Topic 7

Diodes

7.1 I-V Curve

Actual I-V curve for a real diode obtained in lab.

7.2 Rules for diodes based on simple idealized I-V curves

First, determine if diode is forward biased or reverse biased.

- For forward-biased silicon diodes:
  - $\Delta V_{\text{diode}} \simeq 0.6\,\text{V}$. (For other materials the voltage drop will be different.)
  - I_{diode} determined by rest of circuit.
- For reverse-biased diodes:
  - $I_{\text{diode}} \simeq 0$.
  - ΔV_{diode} determined by rest of circuit.

7.3 Diode circuits

- Diodes as rectifiers (as in lab).
- Diodes as voltage clamps.

- Diodes as protection with indcutive loads.

Reading

- Simpson, from bottom of p. 174 to top of p. 176 (we have not discussed the physics behind the diode action); Section 4.11.
- Horowitz & Hill, Sections 1.25–1.31.
- Nahvi & Edminster, Chapter 2.8
- Scherz, Chapter 4.2

Topic 8

Transistors

8.1 The "simplest model" of Tranistor Behavior

- $I_B = 0$.
- Current will flow in at the collector and out at the emitter (with $I_C \simeq I_E$) if
  - the collector is more positive than the emiiter, and
  - the base-emitter junction is forward biased (like a silicon diode), and
  - the magnitude of the collector-emitter current is determined by the rest of the circuit.

8.2 The "simple model" of Transistor Behavior

- Current will flow in at the collector and out at the emitter if
  - the collector is more positive than the emiiter, and
  - the base-emitter junction is forward biased (like a silicon diode).
- The base current is small, but not zero. When the rules above are obeyed, the relationship between the collector current and the base current is given by $I_C = \beta I_B$, where β is a number in the range of 75–100 for many common transistors.

8.3 Transistor Applications

- Transistor as switch.
- Emitter Follower.
- Common Emitter Amplifier.
- Transistor Current Source.

References

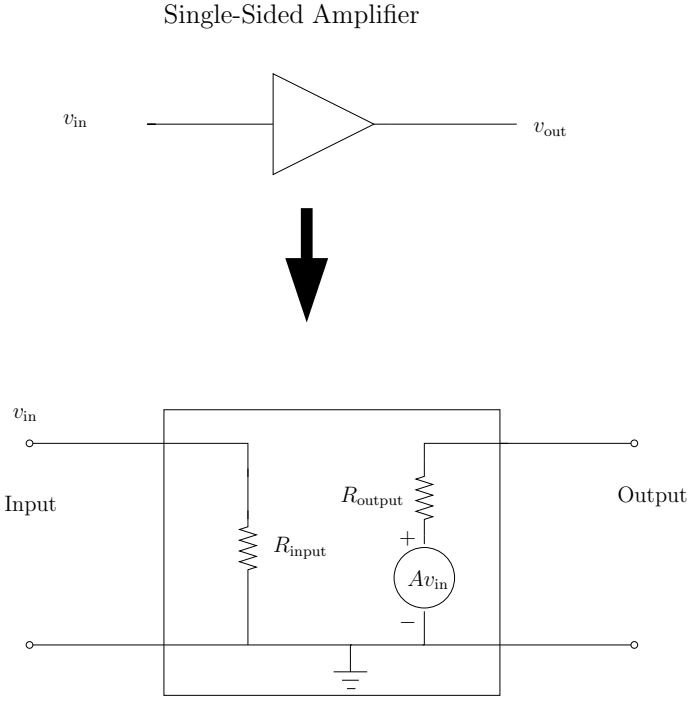
- Handouts from
  - Horowitz and Hill, *The Art of Electronics*, pp. 16–79
  - Hayes and Horowitz, *Lab Manual for the Art of Electronics*, pp. 82–99
- Transistors are covered in many, many electronics texts, but most treatments go beyond the easy-to-use "simple" and "simplest" models I have introduced, and therefore are probably not the easiest references for doing the labs and problems in this course.

Topic 9

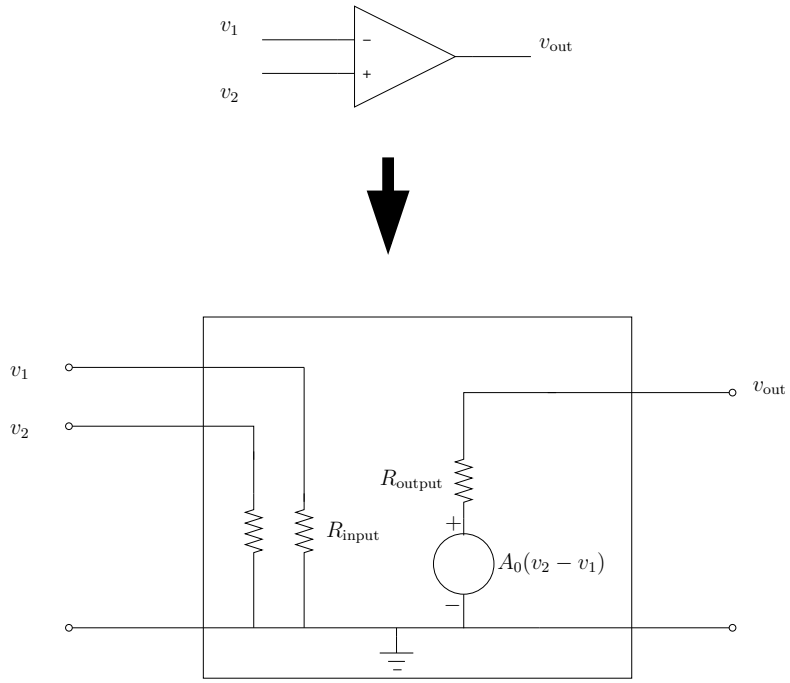
Amplifiers and Operational Amplifiers (Op-Amps)

9.1 General Amplifier Theory

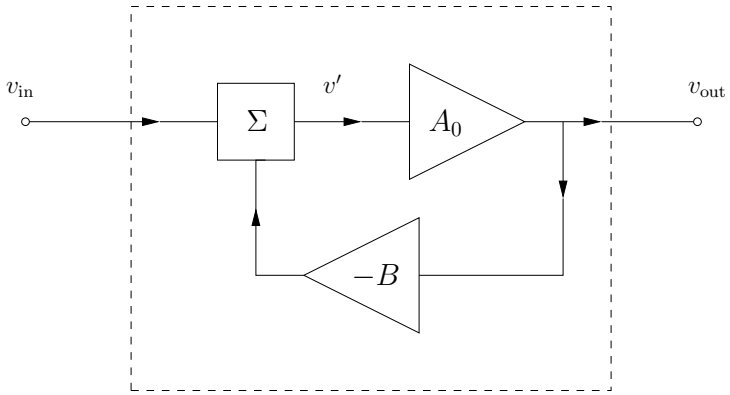
9.1.1 Input Impedance, Output Impedance, & Gain



Differential Amplifier (Ground Implied)



9.1.2 Abstract Model of Negative Feedback



$$v_{\text{out}} = A_0 v' = A_0(v_{\text{in}} - B v_{\text{out}})$$

9.2 Ideal Op-Amps With Negative Feedback

For ideal op-amps with negative feedback:

1. The inputs draw no current.
2. The output attempts to do whatever is necessary to make the voltage difference between the two inputs zero.

Examples discussed in class, lab, and homework:

- Inverting amplifier
- Non-inverting amplifier
- Voltage follower
- Summing amplifier
- Current source

9.3 Ideal Op-Amps with Positive Feedback (or no feedback)

- Comparators and level-crossing detectors.
- Schmitt trigger.
- Square-wave generator.

9.4 Non-Ideal Op-Amps

- Non-zero bias current. $I_B \neq 0$, ($I_{B+} \neq I_{B-}$)
- Output doesn't respond instantly to changes in input; finite *slew rate*.
- Non-zero offset voltage; $v_{\text{out}} \neq 0$ when $v_2 = v_1$.
- Voltage gain not infinite; voltage gain not independent of frequency.
- Input impedance not infinite.
- Upper limit to current an op-amp can source or sink.

Reading

- Handout from Texas Instruments: *Understanding Basic Analog — Ideal Op Amps*
- Simpson, Chapters 9 and 10. Applications of ideal op-amps like those we considered in class and lab are in 9.7, 10.2, 10.3, 10.4 10.7, 10.9, 10.12, and 10.13, 10.18, 10.19, 10.20. (Other sections are good too, but not as close to things we did.) Amplifier theory and non-ideal op-amps are covered in 9.4, 9.6, and 9.8.
- Horowitz & Hill, Chapter 4.01–4.08, 4.11 (there is lots of other good material too, but it gets more detailed than we need)
- O'Malley, Chapter 6
- Nahvi & Edminster, Chapter 5
- Scherz, Chapter 7