6.091
Hands-On Introduction to EE Lab Skills

"You chose wisely…."

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Lab Assistants: Ben Gelb, Danh Vo

6.091 Course

- Day 1
  - Electronic Components (RLC, diodes) and Theory
  - Use of Multi-Meters & Oscilloscopes; Construction & Debugging of Simple Electronic Circuits
- Day 2 LED's, BJT, MOSFETS, Optical Isolators, Op Amps
- Day 3: More Integrated Circuits: Timers, Voltage Regulators, Simple Power Amplifier
- Day 4: Motors, Digital ICs
- Day 5: AD/DA Converters, Digital Design Lab, Wrap Up
- 6 Unit; course grading is pass/fail. Completion of all 5 labs required for passing.

Course Schedule

- Lectures Jan 14, 16, 22, 24, 29
- Lab hours – 3 Sections
  Section 1: 5-9PM; Section 2: 2-6PM, Section 7-11PM

M	T	W	R	F
14 Lecture Sec 1 Lab	15 Sec 2 Lab Sec 3 Lab	16 Lecture Sec 1 Lab	17 Sec 2 Lab Sec 3 Lab	18
21	22 Lecture Sec 1 Lab	23 Sec 2 Lab Sec 3 Lab	24 Lecture Sec 1 Lab	25
28 Sec 2 Lab Sec 3 Lab	29 Lecture Sec 1 Lab	30 Sec 2 Lab Sec 3 Lab	31	

Safety

- 5-10 ma can cause death
- Skin resistance can range from 1k for wet skin to 500k for dry skin.
- Death can result from as low as 50 volts
- Body can sense 9 volts under the right conditions.

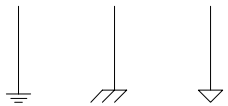
Electrical Units

- Voltage: volts (μv → kv)
- Current: amperes (amps), milliampere (ma 10^{-3})
- Resistance: ohms Ω, k-ohms (k 10^{3}), meg ohms (m 10^{6})
- Capacitance: farad, microfarad (μf 10^{-6}), nanofarad (nf 10^{-9}), picofarad (pf 10^{-12})
- Inductance: henry, millihenry, microhenry
- Frequency: mhz, ghz 10^{9}

Common Acronyms

- BJT – Bipolar Junction Transistor
- MOSFET – Metal Oxide Field Effect Transistor
- PCB – Printed Circuit Board
- DIP – dual inline package
- SMD, SMT Surface mount device/technology
- cap – capacitor
- pot – potentiometer
- AM – amplitude modulation
- FM – frequency modulation
- RF – radio frequency
- IF – intermediate frequency.
- dikes – diagonal pliers
- 1Nxxx diodes
- 2Nxxxx transistors

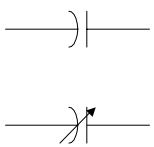
EE Symbols



ground

resistor, variable

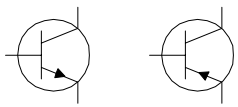
switches



capacitor

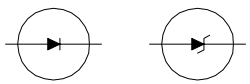
Inductor transformer

speaker fuse



npn, pnp

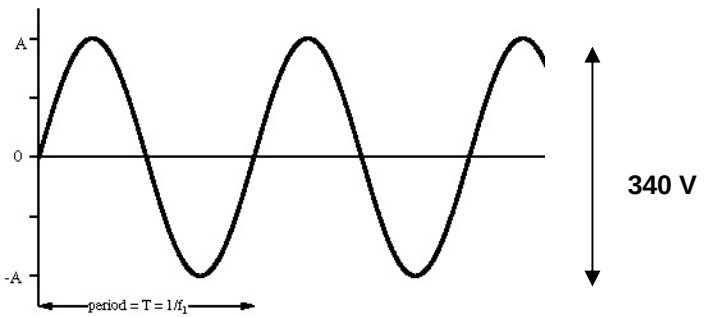
mosfets



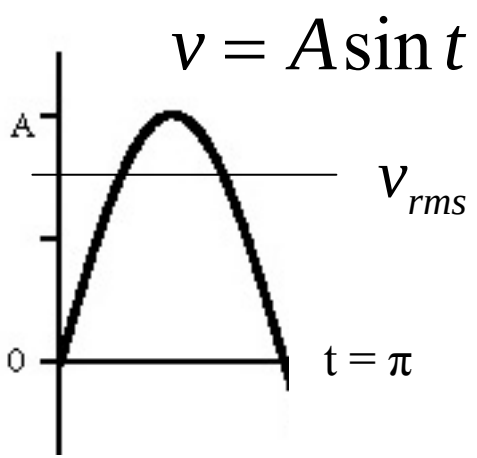
diode, zener diode

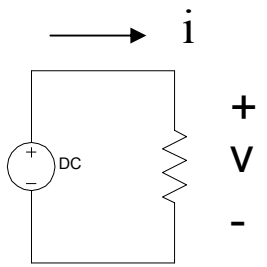
Voltage

- What is the equation describing the voltage from a 120VAC outlet?
- 120 VAC is the RMS (Root Mean Square Voltage)
- 60 is the frequency in hz
- Peak to peak voltage for 120VAC is 340 volts!



RMS Voltage





- The RMS voltage for a sinusoid is that value which will produce the same heating effect (energy) as an equivalent DC voltage.
- Energy = $\int Pdt = \int_0^{\pi} vidt = \frac{1}{r}\int_0^{\pi} v^2 dt$
- For DC, $\frac{v_{rms}^2 \times \pi}{r}$
- Equating and solving, $\mathbf{A} = \sqrt{2}\, v_{rms}$

RMS Derivation

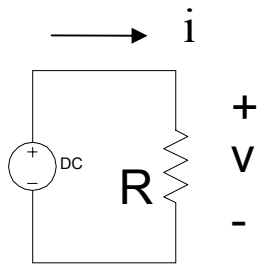
$$\frac{v_{rms}^2 \times \pi}{r} = \frac{1}{r}\int_0^{\pi} v^2 dt = \frac{1}{r}\int_0^{\pi} A^2 \sin^2 t dt$$

$$\int_0^{\pi} \sin^2 dt = \left[\frac{t}{2} - \frac{1}{4}\sin 2t\right]_0^{\pi}$$

$$\frac{v_{rms}^2 \pi}{r} = \frac{A^2}{r}\left[\frac{t}{2} - \frac{1}{4}\sin 2t\right]_0^{\pi}$$

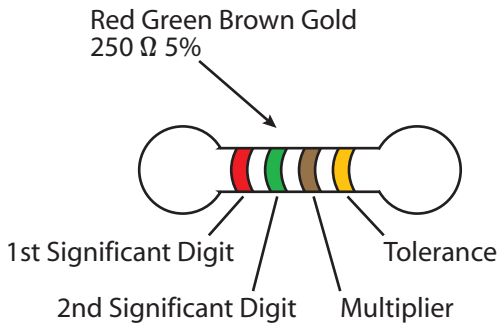
A = $\sqrt{2}\ v_{rms}$

Resistors



- V = IR
- Resistor parameters: resistance, tolerance and power rating.
- Variable resistors: pots
- Resistors are color coded
- **Standard Values 10 12 15 18 22 27 33 39 47 56 68 82**
- Common tolerance: ±5%, ±1%,
- Series/parallel combination
- Why is high voltage used in power lines?

Resistor Color Code



Color	1st-band Digit	2nd-band Digit	3rd-band Digit	4th-band Digit
Black	0	0	10^0 - 1	
Brown	1	1	10^1 - 10	1%
Red	2	2	10^2 - 100	2%
Orange	3	3	10^3 - 1000	3%
Yellow	4	4	10^4 - 10000	4%
Green	5	5	10^5 - 100000	
Blue	6	6	10^6 - 1000000	
Violet	7	7	10^7 - 10000000	
Gray	0	0	10^8 - 100000000	
White	9	9	10^9 - 1000000000	
Gold				5%
Silver				10%
None				20%

Figure by MIT OpenCourseWare.

red green brown gold
2 5 0 Ω 5%

2%, 1% Resistor Codes

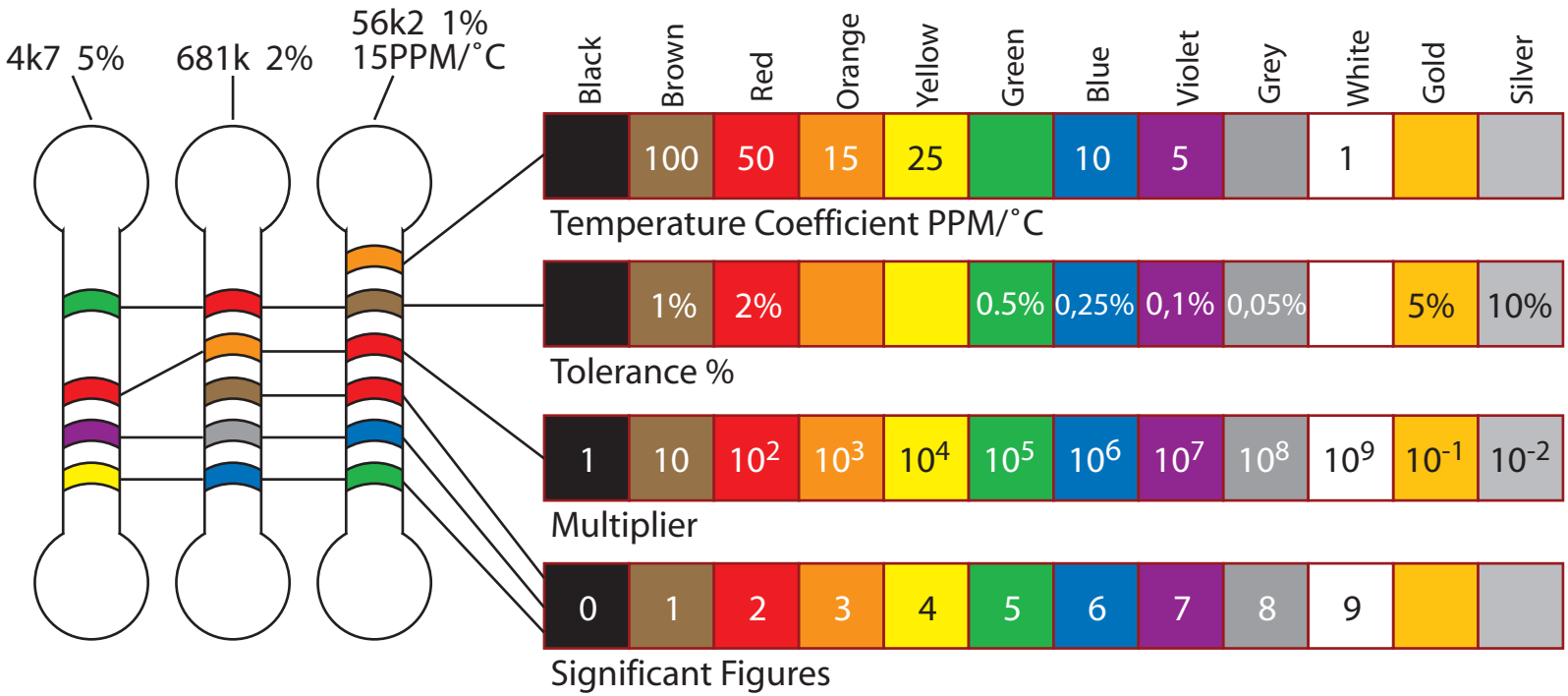
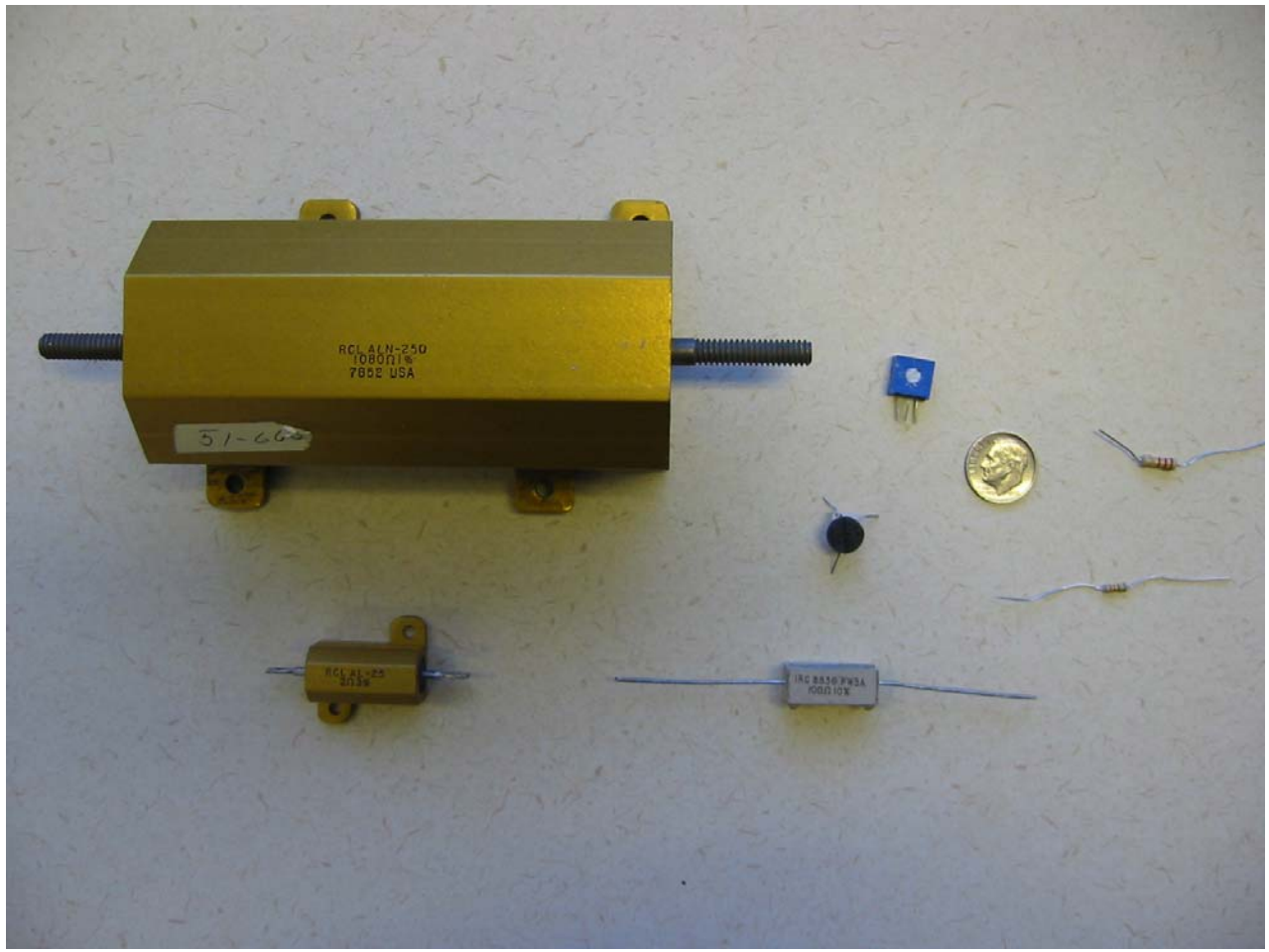
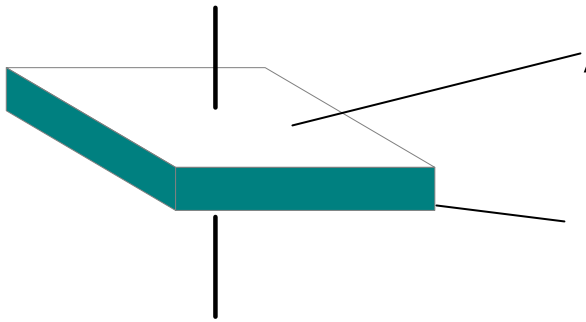


Figure by MIT OpenCourseWare.

Resistors



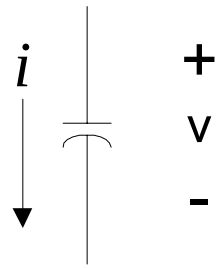
Capacitance



A = surface area of plates

d = distance between plates.

$$c = \frac{K\varepsilon_0 A}{d} \qquad i = C\frac{dv}{dt}$$



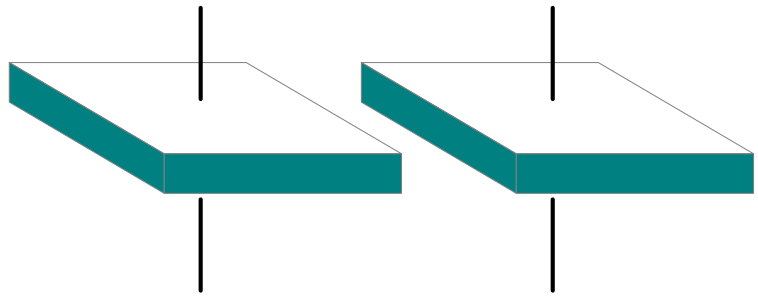
Standard Capacitance Values: 10 12 15 18 22 27 33 39 47 56 68 82

Examples: 100pf, 180pf, 270pf,… 1μf , 2.2μf , 4.7μf ,…

Capacitor marking: 104 = $10x10^4$ pf = 10^5 x 10^{-12} f = 10^{-7}f = 0.1 μf

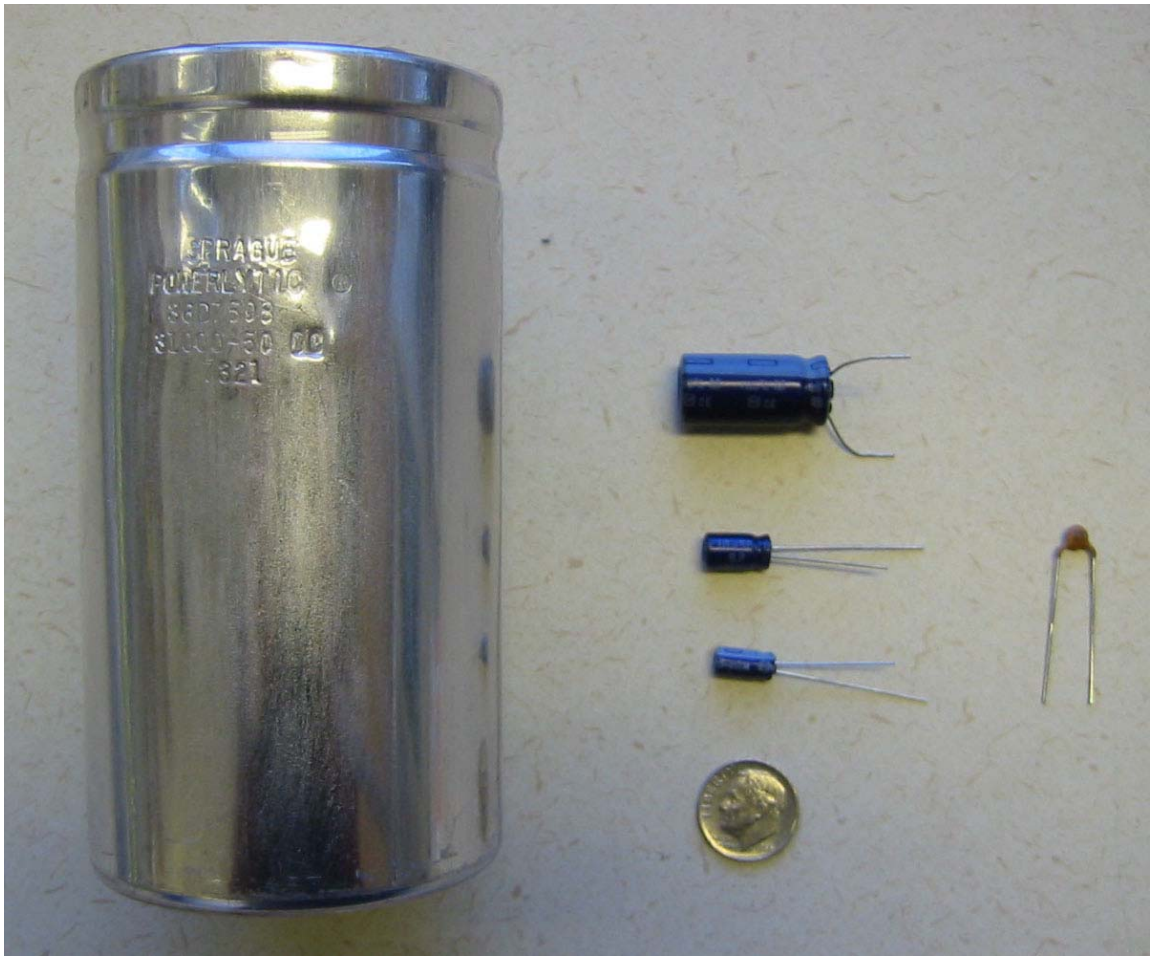
Capacitors

- Parallel / Series combination Think!



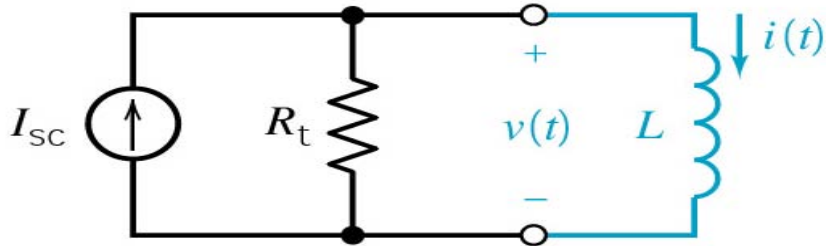
- Capacitors range for 1 pf (10^{-12}) to 100,000 µf (10^{-1})
- Typically capacitors larger than 1µf are polarized. Non polarized units are marked NP (non-polar) or BP (bipolar).
- All capacitors have maximum voltage ratings.

Capacitors



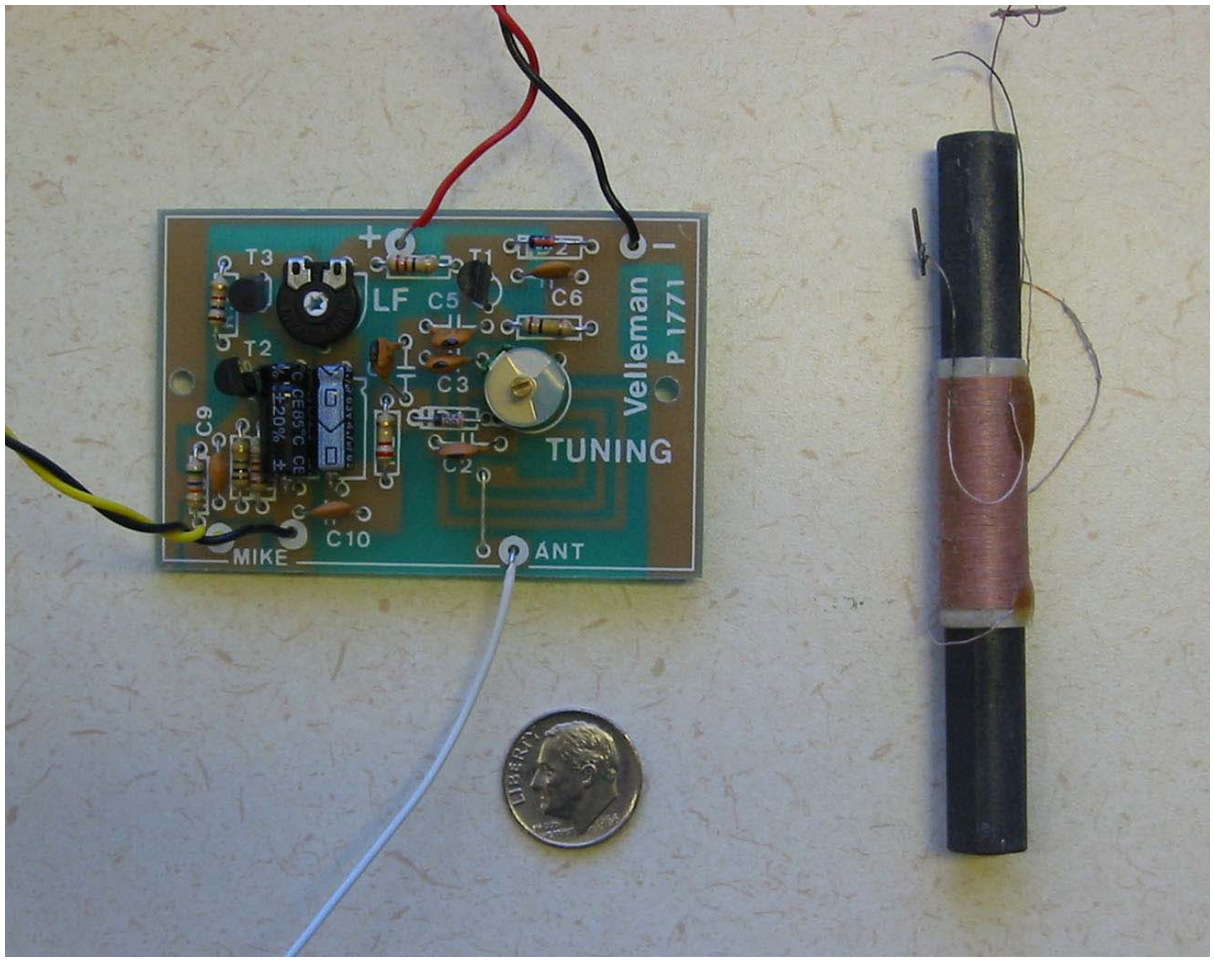
Inductors

$$v(t) = L\frac{d}{dt}i(t)$$



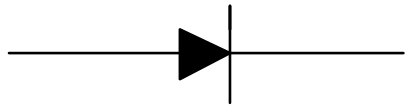
- Inductors are used in tuned circuits, switching power supplies, voltage converters, light dimmers, GFI.
- Inductors vary from a few μh (etched on a pcb) to henries.

Inductors



Diodes

- Diodes allow current to flow in the direction of the arrow.
- Can be modeled as an open circuit in one direction and a short circuit in the other (with a 0.6 volt drop)
- Diode parameters: max current, reverse breakdown voltage, reverse recovery time.

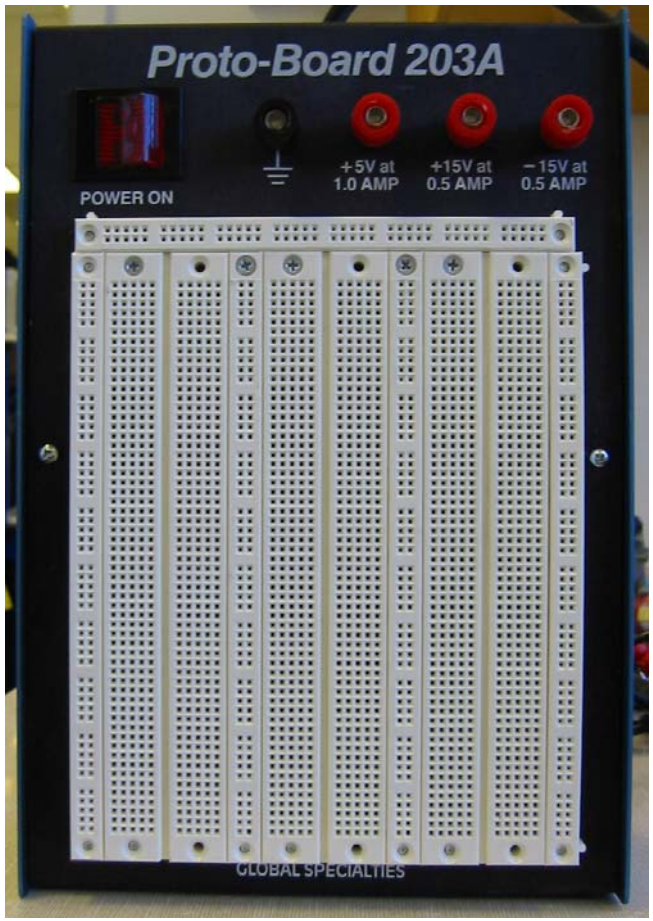


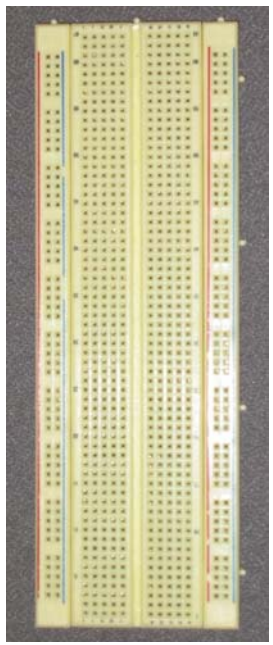
Lab 1

- Display signals on scope
- Measure the time, frequency, and voltage with oscilloscope – manually and scope assisted.
- Voltage measurement across resistor divider
- Build simple circuits on a protoboard.
- Solder a resistor cube and measure resistance between opposite corners.
- Return only the switches.

Proto-Boards

- +5v, +15v, -15v available
- Pins within row or column connected
- Wiring convention:
  - red: positive
  - black: ground (reference point) or negative



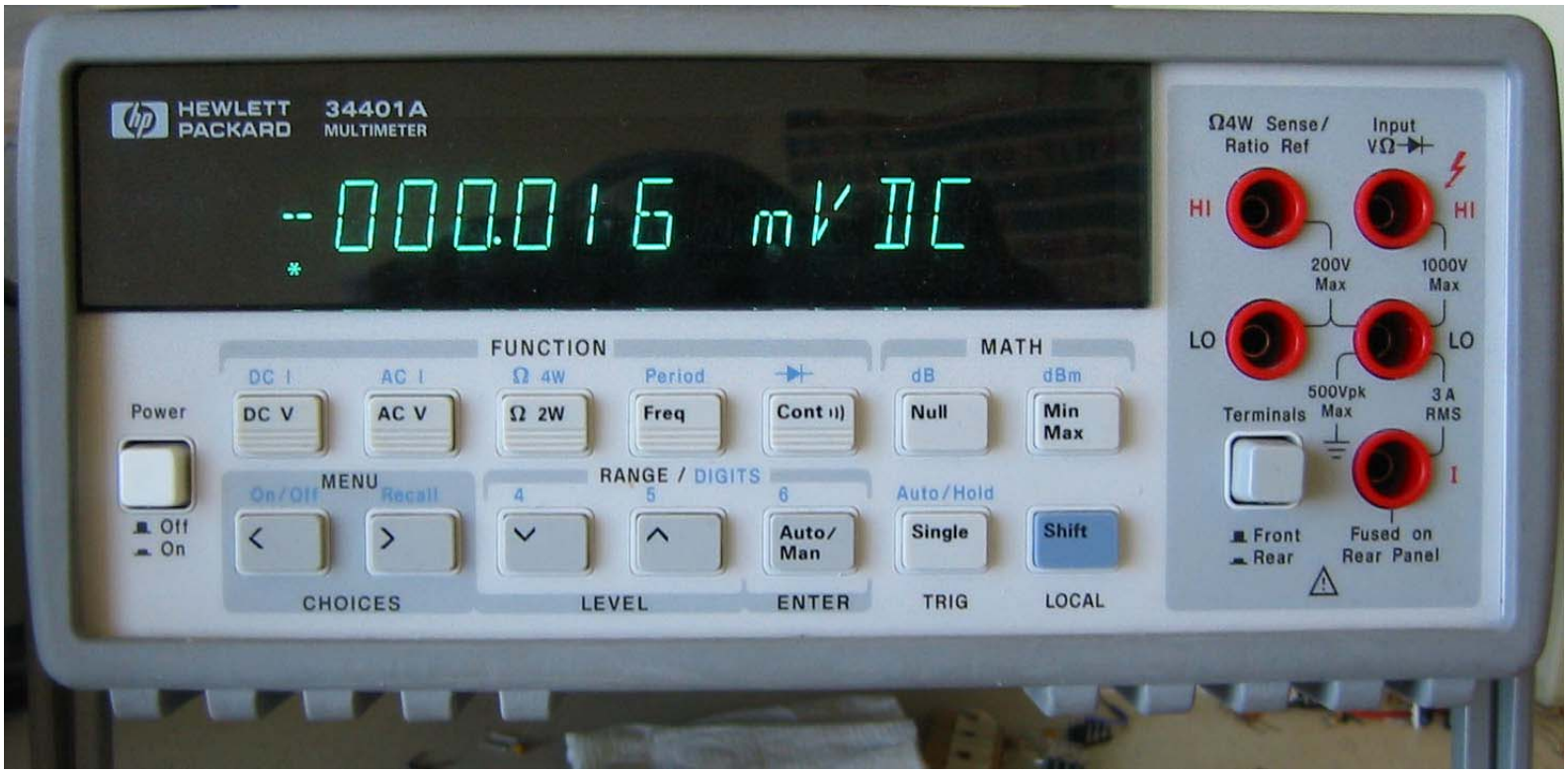


Lab Instruments

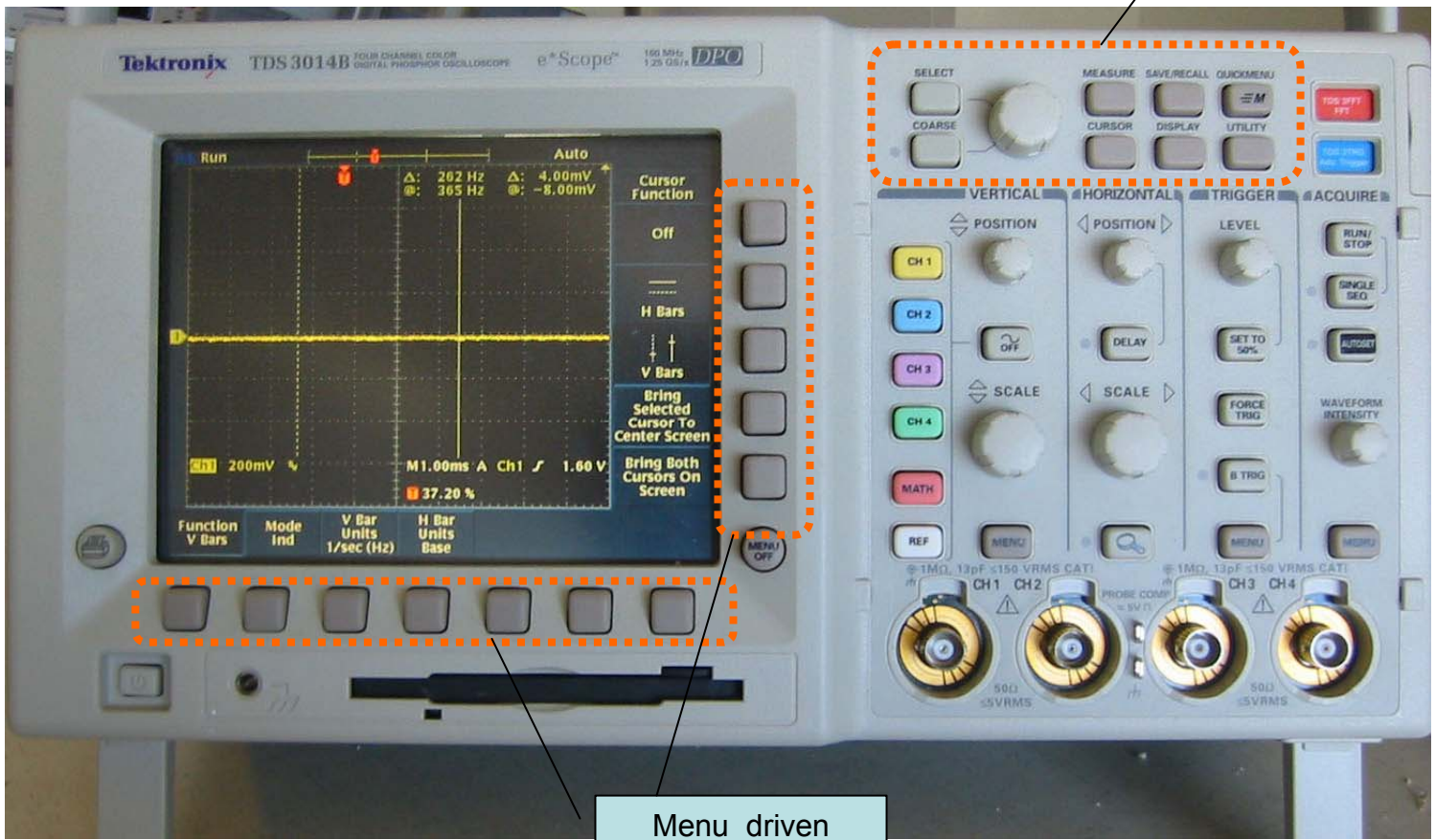
- Function Generator – generate modulated or unmodulated waveform.
- DMM – digital multimeter; measures voltage, current and resistance
- Oscilloscope – displays waveforms x-axis = time; y axis = amplitude

Agilent Function Generator

Agilent DMM


HEWLETT PACKARD
34401A
MULTIMETER
-000.016 mV DC
FUNCTION
MATH
DC I
AC I
Ω 4W
Period
dB
dBm
Power
DC V
AC V
Ω 2W
Freq
Cont
Null
Min Max
MENU
On/Off
Recall
RANGE / DIGITS
4
5
6
Auto/Hold
Off
On
Auto/ Man
Single
Shift
CHOICES
LEVEL
ENTER
TRIG
LOCAL
Ω4W Sense/ Ratio Ref
Input VΩ
HI
HI
200V Max
1000V Max
LO
LO
500Vpk Max
3 A RMS
Terminals
I
Front
Rear
Fused on Rear Panel

Oscilloscope



Oscilloscope Controls

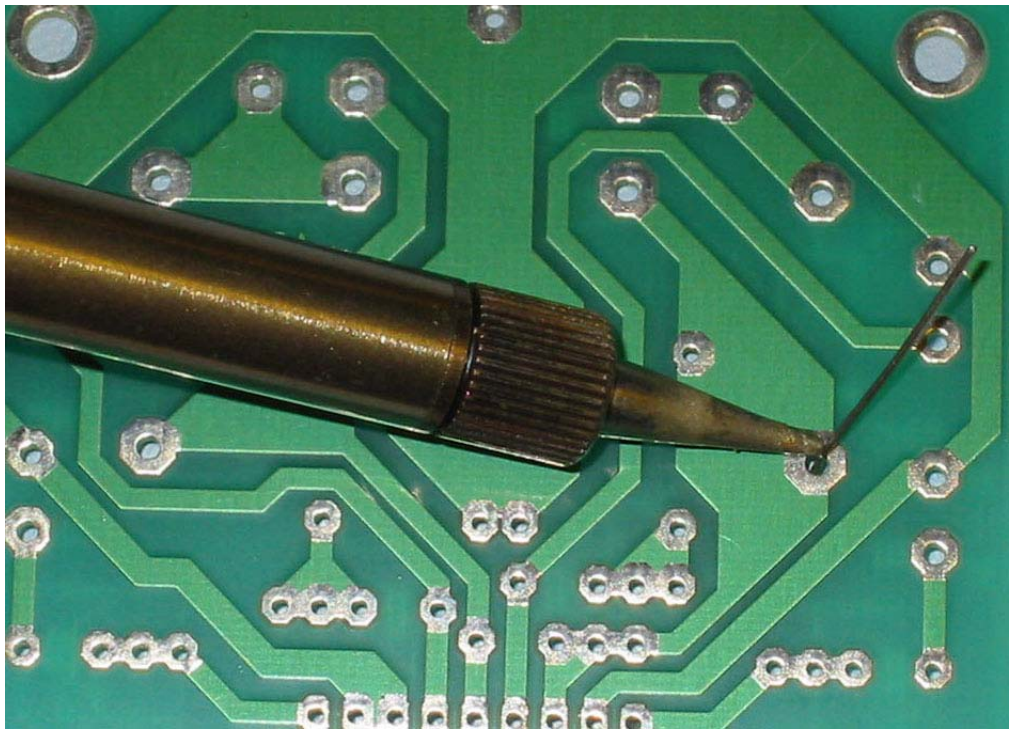
- Auto Set, soft menu keys
- Trigger
  - channel,
  - slope,
  - Level
- Input
  - AC, DC coupling,
  - 10x probe,
  - 1khz calibration source,
  - probe calibration,
  - bandwidth filter
- Signal measurement
  - time,
  - frequency,
  - voltage
  - cursors
  - single sweep
- Image capture

Personal DMM

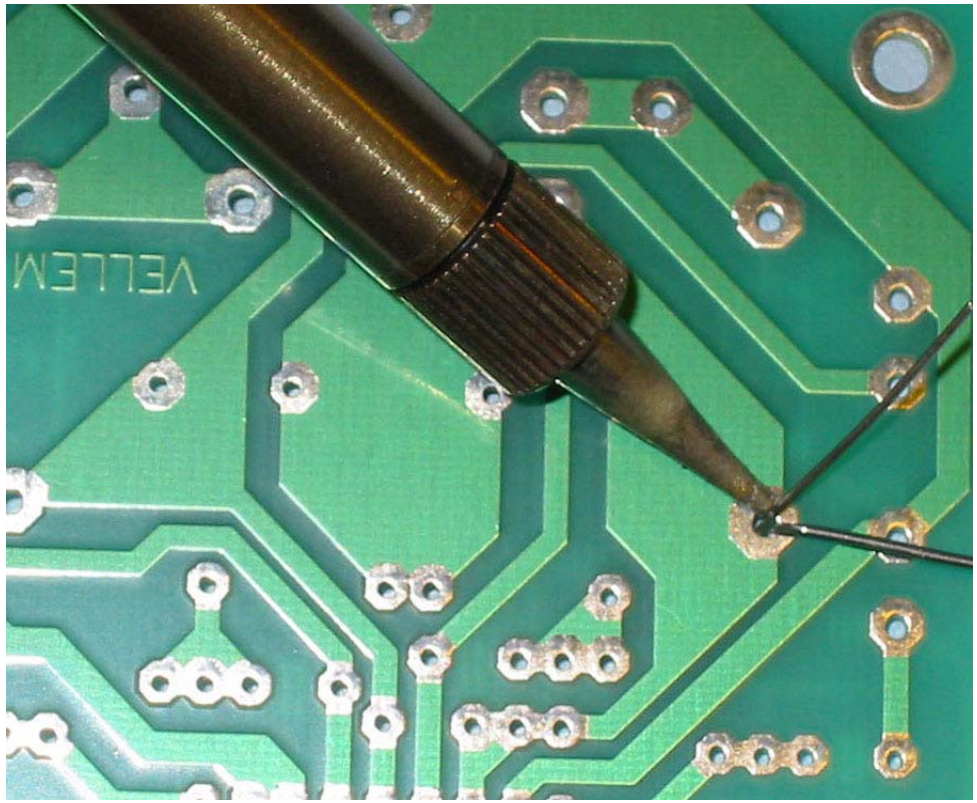
- Voltage DC: 2mv-1000v
- Voltage AC: 2vac-750vac
- Current: 2ua-10A
- Resistance: 2-2m
- BJT: beta test
- Diode test

Soldering Technique

- Use ceramic tile.
- Turn on soldering iron.
- Clean tip on wet sponge.
- Apply heat to circuit board and/or component.
- Apply solder to the component (not the soldering iron). Let the component melt the solder!

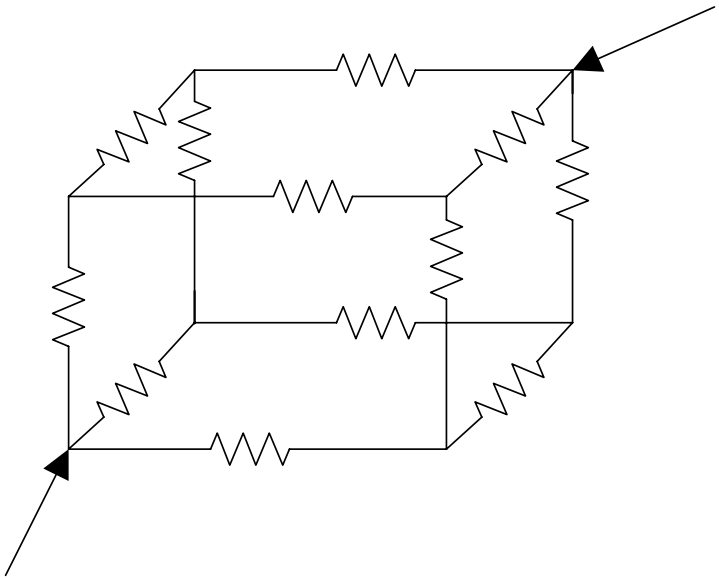


Apply heat to the circuit board



Apply solder to the component, not to the soldering iron

Resistor Cube



Build and solder a resistor cube with (12) 1k resistors.

What is the resistance between the two points?