ECE 498YS3/YS4 Homework 2 Due: Thursday, September 12, 2024, 11:59PM Central Time

Recommended Reading: Paul: Lectures Chapter 3-4

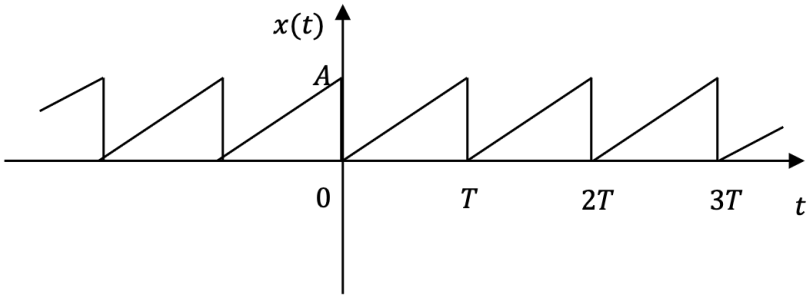
Purpose: This homework addresses the following learning objectives:

1. Understand and apply the Fourier series expansion to periodic waveforms.
2. Analyze the frequency response of systems and determine output magnitudes at specific frequencies.
3. Calculate harmonic reduction in oscillator circuits and estimate harmonic levels using spectrum bounds.
4. Determine the electrical properties of coaxial cables, including capacitance, inductance, and propagation velocity.
5. Analyze microstrip lines to determine their capacitance, inductance, effective relative permittivity, characteristic impedance, and delay.

Tasks and Criteria for Success: Follow these steps to complete the problems and ensure your answers meet the criteria for success. Points will be deducted if any step is skipped.

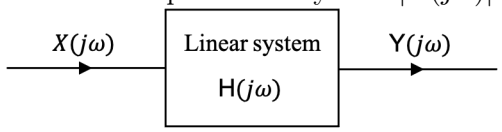
1. Assemble Facts
   a) Clearly state the objectives of each problem.
   b) Identify and list all given data and relevant constants.
   c) Organize the given data into a clear and logical format, such as a table.
2. Analyze
   a) List and define all variables and units involved in the problem.
   b) Clearly state any assumptions made to simplify the problem.
   c) Identify the appropriate equations and principles needed to solve the problem.
   d) Determine any necessary conversions between units (e.g., metric to English units).
3. Calculate
   a) Write down the relevant equations in their standard forms.
   b) Substitute the given data and constants into the equations.
   c) Show all steps of your calculations in a clear and logical order.
   d) Verify the units of your final answer to ensure they are correct.
4. Finalize
   a) Highlight your $\boxed{\text{final answers}}$ with a box and include the requested units.
   b) Justify your answers with proper reasoning and references to the principles used.
   c) Check your results for accuracy and consistency.
   d) Reflect on any potential sources of error or uncertainty in your calculations.

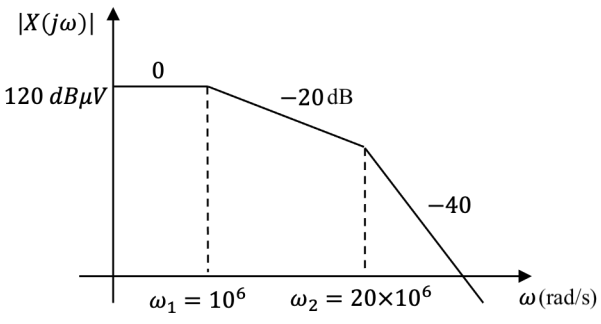
1. Determine one-sided Fourier series expansion coefficients (c_n, $n = 0, 1, 2, ...$) for the periodic waveform below. Also write down the one-sided Fourier series expansion (Compact form).
   Hint: $\int xe^{ax}dx = e^{ax}(\frac{x}{a} - \frac{1}{a^2})$

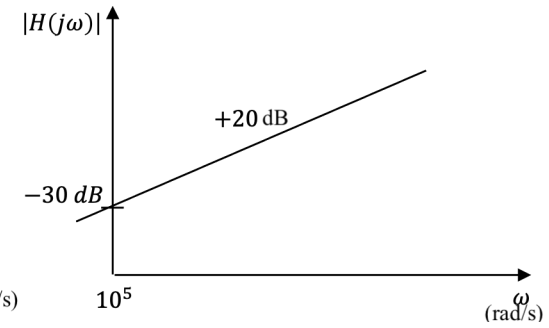


2. A trapezoidal waveform with a peak magnitude of 5V is operating at 10 MHz, with a rise time and fall time of 5 ns and a duty cycle of 50%.
   a) Derive the one-sided Compact form Fourier series representation of the waveform.
   b) Calculate the magnitude of the first five harmonics (A_1 to A_5). Discuss how the harmonics contribute to the overall spectrum AND how this relates to potential EMI concerns.
   c) Determine the magnitude of the first five harmonics if the rise/fall time is changed to 10 ns. Discuss how the change in rise/fall time affects the overall spectrum AND how this relates to potential EMI concerns.
   d) Determine the magnitude of the first five harmonics if the duty cycle is reduced to 40%. Discuss how the change in duty cycle affects the overall spectrum AND how this relates to potential EMI concerns.
   e) Determine the magnitude of the first five harmonics if the waveform operates at 200 MHz instead. Discuss how the change in repetition rate affects the overall spectrum AND how this relates to potential EMI concerns.

3. Determine the magnitude of the output of the system $|Y(j\omega)|$ shown below at $\omega = 50 \times 10^6$ rad/s.





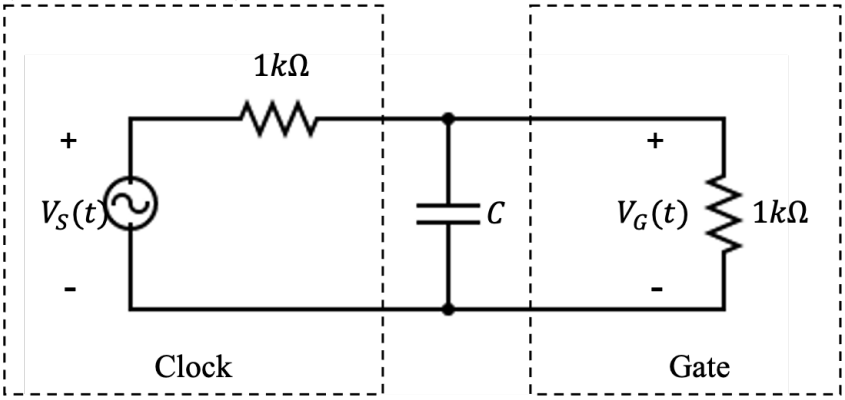


4. A 5 V, 10 MHz oscillator having a rise/fall time of 10ns and a 50% duty cycle is applied to a gate shown below.

   a) Determine the value of the capacitance such that the fifth harmonic is reduced by 20 dB in the gate voltage $V_G(t)$.

   b) Using spectrum bound, estimate the level of this fifth harmonic at the source.

   c) (**Bonus problem**) Calculate the exact value of the fifth harmonic at the source.



5. A typical coaxial cable is RG6U, which has an interior 18-gauge (radius 20.15 mils) solid wire, an interior shield radius of 90 mils (1 mil = 1/1000 inch), and an inner insulation of foamed polyethylene having a relative permittivity of $\epsilon_r = 1.45$. Determine the per-unit-length capacitance, inductance, and the velocity of propagation relative to that of free space.

6. A microstrip line is constructed on a FR-4 board having a relative permittivity of 4.7. The board thickness is 64 mils and the trace width is 10 mils.
   a) Determine the per-unit-length capacitance and inductance.
   b) Determine the effective relative permittivity ϵ_e, characteristic impedance Z_0, and per-unit-length delay T_d.