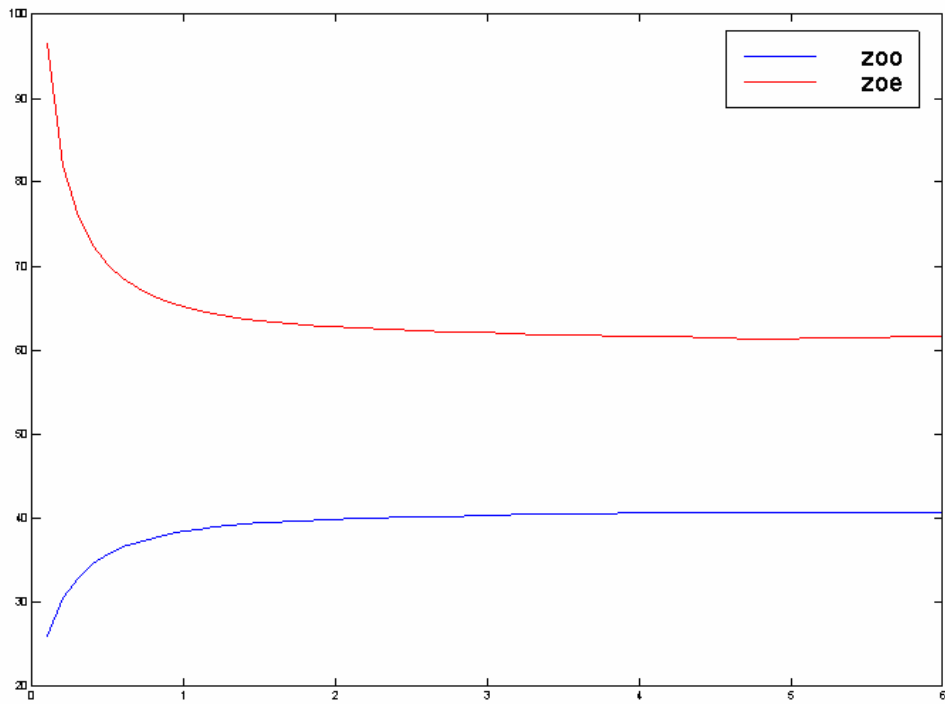


Fig2. Zodd and Zeven VS. S/W

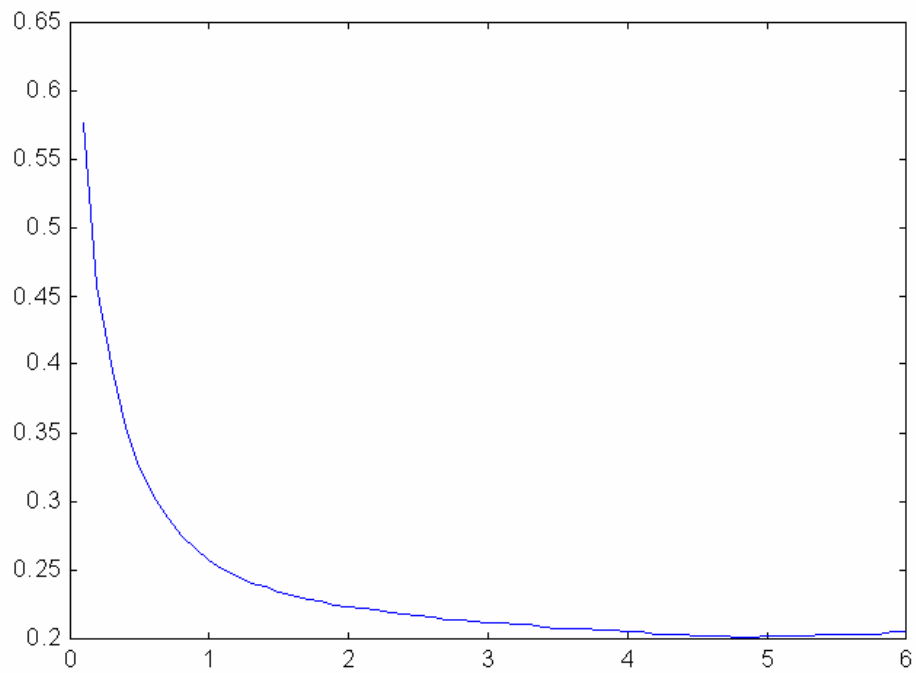


Fig.3 Kc and Km VS. S/W

Smaller S will lead to larger Kc, Km and smaller differential impedance.

3. This model is simulated in Hspice and when terminated by 41ohm, the reflection is the smallest, which proves the correctness. See attached spice file for details.

```
****Matlab file*****
clear all;
close all;
w=22;

h=12;
e0=8.854e-12;
er=4.6;
eeff=(er+1)/2 + ((er-1)/2)/sqrt(1+12*h/w);
z0=50;
c0=120e-12;
c=3e8;

cp=e0*er*w/h;
cf=0.5*(sqrt(eeff)/(c*z0)-cp);

for i=1:300
    s(i)=0.1*i*w;
    k(i)=(s(i)/h)/(s(i)/h+2*w/h);
    k1(i)=sqrt(1-power(k(i),2));
    if power(k(i),2)<0.5
        kk(i)=(1/pi)*log(2*(1+sqrt(k1(i)))/(1-sqrt(k1(i))));
    else
        kk(i)=pi/log(2*(1+sqrt(k(i)))/(1-sqrt(k1(i))));
    end

    cga(i)=e0*kk(i);
    cgd(i)=(e0*er/pi)*log(coth((pi*s(i))/(4*h))) +
    0.65*cf*(0.02*sqrt(er)*h/s(i)+1-power(er,-2));

    cm(i)=cga(i)+cgd(i);

    kc(i)=cm(i)/c0;
    km(i)=kc(i);

    zoo(i)=z0*sqrt((1-km(i))/(1+kc(i)));
    zoe(i)=z0*sqrt((1+km(i))/(1-kc(i)));

end
```

```

figure(1);
grid on;
plot(s/w, zoo, 'b');
hold on;
plot(s/w, zoe, 'r');
xlabel('s/w');
ylabel('zo');
legend('zoo', 'zoe');

```

```

figure(2);
grid on;
plot(s/w, kc, 'b');
xlabel('s/w');
ylabel('kc and km');

```

\*\*\*\*Spice file\*\*\*\*

```
.param Rterm=35
```

```
R10 V_NEG IN_NEG Rterm M=1.0
```

```
R0 V IN Rterm M=1.0
```

```
V2 V_NEG 0 PULSE 1.0 0.0 0.0 50E-12 50E-12 50E-12 10E-9
```

```
V0 V 0 PULSE 0.0 1.0 0.0 50E-12 50E-12 50E-12 10E-9
```

```
R7 OUT_NEG 0 9E6 M=1.0
```

```
R5 OUT 0 9E6 M=1.0
```

```
W1 N=2 IN IN_NEG 0 OUT OUT_NEG 0 RLGCMODEL=ECE733 l=0.1
```

```
.MODEL ECE733 W MODELTYPE=RLGC N=2
```

```
+Lo=
```

```
+300e-9
```

```
+60e-9 300e-9
```

```
+Co=
```

```
+120e-12
```

```
+ -24e-12 120e-12
```

```
+Ro=
```

```
+0.54
```

```
+0 0.54
```

```
+Rs=
```

```
+0.000462
```

```
+0 0.000462
```

```
+Gd=
```

```
+1.4e-11
```

```
+ -0.14e-11 1.4e-11
```

```
* INCLUDE FILES

* END OF NETLIST
.TRAN 1.00000E-12 1.00000E-08 START= 0.
.TEMP 25.0000
.OP
.save
.OPTION INGOLD=2 ARTIST=2 PSF=2 post
+ PROBE=0

.alter
.param Rterm=37
.alter
.param Rterm=39
.alter
.param Rterm=41
.alter
.param Rterm=43
```

.END

Note: the equations in Matlab file is originally used to calculate large coupling lines, so when  $S > 6*W$ , the result is not quite correct. However, it gives the correct result for  $S < 6*W$ .