CRASH COURSE ELECTRONICS AND PCB DESIGN

WITH CIRCUITMAKER AND PROTEUS

Udemy

PARTS LIST

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Parts List Introduction

Below is a list that is a super set (in most cases) of all the parts used in the lectures during the hands-on bench exercises. Please don't go out and buy all these parts until you watch the lectures, and please shop around. You can follow along the bench exercises if you wish (and I recommend it), but if you can't stock up on all the parts, you can always circle back later.

If you do decide to buy parts or stock up, I suggest getting enough of each part to last you. These parts are usually pennies to dimes each, so the shipping cost is much more than the parts. So, if you order something like resistors, capacitors, and other passives, it pays to order at least 10, and I personally order 100 of anything, just so I have them.

Again, you have to decide for yourself, but you don't want to buy a (1) 1 cent resistors and then ship them for $40! Make shipping worth it. Also, some people will tear down equipment to scavenge parts, this isn't a bad idea, but it's usually more trouble than its worth for the most part. I will say for transformers, big capacitors, big inductors, this strategy can save you a lot of money, but if you need (20) 10K resistors for something, that's 25 cents, it's surely not worth hours of time de-soldering them from old PCBs!

That said, you can score big at tech old companies that are going out of business, schools, local "maker" spaces that are going out of business. As well, as many cities have "Parts Malls" of course China is the king of this, they have blocks and blocks of places that you can buy anything! But, even if you don't live in Silicon Valley, Austin, or Shenzhen, usually there are some old electronics stores still kicking around or electronics scrapers that might have some stuff for you by the pound, so get creative if you're on a budget.

So, without further ado, here's the parts used more or less in the lectures from passives to ICs, to equipment.

FETS

(10) 2N7000, N-Channel, TO-92 Package, through hole.
(10) BS170, N-Channel, TO-92 Package, through hole.
(10) IRF510, N-Channel, TO-220 Package, through hole.
(10) IRF710, N-Channel, Power FET, TO-220 Package, through hole.

SMD FETS (Optional)

FDC6xx Series (Great selection of FETs)
(10) FDC606P, P-Channel, SMD

FDV300 Series (Great selection of FETs)
(10) FDV305N, N-Channel, SMD

BJT Transistors (10 of each)

(10) 2N2222, NPN Transistor, TO-92 Package, through hole.
(10) 2N3904, NPN Transistor, TO-92 Package, through hole.
(10) 2N3906, PNP Transistor, TO-92 Package, through hole.

Diodes

(10) Schottky, STPS2L60, DO-41, through hole.
(10) Silicon Diodes, 1N4001, DO-41, through hole.
(10) Zener: 1N751, DO-35, through hole

Resistors

Notes: 1. All resistors 5% (1% is even better), 1/4th Watt, carbon film or metal film, through hole axial, ~6.3mm length.

2. These are starter kit values, some are not used in experiments, and you may want to add more to this list.

3. Suggest 25-100 units of each value, you can never have enough resistors, but at least 10.

10 ohm, 33 ohm, 100 ohm, 220 ohm, 330 ohm, 470 ohm, 1K ohm, 2.2K ohm, 3.3K ohm, 4.7K ohm, 5.1K ohm, 10K ohm, 22K ohm, 47K ohm, 100K ohm, 1M ohm

Capacitors

Similar to the resistors, we want a varied supply of different values of capacitance, so we can experiment with. Since we aren't building a product, we don't care too much about the appearance of the capacitor, but we do care that the voltage rating is higher than we need, and we need both polarized and non-polarized devices. With that in mind, we are going to stick to electrolytic radial can capacitors for our big values, and ceramic capacitors for our smaller values. Both are of course through hole.

Electrolytic Capacitors (Polarized)

(10) 1uF, 25V+, radial, 0.2-0.3" lead pitch, through hole.
(10) 10uF, 25V+, radial, 0.2-0.3" lead pitch, through hole.
(10) 22uF, 25V+, radial, 0.2-0.3" lead pitch, through hole.
(10) 33uF, 25V+, radial, 0.2-0.3" lead pitch, through hole.

(10) 47uF, 25V+, radial, 0.2-0.3” lead pitch, through hole.
(10) 68uF, 25V+, radial, 0.2-0.3” lead pitch, through hole.
(10) 100uF, 25V+, radial, 0.2-0.3” lead pitch, through hole.
(10) 220uF, 25V+, radial, 0.2-0.3” lead pitch, through hole.
(5) 470uF, 25V+, radial, 0.2-0.3” lead pitch, through hole.
(2) 1000uF, 25V+, radial, 0.2-0.3” lead pitch, through hole.

Here’s a general search on Digikey that contains all these values, so you can see what I am talking about here:

https://www.digikey.com/products/en/capacitors/aluminum-electrolytic-capacitors/58?k=electrolytic+capacitors&k=&pkeyword=electrolytic+capacitors&pv405=19&FV=1c0002%2C1c0003%2C402e23%2C1140050%2C1f140000%2Cmu1%C2%B5F%7C2049%2Cmu10%C2%B5F%7C2049%2Cmu100%C2%B5F%7C2049%2Cmu1000%C2%B5F%7C2049%2Cmu22%C2%B5F%7C2049%2Cmu220%C2%B5F%7C2049%2Cmu33%C2%B5F%7C2049%2Cmu330%C2%B5F%7C2049%2Cmu47%C2%B5F%7C2049%2Cmu470%C2%B5F%7C2049%2Cmu68%C2%B5F%7C2049%2Cmu100V%7C2079%2Cmu125V%7C2079%2Cmu150V%7C2079%2Cmu160V%7C2079%2Cmu165V%7C2079%2Cmu175V%7C2079%2Cmu180V%7C2079%2Cmu200V%7C2079%2Cmu210V%7C2079%2Cmu220V%7C2079%2Cmu225V%7C2079%2Cmu230V%7C2079%2Cmu250V%7C2079%2Cmu25V%7C2079%2Cmu280V%7C2079%2Cmu28V%7C2079%2Cmu300V%7C2079%2Cmu30V%7C2079%2Cmu315V%7C2079%2Cmu330V%7C2079%2Cmu350V%7C2079%2Cmu35V%7C2079%2Cmu360V%7C2079%2Cmu385V%7C2079%2Cmu400V%7C2079%2Cmu40V%7C2079%2Cmu415V%7C2079%2Cmu420V%7C2079%2Cmu42V%7C2079%2Cmu450V%7C2079%2Cmu45V%7C2079%2Cmu475V%7C2079%2Cmu500V%7C2079%2Cmu50V%7C2079%2Cmu525V%7C2079%2Cmu550V%7C2079%2Cmu55V%7C2079%2Cmu56V%7C2079%2Cmu575V%7C2079%2Cmu580V%7C2079%2Cmu600V%7C2079%2Cmu60V%7C2079%2Cmu630V%7C2079%2Cmu63V%7C2079%2Cmu650V%7C2079%2Cmu700V%7C2079%2Cmu70V%7C2079%2Cmu71V%7C2079%2Cmu75V%7C2079%2Cmu80V%7C2079%2Cffe0003a%2C7f00001%2C7f00064%2C7f00019%2C7f00117%2C7f00004%2C7f00009&quantity=0&ColumnSort=0&page=1&stock=1&rohs=1&pageSize=25

Ceramic / Monolithic Capacitors (Non-Polarized)

(10) 10pF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 20pF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 33pF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 100pF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 0.01uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 0.1uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 0.22uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 0.33uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.

(10) 0.47uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.

(10) 1uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 2.2uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 3.3uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 4.7uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.
(10) 10uF, 25V+, radial/disc, 0.1-0.2” lead pitch, through hole.

Again, another search on Digikey, so you can see what I am talking about:

https://www.digikey.com/products/en/capacitors/ceramic-capacitors/60?k=ceramic+capacitors&k=&pkeyword=ceramic+capacitors&pv2049=u10pF&pv2049=u20pF&pv2049=u33pF&pv2049=u100pF&pv2049=u10000pF&pv2049=u0.1%C2%B5F&pv2049=u0.22%C2%B5F&pv2049=u0.33%C2%B5F&pv2049=u0.47%C2%B5F&pv2049=u1%C2%B5F&pv2049=u2.2%C2%B5F&pv2049=u3.3%C2%B5F&pv2049=u4.7%C2%B5F&pv2049=u10%C2%B5F&pv3=3&pv3=2&FV=1c0002%2C1c0003%2C1140050%2C1f140000%2Cffe0003c%2C380001%2C38042a%2C380467%2C380071%2C380474%2C380475%2C380477%2C38000e%2C380012%2C3800bd%2C3800c0%2C380002%2C380014%2C380018%2C38001a%2C38001c%2C380132%2C38001f%2C380020%2C3801ec%2C380253%2C38029f%2C3802a5%2C3802a6%2C380306%2C380307&quantity=0&ColumnSort=0&page=1&stock=1&rohs=1&pageSize=25

LEDs / Displays

7-Segment LED Display, common anode, through hole, DIP 10-pin, 7-10mm digit size recommended, dozens to choose from.

(10) Red LED, T-1 3/4 (5mm) diameter, through hole.
(10) Green LED, T-1 3/4 (5mm) diameter, through hole.
(10) Blue LED, T-1 3/4 (5mm) diameter, through hole.
(10) Yellow LED, T-1 3/4 (5mm) diameter, through hole.

Example Digikey Search:

https://www.digikey.com/products/en/optoelectronics/led-indication-discrete/105?k=green+LED&k=&pkeyword=green+LED&pv1291=5101&pv1291=7878&FV=1140050%2Cffe00069%2C1c0002%2C1c0003%2C1f140000&quantity=0&ColumnSort=0&page=1&stock=1&rohs=1&pageSize=25

Also, if you prefer small LEDs, the 3mm size is nice

(10) Red LED, T-1 3/4 (5mm) diameter, through hole.
(10) Green LED, T-1 3/4 (5mm) diameter, through hole.

(10) Blue LED, T-1 3/4 (5mm) diameter, through hole.
(10) Yellow LED, T-1 3/4 (5mm) diameter, through hole.

Example Digikey Search:

https://www.digikey.com/products/en/optoelectronics/led-indication-discrete/105?k=green+LED&k=&pkeyword=green+LED&pv1291=4219&pv1291=7877&FV=1140050%2Cffe00069%2C1c0002%2C1c0003%2C1f140000&quantity=0&ColumnSort=0&page=1&stock=1&rohs=1&pageSize=25

Example Digikey Search:

https://www.digikey.com/products/en/optoelectronics/display-modules-led-character-and-numeric/92?k=7-segment+display&k=&pkeyword=7-segment+display&pv311=87&pv311=1&pv311=131&pv311=123&pv311=2&pv311=44&pv311=9&FV=1c0011%2C1c00c5%2C1c0002%2C1c0003%2C1c0006%2C9800e9%2C980009%2C1f140000%2Cffe0005c%2C4027b0%2C402c68%2C402c6a%2C402fe5%2C402fee%2C40305d%2C403821%2C403825%2C403b20&quantity=0&ColumnSort=0&page=1&stock=1&rohs=1&pageSize=25

Integrated Circuits

Many of these gates and ICs are old or obsolete, but still used for illustrative or educational purposes, thus we use them in many of the basic digital electronics experiments. Also, in the experiments we usually use only one model of the IC, but I give options here that are functionally similar just, so you can see options and pricing. But, if you want to follow along ***EXACTLY*** then make sure you note what the lecture uses and purchase that.

Logic Gates

Notes: XX means LS, HC, LV versions are fine, be consistent though and try not to mix logic families unless you make sure inputs and outputs will tolerate it.

(3) 74XX04, DIP 14-pin, through hole.
(3) 74XX08, DIP 14-pin, through hole.
(3) 74XX32, DIP 14-pin, through hole.

D-Type Flip Flops

(3) 74xx74, DIP 14-pin, through hole.

JK-Type Flip Flops

(3) 74XX73, DIP 14-pin, through hole.
(3) 74XX76, DIP 16-pin, through hole.
(3) 74XX109, DIP 14-pin, through hole.
(3) CD4027B, DIP 14-pin, through hole.

Encoders/Decoders/Multiplexers/Demultiplexers

(3) 3/8 Decoder, 74XX138, DIP 16-pin, through hole.
(3) 2-4 Decoder, 74XX139, DIP 16-pin, through hole.
(3) 7-Segment LED Display Driver, 74LS47, Open collector/Active Low, DIP 16-pin, through hole.

(3) Multiplexer (8:1), 74XX151, DIP 16-pin, through hole.
(3) Multiplexer (8:1), CD4051, DIP 16-pin, through hole.

Shift Registers

(3) Serial to Parallel, 74XX164, DIP 14-pin, through hole.
(3) Parallel/Serial to Serial, 74XX166, DIP 16-pin, through hole.

Math Operations

(3) Counter 4-Bit, 74XX161, DIP 16-pin, through hole.
(3) Counter 4-Bit, 74XX93, DIP 14-pin, through hole.
(3) Comparator, 74XX85, DIP 16-pin, through hole.
(3) Full Adder, 74XX83, DIP 16-pin, through hole.
(3) ALU, 74XX181, DIP 24-Pin, through hole.
(3) ALU, 74F382, DIP 20-Pin, through hole.

Timing

(3) 555 Timer, DIP 8-pin, through hole, there are variations that can hit 3-5Mhz!!

Example Digikey Search:

https://www.digikey.com/products/en/integrated-circuits-ics/clock-timing-programmable-timers-and-oscillators/689?k=555+dip&k=&pkeyword=555+dip&pv183=2698&pv183=2697&pv16=6547&pv1291=177&pv1291=862&FV=ffe002b1&quantity=0&ColumnSort=0&page=1&stock=1&pageSize=25

Mechanicals

(3-5) Single Row Male Header (Get large 20-40 pin size and cut/break apart), 0.1", 12-15mm length, contact finish gold (easier to solder, lasts longer), through hole

Example Digikey Search:

https://www.digikey.com/products/en/connectors-interconnects/rectangular-connectors-headers-male-pins/314?k=header&k=&pkeyword=header&pv1791=2&pv1791=9&FV=1c00c5%2C1c0002%2C1c0003%2C1140050%2C1600085%2C160000e%2C16000b3%2C1600012%2C1600013%2C1600014%2C1600015%2C1600016%2C1600017%2C160001d%2C1600022%2C1600023%2C1600024%2C160002f%2C1600030%2C160003d%2C160004a%2C160004b%2C160004f%2C1600050%2C1600062%2C1680001%2C1bf80001%2C1f140000%2C1f6c0003%2C1f940005%2Cffe0013a%2C1f980064%2C1f980067%2C1f980068%2C1f98006e%2C1f980070%2C1f980071%2C1f98004b%2C1f98004c%2C1f980052%2C1f980053%2C1f980054%2C1f980057%2C1f98005e%2C1f98005f%2C1f980061%2C1f980062%2C1f980063&quantity=0&ColumnSort=0&page=1&stock=1&rohs=1&pageSize=25

(3-5) Single Row Female Header (Get large size 20-40 pin and cut/break apart), 0.1", contact finish gold, through hole, mostly for PCB mount work

Example Digikey Search:

https://www.digikey.com/products/en/connectors-interconnects/rectangular-connectors-headers-receptacles-female-sockets/315?k=sullins+headers&k=&pkeyword=sullins+headers&pv2172=i1&FV=1140050%2C160000a%2C160000b%2C160000c%2C160000d%2C1600012%2C1600013%2C1600014%2C1600015%2C1600016%2C1600017%2C160001a%2C160001b%2C160001d%2C1600003%2C160001e%2C160001f%2C1600020%2C1600021%2C1600022%2C1600023%2C1600024%2C1600004%2C160002f%2C160003d%2C160004b%2C160004f%2C1bf80001%2C1f140000%2Cffe0013b%2C1bfc0002%2C1c0c0006&quantity=0&ColumnSort=0&page=1&stock=1&rohs=1&pageSize=25

(10-20) Momentary Switches - Any push button, on/off, normally open will do, here are some suggestions:

Example Digikey Search:

https://www.digikey.com/products/en/switches/tactile-switches/197?k=evq-&k=&pkeyword=evq-&FV=ffe000c5%2C1140050%2C2080007%2C3ac000e%2C1f140000&quantity=0&ColumnSort=0&page=1&stock=1&rohs=1&pageSize=25

Circuit Fabrication

These tools are optional, and only needed if you want to follow along with bench work, and build your own circuits. These are only suggestions, you may want to purchase more elements to build up your fabrication resources. These tools can be expensive or cheap, it's up to you. I suggest searching on Amazon.com as a resource and search engine to see others reviews and do comparisons, then if you don't have an Amazon.com that ships to your country, you can still find the products on another local site, eBay, etc. But, amazon has a lot of **"Electronic Building Kits"**, and is a great way to get these things. Below under each category, I will provide an Amazon link to a page of suggestions. Hookup wires are one thing, but oscilloscopes are another, thus you will have to do a lot of research and shopping to find what you like if you desire to purchase these more advanced pieces of equipment at some point.

Hookup Wires

You can use 20-24 gauge (22 is just right it seems) solid wire and cut it yourself, or you can buy pre-cut "jumper wires". I suggest both approaches since pre-cut wires are specific lengths, and many times they get messy as you build your circuit. On the other hand, pre-cut jumpers have male and female ends which make using them convenient as well as connecting to male and female headers on external hardware; dev boards, Arduino's, etc. Here are a few searches to get you started:

Solid Hook Up Wire

https://www.amazon.com/Electronix-Express-Hook-Wire-Solid/dp/B00B4ZRPEY/ref=sr_1_3?ie=UTF8&qid=1529462300&sr=8-3&keywords=22+gauge+hookup+wire+solid

Pre-Cut Jumpers

https://www.amazon.com/SIM-NAT-Solderless-Breadboard-Electronic/dp/B0728C8QHN/ref=sr_1_5?s=hi&ie=UTF8&qid=1529462334&sr=1-5&keywords=wire%2Bjumper%2Bkit&th=1

https://www.amazon.com/Yueton-Multicolored-Female-Breadboard-Jumper/dp/B01DDD1LXU/ref=sr_1_9?s=hi&ie=UTF8&qid=1529462334&sr=1-9&keywords=wire+jumper+kit

Solderless Breadboards

These are of course to build your projects on without soldering or wire wrapping. You can get many smaller breadboards, or instead 1-2 larger. I tend to use both approaches.

https://www.amazon.com/SOLDERLESS-EXPERIMENT-BREADBOARD-PRE-FORMED-PROTO-TYPING/dp/B013ND4Y8E/ref=sr_1_1_sspa?s=hi&ie=UTF8&qid=1529462563&sr=1-1-spons&keywords=solderless%2Bbreadboard&th=1

https://www.amazon.com/SOLDERLESS-EXPERIMENT-BREADBOARD-PRE-FORMED-PROTO-TYPING/dp/B013NCV3S4/ref=sr_1_1_sspa?s=hi&ie=UTF8&qid=1529462563&sr=1-1-spons&keywords=solderless+breadboard&psc=1

https://www.amazon.com/SOLDERLESS-EXPERIMENT-BREADBOARD-PRE-FORMED-PROTO-TYPING/dp/B013NCCPB8/ref=sr_1_1_sspa?s=hi&ie=UTF8&qid=1529462563&sr=1-1-spons&keywords=solderless%2Bbreadboard&th=1

https://www.amazon.com/SOLDERLESS-EXPERIMENT-BREADBOARD-PRE-FORMED-PROTO-TYPING/dp/B013MPA9ZA/ref=sr_1_1_sspa?s=hi&ie=UTF8&qid=1529462563&sr=1-1-spons&keywords=solderless%2Bbreadboard&th=1

Wire Wrapping Wire and Tool

You can wire wrap with many different gauge wire's, but typically most digital electronics are done with 28-30 gauge wire and wrapping tool. A little thicker wire (28 gauge) guarantees a slightly better wrap, and higher current support, but 30 gauge allows more delicate work to be done. I suggest you get 30 gauge as your primary wire wrapping wire, but experiment with 28 gauge in situations such as running power or high current connections. Finally, wire wrapping tools and wire are fairly expensive since they are precision tools and fine wire, so shop around to find the best prices. The tools are usually $20-40, and the wire can vary wildly as well. I suggest getting half a dozen colors, so you can color code your designs, i.e. a different color for power, buses, control, analog, etc.

Wire Wrapping Tool

https://www.amazon.com/Wire-Wrap-Gauge-ELECTRONIX-EXPRESS/dp/B00BFYE0CY/ref=sr_1_4?s=hi&ie=UTF8&qid=1529462697&sr=1-4&keywords=wire+wrapping+tool

28 AWG Wire

https://www.amazon.com/Jonard-KSW28R-0100-Insulated-Insulation-Diameter/dp/B06XWQT2LY/ref=sr_1_2?s=hi&ie=UTF8&qid=1529463346&sr=1-2&keywords=28+AWG+solid+wire+wrapping+wire

https://www.amazon.com/Jonard-KSW28R-0100-Insulated-Insulation-Diameter/dp/B006C45RC4/ref=sr_1_2?s=hi&ie=UTF8&qid=1529463346&sr=1-2&keywords=28%2BAWG%2Bsolid%2Bwire%2Bwrapping%2Bwire&th=1

https://www.amazon.com/Jonard-KSW28R-0100-Insulated-Insulation-Diameter/dp/B006C45T68/ref=sr_1_2?s=hi&ie=UTF8&qid=1529463346&sr=1-2&keywords=28%2BAWG%2Bsolid%2Bwire%2Bwrapping%2Bwire&th=1

30 AWG Wire, Multicolor Spool

https://www.amazon.com/ELEGIANT-Colored-Insulation-B-30-1000-Wrapping/dp/B071R92G9H/ref=sr_1_6?s=hi&ie=UTF8&qid=1529463178&sr=1-6&keywords=30+AWG+wire+wrapping+wire

Solder

We talk about this in the lectures. In general, you can't go wrong with 60/40 or 63/37 Rosin Core solder. However, you might want something a less toxic and lead free such as "lead-free" solder. It's all up to you. Each product has slightly different properties, and flows differently, and it's just personal preference when you are prototyping. For example, when I manufacture a product EVERYTHING is lead free and ROHS (Restriction of Hazardous Substances). But, when I prototype, I prefer leaded solder since I like the way it melts and flows.

Next, the manufacturer of solder matters and Kester Inc. is one of my favorites, but by no means the only "good" solder. Finally, diameter of the solder matters. If you are soldering automotive wiring together, then you are going to use a big bulky "gun" soldering iron and probably very thick diameter solder. But, if you are doing electronics work as we are then a "pencil" soldering iron and 0.015-0.030" diameter solder is probably what you want to shoot for.

Here are some options. Again, like anything, you need to try and experiment and see what works for you.

Leaded Solder

https://www.amazon.com/MAIYUM-63-37-solder-electrical-soldering/dp/B076QF1Y85/ref=sr_1_1_sspa?ie=UTF8&qid=1529464167&sr=8-1-spons&keywords=63%2F37%2Brosin%2Bcore%2Bsolder&th=1

https://www.amazon.com/MAIYUM-63-37-solder-electrical-soldering/dp/B076QF1Y85/ref=sr_1_3?ie=UTF8&qid=1529464411&sr=8-3&keywords=63%2F37+rosin+core+solder

Lead Free

https://www.amazon.com/Lead-free-Flux-core-Welding-Electronical-Soldering/dp/B06XHF73VY/ref=sr_1_1_sspa?s=hi&ie=UTF8&qid=1529464429&sr=1-1-spons&keywords=lead+free+solder+for+electronics&psc=1

https://www.amazon.com/Lead-free-Flux-core-Welding-Electronical-Soldering/dp/B0713YJV7V/ref=sr_1_1_sspa?s=hi&ie=UTF8&qid=1529464429&sr=1-1-spons&keywords=lead%2Bfree%2Bsolder%2Bfor%2Belectronics&th=1

Flux

Even though the "rosin" in the solder is flux itself, many times you need MORE flux to heat parts evenly and be able to solder larger components, this is where flux comes in. Now, your choice of flux can be as personal as your choice of foods or clothing. Everyone seems to have types of fluxes that they prefer. For example, some people like "flux pens", some like liquid flux, some like gel flux (like me) and so forth. Therefore, again, you are going to have to try a few to get you started, but I will suggest a couple that work well for me.

Also, there are different chemistries of flux, some more engineered for manufacturing, re-work, when you want to skip the "PCB cleaning" step called "no-clean" and so forth. The bottom line is ALWAYS clean your PCB and soldering with a flux remover and or isopropyl alcohol. Fluxes are typically acidic and can damage a board if left on it. Or at least compromise connections, and parts even if it’s "no-clean" - ALWAYS clean your PCBs!

https://www.amazon.com/MG-Chemicals-8341-10ML-Clean-Syringe/dp/B00425FUW2/ref=sr_1_3?ie=UTF8&qid=1529465111&sr=8-3&keywords=solder+flux+syringe

https://www.amazon.com/ChipQuik-SMD-291-Clean-Syringe-Nozzle/dp/B00CM2A97S/ref=sr_1_4?ie=UTF8&qid=1529465111&sr=8-4&keywords=solder+flux+syringe

Soldering Iron(s)

Soldering irons come in as many sizes and shapes as shoes do. But, at the end of the day, we want a good pencil soldering iron, with removable tips, digitally controlled temp (ideally), and 40-60+ Watt power rating. Of course, budget is everything. There are some very expensive soldering irons out there and some cheap ones. For a stand alone pencil soldering iron, expect to pay $20-50, for a "soldering station" with more features like digital control, expect to pay $100-200 on up. Also, like anything, there are well known brands like Hakko and Weller. These brands tend to be a little more pricey, but overall are better.

On the other hand, there is a Chinese knock off for everything, and the Chinese versions are usually "almost" as good, so $20 vs $100, you might go with the Chinese version and see how it works. But, don't waste your money with $5 soldering irons, they will bring you nothing, but trouble. For a few dollars more you get a good iron and many times they come with stands, extra "tips" and small electronics tools like tweezers which come in handy and is something else we will need.

https://www.amazon.com/Soldering-SOAIY-Adjustable-Temperature-Desoldering/dp/B01C9P7HDQ/ref=sr_1_4?ie=UTF8&qid=1529465331&sr=8-4&keywords=pencil+soldering+iron

https://www.amazon.com/Vastar-Soldering-Iron-Full-Welding/dp/B01712N5C4/ref=sr_1_6?ie=UTF8&qid=1529465453&sr=8-6&keywords=pencil+soldering+iron

https://www.amazon.com/Sywon-Soldering-Adjustable-Temperature-Desoldering/dp/B01E1ISGH0/ref=sr_1_7?ie=UTF8&qid=1529465453&sr=8-7&keywords=pencil+soldering+iron

https://www.amazon.com/dp/B06XZ31W3M/ref=sxbs_sxwds-stvpv2_1?pf_rd_m=ATVPDKIKX0DER&pf_rd_p=3233965245922079678&pd_rd_wg=O0cEc&pf_rd_r=PPA0GTHZJ26NNT9BGNVS&pf_rd_s=desktop-sx-bottom-slot&pf_rd_t=301&pd_rd_i=B06XZ31W3M&pd_rd_w=17hWf&pf_rd_i=pencil+soldering+iron&pd_rd_r=7ce6211a-da9a-46b5-8c0c-5412139bd9c7&ie=UTF8&qid=1529465453&sr=1

https://www.amazon.com/Sywon-Soldering-Switch-Temperature-Adjustable/dp/B01N4571Q6/ref=sr_1_10?ie=UTF8&qid=1529465453&sr=8-10&keywords=pencil+soldering+iron

Soldering Station

A soldering station is a larger product and usually supports closed loop control for temperature, as well as other features such as a solder sucker. Soldering stations are more plug and play, you can change soldering irons, replace things, and the iron typically sits on a nice, safe, stand instead of a simple coil of wire or clip. Here are a few to get you started.

https://www.amazon.com/X-Tronic-3020-XTS-Digital-Display-Soldering/dp/B01DGZFSNE/ref=sr_1_5?s=hi&ie=UTF8&qid=1529465595&sr=1-5&keywords=soldering+station

https://www.amazon.com/Hakko-FX888D-23BY-Digital-Soldering-Station/dp/B00ANZRT4M/ref=sr_1_9?s=hi&ie=UTF8&qid=1529465595&sr=1-9&keywords=soldering+station

Hot Air Rework Station

Finally, we move to the king of the hill in soldering and that's the "re-work station". These typically have a soldering iron, as well as a "hot air" gun that is capable of heating air to 800F or more and melt solder on a PCB and allow you to solder or remove parts (typically SMD). Additionally, many of these devices have "hot plates" that you place your PCB work piece on that heats it with a coil for even heat, therefore making the soldering easier. That said, hot air re-work stations can range from $50-5000, these can get VERY expensive, but there are some good units in the $100-200 range from a number of Chinese companies and others.

One of my favorite low cost units is from X-Tronic Inc. I have been using them for years, and all in all, they get it done. Finally, there are a LOT of Chinese knockoffs of each other, thus you will see a hot air re-work station and 10 more that look exactly like it! They are all the same unit, or a copy, etc. but, some are better than others, have better parts, or support, or return policy, so those are the things you are looking for. And these devices CAN be dangerous, cheap electronics without protection can start fires. So, regardless of my suggestions, make sure you read reviews, do google searches on anything you are thinking of buying as well as look for youtube reviews.

Without further ado, here are some hot air stations to review if you feel like making the investment.

https://www.amazon.com/Kendal-REWORK-SOLDERING-IRON-STATION/dp/B00W6FK8IG/ref=sr_1_12?s=hi&ie=UTF8&qid=1529466210&sr=1-12&keywords=hot+air+soldering+station

https://www.amazon.com/Soldering-Station-Digital-Desoldering-Replacement/dp/B077WDXD6H/ref=sr_1_10?s=hi&ie=UTF8&qid=1529466210&sr=1-10&keywords=hot+air+soldering+station

https://www.amazon.com/YAOGONG-996D-Brushless-Automatic-Soldering/dp/B075TCMQ5Q/ref=sr_1_29?s=hi&ie=UTF8&qid=1529466210&sr=1-29&keywords=hot+air+soldering+station

https://www.amazon.com/Improved-X-Tronic-5040-XR3-Soldering-Preheater/dp/B019LQ5YUE/ref=sr_1_4?s=hi&ie=UTF8&qid=1529466458&sr=1-4&keywords=x-tronic+hot+air+soldering+station

Electronics Tool Kits

I have been building things since I was a little boy, 4-5 years old. I actually have tools from when I was 5 still! That said, you are either the kind of person that has a lot of tools, or you're the kind that has a single Phillips head screw driver and a hammer in a drawer and you're not sure what to do with either of them :) Either way, you probably don't have an

"electronics tool set". These tools are more precision, smaller, and need to be high quality, so they don't strip or break when you are working with small scale fabrications.

Alas, you can never have too many tools, but at very least you should get a small starter kit if you don't have one. Else you will be using your teeth to strip wires, and impaling yourself constantly with sharp implements NOT meant to be used as tools!

And one last piece of advice, you get what you pay for with tools. Cheap tools means cheap metal, Chinese make good and bad tools, cheap and expensive, but most USA, German, Japanese companies make REALLY good tools (as do some other countries), but they cost a lot more, so the thing to keep in mind is your tools are something you want to last a long time, buy them once and take really good care of them.

Nevertheless, if you are on a budget of $20 for a kit, then hey, go Chinese, they may not last, but will do for now probably. Lastly, many kits are more for taking apart iPods/iPhones, etc. they have a lot of precision screw drivers and small prying implements, we are not looking for that. We are more interested in a small screw driver set, a number of wire cutters, wire stripper, tweezers, etc. basically, tools to build, cut, fabricate, not so much to dismantle. Here's some kits that you should take a look at (they even throw in a cheap soldering iron, good to have a backup, but not for prime usage).

Here are some ideas to get you started.

https://www.amazon.com/Hi-Spec-Electronics-Electrical-Tools-Maintenance/dp/B01D4CRUTY/ref=sr_1_fkmr2_3?s=hi&ie=UTF8&qid=1529467266&sr=1-3-fkmr2&keywords=electronics+tool+kit+wire+strippers%2C+diagonal+plyers%2C+screw+driver

https://www.amazon.com/dp/B004H07POS/ref=sspa_dk_detail_4?psc=1&pd_rd_i=B004H07POS&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=1713835751726239774&pf_rd_r=RQDSPMME81JA2AD83QCS&pd_rd_wg=xCQq9&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&pd_rd_w=1A3Ol&pf_rd_i=desktop-dp-sims&pd_rd_r=a7d41b1c-743e-11e8-801c-0fe70e5fee01

Digital Multimeter(s)

Before I say anything, if you haven't watched the lectures yet, at some point, you will see me talk about "multimeters" and I will admit to having many of them. Yes, I LOVE multimeters and you can never have enough of them :) I have 15+ of them, and probably more if I were to count in all my labs. Now, part of it is the same reason women love shoes. My wife has 80-90 pairs of them which by any measure *is* excessive since she rarely wears any of them:) But, she says "I need them". By the same token, I ***need*** my multimeters, and I do actually use all of them. Sometimes I need a meter with a certain scale or feature, or size, or brightness of screen, etc. And I have one for all those occasions. Additionally,

many times in a complex build you really need to measure 3, 5, 7 or more values at the same time, the only way to do this is with multiple meters.

Therefore, as you play with electronics, you are going to get the "meter" bug and probably buy more than one just because they are cool, but also because you will need them. That said, there is a whole lecture on this topic, but here and now, I will tell you meters can be very expensive, the big dog on the block is FLUKE. They make REALLY good tech, but now many other manufacturers have caught up including Chinese and for 25-50% of the cost you can get a meter almost as good as Fluke for most functions. And in some cases, you can get a better meter for a fraction of the cost.

Now, this subject is way too complex to cover here, you need to watch video lectures on how to select and buy meters, but for now, we are looking in the $30-150 range, we want good features, high resolution, nice display, and ideally the ability to measure resistance, inductance, capacitance, transistor gain, voltage, current, high current, high voltage, frequency, light, AC signals, and "RMS" root-mean-square AC ideally. Those are just some of the things we are looking for. Also, serial ports for logging to PC can be very helpful. With that all in mind, here are some to take a look at and see what you think. I suggest you get one GOOD meter, and a couple cheap meters to help measure multiple values in a circuit at the same time.

Very Low Cost

https://www.amazon.com/Multimeter-TACKLIFE-DM03-Resistance-Continuity/dp/B01N68Y73M/ref=sr_1_1_sspa?s=electronics&ie=UTF8&qid=1529468581&sr=1-1-spons&keywords=multimeter&psc=1

https://www.amazon.com/Multimeter-Auto-ranging-Electronic-Continuity-Backlight/dp/B01MXCROEH/ref=sr_1_15_sspa?s=electronics&ie=UTF8&qid=1529468640&sr=1-15-spons&keywords=multimeter&psc=1

Low Cost

https://www.amazon.com/Multimeter-Eventek-ET580-Electronic-Instrument/dp/B06XNRX79X/ref=sr_1_16_sspa?s=electronics&ie=UTF8&qid=1529468640&sr=1-16-spons&keywords=multimeter&th=1

https://www.amazon.com/Multimeter-Morpilot-Auto-Ranging-Capacitance-Temperature/dp/B078JDL61X/ref=sr_1_25_sspa?s=electronics&ie=UTF8&qid=1529468706&sr=1-25-spons&keywords=multimeter&psc=1

https://www.amazon.com/dp/B071JL6LLL/ref=sxbs_sxwds-stppvp_1?pf_rd_m=ATVPDKIKX0DER&pf_rd_p=6297546923292665688&pd_rd_wg=Ntlz8&pf_rd_r=DV87V4Q4EXB2J7MQFMNC&pf_rd_s=desktop-sx-bottom-slot&pf_rd_t=301&pd_rd_i=B071JL6LLL&pd_rd_w=xKQbh&pf_rd_i=multimeter&pd_rd_r=2cae8bb4-72a5-45a7-8212-e18abe5d4d25&ie=UTF8&qid=1529468768&sr=1

Medium Cost

https://www.amazon.com/REED-Instruments-R5007-Multimeter-Non-Contact/dp/B00VYBO37A/ref=sr_1_1_sspa?s=electronics&ie=UTF8&qid=1529468736&sr=1-1-spons&keywords=multimeter&refinements=p_36%3A1253505011&psc=1

https://www.amazon.com/Amprobe-15XP-B-Multimeter-Non-Contact-Indicator/dp/B01MYCP65Q/ref=sr_1_3?s=electronics&ie=UTF8&qid=1529468768&sr=1-3&keywords=multimeter&refinements=p_36%3A1253505011

https://www.amazon.com/Industrial-Thermometer-Humidity-Multimeter-Multi-tester/dp/B00E614L0Y/ref=sr_1_2_sspa?s=electronics&ie=UTF8&qid=1529468768&sr=1-2-spons&keywords=multimeter&refinements=p_36%3A1253505011&psc=1

https://www.amazon.com/TPI-126-Autoranging-Multimeter-Protective/dp/B0095X5O6S/ref=sr_1_4?s=electronics&ie=UTF8&qid=1529468979&sr=8-4&keywords=TPI+multimeter

https://www.amazon.com/dp/B071F1H3PG/ref=sspa_dk_detail_6?psc=1&pd_rd_i=B071F1H3PG&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=1713835751726239774&pf_rd_r=0WTNQYDXAFCQX8YPSJWJ&pd_rd_wg=wqKU9&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&pd_rd_w=nS3K4&pf_rd_i=desktop-dp-sims&pd_rd_r=9fd686b3-7442-11e8-a879-935c5e04125d

High Cost

https://www.amazon.com/Triplett-9055-Autoranging-Multimeter-Measurement/dp/B01E9GL54U/ref=sr_1_1_sspa?s=electronics&rps=1&ie=UTF8&qid=1529468906&sr=1-1-spons&keywords=multimeter&refinements=p_36%3A1253506011%2Cp_85%3A2470955011&th=1

https://www.amazon.com/TPI-183-Multimeter-Protective-Resistance/dp/B0095X64Q2/ref=sr_1_1?s=electronics&ie=UTF8&qid=1529468979&sr=8-1&keywords=TPI+multimeter

Bench Power Supplies

One thing you need when you are developing electronics is CLEAN power. Most newbies to electronics will try hooking up everything from batteries to wall adapters for power. This is usually a very bad idea. What you want is a clean power supply with 3-5 Amps of output, and ideally 2-3 voltage channels. Most hobby electronics these days require 5V and 3.3V, so you either need two supplies or a supply with 2 or more channels, so keep that in mind.

Again, I cover this in detail in the video lecture, but in general there are two kinds of power supplies; linear and switching. The linear supply is going to be bigger, hotter, but usually

puts out a much cleaner signal. This means if you are doing "analog" design like filters, amplifiers, etc. you probably should think about a linear supply. If on the only hand, you are doing mostly digital electronics then a switching supply will usually do. These are based on "switch mode power supplies" which we will learn about in lecture, but in general these are noisy and less tolerated by analog electronics without filtering. Now, depending on the manufacture, you can have a really noisy linear supply and a really quite switching supply. Everything depends on cost.

Now, the bad news -- power supplies can cost up to $100,000.00 or more! Yup, not making that up -- crazy huh? In a GOOD lab, say at a big tech company like National Instruments you will easily find these kind of supplies. However, in college labs you might find supplies in the $500-1500 range. Alas, we are going to shoot for the $50-300 range and see what we can find. Again, as I said, I suggest a multi output supply if you can afford since it's just a cleaner setup than multiple supplies on your table, but if you're on a budget, you get one supply and do what you can to generate any lower voltages on your build. Here are some suggestions including my favorite brand Rigol.

Single Channel Supplies

https://www.amazon.com/Tekpower-TP3005P-Programmable-Variable-Regulated/dp/B06XCQN82X/ref=sr_1_4?ie=UTF8&qid=1529470188&sr=8-4&keywords=bench+power+supply

https://www.amazon.com/YaeCCC-Variable-Adjustable-Bench-Supply/dp/B074C86DSY/ref=sr_1_5?s=industrial&ie=UTF8&qid=1529470264&sr=1-5&keywords=bench+power+supply

https://www.amazon.com/dp/B073TW8H2S/ref=sspa_dk_detail_0?psc=1&pd_rd_i=B073TW8H2S&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=1713835751726239774&pf_rd_r=RDA832V24DHYGWANT2HR&pd_rd_wg=0BgVS&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&pd_rd_w=84NCg&pf_rd_i=desktop-dp-sims&pd_rd_r=f8490355-7445-11e8-a879-935c5e04125d

Multi Channel Supplies

https://www.amazon.com/Rigol-DP832-Triple-Output-Supply/dp/B00ENX02GC/ref=sr_1_2?s=industrial&ie=UTF8&qid=1529470529&sr=1-2&keywords=Rigol+triple+output+power+supply

https://www.amazon.com/Rigol-DP831A-Triple-Output-Supply/dp/B00ENXPELU/ref=sr_1_3?s=industrial&ie=UTF8&qid=1529470571&sr=1-3&keywords=Rigol+triple+output+power+supply

https://www.amazon.com/Tekpower-TP3003D-3-Digital-Variable-Linear-type/dp/B00HV12TZ0/ref=sr_1_fkmr1_2?s=industrial&ie=UTF8&qid=1529470571&sr=1-2-fkmr1&keywords=Rigol+triple+output+power+supply

https://www.amazon.com/Dr-meter-Switching-Single-output-Alligator-HY3005F-3/dp/B009622HC2/ref=sr_1_6_sspa?s=industrial&ie=UTF8&qid=1529470571&sr=1-6-spons&keywords=Rigol+triple+output+power+supply&psc=1

Oscilloscope AKA "Oscope"

As we move onto more and more advanced test equipment, I want to bring something to your attention and that is you don't have to buy "new" stuff. Much of my test equipment is used and many years old. For example, HP/Agilent makes some really good hardware. And something from the 1990's that cost $50,000 new might cost $200-300 today on eBay. As long as it's working (ideally it has been tested or calibrated lately) then there is no reason not to consider used test equipment when you are trying to build your hardware lab.

Also, this is a process -- I have been building my lab for 30+ years, others have been doing it for 50+ years!!! One piece at a time, $100 here, $500 there, $5000 somewhere else, and over time you have a lab that rivals many universities. But, its expensive, so a good electrical or embedded engineer always has his/her eyes out for a deal, companies going out of business, auctions, etc. Considering all that, next up we talk about oscilloscopes.

Again, if you haven't watched the lectures, you probably don't know exactly what an "oscope" does -- in short it measures voltages as a function of time, simple as that. This is absolutely one of the BEST test tools you can have since it allows you to "see" into a circuit in real time without disturbing it and make measurements of the signals as they flow from one block to the next.

Oscopes are serious pieces of tech, and big investments, so make sure you watch the videos, google, learn about them before you buy anything. But, a few things we care about are the following; we want bandwidth of 100-200Mhz at least. This is baseline to analyze modern processors and digital systems, you need to be able to sample signals at least 100Mhz and ideally 500Mhz. But, 100-200Mhz will get it done initially.

Secondly, you need at least (2) input channels, but ideally (4). Just like the multimeter is used to watch a static or slow moving DC signal, the oscope is used to watch AC or high frequency signals, and you might want to look at a few signals at the same time. For example, the input and output of an amplifier, or the TX and RX of a serial line or a few bits of a digital bus. Therefore, 2 channels is barely enough to get it done, 4 is so much better.

Lastly, there are a number of “types” of oscopes, and two primary classes; digital and analog. The lectures talk about all this, but analog scopes are analog in design, they feature CRT long persistence screens, and the signals are processed by analog circuits, amplified, etc. and then sent directly to the CRT drive electronics and the signals are drawn on the screen -- thus, WYSIWYG -- in other words, analog scope don't digitize, process and DSP anything, analog scopes take your input signals and show them to you just as they are.

Therefore, every good EE has 1-2-5 analog scopes lying around :) But, newer digital scopes are basically DSP computers, signals come in, they are digitized, processed by a CPU and

then rendered on an LCD screen (or CRT for older scopes). But, the point is the image in the screen is NOT the original signal it is a digital approximation of it. Don't get me wrong, modern digital scopes can process signals in the GHz range just fine, and they have amazing resolution and precision. However, you can probably get an old analog scope for $100-200 that can display signals as good or better than the $500-100 digital scope. The analog scope won't have all the cool features of the digital scope, but as long as the bandwidth is there, analog is the way to go if you don't want to "miss" anything that the digital process might lose. That said, I have both kinds of scopes. I use my digital scopes 90% of the time, but sometimes I break out my analog and look at the same signal and see something the digital scope missed!

Now, let's talk about the types of scopes (again more on this in the lecture), but there are two main classes of low cost scopes; digitizing (or storage scopes) and non-digitizing. In a nutshell, when you are looking at a signal in real-time, it's going very fast, and when it's gone, it's gone. Many times you want to "trigger" on an event, record a few nano, micro, or milliseconds of signals and then look at the waveforms on the screen. To do this, you need a digitizing scope or an older model "storage scope". The same idea though, the scope has memory and records the signal and plays it back on the screen, very useful. This is what you want.

Taking all that in, oscopes can cost over $100,000 as well, so we are going to keep it on budget and look in the $100-1000 range. Also, there are many USB oscopes on the market now that trade the display hardware, and other hardware pieces and off load them to the PC. This saves money, but also, is tricky for real time, since the signals have to be sent over USB to the PC for display and some processing. This is a valid approach and can reduce cost, but you have to watch out for quality and bandwidth issues. In all honesty, my advice is stick to bench oscopes, but it's up to you.

Here are a few selections to get you started. My favorite low cost units are Rigol and Hantek, both pretty darn good for the price. Also, Rigol and Hantek can be hacked, so if you get the 50Mhz version, you can perform a simple hack (on youtube) to double the sample rate and so forth. Finally, don't buy anything that is USB or PC based until you download the software and take a look at it -- if you can't use the software, or figure it out, no need to buy the USB version to save money. But, like I said, I advise sticking to bench top oscopes.

2 Channel Oscopes

https://www.amazon.com/Hantek-DSO5102P-Digital-Storage-Oscilloscope/dp/B01EJLZYN8/ref=sr_1_17?ie=UTF8&qid=1529474436&sr=8-17&keywords=2+channel+oscilloscope

https://www.amazon.com/Hantek-DSO5202P-oscilloscope-Channels-AC110-220V/dp/B01EJVNNPY/ref=sr_1_18?ie=UTF8&qid=1529474436&sr=8-18&keywords=2+channel+oscilloscope

https://www.amazon.com/Siglent-Technologies-SDS1202X-Oscilloscope-Channels/dp/B06XZML6RD/ref=sr_1_4?ie=UTF8&qid=1529474329&sr=8-4&keywords=oscillscope

https://www.amazon.com/Rigol-DS1102E-Oscilloscope-Channels-Sampling/dp/B0039N9ZBA/ref=sr_1_6?ie=UTF8&qid=1529474411&sr=8-6&keywords=2+channel+oscilloscope

4 Channel Oscopes

https://www.amazon.com/Rigol-DS1054Z-Digital-Oscilloscopes-Bandwidth/dp/B012938E76/ref=sr_1_1?ie=UTF8&qid=1529474329&sr=8-1&keywords=oscillscope

https://www.amazon.com/dp/B0771N1ZF9/ref=sxbs_sxwds-stvpv2_3?pf_rd_m=ATVPDKIKX0DER&pf_rd_p=32339652459220796 78&pd_rd_wg=6TLJs&pf_rd_r=KS7NKV19FXGPPAE7WQKN&pf_rd_s=desktop-sx-bottom-slot&pf_rd_t=301&pd_rd_i=B0771N1ZF9&pd_rd_w=epubf&pf_rd_i=2+channel+oscilloscope&pd_rd_r=51def4d9-38ca-48c0-87f6-2cbd51992387&ie=UTF8&qid=1529474436&sr=3

https://www.amazon.com/Rigol-DS1104Z-Digital-Oscilloscope-Channels/dp/B019CTN0OW/ref=sr_1_4?ie=UTF8&qid=1529474611&sr=8-4&keywords=rigol+4+channel+oscilloscope

Oscope + Logic Analyzer Combos

https://www.amazon.com/Hantek-MSO-5102D-Channels-Oscilloscope/dp/B00Q4J1P4G/ref=sr_1_20?ie=UTF8&qid=1529474436&sr=8-20&keywords=2+channel+oscilloscope

https://www.amazon.com/dp/B01N74XEAN/ref=sxbs_sxwds-stvpv2_3?pf_rd_m=ATVPDKIKX0DER&pf_rd_p=32339652459220796 78&pd_rd_wg=CCJte&pf_rd_r=Q0SGFSTPZ2NJ7GSGQ3SZ&pf_rd_s=desktop-sx-bottom-slot&pf_rd_t=301&pd_rd_i=B01N74XEAN&pd_rd_w=ZpUCA&pf_rd_i=USB+oscilloscope&pd_rd_r=e71afa86-9df5-4db2-b043-ddff2a04f2e1&ie=UTF8&qid=1529474723&sr=3

USB Oscopes

https://www.amazon.com/Hantek-1008A-Oscilloscope-programmable-generator/dp/B00QK2PU0M/ref=sr_1_14?ie=UTF8&qid=1529474537&sr=8-14&keywords=hantek+4+channel+oscilloscope

Logic Analyzer AKA "L.A."

Last, but not least if you really want to save time in digital design then you need a ***Logic Analyzer***. Historically, these were crazy expensive devices that hobbyist would never dream of owning. Even professional electrical/embedded engineers couldn't afford them unless they worked at a company that bought one. That said, things have changed, you can buy a useful LA for low frequency work for $100-500 new or used, and from $500-$5,000 you can get a pretty good higher frequency LA.

So, what's an LA? Well, again, please watch the video lectures, but in short, an LA or "logic analyzer" is a device specifically designed to inspect digital signals in a circuit in real-time and record them -- ***many*** of them. Similar to an oscope, but rather than viewing the analog nature or a signal's voltage as a function of time, we simply want its "digital" nature, if the signal is greater than some threshold, it's a digital "1", if lower, it's a "0". And these 0's and 1's are rendered on a screen in a time line for each channel.

LAs typically can record 8 or more signals, some can record over 100! Typically, you will find 16-32 signals common and frequencies in the 100Mhz to 3Ghz range (or higher). That said, for our work and your work in the near future we are looking for 8-16 channels. We want a bandwidth of at least 100Mhz, and ideally 500Mhz. Also, we want to have enough memory to buffer a good amount of data, and we want to make sure that we read the fine print and if a LA has say 1MB of memory is that per channel or total? Makes a big difference.

Additionally, we ***need*** "Protocal Analyzers" -- these are pieces of software that analyze the signals and if we assign some signals to a SPI bus for example; MOSI, MISO, SCLK, and enable the software can read and interpret the signals and convert into intelligent data that we can read in English and we don't have to sit down and decode a bunch of 0's and 1's and a clock signal -- this is VERY useful.

Considering all that, it used to be that you wanted a bench top LA, but these days, that's a waste of money. Instead, you want a USB LA with really good hardware, with lots of channels, you connect to your hardware, set up the triggering, run your hardware, the event occurs. THEN it downloads the data to the PC for analysis – it's not in real-time, all the capturing is done on the USB box. So, we can save the money of the bulky box, power supply, screen, etc. Plus, it's a lot easier dealing with a mouse and dragging and dropping items on a Windows/Mac or Linux PC than it is twisting knobs on a box.

That said, here are a few USB and bench LAs, but you really need to do your research and decide which one and if you really need one. I can't do my work without one, but if you are just making blinking LEDS then you don't need one. But, the moment you play with microprocessors/microcontrollers and try connecting them to other ICs, this tool will save you 1000's of hours!

Bench Logic Analyzers

https://www.amazon.com/dp/B00HYYCY5O/ref=psdc_14244471_t2_B0027QRPIA

USB Logic Analyzers

https://www.amazon.com/Hantek%C2%AE-LA5034-150MHz-Channels-Analyzer/dp/B00QK2PTI0/ref=pd_sbs_469_3?_encoding=UTF8&pd_rd_i=B00QK2PTI0&pd_rd_r=0b856814-7453-11e8-a0ca-3f2ecd6368f4&pd_rd_w=JKPnL&pd_rd_wg=ikTJg&pf_rd_i=desktop-dp-sims&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=5825442648805390339&pf_rd_r=683F0D4RE6R6CYZ50583&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&psc=1&refRID=683F0D4RE6R6CYZ50583

https://www.amazon.com/Zeroplus-LAP-C-16032-16-channel-Analyzer/dp/B0027QRPIA/ref=sr_1_10?ie=UTF8&qid=1529475990&sr=8-10&keywords=usb+logic+analyzer

https://www.amazon.com/Logic-Pro-Black-Ultra-Portable-Frustration/dp/B074TVSLN1/ref=sr_1_1_sspa?ie=UTF8&qid=1529475924&sr=8-1-spons&keywords=usb+logic+analyzer&psc=1

https://www.amazon.com/Zeroplus-40-channel-channel-compatible-Analyzer/dp/B01M0QS8AI/ref=sr_1_23?s=electronics&ie=UTF8&qid=1529475826&sr=1-23&keywords=logic+analyzer

And if you just want to play with a "logic analyzer" this $15 device actually works!!!

https://www.amazon.com/Logic-Analyzer-Device-Cable-Channel/dp/B06Y2TTFR1/ref=pd_sbs_469_9?_encoding=UTF8&pd_rd_i=B06Y2TTFR1&pd_rd_r=0b856814-7453-11e8-a0ca-3f2ecd6368f4&pd_rd_w=JKPnL&pd_rd_wg=ikTJg&pf_rd_i=desktop-dp-sims&pf_rd_m=ATVPDKIKX0DER&pf_rd_p=5825442648805390339&pf_rd_r=683F0D4RE6R6CYZ50583&pf_rd_s=desktop-dp-sims&pf_rd_t=40701&psc=1&refRID=683F0D4RE6R6CYZ50583

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