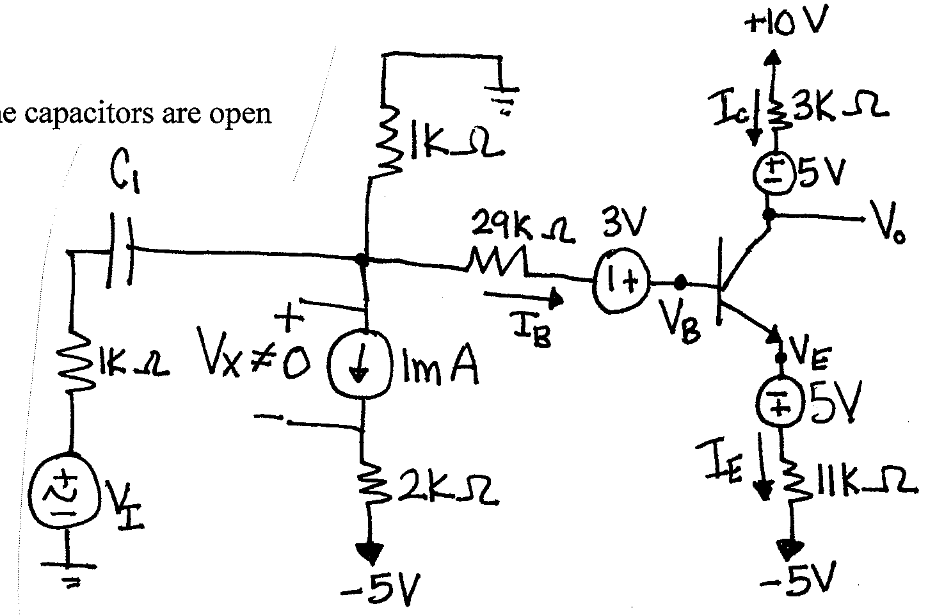
Problem 1 – **(30 points)** SOLUTION

Use: **ignore r_o, $|V_{BE}|=0.7$, $\beta=99$**
$V_I = 20+0.01\sin(20t)$
For DC analysis, assume that the capacitors are open



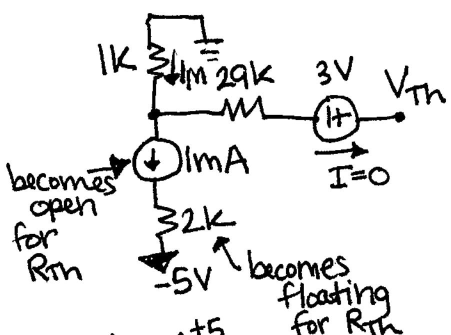
(a) Solve for the DC currents:
  a. I_B
  b. I_E
  c. I_C

(b) Solve for the DC voltages:
  a. V_B
  b. V_E
  c. V_o

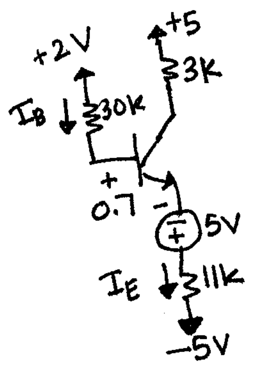
(c) What region of operation is this transistor acting? Active

(d) Sketch the total instantaneous waveform observed for Vo if V_o/V_I=-10V/V.

Thevenin:



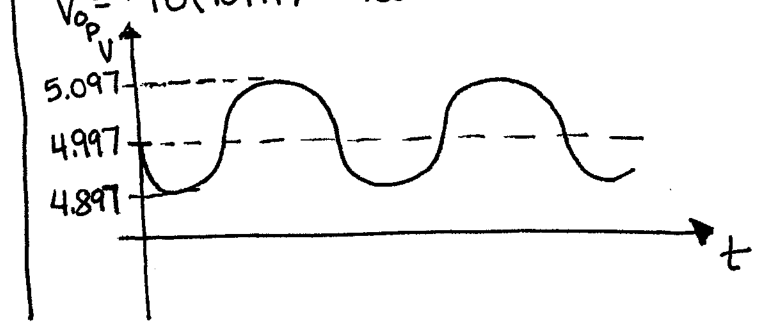
$$-1k(1m)+3-V_{Th}=0$$
$$V_{Th}=3-1=\underline{2V}$$
$$R_{Th}=29k+1k=\underline{30k}$$



$$+2-I_B(30k)-0.7+5-I_E(11k)+5=0 \quad \left(I_B=\frac{I_E}{\beta+1}\right)$$
$$+11.3=I_E\frac{(30k)}{100}+I_E(11k)$$
$$I_E=\frac{11.3}{11.3k}=\boxed{1mA}$$
$$I_B=\frac{1m}{100}=\boxed{10\mu A}$$
$$I_c=\frac{\beta I_E}{\beta+1}=\boxed{0.990mA}$$

$$V_B=2-I_B(30k)=\boxed{+1.7V}$$
$$V_E=V_B-0.7=\boxed{1.0V}$$
$$V_c=5-I_c(3k)\cong\boxed{2V!}$$
$V_c > V_B > V_E$ ∴ ACTIVE

$$V_{o_p}=-10(10m)=-100m$$



Problem 2 – (30 points)

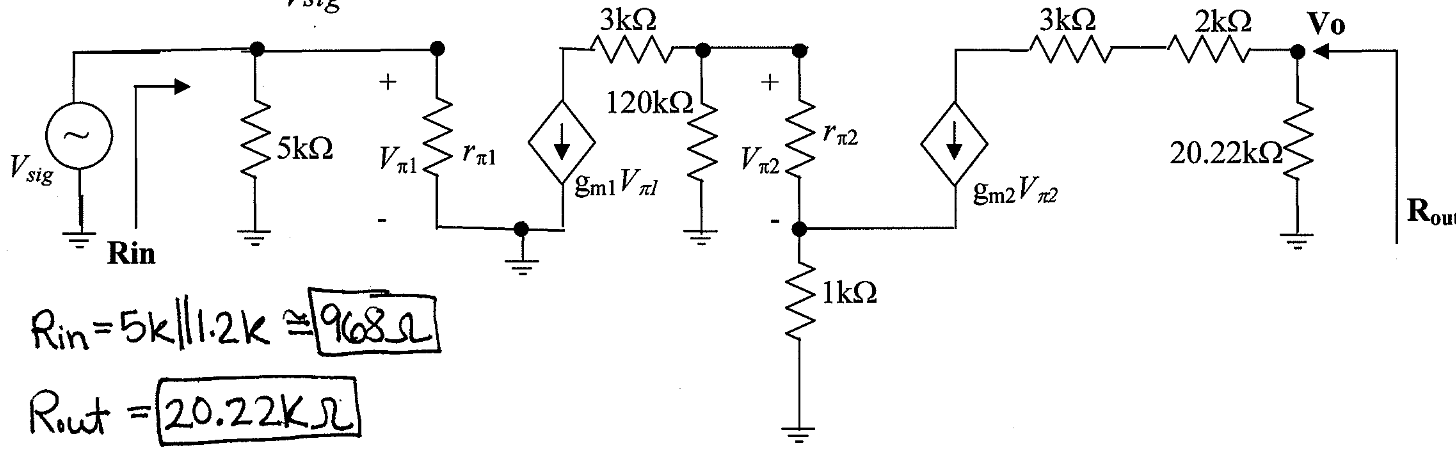
Use: **ignore r_o and r_x, $|V_{BE}|$=0.7, β=99, V_T=25mV**
V_I = 10+0.002sin(20t)

$r_{\pi 1}$=1,200 g_{m2}=4.95mA/V, and I_{B2}=1.25μA

$g_{m1} = \frac{\beta}{r_\pi} = \frac{99}{1.2k} = 82.5m$

$r_{\pi 2} = \frac{\beta}{4.95m} = \frac{99}{4.95m} = 20k$

For the following hybrid-π equivalent circuit below, find the following values:
(a) R_{in} (input resistance –ignore only the input source, Vsig and include all other resistors)
(b) R_{out} (output resistance-include **all** resistors{no load is connected})
(c) midband gain, $\frac{Vo}{Vsig}$



$R_{in} = 5k \| 1.2k \cong \boxed{968\Omega}$

$R_{out} = \boxed{20.22K\Omega}$

$V_o = -g_{m2} V_{\pi 2} \cdot 20.22k$

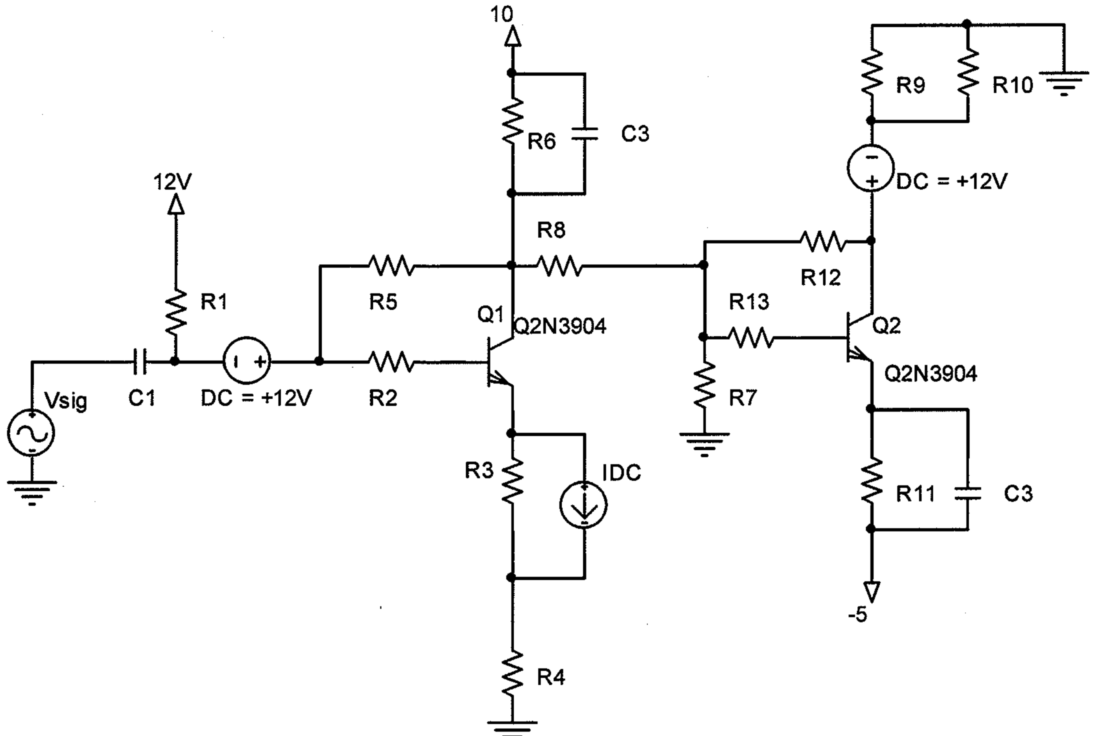
$V_{\pi 2} = \left[\frac{-g_{m1} V_{\pi 1} (120k)}{\underbrace{[120k + \underset{20k}{r_{\pi 2}} + \underset{100k}{1k(\beta+1)}]}_{I}} \right] \cdot r_{\pi 2} = \frac{-82.5m V_{\pi 1} (120k) \cdot 20k}{240k}$

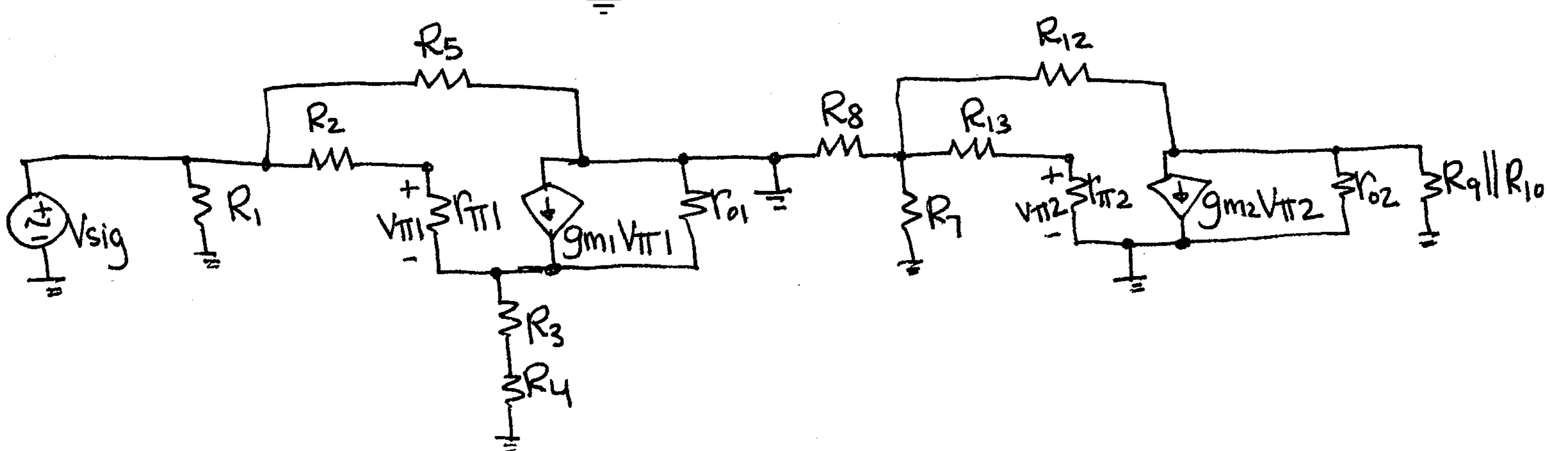
$V_{\pi 1} = V_{sig}$

$\frac{V_o}{V_{sig}} = -4.95m \cdot 20.22k \cdot (-82.5m) \frac{(120k)}{(240k)} \cdot 20k = \boxed{82.6 \; V/V}$

Problem 3 – **(15 points)**

For the circuit shown below, **draw** the AC small-signal equivalent circuit(use hybrid-π or model T). Make sure that everything is labeled in terms of the transistor number. (e.g. g_{m1}, $v_{\pi 2}$, etc.). **Include r_o for all** transistors. v_{sig}=0.001sin(10t) AC. Assume that the capacitors act as a short.



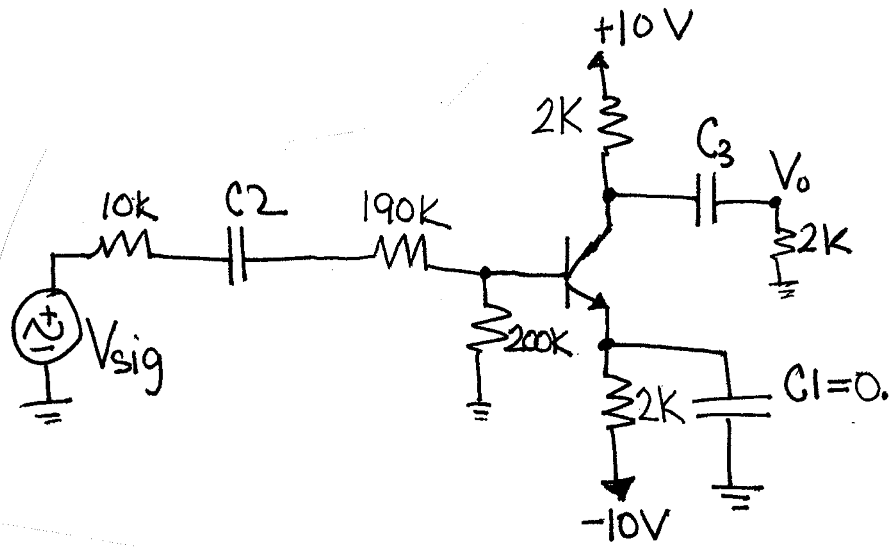


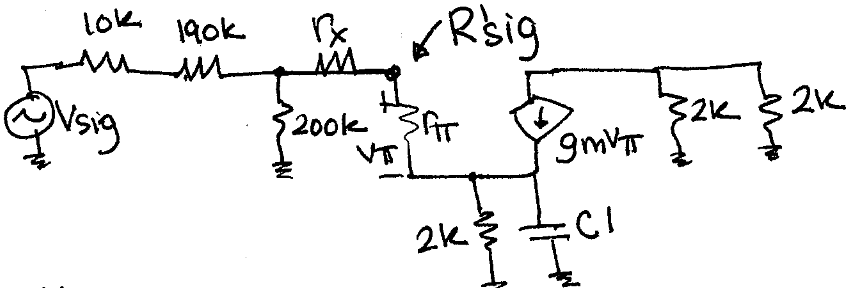
Problem 4 – **(15 points)**

Use: g_m=990µA/V, β=99, V_T=25mV. Ignore r_o and use r_x=50Ω. Use f_T=7.86MHz and the attached datasheet to determine the parasitic capacitance.

Assume C1 yields the highest pole value.

(a) What frequency pole value does C1 create? (express the answer in rad/sec.)
(b) What is the frequency range for this circuit(Hint: Find the high frequency value)? $\boxed{2k \text{ to } 625k\, \frac{rad}{sec}}$





$$r_\pi = \frac{\beta}{g_m} = \frac{99}{990\mu} = 100K$$

LOW:

C1: $$\frac{1}{C1 \cdot R_{eq}} = \frac{1}{0.5\mu \cdot \left[2k \,||\, \underbrace{\frac{r_\pi + 200k||200k}{\beta+1}}_{2k}\right]} = \boxed{2k\, \frac{rad}{sec}}$$

High:

$$C_{in} = C_\pi + C_\mu(1 + g_m \cdot R_L') \quad \text{where } C_\pi = 8p \Rightarrow C_\mu = \frac{g_m}{2\pi f_T} - C_\pi$$

$$C_\mu = \frac{990\mu}{2\pi\, 7.86M} - 8p$$

$$C_{in} = 8p + 12p(1 + 990\mu \cdot 2k||2k) \approx 32p$$

$$C_\mu = 12p$$

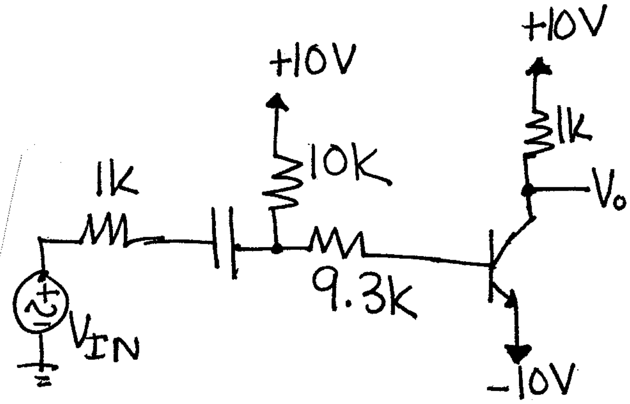
$$\omega_H = \frac{1}{32p(R'_{sig})} \quad \text{where } R'_{sig} = r_\pi || (r_x + 100k) \approx 50K$$

$$\omega_H \approx \boxed{625k\, \frac{rad}{sec}}$$

Problem 5 – **(10 points)**

$|V_{BE}|$=0.7, β=100, V_T=25mV, ignore r_o, and r_x, v_{sig} ={2+0.1sin(ωt)}Volts. Assume that the capacitor acts as an open for DC operation and short for AC operation. Assume saturation for the transistor. Use the attached datasheet.

What is β_{forced}?



$V_{CESAT} = 0.2\,V$

$V_E = -10$

$V_B = -9.3$

$\frac{10+9.3}{19.3k} = I_B = 1mA$

$-10 + 0.2 + I_C(1k) - 10 = 0$

$I_C = \frac{+20-0.2}{1k} = 19.8mA$

$\beta_{forced} = \frac{I_C}{I_B} = \frac{19.8m}{1m} = \boxed{19.8} < \beta = 100$

check $V_C = 10 - 19.8m(1k) = -9.8V$

$-9.8 = V_C < V_B = -9.3 > V_E = -10$ ✓

2N3904 / MMBT3904 / PZT3904

NPN General Purpose Amplifier
(continued)

Electrical Characteristics
$T_A = 25°C$ unless otherwise noted

Symbol	Parameter	Test Conditions	Min	Max	Units
OFF CHARACTERISTICS					
$V_{(BR)CEO}$	Collector-Emitter Breakdown Voltage	$I_C = 1.0$ mA, $I_B = 0$	40		V
$V_{(BR)CBO}$	Collector-Base Breakdown Voltage	$I_C = 10$ µA, $I_E = 0$	60		V
$V_{(BR)EBO}$	Emitter-Base Breakdown Voltage	$I_E = 10$ µA, $I_C = 0$	6.0		V
I_{BL}	Base Cutoff Current	$V_{CE} = 30$ V, $V_{EB} = 3$V		50	nA
I_{CEX}	Collector Cutoff Current	$V_{CE} = 30$ V, $V_{EB} = 3$V		50	nA
ON CHARACTERISTICS*					
h_{FE}	DC Current Gain	$I_C = 0.1$ mA, $V_{CE} = 1.0$ V $I_C = 1.0$ mA, $V_{CE} = 1.0$ V $I_C = 10$ mA, $V_{CE} = 1.0$ V $I_C = 50$ mA, $V_{CE} = 1.0$ V $I_C = 100$ mA, $V_{CE} = 1.0$ V	40 70 100 60 30	 300 	
$V_{CE(sat)}$	Collector-Emitter Saturation Voltage	$I_C = 10$ mA, $I_B = 1.0$ mA $I_C = 50$ mA, $I_B = 5.0$ mA		0.2 0.3	V V
$V_{BE(sat)}$	Base-Emitter Saturation Voltage	$I_C = 10$ mA, $I_B = 1.0$ mA $I_C = 50$ mA, $I_B = 5.0$ mA	0.65	0.85 0.95	V V
SMALL SIGNAL CHARACTERISTICS					
f_T	Current Gain - Bandwidth Product	$I_C = 10$ mA, $V_{CE} = 20$ V, f = 100 MHz	300		MHz
C_{obo}	Output Capacitance	$V_{CB} = 5.0$ V, $I_E = 0$, f = 1.0 MHz		4.0	pF
C_{ibo}	Input Capacitance	$V_{EB} = 0.5$ V, $I_C = 0$, f = 1.0 MHz		8.0	pF
NF	Noise Figure	$I_C = 100$ µA, $V_{CE} = 5.0$ V, $R_S = 1.0$kΩ, f=10 Hz to 15.7kHz		5.0	dB

C_π

E 2280 Midterm #3

Name ____________________________

Scores:

Prob 1 ______________ of a possible 30pts

Prob 2 ______________ of a possible 30pts

Prob 3 ______________ of a possible 15pts

Prob 4 ______________ of a possible 15pts

Prob 5 ______________ of a possible 10pts

Total ______________ of a possible 100 pts