國立雲林科技大學
八十八學年度研究所碩士班入學考試試題

所別：電資所
科目：電子電路

計算題共十題

1. (a)(4%) Write down the main causes of input offset voltage in a MOS differential amplifier.

(b)(6%) For the cascode current mirror of Fig. 1 with $V_t = 1V$, $K = 100\mu A/V^2$, and $V_A = 20V$. $I_{REF} = 100\mu A$, $V_{SS} = 5V$, and $V_O = +5V$, what value of I_O results?

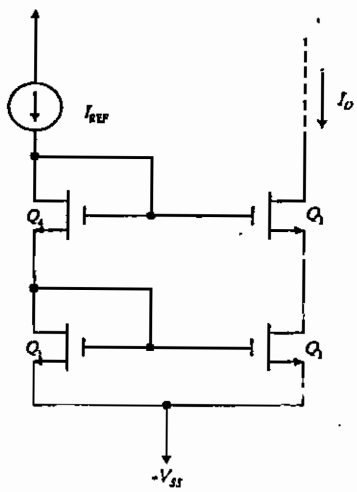

Fig. 1

2. (a)(5%) What value of slope is contributed by each pole in the magnitude response of a transfer function? positive or negative?

(b)(5%) When a MOS Transistor is connected in the common-source amplifier configuration, which internal capacitor of the MOS transistor is effectively multiplied by Miller effect?

3. (a)(4%) For an amplifier to be stable, at what location of the s plane its poles should be?

(b)(6%) Consider a feedback amplifier for which the open-loop gain $A(s)$ is given by

$$A(s) = \frac{1000}{(1+s/10^4)(1+s/10^5)^2}.$$

If the feedback factor β is independent of frequency, find the frequency at which the phase shift is 180^0, and find the critical value of β at which oscillation will commence.

4. (a)(4%) Describe the reason why most CMOS op amps do not need a output stage?

(b)(6%) In a particular design of the CMOS op amp of Fig. 2 the designer wishes to investigate the effects of increasing the W/L ratio of both Q_1 and Q_2 by a factor of 4. Assuming that all other parameters are kept unchanged, what change results in the voltage gain of the input stage? in the overall voltage gain?

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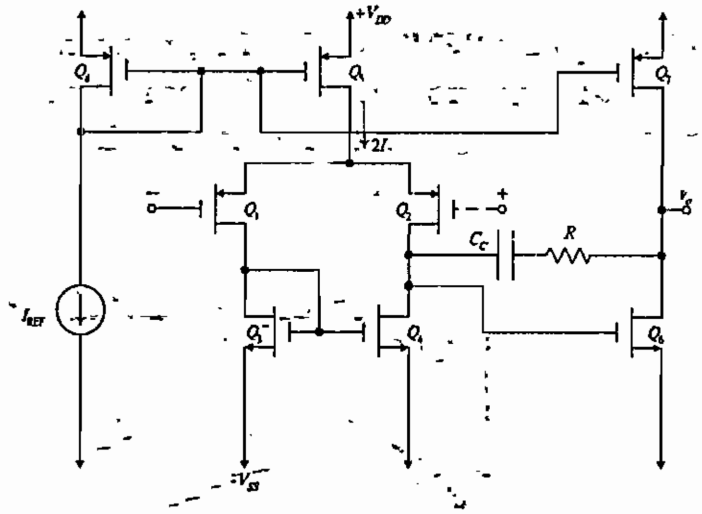

Fig. 2

5. (a)(4%) In a switched-capacitor filter what factors determine the time constant?

(b)(6%) A third-order low-pass filter has transmission zeros at $\omega = 2rad/s$ and $\omega = \infty$. Its natural modes at s=-1 and s=-0.5 $\pm j0.8$. The dc gain is unity. Find its transfer function $T(s)$.

6. In the instrumentation amplifier in Fig. 3, $V_A = 4.99V$ and $V_B = 5.01V$.

(a) (5%) Find the values of node voltage V_O, and currents I_1, I_2,

(b) (5%) What are the values of the common-mode gain, differential-mode gain, and CMRR of the amplifier?

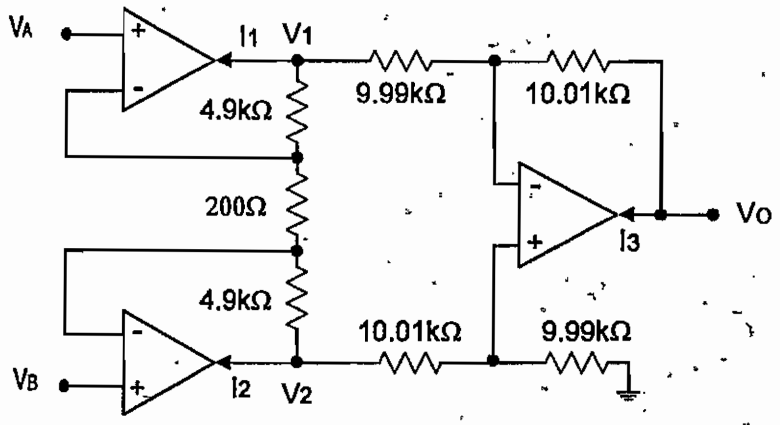

Fig. 3

7. The MOSFET in Fig. 4 has $Kn = 500uA/V^2$ and $V_{TN} = -1.5V$.

(a) (5%) What is the largest permissible signal voltage at the drain that will satisfy the requirements for small-signal operation if $R_D = 15k\Omega$?

(b) (5%) What is the minimum value of V_{DD}?

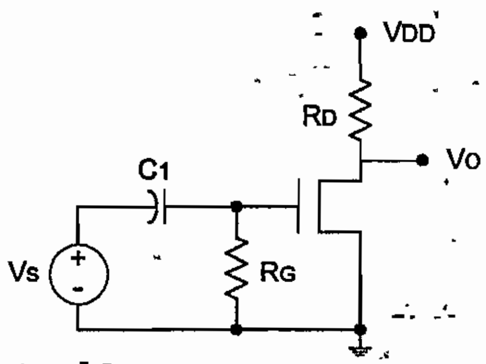

Fig. 4

8. (a) (5%) Find the Q-points of the transistors (i.e. find I_C and V_{CE} for each transistor) in Fig. 5 (β_F=100);

(b) (5%) Find the voltage gain of the amplifier. (assume V_T=25mV)

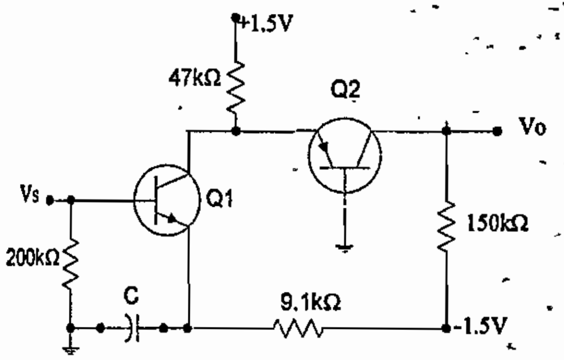

Fig. 5

9. (10%) A CMOS inverter is to be designed to drive a single TTL inverter. When V_O = V_{OL}, the CMOS inverter must sink a current of 1.5 mA and maintain V_{OL} = 0.6 V. When V_O = V_{OH}, the CMOS inverter must source a current of 60 uA and maintain V_{OH} = 2.4 V. What are the minimum W/L ratios of the NMOS and PMOS transistors required to meet these specifications? Assume VDD = 5 V. (Kn = 25uA/V^2, Kp = 10uA/ V^2, V_{TN} = 1V, V_{TP} = -1V)

10. Supposes M_W and M_B in Fig. 6 are 2/1 devices, and M_R is an 8/1 device.

(a) (5%) if the voltage stored on C_C is 1.9 V, and the voltages on the read line and $\overline{BL}$ are 3 V, what are the regions of operation of M_B and M_R? (Kn = 25 uA/ V^2, with V_{TO} = 0.7V, $\gamma = 0.5V^{1/2}$, and $2\phi_F$ = 0.6 V.)

(b) (5%) What are the drain currents of M_B and M_R?

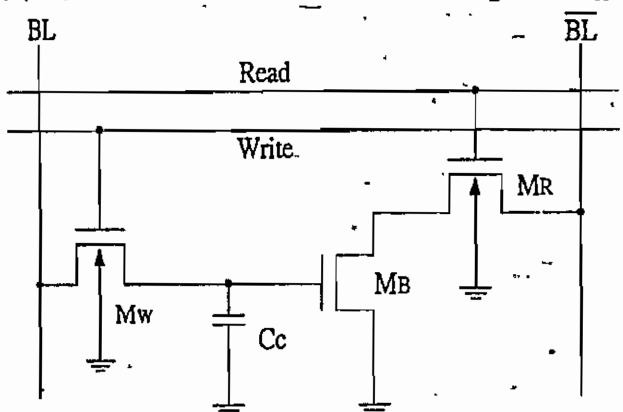

Fig. 6

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所別：電資所
科目：通信系統

1. (20%) A memoryless source has the alphabet $A = \{-5, -3, -1, 0, 1, 3, 5\}$ with corresponding probabilities {0.05,0.06,0.14,0.15,0.02,0.28,0.3}.

   (a) Find the entropy of the source.

   (b) Assume that the source is quantized according to the quantization rule

$$q(-5) = q(-3) = 4$$
$$q(-1) = q(0) = q(1) = 0$$
$$q(3) = q(5) = -4$$

   Find the entropy of the quantized source.

2. (10%) Let the inner product of two functions $x(t)$ and $y(t)$ be defined by $\int_0^1 x(t)y(t)dt$. Using the Gram-Schmidt orthogonalization procedure, find an orthonormal basis for the space of polynomial functions $x_1(t) = 1$, $x_2(t) = t$, $x_3(t) = t^2$, $x_4(t) = t^3$, ...

3. (20%) It is known that the Hilbert transform introduces a 90° phase shift in the components of a signal, and the transfer function of a quadrature filter can be written as

$$H(f) = \begin{cases} e^{-j\pi/2} & f > 0 \\ 0 & f = 0 \\ e^{j\pi/2} & f < 0 \end{cases}$$

   We can generalize this concept to a new transform that introduces a phase shift of θ in the frequency components of a signal by introducing

$$H_\theta(f) = \begin{cases} e^{-j\theta} & f > 0 \\ 0 & f = 0 \\ e^{j\theta} & f < 0 \end{cases}$$

   and denote the result of this transform by $x_\theta(t)$, i.e., $X_\theta(f) = X(f)H_\theta(f)$, where $X_\theta(f)$ denotes the Fourier transform of $x_\theta(t)$. Throughout this problem, assume that the signal $x(t)$ does not contain any DC components.

   (a) Find $h_\theta(t)$, the impulse response of the filter representing the transform described above.

   (b) Show that $x_\theta(t)$ is a linear combination of $x(t)$ and its Hilbert transform.

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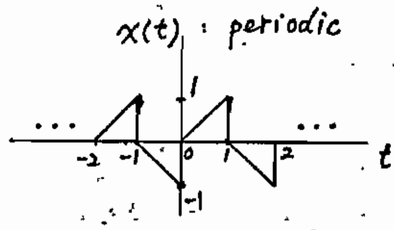
4. (15%) The Fourier series expansion of the signal $x(t)$ is given by

$$x(t) = \frac{a_0}{2} + \sum_{n=1}^{\infty}\left[a_n cos(2\pi\frac{n}{T_0}t) + b_n sin(2\pi\frac{n}{T_0}t)\right],$$

where T_0 is the period of $x(t)$. Find a_n and b_n for the signal $x(t)$ shown below, assuming $T_0 = 2$.



5. (15%) An *upper* single sideband (USSB) signal $s(t)$ is generated by modulating the signal $m(t) = cos(2\pi f_m t) + b_m sin(2\pi f_m t)$ with a carrier $A_c cos(2\pi f_c t)$.

   (a) Find $\hat{m}(t)$, the Hilbert transform of $m(t)$.

   (b) Find $\hat{s}(t)$.

   (c) At the demodulator, the USSB signal $s(t)$ is multiplied by a reference signal $cos(2\pi f_c t + \phi)$ and then passed through a lowpass filter to yield the demodulator output $y(t)$. Which value of the phase ϕ will lead to the demodulator output $y(t) = c \cdot \hat{m}(t)$? ($c$ denotes a constant term.) Explain.

6. (20%) Consider a signal detector with an input

$$r = s + n,$$

where n is an additive noise. The prior probability of the signal s is $P(s = A) = q$, and $P(s = -A) = 1 - q$. (Assume $0 < q < 1$ and $A > 0$.)

   (a) Assume the noise n is zero-mean white Gaussian with a power spectral density $\frac{N_0}{2}$.

      i. Find the optimal (MAP) detector.

      ii. Determine the probability of error for the optimal detector.

   (b) Assume the noise n has a Laplacian probability density function (p.d.f.):

$$f(n) = \frac{\lambda}{2}e^{-\lambda|n|}$$

      i. Find the maximum likelihood (ML) detector.

      ii. Determine the probability of error for the ML detector.

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所別：電資所
科目：計算機概論 (甲)

1. (15pts) For the programs shown in Figure 1, please
   a. measure the tight big-O upper bound on the running time of the program fragment listed in Figure 1(a). (5pts)
   b. determine the tight big-O upper bounds on the running time of the recursive function *value(i, j)* shown in Figure 1(b). (5pts)
   c. explain what the returned value of the function *value(i, j)* is. (5pts)

```
if (A[1][1] = = 0)
  for (i = 0; i < n; i++)
      for (j = 0; j < n; j++)
      A[i][j] = 0;
else
  for (i =0; i < n; i++)
      A[i][i] = 0;
```

Figure 1(a)

```
int value(i, j)
int i, j ;
{
    int r;
    r = i % j;    /* r = i mod j */
    if (r != 0) value (j, r);
    else return j;
}
```

Figure 1(b)

2. (20ps) Please answer the following questions.
   a. If a directed graph is acyclic and has n nodes, what is the largest possible number of arcs? (5pts)
   b. Is a complete graph with 4 nodes a planar graph? Justify your answer. (5pts)
   c. Construct a minimal spanning tree for the graph shown in Figure 2. (5pts)
   d. What is the clique number in Figure 2? Give an example of one largest clique to justify your answer. (5pts)

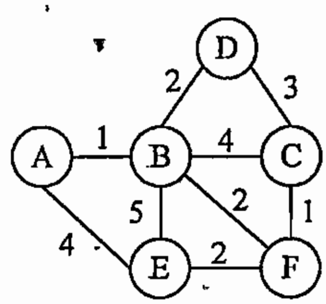

Figure 2

3. (15pts) Given a system described by an N-th order linear constant coefficient difference equation

$\sum_{k=0}^{N} a_k y[n-k] = \sum_{k=0}^{M} b_k x[n-k]$, where a_k, b_k, N and M are constants, $x[n]$ and $y[n]$ correspond to the latest input and the latest output, respectively.

   a. Please write a code (in whatever language you feel comfortable) to evaluate $y[n]$ continuously (5pts)
   b. What is the computing complexity (big-O upper bound) of your code? (5pts)

c. Assume a memory space of 100 words is allocated to store the values of $x[n]$ and $y[n]$, how would you modify your code to meet the constraint? (5pts)

4. ALU design (20pts)

a. Given a 4-bit ripple adder as shown in Figure 3. Please derive an arithmetic unit design subject to the function table as shown in Table 1. (5pts)

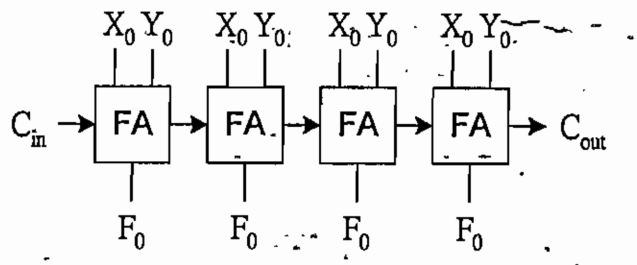

Figure 3.

Select signals		F(A,B)	
S_1	S_0	$C_{in} = 0$	$C_{in} = 1$
0	0	F = A (transfer)	F = A+1 (increment)
0	1	F = A + B (add)	F = A+B+1
1	0	$F = A + \overline{B}$	$F = A+\overline{B}+1$ (subtract)
1	1	F = A–1 (decrement)	F = A (transfer)

Table 1.

b. Please use four 4-to-1 multiplexers plus additional gates to implement a logic unit subject to the function table as shown in Table 2. (5pts)

S_1	S_0	Output	Operation
0	0	$F = A \wedge B$	AND
0	1	$F = A \vee B$	OR
1	0	$F = A \oplus B$	XOR
1	1	$F = \overline{A}$	Complement

Table 2.

c. Please use four 4-to-1 multiplexers to design a barrel shifter subject to the function table as shown in Table 3. (5pts)

select		output				operation
H_1	H_0	Z_3	Z_2	Z_1	Z_0	
0	0	D_3	D_2	D_1	D_0	No shift
0	1	D_2	D_1	D_0	D_3	Rotate once
1	0	D_1	D_0	D_3	D_2	Rotate twice
1	1	D_0	D_3	D_2	D_1	Rotate three times

Table 3.

d. Please sketch an ALU design based on the three components (i.e., arithmetic unit, logic unit, and barrel shifter) designed above. Use a **block** (not detailed circuit) to represent each component and use a third select signal S_2 to distinguish logic from arithmetic functions. (5pts)

5. (15pts) Regarding to programmable logic devices (a generic block diagram is shown in Figure 4), please answer the following questions

a. Please state the circuit differences among a PLA (programmable logic array), a PAL (programmable array logic), and a PROM (6pts)

b. Which of the above three devices can share product terms between different outputs (justify your answer) (3pts)

c. Please derive the PLA programming table for the combinational circuit that squares a 3-bit number, i.e. $Y = A^2$, where $A = A_2A_1A_0$, please minimize the number of product terms. (6pts)

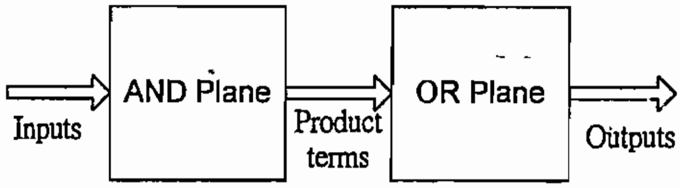

Figure 4.

6. (15pts) For the three finite state machines with an input (X) and an output (Z) shown in Figure 5, please

a. reduce the state table of machine A to a minimum number of states. (5pts)

b. perform a suitable state assignment for the reduced state-table of machine A, which will lead to an economical network with less hardware requirement. (*Please show how you arrive at your state assignment, but do not derive the network equations*) (5pts)

c. show whether the machines B and C are equivalent or not? You need to justify your answer. (5pts)

PS	Next state		Output
	X=0	X=1	Z
A	F	C	0
B	D	F	0
C	H	A	0
D	B	G	0
E	G	F	1
F	A	G	0
G	E	H	1
H	C	E	0

(a) Machine A

Present	Next state		Output (Z)	
State	X=0	X=1	X=0	X=1
A	C	B	0	0
B	C	B	1	0
C	C	A	0	1
D	B	A	0	1

(b) Machine B

Present	Next state		Output (Z)	
State	X=0	X=1	X=0	X=1
S_0	S_2	S_0	1	0
S_1	S_3	S_3	0	1
S_2	S_2	S_3	0	1
S_3	S_2	S_0	0	0

(c) Machine C

Figure 5

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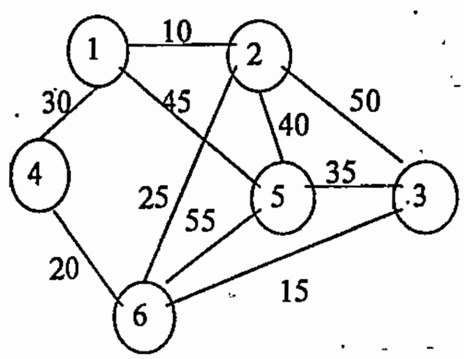
所別：電資所
科目：計算機概論 (乙)

1. Simulate the recursive function MergeSort on an array containing the character string ASORTINGEXAMPLE (10%).

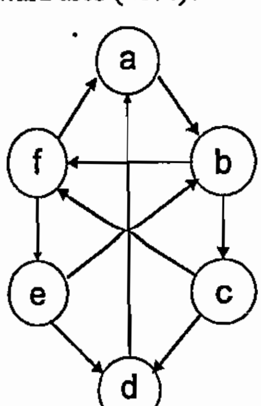
2. Find the languages generated by the following grammars; that is to find L(G)={ ...?....}.
   (a) S→0S1|0A1, A→1A|1 (5%)
   (b) S→AB, A→A1|0, B→2B|3 (5%)

3. Using Kruskal's algorithm to find a minimum spanning tree of the following graph (10%).



4. A subsequence of the list L is a list formed by striking out zero or more elements of L. Try to use a dynamic programming algorithm to compute all the LCSs (Largest Common Subsequences) of the lists **abcabba** and **cbabac** (10%).

5. Build a depth-first search tree **rooted at node b** for the following graph. The order of the edges are according to **the alphabetical order.** What are forward arcs and backward arcs (10%)?



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所別：電資所
科目：計算機概論 (乙)

6. Assume a Bare Bone programming language only provides the following four statements:

clear x;	/* assign 0 to the variable x
incr x;	/* increase the variable x by 1
decr x;	/* decrease the variable x by 1
while x *not 0 do*;	/* a while-end statement pair
...	
end;	

Suppose all variables are associated with natural numbers (0,1,2,3, …). Write a Bare Bone program segment for computing C=A*B (i.e. compute the product of the variable A and the variable B). (10%)

7. Consider the following program segment, where ***i***, ***j*** and ***k*** are integer variables:

```
for i := 1 to 20 do
  for j := 1 to i do
      for k :=1 to j do
          print(i*j+k)
```

How many times is the print statement executed in this program segment? (10%)

8. Suppose we are dealing with a base octal system. Moreover, assume this system doesn't provide the operation of subtraction. Please simulate the following computation of subtraction by using addition operation: 1456 – 3762. You must give the answers step by step and reason it, accordingly. (Hint: use the octal's complement). (10%)

9. Suppose you must sort a list of five names and you have already design an algorithm that sort a list of four names. Design an algorithm to sort the list of five names by talking advantage of the previously design algorithm. (10%)

10. Both a computer-bound process and an I/O bound process are waiting for a time slice in a time-sharing environment, which should be given priority? Why? (10%)

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所別：電資所
科目：計算機系統

1. Answer the following problems for virtual memory processing (15%)
   A. For virtual memory management, describe the purpose of using a TLB in a processor.
   B. Are there any differences between a TLB miss and a page fault? If so, what are they?
   C. Show a flow diagram that illustrates the address translation process, assuming a physically addressed cache is used with the TLB.
2. For a write operation to a cache memory, explain the following terms: (10%)
   A. write-back
   B. write-around
   C. write-allocate (or write-allocation)
   D. write-through
3. For a typical 5-stage pipelined processor, answer the following problems: (15%)
   A. Show the block diagram of a 5-stage pipelined processor and explain the function of each of the stages.
   B. What is a data hazard in such a processor? Use a code sequence to explain.
   C. How does the control unit handle a precise interrupt in this pipelined machine?.
4. About linking process, answer the following problems: (10%)
   A. Describe the steps that a linker may take for linking assembled machine language programs.
   B. What are the typical pieces of information that may present in the object file header?

5. (10%)

A grammar is given as follows.

<S> ::= if <E> then <S> <S1> | a

<S1>::= else <S> | ε

<E> ::= a

Draw the parse tree of the statement "if a then if a then a else a".

6. (10%)

What restrictions would be required for a one-pass linking loader? What would be the advantages and disadvantages of such a one-pass loader?

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7.(15%)

In each of the following problems, determine whether it is True or False(1%) and give your reason(2%).

(a)A time-sharing system is also a multiprogramming system. (3%)

(b)The user's address space is limited by the physical memory space on all of computer systems. (3%)

(c)The Shortest-job-first algorithm is provably optimal, in that it gives the minimum average waiting time for a given set of processes. (3%)

(d)A programming language compiler can detect syntax errors and logic errors. (3%)

(e)A Macro Processor is machine dependent and language independent. (3%)

8.(15%)

What is "thrashing"? The working-set model and the page-fault frequency strategy are used to prevent thrashing. Explain how they work.

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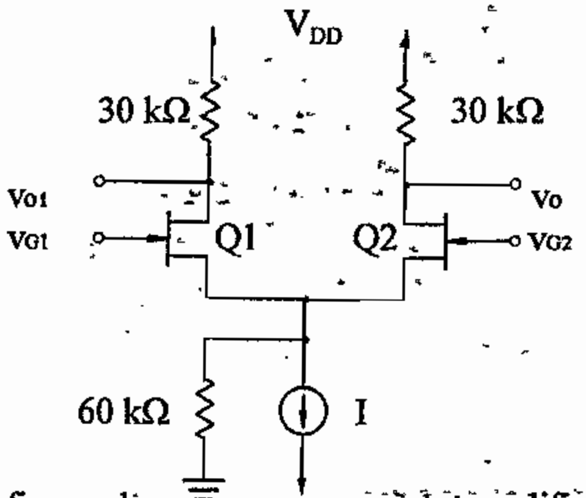
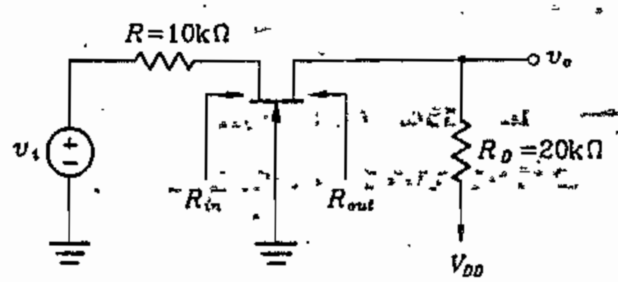
所別：電資所
科目：微電子學

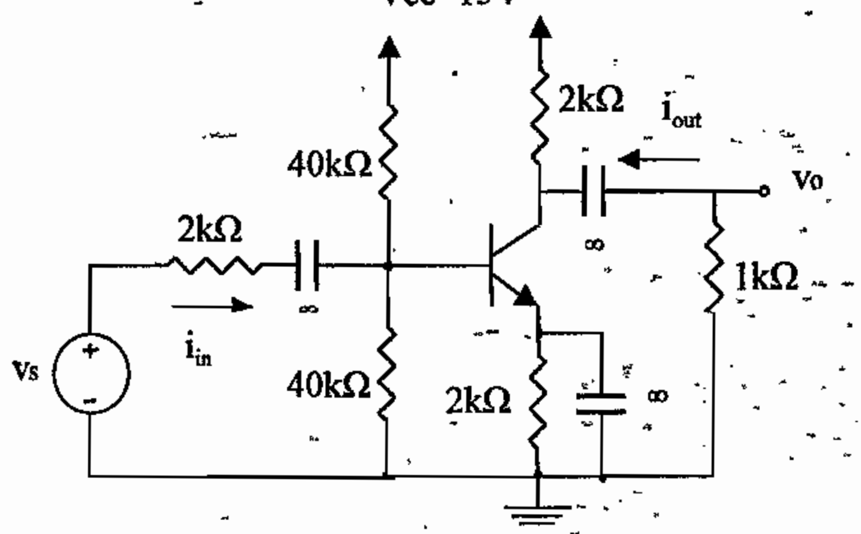
1.圖中 JFET 電晶體 Q1 與 Q2 之特性相同 g_m=1mA/V，r_o=50kΩ，求此放大器之差額增益、共模增益與 CMRR 值為何？ (15%)



2.The following figure shows a common-gate amplifier, where g_m=2mA/V and r_o =100kΩ. Find (a)A_v(=v_o/v_i) and (b) R_{in} and R_{out}. (15%)



3.共射放大電路如圖所示，已知β=100 與 V_A=100V，試計算電流增益與電壓增益。 (20%)



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所別：電資所
科目：微電子學

4. Define or explain the following terms:
   (a) The Early effect in a pnp transistor (5%)
   (b) Mobility of electrons (5%)
   (c) Avalanche breakdown. (5%)

5. Describe briefly the fabrication process sequence of an npn bipolar junction transistor using the planar silicon IC technology. (15%)

6. Sketch the small-signal hybrid-π equivalent circuit of a bipolar junction transistor and explain each element of the equivalent circuit. (20%)

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所別：電資所
科目：半導體元件

1. To determine the time behavior of excess carriers as a semiconductor returns to thermal equilibrium.
   Consider an infinitely large, homogeneous n-type semiconductor with zero applied electric field. Assume that at time $t = 0$, a uniform concentration of excess carriers exists in the crystal, but assume that $g' = 0$ for $t > 0$. If we assume that the concentration of excess carriers is much smaller than the thermal-equilibrium electron concentration, then the low-injection condition applies. Calculate the excess carrier concentration as a function of time for $t >= 0$. (15%)

2. To determine the impurity doping concentration in a p^+n junction. Assume a silicon p^+n junction at T= 300 K with n_i= 1.5×10^{10} cm^{-3}. Assume that the intercept of the curve giving that V_{bi}= 0.855 V and that the slope is 1.32×10^{15} (F/cm^2)$^{-2}$V^{-1}. (20%)

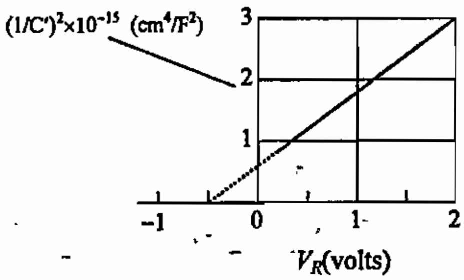
3. To calculate the open-circuit voltage of a silicon pn junction solor cell. Consider a silicon pn junction at T= 300 K with the following parameters:

$$N_a = 5\times10^{18}\ \text{cm}^{-3},\ N_d = 10^{16}\ \text{cm}^{-3},\ D_n = 25\ \text{cm}^2/\text{sec},$$
$$D_p = 10\ \text{cm}^2/\text{sec},\ t_{n0} = 5\times10^{-7}\ \text{sec},\ t_{p0} = 10^{-7}\ \text{sec}.$$

   Let the photocurrent density be J_L=I_L/A= 15 mA/cm^2. (15%)

4. A Schottky diode with n-type silicon at T = 300 K yields the $1/C'^2$ versus V_R plot shown in the figure, where C' is the capacitance per cm^2.

   (a) Determine the doping concentration N_d. (5%)
   (b) Determine the theoretical barrier height ϕ_{B0}. (5%)
   (c) Calculate the current density when a forward bias of 0.4 V is applied. Neglect the image-force-induced barrier lowering. Assume that the Richardson constant A^* is 114 A/K$^2\cdot$cm^2. (5%)



5. A silicon npn bipolar transistor at T = 300 K has a neutral base width of 0.7 μm, and doping concentrations in base and collector of $N_B = N_C = 10^{17}$ cm^{-3}.
   Assuming D_B = 25 cm^2/sec.

   (a) Determine the base transport factor, assuming $\tau_{B0} = 10^{-7}$ sec. (5%)
   (b) Determine the base transit time. (5%)
   (c) Determine the reverse-bias B-C voltage when base punch-through occurs. (5%)

6. The I_D-V_{GS} curve of an n-channel MOSFET is measured at V_{DS} = 0.05 volt. In the ideal region of the curve, I_D = 200 μA at V_{GS} = 1.2 volt and I_D = 260 μA at V_{GS} = 1.4 volt.

   (a) Determine the threshold voltage. (5%)
   (b) If the channel length L = 1 μm, $C_{ox} = 3.45\times10^{-7}$ F/cm^2, and the carrier mobility in the inversion layer is 800 cm^2/V-sec, calculate the channel width W. (10%)
   (c) If L is reduced to 0.25 μm, how does the threshold voltage change? Explain. (5%)

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科目：半導體元件

B.4 Silicon, gallium arsenide, and germanium properties (T = 300°K)

Property	Si	GaAs	Ge
Atoms (cm^{-3})	5.0×10^{22}	4.42×10^{22}	4.42×10^{22}
Atomic weight	28.09	144.63	72.60
Crystal structure	Diamond	Zincblende	Diamond
Density (g/cm^{-3})	2.33	5.32	5.33
Lattice constant (Å)	5.43	5.65	5.65
Melting point (°C)	1415	1238	937
Dielectric constant	11.7	13.1	16.0
Bandgap energy (eV)	1.12	1.42	0.66
Electron affinity, χ, (volts)	4.01	4.07	4.13
Effective density of states in conduction band, N_c, (cm^{-3})	2.8×10^{19}	4.7×10^{17}	1.04×10^{19}
Effective density of states in valence band, N_v, (cm^{-3})	1.04×10^{19}	7.0×10^{18}	6.0×10^{18}
Intrinsic carrier concentration (cm^{-3})	1.5×10^{10}	1.8×10^{6}	2.4×10^{13}
Mobility (cm^2/V-s)			
Electron, μ_n	1350	8500	3900
Hole, μ_p	480	400	1900
Effective mass, $\left(\frac{m^*}{m_0}\right)$			
Electrons	$m_l^* = 0.98$ $m_t^* = 0.19$	0.067	1.64 0.082
Holes	$m_{lh}^* = 0.16$ $m_{hh}^* = 0.49$	0.082 0.45	0.044 0.28
Effective mass (density of states)			
Electrons, $\left(\frac{m_n^*}{m_0}\right)$	1.08	0.067	0.55
Holes, $\left(\frac{m_p^*}{m_0}\right)$	0.56	0.48	0.37

B.3 Physical constants

Avogadro's number	$N_A = 6.02 \times 10^{+23}$ atoms per gram molecular weight
Boltzmann's constant	$k = 1.38 \times 10^{-23}$ J/K $= 8.62 \times 10^{-5}$ eV/K
Electronic charge (magnitude)	$e = 1.60 \times 10^{-19}$ C
Free electron rest mass	$m_0 = 9.11 \times 10^{-31}$ kg
Permeability of free space	$\mu_0 = 4\pi \times 10^{-7}$ H/m
Permittivity of free space	$\epsilon_0 = 8.85 \times 10^{-14}$ F/cm $= 8.85 \times 10^{-12}$ F/m
Planck's constant	$h = 6.625 \times 10^{-34}$ J-s $= 4.135 \times 10^{-15}$ eV-s $\frac{h}{2\pi} = \hbar = 1.054 \times 10^{-34}$ J-s
Proton rest mass	$M = 1.67 \times 10^{-27}$ kg
Speed of light in vacuum	$c = 2.998 \times 10^{10}$ cm/s
Thermal voltage (T = 300°K)	$V_t = \frac{kT}{e} = 0.0259$ volt $kT = 0.0259$ eV

B.6 Properties of SiO_2 and Si_3N_4 (T = 300°K)

Property	SiO_2	Si_3N_4
Crystal structure	[Amorphous for most integrated circuit applications]	
Atomic or molecular density (cm^{-3})	2.2×10^{22}	1.48×10^{22}
Density (g-cm^{-3})	2.2	3.4
Energy gap	≈9 eV	4.7 eV
Dielectric constant	3.9	7.5
Melting point (°C)	≈1700	≈1900

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本試卷共有七大題，總分 100 分

一、圖 1 為一雙狹縫干涉實驗圖。在圖 1 左邊極遠處有一作為光源之單色光源(波長為 λ)，照射在此雙狹縫上(各狹縫之寬度 $W << \lambda$)，其干涉條紋則投射於右側之螢幕上。

假設在狹縫 S_1 與螢幕中心點 P 間放置一片厚度 d 、折射率 n 之玻璃片，現再假設此玻璃片不吸收任何光，則中心點 P 之光強度 (Intensity) 將隨厚度 d 而改變。若 d = 0 時，在中心點 P 之光強度為 I_0，試問：

(a)在中心點 P 處，其光強度 I 與玻璃厚度 d 之關係？ (7 分)

(b)在中心點 P 處，當其光強度 I 為最小值時，請問厚度 d 值應為何？ (5 分)

(c)假設狹縫 S_2 之寬度增為 2W，另一狹縫 S_1 之寬度不變，則在中心點 P 處之光強度 I 與玻璃厚度 d 之關係？ (8 分) (共 20 分)

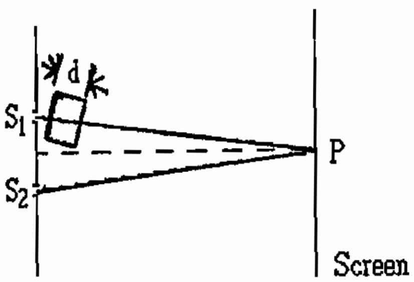

圖 1

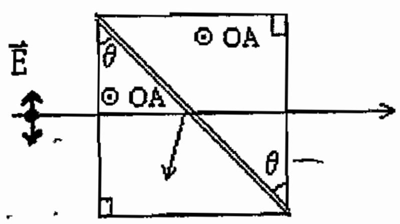

圖 2

二、圖 2 為一個 Glan-Foucault (或稱 Glan-Air) 偏光稜鏡，其為由兩個方解石晶體(calcite, $CaCO_3$)頂角為 θ 之直角三稜鏡結合而成，兩稜鏡之結合界面為空氣間隙，其光軸(optic axis, OA)均垂直於紙面。今已知方解石晶體之雙折射率分別為平常折射率(ordinary refractive index) $n_o = 1.4864$ 及非常折射率(extraordinary refractive index) $n_e = 1.6584$ 。試問：(a) 作為 Glan-Foucault 偏光稜鏡時，方解石稜鏡頂角 θ 值之範圍？ (5 分) (b) 試繪圖說明其穿透光與反射光之光偏極方向？(5 分) (共 10 分)

三、Nd-YAG 雷射有四個幫浦能階(pump level)，分別為在基態能階(ground state energy level)之上的 1.53 eV, 1.653 eV, 2.119 eV, 及 2.361 eV 能階。

(a) 如果使用激發光源來幫浦(pump)此四個幫浦能階，請問每個能階所需之激發光子的波長為何？ (7 分) (b) 已知 Nd-YAG 雷射輸出波長為 1.064 μm 光子，請決定每個幫浦能階所相關之量子效率(quantum efficiency)大小為何？ (8 分) (共 15 分)

四、考慮一個 AlGaAs 平板型波導(slab waveguide)，其具有折射率 $n_1 = 3.6$ 及 $n_2 = 3.55$。今若有一波長為 λ 之光源在此平板型波導中傳播，若僅存在有四個傳播模態(假設已考慮平面光波之不同偏極模態)，請問該平板波導纖蕊寬度 d 值大小？ (共 10 分)

五、四分之一波長厚度之 ZnS 薄膜(n = 2.2)及 MgF_2 薄膜(n = 1.35) 依序先後鍍於矽基板(n = 3.3)上(先鍍 ZnS，再鍍 MgF_2)，以得到在垂直入射時於波長 2μm 處有最低反射率 (a) 請計算每層薄膜之實際厚度?(5 分) b) 該雙層抗反射薄膜折射率比值與理想抗反射薄膜折射率比值相差之百分比有多少？(5 分) (共 10 分)

六、(a) 請解釋用以描述原子能階態(atomic energy states)之四個量子數(n, l, m_l, m_s)的個別意義？ (10 分)
(b)當 n = 4 時，請試繪圖表以列出所有可能之能階態？ (5 分)
(共 15 分)

七、解釋名詞：(20 分)
(a) population inversion (5 分)
(b) phonon (5 分)
(c) photovoltaic effect (5 分)
(d) uncertainty principle (5 分)

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參考公式
（作為考生解題參考之用）

1. (a) In a slab waveguide, the total number of propagating mode is

$$m=\frac{2d}{\lambda}N.A.+1,\qquad N.A.=numerical\ \ aperture$$

Where the "straight through" mode (m=0) is included.
Two independent polarizations are possible for the propagating plane wave, the total number of modes is twice, $m_{max} = 2m$.

(b) In a cylinder fiber, the number of possible modes is

$$m_{max}=\frac{1}{2}\left(\frac{\pi d}{\lambda}N.A.\right)^2$$

2. (a) One-layer antireflecting films
Normal incidence
Quarter-wave thickness

$$R=\left(\frac{n_o n_s-n_1^2}{n_o n_s+n_1^2}\right)^2$$

(b) Two-layer antireflecting films
Normal incidence
Quarter-wave thickness

$$R=\left(\frac{n_o n_2^2-n_s n_1^2}{n_o n_2^2+n_s n_1^2}\right)^2$$

Where
R = the reflectance,
n_o, n_1, n_2, n_s = refractive index of air, 1st film, 2nd film, and substrate, respectively.