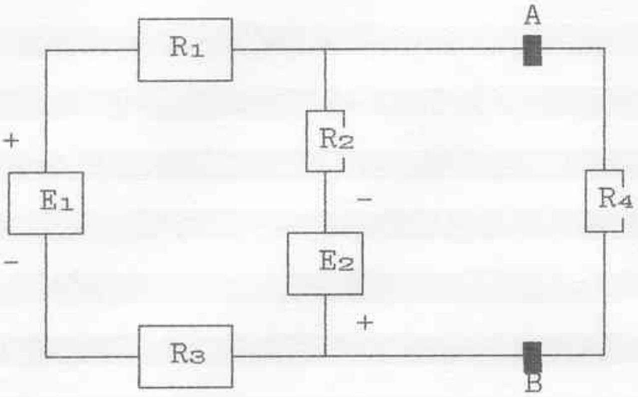
6.1 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

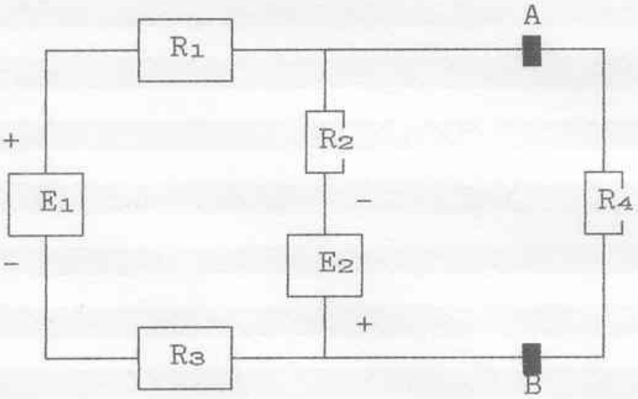


$E_1 = 16$ V ; $E_2 = 8$ V

$R_1 = 2$ KΩ ; $R_2 = 2$ KΩ

$R_3 = 1$ KΩ ; $R_4 = 5$ KΩ

6.2 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

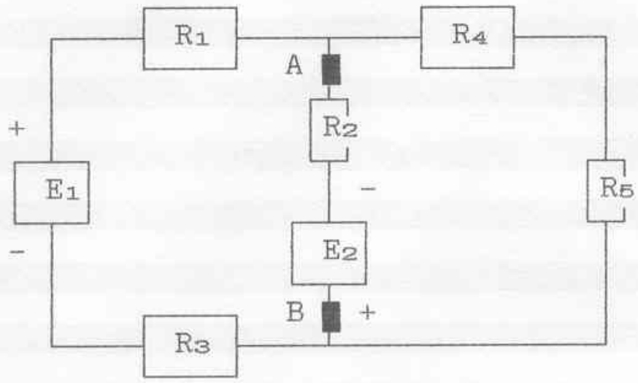


$E_1 = 24$ V ; $E_2 = 12$ V

$R_1 = 1$ KΩ ; $R_2 = 1$ KΩ

$R_3 = 1{,}5$ KΩ ; $R_4 = 3$ KΩ

6.3 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



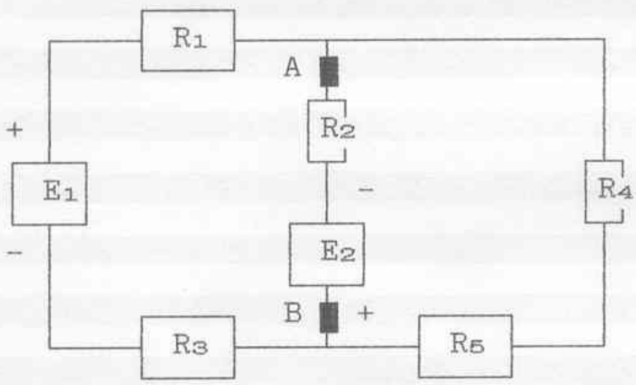
$E_1 = 16\ V$; $E_2 = 8\ V$

$R_1 = 2\ K\Omega$; $R_2 = 2\ K\Omega$

$R_3 = 2\ K\Omega$; $R_4 = 1\ K\Omega$

$R_5 = 1\ K\Omega$

6.4 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



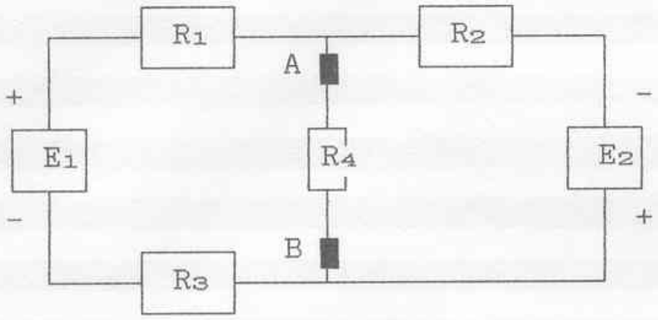
$E_1 = 24\ V$; $E_2 = 12\ V$

$R_1 = 1\ K\Omega$; $R_2 = 1\ K\Omega$

$R_3 = 3\ K\Omega$; $R_4 = 1{,}5\ K\Omega$

$R_5 = 2{,}5\ K\Omega$

6.5 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

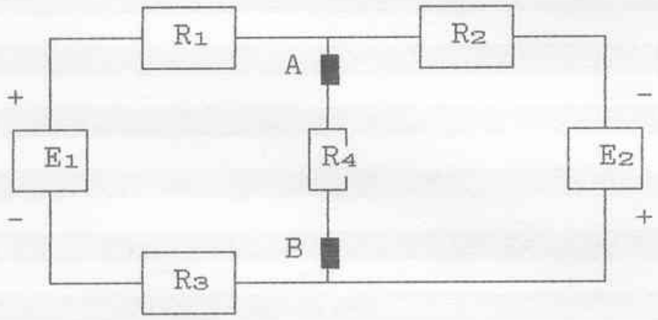


$E_1 = 12\ V$; $E_2 = 8\ V$

$R_1 = 2\ K\Omega$; $R_2 = 4\ K\Omega$

$R_3 = 1\ K\Omega$; $R_4 = 4\ K\Omega$

6.6 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

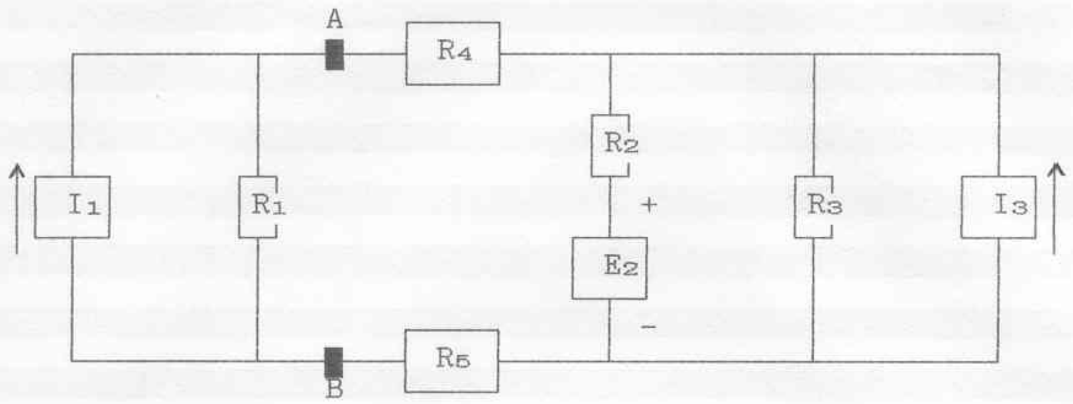


$E_1 = 24\ V$; $E_2 = 12\ V$

$R_1 = 1\ K\Omega$; $R_2 = 2\ K\Omega$

$R_3 = 2\ K\Omega$; $R_4 = 3\ K\Omega$

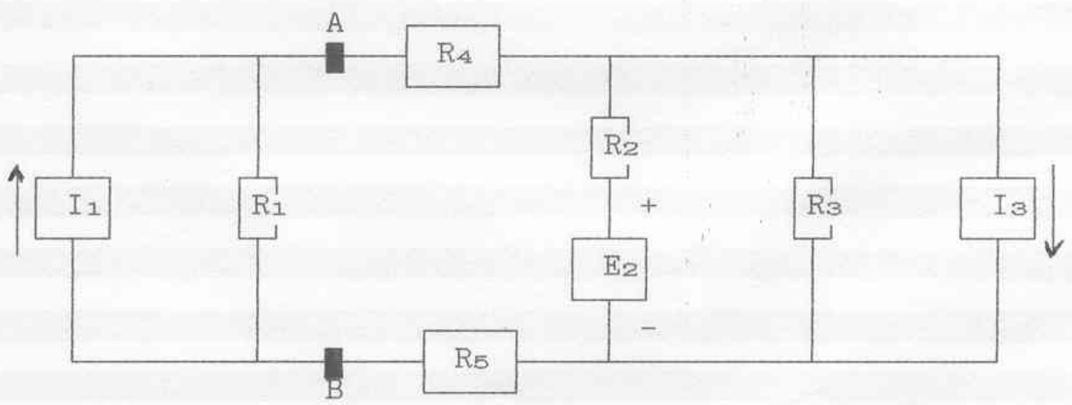
6.7 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$I_1 = 5$ mA ; $E_2 = 10$ V ; $I_3 = 2$ mA ; $R_1 = 2$ KΩ

$R_2 = 1$ KΩ ; $R_3 = 4$ KΩ ; $R_4 = 1$ KΩ ; $R_5 = 4$ KΩ

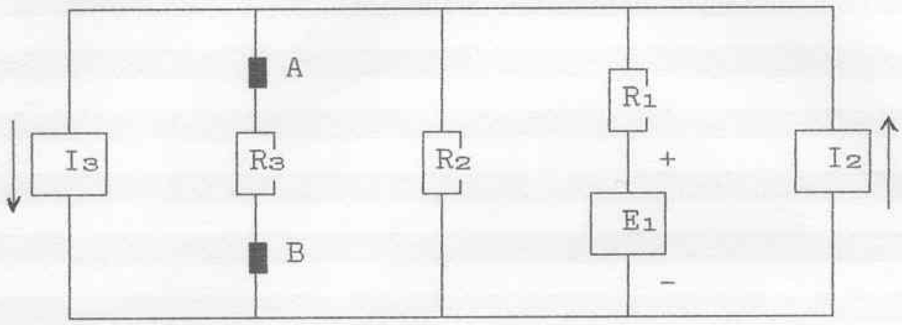
6.8 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$I_1 = 6$ mA ; $E_2 = 8$ V ; $I_3 = 3$ mA ; $R_1 = 1$ KΩ

$R_2 = 1$ KΩ ; $R_3 = 3$ KΩ ; $R_4 = 2$ KΩ ; $R_5 = 3$ KΩ

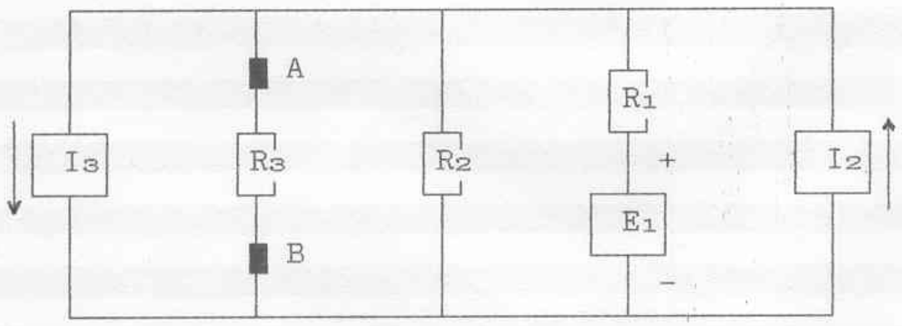
6.9 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



E_1 = 10 V ; I_2 = 4 mA ; I_3 = 3 mA ; R_1 = 1 KΩ

R_2 = 3 KΩ ; R_3 = 6 KΩ

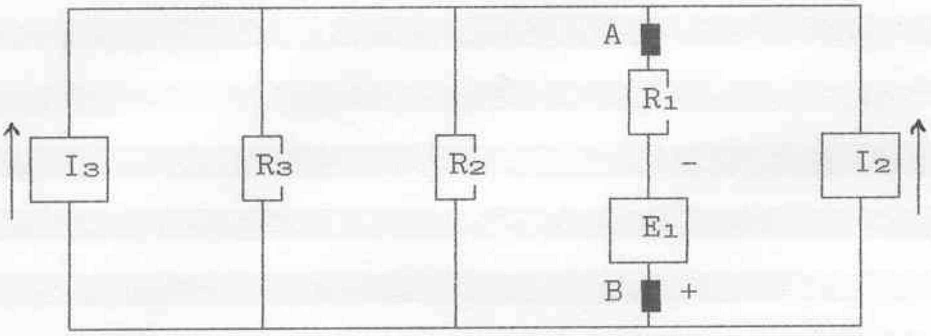
6.10 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



E_1 = 12 V ; I_2 = 3 mA ; I_3 = 1 mA ; R_1 = 2 KΩ

R_2 = 1 KΩ ; R_3 = 3 KΩ

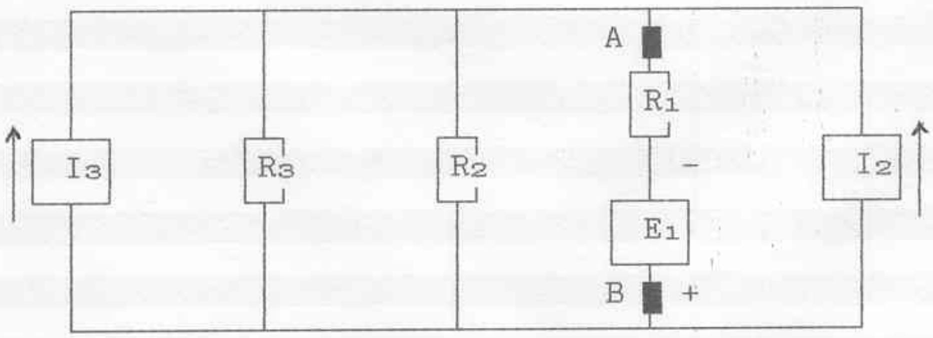
6.11 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$E_1 = 8$ V ; $I_2 = 10$ mA ; $I_3 = 5$ mA ; $R_1 = 3$ KΩ

$R_2 = 6$ KΩ ; $R_3 = 2$ KΩ

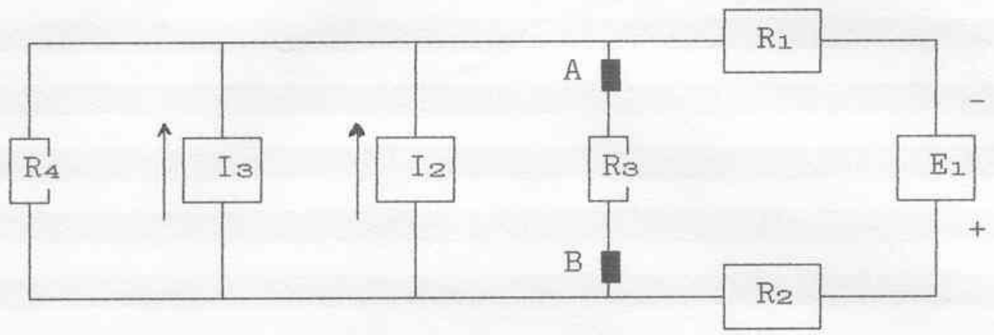
6.12 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$E_1 = 12$ V ; $I_2 = 4$ mA ; $I_3 = 2$ mA ; $R_1 = 10$ KΩ

$R_2 = 12$ KΩ ; $R_3 = 8$ KΩ

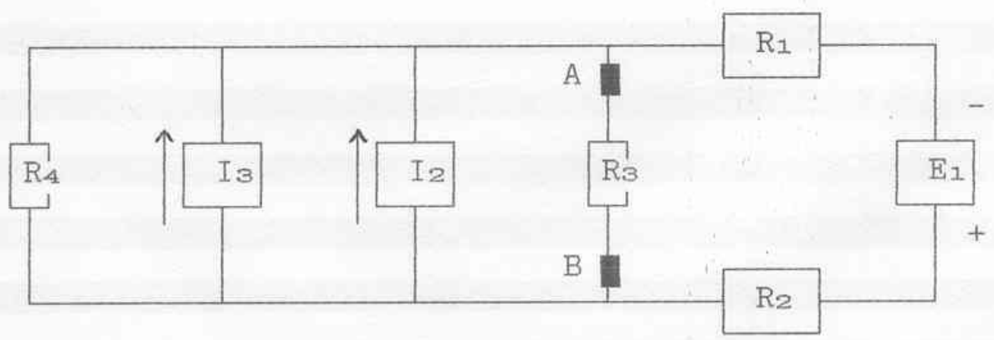
6.13 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$E_1 = 10\ V$; $I_2 = 2\ mA$; $I_3 = 5\ mA$; $R_1 = 3\ K\Omega$

$R_2 = 2\ K\Omega$; $R_3 = 5\ K\Omega$; $R_4 = 1\ K\Omega$

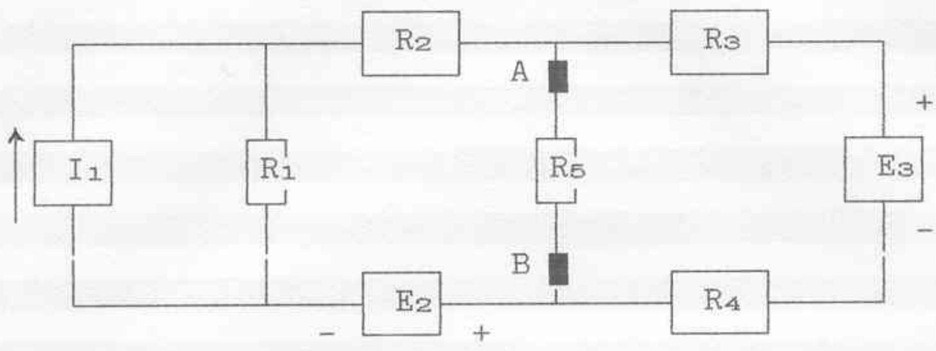
6.14 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$E_1 = 12\ V$; $I_2 = 2\ mA$; $I_3 = 3\ mA$; $R_1 = 5\ K\Omega$

$R_2 = 3\ K\Omega$; $R_3 = 2\ K\Omega$; $R_4 = 4\ K\Omega$

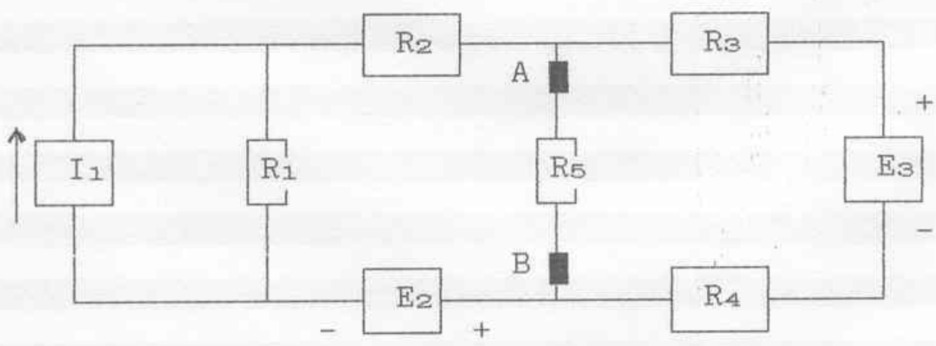
6.15 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$I_1 = 8$ mA ; $E_2 = 6$ V ; $E_3 = 4$ V ; $R_1 = 1{,}5$ KΩ

$R_2 = 1$ KΩ ; $R_3 = 2$ KΩ ; $R_4 = 1$ KΩ ; $R_5 = 8$ KΩ

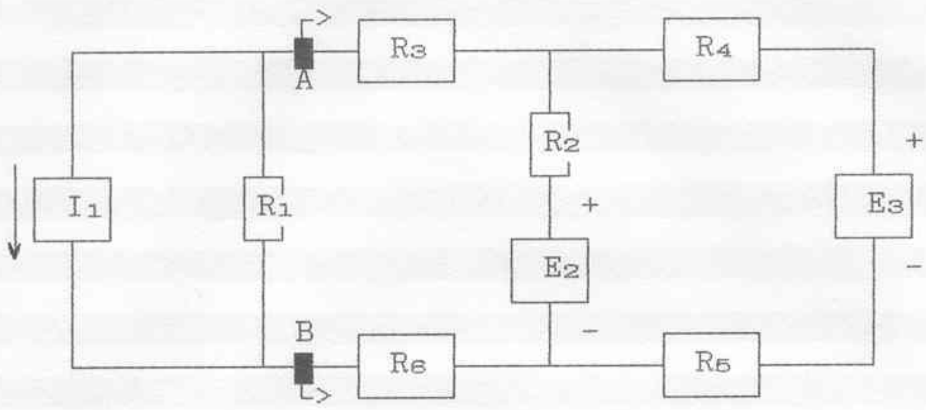
6.16 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$I_1 = 6$ mA ; $E_2 = 3$ V ; $E_3 = 8$ V ; $R_1 = 2$ KΩ

$R_2 = 2$ KΩ ; $R_3 = 1$ KΩ ; $R_4 = 3$ KΩ ; $R_5 = 5$ KΩ

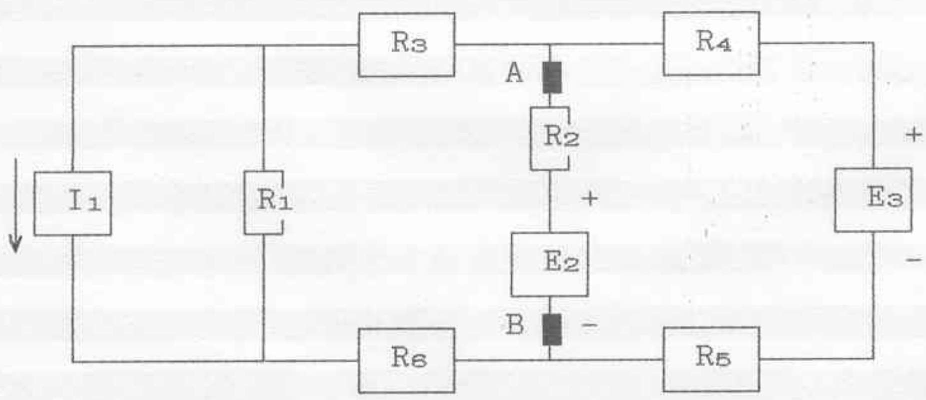
6.17 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$I_1 = 5$ mA ; $E_2 = 6$ V ; $E_3 = 4$ V ; $R_1 = 1{,}6$ KΩ ; $R_2 = 1$ KΩ

$R_3 = 2$ KΩ ; $R_4 = 1{,}5$ KΩ ; $R_5 = 2{,}5$ KΩ ; $R_6 = 3$ KΩ

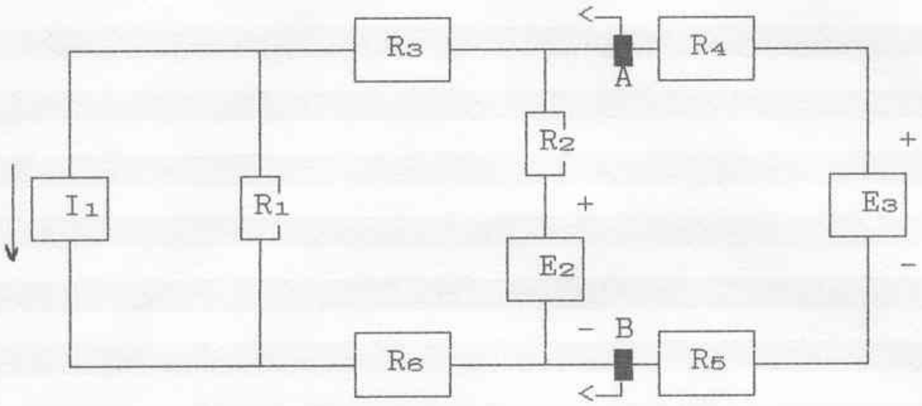
6.18 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$I_1 = 5$ mA ; $E_2 = 6$ V ; $E_3 = 4$ V ; $R_1 = 1{,}6$ KΩ ; $R_2 = 1$ KΩ

$R_3 = 2$ KΩ ; $R_4 = 1{,}5$ KΩ ; $R_5 = 2{,}5$ KΩ ; $R_6 = 3$ KΩ

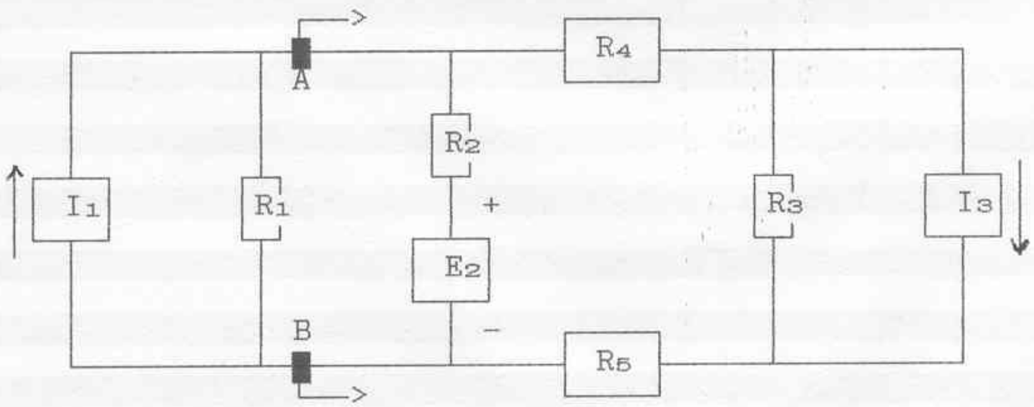
6.19 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$I_1 = 5\ mA$; $E_2 = 6\ V$; $E_3 = 4\ V$; $R_1 = 1,6\ K\Omega$; $R_2 = 1\ K\Omega$

$R_3 = 2\ K\Omega$; $R_4 = 1,5\ K\Omega$; $R_5 = 2,5\ K\Omega$; $R_6 = 3\ K\Omega$

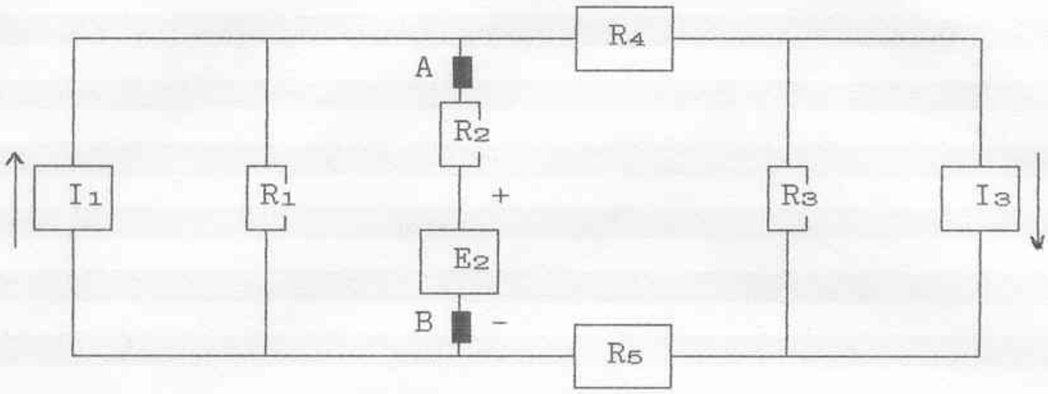
6.20 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$I_1 = 6\ mA$; $E_2 = 6\ V$; $I_3 = 8\ mA$; $R_1 = 1,5\ K\Omega$

$R_2 = 2,5\ K\Omega$; $R_3 = 1\ K\Omega$; $R_4 = 2\ K\Omega$; $R_5 = 1\ K\Omega$

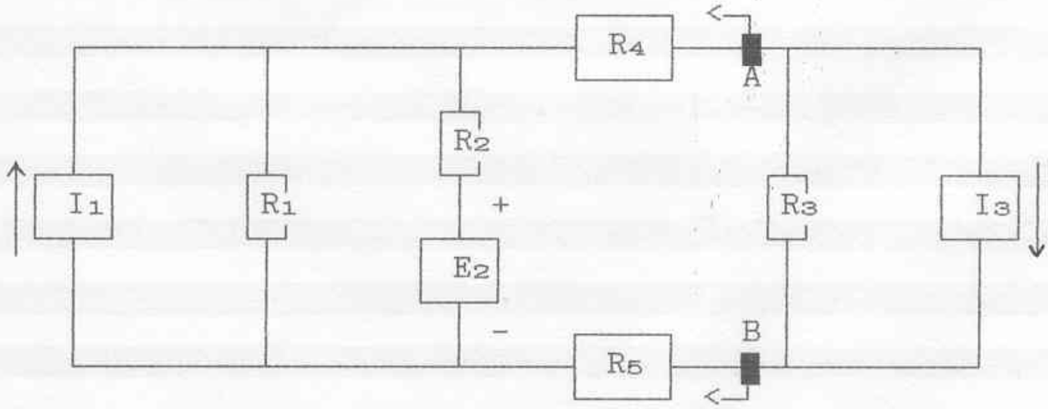
6.21 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



I_1 = 6 mA ; E_2 = 6 V ; I_3 = 8 mA ; R_1 = 1,5 KΩ

R_2 = 2,5 KΩ ; R_3 = 1 KΩ ; R_4 = 2 KΩ ; R_5 = 1 KΩ

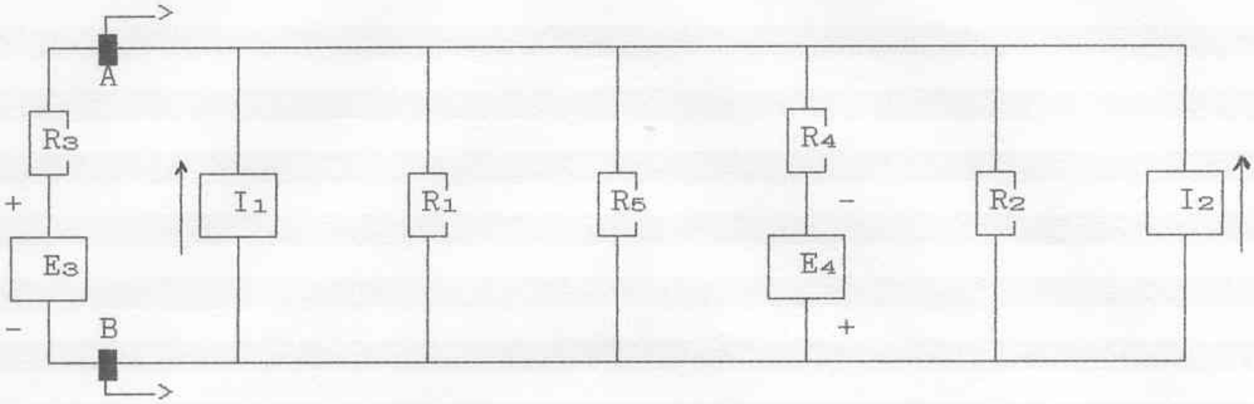
6.22 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



I_1 = 6 mA ; E_2 = 6 V ; I_3 = 8 mA ; R_1 = 1,5 KΩ

R_2 = 2,5 KΩ ; R_3 = 1 KΩ ; R_4 = 2 KΩ ; R_5 = 1 KΩ

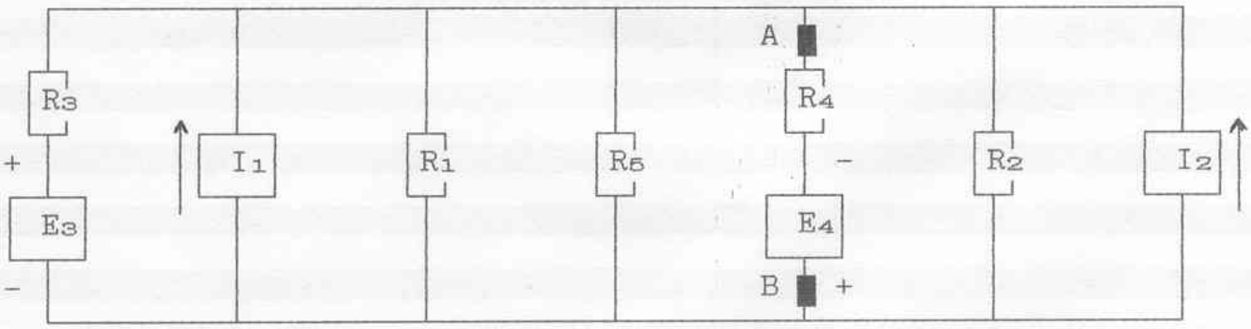
6.23 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



I_1 = 6 mA ; I_2 = 10 mA ; E_3 = 8 V ; E_4 = 10 V

R_1 = 2,5 KΩ ; R_2 = 1 KΩ ; R_3 = 2,5 KΩ ; R_4 = 4 KΩ ; R_5 = 5 KΩ

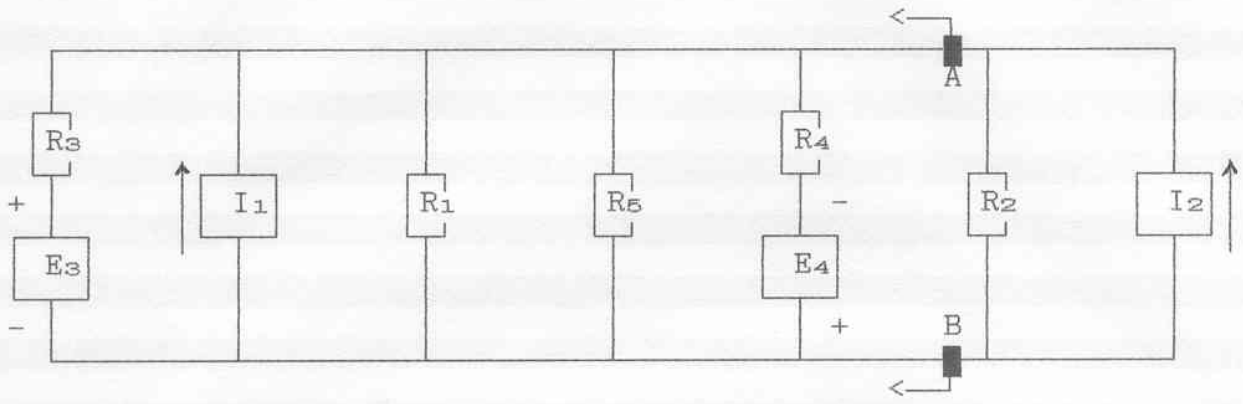
6.24 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



I_1 = 6 mA ; I_2 = 10 mA ; E_3 = 8 V ; E_4 = 10 V

R_1 = 2,5 KΩ ; R_2 = 1 KΩ ; R_3 = 2,5 KΩ ; R_4 = 4 KΩ ; R_5 = 5 KΩ

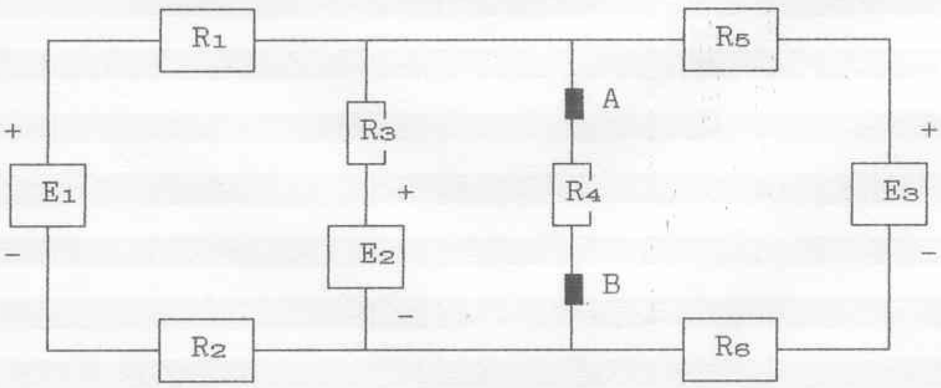
6.25 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



I_1 = 6 mA ; I_2 = 10 mA ; E_3 = 8 V ; E_4 = 10 V

R_1 = 2,5 KΩ ; R_2 = 1 KΩ ; R_3 = 2,5 KΩ ; R_4 = 4 KΩ ; R_5 = 5 KΩ

6.26 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



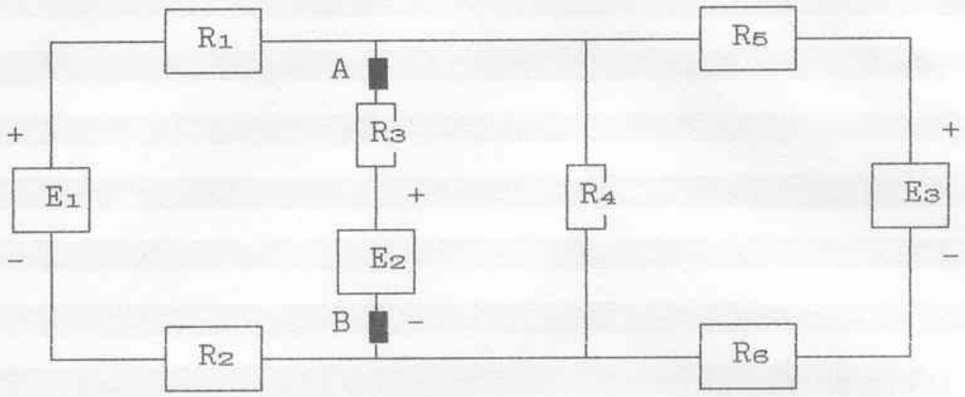
1.- $E_1 = E_2 = E_3$ = 10 V ; $R_1 = R_3 = R_5$ = 2 KΩ ; $R_2 = R_4 = R_6$ = 3 KΩ

2.- $E_1 = E_2 = E_3$ = 6 V ; $R_1 = R_3 = R_5$ = 3 KΩ ; $R_2 = R_4 = R_6$ = 2 KΩ

3.- $E_1 = E_2 = E_3$ = 8 V ; $R_1 = R_3 = R_5$ = 2 KΩ ; $R_2 = R_4 = R_6$ = 4 KΩ

4.- $E_1 = E_2 = E_3$ = 12 V ; $R_1 = R_3 = R_5$ = 3 KΩ ; $R_2 = R_4 = R_6$ = 5 KΩ

6.27 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



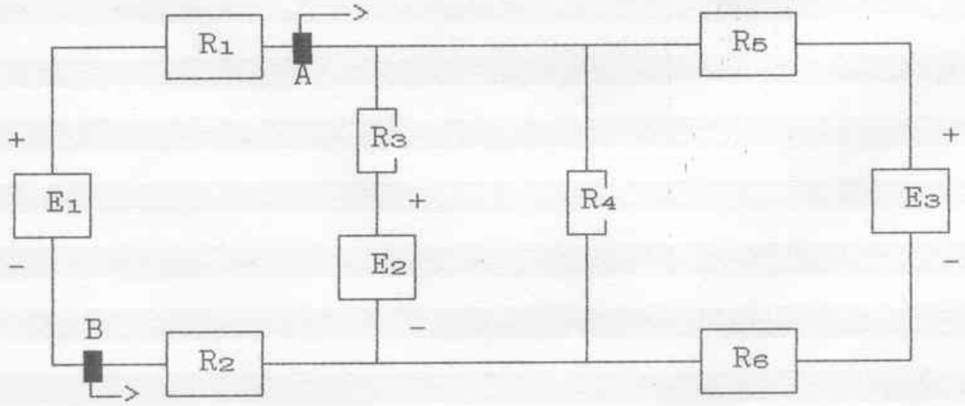
1.- $E_1 = E_2 = E_3 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = E_3 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = E_3 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = E_3 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.28 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



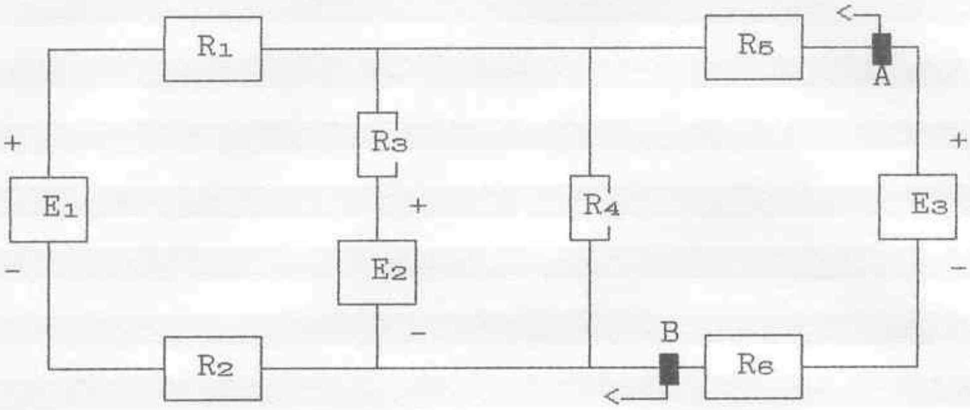
1.- $E_1 = E_2 = E_3 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = E_3 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = E_3 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = E_3 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.29 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



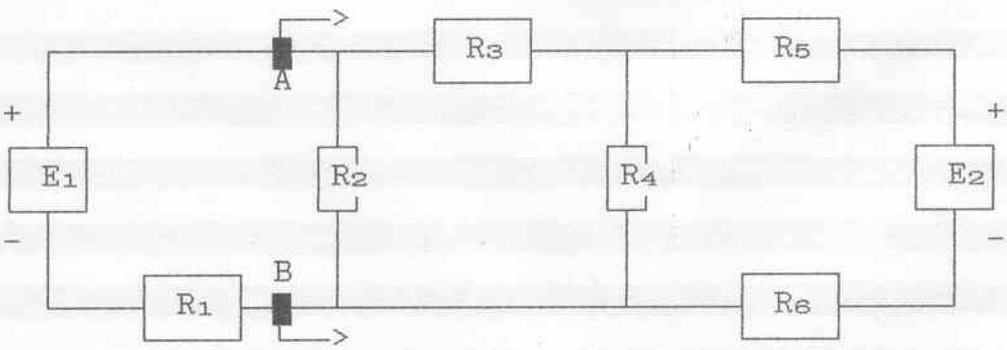
1.- $E_1 = E_2 = E_3 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = E_3 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = E_3 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = E_3 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.30 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



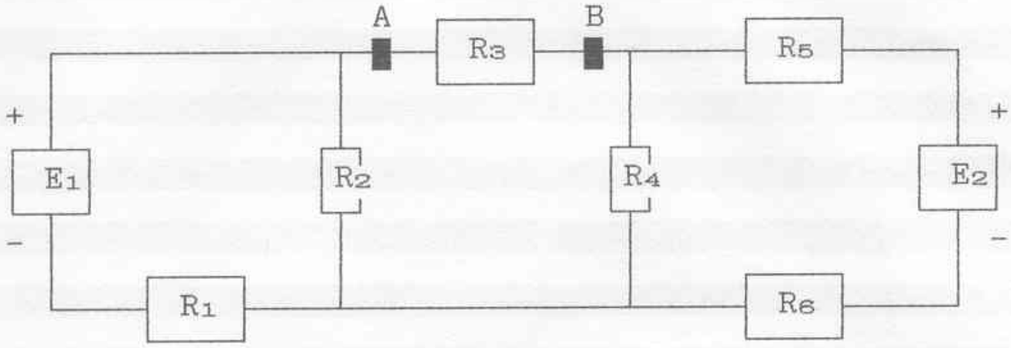
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.31 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



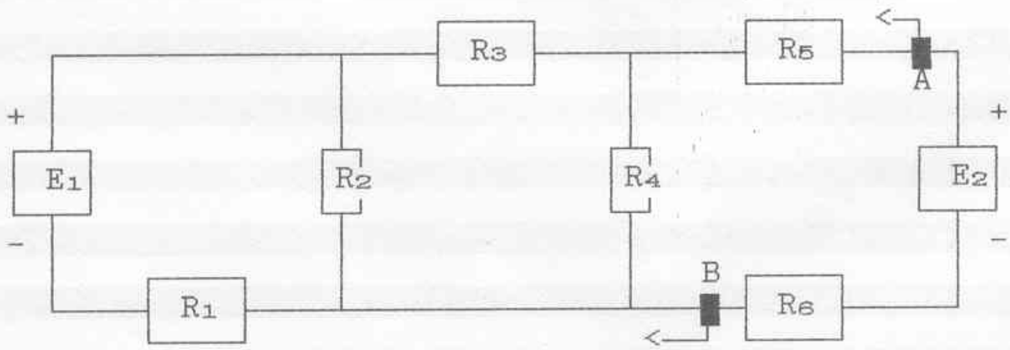
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.32 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



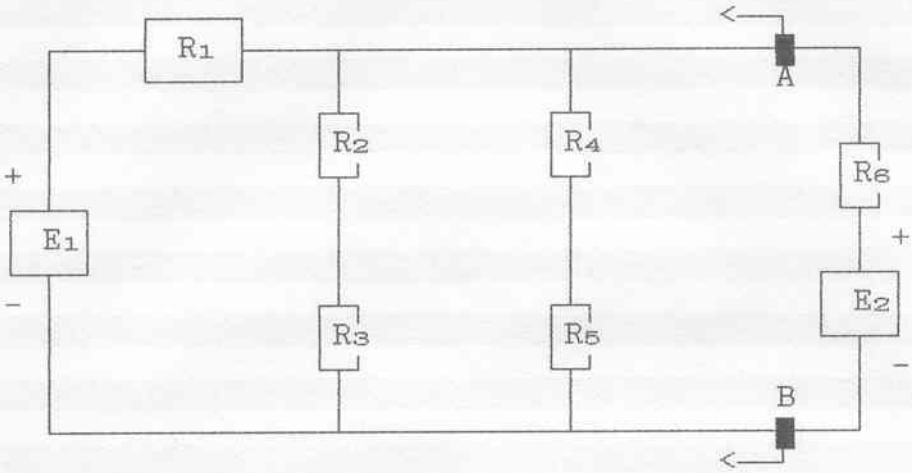
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.33 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



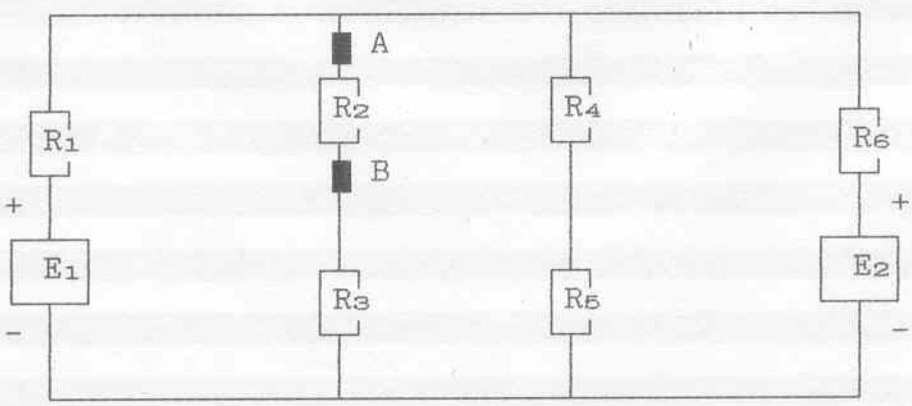
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.34 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

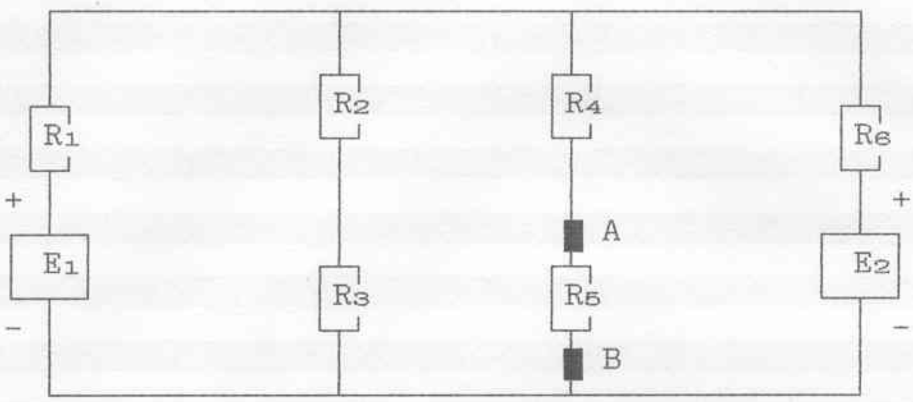


1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

6.35 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



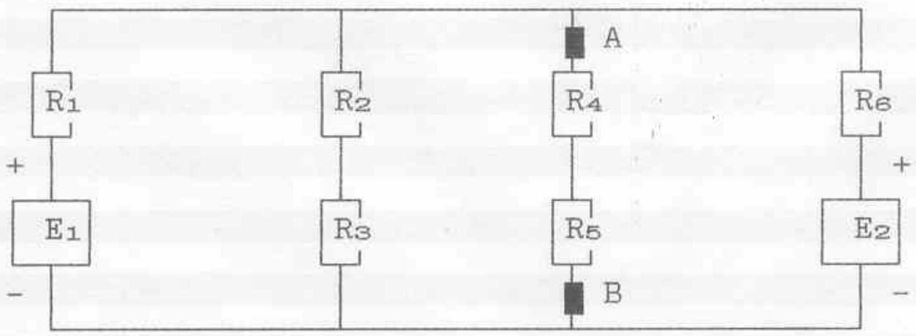
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.36 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



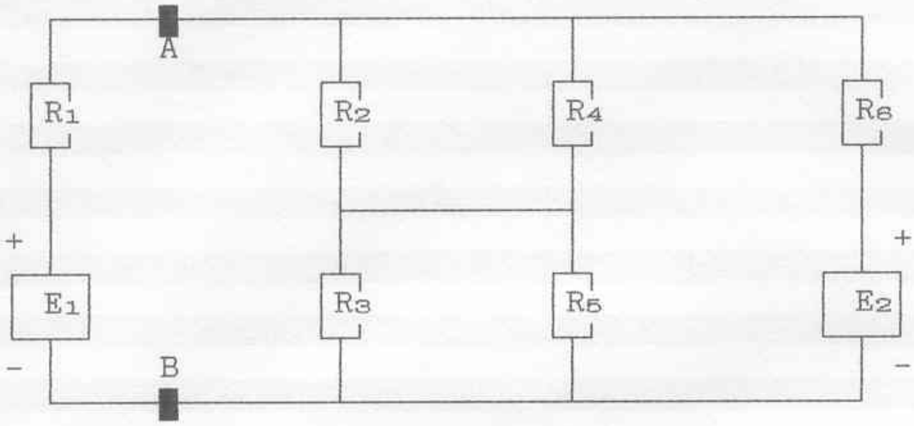
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.37 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



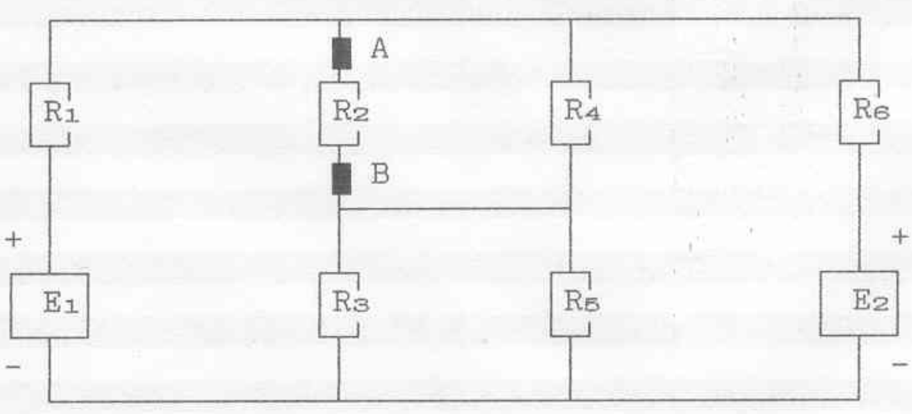
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.38 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



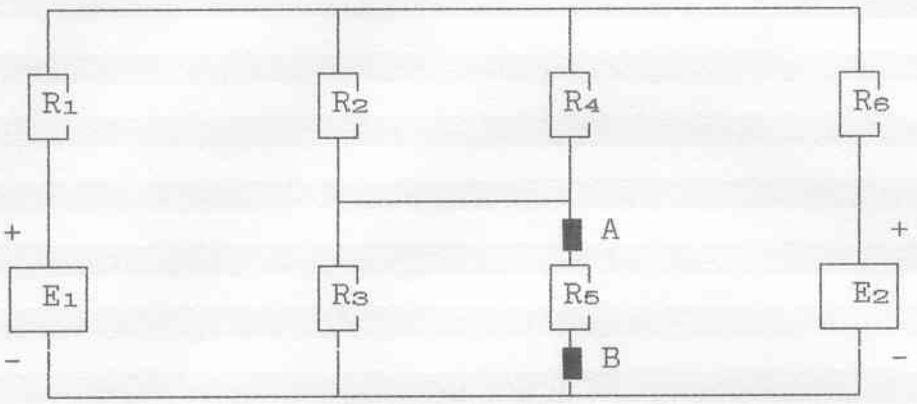
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.39 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



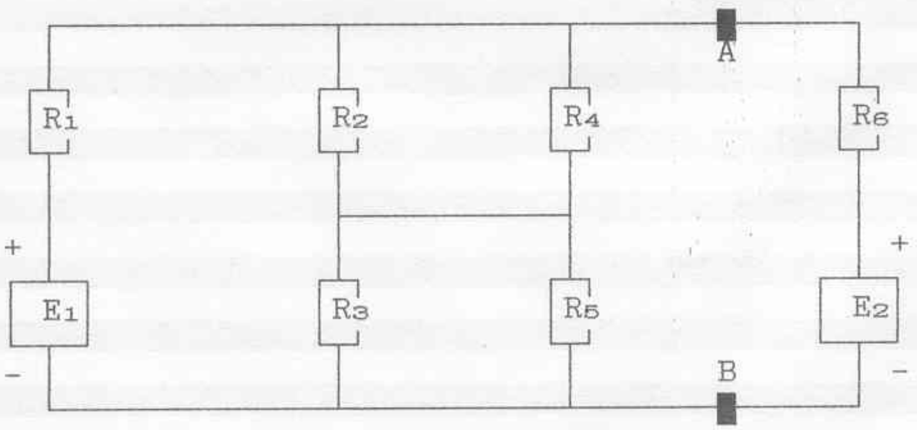
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.40 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



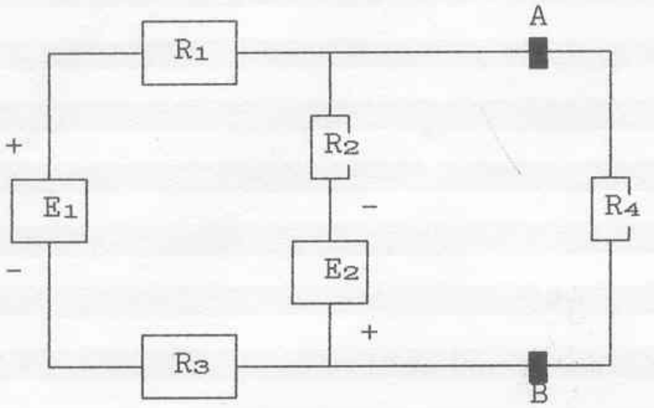
1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

6.1 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



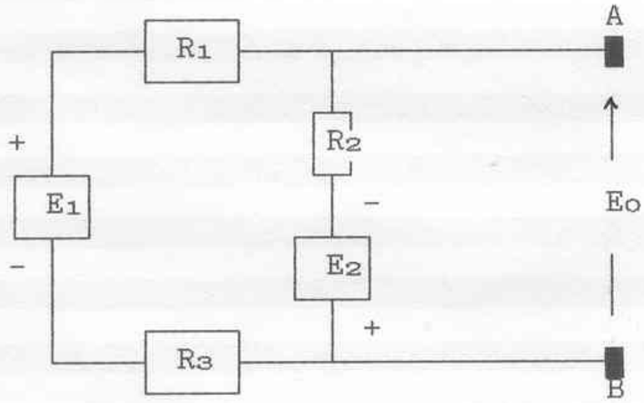
$E_1 = 16\ V \quad ; \quad E_2 = 8\ V$

$R_1 = 2\ K\Omega \quad ; \quad R_2 = 2\ K\Omega$

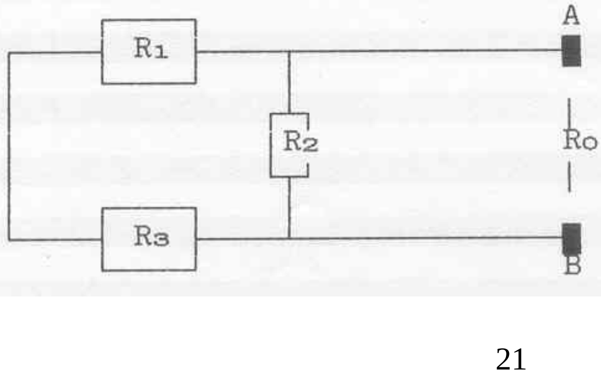
$R_3 = 1\ K\Omega \quad ; \quad R_4 = 5\ K\Omega$

RISOLUZIONE

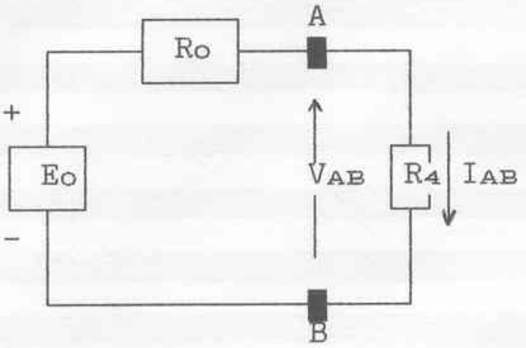
- Teorema di Thèvenin



$$E_o = \frac{\dfrac{E_1}{R_1 + R_3} - \dfrac{E_2}{R_2}}{\dfrac{1}{R_1 + R_3} + \dfrac{1}{R_2}} = \frac{\dfrac{16}{2*10^3 + 1*10^3} - \dfrac{8}{2*10^3}}{\dfrac{1}{2*10^3 + 1*10^3} + \dfrac{1}{2*10^3}} = 1,6\ V$$



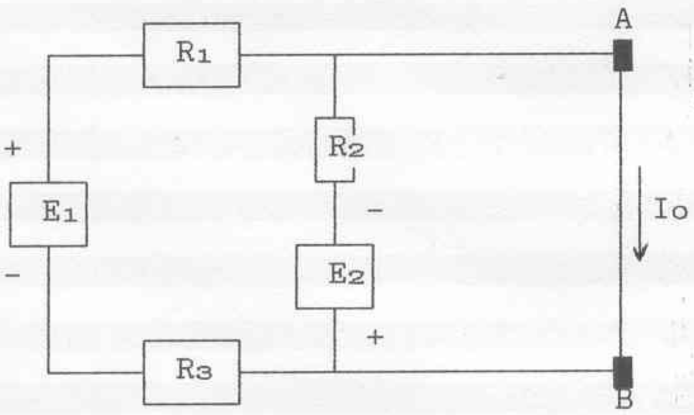
$$R_0 = \frac{R_2 * (R_1 + R_3)}{R_2 + R_1 + R_3} = \frac{2*10^3 * (2*10^3 + 1*10^3)}{2*10^3 + 2*10^3 + 1*10^3} = 1,2\ K\Omega$$



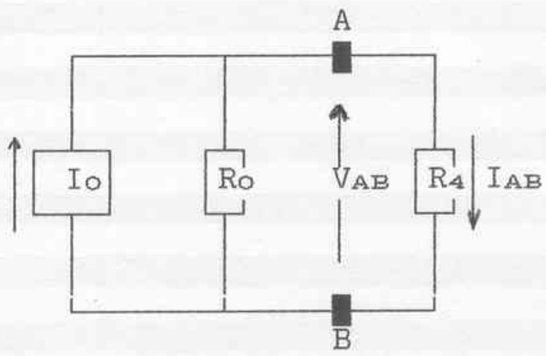
$$I_{AB} = \frac{E_0}{R_0 + R_4} = \frac{1,6}{1,2*10^3 + 5*10^3} = 0,258\ mA$$

$$V_{AB} = R_4 * I_{AB} = 5*10^3 * 0,258*10^{-3} = 1,29\ V$$

- <u>Teorema di Norton</u>



$$I_0 = \frac{E_1}{R_1 + R_3} - \frac{E_2}{R_2} = \frac{16}{2*10^3 + 1*10^3} - \frac{8}{2*10^3} = 1,33\ mA$$

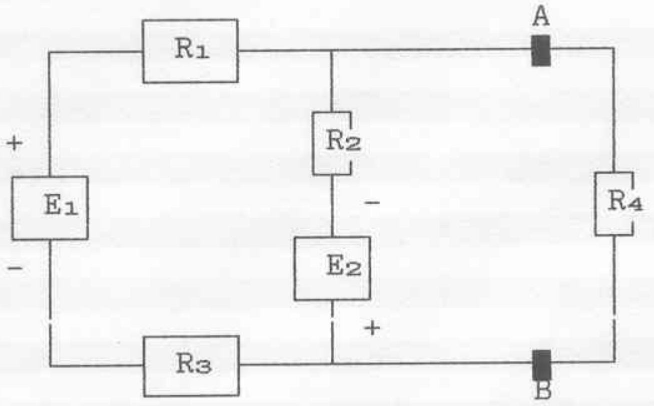


$$R_{O4} = \frac{R_O * R_4}{R_O + R_4} = \frac{1,2*10^3 * 5*10^3}{1,2*10^3 + 5*10^3} = 0,968\ K\Omega$$

$$V_{AB} = R_{O4} * I_O = 0,968*10^3 * 1,33*10^{-3} = 1,29\ V$$

$$I_{AB} = \frac{V_{AB}}{R_4} = \frac{1,29}{5*10^3} = 0,258\ mA$$

6.2 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



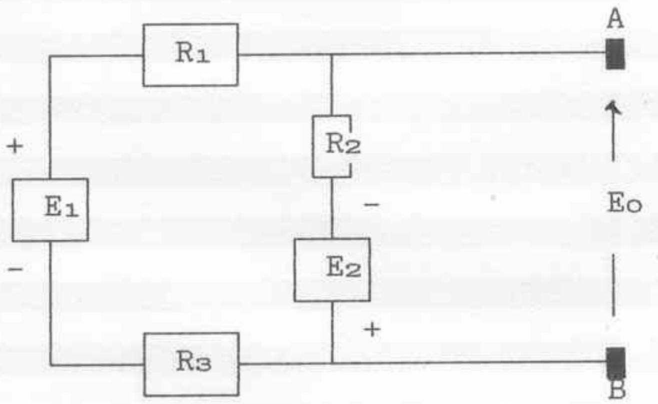
$E_1 = 24\ V$; $E_2 = 12\ V$

$R_1 = 1\ K\Omega$; $R_2 = 1\ K\Omega$

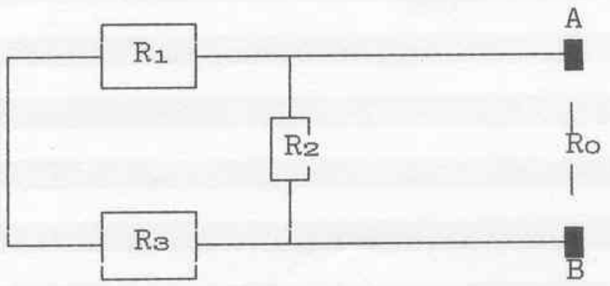
$R_3 = 1{,}5\ K\Omega$; $R_4 = 3\ K\Omega$

RISOLUZIONE

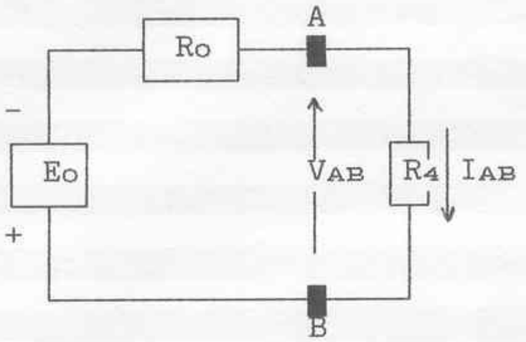
- Teorema di Thèvenin



$$E_o = \frac{\dfrac{E_1}{R_1 + R_3} - \dfrac{E_2}{R_2}}{\dfrac{1}{R_1 + R_3} + \dfrac{1}{R_2}} = \frac{\dfrac{24}{1*10^3 + 1{,}5*10^3} - \dfrac{12}{1*10^3}}{\dfrac{1}{1*10^3 + 1{,}5*10^3} + \dfrac{1}{1*10^3}} = -\ 1{,}71\ V$$



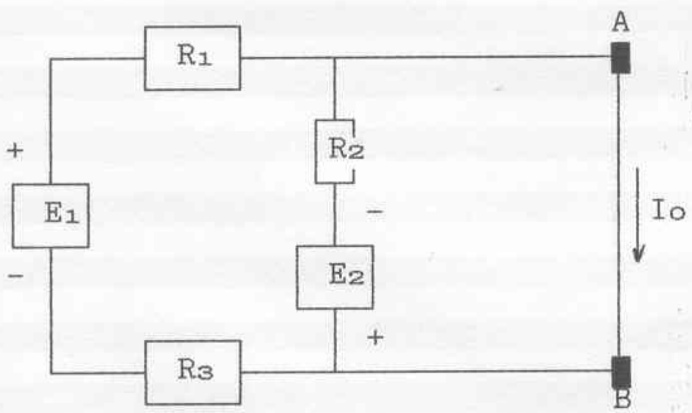
$$R_O = \frac{R_2 * (R_1 + R_3)}{R_2 + R_1 + R_3} = \frac{1*10^3 * (1*10^3 + 1,5*10^3)}{1*10^3 + 1*10^3 + 1,5*10^3} = 0,71\ K\Omega$$



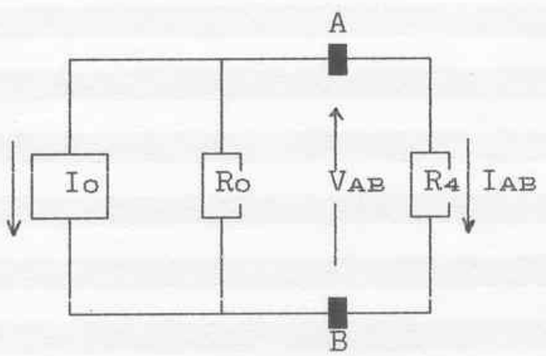
$$I_{AB} = \frac{E_O}{R_O + R_4} = \frac{-1,71}{0,71*10^3 + 3*10^3} = -0,46\ mA$$

$$V_{AB} = R_4 * I_{AB} = 3*10^3 * (-0,46*10^{-3}) = -1,38\ V$$

- Teorema di Norton



$$I_O = \frac{E_1}{R_1 + R_3} - \frac{E_2}{R_2} = \frac{24}{1*10^3 + 1,5*10^3} - \frac{12}{1*10^3} = -2,4\ mA$$

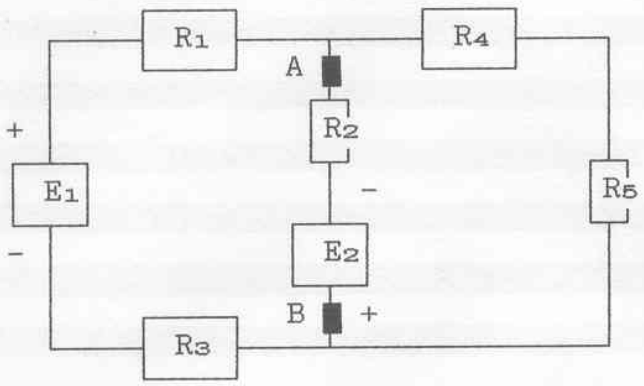


$$R_{O4} = \frac{R_O * R_4}{R_O + R_4} = \frac{0,71*10^3 * 3*10^3}{0,71*10^3 + 3*10^3} = 0,574\ K\Omega$$

$$V_{AB} = R_{O4} * I_O = 0,574*10^3 * (-\ 2,4*10^{-3}) = -\ 1,38\ V$$

$$I_{AB} = \frac{V_{AB}}{R_4} = \frac{-\ 1,29}{5*10^3} = -\ 0,46\ mA$$

6.3 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$E_1 = 16$ V ; $E_2 = 8$ V

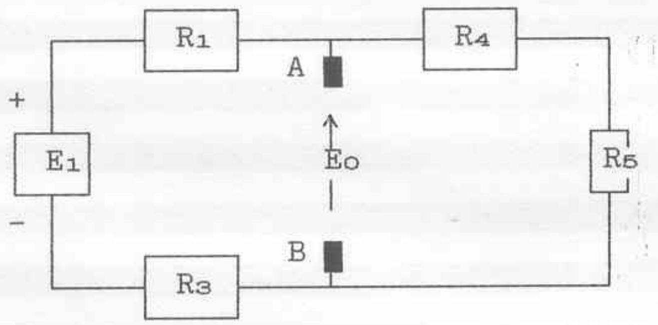
$R_1 = 2$ KΩ ; $R_2 = 2$ KΩ

$R_3 = 2$ KΩ ; $R_4 = 1$ KΩ

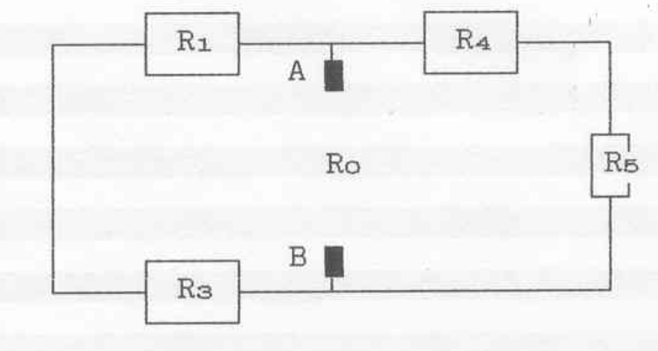
$R_5 = 1$ KΩ

RISOLUZIONE

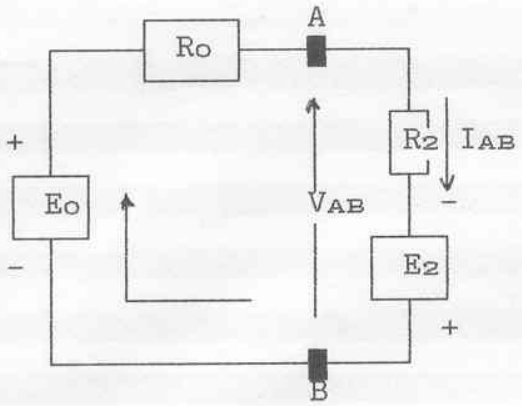
- Teorema di Thèvenin



$$E_o = \frac{R_4 + R_5}{R_1 + R_3 + R_4 + R_5} * E_1 = \frac{1*10^3 + 1*10^3}{2*10^3 + 2*10^3 + 1*10^3 + 1*10^3} * 16 = 5,33 \text{ V}$$



$$R_o = \frac{(R_1 + R_3) * (R_4 + R_5)}{R_1 + R_3 + R_4 + R_5} = \frac{4*10^3 * 2*10^3}{4*10^3 + 2*10^3} = 1,33 \text{ KΩ}$$

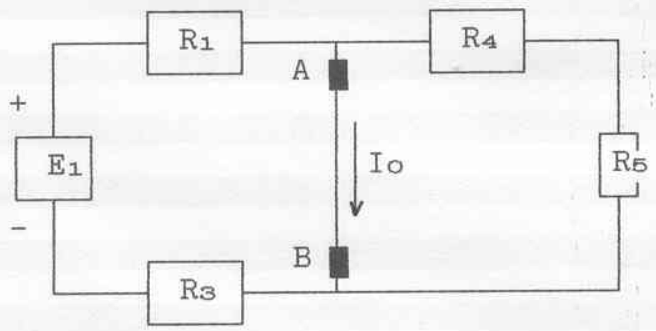


$$E_O + E_2 = (R_O + R_2) * I_{AB} \quad ==>$$

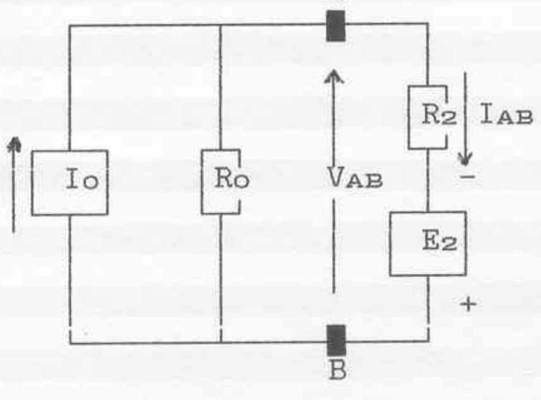
$$==> \quad I_{AB} = \frac{E_O + E_2}{R_O + R_2} = \frac{5,33 + 8}{1,33*10^3 + 2*10^3} = 4 \text{ mA}$$

$$V_{AB} = R_2 * I_{AB} - E_2 = 2*10^3 * 4*10^{-3} - 8 = 0 \text{ V}$$

- <u>Teorema di Norton</u>



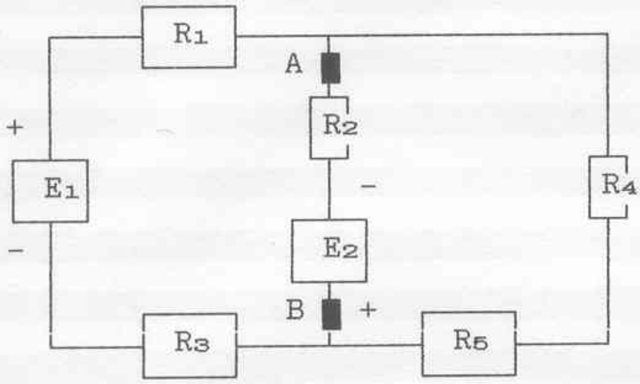
$$I_O = \frac{E_1}{R_1 + R_3} = \frac{16}{2*10^3 + 2*10^3} = 4 \text{ mA}$$



$$V_{AB} = \frac{I_o - \frac{E_2}{R_2}}{\frac{1}{R_o} + \frac{1}{R_2}} = \frac{4*10^{-3} - \frac{8}{2*10^3}}{\frac{1}{2*10^3} + \frac{1}{2*10^3}} = 0$$

$$V_{AB} = R_2 * I_{AB} - E_2 \quad ==> \quad I_{AB} = \frac{E_2 + V_{AB}}{R_2} = \frac{8 - 0}{2*10^3} = 4 \text{ mA}$$

6.4 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



$E_1 = 24$ V ; $E_2 = 12$ V

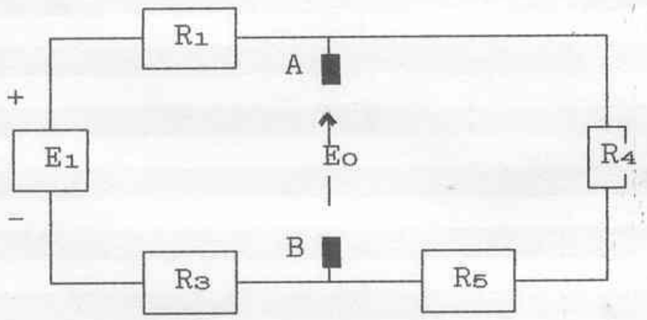
$R_1 = 1$ KΩ ; $R_2 = 1$ KΩ

$R_3 = 3$ KΩ ; $R_4 = 1,5$ KΩ

$R_5 = 2,5$ KΩ

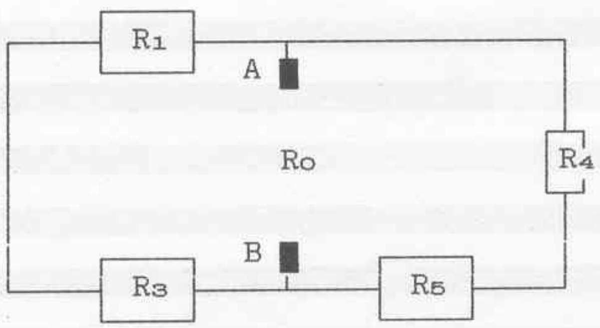
RISOLUZIONE

- Teorema di Thèvenin

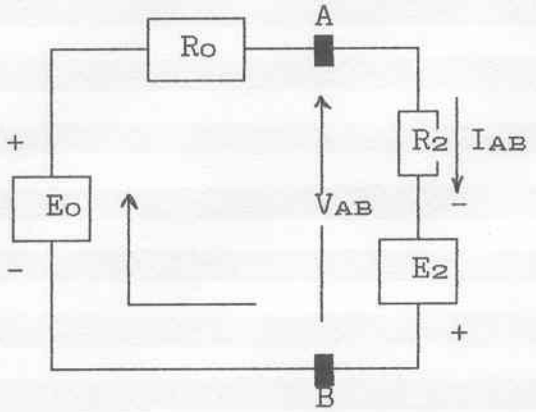


$$E_O = \frac{R_4 + R_5}{R_1 + R_3 + R_4 + R_5} * E_1 =$$

$$= \frac{1,5*10^3 + 2,5*10^3}{1*10^3 + 3*10^3 + 1,5*10^3 + 2,5*10^3} * 24 = 12 \text{ V}$$



$$R_O = \frac{(R_1 + R_3) * (R_4 + R_5)}{R_1 + R_3 + R_4 + R_5} = \frac{4*10^3 * 4*10^3}{4*10^3 + 4*10^3} = 2\ K\Omega$$

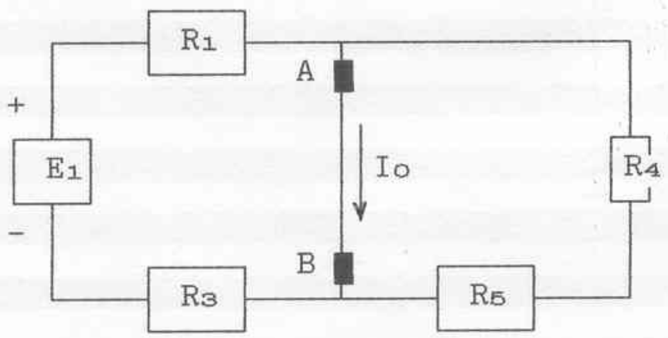


$$E_O + E_2 = (R_O + R_2) * I_{AB} \qquad ==>$$

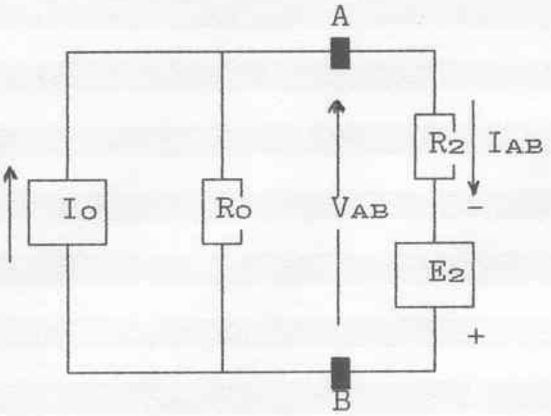
$$==> \quad I_{AB} = \frac{E_O + E_2}{R_O + R_2} = \frac{12 + 12}{2*10^3 + 1*10^3} = 8\ mA$$

$$V_{AB} = R_2 * I_{AB} - E_2 = 1*10^3 * 8*10^{-3} - 12 = - 4\ V$$

- <u>Teorema di Norton</u>



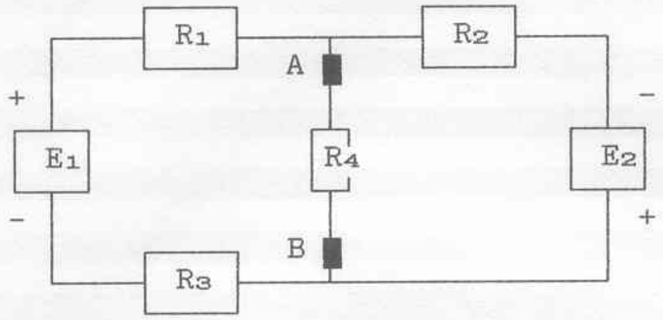
$$I_O = \frac{E_1}{R_1 + R_3} = \frac{24}{1*10^3 + 3*10^3} = 6\ mA$$



$$V_{AB} = \frac{I_o - \dfrac{E_2}{R_2}}{\dfrac{1}{R_o} + \dfrac{1}{R_2}} = \frac{6*10^{-3} - \dfrac{12}{1*10^3}}{\dfrac{1}{2*10^3} + \dfrac{1}{1*10^3}} = -\ 4\ V$$

$$V_{AB} = R_2 * I_{AB} - E_2 \quad ==> \quad I_{AB} = \frac{E_2 + V_{AB}}{R_2} = \frac{12 - 4}{1*10^3} = 8\ mA$$

6.5 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



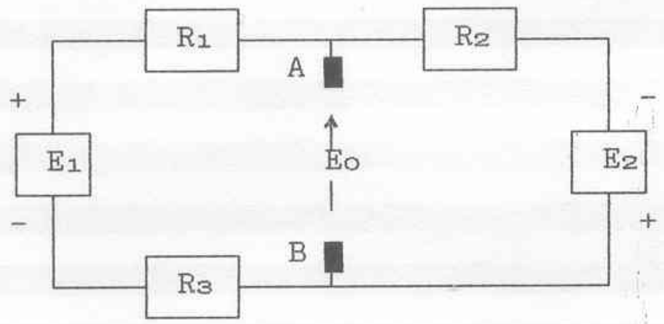
$E_1 = 12\ V$; $E_2 = 8\ V$

$R_1 = 2\ K\Omega$; $R_2 = 4\ K\Omega$

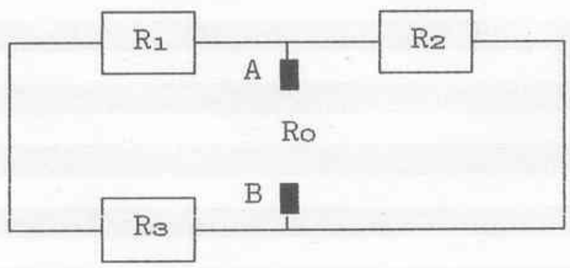
$R_3 = 1\ K\Omega$; $R_4 = 4\ K\Omega$

RISOLUZIONE

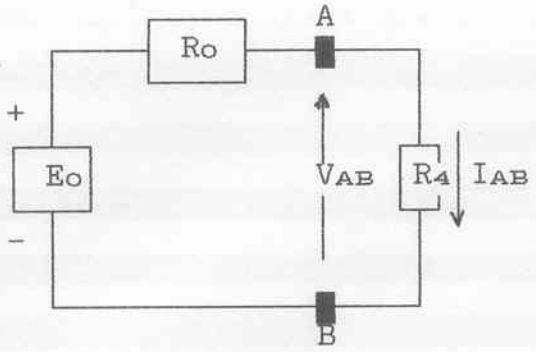
- Teorema di Thèvenin



$$E_o = \frac{\dfrac{E_1}{R_1 + R_3} - \dfrac{E_2}{R_2}}{\dfrac{1}{R_1 + R_3} + \dfrac{1}{R_2}} = \frac{\dfrac{12}{2*10^3 + 1*10^3} - \dfrac{8}{4*10^3}}{\dfrac{1}{2*10^3 + 1*10^3} + \dfrac{1}{4*10^3}} = 3,428\ V$$



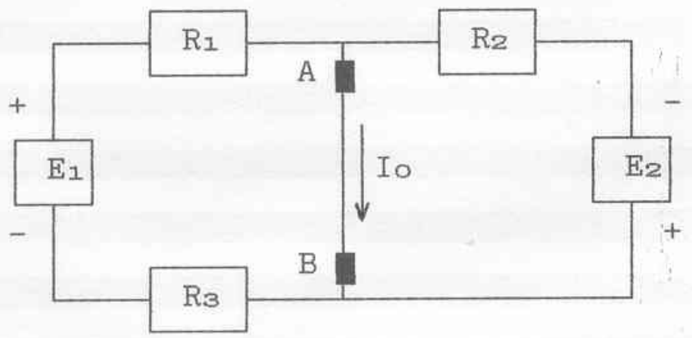
$$R_o = \frac{R_2 * (R_1 + R_3)}{R_2 + R_1 + R_3} = \frac{4*10^3 * (2*10^3 + 1*10^3)}{4*10^3 + 2*10^3 + 1*10^3} = 1,714\ K\Omega$$



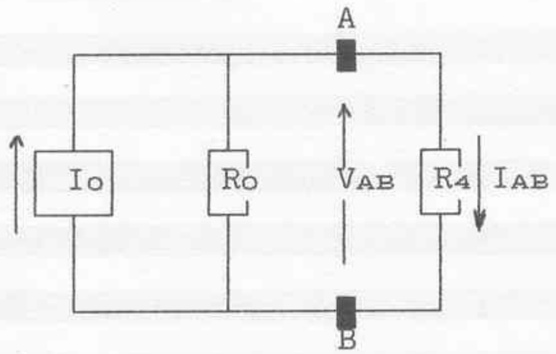
$$I_{AB} = \frac{E_O}{R_O + R_4} = \frac{3,428}{1,71*10^3 + 4*10^3} = 0,6 \text{ mA}$$

$$V_{AB} = R_4 * I_{AB} = 4*10^3 * 0,6*10^{-3} = 2,4 \text{ V}$$

- <u>Teorema di Norton</u>



$$I_O = \frac{E_1}{R_1 + R_3} - \frac{E_2}{R_2} = \frac{12}{2*10^3 + 1*10^3} - \frac{8}{4*10^3} = 2 \text{ mA}$$

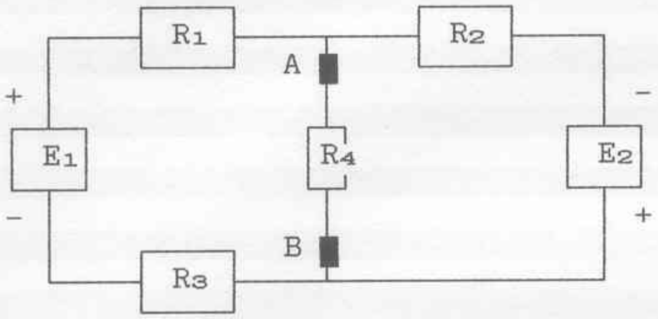


$$R_{O4} = \frac{R_O * R_4}{R_O + R_4} = \frac{1,714*10^3 * 4*10^3}{1,714*10^3 + 4*10^3} = 1,2 \text{ K}\Omega$$

$$V_{AB} = R_{O4} * I_O = 1,2*10^3 * 2*10^{-3} = 2,4 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_4} = \frac{2,4}{4*10^3} = 0,6 \text{ mA}$$

6.6 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



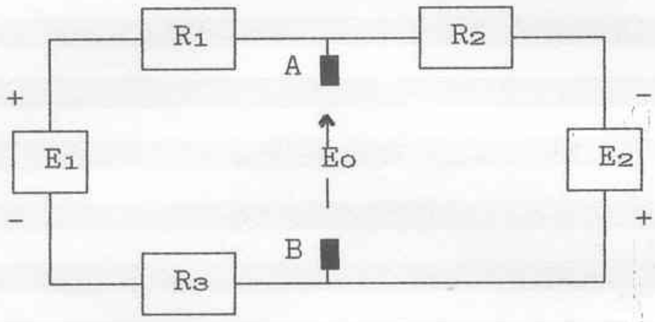
$E_1 = 24\ V$; $E_2 = 12\ V$

$R_1 = 1\ K\Omega$; $R_2 = 2\ K\Omega$

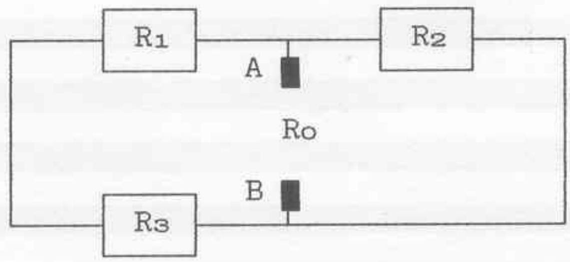
$R_3 = 2\ K\Omega$; $R_4 = 3\ K\Omega$

RISOLUZIONE

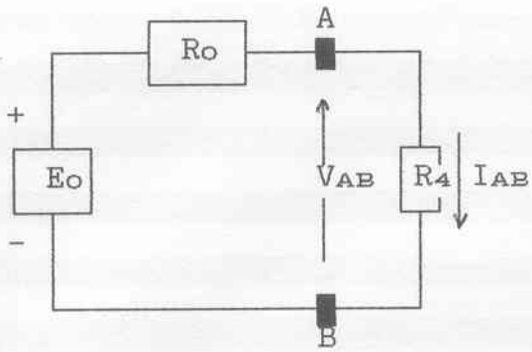
- Teorema di Thèvenin



$$E_o = \frac{\dfrac{E_1}{R_1 + R_3} - \dfrac{E_2}{R_2}}{\dfrac{1}{R_1 + R_3} + \dfrac{1}{R_2}} = \frac{\dfrac{24}{1*10^3 + 2*10^3} - \dfrac{12}{2*10^3}}{\dfrac{1}{1*10^3 + 2*10^3} + \dfrac{1}{2*10^3}} = 2,4\ V$$



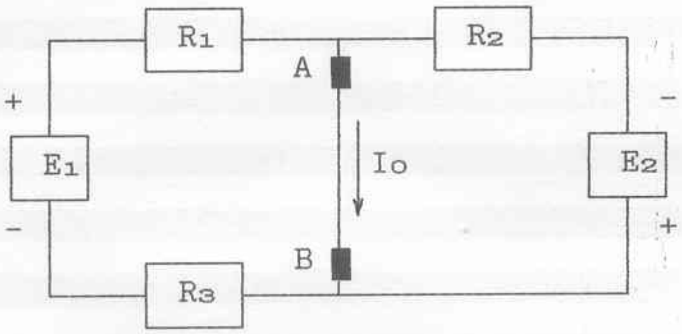
$$R_o = \frac{R_2 * (R_1 + R_3)}{R_2 + R_1 + R_3} = \frac{2*10^3 * (1*10^3 + 2*10^3)}{2*10^3 + 1*10^3 + 2*10^3} = 1,2\ K\Omega$$



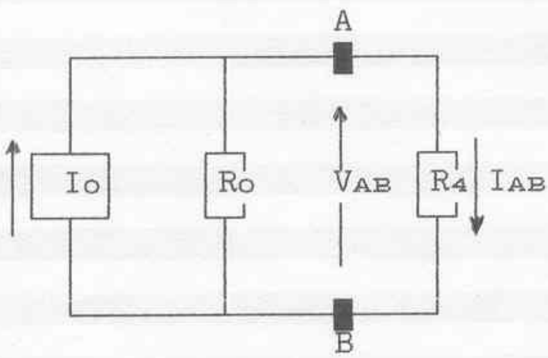
$$I_{AB} = \frac{E_o}{R_o + R_4} = \frac{2}{1,2*10^3 + 3*10^3} = 0,57 \text{ mA}$$

$$V_{AB} = R_4 * I_{AB} = 3*10^3 * 0,57*10^{-3} = 1,71 \text{ V}$$

- <u>Teorema di Norton</u>



$$I_o = \frac{E_1}{R_1 + R_3} - \frac{E_2}{R_2} = \frac{24}{1*10^3 + 2*10^3} - \frac{12}{2*10^3} = 2 \text{ mA}$$

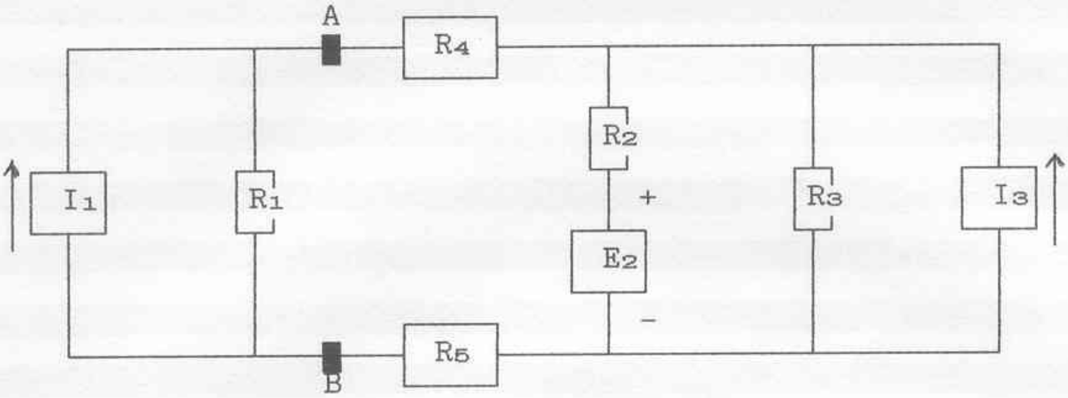


$$R_{o4} = \frac{R_o * R_4}{R_o + R_4} = \frac{1,2*10^3 * 3*10^3}{1,2*10^3 + 3*10^3} = 0,857 \text{ K}\Omega$$

$$V_{AB} = R_{o4} * I_o = 0,857*10^3 * 2*10^{-3} = 1,71 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_4} = \frac{1,71}{3*10^3} = 0,57 \text{ mA}$$

6.7 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

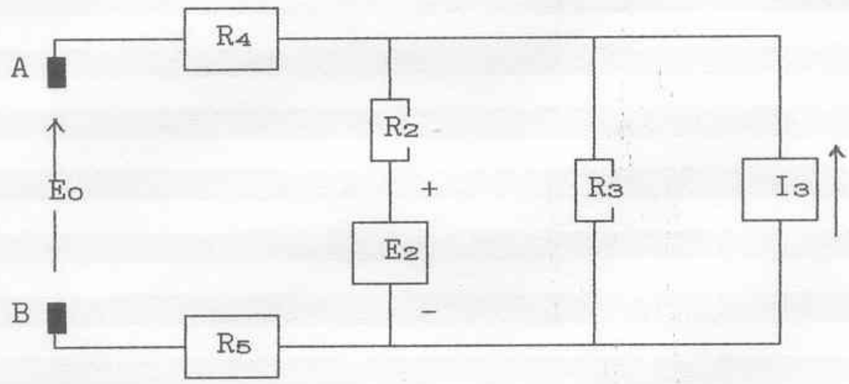


I_1 = 5 mA ; E_2 = 10 V ; I_3 = 2 mA ; R_1 = 2 KΩ

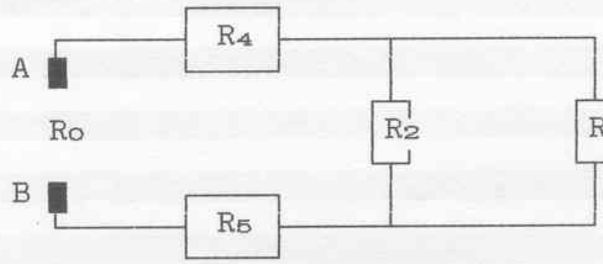
R_2 = 1 KΩ ; R_3 = 4 KΩ ; R_4 = 1 KΩ ; R_5 = 4 KΩ

RISOLUZIONE

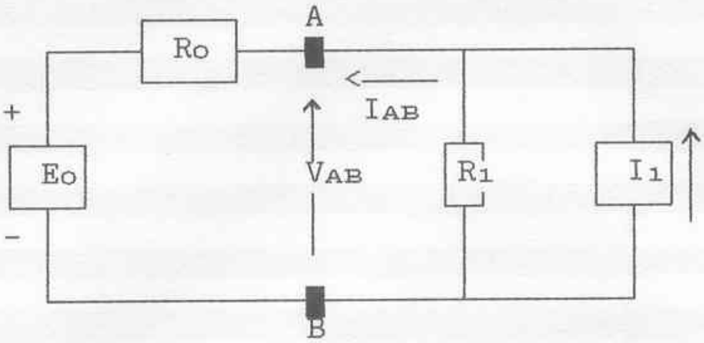
- Teorema di Thèvenin



$$E_0 = \frac{\frac{E_2}{R_2} + I_3}{\frac{1}{R_2} + \frac{1}{R_3}} = \frac{\frac{10}{1*10^3} + 2*10^{-3}}{\frac{1}{1*10^3} + \frac{1}{4*10^3}} = 9,6 \text{ V}$$



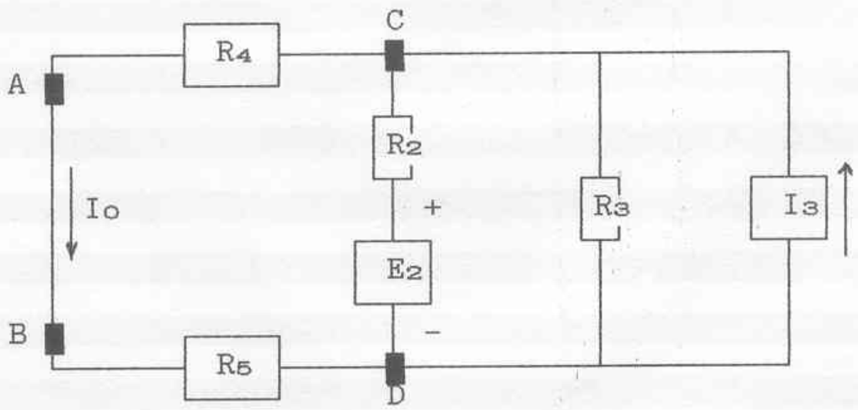
$$R_o = \frac{R_2 * R_3}{R_2 + R_3} + R_4 + R_5 = \frac{1*10^3 * 4*10^3}{1*10^3 + 4*10^3} + 1*10^3 + 4*10^3 = 5,8\ K\Omega$$



$$V_{AB} = \frac{I_1 + \dfrac{E_o}{R_o}}{\dfrac{1}{R_1} + \dfrac{1}{R_o}} = \frac{5*10^{-3} + \dfrac{9,6}{5,8*10^3}}{\dfrac{1}{2*10^3} + \dfrac{1}{5,8*10^3}} = 9,9\ V$$

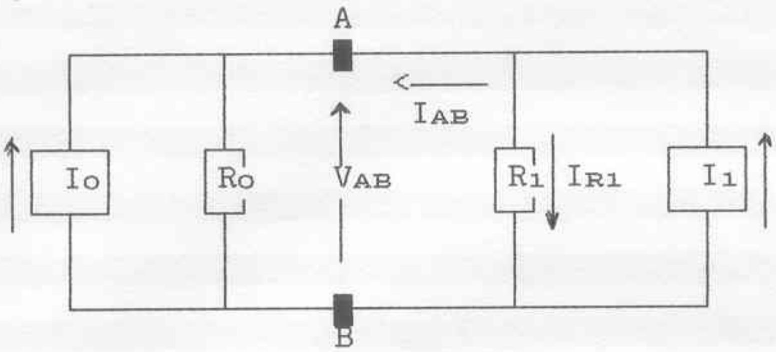
$$V_{AB} = E_o + R_o * I_{AB} \quad ==> \quad I_{AB} = \frac{V_{AB} - E_o}{R_o} = \frac{9,9 - 9,6}{5,8*10^3} = 0,05\ mA$$

- <u>Teorema di Norton</u>



$$V_{CD} = \frac{I_3 + \dfrac{E_2}{R_2}}{\dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4 + R_5}} = \frac{5*10^{-3} + \dfrac{9,6}{5,8*10^3}}{\dfrac{1}{1*10^3} + \dfrac{1}{4*10^3} + \dfrac{1}{5*10^3}} = 8,276\ V$$

$$I_o = \frac{V_{CD}}{R_4 + R_5} = \frac{8,276}{1*10^3 + 4*10^3} = 1,655\ mA$$

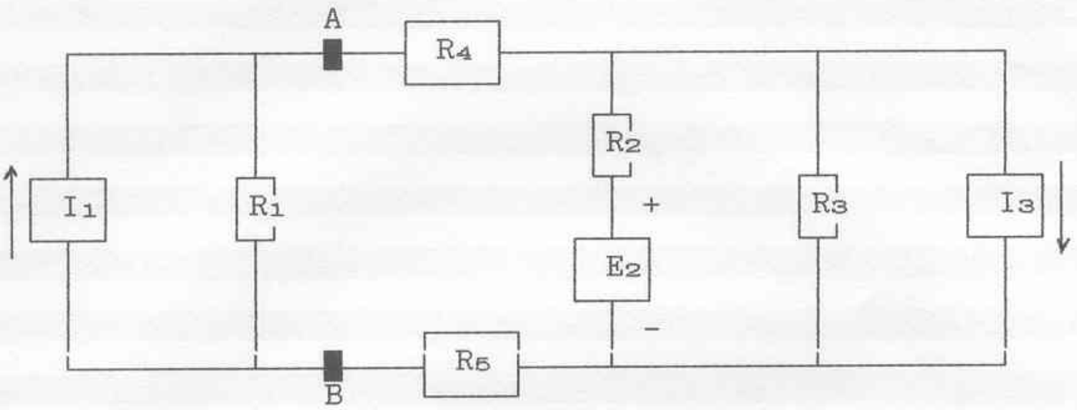


$$V_{AB} = \frac{I_O + I_1}{\frac{1}{R_O} + \frac{1}{R_1}} = \frac{1,655*10^{-3} + 5*10^{-3}}{\frac{1}{5,8*10^3} + \frac{1}{2*10^3}} = 9,9 \text{ V}$$

$$I_{R1} = \frac{V_{AB}}{R_1} = \frac{9,9}{2*10^3} = 4,95 \text{ mA}$$

$$I_{AB} = I_1 - I_{R1} = 5*10^{-3} - 4,95*10^{-3} = 0,05 \text{ mA}$$

6.8 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

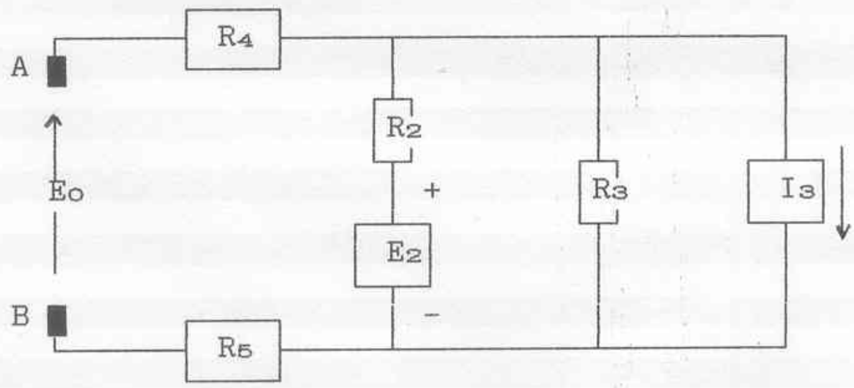


$I_1 = 6\ mA$; $E_2 = 8\ V$; $I_3 = 3\ mA$; $R_1 = 1\ K\Omega$

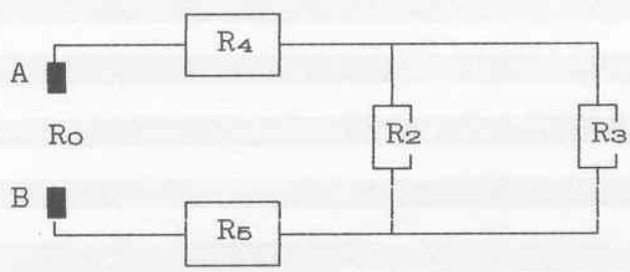
$R_2 = 1\ K\Omega$; $R_3 = 3\ K\Omega$; $R_4 = 2\ K\Omega$; $R_5 = 3\ K\Omega$

RISOLUZIONE

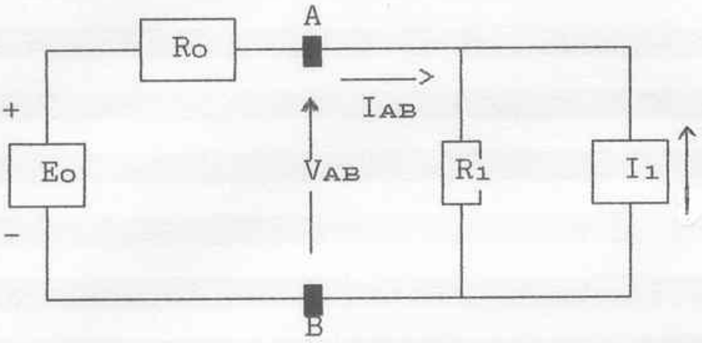
- Teorema di Thèvenin



$$E_0 = \frac{\frac{E_2}{R_2} + I_3}{\frac{1}{R_2} + \frac{1}{R_3}} = \frac{\frac{8}{1*10^3} + 3*10^{-3}}{\frac{1}{1*10^3} + \frac{1}{3*10^3}} = 8,25\ V$$



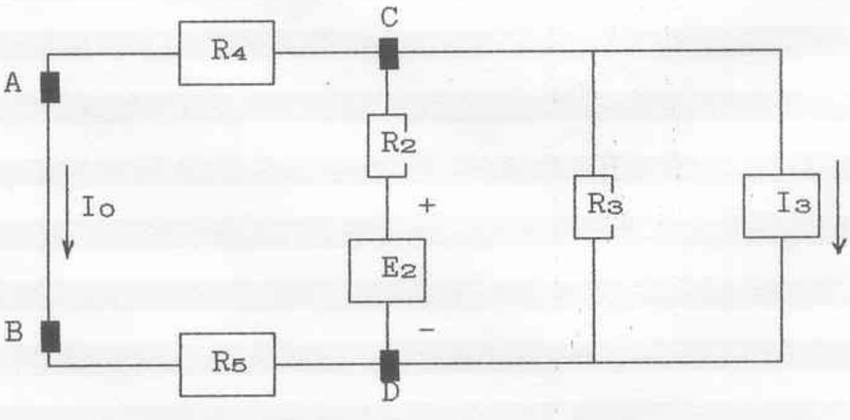
$$R_o = \frac{R_2 * R_3}{R_2 + R_3} + R_4 + R_5 = \frac{1*10^3 * 3*10^3}{1*10^3 + 3*10^3} + 2*10^3 + 3*10^3 = 5,75\ K\Omega$$



$$V_{AB} = \frac{I_1 + \frac{E_o}{R_o}}{\frac{1}{R_1} + \frac{1}{R_o}} = \frac{6*10^{-3} + \frac{8,25}{5,75*10^3}}{\frac{1}{2*10^3} + \frac{1}{5,75*10^3}} = 6,33\ V$$

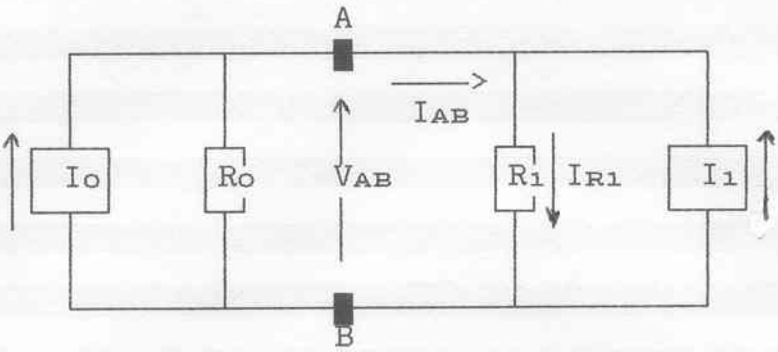
$$V_{AB} = E_o - R_o * I_{AB} \quad ==> \quad I_{AB} = \frac{E_o - V_{AB}}{R_o} = \frac{8,25 - 6,33}{5,75*10^3} = 0,33\ mA$$

- <u>Teorema di Norton</u>



$$V_{CD} = \frac{I_3 + \frac{E_2}{R_2}}{\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4 + R_5}} = \frac{3*10^{-3} + \frac{8}{1*10^3}}{\frac{1}{1*10^3} + \frac{1}{3*10^3} + \frac{1}{5*10^3}} = 7,174\ V$$

$$I_o = \frac{V_{CD}}{R_4 + R_5} = \frac{7,174}{2*10^3 + 3*10^3} = 1,43\ mA$$

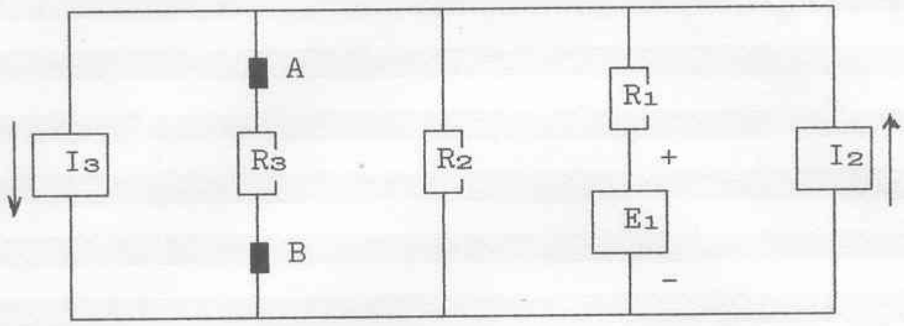


$$V_{AB} = \frac{I_0 + I_1}{\frac{1}{R_0} + \frac{1}{R_1}} = \frac{1,43*10^{-3} + 6*10^{-3}}{\frac{1}{5,75*10^{3}} + \frac{1}{1*10^{3}}} = 6,33\ V$$

$$I_{R1} = \frac{V_{AB}}{R_1} = \frac{6,33}{1*10^{3}} = 6,33\ mA$$

$$I_{AB} = I_{R1} - I_1 = 6,33*10^{-3} - 6*10^{-3} = 0,33\ mA$$

6.9 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

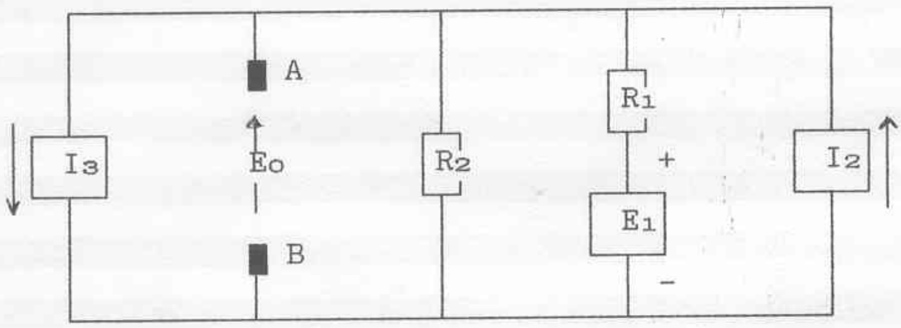


$E_1 = 10\ V$; $I_2 = 4\ mA$; $I_3 = 3\ mA$; $R_1 = 1\ K\Omega$

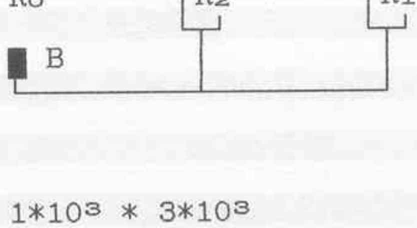
$R_2 = 3\ K\Omega$; $R_3 = 6\ K\Omega$

RISOLUZIONE

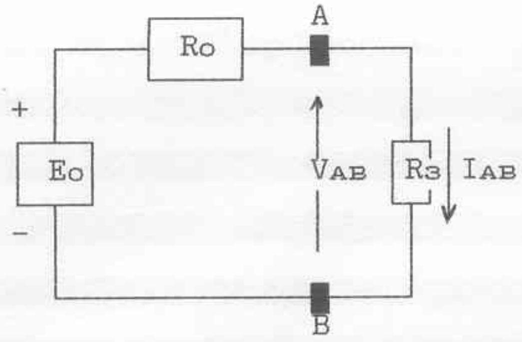
- Teorema di Thèvenin



$$E_o = \frac{-I_3 + \dfrac{E_1}{R_1} + I_2}{\dfrac{1}{R_1} + \dfrac{1}{R_2}} = \frac{-3*10^{-3} + \dfrac{10}{1*10^3} + 4*10^{-3}}{\dfrac{1}{1*10^3} + \dfrac{1}{3*10^3}} = 8,25\ V$$



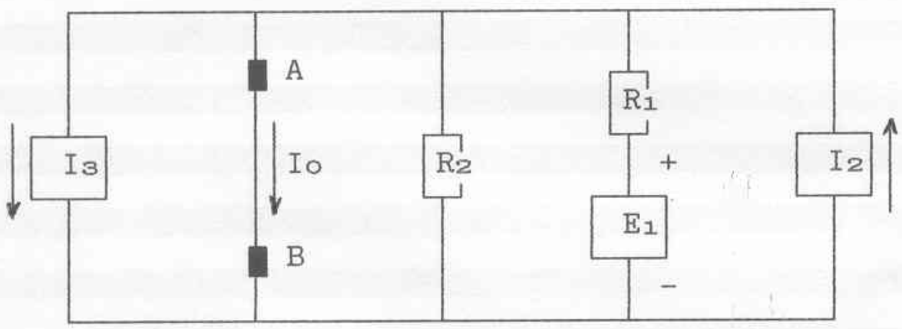
$$R_o = \frac{R_1 * R_2}{R_1 + R_2} = \frac{1*10^3 * 3*10^3}{1*10^3 + 3*10^3} = 0,75\ K\Omega$$



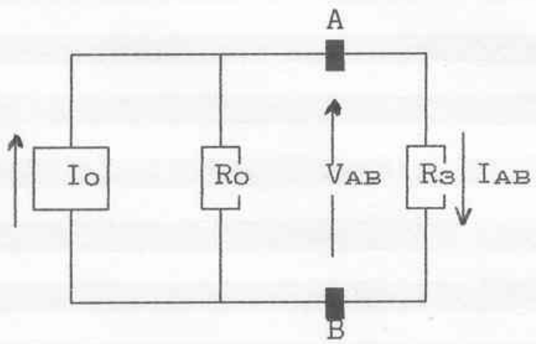
$$I_{AB} = \frac{E_o}{R_o + R_3} = \frac{8,25}{0,75*10^3 + 6*10^3} = 1,22 \text{ mA}$$

$$V_{AB} = R_3 * I_{AB} = 6*10^3 * 1,22*10^{-3} = 7,33 \text{ V}$$

- <u>Teorema di Norton</u>



$$I_o = \frac{E_1}{R_1} + I_2 - I_3 = \frac{10}{1*10^3} + 4*10^{-3} - 3*10^{-3} = 11 \text{ mA}$$

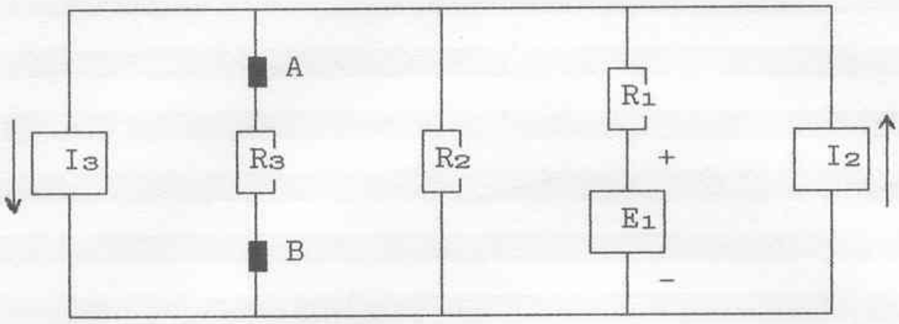


$$R_{o3} = \frac{R_o * R_3}{R_o + R_3} = \frac{0,75*10^3 * 6*10^3}{0,75*10^3 + 6*10^3} = 0,666 \text{ K}\Omega$$

$$V_{AB} = R_{o3} * I_o = 0,666*10^3 * 11*10^{-3} = 7,33 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_3} = \frac{7,33}{6*10^3} = 1,22 \text{ mA}$$

6.10 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

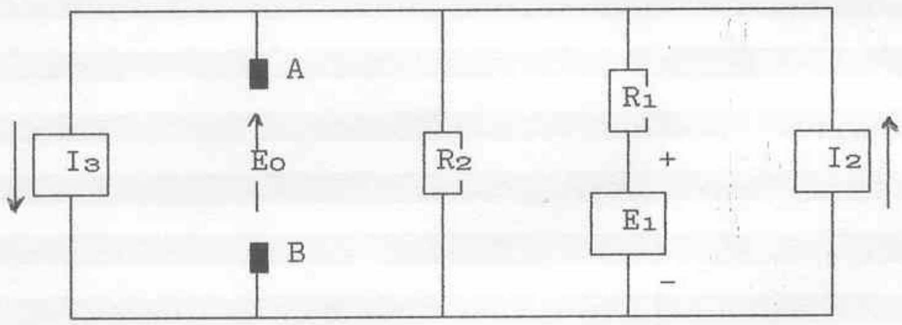


$E_1 = 12\ V$; $I_2 = 3\ mA$; $I_3 = 1\ mA$; $R_1 = 2\ K\Omega$

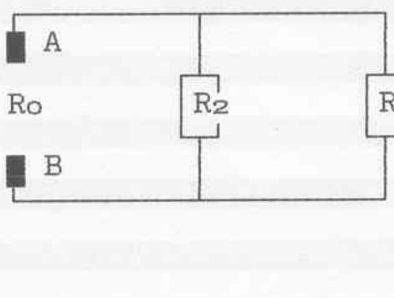
$R_2 = 1\ K\Omega$; $R_3 = 3\ K\Omega$

RISOLUZIONE

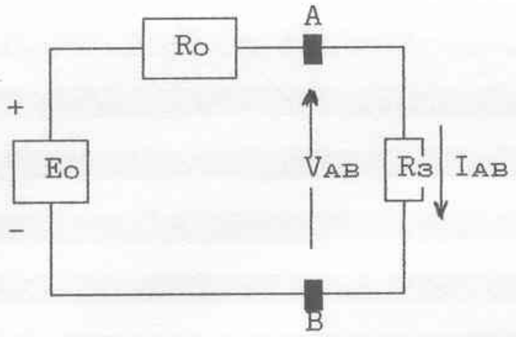
- Teorema di Thèvenin



$$E_o = \frac{- I_3 + \frac{E_1}{R_1} + I_2}{\frac{1}{R_1} + \frac{1}{R_2}} = \frac{- 1*10^{-3} + \frac{12}{2*10^3} + 3*10^{-3}}{\frac{1}{2*10^3} + \frac{1}{1*10^3}} = 5,33\ V$$



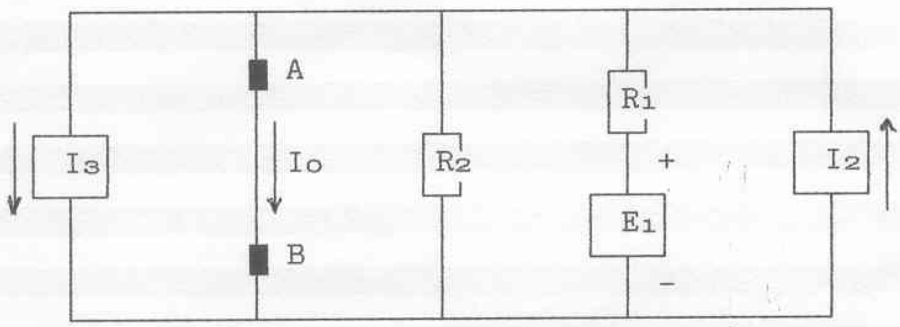
$$R_o = \frac{R_1 * R_2}{R_1 + R_2} = \frac{2*10^3 * 1*10^3}{2*10^3 + 1*10^3} = 0,667\ K\Omega$$



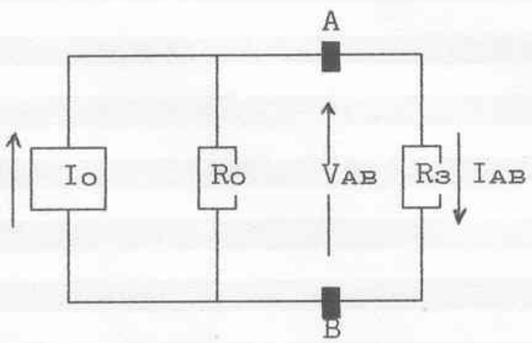
$$I_{AB} = \frac{E_o}{R_o + R_3} = \frac{5{,}33}{0{,}667*10^3 + 3*10^3} = 1{,}454 \text{ mA}$$

$$V_{AB} = R_3 * I_{AB} = 3*10^3 * 1{,}45*10^{-3} = 4{,}353 \text{ V}$$

- <u>Teorema di Norton</u>



$$I_o = \frac{E_1}{R_1} + I_2 - I_3 = \frac{12}{2*10^3} + 3*10^{-3} - 1*10^{-3} = 8 \text{ mA}$$

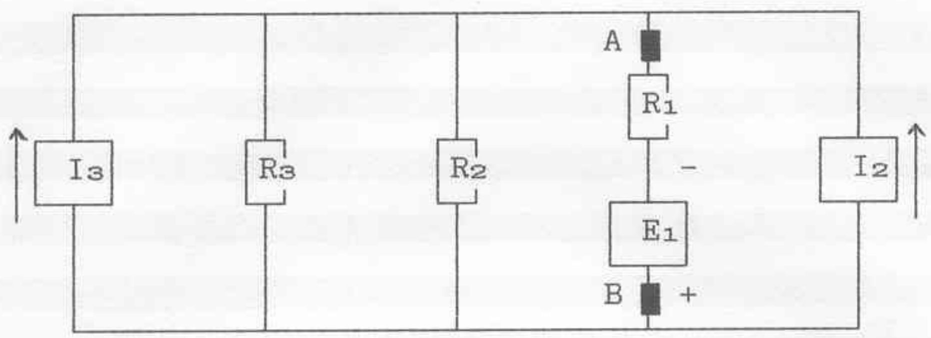


$$R_{o3} = \frac{R_o * R_3}{R_o + R_3} = \frac{0{,}667*10^3 * 3*10^3}{0{,}667*10^3 + 3*10^3} = 0{,}545 \text{ K}\Omega$$

$$V_{AB} = R_{o3} * I_o = 0{,}545*10^3 * 8*10^{-3} = 4{,}36 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_3} = \frac{4{,}36}{3*10^3} = 1{,}45 \text{ mA}$$

6.11 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

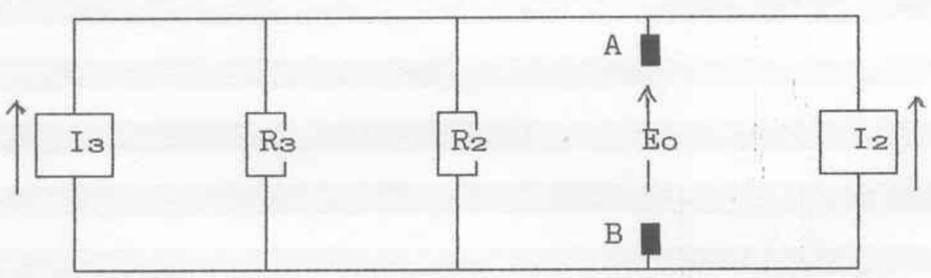


E_1 = 8 V ; I_2 = 10 mA ; I_3 = 5 mA ; R_1 = 3 KΩ

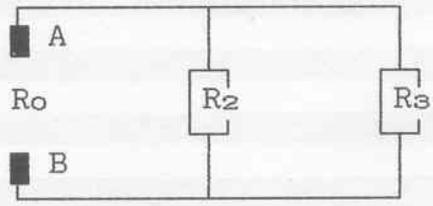
R_2 = 6 KΩ ; R_3 = 2 KΩ

RISOLUZIONE

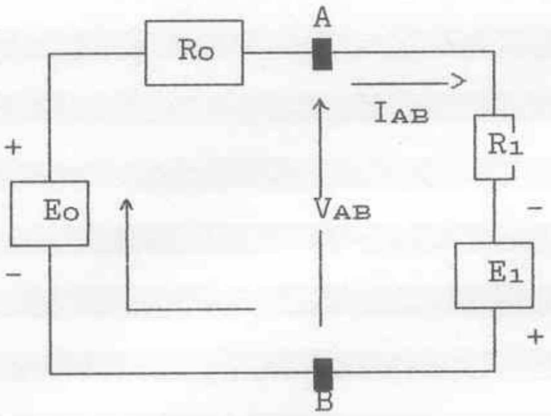
- Teorema di Thèvenin



$$E_o = \frac{I_2 + I_3}{\frac{1}{R_2} + \frac{1}{R_3}} = \frac{10*10^{-3} + 5*10^{-3}}{\frac{1}{6*10^3} + \frac{1}{2*10^3}} = 22{,}5 \text{ V}$$



$$R_o = \frac{R_2 * R_3}{R_2 + R_3} = \frac{6*10^3 * 2*10^3}{6*10^3 + 2*10^3} = 1{,}5 \text{ K}\Omega$$

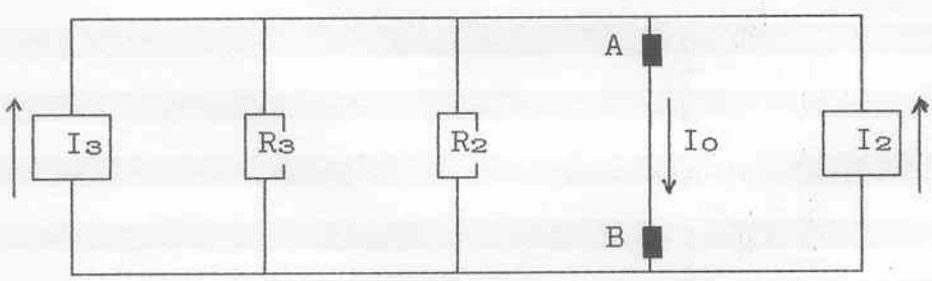


$E_o + E_1 = (R_o + R_1) * I_{AB}$ ==>

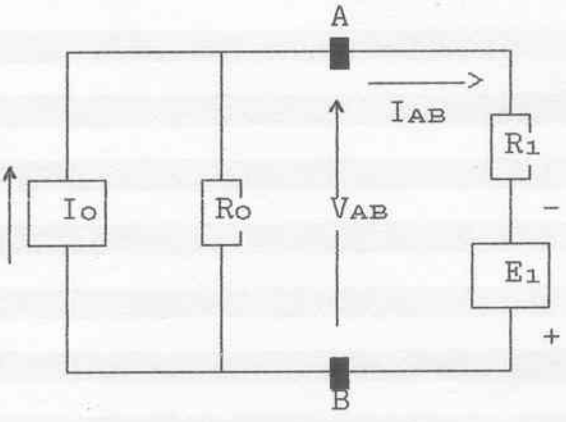
$$\Longrightarrow \quad I_{AB} = \frac{E_o + E_1}{R_o + R_1} = \frac{22,5 + 8}{1,5*10^3 + 3*10^3} = 6,78 \text{ mA}$$

$V_{AB} = R_1 * I_{AB} - E_1 = 3*10^3 * 6,78*10^{-3} - 8 = 12,34$ V

- <u>Teorema di Norton</u>



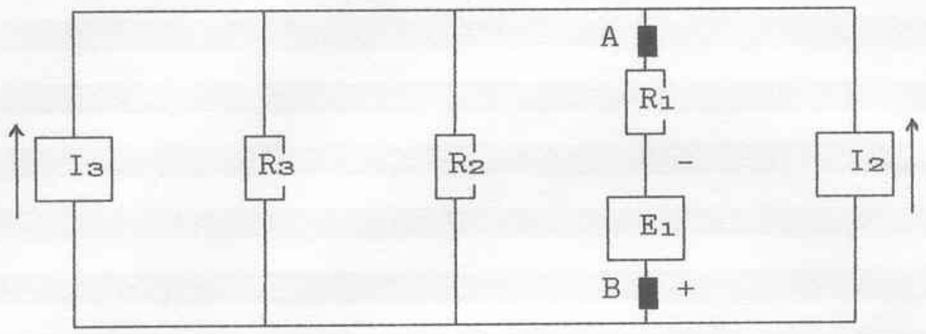
$I_o = I_2 + I_3 = 10*10^{-3} + 5*10^{-3} = 15$ mA



$$V_{AB} = \frac{I_o - \dfrac{E_1}{R_1}}{\dfrac{1}{R_o} + \dfrac{1}{R_1}} = \frac{15*10^{-3} - \dfrac{8}{3*10^3}}{\dfrac{1}{1,5*10^3} + \dfrac{1}{3*10^3}} = 12,33\ V$$

$$V_{AB} = R_1 * I_{AB} - E_1 \quad ==> \quad I_{AB} = \frac{E_1 + V_{AB}}{R_1} = \frac{8 + 12,33}{3*10^3} = 6,78\ mA$$

6.12 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

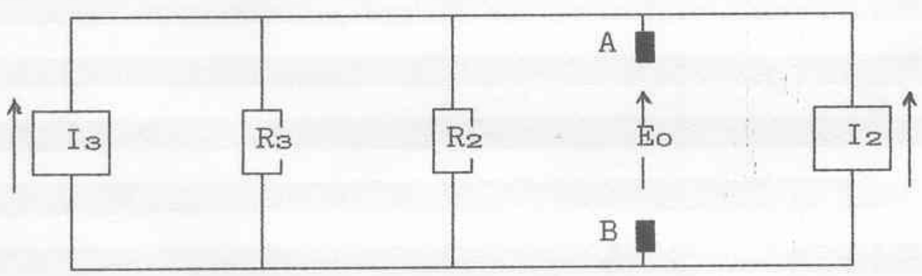


$E_1 = 12$ V ; $I_2 = 4$ mA ; $I_3 = 2$ mA ; $R_1 = 10$ KΩ

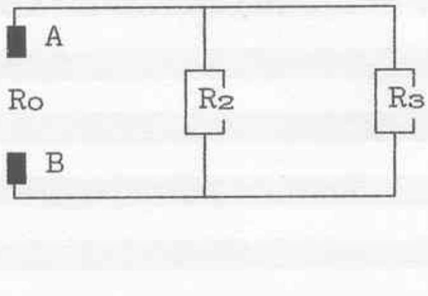
$R_2 = 12$ KΩ ; $R_3 = 8$ KΩ

RISOLUZIONE

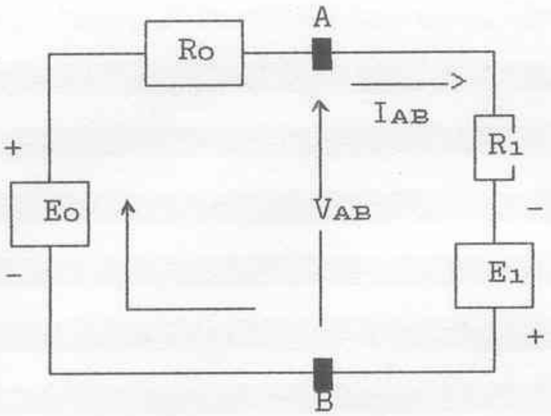
- Teorema di Thèvenin



$$E_o = \frac{I_2 + I_3}{\frac{1}{R_2} + \frac{1}{R_3}} = \frac{4*10^{-3} + 2*10^{-3}}{\frac{1}{12*10^3} + \frac{1}{8*10^3}} = 28,8 \text{ V}$$



$$R_o = \frac{R_2 * R_3}{R_2 + R_3} = \frac{12*10^3 * 8*10^3}{12*10^3 + 8*10^3} = 4,8 \text{ K}\Omega$$

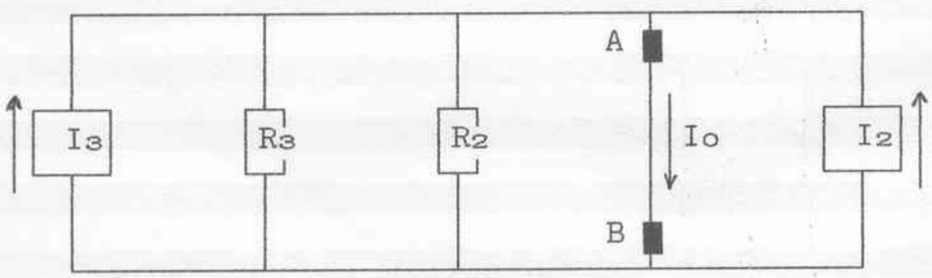


$E_o + E_1 = (R_o + R_1) * I_{AB}$ ==>

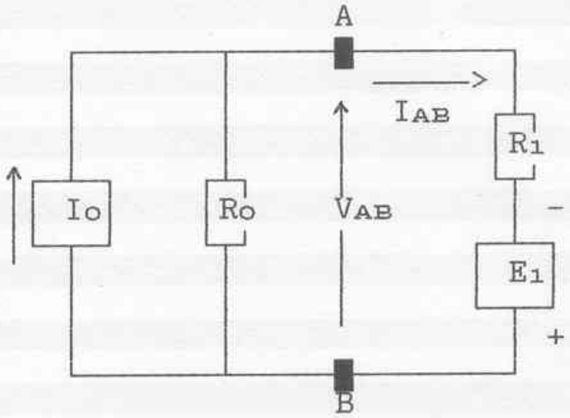
$$\Longrightarrow \quad I_{AB} = \frac{E_o + E_1}{R_o + R_1} = \frac{28,8 + 12}{4,8*10^3 + 10*10^3} = 2,76 \text{ mA}$$

$V_{AB} = R_1 * I_{AB} - E_1 = 10*10^3 * 2,76*10^{-3} - 12 = 15,6$ V

- <u>Teorema di Norton</u>



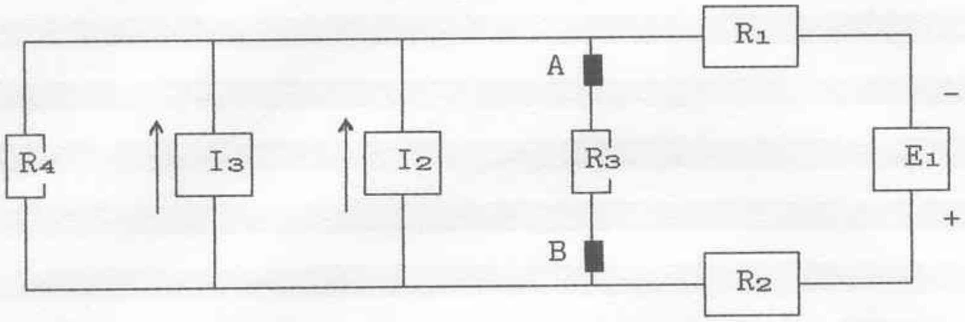
$I_o = I_2 + I_3 = 4*10^{-3} + 2*10^{-3} = 6$ mA



$$V_{AB} = \frac{I_0 - \frac{E_1}{R_1}}{\frac{1}{R_0} + \frac{1}{R_1}} = \frac{6*10^{-3} - \frac{12}{10*10^3}}{\frac{1}{4,8*10^3} + \frac{1}{10*10^3}} = 15,57\ V$$

$$V_{AB} = R_1 * I_{AB} - E_1 \quad ==> \quad I_{AB} = \frac{E_1 + V_{AB}}{R_1} = \frac{12 + 15,57}{10*10^3} = 2,76\ mA$$

6.13 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

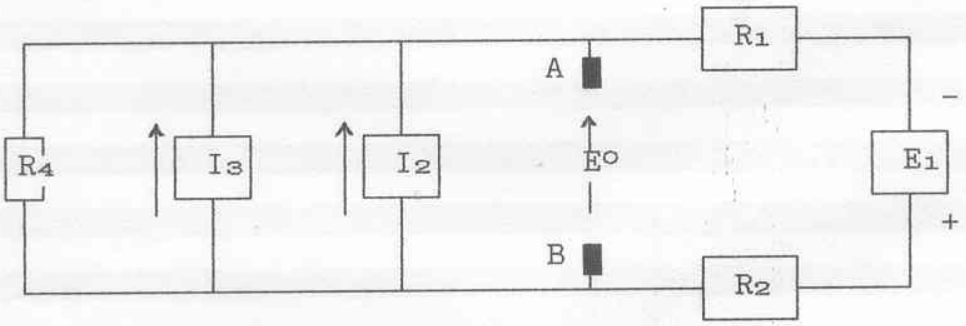


$E_1 = 10\ V$; $I_2 = 2\ mA$; $I_3 = 5\ mA$; $R_1 = 3\ K\Omega$

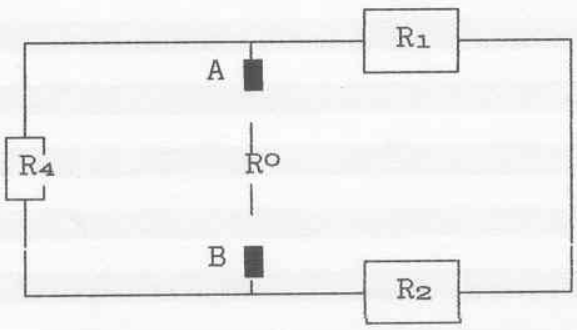
$R_2 = 2\ K\Omega$; $R_3 = 5\ K\Omega$; $R_4 = 1\ K\Omega$

RISOLUZIONE

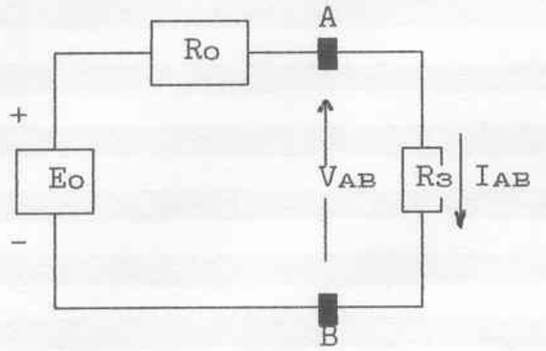
- Teorema di Thèvenin



$$E_o = \frac{I_2 + I_3 - \dfrac{E_1}{R_1 + R_2}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_4}} = \frac{2*10^{-3} + 5*10^{-3} - \dfrac{10}{3*10^3 + 2*10^3}}{\dfrac{1}{3*10^3 + 2*10^3} + \dfrac{1}{1*10^3}} = 4,167\ V$$



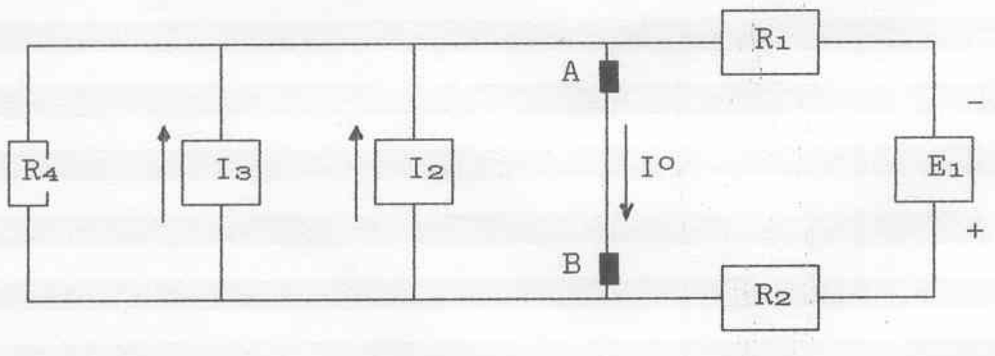
$$R_O = \frac{R_4 * (R_1 + R_2)}{R_4 + R_1 + R_2} = \frac{1*10^3 * (3*10^3 + 2*10^3)}{1*10^3 + 3*10^3 + 2*10^3} = 0,83\ K\Omega$$



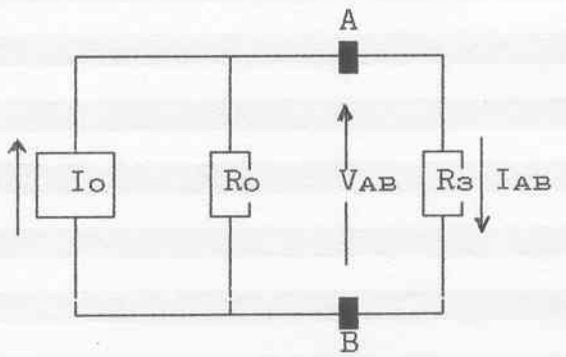
$$I_{AB} = \frac{E_O}{R_O + R_3} = \frac{4,167}{0,83*10^3 + 5*10^3} = 0,714\ mA$$

$$V_{AB} = R_3 * I_{AB} = 5*10^3 * 0,714*10^{-3} = 3,57\ V$$

- <u>Teorema di Norton</u>



$$I_O = I_2 + I_3 - \frac{E_1}{R_1 + R_2} = 2*10^{-3} + 5*10^{-3} - \frac{10}{3*10^3 + 2*10^3} = 5\ mA$$

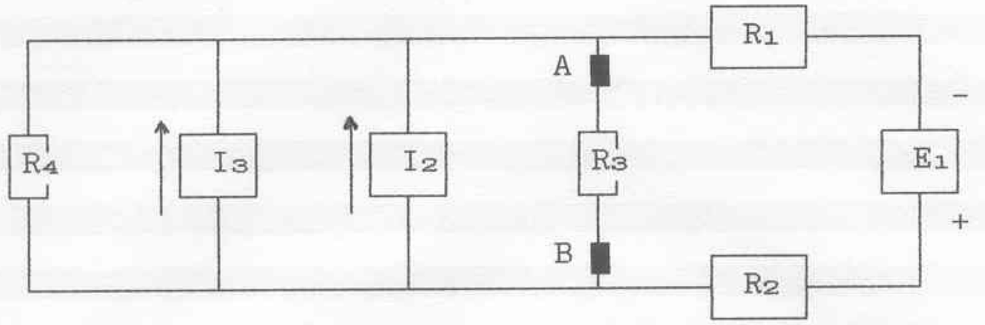


$$R_{o3} = \frac{R_o * R_3}{R_o + R_3} = \frac{0,83*10^3 * 5*10^3}{0,83*10^3 + 5*10^3} = 0,714\ K\Omega$$

$$V_{AB} = R_{o3} * I_o = 0,714*10^3 * 5*10^{-3} = 3,57\ V$$

$$I_{AB} = \frac{V_{AB}}{R_3} = \frac{3,57}{5*10^3} = 0,714\ mA$$

6.14 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

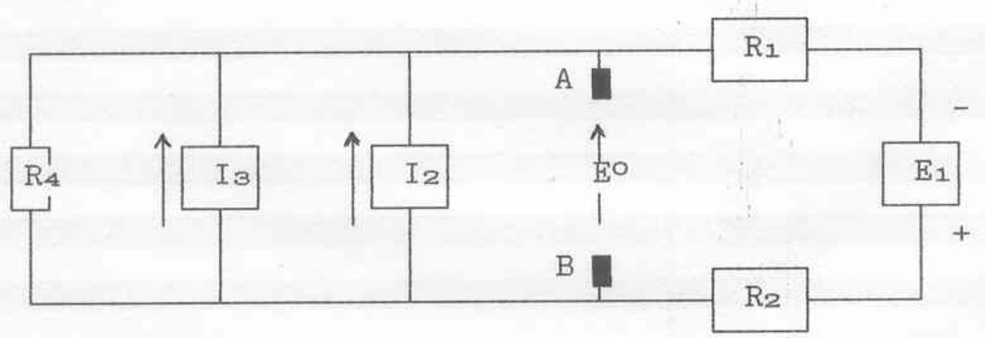


$E_1 = 12$ V ; $I_2 = 2$ mA ; $I_3 = 3$ mA ; $R_1 = 5$ KΩ

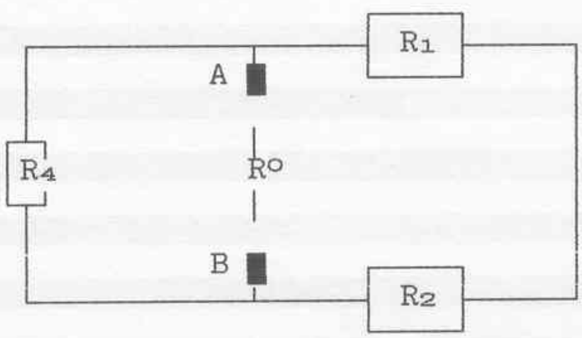
$R_2 = 3$ KΩ ; $R_3 = 2$ KΩ ; $R_4 = 4$ KΩ

RISOLUZIONE

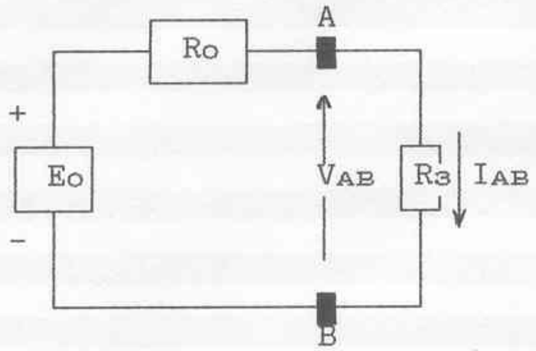
- Teorema di Thèvenin



$$E_o = \frac{I_2 + I_3 - \dfrac{E_1}{R_1 + R_2}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_4}} = \frac{2*10^{-3} + 3*10^{-3} - \dfrac{12}{5*10^3 + 3*10^3}}{\dfrac{1}{5*10^3 + 3*10^3} + \dfrac{1}{4*10^3}} = 9,33 \text{ V}$$



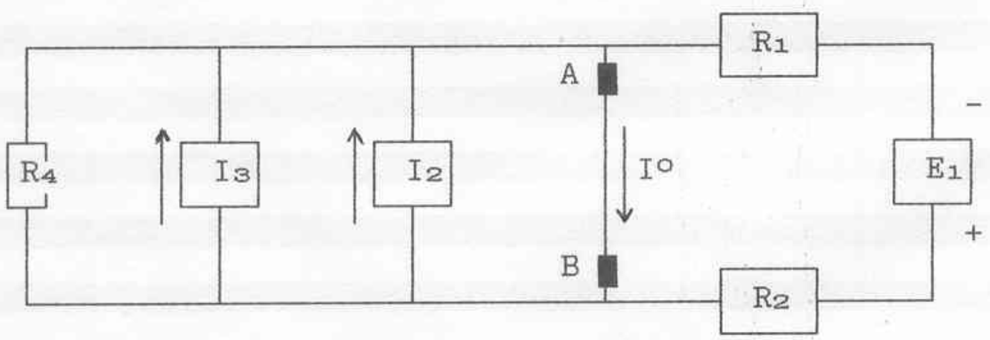
$$R_O = \frac{R_4 * (R_1 + R_2)}{R_4 + R_1 + R_2} = \frac{4*10^3 * (5*10^3 + 3*10^3)}{4*10^3 + 5*10^3 + 3*10^3} = 2,67\ K\Omega$$



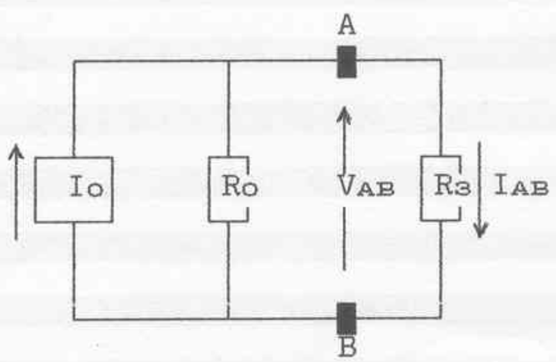
$$I_{AB} = \frac{E_O}{R_O + R_3} = \frac{9,33}{2,67*10^3 + 2*10^3} = 2\ mA$$

$$V_{AB} = R_3 * I_{AB} = 2*10^3 * 2*10^{-3} = 4\ V$$

- <u>Teorema di Norton</u>



$$I_O = I_2 + I_3 - \frac{E_1}{R_1 + R_2} = 2*10^{-3} + 3*10^{-3} - \frac{12}{5*10^3 + 3*10^3} = 3,5\ mA$$

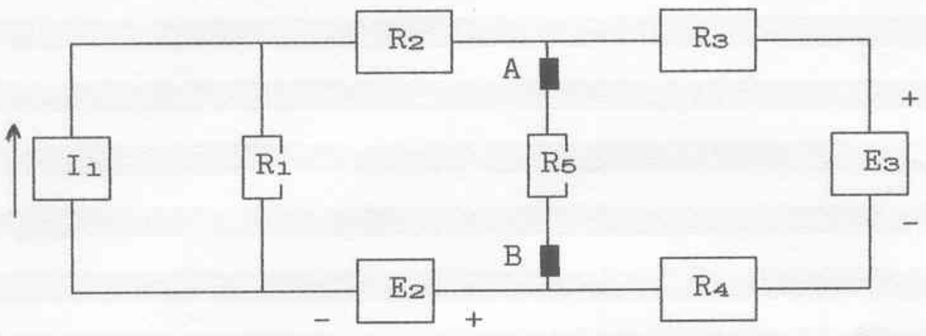


$$R_{O3} = \frac{R_O * R_3}{R_O + R_3} = \frac{2,67*10^3 * 2*10^3}{2,67*10^3 + 2*10^3} = 1,14\ K\Omega$$

$$V_{AB} = R_{O3} * I_O = 1,14*10^3 * 3,5*10^{-3} = 4\ V$$

$$I_{AB} = \frac{V_{AB}}{R_3} = \frac{4}{2*10^3} = 2\ mA$$

6.15 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

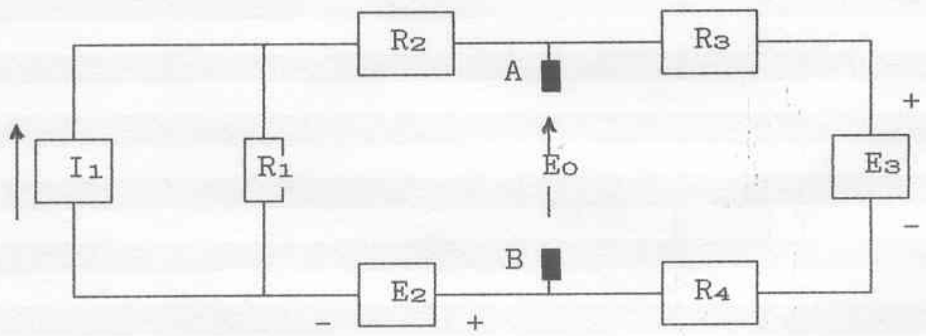


$I_1 = 8$ mA ; $E_2 = 6$ V ; $E_3 = 4$ V ; $R_1 = 1,5$ KΩ

$R_2 = 1$ KΩ ; $R_3 = 2$ KΩ ; $R_4 = 1$ KΩ ; $R_5 = 8$ KΩ

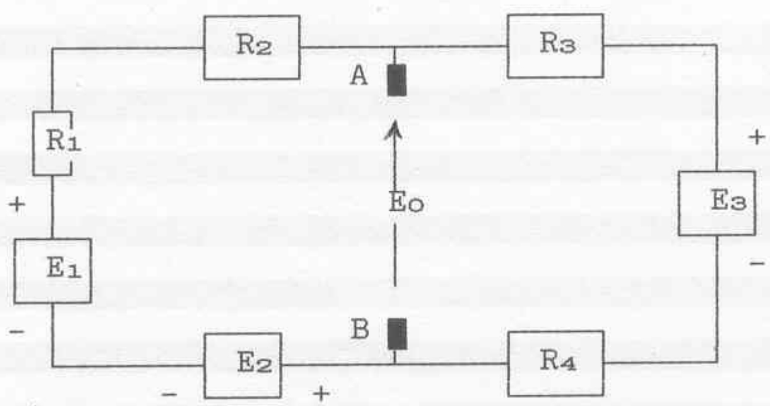
RISOLUZIONE

- Teorema di Thèvenin

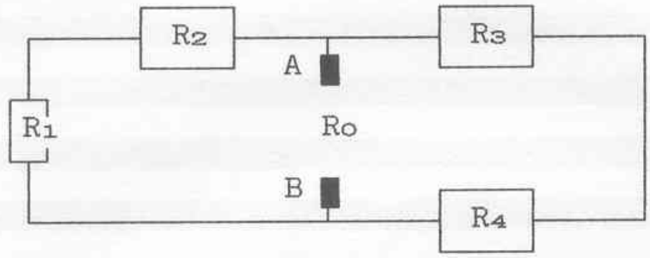


Si trasforma il generatore di corrente in generatore di tensione:

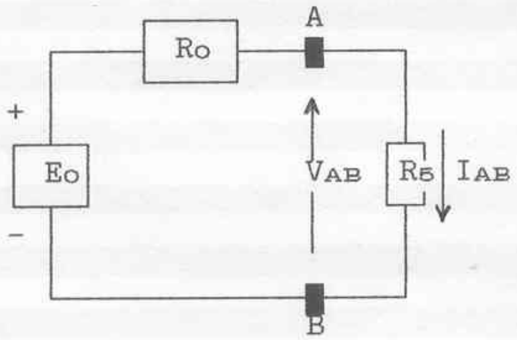
$E_1 = R_1 * I_1 = 1,5*10^3 * 8*10^{-3} = 12$ V



$$E_o = \frac{\dfrac{E_1 - E_2}{R_1 + R_2} + \dfrac{E_3}{R_3 + R_4}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3 + R_4}} = \frac{\dfrac{12 - 6}{2,5*10^3} + \dfrac{4}{3*10^3}}{\dfrac{1}{2,5*10^3} + \dfrac{1}{3*10^3}} = 5,1 \text{ V}$$



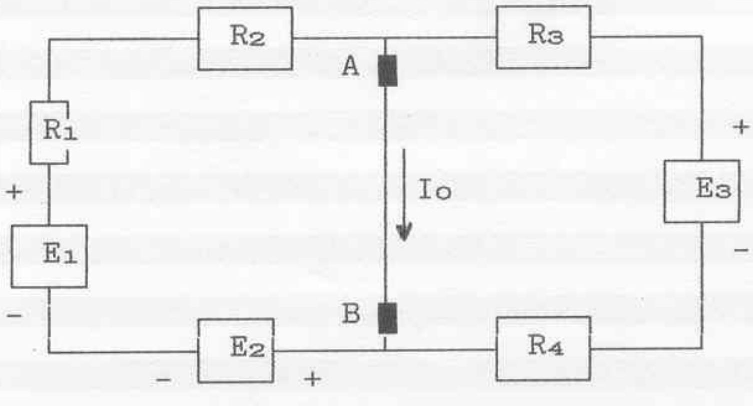
$$R_o = \frac{(R_1 + R_2) * (R_3 + R_4)}{R_1 + R_2 + R_3 + R_4} = \frac{2,5*10^3 * 3*10^3}{2,5*10^3 + 3*10^3} = 1,36 \text{ K}\Omega$$



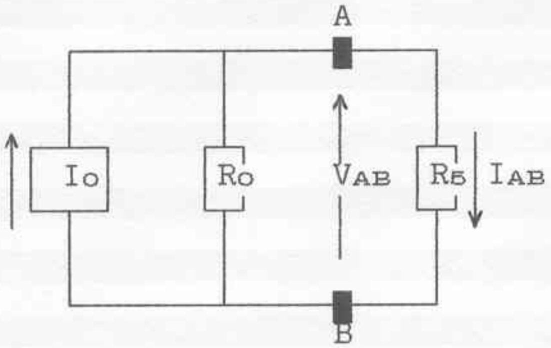
$$I_{AB} = \frac{E_o}{R_o + R_5} = \frac{5,1}{1,36*10^3 + 8*10^3} = 0,544 \text{ mA}$$

$V_{AB} = R_5 * I_{AB} = 8*10^3 * 0,544*10^{-3} = 4,35$ V

- Teorema di Norton



$$I_o = \frac{E_1 - E_2}{R_1 + R_2} + \frac{E_3}{R_3 + R_4} = \frac{12 - 6}{2,5*10^3} + \frac{4}{3*10^3} = 3,73 \text{ mA}$$

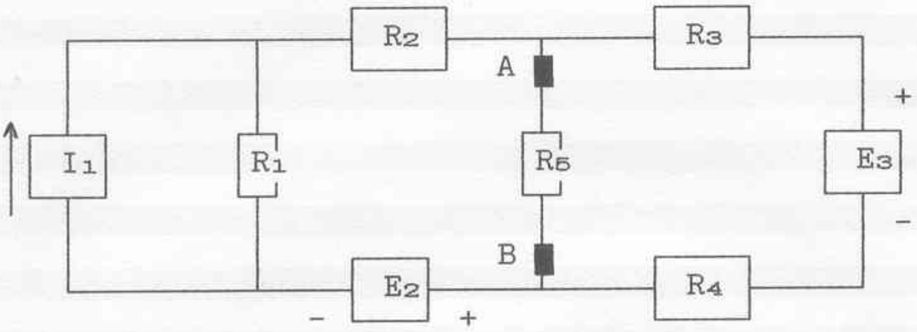


$$R_{o5} = \frac{R_o * R_5}{R_o + R_5} = \frac{1,367*10^3 * 8*10^3}{1,367*10^3 + 8*10^3} = 1,17 \text{ K}\Omega$$

$$V_{AB} = R_{o5} * I_o = 1,17*10^3 * 3,73*10^{-3} = 4,36 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{4,36}{8*10^3} = 0,544 \text{ mA}$$

6.16 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

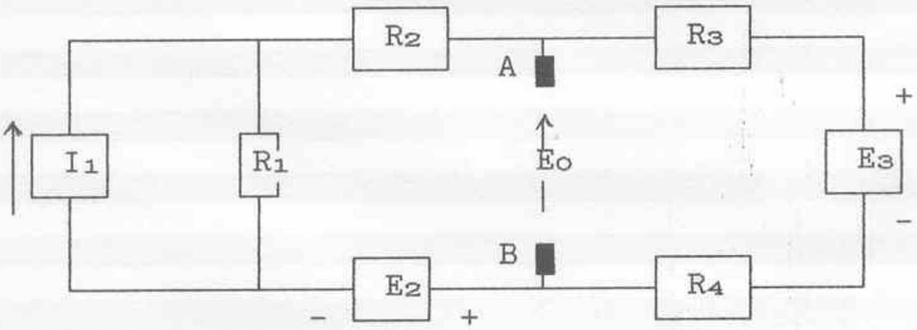


$I_1 = 6$ mA ; $E_2 = 3$ V ; $E_3 = 8$ V ; $R_1 = 2$ KΩ

$R_2 = 2$ KΩ ; $R_3 = 1$ KΩ ; $R_4 = 3$ KΩ ; $R_5 = 5$ KΩ

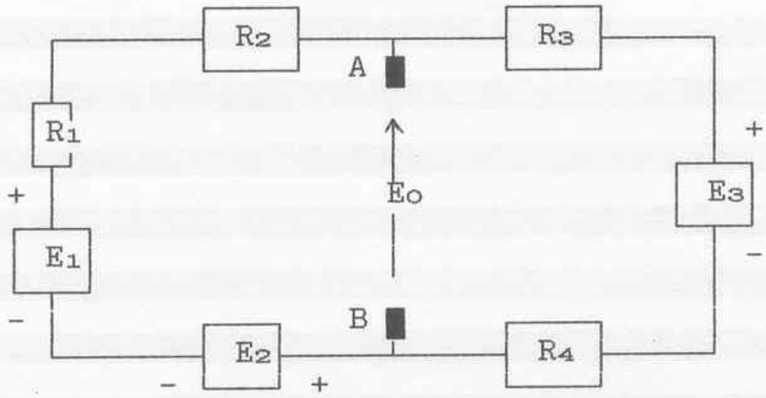
RISOLUZIONE

- Teorema di Thèvenin

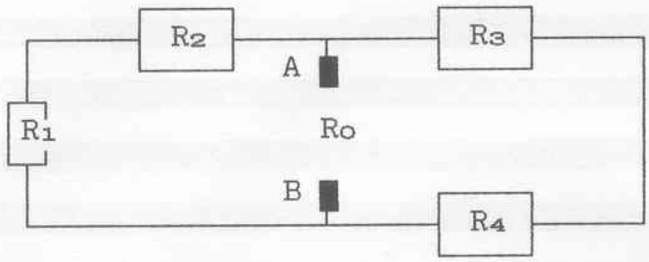


Si trasforma il generatore di corrente in generatore di tensione:

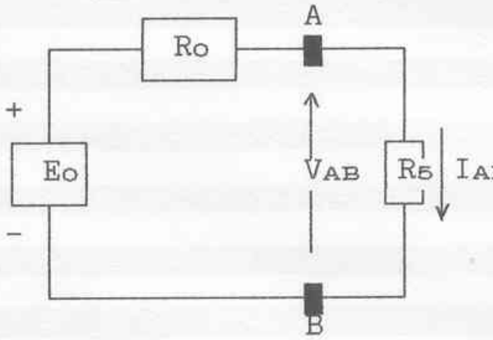
$E_1 = R_1 * I_1 = 2*10^3 * 6*10^{-3} = 12$ V



$$E_O = \frac{\dfrac{E_1 - E_2}{R_1 + R_2} + \dfrac{E_3}{R_3 + R_4}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3 + R_4}} = \frac{\dfrac{12 - 3}{4*10^3} + \dfrac{8}{4*10^3}}{\dfrac{1}{4*10^3} + \dfrac{1}{4*10^3}} = 8,5 \text{ V}$$



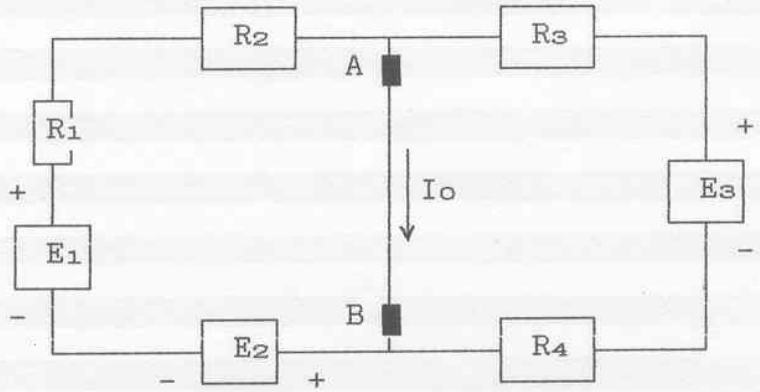
$$R_O = \frac{(R_1 + R_2) * (R_3 + R_4)}{R_1 + R_2 + R_3 + R_4} = \frac{4*10^3 * 4*10^3}{4*10^3 + 4*10^3} = 2 \text{ K}\Omega$$



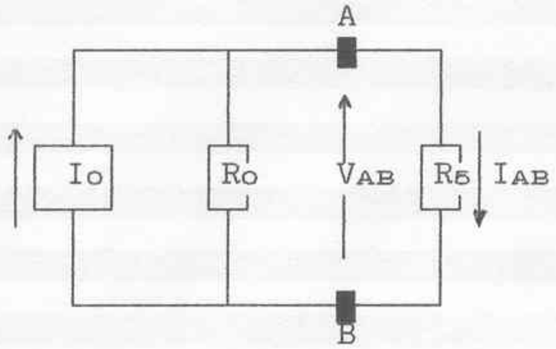
$$I_{AB} = \frac{E_O}{R_O + R_5} = \frac{8,5}{2*10^3 + 5*10^3} = 1,21 \text{ mA}$$

$$V_{AB} = R_5 * I_{AB} = 5*10^3 * 1,21*10^{-3} = 6,05 \text{ V}$$

- Teorema di Norton



$$I_o = \frac{E_1 - E_2}{R_1 + R_2} + \frac{E_3}{R_3 + R_4} = \frac{12 - 3}{4*10^3} + \frac{8}{4*10^3} = 4,25\ mA$$

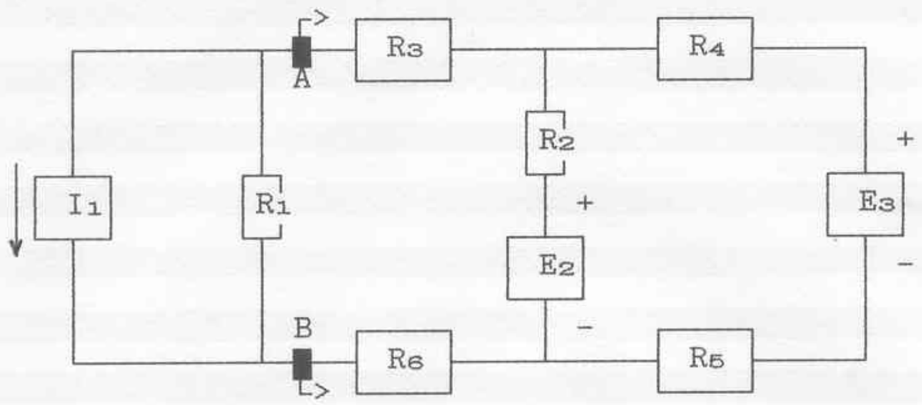


$$R_{o5} = \frac{R_o * R_5}{R_o + R_5} = \frac{2*10^3 * 5*10^3}{2*10^3 + 5*10^3} = 1,43\ K\Omega$$

$$V_{AB} = R_{o5} * I_o = 1,43*10^3 * 4,25*10^{-3} = 6,07\ V$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{6,07}{5*10^3} = 1,21\ mA$$

6.17 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

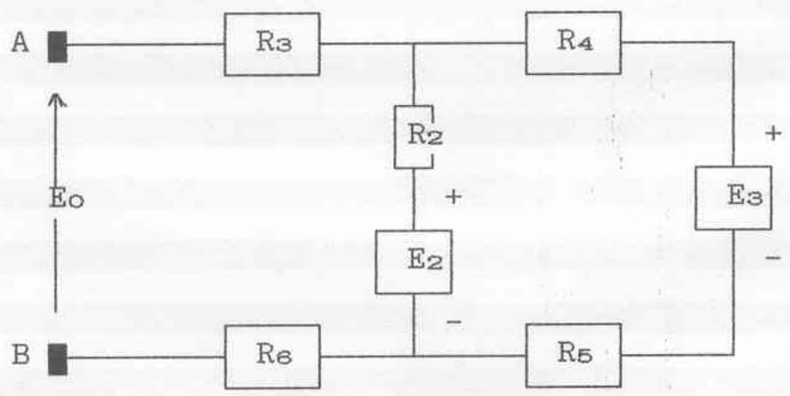


$I_1 = 5$ mA ; $E_2 = 6$ V ; $E_3 = 4$ V ; $R_1 = 1,6$ KΩ ; $R_2 = 1$ KΩ

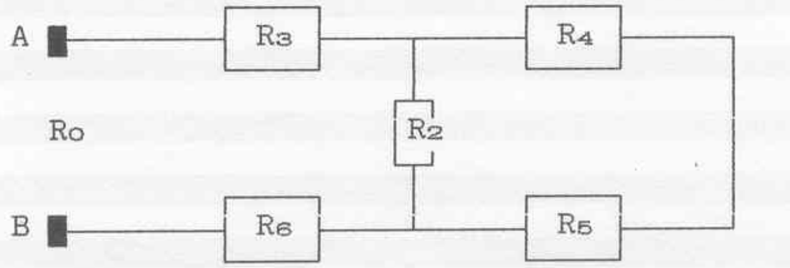
$R_3 = 2$ KΩ ; $R_4 = 1,5$ KΩ ; $R_5 = 2,5$ KΩ ; $R_6 = 3$ KΩ

RISOLUZIONE

- Teorema di Thèvenin

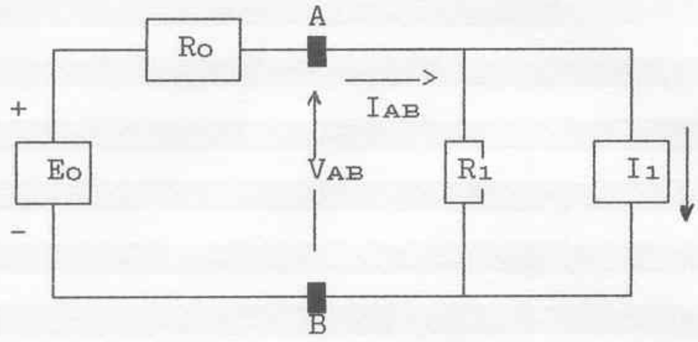


$$E_0 = \frac{\dfrac{E_2}{R_2} + \dfrac{E_3}{R_4 + R_5}}{\dfrac{1}{R_2} + \dfrac{1}{R_4 + R_5}} = \frac{\dfrac{6}{1*10^3} + \dfrac{4}{1,5*10^3 + 2,5*10^3}}{\dfrac{1}{1*10^3} + \dfrac{1}{1,5*10^3 + 2,5*10^3}} = 5,6 \text{ V}$$



$$R_O = R_3 + R_6 + \frac{R_2 * (R_4 + R_5)}{R_2 + R_4 + R_5} =$$

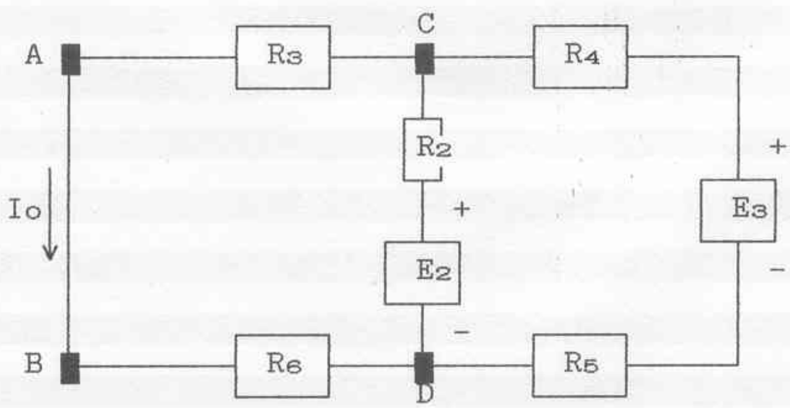
$$= 2*10^3 + 3*10^3 + \frac{1*10^3 * (1,5*10^3 + 2,5*10^3)}{1*10^3 + 1,5*10^3 + 2,5*10^3} = 5,8\ K\Omega$$



$$V_{AB} = \frac{\frac{E_O}{R_O} - I_1}{\frac{1}{R_O} + \frac{1}{R_1}} = \frac{\frac{5,6}{5,8*10^3} - 5*10^{-3}}{\frac{1}{5,8*10^3} + \frac{1}{1,6*10^3}} = - 5,06\ V$$

$$V_{AB} = E_O - R_O * I_{AB} \quad ==> \quad I_{AB} = \frac{E_O - V_{AB}}{R_O} = \frac{5,6 + 5,06}{5,8*10^3} = 1,84\ mA$$

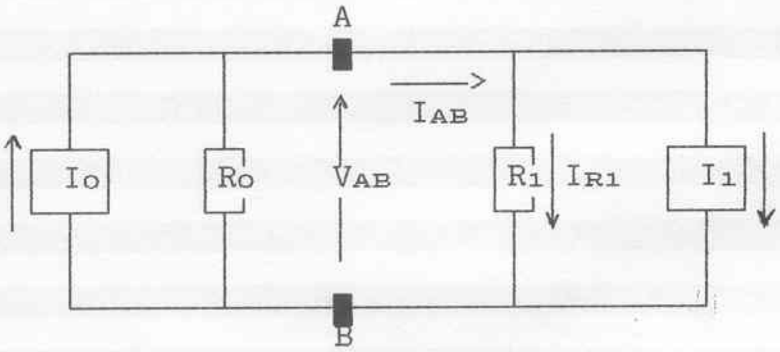
- <u>Teorema di Norton</u>



$$V_{CD} = \frac{\frac{E_2}{R_2} + \frac{E_3}{R_4 + R_5}}{\frac{1}{R_3 + R_6} + \frac{1}{R_2} + \frac{1}{R_4 + R_5}} =$$

$$= \frac{\dfrac{6}{1*10^3} + \dfrac{4}{1,5*10^3 + 2,5*10^3}}{\dfrac{1}{2*10^3 + 3*10^3} + \dfrac{1}{1*10^3} + \dfrac{1}{1,5*10^3 + 2,5*10^3}} = 4,83 \text{ V}$$

$$I_O = \frac{V_{CD}}{R_3 + R_6} = \frac{4,83}{2*10^3 + 3*10^3} = 0,966 \text{ mA}$$

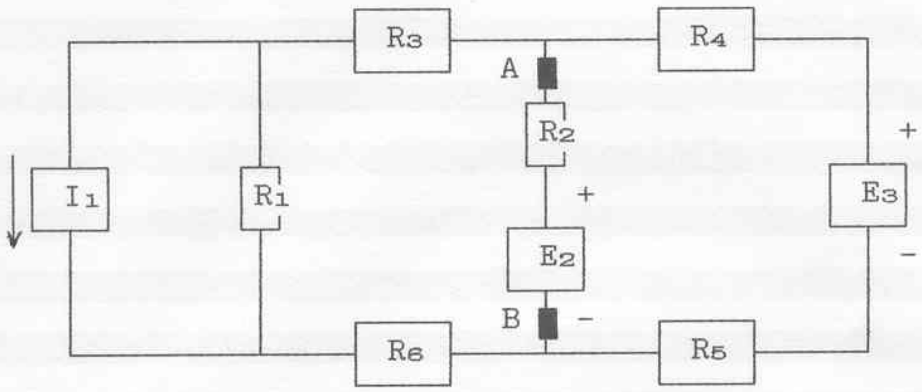


$$V_{AB} = \frac{I_O - I_1}{\dfrac{1}{R_O} + \dfrac{1}{R_1}} = \frac{0,966*10^{-3} - 5*10^{-3}}{\dfrac{1}{5,8*10^3} + \dfrac{1}{1,6*10^3}} = -\ 5,06 \text{ V}$$

$$I_{R1} = \frac{V_{AB}}{R_1} = \frac{-\ 5,06}{1,6*10^3} = -\ 3,1625 \text{ mA}$$

$$I_{AB} = I_1 + I_{R1} = 5*10^{-3} - 3,1625*10^{-3} = 1,8375 \text{ mA}$$

6.18 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

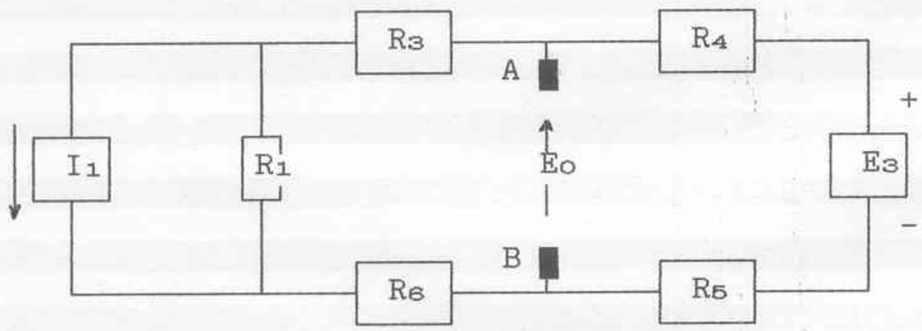


$I_1 = 5$ mA ; $E_2 = 6$ V ; $E_3 = 4$ V ; $R_1 = 1{,}6$ KΩ ; $R_2 = 1$ KΩ

$R_3 = 2$ KΩ ; $R_4 = 1{,}5$ KΩ ; $R_5 = 2{,}5$ KΩ ; $R_6 = 3$ KΩ

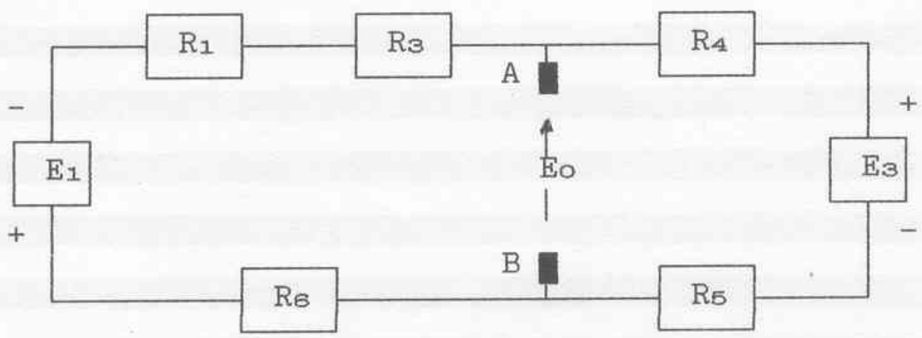
RISOLUZIONE

- Teorema di Thèvenin



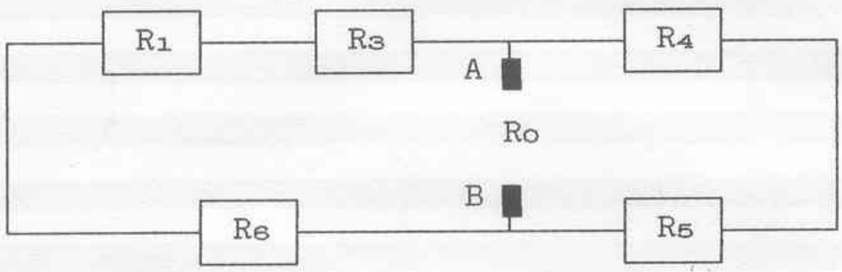
Si trasforma il generatore di corrente in generatore di tensione:

$E_1 = R_1 * I_1 = 1{,}6*10^3 * 5*10^{-3} = 8$ V

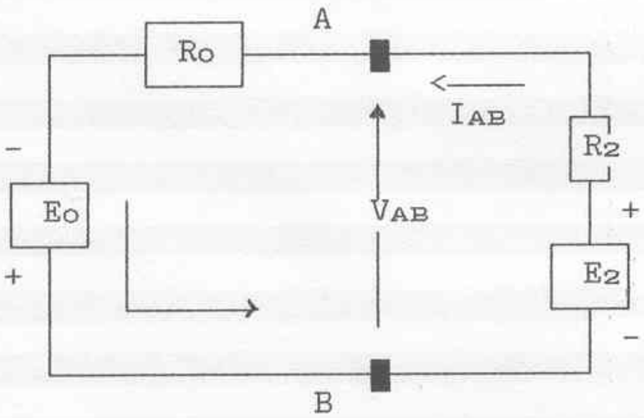


$$E_0 = \frac{-\dfrac{E_1}{R_1 + R_3 + R_6} + \dfrac{E_3}{R_4 + R_5}}{\dfrac{1}{R_1 + R_3 + R_6} + \dfrac{1}{R_4 + R_5}} =$$

$$= \frac{-\dfrac{8}{1,6*10^3 + 2*10^3 + 3*10^3} + \dfrac{4}{1,5*10^3 + 2,5*10^3}}{\dfrac{1}{1,6*10^3 + 2*10^3 + 3*10^3} + \dfrac{1}{1,5*10^3 + 2,5*10^3}} = -\ 0,53\ V$$



$$R_0 = \frac{(R_1 + R_3 + R_6) * (R_4 + R_5)}{R_1 + R_3 + R_6 + R_4 + R_5} = \frac{6,6*10^3 * 4*10^3}{6,6*10^3 + 4*10^3} = 2,49\ K\Omega$$

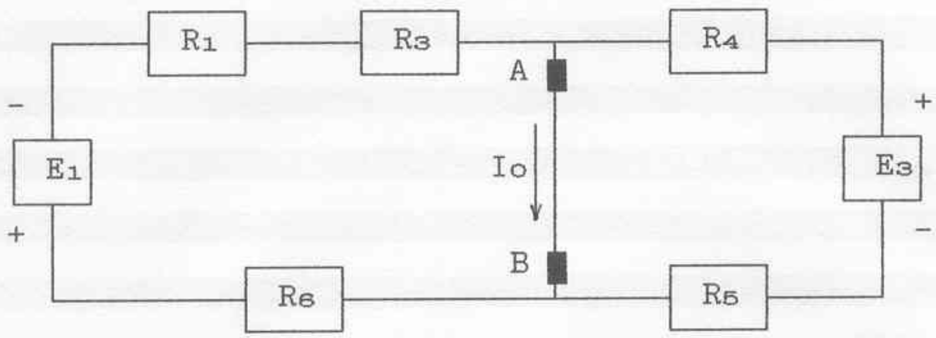


$E_0 + E_2 = (R_0 + R_2) * I_{AB}$ ==>

$$\text{==>} \quad I_{AB} = \frac{E_0 + E_2}{R_0 + R_2} = \frac{0,53 + 6}{2,49*10^3 + 1*10^3} = 1,87\ mA$$

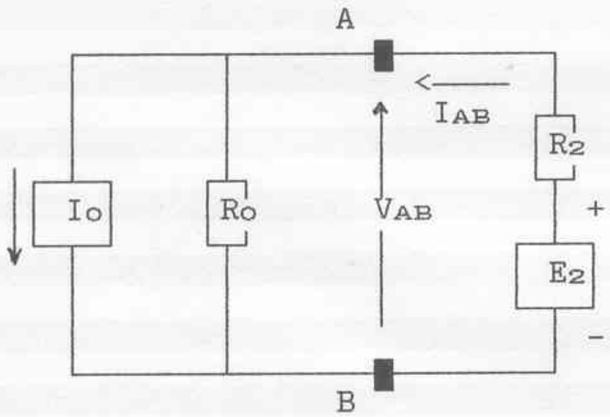
$V_{AB} = E_2 - R_2 * I_{AB} = 6 - 1*10^3 * 1,87*10^{-3} = 4,13\ V$

- Teorema di Norton



$$I_o = -\frac{E_1}{R_1 + R_3 + R_6} + \frac{E_3}{R_4 + R_5} =$$

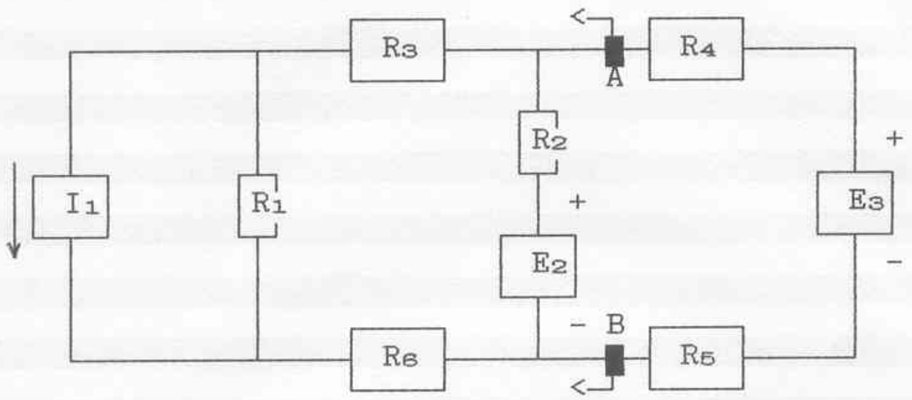
$$= -\frac{8}{1{,}6*10^3 + 2*10^3 + 3*10^3} + \frac{4}{1{,}5*10^3 + 2{,}5*10^3} = -\ 0{,}21\ mA$$



$$V_{AB} = \frac{-\ I_o + \dfrac{E_2}{R_2}}{\dfrac{1}{R_o} + \dfrac{1}{R_2}} = \frac{-\ 0{,}21*10^{-3} + \dfrac{6}{1*10^3}}{\dfrac{1}{2{,}49*10^3} + \dfrac{1}{1*10^3}} = 4{,}13\ V$$

$$V_{AB} = E_2 - R_2 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_2} = \frac{6 - 4{,}13}{1*10^3} = 1{,}87\ mA$$

6.19 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

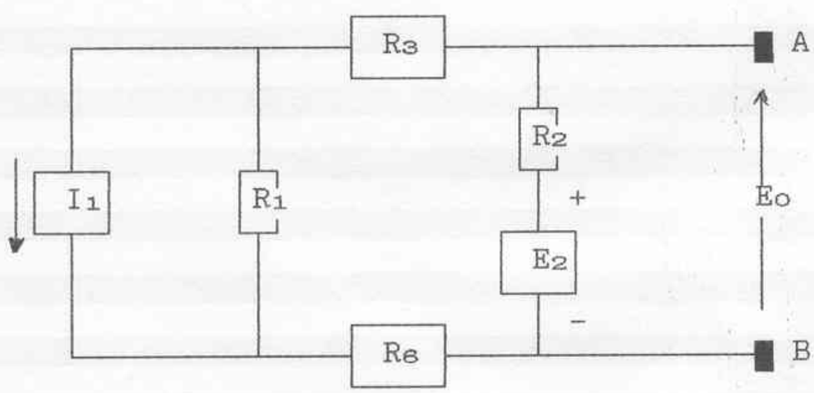


$I_1 = 5\ mA$; $E_2 = 6\ V$; $E_3 = 4\ V$; $R_1 = 1{,}6\ K\Omega$; $R_2 = 1\ K\Omega$

$R_3 = 2\ K\Omega$; $R_4 = 1{,}5\ K\Omega$; $R_5 = 2{,}5\ K\Omega$; $R_6 = 3\ K\Omega$

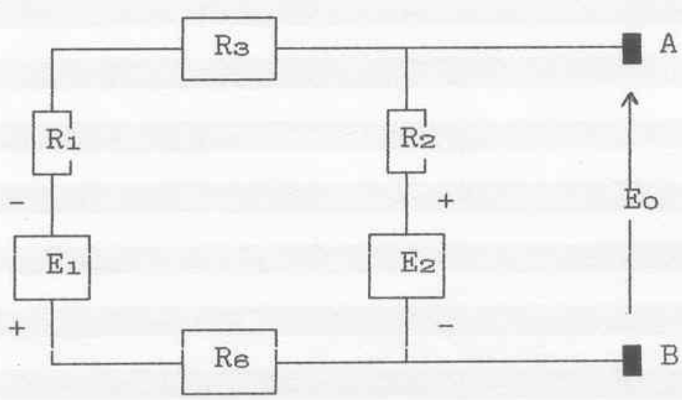
RISOLUZIONE

- Teorema di Thèvenin



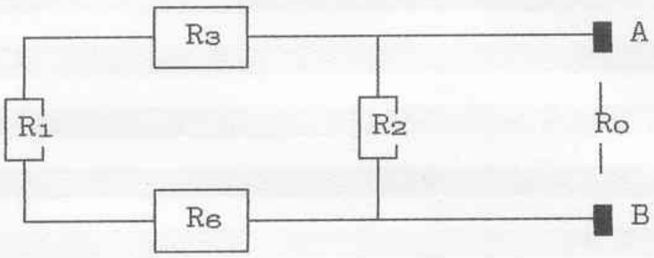
Si trasforma il generatore di corrente in generatore di tensione:

$E_1 = R_1 * I_1 = 1{,}6*10^3 * 5*10^{-3} = 8\ V$

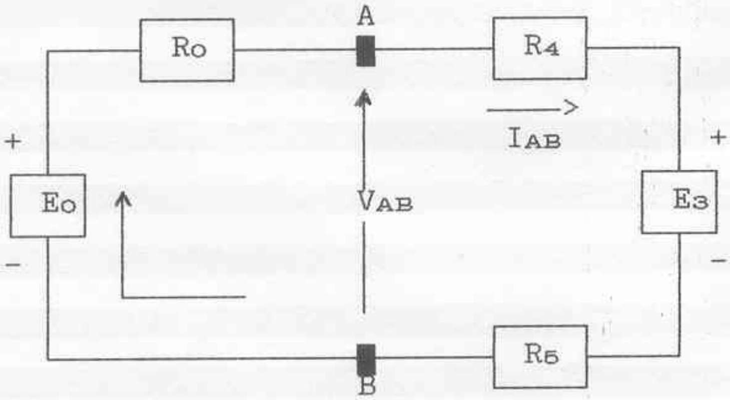


$$E_o = \frac{-\dfrac{E_1}{R_1 + R_3 + R_6} + \dfrac{E_2}{R_2}}{\dfrac{1}{R_1 + R_3 + R_6} + \dfrac{1}{R_2}} =$$

$$= \frac{-\dfrac{8}{1,6*10^3 + 2*10^3 + 3*10^3} + \dfrac{4}{1*10^3}}{\dfrac{1}{1,6*10^3 + 2*10^3 + 3*10^3} + \dfrac{1}{1*10^3}} = 4,16 \text{ V}$$



$$R_o = \frac{(R_1 + R_3 + R_6) * R_2}{R_1 + R_3 + R_6 + R_2} = \frac{6,6*10^3 * 1*10^3}{6,6*10^3 + 1*10^3} = 0,87 \text{ K}\Omega$$

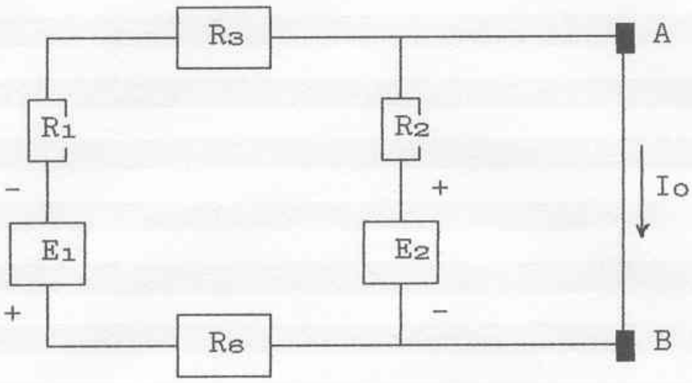


$$E_o - E_3 = (R_o + R_4 + R_5) * I_{AB} \quad ==>$$

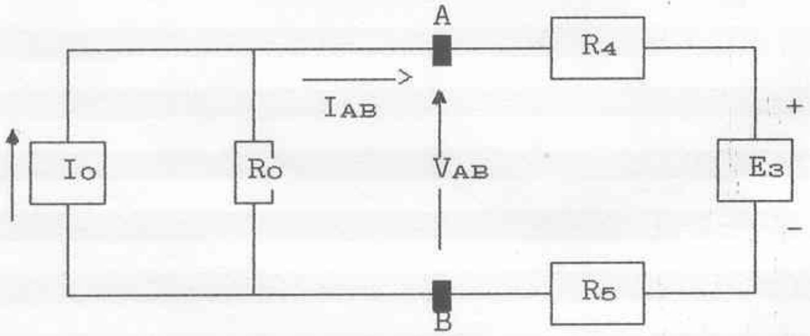
$$==> \quad I_{AB} = \frac{E_o - E_3}{R_o + R_4 + R_5} = \frac{4,16 - 4}{0,87*10^3 + 1,5*10^3 + 2,5*10^3} = 0,033 \text{ mA}$$

$$V_{AB} = E_o - R_o * I_{AB} = 4,16 - 0,87*10^3 * 0,033*10^{-3} = 4,13 \text{ V}$$

- <u>Teorema di Norton</u>



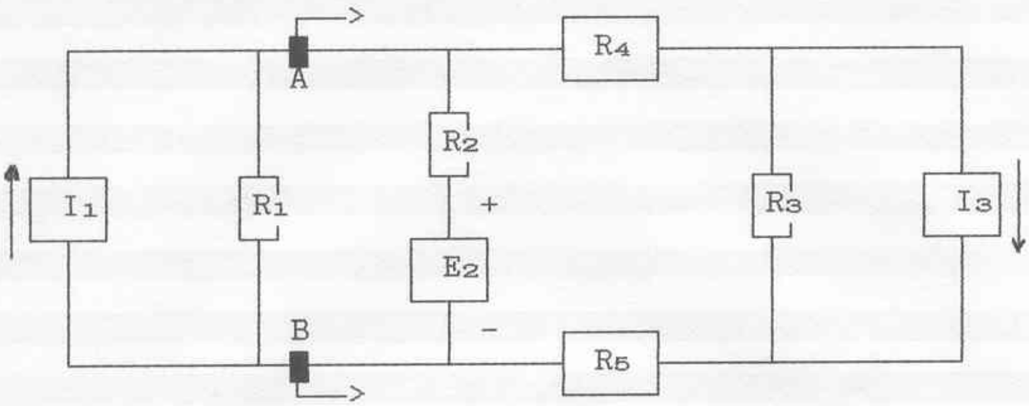
$$I_O = \frac{-E_1}{R_1 + R_3 + R_6} + \frac{E_2}{R_2} = \frac{-8}{1,6*10^3 + 2*10^3 + 3*10^3} + \frac{4}{1*10^3} = 4,79 \text{ mA}$$



$$V_{AB} = \frac{I_O + \dfrac{E_3}{R_4 + R_5}}{\dfrac{1}{R_O} + \dfrac{1}{R_4 + R_5}} = \frac{4,79*10^{-3} - \dfrac{4}{1,5*10^3 + 2,5*10^3}}{\dfrac{1}{0,87*10^3} + \dfrac{1}{1,5*10^3 + 2,5*10^3}} = 4,13 \text{ V}$$

$$V_{AB} = E_3 + (R_4 + R_5) * I_{AB} \implies I_{AB} = \frac{V_{AB} - E_3}{R_4 + R_5} = \frac{4,13 - 4}{4*10^3} = 0,033 \text{ mA}$$

6.20 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

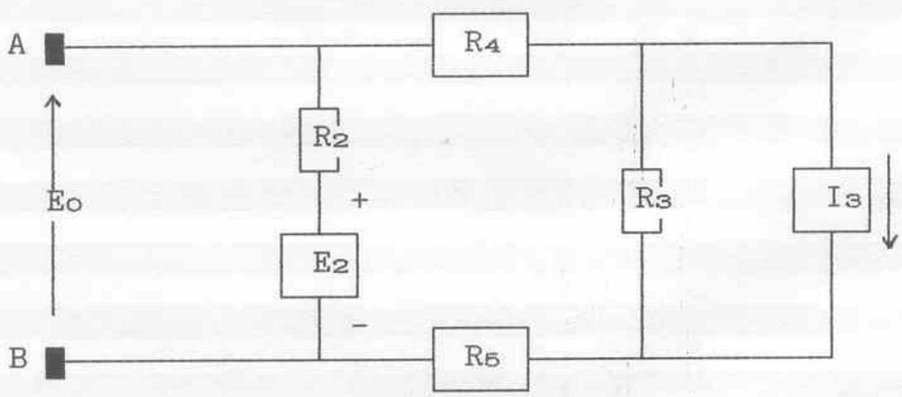


$I_1 = 6$ mA ; $E_2 = 6$ V ; $I_3 = 8$ mA ; $R_1 = 1{,}5$ KΩ

$R_2 = 2{,}5$ KΩ ; $R_3 = 1$ KΩ ; $R_4 = 2$ KΩ ; $R_5 = 1$ KΩ

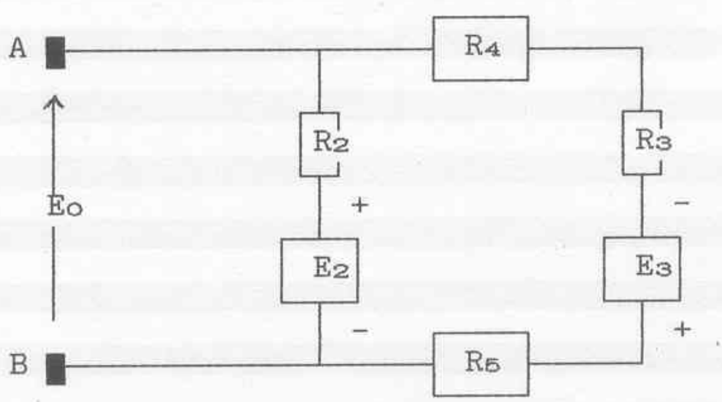
RISOLUZIONE

- Teorema di Thèvenin



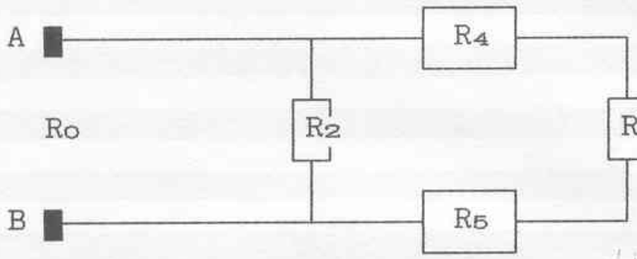
Si trasforma il generatore di corrente in generatore di tensione:

$E_3 = R_3 * I_3 = 1*10^3 * 8*10^{-3} = 8$ V

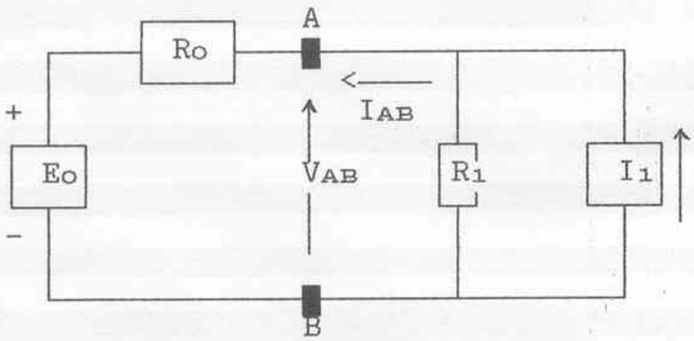


$$E_o = \frac{\dfrac{E_2}{R_2} - \dfrac{E_3}{R_3 + R_4 + R_5}}{\dfrac{1}{R_2} + \dfrac{1}{R_3 + R_4 + R_5}} =$$

$$= \frac{\dfrac{6}{2,5*10^3} - \dfrac{8}{1*10^3 + 2*10^3 + 1*10^3}}{\dfrac{1}{2,5*10^3} + \dfrac{1}{1*10^3 + 2*10^3 + 1*10^3}} = 0,615 \text{ V}$$



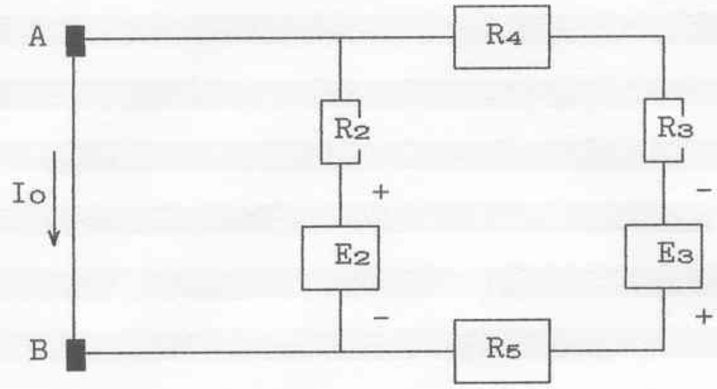
$$R_o = \frac{R_2 * (R_3 + R_4 + R_5)}{R_2 + R_3 + R_4 + R_5} = \frac{2,5*10^3 * (1*10^3 + 2*10^3 + 1*10^3)}{2,5*10^3 + 1*10^3 + 2*10^3 + 1*10^3} = 1,54 \text{ K}\Omega$$



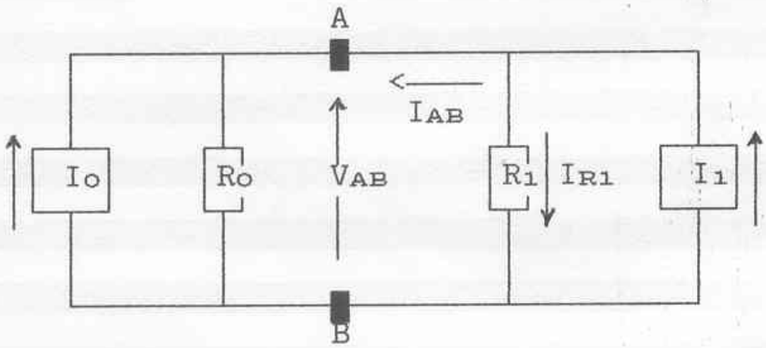
$$V_{AB} = \frac{I_1 + \dfrac{E_o}{R_o}}{\dfrac{1}{R_1} + \dfrac{1}{R_o}} = \frac{6*10^{-3} + \dfrac{0,615}{1,54*10^3}}{\dfrac{1}{1,5*10^3} + \dfrac{1}{1,54*10^3}} = 4,86 \text{ V}$$

$V_{AB} = E_o + R_o * I_{AB}$ ==> $I_{AB} = \dfrac{V_{AB} - E_o}{R_o} = \dfrac{4,86 - 0,615}{1,54*10^3} = 2,756 \text{ mA}$

- Teorema di Norton



$$I_O = \frac{E_2}{R_2} - \frac{E_3}{R_3 + R_4 + R_5} = \frac{6}{2,5*10^3} - \frac{8}{1*10^3 + 2*10^3 + 1*10^3} = 0,4 \text{ mA}$$

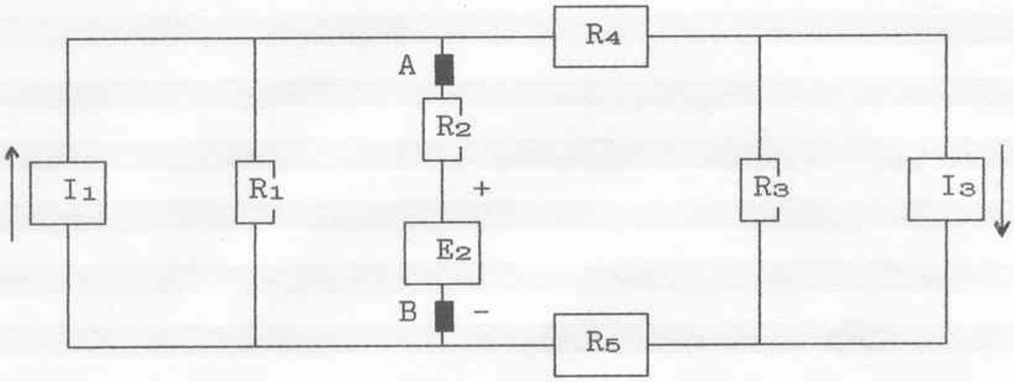


$$V_{AB} = \frac{I_O + I_1}{\frac{1}{R_O} + \frac{1}{R_1}} = \frac{1,655*10^{-3} + 5*10^{-3}}{\frac{1}{1,54*10^3} + \frac{1}{1,5*10^3}} = 4,86 \text{ V}$$

$$I_{R1} = \frac{V_{AB}}{R_1} = \frac{4,86}{1,5*10^3} = 3,24 \text{ mA}$$

$$I_{AB} = I_1 - I_{R1} = 6*10^{-3} - 3,24*10^{-3} = 2,76 \text{ mA}$$

6.21 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

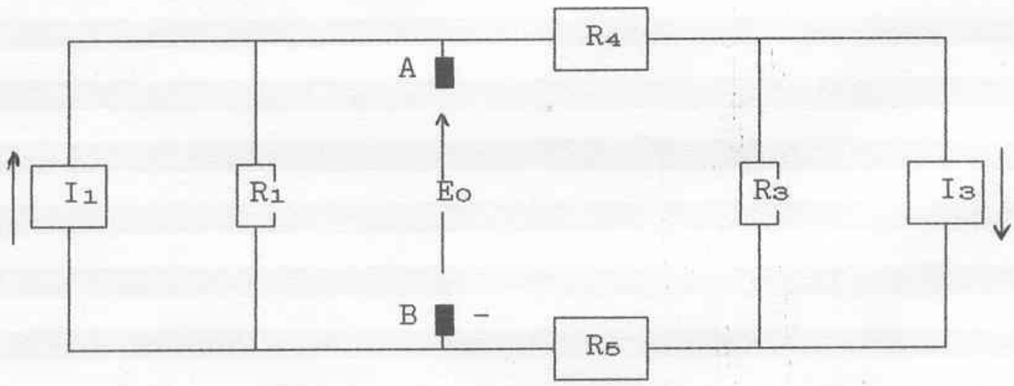


$I_1 = 6$ mA ; $E_2 = 6$ V ; $I_3 = 8$ mA ; $R_1 = 1{,}5$ KΩ

$R_2 = 2{,}5$ KΩ ; $R_3 = 1$ KΩ ; $R_4 = 2$ KΩ ; $R_5 = 1$ KΩ

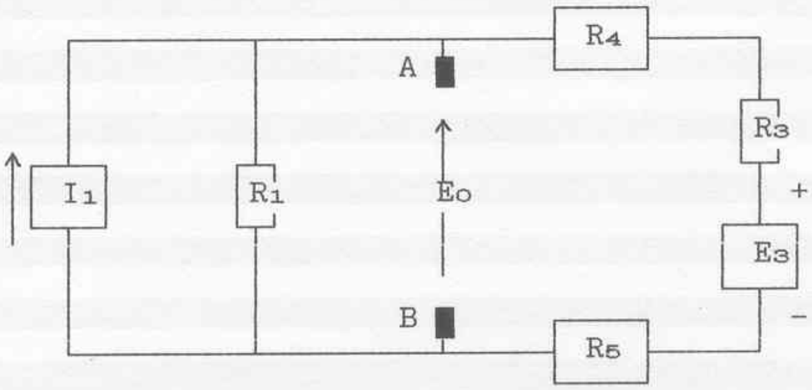
RISOLUZIONE

- Teorema di Thèvenin



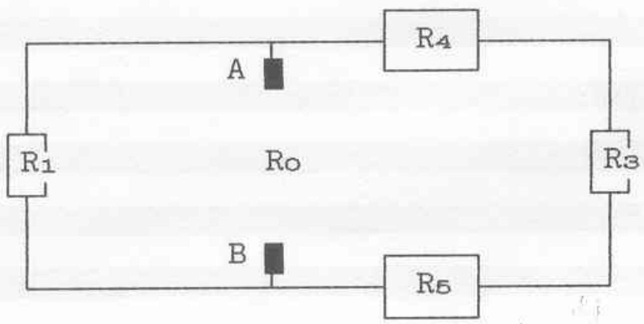
Si trasforma il generatore di corrente I_3 in generatore di tensione:

$E_3 = R_3 * I_3 = 1*10^3 * 8*10^{-3} = 8$ V

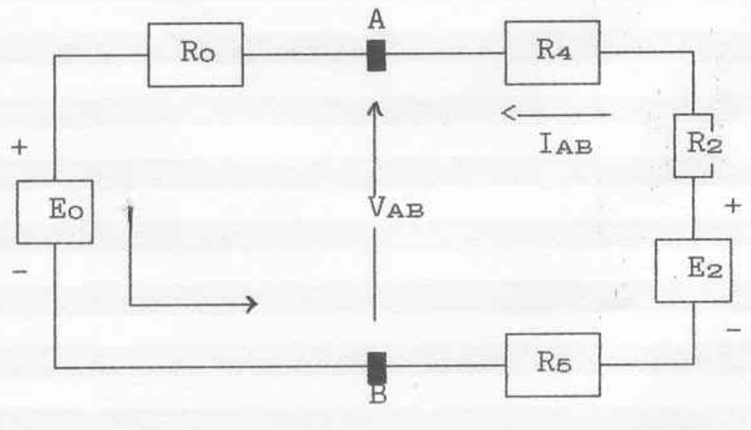


$$E_O = \frac{I_1 - \dfrac{E_3}{R_3 + R_4 + R_5}}{\dfrac{1}{R_1} + \dfrac{1}{R_3 + R_4 + R_5}} =$$

$$= \frac{6*10^{-3} - \dfrac{8}{1*10^3 + 2*10^3 + 1*10^3}}{\dfrac{1}{1,5*10^3} + \dfrac{1}{1*10^3 + 2*10^3 + 1*10^3}} = 4,36 \text{ V}$$



$$R_O = \frac{R_1 * (R_3 + R_4 + R_5)}{R_1 + R_3 + R_4 + R_5} = \frac{1,5*10^3 * (1*10^3 + 2*10^3 + 1*10^3)}{1,5*10^3 + 1*10^3 + 2*10^3 + 1*10^3} = 1,09 \text{ K}\Omega$$

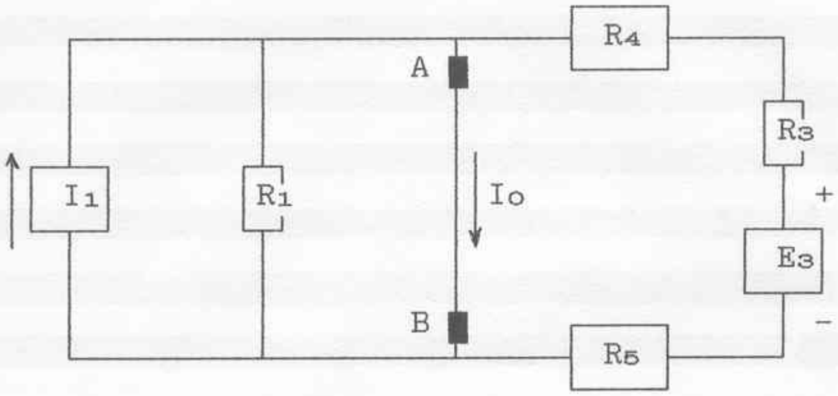


$E_2 - E_O = (R_O + R_2) * I_{AB}$ ==>

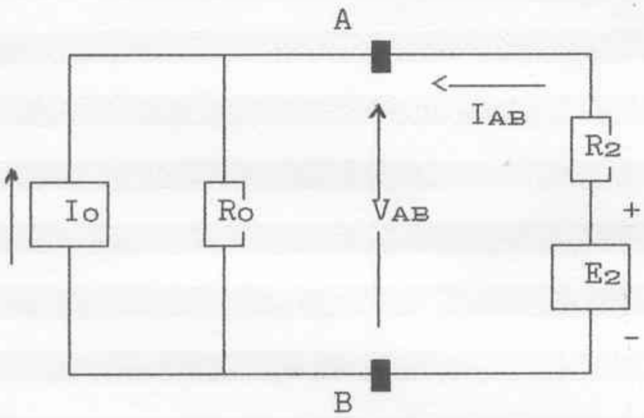
$$\text{==>} \quad I_{AB} = \frac{E_2 - E_O}{R_O + R_2} = \frac{6 - 4,36}{1,09*10^3 + 2,5*10^3} = 0,456 \text{ mA}$$

$V_{AB} = E_2 - R_2 * I_{AB} = 6 - 2,5*10^3 * 0,456*10^{-3} = 4,86$ V

- Teorema di Norton



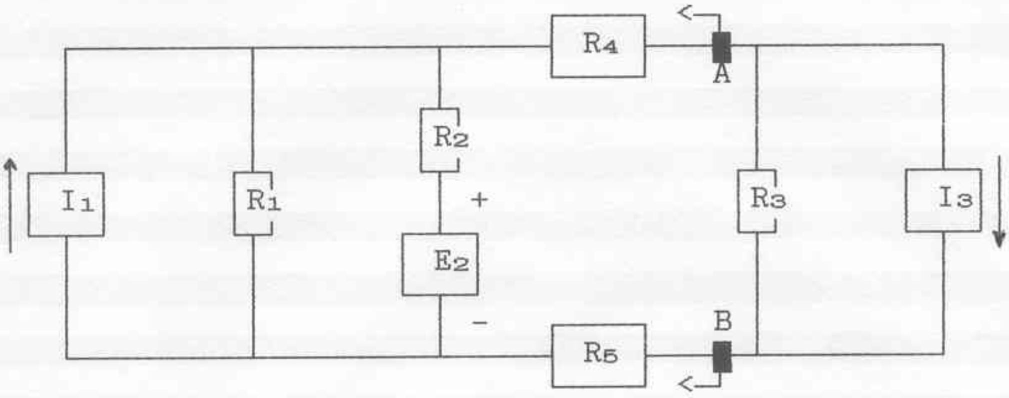
$$I_o = I_1 - \frac{E_3}{R_3 + R_4 + R_5} = 6*10^{-3} - \frac{8}{1*10^3 + 2*10^3 + 1*10^3} = 4 \text{ mA}$$



$$V_{AB} = \frac{I_o + \frac{E_2}{R_2}}{\frac{1}{R_o} + \frac{1}{R_2}} = \frac{4*10^{-3} + \frac{6}{2,5*10^3}}{\frac{1}{1,09*10^3} + \frac{1}{2,5*10^3}} = 4,86 \text{ V}$$

$$V_{AB} = E_2 - R_2 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_2} = \frac{6 - 4,86}{2,5*10^3} = 0,456 \text{ mA}$$

6.22 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

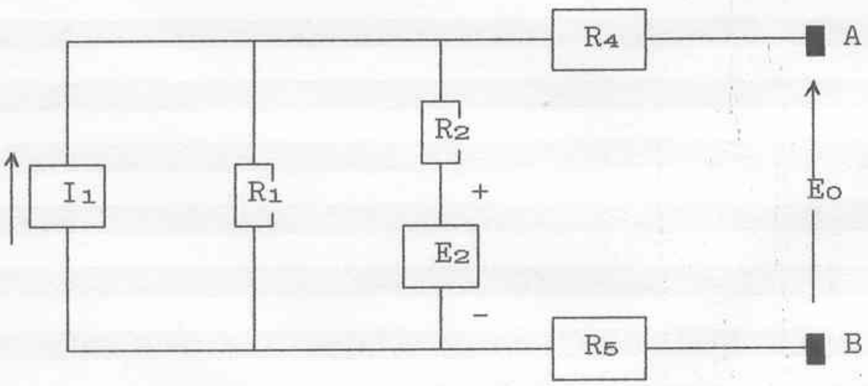


$I_1 = 6\ mA$; $E_2 = 6\ V$; $I_3 = 8\ mA$; $R_1 = 1,5\ K\Omega$

$R_2 = 2,5\ K\Omega$; $R_3 = 1\ K\Omega$; $R_4 = 2\ K\Omega$; $R_5 = 1\ K\Omega$

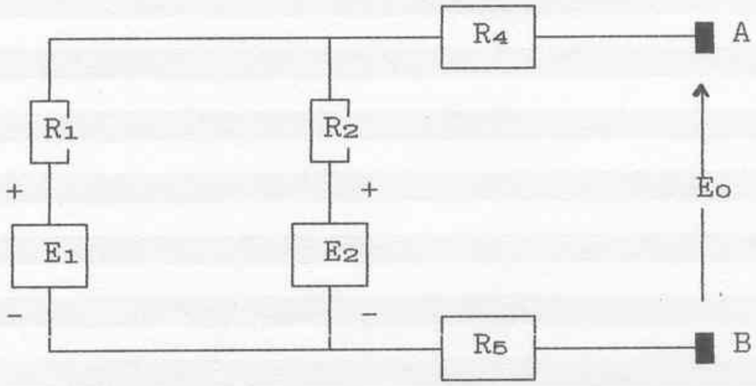
RISOLUZIONE

- Teorema di Thèvenin

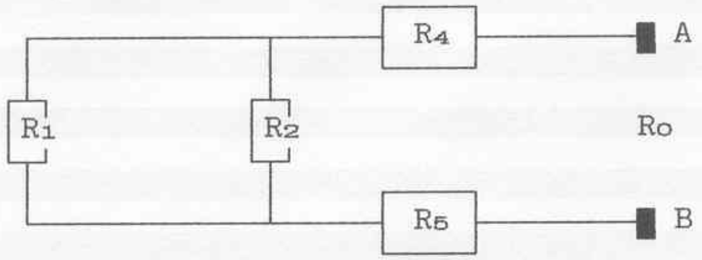


Si trasforma il generatore di corrente I_1 in generatore di tensione:

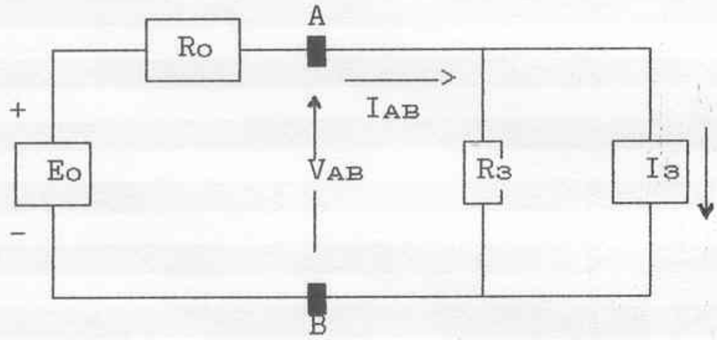
$E_1 = R_1 * I_1 = 1,5*10^3 * 6*10^{-3} = 9\ V$



$$E_O = \frac{\dfrac{E_1}{R_1} + \dfrac{E_2}{R_2}}{\dfrac{1}{R_1} + \dfrac{1}{R_2}} = \frac{\dfrac{9}{1,5*10^3} + \dfrac{6}{2,5*10^3}}{\dfrac{1}{1,5*10^3} + \dfrac{1}{2,5*10^3}} = 7,875\ V$$



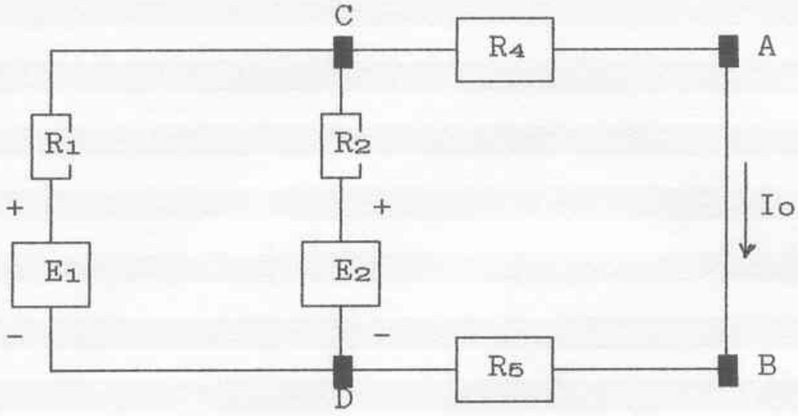
$$R_O = R_4 + R_5 + \frac{R_1 * R_2}{R_1 + R_2} = 2*10^3 + 1*10^3 + \frac{1,5*10^3 * 2,5*10^3}{1,5*10^3 + 2,5*10^3} = 3,94\ K\Omega$$



$$V_{AB} = \frac{\dfrac{E_O}{R_O} - I_3}{\dfrac{1}{R_O} + \dfrac{1}{R_3}} = \frac{\dfrac{7,875}{3,94*10^3} - 8*10^{-3}}{\dfrac{1}{3,94*10^3} + \dfrac{1}{1*10^3}} = -\ 4,786\ V$$

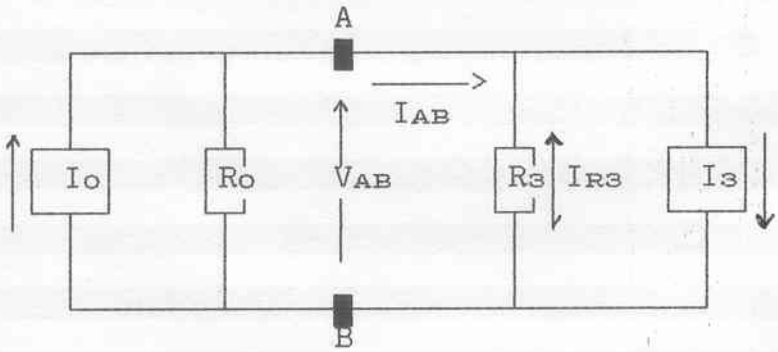
$$V_{AB} = E_O + R_O * I_{AB} \quad ==> \quad I_{AB} = \frac{E_O - V_{AB}}{R_O} = \frac{7,875 + 4,786}{3,94*10^3} = 3,21\ mA$$

- Teorema di Norton



$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_2}}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_4 + R_5}} = \frac{\frac{9}{1,5*10^3} + \frac{6}{2,5*10^3}}{\frac{1}{1,5*10^3} + \frac{1}{2,5*10^3} + \frac{1}{3*10^3}} = 6\ V$$

$$I_O = \frac{V_{CD}}{R_4 + R_5} = \frac{6}{2*10^3 + 1*10^3} = 2\ mA$$

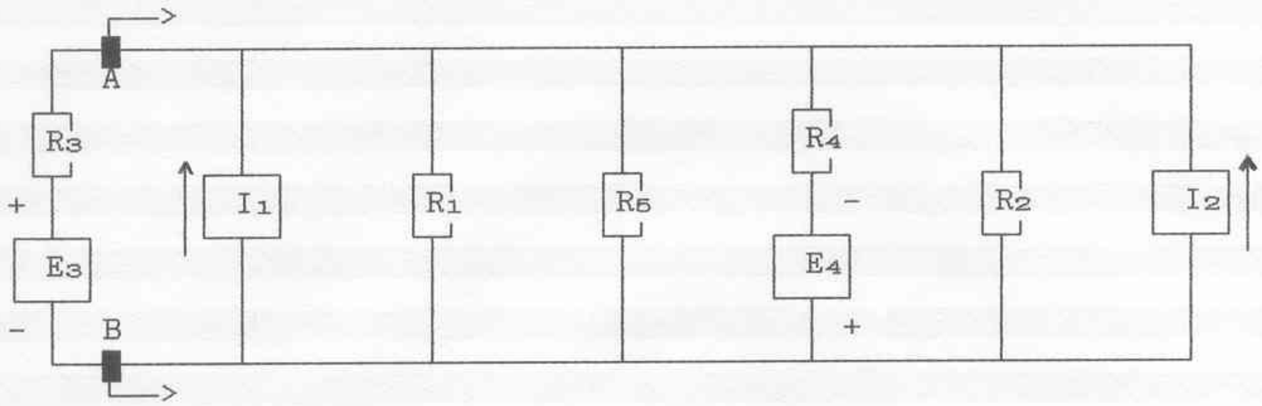


$$V_{AB} = \frac{I_O - I_3}{\frac{1}{R_O} + \frac{1}{R_3}} = \frac{2*10^{-3} - 8*10^{-3}}{\frac{1}{3,94*10^3} + \frac{1}{1*10^3}} = -\ 4,785\ V$$

$$I_{R3} = \frac{V_{AB}}{R_3} = \frac{4,785}{1*10^3} = 4,785\ mA$$

$$I_{AB} = I_3 - I_{R3} = 8*10^{-3} - 4,785*10^{-3} = 3,21\ mA$$

6.23 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

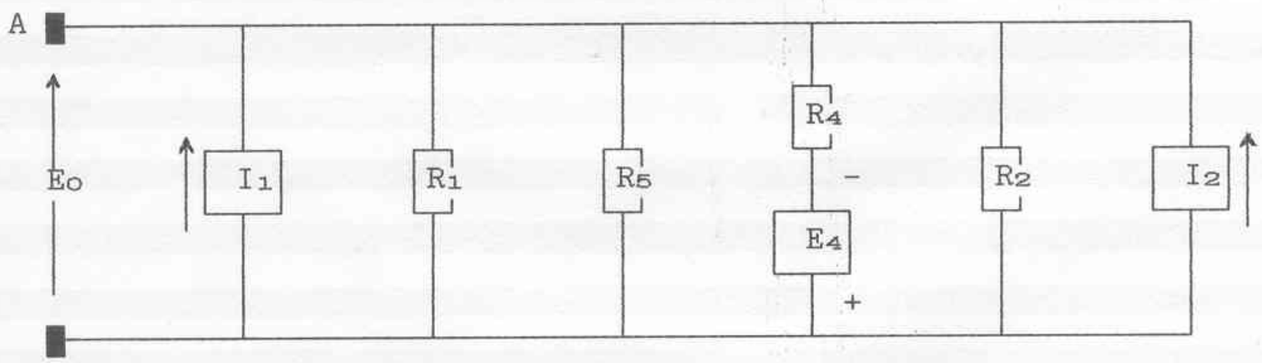


I_1 = 6 mA ; I_2 = 10 mA ; E_3 = 8 V ; E_4 = 10 V

R_1 = 2,5 KΩ ; R_2 = 1 KΩ ; R_3 = 2,5 KΩ ; R_4 = 4 KΩ ; R_5 = 5 KΩ

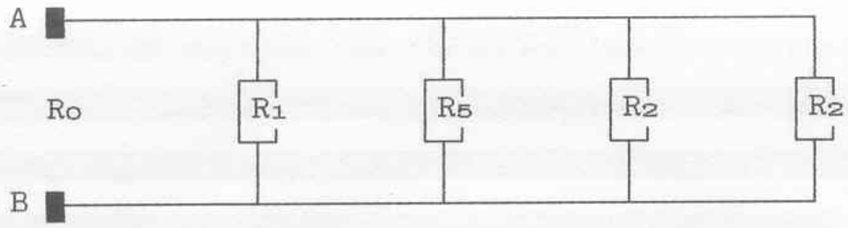
RISOLUZIONE

- Teorema di Thèvenin



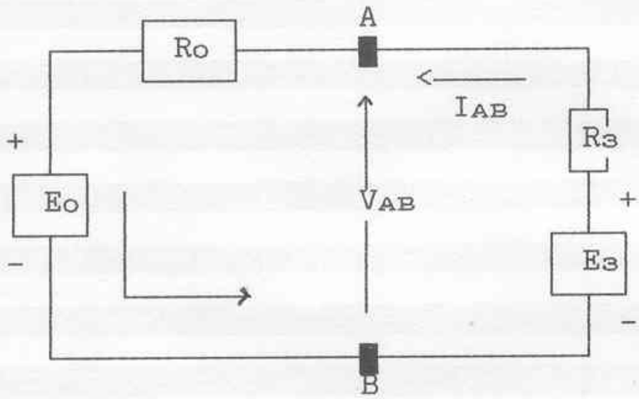
$$E_O = \frac{I_1 + I_2 - \frac{E_4}{R_4}}{\frac{1}{R_1} + \frac{1}{R_5} + \frac{1}{R_4} + \frac{1}{R_2}} =$$

$$= \frac{6*10^{-3} + 10*10^{-3} - \frac{10}{4*10^{3}}}{\frac{1}{2,5*10^{3}} + \frac{1}{5*10^{3}} + \frac{1}{4*10^{3}} + \frac{1}{1*10^{3}}} = 7,3 \text{ V}$$



$$R_O = \frac{1}{\frac{1}{R_1} + \frac{1}{R_5} + \frac{1}{R_4} + \frac{1}{R_2}} =$$

$$= \frac{1}{\frac{1}{2,5*10^3} + \frac{1}{5*10^3} + \frac{1}{4*10^3} + \frac{1}{1*10^3}} = 0,54\ K\Omega$$

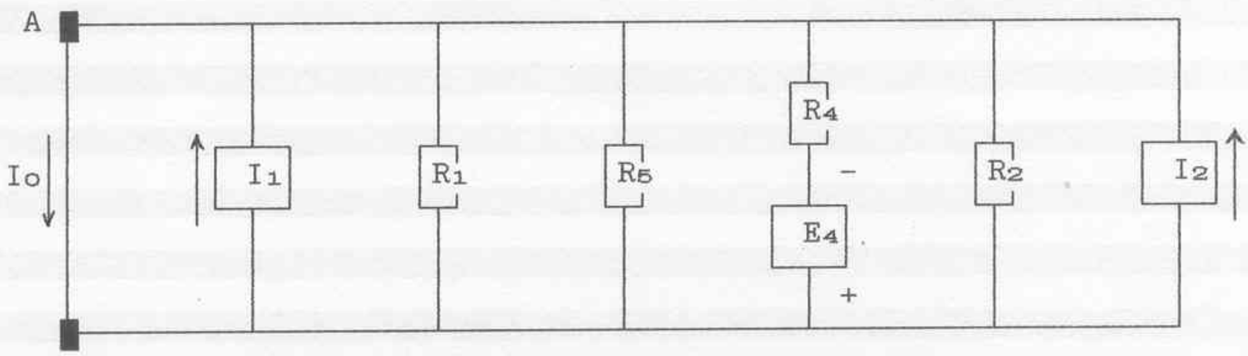


$$E_3 - E_O = (R_O + R_3) * I_{AB} \quad ==>$$

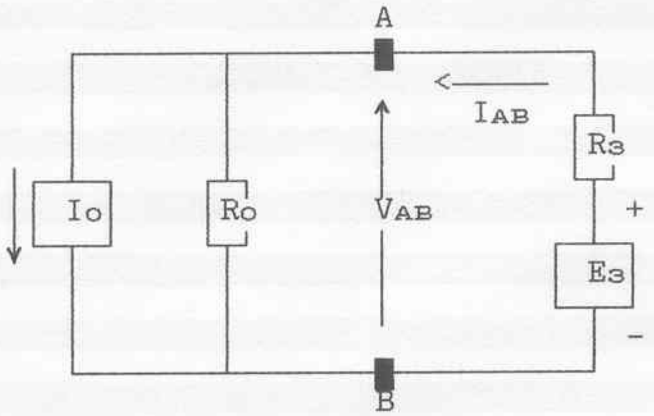
$$==> \quad I_{AB} = \frac{E_3 - E_O}{R_O + R_3} = \frac{8 - 7,3}{0,54*10^3 + 2,5*10^3} = 0,23\ mA$$

$$V_{AB} = E_3 - R_3 * I_{AB} = 8 - 2,5*10^3 * 0,23*10^{-3} = 7,425\ V$$

- <u>Teorema di Norton</u>



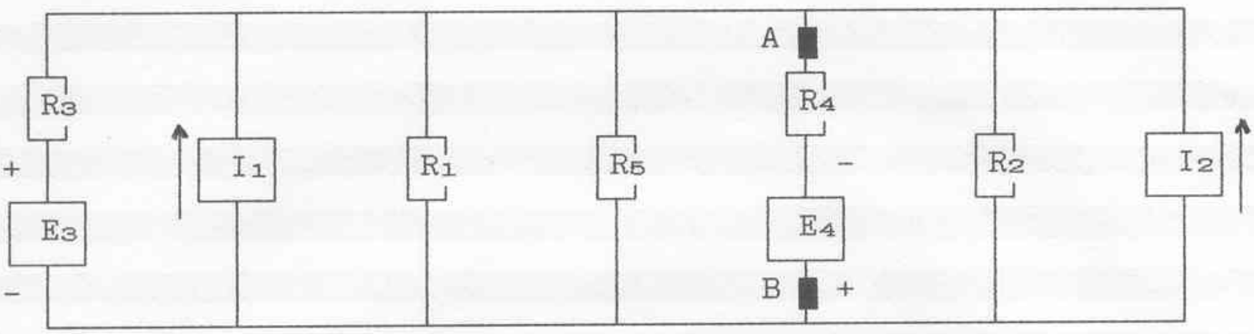
$$I_o = I_1 + I_2 - \frac{E_4}{R_4} = 6*10^{-3} + 10*10^{-3} - \frac{10}{4*10^3} = 13{,}5\ mA$$



$$V_{AB} = \frac{I_o + \frac{E_3}{R_3}}{\frac{1}{R_o} + \frac{1}{R_3}} = \frac{13{,}5*10^{-3} + \frac{8}{2{,}5*10^3}}{\frac{1}{0{,}54*10^3} + \frac{1}{2{,}5*10^3}} = 7{,}416\ V$$

$$V_{AB} = E_3 - R_3 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_3 - V_{AB}}{R_3} = \frac{8 - 7{,}416}{2{,}5*10^3} = 0{,}23\ mA$$

6.24 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

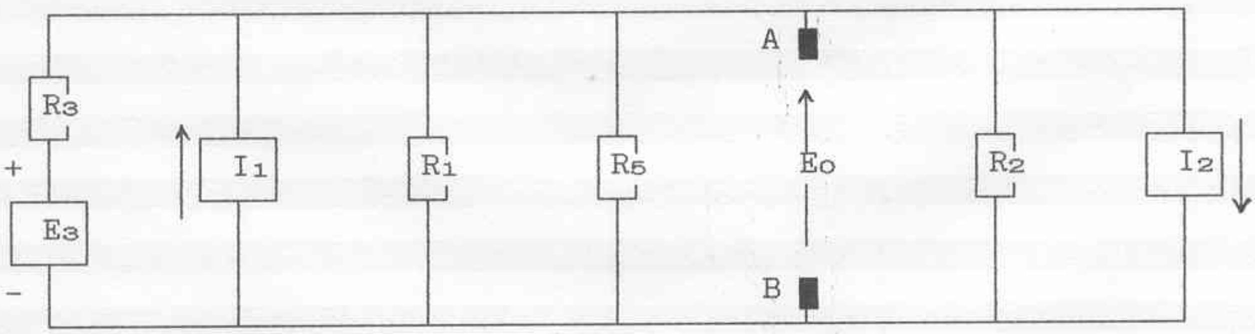


$I_1 = 6$ mA ; $I_2 = 10$ mA ; $E_3 = 8$ V ; $E_4 = 10$ V

$R_1 = 2,5$ KΩ ; $R_2 = 1$ KΩ ; $R_3 = 2,5$ KΩ ; $R_4 = 4$ KΩ ; $R_5 = 5$ KΩ

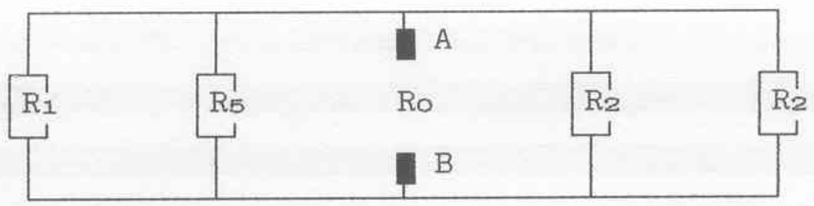
RISOLUZIONE

- Teorema di Thèvenin



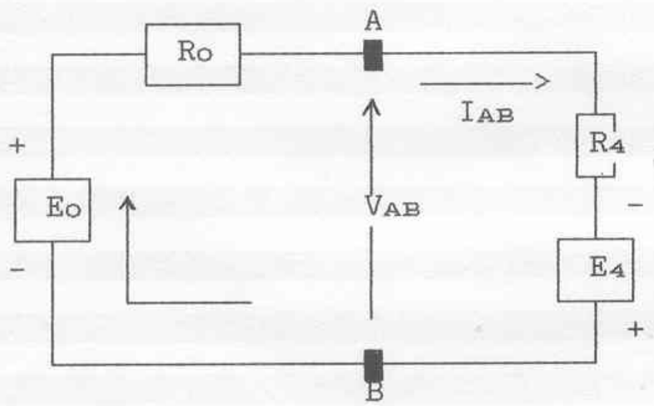
$$E_o = \frac{I_1 + I_2 + \frac{E_3}{R_3}}{\frac{1}{R_1} + \frac{1}{R_5} + \frac{1}{R_3} + \frac{1}{R_2}} =$$

$$= \frac{6*10^{-3} + 10*10^{-3} + \frac{8}{2,5*10^3}}{\frac{1}{2,5*10^3} + \frac{1}{5*10^3} + \frac{1}{2,5*10^3} + \frac{1}{1*10^3}} = 9,6 \text{ V}$$



$$R_O = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_5} + \dfrac{1}{R_3} + \dfrac{1}{R_2}} =$$

$$= \frac{1}{\dfrac{1}{2,5*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{2,5*10^3} + \dfrac{1}{1*10^3}} = 0,5\ K\Omega$$

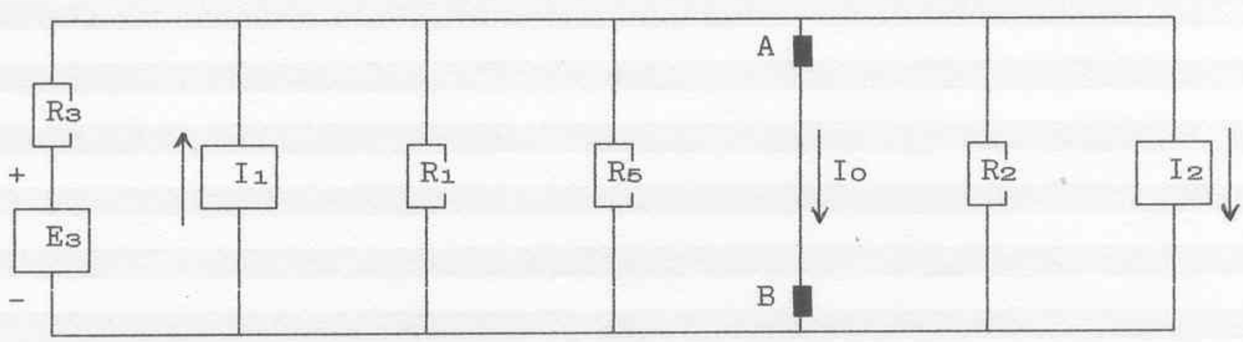


$E_O + E_4 = (R_O + R_4) * I_{AB}$ ==>

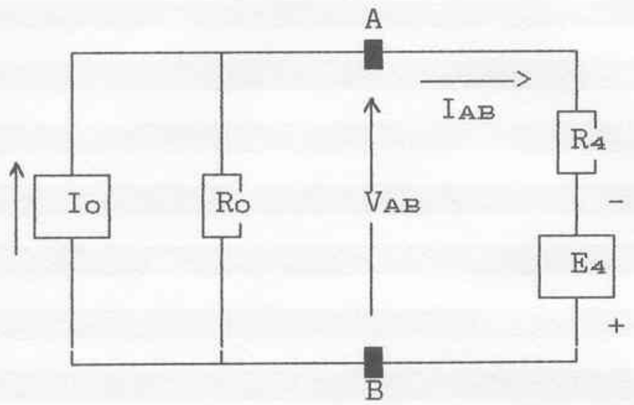
$$\text{==>} \quad I_{AB} = \frac{E_O + E_4}{R_O + R_4} = \frac{9,6 + 10}{0,5*10^3 + 4*10^3} = 4,355\ mA$$

$V_{AB} = - E_4 + R_4 * I_{AB} = - 10 + 4*10^3 * 4,355*10^{-3} = 7,42\ V$

- <u>Teorema di Norton</u>



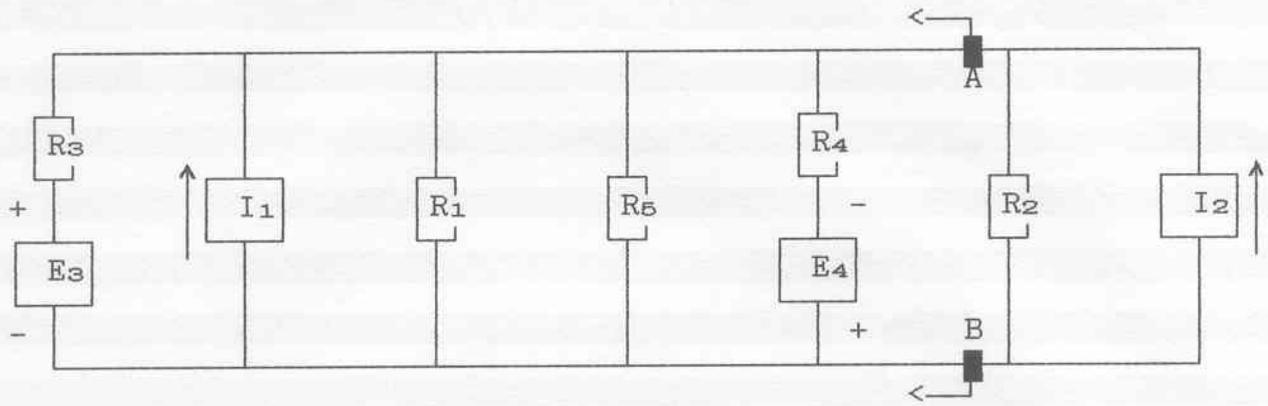
$$I_o = I_1 + I_2 + \frac{E_3}{R_3} = 6*10^{-3} + 10*10^{-3} + \frac{8}{2,5*10^3} = 19,2 \text{ mA}$$



$$V_{AB} = \frac{I_o - \frac{E_4}{R_4}}{\frac{1}{R_o} + \frac{1}{R_4}} = \frac{19,2*10^{-3} - \frac{8}{4*10^3}}{\frac{1}{0,5*10^3} + \frac{1}{4*10^3}} = 7,422 \text{ V}$$

$$V_{AB} = - E_4 + R_4 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_4 + V_{AB}}{R_4} = \frac{10 + 7,422}{4*10^3} = 4,355 \text{ mA}$$

6.25 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.

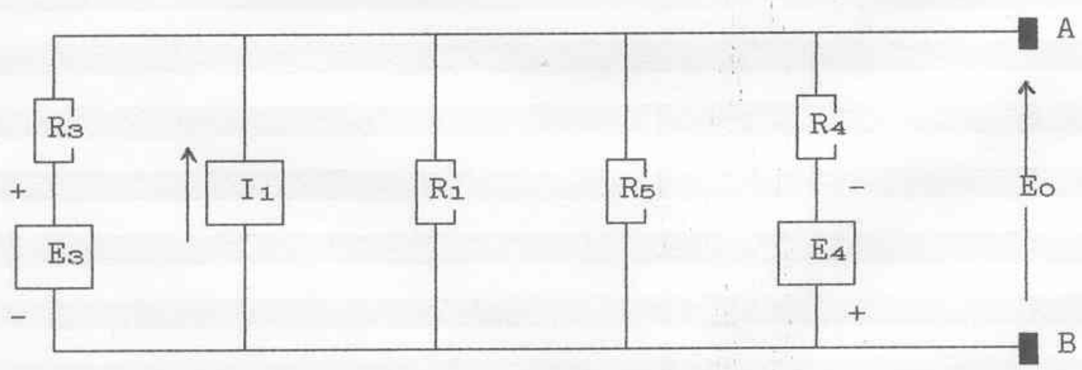


$I_1 = 6\ mA$; $I_2 = 10\ mA$; $E_3 = 8\ V$; $E_4 = 10\ V$

$R_1 = 2{,}5\ K\Omega$; $R_2 = 1\ K\Omega$; $R_3 = 2{,}5\ K\Omega$; $R_4 = 4\ K\Omega$; $R_5 = 5\ K\Omega$

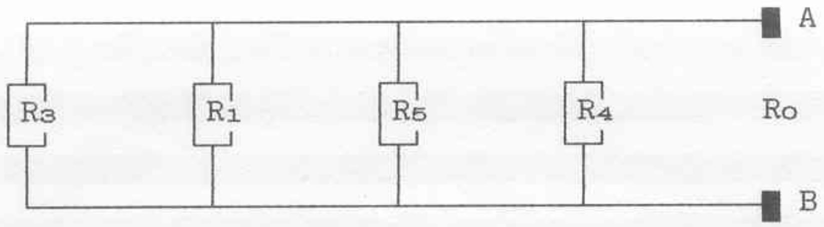
RISOLUZIONE

- Teorema di Thèvenin



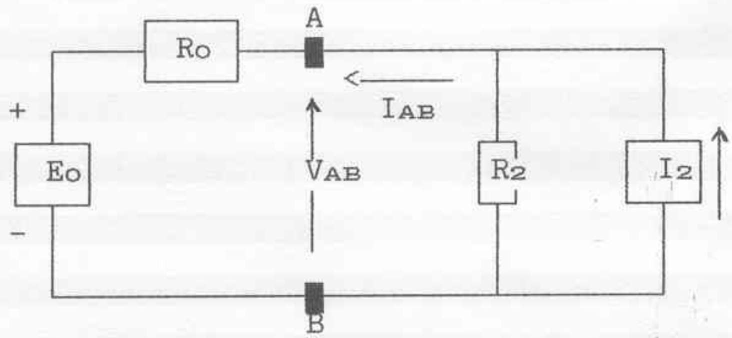
$$E_O = \frac{\frac{E_3}{R_3} + I_1 - \frac{E_4}{R_4}}{\frac{1}{R_1} + \frac{1}{R_5} + \frac{1}{R_3} + \frac{1}{R_4}} =$$

$$= \frac{\frac{8}{2{,}5*10^3} + 6*10^{-3} - \frac{10}{4*10^3}}{\frac{1}{2{,}5*10^3} + \frac{1}{5*10^3} + \frac{1}{2{,}5*10^3} + \frac{1}{4*10^3}} = 5{,}36\ V$$



$$R_O = \frac{1}{\frac{1}{R_1} + \frac{1}{R_5} + \frac{1}{R_3} + \frac{1}{R_4}} =$$

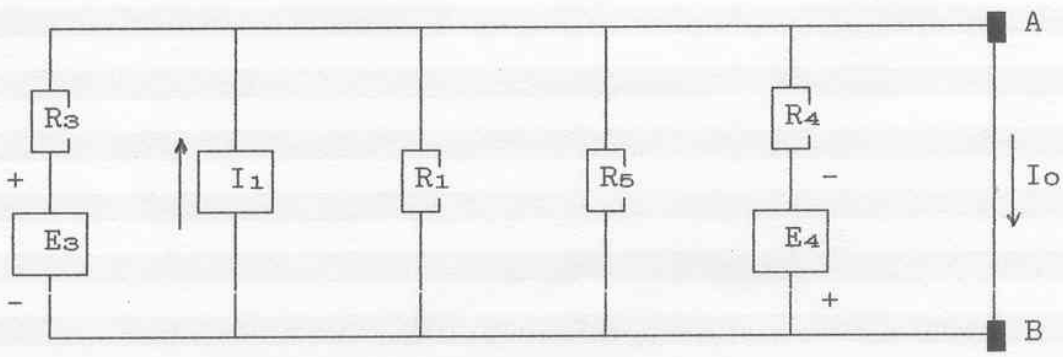
$$= \frac{1}{\frac{1}{2,5*10^3} + \frac{1}{5*10^3} + \frac{1}{2,5*10^3} + \frac{1}{4*10^3}} = 0,8\ K\Omega$$



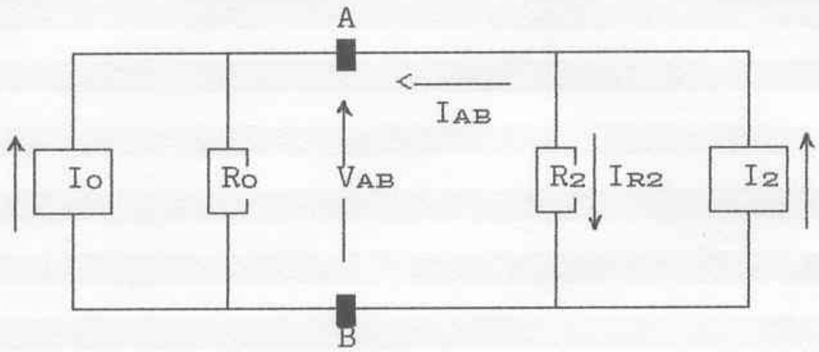
$$V_{AB} = \frac{\frac{E_O}{R_O} + I_2}{\frac{1}{R_O} + \frac{1}{R_2}} = \frac{\frac{5,36}{0,8*10^3} + 10*10^{-3}}{\frac{1}{0,8*10^3} + \frac{1}{1*10^3}} = 7,422\ V$$

$$V_{AB} = R_O * I_{AB} + E_O \quad ==> \quad I_{AB} = \frac{V_{AB} - E_O}{R_O} = \frac{7,422 - 5,36}{0,8*10^3} = 2,58\ mA$$

- <u>Teorema di Norton</u>



$$I_o = \frac{E_3}{R_3} + I_1 - \frac{E_4}{R_4} = \frac{8}{2{,}5*10^3} + 6*10^{-3} - \frac{10}{4*10^3} = 6{,}7 \text{ mA}$$

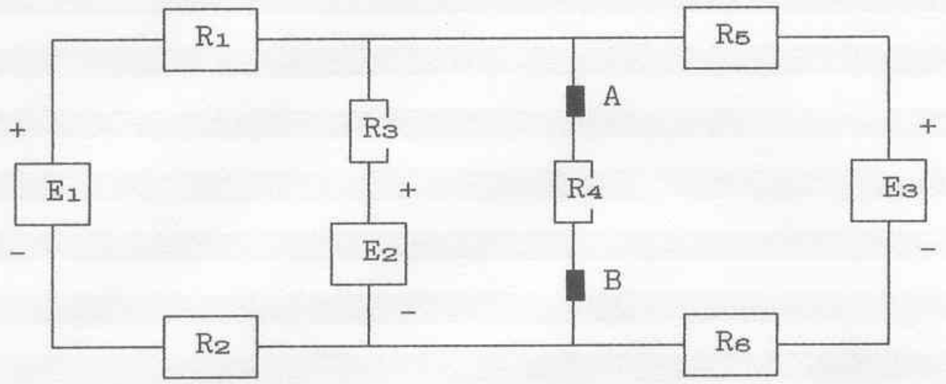


$$V_{AB} = \frac{I_o + I_2}{\frac{1}{R_o} + \frac{1}{R_2}} = \frac{6{,}7*10^{-3} + 10*10^{-3}}{\frac{1}{0{,}8*10^3} + \frac{1}{1*10^3}} = 7{,}422 \text{ V}$$

$$I_{R2} = \frac{V_{AB}}{R_2} = \frac{7{,}422}{1*10^3} = 7{,}422 \text{ mA}$$

$$I_{AB} = I_2 - I_{R2} = 10*10^{-3} - 7{,}422*10^{-3} = 2{,}58 \text{ mA}$$

6.26 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = E_3 = 10\ V$; $R_1 = R_3 = R_5 = 2\ K\Omega$; $R_2 = R_4 = R_6 = 3\ K\Omega$

2.- $E_1 = E_2 = E_3 = 6\ V$; $R_1 = R_3 = R_5 = 3\ K\Omega$; $R_2 = R_4 = R_6 = 2\ K\Omega$

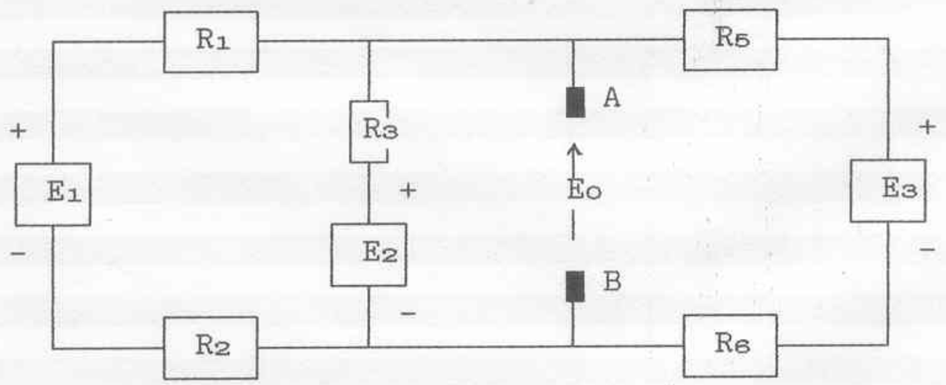
3.- $E_1 = E_2 = E_3 = 8\ V$; $R_1 = R_3 = R_5 = 2\ K\Omega$; $R_2 = R_4 = R_6 = 4\ K\Omega$

4.- $E_1 = E_2 = E_3 = 12\ V$; $R_1 = R_3 = R_5 = 3\ K\Omega$; $R_2 = R_4 = R_6 = 5\ K\Omega$

RISOLUZIONE

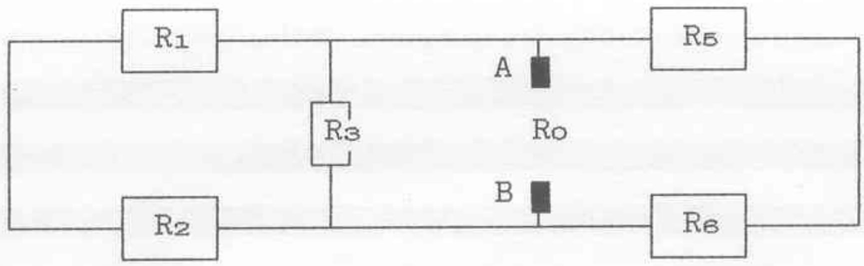
1.- VALORI 1° GRUPPO

- Teorema di Thèvenin



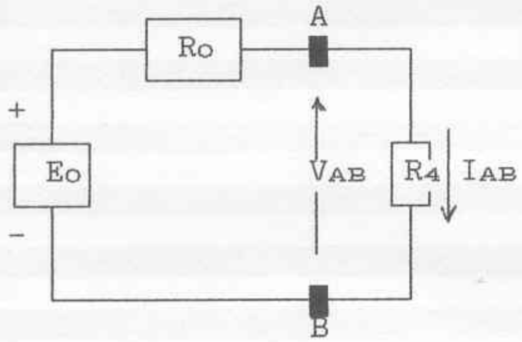
$$E_o = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{10}{2*10^3 + 3*10^3} + \dfrac{10}{2*10^3} + \dfrac{10}{2*10^3 + 3*10^3}}{\dfrac{1}{2*10^3 + 3*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{2*10^3 + 3*10^3}} = 10\ V$$



$$R_O = \frac{1}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_5 + R_6}} =$$

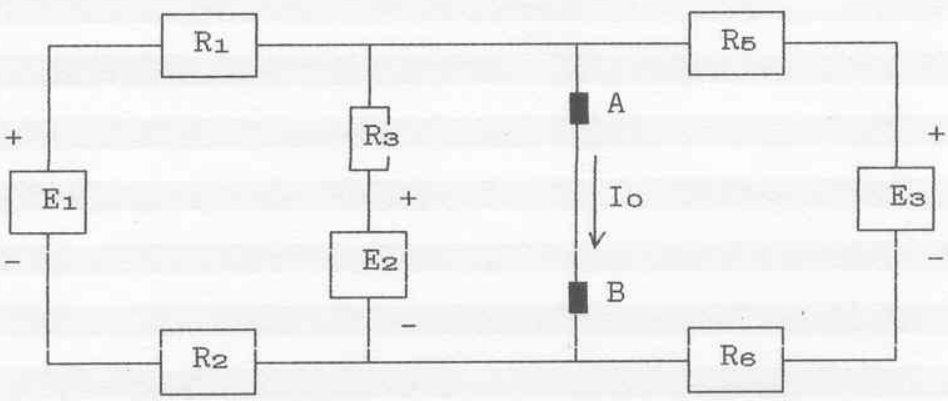
$$= \frac{1}{\dfrac{1}{2*10^3 + 3*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{2*10^3 + 3*10^3}} = 1{,}11\ K\Omega$$



$$I_{AB} = \frac{E_O}{R_O + R_4} = \frac{10}{1{,}11*10^3 + 3*10^3} = 2{,}43\ mA$$

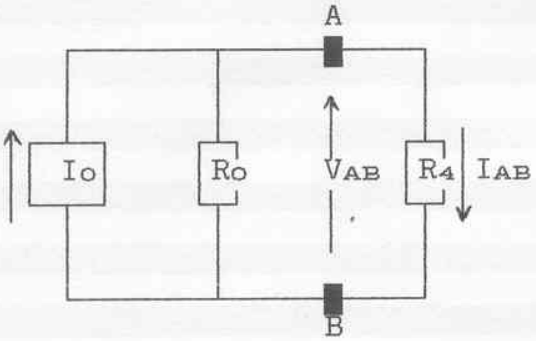
$$V_{AB} = R_4 * I_{AB} = 3*10^3 * 2{,}43*10^{-3} = 7{,}29\ V$$

- <u>Teorema di Norton</u>



$$I_o = \frac{E_1}{R_1 + R_2} + \frac{E_2}{R_3} + \frac{E_3}{R_5 + R_6} =$$

$$= \frac{10}{2*10^3 + 3*10^3} + \frac{10}{2*10^3} + \frac{10}{2*10^3 + 3*10^3} = 9 \text{ mA}$$



$$R_{o4} = \frac{R_o * R_4}{R_o + R_4} = \frac{1,11*10^3 * 3*10^3}{1,11*10^3 + 3*10^3} = 0,81 \text{ K}\Omega$$

$$V_{AB} = R_{o4} * I_o = 0,81*10^3 * 9*10^{-3} = 7,29 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_4} = \frac{7,29}{3*10^3} = 2,43 \text{ mA}$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$E_o = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{6}{3*10^3 + 2*10^3} + \dfrac{6}{3*10^3} + \dfrac{6}{3*10^3 + 2*10^3}}{\dfrac{1}{3*10^3 + 2*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{3*10^3 + 2*10^3}} = 6 \text{ V}$$

$$R_o = \frac{1}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{1}{\dfrac{1}{3*10^3 + 2*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{3*10^3 + 2*10^3}} = 1,36\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_4} = \frac{6}{1,36*10^3 + 2*10^3} = 1,786\ mA$$

$$V_{AB} = R_4 * I_{AB} = 2*10^3 * 1,786*10^{-3} = 3,57\ V$$

- Teorema di Norton

$$I_o = \frac{E_1}{R_1 + R_2} + \frac{E_2}{R_3} + \frac{E_3}{R_5 + R_6} =$$

$$= \frac{6}{3*10^3 + 2*10^3} + \frac{6}{3*10^3} + \frac{6}{3*10^3 + 2*10^3} = 4,4\ mA$$

$$R_{o4} = \frac{R_o * R_4}{R_o + R_4} = \frac{1,36*10^3 * 2*10^3}{1,36*10^3 + 2*10^3} = 0,81\ K\Omega$$

$$V_{AB} = R_{o4} * I_o = 0,81*10^3 * 4,4*10^{-3} = 3,564\ V$$

$$I_{AB} = \frac{V_{AB}}{R_4} = \frac{3,564}{2*10^3} = 1,782\ mA$$

3.- VALORI 3º GRUPPO

- Teorema di Thèvenin

$$E_o = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{8}{2*10^3 + 4*10^3} + \dfrac{8}{2*10^3} + \dfrac{8}{2*10^3 + 4*10^3}}{\dfrac{1}{2*10^3 + 4*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{2*10^3 + 4*10^3}} = 8\ V$$

$$R_o = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_3} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{1}{\frac{1}{2*10^3 + 4*10^3} + \frac{1}{2*10^3} + \frac{1}{2*10^3 + 4*10^3}} = 1,2\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_4} = \frac{8}{1,2*10^3 + 4*10^3} = 1,54\ mA$$

$$V_{AB} = R_4 * I_{AB} = 4*10^3 * 1,54*10^{-3} = 6,15\ V$$

- <u>Teorema di Norton</u>

$$I_o = \frac{E_1}{R_1 + R_2} + \frac{E_2}{R_3} + \frac{E_3}{R_5 + R_6} =$$

$$= \frac{8}{2*10^3 + 4*10^3} + \frac{8}{2*10^3} + \frac{8}{2*10^3 + 4*10^3} = 6,67\ mA$$

$$R_{o4} = \frac{R_o * R_4}{R_o + R_4} = \frac{1,2*10^3 * 4*10^3}{1,2*10^3 + 4*10^3} = 0,92\ K\Omega$$

$$V_{AB} = R_{o4} * I_o = 0,92*10^3 * 6,67*10^{-3} = 6,14\ V$$

$$I_{AB} = \frac{V_{AB}}{R_4} = \frac{6,14}{4*10^3} = 1,535\ mA$$

4.- <u>VALORI 4° GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$E_o = \frac{\frac{E_1}{R_1 + R_2} + \frac{E_2}{R_3} + \frac{E_3}{R_5 + R_6}}{\frac{1}{R_1 + R_2} + \frac{1}{R_3} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{12}{3*10^3 + 5*10^3} + \dfrac{12}{3*10^3} + \dfrac{12}{3*10^3 + 5*10^3}}{\dfrac{1}{3*10^3 + 5*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{3*10^3 + 5*10^3}} = 12 \text{ V}$$

$$R_O = \frac{1}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{1}{\dfrac{1}{3*10^3 + 5*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{3*10^3 + 5*10^3}} = 1,71 \text{ K}\Omega$$

$$I_{AB} = \frac{E_O}{R_O + R_4} = \frac{12}{1,71*10^3 + 5*10^3} = 1,79 \text{ mA}$$

$$V_{AB} = R_4 * I_{AB} = 5*10^3 * 1,79*10^{-3} = 8,94 \text{ V}$$

- <u>Teorema di Norton</u>

$$I_O = \frac{E_1}{R_1 + R_2} + \frac{E_2}{R_3} + \frac{E_3}{R_5 + R_6} =$$

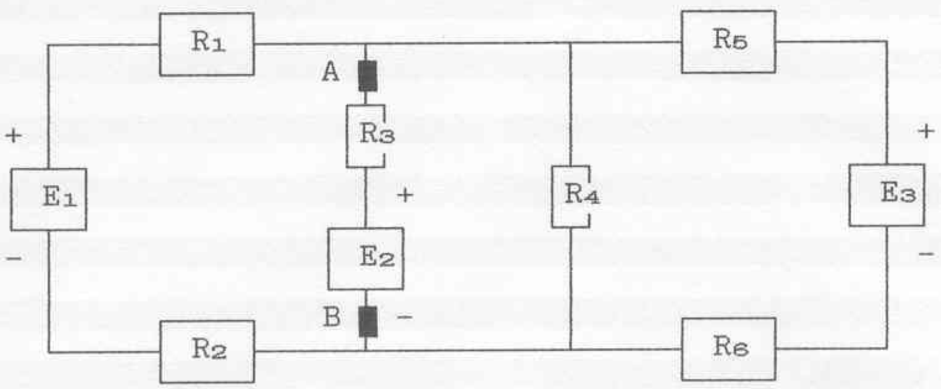
$$= \frac{12}{3*10^3 + 5*10^3} + \frac{12}{3*10^3} + \frac{12}{3*10^3 + 5*10^3} = 7 \text{ mA}$$

$$R_{O4} = \frac{R_O * R_4}{R_O + R_4} = \frac{1,71*10^3 * 5*10^3}{1,71*10^3 + 5*10^3} = 1,274 \text{ K}\Omega$$

$$V_{AB} = R_{O4} * I_O = 1,274*10^3 * 7*10^{-3} = 8,92 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_4} = \frac{8,92}{5*10^3} = 1,784 \text{ mA}$$

6.27 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = E_3 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = E_3 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

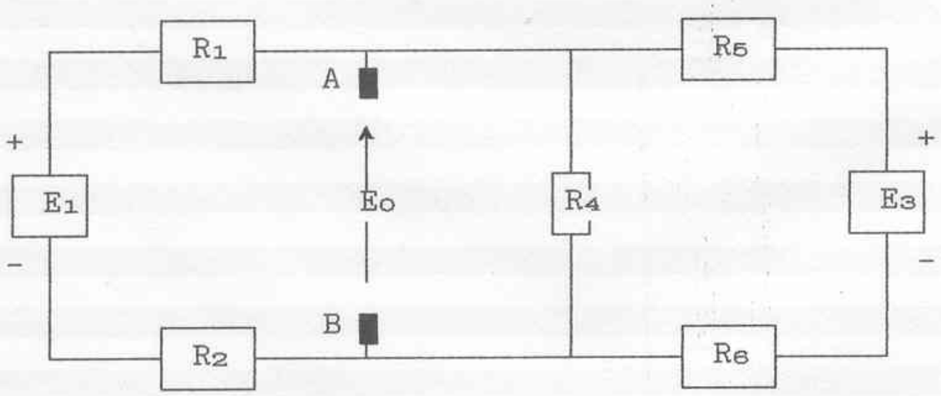
3.- $E_1 = E_2 = E_3 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = E_3 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

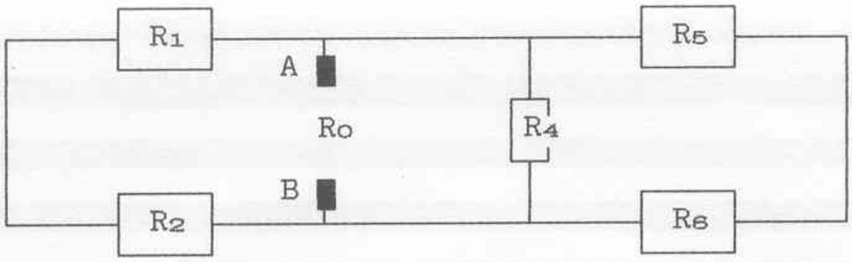
1.- VALORI 1° GRUPPO

- Teorema di Thèvenin



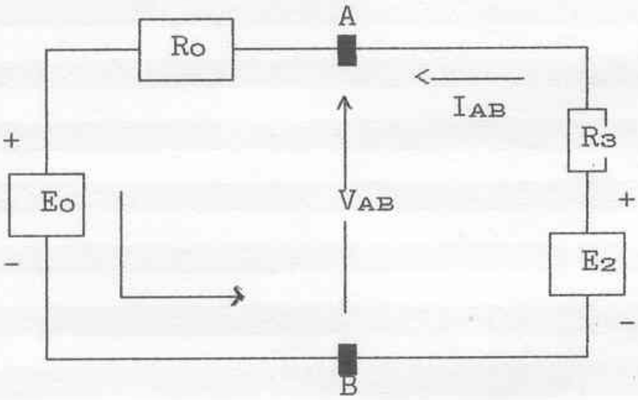
$$E_o = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{10}{2*10^3 + 3*10^3} + \dfrac{10}{2*10^3 + 3*10^3}}{\dfrac{1}{2*10^3 + 3*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{2*10^3 + 3*10^3}} = 5,45 \text{ V}$$



$$R_O = \frac{1}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{1}{\dfrac{1}{2*10^3 + 3*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{2*10^3 + 3*10^3}} = 1,36\ K\Omega$$

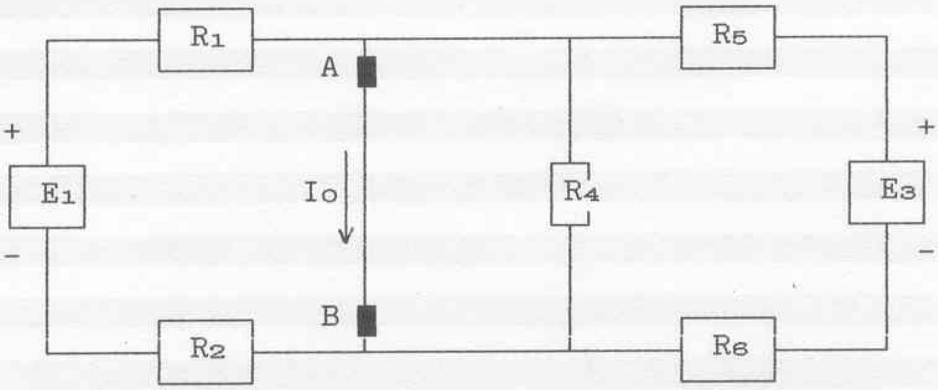


$E_2 - E_O = (R_O + R_3) * I_{AB}$ ==>

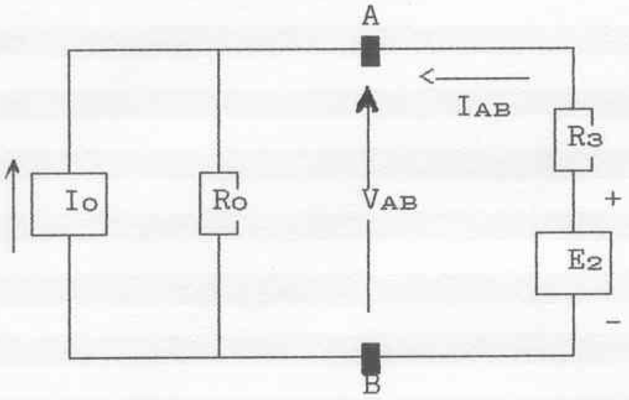
$$\text{==>}\quad I_{AB} = \frac{E_2 - E_O}{R_O + R_3} = \frac{10 - 5,45}{1,36*10^3 + 2*10^3} = 1,35\ mA$$

$V_{AB} = E_2 - R_3 * I_{AB} = 10 - 2*10^3 * 1,35*10^{-3} = 7,3\ V$

- <u>Teorema di Norton</u>



$$I_O = \frac{E_1}{R_1 + R_2} + \frac{E_3}{R_5 + R_6} = \frac{10}{2*10^3 + 3*10^3} + \frac{10}{2*10^3 + 3*10^3} = 4\ mA$$



$$V_{AB} = \frac{I_O + \frac{E_2}{R_3}}{\frac{1}{R_O} + \frac{1}{R_3}} = \frac{4*10^{-3} + \frac{10}{2*10^3}}{\frac{1}{1,36*10^3} + \frac{1}{2*10^3}} = 7,29\ V$$

$$V_{AB} = E_2 - R_3 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_3} = \frac{10 - 7,29}{2*10^3} = 1,35\ mA$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$E_O = \frac{\frac{E_1}{R_1 + R_2} + \frac{E_3}{R_5 + R_6}}{\frac{1}{R_1 + R_2} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{\frac{6}{3*10^3 + 2*10^3} + \frac{6}{3*10^3 + 2*10^3}}{\frac{1}{3*10^3 + 2*10^3} + \frac{1}{2*10^3} + \frac{1}{3*10^3 + 2*10^3}} = 2,67\ V$$

$$R_O = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{1}{\frac{1}{3*10^3 + 2*10^3} + \frac{1}{2*10^3} + \frac{1}{3*10^3 + 2*10^3}} = 1,11\ K\Omega$$

$$E_2 - E_o = (R_o + R_3) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_o}{R_o + R_3} = \frac{6 - 2,67}{1,11*10^3 + 3*10^3} = 0,81\ mA$$

$$V_{AB} = E_2 - R_3 * I_{AB} = 6 - 3*10^3 * 0,81*10^{-3} = 3,57\ V$$

- <u>Teorema di Norton</u>

$$I_o = \frac{E_1}{R_1 + R_2} + \frac{E_3}{R_5 + R_6} = \frac{6}{3*10^3 + 2*10^3} + \frac{6}{3*10^3 + 2*10^3} = 2,4\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_2}{R_3}}{\frac{1}{R_o} + \frac{1}{R_3}} = \frac{2,4*10^{-3} + \frac{6}{3*10^3}}{\frac{1}{1,11*10^3} + \frac{1}{3*10^3}} = 3,57\ V$$

$$V_{AB} = E_2 - R_3 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_3} = \frac{6 - 3,57}{3*10^3} = 0,81\ mA$$

3.- <u>VALORI 3º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$E_o = \frac{\frac{E_1}{R_1 + R_2} + \frac{E_3}{R_5 + R_6}}{\frac{1}{R_1 + R_2} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{\frac{8}{2*10^3 + 4*10^3} + \frac{8}{2*10^3 + 4*10^3}}{\frac{1}{2*10^3 + 4*10^3} + \frac{1}{2*10^3} + \frac{1}{2*10^3 + 4*10^3}} = 3,2\ V$$

$$R_o = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{1}{\frac{1}{2*10^3 + 4*10^3} + \frac{1}{2*10^3} + \frac{1}{2*10^3 + 4*10^3}} = 1,2\ K\Omega$$

$$E_2 - E_o = (R_o + R_3) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_o}{R_o + R_3} = \frac{8 - 3,2}{1,2*10^3 + 2*10^3} = 1,5\ mA$$

$$V_{AB} = E_2 - R_3 * I_{AB} = 8 - 2*10^3 * 1,5*10^{-3} = 5\ V$$

- Teorema di Norton

$$I_o = \frac{E_1}{R_1 + R_2} + \frac{E_3}{R_5 + R_6} = \frac{8}{2*10^3 + 4*10^3} + \frac{8}{2*10^3 + 4*10^3} = 2,67\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_2}{R_3}}{\frac{1}{R_o} + \frac{1}{R_3}} = \frac{2,67*10^{-3} + \frac{8}{2*10^3}}{\frac{1}{1,2*10^3} + \frac{1}{2*10^3}} = 5\ V$$

$$V_{AB} = E_2 - R_3 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_3} = \frac{8 - 5}{2*10^3} = 1,5\ mA$$

4.- VALORI 4º GRUPPO

- Teorema di Thèvenin

$$E_o = \frac{\frac{E_1}{R_1 + R_2} + \frac{E_3}{R_5 + R_6}}{\frac{1}{R_1 + R_2} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{\frac{12}{3*10^3 + 5*10^3} + \frac{12}{3*10^3 + 5*10^3}}{\frac{1}{3*10^3 + 5*10^3} + \frac{1}{5*10^3} + \frac{1}{3*10^3 + 5*10^3}} = 6,67 \text{ V}$$

$$R_O = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{1}{\frac{1}{3*10^3 + 5*10^3} + \frac{1}{5*10^3} + \frac{1}{3*10^3 + 5*10^3}} = 2,22 \text{ K}\Omega$$

$$E_2 - E_O = (R_O + R_3) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_O}{R_O + R_3} = \frac{12 - 6,67}{2,22*10^3 + 3*10^3} = 1,02 \text{ mA}$$

$$V_{AB} = E_2 - R_3 * I_{AB} = 12 - 3*10^3 * 1,02*10^{-3} = 8,94 \text{ V}$$

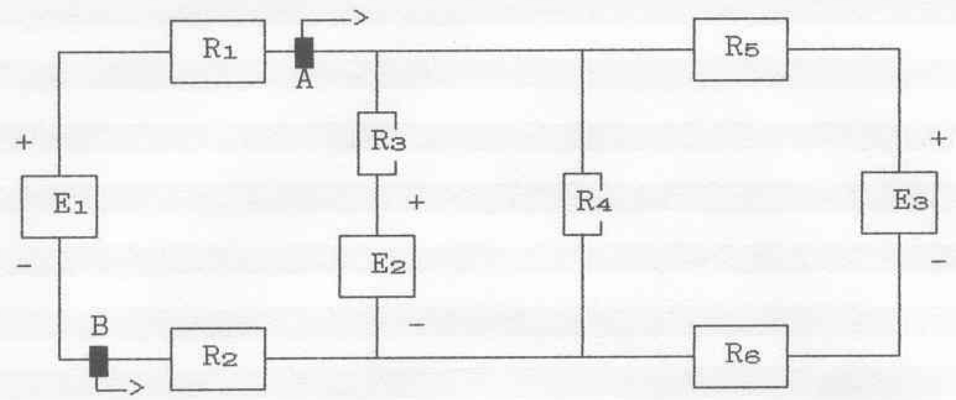
- <u>Teorema di Norton</u>

$$I_O = \frac{E_1}{R_1 + R_2} + \frac{E_3}{R_5 + R_6} = \frac{12}{3*10^3 + 5*10^3} + \frac{12}{3*10^3 + 5*10^3} = 3 \text{ mA}$$

$$V_{AB} = \frac{I_O + \frac{E_2}{R_3}}{\frac{1}{R_O} + \frac{1}{R_3}} = \frac{3*10^{-3} + \frac{12}{3*10^3}}{\frac{1}{2,22*10^3} + \frac{1}{3*10^3}} = 8,93 \text{ V}$$

$$V_{AB} = E_2 - R_3 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_3} = \frac{12 - 8,93}{3*10^3} = 1,02 \text{ mA}$$

6.28 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = E_3 = 10\ V$; $R_1 = R_3 = R_5 = 2\ K\Omega$; $R_2 = R_4 = R_6 = 3\ K\Omega$

2.- $E_1 = E_2 = E_3 = 6\ V$; $R_1 = R_3 = R_5 = 3\ K\Omega$; $R_2 = R_4 = R_6 = 2\ K\Omega$

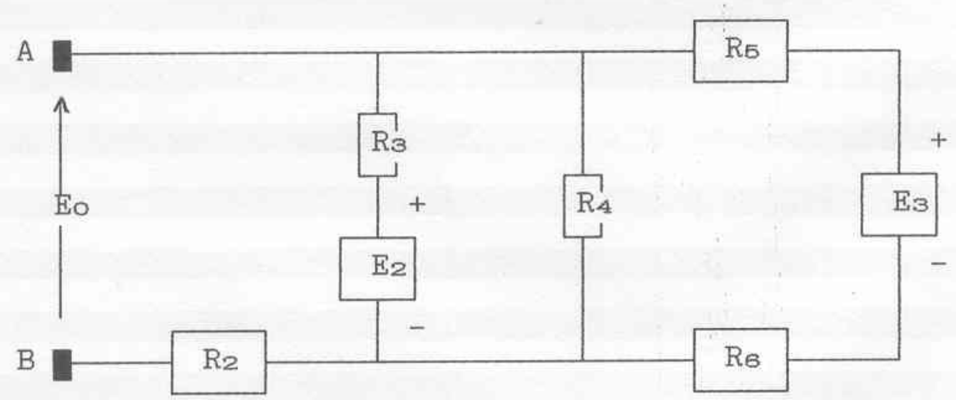
3.- $E_1 = E_2 = E_3 = 8\ V$; $R_1 = R_3 = R_5 = 2\ K\Omega$; $R_2 = R_4 = R_6 = 4\ K\Omega$

4.- $E_1 = E_2 = E_3 = 12\ V$; $R_1 = R_3 = R_5 = 3\ K\Omega$; $R_2 = R_4 = R_6 = 5\ K\Omega$

RISOLUZIONE

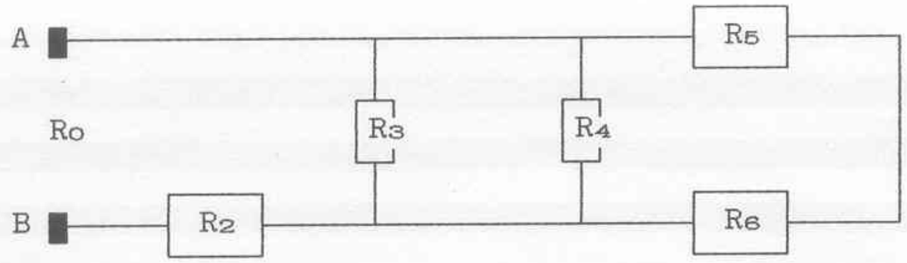
1.- VALORI 1º GRUPPO

- Teorema di Thèvenin



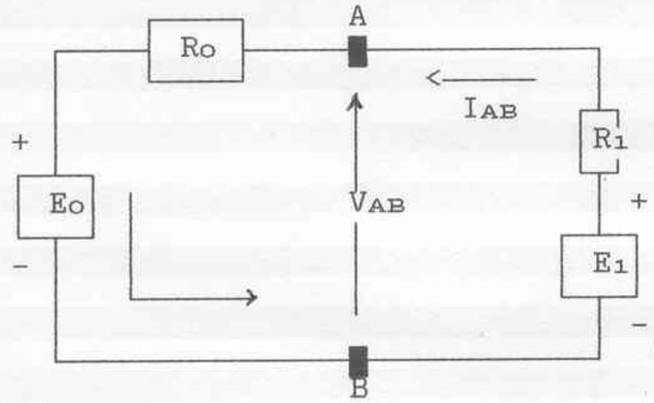
$$E_o = \frac{\dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{10}{2*10^3} + \dfrac{10}{2*10^3 + 3*10^3}}{\dfrac{1}{2*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{2*10^3 + 3*10^3}} = 6,77\ V$$



$$R_O = \frac{1}{\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} + R_2 =$$

$$= \frac{1}{\frac{1}{2*10^3} + \frac{1}{3*10^3} + \frac{1}{2*10^3 + 3*10^3}} + 3*10^3 = 3{,}97\ K\Omega$$

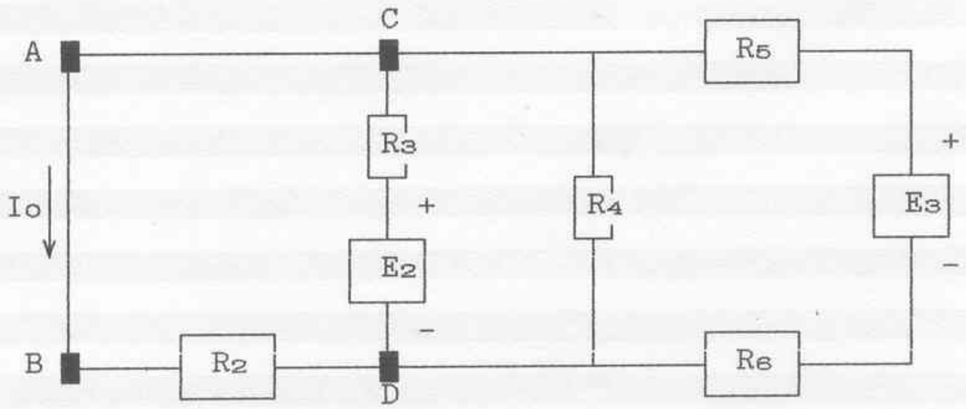


$$E_1 - E_O = (R_O + R_1) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_1 - E_O}{R_O + R_1} = \frac{10 - 6{,}77}{3{,}97*10^3 + 2*10^3} = 0{,}54\ mA$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 10 - 2*10^3 * 0{,}54*10^{-3} = 8{,}92\ V$$

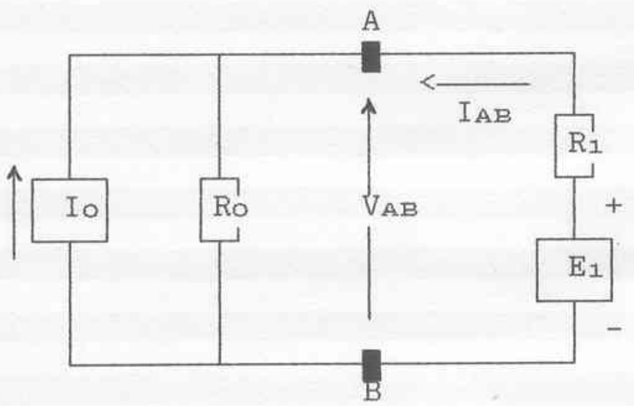
- <u>Teorema di Norton</u>



$$V_{CD} = \frac{\dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{10}{2*10^3} + \dfrac{10}{2*10^3 + 3*10^3}}{\dfrac{1}{3*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{2*10^3 + 3*10^3}} = 5,12 \text{ V}$$

$$I_O = \frac{V_{CD}}{R_2} = \frac{5,12}{3*10^3} = 1,7 \text{ mA}$$



$$V_{AB} = \frac{I_O + \dfrac{E_1}{R_1}}{\dfrac{1}{R_O} + \dfrac{1}{R_1}} = \frac{1,7*10^{-3} + \dfrac{10}{2*10^3}}{\dfrac{1}{3,97*10^3} + \dfrac{1}{2*10^3}} = 8,91 \text{ V}$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{10 - 8,91}{2*10^3} = 0,54 \text{ mA}$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$E_O = \frac{\dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\frac{6}{3*10^3} + \frac{6}{3*10^3 + 2*10^3}}{\frac{1}{3*10^3} + \frac{1}{2*10^3} + \frac{1}{3*10^3 + 2*10^3}} = 3,09 \text{ V}$$

$$R_O = \frac{1}{\frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} + R_2 =$$

$$= \frac{1}{\frac{1}{3*10^3} + \frac{1}{2*10^3} + \frac{1}{3*10^3 + 2*10^3}} + 2*10^3 = 2,97 \text{ K}\Omega$$

$$E_1 - E_O = (R_O + R_1) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_1 - E_O}{R_O + R_1} = \frac{6 - 3,09}{2,97*10^3 + 3*10^3} = 0,49 \text{ mA}$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 6 - 3*10^3 * 0,49*10^{-3} = 4,53 \text{ V}$$

- <u>Teorema di Norton</u>

$$V_{CD} = \frac{\frac{E_2}{R_3} + \frac{E_3}{R_5 + R_6}}{\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5 + R_6}} =$$

$$= \frac{\frac{6}{3*10^3} + \frac{6}{3*10^3 + 2*10^3}}{\frac{1}{2*10^3} + \frac{1}{3*10^3} + \frac{1}{2*10^3} + \frac{1}{3*10^3 + 2*10^3}} = 2,087 \text{ V}$$

$$I_O = \frac{V_{CD}}{R_2} = \frac{2,087}{2*10^3} = 1,04 \text{ mA}$$

$$V_{AB} = \frac{I_O + \frac{E_1}{R_1}}{\frac{1}{R_O} + \frac{1}{R_1}} = \frac{1,04*10^{-3} + \frac{6}{3*10^3}}{\frac{1}{2,97*10^3} + \frac{1}{3*10^3}} = 4,54 \text{ V}$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{6 - 4{,}54}{3*10^3} = 0{,}49 \text{ mA}$$

3.- VALORI 3º GRUPPO

- Teorema di Thèvenin

$$E_O = \frac{\dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{8}{2*10^3} + \dfrac{8}{2*10^3 + 4*10^3}}{\dfrac{1}{2*10^3} + \dfrac{1}{4*10^3} + \dfrac{1}{2*10^3 + 4*10^3}} = 5{,}82 \text{ V}$$

$$R_O = \frac{1}{\dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} + R_2 =$$

$$= \frac{1}{\dfrac{1}{2*10^3} + \dfrac{1}{4*10^3} + \dfrac{1}{2*10^3 + 4*10^3}} + 4*10^3 = 5{,}09 \text{ K}\Omega$$

$$E_1 - E_O = (R_O + R_1) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_1 - E_O}{R_O + R_1} = \frac{8 - 5{,}82}{5{,}09*10^3 + 2*10^3} = 0{,}307 \text{ mA}$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 8 - 2*10^3 * 0{,}307*10^{-3} = 7{,}38 \text{ V}$$

- Teorema di Norton

$$V_{CD} = \frac{\dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{8}{2*10^3} + \dfrac{8}{2*10^3 + 4*10^3}}{\dfrac{1}{4*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{4*10^3} + \dfrac{1}{2*10^3 + 4*10^3}} = 4,57 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_2} = \frac{4,57}{4*10^3} = 1,14 \text{ mA}$$

$$V_{AB} = \frac{I_o + \dfrac{E_1}{R_1}}{\dfrac{1}{R_o} + \dfrac{1}{R_1}} = \frac{1,14*10^{-3} + \dfrac{8}{2*10^3}}{\dfrac{1}{5,09*10^3} + \dfrac{1}{2*10^3}} = 7,38 \text{ V}$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{8 - 7,38}{2*10^3} = 0,31 \text{ mA}$$

4.- VALORI 4° GRUPPO

- Teorema di Thèvenin

$$E_o = \frac{\dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

$$= \frac{\dfrac{12}{3*10^3} + \dfrac{12}{3*10^3 + 5*10^3}}{\dfrac{1}{3*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{3*10^3 + 5*10^3}} = 8,35 \text{ V}$$

$$R_o = \frac{1}{\dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} + R_2 =$$

$$= \frac{1}{\dfrac{1}{3*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{3*10^3 + 5*10^3}} + 5*10^3 = 6,52 \text{ K}\Omega$$

$$E_1 - E_0 = (R_0 + R_1) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_1 - E_0}{R_0 + R_1} = \frac{12 - 8,35}{6,52*10^3 + 3*10^3} = 0,38 \text{ mA}$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 12 - 3*10^3 * 0,38*10^{-3} = 10,86 \text{ V}$$

- <u>Teorema di Norton</u>

$$V_{CD} = \frac{\dfrac{E_2}{R_3} + \dfrac{E_3}{R_5 + R_6}}{\dfrac{1}{R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5 + R_6}} =$$

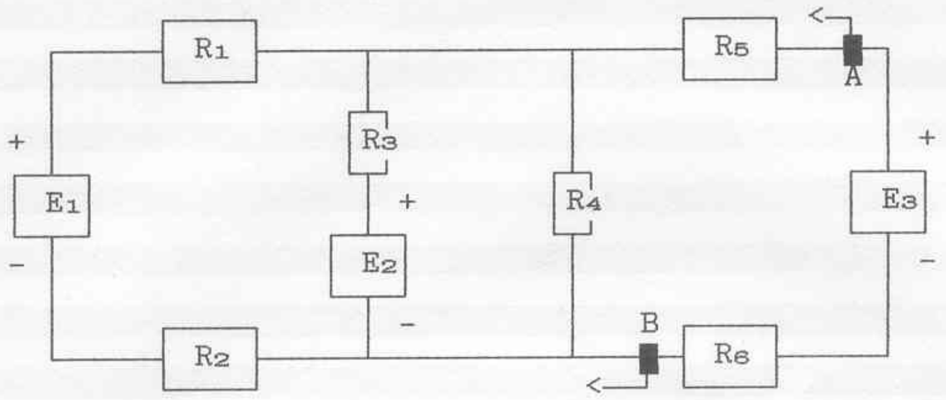
$$= \frac{\dfrac{12}{3*10^3} + \dfrac{12}{3*10^3 + 5*10^3}}{\dfrac{1}{5*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{3*10^3 + 5*10^3}} = 6,41 \text{ V}$$

$$I_0 = \frac{V_{CD}}{R_2} = \frac{6,41}{5*10^3} = 1,28 \text{ mA}$$

$$V_{AB} = \frac{I_0 + \dfrac{E_1}{R_1}}{\dfrac{1}{R_0} + \dfrac{1}{R_1}} = \frac{1,28*10^{-3} + \dfrac{12}{3*10^3}}{\dfrac{1}{6,52*10^3} + \dfrac{1}{3*10^3}} = 10,85 \text{ V}$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{12 - 10,85}{3*10^3} = 0,38 \text{ mA}$$

6.29 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = E_3 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = E_3 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

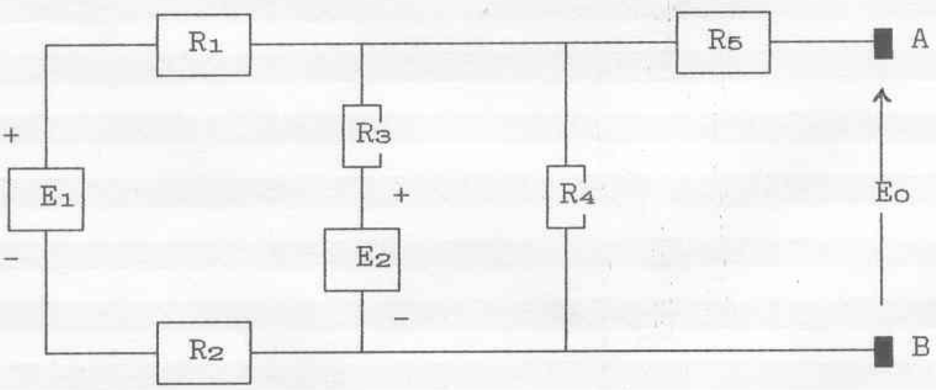
3.- $E_1 = E_2 = E_3 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = E_3 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

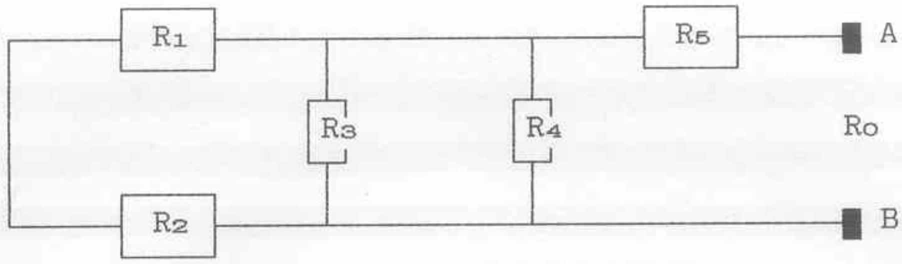
1.- VALORI 1° GRUPPO

- Teorema di Thèvenin



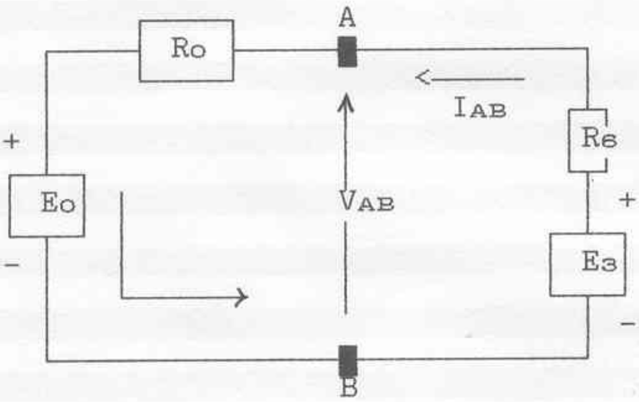
$$E_o = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}} =$$

$$= \frac{\dfrac{10}{2*10^3 + 3*10^3} + \dfrac{10}{2*10^3}}{\dfrac{1}{2*10^3 + 3*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{3*10^3}} = 6,77 \text{ V}$$



$$R_o = \frac{1}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}} + R_5 =$$

$$= \frac{1}{\dfrac{1}{2*10^3 + 3*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{3*10^3}} + 2*10^3 = 2,97\ K\Omega$$

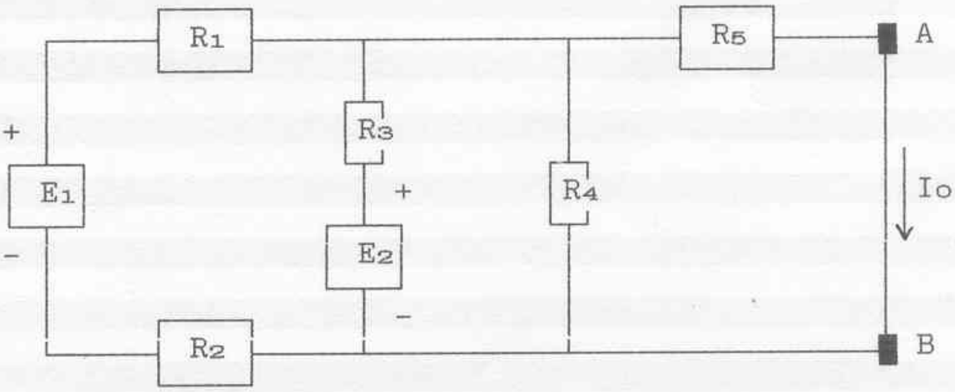


$$E_3 - E_o = (R_o + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_3 - E_o}{R_o + R_6} = \frac{10 - 6,77}{2,97*10^3 + 3*10^3} = 0,54\ mA$$

$$V_{AB} = E_3 - R_6 * I_{AB} = 10 - 3*10^3 * 0,54*10^{-3} = 8,38\ V$$

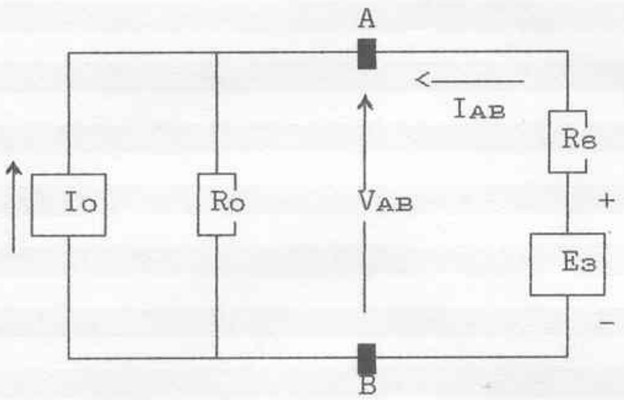
- <u>Teorema di Norton</u>



$$V_{CD} = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5}} =$$

$$= \frac{\dfrac{10}{2*10^3 + 3*10^3} + \dfrac{10}{2*10^3}}{\dfrac{1}{2*10^3 + 3*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{2*10^3}} = 4,56 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_5} = \frac{4,56}{2*10^3} = 2,28 \text{ mA}$$



$$V_{AB} = \frac{I_o + \dfrac{E_3}{R_6}}{\dfrac{1}{R_o} + \dfrac{1}{R_6}} = \frac{2,28*10^{-3} + \dfrac{10}{3*10^3}}{\dfrac{1}{2,97*10^3} + \dfrac{1}{3*10^3}} = 8,38 \text{ V}$$

$$V_{AB} = E_3 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_3 - V_{AB}}{R_6} = \frac{10 - 8,38}{3*10^3} = 0,54 \text{ mA}$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$E_o = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}} =$$

$$= \frac{\dfrac{6}{3*10^3 + 2*10^3} + \dfrac{6}{3*10^3}}{\dfrac{1}{3*10^3 + 2*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{2*10^3}} = 3{,}097 \text{ V}$$

$$R_o = \frac{1}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}} + R_5 =$$

$$= \frac{1}{\dfrac{1}{3*10^3 + 2*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{2*10^3}} + 3*10^3 = 3{,}97 \text{ K}\Omega$$

$$E_3 - E_o = (R_o + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_3 - E_o}{R_o + R_6} = \frac{6 - 3{,}097}{3{,}97*10^3 + 2*10^3} = 0{,}49 \text{ mA}$$

$$V_{AB} = E_3 - R_6 * I_{AB} = 6 - 2*10^3 * 0{,}49*10^{-3} = 5{,}02 \text{ V}$$

- <u>Teorema di Norton</u>

$$V_{CD} = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5}} =$$

$$= \frac{\dfrac{6}{3*10^3 + 2*10^3} + \dfrac{6}{3*10^3}}{\dfrac{1}{3*10^3 + 2*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{3*10^3}} = 2{,}34 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_5} = \frac{2{,}34}{3*10^3} = 0{,}78 \text{ mA}$$

$$V_{AB} = \frac{I_o + \dfrac{E_3}{R_6}}{\dfrac{1}{R_o} + \dfrac{1}{R_6}} = \frac{0{,}78*10^{-3} + \dfrac{6}{2*10^3}}{\dfrac{1}{3{,}97*10^3} + \dfrac{1}{2*10^3}} = 5 \text{ V}$$

$$V_{AB} = E_3 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_3 - V_{AB}}{R_6} = \frac{6 - 5}{2*10^3} = 0,5 \text{ mA}$$

3.- VALORI 3º GRUPPO

- Teorema di Thèvenin

$$E_0 = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}} =$$

$$= \frac{\dfrac{8}{2*10^3 + 4*10^3} + \dfrac{8}{2*10^3}}{\dfrac{1}{2*10^3 + 4*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{4*10^3}} = 5,82 \text{ V}$$

$$R_0 = \frac{1}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4}} + R_5 =$$

$$= \frac{1}{\dfrac{1}{2*10^3 + 4*10^3} + \dfrac{1}{2*10^3} + \dfrac{1}{4*10^3}} + 2*10^3 = 3,09 \text{ K}\Omega$$

$$E_3 - E_0 = (R_0 + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_3 - E_0}{R_0 + R_6} = \frac{8 - 5,82}{3,09*10^3 + 4*10^3} = 0,3 \text{ mA}$$

$$V_{AB} = E_3 - R_6 * I_{AB} = 8 - 4*10^3 * 0,3*10^{-3} = 6,8 \text{ V}$$

- Teorema di Norton

$$V_{CD} = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5}} =$$

$$= \frac{\frac{8}{2*10^3 + 4*10^3} + \frac{8}{2*10^3}}{\frac{1}{2*10^3 + 4*10^3} + \frac{1}{2*10^3} + \frac{1}{4*10^3} + \frac{1}{2*10^3}} = 3{,}765 \text{ V}$$

$$I_O = \frac{V_{CD}}{R_5} = \frac{3{,}765}{2*10^3} = 1{,}88 \text{ mA}$$

$$V_{AB} = \frac{I_O + \frac{E_3}{R_6}}{\frac{1}{R_O} + \frac{1}{R_6}} = \frac{1{,}88*10^{-3} + \frac{8}{4*10^3}}{\frac{1}{3{,}09*10^3} + \frac{1}{4*10^3}} = 6{,}76 \text{ V}$$

$$V_{AB} = E_3 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_3 - V_{AB}}{R_6} = \frac{8 - 6{,}76}{4*10^3} = 0{,}31 \text{ mA}$$

4.- <u>VALORI 4° GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$E_O = \frac{\frac{E_1}{R_1 + R_2} + \frac{E_2}{R_3}}{\frac{1}{R_1 + R_2} + \frac{1}{R_3} + \frac{1}{R_4}} =$$

$$= \frac{\frac{12}{3*10^3 + 5*10^3} + \frac{12}{3*10^3}}{\frac{1}{3*10^3 + 5*10^3} + \frac{1}{3*10^3} + \frac{1}{5*10^3}} = 8{,}35 \text{ V}$$

$$R_O = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_3} + \frac{1}{R_4}} + R_5 =$$

$$= \frac{1}{\frac{1}{3*10^3 + 5*10^3} + \frac{1}{3*10^3} + \frac{1}{5*10^3}} + 3*10^3 = 4{,}52 \text{ K}\Omega$$

$$E_3 - E_0 = (R_0 + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_3 - E_0}{R_0 + R_6} = \frac{12 - 8,35}{4,52*10^3 + 5*10^3} = 0,38 \text{ mA}$$

$$V_{AB} = E_3 - R_6 * I_{AB} = 12 - 5*10^3 * 0,38*10^{-3} = 10,1 \text{ V}$$

- Teorema di Norton

$$V_{CD} = \frac{\dfrac{E_1}{R_1 + R_2} + \dfrac{E_2}{R_3}}{\dfrac{1}{R_1 + R_2} + \dfrac{1}{R_3} + \dfrac{1}{R_4} + \dfrac{1}{R_5}} =$$

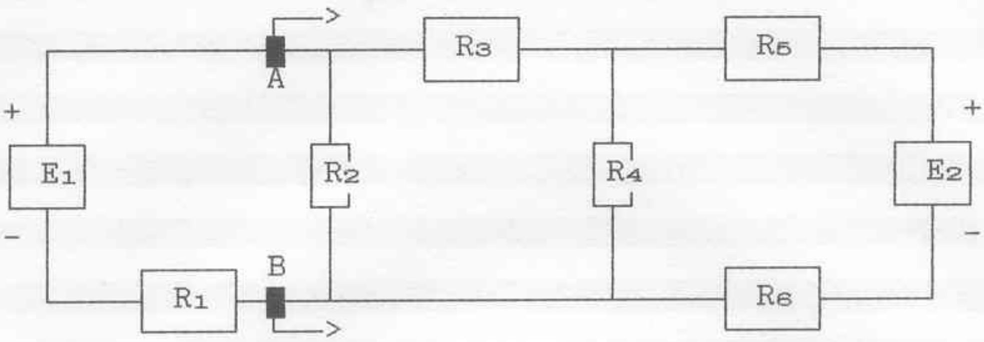
$$= \frac{\dfrac{12}{3*10^3 + 5*10^3} + \dfrac{12}{3*10^3}}{\dfrac{1}{3*10^3 + 5*10^3} + \dfrac{1}{3*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{3*10^3}} = 5,55 \text{ V}$$

$$I_0 = \frac{V_{CD}}{R_5} = \frac{5,55}{3*10^3} = 1,85 \text{ mA}$$

$$V_{AB} = \frac{I_0 + \dfrac{E_3}{R_6}}{\dfrac{1}{R_0} + \dfrac{1}{R_6}} = \frac{1,85*10^{-3} + \dfrac{12}{5*10^3}}{\dfrac{1}{4,52*10^3} + \dfrac{1}{5*10^3}} = 10,09 \text{ V}$$

$$V_{AB} = E_3 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_3 - V_{AB}}{R_6} = \frac{12 - 10,09}{5*10^3} = 0,38 \text{ mA}$$

6.30 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

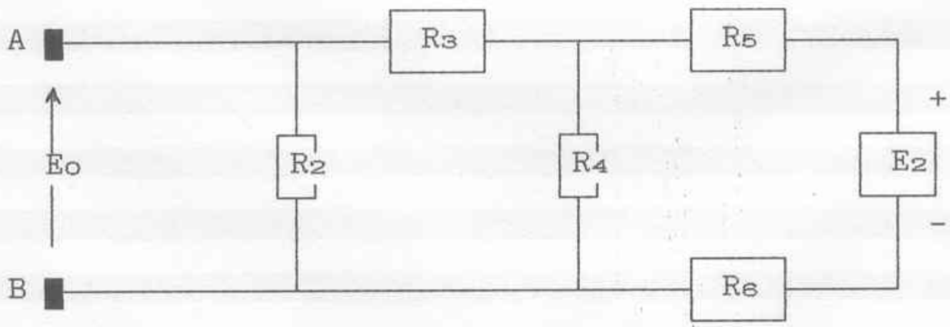
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

1.- VALORI 1° GRUPPO

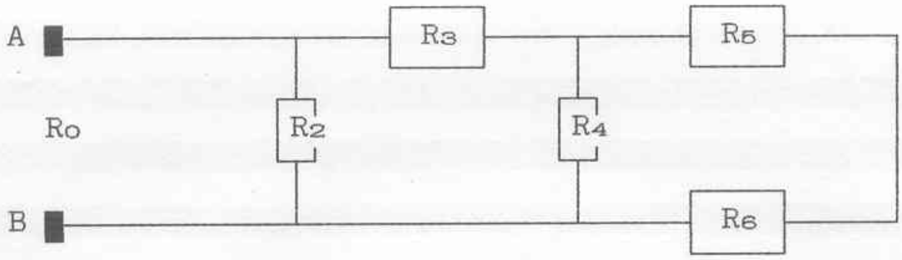
- Teorema di Thèvenin



$$R_{24} = \frac{(R_2 + R_3) * R_4}{R_2 + R_3 + R_4} = \frac{(3*10^3 + 2*10^3) * 3*10^3}{3*10^3 + 2*10^3 + 3*10^3} = 1,875 \text{ K}\Omega$$

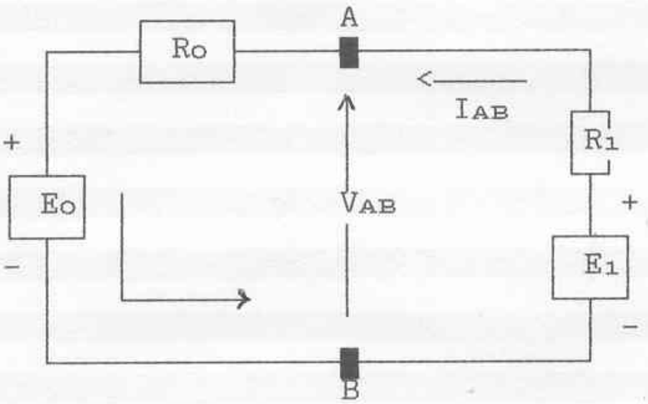
$$V_4 = \frac{R_{24}}{R_{24} + R_5 + R_6} * E_2 = \frac{1,875*10^3}{1,875*10^3 + 2*10^3 + 3*10^3} * 10 = 2,727 \text{ V}$$

$$E_o = \frac{R_2}{R_2 + R_3} * V_4 = \frac{3*10^3}{3*10^3 + 2*10^3} * 2,727 = 1,6362 \text{ V}$$



$$R_{46} = \frac{(R_5 + R_6) * R_4}{R_5 + R_6 + R_4} = \frac{(2*10^3 + 3*10^3) * 3*10^3}{2*10^3 + 3*10^3 + 3*10^3} = 1,875\ K\Omega$$

$$R_0 = \frac{(R_3 + R_{46}) * R_2}{R_3 + R_{46} + R_2} = \frac{(2*10^3 + 1,875*10^3) * 3*10^3}{2*10^3 + 1,875*10^3 + 3*10^3} = 1,6\ldots$$

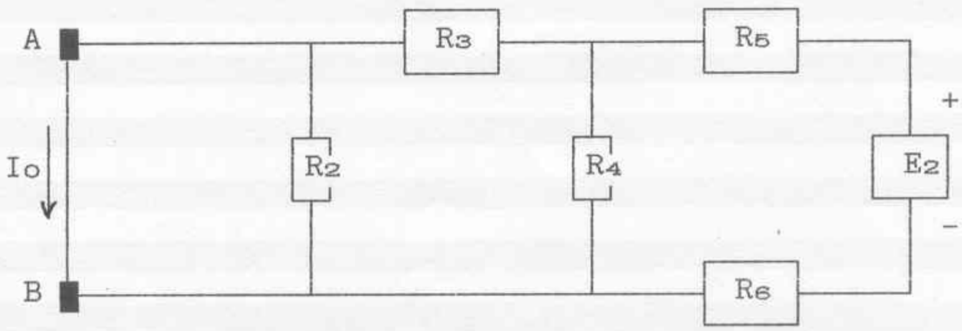


$$E_1 - E_0 = (R_0 + R_1) * I_{AB} \qquad ==>$$

$$==> \qquad I_{AB} = \frac{E_1 - E_0}{R_0 + R_1} = \frac{10 - 1,6362}{1,69*10^3 + 2*10^3} = 2,27\ mA$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 10 - 2*10^3 * 2,27*10^{-3} = 5,46\ V$$

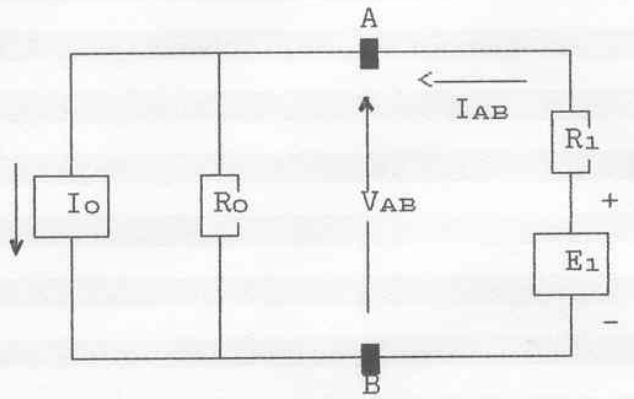
- Teorema di Norton



$$R_{34} = \frac{R_3 * R_4}{R_3 + R_4} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1,2\ K\Omega$$

$$V_4 = \frac{R_{34}}{R_{34} + R_5 + R_6} * E_2 = \frac{1,2*10^3}{1,2*10^3 + 2*10^3 + 3*10^3} * 10 = 1,93\ V$$

$$I_o = \frac{V_4}{R_3} = \frac{1,93}{2*10^3} = 0,965\ mA$$



$$V_{AB} = \frac{I_o + \frac{E_1}{R_1}}{\frac{1}{R_o} + \frac{1}{R_1}} = \frac{0,965*10^{-3} + \frac{10}{2*10^3}}{\frac{1}{1,69*10^3} + \frac{1}{2*10^3}} = 5,46\ V$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{10 - 5,46}{2*10^3} = 2,27\ mA$$

2.- <u>VALORI 2° GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{(R_2 + R_3) * R_4}{R_2 + R_3 + R_4} = \frac{(2*10^3 + 3*10^3) * 2*10^3}{2*10^3 + 3*10^3 + 2*10^3} = 1,43\ K\Omega$$

$$V_4 = \frac{R_{24}}{R_{24} + R_5 + R_6} * E_2 = \frac{1,43*10^3}{1,43*10^3 + 3*10^3 + 2*10^3} * 6 = 1,33\ V$$

$$E_o = \frac{R_2}{R_2 + R_3} * V_4 = \frac{2*10^3}{2*10^3 + 3*10^3} * 1,33 = 0,53\ V$$

$$R_{46} = \frac{(R_5 + R_6) * R_4}{R_5 + R_6 + R_4} = \frac{(3*10^3 + 2*10^3) * 2*10^3}{3*10^3 + 2*10^3 + 2*10^3} = 1,43\ K\Omega$$

$$R_0 = \frac{(R_3 + R_{46}) * R_2}{R_3 + R_{46} + R_2} = \frac{(3*10^3 + 1,43*10^3) * 2*10^3}{3*10^3 + 1,43*10^3 + 2*10^3} = 1,38\ K\Omega$$

$$E_1 - E_0 = (R_0 + R_1) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_1 - E_0}{R_0 + R_1} = \frac{6 - 0,53}{1,38*10^3 + 3*10^3} = 1,25\ mA$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 6 - 3*10^3 * 1,25*10^{-3} = 2,25\ V$$

- Teorema di Norton

$$R_{34} = \frac{R_3 * R_4}{R_3 + R_4} = \frac{3*10^3 * 2*10^3}{3*10^3 + 2*10^3} = 1,2\ K\Omega$$

$$V_4 = \frac{R_{34}}{R_{34} + R_5 + R_6} * E_2 = \frac{1,2*10^3}{1,2*10^3 + 3*10^3 + 2*10^3} * 6 = 1,16\ V$$

$$I_0 = \frac{V_4}{R_3} = \frac{1,16}{3*10^3} = 0,387\ mA$$

$$V_{AB} = \frac{I_0 + \frac{E_1}{R_1}}{\frac{1}{R_0} + \frac{1}{R_1}} = \frac{0,387*10^{-3} + \frac{6}{3*10^3}}{\frac{1}{1,38*10^3} + \frac{1}{3*10^3}} = 2,25\ V$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{6 - 2,25}{3*10^3} = 1,25\ mA$$

3.- VALORI 3º GRUPPO

- Teorema di Thèvenin

$$R_{24} = \frac{(R_2 + R_3) * R_4}{R_2 + R_3 + R_4} = \frac{(4*10^3 + 2*10^3) * 4*10^3}{4*10^3 + 2*10^3 + 4*10^3} = 2,4\ K\Omega$$

$$V_4 = \frac{R_{24}}{R_{24} + R_5 + R_6} * E_2 = \frac{2,4*10^3}{2,4*10^3 + 2*10^3 + 4*10^3} * 8 = 2,286\ V$$

$$E_o = \frac{R_2}{R_2 + R_3} * V_4 = \frac{4*10^3}{2*10^3 + 4*10^3} * 2,286 = 1,52 \ V$$

$$R_{46} = \frac{(R_5 + R_6) * R_4}{R_5 + R_6 + R_4} = \frac{(2*10^3 + 4*10^3) * 4*10^3}{2*10^3 + 4*10^3 + 4*10^3} = 2,4 \ K\Omega$$

$$R_o = \frac{(R_3 + R_{46}) * R_2}{R_3 + R_{46} + R_2} = \frac{(2*10^3 + 2,4*10^3) * 4*10^3}{2*10^3 + 2,4*10^3 + 4*10^3} = 2,1 \ K\Omega$$

$$E_1 - E_o = (R_o + R_1) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_1 - E_o}{R_o + R_1} = \frac{8 - 1,52}{2,1*10^3 + 2*10^3} = 1,58 \ mA$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 8 - 2*10^3 * 1,58*10^{-3} = 4,682 \ V$$

- <u>Teorema di Norton</u>

$$R_{34} = \frac{R_3 * R_4}{R_3 + R_4} = \frac{2*10^3 * 4*10^3}{2*10^3 + 4*10^3} = 1,34 \ K\Omega$$

$$V_4 = \frac{R_{34}}{R_{34} + R_5 + R_6} * E_2 = \frac{1,34*10^3}{1,34*10^3 + 2*10^3 + 4*10^3} * 8 = 1,46 \ V$$

$$I_o = \frac{V_4}{R_3} = \frac{1,46}{2*10^3} = 0,73 \ mA$$

$$V_{AB} = \frac{I_o + \frac{E_1}{R_1}}{\frac{1}{R_o} + \frac{1}{R_1}} = \frac{0,73*10^{-3} + \frac{8}{2*10^3}}{\frac{1}{2,1*10^3} + \frac{1}{2*10^3}} = 4,84 \ V$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{8 - 4,84}{2*10^3} = 1,58 \ mA$$

4.- <u>VALORI 4° GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{(R_2 + R_3) * R_4}{R_2 + R_3 + R_4} = \frac{(5*10^3 + 3*10^3) * 5*10^3}{5*10^3 + 3*10^3 + 5*10^3} = 3,07 \ K\Omega$$

$$V_4 = \frac{R_{24}}{R_{24} + R_5 + R_6} * E_2 = \frac{3{,}07*10^3}{3{,}07*10^3 + 3*10^3 + 5*10^3} * 12 = 3{,}33\ V$$

$$E_o = \frac{R_2}{R_2 + R_3} * V_4 = \frac{5*10^3}{5*10^3 + 3*10^3} * 3{,}33 = 2{,}08\ V$$

$$R_{46} = \frac{(R_5 + R_6) * R_4}{R_5 + R_6 + R_4} = \frac{(3*10^3 + 5*10^3) * 5*10^3}{3*10^3 + 5*10^3 + 5*10^3} = 3{,}07\ K\Omega$$

$$R_o = \frac{(R_3 + R_{46}) * R_2}{R_3 + R_{46} + R_2} = \frac{(3*10^3 + 3{,}07*10^3) * 5*10^3}{3*10^3 + 3{,}07*10^3 + 5*10^3} = 2{,}74\ K\Omega$$

$$E_1 - E_o = (R_o + R_1) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_1 - E_o}{R_o + R_1} = \frac{12 - 2{,}08}{2{,}74*10^3 + 3*10^3} = 1{,}73\ mA$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 12 - 3*10^3 * 1{,}73*10^{-3} = 6{,}81\ V$$

- <u>Teorema di Norton</u>

$$R_{34} = \frac{R_3 * R_4}{R_3 + R_4} = \frac{3*10^3 * 5*10^3}{3*10^3 + 5*10^3} = 1{,}875\ K\Omega$$

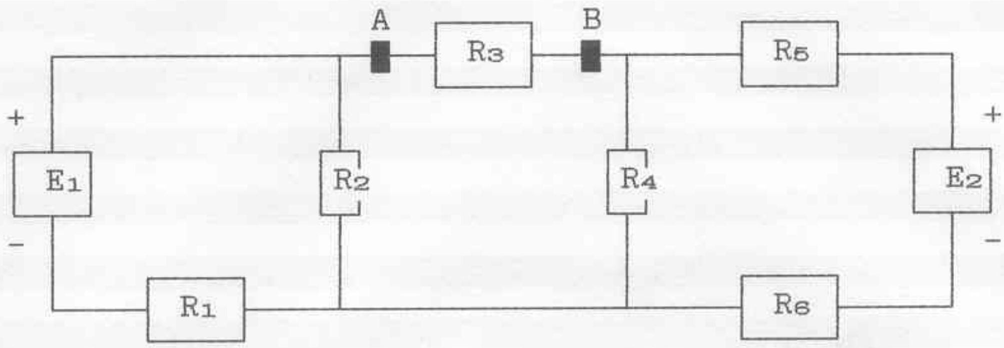
$$V_4 = \frac{R_{34}}{R_{34} + R_5 + R_6} * E_2 = \frac{1{,}875*10^3}{1{,}875*10^3 + 3*10^3 + 5*10^3} * 12 = 2{,}28\ V$$

$$I_o = \frac{V_4}{R_3} = \frac{2{,}28}{3*10^3} = 0{,}76\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_1}{R_1}}{\frac{1}{R_o} + \frac{1}{R_1}} = \frac{0{,}76*10^{-3} + \frac{12}{3*10^3}}{\frac{1}{2{,}74*10^3} + \frac{1}{3*10^3}} = 6{,}81\ V$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{12 - 6{,}81}{3*10^3} = 1{,}73\ mA$$

6.31 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

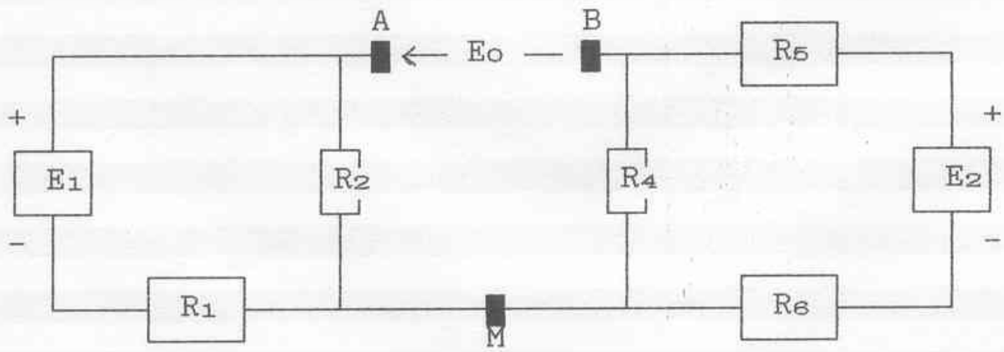
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

1.- VALORI 1º GRUPPO

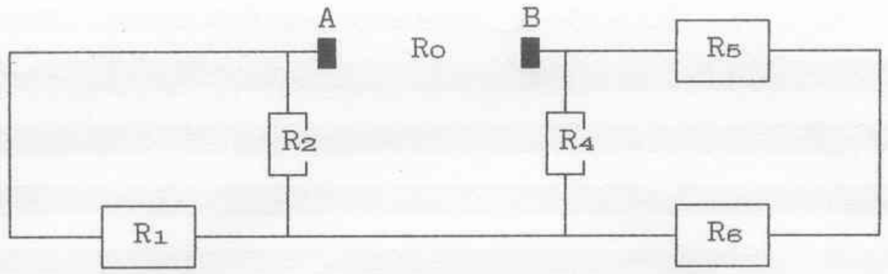
- Teorema di Thèvenin



$$V_{AM} = \frac{R_1}{R_1 + R_2} * E_1 = \frac{3*10^3}{2*10^3 + 3*10^3} * 10 = 6 \text{ V}$$

$$V_{BM} = \frac{R_4}{R_4 + R_5 + R_6} * E_2 = \frac{3*10^3}{3*10^3 + 2*10^3 + 3*10^3} * 10 = 3,75 \text{ V}$$

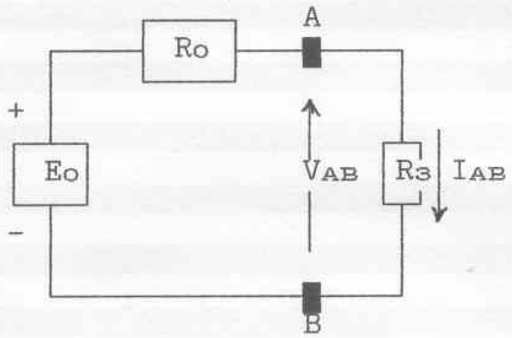
$$E_0 = V_{AM} - V_{BM} = 6 - 3,75 = 2,25 \text{ V}$$



$$R_{12} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1,2\ K\Omega$$

$$R_{46} = \frac{R_4 * (R_5 + R_6)}{R_4 + R_5 + R_6} = \frac{3*10^3 * (2*10^3 + 3*10^3)}{3*10^3 + 2*10^3 + 3*10^3} = 1,875\ K\Omega$$

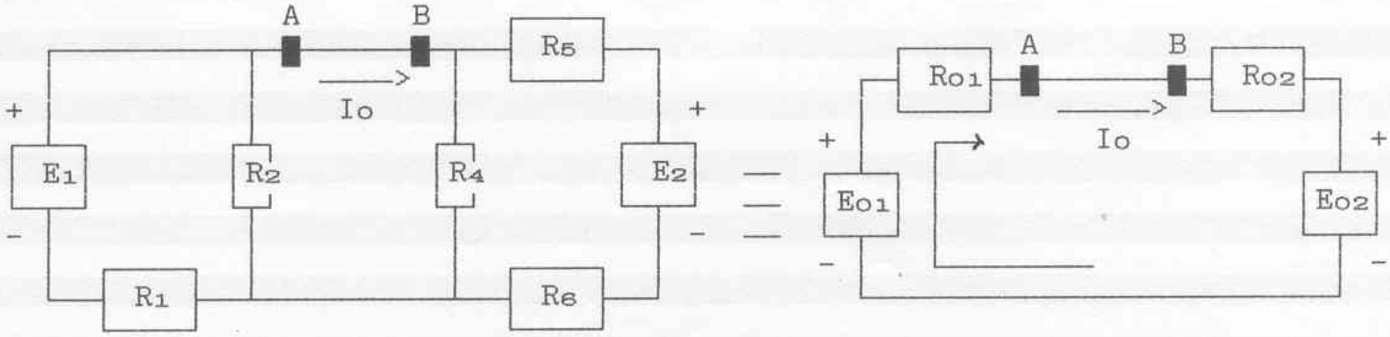
$$R_o = R_{12} + R_{46} = 1,2*10^3 + 1,875*10^3 = 3,075\ K\Omega$$



$$I_{AB} = \frac{E_o}{R_o + R_3} = \frac{2,25}{3,075*10^3 + 2*10^3} = 0,44\ mA$$

$$V_{AB} = R_3 * I_{AB} = 2*10^3 * 0,44*10^{-3} = 0,88\ V$$

- <u>Teorema di Norton</u>



$$E_{o1} = \frac{R_2}{R_1 + R_2} * E_1 = \frac{3*10^3}{2*10^3 + 3*10^3} * 10 = 6\ V$$

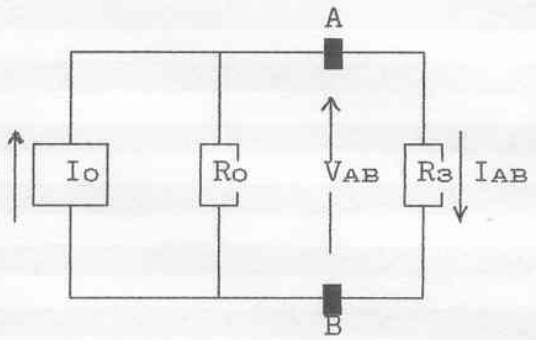
$$E_{o2} = \frac{R_4}{R_4 + R_5 + R_6} * E_2 = \frac{3*10^3}{3*10^3 + 2*10^3 + 3*10^3} * 10 = 3{,}75\ V$$

$$R_{o1} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1{,}2\ K\Omega$$

$$R_{o2} = \frac{R_4 * (R_5 + R_6)}{R_4 + R_5 + R_6} = \frac{3*10^3 * (2*10^3 + 3*10^3)}{3*10^3 + 2*10^3 + 3*10^3} = 1{,}875\ K\Omega$$

$$E_{o1} - E_{o2} = (R_{o1} + R_{o2}) * I_o \quad ==>$$

$$==> \quad I_o = \frac{E_{o1} - E_{o2}}{R_{o1} + R_{o2}} = \frac{6 - 3{,}75}{1{,}2*10^3 + 1{,}875*10^3} = 0{,}73\ mA$$



$$R_{o3} = \frac{R_o * R_3}{R_o + R_3} = \frac{3{,}075*10^3 * 2*10^3}{3{,}075*10^3 + 2*10^3} = 1{,}21\ K\Omega$$

$$V_{AB} = R_{o3} * I_o = 1{,}21*10^3 * 0{,}73*10^{-3} = 0{,}88\ V$$

$$I_{AB} = \frac{V_{AB}}{R_3} = \frac{0{,}88}{2*10^3} = 0{,}44\ mA$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$V_{AM} = \frac{R_1}{R_1 + R_2} * E_1 = \frac{2*10^3}{3*10^3 + 2*10^3} * 6 = 2{,}4\ V$$

$$V_{BM} = \frac{R_4}{R_4 + R_5 + R_6} * E_2 = \frac{2*10^3}{3*10^3 + 2*10^3 + 2*10^3} * 6 = 1,71\ V$$

$$E_o = V_{AM} - V_{BM} = 2,4 - 1,71 = 0,69\ V$$

$$R_{12} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{3*10^3 * 2*10^3}{3*10^3 + 2*10^3} = 1,2\ K\Omega$$

$$R_{46} = \frac{R_4 * (R_5 + R_6)}{R_4 + R_5 + R_6} = \frac{2*10^3 * (3*10^3 + 2*10^3)}{2*10^3 + 3*10^3 + 2*10^3} = 1,43\ K\Omega$$

$$R_o = R_{12} + R_{46} = 1,2*10^3 + 1,43*10^3 = 2,63\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_3} = \frac{0,69}{2,63*10^3 + 3*10^3} = 0,12\ mA$$

$$V_{AB} = R_3 * I_{AB} = 3*10^3 * 0,12*10^{-3} = 0,36\ V$$

- <u>Teorema di Norton</u>

$$E_{o1} = \frac{R_2}{R_1 + R_2} * E_1 = \frac{2*10^3}{2*10^3 + 3*10^3} * 6 = 2,4\ V$$

$$E_{o2} = \frac{R_4}{R_4 + R_5 + R_6} * E_2 = \frac{2*10^3}{3*10^3 + 2*10^3 + 2*10^3} * 6 = 1,71\ V$$

$$R_{o1} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{3*10^3 * 2*10^3}{3*10^3 + 2*10^3} = 1,2\ K\Omega$$

$$R_{o2} = \frac{R_4 * (R_5 + R_6)}{R_4 + R_5 + R_6} = \frac{2*10^3 * (3*10^3 + 2*10^3)}{2*10^3 + 3*10^3 + 2*10^3} = 1,43\ K\Omega$$

$$E_{o1} - E_{o2} = (R_{o1} + R_{o2}) * I_o \quad ==>$$

$$==> \quad I_o = \frac{E_{o1} - E_{o2}}{R_{o1} + R_{o2}} = \frac{2,4 - 1,71}{1,2*10^3 + 1,43*10^3} = 0,262\ mA$$

$$R_{o3} = \frac{R_o * R_3}{R_o + R_3} = \frac{2,63*10^3 * 3*10^3}{2,63*10^3 + 3*10^3} = 1,4\ K\Omega$$

$$V_{AB} = R_{O3} * I_O = 1,4*10^3 * 0,262*10^{-3} = 0,367 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_3} = \frac{0,367}{3*10^3} = 0,122 \text{ mA}$$

3.- <u>VALORI 3º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$V_{AM} = \frac{R_1}{R_1 + R_2} * E_1 = \frac{4*10^3}{2*10^3 + 4*10^3} * 8 = 5,33 \text{ V}$$

$$V_{BM} = \frac{R_4}{R_4 + R_5 + R_6} * E_2 = \frac{4*10^3}{2*10^3 + 4*10^3 + 4*10^3} * 8 = 3,2 \text{ V}$$

$$E_O = V_{AM} - V_{BM} = 5,33 - 3,2 = 2,13 \text{ V}$$

$$R_{12} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{2*10^3 * 4*10^3}{2*10^3 + 4*10^3} = 1,33 \text{ K}\Omega$$

$$R_{46} = \frac{R_4 * (R_5 + R_6)}{R_4 + R_5 + R_6} = \frac{4*10^3 * (2*10^3 + 4*10^3)}{4*10^3 + 2*10^3 + 4*10^3} = 2,4 \text{ K}\Omega$$

$$R_O = R_{12} + R_{46} = 1,33*10^3 + 2,4*10^3 = 3,73 \text{ K}\Omega$$

$$I_{AB} = \frac{E_O}{R_O + R_3} = \frac{2,13}{3,73*10^3 + 2*10^3} = 0,37 \text{ mA}$$

$$V_{AB} = R_3 * I_{AB} = 2*10^3 * 0,37*10^{-3} = 0,74 \text{ V}$$

- <u>Teorema di Norton</u>

$$E_{O1} = \frac{R_2}{R_1 + R_2} * E_1 = \frac{4*10^3}{2*10^3 + 4*10^3} * 8 = 5,33 \text{ V}$$

$$E_{O2} = \frac{R_4}{R_4 + R_5 + R_6} * E_2 = \frac{4*10^3}{2*10^3 + 4*10^3 + 4*10^3} * 8 = 3,2 \text{ V}$$

$$R_{O1} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{2*10^3 * 4*10^3}{2*10^3 + 4*10^3} = 1,33 \text{ K}\Omega$$

$$R_{o2} = \frac{R_4 * (R_5 + R_6)}{R_4 + R_5 + R_6} = \frac{4*10^3 * (2*10^3 + 4*10^3)}{4*10^3 + 2*10^3 + 4*10^3} = 2,4\ K\Omega$$

$$E_{o1} - E_{o2} = (R_{o1} + R_{o2}) * I_o \quad ==>$$

$$==> \quad I_o = \frac{E_{o1} - E_{o2}}{R_{o1} + R_{o2}} = \frac{5,33 - 3,2}{1,33*10^3 + 2,4*10^3} = 0,57\ mA$$

$$R_{o3} = \frac{R_o * R_3}{R_o + R_3} = \frac{3,73*10^3 * 2*10^3}{3,73*10^3 + 2*10^3} = 1,3\ K\Omega$$

$$V_{AB} = R_{o3} * I_o = 1,3*10^3 * 0,57*10^{-3} = 0,74\ V$$

$$I_{AB} = \frac{V_{AB}}{R_3} = \frac{0,74}{2*10^3} = 0,37\ mA$$

4.- VALORI 4° GRUPPO

- Teorema di Thèvenin

$$V_{AM} = \frac{R_1}{R_1 + R_2} * E_1 = \frac{5*10^3}{3*10^3 + 5*10^3} * 12 = 7,5\ V$$

$$V_{BM} = \frac{R_4}{R_4 + R_5 + R_6} * E_2 = \frac{5*10^3}{3*10^3 + 5*10^3 + 5*10^3} * 12 = 4,61\ V$$

$$E_o = V_{AM} - V_{BM} = 7,5 - 4,61 = 2,89\ V$$

$$R_{12} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{3*10^3 * 5*10^3}{3*10^3 + 5*10^3} = 1,875\ K\Omega$$

$$R_{46} = \frac{R_4 * (R_5 + R_6)}{R_4 + R_5 + R_6} = \frac{5*10^3 * (3*10^3 + 5*10^3)}{5*10^3 + 3*10^3 + 5*10^3} = 3,07\ K\Omega$$

$$R_o = R_{12} + R_{46} = 1,875*10^3 + 3,07*10^3 = 4,95\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_3} = \frac{2,89}{4,95*10^3 + 3*10^3} = 0,36\ mA$$

$$V_{AB} = R_3 * I_{AB} = 3*10^3 * 0,36*10^{-3} = 1,09\ V$$

- <u>Teorema di Norton</u>

$$E_{o1} = \frac{R_2}{R_1 + R_2} * E_1 = \frac{5*10^3}{3*10^3 + 5*10^3} * 12 = 7,5 \text{ V}$$

$$E_{o2} = \frac{R_4}{R_4 + R_5 + R_6} * E_2 = \frac{5*10^3}{3*10^3 + 5*10^3 + 5*10^3} * 12 = 4,61 \text{ V}$$

$$R_{o1} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{3*10^3 * 5*10^3}{3*10^3 + 5*10^3} = 1,875 \text{ K}\Omega$$

$$R_{o2} = \frac{R_4 * (R_5 + R_6)}{R_4 + R_5 + R_6} = \frac{5*10^3 * (3*10^3 + 5*10^3)}{5*10^3 + 3*10^3 + 5*10^3} = 3,07 \text{ K}\Omega$$

$$E_{o1} - E_{o2} = (R_{o1} + R_{o2}) * I_o \quad ==>$$

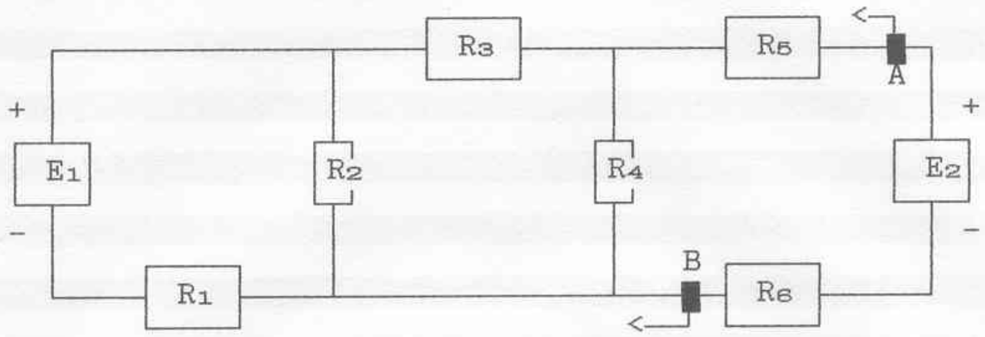
$$==> \quad I_o = \frac{E_{o1} - E_{o2}}{R_{o1} + R_{o2}} = \frac{7,5 - 4,61}{1,875*10^3 + 3,07*10^3} = 0,58 \text{ mA}$$

$$R_{o3} = \frac{R_o * R_3}{R_o + R_3} = \frac{4,95*10^3 * 3*10^3}{4,95*10^3 + 3*10^3} = 1,868 \text{ K}\Omega$$

$$V_{AB} = R_{o3} * I_o = 1,878*10^3 * 0,58*10^{-3} = 1,09 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_3} = \frac{1,09}{3*10^3} = 0,36 \text{ mA}$$

6.32 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

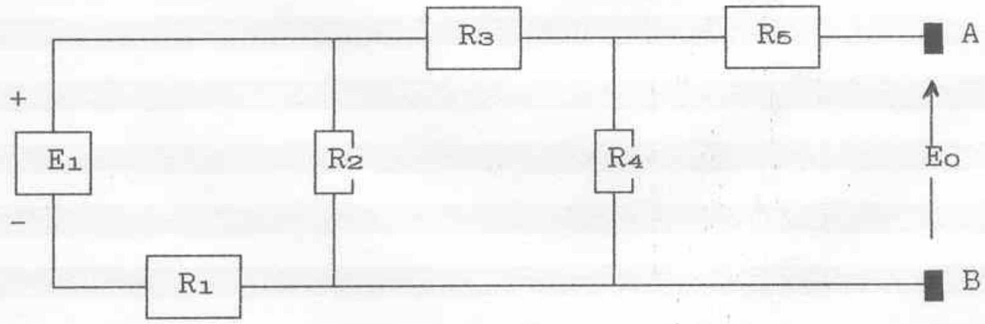
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

1.- VALORI 1º GRUPPO

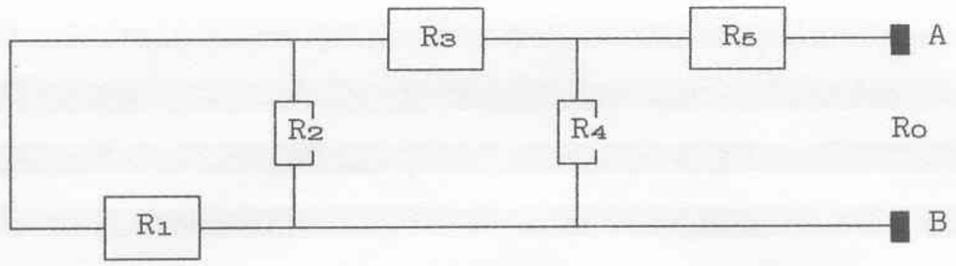
- Teorema di Thèvenin



$$R_{24} = \frac{R_2 * (R_3 + R_4)}{R_2 + R_3 + R_4} = \frac{3*10^3 * (2*10^3 + 3*10^3)}{3*10^3 + 2*10^3 + 3*10^3} = 1,875 \text{ K}\Omega$$

$$V_2 = \frac{R_{24}}{R_{24} + R_1} * E_1 = \frac{1,875*10^3}{1,875*10^3 + 2*10^3} * 10 = 4,84 \text{ V}$$

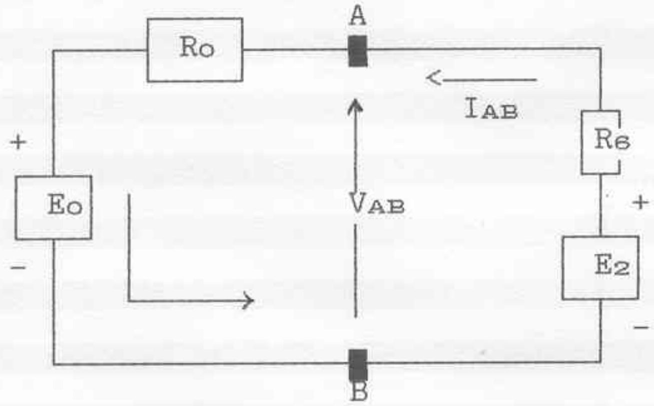
$$E_o = \frac{R_4}{R_3 + R_4} * V_2 = \frac{3*10^3}{2*10^3 + 3*10^3} * 4,84 = 2,9 \text{ V}$$



$$R_{12} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1,2\ K\Omega$$

$$R_{14} = \frac{(R_3 + R_{12}) * R_4}{R_3 + R_{12} + R_4} = \frac{(2*10^3 + 1,2*10^3) * 3*10^3}{2*10^3 + 1,2*10^3 + 3*10^3} = 1,55\ K\Omega$$

$$R_O = R_{14} + R_5 = 1,55*10^3 + 2*10^3 = 3,55\ K\Omega$$

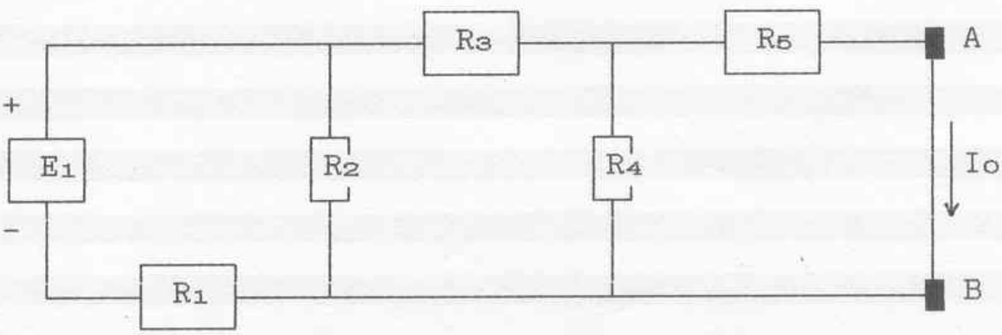


$$E_2 - E_O = (R_O + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_O}{R_O + R_6} = \frac{10 - 2,9}{3,55*10^3 + 3*10^3} = 1,08\ mA$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 10 - 3*10^3 * 1,08*10^{-3} = 6,76\ V$$

- <u>Teorema di Norton</u>



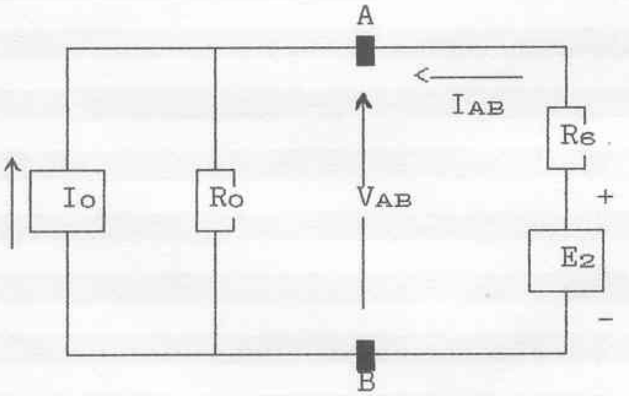
$$R_{45} = \frac{R_4 * R_5}{R_4 + R_5} = \frac{3*10^3 * 2*10^3}{3*10^3 + 2*10^3} = 1,2\ K\Omega$$

$$R_{25} = \frac{R_2 * (R_3 + R_{45})}{R_2 + R_3 + R_{45}} = \frac{3*10^3 * (2*10^3 + 1,2*10^3)}{3*10^3 + 2*10^3 + 1,2*10^3} = 1,55\ K\Omega$$

$$V_2 = \frac{R_{25}}{R_{25} + R_1} * E_1 = \frac{1,55*10^3}{1,55*10^3 + 2*10^3} * 10 = 4,37\ V$$

$$V_5 = \frac{R_{45}}{R_{45} + R_3} * V_2 = \frac{1,2*10^3}{1,2*10^3 + 2*10^3} * 4,37 = 1,64\ V$$

$$I_o = \frac{V_5}{R_5} = \frac{1,64}{2*10^3} = 0,82\ mA$$



$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{0,82*10^{-3} + \frac{10}{3*10^3}}{\frac{1}{3,55*10^3} + \frac{1}{3*10^3}} = 6,75\ V$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{10 - 6,75}{3*10^3} = 1,08\ mA$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{R_2 * (R_3 + R_4)}{R_2 + R_3 + R_4} = \frac{2*10^3 * (3*10^3 + 2*10^3)}{2*10^3 + 3*10^3 + 2*10^3} = 1,43\ K\Omega$$

$$V_2 = \frac{R_{24}}{R_{24} + R_1} * E_1 = \frac{1,43*10^3}{1,43*10^3 + 3*10^3} * 6 = 1,93 \text{ V}$$

$$E_o = \frac{R_4}{R_3 + R_4} * V_2 = \frac{2*10^3}{3*10^3 + 2*10^3} * 1,93 = 0,77 \text{ V}$$

$$R_{12} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{3*10^3 * 2*10^3}{3*10^3 + 2*10^3} = 1,2 \text{ K}\Omega$$

$$R_{14} = \frac{(R_3 + R_{12}) * R_4}{R_3 + R_{12} + R_4} = \frac{(3*10^3 + 1,2*10^3) * 2*10^3}{3*10^3 + 1,2*10^3 + 2*10^3} = 1,35 \text{ K}\Omega$$

$$R_o = R_{14} + R_5 = 1,35*10^3 + 3*10^3 = 4,55 \text{ K}\Omega$$

$$E_2 - E_o = (R_o + R_6) * I_{AB} \quad \Longrightarrow$$

$$\Longrightarrow \quad I_{AB} = \frac{E_2 - E_o}{R_o + R_6} = \frac{6 - 0,77}{4,55*10^3 + 2*10^3} = 0,8 \text{ mA}$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 6 - 2*10^3 * 0,8*10^{-3} = 4,4 \text{ V}$$

- <u>Teorema di Norton</u>

$$R_{45} = \frac{R_4 * R_5}{R_4 + R_5} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1,2 \text{ K}\Omega$$

$$R_{25} = \frac{R_2 * (R_3 + R_{45})}{R_2 + R_3 + R_{45}} = \frac{2*10^3 * (3*10^3 + 1,2*10^3)}{2*10^3 + 3*10^3 + 1,2*10^3} = 1,35 \text{ K}\Omega$$

$$V_2 = \frac{R_{25}}{R_{25} + R_1} * E_1 = \frac{1,35*10^3}{1,35*10^3 + 3*10^3} * 6 = 1,86 \text{ V}$$

$$V_5 = \frac{R_{45}}{R_{45} + R_3} * V_2 = \frac{1,2*10^3}{1,2*10^3 + 3*10^3} * 1,86 = 0,53 \text{ V}$$

$$I_o = \frac{V_5}{R_5} = \frac{0,53}{3*10^3} = 0,177 \text{ mA}$$

$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{0,177*10^{-3} + \frac{6}{2*10^3}}{\frac{1}{4,55*10^3} + \frac{1}{2*10^3}} = 4,4\ V$$

$$V_{AB} = E_2 - R_6 * I_{AB} \implies I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{6 - 4,4}{2*10^3} = 0,8\ mA$$

3.- <u>VALORI 3º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{R_2 * (R_3 + R_4)}{R_2 + R_3 + R_4} = \frac{4*10^3 * (2*10^3 + 4*10^3)}{4*10^3 + 2*10^3 + 4*10^3} = 2,4\ K\Omega$$

$$V_2 = \frac{R_{24}}{R_{24} + R_1} * E_1 = \frac{2,4*10^3}{2,4*10^3 + 2*10^3} * 8 = 4,36\ V$$

$$E_o = \frac{R_4}{R_3 + R_4} * V_2 = \frac{4*10^3}{2*10^3 + 4*10^3} * 4,36 = 2,9\ V$$

$$R_{12} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{2*10^3 * 4*10^3}{2*10^3 + 4*10^3} = 1,33\ K\Omega$$

$$R_{14} = \frac{(R_3 + R_{12}) * R_4}{R_3 + R_{12} + R_4} = \frac{(2*10^3 + 1,33*10^3) * 4*10^3}{2*10^3 + 1,33*10^3 + 4*10^3} = 1,81\ K\Omega$$

$$R_o = R_{14} + R_5 = 1,81*10^3 + 2*10^3 = 3,81\ K\Omega$$

$$E_2 - E_o = (R_o + R_6) * I_{AB} \implies$$

$$\implies I_{AB} = \frac{E_2 - E_o}{R_o + R_6} = \frac{8 - 2,9}{3,81*10^3 + 4*10^3} = 0,65\ mA$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 8 - 4*10^3 * 0,65*10^{-3} = 5,4\ V$$

- <u>Teorema di Norton</u>

$$R_{45} = \frac{R_4 * R_5}{R_4 + R_5} = \frac{4*10^3 * 2*10^3}{4*10^3 + 2*10^3} = 1,33\ K\Omega$$

$$R_{25} = \frac{R_2 * (R_3 + R_{45})}{R_2 + R_3 + R_{45}} = \frac{4*10^3 * (2*10^3 + 1,33*10^3)}{4*10^3 + 2*10^3 + 1,33*10^3} = 1,81\ K\Omega$$

$$V_2 = \frac{R_{25}}{R_{25} + R_1} * E_1 = \frac{1,81*10^3}{1,81*10^3 + 2*10^3} * 8 = 3,8\ V$$

$$V_5 = \frac{R_{45}}{R_{45} + R_3} * V_2 = \frac{1,33*10^3}{1,33*10^3 + 2*10^3} * 3,8 = 1,51\ V$$

$$I_o = \frac{V_5}{R_5} = \frac{1,51}{2*10^3} = 0,755\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{0,755*10^{-3} + \frac{8}{4*10^3}}{\frac{1}{3,81*10^3} + \frac{1}{4*10^3}} = 5,37\ V$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{8 - 5,37}{4*10^3} = 0,65\ mA$$

4.- <u>VALORI 4º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{R_2 * (R_3 + R_4)}{R_2 + R_3 + R_4} = \frac{5*10^3 * (3*10^3 + 5*10^3)}{5*10^3 + 3*10^3 + 5*10^3} = 3,07\ K\Omega$$

$$V_2 = \frac{R_{24}}{R_{24} + R_1} * E_1 = \frac{3,07*10^3}{3,07*10^3 + 3*10^3} * 12 = 6,07\ V$$

$$E_o = \frac{R_4}{R_3 + R_4} * V_2 = \frac{5*10^3}{3*10^3 + 5*10^3} * 6,07 = 3,79\ V$$

$$R_{12} = \frac{R_1 * R_2}{R_1 + R_2} = \frac{3*10^3 * 5*10^3}{3*10^3 + 5*10^3} = 1,875\ K\Omega$$

$$R_{14} = \frac{(R_3 + R_{12}) * R_4}{R_3 + R_{12} + R_4} = \frac{(3*10^3 + 1,875*10^3) * 5*10^3}{3*10^3 + 1,875*10^3 + 5*10^3} = 2,47\ K\Omega$$

$$R_o = R_{14} + R_5 = 2,47*10^3 + 3*10^3 = 5,47\ K\Omega$$

$$E_2 - E_o = (R_o + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_o}{R_o + R_6} = \frac{12 - 3,79}{5,47*10^3 + 5*10^3} = 0,784\ mA$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 12 - 5*10^3 * 0,784*10^{-3} = 8,08\ V$$

- Teorema di Norton

$$R_{45} = \frac{R_4 * R_5}{R_4 + R_5} = \frac{5*10^3 * 3*10^3}{5*10^3 + 3*10^3} = 1,875\ K\Omega$$

$$R_{25} = \frac{R_2 * (R_3 + R_{45})}{R_2 + R_3 + R_{45}} = \frac{5*10^3 * (3*10^3 + 1,875*10^3)}{5*10^3 + 3*10^3 + 1,875*10^3} = 2,47\ K\Omega$$

$$V_2 = \frac{R_{25}}{R_{25} + R_1} * E_1 = \frac{2,47*10^3}{2,47*10^3 + 3*10^3} * 12 = 5,41\ V$$

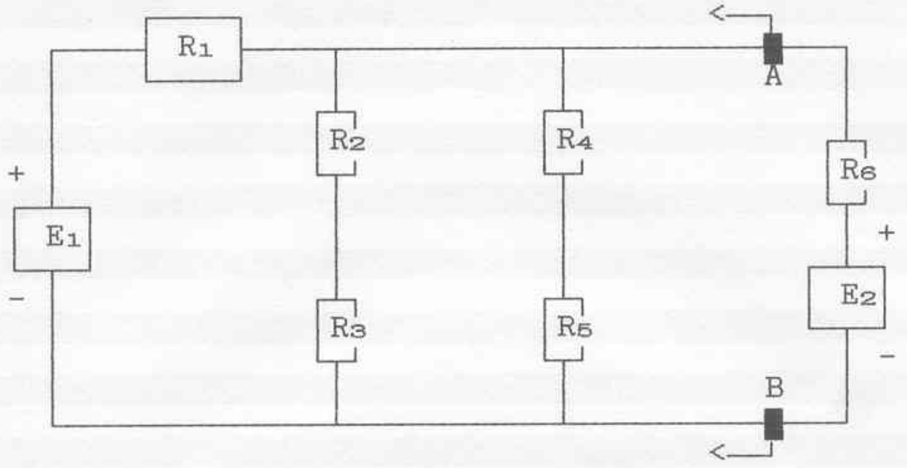
$$V_5 = \frac{R_{45}}{R_{45} + R_3} * V_2 = \frac{1,875*10^3}{1,875*10^3 + 3*10^3} * 5,41 = 2,08\ V$$

$$I_o = \frac{V_5}{R_5} = \frac{2,08}{3*10^3} = 0,694\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{0,694*10^{-3} + \frac{12}{5*10^3}}{\frac{1}{5,47*10^3} + \frac{1}{5*10^3}} = 8,08\ V$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{12 - 8,08}{5*10^3} = 0,784\ mA$$

6.33 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

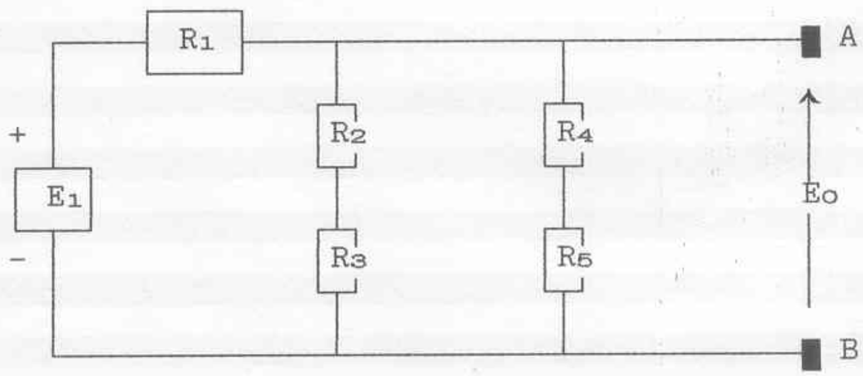
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

1.- VALORI 1º GRUPPO

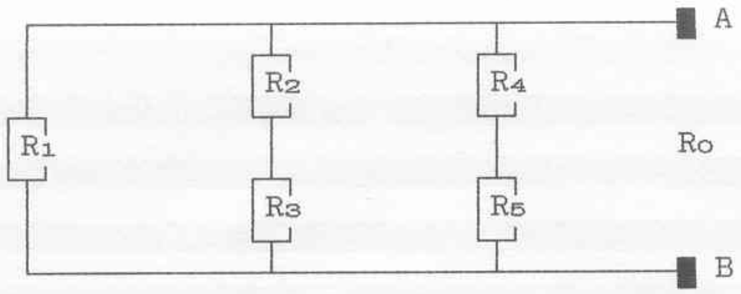
- Teorema di Thèvenin



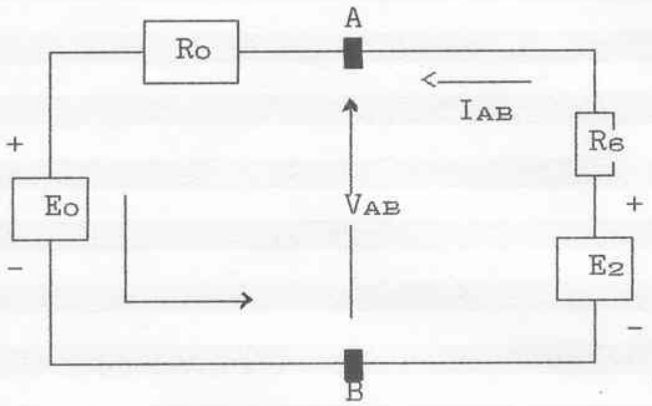
$$R_{23} = R_{45} = R_2 + R_3 = R_4 + R_5 = 3*10^3 + 2*10^3 = 5 \text{ K}\Omega$$

$$R_{25} = \frac{R_{23} * R_{45}}{R_{23} + R_{45}} = \frac{R_{23}}{2} = \frac{5*10^3}{2} = 2,5 \text{ K}\Omega$$

$$E_o = \frac{R_{25}}{R_1 + R_{25}} * E_1 = \frac{2,5*10^3}{2*10^3 + 2,5*10^3} * 10 = 5,56 \text{ V}$$



$$R_O = \frac{R_1 * R_{25}}{R_1 + R_{25}} = \frac{2*10^3 * 2,5*10^3}{2*10^3 + 2,5*10^3} = 1,11\ K\Omega$$

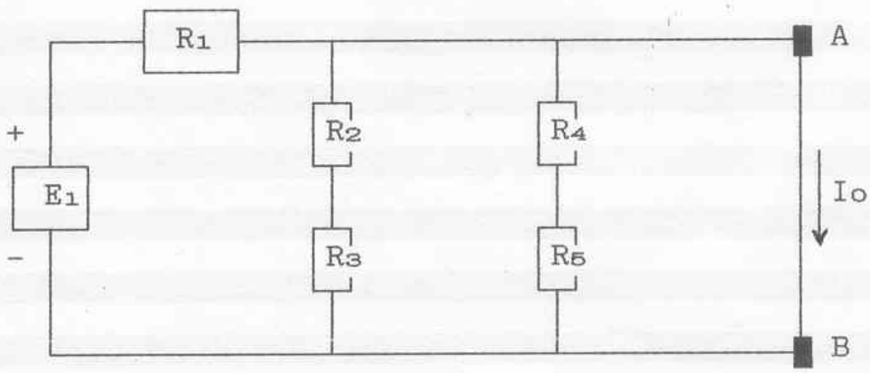


$$E_2 - E_O = (R_O + R_6) * I_{AB} \quad ==>$$

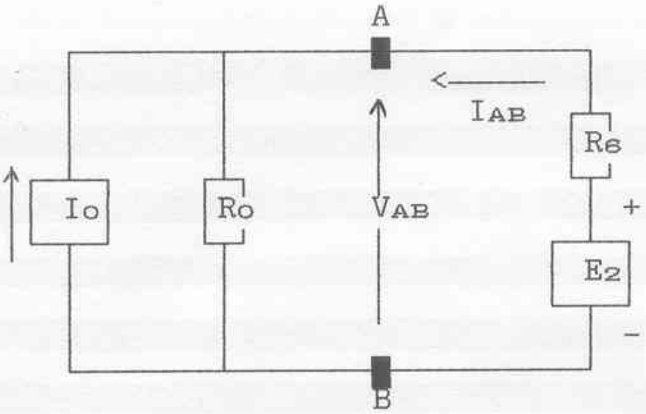
$$==> \quad I_{AB} = \frac{E_2 - E_O}{R_O + R_6} = \frac{10 - 5,56}{1,11*10^3 + 3*10^3} = 1,08\ mA$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 10 - 3*10^3 * 1,08*10^{-3} = 6,76\ V$$

- <u>Teorema di Norton</u>



$$I_O = \frac{E_1}{R_1} = \frac{10}{2*10^3} = 5\ mA$$



$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{5*10^{-3} + \frac{10}{3*10^3}}{\frac{1}{1,11*10^3} + \frac{1}{3*10^3}} = 6,75 \text{ V}$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{10 - 6,75}{3*10^3} = 1,08 \text{ mA}$$

2.- <u>VALORI 2° GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{23} = R_{45} = R_2 + R_3 = R_4 + R_5 = 2*10^3 + 3*10^3 = 5 \text{ K}\Omega$$

$$R_{25} = \frac{R_{23} * R_{45}}{R_{23} + R_{45}} = \frac{R_{23}}{2} = \frac{5*10^3}{2} = 2,5 \text{ K}\Omega$$

$$E_o = \frac{R_{25}}{R_1 + R_{25}} * E_1 = \frac{2,5*10^3}{3*10^3 + 2,5*10^3} * 6 = 2,73 \text{ V}$$

$$R_o = \frac{R_1 * R_{25}}{R_1 + R_{25}} = \frac{3*10^3 * 2,5*10^3}{3*10^3 + 2,5*10^3} = 1,36 \text{ K}\Omega$$

$$E_2 - E_o = (R_o + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_o}{R_o + R_6} = \frac{6 - 2,73}{1,36*10^3 + 2*10^3} = 0,97 \text{ mA}$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 6 - 2*10^3 * 0,97*10^{-3} = 4,06 \text{ V}$$

- Teorema di Norton

$$I_o = \frac{E_1}{R_1} = \frac{6}{3*10^3} = 2\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{2*10^{-3} + \frac{6}{2*10^3}}{\frac{1}{1,36*10^3} + \frac{1}{2*10^3}} = 4,05\ V$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{6 - 4,05}{2*10^3} = 0,975\ mA$$

3.- VALORI 3º GRUPPO

- Teorema di Thèvenin

$$R_{23} = R_{45} = R_2 + R_3 = R_4 + R_5 = 2*10^3 + 4*10^3 = 6\ K\Omega$$

$$R_{25} = \frac{R_{23} * R_{45}}{R_{23} + R_{45}} = \frac{R_{23}}{2} = \frac{6*10^3}{2} = 3\ K\Omega$$

$$E_o = \frac{R_{25}}{R_1 + R_{25}} * E_1 = \frac{3*10^3}{2*10^3 + 3*10^3} * 8 = 4,8\ V$$

$$R_o = \frac{R_1 * R_{25}}{R_1 + R_{25}} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1,2\ K\Omega$$

$$E_2 - E_o = (R_o + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_o}{R_o + R_6} = \frac{8 - 4,8}{1,2*10^3 + 4*10^3} = 0,61\ mA$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 8 - 4*10^3 * 0,61*10^{-3} = 5,56\ V$$

- Teorema di Norton

$$I_o = \frac{E_1}{R_1} = \frac{8}{2*10^3} = 4\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{4*10^{-3} + \frac{8}{4*10^3}}{\frac{1}{1,2*10^3} + \frac{1}{4*10^3}} = 5,54\ V$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{8 - 5,54}{4*10^3} = 0,615\ mA$$

4.- VALORI 4º GRUPPO

- Teorema di Thèvenin

$$R_{23} = R_{45} = R_2 + R_3 = R_4 + R_5 = 3*10^3 + 5*10^3 = 8\ K\Omega$$

$$R_{25} = \frac{R_{23} * R_{45}}{R_{23} + R_{45}} = \frac{R_{23}}{2} = \frac{8*10^3}{2} = 4\ K\Omega$$

$$E_o = \frac{R_{25}}{R_1 + R_{25}} * E_1 = \frac{4*10^3}{3*10^3 + 4*10^3} * 12 = 6,86\ V$$

$$R_o = \frac{R_1 * R_{25}}{R_1 + R_{25}} = \frac{3*10^3 * 4*10^3}{3*10^3 + 4*10^3} = 1,71\ K\Omega$$

$$E_2 - E_o = (R_o + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_o}{R_o + R_6} = \frac{12 - 6,86}{1,71*10^3 + 5*10^3} = 0,77\ mA$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 12 - 5*10^3 * 0,77*10^{-3} = 8,15\ V$$

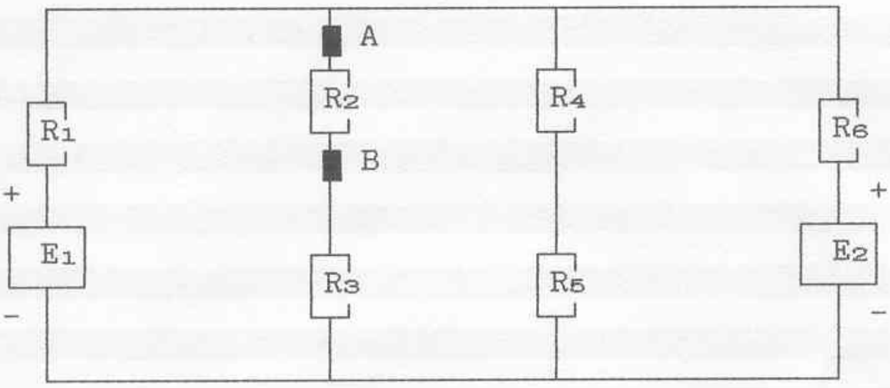
- Teorema di Norton

$$I_o = \frac{E_1}{R_1} = \frac{12}{3*10^3} = 4\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{4*10^{-3} + \frac{12}{5*10^3}}{\frac{1}{1,71*10^3} + \frac{1}{5*10^3}} = 8,15\ V$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{12 - 8,15}{5*10^3} = 0,77 \text{ mA}$$

6.34 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

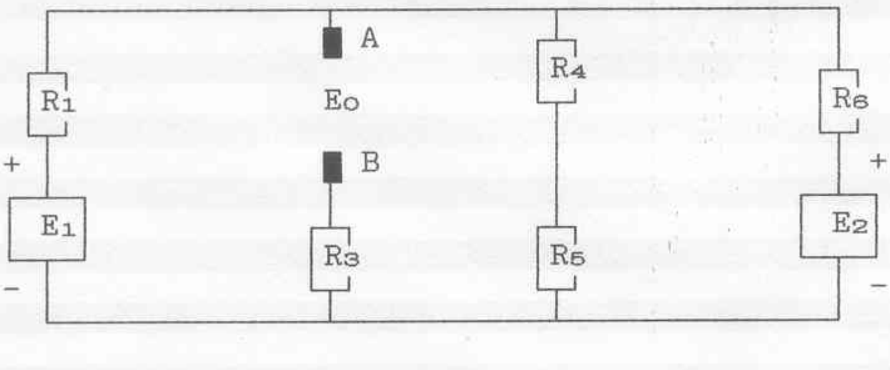
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

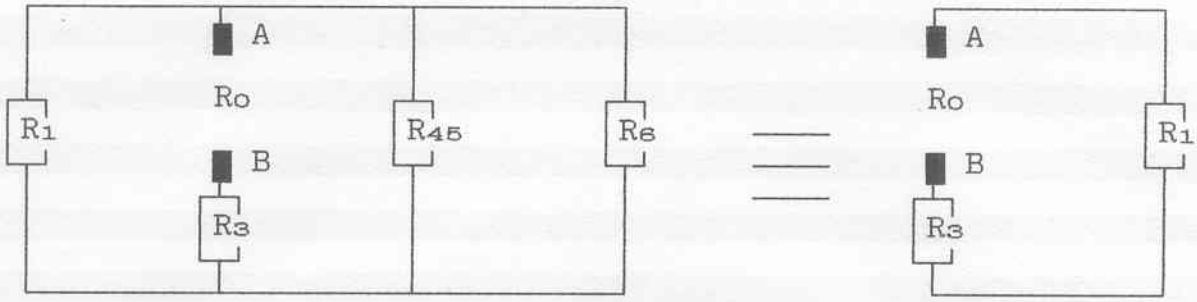
1.- VALORI 1º GRUPPO

- Teorema di Thèvenin



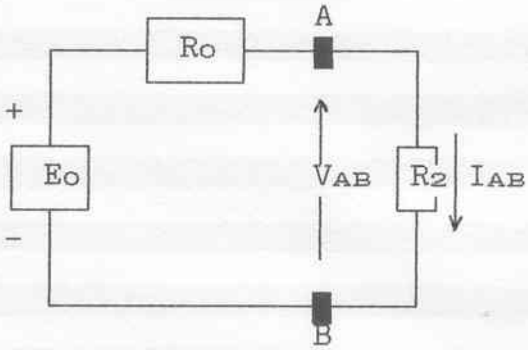
$R_{45} = R_4 + R_5 = 3*10^3 + 2*10^3 = 5$ KΩ

$$E_O = \frac{\dfrac{E_1}{R_1} + \dfrac{E_2}{R_6}}{\dfrac{1}{R_1} + \dfrac{1}{R_{45}} + \dfrac{1}{R_6}} = \frac{\dfrac{10}{2*10^3} + \dfrac{10}{3*10^3}}{\dfrac{1}{2*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{3*10^3}} = 8{,}06 \text{ V}$$



$$R_{16} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{2*10^3} + \frac{1}{5*10^3} + \frac{1}{3*10^3}} = 0,97 \text{ K}\Omega$$

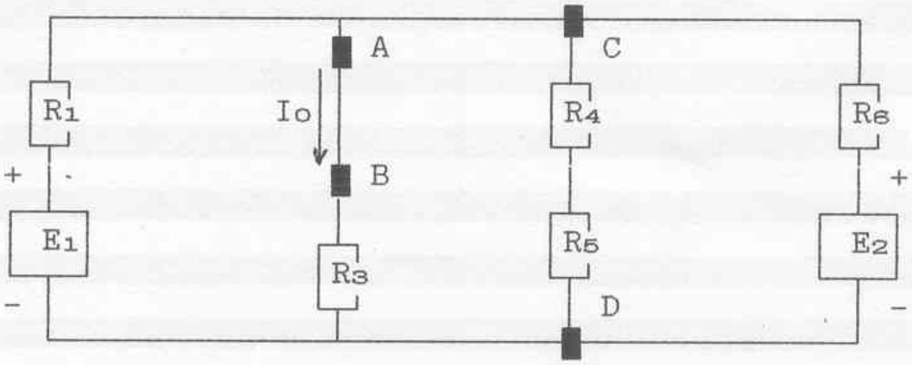
$$R_0 = R_{16} + R_3 = 0,97*10^3 + 2*10^3 = 2,97 \text{ K}\Omega$$



$$I_{AB} = \frac{E_0}{R_0 + R_2} = \frac{8,06}{2,97*10^3 + 3*10^3} = 1,35 \text{ mA}$$

$$V_{AB} = R_2 * I_{AB} = 3*10^3 * 1,35*10^{-3} = 4,05 \text{ V}$$

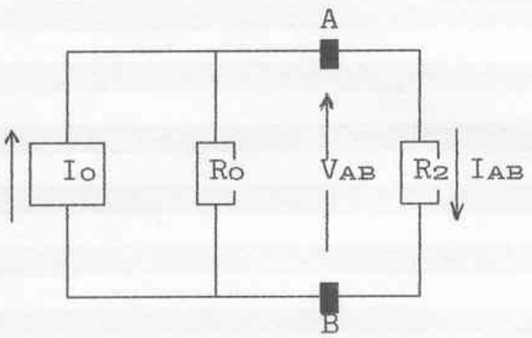
- Teorema di Norton



$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6} + \frac{1}{R_3}} =$$

$$= \frac{\frac{10}{2*10^3} + \frac{10}{3*10^3}}{\frac{1}{2*10^3} + \frac{1}{5*10^3} + \frac{1}{3*10^3} + \frac{1}{2*10^3}} = 5,43 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_3} = \frac{5,43}{2*10^3} = 2,7 \text{ mA}$$



$$R_{o2} = \frac{R_o * R_2}{R_o + R_2} = \frac{2,97*10^3 * 3*10^3}{2,97*10^3 + 3*10^3} = 1,49 \text{ K}\Omega$$

$$V_{AB} = R_{o2} * I_o = 1,49*10^3 * 2,7*10^{-3} = 4,02 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_2} = \frac{4,02}{3*10^3} = 1,34 \text{ mA}$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{45} = R_4 + R_5 = 2*10^3 + 3*10^3 = 5 \text{ K}\Omega$$

$$E_o = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{5*10^3} + \frac{1}{2*10^3}} = 4,84 \text{ V}$$

$$R_{16} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{3*10^3} + \frac{1}{5*10^3} + \frac{1}{2*10^3}} = 0,97\ K\Omega$$

$$R_o = R_{16} + R_3 = 0,97*10^3 + 3*10^3 = 3,97\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_2} = \frac{4,84}{3,97*10^3 + 2*10^3} = 0,81\ mA$$

$$V_{AB} = R_2 * I_{AB} = 2*10^3 * 0,81*10^{-3} = 1,62\ V$$

- Teorema di Norton

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6} + \frac{1}{R_3}} =$$

$$= \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{5*10^3} + \frac{1}{2*10^3} + \frac{1}{3*10^3}} = 3,66\ V$$

$$I_o = \frac{V_{CD}}{R_3} = \frac{3,66}{3*10^3} = 1,22\ mA$$

$$R_{o2} = \frac{R_o * R_2}{R_o + R_2} = \frac{3,97*10^3 * 2*10^3}{3,97*10^3 + 2*10^3} = 1,33\ K\Omega$$

$$V_{AB} = R_{o2} * I_o = 1,33*10^3 * 1,22*10^{-3} = 1,62\ V$$

$$I_{AB} = \frac{V_{AB}}{R_2} = \frac{1,62}{2*10^3} = 0,81\ mA$$

3.- VALORI 3º GRUPPO

- Teorema di Thèvenin

$$R_{45} = R_4 + R_5 = 4*10^3 + 2*10^3 = 6\ K\Omega$$

$$E_o = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{\frac{8}{2*10^3} + \frac{8}{4*10^3}}{\frac{1}{2*10^3} + \frac{1}{6*10^3} + \frac{1}{4*10^3}} = 6,54 \text{ V}$$

$$R_{16} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{2*10^3} + \frac{1}{6*10^3} + \frac{1}{4*10^3}} = 1,09 \text{ K}\Omega$$

$$R_o = R_{16} + R_3 = 1,09*10^3 + 2*10^3 = 3,09 \text{ K}\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_2} = \frac{6,54}{3,09*10^3 + 4*10^3} = 0,92 \text{ mA}$$

$$V_{AB} = R_2 * I_{AB} = 4*10^3 * 0,92*10^{-3} = 3,68 \text{ V}$$

- <u>Teorema di Norton</u>

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6} + \frac{1}{R_3}} =$$

$$= \frac{\frac{8}{2*10^3} + \frac{8}{4*10^3}}{\frac{1}{2*10^3} + \frac{1}{6*10^3} + \frac{1}{4*10^3} + \frac{1}{2*10^3}} = 4,23 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_3} = \frac{4,23}{2*10^3} = 2,12 \text{ mA}$$

$$R_{o2} = \frac{R_o * R_2}{R_o + R_2} = \frac{3,09*10^3 * 4*10^3}{3,09*10^3 + 4*10^3} = 1,74 \text{ K}\Omega$$

$$V_{AB} = R_{o2} * I_o = 1,74*10^3 * 2,12*10^{-3} = 3,69 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_2} = \frac{3,69}{4*10^3} = 0,92 \text{ mA}$$

4.- VALORI 4° GRUPPO

- Teorema di Thèvenin

$R_{45} = R_4 + R_5 = 5*10^3 + 3*10^3 = 8\ K\Omega$

$$E_o = \frac{\dfrac{E_1}{R_1} + \dfrac{E_2}{R_6}}{\dfrac{1}{R_1} + \dfrac{1}{R_{45}} + \dfrac{1}{R_6}} = \frac{\dfrac{12}{3*10^3} + \dfrac{12}{5*10^3}}{\dfrac{1}{3*10^3} + \dfrac{1}{8*10^3} + \dfrac{1}{5*10^3}} = 9,72\ V$$

$$R_{16} = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_{45}} + \dfrac{1}{R_6}} = \frac{1}{\dfrac{1}{3*10^3} + \dfrac{1}{8*10^3} + \dfrac{1}{5*10^3}} = 1,52\ K\Omega$$

$R_o = R_{16} + R_3 = 1,52*10^3 + 3*10^3 = 4,52\ K\Omega$

$$I_{AB} = \frac{E_o}{R_o + R_2} = \frac{9,72}{4,52*10^3 + 5*10^3} = 1,02\ mA$$

$V_{AB} = R_2 * I_{AB} = 5*10^3 * 1,02*10^{-3} = 5,1\ V$

- Teorema di Norton

$$V_{CD} = \frac{\dfrac{E_1}{R_1} + \dfrac{E_2}{R_6}}{\dfrac{1}{R_1} + \dfrac{1}{R_{45}} + \dfrac{1}{R_6} + \dfrac{1}{R_3}} =$$

$$= \frac{\dfrac{12}{3*10^3} + \dfrac{12}{5*10^3}}{\dfrac{1}{3*10^3} + \dfrac{1}{8*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{3*10^3}} = 6,45\ V$$

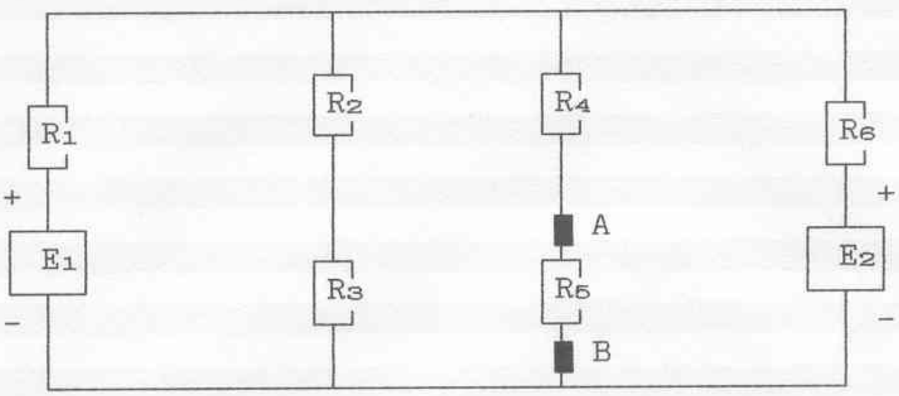
$$I_o = \frac{V_{CD}}{R_3} = \frac{6,45}{3*10^3} = 2,15\ mA$$

$$R_{o2} = \frac{R_o * R_2}{R_o + R_2} = \frac{4,52*10^3 * 5*10^3}{4,52*10^3 + 5*10^3} = 2,37\ K\Omega$$

$$V_{AB} = R_{o2} * I_o = 2,37*10^3 * 2,15*10^{-3} = 5,1\ V$$

$$I_{AB} = \frac{V_{AB}}{R_2} = \frac{5,1}{5*10^3} = 1,02\ mA$$

6.35 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

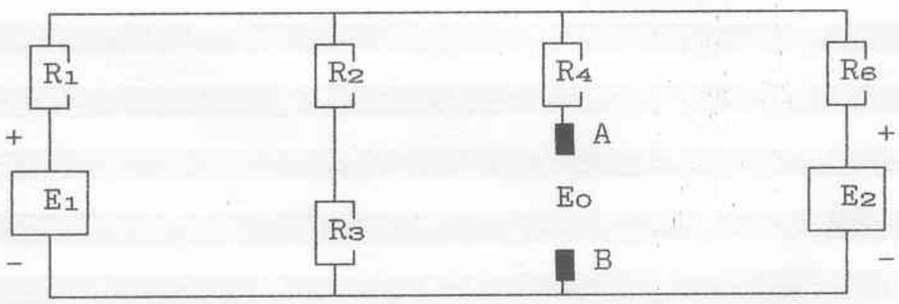
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

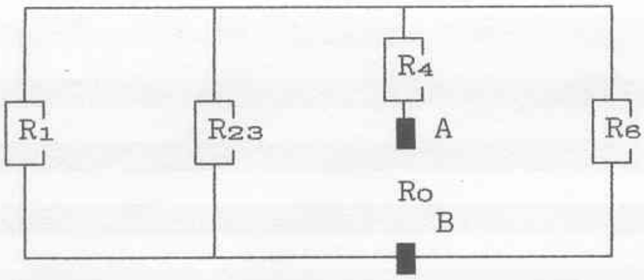
1.- VALORI 1° GRUPPO

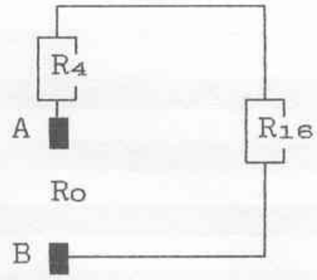
- Teorema di Thèvenin



$$R_{23} = R_2 + R_3 = 3*10^3 + 2*10^3 = 5 \text{ K}\Omega$$

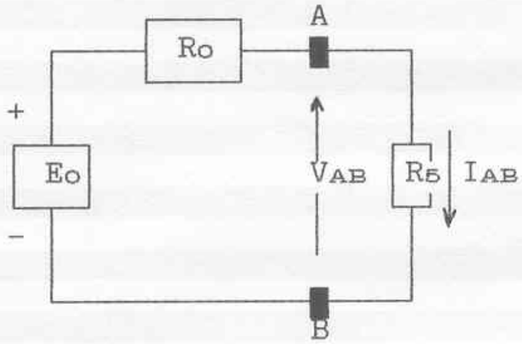
$$E_o = \frac{\dfrac{E_1}{R_1} + \dfrac{E_2}{R_6}}{\dfrac{1}{R_1} + \dfrac{1}{R_{23}} + \dfrac{1}{R_6}} = \frac{\dfrac{10}{2*10^3} + \dfrac{10}{3*10^3}}{\dfrac{1}{2*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{3*10^3}} = 8,06 \text{ V}$$





$$R_{16} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{2*10^3} + \frac{1}{5*10^3} + \frac{1}{3*10^3}} = 0,97\ K\Omega$$

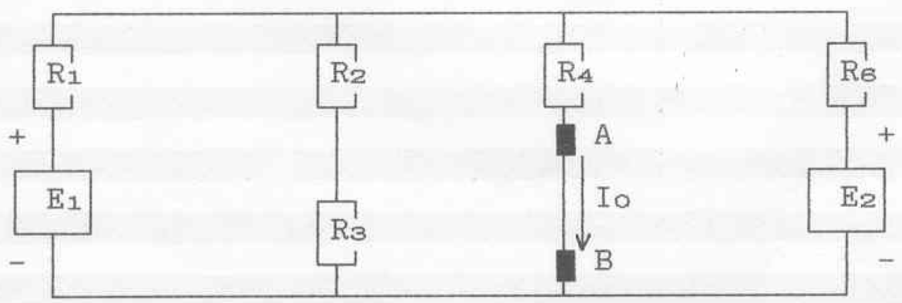
$$R_o = R_{16} + R_3 = 0,97*10^3 + 3*10^3 = 3,97\ K\Omega$$



$$I_{AB} = \frac{E_o}{R_o + R_5} = \frac{8,06}{3,97*10^3 + 2*10^3} = 1,35\ mA$$

$$V_{AB} = R_5 * I_{AB} = 2*10^3 * 1,35*10^{-3} = 2,7\ V$$

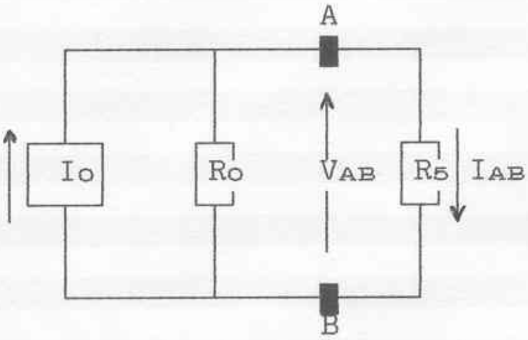
- <u>Teorema di Norton</u>



$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_4} + \frac{1}{R_6}} =$$

$$= \frac{\frac{10}{2*10^3} + \frac{10}{3*10^3}}{\frac{1}{2*10^3} + \frac{1}{5*10^3} + \frac{1}{3*10^3} + \frac{1}{3*10^3}} = 6,1 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_4} = \frac{6,1}{3*10^3} = 2,03 \text{ mA}$$



$$R_{o5} = \frac{R_o * R_5}{R_o + R_5} = \frac{3,97*10^3 * 2*10^3}{3,97*10^3 + 2*10^3} = 1,33 \text{ K}\Omega$$

$$V_{AB} = R_{o5} * I_o = 1,33*10^3 * 2,03*10^{-3} = 2,7 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{2,7}{2*10^3} = 1,35 \text{ mA}$$

2.- <u>VALORI 2° GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{23} = R_2 + R_3 = 2*10^3 + 3*10^3 = 5 \text{ K}\Omega$$

$$E_o = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{5*10^3} + \frac{1}{2*10^3}} = 4,84 \text{ V}$$

$$R_{16} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{3*10^3} + \frac{1}{5*10^3} + \frac{1}{2*10^3}} = 0,97 \text{ K}\Omega$$

$$R_o = R_{16} + R_3 = 0,97*10^3 + 2*10^3 = 2,97 \text{ K}\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_5} = \frac{4,84}{2,97*10^3 + 3*10^3} = 0,81\ mA$$

$$V_{AB} = R_5 * I_{AB} = 3*10^3 * 0,81*10^{-3} = 2,43\ V$$

- Teorema di Norton

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_4} + \frac{1}{R_6}} =$$

$$= \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{5*10^3} + \frac{1}{2*10^3} + \frac{1}{2*10^3}} = 3,26\ V$$

$$I_o = \frac{V_{CD}}{R_4} = \frac{3,26}{2*10^3} = 1,63\ mA$$

$$R_{o5} = \frac{R_o * R_5}{R_o + R_5} = \frac{2,97*10^3 * 3*10^3}{2,97*10^3 + 3*10^3} = 1,49\ K\Omega$$

$$V_{AB} = R_{o5} * I_o = 1,49*10^3 * 1,63*10^{-3} = 2,43\ V$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{2,43}{3*10^3} = 0,81\ mA$$

3.- VALORI 3º GRUPPO

- Teorema di Thèvenin

$$R_{23} = R_2 + R_3 = 4*10^3 + 2*10^3 = 6\ K\Omega$$

$$E_o = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{\frac{8}{2*10^3} + \frac{8}{4*10^3}}{\frac{1}{2*10^3} + \frac{1}{6*10^3} + \frac{1}{4*10^3}} = 6,54\ V$$

$$R_{16} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{2*10^3} + \frac{1}{6*10^3} + \frac{1}{4*10^3}} = 1,09\ K\Omega$$

$$R_o = R_{16} + R_3 = 1,09*10^3 + 4*10^3 = 5,09\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_5} = \frac{6,54}{5,09*10^3 + 2*10^3} = 0,92\ mA$$

$$V_{AB} = R_5 * I_{AB} = 2*10^3 * 0,92*10^{-3} = 1,84\ V$$

- <u>Teorema di Norton</u>

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_4} + \frac{1}{R_6}} =$$

$$= \frac{\frac{8}{2*10^3} + \frac{8}{4*10^3}}{\frac{1}{2*10^3} + \frac{1}{6*10^3} + \frac{1}{4*10^3} + \frac{1}{4*10^3}} = 5,14\ V$$

$$I_o = \frac{V_{CD}}{R_4} = \frac{5,14}{4*10^3} = 1,285\ mA$$

$$R_{o5} = \frac{R_o * R_5}{R_o + R_5} = \frac{5,09*10^3 * 2*10^3}{5,09*10^3 + 2*10^3} = 1,436\ K\Omega$$

$$V_{AB} = R_{o5} * I_o = 1,436*10^3 * 1,285*10^{-3} = 1,845\ V$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{1,845}{2*10^3} = 0,92\ mA$$

4.- <u>VALORI 4º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{23} = R_2 + R_3 = 5*10^3 + 3*10^3 = 8\ K\Omega$$

$$E_O = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{\frac{12}{3*10^3} + \frac{12}{5*10^3}}{\frac{1}{3*10^3} + \frac{1}{8*10^3} + \frac{1}{5*10^3}} = 9,72\ V$$

$$R_{16} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{3*10^3} + \frac{1}{8*10^3} + \frac{1}{5*10^3}} = 1,52\ K\Omega$$

$$R_O = R_{16} + R_3 = 1,52*10^3 + 5*10^3 = 6,52\ K\Omega$$

$$I_{AB} = \frac{E_O}{R_O + R_5} = \frac{9,72}{6,52*10^3 + 3*10^3} = 1,02\ mA$$

$$V_{AB} = R_5 * I_{AB} = 3*10^3 * 1,02*10^{-3} = 3,06\ V$$

- <u>Teorema di Norton</u>

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_4} + \frac{1}{R_6}} =$$

$$= \frac{\frac{12}{3*10^3} + \frac{12}{5*10^3}}{\frac{1}{3*10^3} + \frac{1}{8*10^3} + \frac{1}{5*10^3} + \frac{1}{5*10^3}} = 7,45\ V$$

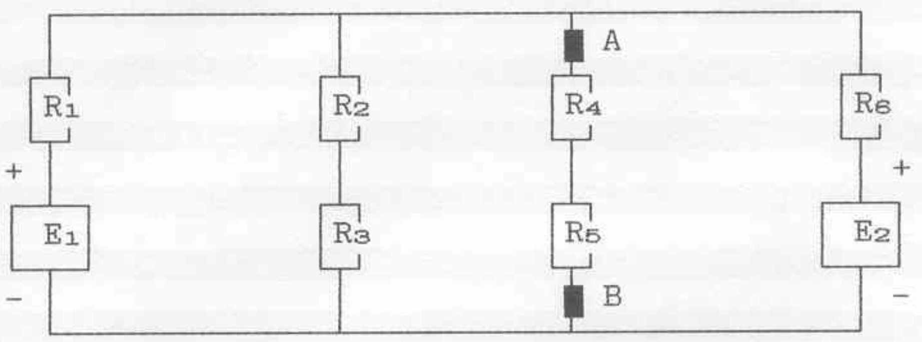
$$I_O = \frac{V_{CD}}{R_4} = \frac{7,45}{5*10^3} = 1,49\ mA$$

$$R_{O5} = \frac{R_O * R_5}{R_O + R_5} = \frac{6,52*10^3 * 3*10^3}{6,52*10^3 + 3*10^3} = 2,05\ K\Omega$$

$$V_{AB} = R_{O5} * I_O = 2,05*10^3 * 1,49*10^{-3} = 3,05\ V$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{3,05}{3*10^3} = 1,02\ mA$$

6.36 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

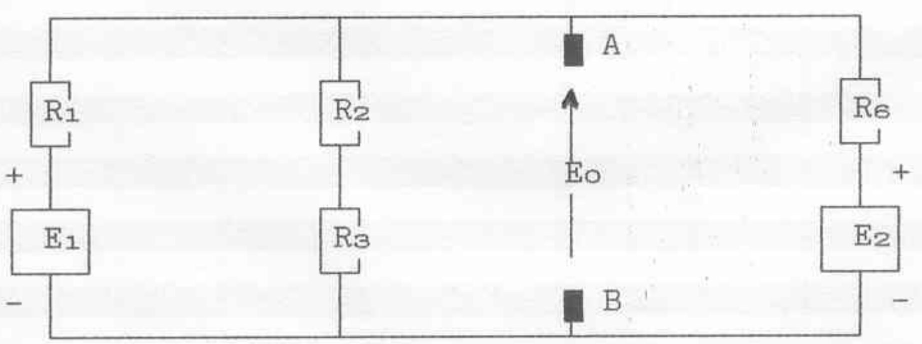
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

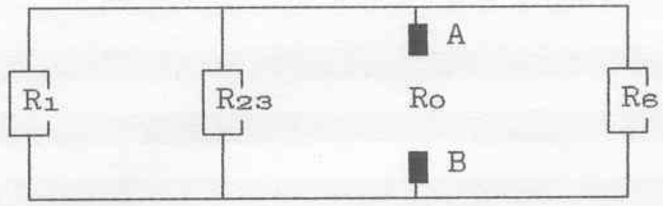
1.- VALORI 1º GRUPPO

- Teorema di Thèvenin

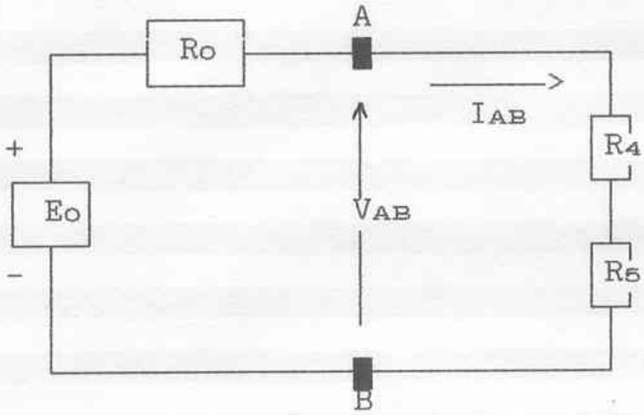


$R_{23} = R_2 + R_3 = 3*10^3 + 2*10^3 = 5$ KΩ

$$E_o = \frac{\dfrac{E_1}{R_1} + \dfrac{E_2}{R_6}}{\dfrac{1}{R_1} + \dfrac{1}{R_{23}} + \dfrac{1}{R_6}} = \frac{\dfrac{10}{2*10^3} + \dfrac{10}{3*10^3}}{\dfrac{1}{2*10^3} + \dfrac{1}{5*10^3} + \dfrac{1}{3*10^3}} = 8,06 \text{ V}$$



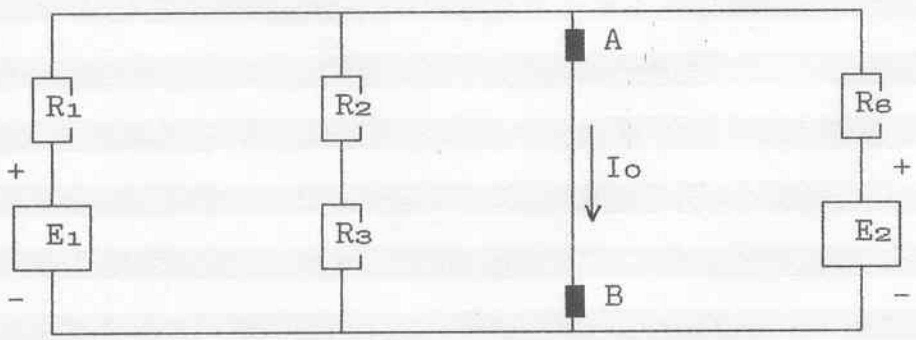
$$R_o = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{2*10^3} + \frac{1}{5*10^3} + \frac{1}{3*10^3}} = 0{,}97\ K\Omega$$



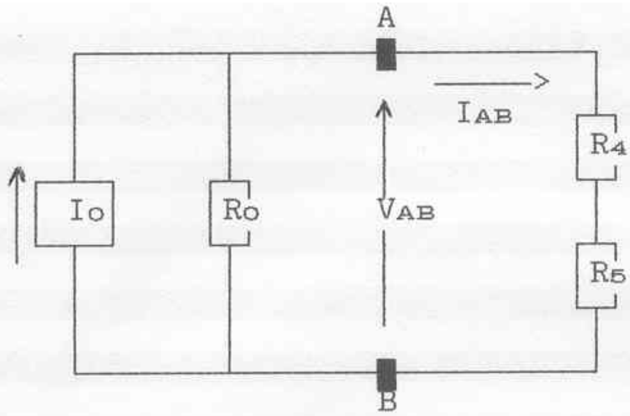
$$I_{AB} = \frac{E_o}{R_o + R_4 + R_5} = \frac{8{,}06}{0{,}97*10^3 + 3*10^3 + 2*10^3} = 1{,}35\ mA$$

$$V_{AB} = (R_4 + R_5) * I_{AB} = (3*10^3 + 2*10^3) * 1{,}35*10^{-3} = 6{,}75\ V$$

- <u>Teorema di Norton</u>



$$I_o = \frac{E_1}{R_1} + \frac{E_2}{R_6} = \frac{10}{2*10^3} + \frac{10}{3*10^3} = 8{,}33\ mA$$



$$R_{o5} = \frac{R_o * (R_4 + R_5)}{R_o + R_4 + R_5} = \frac{0,97*10^3 * (2*10^3 + 3*10^3)}{0,97*10^3 + 2*10^3 + 3*10^3} = 0,81\ K\Omega$$

$$V_{AB} = R_{o5} * I_o = 0,81*10^3 * 8,33*10^{-3} = 6,75\ V$$

$$I_{AB} = \frac{V_{AB}}{R_4 + R_5} = \frac{6,75}{2*10^3 + 3*10^3} = 1,35\ mA$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{23} = R_2 + R_3 = 2*10^3 + 3*10^3 = 5\ K\Omega$$

$$E_o = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{5*10^3} + \frac{1}{2*10^3}} = 4,84\ V$$

$$R_o = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{3*10^3} + \frac{1}{5*10^3} + \frac{1}{2*10^3}} = 0,97\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_4 + R_5} = \frac{4,84}{0,97*10^3 + 2*10^3 + 3*10^3} = 0,81\ mA$$

$$V_{AB} = (R_4 + R_5) * I_{AB} = (2*10^3 + 3*10^3) * 0,81*10^{-3} = 4,05\ V$$

- Teorema di Norton

$$I_o = \frac{E_1}{R_1} + \frac{E_2}{R_6} = \frac{6}{3*10^3} + \frac{6}{2*10^3} = 5 \text{ mA}$$

$$R_{o5} = \frac{R_o * (R_4 + R_5)}{R_o + R_4 + R_5} = \frac{0,97*10^3 * (3*10^3 + 2*10^3)}{0,97*10^3 + 3*10^3 + 2*10^3} = 0,81 \text{ K}\Omega$$

$$V_{AB} = R_{o5} * I_o = 0,81*10^3 * 5*10^{-3} = 4,05 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_4 + R_5} = \frac{4,05}{3*10^3 + 2*10^3} = 0,81 \text{ mA}$$

3.- VALORI 3° GRUPPO

- Teorema di Thèvenin

$$R_{23} = R_2 + R_3 = 4*10^3 + 2*10^3 = 6 \text{ K}\Omega$$

$$E_o = \frac{\dfrac{E_1}{R_1} + \dfrac{E_2}{R_6}}{\dfrac{1}{R_1} + \dfrac{1}{R_{23}} + \dfrac{1}{R_6}} = \frac{\dfrac{8}{2*10^3} + \dfrac{8}{4*10^3}}{\dfrac{1}{2*10^3} + \dfrac{1}{6*10^3} + \dfrac{1}{4*10^3}} = 6,54 \text{ V}$$

$$R_o = \frac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_{23}} + \dfrac{1}{R_6}} = \frac{1}{\dfrac{1}{2*10^3} + \dfrac{1}{6*10^3} + \dfrac{1}{4*10^3}} = 1,09 \text{ K}\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_4 + R_5} = \frac{6,54}{1,09*10^3 + 2*10^3 + 4*10^3} = 0,92 \text{ mA}$$

$$V_{AB} = (R_4 + R_5) * I_{AB} = (2*10^3 + 4*10^3) * 0,92*10^{-3} = 5,52 \text{ V}$$

- Teorema di Norton

$$I_o = \frac{E_1}{R_1} + \frac{E_2}{R_6} = \frac{8}{2*10^3} + \frac{8}{4*10^3} = 6 \text{ mA}$$

$$R_{o5} = \frac{R_o * (R_4 + R_5)}{R_o + R_4 + R_5} = \frac{1,09*10^3 * (2*10^3 + 4*10^3)}{1,09*10^3 + 2*10^3 + 4*10^3} = 0,92 \text{ K}\Omega$$

$V_{AB} = R_{o5} * I_o = 0,92*10^3 * 6*10^{-3} = 5,52\ V$

$$I_{AB} = \frac{V_{AB}}{R_4 + R_5} = \frac{5,52}{2*10^3 + 4*10^3} = 0,92\ mA$$

4.- VALORI 4° GRUPPO

- Teorema di Thèvenin

$R_{23} = R_2 + R_3 = 5*10^3 + 3*10^3 = 8\ K\Omega$

$$E_o = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{\frac{12}{3*10^3} + \frac{12}{5*10^3}}{\frac{1}{3*10^3} + \frac{1}{8*10^3} + \frac{1}{5*10^3}} = 9,72\ V$$

$$R_o = \frac{1}{\frac{1}{R_1} + \frac{1}{R_{23}} + \frac{1}{R_6}} = \frac{1}{\frac{1}{3*10^3} + \frac{1}{8*10^3} + \frac{1}{5*10^3}} = 1,52\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_4 + R_5} = \frac{9,72}{1,52*10^3 + 3*10^3 + 5*10^3} = 1,02\ mA$$

$V_{AB} = (R_4 + R_5) * I_{AB} = (3*10^3 + 5*10^3) * 1,02*10^{-3} = 8,16\ V$

- Teorema di Norton

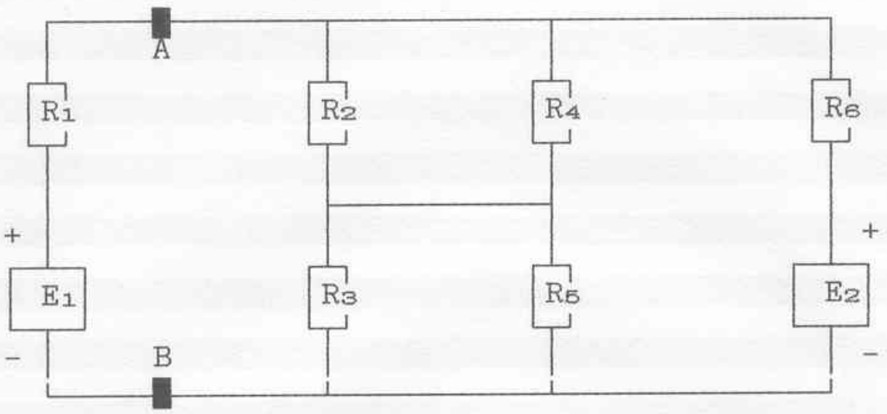
$$I_o = \frac{E_1}{R_1} + \frac{E_2}{R_6} = \frac{12}{3*10^3} + \frac{12}{5*10^3} = 6,4\ mA$$

$$R_{o5} = \frac{R_o * (R_4 + R_5)}{R_o + R_4 + R_5} = \frac{1,52*10^3 * (3*10^3 + 5*10^3)}{1,52*10^3 + 3*10^3 + 5*10^3} = 1,28\ K\Omega$$

$V_{AB} = R_{o5} * I_o = 1,28*10^3 * 6,4*10^{-3} = 8,19\ V$

$$I_{AB} = \frac{V_{AB}}{R_4 + R_5} = \frac{8,19}{3*10^3 + 5*10^3} = 1,02\ mA$$

6.37 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10\ V$; $R_1 = R_3 = R_5 = 2\ K\Omega$; $R_2 = R_4 = R_6 = 3\ K\Omega$

2.- $E_1 = E_2 = 6\ V$; $R_1 = R_3 = R_5 = 3\ K\Omega$; $R_2 = R_4 = R_6 = 2\ K\Omega$

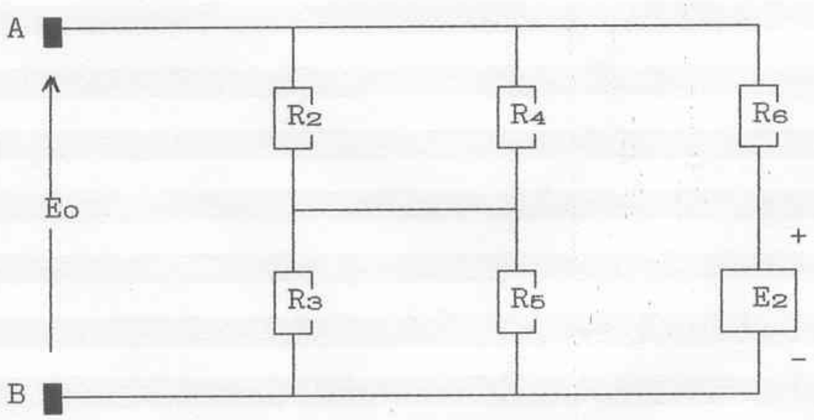
3.- $E_1 = E_2 = 8\ V$; $R_1 = R_3 = R_5 = 2\ K\Omega$; $R_2 = R_4 = R_6 = 4\ K\Omega$

4.- $E_1 = E_2 = 12\ V$; $R_1 = R_3 = R_5 = 3\ K\Omega$; $R_2 = R_4 = R_6 = 5\ K\Omega$

RISOLUZIONE

1.- VALORI 1º GRUPPO

- Teorema di Thèvenin

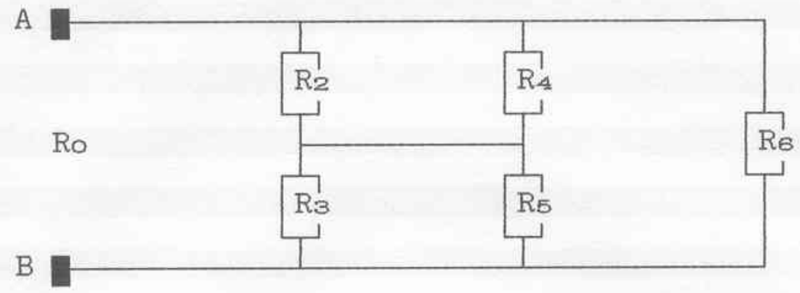


$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{3*10^3}{2} = 1,5\ K\Omega$$

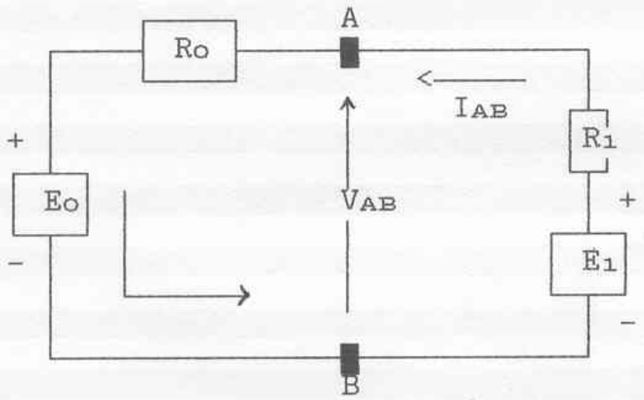
$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{2*10^3}{2} = 1\ K\Omega$$

$$R_{25} = R_{24} + R_{35} = 1,5*10^3 + 1*10^3 = 2,5\ K\Omega$$

$$E_o = \frac{R_{25}}{R_{25} + R_6} * E_2 = \frac{2,5*10^3}{2,5*10^3 + 3*10^3} * 10 = 4,54 \text{ V}$$



$$R_o = \frac{R_{25} * R_6}{R_{25} + R_6} = \frac{2,5*10^3 * 3*10^3}{2,5*10^3 + 3*10^3} = 1,36 \text{ K}\Omega$$

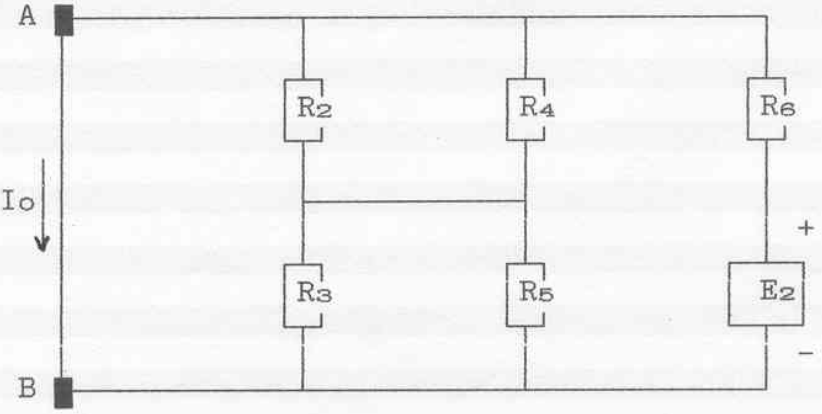


$$E_1 - E_o = (R_o + R_1) * I_{AB} \qquad ==>$$

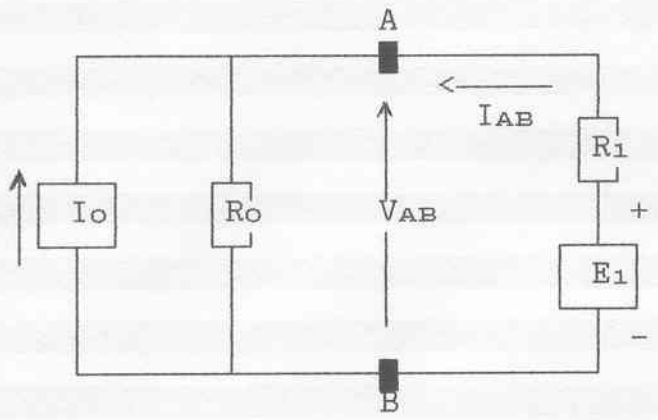
$$==> \qquad I_{AB} = \frac{E_1 - E_o}{R_o + R_1} = \frac{10 - 4,54}{1,36*10^3 + 2*10^3} = 1,625 \text{ mA}$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 10 - 2*10^3 * 1,625*10^{-3} = 6,75 \text{ V}$$

- <u>Teorema di Norton</u>



$$I_o = \frac{E_2}{R_6} = \frac{10}{3*10^3} = 3,33\ mA$$



$$V_{AB} = \frac{I_o + \frac{E_1}{R_1}}{\frac{1}{R_o} + \frac{1}{R_1}} = \frac{3,33*10^{-3} + \frac{10}{2*10^3}}{\frac{1}{1,36*10^3} + \frac{1}{2*10^3}} = 6,74\ V$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{10 - 6,74}{2*10^3} = 1,63\ mA$$

2.- <u>VALORI 2° GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{2*10^3}{2} = 1\ K\Omega$$

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{3*10^3}{2} = 1,5\ K\Omega$$

$$R_{25} = R_{24} + R_{35} = 1*10^3 + 1,5*10^3 = 2,5\ K\Omega$$

$$E_o = \frac{R_{25}}{R_{25} + R_6} * E_2 = \frac{2,5*10^3}{2,5*10^3 + 2*10^3} * 6 = 3,33\ V$$

$$R_o = \frac{R_{25} * R_6}{R_{25} + R_6} = \frac{2,5*10^3 * 2*10^3}{2,5*10^3 + 2*10^3} = 1,11\ K\Omega$$

$E_1 - E_0 = (R_0 + R_1) * I_{AB} \quad ==>$

$$==> \quad I_{AB} = \frac{E_1 - E_0}{R_0 + R_1} = \frac{6 - 3,33}{1,11*10^3 + 3*10^3} = 0,65 \text{ mA}$$

$V_{AB} = E_1 - R_1 * I_{AB} = 6 - 3*10^3 * 0,65*10^{-3} = 4,05 \text{ V}$

- Teorema di Norton

$$I_0 = \frac{E_2}{R_6} = \frac{6}{2*10^3} = 3 \text{ mA}$$

$$V_{AB} = \frac{I_0 + \frac{E_1}{R_1}}{\frac{1}{R_0} + \frac{1}{R_1}} = \frac{3*10^{-3} + \frac{6}{3*10^3}}{\frac{1}{1,11*10^3} + \frac{1}{3*10^3}} = 4,05 \text{ V}$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{6 - 4,05}{3*10^3} = 0,65 \text{ mA}$$

3.- VALORI 3º GRUPPO

- Teorema di Thèvenin

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{4*10^3}{2} = 2 \text{ K}\Omega$$

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{2*10^3}{2} = 1 \text{ K}\Omega$$

$R_{25} = R_{24} + R_{35} = 2*10^3 + 1*10^3 = 3 \text{ K}\Omega$

$$E_0 = \frac{R_{25}}{R_{25} + R_6} * E_2 = \frac{3*10^3}{3*10^3 + 4*10^3} * 8 = 3,43 \text{ V}$$

$$R_0 = \frac{R_{25} * R_6}{R_{25} + R_6} = \frac{3*10^3 * 4*10^3}{3*10^3 + 4*10^3} = 1,71 \text{ K}\Omega$$

$E_1 - E_0 = (R_0 + R_1) * I_{AB} \quad ==>$

$$\Longrightarrow \quad I_{AB} = \frac{E_1 - E_o}{R_o + R_1} = \frac{8 - 3,43}{1,71*10^3 + 2*10^3} = 1,23 \text{ mA}$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 8 - 2*10^3 * 1,23*10^{-3} = 5,53 \text{ V}$$

- Teorema di Norton

$$I_o = \frac{E_2}{R_6} = \frac{8}{4*10^3} = 2 \text{ mA}$$

$$V_{AB} = \frac{I_o + \frac{E_1}{R_1}}{\frac{1}{R_o} + \frac{1}{R_1}} = \frac{2*10^{-3} + \frac{8}{2*10^3}}{\frac{1}{1,71*10^3} + \frac{1}{2*10^3}} = 5,53 \text{ V}$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad \Longrightarrow \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{8 - 5,53}{2*10^3} = 1,235 \text{ mA}$$

4.- VALORI 4° GRUPPO

- Teorema di Thèvenin

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{5*10^3}{2} = 2,5 \text{ K}\Omega$$

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{3*10^3}{2} = 1,5 \text{ K}\Omega$$

$$R_{25} = R_{24} + R_{35} = 2,5*10^3 + 1,5*10^3 = 4 \text{ K}\Omega$$

$$E_o = \frac{R_{25}}{R_{25} + R_6} * E_2 = \frac{4*10^3}{4*10^3 + 5*10^3} * 12 = 5,33 \text{ V}$$

$$R_o = \frac{R_{25} * R_6}{R_{25} + R_6} = \frac{4*10^3 * 5*10^3}{4*10^3 + 5*10^3} = 2,22 \text{ K}\Omega$$

$$E_1 - E_o = (R_o + R_1) * I_{AB} \quad \Longrightarrow$$

$$\Longrightarrow \quad I_{AB} = \frac{E_1 - E_o}{R_o + R_1} = \frac{12 - 5,33}{2,22*10^3 + 3*10^3} = 1,28 \text{ mA}$$

$$V_{AB} = E_1 - R_1 * I_{AB} = 12 - 3*10^3 * 1,28*10^{-3} = 8,16\ V$$

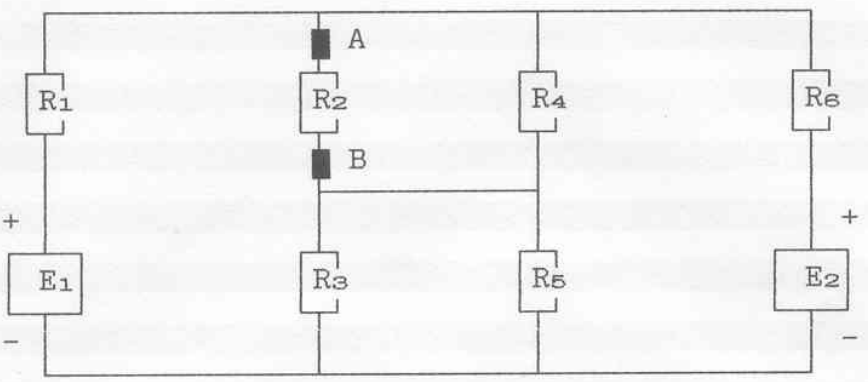
- <u>Teorema di Norton</u>

$$I_o = \frac{E_2}{R_6} = \frac{12}{5*10^3} = 2,4\ mA$$

$$V_{AB} = \frac{I_o + \frac{E_1}{R_1}}{\frac{1}{R_o} + \frac{1}{R_1}} = \frac{2,4*10^{-3} + \frac{12}{3*10^3}}{\frac{1}{2,22*10^3} + \frac{1}{3*10^3}} = 8,17\ V$$

$$V_{AB} = E_1 - R_1 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_1 - V_{AB}}{R_1} = \frac{12 - 8,17}{3*10^3} = 1,28\ mA$$

6.38 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

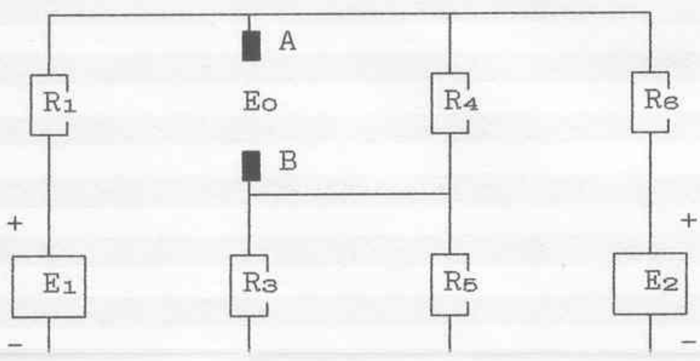
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

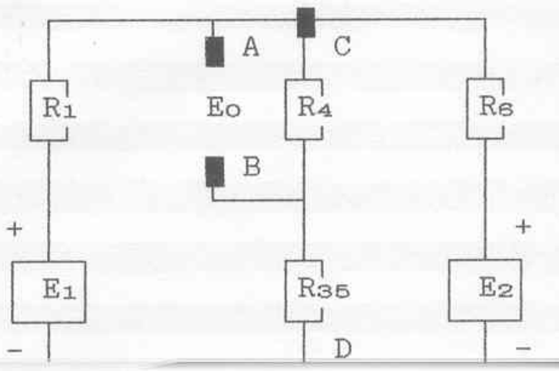
4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

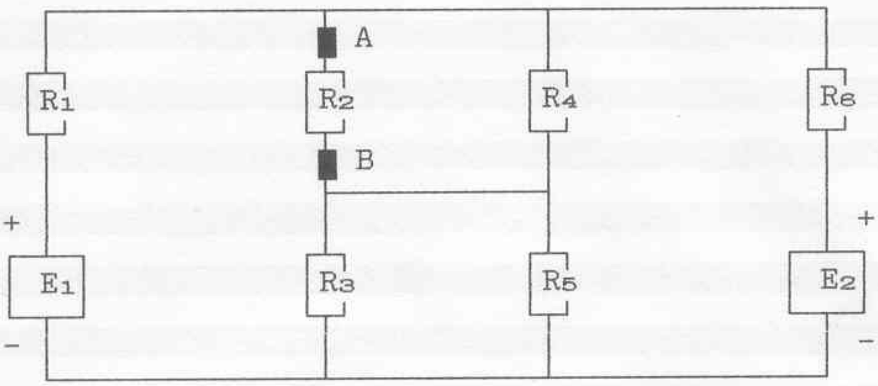
1.- VALORI 1° GRUPPO

- Teorema di Thèvenin





6.38 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

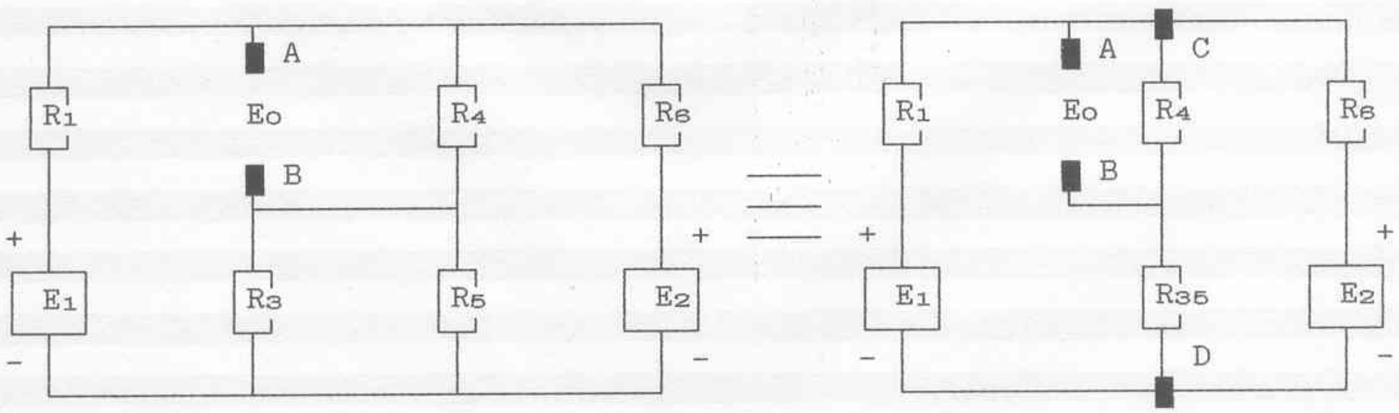
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

1.- VALORI 1° GRUPPO

- Teorema di Thèvenin

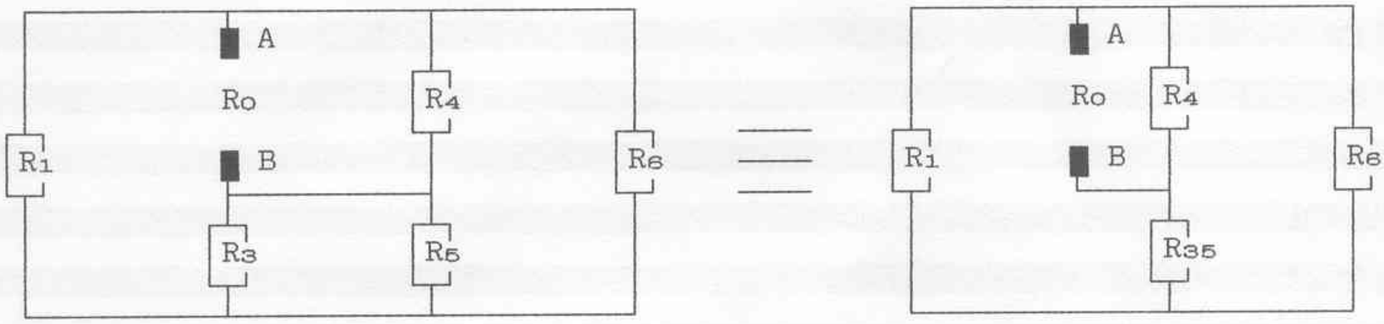


$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{2*10^3}{2} = 1 \text{ K}\Omega$$

$$R_{45} = R_4 + R_{35} = 3*10^3 + 1*10^3 = 4 \text{ K}\Omega$$

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{\frac{10}{2*10^3} + \frac{10}{3*10^3}}{\frac{1}{2*10^3} + \frac{1}{4*10^3} + \frac{1}{3*10^3}} = 7,69 \text{ V}$$

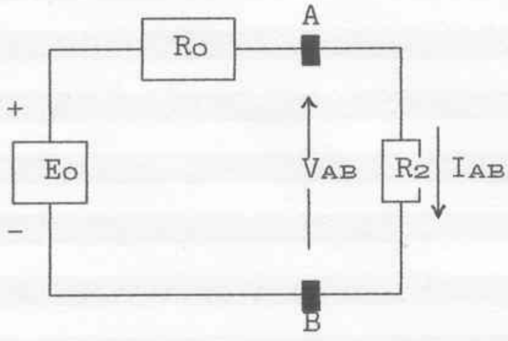
$$E_O = \frac{R_4}{R_4 + R_{35}} * V_{CD} = \frac{3*10^3}{3*10^3 + 1*10^3} * 7,69 = 5,77 \text{ V}$$



$$R_{16} = \frac{R_1 * R_6}{R_1 + R_6} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1,2 \text{ K}\Omega$$

$$R_{15} = R_{16} + R_{35} = 1,2*10^3 + 1*10^3 = 2,2 \text{ K}\Omega$$

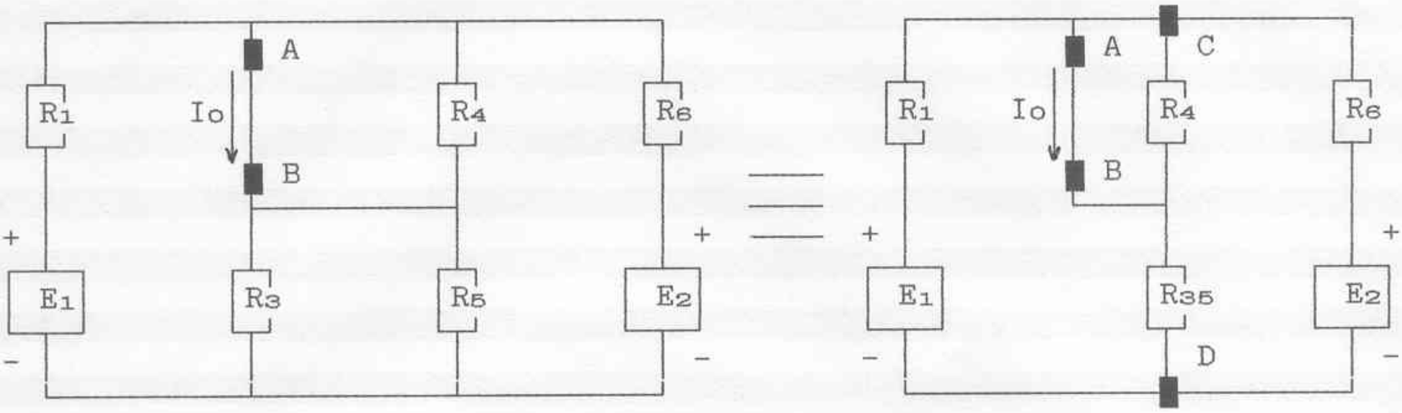
$$R_O = \frac{R_{15} * R_4}{R_{15} + R_4} = \frac{2,2*10^3 * 3*10^3}{2,2*10^3 + 3*10^3} = 1,27 \text{ K}\Omega$$



$$I_{AB} = \frac{E_O}{R_O + R_2} = \frac{5,77}{1,27*10^3 + 3*10^3} = 1,35 \text{ mA}$$

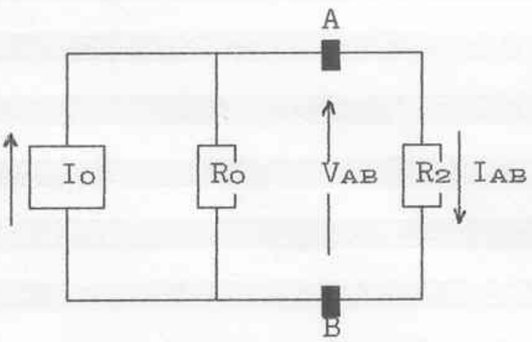
$$V_{AB} = R_2 * I_{AB} = 3*10^3 * 1,35*10^{-3} = 4,05 \text{ V}$$

- Teorema di Norton



$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{35}} + \frac{1}{R_6}} = \frac{\frac{10}{2*10^3} + \frac{10}{3*10^3}}{\frac{1}{2*10^3} + \frac{1}{1*10^3} + \frac{1}{3*10^3}} = 4,54 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_{35}} = \frac{4,54}{1*10^3} = 4,54 \text{ mA}$$



$$R_{o2} = \frac{R_o * R_2}{R_o + R_2} = \frac{1,27*10^3 * 3*10^3}{1,27*10^3 + 3*10^3} = 0,89 \text{ K}\Omega$$

$$V_{AB} = R_{o2} * I_o = 0,89*10^3 * 4,54*10^{-3} = 4,04 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_2} = \frac{4,04}{3*10^3} = 1,35 \text{ mA}$$

2.- VALORI 2° GRUPPO

- Teorema di Thèvenin

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{3*10^3}{2} = 1,5\ K\Omega$$

$$R_{45} = R_4 + R_{35} = 2*10^3 + 1,5*10^3 = 3,5\ K\Omega$$

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{3,5*10^3} + \frac{1}{2*10^3}} = 4,47\ V$$

$$E_O = \frac{R_4}{R_4 + R_{35}} * V_{CD} = \frac{2*10^3}{2*10^3 + 1,5*10^3} * 4,47 = 2,55\ V$$

$$R_{16} = \frac{R_1 * R_6}{R_1 + R_6} = \frac{3*10^3 * 2*10^3}{3*10^3 + 2*10^3} = 1,2\ K\Omega$$

$$R_{15} = R_{16} + R_{35} = 1,2*10^3 + 1,5*10^3 = 2,7\ K\Omega$$

$$R_O = \frac{R_{15} * R_4}{R_{15} + R_4} = \frac{2,7*10^3 * 2*10^3}{2,7*10^3 + 2*10^3} = 1,15\ K\Omega$$

$$I_{AB} = \frac{E_O}{R_O + R_2} = \frac{2,55}{1,15*10^3 + 2*10^3} = 0,81\ mA$$

$$V_{AB} = R_2 * I_{AB} = 2*10^3 * 0,81*10^{-3} = 1,62\ V$$

- Teorema di Norton

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{35}} + \frac{1}{R_6}} = \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{1,5*10^3} + \frac{1}{2*10^3}} = 3,33\ V$$

$$I_O = \frac{V_{CD}}{R_{35}} = \frac{3,33}{1,5*10^3} = 2,22\ mA$$

$$R_{O2} = \frac{R_O * R_2}{R_O + R_2} = \frac{1,15*10^3 * 2*10^3}{1,15*10^3 + 2*10^3} = 0,73\ K\Omega$$

$$V_{AB} = R_{O2} * I_O = 0,73*10^3 * 2,22*10^{-3} = 1,62\ V$$

$$I_{AB} = \frac{V_{AB}}{R_2} = \frac{1,62}{2*10^3} = 0,81\ mA$$

3.- <u>VALORI 3º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{2*10^3}{2} = 1\ K\Omega$$

$$R_{45} = R_4 + R_{35} = 4*10^3 + 1*10^3 = 5\ K\Omega$$

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{\frac{8}{2*10^3} + \frac{8}{4*10^3}}{\frac{1}{2*10^3} + \frac{1}{5*10^3} + \frac{1}{4*10^3}} = 6,31\ V$$

$$E_O = \frac{R_4}{R_4 + R_{35}} * V_{CD} = \frac{4*10^3}{4*10^3 + 1*10^3} * 6,31 = 5,05\ V$$

$$R_{16} = \frac{R_1 * R_6}{R_1 + R_6} = \frac{2*10^3 * 4*10^3}{2*10^3 + 4*10^3} = 1,33\ K\Omega$$

$$R_{15} = R_{16} + R_{35} = 1,33*10^3 + 1*10^3 = 2,33\ K\Omega$$

$$R_O = \frac{R_{15} * R_4}{R_{15} + R_4} = \frac{2,33*10^3 * 4*10^3}{2,33*10^3 + 4*10^3} = 1,47\ K\Omega$$

$$I_{AB} = \frac{E_O}{R_O + R_2} = \frac{5,05}{1,47*10^3 + 4*10^3} = 0,92\ mA$$

$$V_{AB} = R_2 * I_{AB} = 4*10^3 * 0,92*10^{-3} = 3,68\ V$$

- Teorema di Norton

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{35}} + \frac{1}{R_6}} = \frac{\frac{8}{2*10^3} + \frac{8}{4*10^3}}{\frac{1}{2*10^3} + \frac{1}{1*10^3} + \frac{1}{4*10^3}} = 3,43 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_{35}} = \frac{3,43}{1*10^3} = 3,43 \text{ mA}$$

$$R_{o2} = \frac{R_o * R_2}{R_o + R_2} = \frac{1,47*10^3 * 4*10^3}{1,47*10^3 + 4*10^3} = 1,075 \text{ K}\Omega$$

$$V_{AB} = R_{o2} * I_o = 1,075*10^3 * 3,43*10^{-3} = 3,68 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_2} = \frac{3,68}{4*10^3} = 0,92 \text{ mA}$$

4.- VALORI 4º GRUPPO

- Teorema di Thèvenin

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{3*10^3}{2} = 1,5 \text{ K}\Omega$$

$$R_{45} = R_4 + R_{35} = 5*10^3 + 1,5*10^3 = 6,5 \text{ K}\Omega$$

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{45}} + \frac{1}{R_6}} = \frac{\frac{12}{3*10^3} + \frac{12}{5*10^3}}{\frac{1}{3*10^3} + \frac{1}{6,5*10^3} + \frac{1}{5*10^3}} = 9,31 \text{ V}$$

$$E_o = \frac{R_4}{R_4 + R_{35}} * V_{CD} = \frac{5*10^3}{5*10^3 + 1,5*10^3} * 9,31 = 7,16 \text{ V}$$

$$R_{16} = \frac{R_1 * R_6}{R_1 + R_6} = \frac{3*10^3 * 5*10^3}{3*10^3 + 5*10^3} = 1,875 \text{ K}\Omega$$

$$R_{15} = R_{16} + R_{35} = 1,875*10^3 + 1,5*10^3 = 3,375 \text{ K}\Omega$$

$$R_o = \frac{R_{15} * R_4}{R_{15} + R_4} = \frac{3,375*10^3 * 5*10^3}{3,375*10^3 + 5*10^3} = 2\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_2} = \frac{7,16}{2*10^3 + 5*10^3} = 1,02\ mA$$

$$V_{AB} = R_2 * I_{AB} = 5*10^3 * 1,02*10^{-3} = 5,1\ V$$

- Teorema di Norton

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{35}} + \frac{1}{R_6}} = \frac{\frac{12}{3*10^3} + \frac{12}{5*10^3}}{\frac{1}{3*10^3} + \frac{1}{1,5*10^3} + \frac{1}{5*10^3}} = 5,33\ V$$

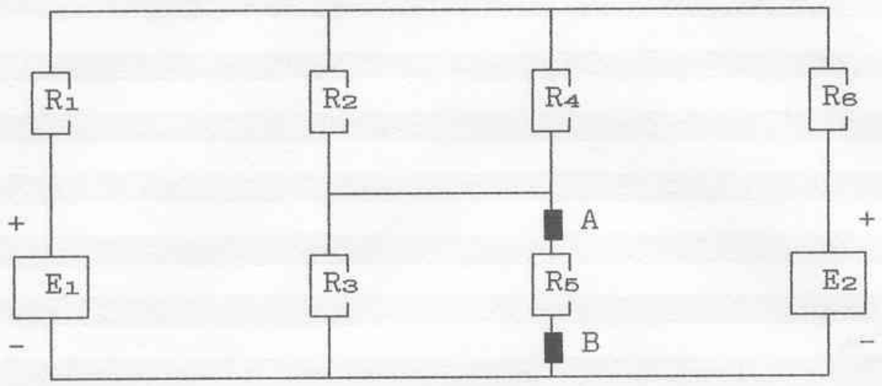
$$I_o = \frac{V_{CD}}{R_{35}} = \frac{5,33}{1,5*10^3} = 3,55\ mA$$

$$R_{o2} = \frac{R_o * R_2}{R_o + R_2} = \frac{2*10^3 * 5*10^3}{2*10^3 + 5*10^3} = 1,43\ K\Omega$$

$$V_{AB} = R_{o2} * I_o = 1,43*10^3 * 3,55*10^{-3} = 5,07\ V$$

$$I_{AB} = \frac{V_{AB}}{R_2} = \frac{5,07}{5*10^3} = 1,01\ mA$$

6.39 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

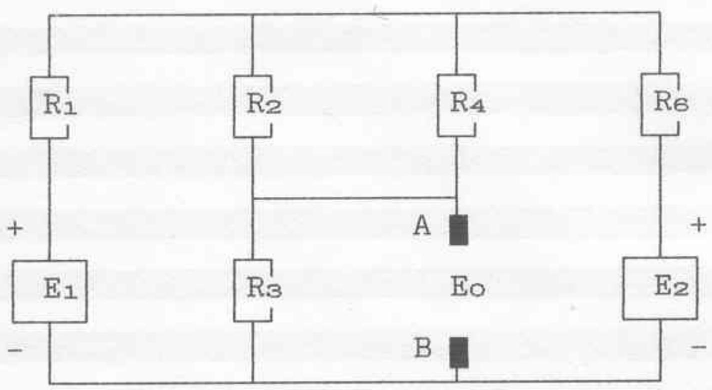
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

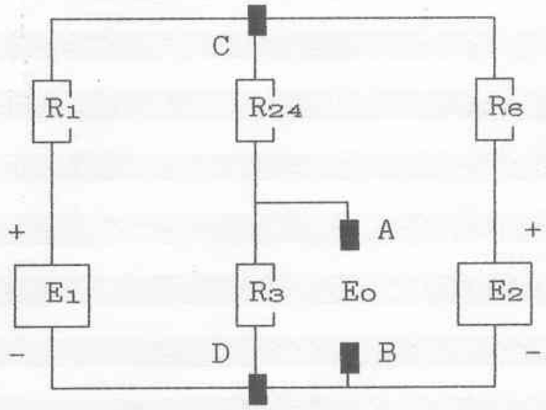
4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

VALORI 1o GRUPPO

- Teorema di Thèvenin



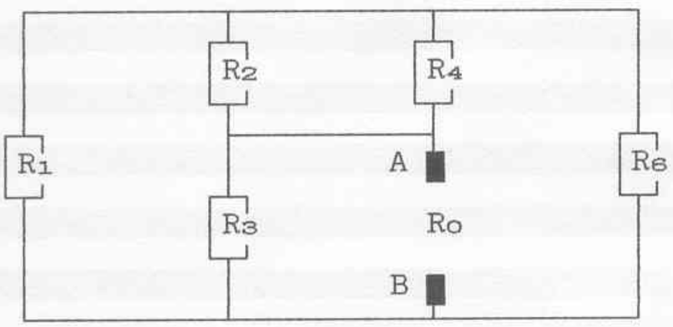


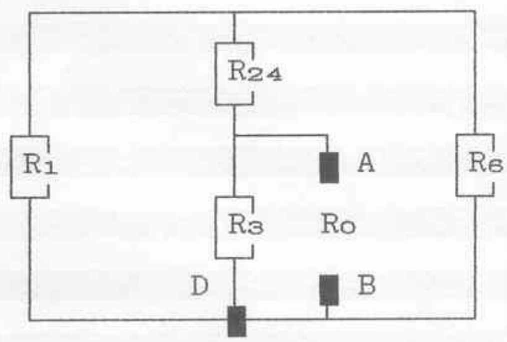
$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{3*10^3}{2} = 1,5 \text{ K}\Omega$$

$$R_{34} = R_3 + R_{24} = 2*10^3 + 1,5*10^3 = 3,5 \text{ K}\Omega$$

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{34}} + \frac{1}{R_6}} = \frac{\frac{10}{2*10^3} + \frac{10}{3*10^3}}{\frac{1}{2*10^3} + \frac{1}{3,5*10^3} + \frac{1}{3*10^3}} = 7,45 \text{ V}$$

$$E_O = \frac{R_3}{R_3 + R_{24}} * V_{CD} = \frac{2*10^3}{2*10^3 + 1,5*10^3} * 7,45 = 4,25 \text{ V}$$

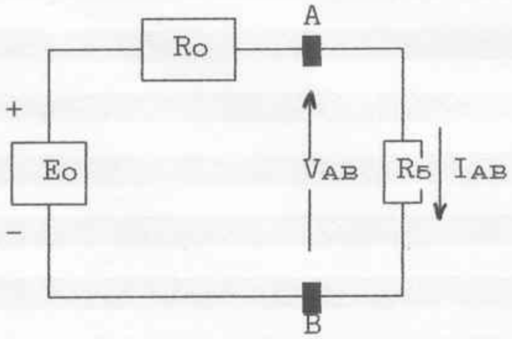




$$R_{16} = \frac{R_1 * R_6}{R_1 + R_6} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1,2 \text{ K}\Omega$$

$$R_{14} = R_{16} + R_{24} = 1,2*10^3 + 1,5*10^3 = 2,7 \text{ K}\Omega$$

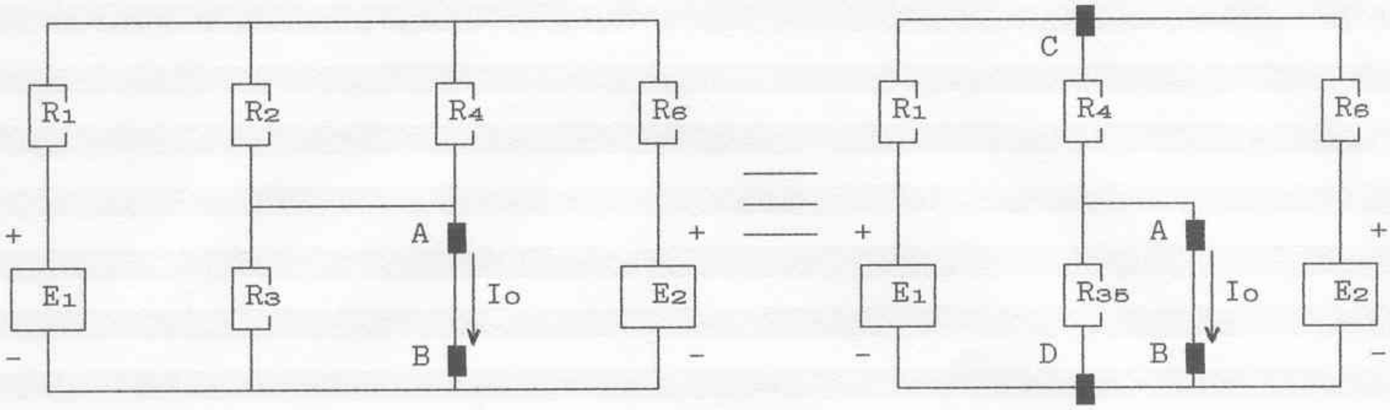
$$R_O = \frac{R_{14} * R_3}{R_{14} + R_3} = \frac{2,7*10^3 * 2*10^3}{2,7*10^3 + 2*10^3} = 1,15 \text{ K}\Omega$$



$$I_{AB} = \frac{E_O}{R_O + R_5} = \frac{4,25}{1,15*10^3 + 2*10^3} = 1,35 \text{ mA}$$

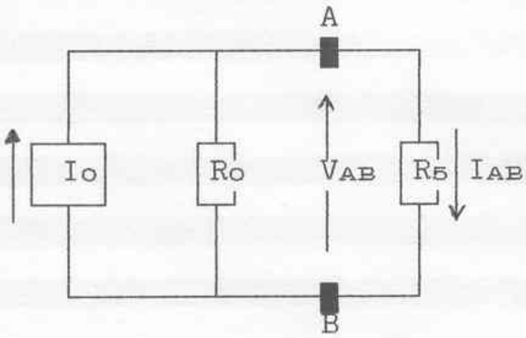
$$V_{AB} = R_5 * I_{AB} = 2*10^3 * 1,35*10^{-3} = 2,7 \text{ V}$$

- <u>Teorema di Norton</u>



$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{24}} + \frac{1}{R_6}} = \frac{\frac{10}{2*10^3} + \frac{10}{3*10^3}}{\frac{1}{2*10^3} + \frac{1}{1,5*10^3} + \frac{1}{3*10^3}} = 5,56 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_{24}} = \frac{5,56}{1,5*10^3} = 3,7 \text{ mA}$$



$$R_{o5} = \frac{R_o * R_5}{R_o + R_5} = \frac{1,15*10^3 * 2*10^3}{1,15*10^3 + 2*10^3} = 0,73 \text{ K}\Omega$$

$$V_{AB} = R_{o5} * I_o = 0,73*10^3 * 3,7*10^{-3} = 2,7 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{2,7}{2*10^3} = 1,35 \text{ mA}$$

2.- <u>VALORI 2º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{2*10^3}{2} = 1\ K\Omega$$

$$R_{34} = R_3 + R_{24} = 3*10^3 + 1*10^3 = 4\ K\Omega$$

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{34}} + \frac{1}{R_6}} = \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{4*10^3} + \frac{1}{2*10^3}} = 4,6\ V$$

$$E_o = \frac{R_3}{R_3 + R_{24}} * V_{CD} = \frac{3*10^3}{3*10^3 + 1*10^3} * 4,6 = 3,45\ V$$

$$R_{16} = \frac{R_1 * R_6}{R_1 + R_6} = \frac{3*10^3 * 2*10^3}{3*10^3 + 2*10^3} = 1,2\ K\Omega$$

$$R_{14} = R_{16} + R_{24} = 1,2*10^3 + 1*10^3 = 2,2\ K\Omega$$

$$R_o = \frac{R_{14} * R_3}{R_{14} + R_3} = \frac{2,2*10^3 * 3*10^3}{2,2*10^3 + 3*10^3} = 1,27\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_5} = \frac{3,45}{1,27*10^3 + 3*10^3} = 0,81\ mA$$

$$V_{AB} = R_5 * I_{AB} = 3*10^3 * 0,81*10^{-3} = 2,43\ V$$

- <u>Teorema di Norton</u>

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{24}} + \frac{1}{R_6}} = \frac{\frac{6}{3*10^3} + \frac{6}{2*10^3}}{\frac{1}{3*10^3} + \frac{1}{1*10^3} + \frac{1}{2*10^3}} = 2,72\ V$$

$$I_o = \frac{V_{CD}}{R_{24}} = \frac{2,72}{1*10^3} = 2,72\ mA$$

$$R_{O5} = \frac{R_O * R_5}{R_O + R_5} = \frac{1,27*10^3 * 3*10^3}{1,27*10^3 + 3*10^3} = 0,89\ K\Omega$$

$$V_{AB} = R_{O5} * I_O = 0,89*10^3 * 2,72*10^{-3} = 2,42\ V$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{2,42}{3*10^3} = 0,81\ mA$$

3.- <u>VALORI 3º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{4*10^3}{2} = 2\ K\Omega$$

$$R_{34} = R_3 + R_{24} = 2*10^3 + 2*10^3 = 4\ K\Omega$$

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{34}} + \frac{1}{R_6}} = \frac{\frac{8}{2*10^3} + \frac{8}{4*10^3}}{\frac{1}{2*10^3} + \frac{1}{4*10^3} + \frac{1}{4*10^3}} = 6\ V$$

$$E_O = \frac{R_3}{R_3 + R_{24}} * V_{CD} = \frac{2*10^3}{2*10^3 + 2*10^3} * 6 = 3\ V$$

$$R_{16} = \frac{R_1 * R_6}{R_1 + R_6} = \frac{2*10^3 * 4*10^3}{2*10^3 + 4*10^3} = 1,33\ K\Omega$$

$$R_{14} = R_{16} + R_{24} = 1,33*10^3 + 2*10^3 = 3,33\ K\Omega$$

$$R_O = \frac{R_{14} * R_3}{R_{14} + R_3} = \frac{3,33*10^3 * 2*10^3}{3,33*10^3 + 2*10^3} = 1,25\ K\Omega$$

$$I_{AB} = \frac{E_O}{R_O + R_5} = \frac{3}{1,25*10^3 + 2*10^3} = 0,92\ mA$$

$$V_{AB} = R_5 * I_{AB} = 2*10^3 * 0,92*10^{-3} = 1,84\ V$$

- Teorema di Norton

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{24}} + \frac{1}{R_6}} = \frac{\frac{8}{2*10^3} + \frac{8}{4*10^3}}{\frac{1}{2*10^3} + \frac{1}{2*10^3} + \frac{1}{4*10^3}} = 4,8 \text{ V}$$

$$I_o = \frac{V_{CD}}{R_{24}} = \frac{4,8}{2*10^3} = 2,4 \text{ mA}$$

$$R_{o5} = \frac{R_o * R_5}{R_o + R_5} = \frac{1,25*10^3 * 2*10^3}{1,25*10^3 + 2*10^3} = 0,77 \text{ K}\Omega$$

$$V_{AB} = R_{o5} * I_o = 0,77*10^3 * 2,4*10^{-3} = 1,85 \text{ V}$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{1,85}{2*10^3} = 0,92 \text{ mA}$$

4.- VALORI 4° GRUPPO

- Teorema di Thèvenin

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{5*10^3}{2} = 2,5 \text{ K}\Omega$$

$$R_{34} = R_3 + R_{24} = 3*10^3 + 2,5*10^3 = 5,5 \text{ K}\Omega$$

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{34}} + \frac{1}{R_6}} = \frac{\frac{12}{3*10^3} + \frac{12}{5*10^3}}{\frac{1}{3*10^3} + \frac{1}{5,5*10^3} + \frac{1}{5*10^3}} = 8,95 \text{ V}$$

$$E_o = \frac{R_3}{R_3 + R_{24}} * V_{CD} = \frac{3*10^3}{3*10^3 + 2,5*10^3} * 8,95 = 4,88 \text{ V}$$

$$R_{16} = \frac{R_1 * R_6}{R_1 + R_6} = \frac{3*10^3 * 5*10^3}{3*10^3 + 5*10^3} = 1,875 \text{ K}\Omega$$

$$R_{14} = R_{16} + R_{24} = 1,875*10^3 + 2,5*10^3 = 4,375\ K\Omega$$

$$R_o = \frac{R_{14} * R_3}{R_{14} + R_3} = \frac{4,375*10^3 * 3*10^3}{4,375*10^3 + 3*10^3} = 1,78\ K\Omega$$

$$I_{AB} = \frac{E_o}{R_o + R_5} = \frac{4,88}{1,78*10^3 + 3*10^3} = 1,02\ mA$$

$$V_{AB} = R_5 * I_{AB} = 3*10^3 * 1,02*10^{-3} = 3,06\ V$$

- <u>Teorema di Norton</u>

$$V_{CD} = \frac{\frac{E_1}{R_1} + \frac{E_2}{R_6}}{\frac{1}{R_1} + \frac{1}{R_{24}} + \frac{1}{R_6}} = \frac{\frac{12}{3*10^3} + \frac{12}{5*10^3}}{\frac{1}{3*10^3} + \frac{1}{2,5*10^3} + \frac{1}{5*10^3}} = 6,86\ V$$

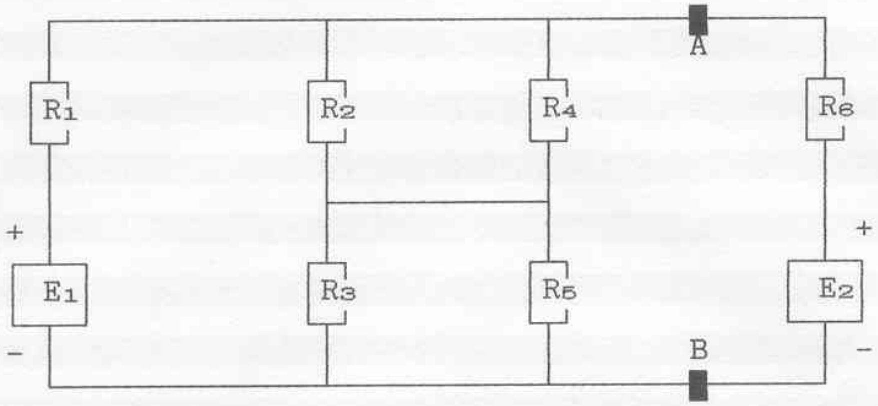
$$I_o = \frac{V_{CD}}{R_{24}} = \frac{6,86}{2,5*10^3} = 2,74\ mA$$

$$R_{o5} = \frac{R_o * R_5}{R_o + R_5} = \frac{1,78*10^3 * 3*10^3}{1,78*10^3 + 3*10^3} = 1,12\ K\Omega$$

$$V_{AB} = R_{o5} * I_o = 1,12*10^3 * 2,74*10^{-3} = 3,06\ V$$

$$I_{AB} = \frac{V_{AB}}{R_5} = \frac{3,06}{3*10^3} = 1,02\ mA$$

6.40 - Dato il circuito di figura, applicare il teorema di Thèvenin (Norton) tra i punti A e B. Del circuito equivalente ottenuto calcolare la tensione e la corrente tra i punti A e B.



1.- $E_1 = E_2 = 10$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 3$ KΩ

2.- $E_1 = E_2 = 6$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 2$ KΩ

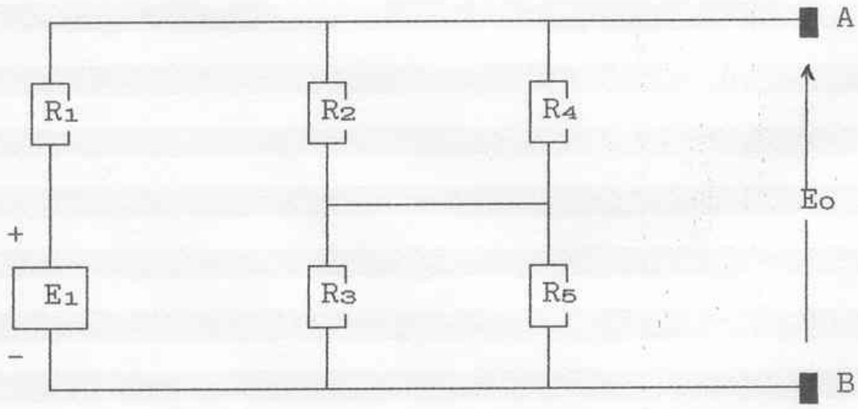
3.- $E_1 = E_2 = 8$ V ; $R_1 = R_3 = R_5 = 2$ KΩ ; $R_2 = R_4 = R_6 = 4$ KΩ

4.- $E_1 = E_2 = 12$ V ; $R_1 = R_3 = R_5 = 3$ KΩ ; $R_2 = R_4 = R_6 = 5$ KΩ

RISOLUZIONE

1.- VALORI 1° GRUPPO

- Teorema di Thèvenin

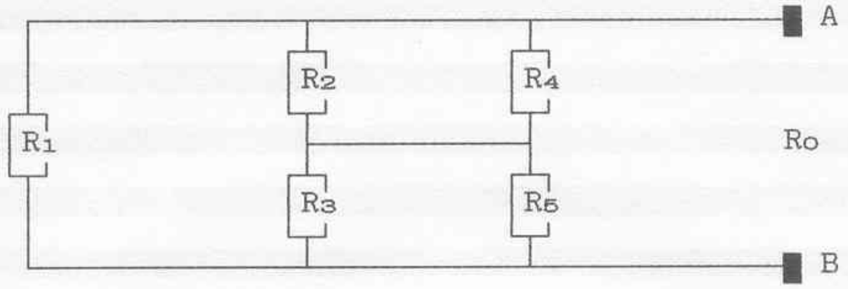


$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{3*10^3}{2} = 1,5 \text{ K}\Omega$$

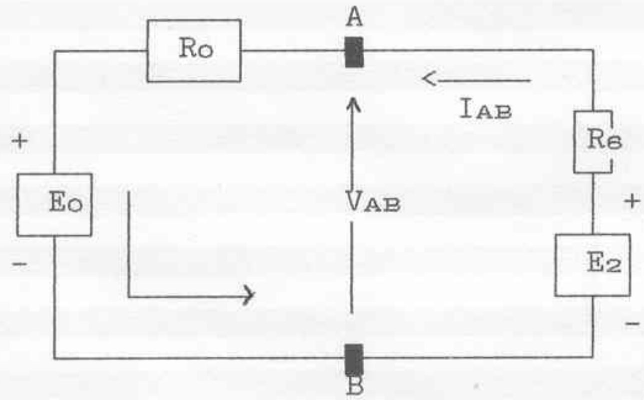
$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{2*10^3}{2} = 1 \text{ K}\Omega$$

$$R_{25} = R_{24} + R_{35} = 1,5*10^3 + 1*10^3 = 2,5 \text{ K}\Omega$$

$$E_O = \frac{R_{25}}{R_{25} + R_1} * E_1 = \frac{2,5*10^3}{2,5*10^3 + 2*10^3} * 10 = 5,55\ V$$



$$R_O = \frac{R_{25} * R_1}{R_{25} + R_1} = \frac{2,5*10^3 * 2*10^3}{2,5*10^3 + 2*10^3} = 1,11\ K\Omega$$

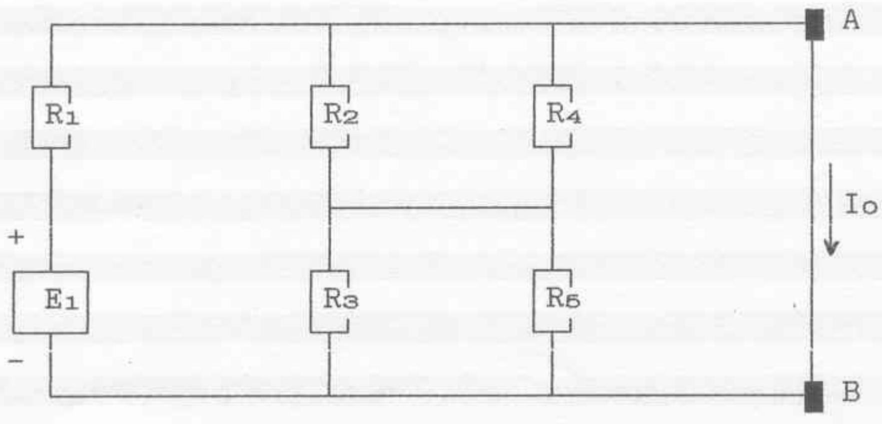


$E_2 - E_O = (R_O + R_6) * I_{AB}$ ==>

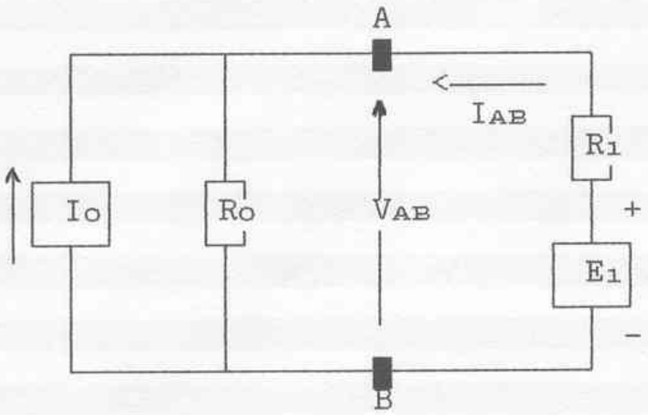
$$\text{==>}\quad I_{AB} = \frac{E_2 - E_O}{R_O + R_6} = \frac{10 - 5,55}{1,11*10^3 + 3*10^3} = 1,08\ mA$$

$V_{AB} = E_2 - R_6 * I_{AB} = 10 - 3*10^3 * 1,08*10^{-3} = 6,76\ V$

- <u>Teorema di Norton</u>



$$I_o = \frac{E_1}{R_1} = \frac{10}{2*10^3} = 5 \text{ mA}$$



$$V_{AB} = \frac{I_o + \frac{E_2}{R_6}}{\frac{1}{R_o} + \frac{1}{R_6}} = \frac{5*10^{-3} + \frac{10}{3*10^3}}{\frac{1}{1,11*10^3} + \frac{1}{3*10^3}} = 6,75 \text{ V}$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{10 - 6,75}{3*10^3} = 1,08 \text{ mA}$$

2.- VALORI 2º GRUPPO

- Teorema di Thèvenin

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{2*10^3}{2} = 1 \text{ K}\Omega$$

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{3*10^3}{2} = 1,5 \text{ K}\Omega$$

$$R_{25} = R_{24} + R_{35} = 1*10^3 + 1,5*10^3 = 2,5 \text{ K}\Omega$$

$$E_o = \frac{R_{25}}{R_{25} + R_1} * E_1 = \frac{2,5*10^3}{2,5*10^3 + 3*10^3} * 6 = 2,73 \text{ V}$$

$$R_o = \frac{R_{25} * R_1}{R_{25} + R_1} = \frac{2,5*10^3 * 3*10^3}{2,5*10^3 + 3*10^3} = 1,36 \text{ K}\Omega$$

$$E_2 - E_0 = (R_0 + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_0}{R_0 + R_6} = \frac{6 - 2,73}{1,36*10^3 + 2*10^3} = 0,97 \text{ mA}$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 6 - 2*10^3 * 0,97*10^{-3} = 4,06 \text{ V}$$

- <u>Teorema di Norton</u>

$$I_0 = \frac{E_1}{R_1} = \frac{6}{3*10^3} = 2 \text{ mA}$$

$$V_{AB} = \frac{I_0 + \frac{E_2}{R_6}}{\frac{1}{R_0} + \frac{1}{R_6}} = \frac{2*10^{-3} + \frac{6}{2*10^3}}{\frac{1}{1,36*10^3} + \frac{1}{2*10^3}} = 4,05 \text{ V}$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{6 - 4,05}{2*10^3} = 0,975 \text{ mA}$$

3.- <u>VALORI 3º GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{4*10^3}{2} = 2 \text{ K}\Omega$$

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{2*10^3}{2} = 1 \text{ K}\Omega$$

$$R_{25} = R_{24} + R_{35} = 2*10^3 + 1*10^3 = 3 \text{ K}\Omega$$

$$E_0 = \frac{R_{25}}{R_{25} + R_1} * E_1 = \frac{3*10^3}{3*10^3 + 2*10^3} * 8 = 4,8 \text{ V}$$

$$R_0 = \frac{R_{25} * R_1}{R_{25} + R_1} = \frac{2*10^3 * 3*10^3}{2*10^3 + 3*10^3} = 1,2 \text{ K}\Omega$$

$$E_2 - E_0 = (R_0 + R_6) * I_{AB} \quad ==>$$

$$==> \quad I_{AB} = \frac{E_2 - E_0}{R_0 + R_6} = \frac{8 - 4,8}{1,2*10^3 + 4*10^3} = 0,615 \text{ mA}$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 8 - 4*10^3 * 0,615*10^{-3} = 5,54 \text{ V}$$

- <u>Teorema di Norton</u>

$$I_0 = \frac{E_1}{R_1} = \frac{8}{2*10^3} = 4 \text{ mA}$$

$$V_{AB} = \frac{I_0 + \frac{E_2}{R_6}}{\frac{1}{R_0} + \frac{1}{R_6}} = \frac{4*10^{-3} + \frac{8}{4*10^3}}{\frac{1}{1,2*10^3} + \frac{1}{4*10^3}} = 5,54 \text{ V}$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad ==> \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{8 - 5,54}{4*10^3} = 0,615 \text{ mA}$$

4.- <u>VALORI 4° GRUPPO</u>

- <u>Teorema di Thèvenin</u>

$$R_{24} = \frac{R_2 * R_4}{R_2 + R_4} = \frac{R_2}{2} = \frac{5*10^3}{2} = 2,5 \text{ K}\Omega$$

$$R_{35} = \frac{R_3 * R_5}{R_3 + R_5} = \frac{R_3}{2} = \frac{3*10^3}{2} = 1,5 \text{ K}\Omega$$

$$R_{25} = R_{24} + R_{35} = 2,5*10^3 + 1,5*10^3 = 4 \text{ K}\Omega$$

$$E_0 = \frac{R_{25}}{R_{25} + R_1} * E_1 = \frac{4*10^3}{4*10^3 + 3*10^3} * 12 = 6,857 \text{ V}$$

$$R_0 = \frac{R_{25} * R_1}{R_{25} + R_1} = \frac{3*10^3 * 4*10^3}{3*10^3 + 4*10^3} = 1,71 \text{ K}\Omega$$

$$E_2 - E_0 = (R_0 + R_6) * I_{AB} \quad ==>$$

$$\Longrightarrow \quad I_{AB} = \frac{E_2 - E_0}{R_0 + R_6} = \frac{12 - 6,857}{1,71*10^3 + 5*10^3} = 0,766 \text{ mA}$$

$$V_{AB} = E_2 - R_6 * I_{AB} = 12 - 5*10^3 * 0,766*10^{-3} = 8,17 \text{ V}$$

- Teorema di Norton

$$I_0 = \frac{E_1}{R_1} = \frac{12}{3*10^3} = 4 \text{ mA}$$

$$V_{AB} = \frac{I_0 + \frac{E_2}{R_6}}{\frac{1}{R_0} + \frac{1}{R_6}} = \frac{4*10^{-3} + \frac{12}{5*10^3}}{\frac{1}{1,71*10^3} + \frac{1}{5*10^3}} = 8,15 \text{ V}$$

$$V_{AB} = E_2 - R_6 * I_{AB} \quad \Longrightarrow \quad I_{AB} = \frac{E_2 - V_{AB}}{R_6} = \frac{12 - 8,15}{5*10^3} = 0,77 \text{ mA}$$