LECTURE XI

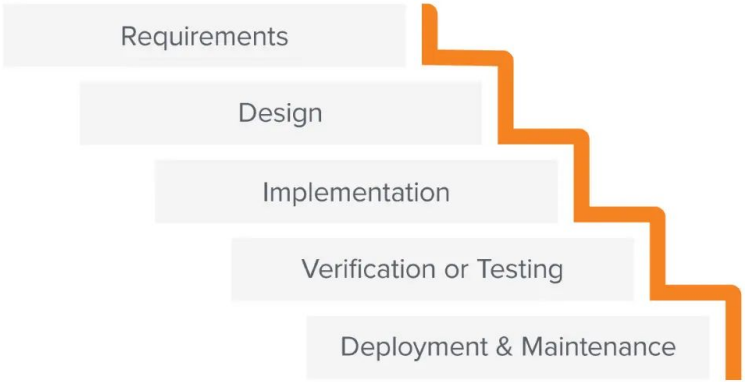
Designing Projects and Picking Parts

SECTION I

Defining the Problem

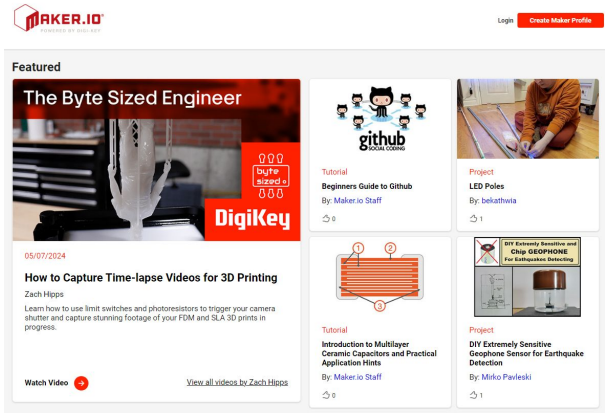
Defining the Problem

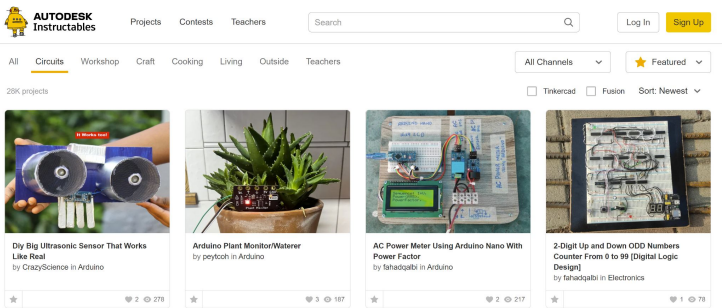
- **What is the goal of the project?** What problem are you trying to solve?
- Consider the lecture on Software Engineering… **Requirements engineering** (in the waterfall model) was the first step of the process
    - Defines the problem that must be solve and outlines the scope of the project

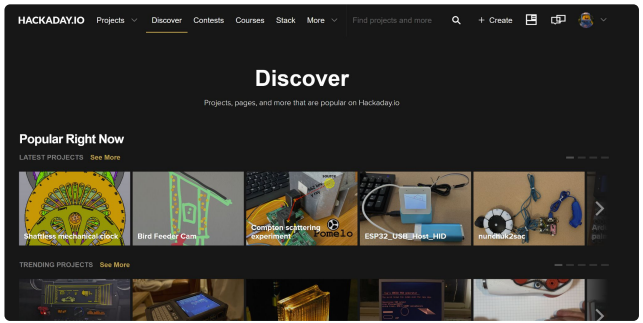


Brainstorming the Problem

- If you do not have a project idea, you can always **look for inspiration** online…
  - Hackaday.io
  - Autodesk's Instructables
  - DigiKey's Maker.io







Brainstorming the Problem (Cont'd)

- Hackaday, Instructables, and Make.io are all **community-driven forums with projects** (often open source) for you to replicate or augment
  - Take note at how good projects are **well-documented**
    - They feature parts lists, video demos, schematics, CAD files, etc.
- As you brainstorm, consider your **design constraints** early on…
  - **Cost** – How much are you willing to spend on parts?
  - **Time** – How much time can you commit?
  - **Complexity** – Do you have a sufficient understanding to create this?
  - **Equipment** – What tools and lab space are available to you?

SECTION II

Researching the Solution

Researching the Solution (Example)

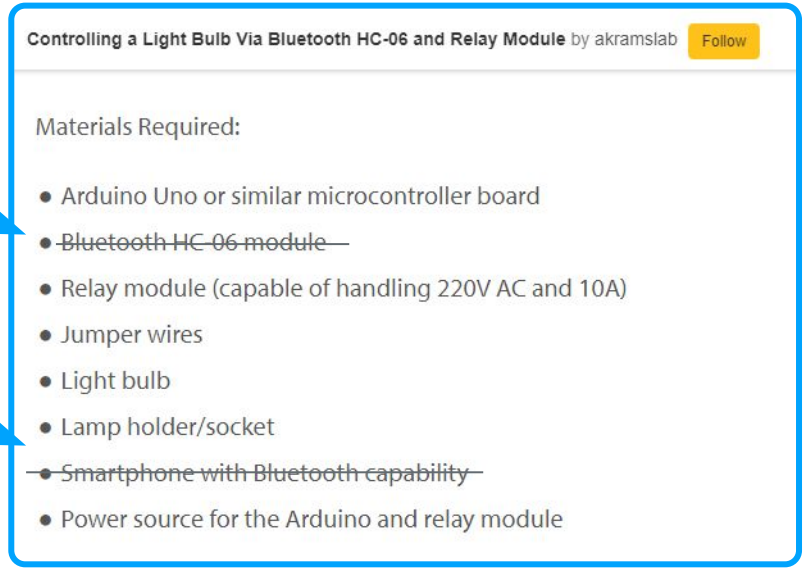
- Let's say you have decided on a **project idea**:
  - You want to create a **battery-powered remote light switch for an old lamp** using an NRF24 radio
- The **next step is to synthesize a solution**. If you already have a design in mind, that's great! Otherwise, you may need to **perform some research**…
  - Use sites like Hackaday and Instructables to **find related projects**
    - We can find a similar project that uses bluetooth radio instead of an NRF24 (close enough!)
      - In this project, an Arduino is control the lightbulb while awaiting commands from a bluetooth-enabled phone

Researching the Solution (Example) (Cont'd)

- What if there is **no similar project**?
  - **Widen your search** to loosely related projects
    - No idea is 100% novel…
  - Look for **projects that use similar parts** with different end goals
    - Information/tips just about using certain components can be immensely helpful
  - Investigate **research papers** and other **professional publications**
    - If you choose cutting-edge project ideas, you may need to explore more academic databases

Refining Design Requirements (Example)

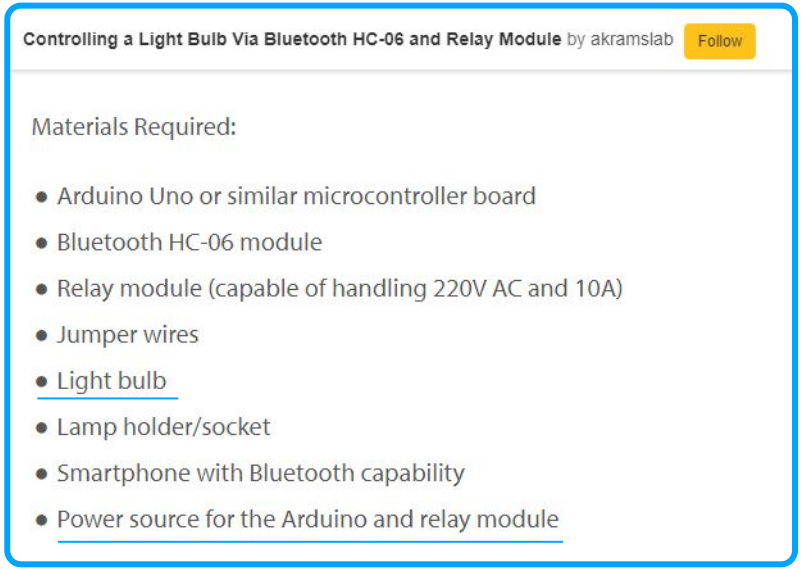
- **Augment the reference project** according to your own requirements
  - **We want to use an NRF24 radio instead** of the Bluetooth module
  - Instead of using a phone, **we want to create a remote control with Arduino**
- You should **document any changes you make** with respect to the reference project



Reference Instructables Project

Refining Design Constraints (Example)

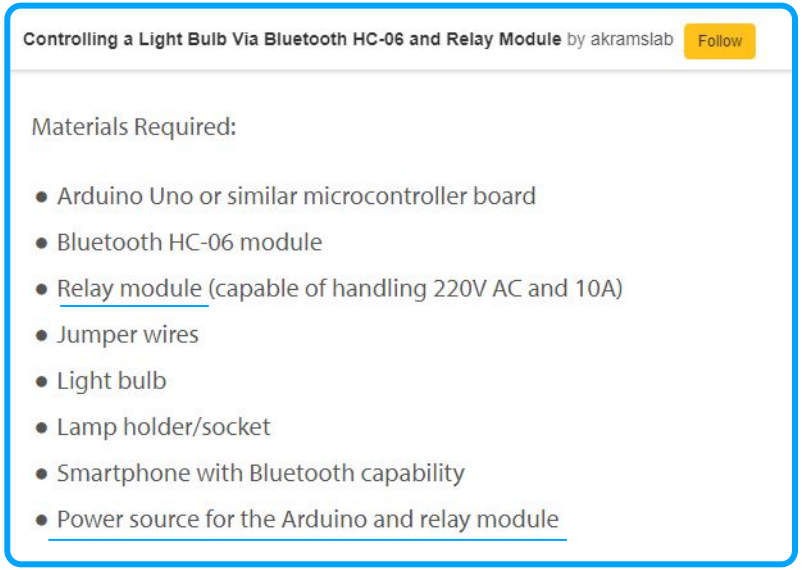
- **Skim the reference project**'s parts list and schematics to get an idea of the **overall constraints…**
    - What is **each components input/output voltage/current requirements**? Look up their datasheets!
        - Light bulbs accept 120V AC from a standard outlet
        - Arduino takes ~6-12V DC as input and outputs 5V logic



Reference Instructables Project

Refining Design Constraints (Example) (Cont'd)

- Clearly, an **Arduino with 5V output can't directly switch a lightbulb** which requires 120V AC. How do we get around this?
    - The reference project suggests using a **relay module** which **allows a circuit to open and close another circuit** of a different voltage/current
- We will also **require separate power sources** as input to the lightbulb and Arduino!



Reference Instructables Project

Early Documentation (Example)

- Based on your newly defined constraints, **write a rough draft list of parts** you require and their most important specs….

Example Parts List

- *MCU boards (x2) 6-12V input, 3.3-5V output*
- *Relay module 5V logic input, 120V AC output*
- *Light bulb 120V AC, standard bulb size*
- *Lamp with wall plug, standard bulb size*
- *Jumper wire, appropriate gauge*
- *NRF24 Radios (x2), 3.3V input*
- *US Standard Outlet, 120V AC output*
- *USB cables (x2)*
- *Portable USB batteries (x2)*

Which board is the right one? **Consider your speed, storage, and I/O requirements…** We chose Arduino there is a lot of online documentation and it meets our requirements

If you don’t know the standard bulb size or an appropriate wire gauge, **seek advice** online or **from real, living human beings**!

Seeking Advice

- **Don’t forget to visit the IEEE Room!** We will help you create your projects
- Using the Internet
  - Reddit, when exercising healthy skepticism, can be immensely helpful. Try the following subreddits…
    - r/AskElectronics
    - r/Arduino
    - r/Raspberry_Pi
  - StackExchange can also be a useful tool for asking questions

SECTION III

Picking Parts and Drawing the Schematic

Picking Parts

- Now, it's time to start looking for parts to buy…
- Choose a seller that's right for you!
  - If you want **quality parts** and **reliable shipping**, consider buying from a more reputable supplier:
    - DigiKey, Mouser, or Newark
  - If you want to **save money** with a reasonable chance of quality parts, consider one of the following options:
    - Amazon, Ebay, or Aliexpress
    - **Exercise caution**: Examine the listings' reviews and descriptions

Picking Parts from DigiKey

- An advantage to buying from an electronics supplier is that they typically have **part search tools**
  - You can **define all the part's specifications to refine the search**
  - Ex) Looking for a resistor? Specify its resistance (Ω), tolerance, max power rating, and packaging
- Let's use DigiKey to demonstrate the power of a parts search tool by looking for the following resistor:
  - 130Ω ± 5%, THT, Axial, 2W, Cut Tape

DigiKey

Drawing the Schematic

- **While you pick the parts**, you should also **draw the first draft schematic**
  - The advantage of performing these tasks simultaneously is that **you research the datasheets/pinouts before committing to the parts**
- Use a schematic capture tool:
  - Fritzing (Small one-time license fee)
    - Fritzing is beginner-friendly and offers a “breadboard”-level visual representation of parts and connections
  - KiCAD EDA (Free)
    - If your design is more sophisticated, KiCAD is the better option

SECTION IV

Prototyping

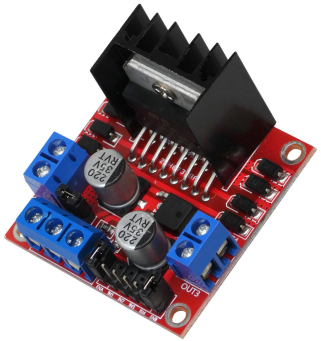
Implementing Solutions *Safely*

- Always consider safety requirements when working with **high voltage and current:**
  - Make sure designs are properly grounded
  - Watch where power is dissipated… Heat can build up *fast*
  - Exercise caution when testing live AC circuits so you don't electrocute yourself
  - Always check that power sources are unplugged before manipulating circuits

Components for Prototypes

- For microcontrollers, **use development boards** instead of the standalone chips
- Consider using **breakout boards** where compactness is not important
    - **Breakout boards** take small components and spread out their pins for ease of use
- **Do not use breadboards with AC, high current, or high voltage circuits**

ESP32 Development Board



L298 Breakout Board

SECTION V

Testing and Finalizing the Design

Testing and Evaluation

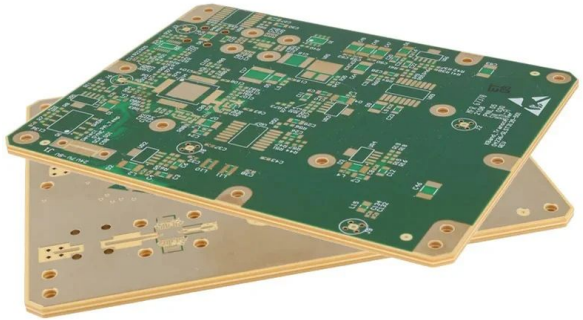
- **Create a test plan** for your project
  - Generate a list of common workflows/use cases
  - Think of interesting **edge cases** – extreme conditions or inputs – that may mess with the behavior of the electronics
- Execute the test plan and **document where the project passes/fails**
- The final design should at least account for where the project fails testing
- Compare your prototype to **alternative designs**
  - Never settle on a solution until you have evaluated and defended it against the alternatives
  - **“Why did you choose *x* technology over *y* technology?”**

Finalizing the Design

- At this, point you will have generated the following documentation:
  - **Parts List/Bill of Materials**
  - **Schematic**
  - **Test Plan**
- According to the results of your testings, **you will create a final design:**
  - You may choose to **fabricate a PCB** for your circuit
  - The schematic may be redesigned according to new parts chosen in the final plan

PCB Fabrication

- PCBs are a good option for implementing complex circuits and adding structural support
- Here are to common manufacturers:
  - JLCPCB
    - Inexpensive 2-layer FR-4 boards
    - Fast manufacturing and shipping
    - Used by hobbyists
  - PCBWay
    - Better for more precise design requirements (small traces, vias, etc.)
    - Advanced manufacturing options



Final Documentation

- Compile your documentation:
  - **Parts List/Bill of Materials**
  - **Schematic**
  - **Test Plan and Results**
  - **High-level Explanation and Defense of your Project/Solution**
  - **Photo or Video Demonstration**

- Your documentation **will aid your job search**
  - Employers will ask about past projects, even inquire about your approach (i.e. why you used certain components/frameworks over others)

SECTION VI

Final Thoughts

Projects as Means for Growth

- Picking up personal projects **teach you** to **build with different components increasingly complex software and hardware**
  - Each project is an opportunity to explore new topics incrementally
- **Your documentation will be a valuable resource** for your future projects
  - This is how you'll avoid making the same mistake twice
- **Sharing your projects will support other learners**
  - Just as you will search for help on forums or in the IEEE room, your work can serve as inspiration for others
  - **Post articles** about your projects!

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