LECTURE XI

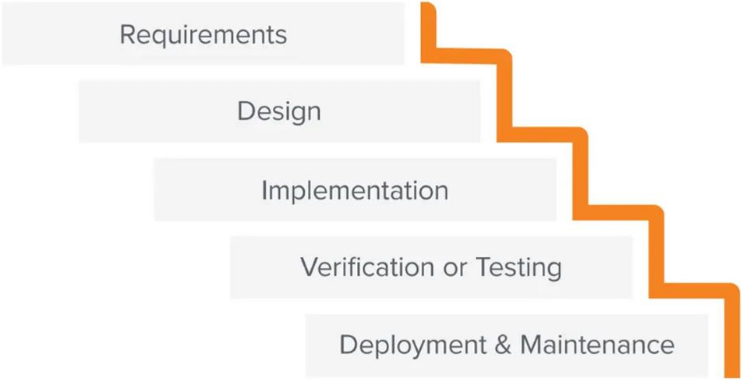
Designing Projects and Picking Parts

SECTION I

Defining the Problem

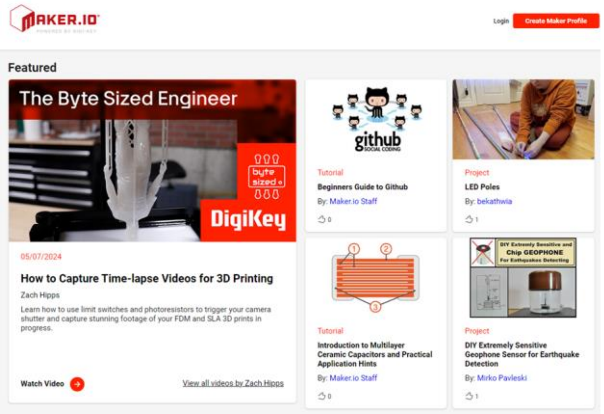
Defining the Problem

- **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



Featured

05/07/2024

How to Capture Time-lapse Videos for 3D Printing

Zach Hipps

Learn how to use limit switches and photoresistors to trigger your camera shutter and capture stunning footage of your FDM and SLA 3D prints in progress.

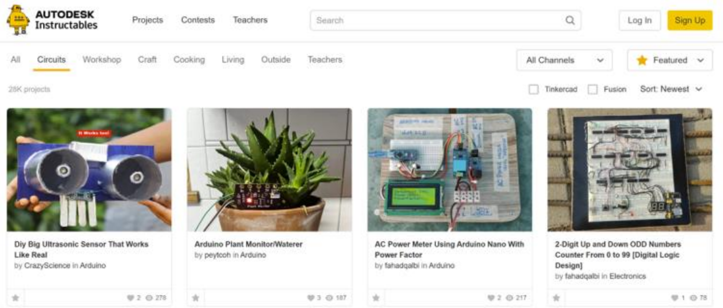
View all videos by Zach Hipps

Tutorial
Beginners Guide to Github
By: Maker.io Staff
0

Project
LED Poles
By: bekathwia
1

Tutorial
Introduction to Multilayer Ceramic Capacitors and Practical Application Hints
By: Maker.io Staff
0

Project
DIY Extremely Sensitive Geophone Sensor for Earthquake Detection
By: Mirko Pavleski
1



28K projects

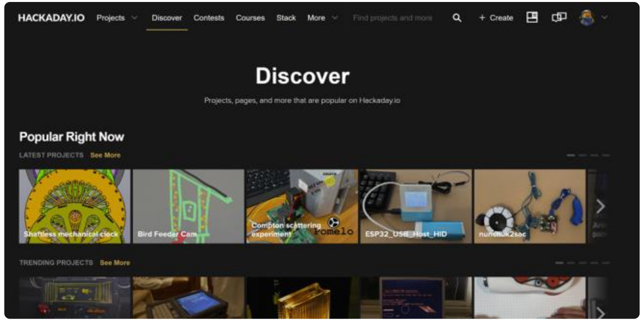
□ Tinkercad □ Fusion Sort: Newest

Diy Big Ultrasonic Sensor That Works Like Real
by CrazyScience in Arduino
2 278

Arduino Plant Monitor/Waterer
by peytcoh in Arduino
3 187

AC Power Meter Using Arduino Nano With Power Factor
by fahadqalbi in Arduino
2 217

2-Digit Up and Down ODD Numbers Counter From 0 to 99 [Digital Logic Design]
by fahadqalbi in Electronics
1 78



Discover

Projects, pages, and more that are popular on Hackaday.io

Popular Right Now

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)

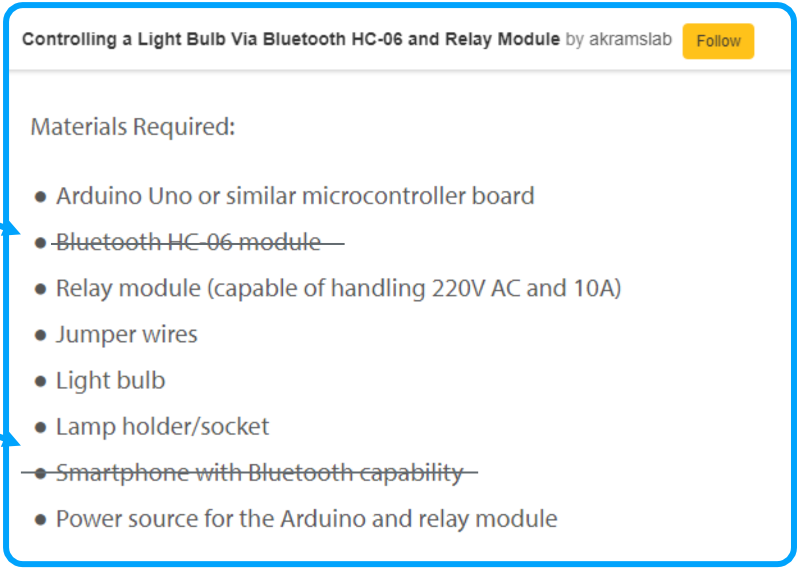
- Let’s say you have decided on a **project idea**:
    - You want to create a **battery-powered remote light switch for an old lamp** using an NRF24 radio
- The **next step is to synthesize a solution**. If you already have a design in mind, that’s great! Otherwise, you may need to **perform some research**…
    - 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



Controlling a Light Bulb Via Bluetooth HC-06 and Relay Module by akramslab

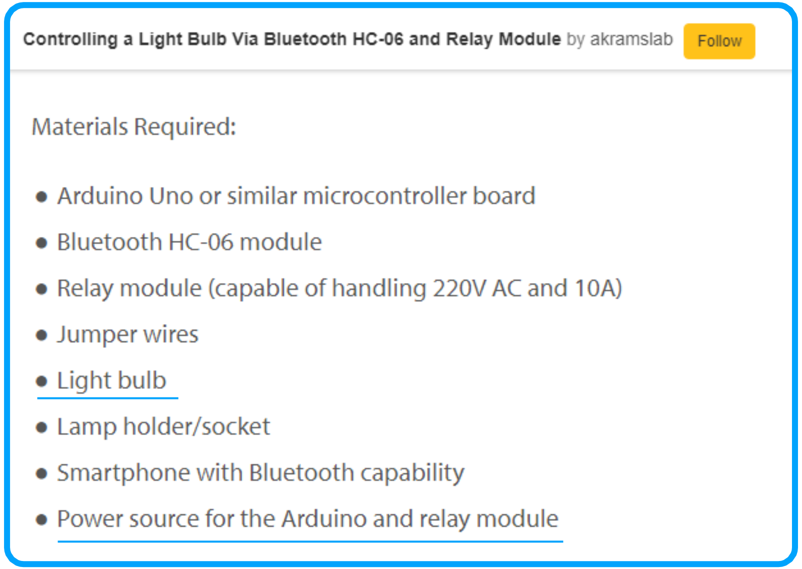
Materials Required:

- Arduino Uno or similar microcontroller board
- ~~Bluetooth HC-06 module~~
- Relay module (capable of handling 220V AC and 10A)
- Jumper wires
- Light bulb
- Lamp holder/socket
- ~~Smartphone with Bluetooth capability~~
- Power source for the Arduino and relay module

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



Controlling a Light Bulb Via Bluetooth HC-06 and Relay Module by akramslab

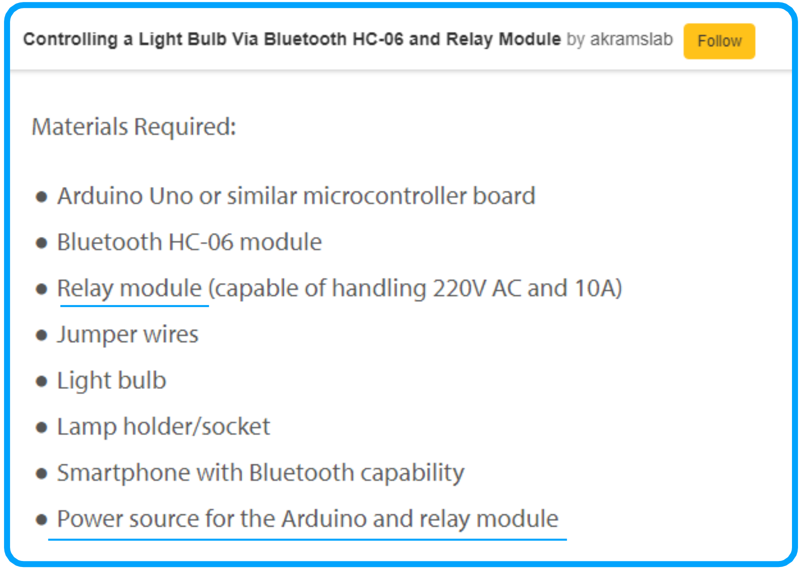
Materials Required:

- Arduino Uno or similar microcontroller board
- Bluetooth HC-06 module
- Relay module (capable of handling 220V AC and 10A)
- Jumper wires
- Light bulb
- Lamp holder/socket
- Smartphone with Bluetooth capability
- Power source for the Arduino and relay module

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!



Controlling a Light Bulb Via Bluetooth HC-06 and Relay Module by akramslab

Materials Required:

- Arduino Uno or similar microcontroller board
- Bluetooth HC-06 module
- Relay module (capable of handling 220V AC and 10A)
- Jumper wires
- Light bulb
- Lamp holder/socket
- Smartphone with Bluetooth capability
- Power source for the Arduino and relay module

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

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

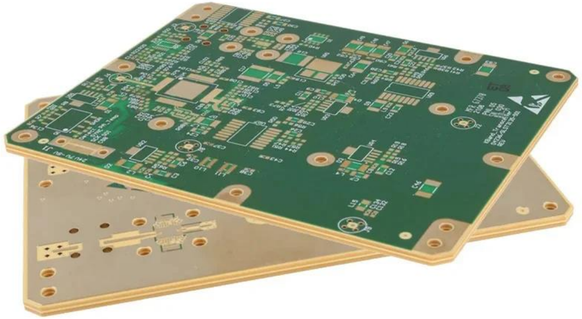
- **Create a test plan** for your project
  - Generate a list of common workflows/use cases
  - Think of interesting **edge cases** – extreme conditions or inputs – that may mess with the behavior of the electronics
- Execute the test plan and **document where the project passes/fails**
- The final design 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!

FAIR USE DISCLAIMER

Copyright Disclaimer under section 107 of the Copyright Act 1976, allowance is made for “fair use” for purposes such as criticism, comment, news reporting, teaching, scholarship, education and research.

Fair use is a use permitted by copyright statute that might otherwise be infringing.

Non-profit, educational or personal use tips the balance in favor of fair use.

CC BY-NC-SA 4.0