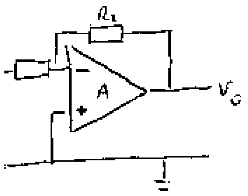
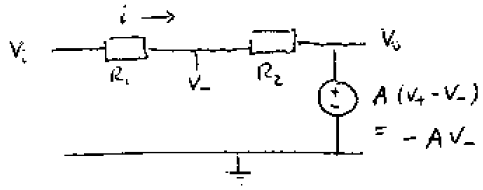
1)



⟹



$$i = \frac{(V_i - V_-)}{R_1} = \frac{V_- - V_o}{R_2}$$

$$V_- = -V_o/A$$

$$i = \frac{(V_i + V_o/A)}{R_1} = \frac{(-V_o/A - V_o)}{R_2}$$

$$\Rightarrow \frac{V_o}{V_i} = -\frac{R_2}{R_1}\frac{1}{1 + (1 + R_2/R_1)/A} \approx -\frac{R_2}{R_1} \quad (A \gg 1)$$

R_1	R_2	A	V_o/V_i
10 kΩ	100 kΩ	100	−9.009
10 kΩ	100 kΩ	10^4	−9.989
10 kΩ	100 kΩ	10^6	−9.9999
10 kΩ	100 kΩ	∞	−10

$$V_o/V_i = -\frac{10A}{A+11}$$

2) (a) $A \rightarrow \infty$, $\frac{V_o}{V_i} = 1 + \frac{R_2}{R_1} = 1 + \frac{10^4}{10^4} = 2$

mínimo : $1 + \frac{0.95 \cdot 10^4}{1.05 \cdot 10^4} = 1.905$

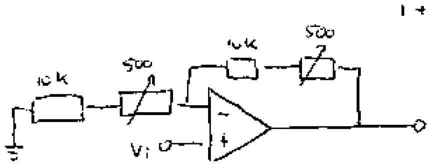
máximo : $1 + \frac{1.05 \cdot 10^4}{0.95 \cdot 10^4} = 2.105$

} $2 \pm 5\%$

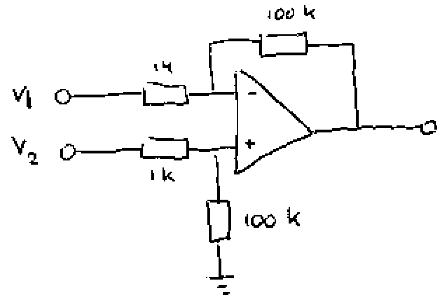
Stat. : $R_2 (\pm 5\%)$, $R_1 (\pm 5\%)$. R_2/R_1 $(\pm \sqrt{2}\, 5\%)$

$1 + R_2/R_1$, $(\pm \frac{1}{\sqrt{2}} 5\% = 3.5\%)$

(b)

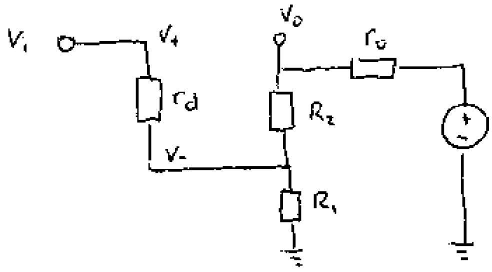


3)



$V_o = 100\,(V_2 - V_1)$

4)



(*) $r_o \ll R_1, R_2$

$V_o = A\,(V_+ - V_-) = A\,(V_i - V_-)$

(*) $r_d \gg R_1$

$V_- = \frac{R_1}{R_1+R_2} V_o = \beta V_o \qquad \left(\beta = \frac{R_1}{R_1+R_2}\right)$

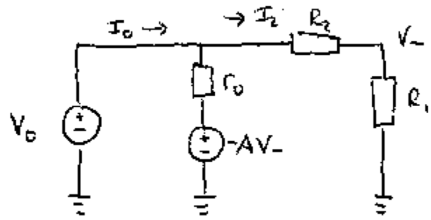
(a) $V_o = A\,(V_i - \beta V_o) \Rightarrow \frac{V_o}{V_i} = \frac{A}{1 + A\beta}$

$V_- = \beta V_o = \frac{A\beta}{1+A\beta} V_i$

$I_i = (V_+ - V_-)/r_d = \left(V_i - \frac{A\beta}{1+A\beta} V_i\right)/r_d = \frac{1}{r_d} \cdot \frac{1}{1+A\beta} V_i$

(b) $R_i = \frac{V_i}{I_i} = r_d\,(1 + A\beta)$

(c)



$V_+ = 0$

$r_d \gg R_1$

$V_o = I_2 (R_1 + R_2)$ (I) $\quad I_2 = V_o / (R_1 + R_2)$

e $V_o = -AV_- + (I_o - I_2) r_o$ (II)

$V_- = R_1 I_2$ (III)

(III) em (II) :

$$V_o = -A R_1 I_2 + (I_o - I_2) r_o$$

$$= I_o r_o - I_2 (r_o + A R_1) \quad \text{(IV)}$$

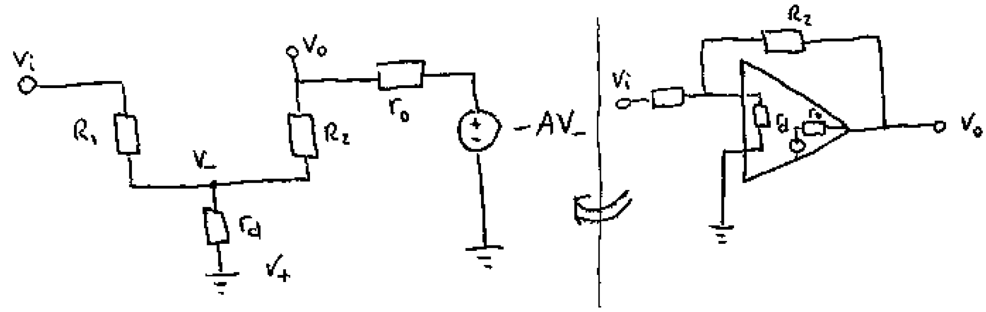
(I) em (IV)

$$V_o = I_o r_o - V_o \frac{(r_o + A R_1)}{R_1 + R_2}$$

$$V_o \left(1 + \frac{r_o + A R_1}{R_1 + R_2}\right) = I_o r_o \qquad \beta = R_1 / (R_1 + R_2)$$

$$R_{out} = \frac{V_o}{I_o} = \frac{r_o}{1 + \frac{r_o + AR_1}{R_1 + R_2}} \approx r_o \frac{1}{1 + A\beta}$$

5)



(a) $r_d >> R_1, R_2$

$$V_- = V_o \cdot \frac{R_1}{R_1 + R_2} + V_i \frac{R_2}{R_1 + R_2} \qquad \left(\beta = \frac{R_1}{R_1 + R_2}\right)$$

$$= V_o \beta + V_i (1 - \beta)$$

$$V_o = -A V_- \qquad (r_o << R_2)$$

$$= -A (V_o \beta + V_i (1 - \beta))$$

$$V_o + A \beta V_o = A(\beta - 1) V_i$$

$$(1+A\beta)V_o = A(\beta-1)V_i$$

ganho : $\frac{V_o}{V_i} = \frac{(\beta-1)A}{1+A\beta}$. $\left(A\to\infty,\ \frac{V_o}{V_i}\to -\frac{R_2}{R_1}\right)$

(b) $I_i = (V_i - V_-)/R_1$ $\left(\begin{aligned} V_- &= -V_o/A \\ &= -\frac{(\beta-1)}{1+A\beta}V_i \end{aligned}\right)$

$$I_i = \frac{1}{R_1}\left(V_i + \frac{\beta-1}{1+A\beta}V_i\right)$$

$$= \frac{V_i}{R_1}\left(1+\frac{\beta-1}{1+A\beta}\right)$$

$$\frac{V_i}{I_i} = \frac{1+A\beta}{A\beta+\beta}R_1 \approx R_1$$

(c) igual a 4c