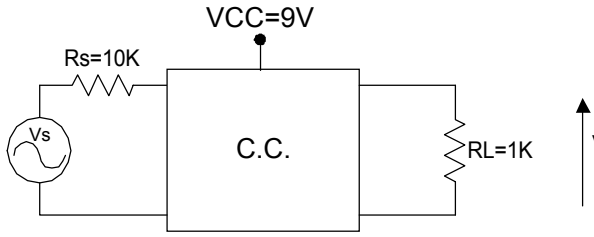
Problema 19

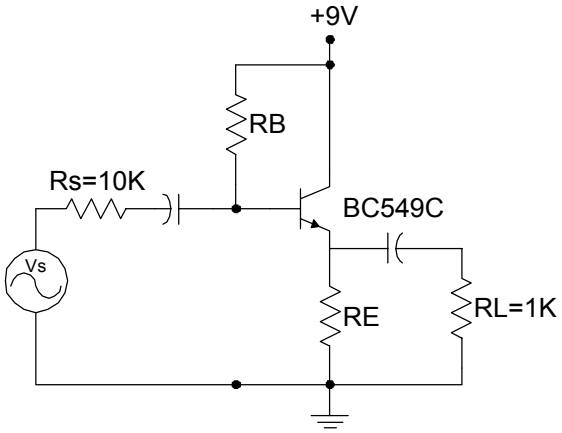
Diseñar una etapa adaptadora en configuración “colector común” de manera que en RL se obtenga por lo menos el 90% de la tensión Vs.



$$|V'o| = 100mV$$

$$Vo \geq 0{,}9Vs$$

circuito propuesto:



$$BVCE0 = 20V \quad \Rightarrow \quad 9V < 0{,}75BVCE0$$

Adoptamos $ICQ = 1mA$

Del manual:

$$hFE = 490$$

$$hie \cong 13K \quad \text{o} \quad hie = \frac{VT}{|IC|} \cdot hFE = 12250\Omega$$

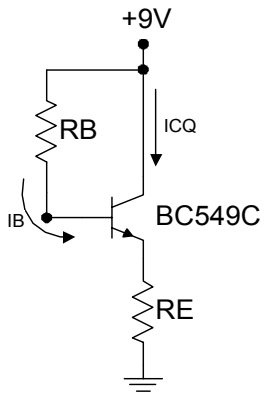
$$hfe = 600$$

$$hoe = 35^{\mu A}\!/_{V} \quad \Rightarrow \quad \frac{1}{hoe} = 28{,}5K$$

$$gm = 40 \cdot ICQ = 0{,}045\frac{1}{\Omega} \quad \text{o} \quad gm \cong \frac{hfe}{hie} = 0{,}046\frac{1}{\Omega}$$

$$\frac{\beta_{(2mA)}}{\beta_{min(2mA)}} = \frac{\beta_{(1mA)}}{\beta_{min(1mA)}} \Rightarrow \beta_{min(1mA)} = 395$$

Polarización contínua:



$$VCC - IB \cdot RB - VBE - IE \cdot RE = 0$$

como $IB \cong \frac{IC}{hFE}$

$$IE \cong IC$$

$$ICQ = \frac{VCC - VBE}{RE + \frac{RB}{hFE}} \quad \textbf{(I)}$$

luego: $RE \cong 5\frac{RB}{hFE_{min}}$ **(II)**

reemplazando (II) en (I), obtenemos:

$$RE = 7147\Omega \rightarrow RE = 6K8$$

$$RB = 564{,}6K \rightarrow RB = 560K$$

verificamos ICQ:

$$ICQ = \frac{VCC - VBE}{RE}\Big|_{hFE=\infty} = 1{,}22mA \rightarrow hFE = 500$$

$$ICQ = \frac{VCC - VBE}{RE + \frac{RB}{hFE}} = 1{,}05mA \rightarrow hFE = 490$$

luego hallamos $VCEQ$:

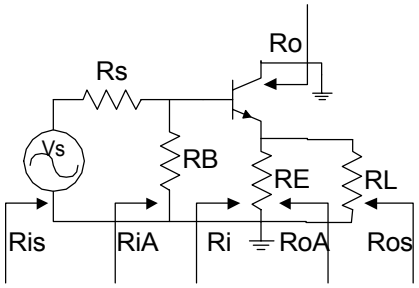
$$VCEQ = VCC - ICQ \cdot RE = 1{,}86V$$

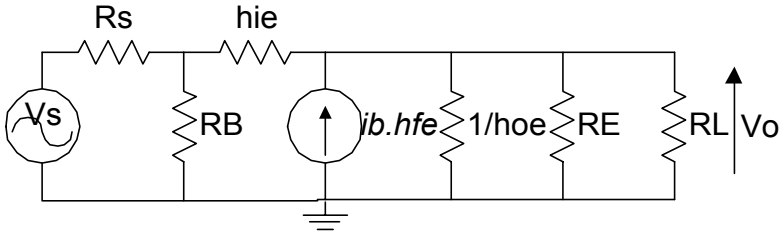
de la recta de carga dinámica:

$$ICQ \cdot Rd = 0{,}87V$$

$$Vd_{MAX} = 0{,}87V > 100mV$$

Análisis para señal:





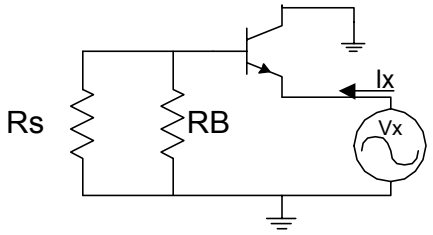
$$Ri = \frac{Vi}{Ib} = \frac{Ib\left[hie + \left(1 + hfe\right) \cdot Rd\right]}{Ib} = 537K$$

$$Ri_A = RB \| Ri = 274K$$

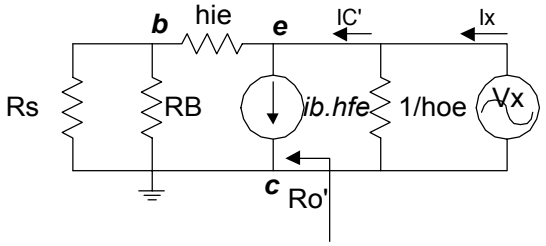
$$AV = \frac{Vo}{Vi} = \frac{Ib\left(1 + hfe\right) \cdot Rd}{Ib \cdot Ri} = \frac{\left(1 + hfe\right) \cdot Rd}{hie + \left(1 + hfe\right) \cdot RE} = 0{,}976$$

$$AVS = \frac{Vo}{Vs} = \frac{Vo}{Vi} \cdot \frac{Vi}{Vs} = AV \cdot \frac{Ri_A}{Ri_A + Rs} = 0{,}94$$

Para calcular la impedancia de salida:



$$Ro = \frac{Vx}{Ix}$$



$$Ro = Ro' \left\| \frac{1}{hoe} \cong Ro' \right.$$

$$Ro' = \frac{Vx}{Ix'} = \frac{Ib\left[hie + \left(Rs \| RB\right)\right]}{Ib\left(1 + hfe\right)} = \frac{hie}{1 + hfe} + \frac{Rs \| RB}{1 + hfe}$$

$$Ro' = hib + \frac{Rs \| RB}{1 + hfe} \quad \Rightarrow \quad Ro = Ro' = 38\Omega$$

luego:

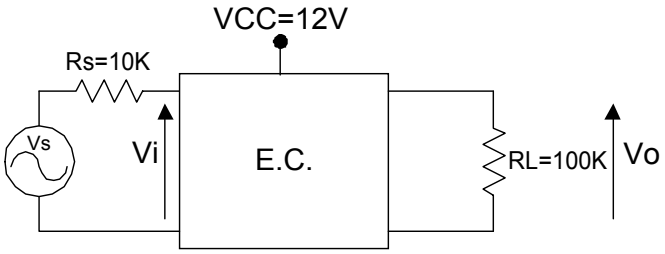
$$Ro_A = Ro \| RE \cong Ro$$

$$Ro_S = Ro_A \| RL \cong Ro$$

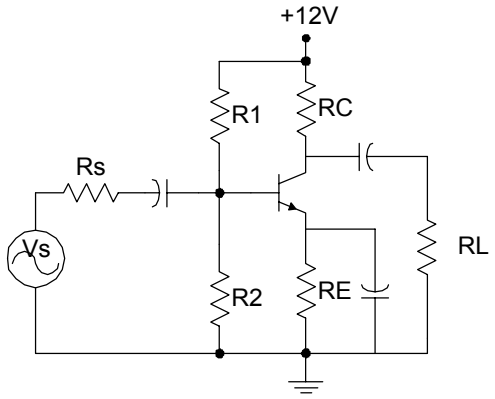
Problema 20

Diseñar una etapa en configuración “emisor común” que cumpla con la siguiente condición:

$$190 \le \left| \frac{Vo}{Vi} \right| \le 200$$



Circuito propuesto:



Transistor: *BC549B*
Corriente de colector propuesta: *ICQ=2mA*
Valores obtenidos del manual:

$$hFE = 290 \qquad hfe = 330$$
$$hFE_{min} = 200 \qquad hie = 4{,}5K$$
$$hoe = 30\mu\Omega^{-1} \Rightarrow \; ro = 33K$$
$$hre = 2 \cdot 10^{-4}$$

$$gm = \frac{hfe}{hie} = \frac{290}{4{,}5K} = 0{,}064\ {}^{1}\!/\!_{\Omega}$$

$$AV = -gm \cdot Rd \qquad \Rightarrow \qquad Rd = \left|\frac{AV}{gm}\right| = \left|\frac{195}{0{,}064\ {}^{1}\!/\!_{\Omega}}\right| = 3046{,}8\Omega$$

$$RC = \frac{Rd \cdot RL}{RL - Rd} = 3142{,}5\Omega \cong 3{,}2K$$

Se propone *VCEQ=5V*: $\left(VRE \cong 1V\right)$

$$VCC = VCEQ + ICQ \cdot \left(RC + RE\right)$$

$$RE = \frac{VCC - VCEQ - ICQ \cdot RC}{ICQ} = \frac{12V - 5V - 2mA \cdot 3{,}2K}{2mA} = 300\Omega$$

Propongo *n=10*:

$$RE = 10 \cdot \frac{RB}{hFE_{min}} \quad \Rightarrow \quad RB = \frac{RE \cdot hFE_{min}}{10} = 6600\Omega$$

$$ICQ = \frac{VBB - O,7V}{RE + \frac{RB}{hFE}} \quad \Rightarrow \quad VBB = ICQ \cdot \left(RE + \frac{RB}{hFE} \right) + 0,7V = 1,4V$$

$$VBB = VCC \cdot \frac{R2}{R1 + R2} \qquad RB = \frac{R1 \cdot R2}{R1 + R2}$$

$$R1 = 56K \qquad R2 = 7,5K$$

Verificación:

$$ICQ = \frac{VBB - 0,7V}{RE + \frac{RB}{hFE}} = 2mA$$

$$n = \frac{RE \cdot hFE_{min}}{RB} = 10$$

$$Rd = RC \| RL = 3100,7\Omega$$

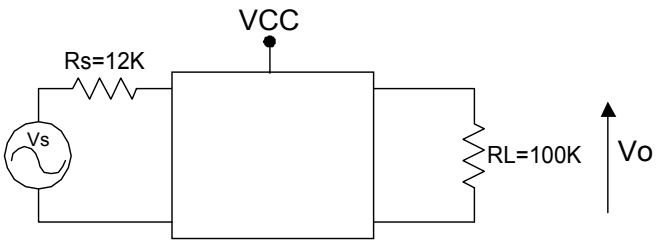
$$AV = -\frac{hfe}{hie} \cdot Rd = -208 \qquad \Rightarrow \textbf{se debe bajar RC}$$

$$\left.\begin{array}{l} V\hat{o}_1 = VCEQ - VCE_{SAT} = 4,9V \\ V\hat{o}_2 = ICQ \cdot Rd = 6,2V \end{array}\right\} \quad V\hat{o}_{MAX} = 4,9V$$

$$Ri_A = RB \| hie = 2,7K$$

Problema 21

Diseñar una etapa amplificadora que tenga las siguientes características:



$$AVS = 140$$

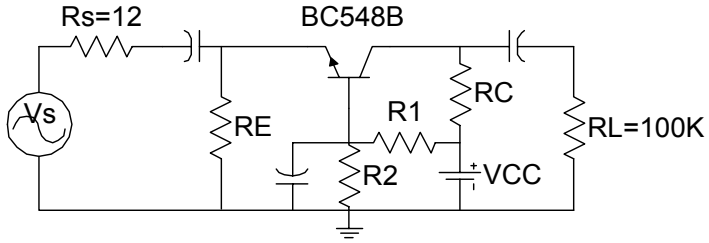
$$Ri_A = Rs \pm 10\%$$

$$n \geq 5$$

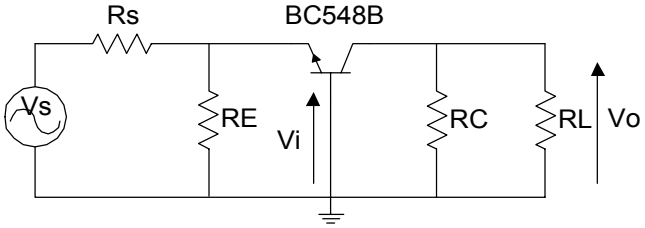
$$VCC \leq 0{,}75 \cdot BVCE0$$

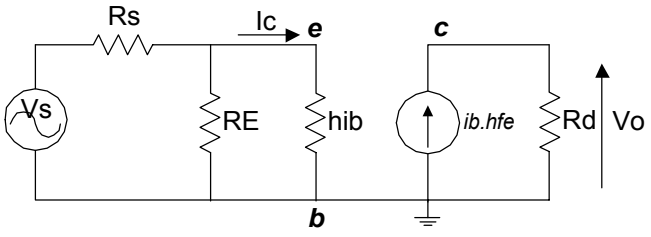
$$|Vd| = 3V$$

Proponemos el siguiente circuito:



Análisis para señal:





$$Ri_A = RE \| hib = RE \left\| \frac{1}{gm} \right.$$

como $RE \| hib \cong hib \Rightarrow$ despreciamos RE

$$Ri_A \cong \frac{1}{gm} = \frac{1}{40 \cdot ICQ} = 12\Omega \qquad \Rightarrow \qquad ICQ = 2mA$$

del manual:

$$hfe = 330 \qquad\qquad hoe = 30 \frac{\mu A}{V} \Rightarrow \frac{1}{hoe} = 33{,}3K$$

$$hie = 4K5 \qquad\qquad hre = 2 \cdot 10^{-4}$$

$$\beta = 290 \quad \Rightarrow \qquad\qquad \beta_{min} = 200$$

entonces:

$$hob = \frac{hoe}{1 + hfe} \Rightarrow \frac{1}{hob} \cong 11M\Omega$$

$$hib = \frac{hie}{1 + hfe} = 13{,}6\Omega$$

con las ganancias:

$$AV = \frac{Vo}{Vi} = \frac{hfb \cdot Ie \cdot Rd}{Ie \cdot hib} = \frac{\left(\frac{hfe}{1 + hfe} \right) \cdot Rd}{\left(\frac{hie}{1 + hfe} \right)} \cong gm \cdot Rd$$

$$AVS = \frac{Vo}{Vs} = \frac{Vo}{Vi} \cdot \frac{Vi}{Vs} = AV \cdot \frac{Ri_A}{Ri_A + Rs} = AV \cdot \frac{1}{2} = 140 \quad \text{(dato)}$$

$$AV = 280$$

entonces:

$$AV = \frac{hfe}{hie} \cdot \left(RC \| RL \right) = 280$$

luego:

$$RC \| RL = 3818{,}18\Omega \qquad\qquad \text{como } RL = 100K \Rightarrow RC = 3K9$$

Para la excursión de la señal de salida, según las curvas del base común:

$VCB \geq 3V$ para que no sature el transistor.

como $ICQ \cdot Rd = 7{,}8V \quad \Rightarrow \quad VCB = 3{,}5V$

calculamos $VCEQ$:

$$VCEQ = VCB + VBE = 4{,}2V$$

Para calcular VCC:

$$VCC = 15V \leq 0{,}75BVCE0$$

luego:

$$ICQ \cdot RE = VCC - ICQ \cdot RC - VCEQ = 3V$$

$$RE = \frac{3V}{ICQ} = 1K5$$

para hallar $R1\ y\ R2$

sabiendo que:

$$ICQ = 2mA \qquad\qquad VCEQ = 4{,}2V$$

y:
$$\frac{\frac{RE}{RB}}{\beta_{min}} \geq 5$$

obtenemos que:

$$RB \leq 60K$$

adoptamos $RB \cong 50K$ para no trabajar en el límite, entonces:

$$ICQ = \frac{VBB - VBE}{RE + \frac{RB}{hFE}}$$

$$VBB = ICQ \cdot \left(RE + \frac{RB}{hFE} \right) + VBE = 4V$$

como $VBB = VCC \cdot \frac{R2}{R1 + R2}$, multiplicando m. a m. por *R1* nos queda:

$$R1 \cdot VBB = VCC \cdot RB \quad \Rightarrow \quad R1 = VCC \cdot \frac{RB}{VBB} = 187{,}5K$$

$$\frac{1}{R1} + \frac{1}{R2} = \frac{1}{RB} \quad \Rightarrow \quad R2 = 68{,}18K$$

adoptamos los valores comerciales de *R1 y R2*:

$$R1 = 180K \qquad R2 = 68K$$

Verificación:

$$VBB = VCC \cdot \frac{R2}{R1 + R2} = 4{,}11V \qquad RB = R1 \| R2 = 49{,}35K$$

$$ICQ = \frac{VBB - VBE}{RE + \frac{RB}{hFE}} = 2{,}04mA$$

$$VCEQ = VCC - ICQ \cdot (RC + RE) = 3{,}98V$$

$$VCBQ = VCEQ - VBE = 3{,}28V$$

$$n = \frac{RE}{\frac{RB}{hFE_{min}}} = 6$$

$$AV_1 = gm \cdot Rd \qquad gm = 40 \cdot ICQ = 0{,}082 \frac{1}{\Omega}$$

$$AV_1 = 306{,}29$$

$$AV_2 = \frac{hfe}{hie} \cdot Rd = 275{,}26$$

$$hib = 12{,}25\Omega \quad \Rightarrow \quad Ri_A = hib \| RE = 12{,}15\Omega$$

$$AVS_1 = AV_1 \cdot \frac{Ri_A}{Ri_S} = 152{,}2$$

$$AVS_2 = AV_2 \cdot \frac{Ri_A}{Ri_S} = 136{,}78$$

Vemos que se verifican todos los cálculos.