BIOS and Embedded Systems

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EECS 373
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Overview

- What is the BIOS?
- What does it do?
- Why is it necessary?
- Can it be used in embedded systems?
- Embedded BIOS

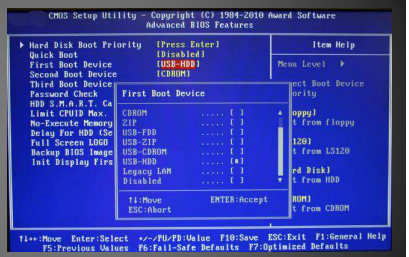
What is the BIOS?

- BIOS stands for **B**asic **I**nput/**O**utput **S**ystem.
- Low-level software (lower than the OS) that provides link between hardware and software in a PC.
- Invented in 1975 for the CP/M operating system.
- Found in IBM PC compatible computers (pretty much all PCs today).
- Located in ROM (old days) or flash memory (nowadays) on the motherboard rather than disk.

Source: http://www.ecomputerz.com/american-megatrends-bios.html

What does it do?

- First software that runs on system power-up, before OS.
  - Performs POST and other hardware checks.
  - Allows user to change system configuration settings (which are saved in another chip on the motherboard).
  - Initialises device drivers (hardware interrupt handlers).
  - Initiates OS boot process.
  - Provides routines to access system hardware.



Source: https://commons.wikimedia.org/wiki/File:Bios-configuracion-orden-arranque.png

Why is it necessary?

- Need to load OS into main memory, but OS in disk.
  - BIOS initiates OS load from disk to memory.
- BIOS is abstraction layer under OS, hides most hardware details.

Can it be used in embedded systems?

- BIOS widespread on PCs; can it be used in embedded systems?
  - Yes, if the embedded system uses x86 architecture.
- BIOS-related issues:
  - Long BIOS start-up time (as long as 13 seconds).
  - Many BIOS implementations rigidly geared towards a PC, not embedded systems.

Embedded BIOS

- One solution for embedded is Embedded Bios with StrongFrame Technology, from Phoenix Technologies.
  - Built with configurability and extendibility in mind.
  - Easy to modify for desired application.
  - System hardware already known; can eliminate checks for…
    - Mouse and keyboard.
    - Video subsystem.
    - Hard disk.
    - ✓ Gives faster boot time.

References

- *Upgrading and Repairing PCs*, 22nd Edition, by Scott Mueller.
- http://www.pcguide.com/ref/mbsys/bios/index.htm
- https://www.pddnet.com/article/2010/01/embedded-bios-increases-x86-leverage

Embedded Systems in Advanced Prosthetics

AARON CLAUSSEN

EECS 373

Background

Hugh Herr
- Mechanical engineer, biophysicist, and rock climber
- Double amputee due to frostbite during a climb
- Designer of his own specialized prosthetic legs
- Head of MIT Media Lab's Biomechatronics group

BiOM Ankle-Foot Prosthesis

Simulates work done at ankle during walking

Sensors track position, motion, phase of stepping process

Microprocessors control springs and motors to deliver proper force and torque

Significance

Walking with prosthetics now feels more natural
- Quicker rehabilitation
- Reduced risk of consequential afflictions
- Restored ability for users

References

https://www.ted.com/talks/hugh_herr_the_new_bionics_that_let_us_run_climb_and_dance/transcript?language=en

https://dam-prod.media.mit.edu/x/files/wp-content/uploads/sites/3/2013/07/au-weber-herr-2007-IEEE-biomech-design-of-PAFP.pdf

https://en.wikipedia.org/wiki/Hugh_Herr

http://www.bostonmagazine.com/health/article/2013/11/26/prosthetics-research-boston-biom-ankle-prosthetic/

http://www.dailymail.co.uk/news/article-2181527/Who-Says-I-Cant-climber-scales-200ft-cliff-despite-having-legs--false-limbs-falling-halfway-up.html

http://www.bizjournals.com/boston/blog/startups/2014/12/bedford-bionics-maker-biom-may-go-public-but-not.html

Questions?

RFID

NEAL TATUM

Radio Frequency Identification

Up to 1000's of items

Possibility of >100m range

Instant data
- Manufacturer
- Product details
- Location of items
- Supply count

Types of RFID

Active Tags
- Requires internal battery
- Read/Write
- Partner w/ other technology/sensors
- Larger signal range
- Expensive
- Larger in size

Passive Tags
- Powered by the reader
- Smaller, lighter
- Unlimited lifetime
- Low signal range
- Typically less data
- Cheaper

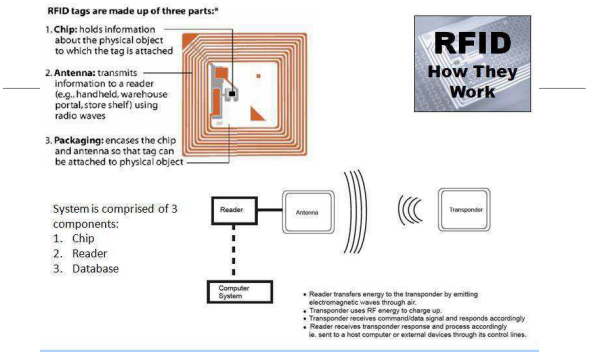
Passive RFID

Reader, antenna, tags

Reader sends RF signal

Tag antenna -> power -> tag IC -> antenna

Reader receives data -> processor/database



Information on the tag

Identifies EPC Format Being Used	Identifies Product Manufacturer	Identifies Exact Type of Product	Unique to Individual Item
Header	EPC Manager Number	Object Class	Serial Number
01*	12345ABC*	00012E*	000123ABC*
	Assigned by EPCglobal	Assigned by EPC Manager	

* Hexidecimal Number where A-F=10-15

Current Real World Examples

Item inventory
- Location
- Condition
- Count

Animal identification

Credit cards

Toll Tags

Attendance Tracking

Race Timing

Access Control

Kiosks / Library-like systems

Future of RFID

Grocery store example

Pantry/refrigerator example

Printed directly on products

People are RFID tagged

RFID will play a huge role in embedded systems

Internet of Things

Aidan Connolly

Introduction

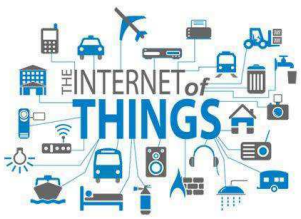


Image: Computer Business Review

- Interconnectivity of physical devices with embedded systems
- Integration of the digital and physical worlds

Origins

"The Internet of Things, or IoT, is the integration of people, processes and technology with connectable devices and sensors to enable remote monitoring, status, manipulation and evaluation of trends of such devices."

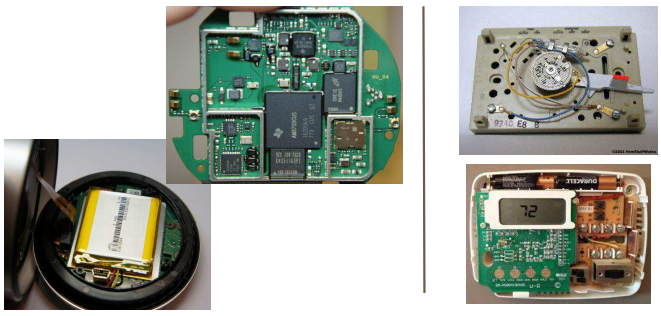
- Peter T. Lewis to the FCC, 1985

Modern Consumer Example - Nest Thermostat

Image: sparkfun.com

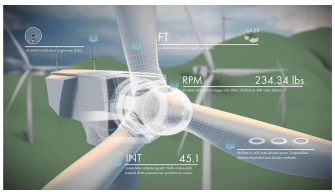
- Self-learning, wifi enabled thermostat
- Optimizes HVAC to conserve energy
- Nest can remotely push updates

Nest Teardown



Another IoT Application - Industrial

- IoT's impact is not limited to consumers
- General Electric's industrial software platform
  - "The world's first industrial internet platform"
  - GE and Intel partnership to bring IoT to the industrial world



Energy Scavenging

KC Bruner

•••

What is energy scavenging?

Energy scavenging is the process by which energy is derived and captured from external sources (e.g., solar power, thermal energy, wind energy, salinity gradients, and kinetic energy) [5]

Energy Scavenging in embedded systems

Energy scavenging results in small quantities of power.
-> Not exactly useful for power hungry circuits.

Low power circuits -> Energy scavenging is incredibly useful, having the potential provide adequate power to run the device Indefinitely.

Can make active circuit elements into passive circuit elements, reducing the number of wires running from your main power source.

Where does energy scavenging shine? Sensors.

Piezoelectric

Basic idea: Applying a force to the material generates will generate an electrical current (and vice versa). [3]

This force can from from things like human motion, acoustic noise, and low frequency seismic vibrations. [5]

Energy produced is generally ~mW

Availability is limited, and fairly expensive.
Piezo Systems, Inc -> Energy harvesting kit for $660

Triboelectric

Basic idea:
Two sheets of dissimilar materials; an electron donor and an electron acceptor.
Materials touch -> electrons flow from donor to acceptor.
After materials are separated -> one sheet holds an electrical charge isolated by the gap between them.
Connecting a load to electrodes placed at outer edges results in current flow equalizing the charges. [3]

Wide ranging implications for new types of sensors.

Brief search for availability yielded no results.

Thermoelectric Generation

Basic idea: Thermal gradient between two dissimilar conductors results in a voltage.

Solid state device

Efficiency is generally very low : ~ 0.001 - 0.1
-> For embedded applications, on the lower end

Potential to turn active cooling elements into passive elements [4]

Available at a reasonable price
-> 4 different TEGs on digikey, some for ~$20

Solar

Widely available, cheap (112 different items on digikey alone)

Can generate power both indoors and outdoors, depending on the solar cell

Power generated ranges from ~ 15μW - 5W

As small as 8.8mm^2

[1] A. Poor, *Three Technologies for Harvesting Ambient Energy*, IEEE, Mar. 2015. [Online]. Available: http://spectrum.ieee.org/consumer-electronics/gadgets/three-technologies-for-harvesting-ambient-energy [Accessed: 20 Mar. 2017]

[2] W. Jung et al., *High Output Piezo/Triboelectric Hybrid Generator*, Macmillan Publishers, Mar. 2015. [Online]. Available: http://www.nature.com/articles/srep09309#s1 [Accessed: 20 Mar. 2017].

[3] J. Toon, *Harvesting Electricity: Triboelectric Generators Capture Wasted Power*, Georgia Institute of Technology, Dec. 2013. [Online]. Available: http://www.news.gatech.edu/2013/12/07/harvesting-electricity-triboelectric-generators-capture-wasted-power [Accessed: 20 Mar. 2017].

[4] O. Sullivan et al., "On-Chip Power Generation Using Ultrathin Thermoelectric Generators," *Journal of Electronic Packaging*, vol. 137, no. 1, Mar. 2015, pp. 1-7. [Online]. Available: http://minds.gatech.edu/Publications/Papers_2014/Owen_JEP_2014.pdf [Accessed: 20 Mar. 2017].

[5] *Energy Harvesting*, Wikipedia, Mar. 2017. [Online]. Available: https://en.wikipedia.org/wiki/Energy_harvesting [Accessed: 20 Mar. 2017].

Rectifier Circuits

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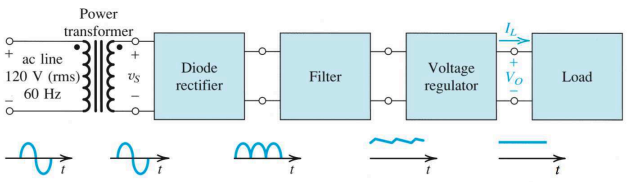
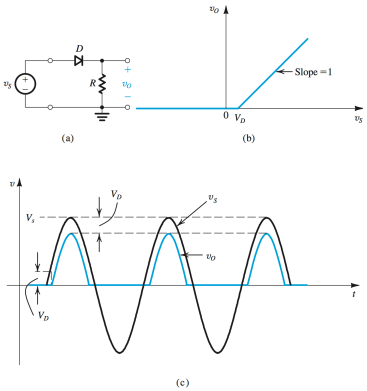
Block diagram of a DC power supply



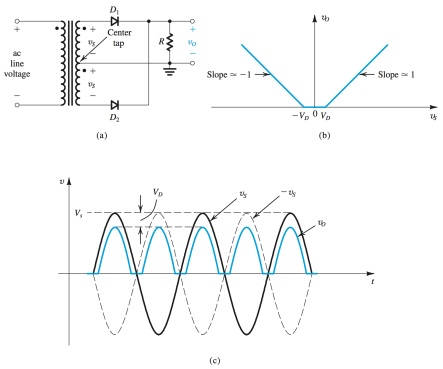
Half-wave rectifier

- Using constant-voltage-drop model for the diode.
- Peak Inverse Voltage (PIV) = V_s



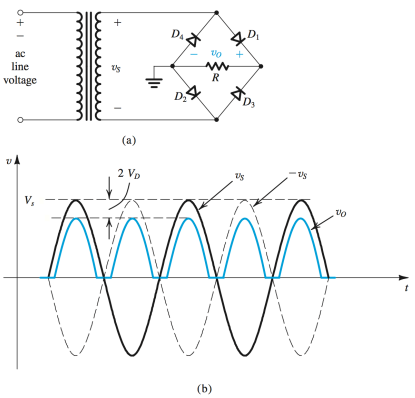
Full-wave rectifier

- Need a center-tapped winding.
- More "energetic" than half-wave.
- PIV = 2V_s - V_D

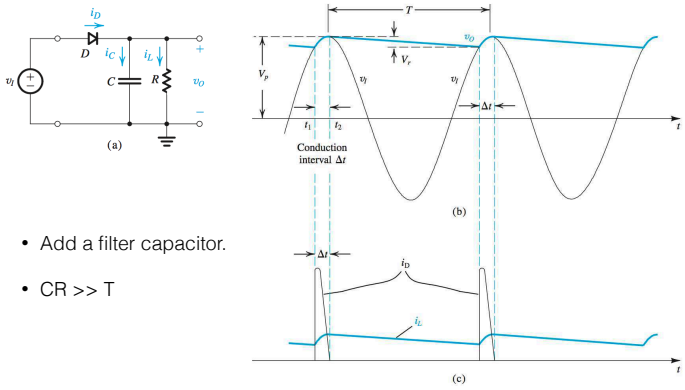


The bridge rectifier

- Configuration similar to Wheatstone bridge
- No need of center-tap.
- Only half as many turns as center-tapped rectifier.
- Require 4 diodes (cheap).
- PIV = V_s - V_D



The peak rectifier



- Add a filter capacitor.
- CR >> T

Reference

- Adel S. Sedra, Kenneth C. Smith, Microelectronic Circuits, 7th edition. Oxford University Press.

Bad USB

Christopher Niemann

21 March, 2017

Outline

- What is it
- How it works
- Fixes

What is Bad USB?

Exploit of hardware oversight in USB devices
Became well-known in 2014
Extraordinarily hard to detect by anti-virus programs

How does Bad USB work?

Computers don't trust external software, but do trust external firmware
By reprogramming a USB's firmware, can add malicious code
Trick OS into thinking that USB is an HID (Human Interface Device)

Effects of the Payload

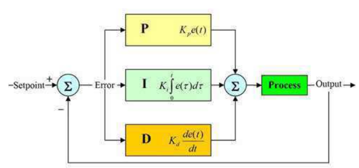
Attacker can emulate keyboard, mouse, etc.
The limit is the attacker's imagination

Image source: http://i.imgur.com/rWwBace.jpg

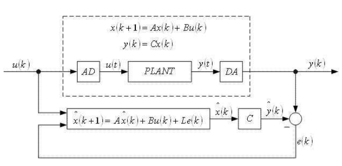
Fixes for Bad USB

Prevent firmware changes altogether
Force firmware updates to be signed, authenticated by manufacturer
Tamper-proofing USB devices

Questions?




```
//roll acts on x, pitch acts on y, thrust acts on z
save pose and setpoints from state struct
for each roll, pitch, and thrust
        error = pose − setpoint
    accumulated error +=  trapezoidal integrated
        error
    if the error is outside of the saturation bounds
        , saturate
    if reset error flag is set, clear accumulated
        error
    errordot = 0 − posedot //0 is desired velocity
    run errordot through tenth order FIR filter (
        simple moving average)
    output = error * KP + accumulated error * KI +
        errordot * KD
    output+=1500+trim bias
    pass to channels structure to go to Blocks
end
```




```
for each predicted state in model
    apply model to each predicted state
    add input to each predicted state
    add error to each predicted state
    collect measurements from actual system state
    calculate error in estimation and measurement
    feed error back
    use state estimation to choose control input
end
```

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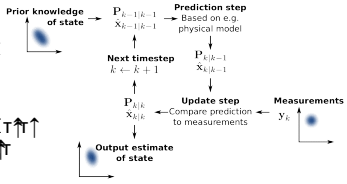

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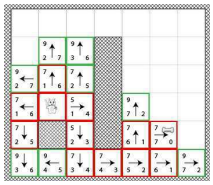

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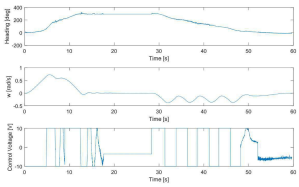

Figure 34: Pointing test case 4, 290 degrees to 0 degrees

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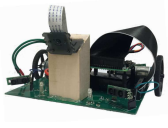

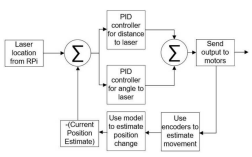

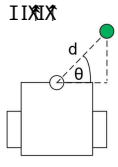

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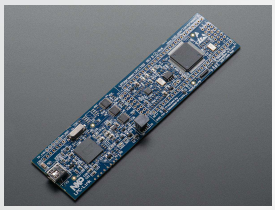


LPC1769 LPCXpresso

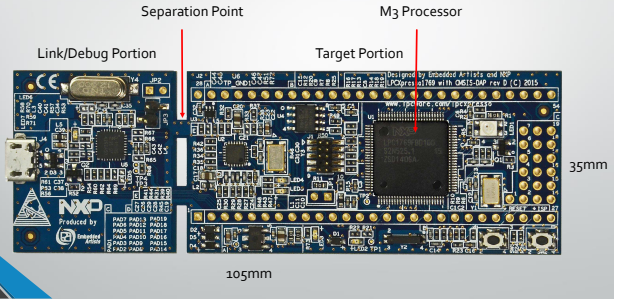
Samuel Habbo-Gavin

Why use this board?

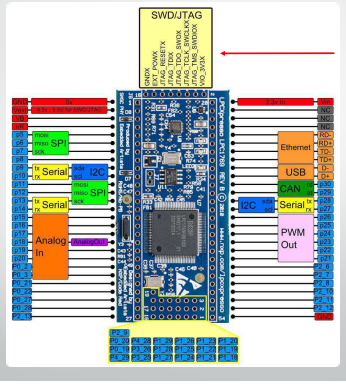
- LCPXpresso is smaller than the SmartFusion board
- Low power consumption
- Uses a similar Eclipse based IDE
- Cortex M3 processor

Board Layout

Note: No FPGA



Pin Layout



Process for using LPCXpresso

- Use Eclipse-based IDE to program the board
- Debug the system using built in debugger
- Permanently remove debugging portion
- Power and run the target portion
- LPC Link2 Debugger Hardware needed after separation

References

Board:

https://www.embeddedartists.com/products/lpcxpresso/lpc1769_cmsis_xpr.php

IDE:

http://www.nxp.com/products/software-and-tools/software-development-tools/software-tools/lpc-microcontroller-utilities/lpcxpresso-ide-v8.2.2:LPCXPRESSO?tid=vanLPCXPRESSO

Images:

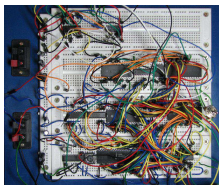
https://www.google.com/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&ved=0ahUKEwjPp9mL5ubSAhXCKiYKHbOpBwsQjRwIBw&url=https%3A%2F%2Fdeveloper.mbed.org%2Fusers%2Fnameless129%2Fnotebook%2Flpcxpresso-lpc1769-pinout%2F&psig=AFQjCNHGPPq1EQoKZPYfNqgfH-KFUnrtQ&ust=1490158217228545

Paper Circuits

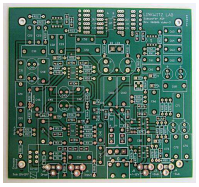
Qihan Sun

What we have learned

- Breadboard-based prototyping
  - Fast to build
  - Rework easily
  - Cheap
  - Not so scalable



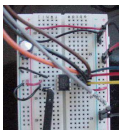
- PCB-based prototyping
  - Slow to manufacture
  - In-place rework is nearly impossible
  - Expensive
  - Clean layout, scalable



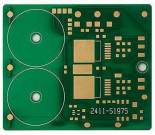
https://en.wikipedia.org/wiki/Breadboard#/media/File:Breadboard_complex.jpg
http://www.linkwitzlab.com/Pluto/supplies-subw.htm

Something in between

Breadboard-based prototyping



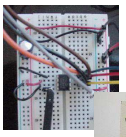
PCB-based prototyping



http://eecs.umich.edu/courses/eecs373/labs/lab6/spidac%20wiring%20photos.html
http://www.pcbcart.com/pcb-fab/pcb-prototype.html

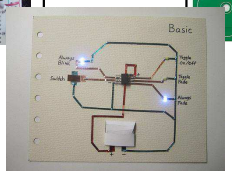
Paper circuits

Breadboard-based prototyping

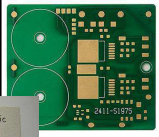


Paper circuits

- Moderate build time
- Moderate rework effort
- Moderate price
- Moderate scalability

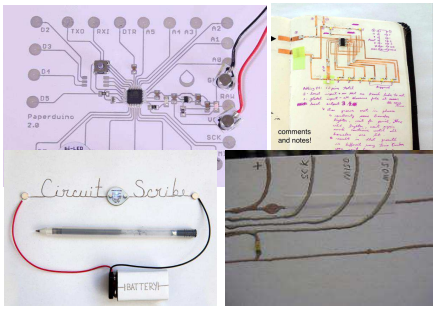


PCB-based prototyping



https://simonetti.media.mit.edu/~jieqi/2012/01/basic-microcontroller-example/

Paper circuits



http://www.instructables.com/id/Paperduino-20-with-Circuit-Scribe/ http://technologie.com/circuit_sketchbook/
https://www.kickstarter.com/projects/electroninks/circuit-scribe-draw-circuits-instantly
http://highlowtech.org/wiki/pmwiki.php?n=Main.PaperCircuits

Comparison

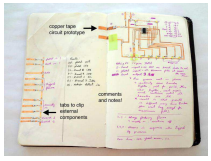
	Breadboard	Paper circuits	PCB
Build time	Minutes	Hours	Hours (soldering only)
Rework time	Seconds to Minutes	Minutes to Hours	Days (including time waiting for the new PCB)
Price	10$ for the board 2$ for wires	$3 for tape $10 for paint $20 for ink	Depend on layers of board Usually starts at $10
Scalability	Lowest, could be messy	Moderate, equivalent as single/double-layer PCB	Highest, machine manufactured, multi-layer available
Extras	Lots of resources immediately available in lab	Low-profile, flexible circuits achievable	Routing tool available, milling technique

Building paper circuits

- Conductive tape
- Conductive paint
- Conductive ink

Conductive tape

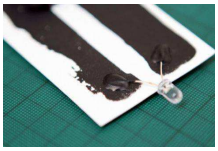
- Pro
  - No dry time
  - Solderable
  - Cheapest
- Con
  - Only straight line possible
  - Fixed trace width

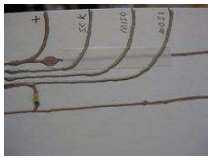


https://learn.sparkfun.com/tutorials/the-great-big-guide-to-paper-circuits/all#making-connections
http://technologie.com/circuit_sketchbook

Conductive paint

- Pro
  - Easy to draw smooth lines
  - Can used as cold solder joint to attach components to traces
  - Layer more paint on existing trace to easy fix connection
- Con
  - Not conductive until fully dry
  - Copper based paints could oxidize and lost conductivity
  - Could crack when under strain

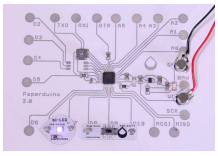




https://web.archive.org/web/20160103150217/http://www.bareconductive.com/make/how-to-cold-solder-with-bare-paint/
http://highlowtech.org/wiki/pmwiki.php?n=Main.PaperCircuits

Conductive ink

- Pro
  - Fast dry time
  - Precise lines
  - Machine drawing possible
- Con
  - Components attachment could be tricky
  - Higher price



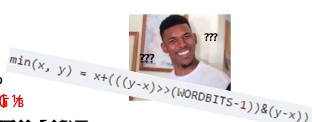
http://www.instructables.com/id/Paperduino-20-with-Circuit-Scribe

Q&A

References: https://learn.sparkfun.com/tutorials/the-great-big-guide-to-paper-circuits/all

https://en.wikipedia.org/wiki/Breadboard

http://eecs.umich.edu/courses/eecs373/lectures/lta.pdf


???
???
min(x, y) = x+(((y-x)>>(WORDBITS-1))&(y-x))


P The number of cycles required for a pipeline refill. This ranges from 1 to 3 depending on the alignment and width of the target instruction, and whether the processor manages to speculate the address early.

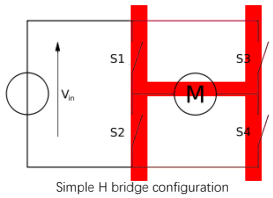
Branch	Conditional	B<cc> <label>	1 or 1 + P
	Unconditional	B <label>	1 + P
	With link	BL <label>	1 + P
	With exchange	BX Rm	1 + P
	With link and exchange	BLX Rm	1 + P
	Branch if zero	CBZ Rn, <label>	1 or 1 + P
	Branch if non-zero	CBNZ Rn, <label>	1 or 1 + P
	Byte table branch	TBB [Rn, Rm]	2 + P
	Halfword table branch	TBH [Rn, Rm, LSL#1]	2 + P

H Bridge DC Motor Driver

Yuan Yao
yaoyua@umich.edu

Working Principle

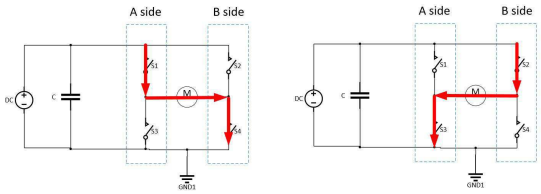
- A circuit that can control the direction and speed of a dc motor.



Simple H bridge configuration

Source: Wikipedia.org

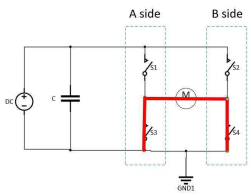
Operation: Rotate



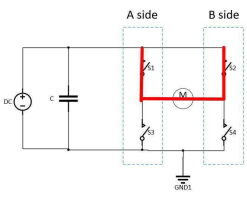
Rotate Right

Rotate Left

Operation: Brake

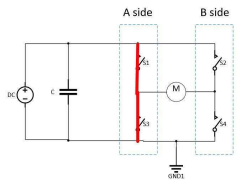


Brake Operation 1

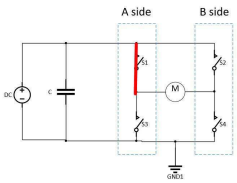


Brake Operation 2

Operation: Others

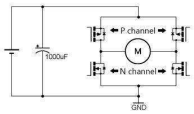


Short Circuit

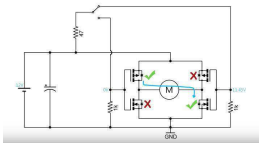


Motor Coast

Short Circuit Avoidance



Original Circuit

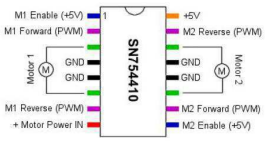


Protective Circuit

Source: youtube.com

Real H Bridge driver usage

- Common Component
  - SN754410
  - L293D



SN754410

source: hobbytronics

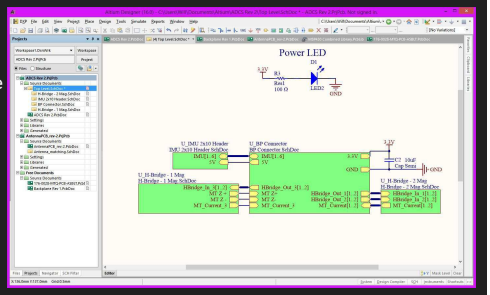
Reference

- https://en.wikipedia.org/wiki/H_bridge
- https://www.youtube.com/watch?v=iYafyPZ15g8
- http://www.hobbytronics.co.uk/h-bridge-driver-sn754410

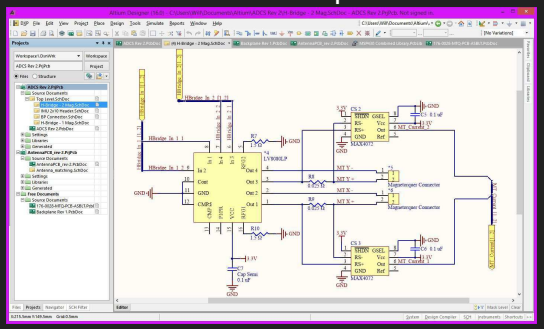
Q & A

Welcome to Altium

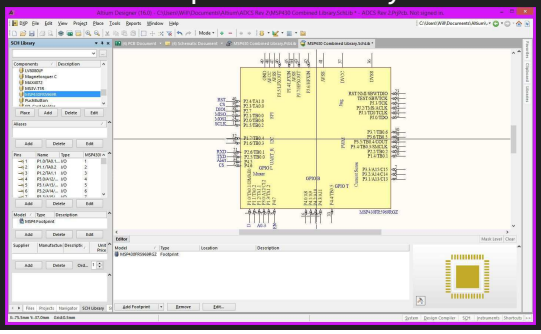
- Schematic capture
- PCB Design and Layout
- FPGA Design



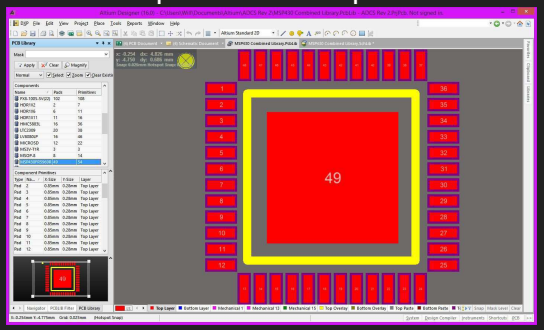
Schematic Capture



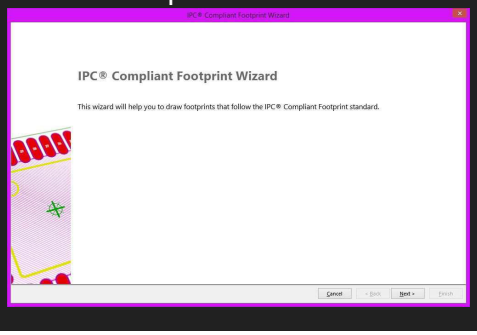
Component Entry



Component Footprint



Footprint Wizard



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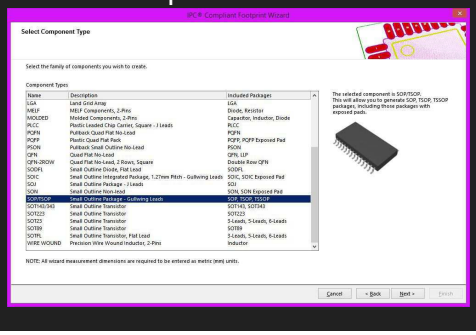

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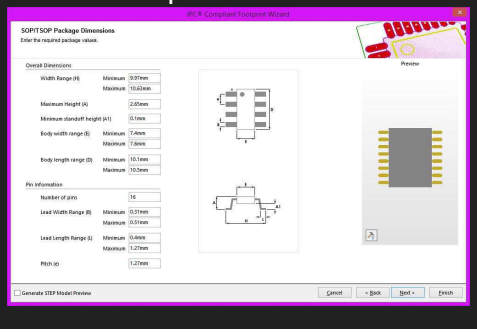

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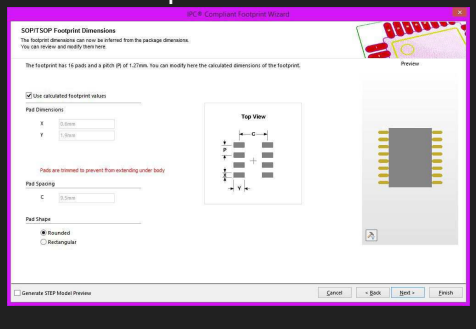

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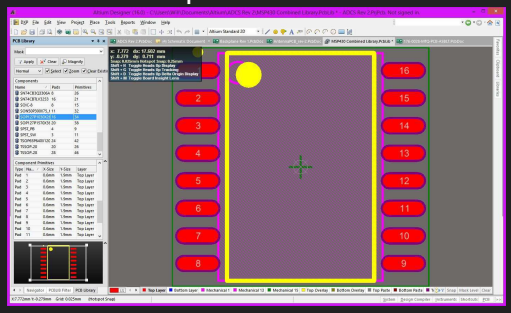
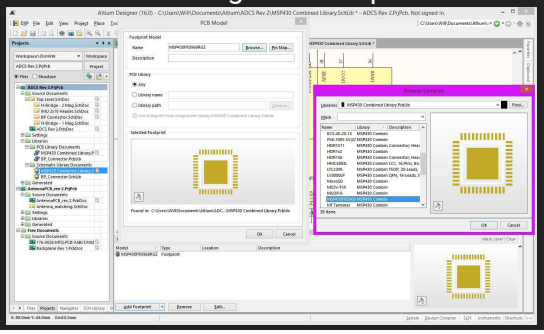
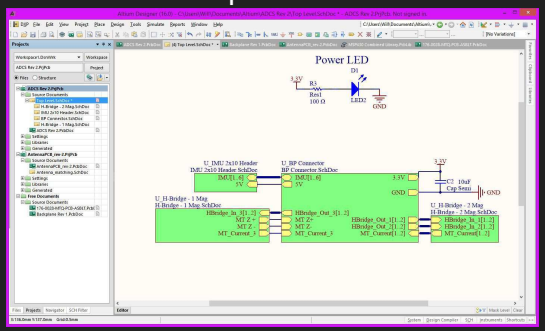


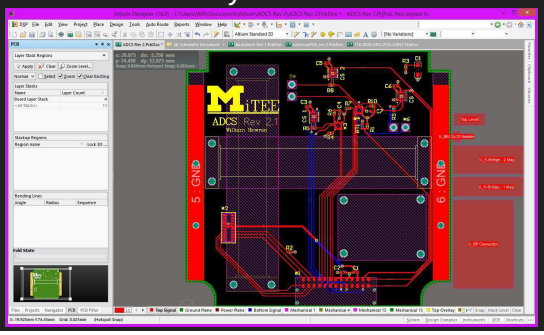
Attaching a Footprint



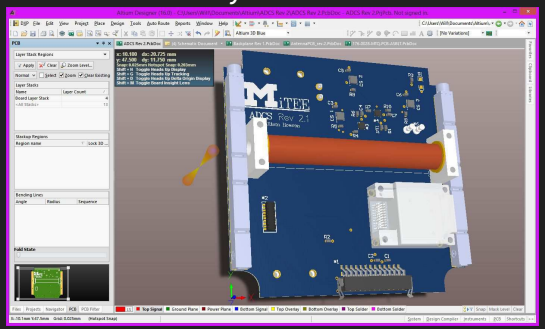
Top Level



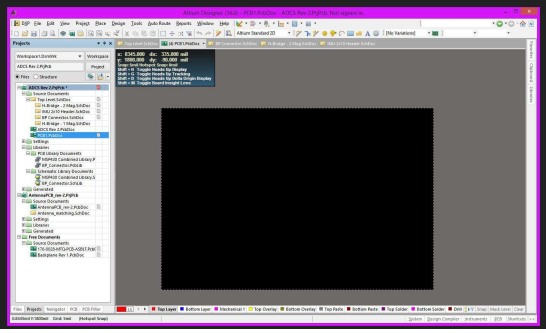
PCB Layout Editor



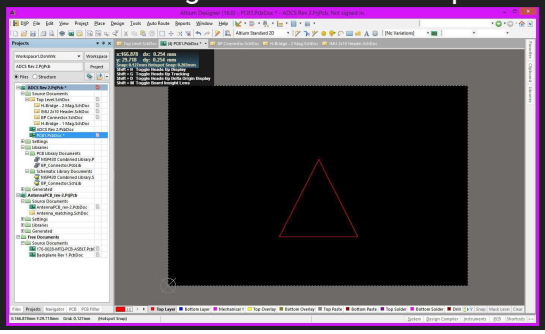
PCB Layout Editor



Blank PCB



Defining the Board Shape



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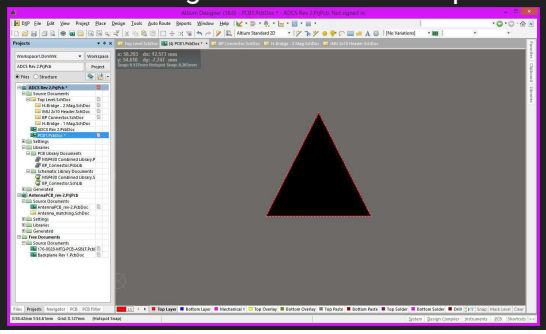

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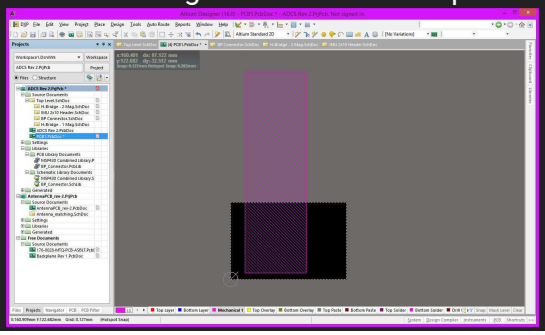

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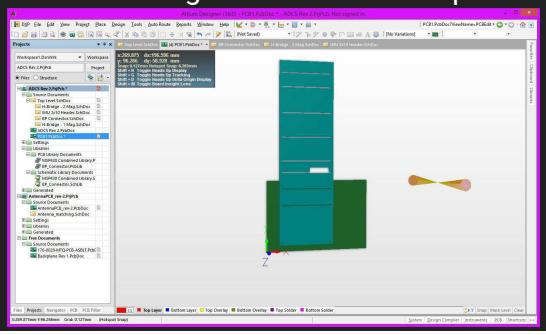

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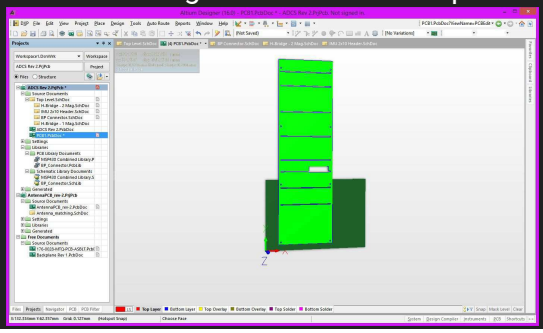

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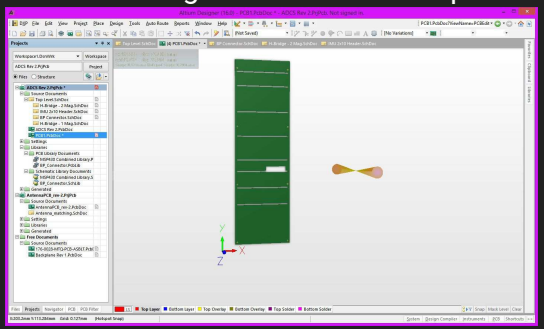
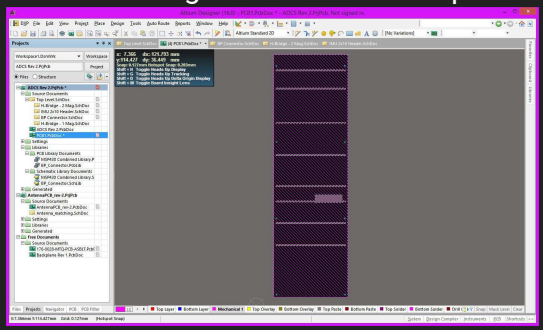
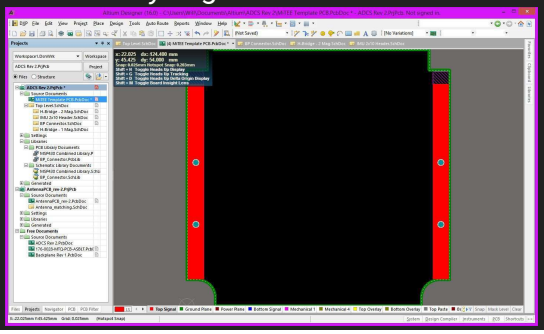


Defining the Board Shape



Laying Out the PCB



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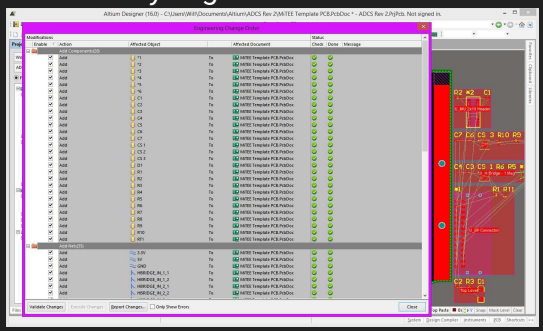
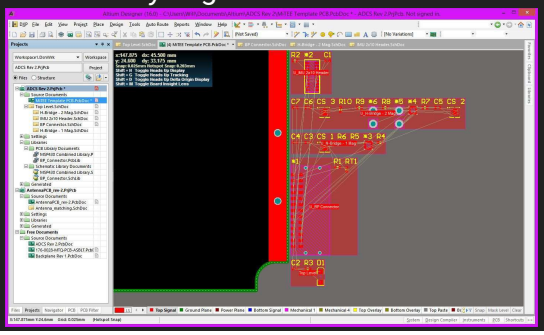
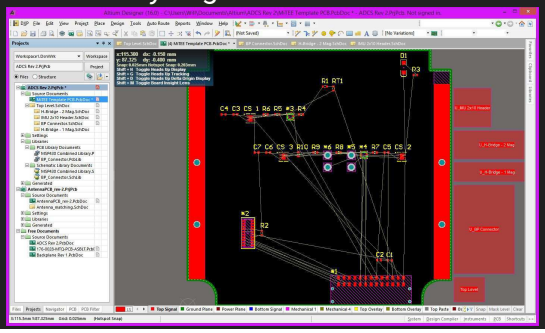


Laying Out the PCB



Laying Out the PCB



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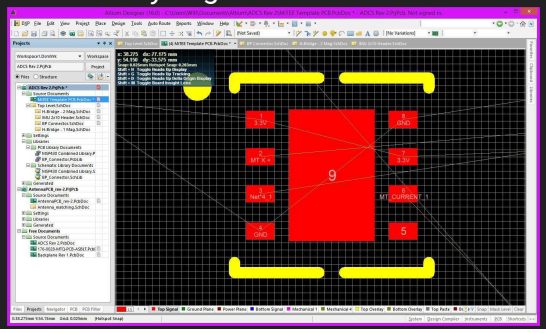
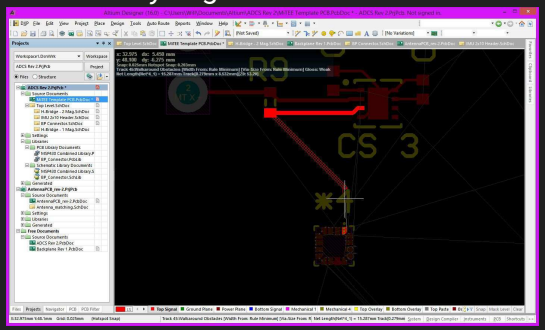


Laying Out the PCB



Final Thoughts

- Quirky
- Expensive
- Powerful

Dealing with brushed DC Motor noise

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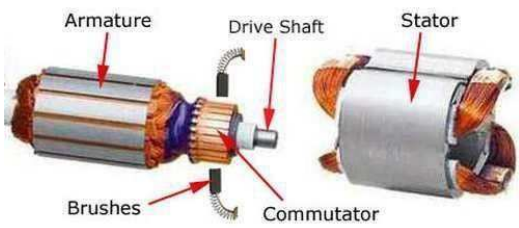
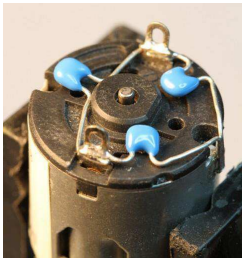
Source of the noise



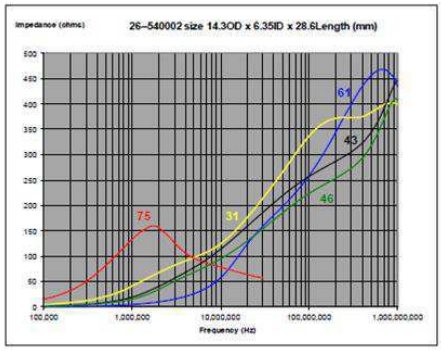
Adding capacitors

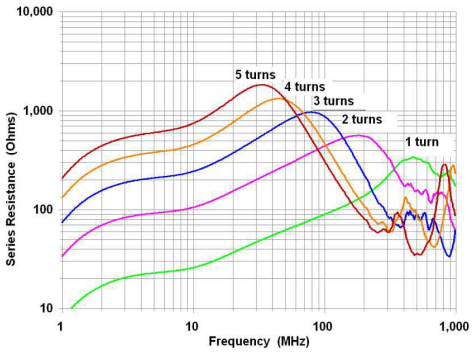
- Between positive and negative terminal and between each terminal and motor casing
- Generally recommended value of 0.1uF
- Acts as a short at high frequencies



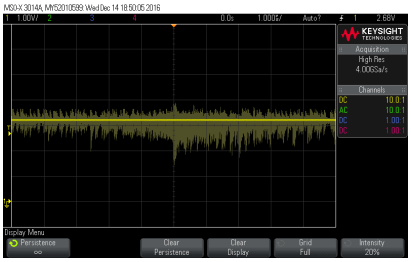
What if capacitors don't work?

- Adding a ferrite choke acts as a resistor at high frequencies
- Many types of ferrite with different frequency response
- Easy to add to existing motors

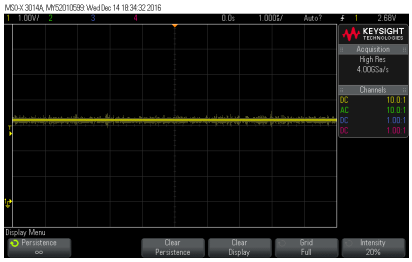




Brushed DC motor no ferrite choke



Brushed DC motor with ferrite choke



Questions?