Data Provided: None

The University Of Sheffield.

DEPARTMENT OF ELECTRONIC AND ELECTRICAL ENGINEERING

Spring Semester 2012-13 (2.0 hours)

EEE6037 Analogue Electronics

Answer **THREE** questions. **No marks will be awarded for solutions to a fourth question.** Solutions will be considered in the order that they are presented in the answer book. Trial answers will be ignored if they are clearly crossed out. **The numbers given after each section of a question indicate the relative weighting of that section.**

1. **a.** Draw the small-signal equivalent circuit for an emitter follower with load resistor R_L and signal resistor R_S. Derive an expression for the voltage gain v_o/v_i, taking into account the resistance of the base-emitter junction, r_{BE}, and the resistance of the collector-emitter junction, r_{CE}. Under what conditions does the gain approximate to unity? **(7)**

b. For the single stage amplifier shown in Figure 1, draw the small-signal equivalent circuit for low frequency operation. State the functions of resistors R_1 and R_2. Derive an expression for the small signal voltage gain, assuming R_1>>$1/g_m$. Show how the expression for the voltage gain can be simplified for large values of R_1 and R_2.

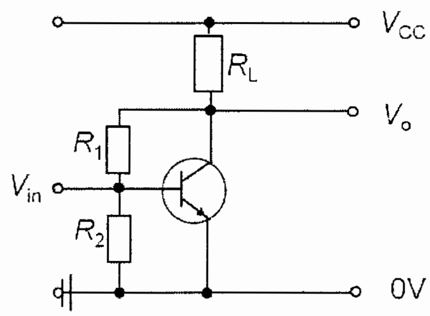

Figure 1 **(8)**

c. Figure 2 shows the circuit of an unbiased single stage amplifier. Identify the type of circuit and state what amplifier class it is, giving reasons for your decisions. Draw small-signal equivalent circuits for both input and output sides when the amplifier in Figure 2 operates at high frequencies. Calculate the cut-off frequency of the amplifier in Figure 2 for a transistor with emitter capacitance and base-collector capacitance of C_E=C_{BC}=20pF, a transconductance of g_m=40mS and a low-frequency current gain of β_0=200. Take the Miller effect for the capacitance between input and output into account but neglect r_{CE}.

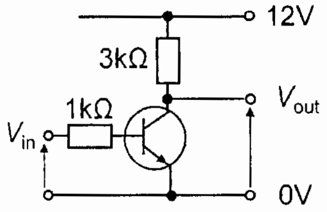

Figure 2

(5)

2. **a.** Draw a set of common emitter output characteristic curves of I_C vs. V_{CE} for four significantly different values of v_{BE} and include the Early voltage V_A in your diagram. Describe the physical processes that lead to the Early effect. What would be the output resistance of a BJT without the Early effect? **(6)**

b. Figure 3 shows an N-output current mirror. Assume all transistors are matched and have finite small-signal current gain of β. Ignore the effect of finite output resistance. Calculate the ratio of the current at the collector of transistor Q_N, I_N, relative to the input current I_{ref}. Compare your result to that of a simple current mirror consisting of only two transistors Q_{ref} and Q_1 where the output is at the collector of Q_1. How many outputs (N) can the current mirror support if the individual output currents current (I_N) are to stay within 98% of the reference current (I_{ref}) and if β=200 is assumed for all transistors?

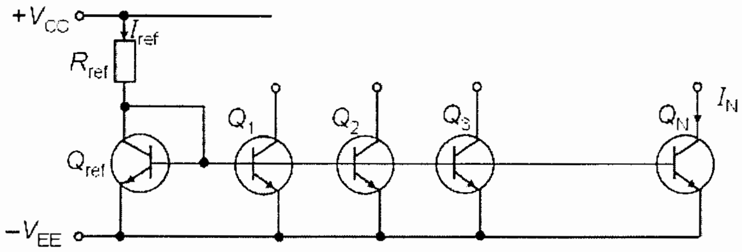

Figure 3 **(5)**

c. Sketch the circuit for a class B push-pull amplifier configuration. Draw the voltage characteristic V_{out}/V_{in} and describe the distortion you would expect. How could the distortion be reduced by biasing to produce a class AB output stage? **(4)**

d. The output characteristic of an emitter coupled pair of BJTs can be written as

$$v_o^{diff} = \alpha\, I_E\, R_C \tanh\left[-v_i^{diff}/(2V_{to})\right].$$

Define all six parameters in this equation, sketch the curve of v_o^{diff} as function of v_i^{diff} and comment on sign, slope and range of the linear approximation. **(5)**

3. a. The square law below describes the drain current, I_D, of a MOSFET as function of gate-source voltage, V_{GS}:

$$I_D = 0.5\mu C_{ox} (W/L) (V_{GS}-V_{to})^2 (1+V_{DS}/V_A)$$

where V_{to} is a threshold voltage, V_{DS} the drain-source voltage and V_A the Early voltage. μ, C_{ox}, W and L are device parameters. Derive an expression for the mutual conductance g_m in the active region. State how drain current and over-voltage influence the mutual conductance. **(3)**

b. Figure 4 shows a MOSFET circuit called centroid layout. Draw the circuit diagram corresponding to the figure, explain how the transistors are interconnected and describe the function of the circuit. What are the advantages and disadvantages of this layout compared to a simple layout using only two transistors?

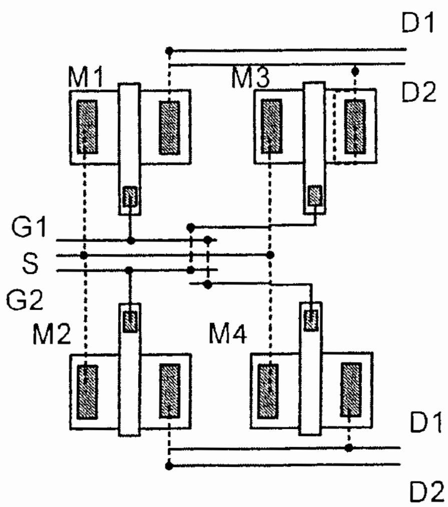

Figure 4 **(6)**

c. Describe the function of each transistor (Q_1, Q_2 and Q_3) in the circuit shown in Figure 5. Explain the advantage of combining BJTs with a MOSFET in this circuit.

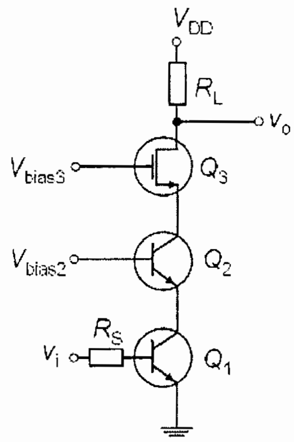

Figure 5 **(4)**

d. Transistor T_1 in the emitter follower of Figure 6 is biased by a quiescent current I_Q supplied by transistor T_2. What class of amplifier output stage is this? For a sinusoidal input voltage V_i, sketch the waveforms for the full range of output voltage, output current and instantaneous power as a function of time. You may neglect $V_{CE,sat}$. Derive an expression for the power conversion efficiency of this output stage amplifier.

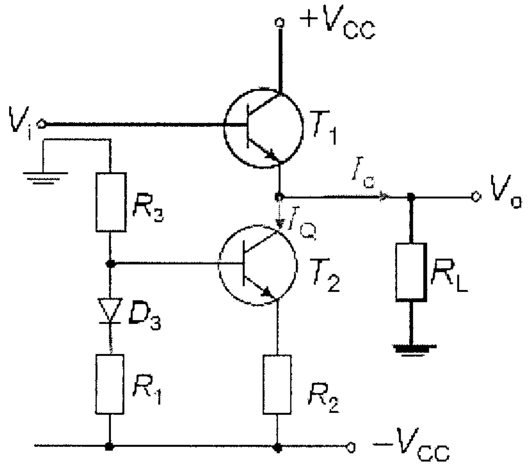

Figure 6 **(7)**

4. **a.** State what class of filter is shown in Figure 7. Using qualitative arguments, describe the frequency behaviour of the filter. Draw the leap-frog structure diagram of the filter, deriving equations for the voltages and currents of all components in your leap-frog diagram.

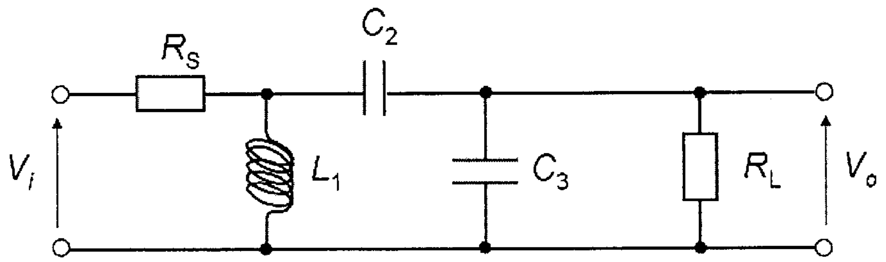

Figure 7 **(6)**

b. Determine the transfer function of the circuit shown in Figure 8. Write down expressions for its zeros and poles. What classification of filter is it? Compare the pole frequency to the time constant of the RC network.

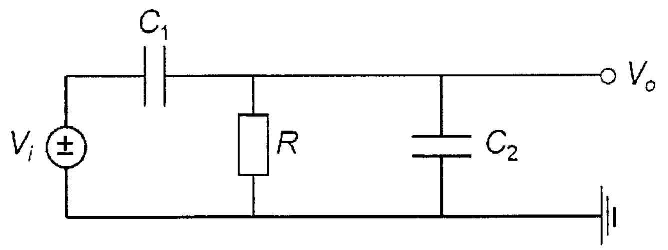

Figure 8 **(5)**

c. For the transfer function below write down the location of the poles and zeros and sketch the magnitude of the Bode plot:

$$T(s) = \frac{10s^2}{(1+s/10^1)\ (1+s/10^4)\ (1+s/10^6)}$$

Name the order and the classification of filter. What is the transition frequency of unity gain?

(6)

d. Explain the principle stages within a typical three-stage operational amplifier. Name all three basic stages, explain their function and briefly discuss possible methods of implementation. **(3)**

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