FIJI NATIONAL UNIVERSITY
College of Engineering, Science and Technology (CEST)

EEE606 CIRCUITS & SIGNALS

Final Examination

Monday 16th June, 2014 0900 - 1210 hours Venue: B314

INSTRUCTIONS TO CANDIDATES

1. Candidates are reminded that they should have no books, notes, paper or other material in their possession unless their use is specifically permitted by "Instructions to Candidates" set out below.
2. Reading time is of 10 minutes duration.
3. Examination time is of 3 hours duration.
4. Write your candidate number at the top of each attached sheet.
5. This paper consists of two (2) sections: A and B.
6. Attempt ALL four (4) questions in Section A and one (1) out of three (3) questions in Section B.
7. Each question carries 20 marks.
8. The following sets of Table are provided: Laplace Transform; Fourier Transform, Standard Integrals, and Trigonometric Identities.
9. Matlab is also available for use.
10. Cellphones are not allowed inside the examination venue.

SECTION A

This section is compulsory and all questions are to be attempted.

QUESTION 1: THEVENIN THEOREM, NORTON THEOREM & SOURCE TRANSFOMATION

Q 1 - 1: Thevenin Theorem

Refer to Figure 1. The circuit load is $R_L = 8\Omega$

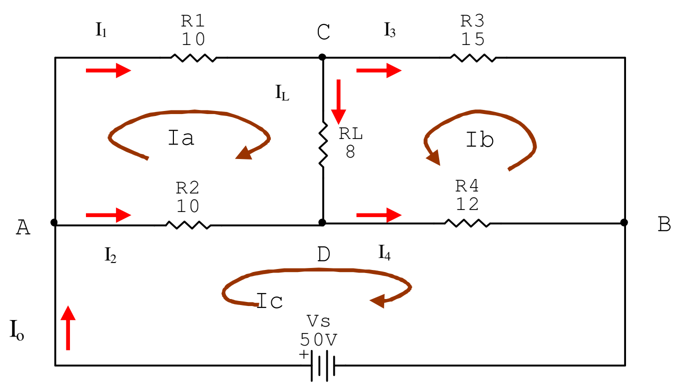


Figure 1: Bridge Network

(a) Synthesize Thevenin's equivalent circuit. **[6 marks]**

(b) Calculate the current through the load, $R_L = 8\Omega$. **[2 marks]**

(c) Solve for the power absorbed by the load. **[2 marks]**

Q1 - 2: Norton Theorem

Refer to Figure 1.

(a) Derive the Norton equivalent circuit. **[4 marks]**

(b) Confirm the current through the load, $R_L = 8\Omega$. **[2 marks]**

Q1 - 3: Maximum Power Transfer

(a) Refer to Figure 1. Find the value of the load resistance that will enable Maximum Power Transfer to occur. [2 marks]

(b) Calculate the maximum power that will be transferred to the load under the condition in (a). [2 marks]

[TOTAL = 20 MARKS]

QUESTION 2: *RLC* NETWORK MODELLING & LAPLACE TRANSFORMS APPLICATION

Q2 - 1: Analyze the *RLC* Series circuit shown. The output is taken across the resistor, *R*. Assume zero initial conditions.

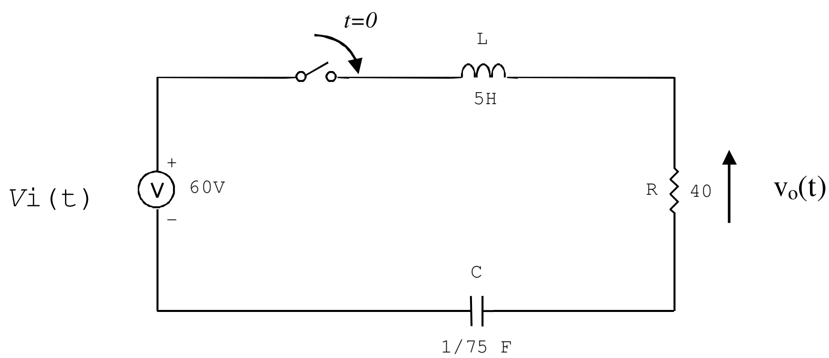


Figure 2: Series *RLC* circuit

(a) Derive the Second Order Differential Equation model of the system using Kirchoff's Voltage Law (KVL). [2 marks]

(b) Transform the Differential Equation from time to s-domain using Laplace Transforms, to obtain $Q(s)$. [5 marks]

(c) Determine *q(t)*.from the *Q(s)*obtained in (b). [3 marks]

(d) Express the mathematical model as a first order Differential Equation. [2 marks]

(e) Determine the Laplace transformed circuit using any suitable method. [3 marks]

(f) Solve for the Transfer Function, G(s), when output is taken across *R*.
[3 marks]

(g) Identify, with reason, the type of damping in the system. [2 marks]

[TOTAL = 20 MARKS]

QUESTION 3: FOURIER SERIES, FOURIER TRANSFORM & CONVOLUTION

Q3 – 1: A periodic current waveform is given by, $i(t)=\begin{cases}20, & 0\le t<2\\ 0, & 2\le t<4\end{cases}$ Amps, and $i(t+4)=i(t)$.

(a) Sketch 3 periods of the function *i(t)* and label clearly. [2 marks]

(b) Determine the coefficients a_o, a_n, and b_n. [4 marks]

(c) Synthesize the first 3 terms of the Fourier series of *i(t)*. [4 marks]

Q3 - 2: Fourier Transform & Convolution

(a) Derive the Fourier Transform of the following systems using the Fourier Transform table.

(i) $q(t)=u(t)e^{-3t}$ [2 marks]

(ii) $i(t)=4u(t)e^{-5t}\sin(2t)$ [2 marks]

(b) From the Convolution Theorem, $h(t)=(f*g)(t)=\int_0^t f(\tau)g(t-\tau)d\tau$,

determine the inverse, *h*(*t*), of the function,

$$H(s)=\frac{2}{s^2+4}\bullet\frac{s}{s^2+9}$$ [6 marks]

[TOTAL = 20 MARKS]

QUESTION 4: PASSIVE FILTERS & ACTIVE FILTERS

Q4 – 1: Derive the expression for the Voltage Gain of the Non-Inverting amplifier with a voltage divider as shown in Figure 3.

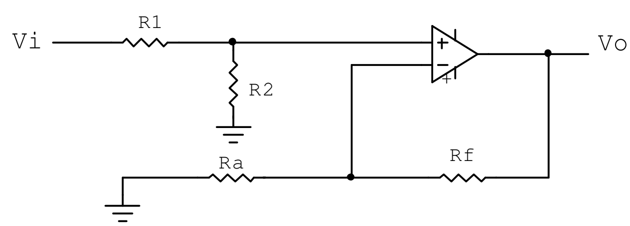


Figure 3: Non-Inverting amplifier with voltage divider

Q4 – 2: Determine the Transfer Functions, $H(s)$, of the Passive Low-pass filter and the Passive High-pass filter shown in Figure 4 and Figure 5.

[3.5 + 3.5 = 7 marks]

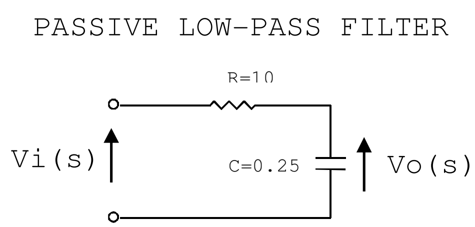


Figure 4: Passive LPF

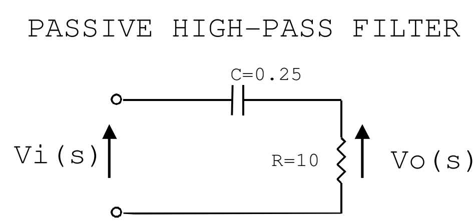
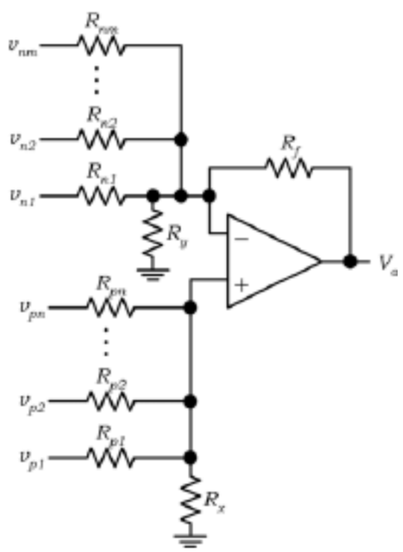


Figure 5: Passive HPF

Q4 - 3: OPERATIONAL AMPLIFIERS – ANALOGUE COMPUTERS [TOTAL: 10 MARKS]

Design an Analogue Computer using Operational amplifiers to solve the second order differential equation, $v'' = 8v' - 3v + 2\sin 4t$. Use integrators whose time constant *RC* = 1. Assume the initial conditions v'(0) = 1 and v''(0) = 3 V. Provide a block diagrammatic representation of the circuit first. State any assumptions you make. Do note the General Add-Subtract circuit shown in Figure 6, and the parameters that need to be evaluated. [10 marks]



$$V_o = \sum_{i=1}^{n} A_i v_{pi} - \sum_{i=1}^{m} B_i v_{ni}$$

where, $A_i = \frac{R_f}{R_{pi}}, B_i = \frac{R_f}{R_{ni}}$

Let $A = \sum A_i, B = \sum B_i$

Let $C = A - B - 1$

If

$$\begin{cases} C \geq 0 & R_x = \infty & R_y = \frac{R_f}{C} \\ C < 0 & R_x = -\frac{R_f}{C} & R_y = \infty \end{cases}$$

Figure 6: General Add-Subtract circuit

SECTION B

Answer only one (1) question in Section B.

QUESTION 5: LOOP ANALYSIS & NODAL ANALYSIS
Q5 - 1: Loop Analysis

Consider Error! Reference source not found.. **Using the Loop Analysis method, determine the branch currents I_1, I_2 and I_3 in Figure 7.**
[10 marks]

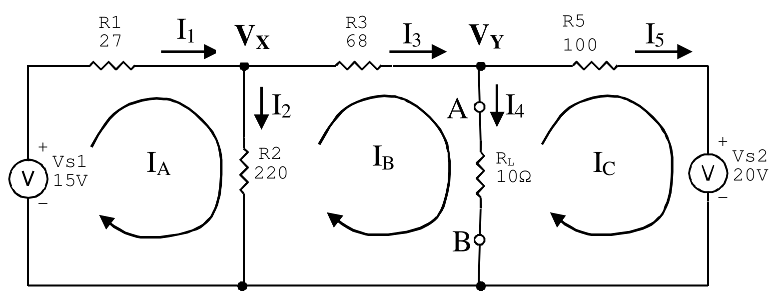


Figure 7: Circuit for Loop Analysis

Q5 - 2: Nodal Analysis
Refer to Figure 7 above.

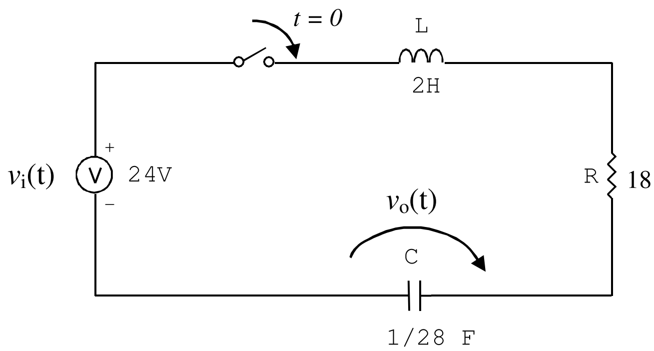
(a) Determine V_X and V_Y using the Nodal Analysis approach [8 marks]

(b) Determine the load current, I_L, through R_L= 10Ω. [2 marks]

[TOTAL = 20 MARKS]

QUESTION 6: SECOND ORDER DIFFERENTIAL EQUATIONS & RLC NETWORK MODELLING APPLICATION

Q6: Analyze the *RLC* network shown. The output is taken across the capacitor , *C*. Assume zero initial conditions.



Solve for the following:

(a) Characteristic (Auxiliary) Equation. [Hint: first find the Secondary Order Differential equation]. [3 marks]

(b) Characteristic Roots & Characteristic Modes. [3 marks]

(c) Complementary Function. [2 marks]

(d) Briefly explain the term "Zero Input Solution". [2 marks]

(e) Particular Integral. [3 marks]

(f) General Solution. [2 marks]

(g) Particular Solution. [5 marks]

[TOTAL = 20 MARKS]

QUESTION 7: COMMUNICATION SYSTEMS, APPLICATION OF FOURIER TRANSFORMS & FREQUENCY SPECTRUMS

Q7 – 1: From the Fourier Transform, we know that,

$$F\{\cos 2\pi f_C t\} = \delta(f - f_C) + \delta(f + f_C).$$

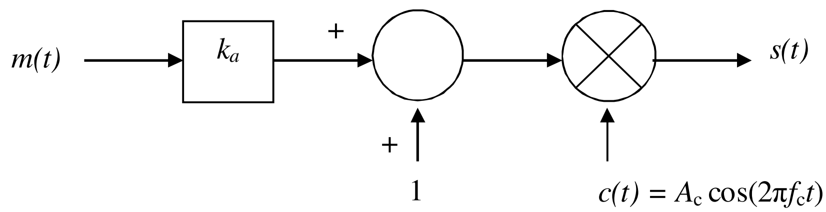
The Frequency Shifting property states that the Fourier Transform pairs are

$$g(t)e^{j2\pi f_c t} \quad \Leftrightarrow \quad G(f - f_c)$$

We also know from the Modulation Property of the Fourier Transform that,

$$F\{g(t)\cos(2\pi f_C t)\} = F\left\{g(t)\left(\frac{e^{j2\pi f_C t} + e^{-j2\pi f_C t}}{2}\right)\right\} = \frac{1}{2}[G(f - f_C) + G(f + f_C)]$$

The block diagram of the AM Modulator is given below.



(a) Consider the following facts:

$m(t) = \cos(2\pi \times 4{,}000t)\ V, \quad c(t) = 220\cos(2\pi \times 10^6 t)\ V$

(a) Derive the expression for the AM signal in the time domain, *s*(*t*), given the general form $s(t) = A_C[1 + k_a m(t)]\cos(2\pi f_C t)$ **. Assume k_a = 1.** **[2 marks]**

(b) Derive the formula for the AM signal in the Frequency domain, S(*f*), and substitute for the values of the modulating frequency and carrier frequency. **[8 marks]**

(c) Sketch the Frequency Spectrum of both the Modulating signal and the AM signal. **[5 marks]**

Q7 - 3: Consider the AM signal, $s(t)=180\left[1+\left(\frac{160}{180}\right)\cos\left(2\pi\times10^{3}t\right)\right]\cos\left(2\pi\times10^{6}t\right)$ **volts. The total power content of the AM signal is 8 kW.**

(i) Sketch the waveform of the AM signal, *e(t).* Label it fully. **[2 marks]**

(ii) Solve for the power content of the carrier. **[2 marks]**

(iii)Calculate the power transmitted at each of the sidebands. **[1 mark]**

[TOTAL = 20 marks]

[THE END]