

task_6tqttque1e2nf2c7_with_calculation

Student Group

First Name	Surname	Matrikel Nr.

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dc network analysis, pure resistor network simplification, delta wye transformation, exam ee1 WS2022

Exercise 1.1 : Equivalent Linear Source

(written test, approx. 14% of a 60-minute written test, WS2022)

The circuit in the following has to be simplified.



Calculated the internal resistance R_i and the source voltage U_s of an equivalent linear voltage source on the connectors A and B . $\begin{align*} R_1=5.0 \sim \Omega, \&\& U_2=6.0 \sim \text{V}, \&\& R_3=10 \sim \Omega, \&\& I_4=4.2 \sim \text{A}, \&\& R_5=10 \sim \Omega, \&\& R_6=7.5 \sim \Omega, \&\& R_7=15 \sim \Omega \end{align*}$ Use equivalent sources in order to simplify the circuit!

Solution

Best thing is to re-think the wiring like rubber bands and adjust them:



The linear voltage source of U_2 and R_1 can be transformed into a current source $I_2 = \frac{U_2}{R_1}$ and R_1 :



Now a lot of can be combined. The resistors R_1 , R_3 , R_5 are in parallel, like also I_2 and I_4 :
$$R_{135} = R_1 || R_3 || R_5$$

$$I_{24} = I_2 - I_4 = \left\{ \frac{U_2}{R_1} \right\} - I_4$$
 The resulting circuit can again be transformed:



Here, the U_{24} is calculated by I_{24} as the following:
$$U_{24} = R_{135} \cdot I_{24} = \left(\frac{U_2}{R_1} - I_4 \right) \cdot R_1 || R_3 || R_5$$

On the right side of the last circuit there is a voltage divider given by R_{135} , R_6 and R_7 .

Therefore the voltage between A and B is given as:
$$U_{AB} = U_{24} \cdot \frac{R_7}{R_6 + R_7 + R_1 || R_3 || R_5} = \left(\frac{U_2}{R_1} - I_4 \right) \cdot \frac{R_7 \cdot R_1 || R_3 || R_5}{R_6 + R_7 + R_1 || R_3 || R_5}$$

For the internal resistance R_i the ideal voltage source is substituted by its resistance ($=0 \Omega$, so a short-circuit):
$$R_{AB} = R_7 || (R_6 + R_1 || R_3 || R_5)$$

with $R_1 || R_3 || R_5 = 5 \Omega || 10 \Omega || 10 \Omega = 5 \Omega || 5 \Omega = 2.5 \Omega$:

$$U_{AB} = \left(\frac{6.0 \text{ V}}{5.0 \Omega} - 4.2 \Omega \right) \cdot \frac{15 \Omega \cdot 2.5 \Omega}{7.5 \Omega + 15 \Omega + 2.5 \Omega} || R_{AB} = 15 \Omega || (7.5 \Omega + 2.5 \Omega)$$

Final result

$$U_{AB} = 4.5 \text{ V} || R_{AB} = 6 \Omega$$

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