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IMPERIAL COLLEGE LONDON

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DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2008

MSc Analogue Systems

CURRENT-MODE ANALOGUE SIGNAL PROCESSING

Monday, 12 May 10:00 am

Time allowed: 3:00 hours

Corrected Copy

There are FIVE questions on this paper.

Answer FOUR questions.

All questions carry equal marks

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible First Marker(s) : C. Papavassiliou
Second Marker(s) : E. Rodriguez-Villegas

The Questions

1.

(a) Draw a circuit diagram of a first generation switched current memory cell. Explain its operation. Discuss the transistor mismatch limitation of the first generation switched current memory cell. Draw a diagram of a switched current memory cell which overcomes transistor mismatch limitation of the first generation cell, and explain its operation.

[5]

(b) Write an expression for the step response of the first generation switched current memory cell. Assume that all switches in the circuit are ideal, and all transistors are identical and have transit frequency $f_T = 1$ GHz , transconductance $g_m = 10$ μS, and vanishing output conductance. Assume also that the gate-to-drain capacitance is negligible. What is the time constant of the step response?

[5]

(c) Calculate the maximum switching rate and maximum low-pass signal bandwidth of this memory cell if a maximum error of 0.01% of full scale can be tolerated.

[5]

(d) Design a switched-current Infinite Impulse Response filter implementing the following equation: $Y_N = \frac{2}{3}Y_{N-1} + \frac{1}{3}(X_N + X_{N-1})$, where X is the input signal, and Y the output signal.

[5]

2.

(a) Describe the current feedback op-amp (CFOA); draw a block diagram of a current feedback op-amp. Explain why a current feedback op-amp has a theoretically infinite slew rate, unlike the conventional op-amp which has a finite slew rate. What is the CFOA slew rate limited by?

[5]

(b) Calculate the open loop transfer function of a CFOA considering if the input signal is applied on the inverting terminal and the non-inverting terminal is grounded. What are the units of the gain? What is the dominant frequency dependence of this gain?

[5]

(c) Ignore the frequency response of any voltage buffers and current mirrors to show that a non-inverting amplifier built with a current feedback op-amp has a bandwidth which is independent of the gain.

[10]

3.

(a) Answer the following short questions:

i. Describe the second generation current conveyor. Write equations relating its port voltages and currents

ii. How does a second generation current conveyor differ from a first generation current conveyor?

iii. How does a current conveyor differ from a standard op-amp?

iv. How does a current conveyor differ from a current feedback op-amp?

v. Which common device behaves (approximately) like a current conveyor?

[5]

(b) Using current conveyors draw circuit diagrams for the following functional blocks:

i. Voltage amplifier

ii. Transconductor

iii. Gyrator

iv. Transimpedance

v. Current Feedback op-amp

[10]

(c) Design a floating inductor using only grounded capacitors, resistors and current conveyors.
HINT: what is a grounded capacitor placed between two gyrators equivalent to?

[5]

4.

a) State the bipolar translinear principle. State the conditions for the translinear principle to be valid.

[5]

b) State the CMOS translinear principle. Comment on its advantages and disadvantages relative to the bipolar case.

[5]

c) In the circuit of figure 4 I_1 and I_3 are input signals and I_2 and I_4 are constant bias currents. The output is indicated on the figure.

i. Derive a relationship between the inputs and the output.

[5]

ii. Show that the amplitude of the output current is proportional to the frequency of a sinusoidal input current I_{in} if $I_3 \propto \frac{d}{dt} I_{in}$ and $I_1 \propto \int I_{in} dt$.

[5]

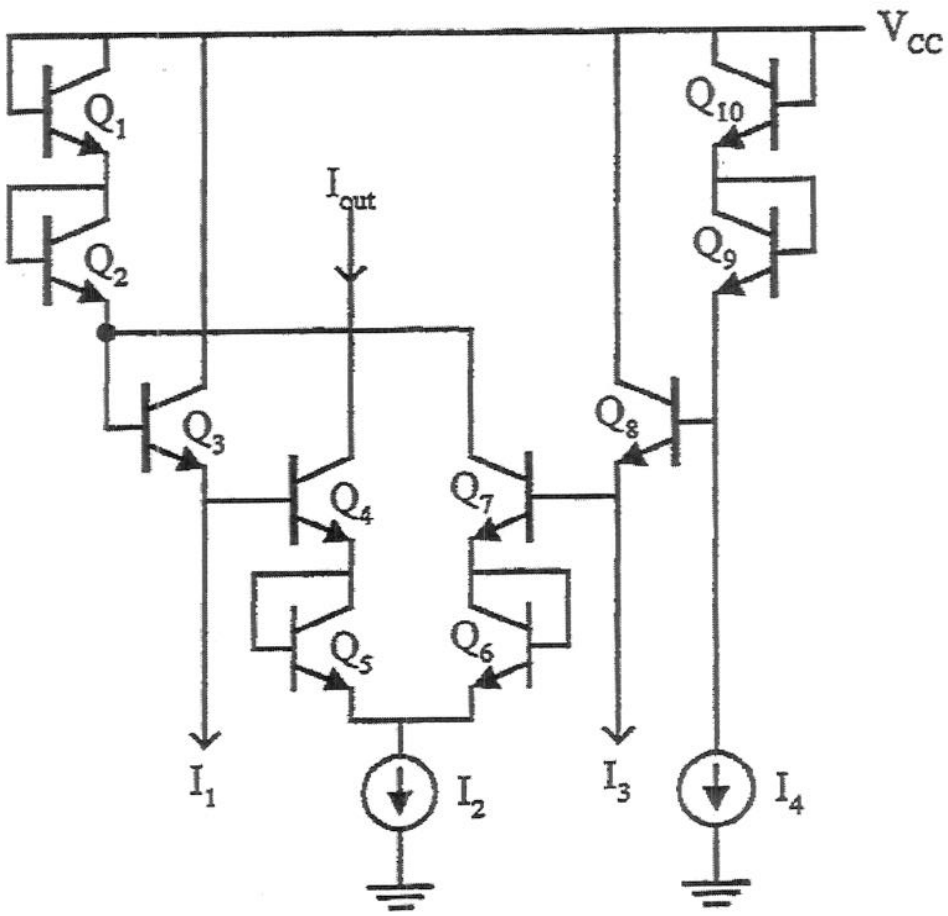

Figure 4: Circuit diagram for question 4.

5.

a) Write a differential equation relating the input and output currents in the Adams Log-Domain Cell shown on figure 5a.

[5]

b) Draw a circuit diagram of a bipolar transistor log domain cell. Write a differential equation relating the input and output currents of your circuit.

[5]

c) Show that the circuit in figure 5b implements the function:

$$u(t) = I_{ref} \exp\left[\frac{q}{kT}\left(V_{REF} - V_k(t)\right)\right].$$

Explain why this is a useful feedback element in log-domain circuits.

[5]

d) An oscillator is a circuit which solves the differential equation: $\frac{d^2y}{dt^2} + \omega_0^2 y = \omega_0^2 U$.

Write a set of state space equations implementing a log-domain oscillator.

[5]

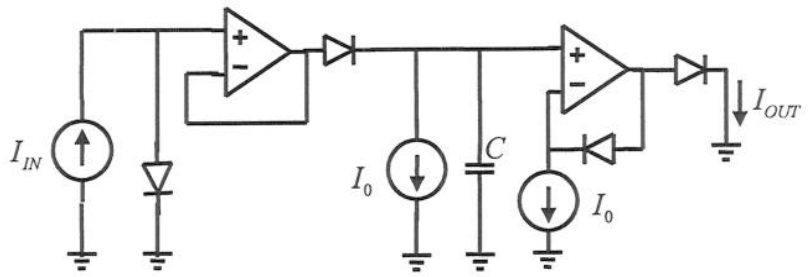

Figure 5a: The Adams Log Domain Cell

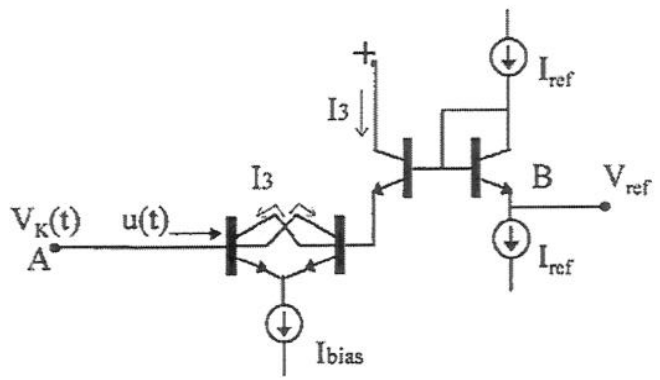

Figure 5b: Feedback structure for Log Domain Circuits