Electronics: Class two

- Series and parallel
- Loading and impedance
- Diode and potentiometer

Series and Parallel

- Elements are in series if there are no branching nodes between them.

- Elements are in parallel if they are connected between the same nodes.
Series or Parallel?

Elements in series have the same current through them.

- Elements in series have the same current through them.
Series

Elements in series have the same current through them

\[ V - IR_1 - IR_2 = 0 \]
\[ V = IR_1 + IR_2 = I(R_1 + R_2) \]
\[ V = IR_{\text{equivalent}} \]
\[ R_{\text{equivalent}} = R_1 + R_2 \]

Parallel

Elements in parallel have the same voltage across them
Parallel

- Elements in parallel have the same voltage across them

\[ V = I_1R_1 = I_2R_2 \]
\[ I = I_1 + I_2 \]
\[ I = V/R_1 + V/R_2 = V(1/R_1 + 1/R_2) \]
\[ I = V/R_{\text{equivalent}} \]

\[ 1/R_{\text{equivalent}} = 1/R_1 + 1/R_2 \]

Voltage Divider: \( I_{\text{out}} = 0 \)

Assume no current flows out
So \( I_3 = 0 \) and \( I_1 = I_2 = I \)

\[ V_{\text{in}} - IR_1 - IR_2 = 0 \]
\[ V_{\text{in}} - I(R_1 + R_2) = 0 \]
\[ V_{\text{out}} = IR_2 \Rightarrow I = V_{\text{out}}/R_2 \]
\[ V_{\text{in}} - (V_{\text{out}}/R_2)(R_1 + R_2) = 0 \]
\[ V_{\text{in}} = V_{\text{out}}(R_1 + R_2)/R_2 \]

\[ V_{\text{out}}/V_{\text{in}} = R_2/(R_1 + R_2) \]
### Voltage Divider: \( I_{\text{out}} = 0 \)

If \( V_{\text{in}} = 10 \text{ Volts} \)
\( R_1 = 1000 \text{ } \Omega \)
\( R_2 = 2000 \text{ } \Omega \)

What is \( V_{\text{out}} ? \)

\[
\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{R_2}{(R_1 + R_2)}
\]

\( V_{\text{out}} = 6.7 \text{ V} \)

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### Voltage Divider: Loading

What if current flows out
So \( I_3 \neq 0 \) and \( I_1 = I_2 + I_3 \)

We can treat the problem the same way only now \( R_2 \) and \( R_{\text{load}} \) are in parallel

\[
\frac{1}{R_{\text{equivalent}}} = \frac{1}{R_{\text{load}}} + \frac{1}{R_2}
\]

\[
\frac{V_{\text{out}}}{V_{\text{in}}} = \frac{R_{\text{eq}}}{(R_1 + R_{\text{eq}})}
\]

\( R_{\text{load}} \) is the internal resistance of the voltmeter
Voltage Divider: Loading

If $V_{in} = 10$ Volts
$R_1 = 1000 \, \Omega$
$R_2 = 2000 \, \Omega$
$R_{load} = 20,000 \, \Omega$

What is $V_{out}$?

1/$R_{eq} = 1/R_{load} + 1/R_2$

$V_{out}/V_{in} = R_{eq}/(R_1 + R_{eq})$

$V_{out} = 6.5$ Volts

$R_{load}$ is the internal resistance of the voltmeter

If $V_{in} = 10$ Volts
$R_1 = 1000 \, \Omega$
$R_2 = 2000 \, \Omega$
$R_{load} = 3000 \, \Omega$

What is $V_{out}$?

1/$R_{eq} = 1/R_{load} + 1/R_2$

$V_{out}/V_{in} = R_{eq}/(R_1 + R_{eq})$

$V_{out} = 5.5$ Volts

$R_{load}$ is the internal resistance of the voltmeter
Input and output Impedance

- For now Impedance = resistance

Circuit A

We want to design circuits so that what we connect To the input side or the output side DOES NOT effect the performance of the circuit

Input and Output Impedance

If we don’t want the voltmeter to effect the output of our voltage divider, what should its resistance be?

BIG or Small

Therefore,

INPUT impedance should be BIG

OUTPUT impedance should be small
Diode and Potentiometer

What they look like in a circuit diagram

What they really look like

It matters which way you put it in the circuit

The resistance between 1 and 3 is constant. The resistance between 1 and 2 or 2 and 3 changes when you turn the screw.