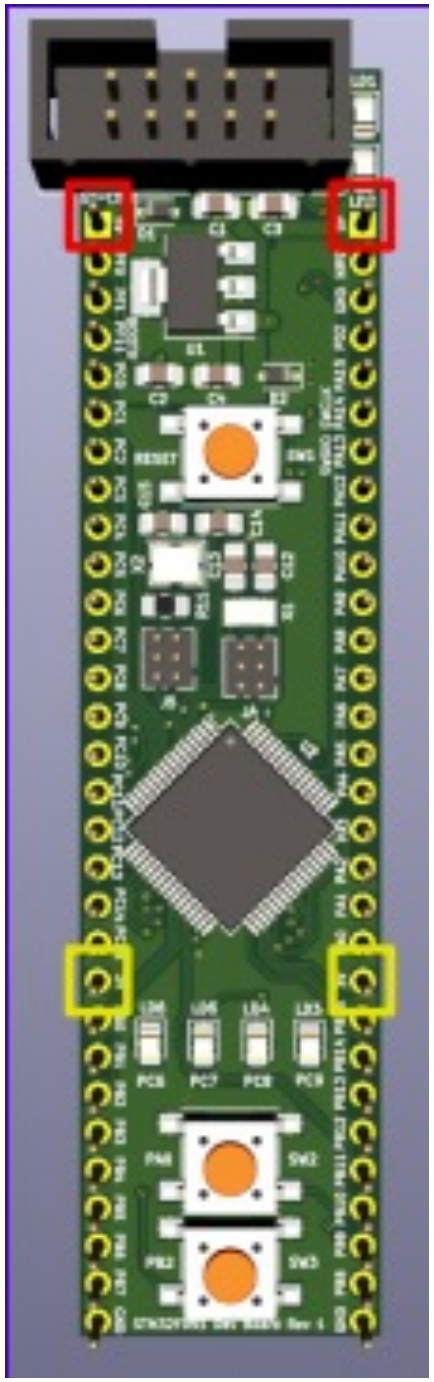
Module 4

Power Supplies

Tim Rogers 2022



New development board

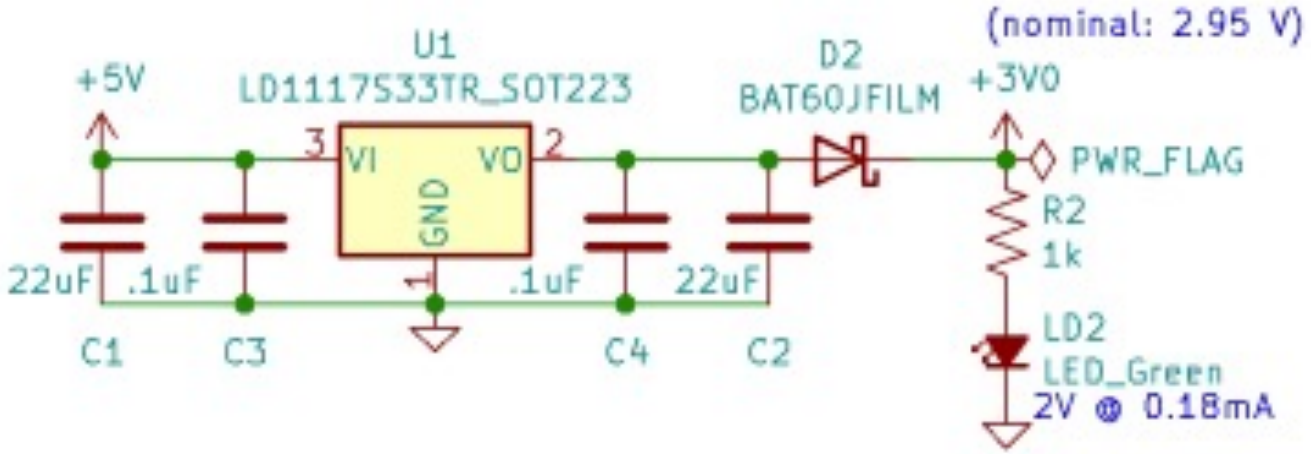
- There are **5V** (actually about 4.65V) output pins
  - See user manual, page 17 for limit
  - You can also use it as an input.
- There are **3V** (actually 2.95V) output pins
- You can use that as an input.

What happens if current flow out of the 5V pin is too high?

- You will blow the diode (D1) between USB input and 5V output.
  - Our lab engineer can replace it.
    - But not on a weekend or a holiday.
      - Or at 3am before your project demonstration.
- If you have project that needs more than 100mA, you need an external power supply.
- If you have a project that needs 3.3 V (instead of 2.95 V), you will need an external power supply.

Why is 3 V output not 3.3 V?

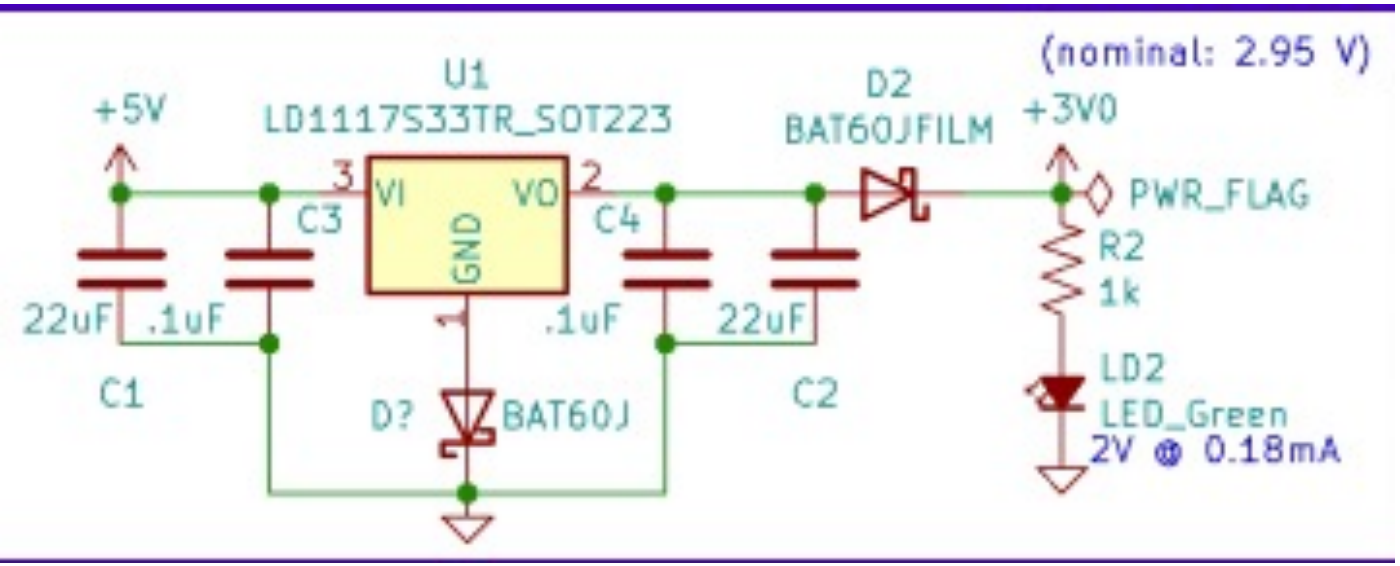
- The old development board had a particular regulator configuration, and we used the same thing:



- LD1117S33 VO output is 3.3 V above GND
- BAT60J (D2) has a .35 V drop.
- +3V0 is actually 2.95 V

When you design your PCB...

- You can make a true 3.3 V supply...



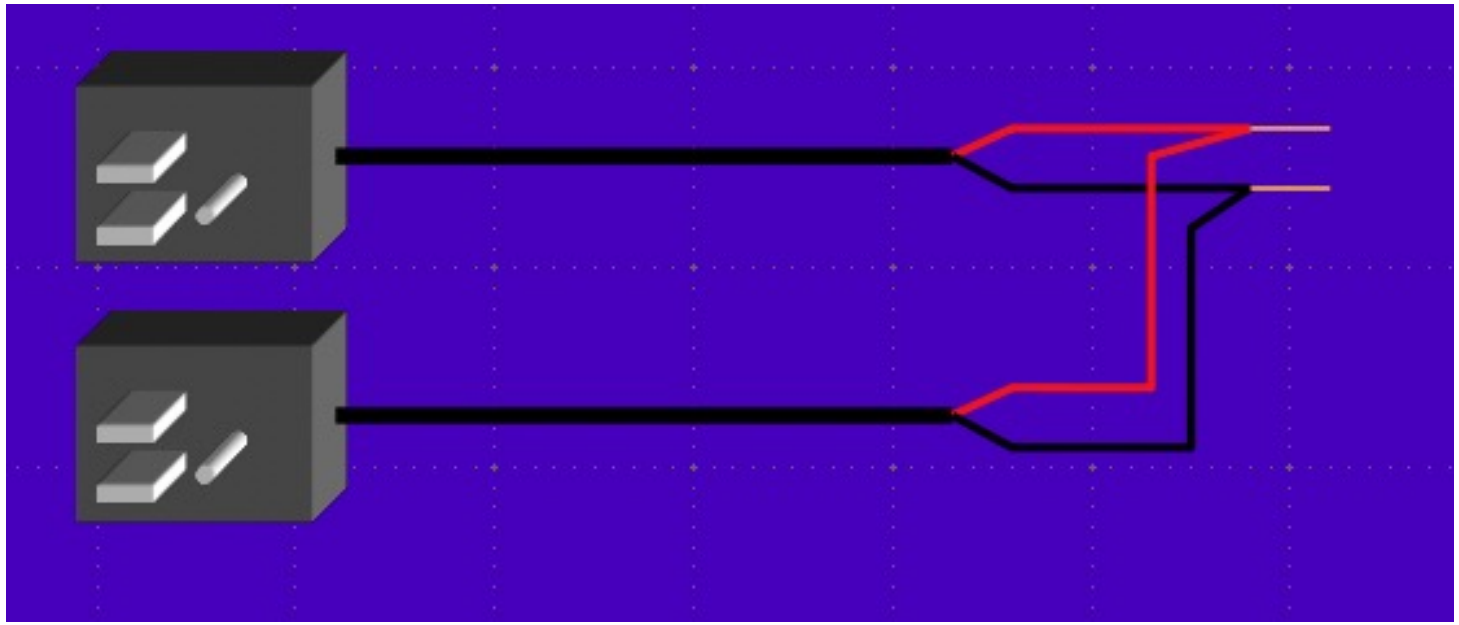
- LD1117S33 VO output is 3.3 V above GND pin
- BAT60J (D?) has a .35 V drop.
- VO is 3.65 V above the ground reference now
- +3V0 is actually 3.3 V

Providing power for projects

- No computers for demonstrations
  - No USB ports to power STM32 and extras
- You may use USB phone chargers
  - Plug-in or battery.
  - We have a dozen 5.2V 2A chargers. Plenty to loan.
- External power supply to power STM32 as well as other devices.

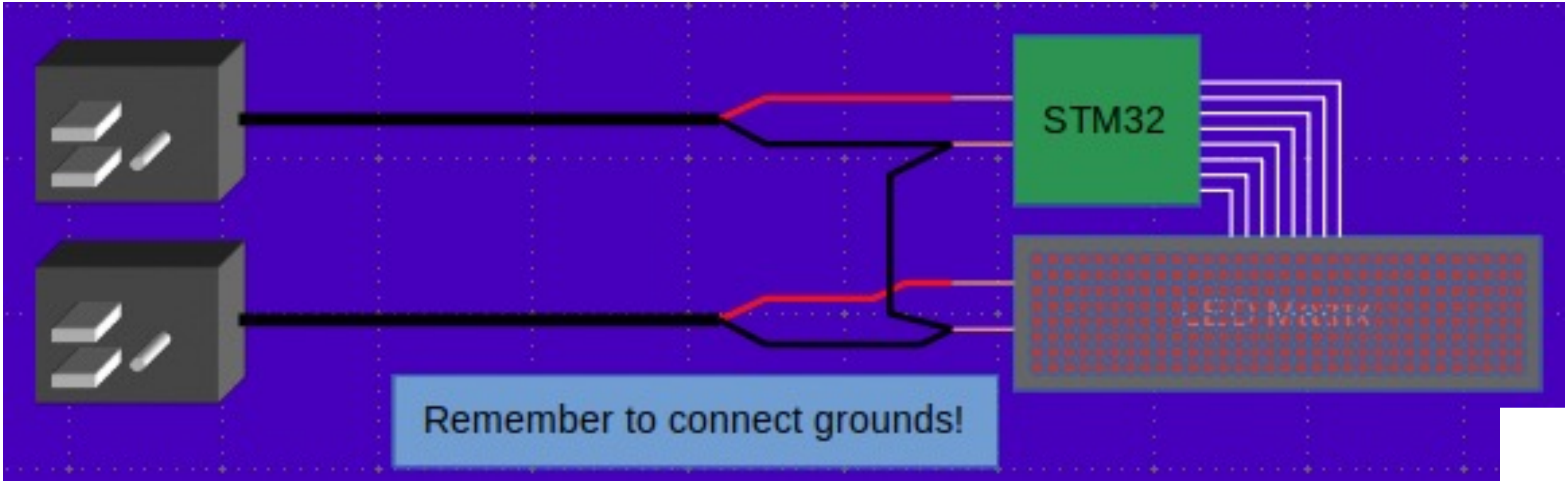
Projects that need lots of power

- Combine multiple power adapters.
  - If they’re the same type and rating.



Projects that need lots of power

- Combine multiple power adapters (of potentially different types) with shared grounds.
  - Segregate the power distribution to the things that need it.

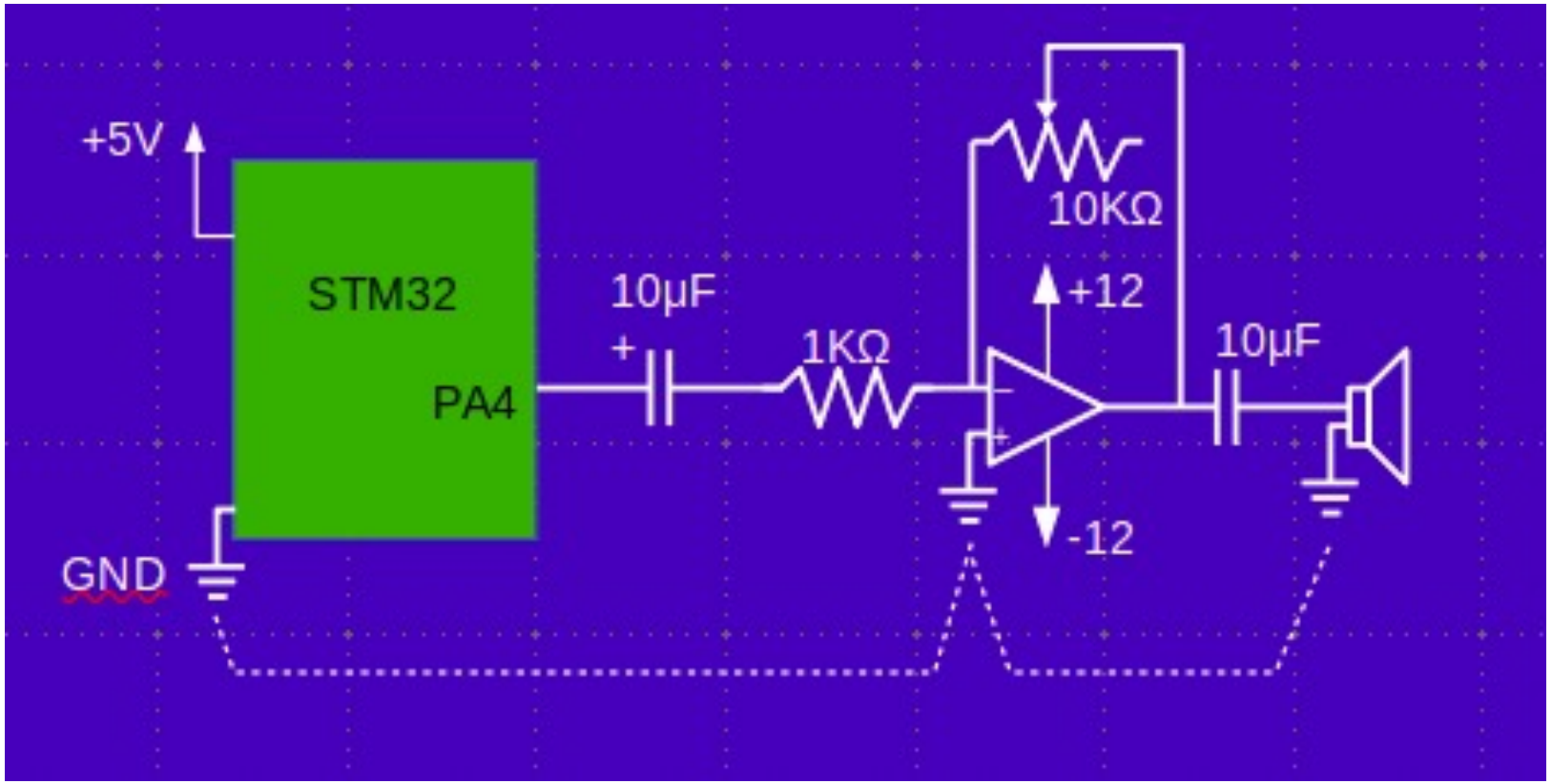


Projects that need audio power

- Op-amps work best with +/- voltage.
  - e.g. +12, -12 for a 24-volt range.
  - With a single-ended supply (0 – +V), you will produce a distorted output unless you have unity gain.

Audio example

- Make sure that grounds are connected.



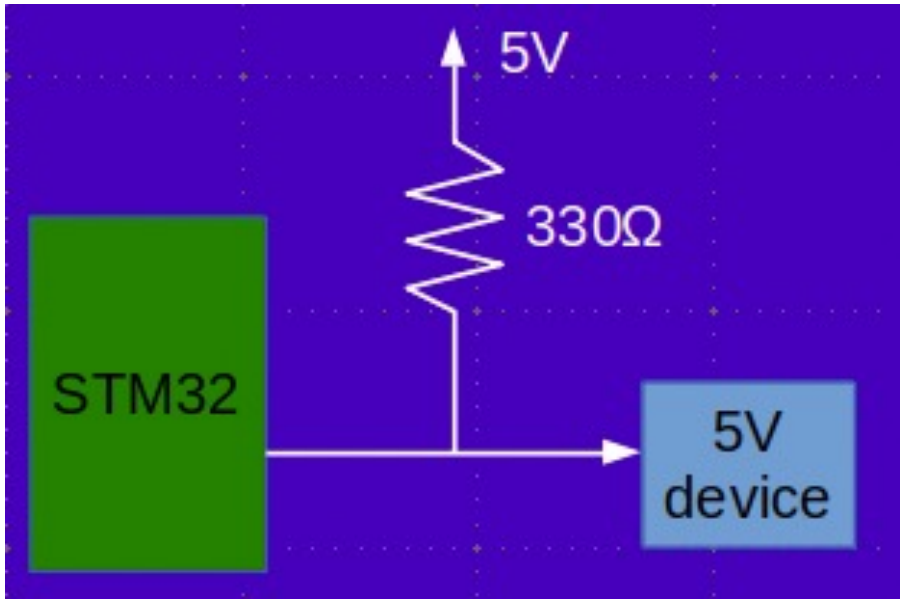
High current example

- LED matrix draws 157mA from 5V output of STM32. ("How has this not failed?")
  - USB port power limits the current to 250mA unless the device negotiates for higher current.
    - When you plug STM32 into phone charger, you blow diode D1.
- Solution: Wire external ECE 270 supply to LED matrix **and** STM32 5V input.
- New problem: LED matrix now has strange streaks and bad picture.

Power supplies and logic levels

- The OLED display in your dev kit is supposed to run on 5V (4.56V).
  - Logic "high" is 0.7 * Vdd = 0.7 * 4.56V = 3.192V
  - STM32 outputs 2.95V high. Close enough to work.
- When LED display runs on 5.0V:
  - Logic "high" is 0.7 * Vdd = 3.5V.
  - STM32 is not going anywhere near that.

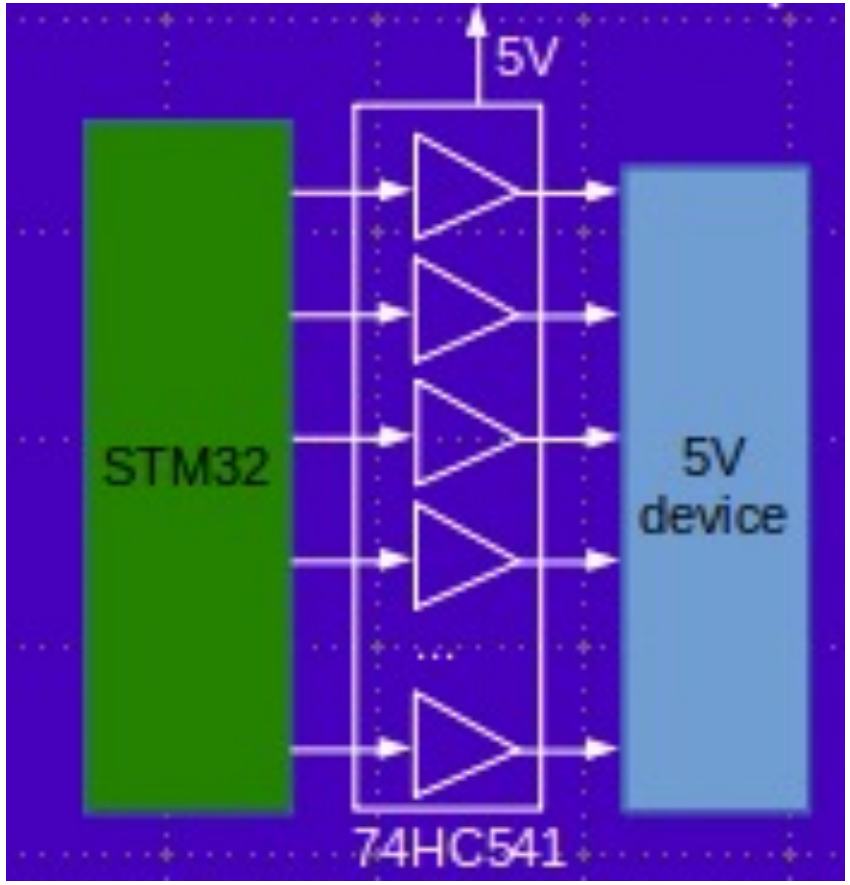
Pull-up resistors



- You can pull 2.95V up to 3.5V.
  - 330Ω between signal and 5V.
- When STM32 pulls line low:
  - 5V / .330 kΩ = 15.15mA (at most) flows into pin.
    - Not going to cause problems.

Another solution: level shifters

- Use a buffer (such as a 74HC541 octal buffer)
- Power it at 5V.
- Recognizes 2.95V high.
- Outputs a 5V high.



Another solution: Drop device VDD

- Your OLED LCD is supposed to run at >= 4.5V.
- Works fine at 2.95V. (?!)
- How about other devices.
- LED matrix displays supposedly require 5V (2A).
  - But they don’t reliably understand STM32 levels.
  - When they run at 4.3V, they work fine with STM32.

Other power supplies

- Batteries are too variable to be directly connected since their voltage will change as they are depleted.
  - Use a "boost" converter to raise a low voltage to a higher voltage (with a lower current than battery supplies).
  - Use a "buck" converter to lower a high voltage to a lower voltage.
  - Either/both of these are very efficient.
  - Either/both add noise.

Linear Regulators

- These take a moderately higher DC voltage and drop it to 5V. E.g. LM7805 regulator.
  - Max 1A.
  - Input must be >=7V.
  - Higher voltages mean larger voltage drop.
  - High current * voltage drop = power dissipation.
    - e.g. 1A through a 2V drop is 2W. Hot.
    - Inefficient (30% – 50%, typically)
  - Fine for STM32, and very low current peripherals, it's fine.

Low Drop-Out Regulators

- Like the LM7805, but can operate with lower input voltage margin.
  - There are still I*V power losses.
  - Still bad for high current / high input voltage.

Before you connect a power supply

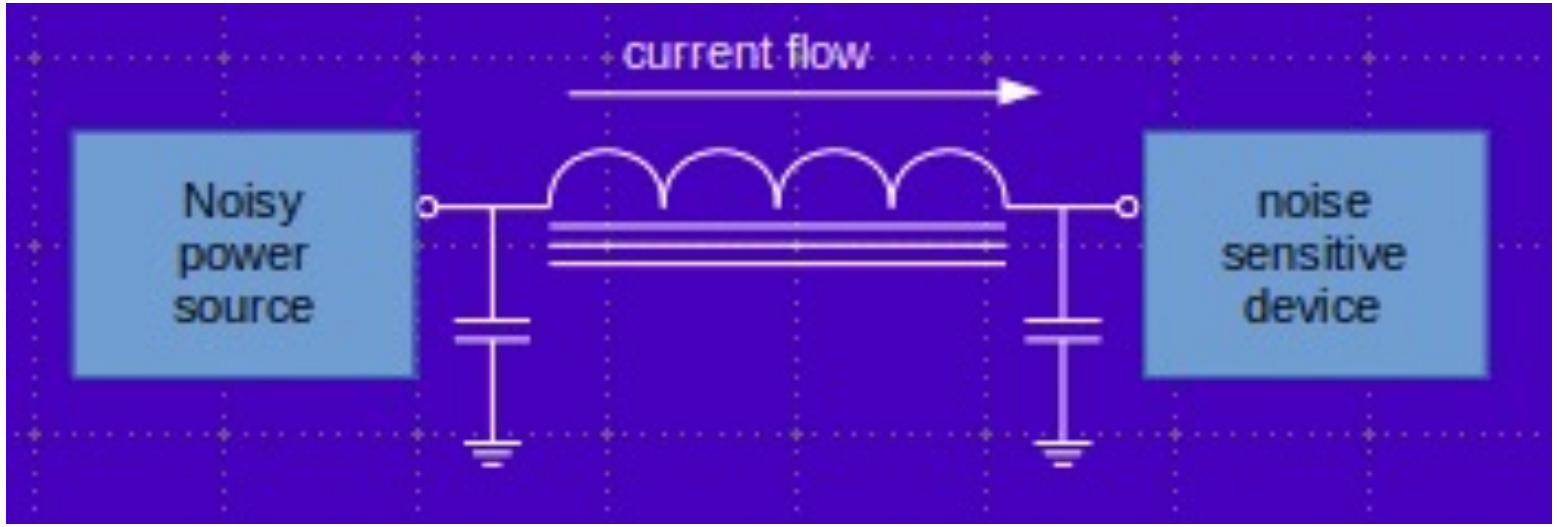
- Let’s say you have a 5V power supply you want to use.
- Test the power supply with no load.
  - Use a DMM on voltage setting.
  - Test the voltage with no load.
  - If the voltage exceeds 5.5V, don’t use it.
- Test the power supply with a low-value resistor.
  - If the voltage exceeds 5.5V, don’t use it.

Noise

- Any AC-to-DC converter will have residual 60-Hz noise.
- Switching power supplies will have higher frequency noise.
- Examine this on an oscilloscope.
- Capacitors help, serial inductors help.

“Pi” filter

- So named, because the legs of the capacitors on either side of the inductor look like the Greek letter Pi.



Potentially Damaging Circuits

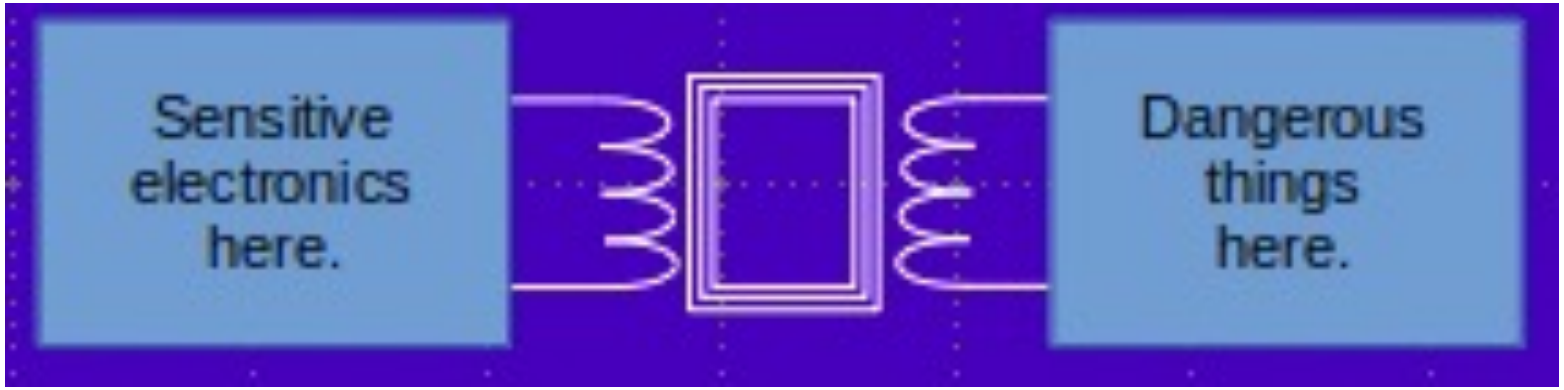
- Some times the things you want to use are the sources of noise or dangerous voltage potentials that may damage or otherwise harm the functionality of your system.
  - High-current loads: electromagnets, motors, things that produce sparks.
  - Point-of-entry for external cables: Could be affected by accidental contact with high voltage, electrostatic discharge, lightning, etc.

Use Isolation Where Needed

- A number of devices can be used to electrically isolate dangerous circuitry from sensitive electronics:
  - Transformers: Isolation via magnetic coupling between coils.
  - Opto-isolators/Optocouplers: air-gap LED and phototransistor.
  - Hall-Effect Sensors: Use magnetic field as a switch.
  - Relays/Solenoids: Another way to use a magnetic field as a switch.

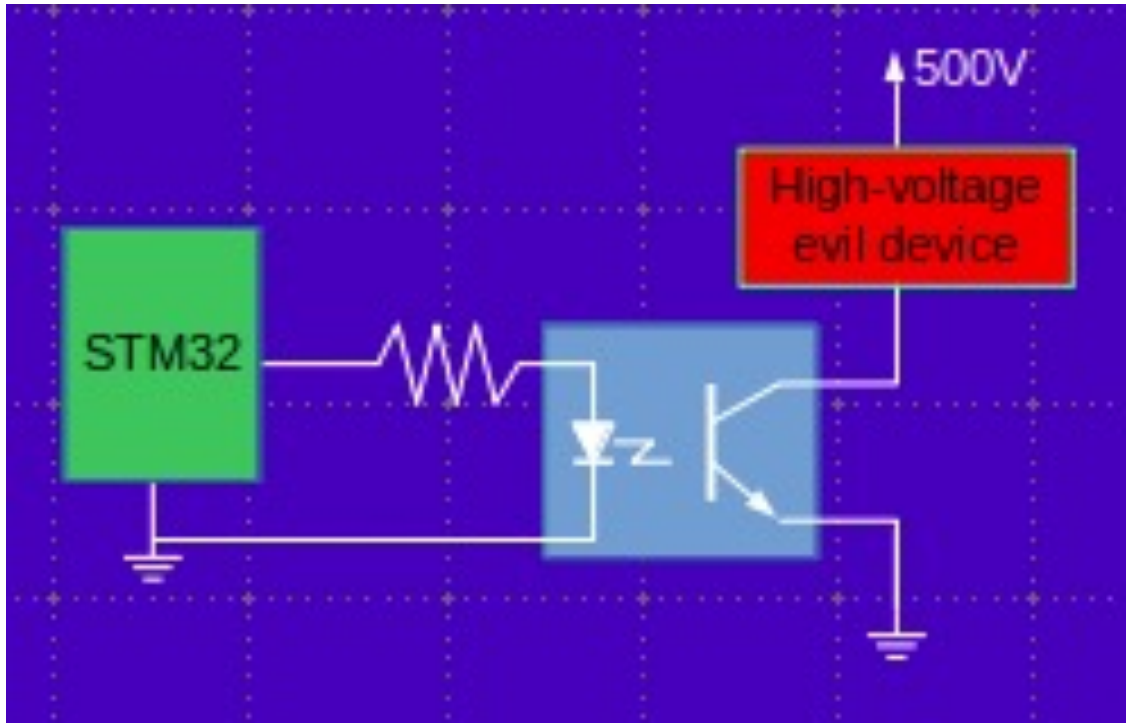
Transformers

- Separate coils of wire that "communicate" through magnetic coupling.
  - Not good for digital signals.
  - Low-speed alternating current only.
  - Good for audio.



Optically Isolated Transistor

- Separate sensitive electronics from danger



No matter what happens with the high-voltage device, the microcontroller is protected because it is isolated from the high-voltage side by an air-gap.

Relays

- Electromechanical switches
  - An electromagnet pulls a switch to a contact.
  - Downsides: low-speed, needs isolation