

## Lab 02

### PRBS and Eye Diagram

## Intended Learning Objectives

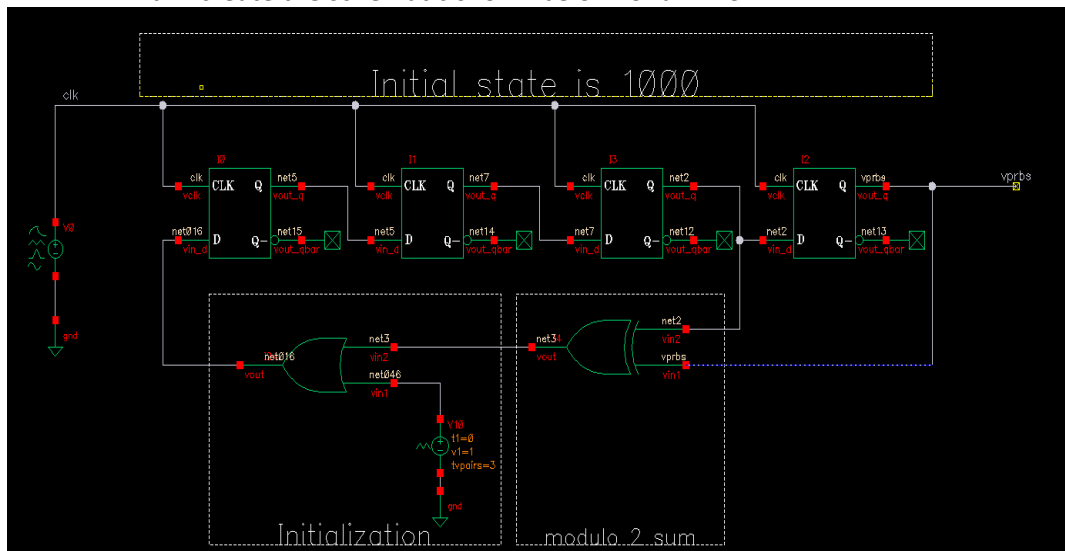
This lab is divided into two parts:

- In Part 1 you will
  - Learn how to generate a pseudo random bit sequence using LFSR (linear feedback shift registers).
  - Learn about the defining characteristics of PRBS.
- In Part 2 you will
  - Use the model of 1-inch FR4 trace (that can be cascaded to get the model of a longer trace) to plot the eye diagram and pulse response of a 6-inch FR4 trace.
  - Compare the worst-case eye opening between simulation and theoretical calculation.

## PART 1: Pseudo Random Bit Sequence (PRBS)

### 1. Schematic of a PRBS4

a. create the schematic shown below for a PRBS4



b. The settings of the d flip flops are as shown below

Property	Value	Display
Library Name	ahd1Lib	off
Cell Name	d_ff	off
View Name	symbol	off
Instance Name	I0	off

CDF Parameter of view	Value	Display
model		off
vlogic_high	1	off
vlogic_low	-1	off
vtrans_clk	0	off
vtrans	0	off
tdel	1f	off
trise	1f	off
tfall	1f	off

c. The settings of the clock are as shown below

Property	Value	Display
Library Name	analogLib	off
Cell Name	vsource	off
View Name	symbol	off
Instance Name	V0	off

User Property	Master Value	Local Value	Display
lvlsignore	TRUE		off

CDF Parameter	Value	Display
DC voltage		off
Source type	pulse	off
Frequency name 1		off
Delay time		off
Zero value	-1 V	off
One value	1 V	off
Period of waveform	125p s	off
Rise time	1f s	off
Fall time	1f s	off
Type of rising & falling edge		off
Pulse width	62.5p s	off

d. The settings of the initializer source (connected to the OR gate)

Property	Value	Display
Library Name	analogLib	off
Cell Name	vpw1	off
View Name	symbol	off
Instance Name	V10	off

User Property	Master Value	Local Value	Display
lvsignore	TRUE		off

CDF Parameter	Value	Display
Frequency name for 1/period		off
Number of pairs of points	2	off
Time 1	0 s	off
Voltage 1	1 V	off
Time 2	1 f s	off
Voltage 2	0 V	off
Noise file name		off
Number of noise/freq pairs	0	off
DC voltage		off
AC magnitude		off
AC phase		off
XF magnitude		off
PAC magnitude		off
PAC phase		off

## 2. Transient simulation

- Run a 40 nS transient simulation
- Plot the output vprbs and note the periodicity of the output and how many ones and zeroes in a period and use the calculator to plot the autocorrelation of the output and the correlation of the output with cyclical shifted versions of itself with various values for this shift and comment on the output waveform
- After plotting the output and the autocorrelation, list the characteristics of the output that made us call it "pseudo random"

[Output plots:](#)

[vprbs:](#)

### Autocorrelation:

#### Hints:

- a. The autocorrelation function is calculated using the expression below

$$R_x(\tau) = \frac{1}{K} \frac{1}{T_0} \int_{-T_0/2}^{T_0/2} x(t) x(t + \tau) dt$$

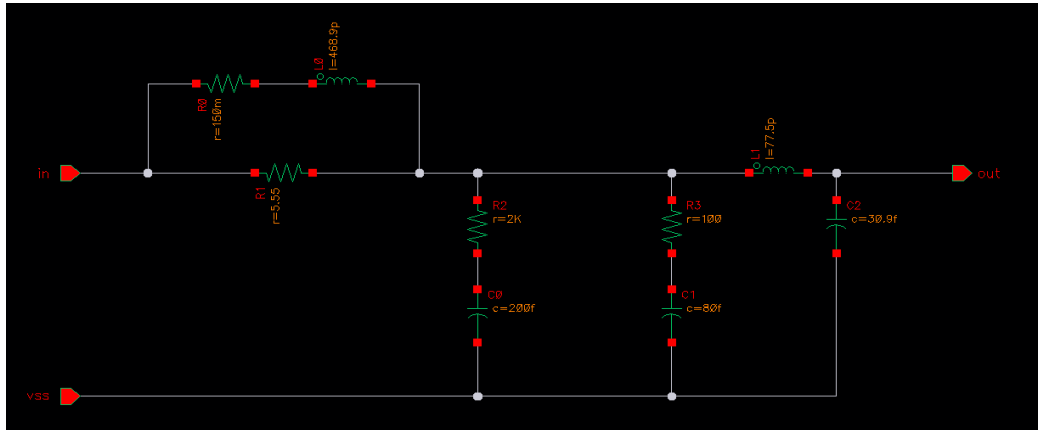
Where  $T_0$  is the period,  $x(t)$  is the function,  $x(t+\tau)$  is a shifted version of the function and  $K$  is a normalization factor (we'll set it as 1)

- b. Make a variable "tau" and use the expression shown below to calculate the autocorrelation  
`[integ(v("/vprbs" ?result "tran")*lshift(v("/vprbs" ?result "tran") pv("/tau" "value" ?result "variables") ) 0 1.875n )/1.875e-9]` (remove the square brackets) which integrates the function times itself but shifted by tau over the period and the divides by the period
- c. Use parametric analysis to generate the autocorrelation plot when you sweep the "tau" variable from 0 to 10 nS in steps of 125 pS (bit period)

## Part 2: Eye Diagram & Pulse Response

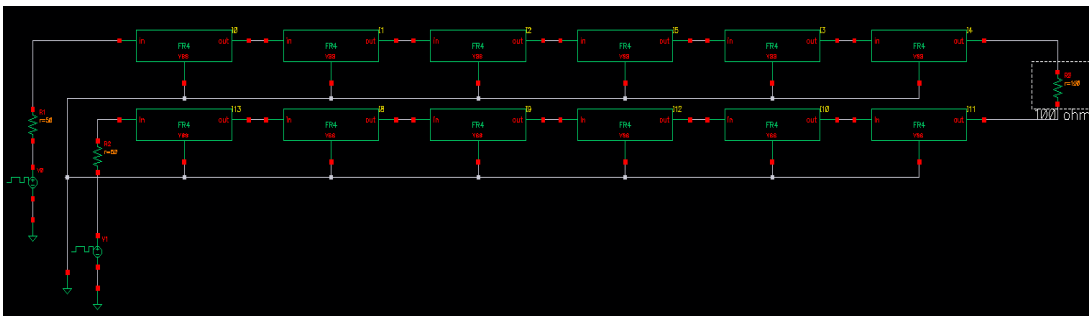
### 1. Schematic of the 1-inch model

- Create the schematic shown below for a model of a 1-inch FR4 trace

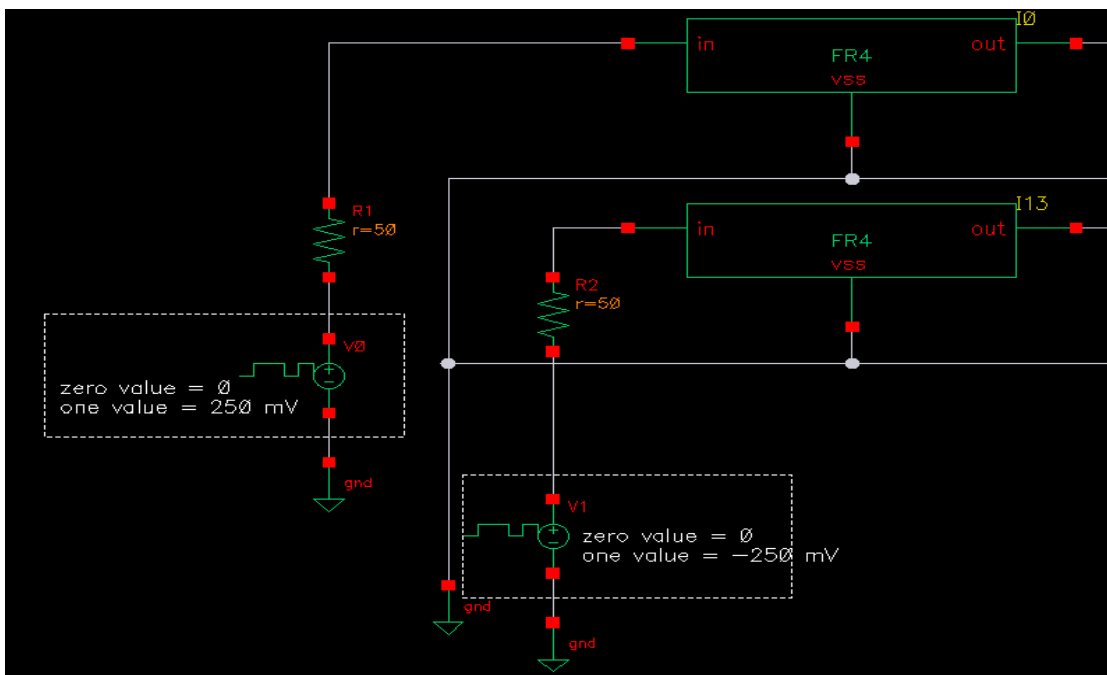


### 2. Schematic of the 6-inch channel

- Create the schematic shown below for a model of the differential 6-inch FR4 trace



- Place two differential PRBS sources as shown below with 50 ohms connected in series





- c. Adjust the setting of the PRBS sources as shown below

Property	Value	Display
Library Name	analogLib	off
Cell Name	vprbs	off
View Name	symbol1	off
Instance Name	v0	off

User Property	Master Value	Local Value	Display
lvignore	TRUE		off

CDF Parameter	Value	Display
Delay time		off
Zero value	0 V	off
One value	250.00m V	off
Bit period	125p s	off
Rise time	6.25p s	off
Fall time	6.25p s	off
Edge type	linear	off
LFSR Mode	PN32	off
Seed	17 19 21 23 25 27 29 31	off
Encode		off
Running Disparity Initial		off

### 3. Transient simulation and eye diagram plotting

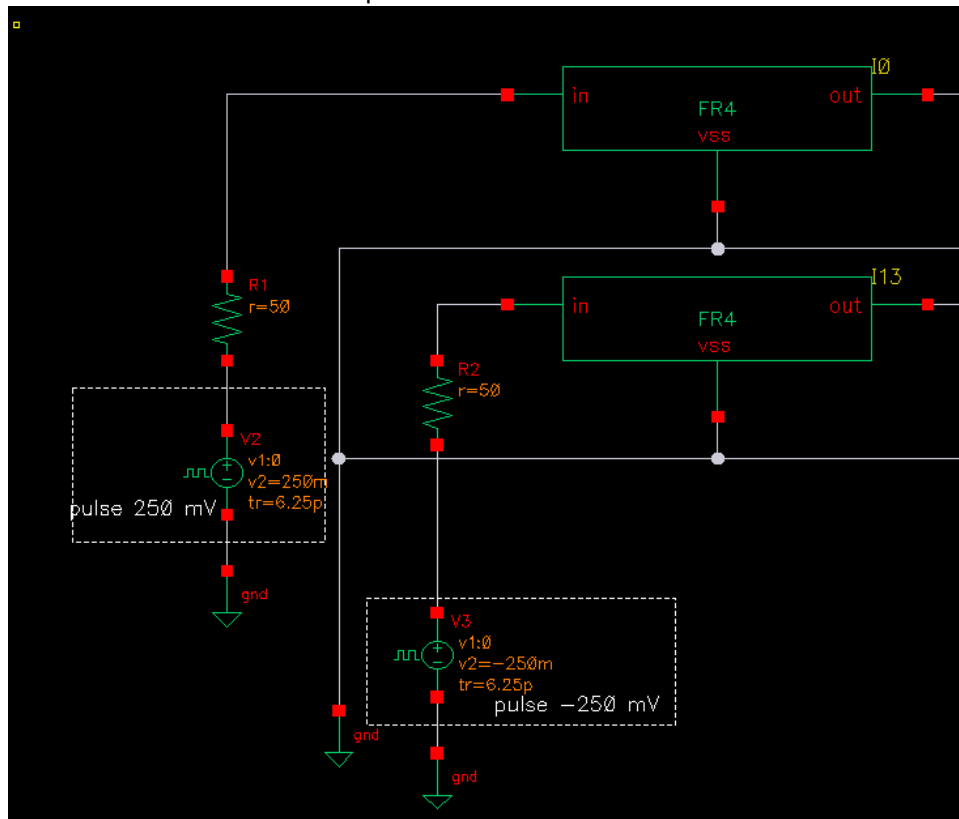
- Run transient simulation for 200 nS
- Make sure to set step = 1 pS from transient simulation's options
- Take the differential output and plot the eye diagram from measurement tools (or from eyedigram function in calculator)

[Output plots:](#)

[Eye diagram:](#)

#### 4. Transient simulation and pulse response plotting

- a. Place two differential pulse sources as shown below with 50 ohms connected in series



- b. Adjust the setting of the pulse sources as shown below



**Edit Object Properties**

Browse    Reset Instance Labels Display

Property	Value	Display
Library Name	analogLib	off
Cell Name	vpulse	off
View Name	symbol	off
Instance Name	V2	off

Add    Delete    Modify

User Property	Master Value	Local Value	Display
Ivsignore	TRUE		off

CDF Parameter	Value	Display
DC voltage		off
AC magnitude		off
AC phase		off
Voltage 1	0 V	off
Voltage 2	250.00m V	off
Period	10u s	off
Delay time	5n s	off
Rise time	6.25p s	off
Fall time	6.25p s	off
Pulse width	125p s	off
DC source		off
Resistance		off

OK    Cancel    Apply    Defaults    Previous    Next    Help

Output plots:

Pulse response:

- Determine main, pre and post cursors from the pulse response

- b. Using the relation shown below, compare between simulated and measured worst case eye opening

$$s(t) = \left( \underbrace{y_0^{(1)}(t) + \sum_{\substack{k=-\infty \\ k \neq 0}}^{\infty} y^{(1)}(t-kT)}_{\substack{\text{"1" pulse worst-} \\ \text{case "1" edge}}} \Big|_{y(t-kT) < 0} - \underbrace{\sum_{\substack{k=-\infty \\ k \neq 0}}^{\infty} y^{(1)}(t-kT)}_{\substack{\text{"1" pulse worst-} \\ \text{case "0" edge}}} \Big|_{y(t-kT) > 0} \right)$$