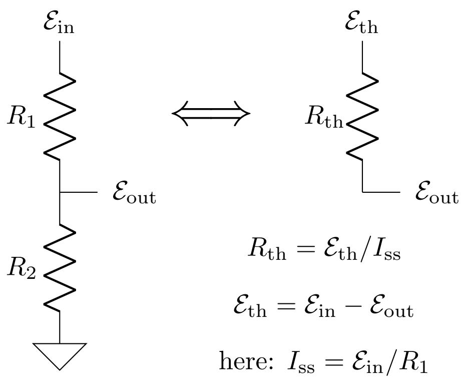
Thévenin's Theorem

Any network of resistors, voltage sources, and current sources is equivalent to a single voltage source $\mathcal{E}_{\text{th}}$ in series with a resistor R_{th}.
Ex. For a voltage divider:



$$R_{\text{th}} = \mathcal{E}_{\text{th}}/I_{\text{ss}}$$

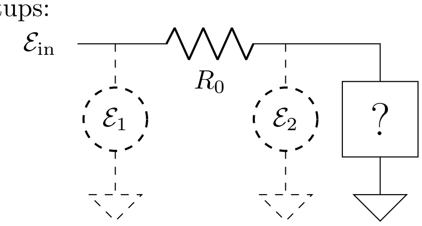
$$\mathcal{E}_{\text{th}} = \mathcal{E}_{\text{in}} - \mathcal{E}_{\text{out}}$$

$$\text{here: } I_{\text{ss}} = \mathcal{E}_{\text{in}}/R_1$$

Input and output impedances:

$$Z_{\text{in}} = \frac{\mathcal{E}_{\text{in}}}{I_{\text{in}}}; \qquad Z_{\text{out}} = \frac{\mathcal{E}_{\text{out}}}{I_{\text{out}}}$$

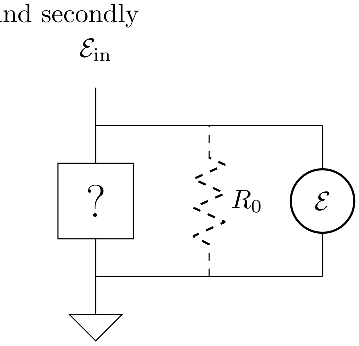
Above: $Z_{\text{in}} = R_1 + R_2$ and $Z_{\text{out}} = R_{\text{th}}$
More generally, find in/outpedances using the following measurement setups:



The in-pedence is

$$Z_{\text{in}} = \frac{\mathcal{E}_2 R_0}{\mathcal{E}_1 - \mathcal{E}_2}$$

And secondly



The out-pedence is

$$Z_{\text{out}} = \frac{\mathcal{E} - \mathcal{E}_0}{\mathcal{E}_0} R_0$$

Kirchhoff's Laws

Voltage is single-valued, so the sum of voltages around any loop is zero:

$$\sum_{\circlearrowleft} \mathcal{E} = 0$$

Charge is conserved (no accumulation), so at any junction currents sum to zero:

$$\sum_{\perp} I = 0$$

Alternating Current

AC circuits are periodically driven:

$$\mathcal{E}_{\text{source}} = \mathcal{E}_0 \cos(\omega t)$$

$$I_{\text{source}} = I_0 \cos(\omega t)$$

Ohm's Law with complex impedances:

$$\mathcal{E} = IZ$$

Where the impedances are given by:

$$Z_{\text{resistor}} = R$$

$$Z_{\text{capacitor}} = 1/i\omega C$$

$$Z_{\text{inductor}} = i\omega L$$

Series and parallel impedances add as:

$$Z_{\text{series}} = Z_1 + Z_2 + \cdots + Z_n$$

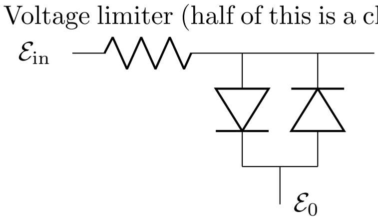
$$Z_{\text{parallel}} = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2} + \cdots + \frac{1}{Z_n}}$$

If we only care about the amplitudes then we can consider the magnitude:

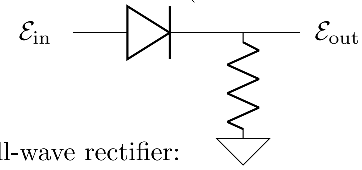
$$|Z| = \sqrt{\text{Re}(Z)^2 + \text{Im}(Z)^2}$$

Diodes

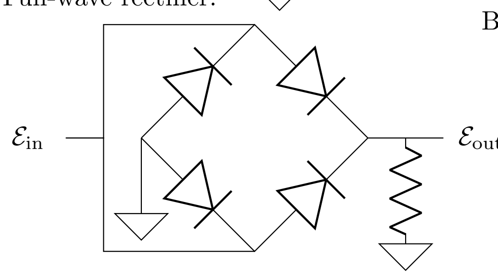
Voltage limiter (half of this is a clamp):



Half-wave rectifier (smooth with cap):

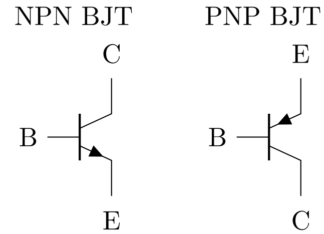


Full-wave rectifier:



Bipolar Junction Transistors

There are NPN, ex. 2N3904, and PNP, ex. 2N3906, transistors with base, collectors, and emitters arranged as:

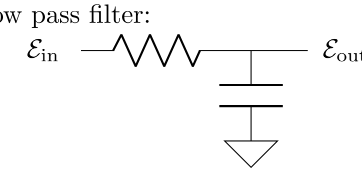


Filters

Filters are described by the 3dB point:

$$\text{Amplitude} \mapsto \frac{\text{Amplitude}}{\sqrt{2}}$$

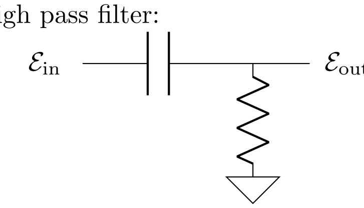
Low pass filter:



with

$$f^{-1} = 2\pi RC$$

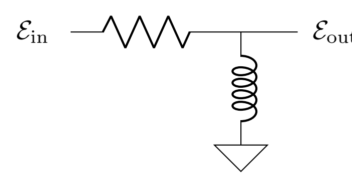
High pass filter:



with

$$f^{-1} = 2\pi RC$$

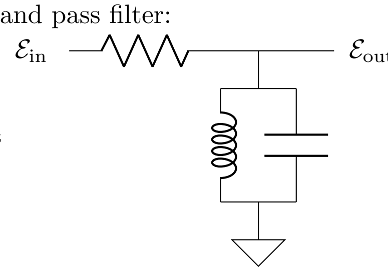
or



with

$$f^{-1} = 2\pi L/R$$

Band pass filter:



Note

The materials on the first page only cover through roughly the first practical midterm exam. After that exam, the COVID-19 pandemic hit and my living situation and the instruction were modified. The second half of the course largely focused on digital logic and building simple digital circuits. Of course, Physics 117 is a lab course, so while this is a formula sheet, spending time with real electronic components building circuits is more important than a theoretical understanding of the material: often the components will behave rather different that theory says they ought to and you will have to figure out why.