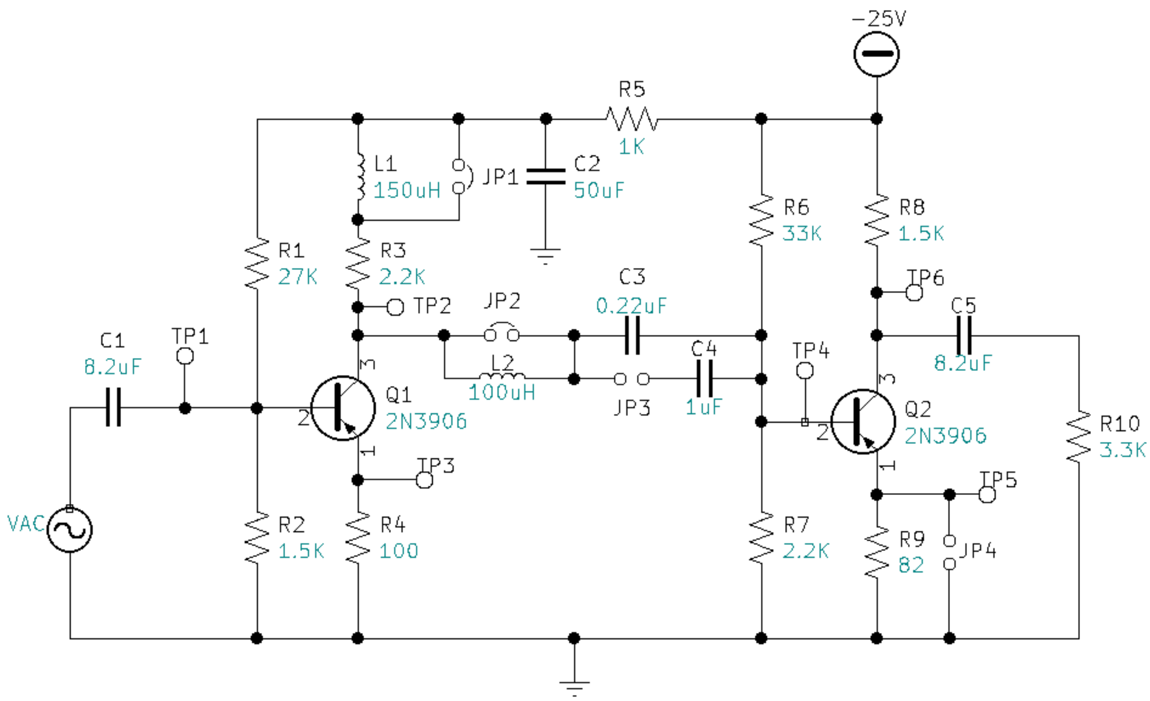
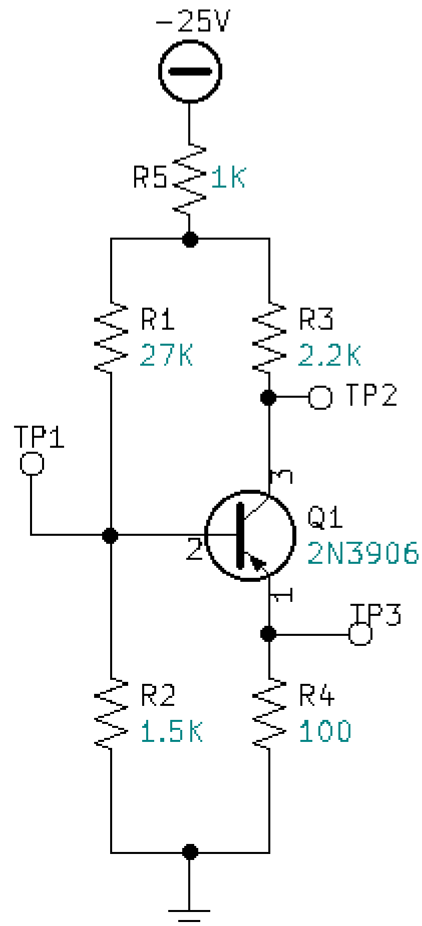
Consider the following circuit:



NOTE: On the 2-stage schematic, VCC=25V. There is a jumper on JP1 and JP2. No Jumper on JP3 and JP4.

DC Redraw for Stage 1:



DC Calculations for Stage 1:

Kirchhoff Loop Equation 1:

- $VCC - VR5 - VR1 - VBE - VRE = 0$
- $IR5(1K) + IR1(27K) + IE(82) = 24.3V$

Kirchhoff Loop Equation 2:

- $VCC - VR5 - VR1 - VR2 = 0$
- $IR5(1K) + IR1(27K) + IR2(1.5K) = 25V$

Kirchhoff's Current Law:

- $IR5 = IR1 + ICQ1$
- $IR2 = IR1 - IBQ1$

Substitute Currents:

- $(IR1 + ICQ1)(1K) + IR1(27K) + IE(100) = 24.3V$
- $(IR1 + ICQ1)(1K) + IR1(27K) + (IR1 - IBQ1)(1.5K) = 25V$

Manipulate into terms of IR1 and IB:

- $(IR1 + (IBxB))(1K) + IR1(27K) + (IBx(B + 1))(100) = 24.3V$
- $(IR1 + (IBxB))(1K) + IR1(27K) + (IR1 - IB)(1.5K) = 25V$

Beta = 100:

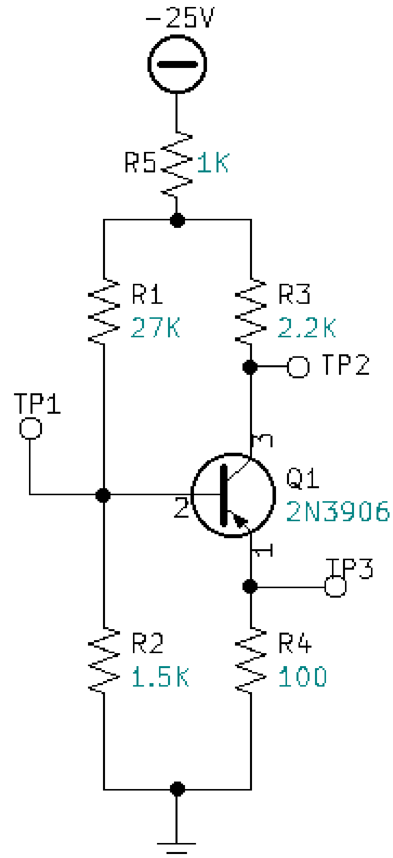
- $(IR1 + (IBx100))(1K) + IR1(27K) + (IBx(100 + 1))(100) = 24.3V$
- $(IR1 + (IBx100))(1K) + IR1(27K) + (IR1 - IB)(1.5K) = 25V$

Simplify:

- $(1KIR1 + (100KIB) + IR1(27K) + (10.1KKIB) = 24.3V$
- $(1KIR1 + (100KIB) + IR1(27K) + (1.5KIR1 - 1.5KIB) = 25V$

Simplify:

- $28KIR1 + 110.1KIB = 24.3V$
- $29.5KIR1 + 98.5KIB = 25V$



Simultaneous Equation Solution:

- $IR1 = 732.626uA$
- $IB = 34.391uA$

DC/Bias Voltages:

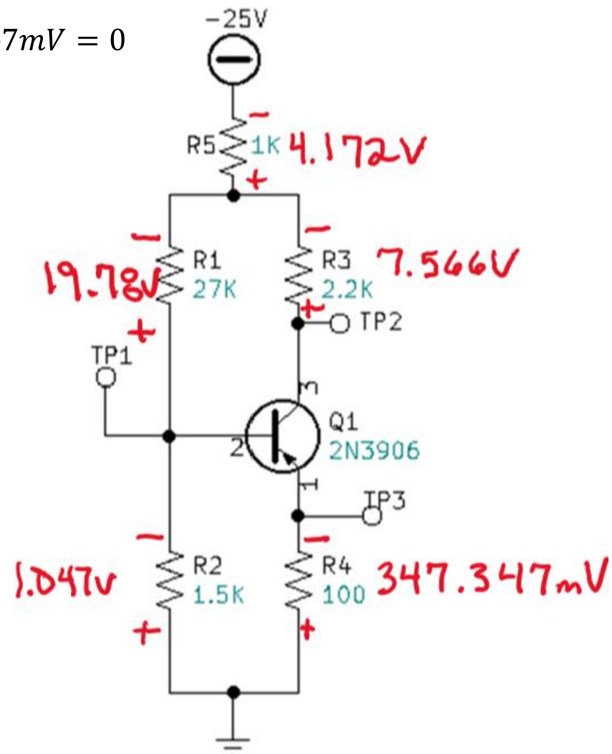
- $VR1 = IR1 \times R1$
  - $VR1 = 732.626uA \times 27K$
  - $VR1 = 19.78V$
- $VR2 = IR2 \times R2$
  - $VR2 = (IR1 - IB) \times R2$
  - $VR2 = (732.626uA - 34.391uA) \times 1.5K$
  - $VR2 = 1.047V$
- $VR4 = (IBX(B + 1)) \times R4$
  - $VR4 = (34.391uAX(101)) \times 100$
  - $VR4 = 347.349mV$
- $VR3 = (IBX(B)) \times R3$
  - $VR3 = (34.391uAX(100)) \times 2.2K$
  - $VR3 = 7.566V$
- $VR5 = (IBX(B) + IR1) \times R5$
  - $VR5 = (34.391uAX(100) + 732.626uA) \times 1K$
  - $VR5 = 4.172V$

Kirchhoff, check math:

- $+25V - 4.172V - 19.78V - 1.047V = 0$
- ☑ $0 = 0$

Find VCE:

- $+VCC - VR5 - VR3 - VCE - VR4 = 0$
- $+25V - 4.172V - 7.566 - VCE - 347.347mV = 0$
- $+13.142V - VCE = 0$
- $VCE = 13.142V$

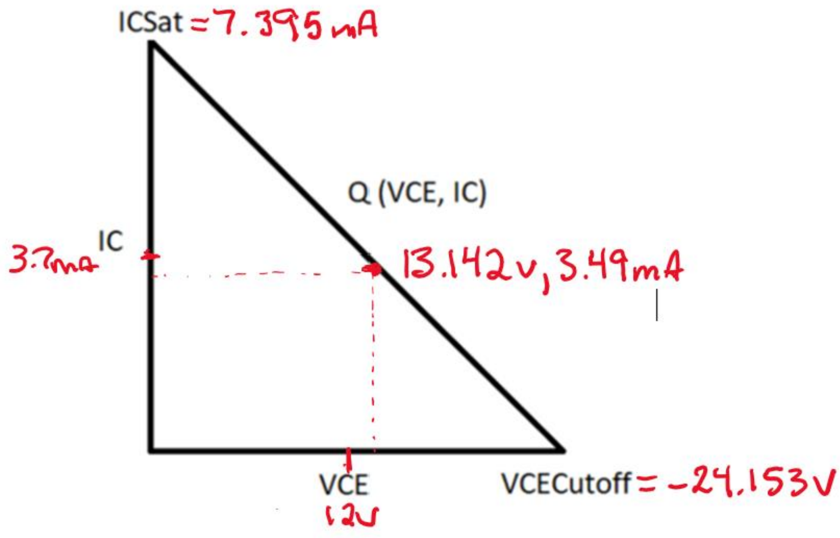


Test Point Voltages:

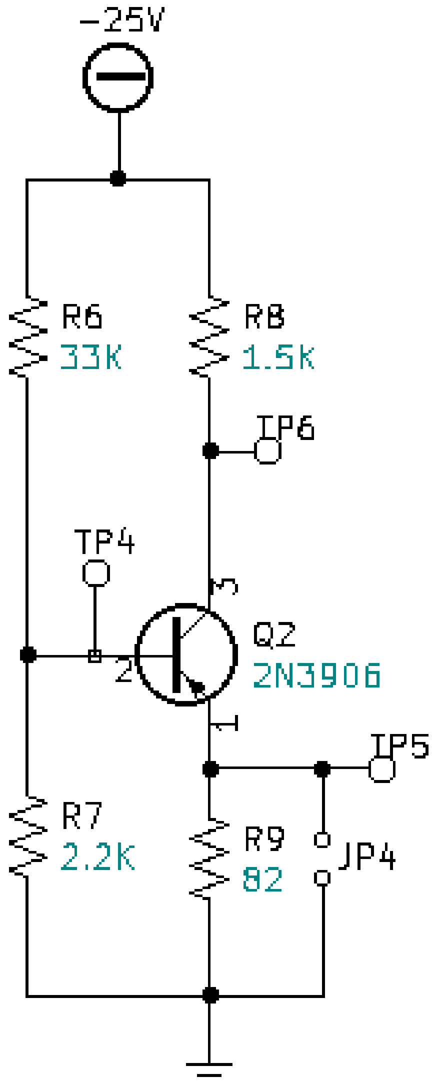
- $TP1 = VR2$
  - $TP1 = -1.047V$
- $TP2 = VCE + VR4$
  - $TP2 = -13.142V - 347.347mV$
  - $TP2 = -13.489V$
- $TP3 = VR4$
  - $TP3 = -347.347mV$

DC Load Line for Q1:

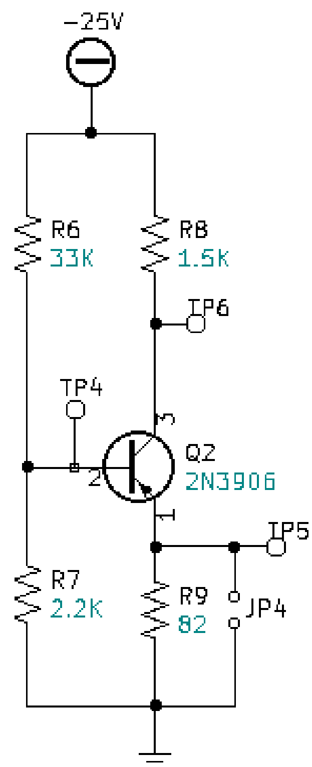
- $VCE_{Cutoff} = \frac{VCC}{R5+R1+R2}(R2 + R3)$
  - $VCE_{Cutoff} = \frac{25}{29.5K}(28.5K)$
  - $VCE_{Cutoff} = 24.153V$
- $IC_{Saturation} = \frac{VCC - [\frac{VCC}{R5+(RC+RE)//(R1+R2)}](R5)}{RC+RE}$
  - $IC_{Saturation} = \frac{25 - [\frac{25}{1K+(2.2K+100)//(28.5K)}](1K)}{2.2K+100}$
  - $IC_{Saturation} = \frac{25 - [\frac{25}{1K+(2.128K)}](1K)}{2.3K}$
  - $IC_{Saturation} = \frac{25 - [\frac{25}{(3.128K)}](1K)}{2.3K}$
  - $IC_{Saturation} = \frac{25 - 7.99233}{2.3K}$
  - $IC_{Saturation} = 7.395mA$



DC Redraw for Stage 2:



DC Calculations for Stage 2:



Kirchhoff Loop Equation 1:

- $VCC - VR6 - VR7 = 0$

Kirchhoff Loop Equation 2:

- $VCC - VR6 - VBE - VR9 = 0$

Substitute Currents & known values:

- $25V - 33K(IR6) - 2.2K(IR7) = 0$
- $25V - 33K(IR6) - 0.7V - 82(IR9) = 0$

Substitute Currents in terms of IR6 & IB:

- $25V - 33K(IR6) - 2.2K(IR6 - IB) = 0$
- $25V - 33K(IR6) - 0.7V - 82(IB(B+1)) = 0$

Simplify:

- $25V - 33K(IR6) - 2.2KIR6 + 2.2K(IB) = 0$
- $25V - 33K(IR6) - 0.7V - 82(IB(101)) = 0$

Simplify:

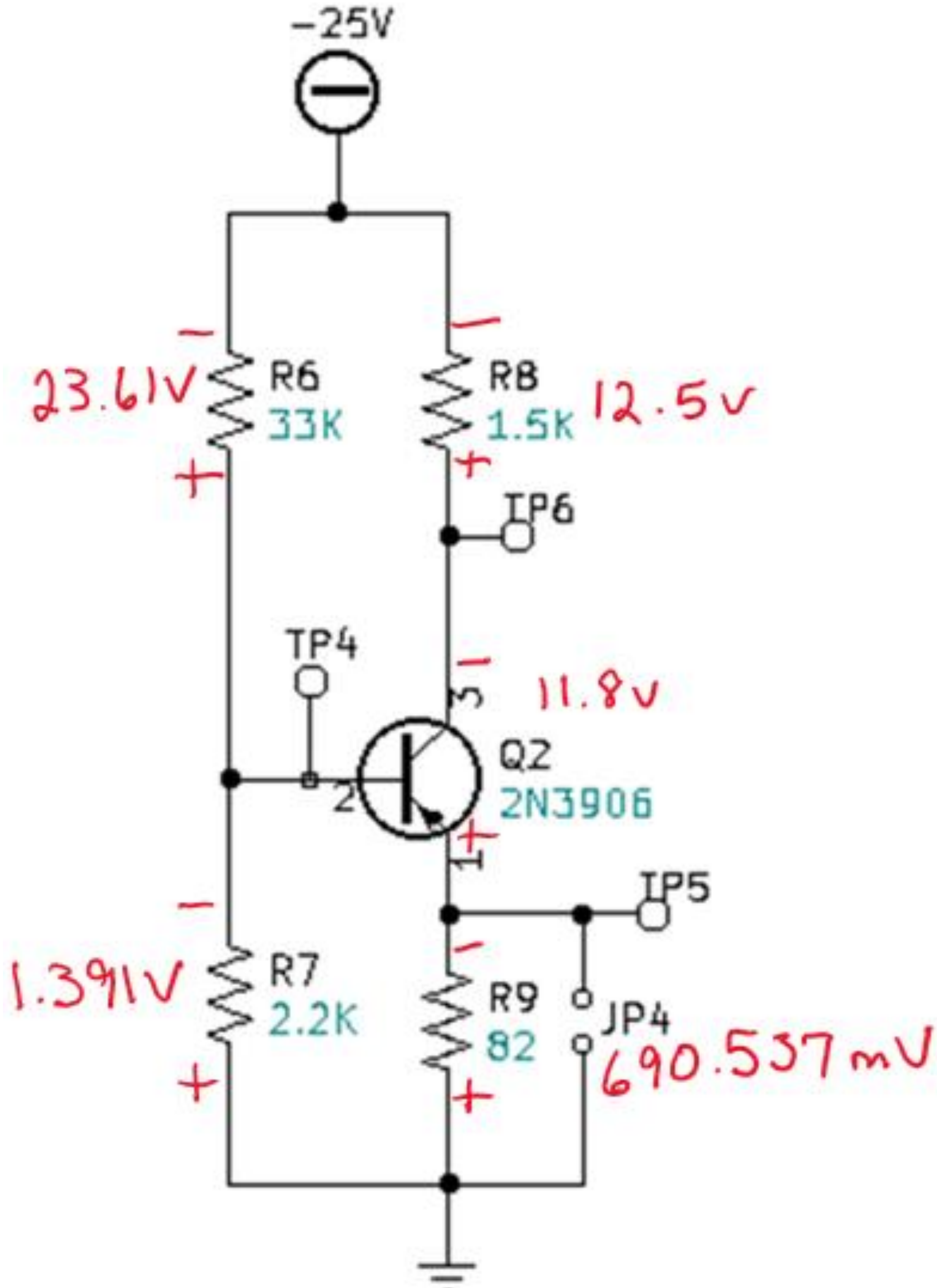
- $35.2K(IR6) - 2.2K(IB) = 25V$
- $33K(IR6) + 8.282K(IB) = 24.3$

Simultaneous Equation Solution:

- $IR6 = 715.438uA$
- $IB = 83.378uA$

DC/Bias Voltages:

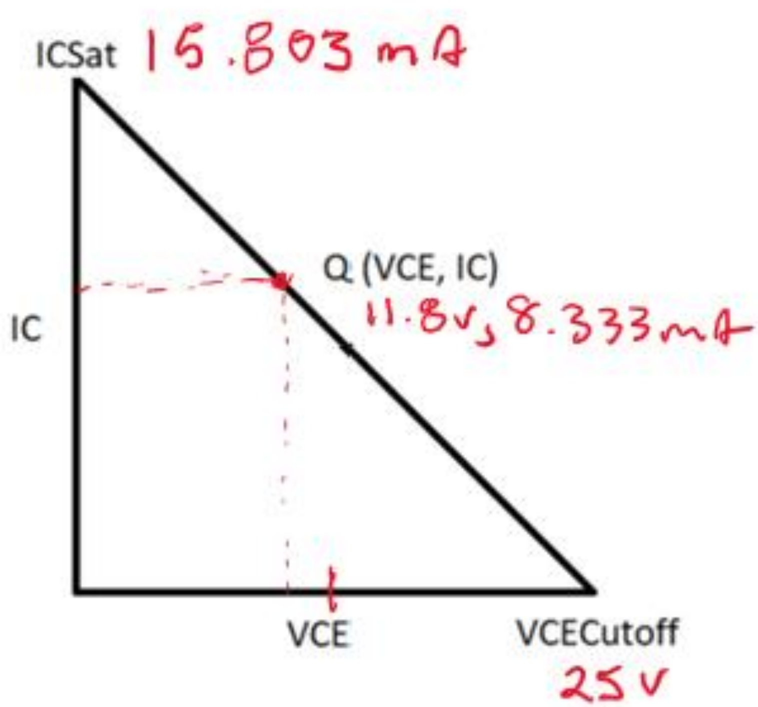
- $VR6 = IR6 \times R6$
  - $VR6 = 715.438 \times 33K$
  - $VR6 = 23.61V$
- $VR7 = IR7 \times R7$
  - $VR7 = (715.438 - 83.378uA) \times 2.2K$
  - $VR7 = 1.391V$
- $VR8 = IR8 \times R8$
  - $VR8 = IB(beta) \times 1.5K$
  - $VR8 = 83.378uA(100) \times 1.5K$
  - $VR8 = 12.51V$
- $VR9 = IR9 \times R9$
  - $VR9 = IB(beta + 1) \times 82$
  - $VR9 = 83.378uA(101) \times 82$
  - $VR9 = 690.537mV$
- $VCE = VCC - VR8 - VR9$
  - $VCE = 25 - 12.51 - 690.537mV$
  - $VCE = 11.8V$
- $TP4 = 1.391V$
- $TP5 = 690.537mV$
- $TP6 = 12.5V$



-25V
R6
33K
23.61V
R8
1.5K
12.5v
TP6
TP4
11.8v
Q2
2N3906
TP5
R7
2.2K
1.391V
R9
82
JP4
690.537mV

DC Load Line for Q2:

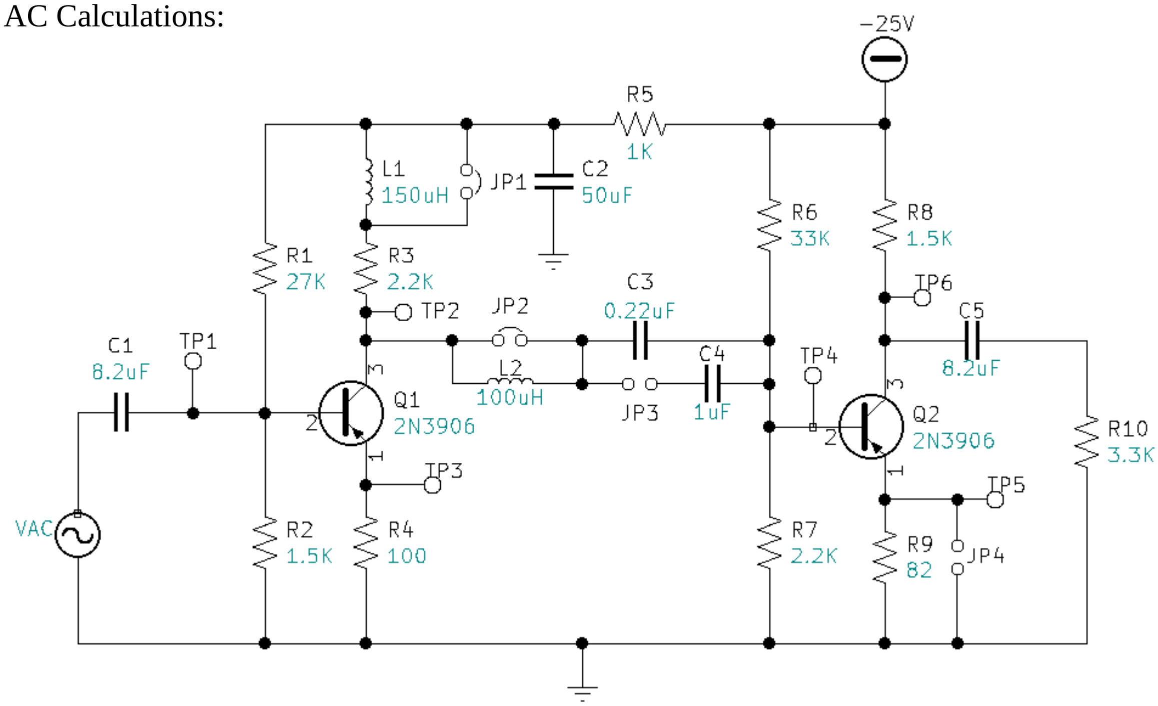
- $VCE_{Cutoff} = VCC$
  - $VCE_{Cutoff} = 25V$
- $IC_{Saturation} = \frac{VCC}{R8+R9}$
  - $IC_{Saturation} = \frac{25}{1.5K+82}$
  - $IC_{Saturation} = 15.803mA$



DC Calculations Tabulated:

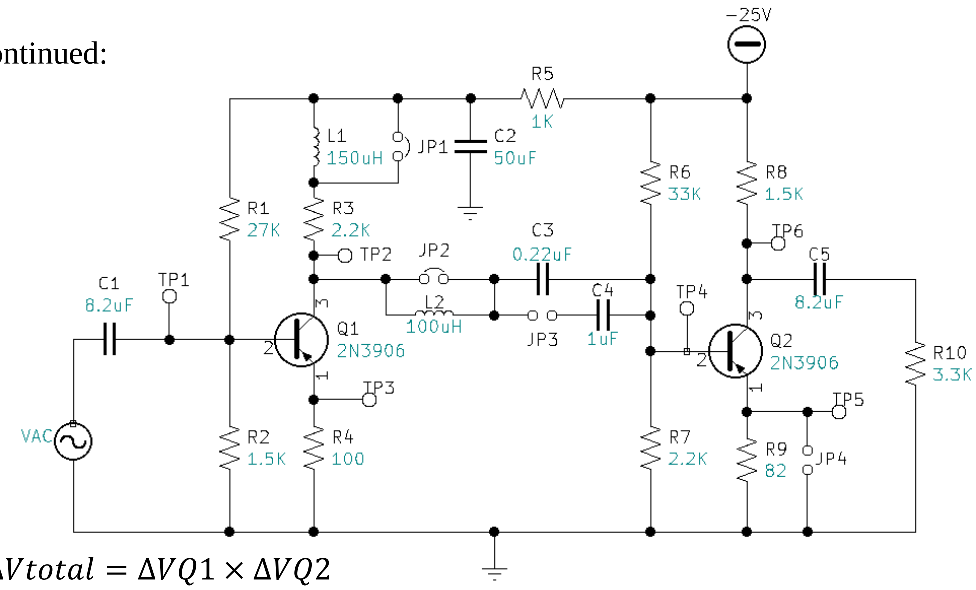
	A	B	C
1	DC Values	Calculated	Measured
2	VR1	19.78V	
3	VR2	1.047V	
4	VR3	7.566V	
5	VR4	347.347mV	
6	VR5	4.172V	
7	VR6	23.61V	
8	VR7	1.391V	
9	VR8	12.5V	
10	VR9	690.537mV	
11	VCEQ1	13.142V	
12	VCEQ2	11.8V	
13	TP1	-1.047V	
14	TP2	-13.489V	
15	TP3	-347.347mV	
16	TP4	-1.391V	
17	TP5	-690.537mV	
18	TP6	-12.5V	
19			

AC Calculations:



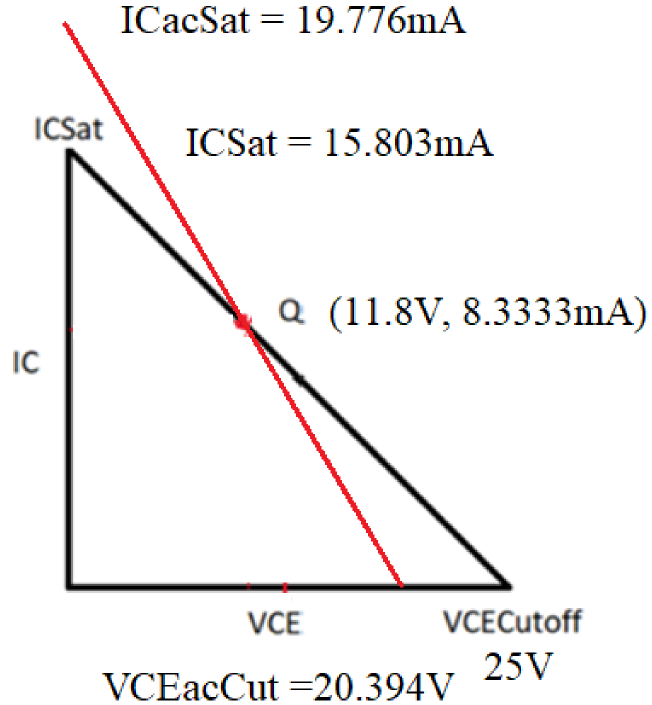
- $\Delta VQ2 = \frac{Vout}{Vin}$
    - $\Delta VQ2 = \frac{IC(R8//R10)}{IB(R9+r'e)(B+1)}$
    - $\Delta VQ2 = Beta\frac{(1.5K//3.3K)}{(82+3.087)(101)}$
    - $\Delta VQ2 = 100\frac{(1.03125K)}{(8.594K)}$
    - $\Delta VQ2 = -12$
- $\Delta VQ1 = \frac{Vout}{Vin}$
    - $\Delta VQ1 = \frac{IC((R3//R6//R7//(R9+r'e)(B+1)}{IB(R4+r'e)(B+1)}$
    - $\Delta VQ1 = Beta\frac{((2.2K//33K//2.2K//(82+3.087)(101))}{(100+7.485)(101)}$
    - $\Delta VQ1 = 100\frac{((2.2K//33K//2.2K//(8.594K))}{(107.485)(101)}$
    - $\Delta VQ1 = 100\frac{947.19}{10.856K}$
    - $\Delta VQ1 = -8.725$

AC Calculations Continued:

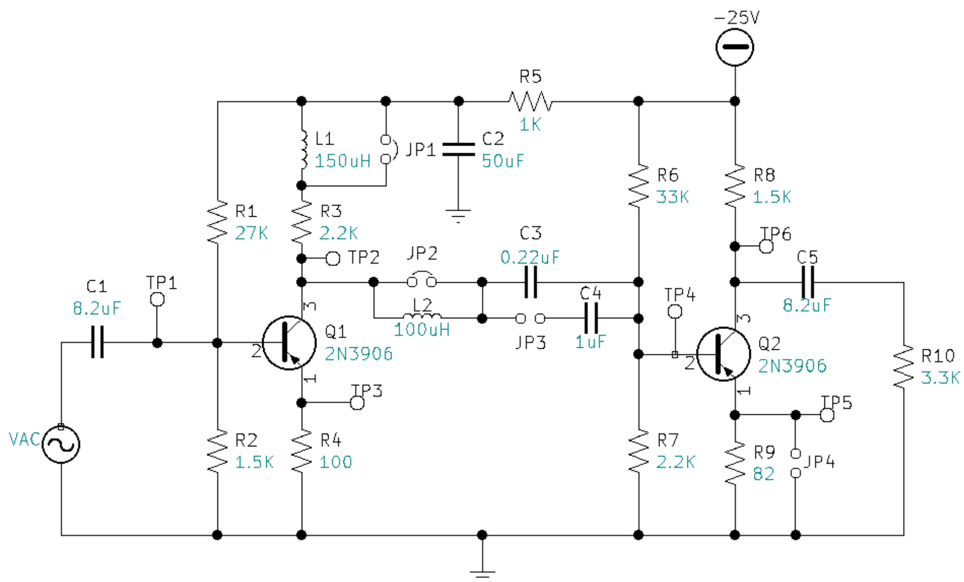


- $\Delta Vtotal = \Delta VQ1 \times \Delta VQ2$
  - $\Delta VTotal = -8.725 \times -12$
  - $\Delta VTotal = 104.7$
- $Zout = R8$
  - $Zout = 1.5K\Omega$
- $Zin = (R4 + r'e)(B+1)//R1//R2$
  - $Zin = (100 + 7.485)(101)//27K//1.5K$
  - $Zin = (755.985)//27K//1.5K$
  - $Zin = 493.466\Omega$
- $\Delta Itotal = \frac{Iout}{Iin} = \frac{\frac{Vout}{RL}}{\frac{Vin}{Zin}} = \frac{Vout}{RL} \times \frac{Zin}{Vin} = \frac{Vout}{Vin} \times \frac{Zin}{RL}$
  - $\Delta Itotal = \Delta Vtotal \times \frac{Zin}{RL}$
  - $\Delta Itotal = 104.7 \times \frac{493.466}{3.3K}$
  - $\Delta Itotal = 15.656$
- $\Delta Ptotal = \Delta Vtotal \times \Delta Itotal = 104.7 \times 15.656$
  - $\Delta Ptotal = 1.639K$

- $VCEacCut = VCE + IC(R8//R10)$
  - $VCEacCut = 11.8 + 8.333mA(1.031K)$
  - $VCEacCut = 11.8 + 8.333mA(1.031K)$
  - $VCEacCut = 20.394V$
- $ICacSat = IC + \frac{VCE}{R8//R10}$
  - $ICacSat = 8.333mA + \frac{11.8}{1.031K}$
  - $ICacSat = 19.776mA$



- $VoutMaxP = VCEacCut - VCE$
  - $VoutMaxP = 20.394 - 11.8$
  - $VoutMaxP = 8.594vP$
- $VinMaxP = \frac{VoutMaxP}{AVT} = \frac{8.594}{104.7}$
  - $VinMaxP = 82.082mVp$



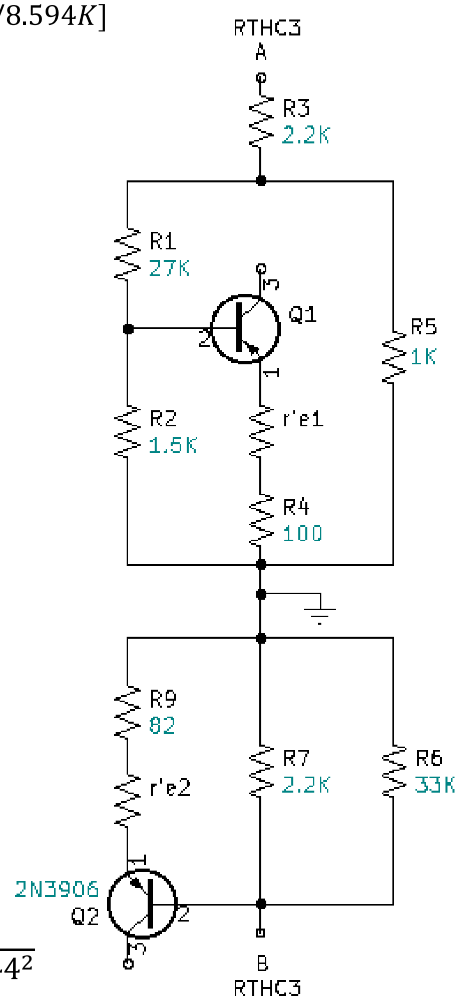
Frequency Response Low:

- Rules:
  - Treat all caps like opens.
  - Thevenize each and find Fc for each cap
  - $FCL = \sqrt{FC1^2 + FC2^2 + FC3^2 \ldots}$
- $RthC1 = R2//((R4 + r'e1)(B + 1))//(R1 + R5)$
  - $RthC1 = 1.5K//((100 + 7.485)(101))//(27K + 1K)$
  - $RthC1 = 1.258K$
- $FcC1 = \frac{1}{2\pi Rth_{C1}C1} = \frac{1}{2\pi \times 1.258K \times 8.2uF}$
  - $FcC1 = 15.429hz$
- $RthC2 = R5//[(R1 + (R2//((r'e1 + R4)(B + 1))]$
  - $RthC2 = 1K//[(27K + (1.5K//((7.485 + 100)(101))]$
  - $RthC2 = 1K//[(27K + (1.5K//(10.856K)]$
  - $RthC2 = 1K//[(27K + 1.318K]$
  - $RthC2 = 1K//28.318K$

- $RthC2 = 965.891\Omega$

- $FcC2 = \frac{1}{2\pi Rth_{C2}C2} = \frac{1}{2\pi \times 965.892 \times 50uF}$
  - $FcC1 = 3.327hz$

- $RthC3 = R3 + [R5//(R1 + R2//(R4 + r'e1)(B + 1))] + [R6//R7//(R9 + r'e2)(B + 1)]$
  - $RthC3 = 2.2K + [1K//(27K + 1.5K//(100 + 7.485)(101))] + [33K//2.2K//(82 + 3.087)(101)]$
  - $RthC3 = 2.2K + [1K//(27K + 1.5K//10.856K] + [33K//2.2K//8.594K]$
  - $RthC3 = 2.2K + [1K//28.318K] + [33K//2.2K//8.594K]$
  - $RthC3 = 2.2K + [965.891] + [1.663K]$
  - $RthC3 = 4.829K\Omega$



- $FcC3 = \frac{1}{2\pi Rth_{C3}C3} = \frac{1}{2\pi 4.829K \times 0.22uF}$
  - $FcC3 = 149.81hz$

- $FcC3w/C4 = \frac{1}{2\pi Rth_{C3}C3+C4} = \frac{1}{2\pi 4.829K \times 1.22uF}$
  - $FcC3w/C4 = 27.015hz$

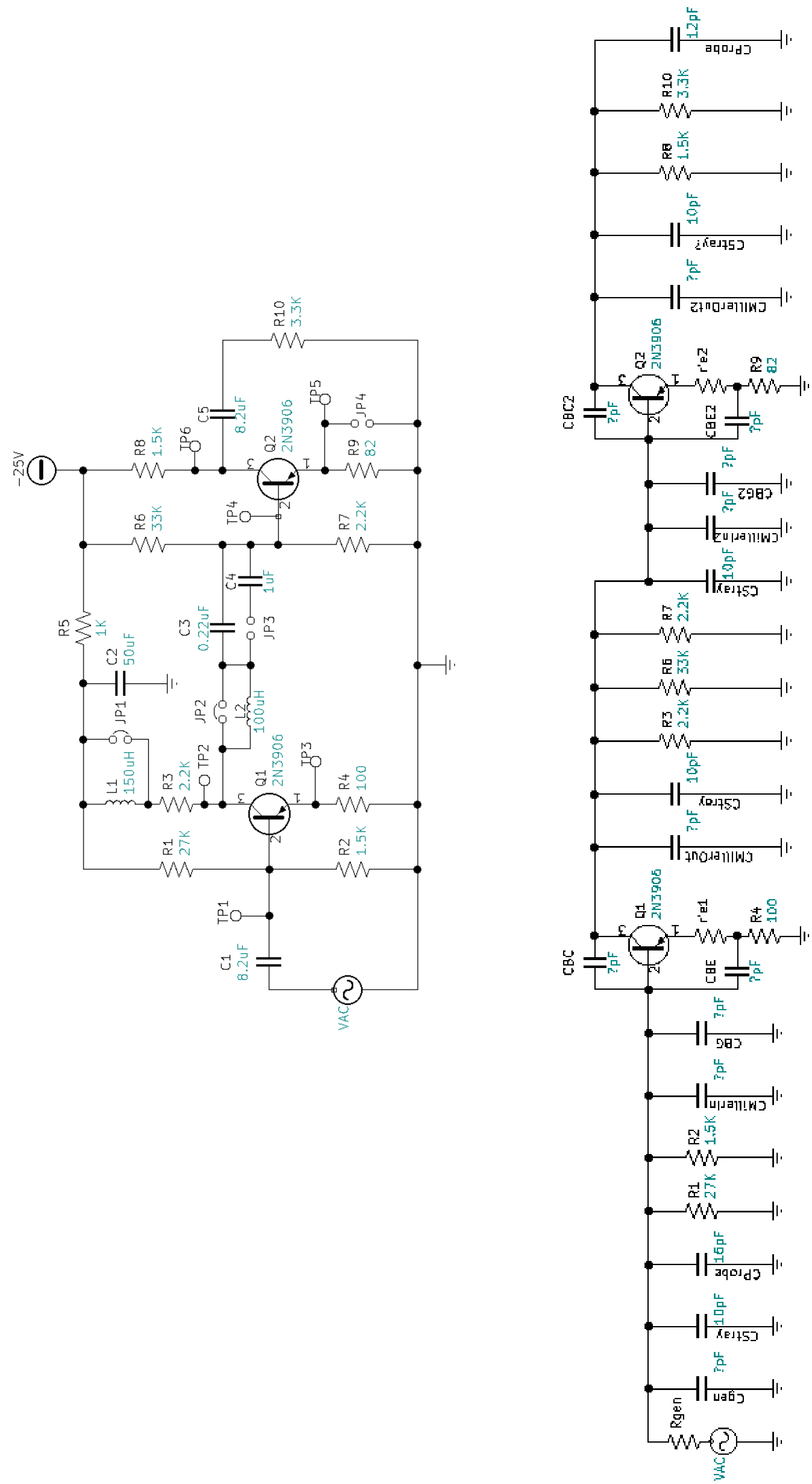
- $RthC5 = R8 + R10 = 1.5K + 3.3K$
  - $RthC5 = 4.8K\Omega$

- $FcC5 = \frac{1}{2\pi Rth_{C5}C5} = \frac{1}{2\pi 4.8K8.2uF}$
  - $FcC5 = 4.044hz$

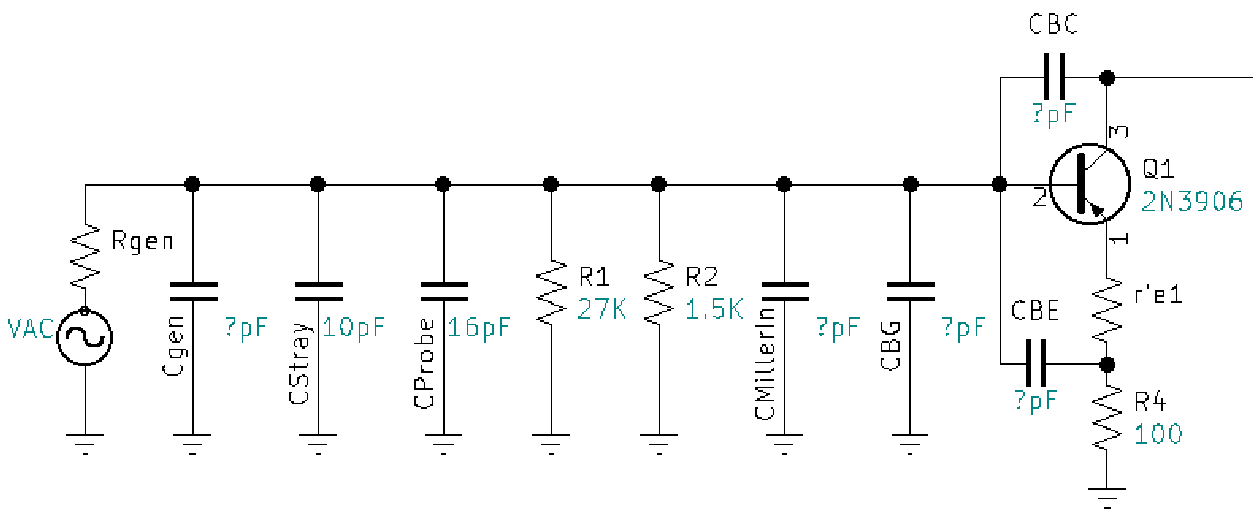
  $FCL = \sqrt{FC1^2 + FC2^2 + FC3^2 \ldots}$

  - $FCL = \sqrt{15.429^2 + 3.327^2 + FC(3/4)^2 + 4.044^2}$
  - $FCL = 150hz * w/C3\ (open\ JP3)$
  - $FCL = 31.548hz * w/(Closed\ JP3, C3 + C4)$

Frequency Response High:



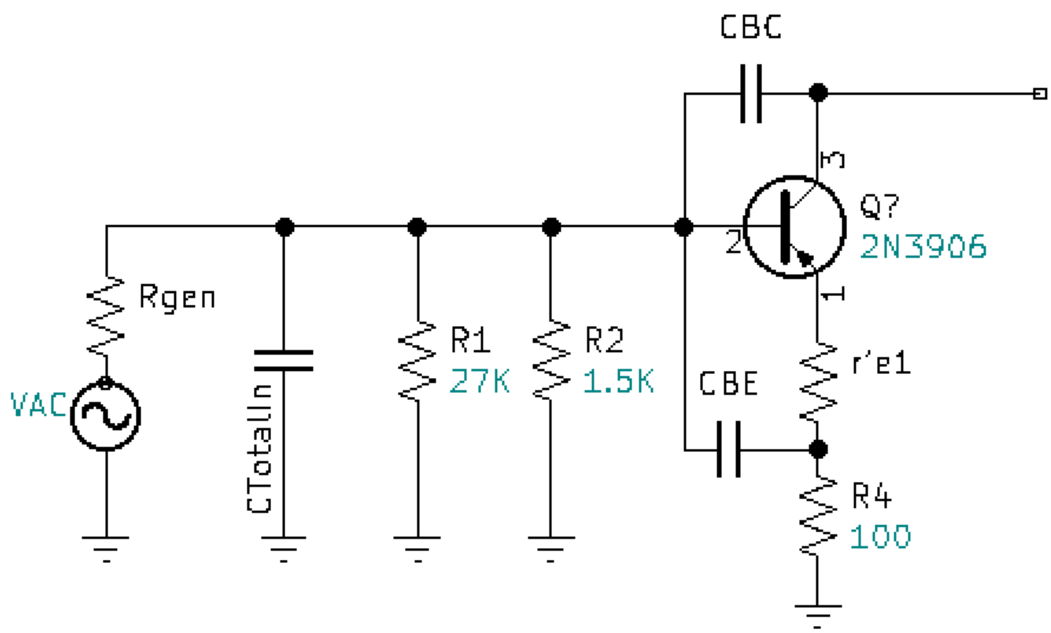
Frequency Response High (Front End):



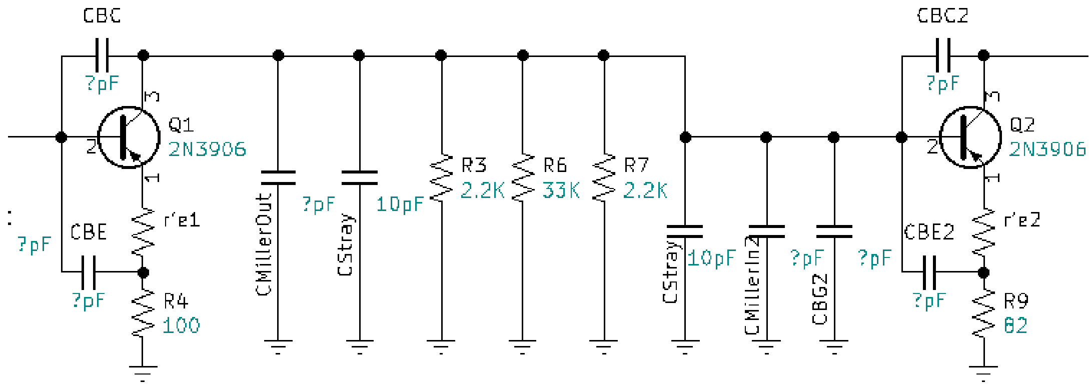
- $CtotalIN = Cgen + Cstray + Cprobe + CmillerIN + CBG$
  - $Cgen \approx 40pF\ (User\ Manual)$
  - $Cstray\ \approx 10pF$
  - $Cprobe \approx 16pF$
  - $CmillerIN\ = CBC(1 + \Delta V_{CE})$
    - $CBC \approx 4pF\ \approx Cibo\ (from\ the\ data\ sheet)$
    - $CmillerIN\ = 4.5pF(1 + 8.725)$
    - $CmillerIN\ = 43.763pF$

SMALL–SIGNAL CHARACTERISTICS					
Current–Gain – Bandwidth Product	(I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	250	–	MHz
Output Capacitance	(V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{obo}	–	4.5	pF
Input Capacitance	(V_{EB} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ibo}	–	10	pF

SMALL–SIGNAL CHARACTERISTICS					
Current–Gain – Bandwidth Product (I_C = 10 mAdc, V_{CE} = 20 Vdc, f = 100 MHz)	f_T	250	–	MHz
Output Capacitance (V_{CB} = 5.0 Vdc, I_E = 0, f = 1.0 MHz)	C_{obo}	–	4.5	pF
Input Capacitance (V_{EB} = 0.5 Vdc, I_C = 0, f = 1.0 MHz)	C_{ibo}	–	10	pF



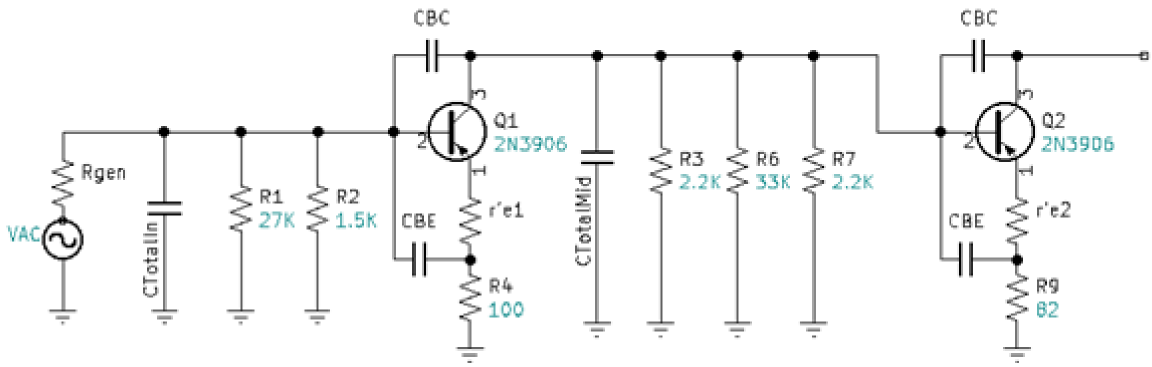
- $CBG = CBE(1 - \Delta V_{CC})$
  - $\Delta V_{CC} = \frac{IE(RE)}{IE(RE+r'e)}$ or $\frac{(RE)}{(RE+r'e)}$
  - $\Delta V_{CC} = \frac{(100)}{(100+7.485)} = 0.930$
  - $CBE = \frac{1}{(2\pi)(r'e)(f_T)} = \frac{1}{(2\pi)(7.485)(250M)} = 85.053pF$
  - $CBG = 85.053pF(1 - 0.93)$
  - $CBG = 5.954pF$
- $CtotalIN = Cgen + Cstray + Cprobe + CmillerIN + CBG$
  - $CtotalIN = 40pF + 10pF + 16pF + 43.763pF + 5.954pF$
  - $CtotalIN = 115.717pF$

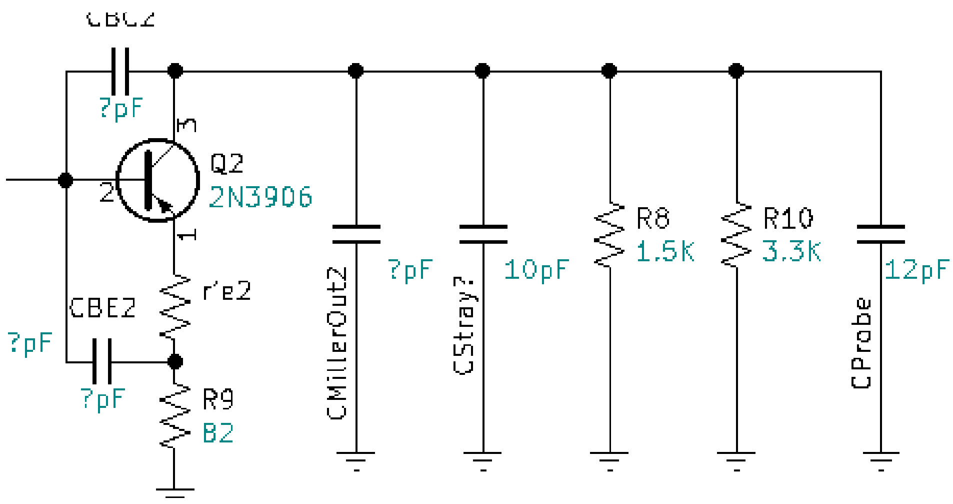


Frequency Response High (Middle):

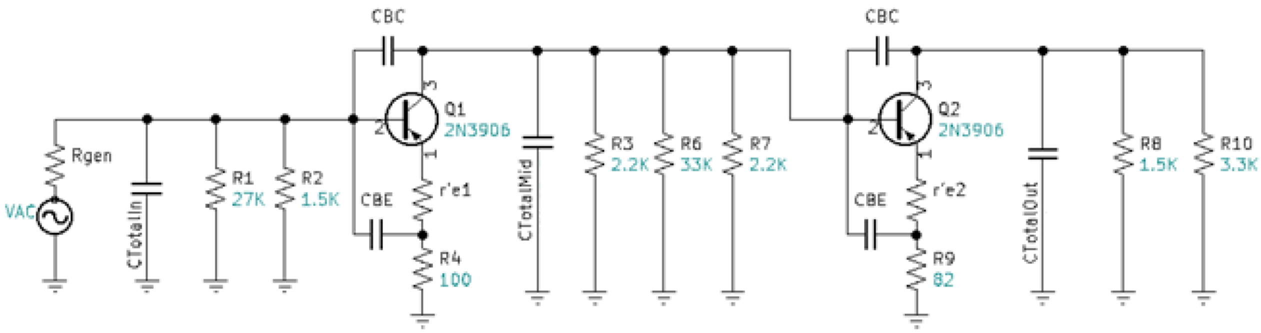
- $CtotalMid = CMillerOut1 + Cstray + Cstray + CmillerIN2 + CBG2$
  - $CMillerOUT = CBC(\frac{1+\Delta V_{CE}}{\Delta V_{CE}})$
    - $CBC \approx 4pF \ \approx Cibo\ (from\ the\ data\ sheet)$
    - $CMillerOUT1 = 4.5pF(\frac{1+8.725}{8.725}) = 5.016pF$
  - $CMillerIN = CBC(1 + \Delta V_{CE})$
    - $CMillerIN2 = 4.5pF(1 + 12) = 58pF$
  - $CBG = CBE(1 - \Delta V_{CC})$
    - $\Delta V_{CC} = \frac{IE(RE)}{IE(RE+r'e)}$ or $\frac{(RE)}{(RE+r'e)}$
    - $\Delta V_{CC} = \frac{(82)}{(82+3.087)} = 0.964$
    - $CBE2 = \frac{1}{(2\pi)(r'e)(f_T)} = \frac{1}{(2\pi)(3.087)(250M)} = 206.226pF$
    - $CBG2 = 206.226pF(1 - 0.964)$
    - $CBG2 = 7.424pF$
  - $CtotalMid = 5.016pF + 10pF + 10pF + 58pF + 7.424pF$
    - $CtotalMid = 90.44pF$

Frequency Response High (Back End):



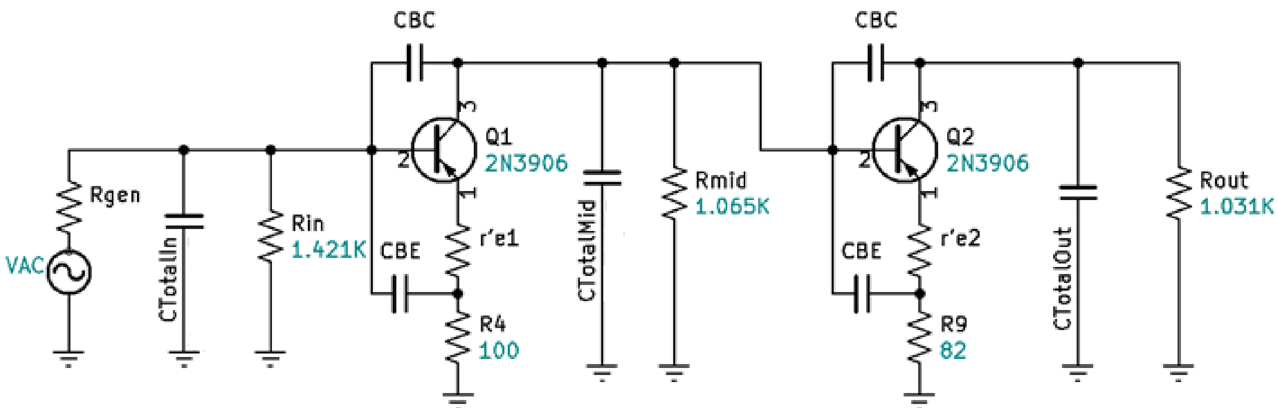


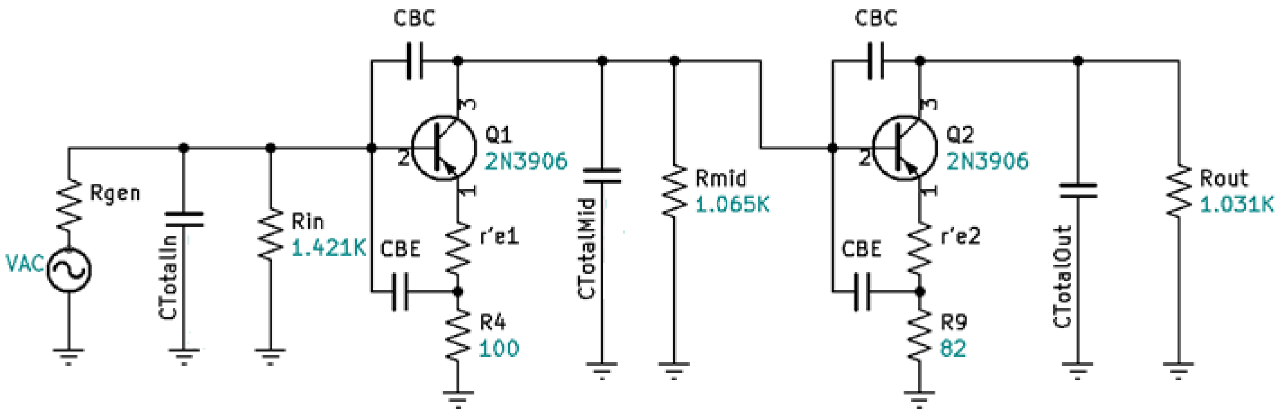
- $CtotalOut = CMillerOut2 + Cstray + CProbe$
  - $CMillerOUT = CBC(\frac{1 + \Delta V_{CE}}{\Delta V_{CE}})$
    - $CBC \approx 4pF \ \approx Cobo\ (from\ the\ data\ sheet)$
      - $CMillerOut2 = 4.5pF(\frac{1+12}{12})$
      - $CMillerOut2 = 4.767pF$
  - $CtotalOut = 4.767pF + 10pF + 16pF$
  - $CtotalOut = 30.767pf$



Simplify parallel resistances:

- $Rin = R1//R2 = 27K//1.5K$
    - $Rin == 1.421K\Omega$
- $Rmid = R3//R6//R7 = 2.2K//33K//2.2K$
    - $Rmid = 1.065K\Omega$
- $Rout = R8//R10 = 1.5K//3.3K$
    - $Rout = 1.031K\Omega$





Thevenize for CTin, CTmid, & CTout:

- $RthCtin = Rgen//Rin//[(r'e1 + R4)(B + 1)]$
  - $RthCtin = 50//1.421K//[(7.485 + 100)(101)] = 48.0865\Omega$
- $RthCtmid = Rmid//[(r'e2 + R9)(B + 1)]$
  - $RthCtmid = 1.065K//[(3.087 + 82)(101)] = 947.571\Omega$
- $RthCtout = Rout = 1.031K\Omega$

Find FCH for each stage:

- $FCH = \frac{1}{2\pi R_{Thev} CT}$
  - $FCH_{CTin} = \frac{1}{2\pi \times 48.0865 \times 115.717pF} = 28.6022Mhz$
  - $FCH_{CTmid} = \frac{1}{2\pi \times 947.571 \times 90.44pF} = 1.857Mhz$
  - $FCH_{CTout} = \frac{1}{2\pi \times 1.031K \times 30.767pf} = 5.0174Mhz$

Find FCHtotal:

- $FCH_{Total} = \frac{.35}{\sqrt{(\frac{.35}{FCH_{IN}})^2+(\frac{.35}{FCH_{OUT}})^2}}$
- $FCH_{Total} = \frac{.35}{\sqrt{(\frac{.35}{28.602Mhz})^2+(\frac{.35}{1.857Mhz})^2+(\frac{.35}{5.0174Mhz})^2}}$
- $FCH_{Total} = 1.738Mhz$

	A	B	C	D	E	F
1	DC Values	Calculated	Measured	AC Values	Calculated	Measured
2	VR1	19.78V		r'e1	7.485Ω	
3	VR2	1.047V		r'e2	3.087Ω	
4	VR3	7.566V		Zin	493.466Ω	
5	VR4	347.347mV		Zout	1.5KΩ	
6	VR5	4.172V		AVQ1	-8.725	
7	VR6	23.61V		AVQ2	-12	
8	VR7	1.391V		AVT	104.7	
9	VR8	12.5V		AIT	15.656	
10	VR9	690.537mV		APT	1.639K	
11	VCEQ1	13.142V		VCEacCut	20.394V	
12	VCEQ2	11.8V		ICacSat	19.776mA	
13	TP1	-1.047V		VoutMaxP	8.594vp	
14	TP2	-13.489V		VinMaxP	82.082mVp	
15	TP3	-347.347mV		RthC1	1.258KΩ	
16	TP4	-1.391V		RthC2	965.891Ω	
17	TP5	-690.537mV		RthC3&C4	4.829KΩ	
18	TP6	-12.5V		RthC5	4.8KΩ	
19	ICSatQ1	7.395mA		FcC1	15.429hz	
20	VCECutQ1	-24.153V		FcC2	3.327hz	
21	Q1	13.142V, 3.49mA		FcC3	149.81hz	
22	ICSatQ2	15.803mA		FcC3&C4	27.015hz	
23	VCECutQ2	-25V		FcC5	4.044hz	
24	Q2	11.8V, 8.333mA		FCL	150hz (JP3 Open)	
25				FCL	31.548hz (JP3 jumped)	
26				FCH	1.738Mhz	