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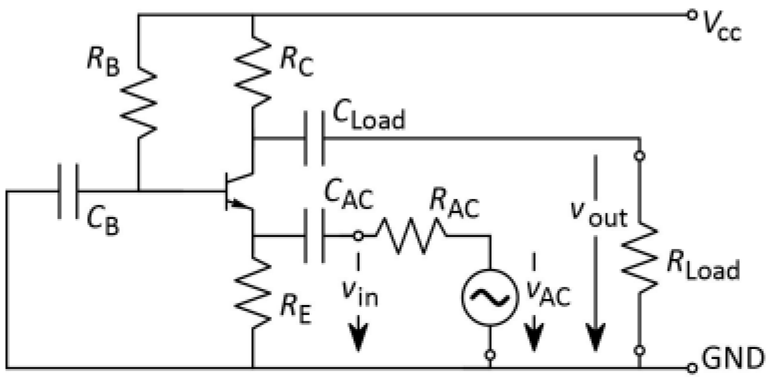
Intro to Electronics HW7

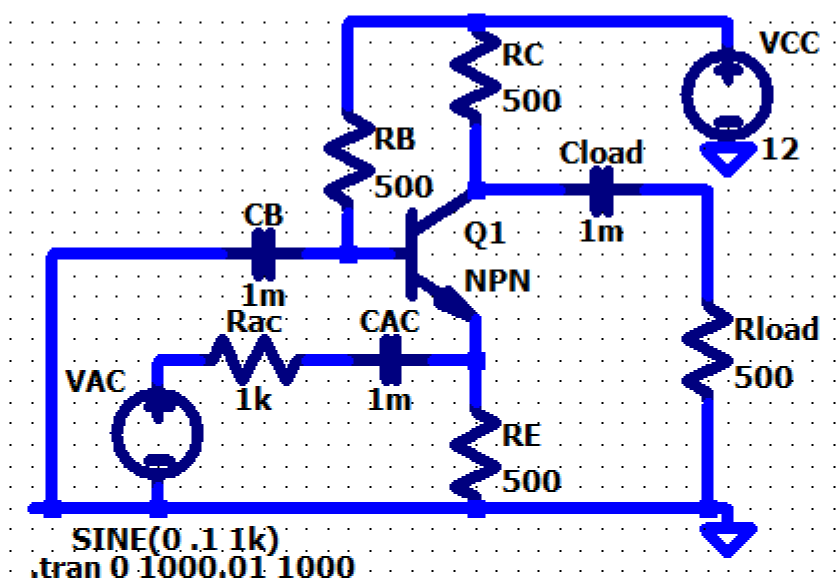
1. 1. Small signal equivalent circuit: Consider the amplifier circuit shown below. The circuit has an input signal source and an output load. Assume that Vcc = 12 V. Assume further that all capacitors are large enough to let pass AC signals (zero impedance of capacitors for AC) and block DC supply voltages (infinite impedance of capacitors for DC). The transistor has an $\alpha = 0.99$. Assume that RAC = 1 kΩ and RLoad = 500 Ω.




a. (a) Which mathematical symbol (latin or greek letter) do we generally use for the current amplification of a transistor in the common-emitter (common-E) configuration? What is the current amplification of the transistor in the common-E configuration (symbolic expression and numerical value)?

β beta, β=a/(1-a)=.99/(1-.99)=99

b. (b) The diagram of the circuit above is a bit unusual in that both input and output are on the RHS (right-hand side) of the transistor. Redraw the diagram above so that the input is on the very LHS (left-hand side) and the output is on the very RHS.



c. (c) Which transistor terminal is shared (for AC signals) between input and output? Which of the three basic transistor amplifier configurations has the circuit shown above?

Base, Common Base Amplifier

d. (d) Assume that RC = RE = 500 Ω. Assume further that at the Q-point, the voltage drop across RC is 3.0 V. Determine the three transistor currents at the Q-point (IE , IC , and IB ). Determine RB .

IC=3/500=6mA

a=IC/IE, IE=IC/a=6.(06)mA

IE=IB+IC, IB=IE-IC=6.(06)-6=0.(06)mA

VB=12V

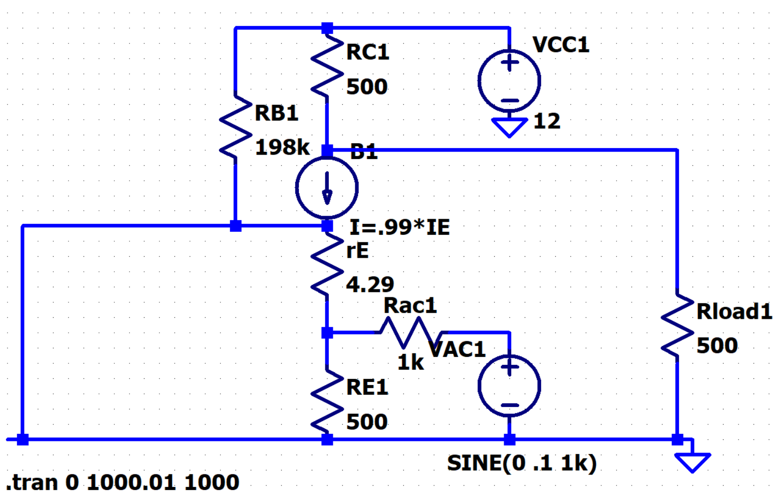
R=V/I

RB=12V/0.(06)mA=198kohm

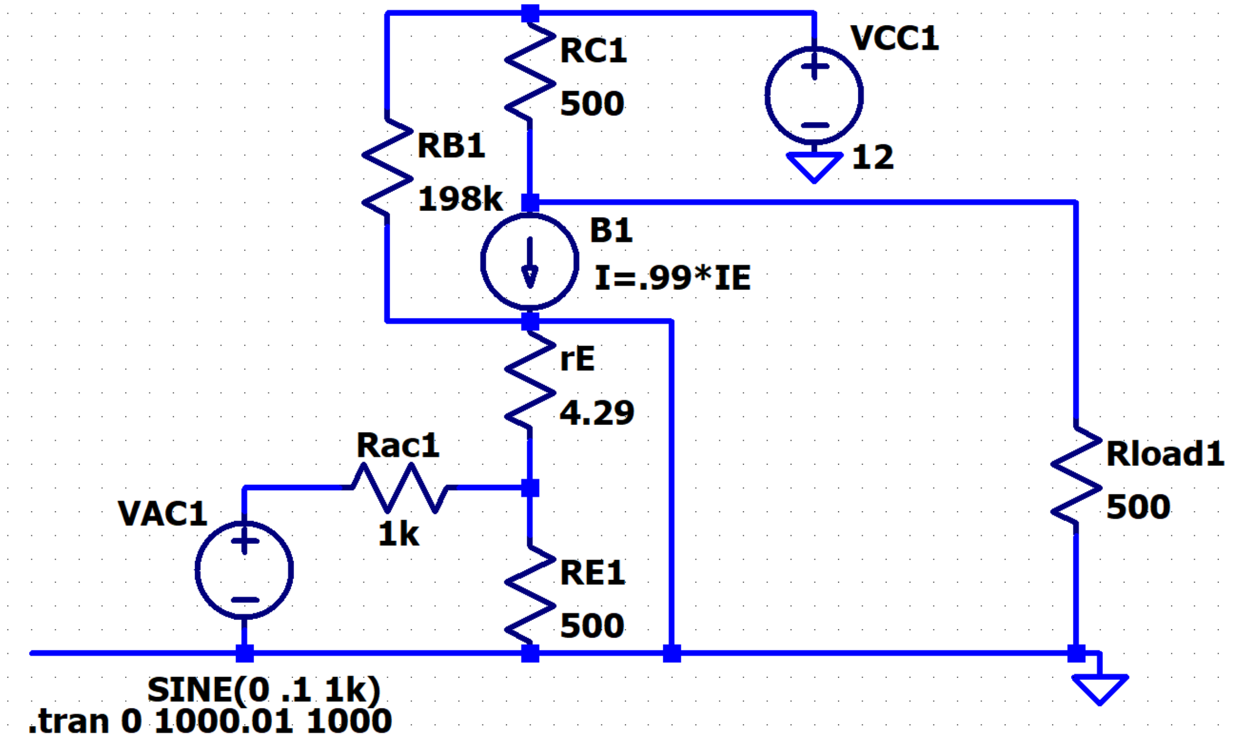
e. (e) Determine the differential emitter resistance rE (numerical value).

rE=Vt/IE=26mV/6.(06)mA=4.29ohm

f. (f) Draw the AC small-signal equivalent circuit. Closely follow the layout shown above. Feel free to assume that all capacitances have zero impedance under AC conditions.




g. (g) Redraw the AC small-signal equivalent circuit so that the input is on the very LHS and the output is on the very RHS.




h. (h) Calculate the input impedance of the circuit. Would the value you just calculated be considered a relatively low value or a high value?

Zin=rE=4.29ohm

i. (i) Calculate the output impedance of the circuit.

Zout=Vout/Iout=Vout/aIE=IC*Rload/IE=495Ohm

j. (j) Calculate AVOC (open-circuit voltage amplification; RLoad = ∞), and give its numerical value.

AVOC=Vout/Vin=IC*Rload/IE*rE=115

k. (k) Calculate AISC (short-circuit current amplification; RLoad = 0), and give its numerical value.

AISC=Iout/Iin=IC/IE=a=.99

l. (l) Calculate the voltage amplification of the circuit above (taking into account the load resistance), and give its numerical value.

IC*Rload/(RC+Rload)*Rload/(IE*RE)=.495

m. (m) Calculate the current amplification of the circuit above (taking into account the load resistance), and give its numerical value.

6mA*500/(500+500)/6.06mA=.495

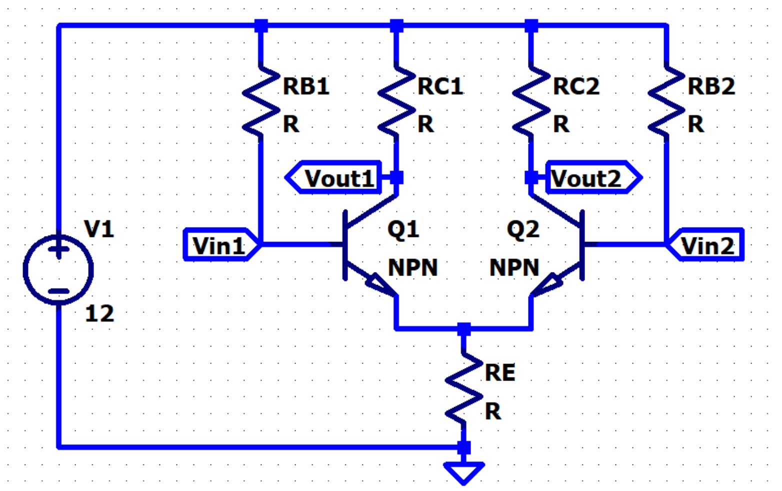
n. (n) There is a capacitor between the collector and the load resistor. Does the capacitor (plus surrounding resistors) act as a low-frequency-pass filter or as a high-frequency-pass filter? Give an expression for the cutoff frequency (symbolic expression).

High pass filter, 1/(2pi*Rload*Cload)

o. (o) Choose the numerical value of the capacitance for the cutoff frequency to be 1 kHz.

C=1/(2pi*500*1000)=3.18nF

2. 2. Differential amplifier: Consider a 2-transistor (BJT) differential amplifier with two collector resistors (RC , equal value, connected to VCC ), one shared emitter resistor (RE , connected to ground, GND), and two base resistors (RB , equal value, connected to VCC ). The transistors have a current amplification of β = 100. The power supply has a voltage of VCC = 12 V.
    a. (a) Sketch the circuit diagram and label all circuit elements.




    b. (b) At the quiescent point, assume that a current of 20 mA flows through RE causing a voltage drop of 1 V across RE . Also assume that VCE = 5 V. Determine the values of RE , RC , and RB (numerical values).

RE=VE/IE=1/.020=50ohm

VC=12-5-1=6V

IB=IC/B=IC/100

IB+IC=1.01*IC

0.020=2.02IC

IC=.020/2.02=0.(0099)A

RC=VC/IE=6V/0.(0099)A=606ohm

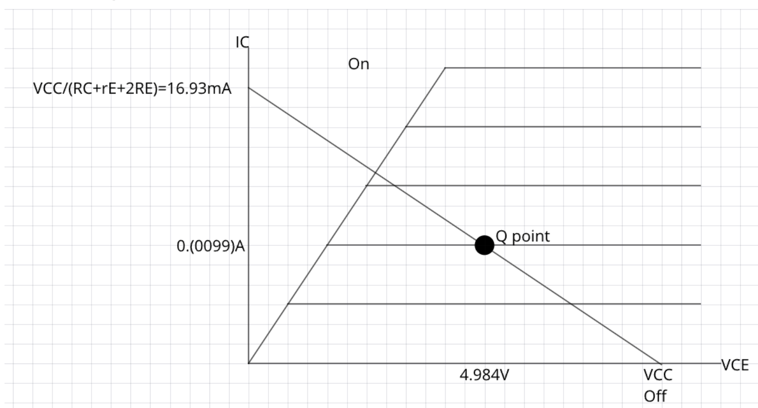
IB=IC/B=0.(0099)A/100=0.00(0099)A

VB=12-.7-1=10.3

RB=VB/IB=10.3/0.00(0099)A=104030ohm=104kohm

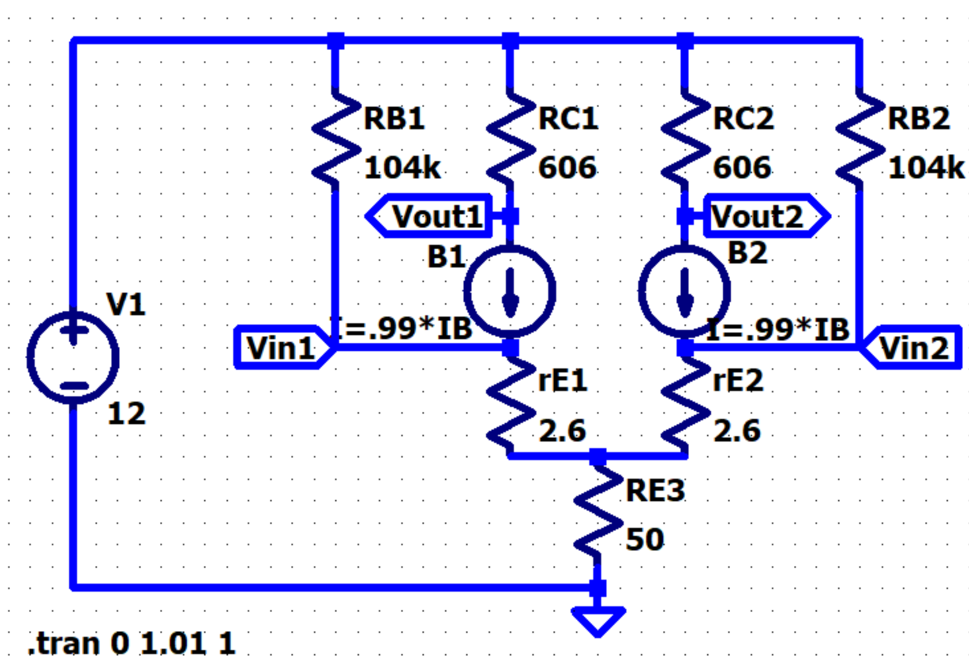
c. (c) Give the quiescent point of the circuit, that is, values of VE , VC , VCE , and IC . Explain why VE can be considered a “virtual ground.” Draw the transistor output characteristics, the RC load line, and indicate all significant points (hand-drawn quantitative drawing).

From the part b:
VE=1V
VC=6V
VCE=5V
IC=0.(0099)A
It’s a virtual ground because it’s held at a steady voltage when the circuit is under normal operating conditions.




d. (d) Give the value of rE . Sketch the small signal equivalent circuit.

rE=Vt/IE=26mV/10mA=2.6ohm



e. (e) Derive the formula (symbolic expression) for the small-signal voltage amplification (AVOC ) for differential input (two-ended input) and differential output (two-ended output).

AVOC=(Vout1-Vout2)/(2Vin1)=RC/2rE

f. (f) Calculate the numerical value of the open-circuit voltage amplification AVOC .

AVOC=116.5

g. (g) Assume that two such amplifier stages are circuited in series. What would be the total amplification of the two-stage amplifier?

AVOC^2=13572

3. 3. True / false questions: Are the following statements true or false? Explain your answer with one or two sentences.
   a. (a) Under normal operation conditions, the collector current of a BJT is smaller than the emitter current.

True, a*IE=IC, a~=0.99, and IE=IC+IB

b. (b) If an engineer reverses the base and collector terminal of a BJT, the circuit will not work.

True, the base will likely be fully on, and the collector will have a very large resistor attached limiting current flow, making the BJT act more like a diode

c. (c) If an engineer reverses the emitter and collector terminal of a BJT, the circuit will not work optimally.

True, the current will be amplified in the wrong direction, and the bjt will be unable to provide the expected current

d. (d) If an engineer reverses the emitter and collector terminal of a BJT, the circuit will not work at all.

False, it won't work well, but it'll work with very decreased amplification

e. (e) If an engineer reverses the emitter and collector terminal of a BJT, the amplification of the transistor decreases (which is undesirable).

True, the amplification will be very small

f. (f) Under normal operation conditions, the base current of a BJT, IB , is the smallest of the three terminal currents IE , IB , and IC .

True, IE=IC+IB, and IC=B*IB

g. (g) Under normal BJT operation conditions, the base-emitter junction is forward biased, and the base-collector junction is reverse-biased.

True, that allows for current to flow from E to B, but not B to C