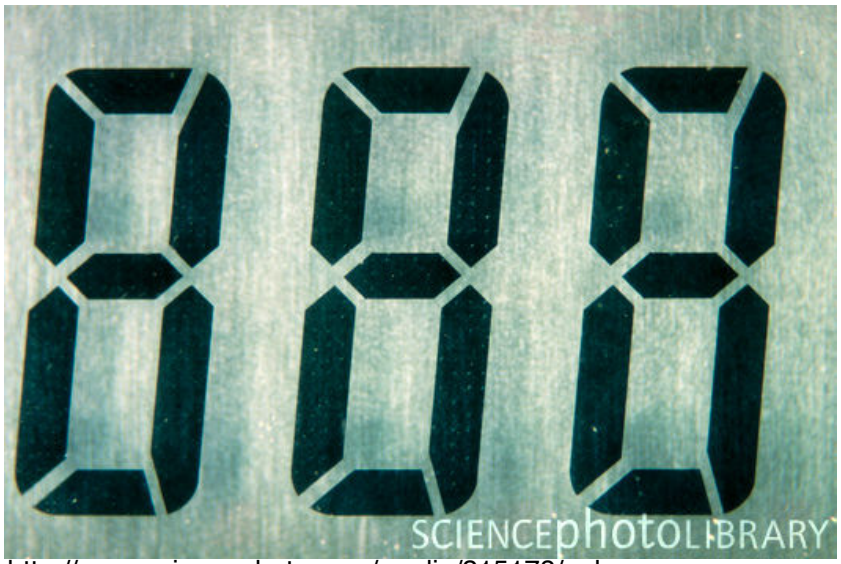
Liquid Crystals

How they work and how to drive them



http://www.sciencephoto.com/media/215178/enlarge

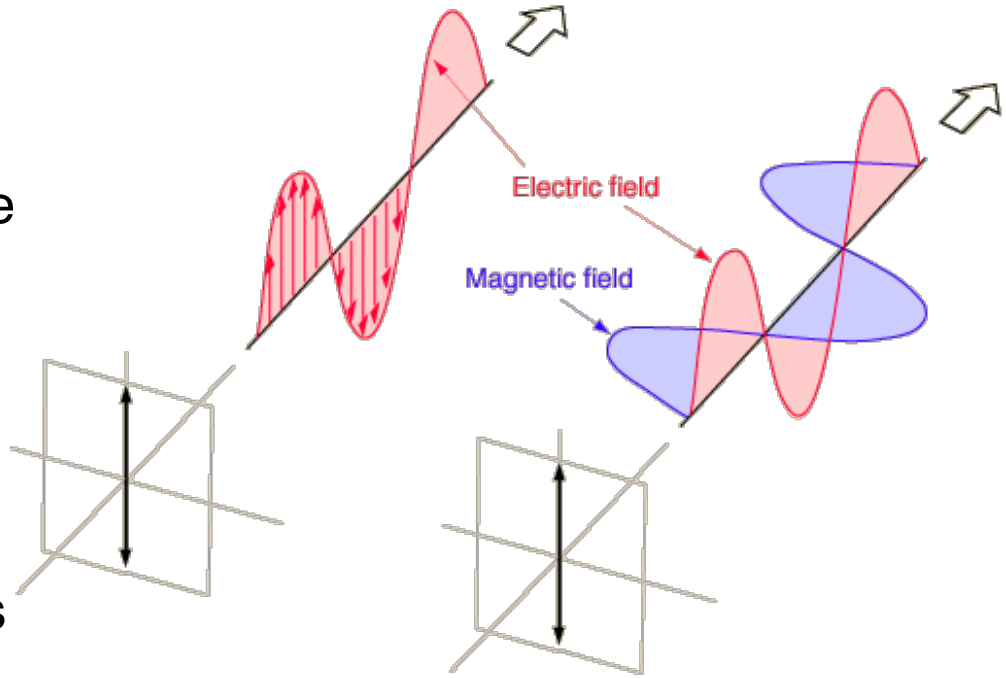
Key things

- Liquid crystals do NOT emit light!
- Liquid crystals should NOT be run on DC

http://en.wikipedia.org/wiki/File:LCD_Clock_Grey.jpg

How do they work?

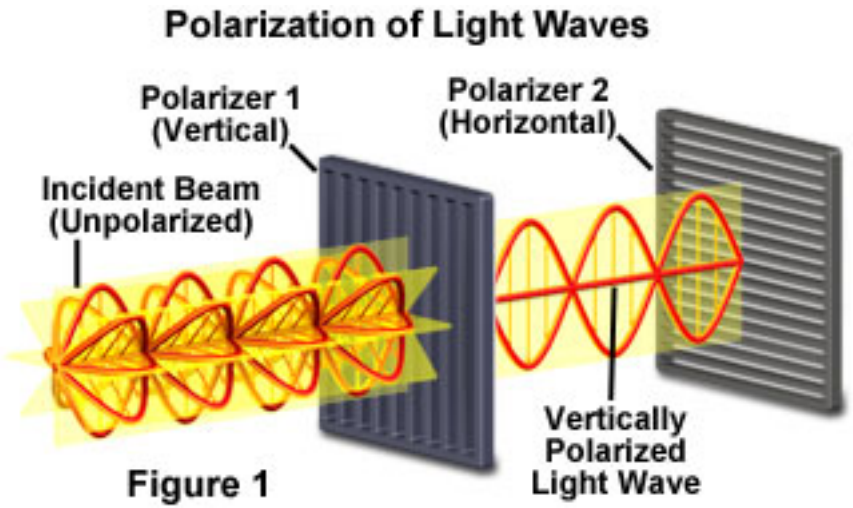
- They use polarization
- Light is a wave
  - An electromagnetic wave
    - Has an electric field
    - And a magnetic field
  - The polarization is the direction of the electric field
  - In this picture, the light is polarized vertically

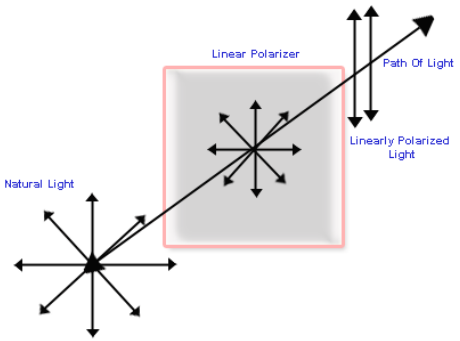


http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/polclas.html#c2

Light might or might not be polarized

- Some “rays” might be vertical, others horizontal, or every which way
- Can polarize it by running it through a polarizer



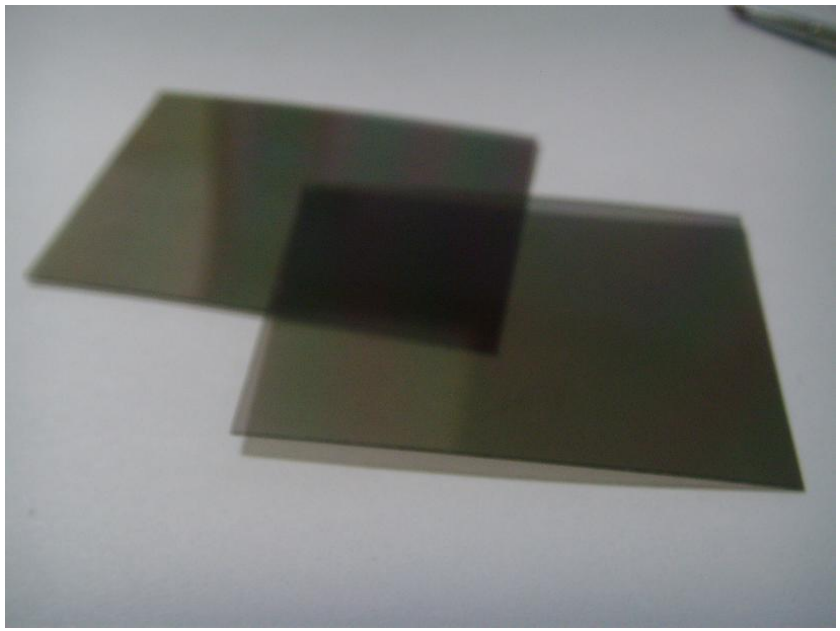


http://www.microscopyu.com/articles/polarized/polarizedlightintro.html

http://www.screentekinc.com/resource-center/linear-polarizer.shtml

Experiment:

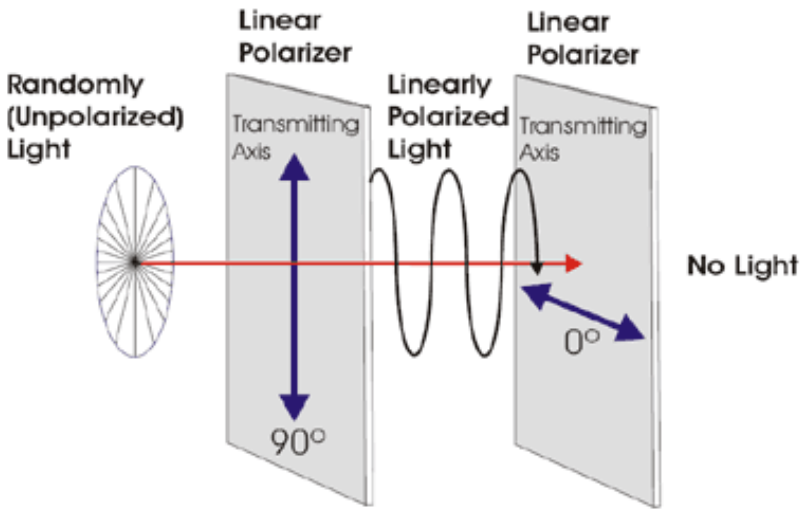
- Look around the room through a polarizer
- Does anything look different?
- People cannot detect polarization, but some animals can
  - Some insects
  - Octopuses



http://www.alibaba.com/product-gs/262818917/lcd_polarizer/showimage.html

Suppose light is polarized already?

- What if light is polarized vertically?
- What if you try to pass it through a horizontal polarizer?

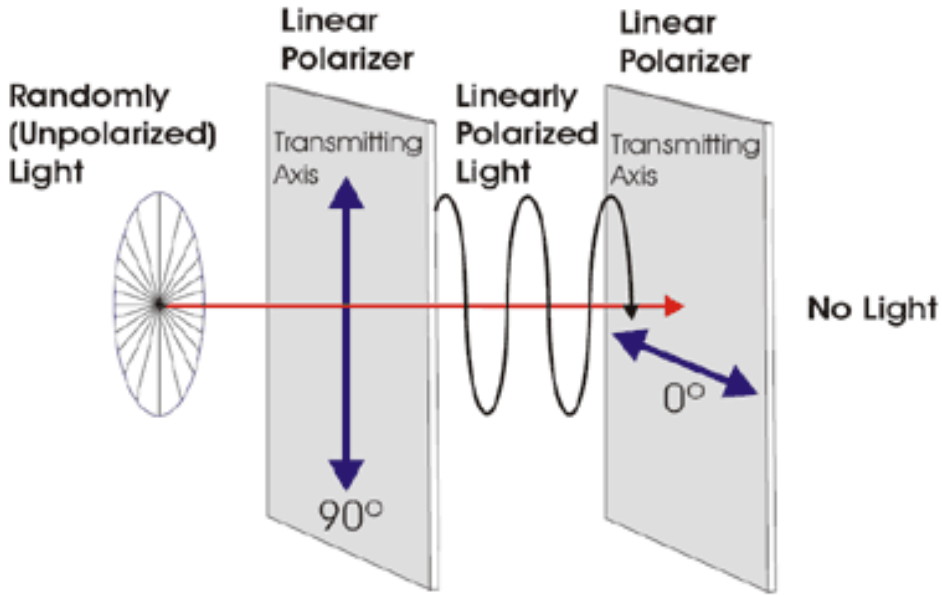


It won't go through!

http://www.apioptics.com/linear-polarizers.html

What would you see if you looked through them?

- Try it and see



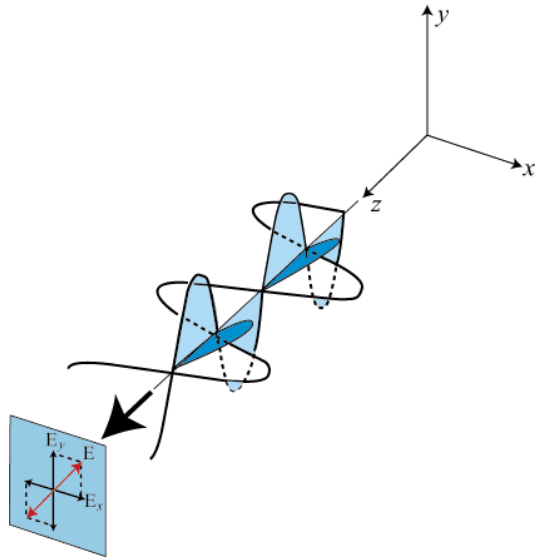
http://www.apioptics.com/linear-polarizers.html

So, we have established…

- If you look at randomly polarized light, you don't notice anything
- You can polarize light with a polarizer
- Vertically polarized light will pass through another polarizer that's vertical
- Vertically polarized light will NOT pass through a horizontal polarizer

Weirdness

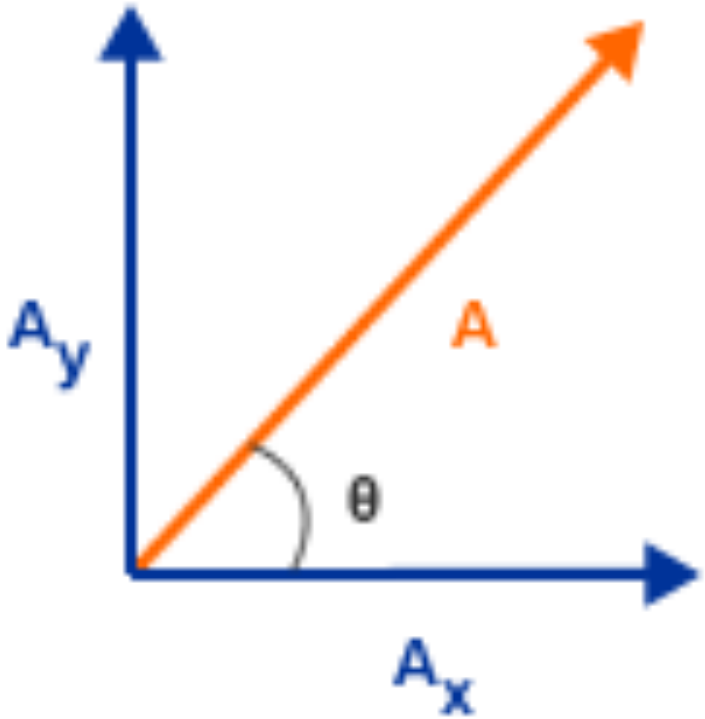
- If you add vertically polarized light to horizontally polarized light, you get…
- 45° polarized light!



http://www.sparknotes.com/physics/optics/phenom/section3.rhtml

Look at that backward

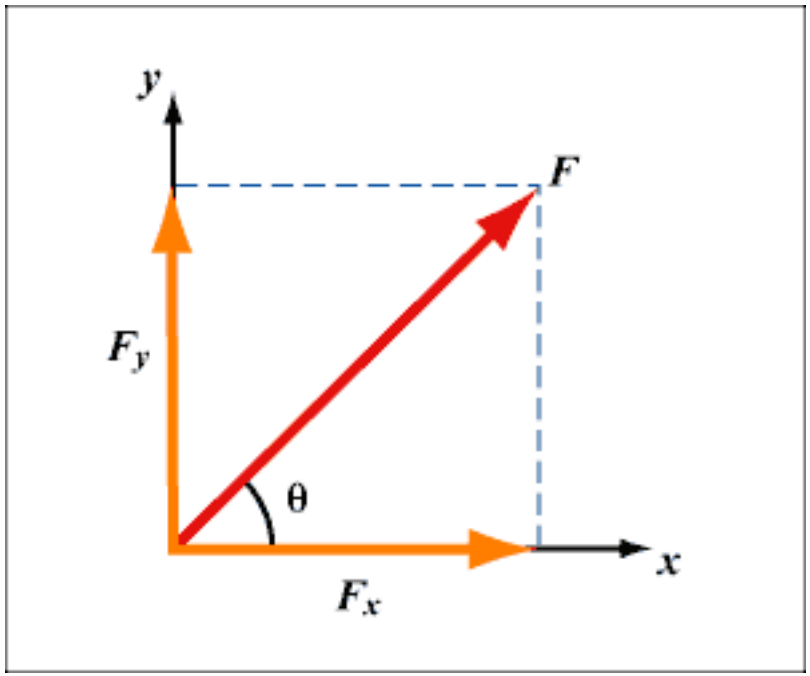
- If you have 45° light, you can “resolve” it into vertical and horizontal components



http://www.revisesmart.co.uk/physics/mechanics/vectors-and-scalars.html

What should you see…

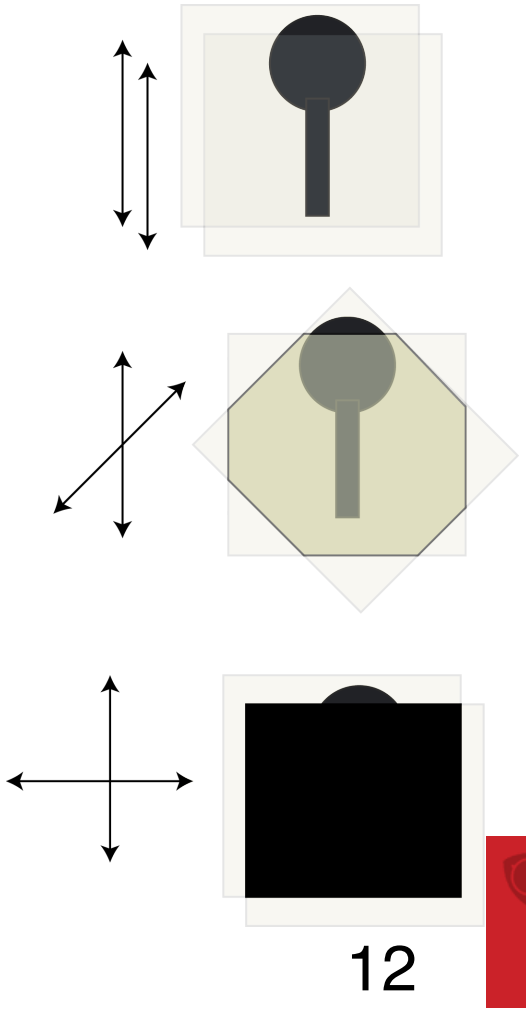
- If you start with 45° light, and try to pass it through a vertical (or horizontal) polarizer?
- Light will still pass, but not all of it
  - The passed component will be dimmer



http://www.hk-phy.org/contextual/mechanics/for/ad_fo02_e.html

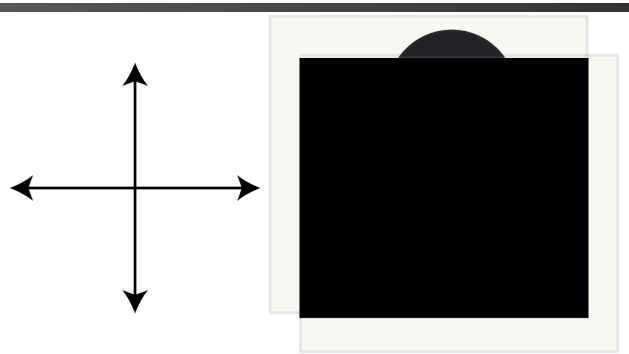
Experiment

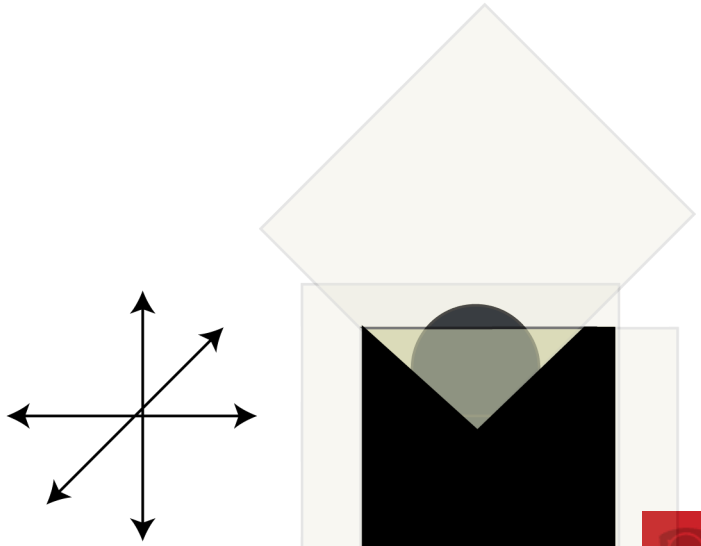
- Hold a polarizer up to the light
- Hold up a second one
  - Line it up
  - Turn it to 45°
  - Turn it to 90°



Advanced experiment

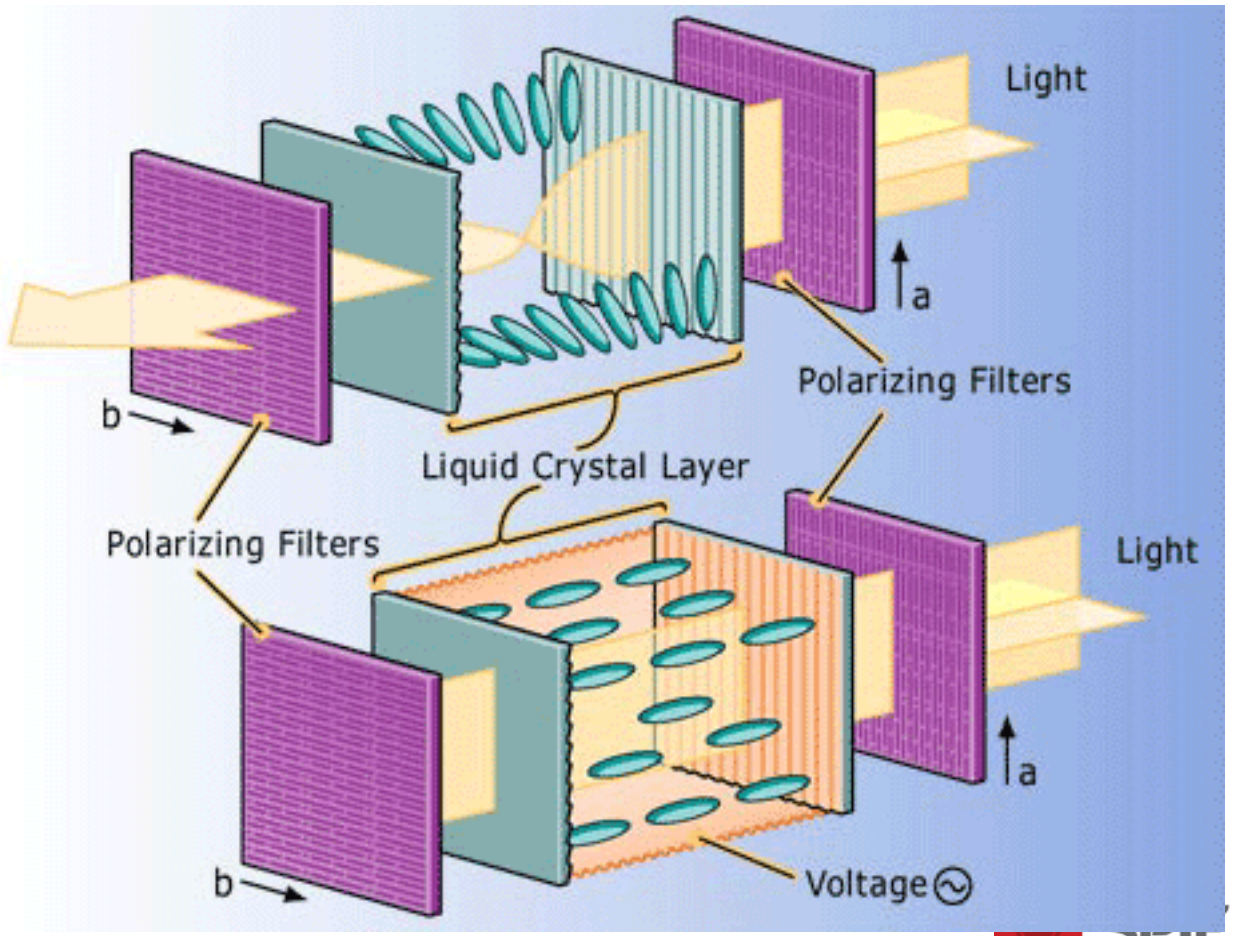
- Take two crossed polarizers
- Can't see through them
- Add a third one *between* them
- Turn third one to 45°
- What's going on?





How do liquid crystals work?

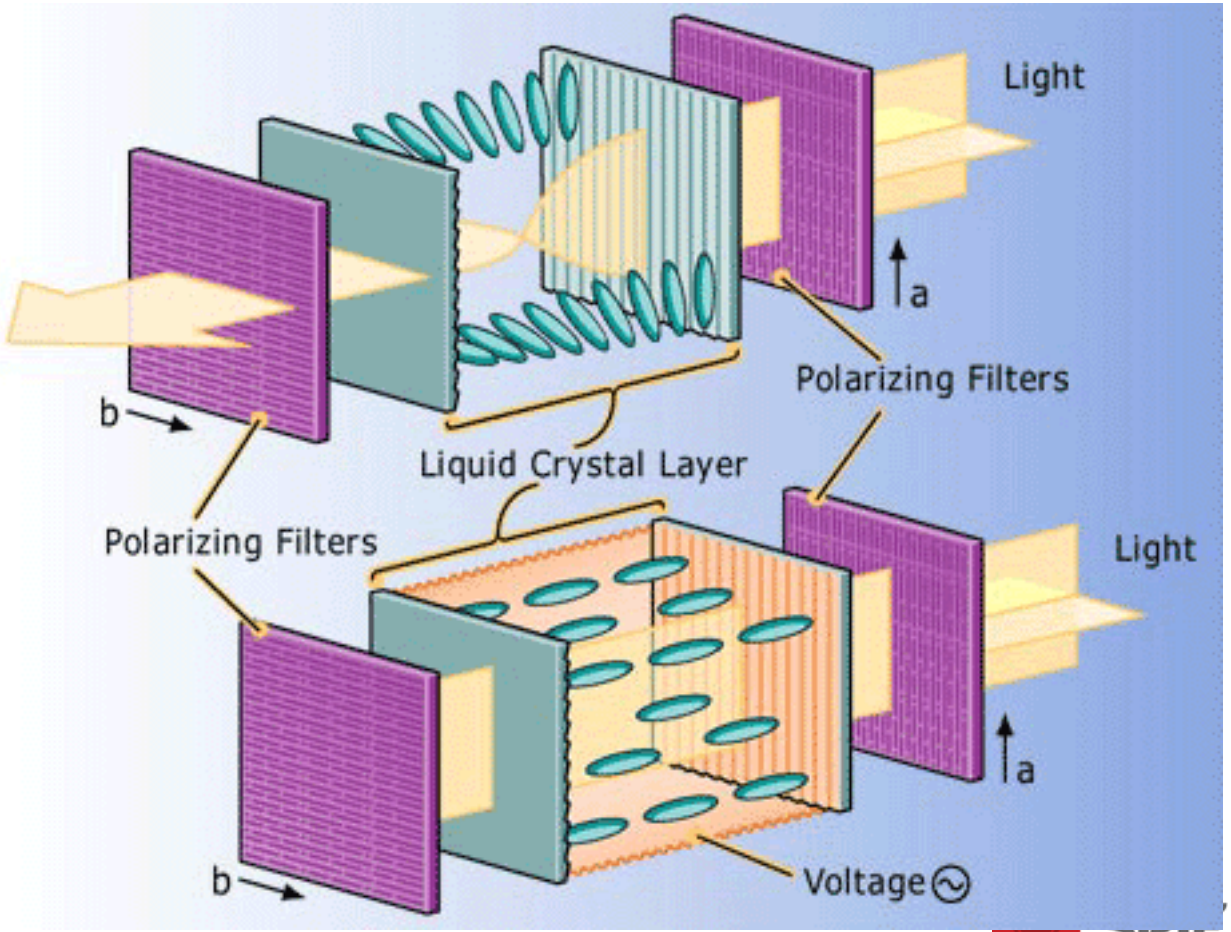
- They change the polarization of the light
- Put a polarizer on the front and back
- The molecules are arranged in a twist
- They twist the polarization so it passes through the back
  - With no voltage applied



http://images.yourdictionary.com/liquid-crystal-display

When you apply the voltage

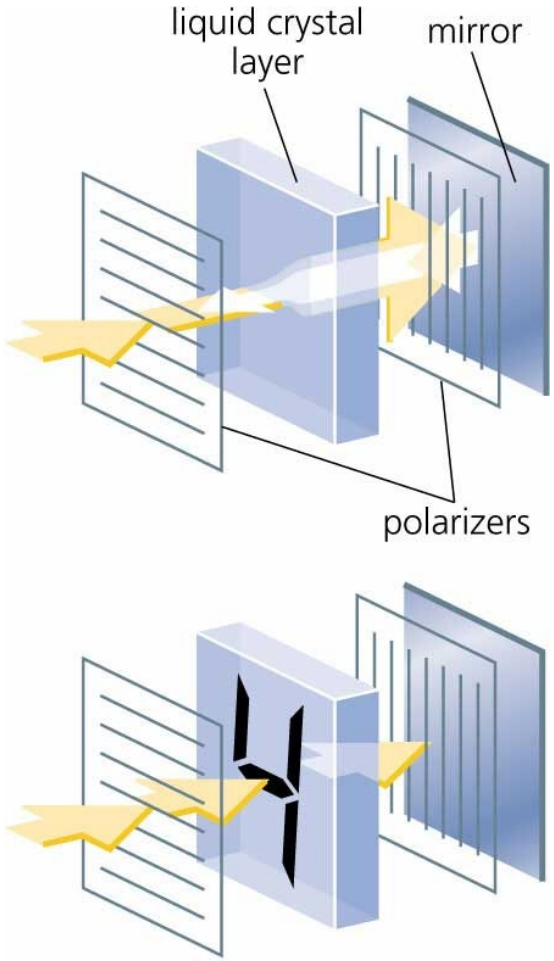
- The molecules turn end-on so the light doesn't get twisted
- Light can't pass through the second polarizer
- Looks black
- This is a transmissive display
  - It's lighted from the back



http://images.yourdictionary.com/liquid-crystal-display

Reflective LCD

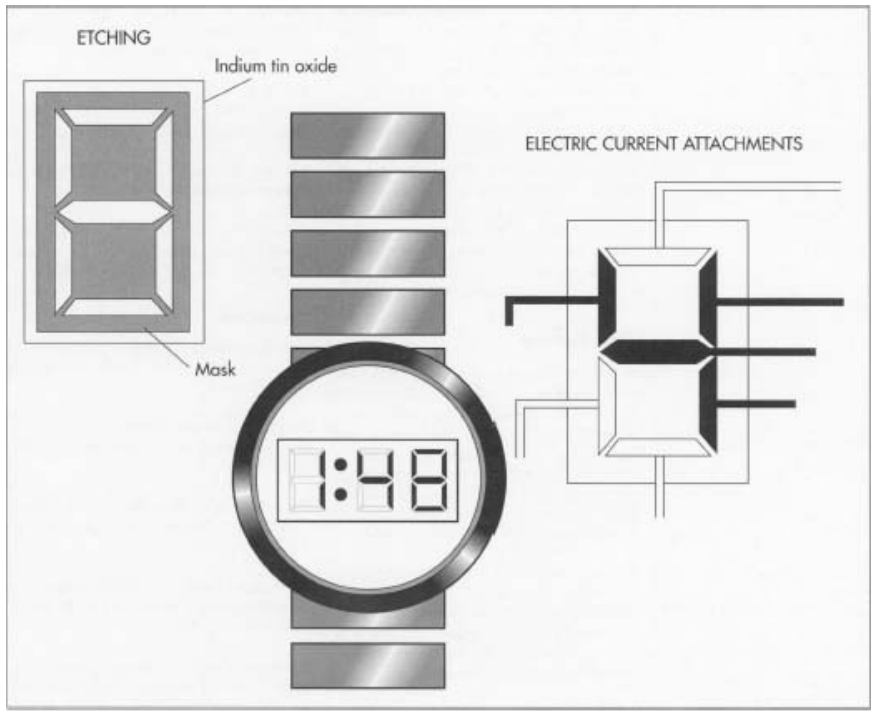
- Mirror on the back
- Light comes from front



http://images.yourdictionary.com/liquid-crystal-display

How do you apply the voltage?

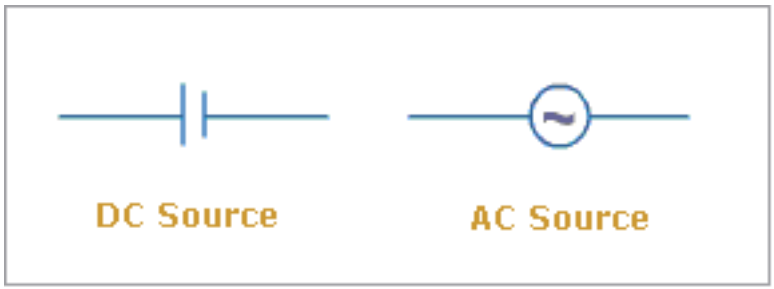
- There are transparent electrodes on the front- one for each segment
- Voltage only applies where the electrode is
- Has to be AC

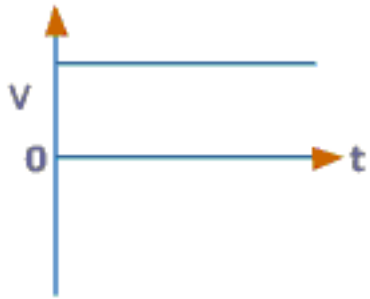


http://www.madehow.com/Volume-1/Liquid-Crystal-Display-LCD.html#b

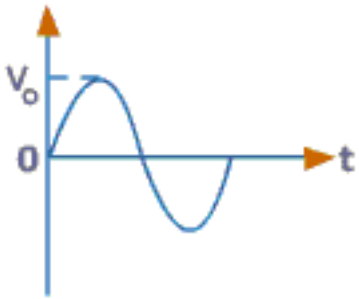
AC vs DC

- DC: direct current
- AC: Alternating current





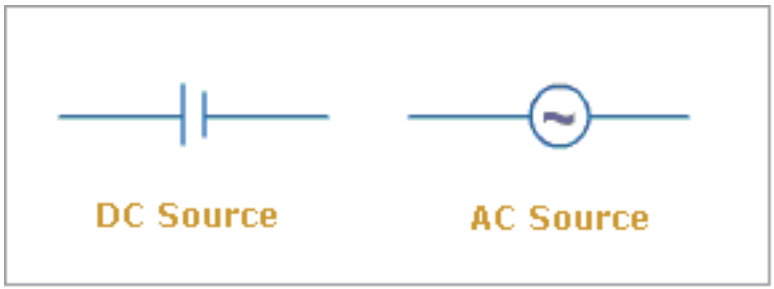
DC Source

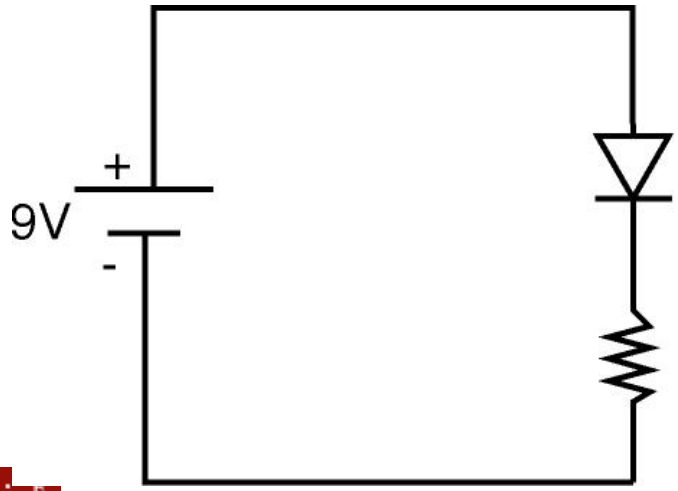


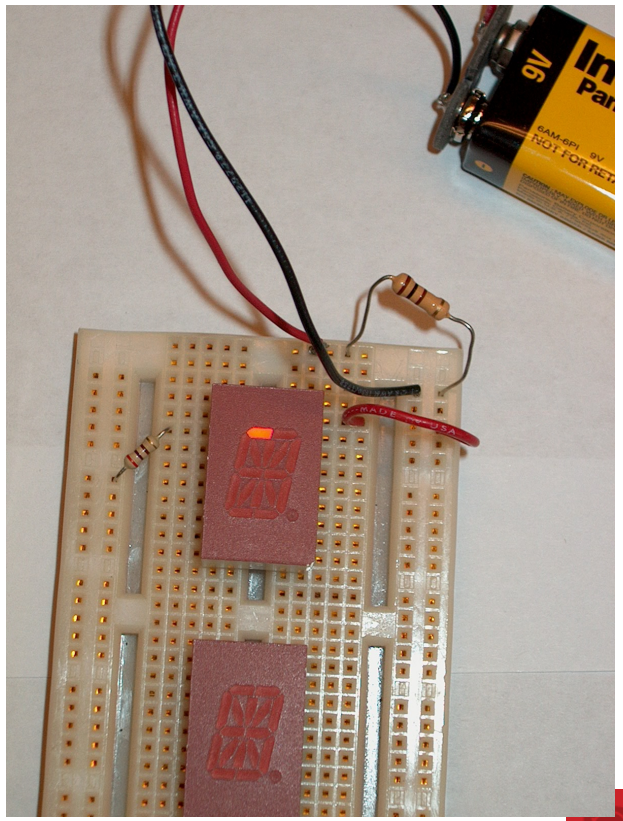
AC Source

http://www.tutorvista.com/content/physics/physics-ii/electricity/direct-and-alternating-current.php

Quiz: Which one did we use for the LEDs?



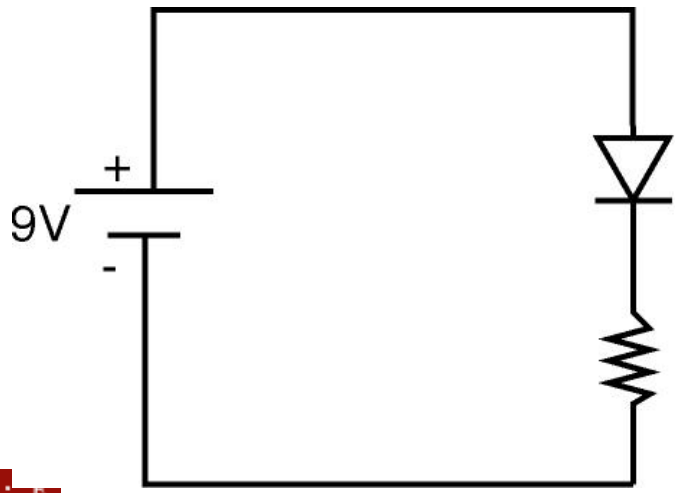


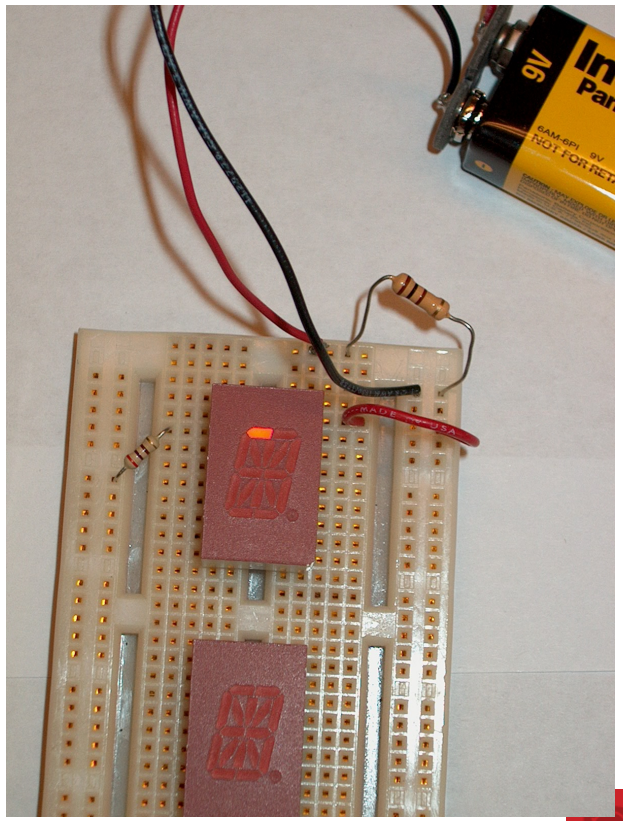


http://www.tutorvista.com/content/physics/physics-ii/electricity/direct-and-alternating-current.php

Advantage of LEDs:

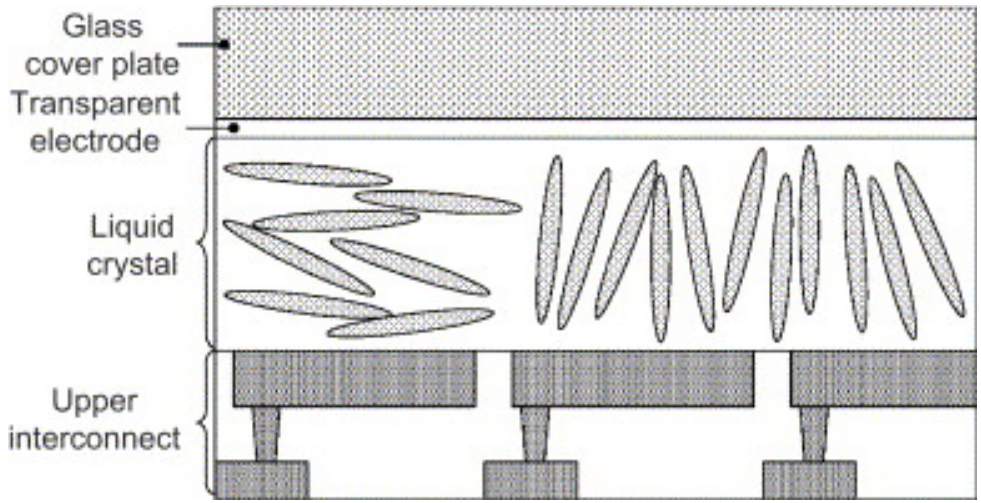
- Drive circuitry is simple!





Liquid crystals

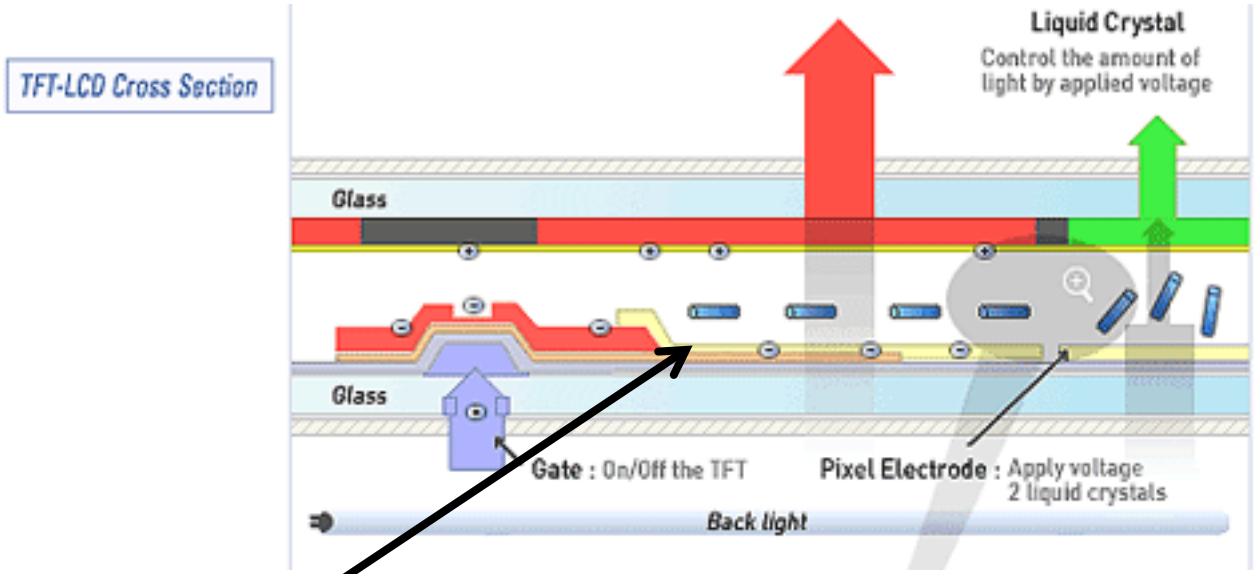
- Have very thin transparent electrodes plated onto the glass
- Electric field will cause particles to migrate from one side of the display to the other
- Will deplate the electrodes



http://www.sciencedirect.com/science/article/pii/S0168900207002288

But, can work around it

- If you reverse the voltage, you reverse the direction of the molecule migration
- Saves the electrodes!

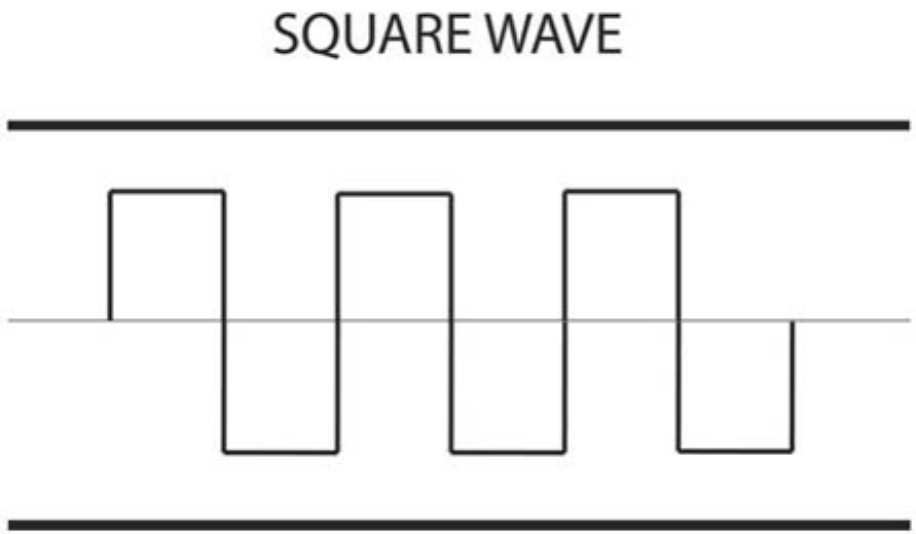


THIN!

http://hothardware.com/Reviews/Dell-UltraSharp-3007WFPHC--92-Color-Gamut-30-Inch-LCD/?page=2

Need a circuit to make a square wave

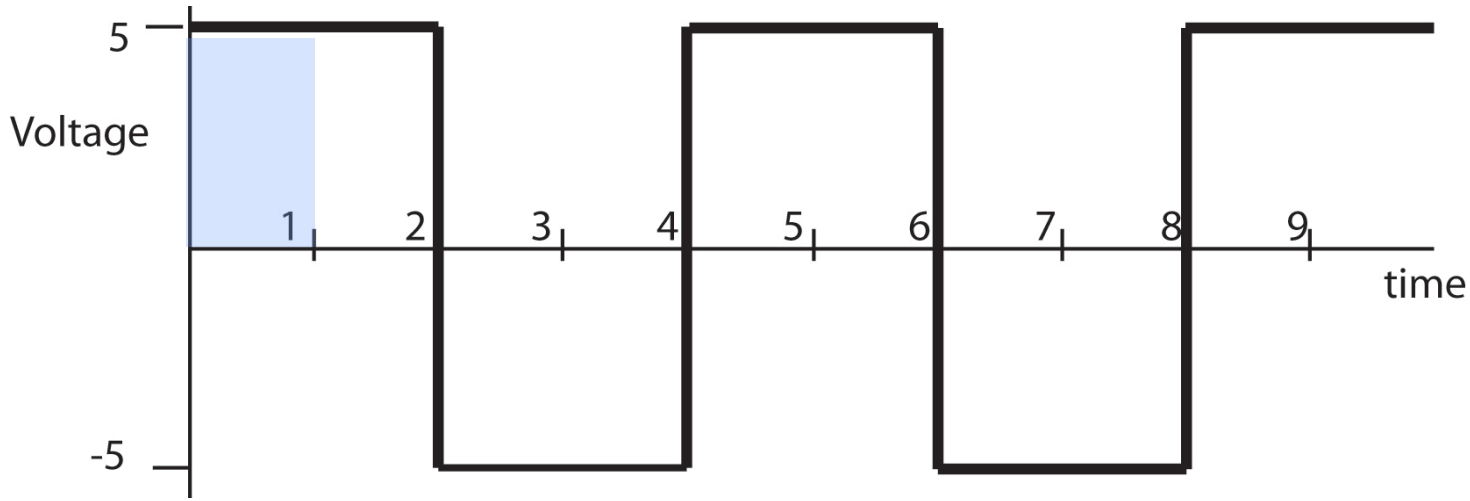
- Has to go positive and negative
- Has to spend same amount of time positive as negative



http://www.thedawstudio.com/Tips/Soundwaves.html

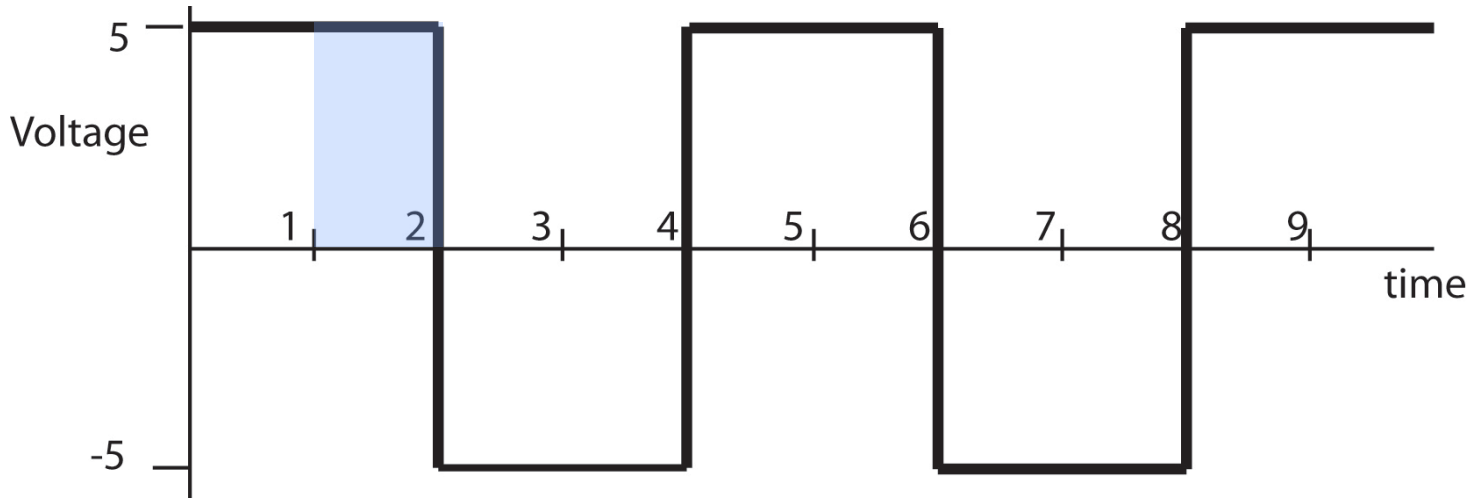
Let's examine this

- What is the average value in this section?
- Right, 5 Volts



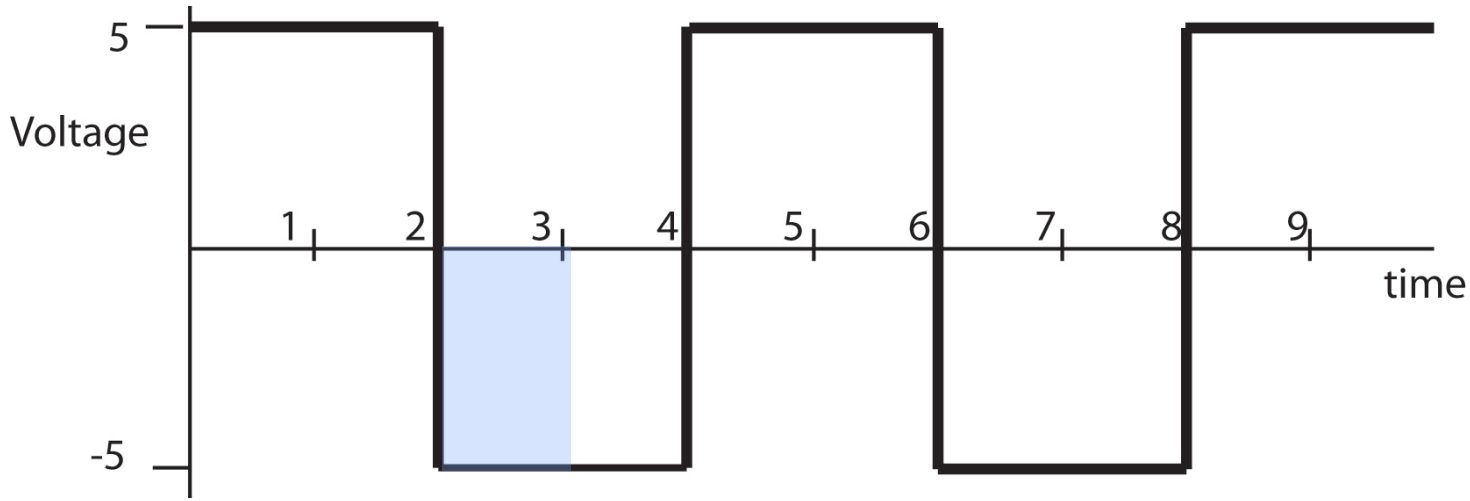
What about here?

- What is the average value in this section?
- Right, 5 Volts



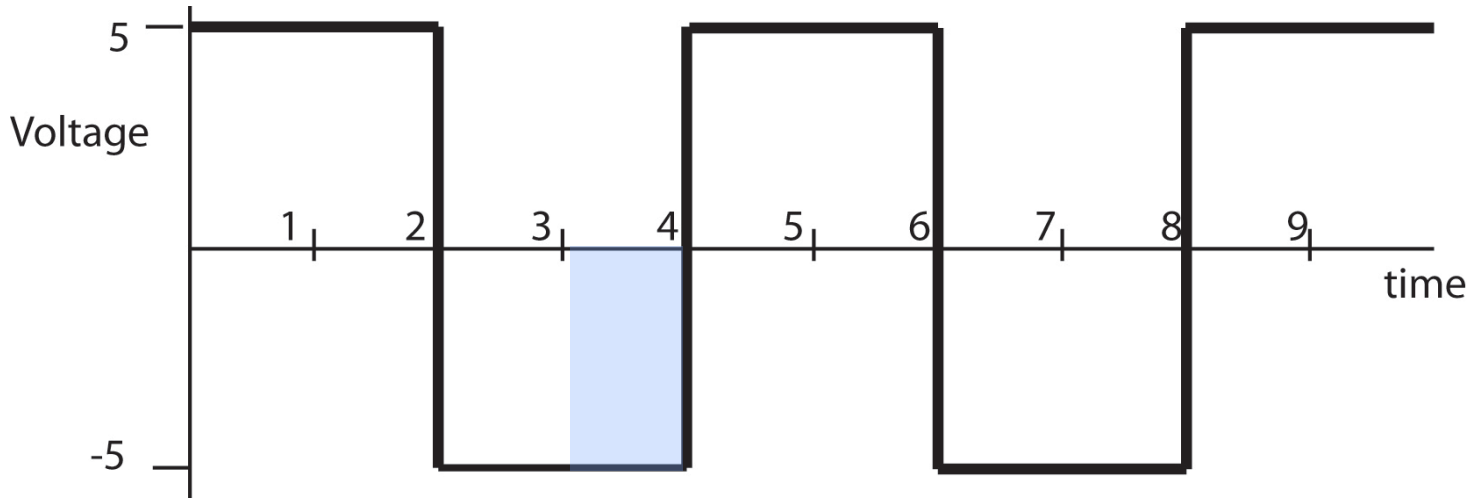
What about here?

- Average= -5



What about here?

- Average= -5

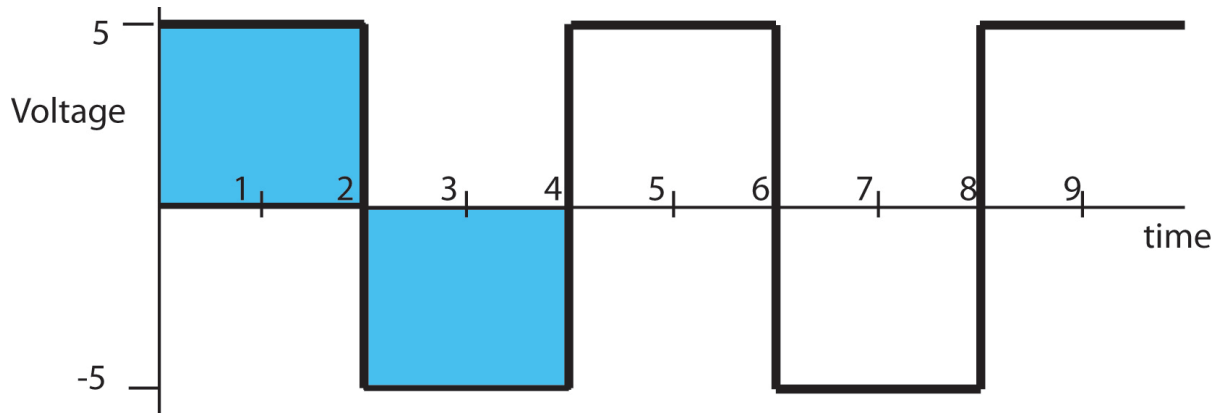


What is the *average* voltage over one cycle?

- Average of four things: add them, then divide by four

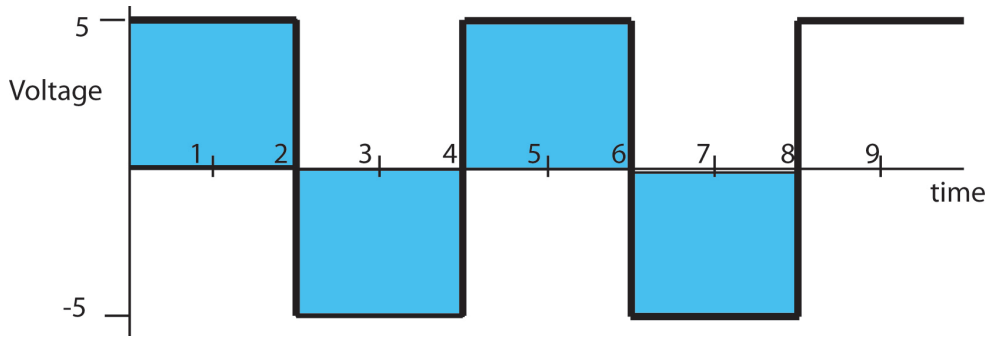
$$\frac{(+5)+(+5)+(-5)+(-5)}{4} = \frac{0}{4} = 0$$

- That's what we wanted: zero average volts over time



What is the average over two cycles?

- Average of two things is the sum of the two divided by zero
- We know the average over one cycle is 0
- (0+0)÷2=0

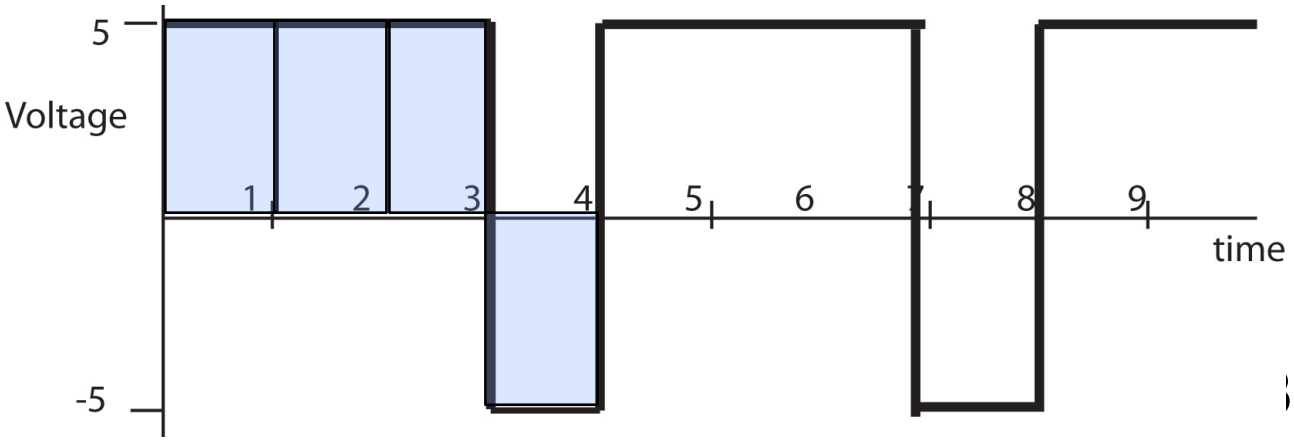


What about this one?

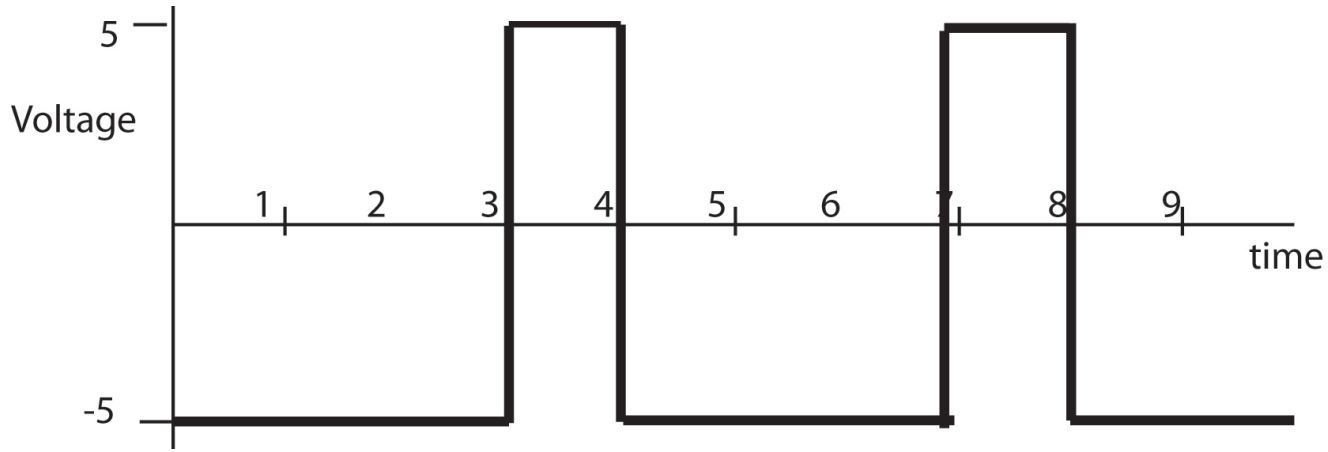
- Average value of first section?
  - +5+5+5
- Average value of second part?
  - -5 x 1 = -5

What is the average value?

$$\frac{+5+5+5+(-5)}{4} = \frac{10}{4} = 2\frac{1}{2} = 2.5$$



What do you think the average value of this one is?

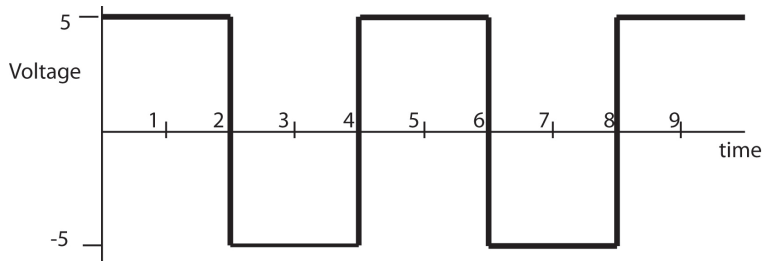


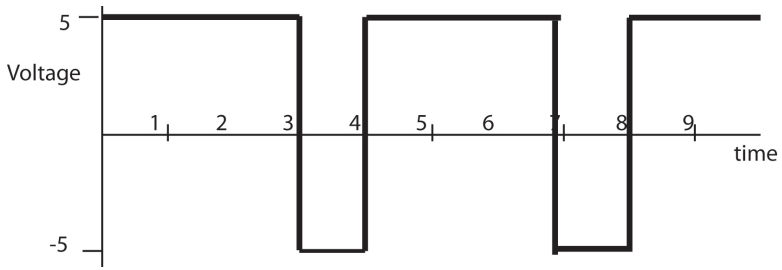
- Right!
  - -2.5 V

$$\frac{(-5)+(-5)+(-5)+(+5)}{4} = \frac{-10}{4} - 2.5$$

So! We require:

- An AC (alternating current) signal
- A zero average value over time
- Therefore we require this
- Not this





So, you'll build two things

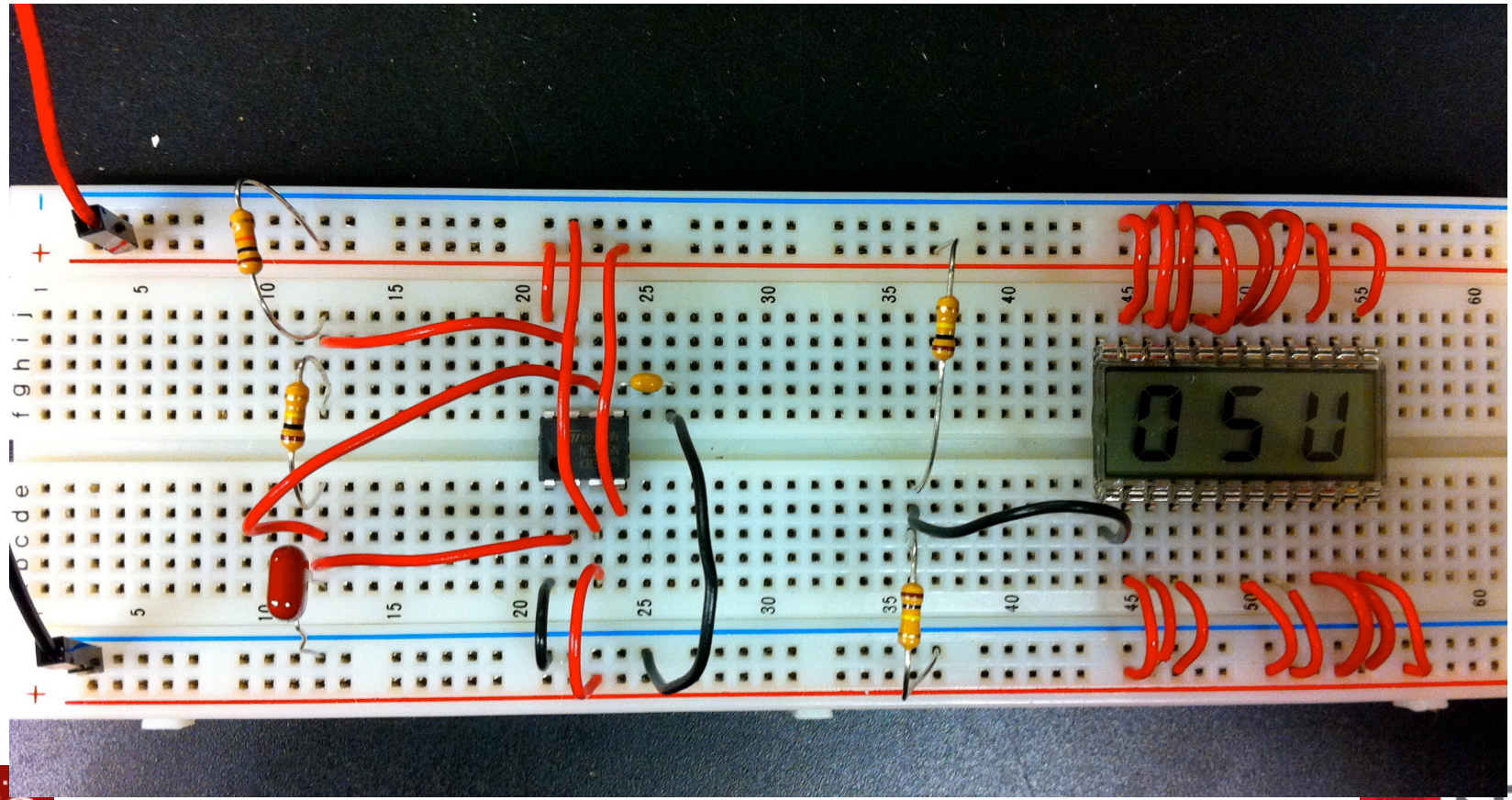
Driver circuit

- Converts DC form battery to square wave
- Must have zero average value
- Check with oscilloscope
  - » Engineer's favorite instrument!
- Once working, build second part

LCD Display

- This one is numeric
- You can "write" whatever you like

Here is what you will build



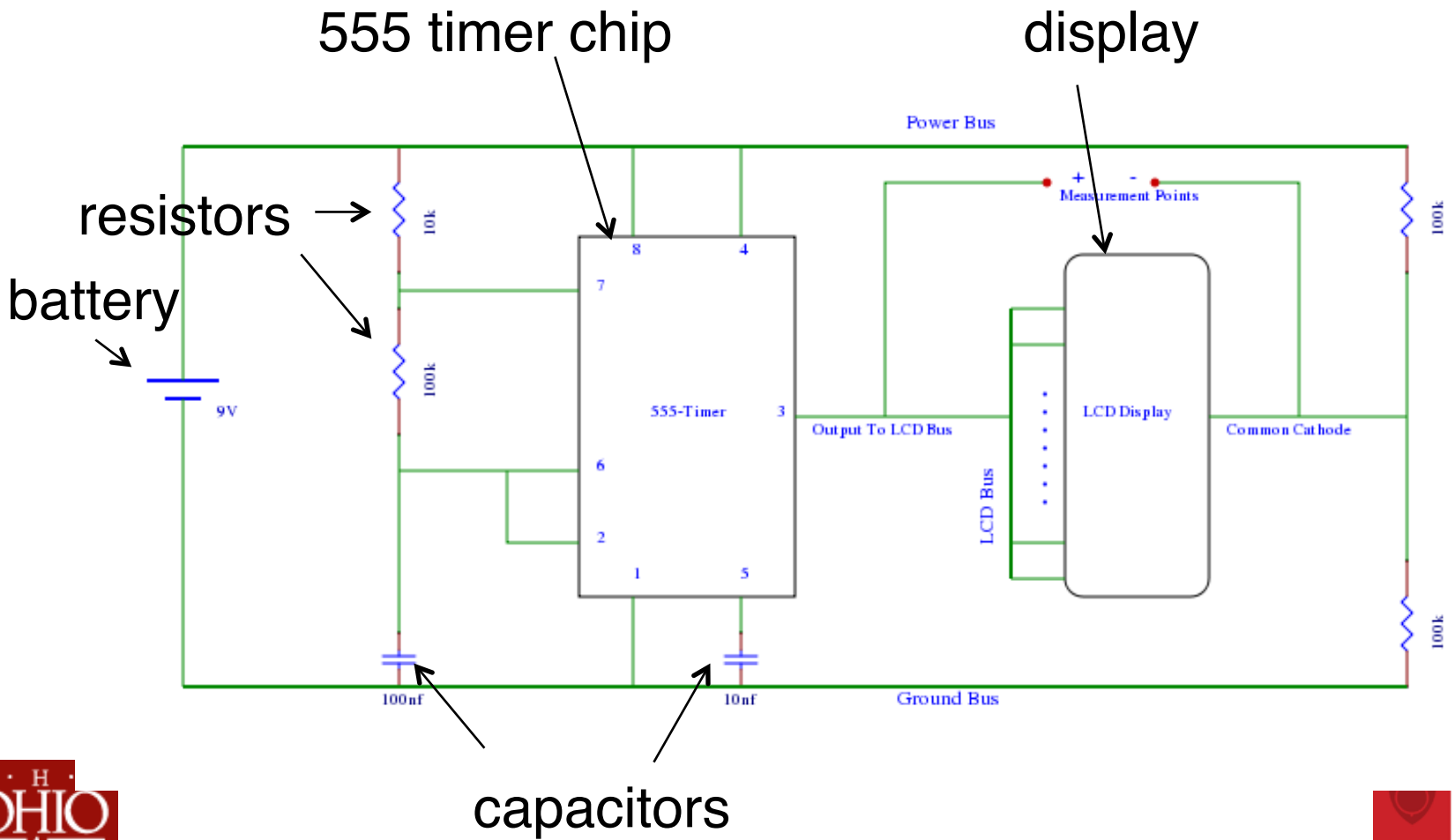
You already know…

- How to use a breadboard
- How to read a schematic
- So go for it!
- Build the circuit
- Check it with the oscilloscope
- Once working, connect it to the liquid crystal display

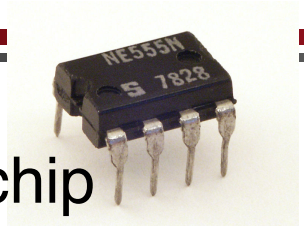
THE OHIO STATE UNIVERSITY

SPIE

Here is the schematic



You should have the following



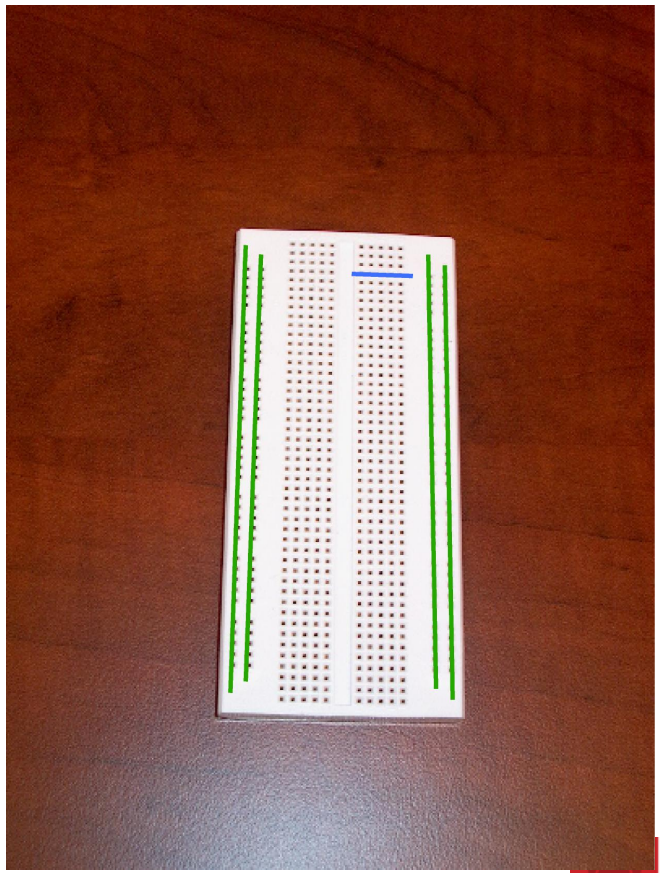
- One 555 timer chip
- Four resistors
  - 100KΩ (brown black yellow) (three of them)
  - 10KΩ (brown black orange)

- 100nF capacitor
- 10 nF capacitor

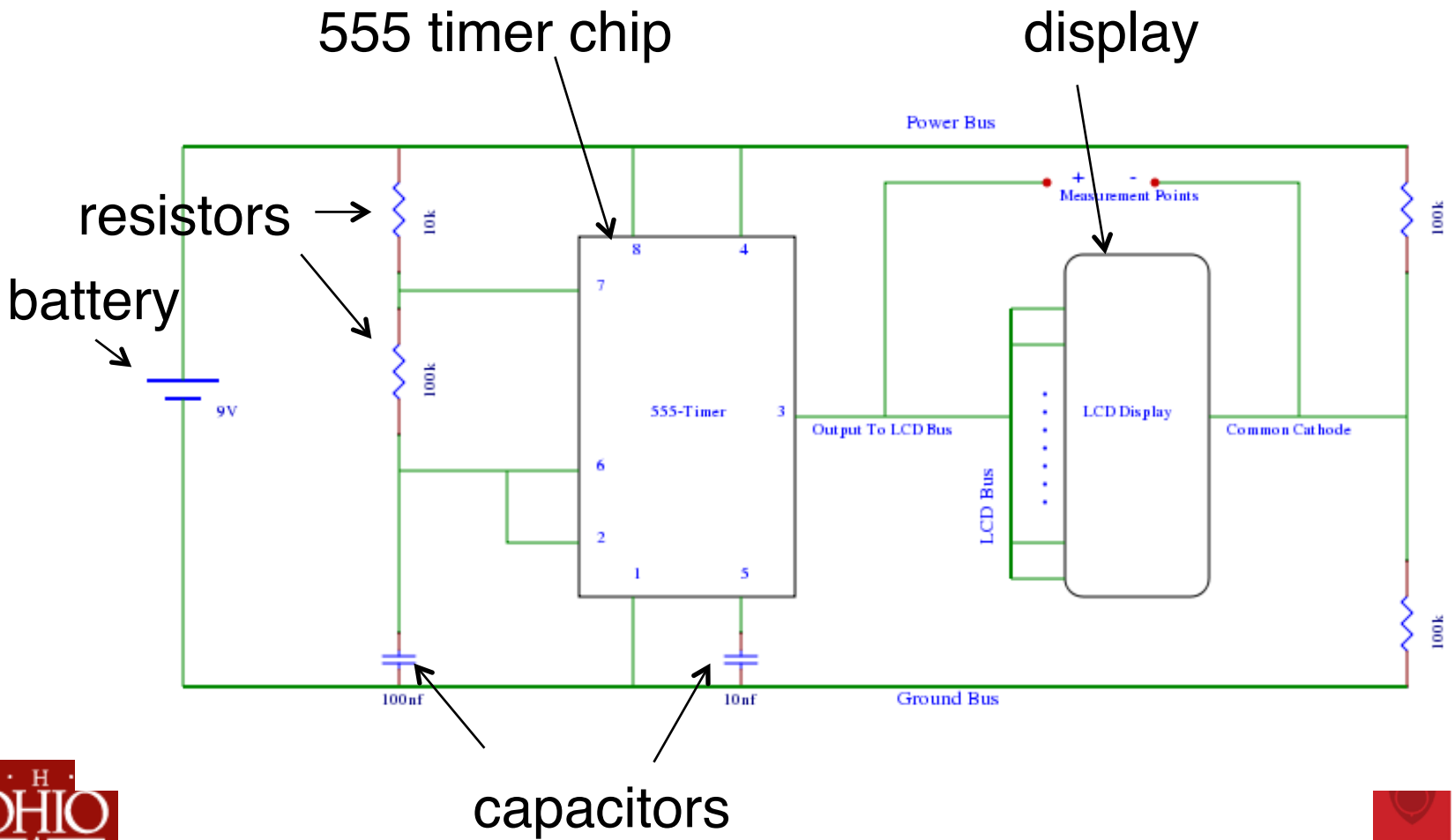
- Battery
- Battery snap
- Breadboard
- Display (we'll give you later)
- Pieces of wire (lots)

Now we're ready to build

- Well use a breadboard
- All holes in long columns connected together
  - These are called "buses"
  - Handy for when you have to connect many things to the same point
- Holes in short rows connected

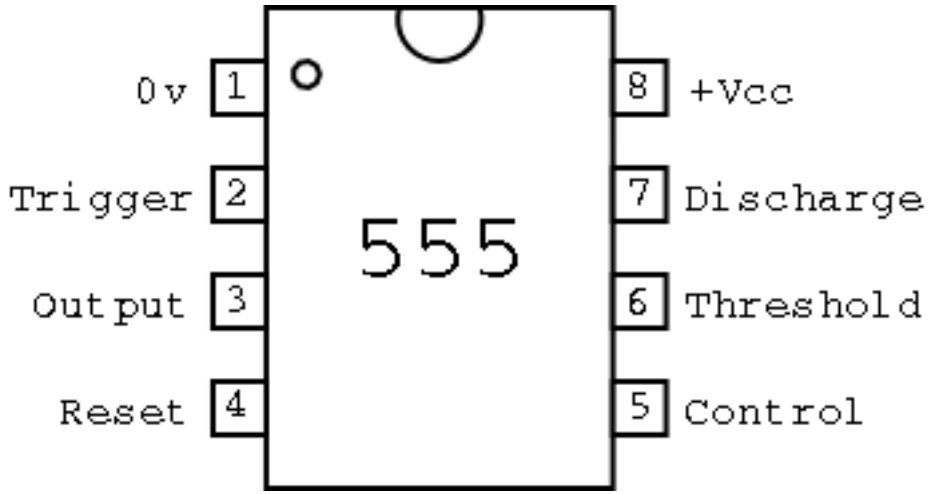


Here is the schematic



Pinout of the 555 Timer

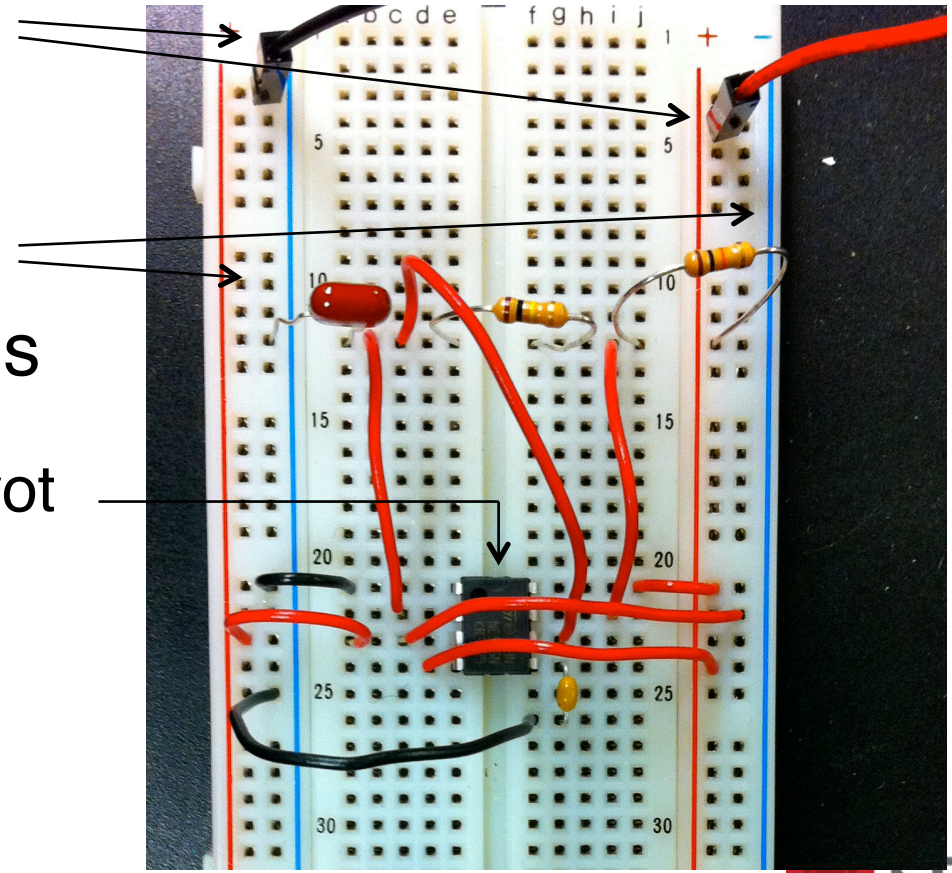
- Divot on end of chip is “up”
- Pins numbered from upper left-hand corner
- Pin numbers go down one side and up the other

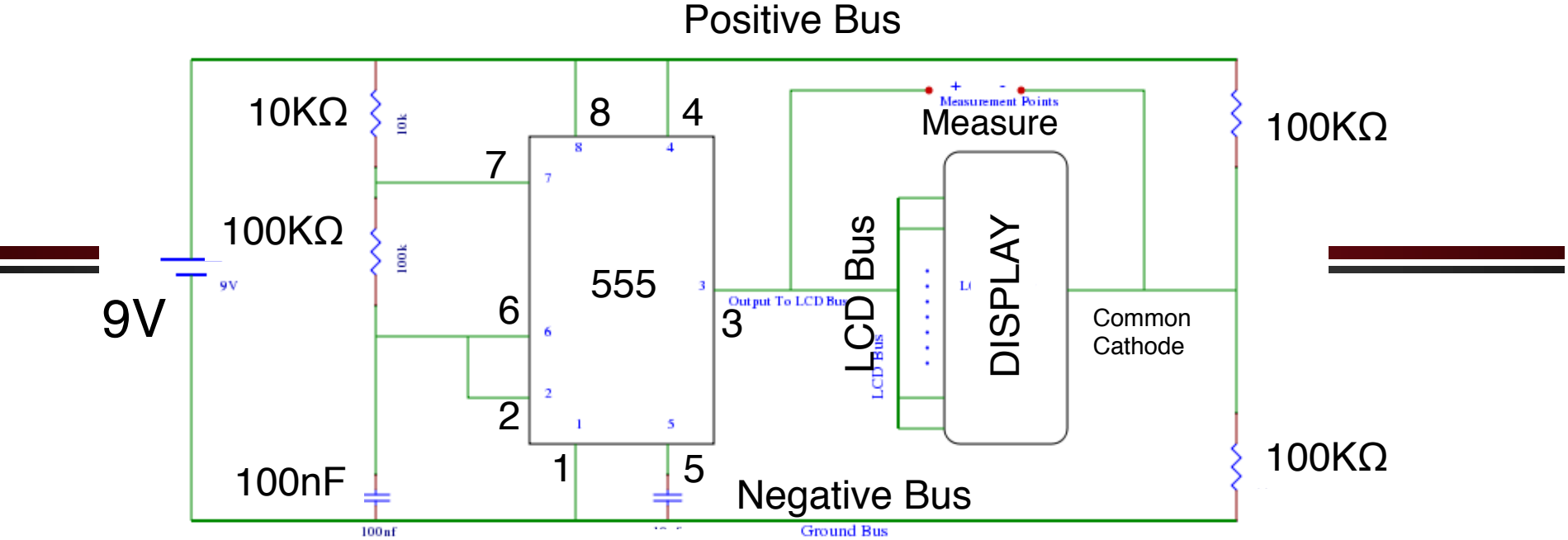


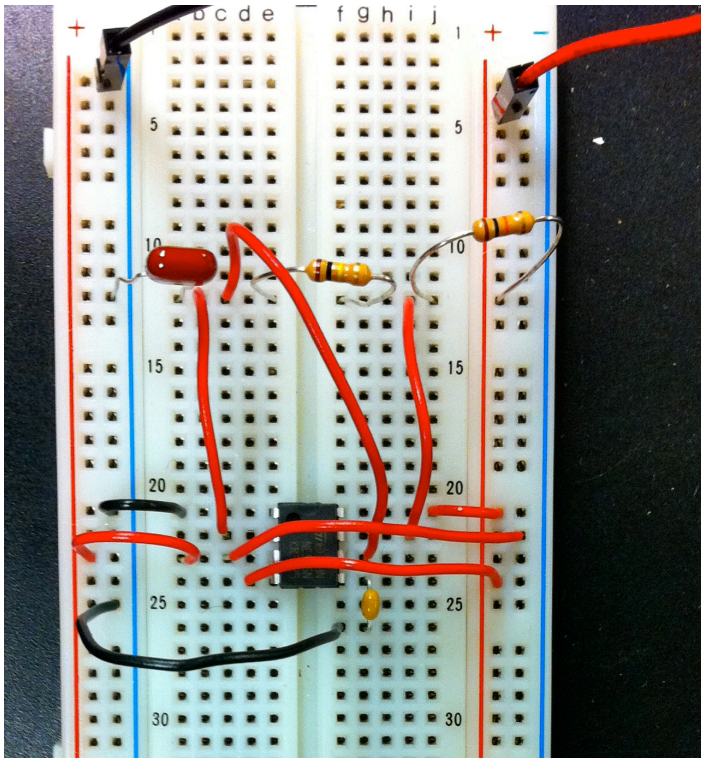
http://aidanross2.wordpress.com/2011/03/14/555-timer/

Square wave portion of circuit

- Note positive and negative busses
- Other two busses will be LCD busses

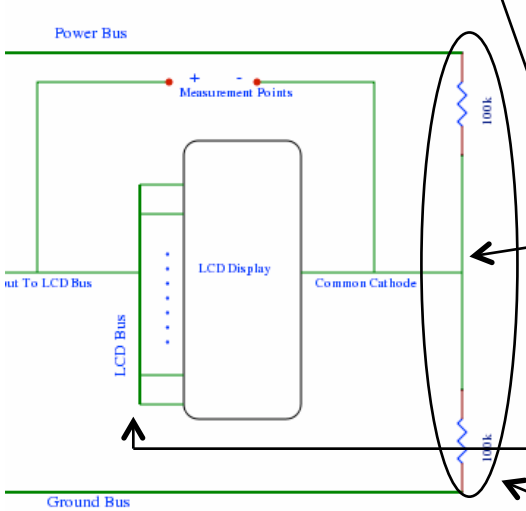


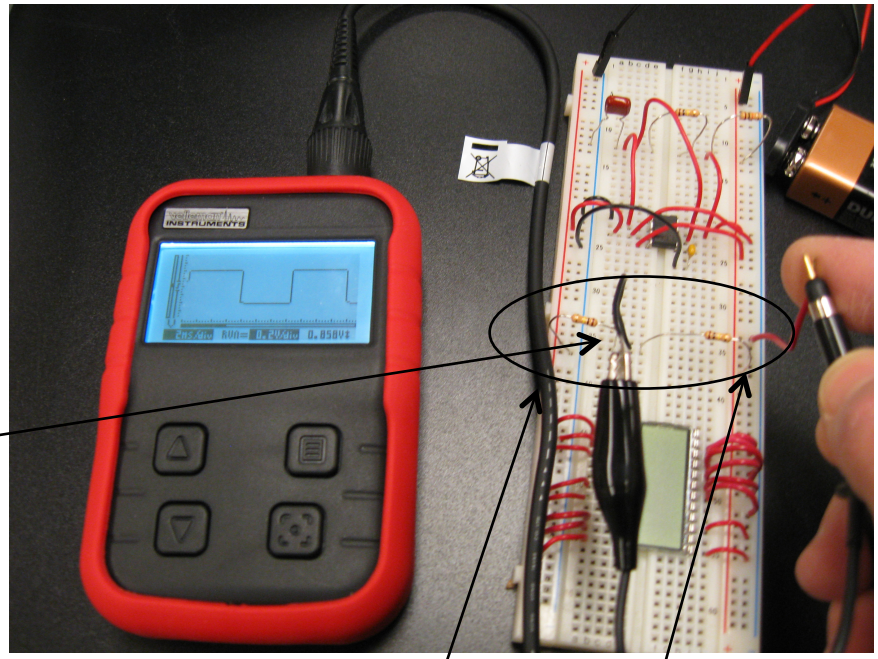

Positive Bus
10KΩ
100KΩ
9V
100nF
8
4
7
6
2
1
5
555
3
Output To LCD Bus
LCD Bus
DISPLAY
Measurement Points
Measure
Common
Cathode
100KΩ
100KΩ
Negative Bus
Ground Bus
10nF



Now add “voltage divider” ad measure (before adding display)

- Alligator clip from scope probe connects here

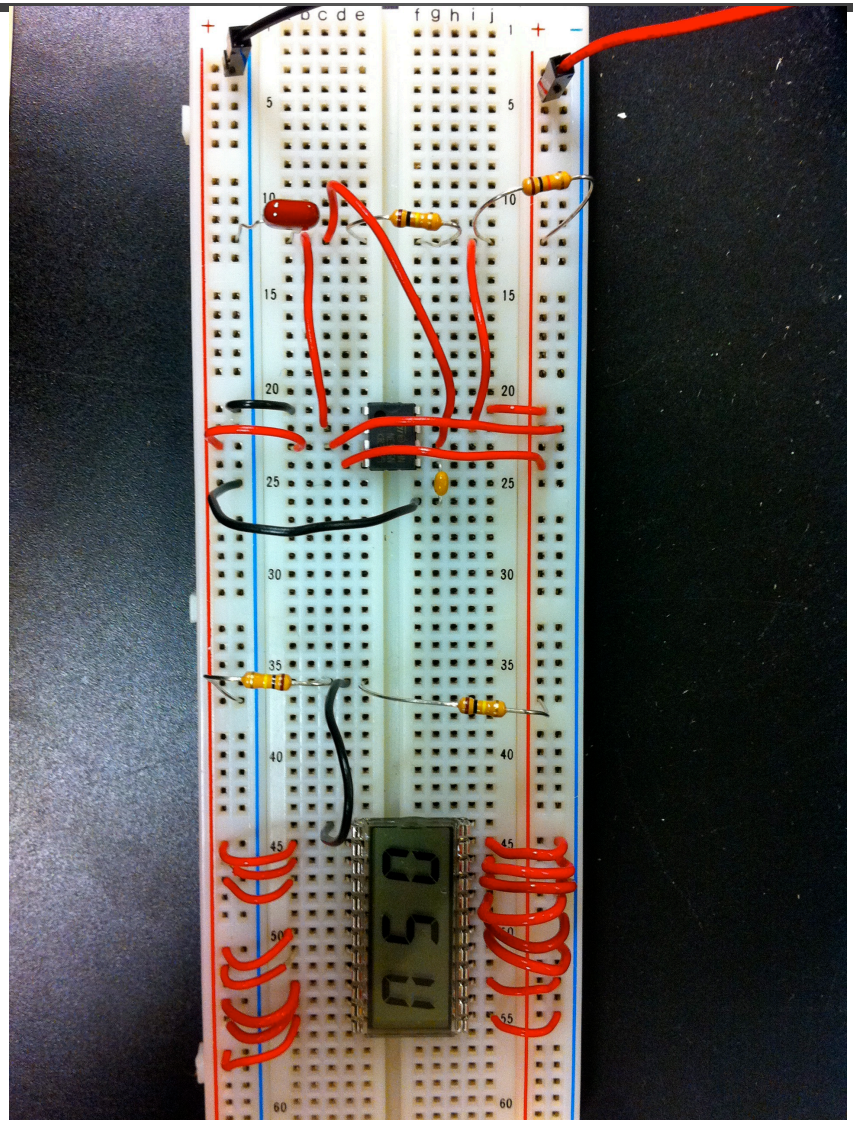




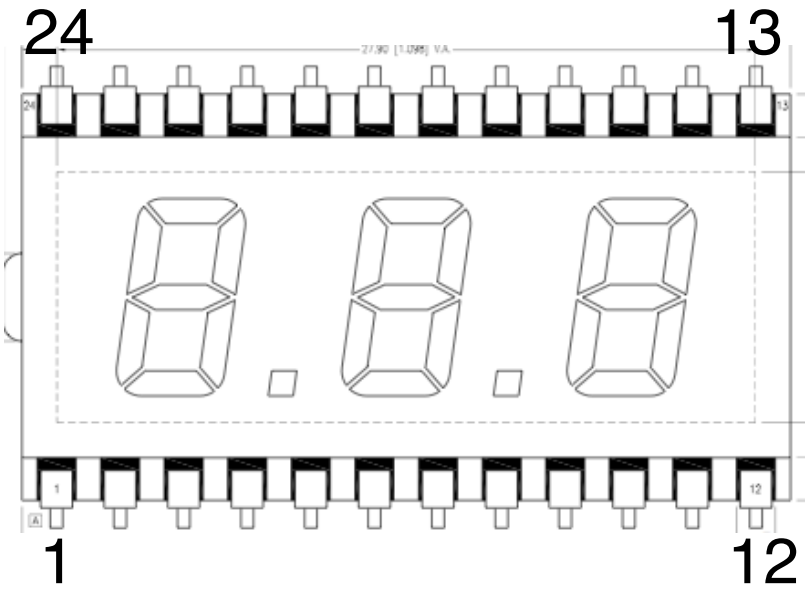
Voltage divider

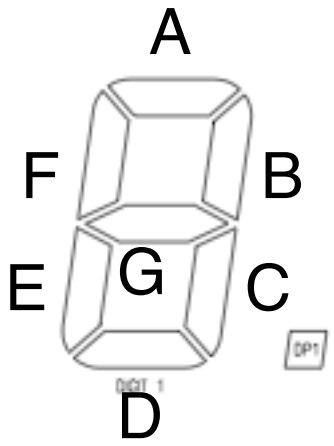
- Probe connects to LCD bus

Now add display



LCD pinout





PIN	1	2	3	4	5	6	7	8	9	10	11	12
SEGMENT	COM	E1	D1	C1	DP1	E2	D2	C2	DP2	E3	D3	C3
PIN	13	14	15	16	17	18	19	20	21	22	23	24
SEGMENT	B3	A3	F3	G3	B2	A2	F2	G2	B1	A1	F1	G1

To remove parts

- PLEASE use IC removal tool
- Avoids bending leads
- Avoids breaking PCD
- Avoids puncturing fingers

http://www.beckwithelectronics.com/ARIES/t90.htm