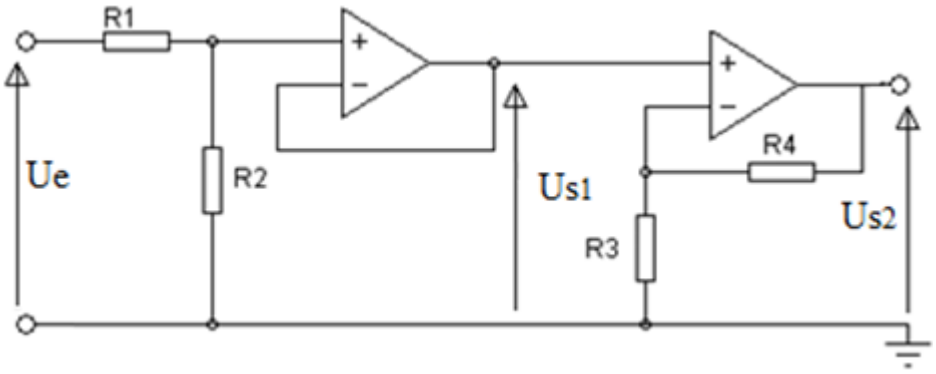
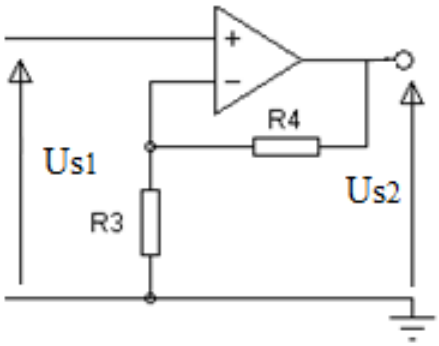
Amplificateur opérationnel en régime linéaire

Exercice 1



R1 = 10kΩ R2 = 20kΩ R3 = 100kΩ

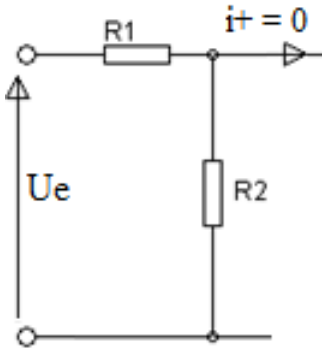
1.



$$U_{S2} = \left(1 + \frac{R_4}{R_3}\right) U_{S1}$$

On a un montage non-inverseur.

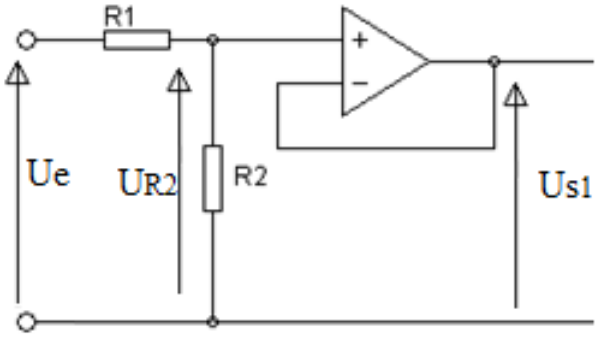
2.



$$U_{R2} = \frac{R_2}{R_1 + R_2} U_e$$

On a un diviseur de tension.

3.



$$U_{S1} = U_{R2} = \frac{R_2}{R_1 + R_2} U_e$$

On a un montage suiveur.

4.

$$U_{S2} = \left(1 + \frac{R_4}{R_3}\right) U_{S1} = \left(1 + \frac{R_4}{R_3}\right) \frac{R_2}{R_1 + R_2} U_e = \left(1 + \frac{R_4}{100k\Omega}\right) \frac{20k\Omega}{10k\Omega + 20k\Omega} U_e$$

$$U_{S2} = \frac{2}{3}\left(1 + \frac{R_4}{100k\Omega}\right) U_e$$

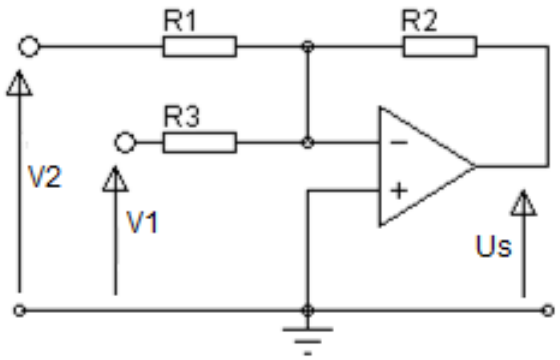
5.

$U_{S2} = 2\ Ue \Rightarrow \quad 2 = \frac{2}{3}\left(1 + \frac{R_4}{100k\Omega}\right)$

$R_4 = 200k\Omega$

Exercice 2

1. On utilise le théorème de Millman pour déterminer v^- :

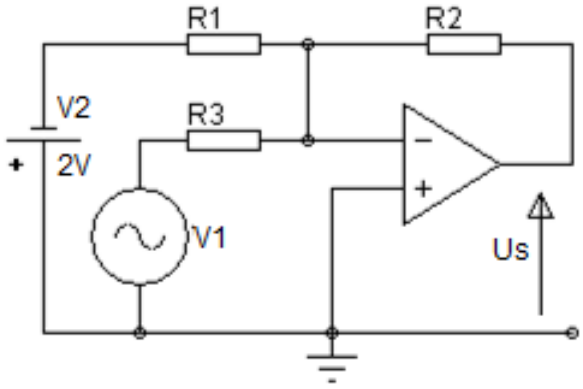


$$v^- = \frac{\frac{V_1}{R_3} + \frac{V_2}{R_1} + \frac{U_S}{R_2}}{\frac{1}{R_3} + \frac{1}{R_3} + \frac{1}{R_3}} = v^+ = 0 \quad \Rightarrow \quad \frac{V_1}{R_3} + \frac{V_2}{R_1} + \frac{U_S}{R_2} = 0$$

$$\frac{U_S}{R_2} = -\frac{V_1}{R_3} - \frac{V_2}{R_1} \quad \Rightarrow \quad \boxed{U_S = -R_2\left(\frac{V_1}{R_3} + \frac{V_2}{R_1}\right)}$$

On a un montage sommateur inverseur.

2.



$$U_S = -R_2\left(\frac{V_1}{R_3} + \frac{V_2}{R_1}\right) = -10k\Omega\left(\frac{1V\sin\omega t}{10k\Omega} + \frac{-2V}{5k\Omega}\right) \quad \Rightarrow \quad \boxed{U_S = -1V\sin\omega t + 2V}$$

Exercice 3

1.

$$\frac{U_A}{U_e} = \frac{U_A}{U_{R3}} x \frac{U_{R3}}{U_e}$$

$$\frac{U_A}{U_{R3}} = 1 + \frac{R_5}{R_4} \text{ (amplificateur non inverseur)}$$

$$\frac{U_{R3}}{U_e} = \frac{R_3}{R_3 + R_2 + R_1} \text{ (diviseur de tension)}$$

$$\frac{U_A}{U_e} = \left(1 + \frac{R_5}{R_4}\right) x \frac{R_3}{R_3 + R_2 + R_1}$$

$$\frac{U_s}{U_A} = \frac{U_s}{U_{R7}} x \frac{U_{R7}}{U_A} \qquad \frac{U_s}{U_A} = \left(1 + \frac{R_8}{R_9}\right) x \frac{R_7}{R_7 + R_6}$$

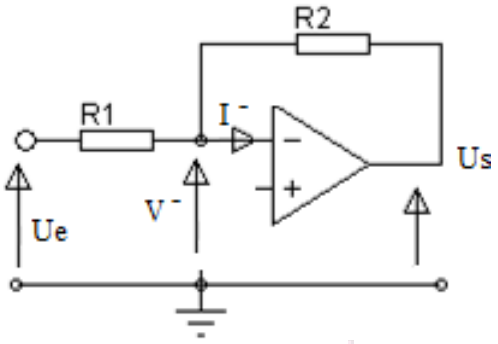
$$\frac{U_s}{U_e} = \frac{U_s}{U_A} x \frac{U_A}{U_e} \quad \Rightarrow \quad \frac{U_s}{U_e} = \left(1 + \frac{R_8}{R_9}\right) x \frac{R_7}{R_7 + R_6} x \left(1 + \frac{R_5}{R_4}\right) x \frac{R_3}{R_3 + R_2 + R_1}$$

2.

$$\frac{U_s}{U_e} = \left(1 + \frac{100}{50}\right) x \frac{100}{100 + 100} x \left(1 + \frac{20}{5}\right) x \frac{18}{18 + 3{,}3 + 2{,}7} \quad \Rightarrow \quad \frac{U_s}{U_e} = 5{,}625$$

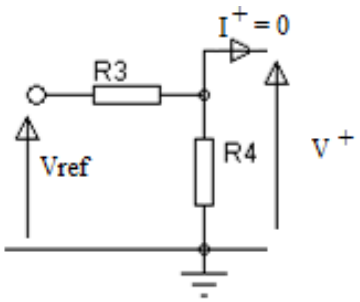
Exercice 4

1.



$$v^- = \frac{\frac{U_e}{R_1} + \frac{U_s}{R_2} + I^-}{\frac{1}{R_1} + \frac{1}{R_2}} \quad \text{et} \quad I^- = 0 \quad \Rightarrow \quad v^- = \frac{\frac{U_e}{R_1} + \frac{U_s}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2}} \quad \Rightarrow \quad v^- = \frac{R_1 U_S + R_2 U_e}{R_1 + R_2}$$

2.



$$\mathbf{v^+ = \frac{R_4}{R_3 + R_4} Vref}$$

3.

$$v^- = v^+ \quad \Rightarrow \quad \frac{R_1 U_S + R_2 U_e}{R_1 + R_2} = \frac{R_4}{R_3 + R_4} Vref$$

$$R_1 U_S + R_2 U_e = \frac{R_4(R_1 + R_2)}{R_3 + R_4} Vref \quad \Rightarrow \quad \mathbf{U_S = \frac{R_4(R_1 + R_2)}{R_1(R_3 + R_4)} Vref - \frac{R_2}{R_1} U_e}$$

4. $R_2 = 5R_1$

$$U_S = \frac{R_4(R_1 + 5R_1)}{R_1(R_3 + R_4)} Vref - \frac{5R_1}{R_1} U_e = \frac{6R_4}{R_3 + R_4} Vref - 5U_e$$

$$U_S = \frac{6}{\frac{R_3}{R_4} + 1} Vref - 5U_e = 5\,(Vref - Ue) \quad \Rightarrow \quad \frac{6}{\frac{R_3}{R_4} + 1} = 5$$

$$6 = 5\left(\frac{R_3}{R_4} + 1\right) \quad \Rightarrow \quad 6 - 5 = 5\frac{R_3}{R_4} \quad \Rightarrow \quad \frac{R_3}{R_4} = \frac{1}{5} \quad \Rightarrow \quad \mathbf{\frac{R_4}{R_3} = 5}$$

Exercice 5

1. Les AOp fonctionnent en régime linéaire $\Rightarrow v^- = v^+$

2.

$$\frac{U}{V_1} = 1 + \frac{R/a}{R} \text{ (amplificateur non inverseur)} \quad \Rightarrow \quad \frac{U}{V_1} = 1 + \frac{1}{a}$$

$$\mathbf{U = \left(1 + \frac{1}{a}\right) V_1}$$

3. $v^- = v^+$

$$v^- = V_2 = \frac{\frac{U}{R} + \frac{Vs}{aR}}{\frac{1}{R} + \frac{1}{aR}} = \frac{aU + Vs}{a+1} \quad \Rightarrow \quad (a+1)V_2 = aU + Vs$$

$$\boxed{Vs = (a+1)V_2 - aU}$$

4.

$$Vs = (a+1)V_2 - aU \text{ et } U = \left(1 + \frac{1}{a}\right)V_1 \quad \Rightarrow \quad Vs = (a+1)V_2 - a\left(1 + \frac{1}{a}\right)V_1$$

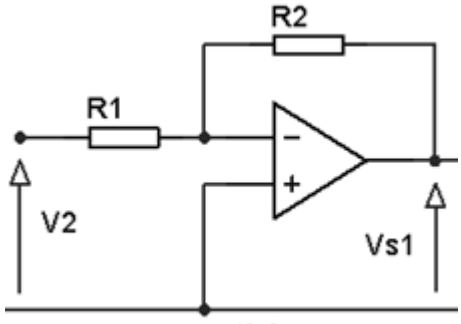
$$\boxed{Vs = (a+1)(V_2 - V_1)}$$

$Vs = k(V_2 - V_1) \Rightarrow \quad k = a + 1 = 10$ $\boxed{a = 9}$

5. Le montage obtenu est un amplificateur différentiel, réalisé avec 2 amplificateurs opérationnels.

Exercice 6

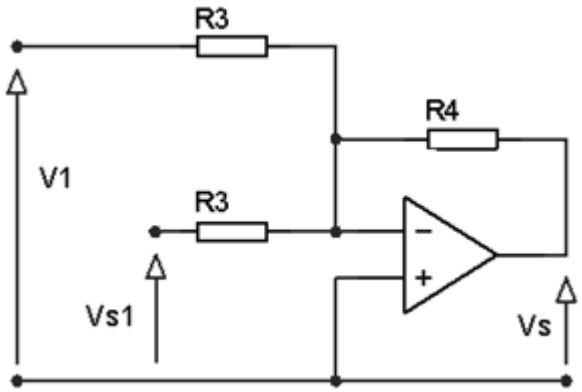
1.



$\frac{V_{S1}}{V_2} = -\frac{R_2}{R_1}$ (montage non inverseur) $\Rightarrow$ $\boxed{V_{S1} = -\frac{R_2}{R_1}V_2}$

$R_1 = R_2 = 10k\Omega$ $\boxed{V_{S1} = -V_2}$

2.



On a un montage sommateur inverseur : $V_S = -R_4\left(\frac{V_1}{R_3} + \frac{V_{S1}}{R_3}\right)V$

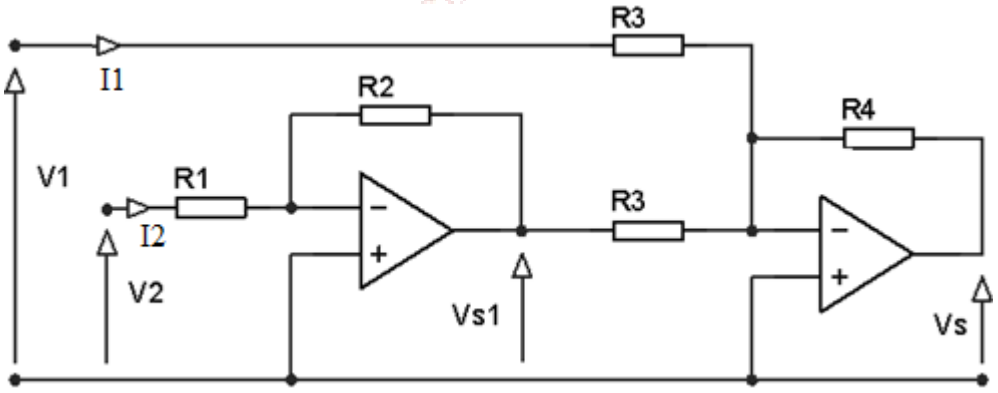
$$\mathbf{V_S = -\frac{R_4}{R_3}(V_1 + V_{S1})}$$

3. $R_3 = 10k\Omega$, $R_4 = 100k\Omega$ → **$V_S = -10(V_{S1} + V_1)$**

4. $V_S = -10(V_{S1} + V_1)$ et $V_{S1} = -V_2$ → **$V_S = -10(V_1 - V_2)$**

$V_S = A\,(V_2 - V_1) = -10(V_1 - V_2)$ → **$A = 10$**

5. $V_1 = 0{,}5V$, $V_2 = 1V$



$V_1 = I_1R_3$ et $V_1 = 0{,}5V$, $R_3 = 10k\Omega$ → **$I_1 = 50\mu A$**

$V_2 = I_2R_1$ et $V_2 = 1V$, $R_4 = 100k\Omega$ → **$I_2 = 10\mu A$**

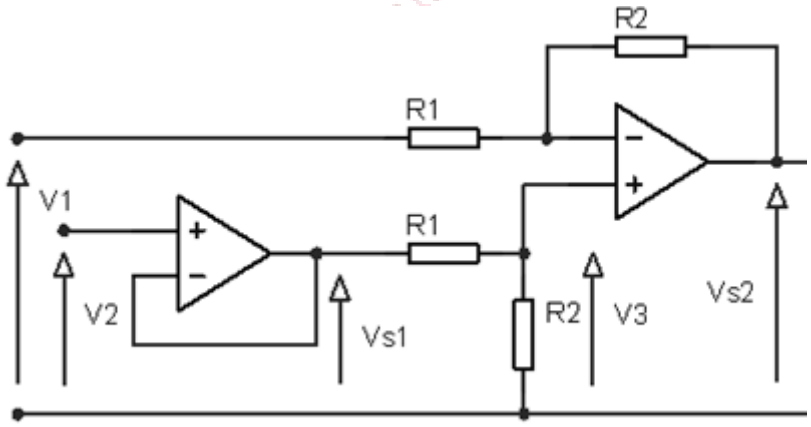
$V_S = -10(V_2 - V_1) = -10(1V - 0{,}5V)$ → **$V_S = -5V$**

Exercice 7

1.

$$V_3 = \frac{R_2}{R_1 + R_2} V_{S1} \text{ et } V_{S1} = V_2 \text{(montage suiveur)} \quad \Rightarrow \quad \boxed{V_3 = \frac{R_2}{R_1 + R_2} V_2}$$

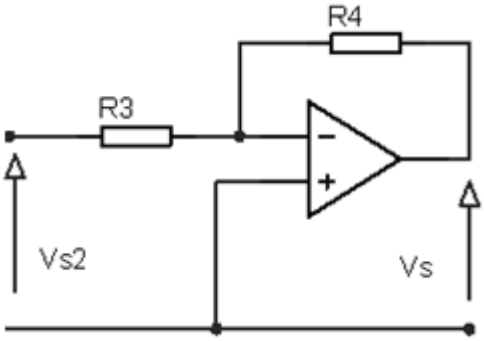
2.



$$v^- = \frac{\frac{V_1}{R_1} + \frac{V_{S2}}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{V_1 R_2 + V_{S2} R_1}{R_1 + R_2} \quad \text{et} \quad v^+ = V_3 = \frac{R_2}{R_1 + R_2} V_2$$

$$v^- = v^+ = V_3 \Rightarrow V_1 R_2 + V_{S2} R_1 = V_2 R_2 \qquad \boxed{V_{S2} = \frac{R_2}{R_1}(V_2 - V_1)}$$

3.



(montage inverseur) $\boxed{V_S = -\frac{R_4}{R_3} V_{S2}}$

4.

$$V_S = -\frac{R_4}{R_3} V_{S2} = -\frac{R_4}{R_3}\left(\frac{R_2}{R_1}(V_2 - V_1)\right) \qquad \boxed{V_S = -\frac{R_2 R_4}{R_1 R_3}(V_2 - V_1)}$$

1. $V_1 = 0,7V$ $V_2 = 0,7V - a\theta$ et $a = 2mV/°C$ (θ est exprimé en °C).

$R_1 = 10\ k\Omega$, $R_2 = 22k\Omega$ et $R_4 = 47\ k\Omega$ $Vsat = \pm 12V$

$$V_S = -\frac{R_2R_4}{R_1R_3}(V_2 - V_1) = -\frac{22x47}{10R_3}(0,7V - a\theta - 0,7V) = \frac{103,4}{R_3}a\theta$$

$$V_S = \frac{103,4}{R_3}(2mV/°C)\theta = \frac{0,2068}{R_3}\theta(V/°C)$$

$$V_S = 0,1\theta = \frac{0,2068}{R_3}\theta(V/°C) \quad \Rightarrow \quad R_3 = \frac{0,2068}{0,1}k\Omega$$ **R3 = 2,068kΩ**

$V_{Smax} = +Vsat = 12V = 0,1\theta_{max}$ **θ_{max} = 120°C**

Exercice 8

1. On utilise le théorème de Millman pour déterminer U_A :

$$v^- = \frac{\frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{U_A}{R_3}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = v^+ = 0 \quad \Rightarrow \quad \frac{V_1}{R_1} + \frac{V_2}{R_2} + \frac{U_A}{R_3} = 0$$

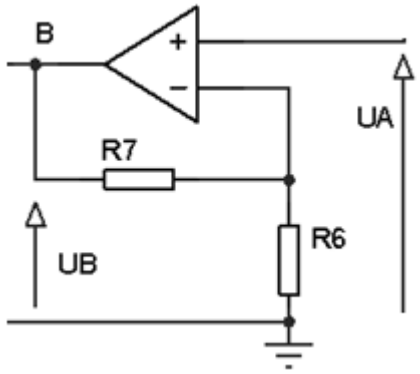
$$U_A = -R_3\left(\frac{V_1}{R_1} + \frac{V_2}{R_2}\right) \quad \Rightarrow \quad U_A = -10\left(\frac{1V}{10} + \frac{1V}{10}\right)$$ **U_A = -2V**

2.

$$U_A = \frac{\frac{v^-}{R_3} + \frac{U_{s1}}{R_4} + I^+}{\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}} \quad v^- = v^+ = 0 \text{ et } I^+ = 0 \quad \Rightarrow \quad U_A = \frac{\frac{U_{s1}}{R_4}}{\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}}$$

$$U_{s1} = R_4\left(\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5}\right)U_A \quad \Rightarrow \quad U_{s1} = 10\left(\frac{1}{10} + \frac{1}{10} + \frac{1}{10}\right)x\,(-2V)$$ **U_{S1} = -6V**

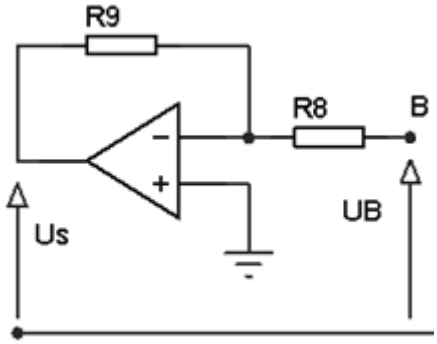
3.



$$\frac{U_B}{U_A} = 1 + \frac{R_7}{R_6}$$

$$\frac{U_B}{U_A} = 2$$

Montage non inverseur



$$\frac{U_S}{U_B} = -\frac{R_9}{R_8}$$

$$\frac{U_S}{U_B} = -1$$

Montage inverseur

4.

$$\frac{U_S}{U_A} = \frac{U_S}{U_B} x \frac{U_B}{U_A} = 2x(-1)$$

$$\frac{U_S}{U_A} = -2$$

$U_S = -2U_A = -2 \times (-2V)$

$U_S = 4V$