THE CITADEL
THE MILITARY COLLEGE OF SOUTH CAROLINA

Dr. Gregory J. Mazzaro

Fall 2013

ELEC 313 – *Electronics Laboratory*

Lab Orientation
& Quick Reference

Lab Orientation Outline

- **ELEC 313 introduction**
  - Syllabus, lab notebooks, lab reports
- **Laboratory equipment**
  - Signal generation & capture hardware
- **Circuit terminology**
  - Essentials from ELEC 201, 202, 204
- **Electronic components & breadboarding**
  - Parts used for experiments
- **PSpice circuit simulator**

Syllabus Highlights

Instructor: **Dr. Gregory J. Mazzaro**, Grimsley Hall Room 312
phone: 843-953-0429, e-mail: gmazzaro@citadel.edu
office hours: MW 16:00-17:00, TR 13:30-17:00 (and by appointment)

Skills to be developed:

(1) DC characterization of diodes
(2) DC characterization of transistors
(3) Design and measurement of op-amp circuits
(4) AC measurements using voltmeters and oscilloscopes
(5) Frequency response measurements
(6) Preparation of lucid, succinct technical reports
(7) Working as part of a technical team

Grading:

Pre-lab exercises, 20%	90% ≤ A < 100%
Lab notebook, 10%	80% ≤ B < 90%
Lab reports, 60%	70% ≤ C < 80%
Lab practical, 10%	60% ≤ D < 70%
	F < 60%

Syllabus Highlights

Dr. Gregory J. Mazzaro

Assistant Professor of Electrical Engineering at The Citadel
Department of Electrical & Computer Engineering, Grimsley Hall, Room 312

Office Hours

Email

CV, Short

Publications

Participations

Fall 2013 courses:

ELEC 201

ELEC 313

Education

- **Ph.D., Electrical Engineering**, North Carolina State University, *Raleigh, NC*, 2009
- **M.S., Electrical Engineering**, State University of New York at Binghamton, *Binghamton, NY*, 2006
- **B.S., Electrical Engineering**, Boston University, *Boston, MA*, 2004, *summa cum laude*

Areas of Expertise

- Radar: Non-linear and ultra-wideband
- RF electronics and systems
- Electromagnetics

Experience

- **Electronics Engineer**, U.S. Army Research Laboratory, *Adelphi, MD*, 2009-2013
- **Intern**, U.S. Army Research Laboratory, *Adelphi, MD*, Summer 2007
- **Research Assistant**, Electronics Research Laboratory, N.C. State University, *Raleigh, NC*, 2006-2009
- **Intern**, U.S. Air Force Research Laboratory, *Rome, NY*, Summer 2006
- **Teaching Assistant**, State University of New York, *Binghamton, NY*, 2004-2006
- **Engineering Tutor**, Boston University College of Engineering, *Boston, MA*, 2003-2004

Syllabus Highlights

Attendance: A student missing a lab must work out a time with the instructor to make it up.

Lab teams: The students will be divided into teams of two to three individuals. The lab work, lab notebook, and technical reports are the responsibility of all team members.

Website: Assignments and course announcements will be distributed to the class via the course website. http://ece.citadel.edu/mazzaro ("ELEC 313", left-hand menu)

Decorum: Each lab team member is expected to earnestly participate in each experiment. Students must respect the lab equipment and clean their lab bench by properly stowing all wires and components after each experiment. Food and drink are not permitted at any time in the laboratories.

Notebooks: Each lab team will keep a handwritten lab notebook.

Reports: Lab reports are to be submitted at the *beginning* of class on the due date.

Additional policies are listed in the full syllabus.

Syllabus Highlights

Week	(Mon)	(Wed)	Due at start of class	Activity
1	26-Aug	28-Aug		Lab orientation
2	2-Sept	4-Sept		(no lab)
3	9-Sept	11-Sept	Pre-lab #1	Lab #1, Amplifier models
4	16-Sept	18-Sept	Pre-lab #2, Report #1	Lab #2, Diode characterization
5	23-Sept	25-Sept	Pre-lab #3, Report #2	Lab #3, Diode circuits
6	30-Sept	2-Oct	Pre-lab #4a, Report #3	Lab #4a, DC Motor Driver Kit
7	7-Oct	9-Oct	Pre-lab #4b, Report #4a	Lab #4b, DC Motor Driver
8	14-Oct	16-Oct	Pre-lab #5, Report #4b	Lab #5, CMOS circuits
9	21-Oct	23-Oct		(no lab – office hours instead)
10	28-Oct	30-Oct	Pre-lab #6, Report #5	Lab #6, MOSFET characterization
11	4-Nov	6-Nov	Pre-lab #7, Report #6	Lab #7, MOSFET amplifier configurations
12	11-Nov	13-Nov	Pre-lab #8, Report #7	Lab #8, BJT characterization
13	18-Nov	20-Nov	Pre-lab #9, Report #8	Lab #9, Common-emitter transistor amplifier
14	25-Nov	27-Nov		(no lab)
15		4-Dec	Notebooks, Report #9	Lab practical
16	9-Dec			

Sequence of Events for Each Week

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1. The instructor performs a demonstration of the current laboratory experiment.

2. The instructor approaches each team (individually) while students begin the current lab experiment.

   (a) The instructor returns the **team's** graded report (submitted previously).
   (b) The **team** turns in its new lab report (for the previous experiment).
   (c) The instructor checks & grades the **team's** current pre-lab assignment.

3. The instructor monitors students' experiments & assists each team as necessary.

   Students complete the lab experiment (i.e. record all required data) during class.

4. Outside of class… Each **team** creates a lab report for the current experiment.

   Each **team** completes the next pre-lab assignment.

Lab Notebooks

Why keep a laboratory notebook?

(1) Most companies **require** their engineers to keep notebooks of their work.

(2) Notebooks serve as legal protection of **intellectual property**.

How will we keep our notebooks?

(1) Team members are expected to **alternate** each week in keeping the notebook.

(2) The notebook must be **bound**. Loose-leaf notebooks are not acceptable.

(3) All **pages** must be **sequentially numbered**. Each side is 1 page.

(4) The first sheet is the **Table of Contents**. Numbering starts after this sheet.

(5) Label the first page used to record data for a particular experiment with **the title of the experiment**. Record the page number in the Table of Contents.

(6) All entries are made in **ink**. (Do not erase anything.)

Lab Notebooks (Continued)

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How will we keep our notebooks?

(7) Do not remove **any** pages. If changes need to be made, draw a line through the material that is to be deleted even if you have to cross out an entire page.

(8) The **date** that the entries were made must appear on **every page**.

(9) Each page is **signed** by the engineer taking the data.

(10) No blank numbered pages are permitted. If a page needs to be left blank, write "Intentionally Blank" and draw a diagonal line across the page.

(11) Any **material added**, such as a computer print out, must be **permanently affixed** (staples, tape, glue) to the notebook page. The material itself must be signed and dated.

Guidelines for notebooks are posted on the course website.

Lab Reports: General

Why create a lab report?

The lab report is a document that allows a reader (familiar with basic electrical measurements and procedures) to **reproduce** an experiment.

How will we generate lab reports?

(1) Reports will be composed on a word processor and printed out.

(2) Reports will be **succinct**, grammatically correct, and **typo-free**.

-- *past* tense describes the experiment; *present* tense discusses the report
-- each figure & table is *referenced* in the discussion (e.g. "According to Figure 2…")

(3) Each lab report should include:

-- Cover page signed by each team member
-- Purpose of the experiment
-- Block diagram of the test configuration(s) and/or circuit schematic(s)
-- Test procedure (in the student's own words)
-- Measured results
-- Comparison with theoretical results
-- Conclusions

An example report is provided on the course website.

Lab Reports: Grading

ELEC 313 Lab Report Grading Sheet

Student 1 ____________________ **Lab #** _____________

Student 2 ____________________

Item	Pts	Comments
Pre – Lab & Lab Notebook (2)		
Lab Performance (1)		
Introduction (1) Objectives/Background/ Principles		
Procedure (1) Paragraph form/Circuit diagrams		
Presentation & Discussion of Results (3) All theoretical & experimental data Differences explained Sample calculations Tables & plots easy to read		
Conclusions (1) Support of objectives & general principles **Lab questions answered**		
General (1) Spelling/grammar/neatness		
Total Points (10)		

Lab Notebooks: Data

Best practices: (1) Record the **conditions** under which the data is taken.

What do I need to remember to *reproduce* the experiment?
-- Record those details.

(2) Take enough data to show a **clear** trend.

Does the data *clearly* indicate a particular pattern?
-- If not, take more data outside/within the record.

$$\%\ \text{error} = \frac{\left|\text{measured} - \text{nominal}\right|}{\text{nominal}} \times 100\%$$

…always *positive* by convention

"nominal" = *true* or *ideal* value

Lab Reports: Tables & Plots

Best practices:

(1) **Do not skip** any table entries.

(2) Add more table entries (rows, columns) **as necessary**.

(3) Clearly label plot **axes** (horizontal, vertical).

(4) Denote proper **units** for all recorded data entries & plot points.

Shortcuts: Write units at top/left of column/row.

Write units in the horizontal/vertical axis label.

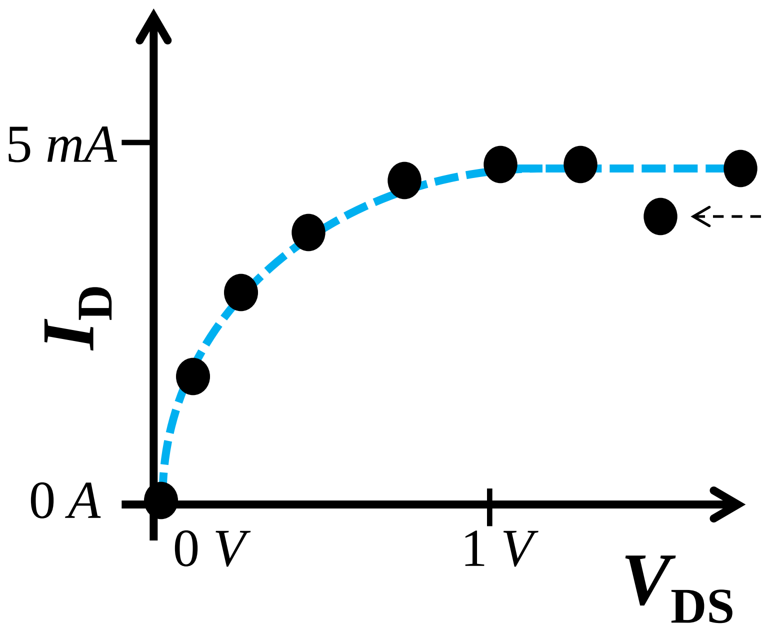
(5) Note **points-of-interest**.

Examples: --where a trend stops/reverses

--where the measured data deviates substantially from the trend

Lab Reports: Tables & Plots

V_{DS} (V)	0.0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6
I_D (mA)	0.0	2.4	3.6	4.2	4.5	4.7	4.8	4.6	4.9



error in measurement?

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Direct Current (DC) Power Supply

- <u>Triple output</u>: up to 6 V at 5 A, up to 25 V at 1 A, down to –25 V at 1 A
- <u>Current limiting</u>: can set current limits (below 5A, 1A)

- controlled by knob (up/down) and arrows (decimal place)

HP E3631A

Function Generator

- <u>Multiple waveforms</u>: sinusoid, square wave, triangular, modulations
- <u>Frequencies up to 15 MHz</u>: set using “Freq” button; entered w/ knob & arrows
- <u>Amplitudes up to 20 V</u>: set using “Ampl” button; entered w/ knob & arrows

HP 33120A

<u>To set high-impedance mode</u>:

(1) “Shift” button
(2) “MENU” button
(3) “>” until “D: SYS” shows
(4) “v” until “PARAMETER” shows “50 OHM”
(5) “>” until “HIGH Z” shows
(6) “Enter” button

Multimeter

- measures AC/DC voltage, current, resistance

Fluke 8010A

HP 34401A

Oscilloscope

- <u>2-channel signal capture</u>: observe two signals simultaneously
- <u>100 MHz bandwidth</u>: capture signals at 200 x 10^6 samples/s (200 MSa/s)

Agilent 54622D

Laboratory Safety

100 mA	Burns, breathing stops
80 mA	Extreme breathing difficulty
60 mA	Breathing difficulty
40 mA	Severe shock
20 mA	Muscular paralysis
10 mA	Pain, cannot let go of wire
1 mA	Threshold of sensation

Physiological reaction to current

DISCONNECT POWER AT THE FIRST SIGN OF TROUBLE

Best practices:

- Check equipment for damage. Replace cut cords, cracked terminals, etc.
- Avoid creating a pathway for current with your free hand (especially while measuring V, I, R).
- **Do not work with power connected unless it is absolutely necessary.**
- Do not work at your bench while wearing wet clothes, shoes, etc.
- Do not wear jewelry or headphones that might touch your equipment.
- **Do not touch components until after they have cooled.**
- Discharge large capacitors before handling them.

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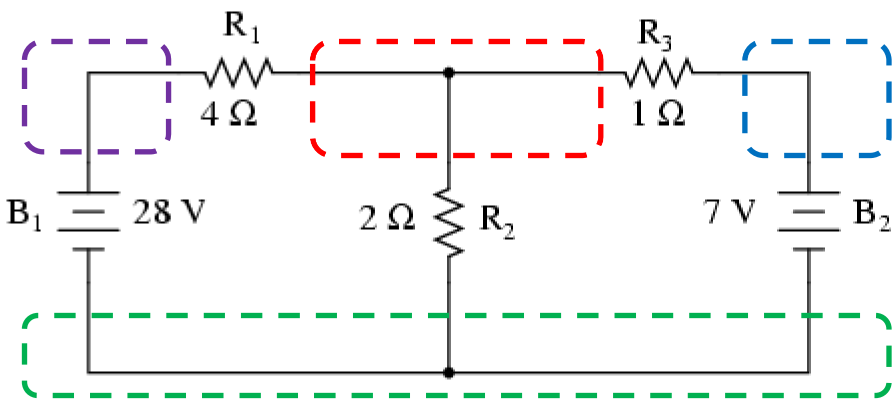
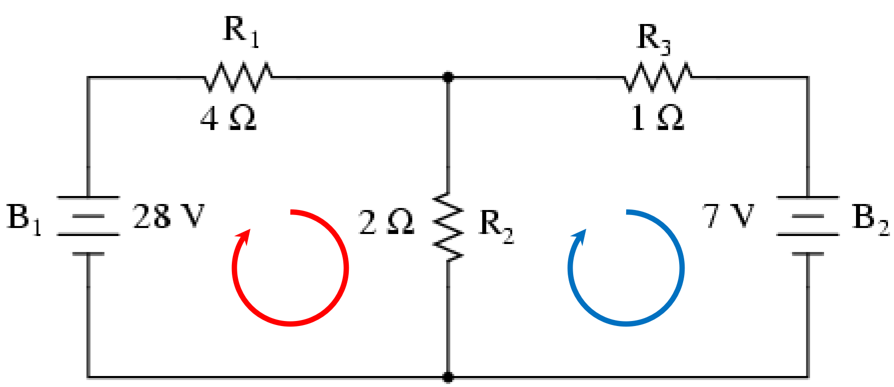
Terminology

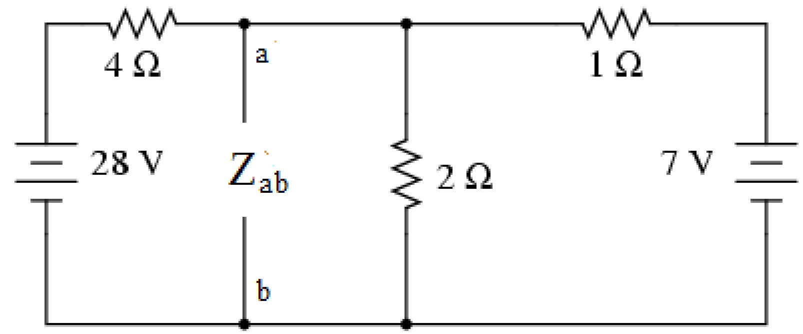
node: a collection of points of equal voltage

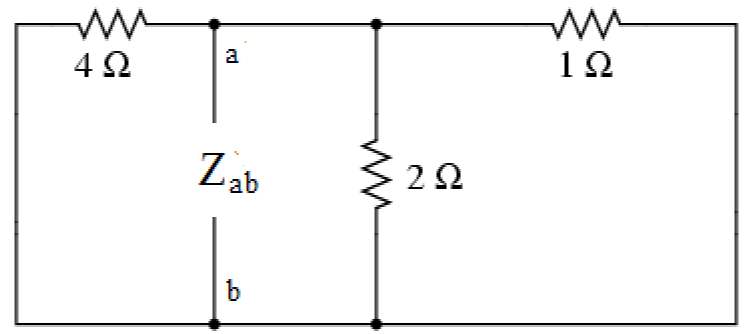


mesh: a loop of current that
does not contain other loops



impedance: ratio of voltage to current,
measured between 2 nodes





$$Z_{ab} = (4\,\Omega)\,\|\,(2\,\Omega)\,\|\,(1\,\Omega) = 571\,\mathrm{m}\Omega$$

Terminology

<u>Voltage gain</u>: $G_v = \frac{v_{\text{out}}}{v_{\text{in}}}$ $\cancel{G_v = v_{\text{out}} - v_{\text{in}}}$

<u>Current gain</u>: $G_i = \frac{i_{\text{out}}}{i_{\text{in}}}$ $\cancel{G_i = i_{\text{out}} - i_{\text{in}}}$

<u>Transresistance</u>: $r = \frac{v_{\text{out}}}{i_{\text{in}}}$

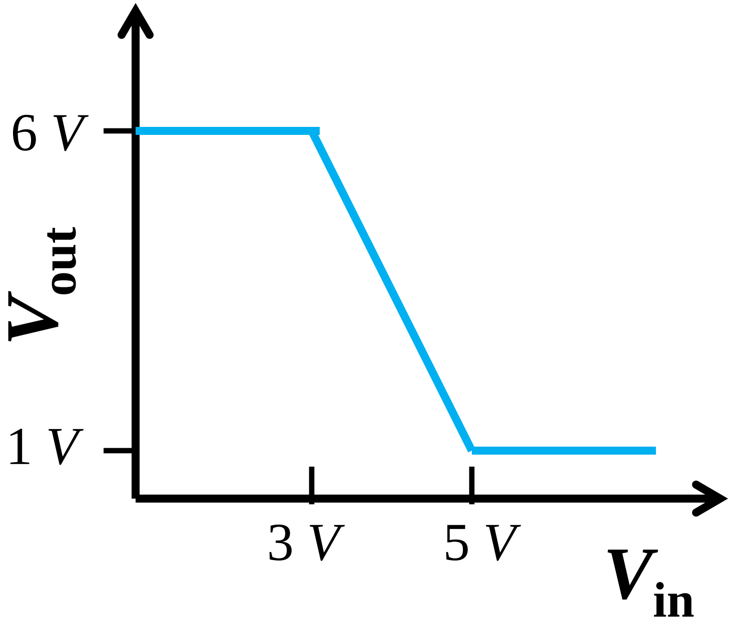
<u>Transconductance</u>: $g = \frac{i_{\text{out}}}{v_{\text{in}}}$

<u>Truth table</u>: indicates output state(s) for different combinations of input state(s)

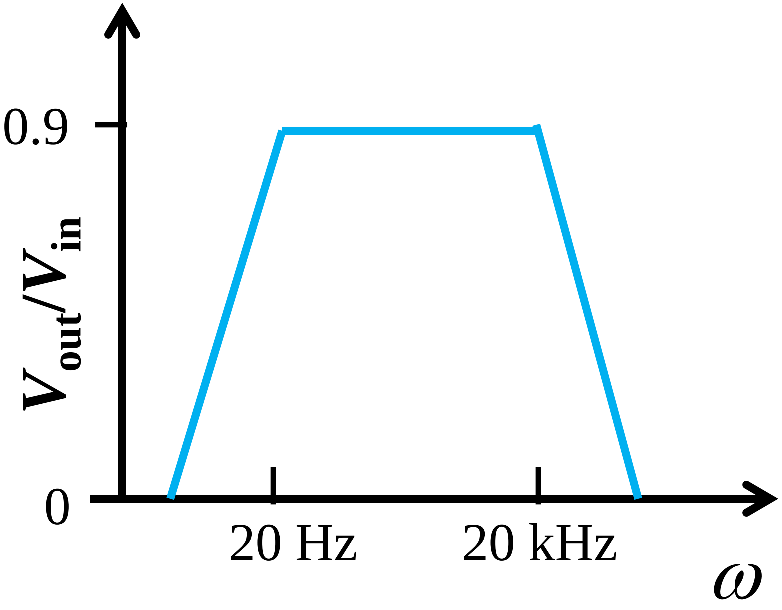
	V_1 = 0 V	V_1 = 5 V
V_2 = 0 V	V_{out} = 0 V	V_{out} = 5 V
V_2 = 5 V	V_{out} = 5 V	V_{out} = 0 V

Transfer function:

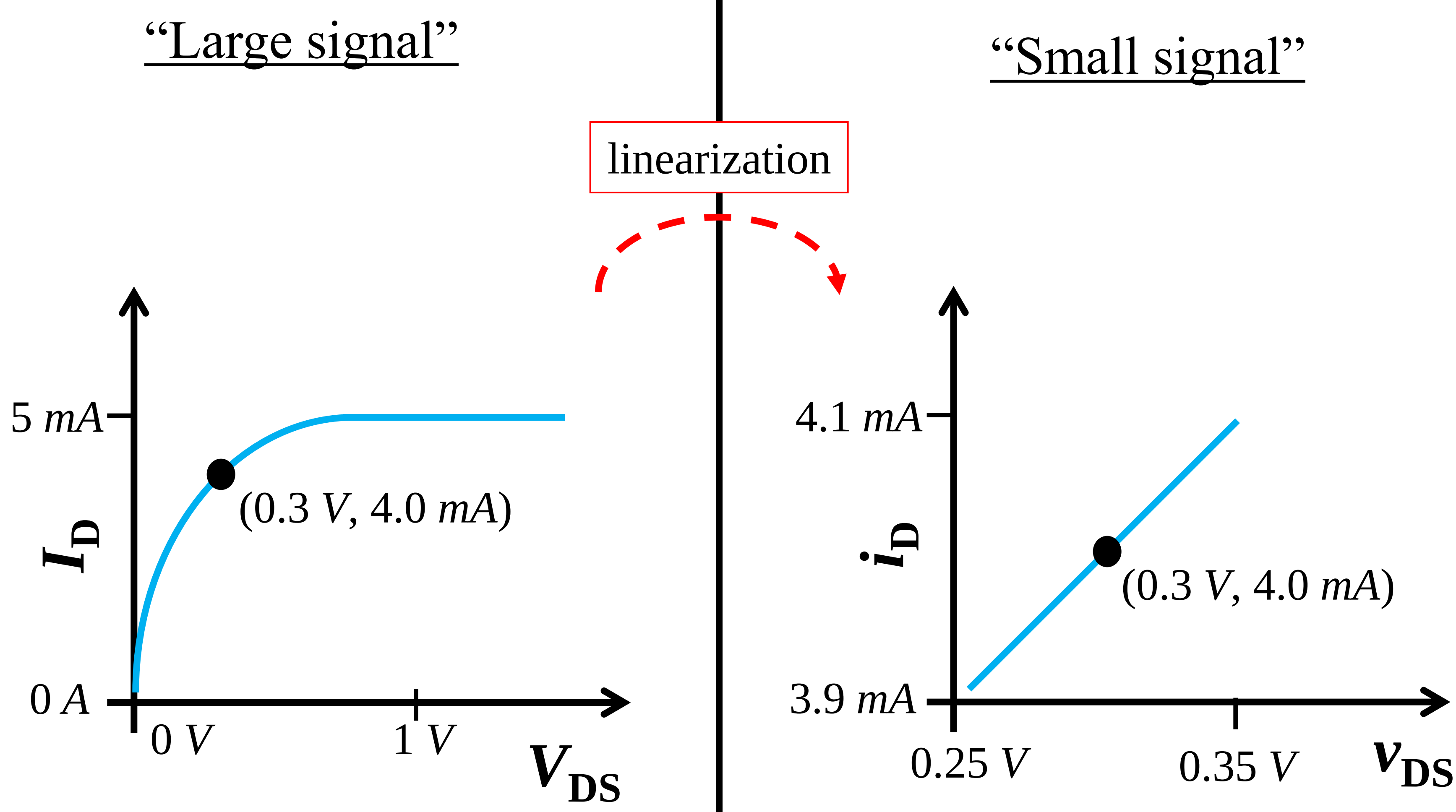
$$H_{DC} = V_{out}\left(V_{in}\right)$$



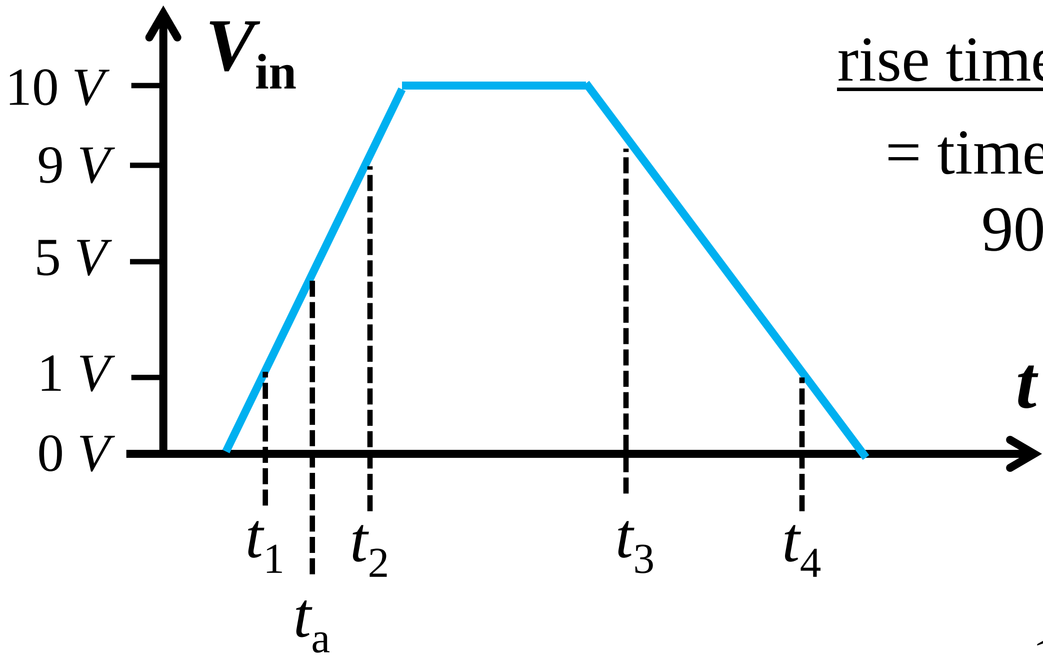
$$H_{AC} = \frac{v_{out}(\omega)}{v_{in}(\omega)}$$



Terminology



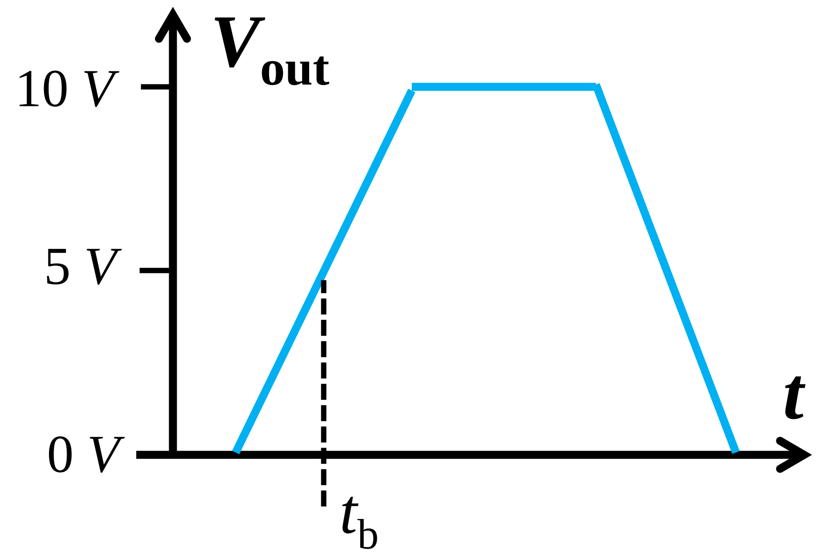
Pulse Waveforms



<u>rise time</u> = $t_2 - t_1$

= time difference between 90% and 10% of high value

<u>fall time</u> = $t_4 - t_3$



<u>delay time / propagation delay</u>

= $t_b - t_a$

= time between input at 50% and output at 50%

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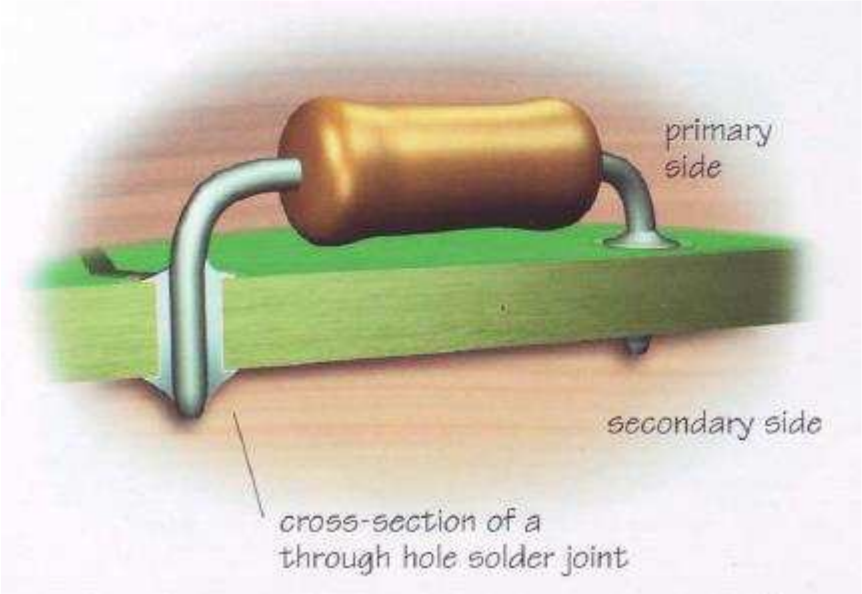
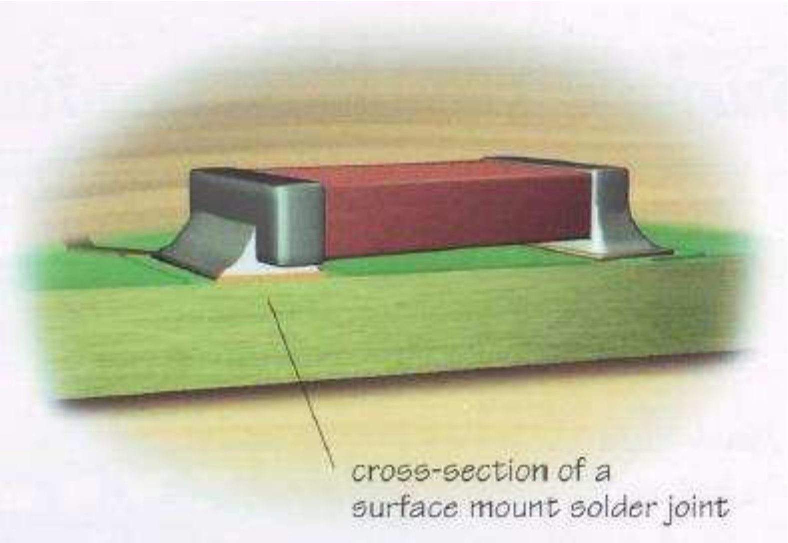


"through-hole"

-- readily breadboarded and
soldered (after leads are clipped)



"surface-mount"

-- very short leads; soldered as part
of a "brass-board" or final assembly

Breadboard

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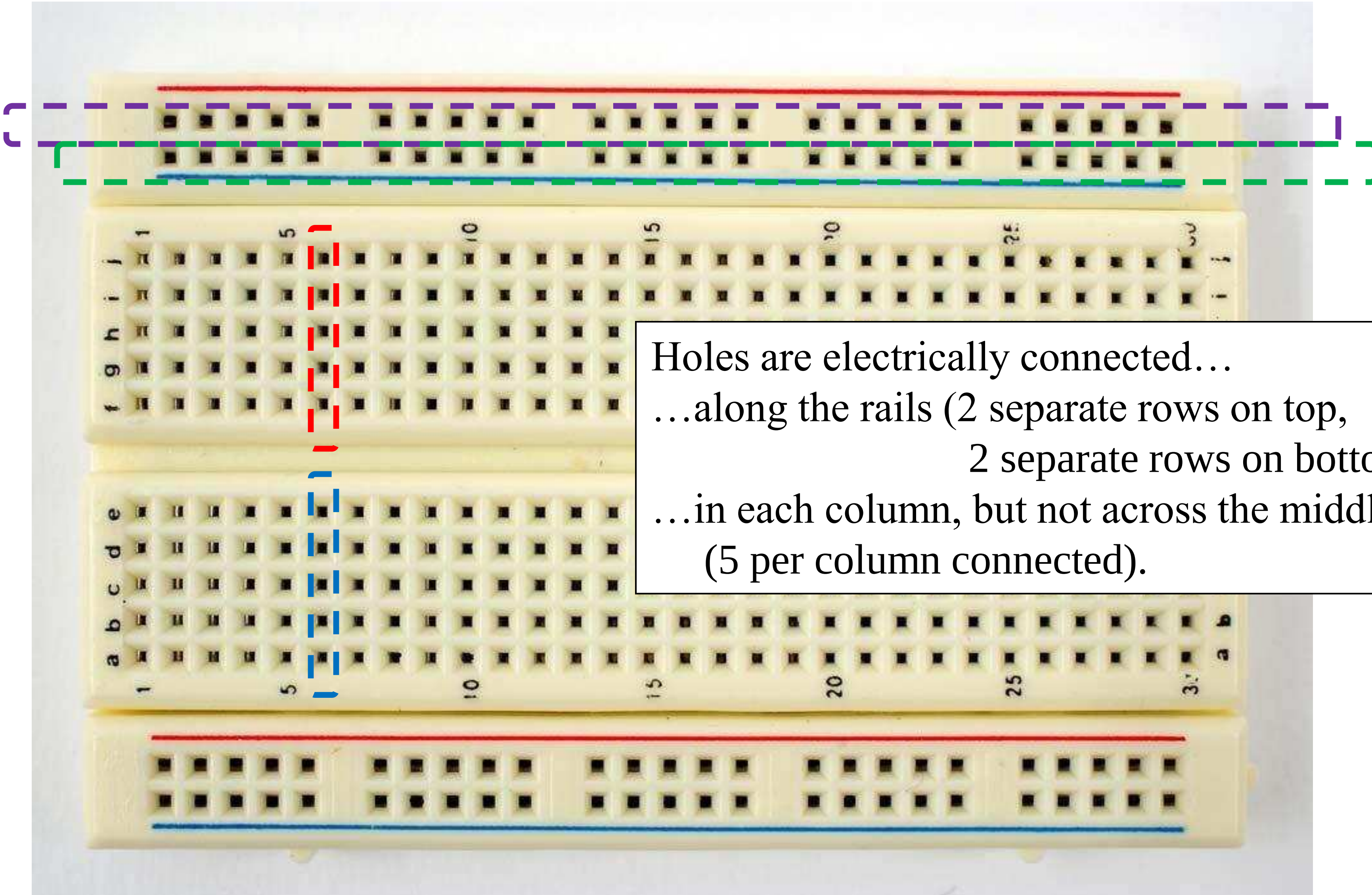
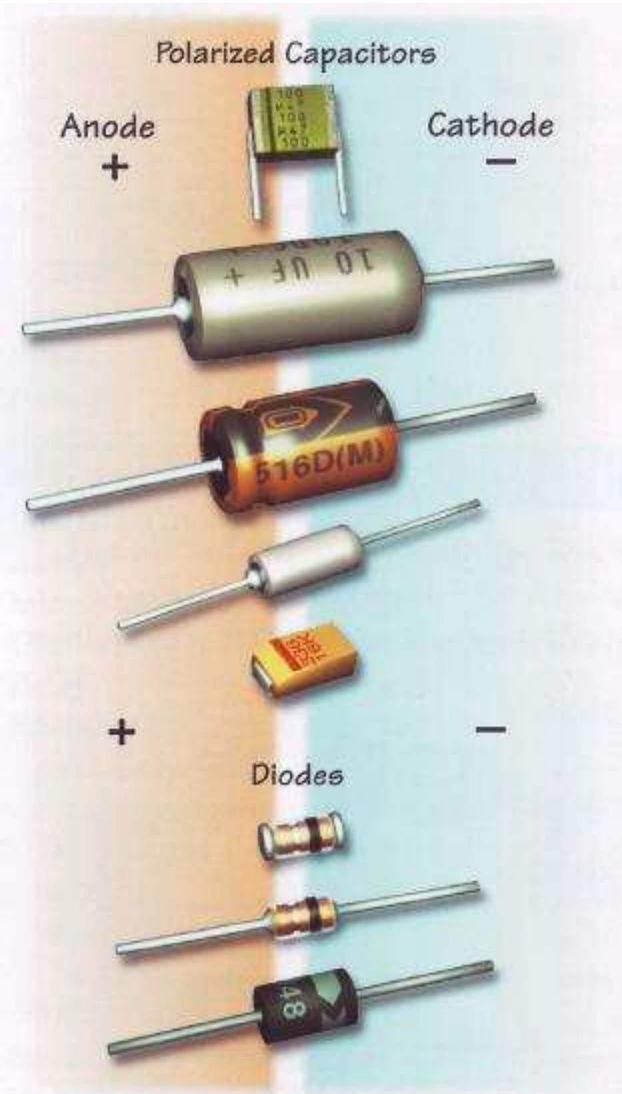
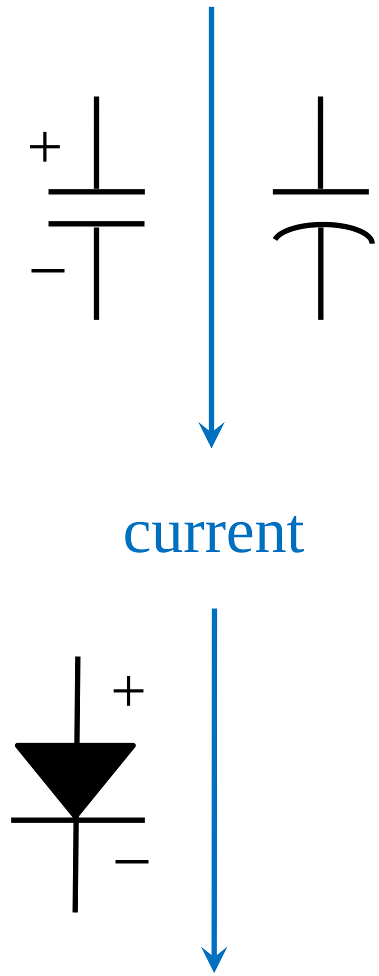


Holes are electrically connected…
…along the rails (2 separate rows on top,
2 separate rows on bottom).
…in each column, but not across the middle
(5 per column connected).

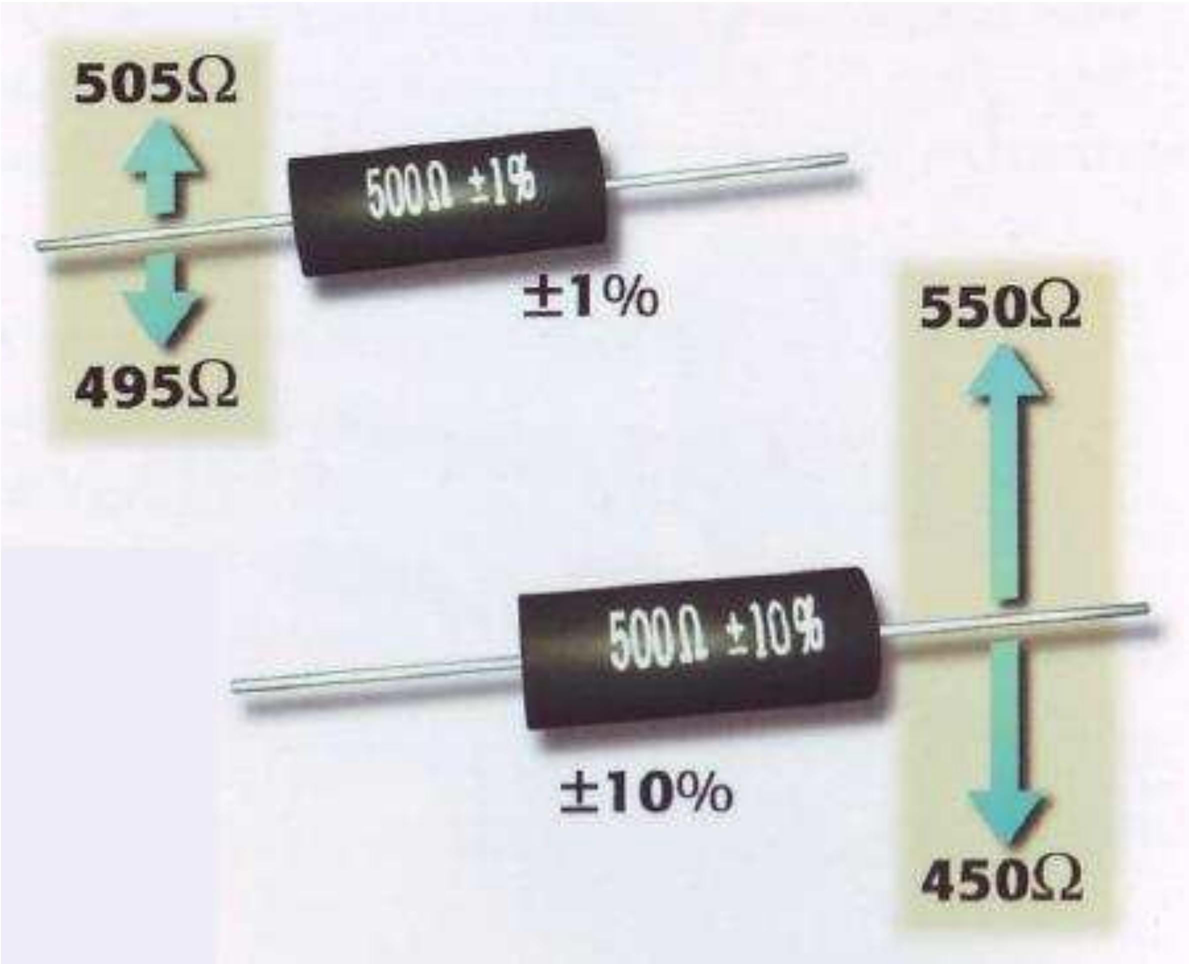
Polarity





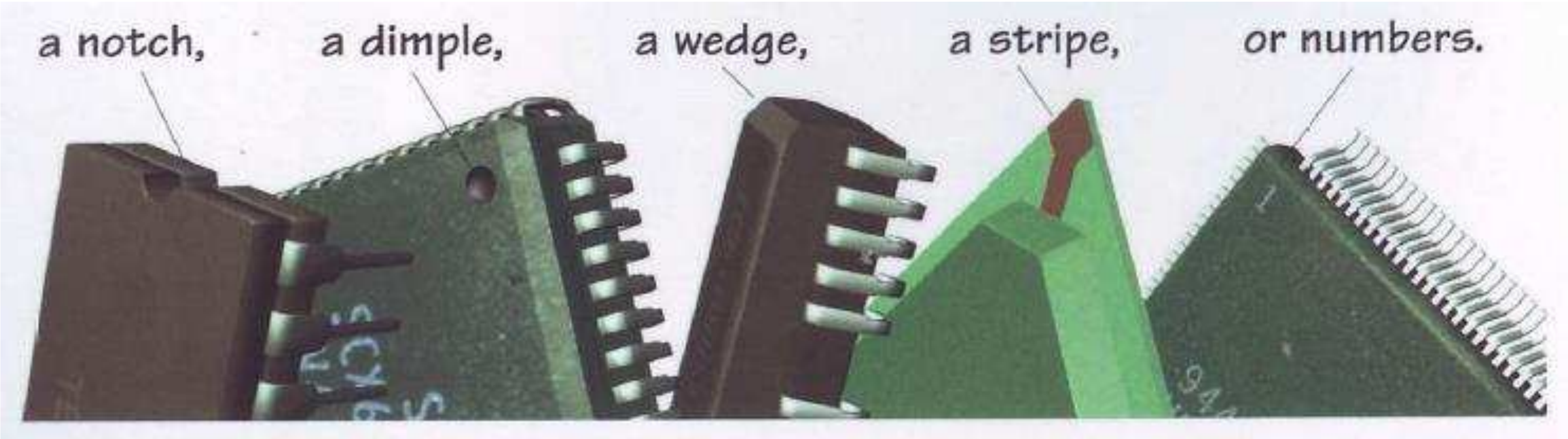
- The part is designed for current to flow along a designated direction.
- Forcing current flow in the opposite direction may damage the part.

Tolerance



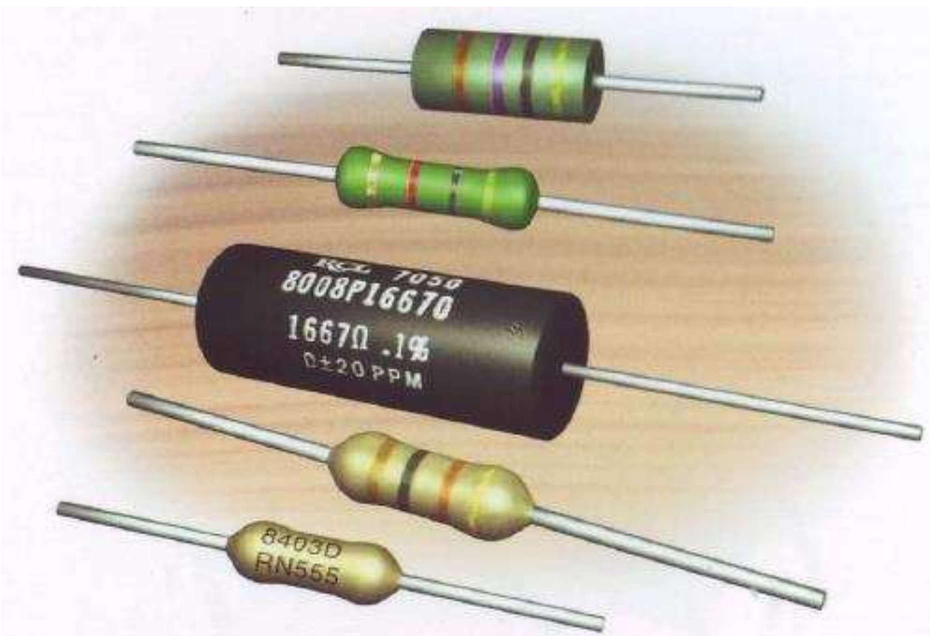
- The manufacturer guarantees that the part's value will fall within a certain percentage of the *nominal* value (above or below).
- Multiple parts cascaded together may deviate substantially from the nominal cascaded value.

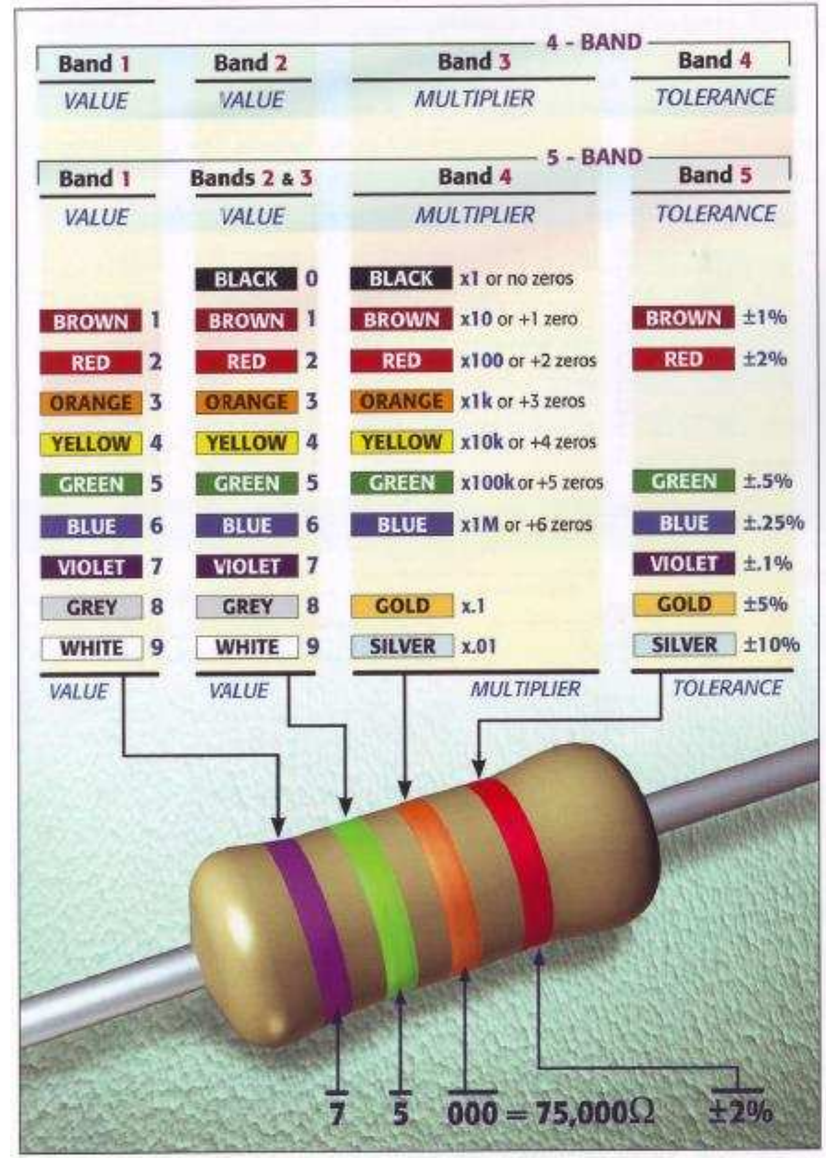
Component Orientation



- important to note for parts with multiple (3+) pins
- notch, dimple, wedge, etc. denotes **PIN 1**
- Numbering usually proceeds *around* the part
  (i.e. not criss-crossing *across* the part).
- When in doubt, check the manufacturer's datasheet.

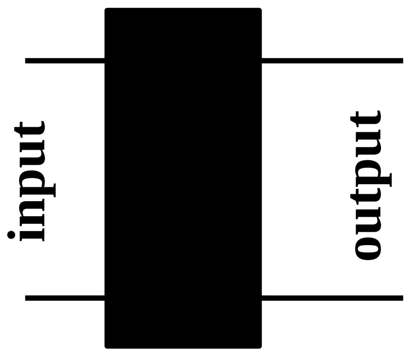
Resistors & Values



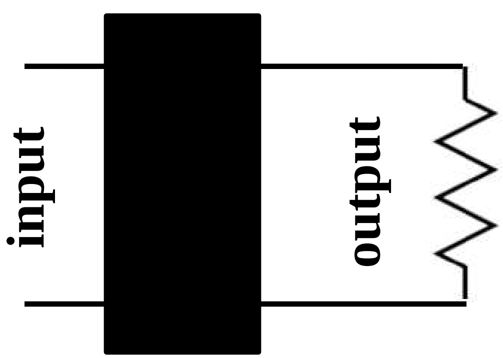


Resistance, Measured

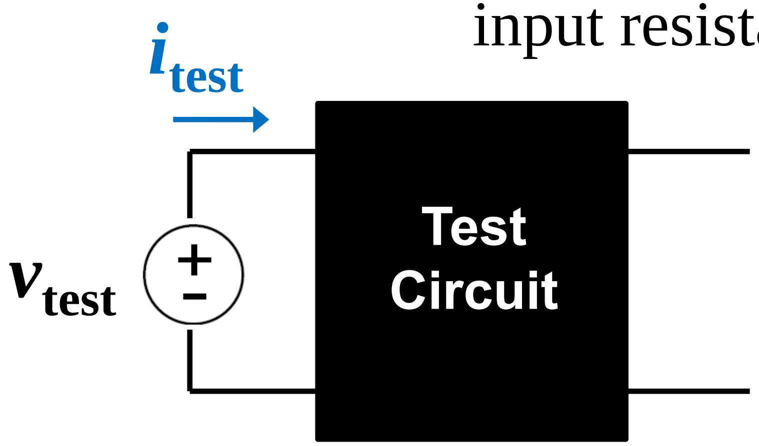
“unloaded” (output)



“loaded” (output)

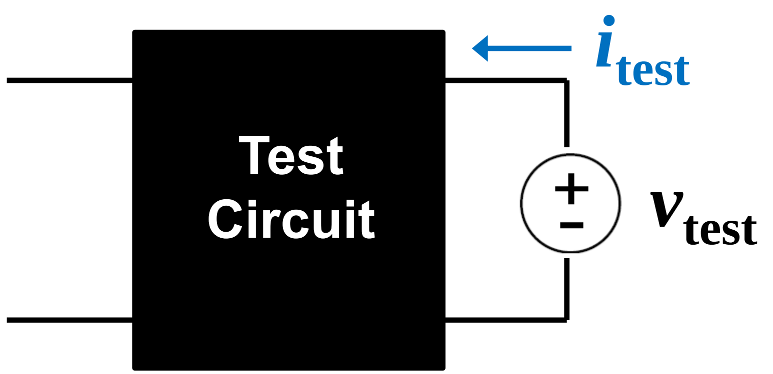


input resistance



$$r_{in} = \frac{v_{test}}{i_{test}}$$

output resistance



$$r_{out} = \frac{v_{test}}{i_{test}}$$

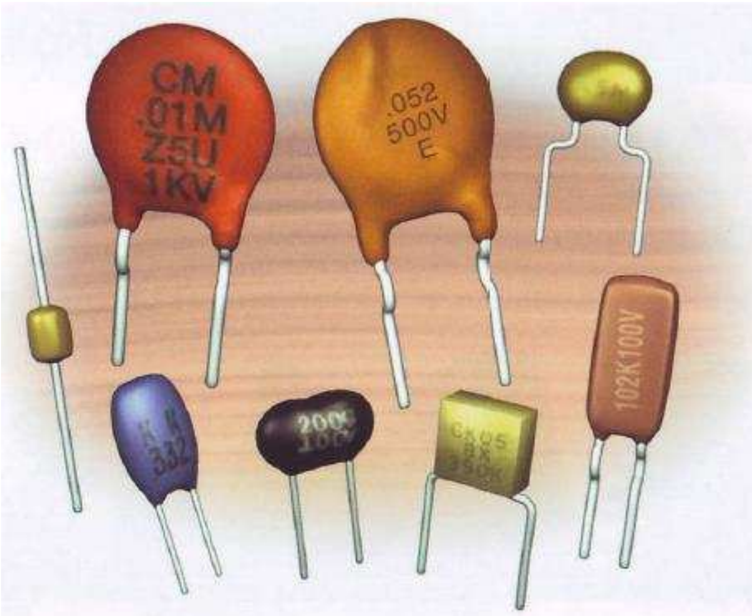
Resistive Decade Box

- resistance = 1 Ω to 999,999 Ω in 1-Ω increments
- set by adjusting the knobs on the front of the box (values add in series)

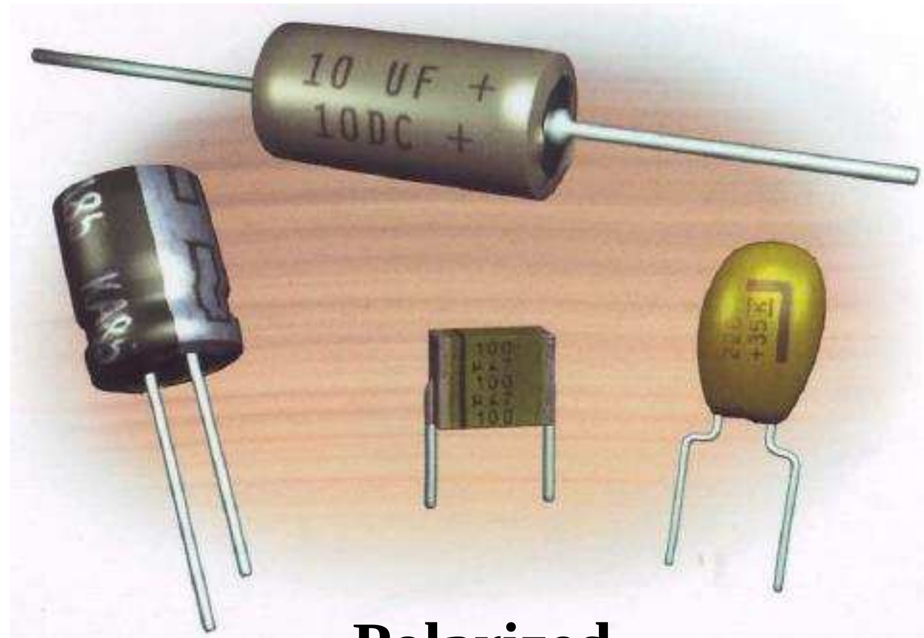
General Radio 1434-N

HeathKit IN-3117

Capacitors

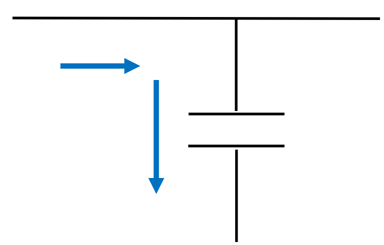


Non-polarized



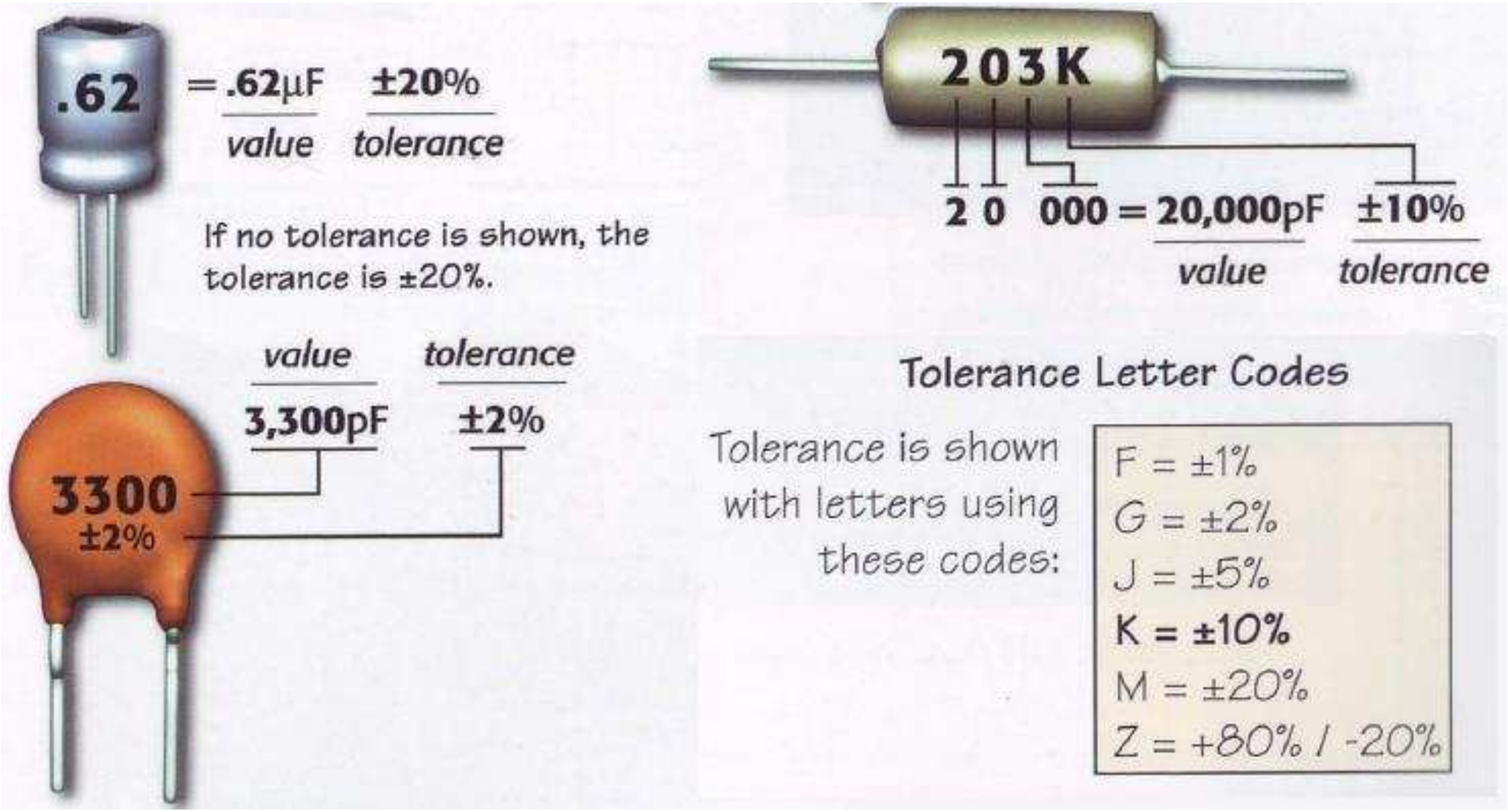
Polarized

A **bypass capacitor** allows an AC signal to follow a low-impedance path (i.e. to avoid being blocked by a high-impedance path).



(bypassed)

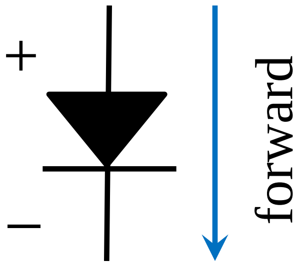
Capacitor Values



Diodes

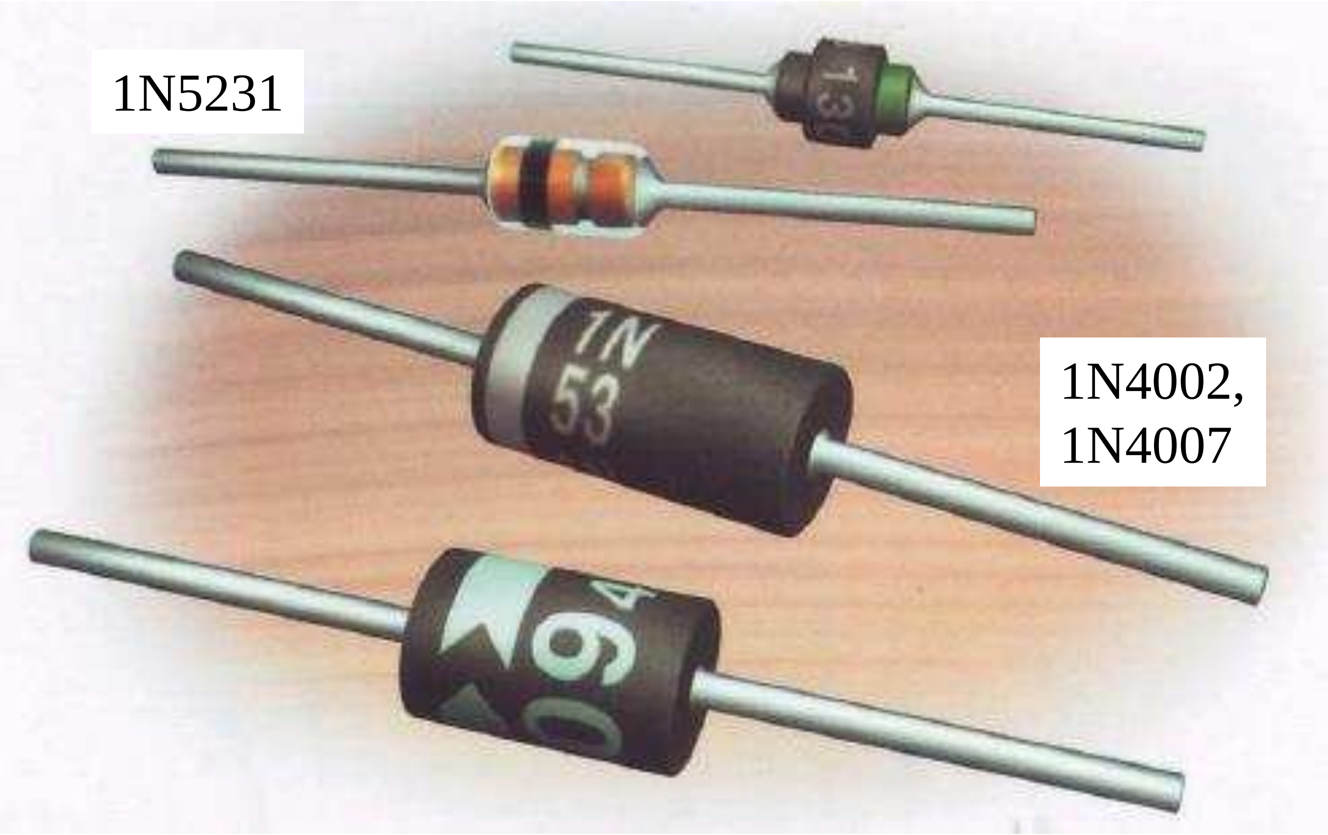
<u>turn-on voltage</u>

threshold for
forward conduction

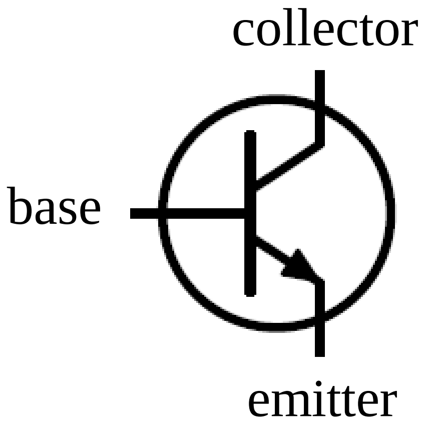


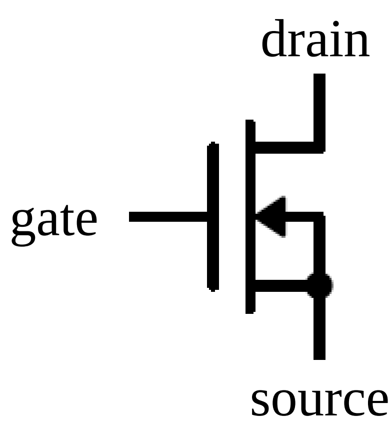
<u>break-down voltage</u>

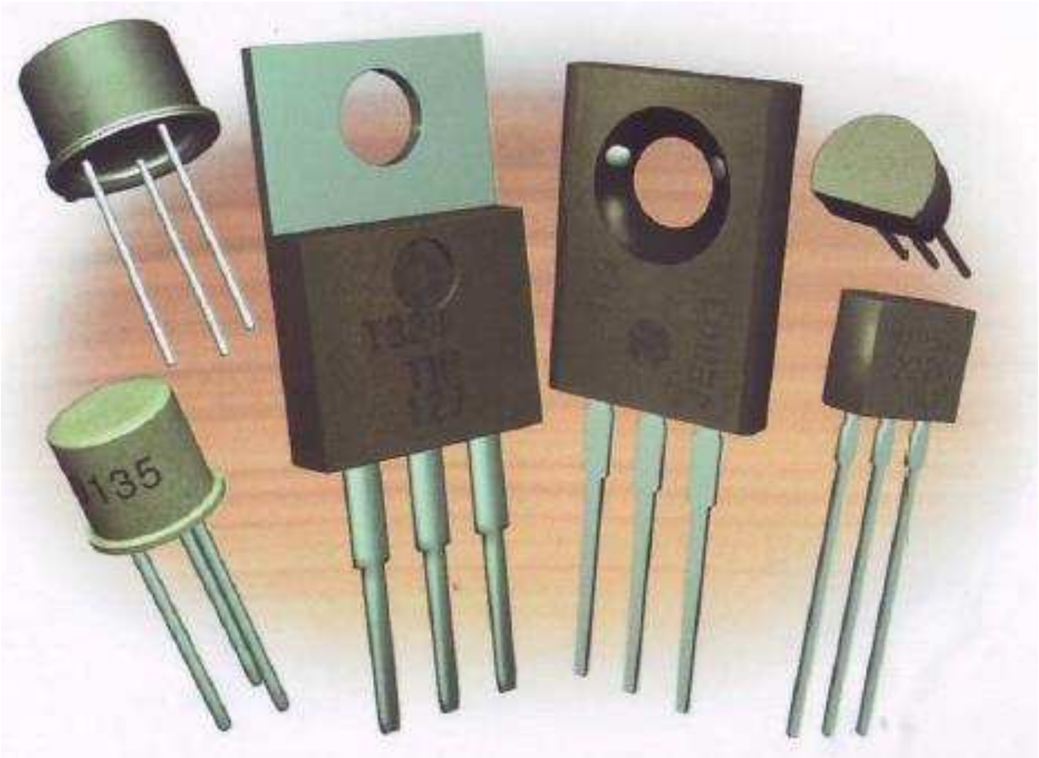
threshold for
backward conduction



Transistors



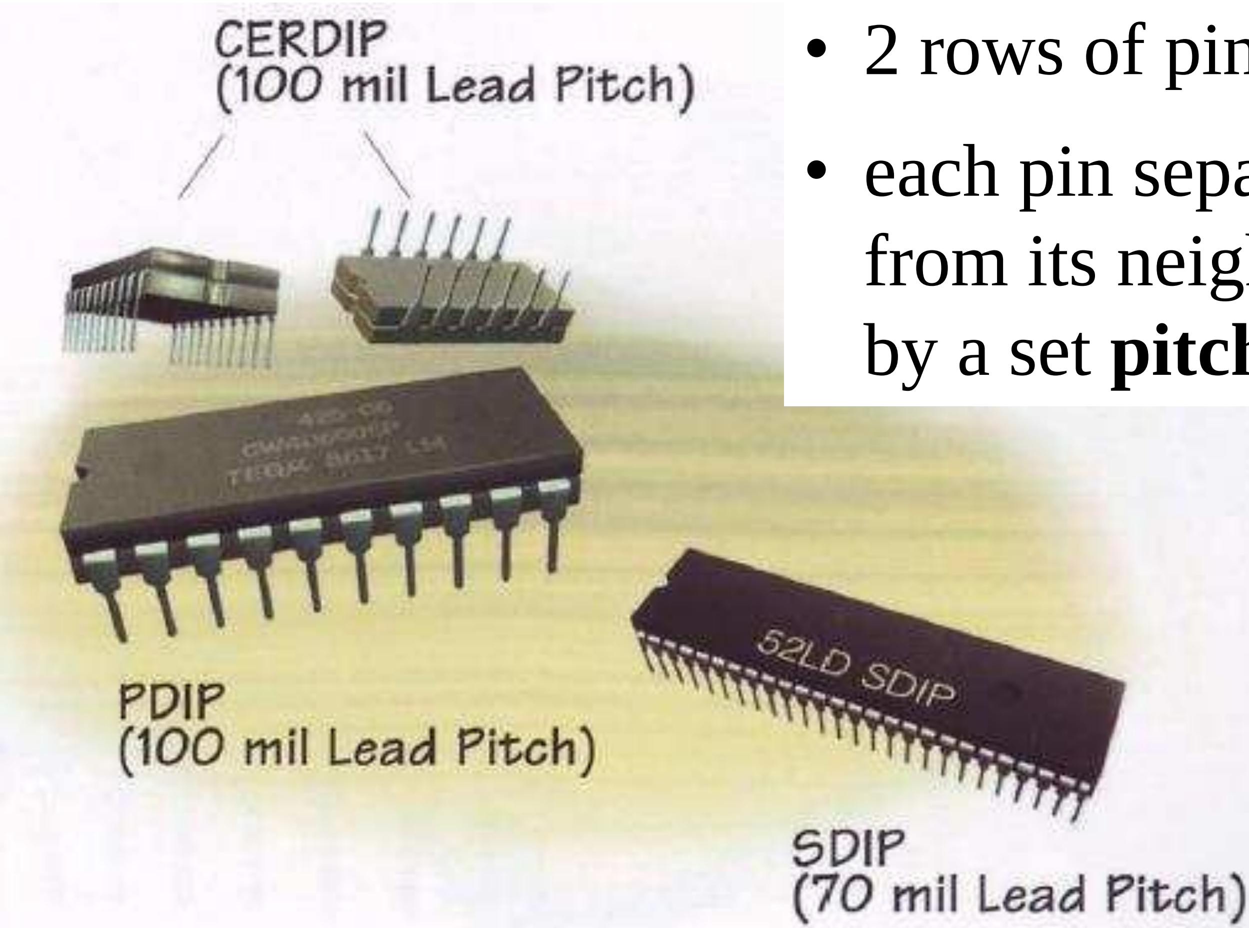




2N2222A
2N7000

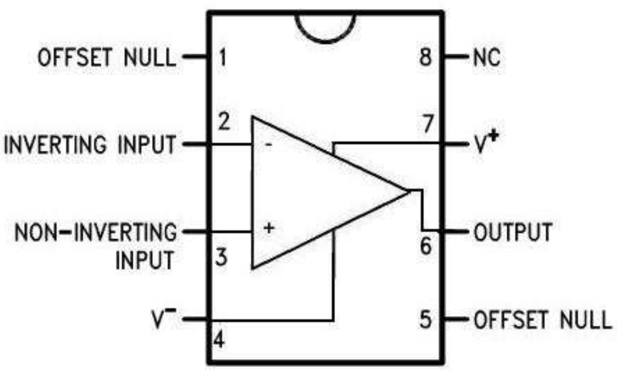
<u>threshold voltage</u>: minimum (base-emitter, gate-source) voltage to conduct current

Dual In-Line Package (DIP)

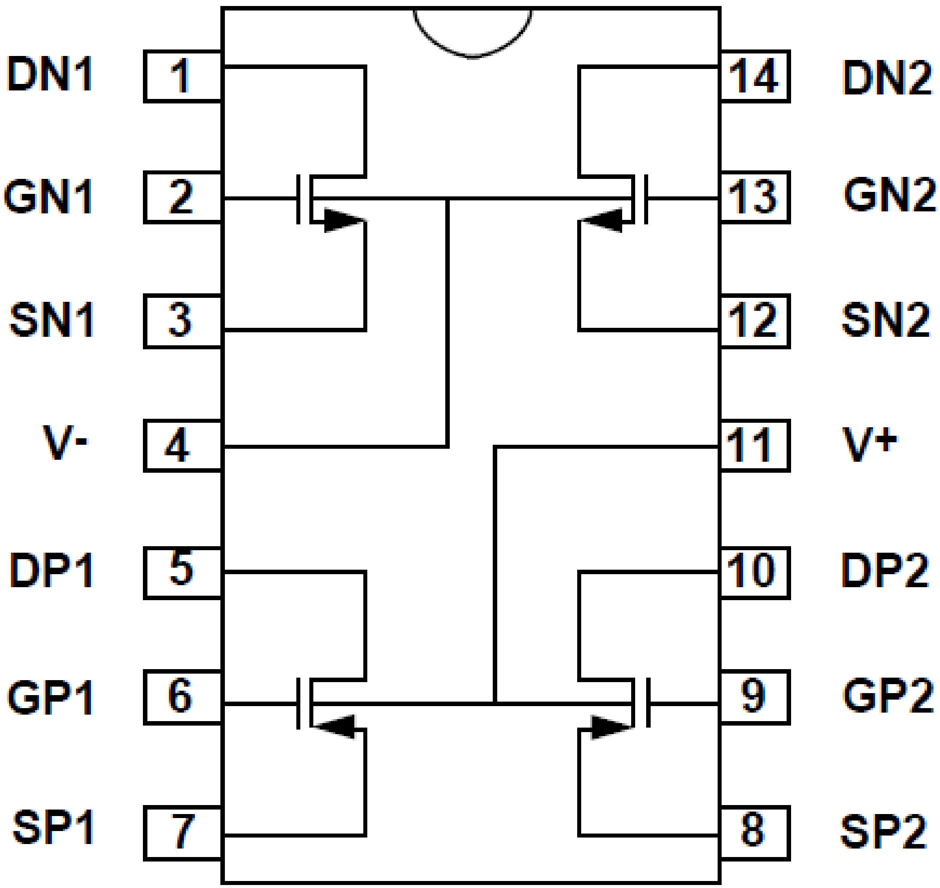


- 2 rows of pins
- each pin separated from its neighbors by a set **pitch**

<u>LM741</u>
operational
amplifier



Complementary Metal Oxide Semiconductor (CMOS) Circuits



ALD1105

<u>NMOS</u>:

conducts current from Drain to Source when Gate-Source voltage is **above** V_{th} (positive value)

<u>PMOS</u>:

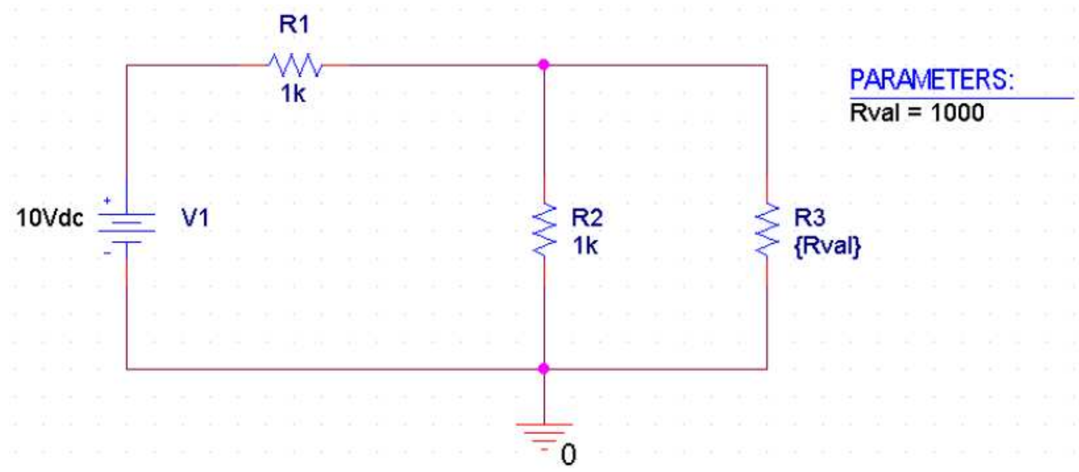
conducts current from Drain to Source when Gate-Source voltage is **below** V_{th} (negative value)

Lab Orientation Outline

- **ELEC 313 introduction**
  - Syllabus, lab notebooks, lab reports
- **Laboratory equipment**
  - Signal generation & capture hardware
- **Circuit terminology**
  - Essentials from ELEC 201, 202, 204
- **Electronic components & breadboarding**
  - Parts used for experiments
- **PSpice circuit simulator**

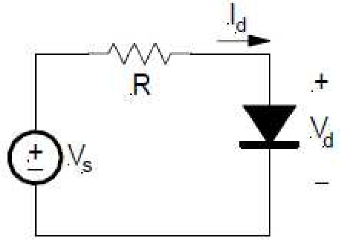
PSpice

- tutorial & download instructions available on the course website
- software is available on ECE Dept computers
- PSpice exercises start with Pre-Lab #2



PSPICE Models

1. Model the following circuit using PSPICE. The diode is a 1N4002.



Given V_s=10 V, determine the dc operating point for R= 200, 500, 1K, 2K, 5K, 10K, 20K, 50K, and 100K. Make a table of your results.

for Next Class (Lab #1)

Check that you received an e-mail from your instructor.

Choose a lab partner and obtain a lab notebook (1 per team).

- Complete the pre-lab assignment for Lab #1.

Using the course website…

- read the Lab Notebook Guidelines.
- read the Lab Report Guidelines.

If you have time…

- follow the PSpice Tutorial: download & install

Remember: There is no lab next week.
Labs begin the week of 9-Sept.