FNU FIJI NATIONAL UNIVERSITY

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SCHOOL OF ELECTRICAL & ELECTRONICS ENGINEERING

DIPLOMA IN ELECTRICAL ENGINEERING (ELECTRONICS)

EEE529 – CONTROL SYSTEMS ENGINEERING

Tuesday 29th October, 2013 0900 - 1110 hours Venue:

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 2 hours duration.
4. This paper consists of 7 questions printed on 8 pages.
5. Attempt all 7 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 3.
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) $f(t) = 6e^{-3t} + 2t^5 - 4\cosh 3t$ [3 marks]

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

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

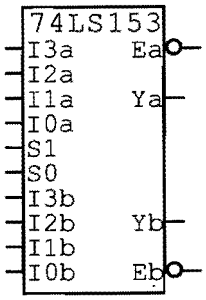
(b) Sketch the graphs of the following functions,

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

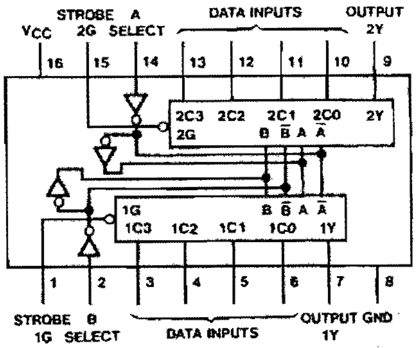
(ii) $f(t) = 12u\left(t - \frac{\pi}{2}\right)\sin t, \quad 0 \le t \le 2\pi$ [3 marks]

QUESTION 2: 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. 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

[4 marks]

(b) The block diagram of an Analog-to-Digital Converter (ADC) is shown in
(c) Figure 1. Explain clearly as to how the analog input V_A is converted to its digital output equivalent.

[6 marks]

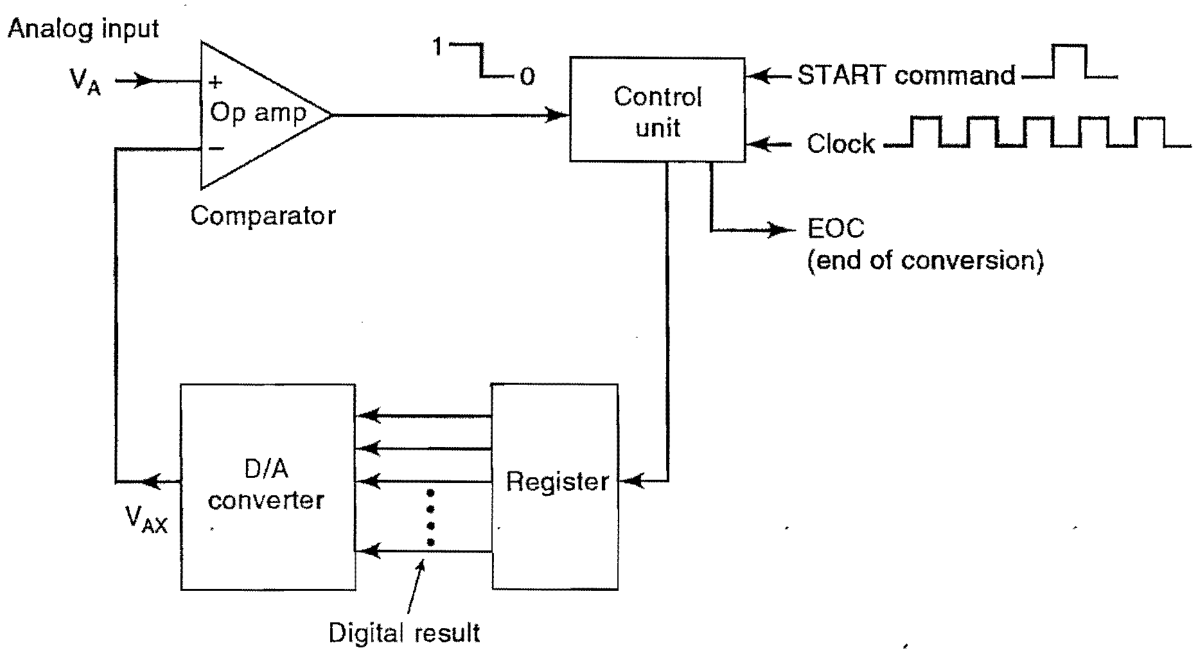
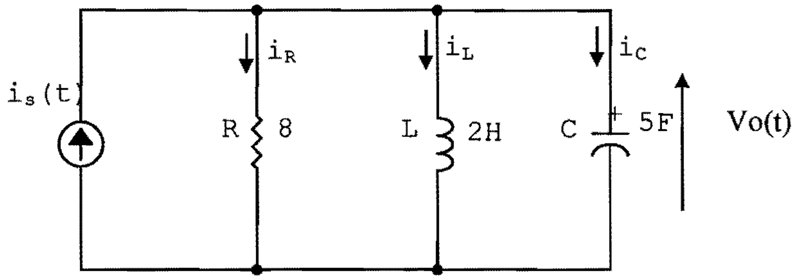


Figure 1: ADC block diagram

QUESTION 3: PARALLEL RLC NETWORK **[TOTAL: 15 MARKS]**

(a) Consider the Parallel RLC network shown.



(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.

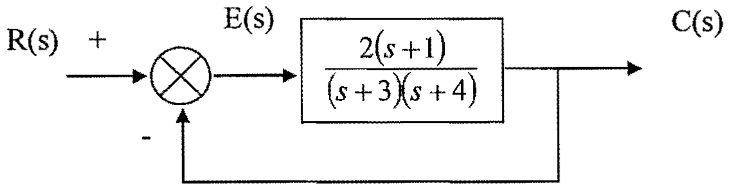
[4 marks]

(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 4: FOURIER SERIES **[TOTAL: 15 MARKS]**

(a) A periodic signal waveform is given by, $i(t) = \begin{cases} 24, & -1 \le t \le 1 \\ 0, & 1 \le t \le 3 \end{cases}$, 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 *v(t)*. **[6 marks]**

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

QUESTION 5: FIRST ORDER RC NETWORK **[TOTAL MARKS: 15]**

Refer to the network shown.

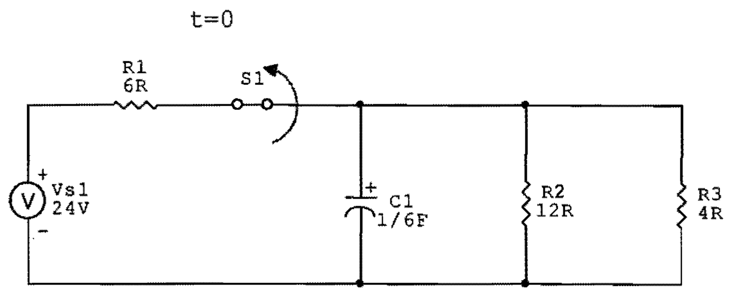


Figure 2: Sourceless RC Circuit

(a) Verify the voltage drop, V_0, across C at $t = 0$. [3 marks]

(b) If the switch in Figure 2 opens at $t = 0$, determine $v(t)$ for $t \geq 0$ using conventional Calculus. [6 marks]

(c) If the switch in Figure 2 opens at $t = 0$, determine $v(t)$ for $t \geq 0$, using Laplace Transforms. Compare your answer with part (b). [6 marks]

QUESTION 6: SECOND ORDER SYSTEMS [TOTAL: 20 MARKS]

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

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

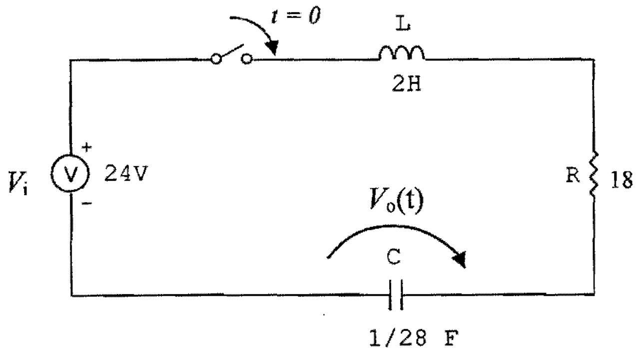
Solve for the following parameters:

(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.

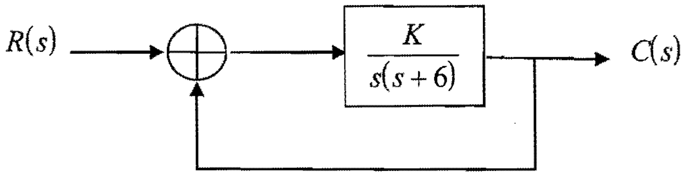


[10 marks]

[TOTAL: 10 MARKS]

QUESTION 7: STABILITY – ROOL LOCUS

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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TABLE OF LAPLACE TRANSFORMS

$F(s)= L[f(t)]$	$f(t),\ t \geq 0$
1. 1	$\delta(t_0)$, Unit Impulse at $t = t_0$.
2. $\frac{1}{s}$	1, Unit Step
3. $\frac{n!}{s^{n+1}}$	t^n
4. $\frac{1}{s+a}$	e^{-at}
5. $\frac{1}{(s+a)^n}$	$\frac{1}{(n-1)!}t^{n-1}e^{-at}$
6. $\frac{a}{s(s+a)}$	$1-e^{-at}$
7. $\frac{1}{(s+a)(s+b)}$	$\frac{1}{(b-a)}\left(e^{-at}-e^{-bt}\right)$
8. $\frac{s+\alpha}{(s+a)(s+b)}$	$\frac{1}{(b-a)}\left[(\alpha-a)e^{-at}-(\alpha-b)e^{-bt}\right]$
9. $\frac{ab}{s(s+a)(s+b)}$	$1-\frac{b}{(b-a)}e^{-at}+\frac{a}{(b-a)}e^{-bt}$
10. $\frac{1}{(s+a)(s+b)(s+c)}$	$\frac{e^{-at}}{(b-a)(c-a)}+\frac{e^{-bt}}{(c-a)(a-b)}+\frac{e^{-ct}}{(a-c)(b-c)}$
11. $\frac{s+\alpha}{(s+a)(s+b)(s+c)}$	$\frac{(\alpha-a)e^{-at}}{(b-a)(c-a)}+\frac{(\alpha-b)e^{-bt}}{(c-b)(a-b)}+\frac{(\alpha-c)e^{-ct}}{(a-c)(b-c)}$
12. $\frac{ab(s+\alpha)}{s(s+a)(s+b)}$	$\alpha-\frac{b(\alpha-a)}{(b-a)}e^{-at}+\frac{a(\alpha-a)}{(b-a)}e^{-bt}$
13. $\frac{\omega}{s^2+\omega^2}$	$\sin \omega t$
14. $\frac{s}{s^2+\omega^2}$	$\cos \omega t$
15. $\frac{s+a}{s^2+\omega^2}$	$\frac{\sqrt{\alpha^2+\omega^2}}{\omega}\sin(\omega t+\phi)$, $\phi = \tan^{-1}\left(\frac{\omega}{\alpha}\right)$
16. $\frac{\omega}{(s+a)^2+\omega^2}$	$e^{-at}\sin \omega t$

Please turn over...

$F(s) = L[f(t)]$	$f(t),\ t \geq 0$
17. $\dfrac{(s+a)}{(s+a)^2+\omega^2}$	$e^{-at}\cos \omega t$
18. $\dfrac{s+\alpha}{(s+a)^2+\omega^2}$	$\dfrac{1}{\omega}\left[(\alpha-a)^2+\omega^2\right]^{\frac{1}{2}} e^{-at}\sin(\omega t+\phi)$, $\phi = \tan^{-1}\left(\dfrac{\omega}{\alpha-a}\right)$
19. $\dfrac{\omega_n^2}{s^2+2\zeta\omega_n s+\omega_n^2}$	$\dfrac{\omega_n}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t}\sin \omega_n\sqrt{1-\zeta^2}\,t,\ \zeta<1$
20. $\dfrac{1}{s\left[(s+a)^2+\omega^2\right]}$	$\dfrac{1}{a^2+\omega^2}+\dfrac{1}{\omega\sqrt{a^2+\omega^2}} e^{-at}\sin(\omega t-\phi)$, $\phi = \tan^{-1}\left(\dfrac{\omega}{-a}\right)$
21. $\dfrac{\omega_n^2}{s\left(s^2+2\zeta\omega_n s+\omega_n^2\right)}$	$1-\dfrac{1}{\sqrt{1-\zeta^2}} e^{-\zeta\omega_n t}\sin\left(\omega_n\sqrt{1-\zeta^2}\,t+\phi\right)$, $\phi = \cos^{-1}\zeta, \zeta<1$
22. $\dfrac{(s+\alpha)}{s\left[(s+a)^2+\omega^2\right]}$	$\dfrac{\alpha}{a^2+\omega^2}+\dfrac{1}{\omega}\left[\dfrac{(\alpha-a)^2+\omega^2}{a^2+\omega^2}\right]^{\frac{1}{2}} e^{-at}\sin(\omega t+\phi)$, $\phi = \tan^{-1}\left(\dfrac{\omega}{\alpha-a}\right)-\tan^{-1}\left(\dfrac{\omega}{-a}\right)$
23. $\dfrac{1}{(s+c)\left[(s+a)^2+\omega^2\right]}$	$\dfrac{e^{-ct}}{(c-a)^2+\omega^2}+\dfrac{e^{-at}\sin(\omega t+\phi)}{\omega\left[(c-a)^2+\omega^2\right]^{\frac{1}{2}}}$, $\phi = \tan^{-1}\left(\dfrac{\omega}{c-a}\right)$

24. $\dfrac{a}{s^2 - a^2}$	$\sinh at$
25. $\dfrac{s}{s^2 - a^2}$	$\cosh at$
26. $\dfrac{\omega^2}{s(s^2 + \omega^2)}$	$1 - \cos \omega t$
27. $\dfrac{\omega^3}{s^2(s^2 + \omega^2)}$	$\omega t - \sin \omega t$
28. $\dfrac{2\omega^3}{(s^2 + \omega^2)^2}$	$\sin \omega t - \omega t \cos \omega t$

$F(s) = L[f(t)]$	$f(t),\ t \geq 0$
29. $\dfrac{s}{(s^2+\omega^2)^2}$	$\dfrac{t}{2\omega}\sin\omega t$
30. $\dfrac{s^2}{(s^2+\omega^2)^2}$	$\dfrac{1}{2\omega}(\sin\omega t + \omega t\cos\omega t)$
31. $\dfrac{s}{(s^2+a^2)(s^2+b^2)}$ $(a^2 \neq b^2)$	$\dfrac{1}{b^2-a^2}(\cos at - \cos bt)$

LAPLACE TRANSFORM OF DERIVATIVES

32. $sF(s) - f(0)$	$f'(t)$, First Derivative
33. $s^2F(s) - sf(0) - f'(0)$	$f''(t)$, Second Derivative

GENERAL PROPERTIES OF LAPLACE TRANSFORMS

1. Linearity $L[af_1(t)+bf_2(t)] = aF_1(s)+bF_2(s)$

2. Scaling $L[f(at)] = \dfrac{1}{a}F\left(\dfrac{s}{a}\right)$

3. Transform of a Derivative
$$L[f^{(n)}(t)] = s^nF(s) - s^{n-1}f(0) - s^{n-2}f'(0) - \ldots - sf^{(n-2)}(0) - f^{(n-1)}(0)$$

4. First Shifting Theorem $L[e^{at}f(t)] = F(s-a)$
(Complex Translation; s-shifting)

5. Second Shifting Theorem $L[u(t-a)f(t-a)] = e^{-as}F(s)$
(Real Translation; t—shifting)

6. Integration $L\left[\int_0^t f(\tau)d\tau\right] = \dfrac{1}{s}F(s)$

7. Complex Differentiation $L[tf(t)] = -\dfrac{dF(s)}{ds}$

8. Final Value Theorem $f(\infty) = \lim_{s\to 0} sF(s)$

9. Initial Value Theorem $f(0+) = \lim_{s\to\infty} sF(s)$