

Equivalent Circuits & Reduction (T&R Chap 2,3)

Circuit Equivalence

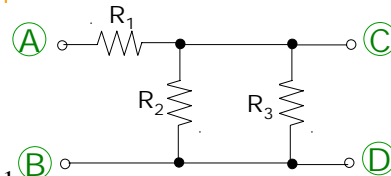
Two circuits are equivalent if they have the same $i-v$ characteristics at a specified pair of terminals

Terminal = external connection to two nodes = port

Our aim is to simplify analysis replacing complicated subcircuits by simpler equivalent circuits

Consider the circuit

Compute equivalent ccts from AB and from CD



$$R_{EQCD} = R_2 \parallel R_3 = \left(\frac{1}{R_2} + \frac{1}{R_3} \right)^{-1} = \frac{R_2 R_3}{R_2 + R_3}$$

$$R_{EQAB} = R_1 + R_2 \parallel R_3 = R_1 + \frac{R_2 R_3}{R_2 + R_3}$$

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26

Equivalent ccts

Equivalent ccts for resistive networks are familiar reductions of parallel and series connections

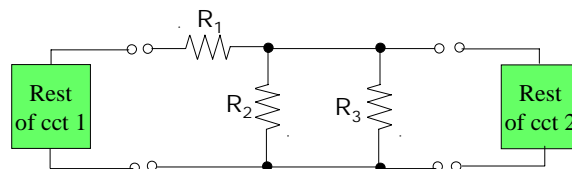
The equivalent cct depends on the port

From an external view the cct could be replaced by its equivalent

The internal cct variables are now unavailable

How would you compute them?

Could we substitute for the cct below?

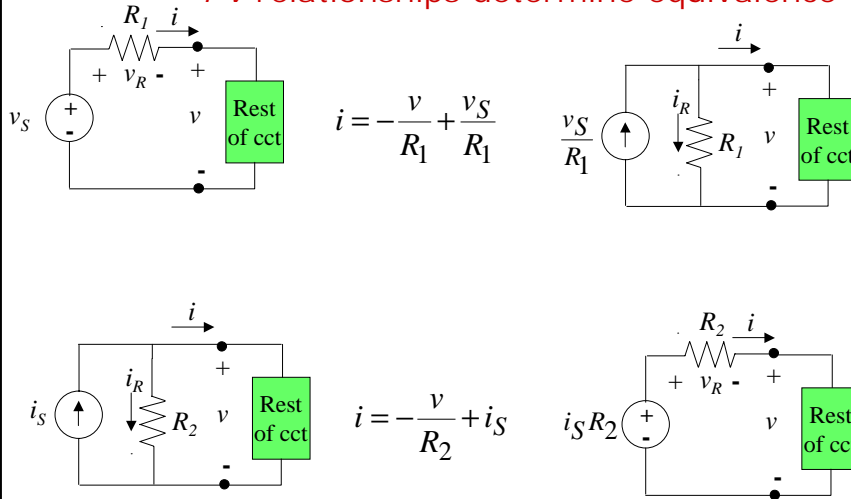


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27

Equivalent sources

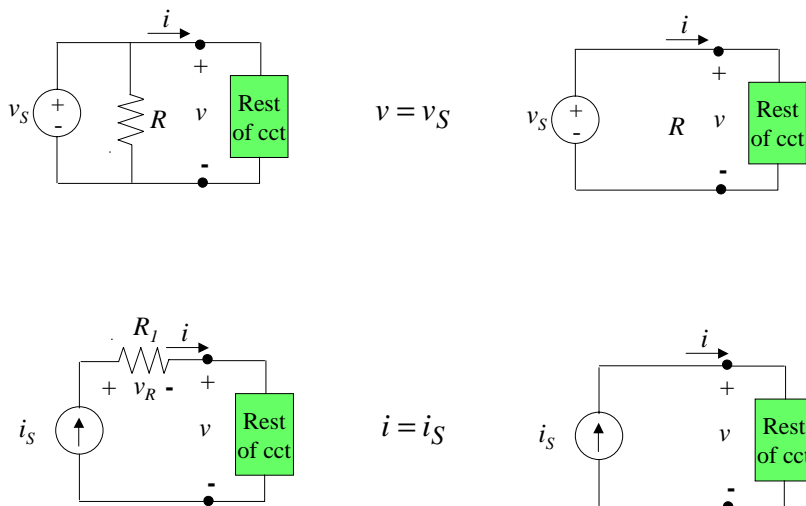
i-v relationships determine equivalence



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28

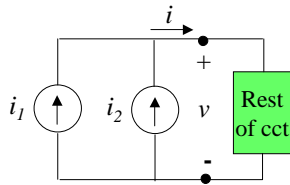
Equivalent Sources (cntd)



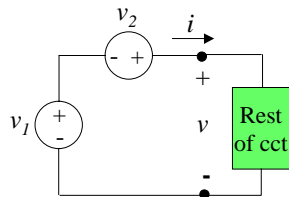
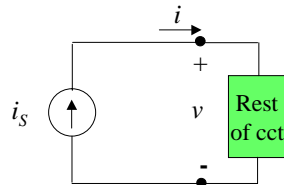
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29

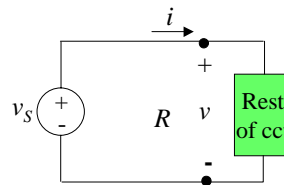
Equivalent Sources (cntd)



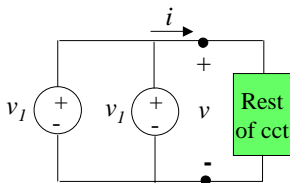
$$i_S = i_1 + i_2$$



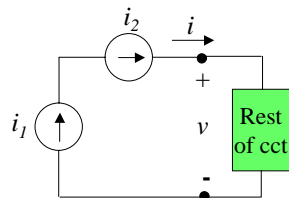
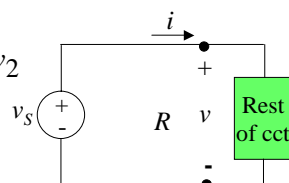
$$v_S = v_1 + v_2$$



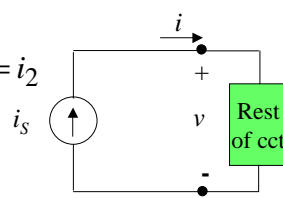
Equivalent Sources (cntd)



Only works if $v_1 = v_2$
then $v_S = v_1 = v_2$

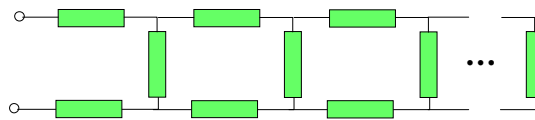


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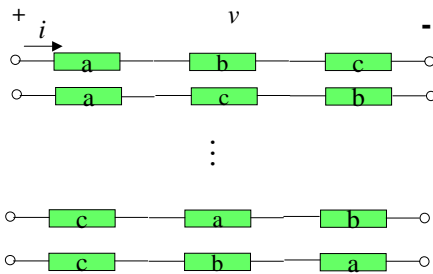
Circuit Reduction

For ladder networks



Reduce complexity by successively replacing elements by their equivalents

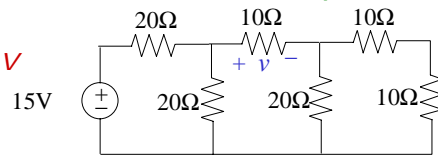
What happens with three elements in series or in parallel?



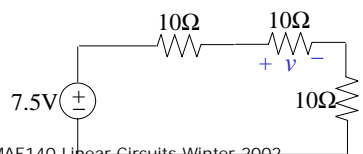
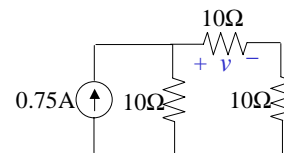
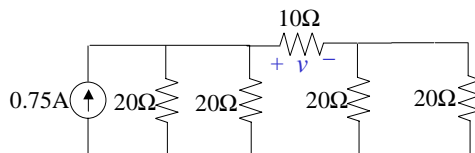
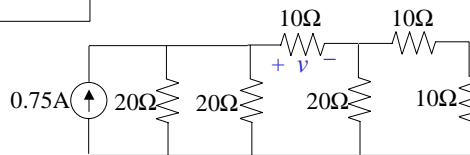
They are all equivalent
We can commute elements

T&R Example 2-22 p 51

Find v

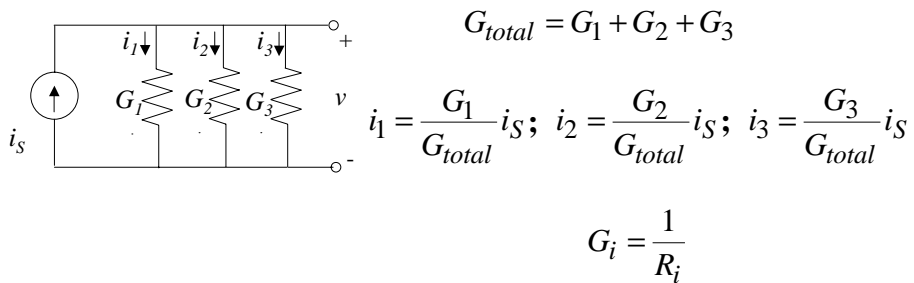
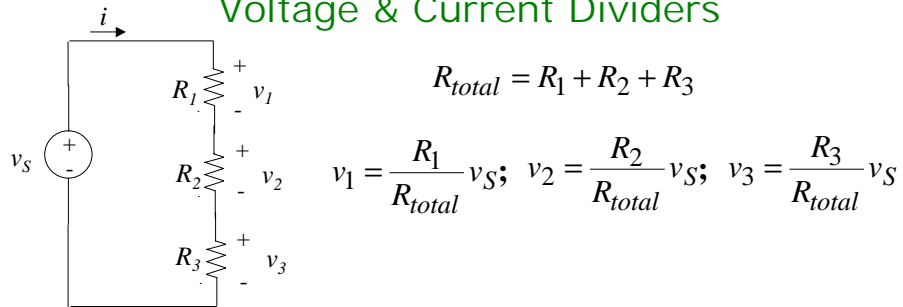


Reduce the left end



$v = 2.5V$

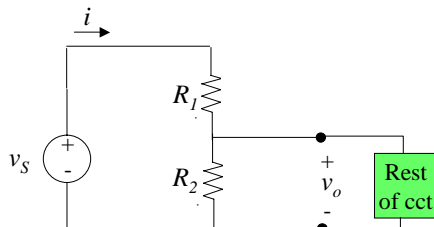
Voltage & Current Dividers



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34

Voltage Dividers



Often we use a voltage divider to provide an input voltage to a cct element

When would this work?

When the "rest of cct" does not draw much current compared to R_2

Why is this?

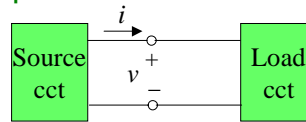
What is it asking of the equivalent of the rest of cct?

Note that this is a very common circuit used to "bias" a transistor to an operating voltage

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35

Thévenin and Norton Equivalent Ccts



Thévenin's Theorem

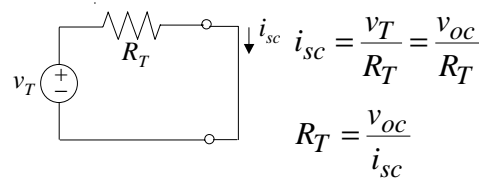
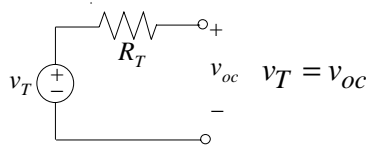
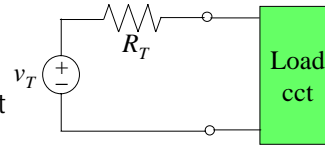
If the source cct in a two-terminal interface is linear, then the interface signals v and i do not change when the source cct is replaced by its Thévenin equivalent

Note: nobody says the load must be linear!

Thévenin Equivalent Circuit

v_T is the open-cct voltage of source

R_T is evaluated from short-cct current

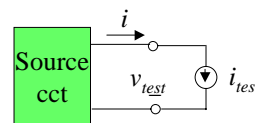


Thévenin's Theorem Proof

Linearity of the Source cct is the key – superposition

Hook up a test current source to cct

i_{test} yields voltage v_{test}



Part I, $i_{test,1} = 0$ but i and v sources

in Source cct left ON then $v_{test,1} = v_{oc} = v_T$

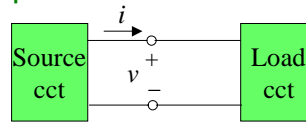
Part II, $i_{test,2} \neq 0$ and sources left OFF

in Source cct then $v_{test,2} = -R_T i_{test,2}$

By linearity of the Source cct v_{test} is the sum of these parts for any choice of i_{test}

This establishes the i - v relationship for any load cct

Thévenin and Norton Equivalent Ccts

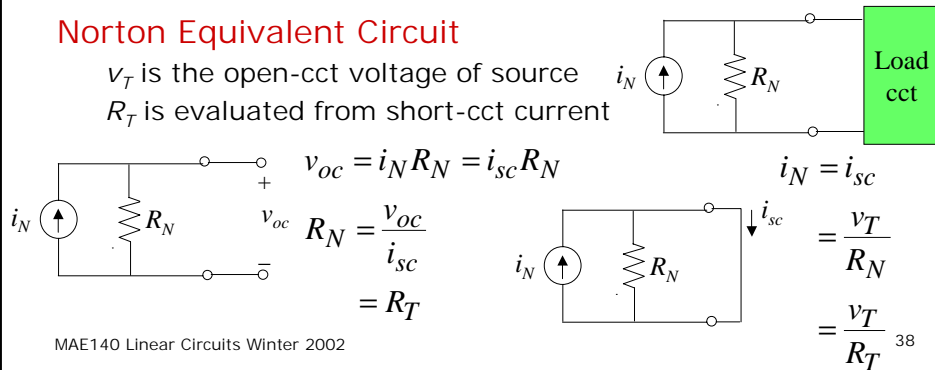


Norton's Theorem

If the source cct in a two-terminal interface is linear, then the interface signals v and i do not change when the source cct is replaced by its Norton equivalent

Norton Equivalent Circuit

v_T is the open-cct voltage of source
 R_T is evaluated from short-cct current

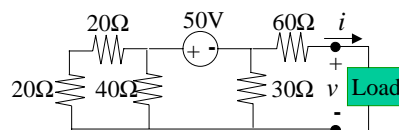


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38

Example 3-16 p.114 T&R

Find the Thévenin and Norton equivalent ccts of



Find the voltage, current and power if load is 50Ω

Answer: $v_T = -30V$; $i_N = -417mA$; $R_N = R_T = 72\Omega$
 $V = -12.3V$; $i = -246mA$; $p = 3.03W$

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39