香港中文大學
The Chinese University of Hong Kong

二零二一至二二年度上學期科目考試
Course Examination 1st Term, 2021-22

科目編號及名稱
Course Code & Title : IERG2060/ESTR2304 — Basic Analog and Digital Circuits

時間　　小時　　分鐘
Time allowed : 2 hours 0 minutes

學號　　座號
Student I.D. No. : .... Seat No. : ....

Notes:

1. Correct the final answers to 4 significant figures when necessary.
2. Answer ALL five (5) questions.
3. Each question carries 20%.
4. Put your answers on the answer book.

Q1 — Sinusoidal Signals (20%):

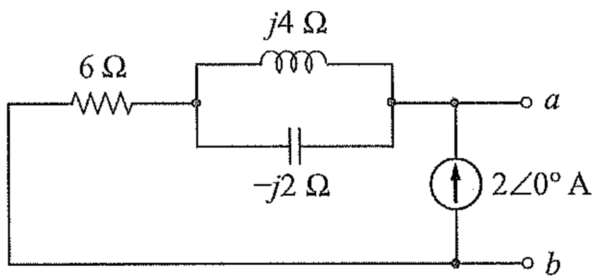


Fig. 1

Refer to the circuit in Fig. 1 for parts (a) to (c).

(a) Determine the Thevenin and Norton equivalents ($\mathbf{V}_{Th}$, $\mathbf{I}_N$ and $\mathbf{Z}_{Th}$) at terminals a-b in polar form ($R\angle\theta$). (12%)

(b) If a load $\mathbf{Z}_L$ is connected to the terminals a-b, determine the value of $\mathbf{Z}_L$ in polar form ($R\angle\theta$) for maximum average power transfer. (2%)

(c) Find that maximum average power P_{max}. (2%)

Consider the following for parts (d) to (f).

The voltage across a load and the current through it are given by

$$v(t) = 339.4\cos(60t + 90°)\text{ V}$$

$$i(t) = 5.657\cos(60t + 45°)\text{ A}$$

(d) Determine the complex power, **S**. (2%)

(e) Determine apparent power, S. (1%)

(f) Determine the power factor, pf. (1%)

Q2 — Operational Amplifier (20%):

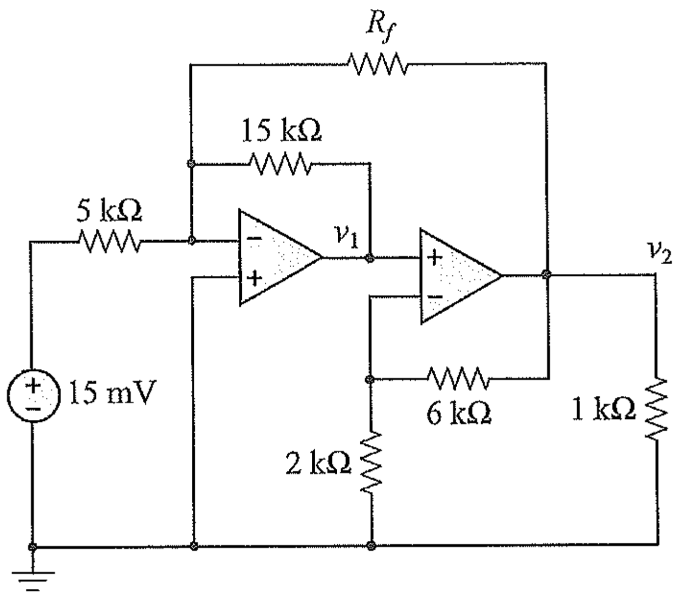


Fig. 2

Assuming that $R_f = \infty$ for parts (a) and (b).

(a) Determine the value of v_1. (5%)

(b) Determine the value of v_2. (5%)

Consider $R_f = 10$ kΩ for part (c).

(c) Determine the value of v_1 and v_2. (10%)

Q3 — Boolean Algebra (20%):

(a) Simplify the following expression by applying only one of the theorems. State the theorem used. (4%)

$$(V' + U + W)[(W + X) + Y + UZ'] + [(W + X) + UZ' + Y]$$

(b) Factor the following expression to obtain a product-of-sums (POS). (4%)

$$A'B'C + B'CD' + EF'$$

(c) Simplify the following expression to obtain a sum-of-products (SOP). (4%)

$$\{X + [Y'(Z + W)']'\}'$$

(d) (i) Simplify the following function so that it can be realized using two OR gates and two AND gates. (4%)

$$F = (V + W + X)(V + X + Y)(V + Z)$$

(ii) Draw that circuit (using two OR gates and two AND gates). (4%)

Q4 — Combinational Logic (20%):

Consider a logic function F that has four inputs A, B, C and D, which are binary representation of the number 0 to 15. A is the most significant bit and D is the least significant bit. Therefore,

$ABCD = 0111$ represents 7 (0111_2), and

$ABCD = 1100$ represents 12 (1100_2).

The function $F = 1$ if the input number is a prime number, and $F = 0$ if not. For this question, 1 is consider to be a prime while 0 is not. In other words,

$$F = \Sigma m(1, 2, 3, 5, 7, 11, 13)$$

(a) Draw a 4-input Karnaugh map for output F. (8%)

(b) Find the minimum sum-of-products (SOP) for F using the Karnaugh map. (4%)

(c) Find the minimum sum-of-products (SOP) for F' using the Karnaugh map. (4%)

(d) Find the minimum product-of-sums (POS) for F' using answer in (c). (4%)

Q5 — Sequential Logic (20%):

Using D flip-flops, design a 3-bit counter (ABC) which counts in the sequence:

000, 010, 111, 101, 011, 110, (repeat) 000, …

(a) Complete the following transition table. (8%)

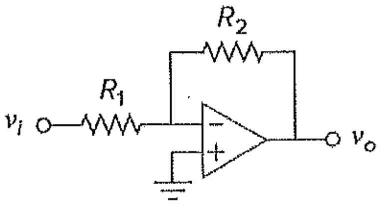
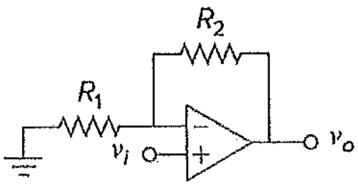
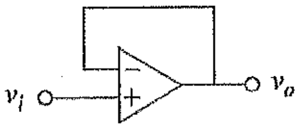
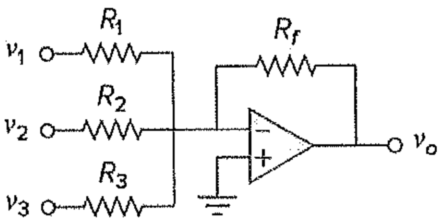
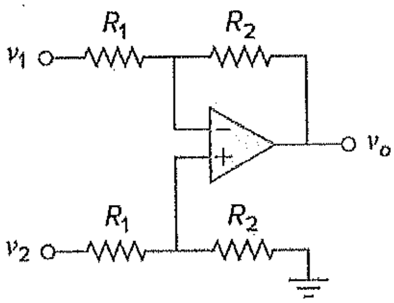
ABC	$A^+B^+C^+$
000	
001	
…	

(b) Draw the Karnaugh maps for D_A, D_B and D_C. (3%)

(c) Using the Karnaugh maps, find the minimum sum-of-products for D_A, D_B and D_C. (3%)

(d) Draw the designed circuit using <u>D flip-flops</u>, <u>AND gates</u> and <u>OR gates</u>. Note that each D flip-flop is capable of producing both Q and Q', and is negative-edge-triggered. (6%)

APPENDIX

Op amp circuit	Name/output-input relationship
	Inverting amplifier $v_o = -\frac{R_2}{R_1} v_i$
	Noninverting amplifier $v_o = \left(1 + \frac{R_2}{R_1}\right) v_i$
	Voltage follower $v_o = v_i$
	Summer $v_o = -\left(\frac{R_f}{R_1} v_1 + \frac{R_f}{R_2} v_2 + \frac{R_f}{R_3} v_3\right)$
	Difference amplifier $v_o = \frac{R_2}{R_1}(v_2 - v_1)$

Operations with 0 and 1:

1. $X + 0 = X$ — 1D. $X \cdot 1 = X$
2. $X + 1 = 1$ — 2D. $X \cdot 0 = 0$

Idempotent laws:

3. $X + X = X$ — 3D. $X \cdot X = X$

Involution law:

4. $(X')' = X$

Laws of complementarity:

5. $X + X' = 1$ — 5D. $X \cdot X' = 0$

Commutative laws:

6. $X + Y = Y + X$ — 6D. $XY = YX$

Associative laws:

7. $(X + Y) + Z = X + (Y + Z) = X + Y + Z$ — 7D. $(XY)Z = X(YZ) = XYZ$

Distributive laws:

8. $X(Y + Z) = XY + XZ$ — 8D. $X + YZ = (X + Y)(X + Z)$

DeMorgan's laws:

9. $(X + Y)' = X'Y'$ — 9D. $(XY)' = X' + Y'$

✓

Uniting theorems:

1. $XY + XY' = X$ — 1D. $(X + Y)(X + Y') = X$

Absorption theorems:

2. $X + XY = X$ — 2D. $X(X + Y) = X$

Elimination theorems:

3. $X + X'Y = X + Y$ — 3D. $X(X' + Y) = XY$

Duality:

4. $(X + Y + Z + \cdots)^D = XYZ\ldots$ — 4D. $(XYZ\ldots)^D = X + Y + Z + \cdots$

Theorems for multiplying out and factoring:

5. $(X + Y)(X' + Z) = XZ + X'Y$ — 5D. $XY + X'Z = (X + Z)(X' + Y)$

Consensus theorems:

6. $XY + YZ + X'Z = XY + X'Z$ — 6D. $(X + Y)(Y + Z)(X' + Z) = (X + Y)(X' + Z)$

✓

D Flip-Flop		
D	Q^+	Operation
0	0	Reset
1	1	Set

SR Flip-Flop			
S	*R*	Q^+	Operation
0	0	Q	No change
0	1	0	Reset
1	0	1	Set
1	1	?	Undefined

$$Q^+ = JQ' + K'Q$$

JK Flip-Flop			
J	*K*	Q^+	Operation
0	0	Q	No change
0	1	0	Reset
1	0	1	Set
1	1	Q'	Complement

$$Q^+ = T \oplus Q = TQ' + T'Q$$

T Flip-Flop		
T	Q^+	Operation
0	Q	No change
1	Q'	Complement

— END —