ELEC 5401 – Winter 2024, Carleton University
Signal Integrity in High-Speed Designs

Instructor: Prof. R. Achar, 3036 MC

Assignment - 1

Due by 1pm, Wed Feb. 28, 2024 (Tue) at the beginning of the class.

Q1. Square Wave and its Harmonics (4 Marks).

a) Write a MATLAB function to compute the Harmonics of a square wave with period '*T*', 50% duty cycle and amplitude (*A*).

If *T* = *2nsec* and *A* swings between '0V' and '5V'

b) Plot the amplitude versus the Harmonic Number (include up to 40 Harmonics)

c) Plot the 0^{th}, 1^{st}, 3^{rd} and 5^{th} Harmonics (*A v/s t*) on a same graph, overlappingly.

d) Plot the progressive sum of the above Harmonics [ie, (0^{th}+1^{st}), (0^{th}+1^{st} +3^{rd}), (0^{th}+1^{st} +3^{rd}+5^{th}) Harmonics) on a same graph, overlappingly (*A v/s t*).

e) Plot an enlarged view of the rising edge of the progressive sum of the following four combination of Harmonics: (0^{th}+1^{st}), (0^{th}+1^{st} +3^{rd}), (0^{th}+1^{st} +3^{rd}+5^{th}) and (0^{th}+1^{st} +3^{rd}+5^{th}) + ...35^{th}).

f) Provide your detailed inferences from the observations of the above experiments on the relationship between Time-domain Square Wave, its harmonics and the rising edge.

g) From the observations of the behavior of Harmonics, draw inferences to classify an interconnect as a long interconnect or as a short interconnect.

Q2. R, L, C, G Parameters (4 Marks).

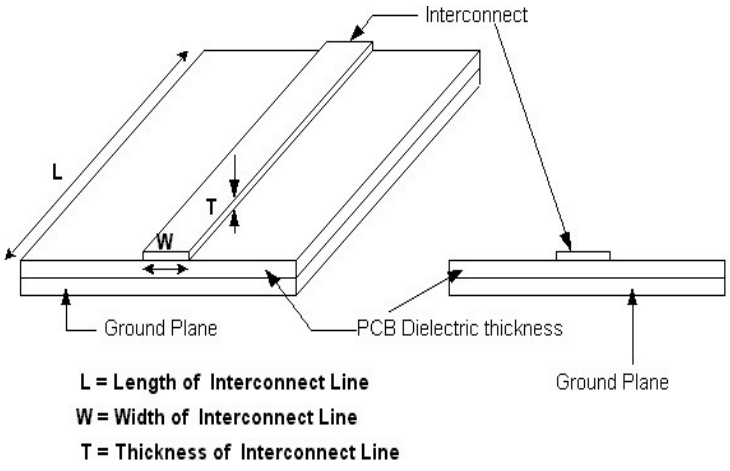
(a) For the Microstrip interconnect shown, compute its R, L, G, C p.u.l. parameters using the HSPICE field solver (if any parameter is missing, make a reasonable assumption and provide it).

b) Compare the capacitance obtained above using the parallel plate approximation

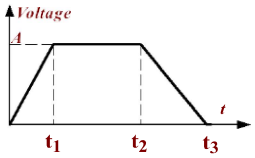
c) Compare and comment on the above C, & L values using the results from an improved analytical formula for C & L (you can pick the one of your choice through a literature survey, define all the parameters of the equation and cite the source)

Physical Parameters of Microstrip

Line Type = Microstrip Model
Type = Lossy Wide Number
of Line = 1
Dielectric Thickness = 160 µm
Dielectric constant (ε_r)= 4.8
Gnd Thickness = 20 µm
Conductor Width = W = 120 µm
Conductor Thickness = T = 25 µm
Conductor Length = L = 12000 µm
Ground plane, Signal conductor's
Conductivity = 5.6e7 S/m



Q3. A Practical Digital Pulse, Frequency/Time Relations (4 Marks).



a) Derive from fundamentals, the frequency spectrum of a ramp and a delayed ramp. Using a combination of appropriately time ramps, derive an expression for the frequency-spectrum of a Trapezoidal pulse.

b) Write a general MATLAB function to compute the frequency spectrum of a trapezoidal pulse.

c) If $t_1 = t_r$, $t_2 - t_1 = PW$ and $t_3 - t_2 = t_f$, compute and plot the magnitude-frequency-response at 1000 points on a linear scale from 1Hz to f_{max} Hz on a linear scale, for the following cases:

(i) t_r: 1us, t_f: 0.1us, PW: 4us, f_{max}: 50MHz

(ii) t_r: 1ns, t_f: 1ns, PW: 10ns, max: f_{max}: 1GHz

(iii) t_r: 0.1ns, t_f: 0.2ns, PW: 1ns, f_{max}: 15GHz

d) Based on the observation of the above plots, provide your conclusions on the significance/validity of the rule-of-thumb ($f_{max}=0.35/t_r$) used to determine the max frequency content in digital circuits.

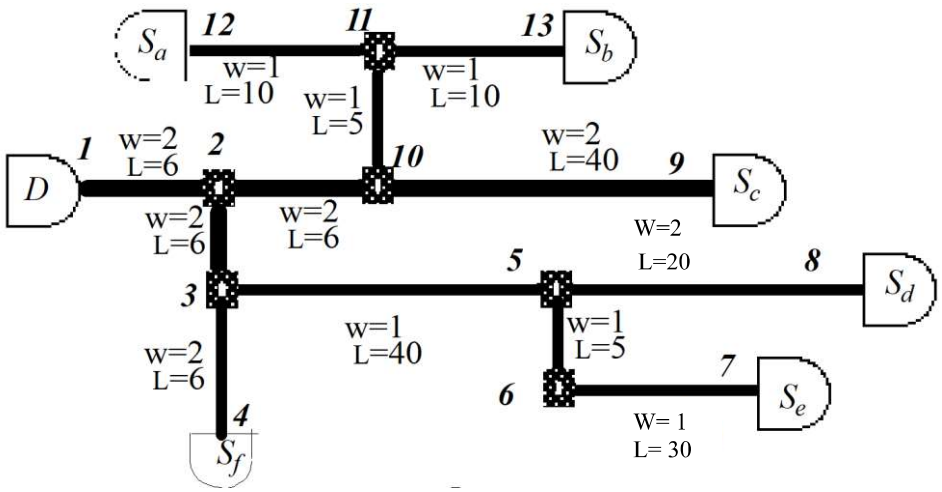
Q4. Elmore Delay (4 Marks)

Elmore delay provides a quick option to estimate the delay in RC circuits. For the following circuit with the given layout and trace parameters:

a) Draw the corresponding RC tree (use the lumped-π model). Assume the driver is modeled to be a resistance of 2 Ω and the receivers with a capacitance of $6nF$ each. Normalized resistance and capacitances of the traces are given as: $R = 0.1(L/W)\Omega;\ C = 0.2(LW)pF;$ where L is the length and W is the width of the trace.

b) Identify the receivers with the maximum and minimum delay, from the driver.

Show the detailed calculations for the corresponding Elmore Delays leading to your conclusion.



Q5. Literature/Industry Survey Question (4 Marks).

(a) Conduct a literature survey and outline current signal and power integrity issues in high-speed designs.

(b) For what type of industries signal/power integrity issues are of importance? Name the major companies among them. What is their approach in addressing the emerging signal and power integrity issues?

(c) What are the major CAD tools that are specifically available for signal and power integrity modeling/analysis - present the collected information in the form of a table (company, tool, purpose) It is expected that you will do a comprehensive survey.

(d) What are the major IEEE Transactions/conferences/forums, books that are focused on signal/power integrity issues?

(Note: A short print-report addressing all the above (a - d), total up to a maximum of 15 pages (single-lined) would suffice).

Note: (applies to all questions in this assignment, as relevant to the questions):

- Submit a hard copy of the report (with answers and results). Do not forget to include your name and student number on report cover page.
- Also upload two files online: **a pdf copy of the report** (named your firstname_lastname.pdf) and a .zip file with all *.m files of programs, netlists and the pdf files of plots (named your firstname_lastname.zip; only .zip format will be accepted).
- **MAKE SURE** to provide all the Curves in a Graph are clearly distinguishable from one another (it is important to note that - **not to simply dump the graphs from the tools - use different markers for each waveform of interest; clearly mark all the axis and with appropriate legends**).
- Document your program (how to run the program and insert comments in the program to understand the modules).
- *No copying of figures or text from external sources*. Prepare the report in your own words and illustrations. **Any instance of plagiarism will be strictly dealt with, may lead to disallowing from further continuing in the course as well as referring to the academic disciplinary committee.**