ELECTRIC CIRCUITS
ECSE-2010

Lecture 5.1

Rensselaer

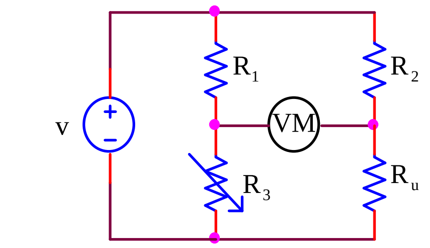
LECTURE 5.1 AGENDA

- Wheatstone bridge
- Norton/Thevinin equivalent circuits
- Norton/Thevinin equivalent circuit example

BRIDGE CIRCUITS

- Bridge circuits are circuits used to accurately measure circuit elements:
  - ***Provide measurements with minimal disturbance***
  - A Wheatstone Bridge is used to measure resistance
  - Will Use a Maxwell Bridge later to measure inductance

WHEATSTONE BRIDGE

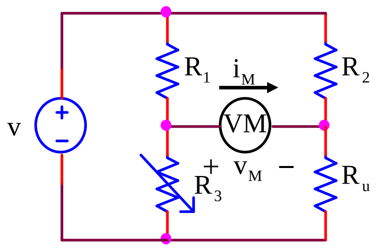


Connect Voltmeter Across "Bridge"

Adjust R_3 such that VM reads 0 V

Provides Measurement of R_u

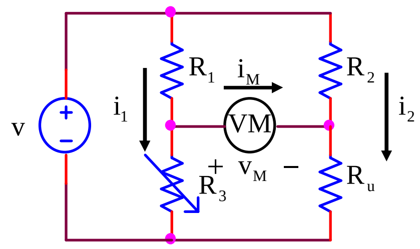
WHEATSTONE BRIDGE



When Bridge is Balanced, $i_M = 0;\ v_M = 0$

Meter Draws No Current

WHEATSTONE BRIDGE



Bridge Balanced

$$i_1(R_3 + R_1) = i_2(R_u + R_2)$$

$$i_1R_3 = i_2R_u;\ i_1R_1 = i_2R_2;$$

ELECTRIC CIRCUITS
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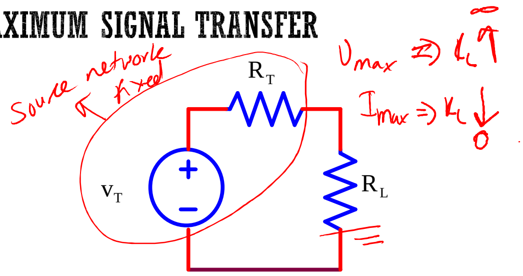
Lecture 5.2

LECTURE 5.2 AGENDA

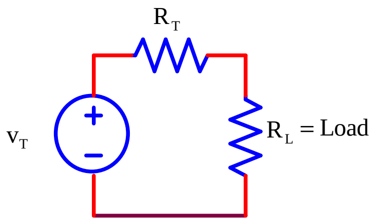
- Maximum signal transfer (Power)
- Interface circuit design

MAXIMUM SIGNAL TRANSFER



Model for Any Linear Circuit
Source Network is Often Fixed
Designer has Control over R_L

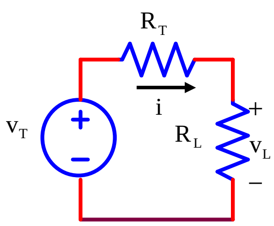
MAXIMUM SIGNAL TRANSFER



Want to get Maximum Power delivered to Load
For fixed v_T, R_T; Want to Choose R_L
to get Maximum Power to R_L

MAXIMUM SIGNAL TRANSFER

$p_L = v_L \; x \; i$



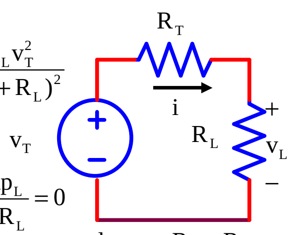
$$i = \frac{v_T}{R_T + R_L}$$

$$v_L = \left(\frac{R_L}{R_T + R_L}\right) v_T$$

$$p_L = \frac{R_L v_T^2}{(R_T + R_L)^2}$$

MAXIMUM SIGNAL TRANSFER

$$p_L = \frac{R_L v_T^2}{(R_T + R_L)^2}$$

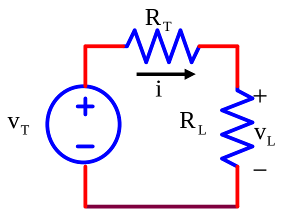


For p_{max}; $\frac{dp_L}{dR_L} = 0$

Solve for R_L $\quad \frac{dp_L}{dR_L} = \frac{R_T - R_L}{(R_T + R_L)^3} v_T^2 = 0$

For p_{max}; Choose $R_L = R_T$

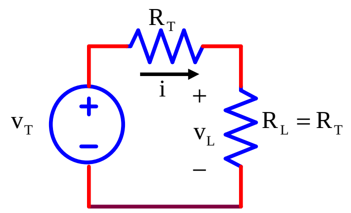
MAXIMUM SIGNAL TRANSFER



For Maximum Power Transfer; Choose $R_L = R_T$

Best You Can Do

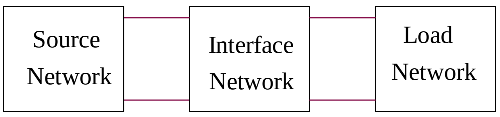
MAXIMUM SIGNAL TRANSFER



$$p_{max} = \frac{v_T^2}{4R_T} = \frac{i_N^2 R_T}{4}$$

$$Efficiency_{max} = \frac{p_{max}}{p_{source}} = 50\%$$

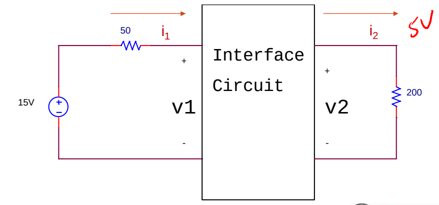
INTERFACE CIRCUIT DESIGN



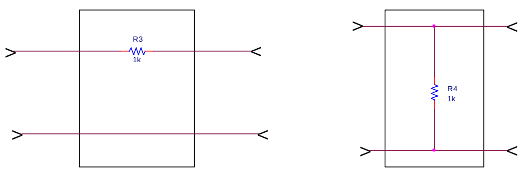
Often Need an Interface Network or Interface Circuit to Properly "Match" a Source Network to a Load Network

DESIGN EXAMPLE

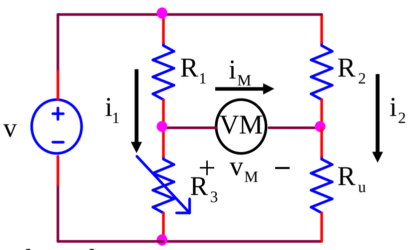
- Design two versions of the interface circuit below that deliver v_2 = 5V to the 200-Ω load. Evaluate the two designs in terms of power loss in the interface circuit.



DESIGN EXAMPLE



WHEATSTONE BRIDGE

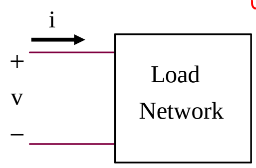


Bridge Balanced

Solve for R_u

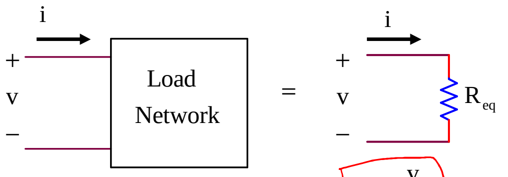
$$R_u = \frac{R_2 R_3}{R_1}$$

LOAD NETWORKS



- Resistive (linear) circuit
- No independent sources (Voltage or Current)
- May have dependent sources (VCVS, CCVS, VCCS, CCCs)

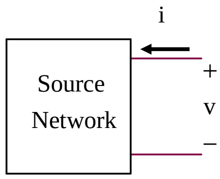
LOAD NETWORKS



$R_{eq} = \frac{v}{i}$

Any Load Network may be Replaced by an Equivalent Resistance, R_{eq}

SOURCE NETWORKS



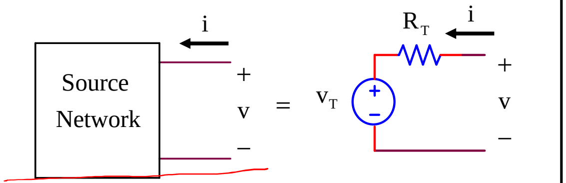
Linear Circuit

At Least One Independent Source

May have Dependent Sources

May have Resistors

THEVENIN'S THEOREM

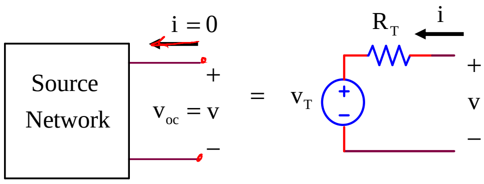


Any Source Network May be Replaced with its Thevenin Equivalent Circuit

v_T = Thevenin Voltage

R_T = Thevenin Resistance

THEVENIN'S THEOREM

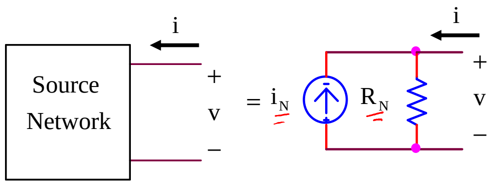


$v_T = v_{oc}$ = Open Circuit Voltage

$v_T = v_{oc} = v$ when $i = 0$

R_T = Thevenin Resistance

NORTON'S THEOREM

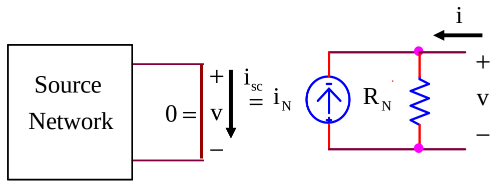


Any Source Network May be Replaced with its Norton Equivalent Circuit

i_N = Norton Current

R_N = Norton Resistance

NORTON'S THEOREM

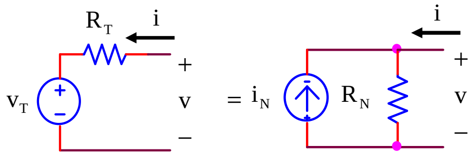


$i_N = i_{sc} =$ Short Circuit Current

$i_N = i_{sc} =$ Current Flowing from + to – when v = 0

R_N = Norton Resistance

EQUIVALENT CIRCUITS



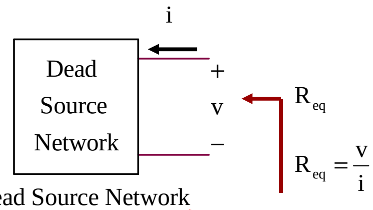
Thevenin Equivalent Circuit Norton Equivalent Circuit

From Source Conversions: $i_N = \frac{v_T}{R_T}$ and $R_N = R_T$

$v_T = v_{oc} =$ Open Circuit Voltage

$i_N = i_{sc} =$ Short Circuit Current

THEVENIN RESISTANCE



Dead Source Network

Source Network with All Independent Sources Set = 0

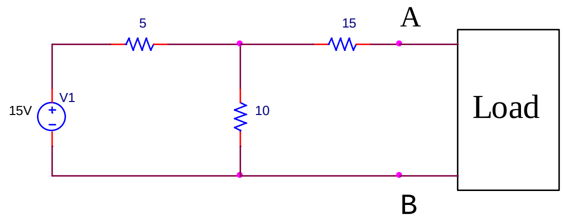
Dead Source Network = Load Network

$R_T = R_{eq}$ of Dead Source Network

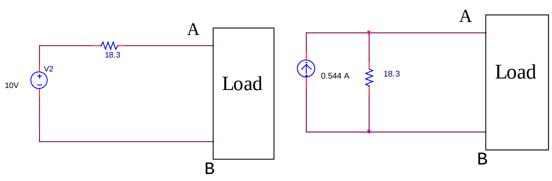
THEVENIN/NORTON SOURCES-SOLVING PROCEDURE

1. **Thevenin – Remove the load**
   1. **Find the voltage ($V_{oc} = V_{TH}$) between the two nodes where the load was connected, using any method**
2. **Norton – Remove the load and connect a short circuit (wire) between the two nodes where the load was attached**
   1. **Find the current ($I_{sc} = I_N$ through that short circuit (wire), using any method**
   2. **Note: the short circuit may 'combine' nodes. Recognize that you can do KCL at a node to find current through an individual wire connecting components.**
3. **Resistance – Remove the load**
   1. **Apply a test voltage source, V_{test}, at the nodes where the load was attached**
   2. **Short circuit all other independent voltage sources and open circuit all other independent current sources.**
   3. **Find the current through that source, I_{test}**
   4. **$R_{EQ} = R_N = R_{TH} = V_{test}/I_{test}$**
4. **Note: only two of these are needed since $V_{TH} = (R_{TH})(I_N)$**

EXAMPLE



EXAMPLE



EXAMPLE