Université d'Ottawa
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École de science informatique
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L'Université canadienne
Canada's university

University of Ottawa
Faculty of Engineering

School of Electrical Engineering
and Computer Science

ELG 7132D Topics in Electronics:

Final EXAMINATION (3 hours)

Professor E. Gad

Student Name: ____________________________

Sttudent Number #: ____________________________

Question (1) **/35**	**Question (2)** **/10**	**Question (3)** **15**	**Question(4)** **/15**	**Question (5)** **/25**	**Total** **/100**

Question 1

Consider the circuit shown in Figure 1, where the MOSFET transistor is modelled by the circuit shown in Figure 2.
Use the space provided in the following pages to write down the MNA formulation for the entire circuit and using the MOSFET model shown below in Figure 2. The following equations describe the nonlinearity in the transistor model.

$$i_{ds} = \begin{cases} \frac{1}{2}\mu_n C_{ox}\left(v_{gs} - V_{th}\right)^2 & v_{ds} > v_{gs} - V_{th}, \text{ and } v_{gs} > V_{th} \\ \mu_n C_{ox}\left(\left(v_{gs} - V_{th}\right) v_{ds} - 1/2 v_{ds}^2\right) & v_{ds} \le v_{gs} - V_{th}, \text{ and } v_{gs} > V_{th} \\ 0 & v_{gs} \le V_{th} \end{cases}$$

$$i_{bs} = I_s \left(\exp\left(\frac{v_{bs}}{V_T}\right) - 1\right),$$

$$i_{bd} = I_s \left(\exp\left(\frac{v_{bd}}{V_T}\right) - 1\right)$$

where,

$$v_{ds} = v_{\text{drain}} - v_{\text{source}},$$
$$v_{gs} = v_{\text{gate}} - v_{\text{source}},$$
$$v_{bs} = v_{\text{substrate}} - v_{\text{source}},$$
$$v_{bd} = v_{\text{substrate}} - v_{\text{drain}}$$

and μ_n, C_{ox}, V_T, V_{th} and I_s are all constants.

Important Notes to consider as you write down the MNA formulation.

- Use only the space provided on pages 5-9 to write the MNA matrices and various vectors. Any writing outside this space will not be marked.
- Draw the equivalent by completing the circuit given in Figure 3.
- Indicate clearly the numbering of the circuit nodes, and the names additional variables that the MNA formulation requires.
- Please note that the space provided may allow for more room than is actually needed for the MNA formulation of this circuit.
    - Cross out extra entries in the provided space that are not needed by the formulation.
    - Make sure to write zeros in the places where there are no entries.
- Use the symbolical names for the circuit elements provided on the schematic to describe the MNA formulation.

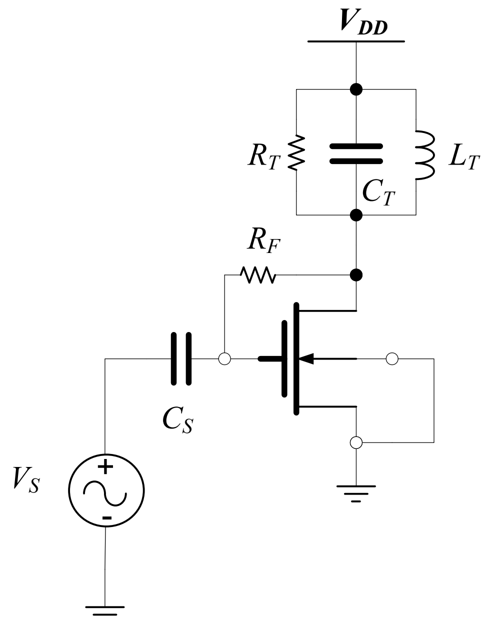


Figure 1

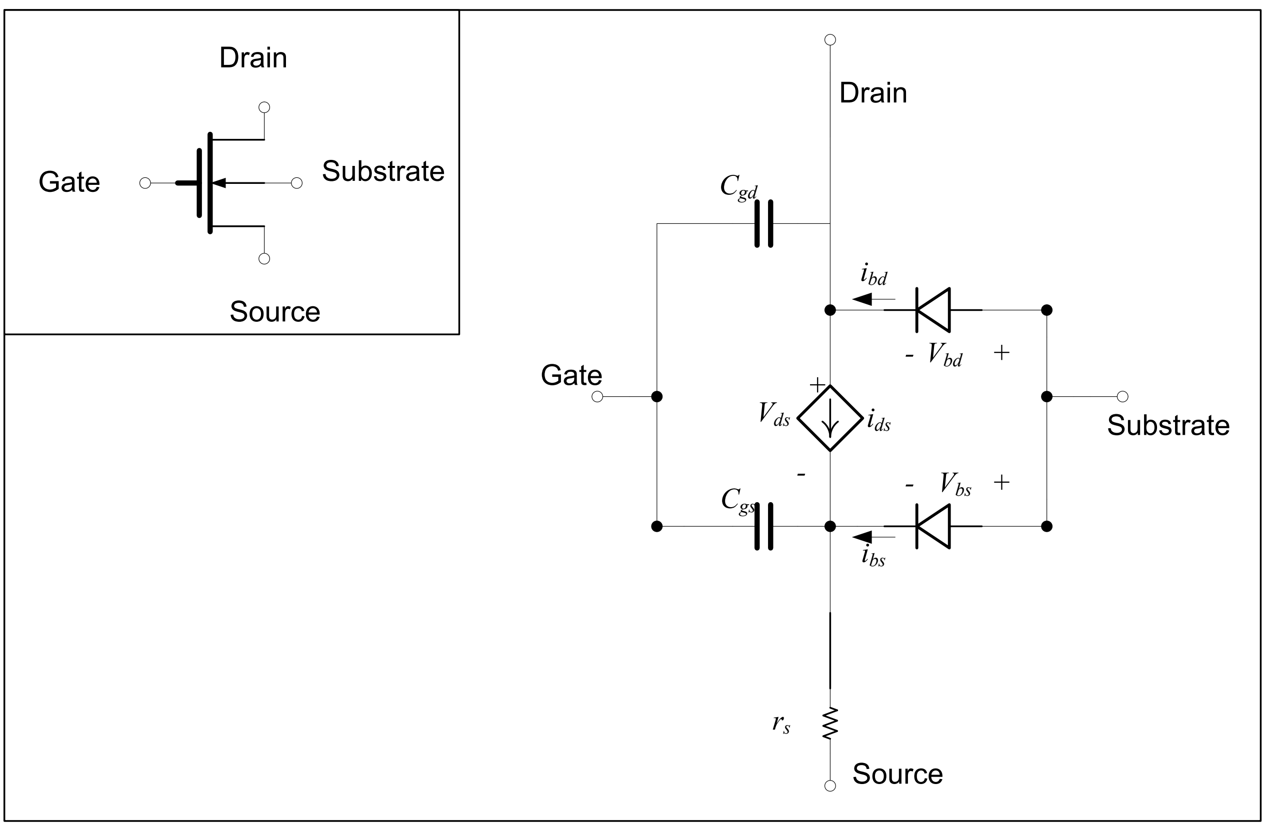


Figure 2

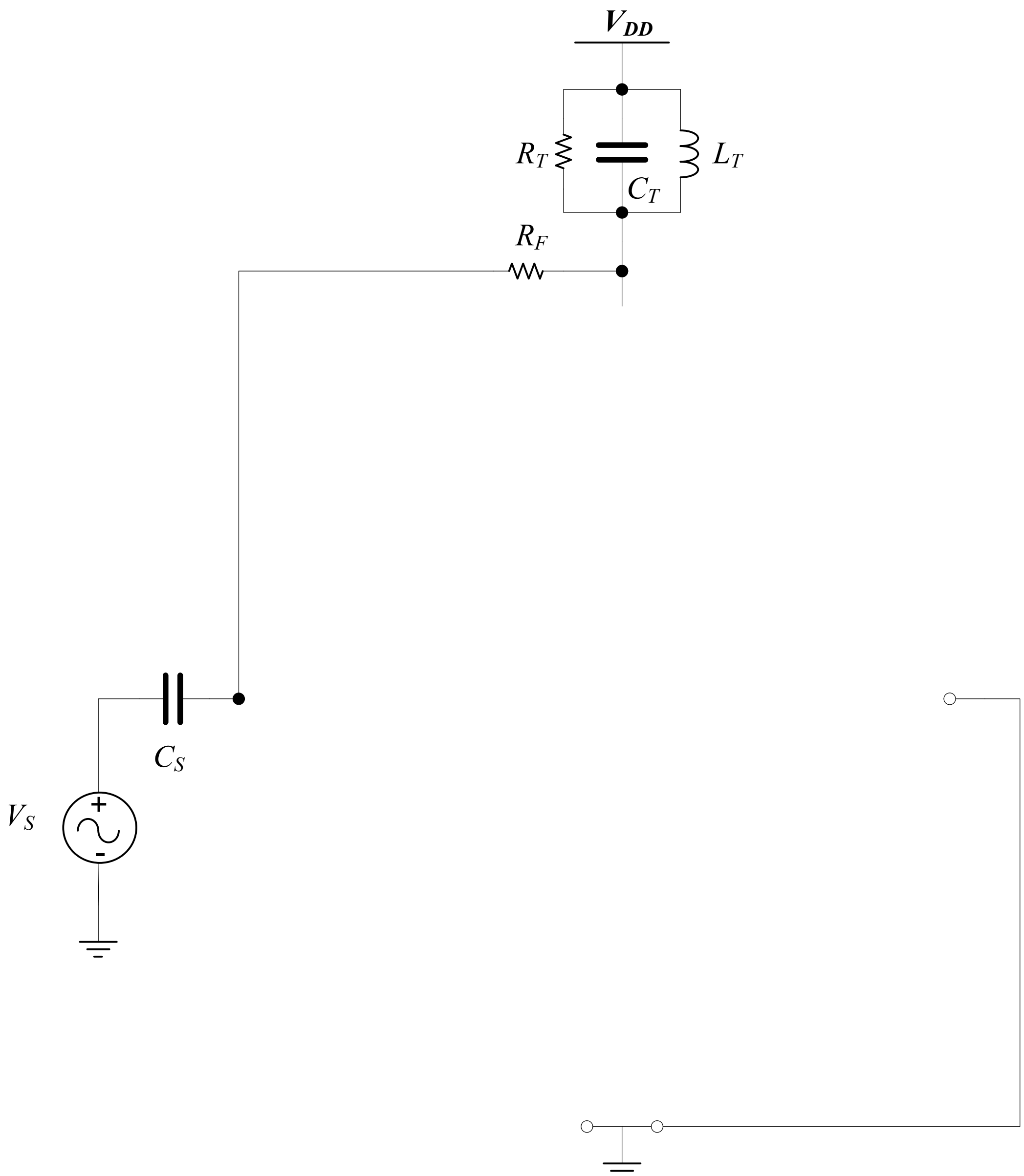
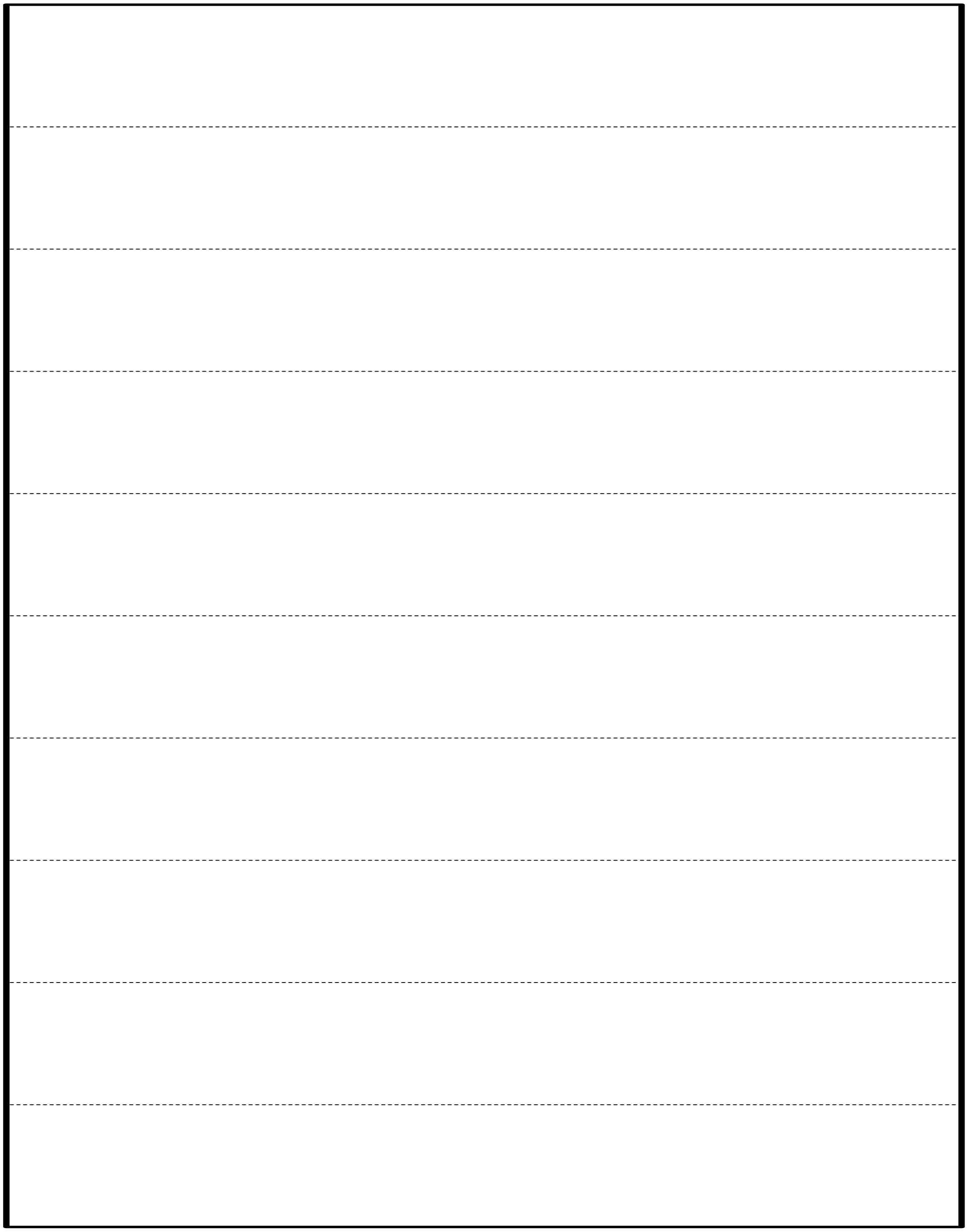


Figure 3

$x(t),$ $b(t),$

$$\begin{bmatrix} \; \\ \; \\ \; \\ \; \\ \; \\ \; \\ \; \\ \; \\ \; \\ \; \end{bmatrix}, \qquad \begin{bmatrix} \; \\ \; \\ \; \\ \; \\ \; \\ \; \\ \; \\ \; \\ \; \\ \; \end{bmatrix},$$

$f(x(t))$



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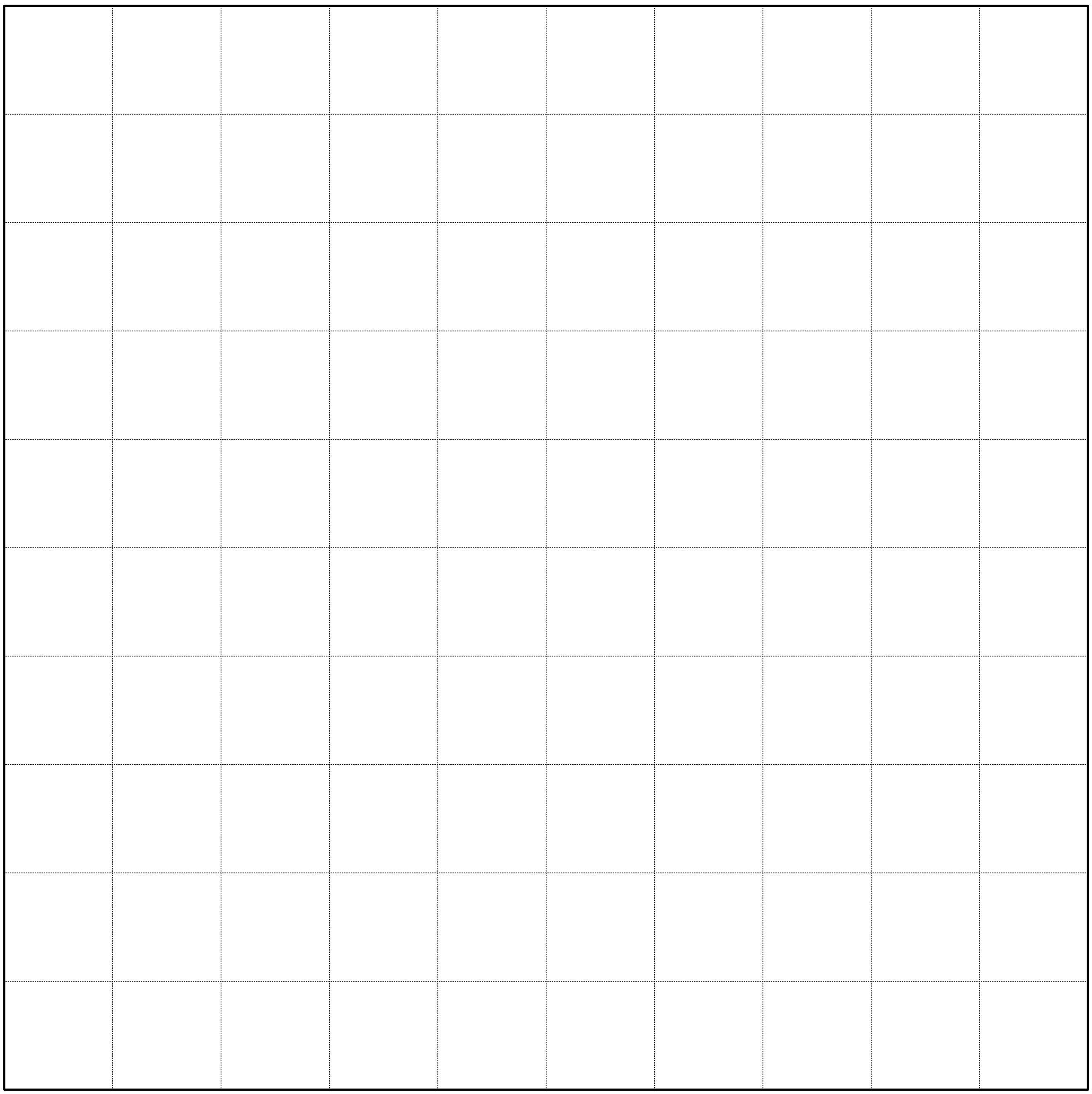

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Question 2

a. Assume that the Harmonic Balance (HB) technique has been used to simulate the steady-state response of the circuit given in Question 1, and let the HB unknowns be ordered in ***Node-Major/Harmonic-Minor***. Consider that the diagram in Figure 4 represents the block structure of the resulting Jacobian matrix, where each block is represented by a square. Use this diagram to describe the structure of the Jacobian matrix by utilizing the following notation,

    i. A full block is represented by "X" marker
    ii. A zero block represented by a "0" (zero) marker.
    iii. A diagonal block is represented by a diagonal line "$\boxed{\diagdown}$"
    iv. Any block not listed above is to be marked with a "L" marker.

b. Describe in the space immediately following this question the structure of a sample block of the type indicted in (iv). For that purpose you may assume that the input stimulus is single tone with a fundamental frequency equal to ω_0 and the steady-state response is truncated at an integer value of M=3. First indicate the block row and column number of your choice and then write the contents of this block.

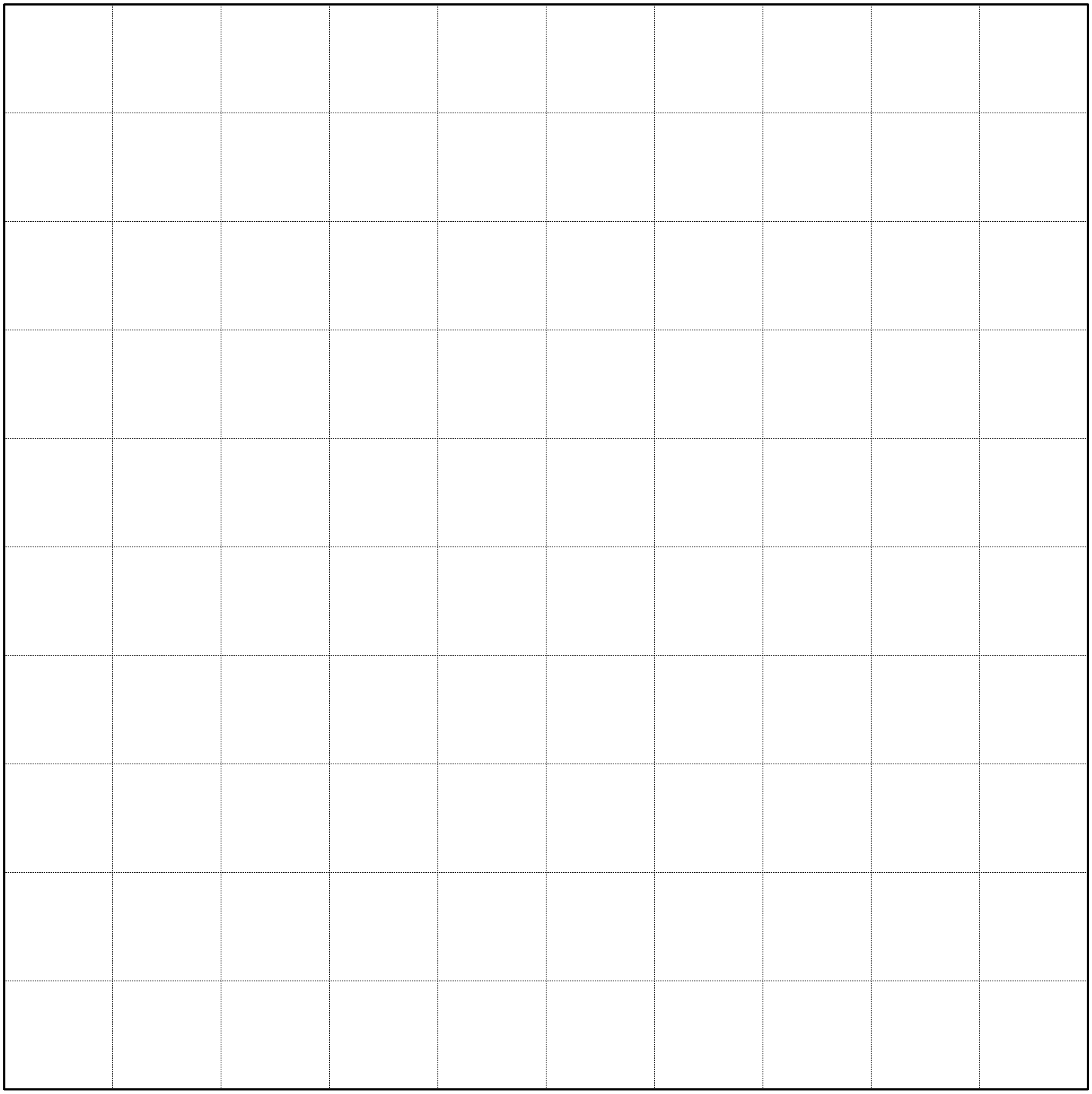

Figure 4

Question 3

(1) Assume that the input source to general nonlinear circuit is a two-tone source and denote the amplitudes of the constituent tones by A_1 and A_2, respectively. Let A_1 and A_2 be relatively small amplitudes that will stimulate each a small number of frequency components in the response of the MNA variables. Furthermore let f_1, the frequency of the first tone, be given by 1GHz while the second one, f_2, be given by 1.01 GHz. Rank the following steady-state methods according to the level of preference in the sense of the anticipated performance, with 1 corresponding to the best and 4 corresponding to the poorest performance. Indicate your rank by writing the number you choose between the brackets given beside each method. You may assign the same rank number to more than one method.

- Single-tone HB ( )
- Shooting Method ( )
- Multi-tone HB ( )
- A Mixed-domain method based on the Partial Differential Equations. ( )

(2) Rank the methods listed above once more assuming that the conditions described in part (1) above hold, except that f_1 and f_2 are given by 1GHz and 2 GHz, receptively.

- Single-tone HB ( )
- Shooting Method ( )
- Multi-tone HB ( )
- A Mixed-domain method based on the Partial Differential Equations. ( )

Question 4

Define a periodic pulse waveform as follows,

$$\text{pulse}(t, d, T) = \begin{cases} 1 & \bmod\ (t, T) < dT \\ 0 & \bmod\ (t, T) \geq dT \end{cases}$$

where $d < 1$,

$$\bmod\ (t, T) = t - \left\lfloor \frac{t}{T} \right\rfloor T$$

and $\lfloor x \rfloor$ is an function that rounds x to the nearest integer from the -∞ side.

Assume that a circuit is excited by the input following waveform, similar to the one described above, except that the pulse width has been modulated, as described next

$$\text{pulse}\left(t, \underbrace{0.5 \times (\text{pulse}[t, d, T_1] - 1) + 0.75}_{\text{modulated width}, d(t)}, T_2 \right)$$

where T_1 = 1msec, and T_2 = 0.1μsec.

1. Discuss what type of input excitation this can be considered? i.e., whether this should be considered a periodic or Quasi-periodic. Explain your answers.
   Hint. Count the number of the fast cycles within the global period. If this number is much larger than 10, then this whould be considered quasi-periodic.

In answering the following questions, assume that the periodic pulse(t,d,T) described above is being approximated by the waveform shown in Figure 5, which has a small finite rise and fall time.

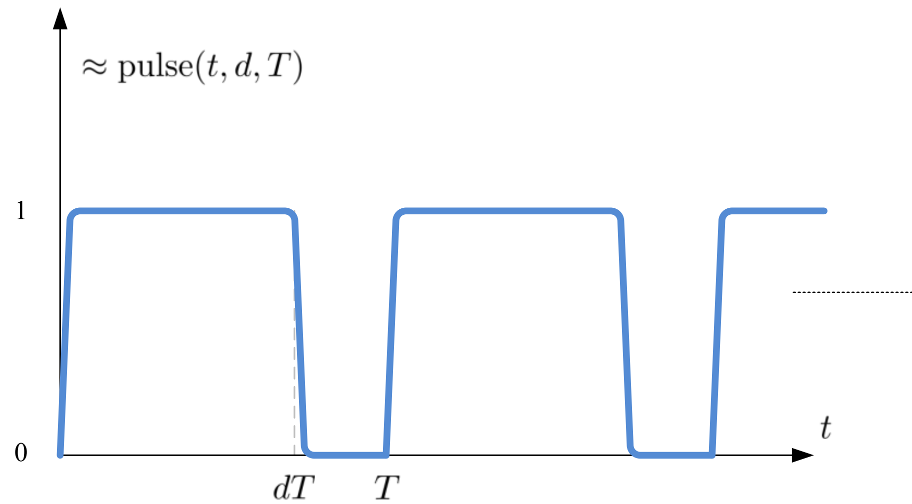

Figure 5

2. Considering that the circuit is a **linear** circuit, discuss which steady-state approach (time-domain or Frequency-Domain) you would consider to be the natural choice to compute the steady-state response of the circuit.

3. Considering that the circuit is **nonlinear** circuit, discuss which steady-state approach (time-domain or Frequency-Domain, or Mixed Frequency-Time Method, or any other) you would consider being the natural choice to compute the steady-state response of the circuit.

Question 5

Consider a nonlinear circuit, with ***N*** MNA variables, excited by a periodic input signal, with period ***T***, and let the Newton Shooting method be the approach used to compute its steady-state response. Assume that it takes m time steps using a transient solver to compute the waveform at ***m*** discrete time point from t=0, …, T, and that Newton-Raphson method requires about **3** iterations to converge at each discrete time point. Finally assume that it takes the Newton–Raphson P iterations to reach the final steady-state solution using the shooting method.

Answer the following questions by writing down expressions involving N, T, P, m, or any combination thereof.

(1) Write down the required number of LU factorization (i.e., Matrix Inversion operations) involving ***sparse*** matrices.

(2) Write down the required number of LU factorization (i.e., Matrix Inversion operations) involving ***Full*** matrices.

(3) Write down the needed number of **Full** Matrix/Matrix multiplications.