EE122A - Introduction to Electronic Circuit Design

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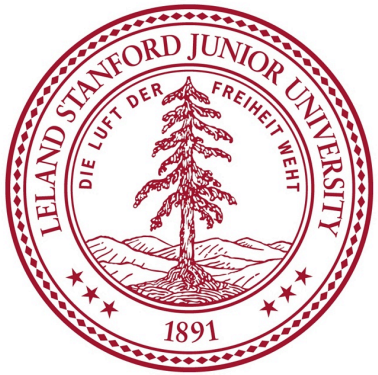


About EE122A

- As taught at Stanford, EE122A was hands-on, based on laboratory learning. Over time, it evolved so that many of the labs could be done "at home" with loaned out kits.
- **Prerequisite**: basic electronics laboratory experience with ***solid working knowledge*** of circuit analysis, Fourier and Laplace methods. Sadly, this working knowledge is getting less common in EE students as the "menu" of courses broadens and fewer universities maintain "core competency" mandatory course requirements for EE undergraduates.
- Practical content but learning depends on student involvement and effort, particularly reading ahead.
- Preparation for laboratories will involve reading, research and design.
- **Lab books** were used for data taking and considered in grading for completeness, logic and neatness. These days, much of this has become electronic.
- **Mandatory final demos** were given by each team to the entire class. Projects that did not "work" were ok, as long as it could be explained and there was a "get well plan" that could be followed if there was time.
- **Final reports** were in the form of an "Instructable" (open-source, hacker-oriented project guide as seen here: http://www.instructables.com

EE122A Course Goals

- Understand how real electronics work and learn how to design, build and debug circuits.
- Build intuitive circuit design knowledge.
- Understand the role of digital circuits and digital signal processing (DSP) in modern mixed-signal circuits, and the *continuum between analog and digital modes.*
- Learn about sensors, actuators and interface circuits.
- Learn the Arduino microcontroller and see how it facilitates mixed-signal designs.
- Get hands-on experience with teamwork in experimentation, documentation, and design.
- Have fun!

Some Basic Things You Need to Handle ASAP

- Know how to use Excel, Word and ideally Matlab.
- Be prepared to spend *significant time* learning how instruments work in the lab (including Electronics Explorer, Analog Discovery and the Waveforms™ software for it), how to use the Arduino environment, and how to use other hardware/ software tools.
- Find a form of SPICE that you are comfortable with. TA will help. We will provide a version of SPICE (TINA) on the lab computers.
- Understand the format and intent of "Instructables" so that you can plan your final report.

Simulation Tools

- TINA will be installed on the lab machines.
- Some students like MultiSim.
  If you wish, you can download the trial version: http://www.ni.com/academic/multisim.htm
- Note that a free version, limited to Analog Devices components, can also be downloaded at:
  http://www.analog.com/en/content/CU_multisim_SPICE_program_download/fca.html
- Another option is LTspice, freely available on Linear Technologies website: http://www.linear.com/designtools/software/ltspice.jsp
- Your TA will be giving a tutorial on SPICE simulations during the first week of classes.

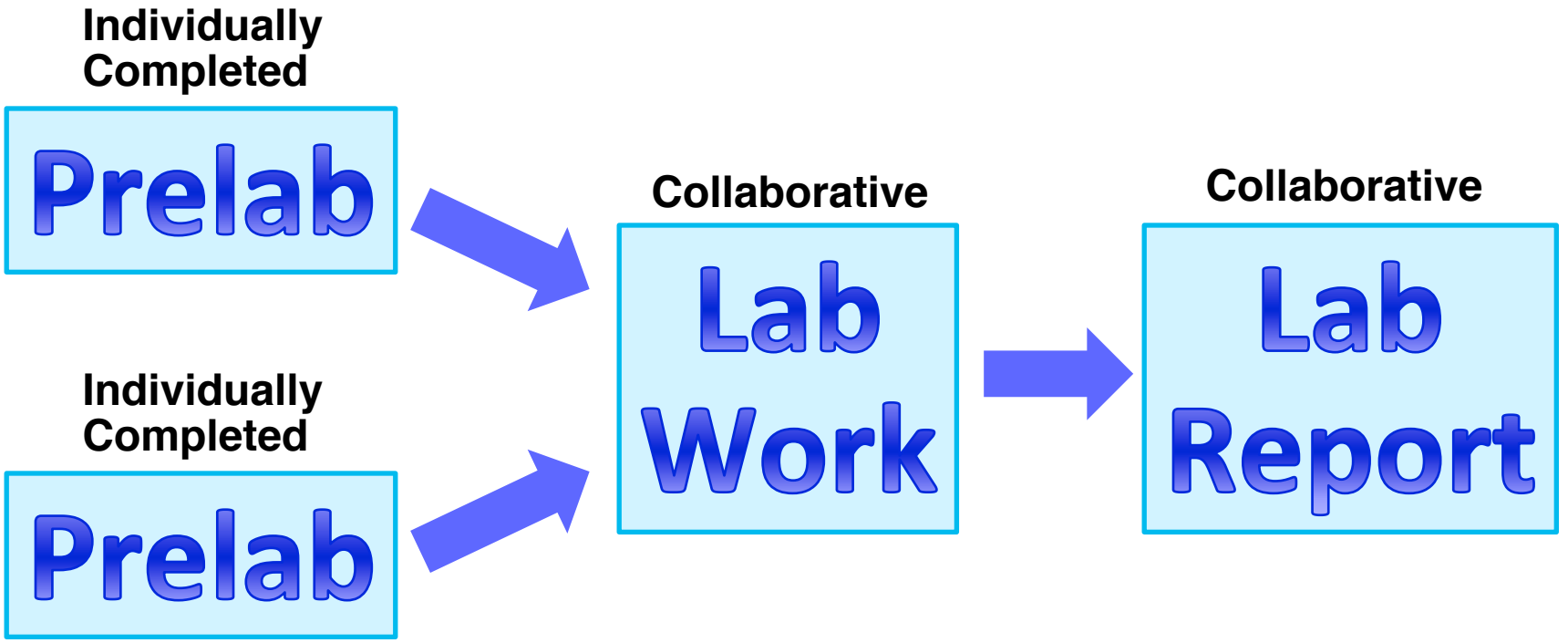
Grading

- Prelabs (individual) – 10%
- Formal lab write-ups (team) – 20%
- Midterm (take-home, individual, TBD) – 20%
- Final project including lab books and report (team, 30% write-up, 10% demo) – 40%
- TA evaluation of laboratory skills (individual) – 10%
- *Optional* extra credit projects (ask if you want one).

Lab Workflow

- Prelabs are ***due electronically*** at or before the beginning of the lab in question. Students need to bring a hard- or soft-copy to refer to during the lab. Beware – you will not be allowed to start your lab before handing in the pre-lab!
- Students will compare notes during the lab and carry out the physical work together and write it up together later.

Lab Workflow



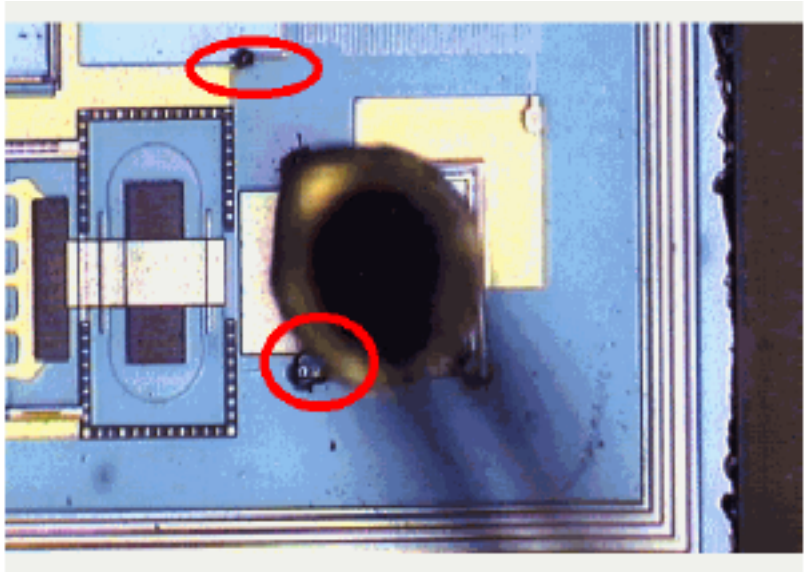
Lab Reports

- Lab write-ups are ***due electronically*** the Monday *after* the lab in question.
- Students are expected to work together on all aspects of each lab report.
- Lab write-up guidelines:
  - Complete info on methods (voltages, currents, etc.) – enough to replicate the work correctly.
  - Data and plots as necessary.
  - No unnecessary "fluff" like datasheets, paragraphs of poetry, etc.
  - Schematics - clear and readable - as needed (can be entered on computer or just hand-drawn and scanned in).
  - Clear observations and conclusions, supported by data.
  - Keep the whole thing concise, neat, and organized.

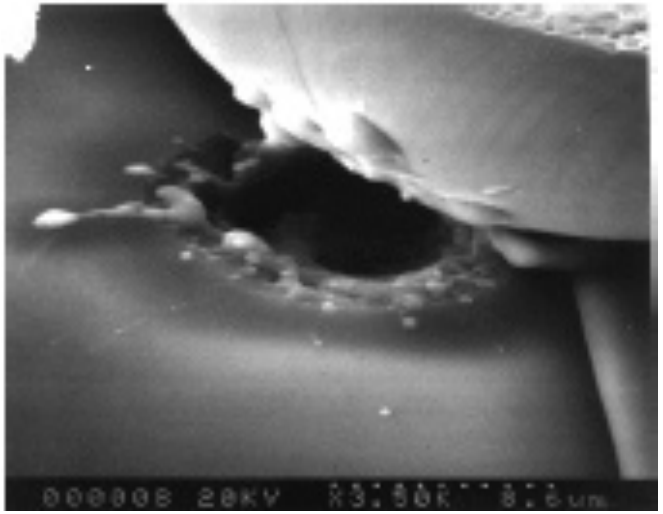
Safety Issues

- **Electricity can kill you.**
- **No students can work in the lab without a TA present. No exceptions. Do not ask for exceptions.**
- **Keep voltages below +/-15 V unless specifically authorized.**
- **No line-powered projects please. Use the bench power supplies, "wall wart" AC adapters, solar cells, or batteries.**
- **No circuits may directly (electrically) interface to the body (unless explicitly approved and always isolated).**
- **You must sign and turn in the EE122A Safety Agreement before taking this class.**

Electrostatic Discharges



- "Normal" static electricity we carry can severely damage CMOS chips.
- With POWER OFF, touch something grounded before handling a chip.
- Once on a board, the chips are pretty safe.



Photos Courtesy of Analog Devices.

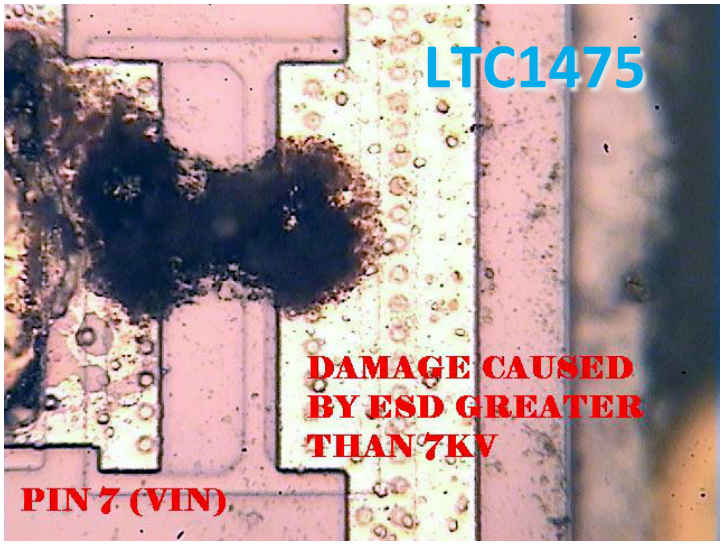


Photo Courtesy Linear Technology.

Important Point:
Groups who do not clean up their bench will forfeit their entire TA lab evaluation score, which is 10% of the overall grade.

Clean up means (at the very least):

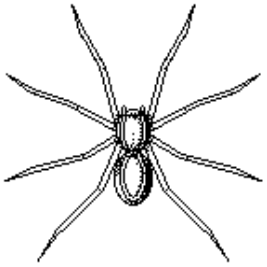
1. **Parts returned to bins or TA.**
2. **Soldering iron unplugged (off!).**
3. **Tools and scope probes accounted for and put away in box.**
4. **Bench surface clean and neat.**

Keep It Neat

How To De-Bug A Circuit...

INITIAL STEPS

1) IF THE POWER IS ON AND NOTHING WORKS, BE SURE TO TURN IT OFF!
2) CHECK THE ORIENTATION OF ALL TRANSISTORS, DIODES, INTEGRATED CIRCUITS, POLARIZED CAPACITORS, ETC.
3) CHECK ALL COMPONENT TYPES/VALUES TO MAKE SURE THEY ARE CORRECT.



ONLY IF THIS ALL CHECKS OUT SHOULD YOU GO ON TO THE NEXT STEPS WITH THE POWER ON...

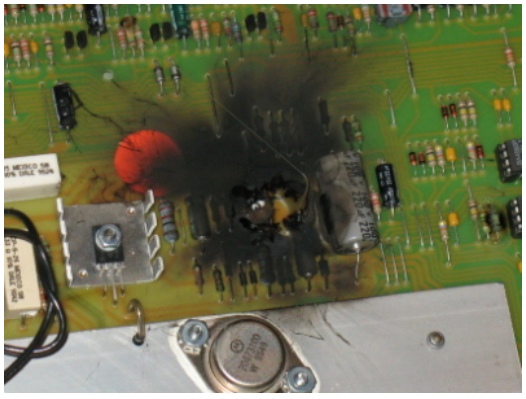
4) TURN ON THE POWER AND MEASURE VOLTAGES AROUND THE CIRCUIT....

   USE YOUR HEAD! THINK ABOUT WHAT VOLTAGE LEVELS *SHOULD* BE.

5) IF THERE ARE ANY POTENTIOMETERS IN THE CIRCUIT, TRY SETTING THEM TO THE MIDDLE OF THEIR RANGES....

6) IF THAT FAILS TO MAKE YOUR CIRCUIT WORK, CHECK ALL SEMICONDUCTOR COMPONENTS (TRANSISTORS, DIODES, INTEGRATED CIRCUITS, ETC.) IN CASE THEY ARE BURNED-OUT.....

7) ASK FOR HELP FROM THE PROF OR TA!!!



http://www.diyaudio.com/forums/solid-state/119770-blown-peavey-supreme.html

Projects

- A good project is vital for EE122A.
- We have a list of **pre-approved projects** for you to choose from.
- You may, if you do it within the first few weeks of the quarter, propose your own project idea. If you do, you will need to address the following points (not easy):
  - Original concepts.
  - Non-repetitive design (a bank of ten filters at different frequencies is considered repetitive).
  - Sufficiently complex to be significant - not a "lightbulb and switch."
  - Carefully designed - not copied from a book or the web.
  - Fairly divided workload between team members.
  - Short, clear and organized presentation and demo.
  - Not using RF.
  - Not using too much digital (if in doubt, ask) – an Arduino is ok.
- ***Teams must finalize their projects within a few weeks. Think about it.***

Pre-Approved Project Ideas

- Op-amp tester (Arduino-controlled, read-out on laptop screen).
- Semiconductor curve tracer (Arduino-controlled, read-out on laptop screen).
- Digital audio analyzer (spectrum analyzer) with remote microphone and creative display (e.g., giant LED display).
- Digitally controlled, three-channel power supply.
- Programmable LED lighting system with high-efficiency.
- Noise-canceling headphones (requires a lot of thought).
- Polyphonic (multiple voice) analog synthesizer controlled by a digital system (Arduino).
- All-analog control loop (PID) for mechanical system to be determined together.

Project Design Proposals

- **For each project, we require a well-researched (i.e., study the issues, talk to your TA - no last-minute crap) paragraph and block diagram describing:**
  - **Overall goals and functions (i.e., what we would look for to be well done when grading the project!) and some comment on why your approach is creative.**
  - **Indication that this project uses significant knowledge from EE122 (*you absolutely must look through the later lectures to understand the scope of this knowledge*).**
  - **Clear indication that you understand more-or-less how to design and build your proposed circuit.**
- **You must involve and agree with your lab partner(s).**

Final Project Write-Ups

- **Final project write-ups will be in the form of "Instructables" – an open-source concept for sharing creative ideas.**
- **Demo video, detailed construction plans, schematics, code and any other necessary details must be embedded in the document, which may be submitted as a PDF.**
- **Completeness – someone else being able to replicate the project – is critical.**
- **Extra effort should go into explaining how the circuit and code work.**

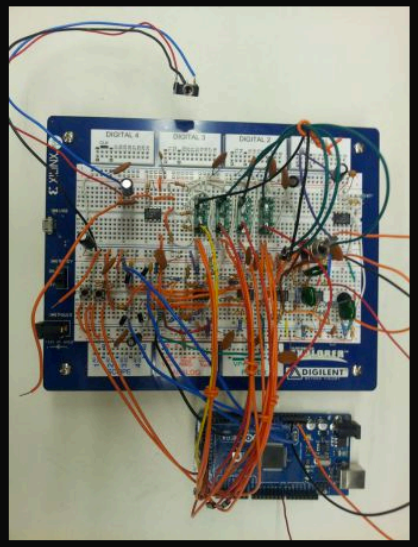
Example EE122A Project On Hackaday

HACK A DAY

HOME | OUR VIDEOS | SUBMIT A TIP | FORUMS | STAFF | DECEMBER 16, 2013

DIY Hearing Aid

December 15, 2013 by Eric Evenchick · 13 Comments



Hearing aids are expensive little devices, typically costing a few thousand dollars each. They need to be highly integrated to fit in the ear, while still providing signal processing to ensure good audio quality.

This DIY hearing aid does some intelligent signal processing. It uses an electret to capture audio, then uses a pre-amplifier to increase the gain 100 times. The next stage consists of four filters, dividing the input signal by frequency into four parts. These are passed into four LTC6910 programmable gain amplifiers, which allow an Arduino to control the gain of each channel. The LTC6910 takes 3 digital inputs that are used to set the gain value.

To determine which gain to use for each frequency band, the Arduino needs to know how much power is in each band. This could be done using a Fast Fourier Transform, but that would require quite a bit of processing power. Instead, an envelope detector averages the signal, which can be read by an analog input on the Arduino. Using this information, the hearing aid can boost specific frequencies when it detects conversation.

This hearing aid won't quite fit in your ear, but there is a lot of interesting signal processing going on. The schematic, Arduino source code, and a MATLAB simulation are provided.

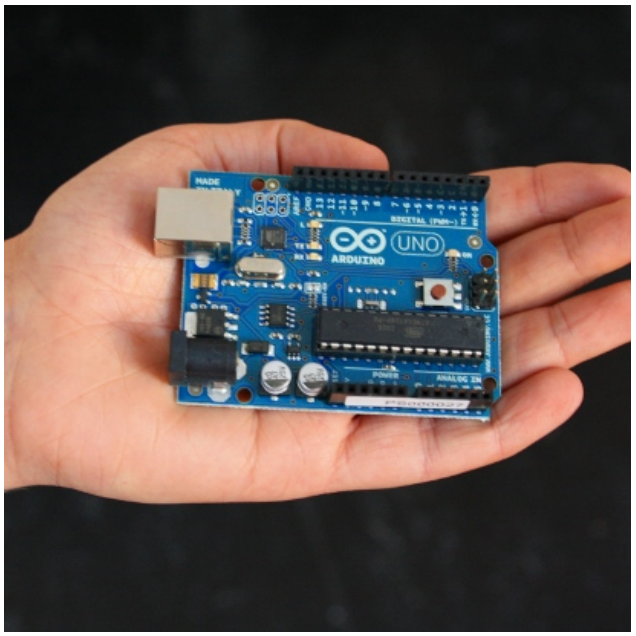
Related Hacks

Arduino + Shields

Brains For EE122A

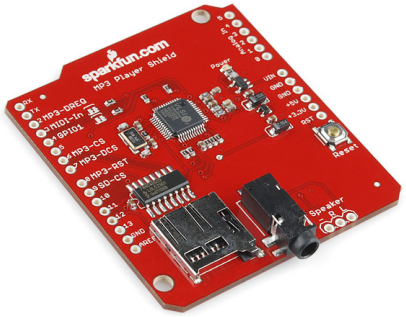
Arduino

- http://www.arduino.cc/
- Open-source microcontroller with analog I/O.
- Cheap ($30), easy, and ok to use to control EE122A/B projects.
- Uses add-on cards or “shields” to add capabilities – we will do that.
- Tutorials, examples will be provided.

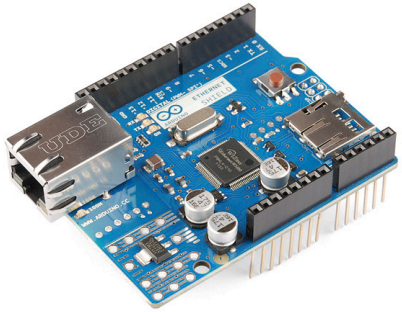


Arduino Shields

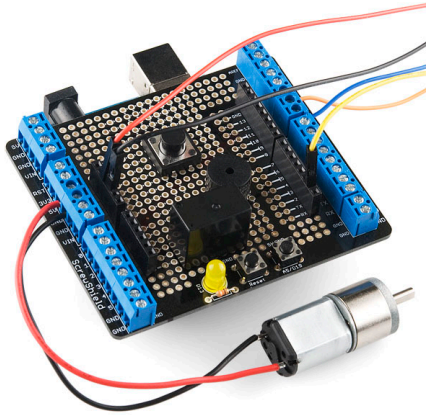
- http://www.arduino.cc/
- **Plug-in circuit boards that add functions like displays, switches, relays, robot motor drivers, WiFi, etc., etc.**



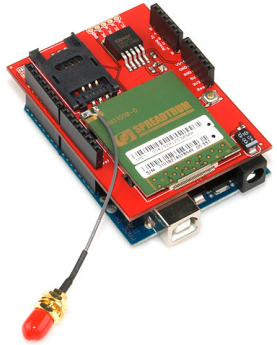
MP3 Player



Ethernet



Prototype



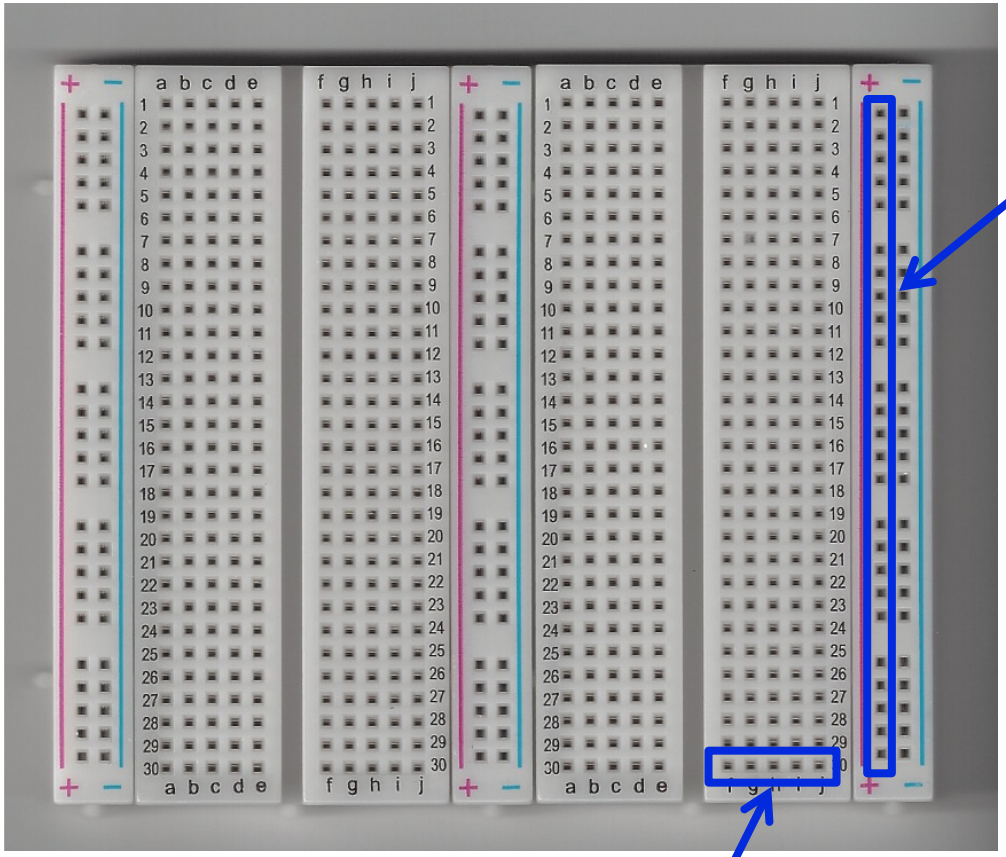
Cellular Phone

https://www.sparkfun.com/categories/240

Electronic Components

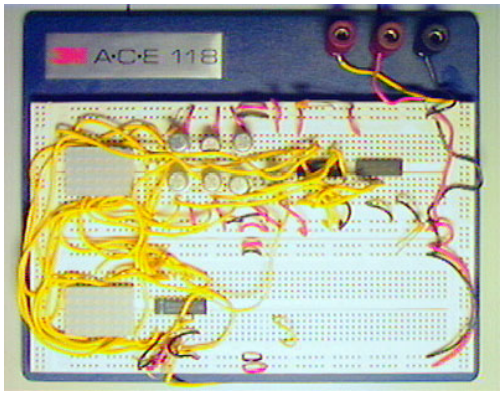
The Raw Materials For EE122A

Prototyping Boards

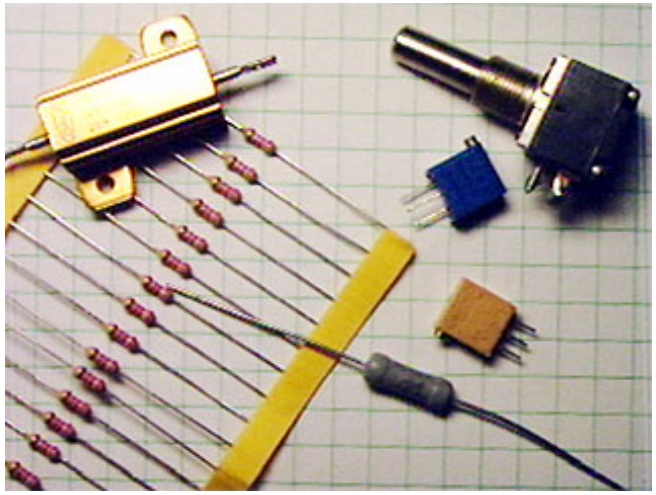


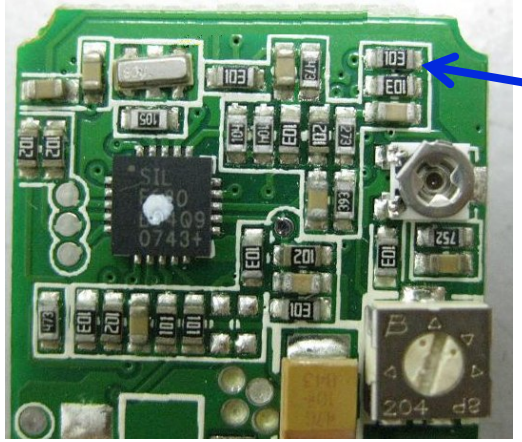
Buses for power and ground.

Rows of five pins connected together for wiring.



RESISTORS



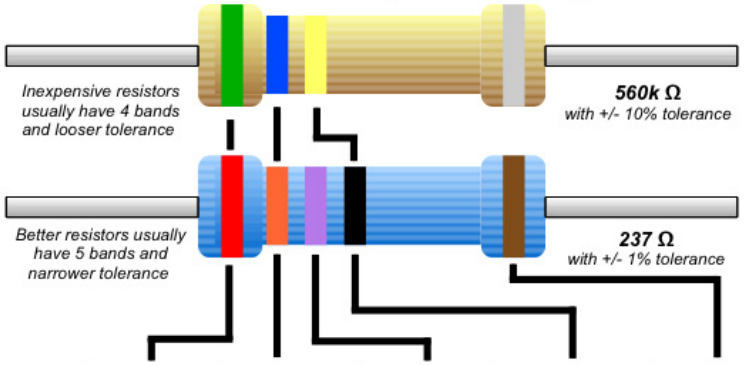


Surface-mount resistors

http://www.talkingelectronics.com/projects/Testing%20Electronic%20Components/TestingComponents.html

Resistor Identification

The end with more bands should point left when reading colors.



Color	1st Band	2nd Band	3rd Band	Multiplier	Tolerance
Black	0	0	0	x 1 Ω	
Brown	1	1	1	x 10 Ω	+/- 1%
Red	2	2	2	x 100 Ω	+/- 2%
Orange	3	3	3	x 1K Ω	
Yellow	4	4	4	x 10K Ω	
Green	5	5	5	x 100K Ω	+/- .5%
Blue	6	6	6	x 1M Ω	+/- .25%
Violet	7	7	7	x 10M Ω	+/- .1%
Grey	8	8	8		+/- .05%
White	9	9	9		
Gold				x .1 Ω	+/- 5%
Silver				x .01 Ω	+/- 10%

Surface-Mount

Surface-Mount (SMD) resistors use a similar system. Resistance is indicated by a 3-digit code like 104, sometimes followed by a letter. Rare, precision resistors have 4 digits (3+multiplier).

104

1st Digit	2nd Digit	3rd Digit (rare)	Multiplier
1	0		4

(10 with 4 zeros) = **100k Ω**

- 0 Ω resistors (marked "0") are used instead of wire links to simplify robotic assembly.
- Resistors less than 100Ω use a 0 multiplier to mean "x 1" so "100" = 10Ω, "470" = 47Ω

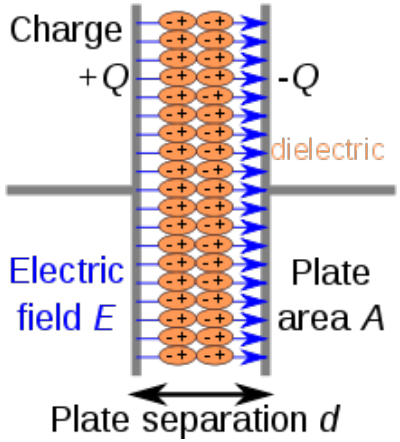
This is a low-res version of the PDF available on www.zachpoff.com

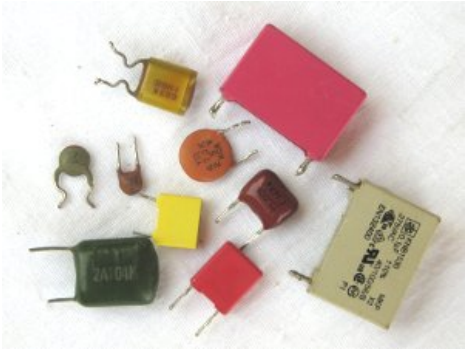
http://interactivecollege.com/Electronics%20and%20Computers/Resistor%20Identification.jpg

CAPACITORS

POLARIZED!

Tantalum





Polystyrene, Mica, etc.

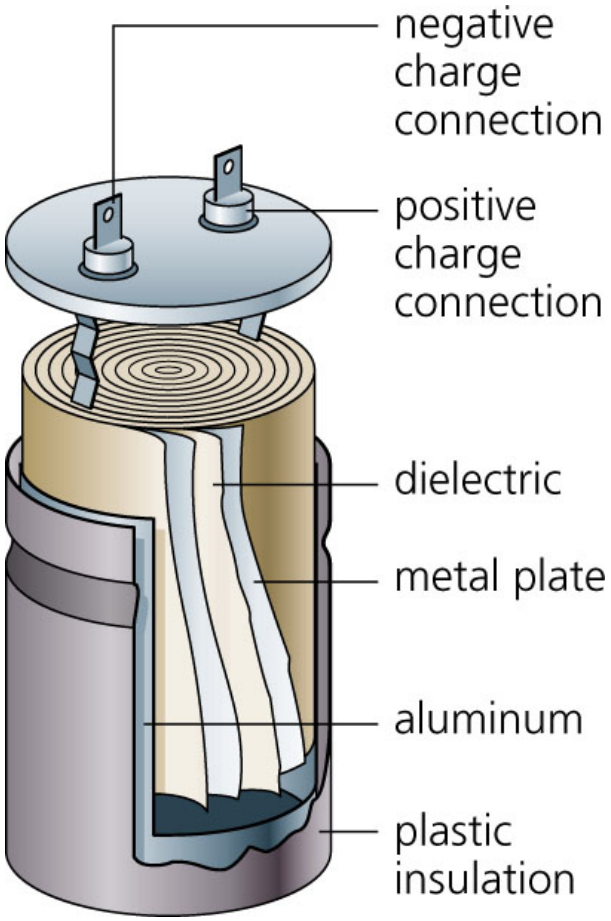
http://www.frankshospitalworkshop.com/electronics/training_course_capacitor.html

POLARIZED!

Electrolytic

http://en.wikipedia.org/wiki/Capacitor

CAPACITORS CONSTRUCTION



Electrolytic capacitor

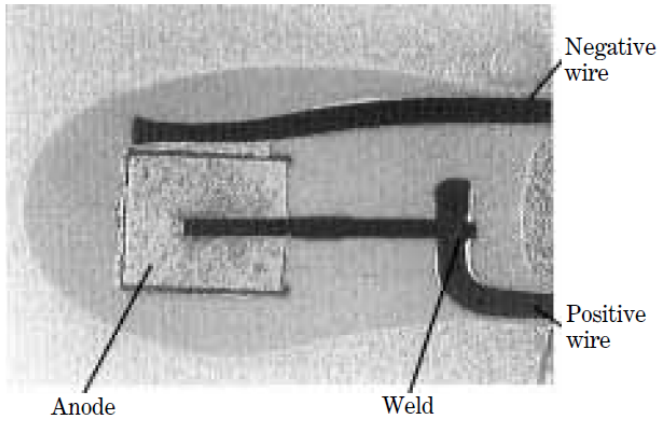
http://freecircuits.org/wp-content/uploads/2012/01/Inside-capacitor.jpg

Electrolytic capacitors contain nasty liquid ooze that stores charge in an electrochemical reaction...

They are polarized... If you hook them up backwards, they tend to explode!
Note that tantalum capacitors are also polarized.

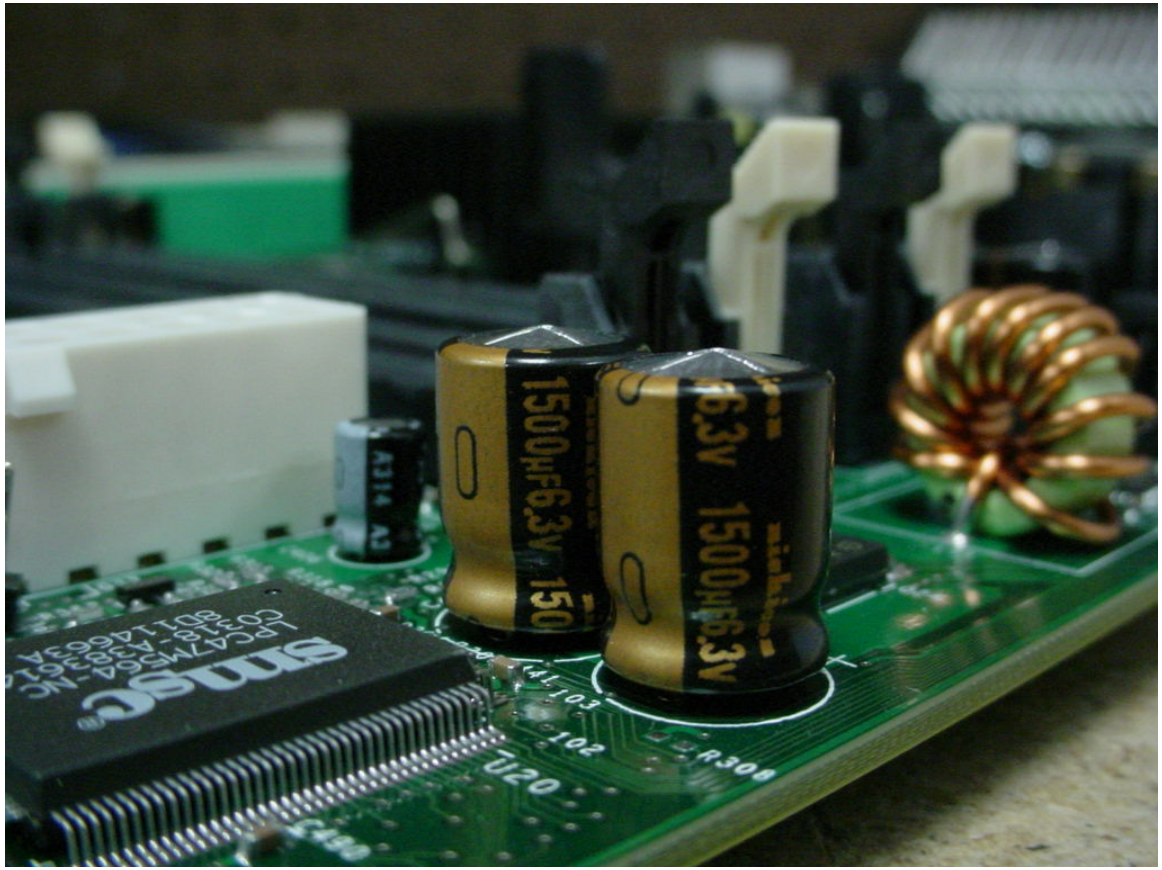
Mica or polystyrene capacitors are made of parallel plates (just like they told you in physics class)...
They are not polarized.

Tantalum capacitor (from John Gill, AVX Ltd.)



Exploding Caps Plague Dell

- Poor industrial espionage in Taiwan led to the manufacture of tons of capacitors but without a few key chemicals in the electrolyte, greatly reducing their service lives…
- This cost Dell at least $300 Million!

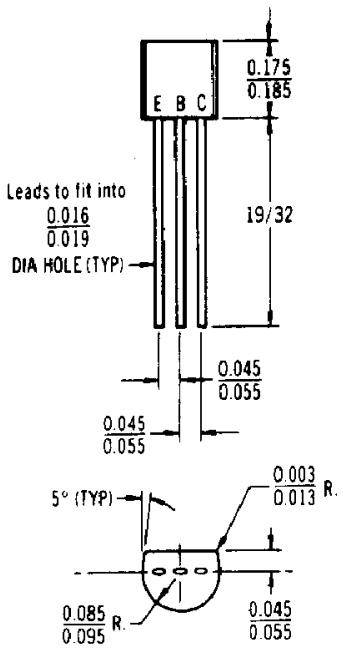


http://img.photobucket.com/albums/v711/whurd/Bad.jpg

http://news.com.com/PCs+plagued+by+bad+capacitors/2100-1041_3-5942647.html

Capacitor Rule of Thumb

- If there is one single thing that confuses students about capacitors, it is their frequency response.
- Rule of thumb Part 1: at zero frequency (DC), all capacitors have an effective impedance of **INFINITY Ohms**.
- Rule of thumb Part 2: at infinite frequency, all capacitors have an effective impedance of **ZERO Ohms**.
- In your mind, you can look at a schematic and replace caps at DC with open-circuits and at very high frequencies with short circuits. In between, their impedances are, well, "in between!"



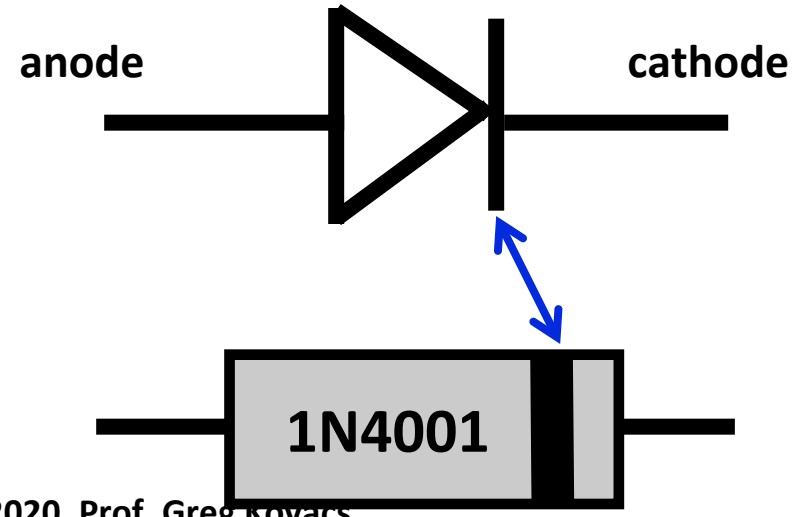
TRANSISTORS

Not all transistors look like this...

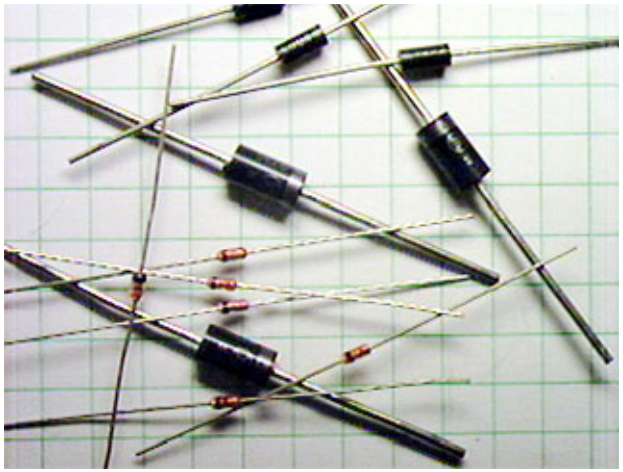
All transistors that look like this do not necessarily have the same arrangement of E, B, and C…

Also, do not assume that a component you pull from a parts bin actually works! Students Sometimes inadvertently place blown parts back in there.

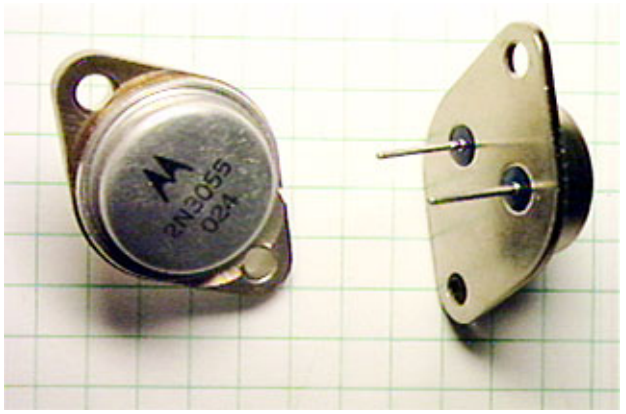
DIODES



Discrete Semiconductors

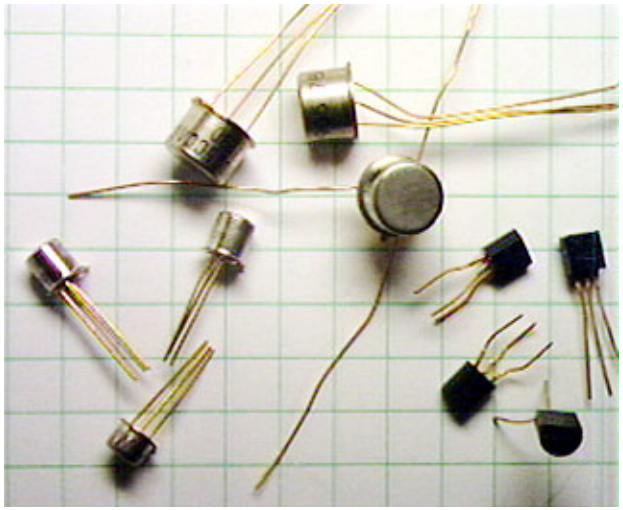


Diodes

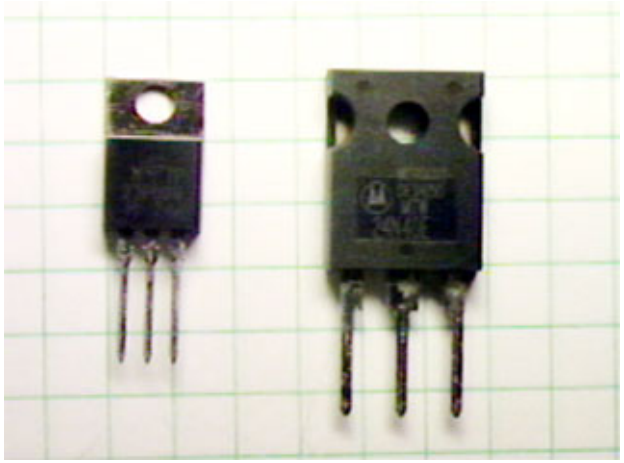


Power transistors

Small-signal transistors

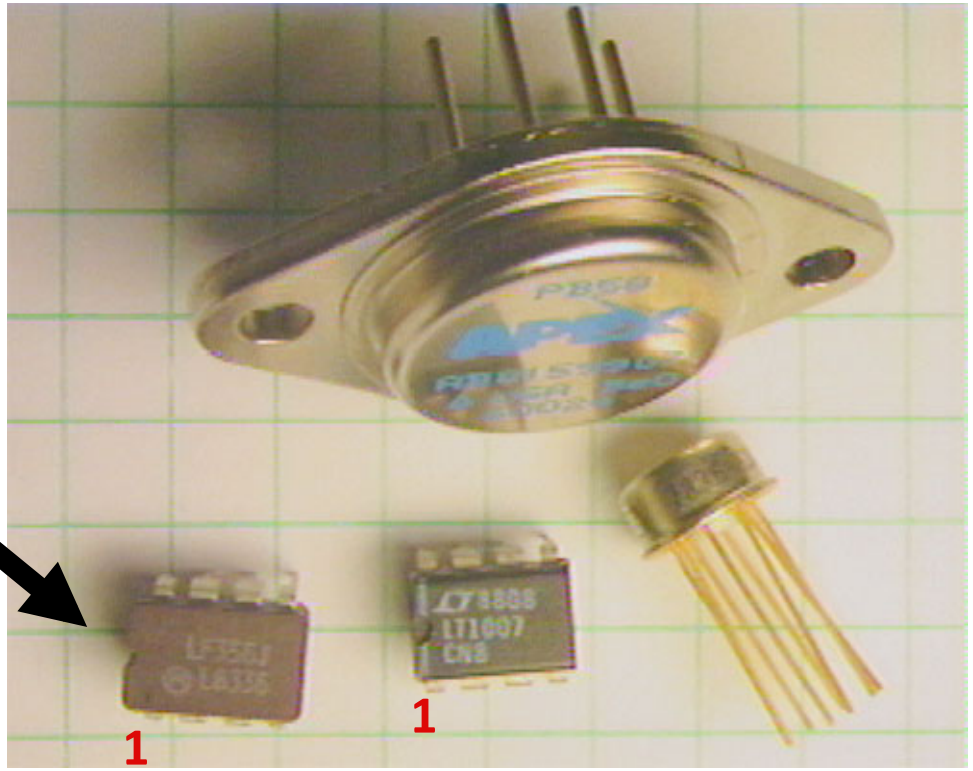


Power transistors

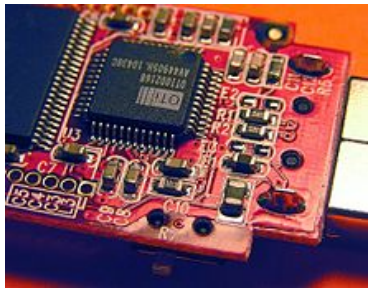


Integrated Circuits

PIN ONE IS THE KEY!
Find the dot or notch...



Many now are surface-mount, but these are not very practical in EE122A/B.

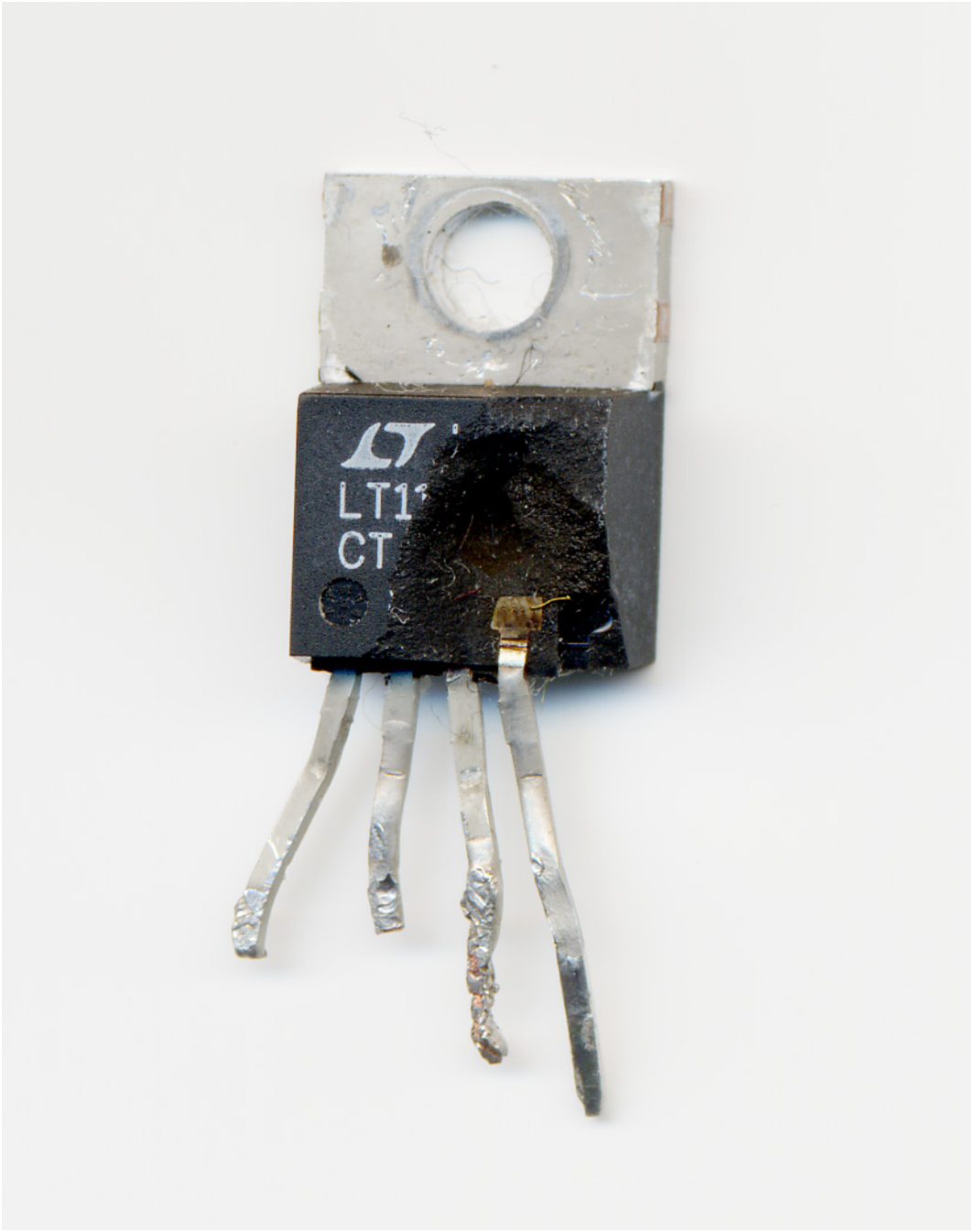


http://en.wikipedia.org/wiki/Surface-mount_technology

Chips Do Blow Up!

Be Careful!

Example – switching regulator that blew up in the field (South Pacific, on a boat) due to a stupid mistake made by your professor…



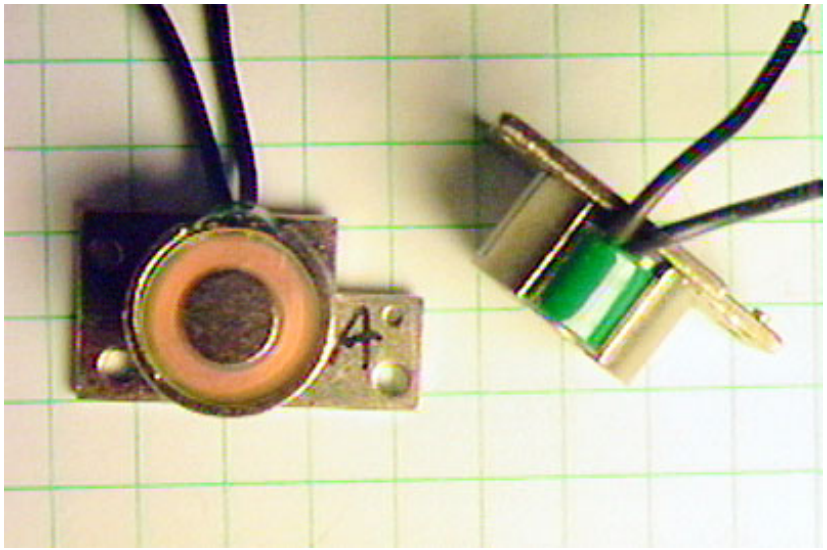
LEDs – Amazing Devices!

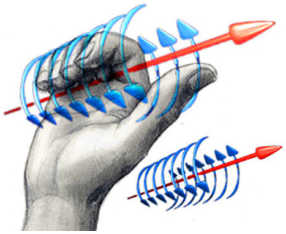
LEDs were once expensive and dim.

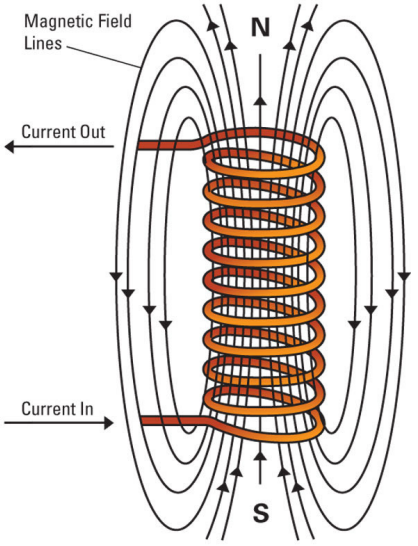
Now they are becoming the long-sought replacement for incandescent lighting.

http://www.enlighted.com/pages/ledsuits.shtml

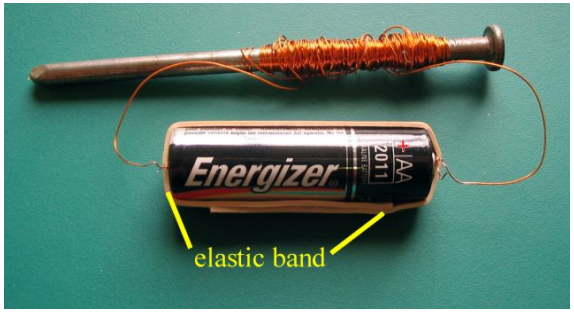
Electromagnets







http://www.ece.neu.edu/faculty/nian/mom/electromagnets.html



http://hilaroad.com/camp/projects/magnet.html

- Basic structure is a coil of wire wrapped around a ferromagnetic core.
- Magnetic field is present when current flows, and can be AC or DC.
- They are reciprocal in the sense that when exposed to AC magnetic fields, they convert them into AC potentials on their leads.

Good (New) Parts Sources

- Digi-Key - www.digikey.com
- Jameco - www.jameco.com
- Fry's (but don't ask for help) - www.frys.com (doesn't list all items in store)
- Allied - www.alliedelec.com
- Sparkfun – www.sparkfun.com
- Adafruit Industries – www.adafruit.com
- Newark - www.newark.com
- Radio Shack - www.radioshack.com
- Hosfelt (yes, it's real) - www.hosfelt.com

- Let us know of any others you find - they will be added to this list!

Good Surplus Sources

- Halted Specialties, Inc., Santa Clara, CA
  - 3500 Ryder St., Santa Clara, (408) 732-1573
  - www.halted.com
  - Great selection of parts.
- Alltronics
  - Parts, some instruments, much junk (catch owner in a good mood).
  - 2300D Zanker Road, San Jose, (408) 943-9773, www.alltronics.com
- All Electronics, Van Nuys, CA
  - http://www.allelectronics.com/
  - 888-826-5432
- Gateway electronics, St. Louis, Mo
  - http://www.gatewaycatalog.com/
  - (800) 669-5810
  - Cool surplus parts.
- Davylin Corp., Oxnard, CA
  - www.Davylin.com/
  - Test instruments, weird military stuff.
  - Need part number!
- Anchor Electronics, 2040 Walsh Avenue, Santa Clara, CA
  - Awesome, Mom & Pop style parts store.
  - (408) 727-3693, www.anchor-electronics.com
- Foothill and Livermore Swap Meets
  - Livermore 1st Sunday of every month all year
  - Foothill/De Anza 2nd Saturday of every month summer/fall only
  - http://www.electronicsfleamarket.com/

More Surplus Sources

- **Marlin P. Jones & Assoc., Inc.**
  - P.O. Box 12685, Lake Park, FL 33403-0685
  - (800) 652-6733
  - www.mpja.com
  - Lots of cool video stuff, kits and parts.

- **American Science and Surplus**
  - www.sciplus.com
  - Weird assortment…

http://community.webshots.com/photo/1297708/1510906PaIhCjlKGC

Local Geek Swap Meets

- Excellent sources of off-EBay electronics stuff, and a chance to meet some real geeks!
- Remember, you can't spell Geek without EE!

- Livermore - first Sunday of every month, March through November
  - http://www.livermoreark.org/swap/swap.html
- DeAnza College - second Saturday of each month, March through October
  - http://www.electronicsfleamarket.com/

Where To Find Circuit Ideas

On the Shoulders of Giants

Check Out On-Line Circuit Libraries

- **Good starting point:**

  http://www.discovercircuits.com/list.htm

- **Remember though - copying circuits without giving credit is plagiarism and an Honor Code violation of a most serious kind.**

- **Please forward good links as you find them.**

Online Sources

- https://www.edn.com/
- http://www.allaboutcircuits.com/

Good Magazines

- **Nuts and Volts (tends to run more amateur articles, quite accessible content)** https://www.nutsvolts.com/
- **Elektor (impressive, very professional content)** http://www.elektor-electronics.co.uk/index.html
- **Make Magazine (cool concepts, often weak on engineering)** http://www.makezine.com/
- **Wireless World – extinct, but back issues are available.**
- **Popular Electronics – extinct, but back issues are available.**