- $V_{BIAS} = V_{BE18} + V_{BE19} = V_{BE14} + V_{EB20}$

  $\Rightarrow V_T \ln(I_{C18}/I_{S18}) + V_T \ln(I_{C19}/I_{S19})$

  $= V_T \ln(I_{C14}/I_{S14}) + V_T \ln(I_{C20}/I_{S20})$

- ***Since $I_L = 0$***:

  $$\Rightarrow I_{C14} = I_{C20} = \sqrt{\frac{I_{S14} I_{S20}}{I_{S18} I_{S19}}} \sqrt{I_{C18} I_{C19}}$$

- The ***sizes*** of the ***output transistors*** are typically ***much larger*** than the other devices, to be able to ***supply large current to the load without overheating***

- Assuming $I_{S14} = I_{S20} = 4I_{S18} = 4I_{S19}$:

  $I_{C14} = I_{C20} = 216\ \mu A$

- Thus, the ***idling*** (***standby***) ***power dissipation*** of the ***output branch*** = (30 V) × (216 μA) = 6.5 mW

- Assuming $I_{S18} = I_{S19} = 1$ fA:
  $V_{BIAS} = V_T \ln[I_{C18} I_{C19} / (I_{S18} I_{S19})] = 1.285$ V
- This produces a ***DC bias*** of ***~ 643 mV*** across the ***BE junctions*** of Q_{14} and Q_{20}, keeping them at the ***verge of conduction***
- Note that instead of the ***prebias combination*** used, if simply ***two diodes*** were used in ***series***, then the ***current*** through that ***branch*** would have been ***183.3 μA***, resulting in a current of ***733.2 μA*** in the ***output branch***, thus creating ***standby power dissipation*** in the ***output branch*** of ***22 mW*** (***3.4 times***)
- Finally, $I_{C23A} = I_{C13A} = 183.3\ \mu A$

Transistor(s)	Magnitude (μA)
I_{C1}, I_{C2}, I_{C3}, I_{C4}, I_{C5}, I_{C6}	9.5
I_{C7}	12.1
I_{C8}, I_{C9}, I_{C10}	19
I_{C11}, I_{C12}	733.3
I_{C13A}, I_{C23A}	183.3
I_{C13B}, I_{C17}	550
I_{C14}, I_{C20}	216
I_{C16}	17.9
I_{C18}	165.7
I_{C19}	17.6

The DC Bias Currents of Different Transistors

- The ***DC power dissipation*** of the circuit:

$$P_{DC} = V_{CC} \times (I_{C12} + I_{C9} + I_{C8} + I_{C13A} + I_{C13B} + I_{C14} + I_{C7} + I_{C16}) + |-V_{CC}| \times (I_{C11} + I_{C10} + I_{C5} + I_{C7} + I_{C6} + I_{R9} + I_{C17} + I_{C23A} + I_{C20})$$

$$= 52.3 \text{ mW}$$

- Note that the ***reference branch*** consumes the ***highest DC power***, followed by the ***Darlington branch***
- On the other hand, the ***least DC power*** is consumed by the ***DA branch***

- ***ac Analysis***:
  - ***Primary Goal***:
    - ***To find R_i, R_0, and A_{vOL}***
  - We will adopt a ***modular approach***:
    - ***Considering each stage individually***
    - ***Finding the 2-port equivalent for each of them***
    - ***Eventually joining them together to get the total response***

- Assumed:

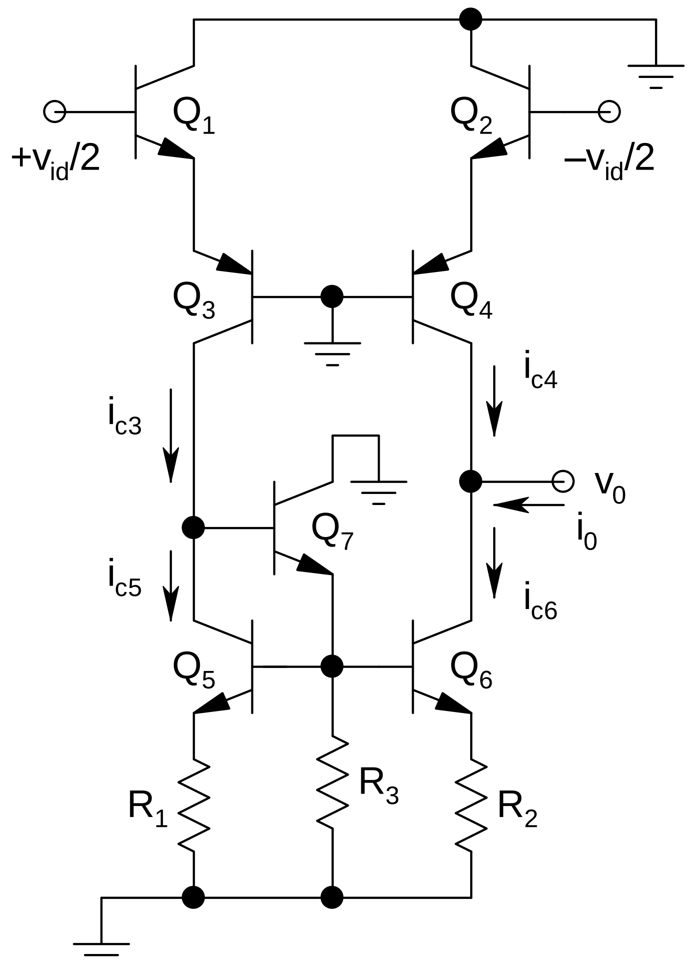
  $\beta_N = 200$, $\beta_P = 100$, $V_{AN} = 130$ V, $V_{AP} = 50$ V

- We will also ***evaluate*** the ***required value*** of the ***compensation capacitor*** C_C

- The ***analysis*** will be ***simple*** and ***highly approximate***, however, the ***results*** will ***definitely lie*** within ***±10%*** of the ***actual***

➢ ***Input Stage***:

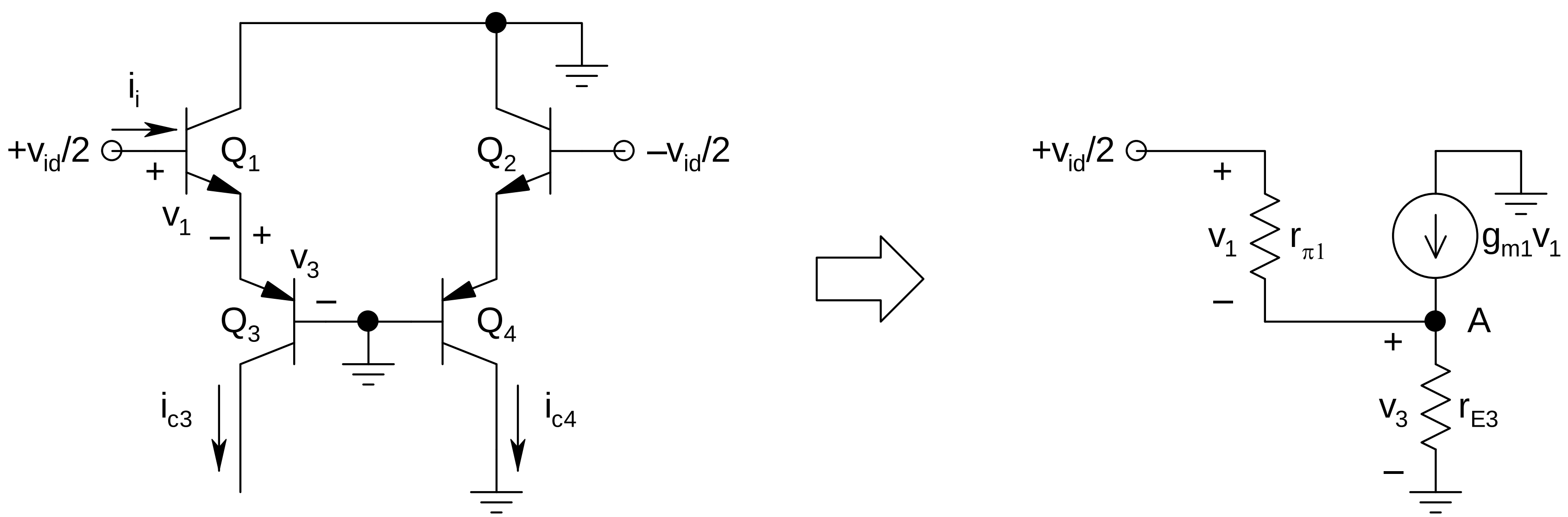
- ***Differential-mode input*** v_{id} ***split*** into $+v_{id}/2$ and $-v_{id}/2$, and ***applied*** at the ***bases*** of Q_1-Q_2
- All ***terminals*** having ***fixed DC potentials*** have been tied to ***ac ground***
- ***Bases*** of Q_3-Q_4 are at ***ac ground*** due to ***perfect symmetry*** of the circuit



- $i_{c3} = i_{c5}$ (***neglecting base current of Q_7***)
- $i_{c6} = i_{c5}$ (***ratioed mirror with $R_1 = R_2$***)
- ***Output current***:

  $$i_0 = i_{c6} - i_{c4} = i_{c5} - i_{c4} = i_{c3} - i_{c4}$$

- To find the ***short-circuit transconductance*** of this stage, we ***short the output node to ground***



- $v_{id}/2 = v_1 + v_3$
- ***KCL at node A***:

$v_1/r_{\pi 1} + g_{m1}v_1 = v_3/r_{E3}$

$$\Rightarrow v_1 = \frac{r_{\pi 1}}{r_{E3}}\frac{1}{1+g_{m1}r_{\pi 1}}v_3 = \frac{r_{\pi 1}}{r_{E3}}\frac{1}{1+\beta_1}v_3 \simeq \frac{r_{\pi 1}}{\beta_1}\frac{1}{r_{E3}}v_3 \simeq \frac{r_{E1}}{r_{E3}}v_3 = v_3$$

$$\Rightarrow v_{id} = 4v_3 \Rightarrow v_3 = v_{id}/4$$

$$\Rightarrow i_{c3} = g_{m3}v_3 = g_{m3}v_{id}/4 \text{ and } i_{c4} = -g_{m3}v_{id}/4$$

$$\Rightarrow i_0 = i_{c3} - i_{c4} = +g_{m3}v_{id}/2$$

- Thus, the ***short-circuit transcoductance***:

$$G_{m1} \triangleq \left.\frac{i_0}{v_{id}}\right|_{v_0=0} = \frac{g_{m3}}{2} = \frac{I_{C3}}{2V_T} = 182.7\ \mu℧$$