FNU FIJI NATIONAL UNIVERSITY

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SCHOOL OF ELECTRICAL & ELECTRONICS ENGINEERING

DIPLOMA IN ELECTRICAL ENGINEERING (ELECTRONICS)

EEE583 – CONTROL SYSTEMS ENGINEERING

Wednesday 29th April, 2015 1400 - 1710 hours Venue: C101

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. This paper consists of 8 questions printed on 10 pages.
5. Attempt all 8 questions. Each question may carry a different mark.
6. A set of Laplace Transforms Table is attached.
7. The datasheet for the 74LS153 Multiplexer is on page 10.
8. Write your candidate number at the top of each attached sheet.
9. Start each question on a new page.
10. Non-Programmable Calculators may be used.
11. Mobile phones are not allowed inside the examination venue.

QUESTION 1: LAPLACE TRANSFORMS; UNIT STEP FUNCTION [TOTAL: 15 MARKS]

(a) Determine the Laplace Transform of the following functions.

(i) $f(t) = 6e^{-3t} + 2t^5 - 4\cosh 3t$ [2 marks]

(ii) $f(t) = 10e^{4t}\cos 5t$ [3 marks]

(iii) $f(t) = \begin{cases} 0, & t < 8 \\ (t-8)^4 & t > 8 \end{cases} = u(t-8)(t-8)^4$ [2 marks] [3 marks]

(b) Sketch the graphs of the following functions,

(i) $f(t) = 3u(t) + u(t-5)$ [2 marks]

(ii) $f(t) = 12u\left(t - \frac{\pi}{2}\right)\sin t, \quad 0 \le t \le 2\pi$ [2 marks]

(iii) $f(t) = u(t).t^2, \quad f(t+2) = f(t); \quad 0 \le t \le 6$ [3 marks]

QUESTION 2: FIRST ORDER *RL* NETWORK [TOTAL MARKS: 15]

Refer to the network shown.

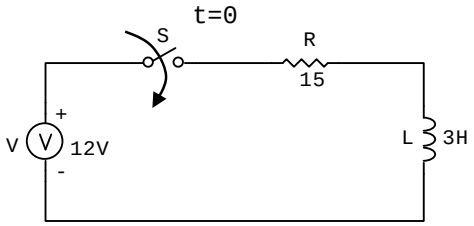


Figure 1: Step Input *RL* circuit

(a) The 1st Order *RL* circuit in **Error! Reference source not found.** has zero initial conditions. The switch S is closed at time $t = 0$.

(i) Determine the solution, $i(t)$, by applying Kirchoff's Voltage Law (KVL) and using conventional Calculus. Identify the Steady State and the Transient State. [**5 marks**]

(ii) Resolve for $i(t)$ using Laplace Transforms. [**4 marks**]

(iii) Derive the expression for the instantaneous voltage $v(t)$ across resistor R = 15 Ω [**2 marks**]

(iv) The step response of a 1st Order System is $C(s) = \frac{4}{s(s+3)}$. Use the method of Poles & Zeros to determine time-domain response. [**3 marks**]

QUESTION 3: SECOND ORDER SYSTEMS **[TOTAL: 20 MARKS]**

(a) The Transfer Function for an Underdamped system is given by

$$G(s) = \frac{81}{s^2 + 12s + 81}$$

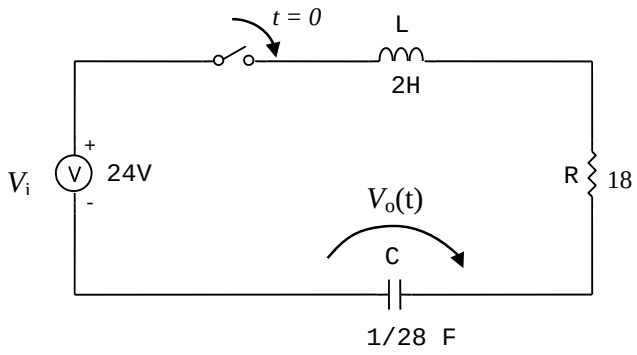
Solve for the following parameters:

(i) Peak time (T_p) **[5 marks]**

(ii) % Overshoot **[3 marks]**

(iii)Settling time (T_s) **[2 marks]**

(b) Consider the *RLC* Series circuit shown. The output is taken across the capacitor, *C*. Use Laplace Transforms to derive the solution of q(t). Assume zero initial conditions.



[10 marks]

Figure 2: Series *RLC* circuit

QUESTION 4: PARALLEL RLC NETWORK

[TOTAL: 15 MARKS]

(a) Consider the Parallel RLC network shown in Figure 1.

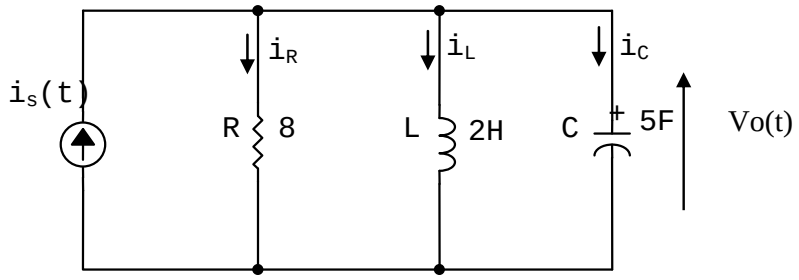


Figure 3: Parallel *RLC* network

(i) Analyze the network and derive the mathematical model. Assume zero initial conditions.

[4 marks]

(ii) Construct the block diagram of the network, then reduce it to its simplest Closed-loop form using the block reduction technique.

[4 marks]

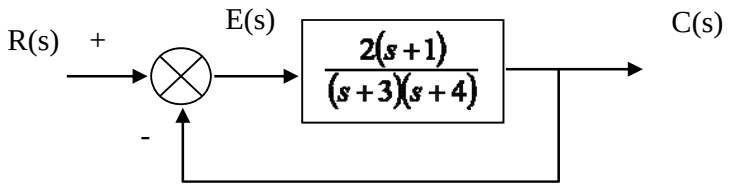
(iii)Find the Closed-loop Transfer Function and represent this via block diagram. **[4 marks]**

(b) The Final Value Theorem states that,

$$\lim_{t \to \infty} e(t) = \lim_{s \to 0} s\{L[e(t)]\} = \lim_{s \to 0} \frac{sR(s)}{1+G(s)},$$

Determine the Steady State Error for the Unity Feedback system shown if the Unit Step is the input.

[3 marks]



[TOTAL: 15 MARKS]

QUESTION 5: FOURIER SERIES **[TOTAL: 15 MARKS]**

(a) A periodic signal waveform is given by, $i(t) = \begin{cases} 24, & -1 \le t < 1 \\ 0, & 1 \le t < 3 \end{cases}$, and $i(t+4) = i(t)$ **Amps.**

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

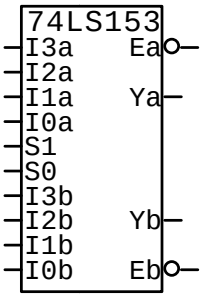
(ii) Determine the coefficients a_o, a_n, and b_n. **[4 marks**]

(iii) Synthesize the first 5 terms of the Fourier series of *i(t).*
[6 marks]

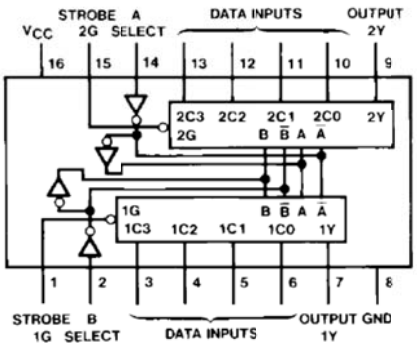
(iv) Derive the frequency and the amplitude of the first 3 terms of the Fourier series of *i(t).*
[4 marks]

QUESTION 6: MULTIPLEXER & SIGNAL CONDITIONING [TOTAL: 10 MARKS]

(a) Two mutually exclusive control circuits are described by the Boolean functions, $f_1(C,B,A) = \sum_m (1, 2, 5, 6, 7)$ and $f_2 = (C,B,A) = \sum_m (0, 1, 3, 4)$. Realize the Boolean functions using the **74LS153** Dual 4-to-1 **Multiplexer** where only one function is active at a time, i.e. f_1 and f_2 are mutually exclusive. Give explanations where appropriate. Data sheet for the 74LS153 is given below



Connection Diagram



Function Table

Select Inputs		Data Inputs				Strobe	Output
B	A	C0	C1	C2	C3	G	Y
X	X	X	X	X	X	H	L
L	L	L	X	X	X	L	L
L	L	H	X	X	X	L	H
L	H	X	L	X	X	L	L
L	H	X	H	X	X	L	H
H	L	X	X	L	X	L	L
H	L	X	X	H	X	L	H
H	H	X	X	X	L	L	L
H	H	X	X	X	H	L	H

Select inputs A and B are common to both sections.
H = HIGH Level
L = LOW Level
X = Don't Care

[5 marks]

(b) The block diagram of an Analog-to-Digital Converter (ADC) is shown in
(c) Figure 4. Explain clearly as to how the analog input V_A is converted to its digital output equivalent.

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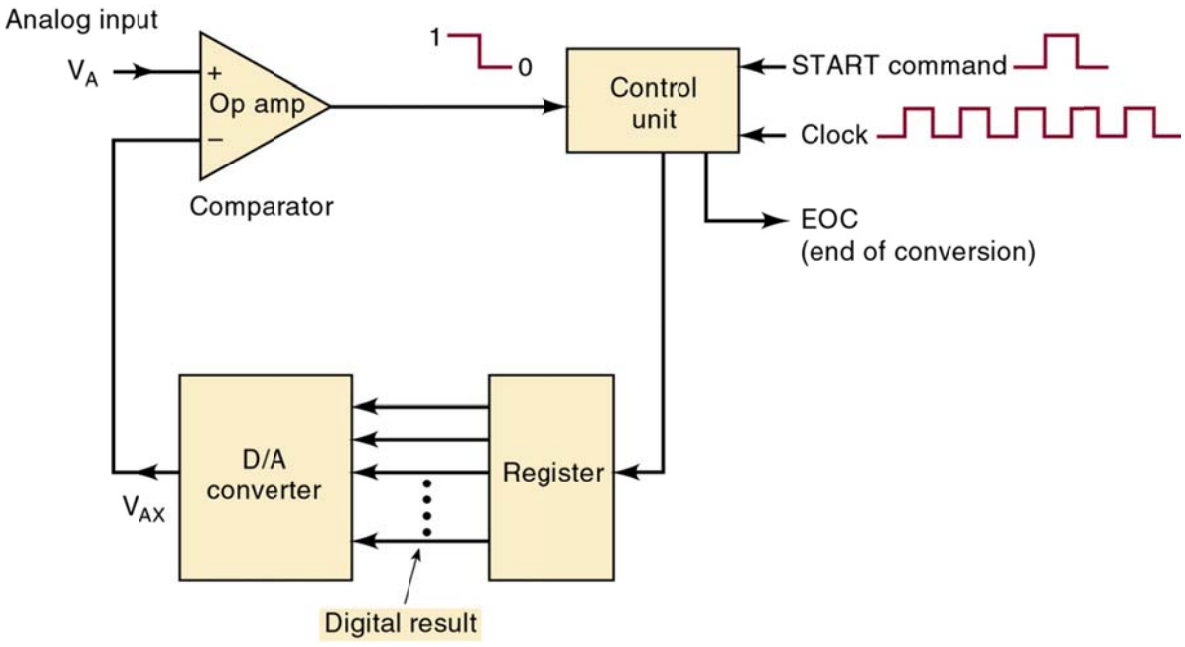


Figure 4: ADC block diagram

QUESTION 7 OPERATIONAL AMPLIFIERS – ANALOGUE COMPUTERS [TOTAL: 10 MARKS]

Design an Analogue Computer using Operational amplifiers to solve the second order differential equation, $v'' = 5v' - 4v + 3\cos 2t$. 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 5, and the parameters that need to be evaluated. [10 marks]

$B_i v_{ni}$

$= \frac{R_f}{R_{ni}}$

B_i

$R_y = \frac{R_f}{C}$

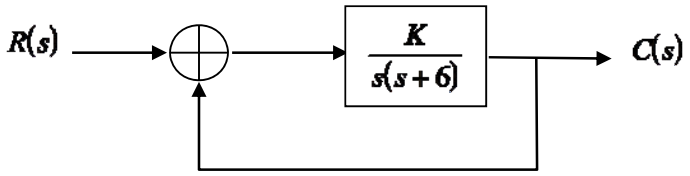
$R_y = \infty$

Figure 5: General Add-Subtract circuit

QUESTION 8: STABILITY – ROOL LOCUS

[TOTAL: 10 MARKS]

Consider the system shown.



(a) Obtain the Characteristic Equation in quadratic form. [2 marks]

(b) Draw the Root Locus. [Hint: Obtain roots for k = 0, 1, 3, 6, 9, 12, 15] [4 marks]

(c) Find the value(s) of k, which will keep the system stable. [2 marks]

(d) What other information can be derived from the Root Locus? [2 marks]

[TOTAL = 10 MARKS]

THE END

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