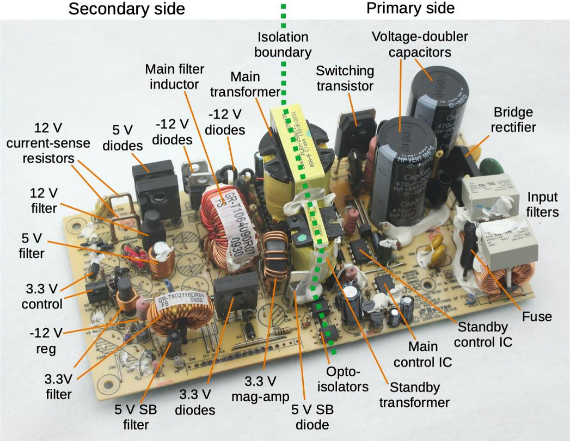

https://qiriro.com/epe2165/

Circuit models for an amplifier

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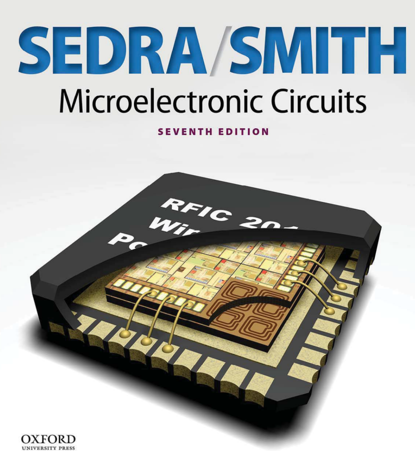
Readings

- **Section 1.5 (pages 23-32)**
- **Example 1.3 on page 25**
- **Table 1.1. on page 28**
- Section 1.5.5 on page 29



[1] Readings are based on Sedra & Smith (2014), Microelectronic Circuits 7th edition.
[2] Bold reading section are mandatory. Other sections are suggested but not required readings

Why circuit models?

- A conceptual model is a representation of a system and is used to communicate a set of concepts[1]
- model is the description of component's terminal behavior and ignores internal operation and components design (Fig. 1)

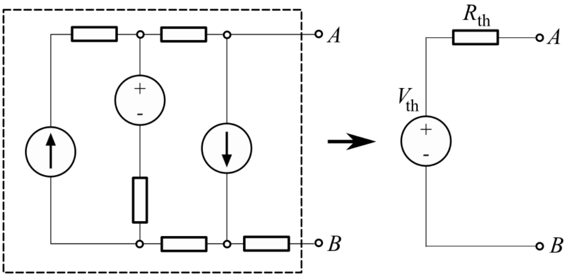


FIG 1. Thevenin model of a circuit[2]
Any black box containing resistances only and voltage and current sources can be replaced by a Thévenin equivalent circuit consisting of an equivalent voltage source in series connection with an equivalent resistance.

[1] https://en.wikipedia.org/wiki/Conceptual_model
[2] https://en.wikipedia.org/wiki/Th%C3%A9venin%27s_theorem

Voltage amplifier model

- Voltage-controlled with source v_s with a gain A_{vo}, an input resistance R_i and an output resistance R_o
- Using the voltage-divider rule, v_o is represented by Equation (1)

$$v_o = V_{vo} v_i \frac{R_L}{R_L + R_o} \qquad (1)$$

- Thus, the voltage gain can be expressed by Equation (2)

$$A_v \equiv \frac{v_o}{v_i} = A_{vo} \frac{R_L}{R_L + R_o} \qquad (2)$$

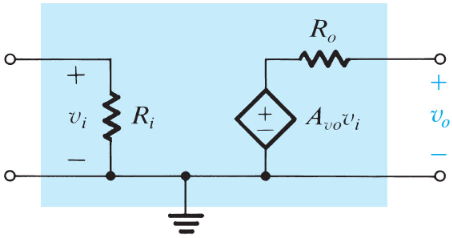


FIG 2. Circuit model for the voltage amplifier

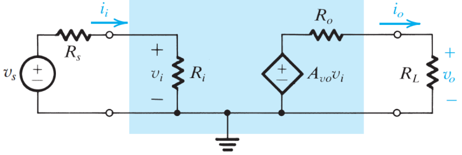


FIG 3. Voltage amplifier with input signal source

Important remarks

- From Equation (2), the optimum gain is achieved when the output resistance R_o should be much smaller than the load resistance RL.
- when designing an amplifier circuit in which R_L is known to vary over a certain range, R_o should be much smaller than the lowest value of R_L.
- An ideal voltage amplifier is one with $R_o = 0$.
- Equation (2) shows that when $R_L = \infty$, then $A_v = A_{vo}$. Thus A_{vo} is the voltage gain of the unloaded amplifier, or the open-circuit voltage gain.
- When specifying the voltage gain of an amplifier, one must also specify the value of load resistance R_L at which this gain is measured or calculated.
- If a load resistance is not specified, it is normally assumed that the given voltage gain is the open-circuit gain A_{vo}.

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Important remarks

- The input resistance R_i reduces the actual value of the source signal v_s that reaches the input terminals of the amplifier (Equation (3))

$$v_i = v_s \frac{R_i}{R_i + R_s} \tag{3}$$

- Equation (3) shows that in order not to lose a much of the input signal in coupling the signal source to the amplifier input, the input resistance R_i must be much greater than the resistance of the signal source R_s, i.e., $Ri \gg R_s$
- When designing an amplifier circuit in which the source resistance vary over a certain range, R_i should be much greater than the largest value of Rs.
- An ideal voltage amplifier is one with $R_i = \infty$. In this ideal case both the current gain and power gain become infinite
- The overall voltage gain ($A = vo/vs$) is obtained by combining Equation (2) and Equation (3) as shown in Equation (4)

$$\frac{v_o}{v_s} = A_{v_v o} \frac{R_i}{R_i + R_s} \cdot \frac{R_L}{R_L + R_o} \tag{4}$$

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Cascaded amplifiers

- Real amplifiers are not ideal and they do not have infinite input impedance or zero output impedance.
- Cascading of amplifiers is used to solve this (Fig. 4).
  - First amplifier —high R_i, medium R_o
  - Last amplifier —medium R_i, low R_o
  - Aggregate —high R_i, low R_o

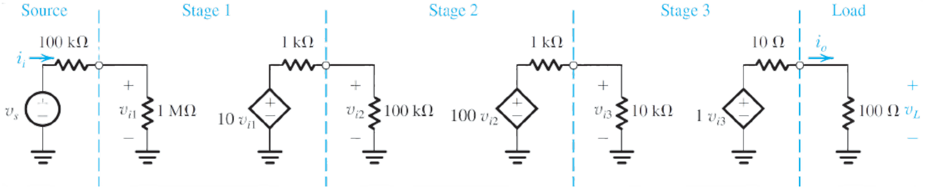

FIG 4. Three-stage amplifier

The first stage has a large input resistance ($R_i = 1\text{M}\Omega$).The second stage achieves the required voltage gain. The final stage functions as a buffer amplifier, providing a relatively large input resistance and a low output resistance, much lower than R_L. It is this stage that enables connecting the amplifier to the 100■ load.

The end