# ECE ECE145C (undergrad) and ECE218c (graduate)

## Mid-Term Exam. Nov 13, 2003

Do not open exam until instructed to.

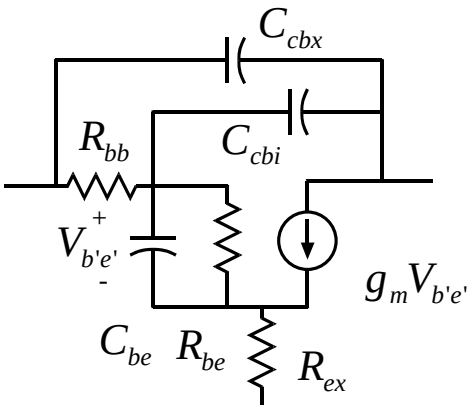
Open book

Use any and all reasonable approximations (5% accuracy is fine. ) , ***AFTER STATING THEM.***

**Name: _____**

**Problem 1, 50 points**

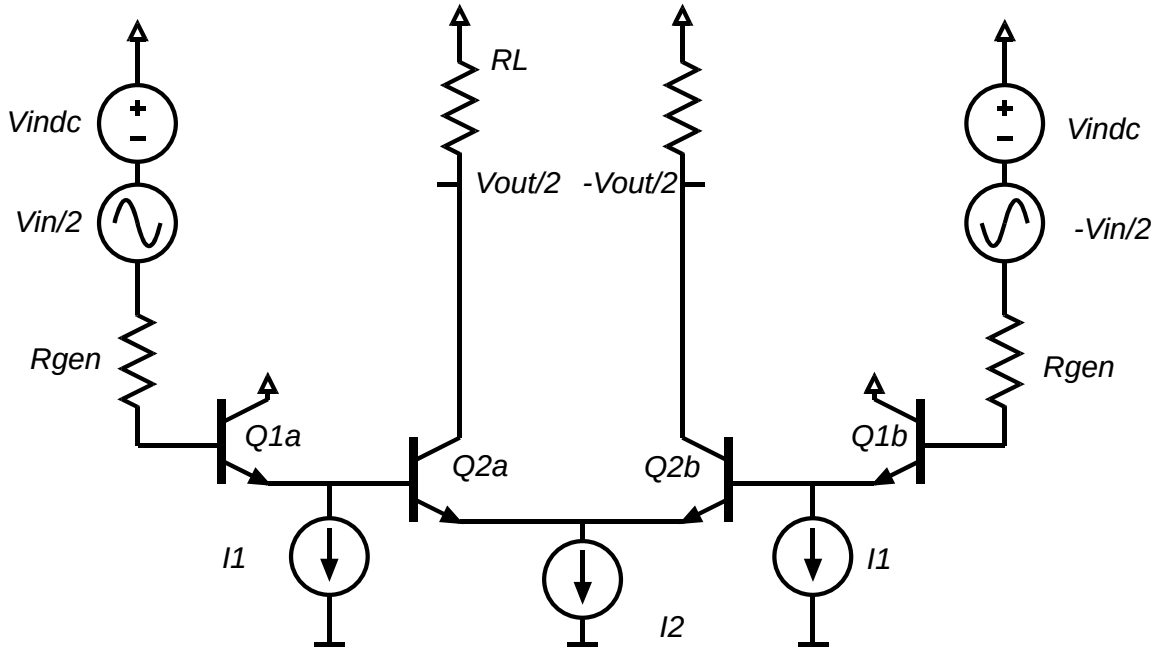
You will be using the device model below:




$C_{be} = C_{be,depl} + g_m \tau_f$ . Cje=14 fF, beta=infinity, Ccbi=2.2 fF, Ccb_total=4.3 fF, Rbb=21 Ohms, Rex=4 Ohms, and tau_f=0.44 ps. This transistor model has 2.5 um^2 emitter area

The transistors have a Vbe=0.9 Volts when operating at 2.0 mA/um^2.

You will be working on the circuit below. Please note that because the exam is open-book, the circuit is by necessity somewhat unusual.

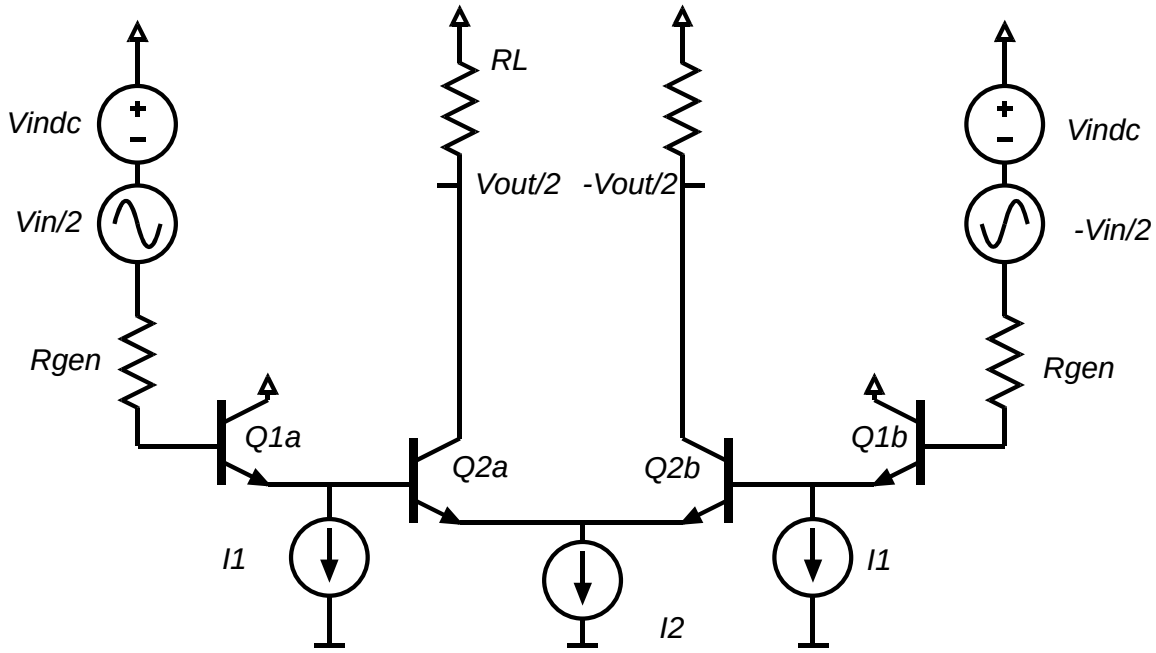



The circuit diagram is 100% mirror-symmetric.
All transistors are 2.5 um^2 emitter area
I1=I2=I3=5mA, RL=200 Ohms, Rf=Rgen=50 Ohms. Vindc=500 mV (e.g. the inputs are at -500 mVdc).

Part a, 5 points

*DC bias.*

Draw all DC node voltages and branch currents directly on the circuit diagram.



Part b, 15 points
*Midband gains*

Find the mid-band gain Vout/Vin=_____

In order to receive partial credit , it is essential to show appropriate work and small-signal equivalent circuit diagrams.

Part c, 5 points
*device models*

Please enter the device parameter values below.

| transistor | Rbe | Rbb | Rex | Cbe | Ccbi | gm |
|---|---|---|---|---|---|---|
| Q1a | | | | | | |
| Q2a | | | | | | |
| Q3a | | | | | | |

Part d, 25 points
*high frequency analysis*

**Find the first-order time constants of the circuit**:
first order time constant due to Ccbx of Q1a=_____
first order time constant due to Ccbi of Q1a=_____
first order time constant due to Cbe of Q1a=_____

first order time constant due to Ccbx of Q2a=_____
first order time constant due to Ccbi of Q2a=_____
first order time constant due to Cbe of Q2a=_____

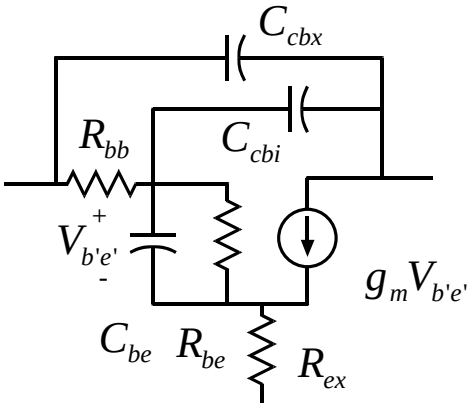
Total first order time constant=_____

There are too many 2nd-order time constants to calculate them all; please find only one:
second order time constant due to Cbe of Q1a and Cbe of Q2a=_____

Please show all your work clearly below

**Problem 2, 50 points**

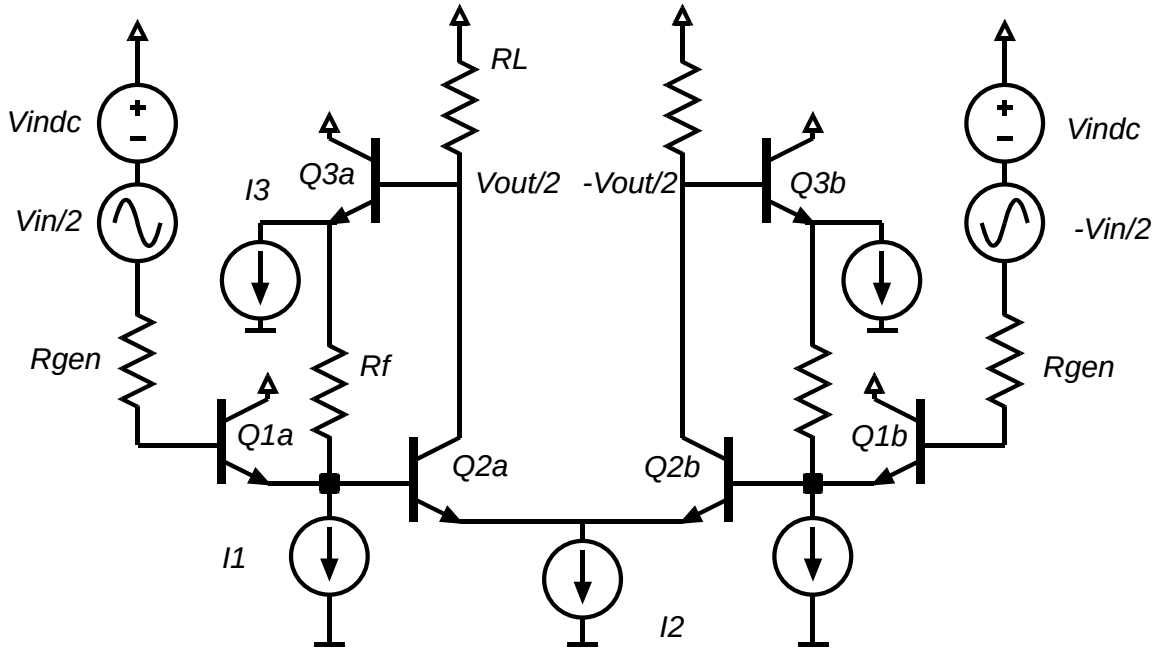
You will be using the device model below:




$C_{be} = C_{be,depl} + g_m \tau_f$. Cje=14 fF, beta=infinity, Ccbi=4.3 fF, Ccbx=0 fF, Rbb=0 Ohms, Rex=0 Ohms, and tau_f=0.44 ps. This transistor model has 2.5 um^2 emitter area.

The transistors have a Vbe=0.9 Volts when operating at 2.0 mA/um^2.

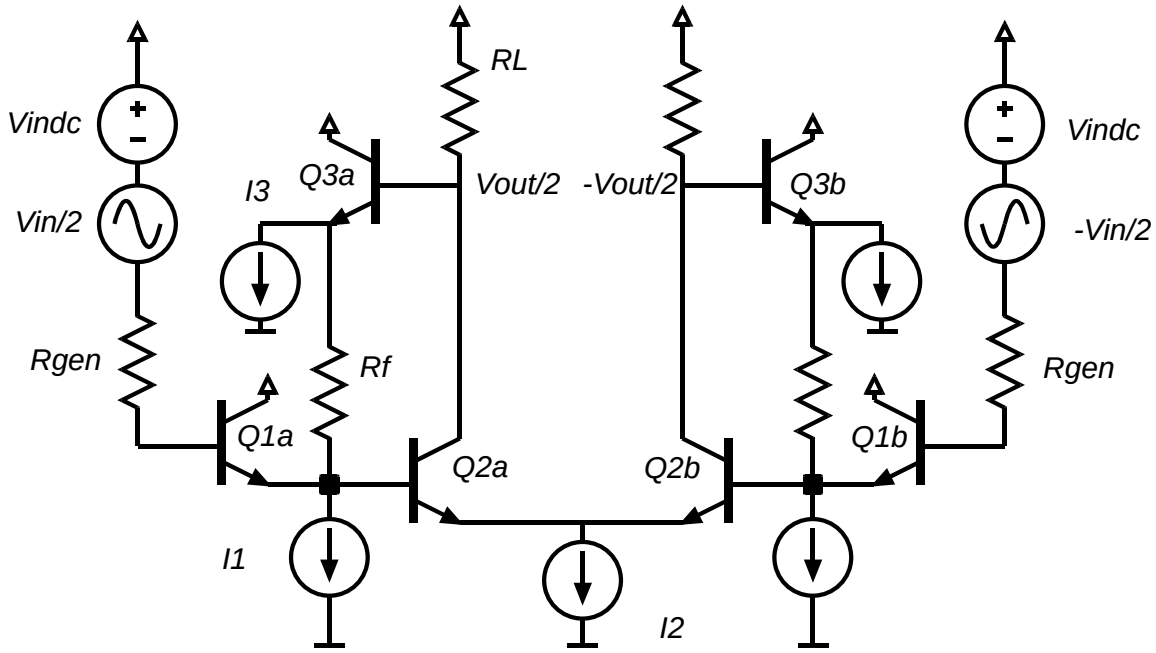
***You will be working on the circuit below. Please note that because the exam is open-book, the circuit is by necessity somewhat unusual. This problem most definitely requires thinking, rather than "plug and grind".***




The circuit diagram is 100% mirror-symmetric.
All transistors are 2.5 um^2 emitter area
I1=I2=I3=5 mA, RL=200 Ohms, Rf=Rgen=50 Ohms. Vindc=500 mV (e.g. the inputs are at -500 mVdc).
**Q1a/b and Q3a/b have zero base-emitter and base-collector capacitance**

Part a, 5 points
*DC bias.*

Draw all DC node voltages and branch currents directly on the circuit diagram.



Part b, 5 points

*Circuit representations*

First draw a half-circuit equivalent circuit model of the amplifier, representing the transistors with transistor symbols. Then draw a second half-circuit equivalent circuit model of the amplifier, representing the transistors with hybrid pi models.

Part c, 15 points

*Midband gains (NOT EASY!)*

Using nodal analysis (or other methods you prefer), find the mid-band gain Vout/Vin. Please note that the feedback effect of Rf has a major effect and cannot be ignored.

Part d, 5 points
*device models*

Please enter the device parameter values below.

| transistor | Cbe | Ccbi | gm |
|---|---|---|---|
| Q1a | | | |
| Q2a | | | |
| Q3a | | | |

Part e, 20 points
*high frequency analysis*

Now find the first-order and second order time constants of the circuit. ***This is quite difficult, and will require clear understanding of the definitions of*** $R_{11}^{0}$***, etc.*** Defining Cbe of Q2a as $C_1$ and Ccb of Q2a as $C_2$, Find $R_{11}^{0}$, $R_{22}^{0}$, $R_{22}^{1}$. Show all of your work clearly