Introduction to the Scientific Method

– Tutorial –

Ralph J. Steinhagen, CERN

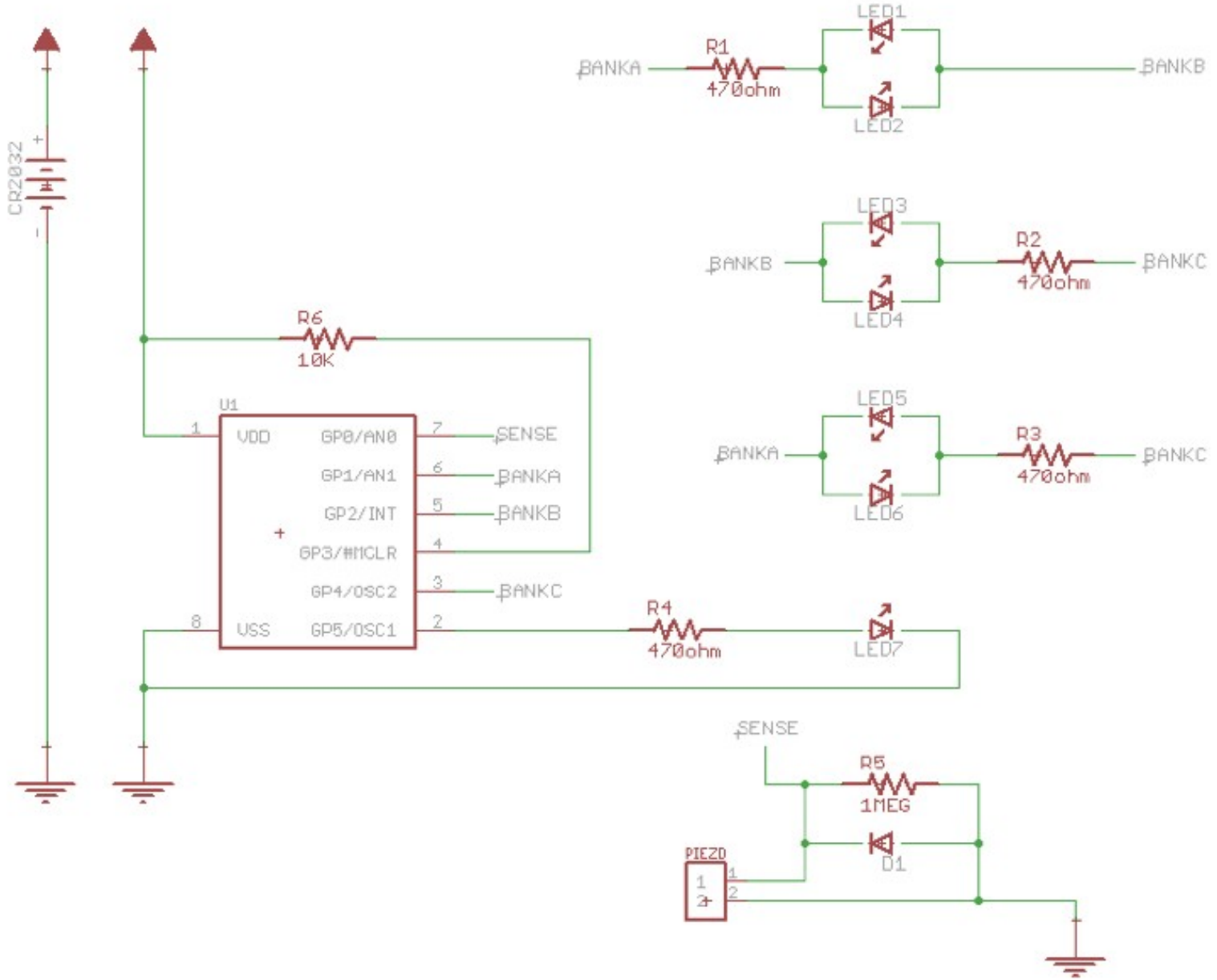
Practise makes perfect

- Scientific method needs to honed...
  … like any other skill (e.g. musical instrument, sports, …)

- First tutorial: 'Electronic Dice'
  Learn to construct simple electronic circuit, apply what you just learned:
  1. Given Questions:
     “Did your tutor temper with your dice kit – is it a fair dice?”
  2. Form Hypotheses
  3. Perform Experiments
  4. Analyse the Data
  5. Interpret the Data
  6. Peer Review → student session on Wednesday
  7. Repeat the Experiment
  8. Continual Review

- Prizes await you for best 'analysis', 'original idea' and 'presentation'!

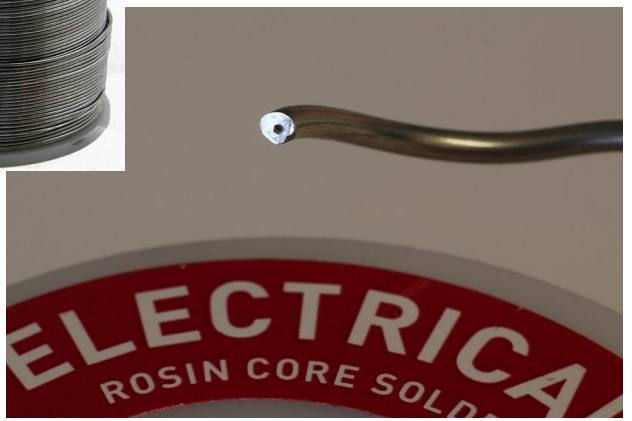
Schematic


CR2032
R6
10K
U1
VDD
VSS
GP0/AN0
GP1/AN1
GP2/INT
GP3/#MCLR
GP4/OSC2
GP5/OSC1
SENSE
BANKA
BANKB
BANKC
R1
470ohm
LED1
LED2
R2
470ohm
LED3
LED4
R3
470ohm
LED5
LED6
R4
470ohm
LED7
R5
1MEG
D1
PIEZO

Solder & Soldering Ion

- … metal “glue” used to join metal parts
  - made of Sn-Ag-Cu, sometimes (/traditionally) Sn-Pb
    - wash hands before/after eating (which is anyway a sensible thing)
  - contains rosin flux
    - lowers metal surface tension (ie. easier adherence/creeping into gaps)
    - some seem to use extra flux pens to increase the flux

Use this to …



… melt this

Soldering tips

- … come in many shapes
  - often a personal choice but conical fits most applications
  - need to be kept clean

hoof conical chisel

Sponge

- Used to clean off soldering iron tip (often comes with a holder)
- Can be made of various materials
- Should be used every time before soldering a joint!

this needs to be wet!

Soldering – Addition Tools

- Additional tools used to handle components and PCBs

tweezers

clippers

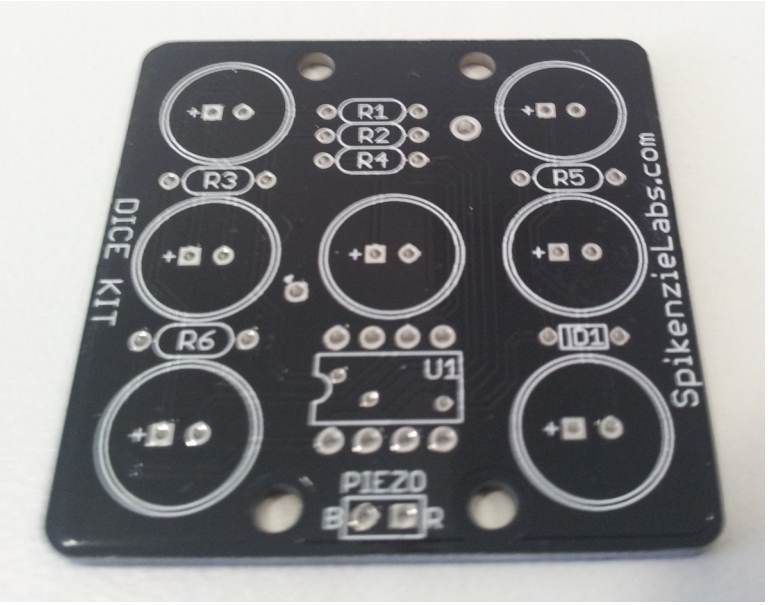
pliers

- Also useful:
  - Semi-fireproof work surface (wooden boards work just fine)
  - Eye-loop (10x): cost-effective option to see small defects
    – more needed when dealing with surface-mount-devices (SMDs)

Printed Circuit Board

- … mostly woven resin-enforced fibre glass and copper layers
  - Commonly one uses 'FR4' – 'flame-resistant epoxy resin' (weak standard)
  - Teflon & ceramics more common for RF applications (more stable properties)

- Has a 'top' and 'bottom', and often many intermediate layers
  - Solder stop (coloured varnish that prevents solder adhering to it)
  - printed silk-screen indicating and aiding component location and orientation

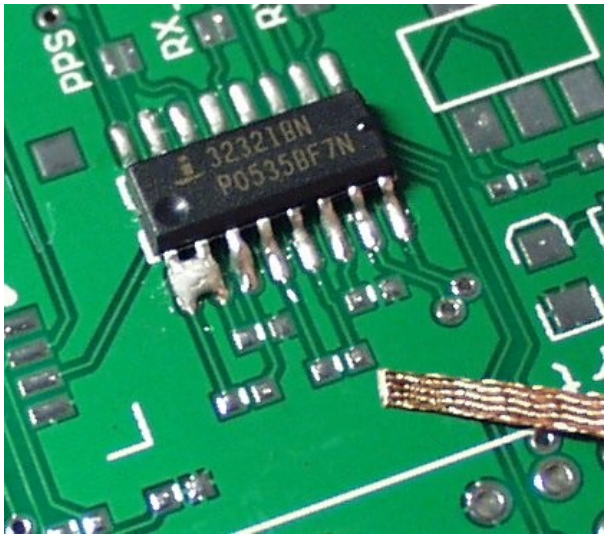


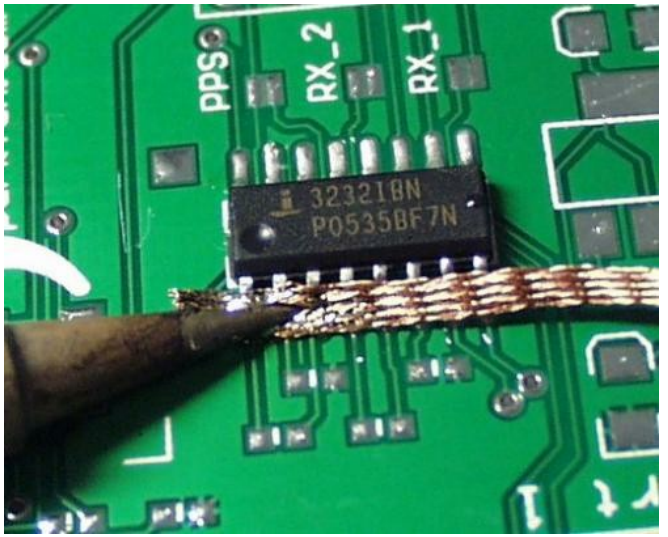
Trouble Shooting I/II – Multimeter

- … you can solder without!
- However, a great aid for SMD work to check/identify components values, short-circuits and general debugging (15 ↔ 60 AUD)

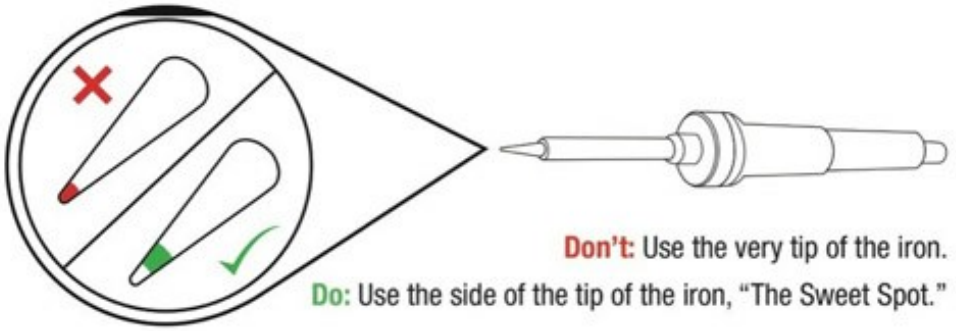
Trouble Shooting II/II – Soldering Wick

- Used to remove solder
  - (small braided wire have higher surface tension than component legs)
- Careful, this can get hot





Soldering – The Essentials



Don't: Use the very tip of the iron.

Do: Use the side of the tip of the iron, "The Sweet Spot."

Do: Touch the iron to the component leg and metal ring at the same time.

Do: While continuing to hold the iron in contact with the leg and metal ring, feed solder into the joint.

Don't: Glob the solder straight onto the iron and try to apply the solder with the iron.

Do: Use a sponge to clean your iron whenever black oxidization builds up on the tip.

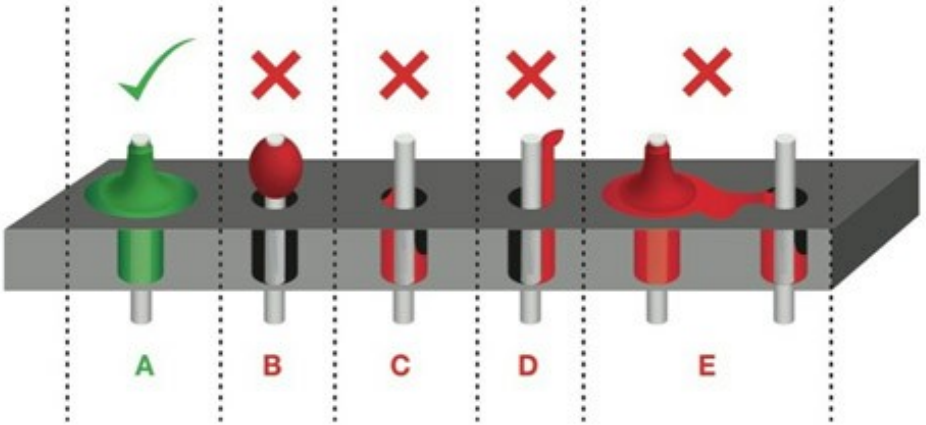
A Solder flows around the leg and fills the hole - forming a volcano-shaped mound of solder.

B Error: Solder balls up on the leg, not connecting the leg to the metal ring.
Solution: Add flux, then touch up with iron.

C Error: Bad Connection (i.e. it doesn't look like a volcano)
Solution: Flux then add solder.

D Error: Bad Connection...and ugly...oh so ugly.
Solution: Flux then add solder.

E Error: Too much solder connecting adjacent legs (aka a solder jumper).
Solution: Wick off excess solder.



Some Simple Soldering Rules

- Soldering is like gluing but with hot metal
  - Pick-up the soldering ion at the right end
  - Metal parts conduct heat – watch what you are touching
- Keep your soldering tip clean → use your wet/brass sponge
- Always solder first one pin → adjust/check polarity → solder other(s)
- Start with the lowest profile component
- Apply heat to the pad and pin and move the solder to the pin (not the ion)
- Check (at appropriate intervals) whether your joints are 'short-free' i.e. not only at the end → this helps to isolate potential problems early

Let's get started

Step 1 – Resistors

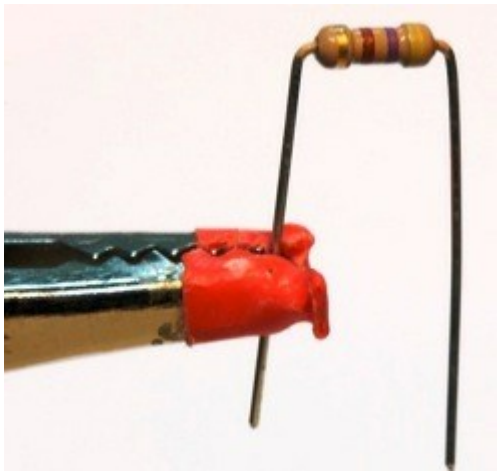
- Start with simple resistors
  - you should have: 4 x 470 Ohm, 1 x 10k, and 1 x 1M resistors.
    - colour-coding for 1st (X), 2nd (Y), exponent (E) and precision (P) → $R=X.Y\cdot10^{E} \pm P\%$ (old fashioned) or: use multi-metre in resistance mode (more precise/modern)

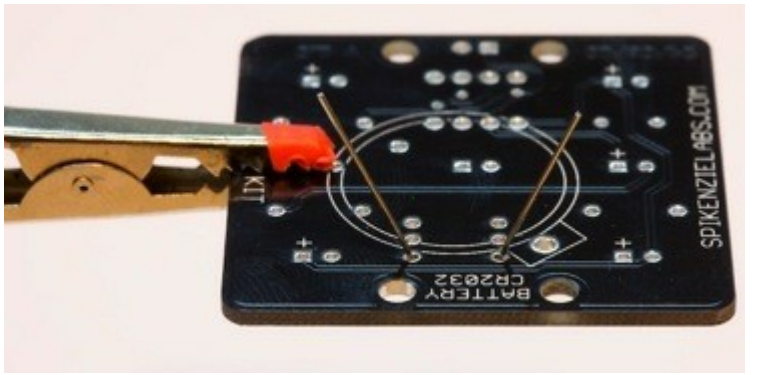
1 MOhm

470 Ohm

10 kOhm

- Bend legs and place resistor (note silkscreen)

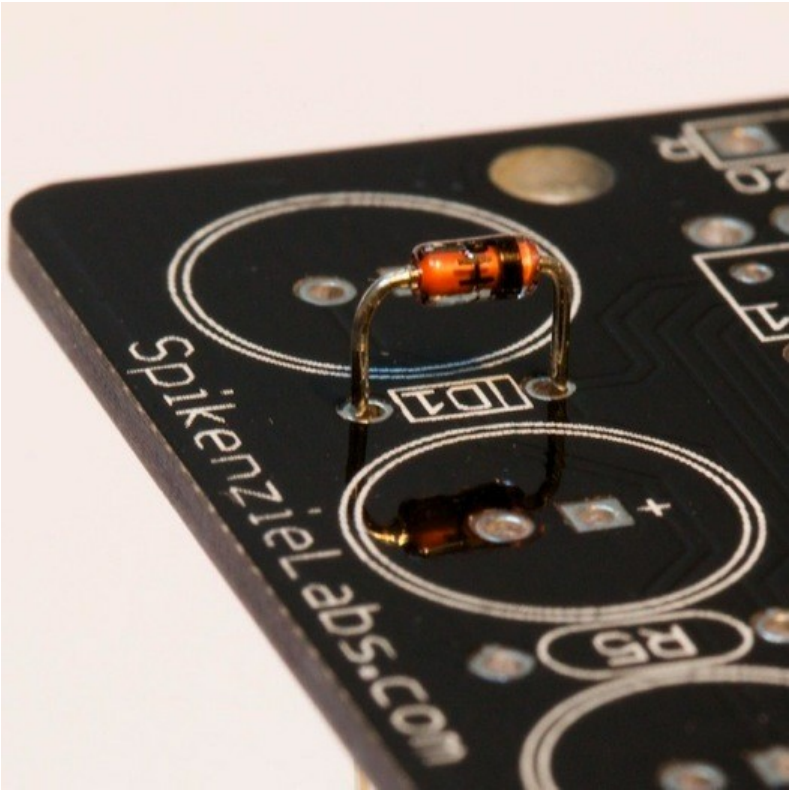




- Trim the excess leg

Step 2 – Diode

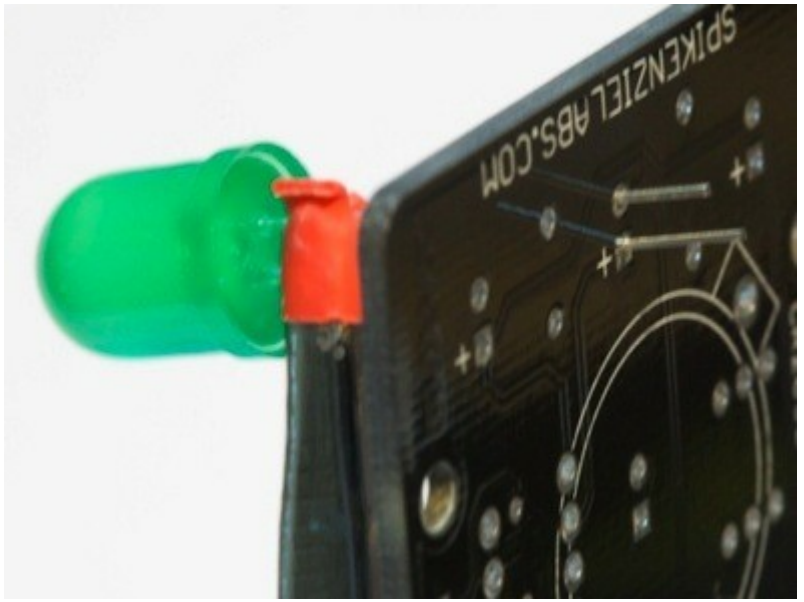
- Installation of Diode 'D1' – bend legs similar to resistors and insert
- Important: Diode is polarity sensitive
  - Ring marking indicates cathode (-) on both diode and silk screen

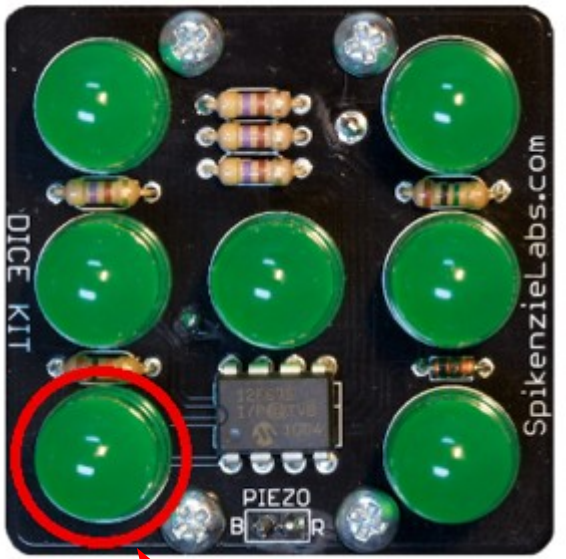


- Trim the excess legs

Step 3 – Light Emitting Diodes (LEDs)

- Install most of the LEDs
  - Also polarity sensitive – for PTH long leg is (always) the anode (+)
- Tip:
  - you may solder first one leg of the LED, use your finger to keep the diode flush (while re-heating the leg) and then solder the other leg.
  - Solder the marked LED last (after battery holder) to have some space for the soldering iron later.

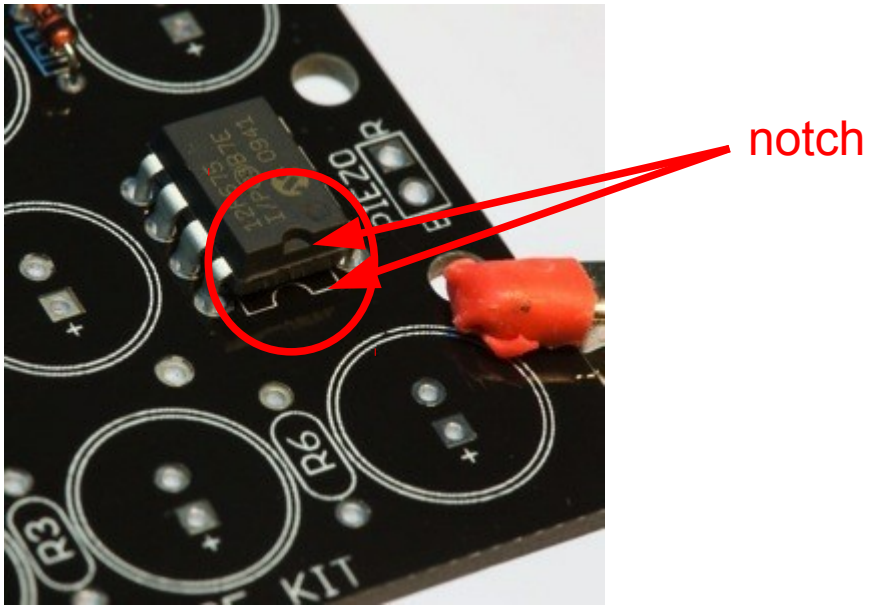




N.B. solder this after the battery holder

Step 4 – Install the PIC Chip

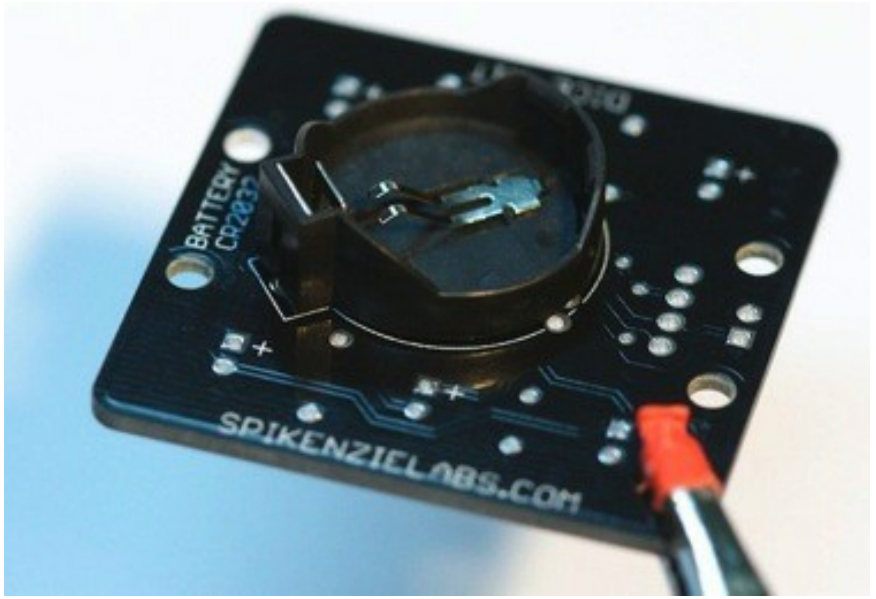
- The PIC micro controller unit (MCU) is already pre-programmed
  - N.B. Your tutor may or may not have tempered with the programming of your specific MCU → to be tested later
  - Direction matters – the notch on the chip and silk screen should line up
- Tip – similar to LEDs
  - First solder one leg (corner), align the chip until flush and aligned, then the opposite corner, then solder the rest

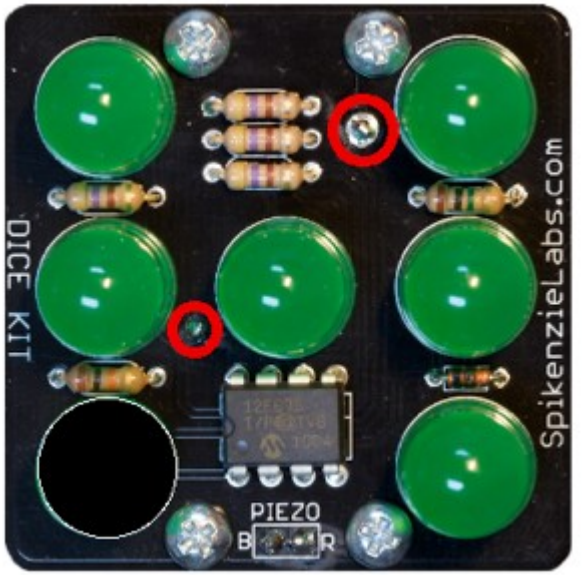


- Trim excess legs (even if short, you need the space for the batter holder)

Step 5 – Battery Holder

- By now, should have soldered all other parts (except last LED)

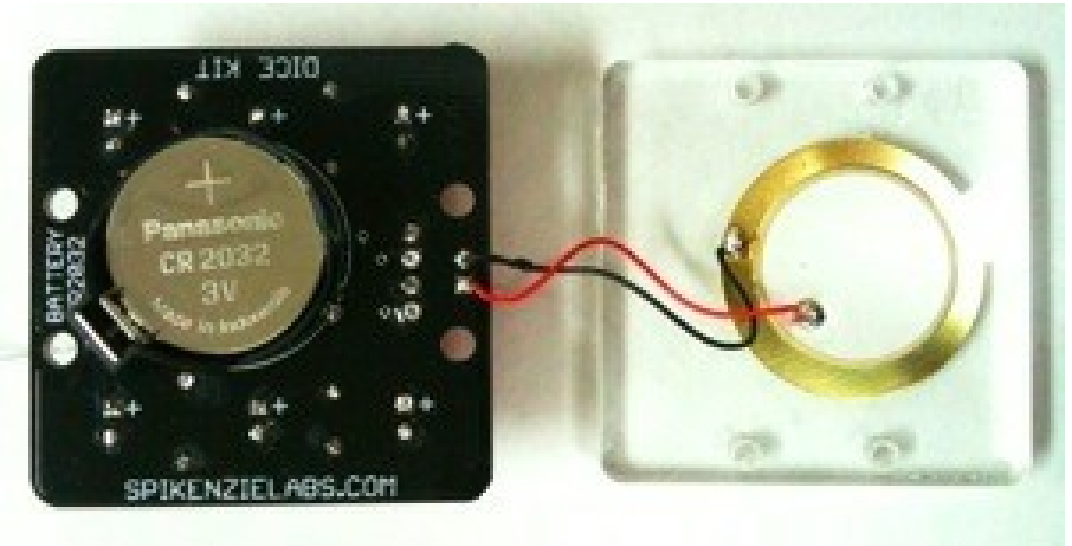




- Add some glue (solder), don't get burned and solder the remaining LED

Step 6 – Piezo Connection

- Almost done. The last component that we have to solder is the Piezo.
- Wires are really thin, and very flexible.
  - Send the wires up through the bottom of the PCB one at a time.
  - Trim excess wire length
  - Note: once the piezo is soldered, handle the PCB and piezo with great care. Try not to stress these wires, they are very thin, and you really do not want them to come loose from the piezo.
- Tip: holding the wire in place with a small piece of tape helps.



- Glue piezo with metal-side down onto the acrylic base-plate

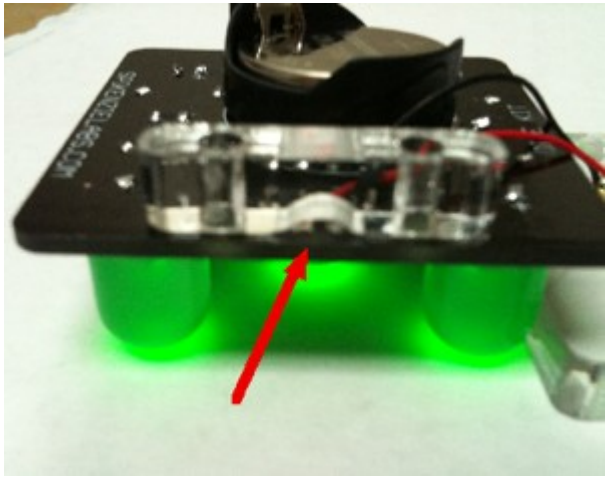
Step 7 – Quick Check

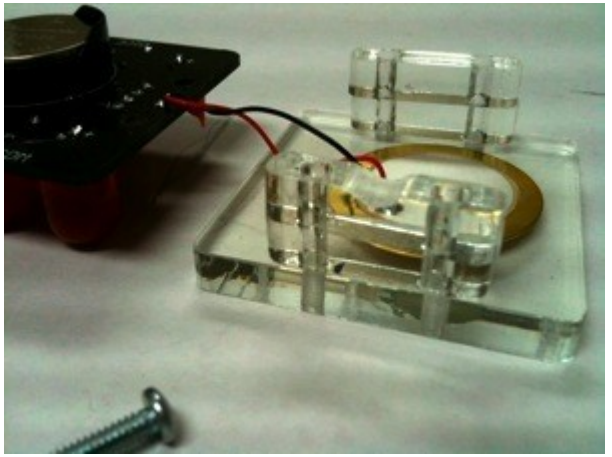
- Before inserting the battery, check for solder-bridges and shorts
- Test I: insert battery and test that you're getting some LED lighting action
  - N.B. piezo is metallic, and could possibly cause a short if contacting the PCB
- Test II: test that every number shows up more or less regularly
  - N.B. in case you one of the kits that are possibly tempered with – the 'tempering' will not show up for very low statistic

- If not → check with your tutor to verify your solder joints/assembly.

Step 6 – Acrylic Base Plate

- Assemble the acrylic base plate
  - watch the notch for the piezo cables!





Congratulations you finished the Assembly

- Enjoy your work and you may get a 'Lear to solder' badge

Practise makes perfect

- Scientific method needs to honed...
  … like any other skill (e.g. musical instrument, sports, …)

- First tutorial: 'Electronic Dice'
  Learn to construct simple electronic circuit, apply what you just learned:
  1. Given Questions:
     “Did your tutor temper with your dice kit – is it a fair dice?”
  2. Form Hypotheses
  3. Perform Experiments
  4. Analyse the Data
  5. Interpret the Data
  6. Peer Review → student session on Wednesday
  7. Repeat the Experiment
  8. Continual Review

- Prizes await you for best 'analysis', 'original idea' and 'presentation'!

Things to Test

- The fault is possibly very rare....
  - you need a sufficient statistics (i.e. > 1000 rolls)

- Ideas to check the 'randomness' of your die
  - frequency → should be equal distribution
  - combined throws A_1, A_2→ result of $P(A_1)$ should be independent of $P(A_2)$
  - Periodicity

Reference and Acknowledgements

- The kit was designed and produced by: http://spikenzielabs.com/
- Great resource to dive more into electronics (many plots taken from there): https://learn.sparkfun.com/tutorials
- On the power of building things yourself:
  M. I. Norton, D. Mochon, D. Ariely, “The 'IKEA Effect': When Labor Leads to Love”, Havard Business School, Working Paper 11-091, 2001
  http://www.hbs.edu/faculty/Publication%20Files/11-091.pdf
- Wikipedia is your friend (other resource of plots and diagrams): http://en.wikipedia.org/wiki/Book:An_introduction_to_electronics
- Check-out: Open-Source and Open-Hardware https://www.sparkfun.com/news/1229