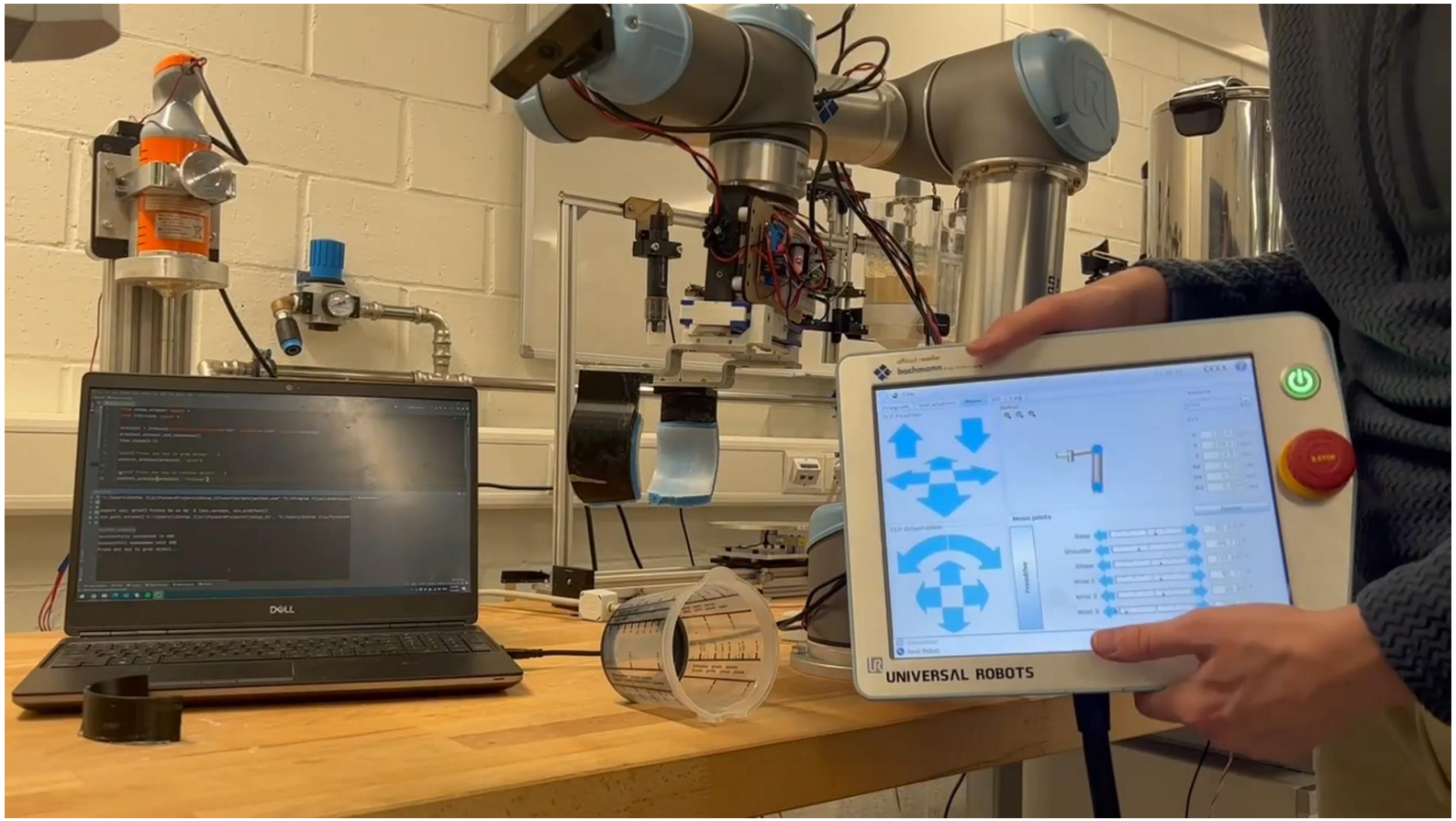
Product development & engineering design

ME-320

PROF. JOSIE HUGHES

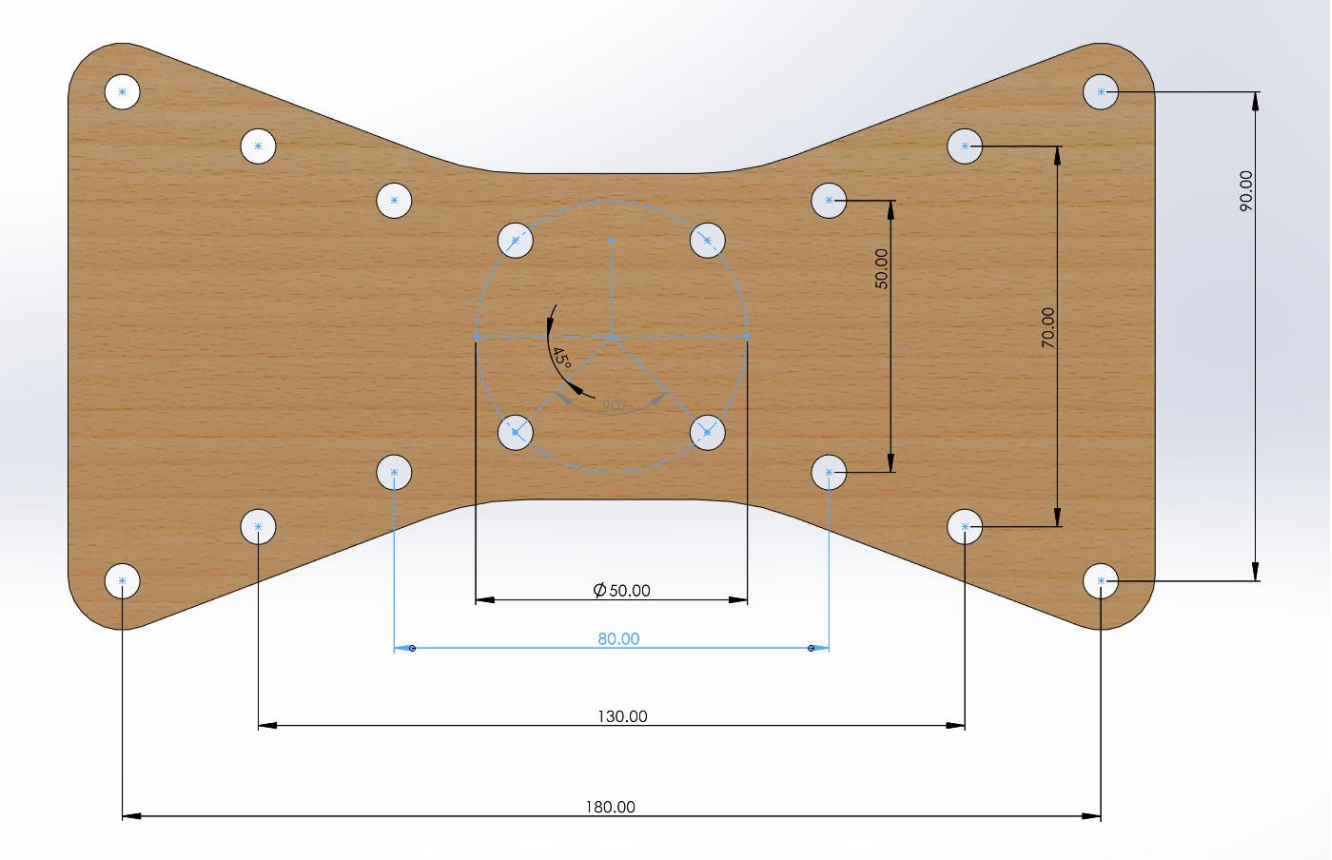
Lecture 9: CAD & Electrical Drawings

Video: Demonstration of the control process



Using the touch pad to control the robot

Attachment/mounting point



This is attached to the robot arm. You must attach to this mounting point.

6mm bolts will be given!

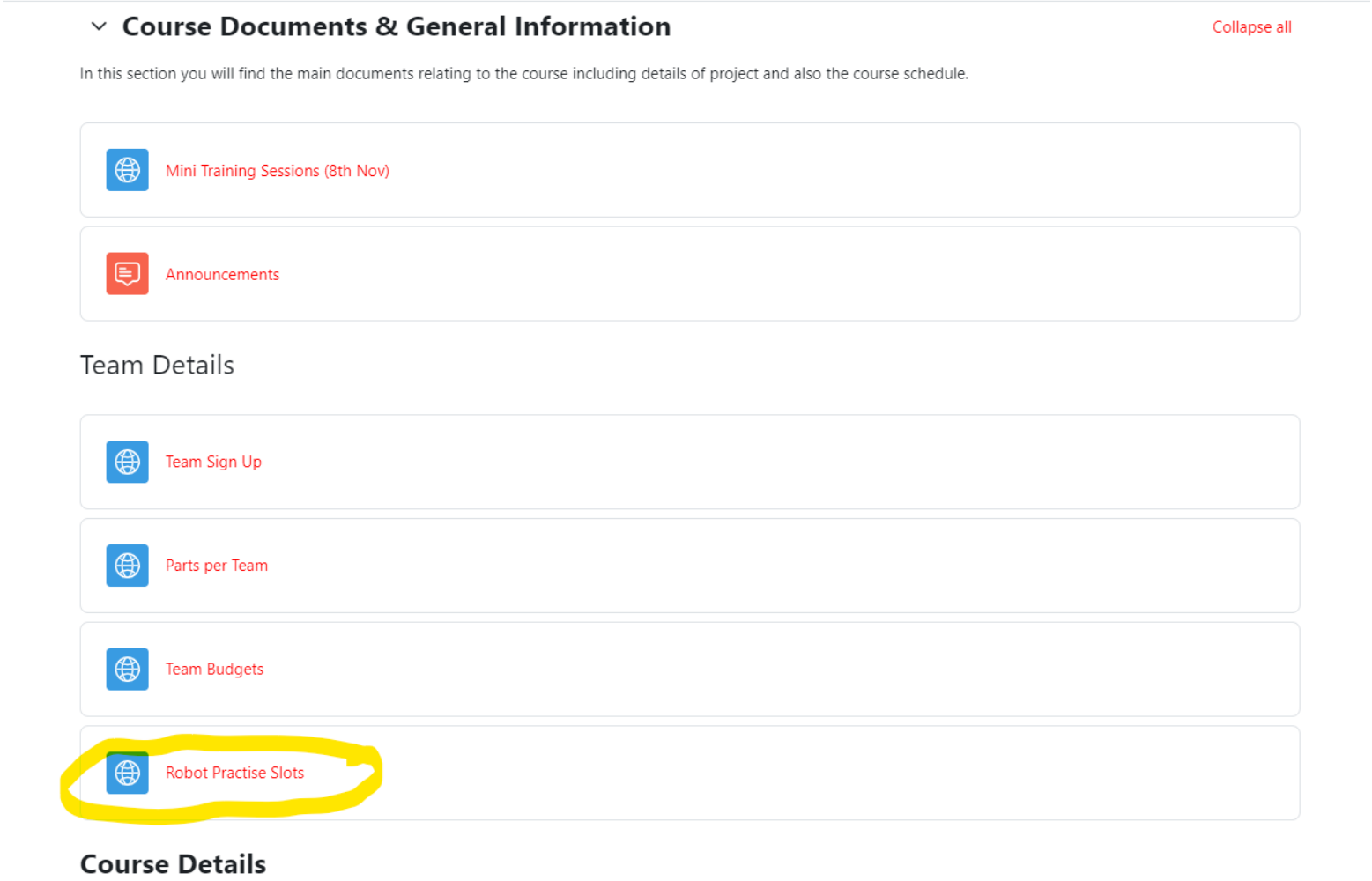
A longer USB cable will be provided!

Final Demonstration/Competition Dates

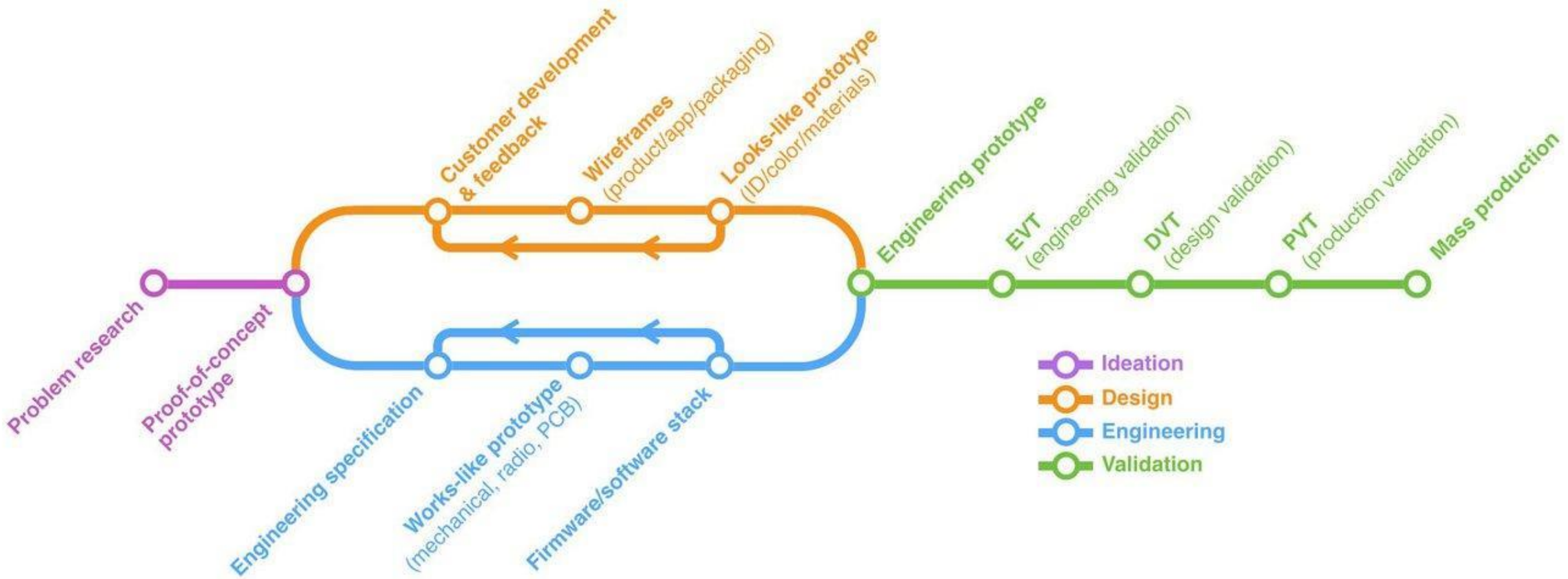
Robot Testing: Bookable slots for testing with the robot will be available from the 6th December. These will be in the CREATE Lab.

Wednesday 13th December: Testing in the SPOT (plus any teams that want to go early).

Wednesday 20th December: Competition. Starts at 8am! Two teams in parallel!



Prototyping Tools for Different Prototype Stages



Prototyping Tools for Different Prototype Stages

Proof-of-Concept (PoC) Prototype

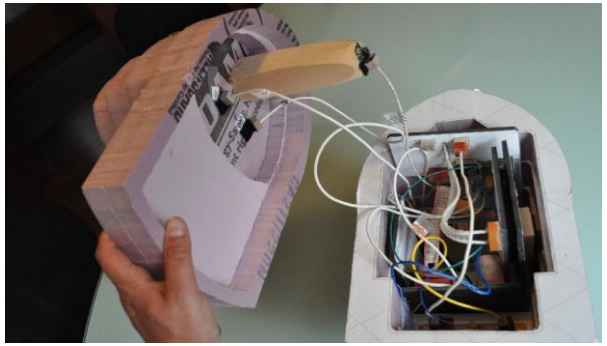
- Fast to create
- Validates the concept
- Limited functionality
- 3D print/basic model making

Looks Like Prototype

- No functionality
- Visually correct
- Good for testing with consumers
- 3D print/model make

Works like prototype

- Shows engineering concepts
- May not be visually correct
- May be modularized
- 3D print/model making



Engineering Prototype

- As close as possible to the final design & manufacturing method

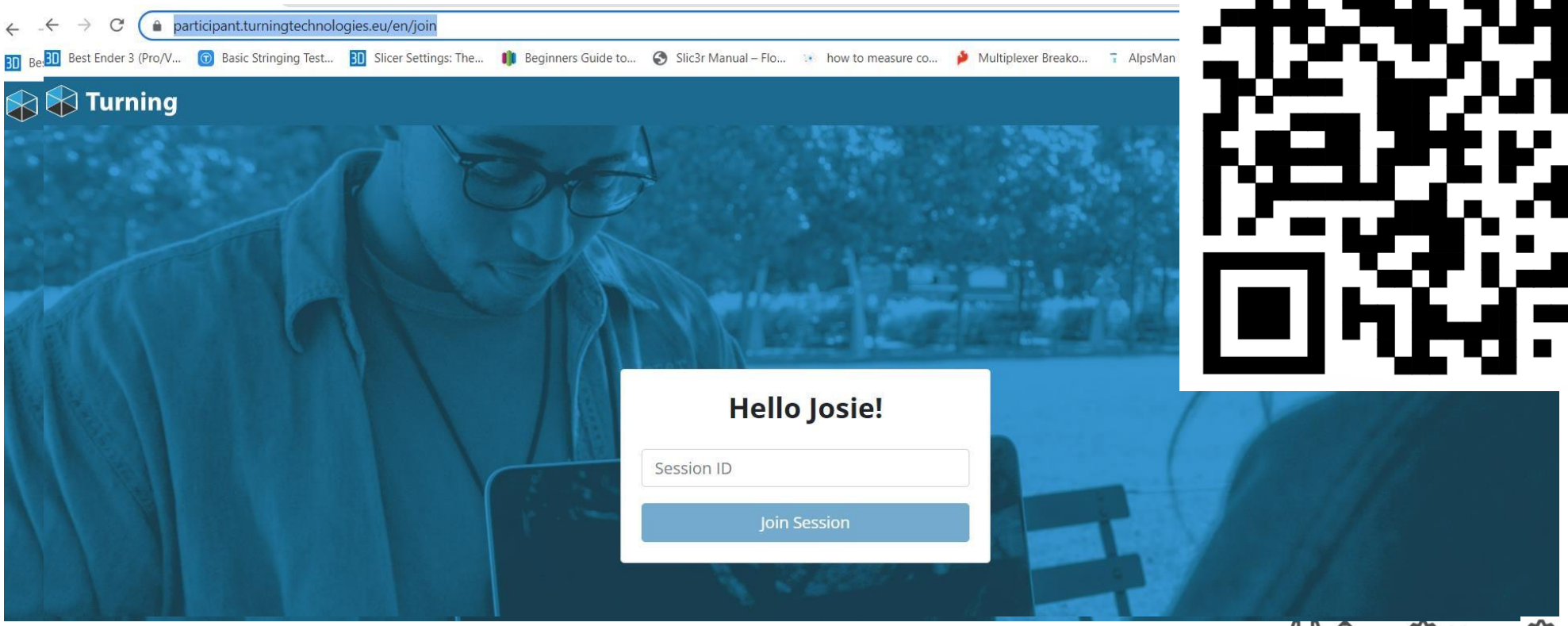
Prototyping Quiz

https://participant.turningtechnologies.eu/en/join

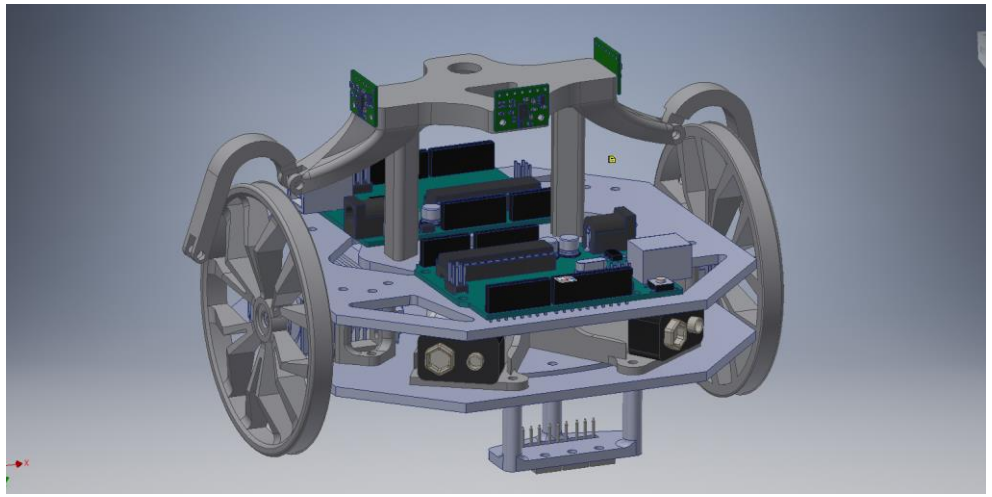
https://participant.turningtechnologies.eu

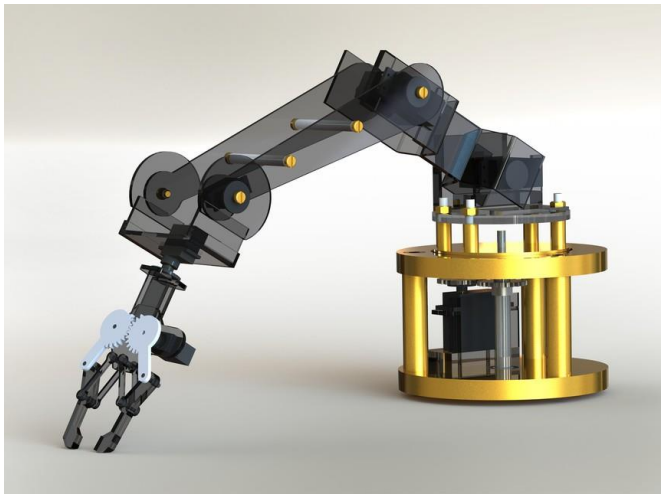
SessionID: datadriven

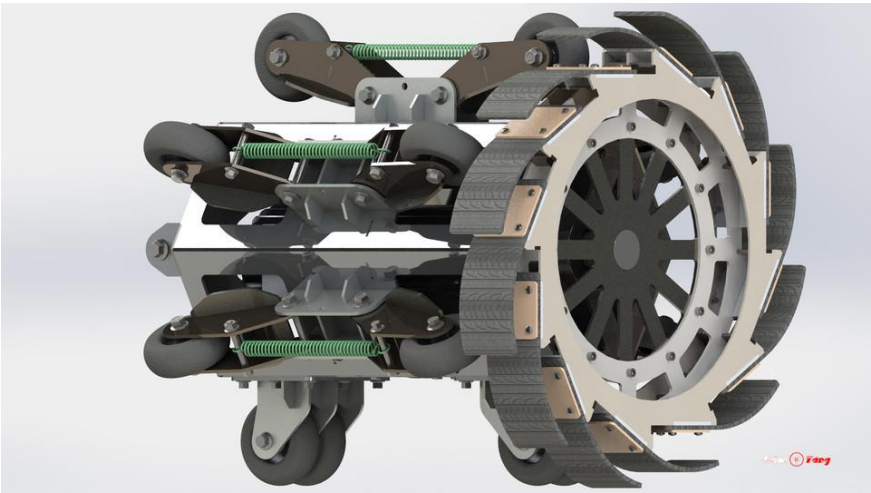
https://ttpoll.eu/p/datadriven



How do we communicate design?



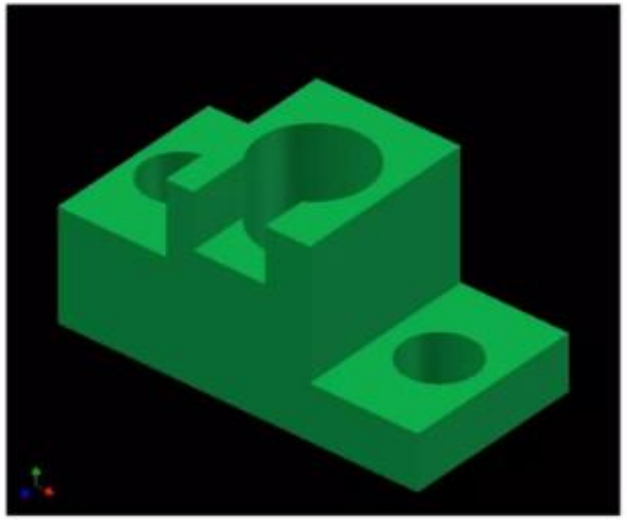




Engineering Drawings

1. Try to write a *description* of this object.
2. Test your written description by having someone attempt to *make a sketch* or *visualize* from your description.

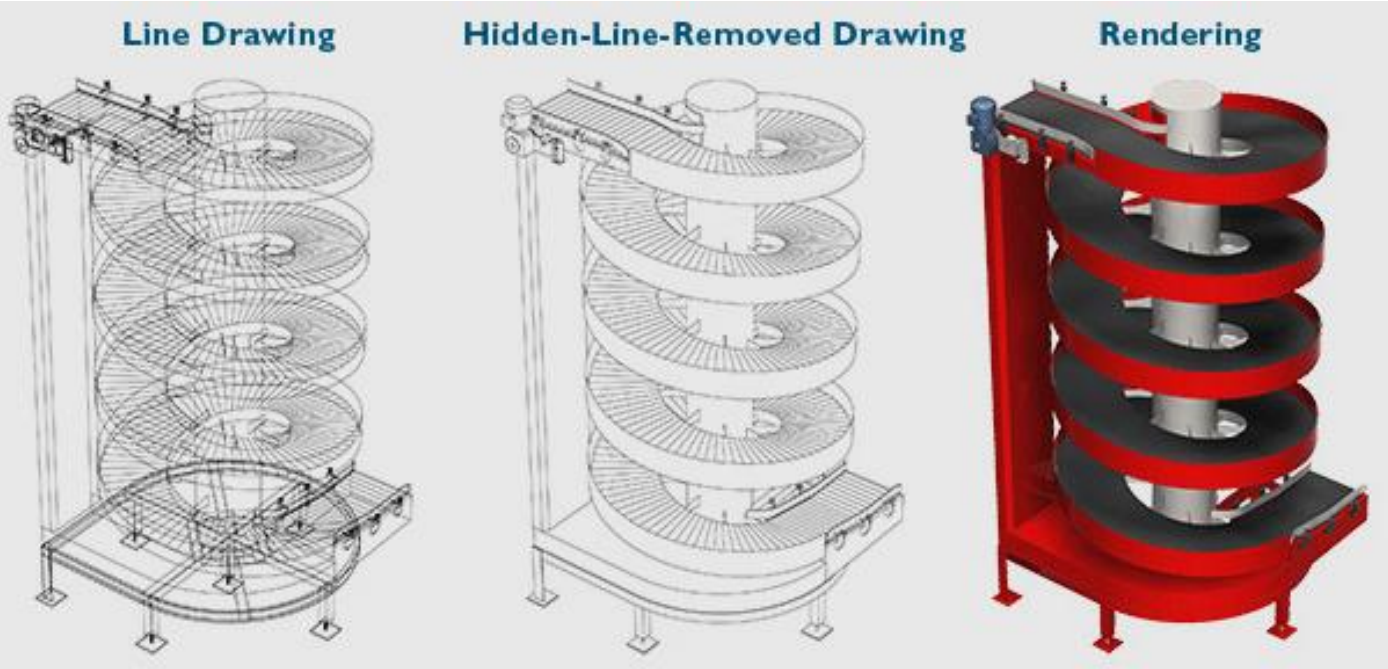
You can easily understand that …



Language is inadequate for describing the size, shape and features completely and concisely….

We need graphics and drawings for communication

Rendering

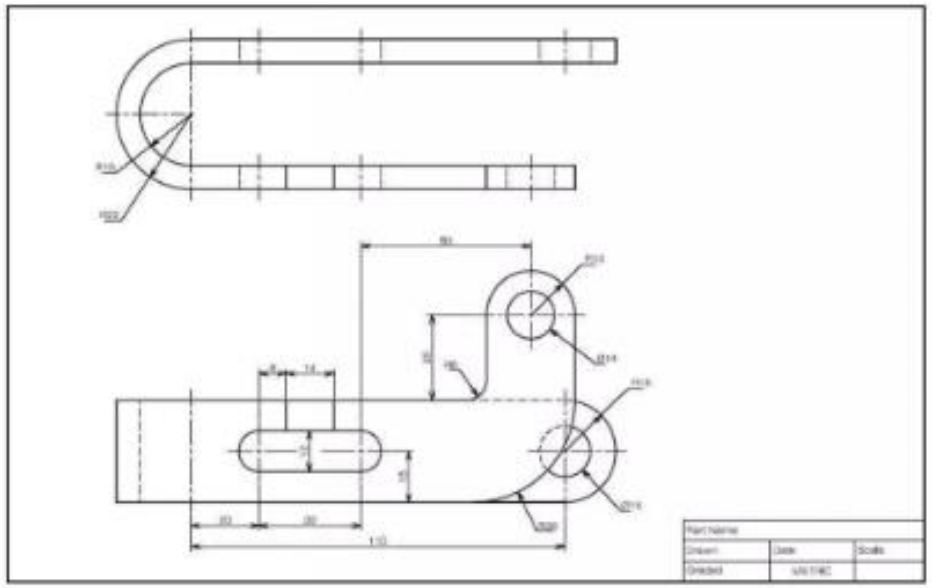


- Specify material properties
- Specify colours
- Specify lighting

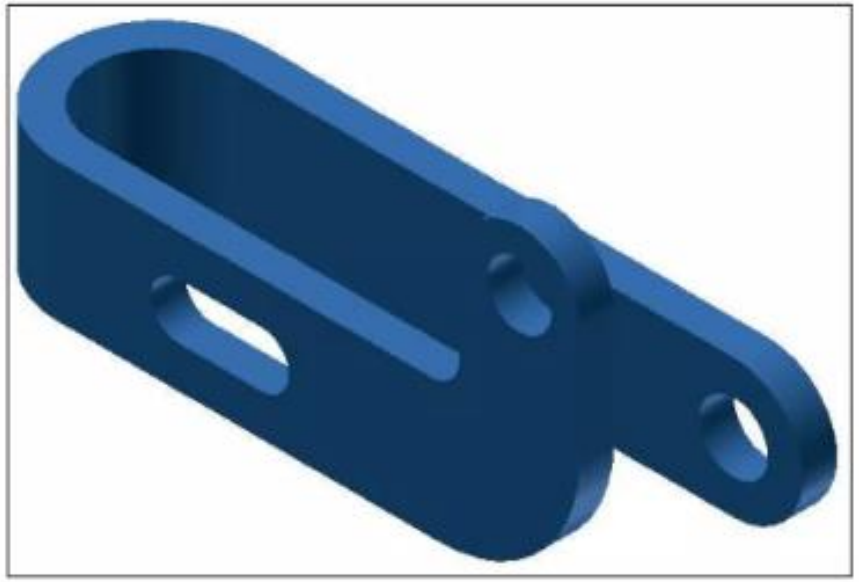
Use for visualization and optimization of the **industrial design**.

However, challenging to communicate all the functioning, design and means of fabrication

Engineering Drawings



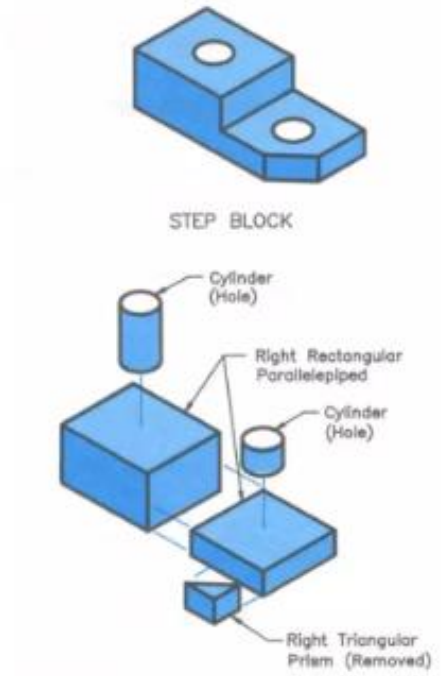
2D drawing



Solid modeling

Purpose of Engineering Drawings

1. An engineering drawing is not an illustration.
2. It is a specification of the size and shape of a part or assembly.
3. The important information on a drawing is the dimension and tolerance of all of its features.



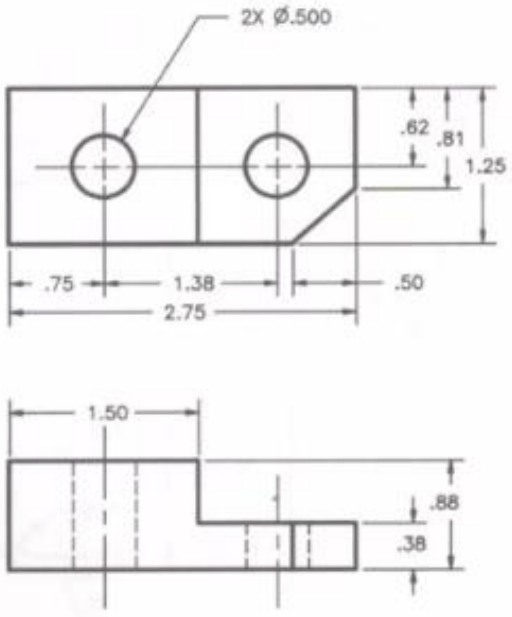
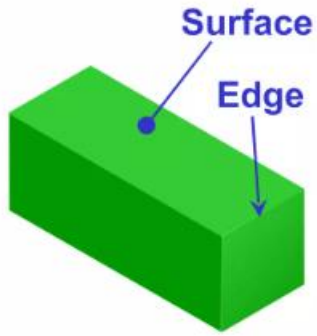


Figure 3-23. Mentally breaking a part into the geometric shapes that form the part is one method for determining the dimensions needed on a drawing.

The graphical language of engineering drawing

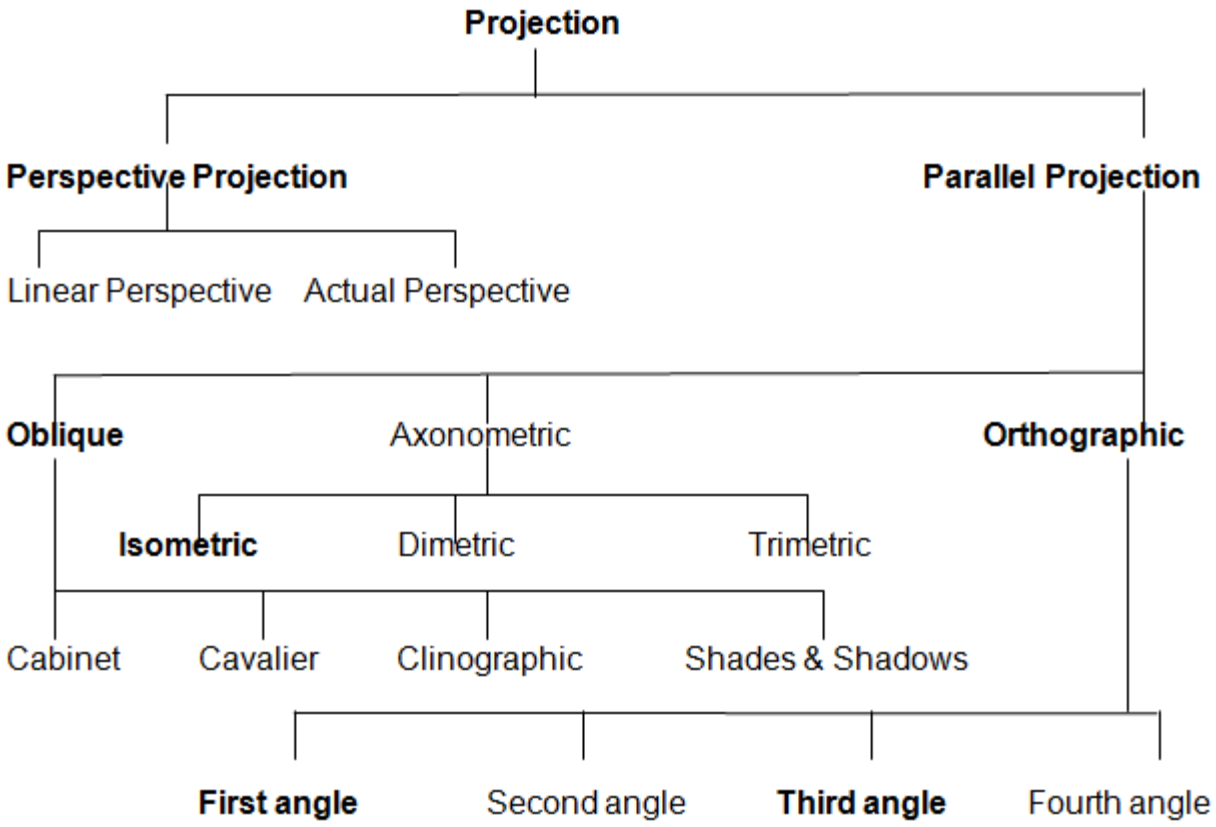
- **"Engineering drawing"** or **"blueprint"** uses ***lines*** to represent the ***features*** of an object.
- Features of an object are ***surface*** (include ***plane***) and ***edge***.



A drawing can be created in 3 ways

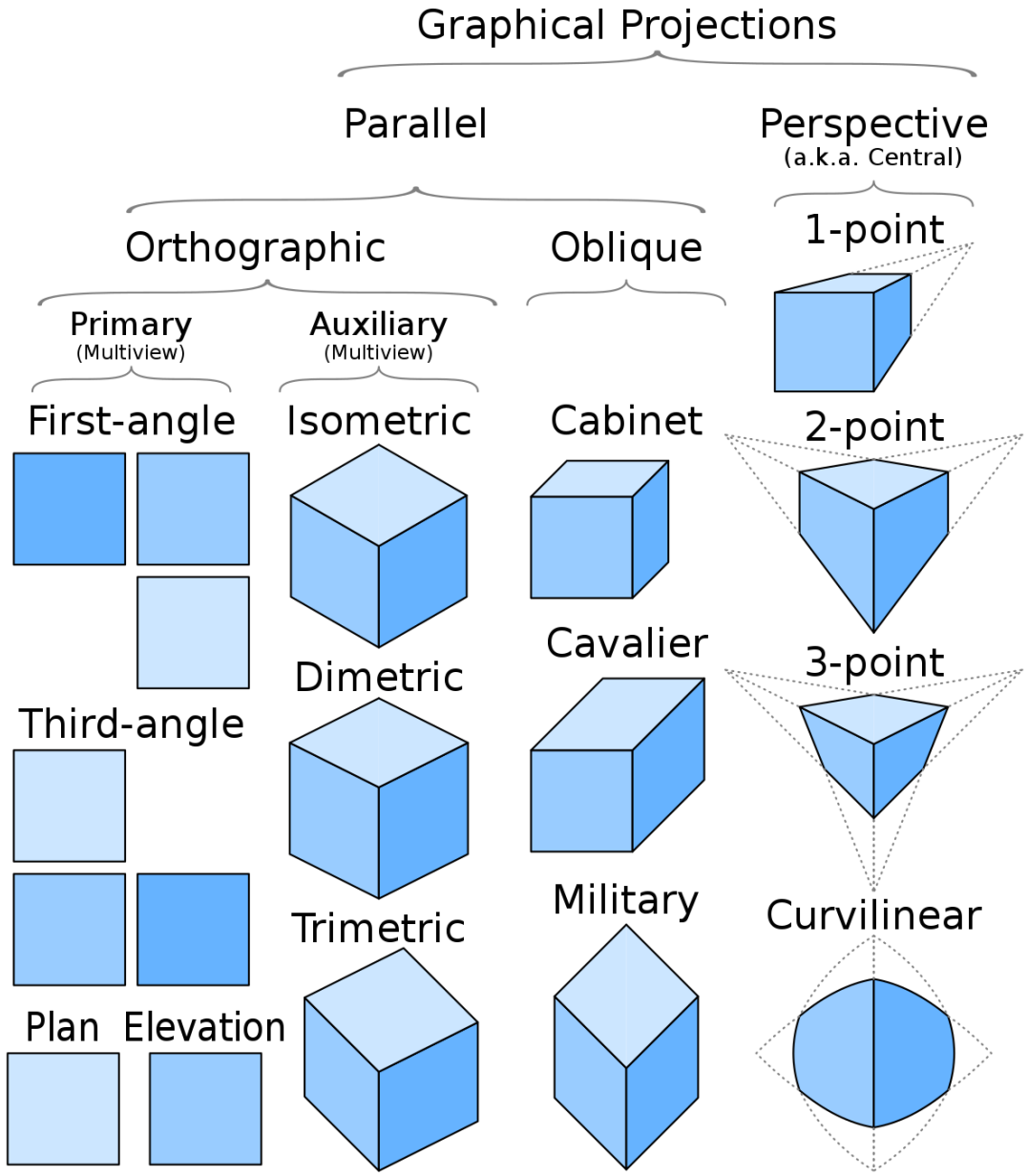
1. Freehand sketch
2. Using typical drawing instruments
3. Using a computer

Engineering Drawings



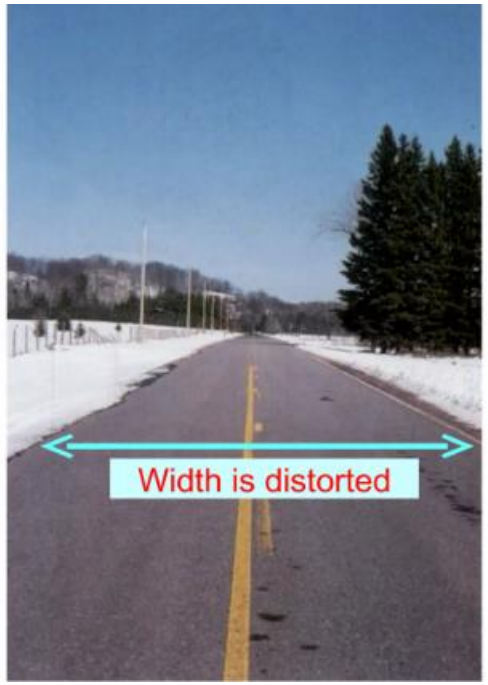
Many different drawing types

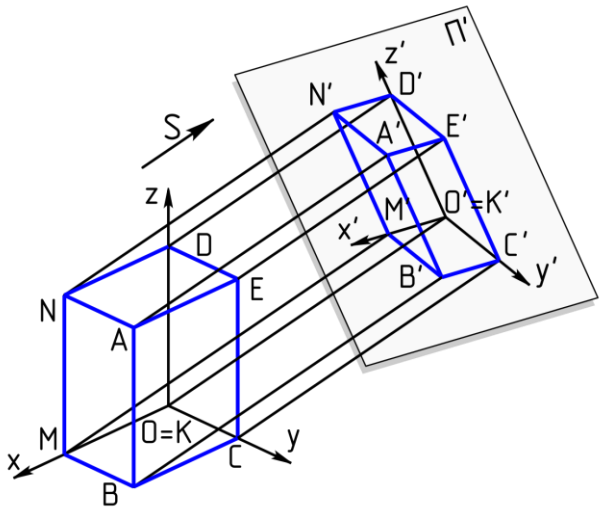
Use different **projections**



- Perspective projection is ***not*** used by engineer for manufacturing of parts, because

1) It is difficult to create.
2) It does not reveal exact shape and size.





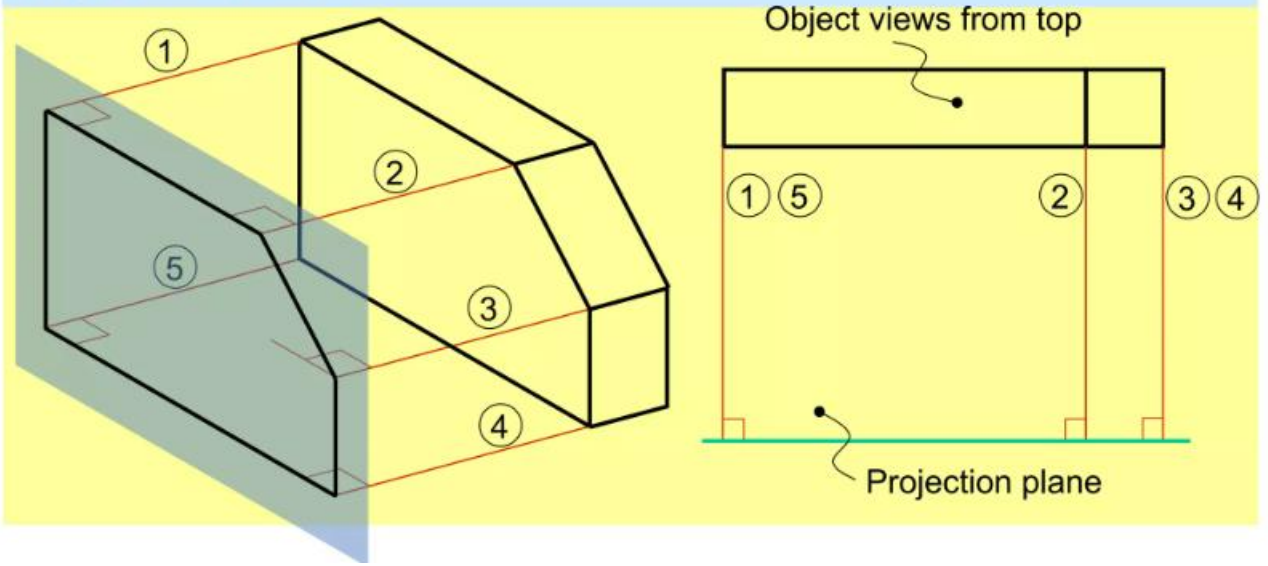
Parallel Projections

- No distortion
- Easier to communicate shape/size
- Doesn't always communicate global form

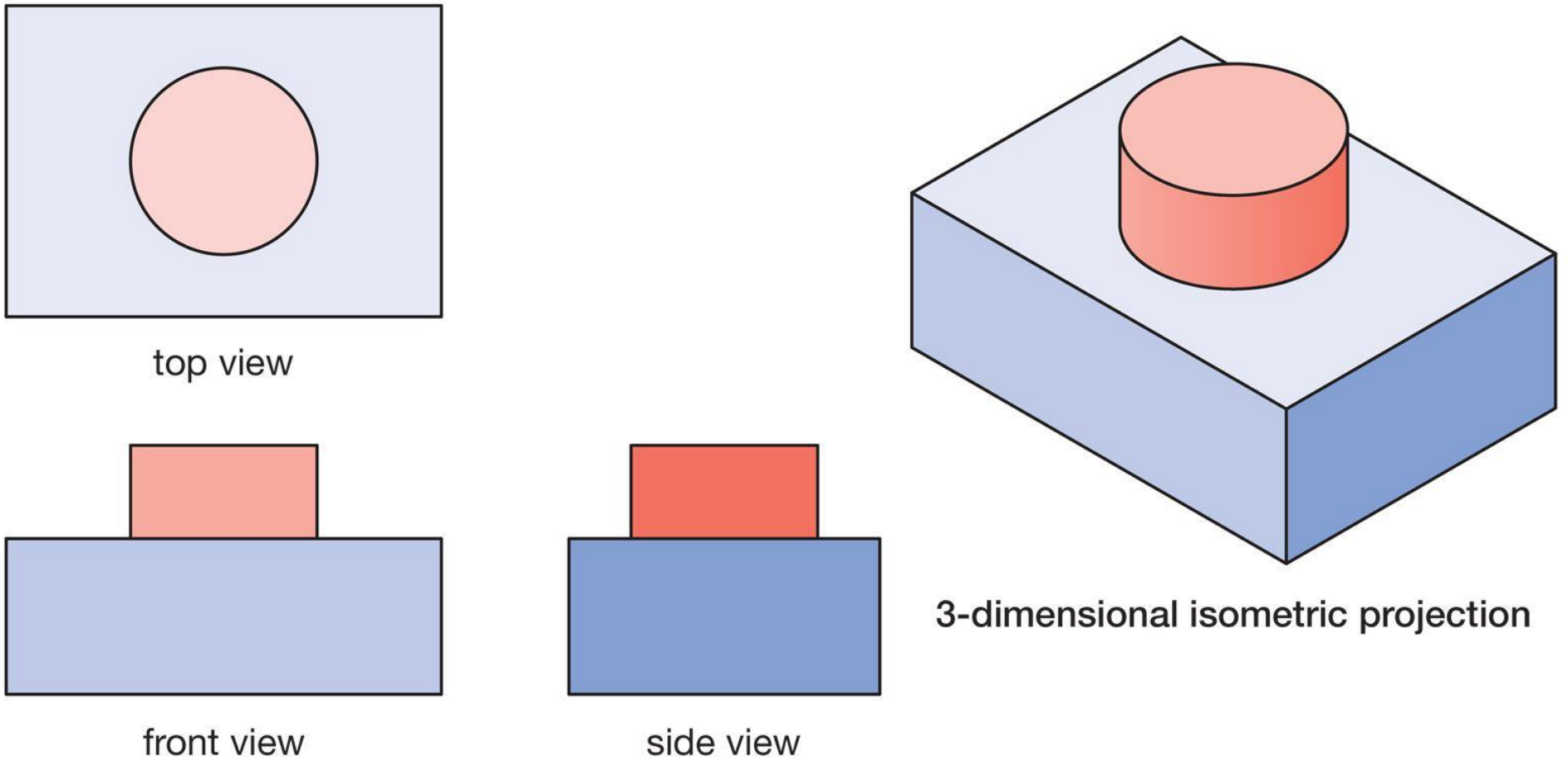
Orthographic Projection

- Orthographic" comes from the Greek word for "straight writing (or drawing)." This projection shows the object as it looks from the front, right, left, top, bottom, or back, and are typically positioned relative to each other according to the rules of either “First Angle” or “Third Angle” projection.

Orthographic projection is a parallel projection technique in which the parallel lines of sight are ***perpendicular*** to the projection plane



Orthographic and isometric projections of an object



First View

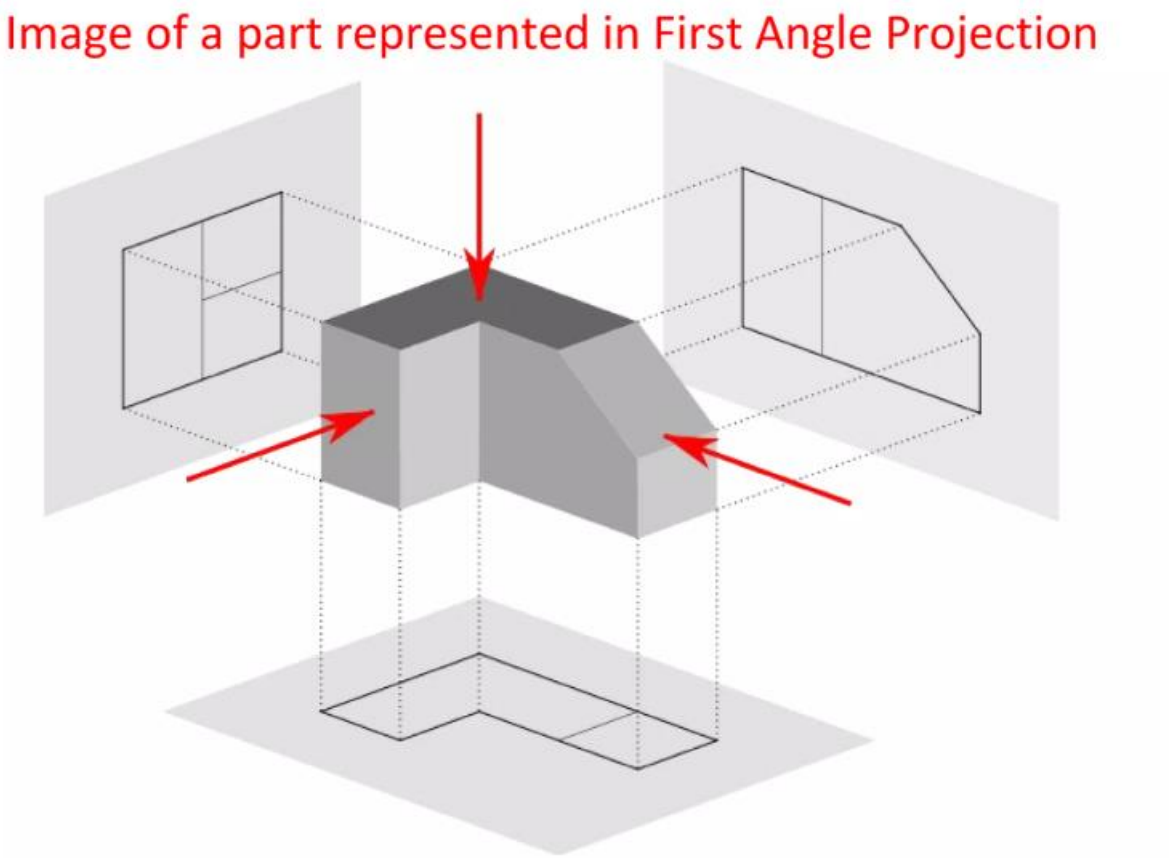
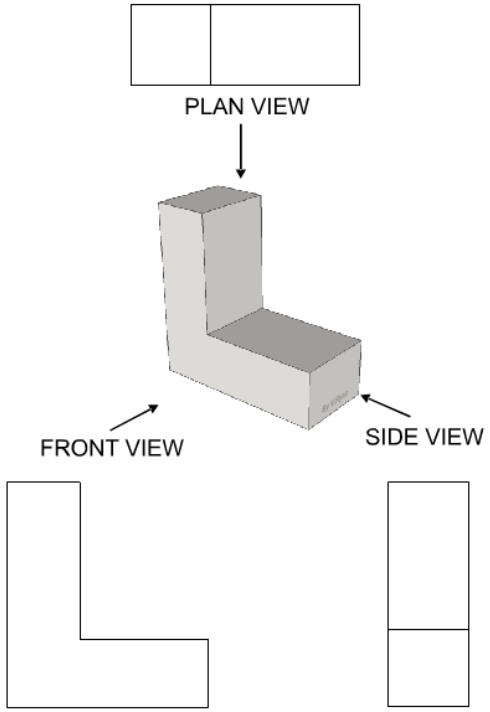
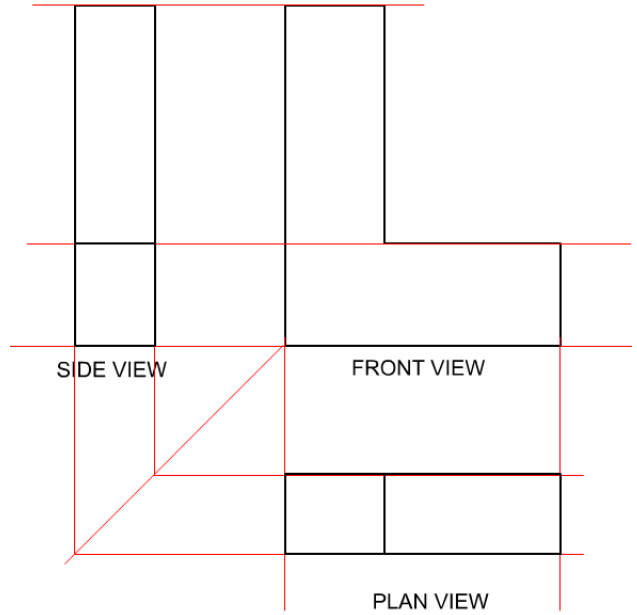


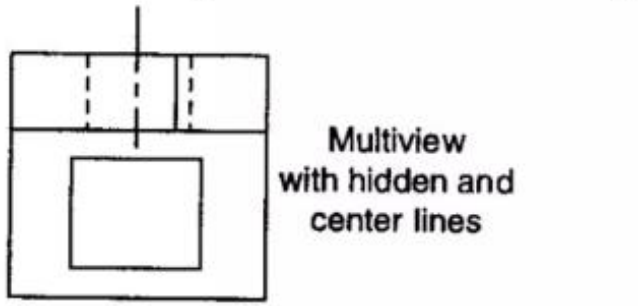
Image of a part represented in First Angle Projection


PLAN VIEW
FRONT VIEW
SIDE VIEW

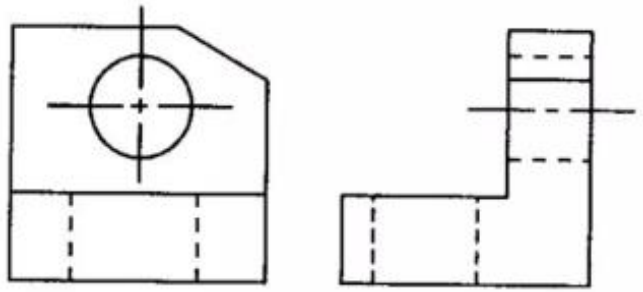

SIDE VIEW
FRONT VIEW
PLAN VIEW

Combined View: Orthographic/Multiview

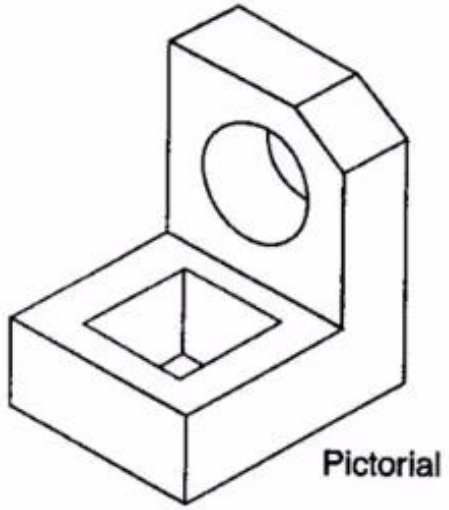
- Draw object from two / three perpendicular views



Multiview with hidden and center lines



Multiview drawing. / Orthographic



Pictorial

What it looks like pictorially

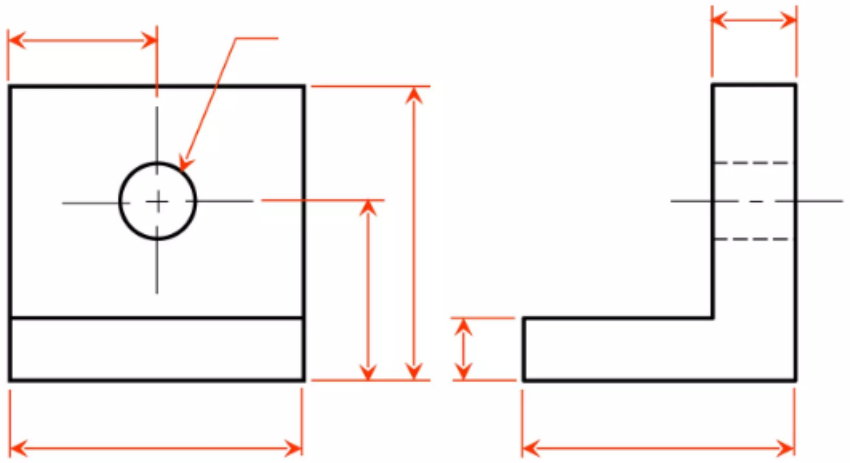
Combined View: Orthographic/Multiview

Multiview Drawing

Advantage It represents accurate **shape and size.**

Disadvantage Require practice in writing and reading.

Example Multiviews drawing (2-view drawing)

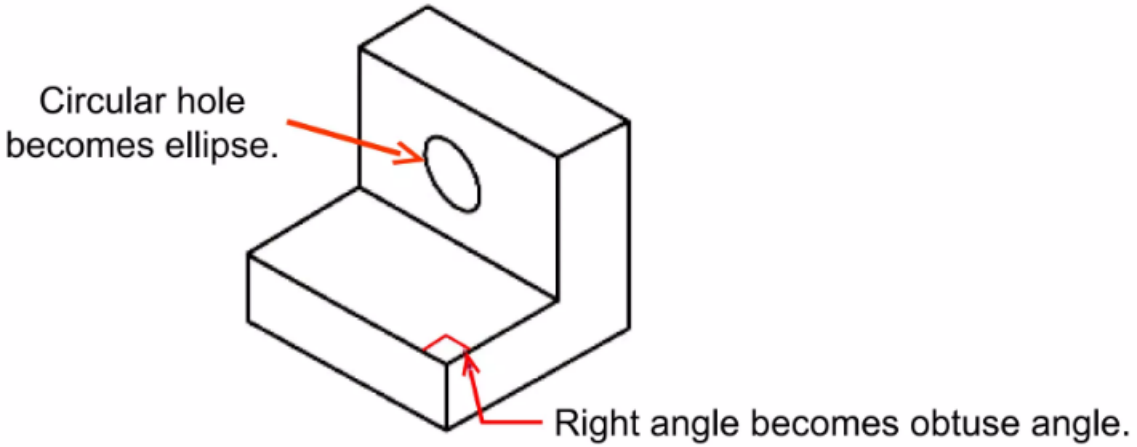


Axonometric (Isometric) Drawing

Advantage Easy to understand

Disadvantage Shape and angle distortion

Example Distortions of shape and size in isometric drawing



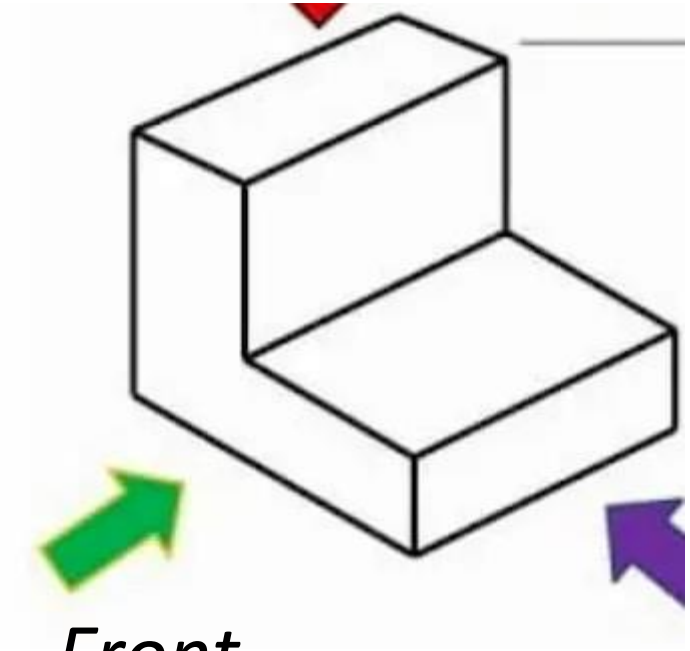
First View Drawing!

Draw the first view projections

Side

Front

Plan/Top



Front

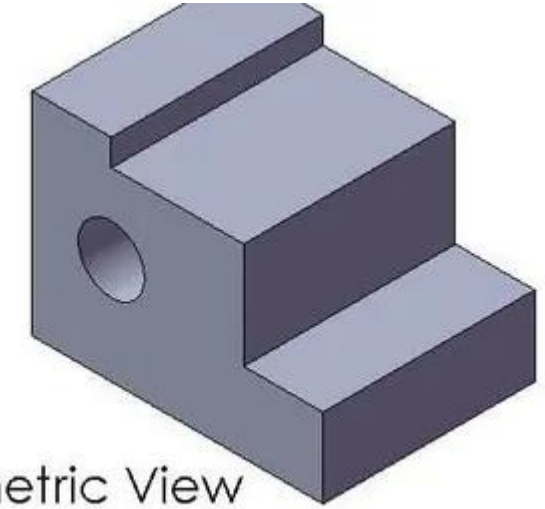
First View Drawing!

Draw the first view projections

Side

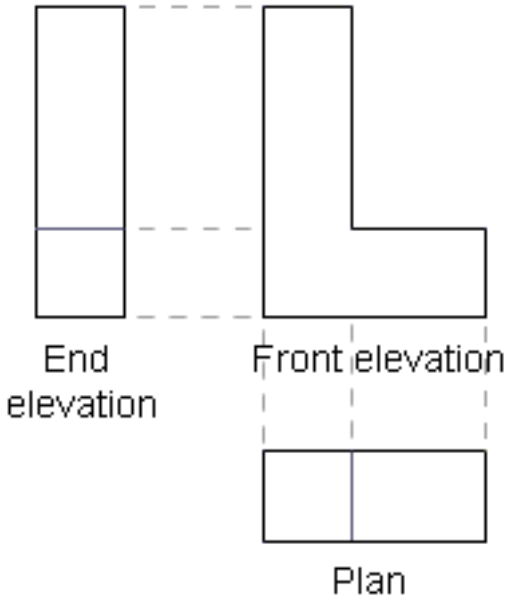
Front

Plan/Top

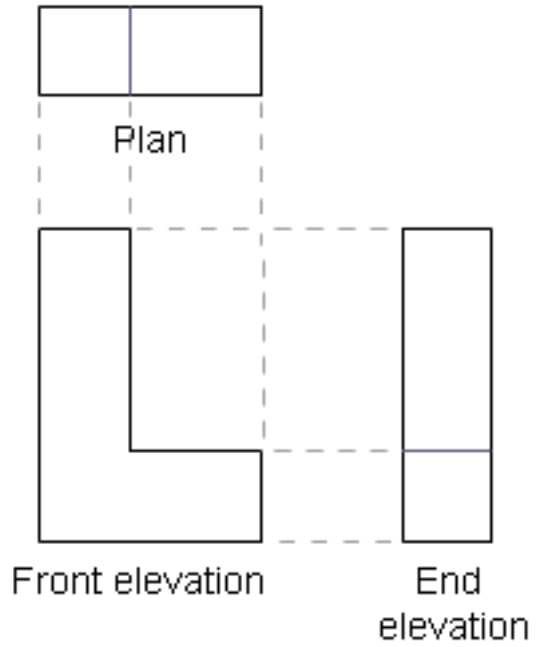


Isometric View

First Angle vs. Third Angle



First Angle Projection



Third Angle Projection

Elements of Engineering Drawings

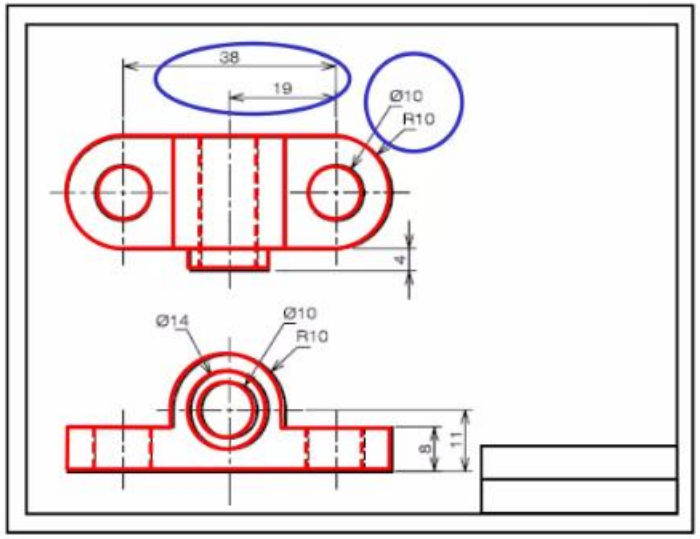
A clear and precise engineering drawing requires both ***graphics*** and ***word*** languages.

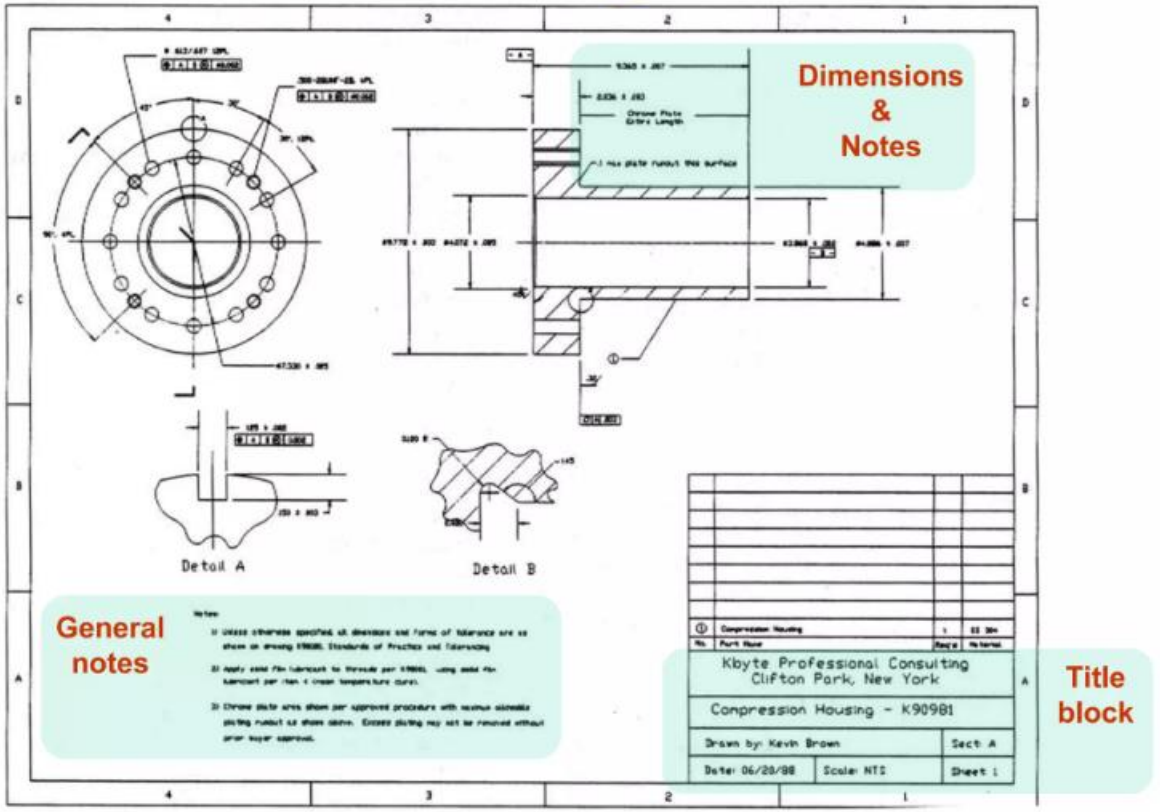
Graphics language

Describe a shape (mainly).

Word language

Describe an exact size, location and specification of the object.





Drawings: Fundamentals

Basic Line Types & Name according to application

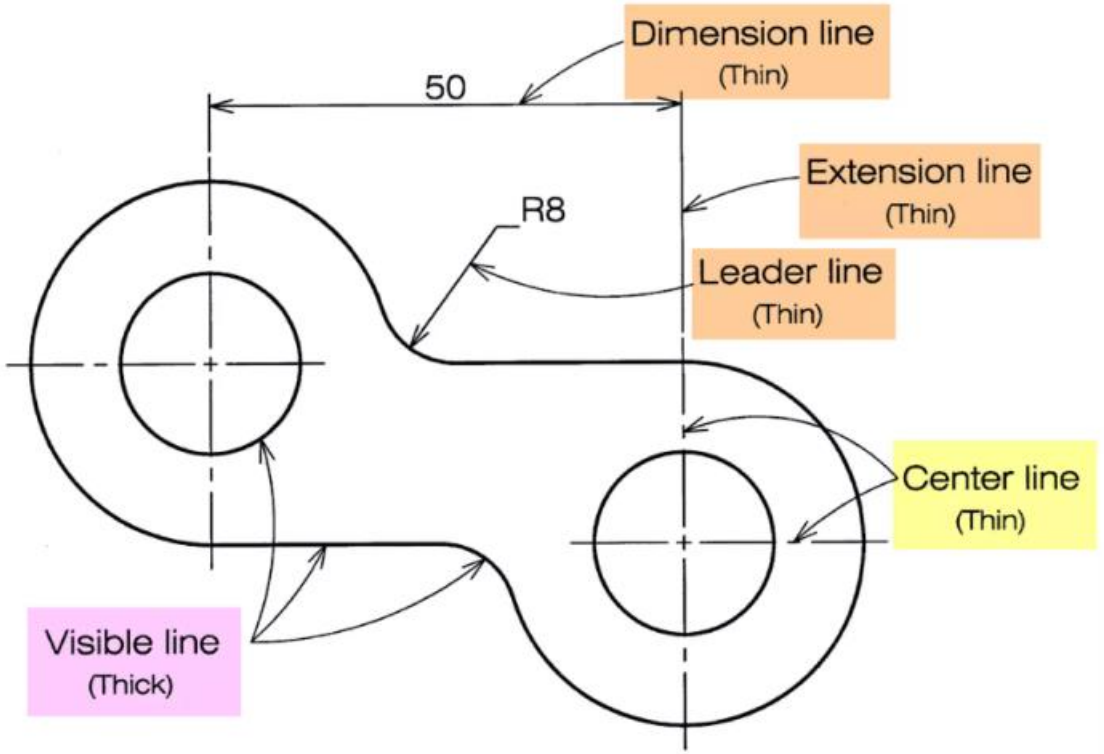
Style \ Thickness	Thick	Thin
Continuous	Visible line	1. Dimension line 2. Extension line 3. Leader line
Dash		Hidden line
Chain		Center line

1. Visible line represent features that can be seen in the current view.

2. Dimension line
Extension line
Leader line indicate the sizes and location of features.

3. Hidden line represent features that can not be seen in the current view.

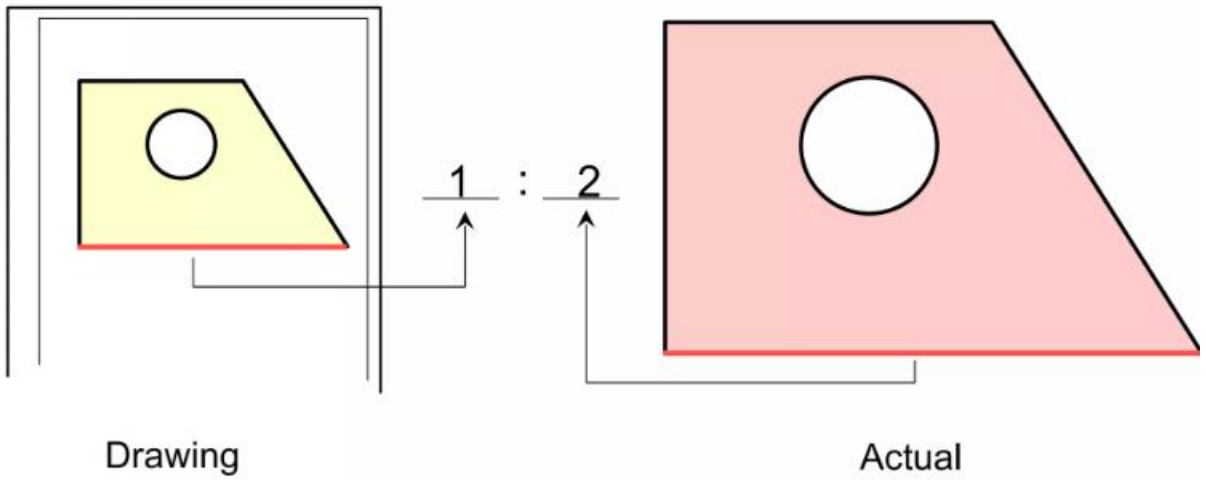
4. Center line represents symmetry, path of motion, centers of circles, axis of axisymmetrical parts



Drawings: Fundamentals

Length, size

- **Scale** is a ratio between the linear dimension of a drawn representation of an object and the actual object.



- Designation of a scale consists of the word "SCALE" followed by the indication of its ratio, as follows

  SCALE 1:1 for full size
  SCALE **X**:1 (X > 1) for an ***enlargement*** scales
  SCALE 1:**X** (X > 1) for a ***reduction*** scales

- Drawing scale is commonly found in a title block.

- ***Dimension numbers*** shown in the drawing represent the "true size" of an object and they are independent of the drawing scale used.

Drawings: Fundamentals

Dimensioning Guidelines

The term “feature” refers to surfaces, faces, holes, slots, corners, bends, arcs and fillets that add up to form an engineering part.

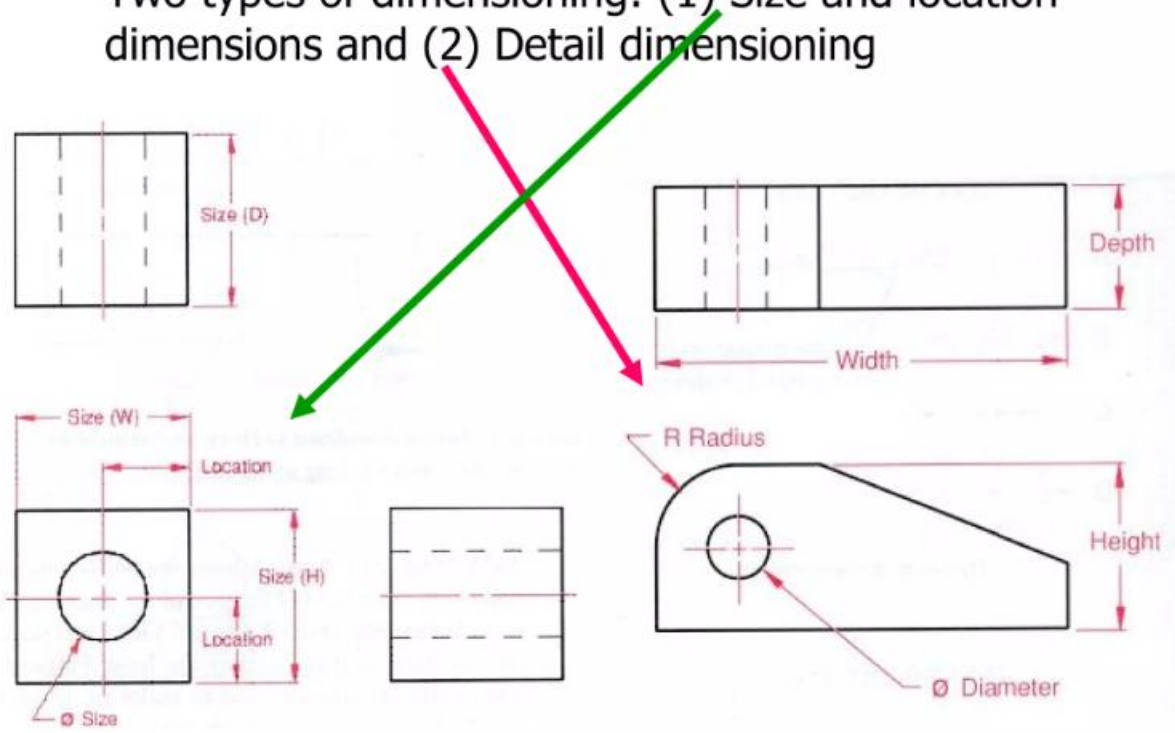
Dimensions define the **size** of a feature or its **location** relative to other features or a frame of reference, called a datum.

The basic rules of dimensioning are:

1. Dimension where the feature contour is shown;
2. Place dimensions between the views;
3. Dimension off the views;
4. Dimension mating features for assembly;
5. Do not dimension to hidden lines;
6. Stagger dimensioning values;
7. Create a logical arrangement of dimensions;
8. Consider fabrication processes and capabilities;
9. Consider inspection processes and capabilities.

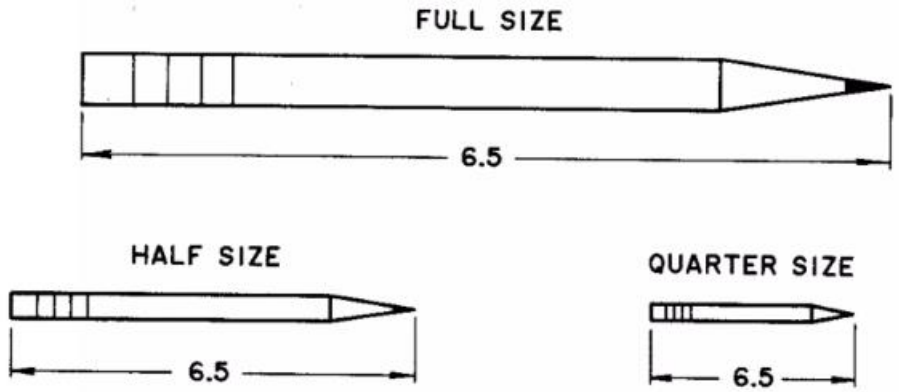
Important elements of dimensioning

Two types of dimensioning: (1) Size and location dimensions and (2) Detail dimensioning



Drawings: Fundamentals
Scaling vs. Dimensioning

- Drawings can be a different scales, but dimensions are ALWAYS at full scale.



Drawings: Fundamentals
Arrangement of Dimensions

- Keep dimension off of the part where possible.
- Arrange extension lines so the larger dimensions are outside of the smaller dimensions.
- Stagger the dimension value labels to ensure they are clearly defined.

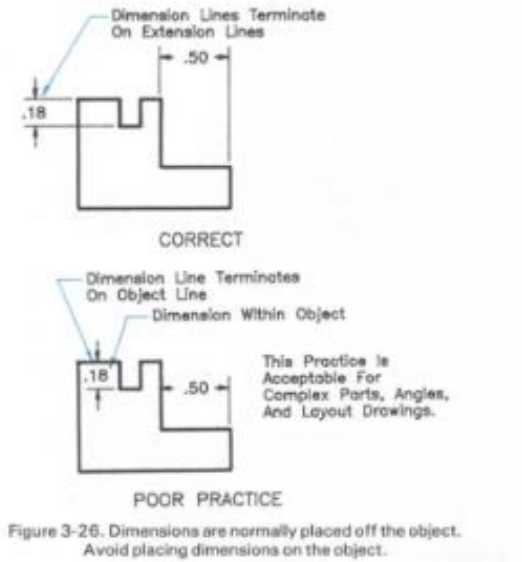


Figure 3-26. Dimensions are normally placed off the object. Avoid placing dimensions on the object.

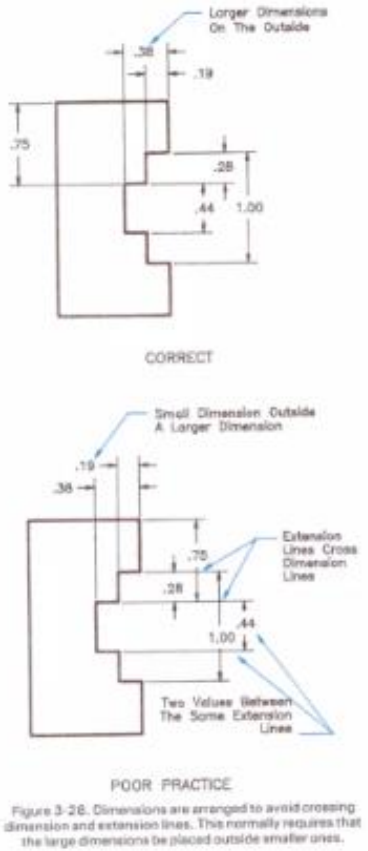


Figure 3-28. Dimensions are arranged to avoid crossing dimension and extension lines. This normally requires that the large dimensions be placed outside smaller ones.

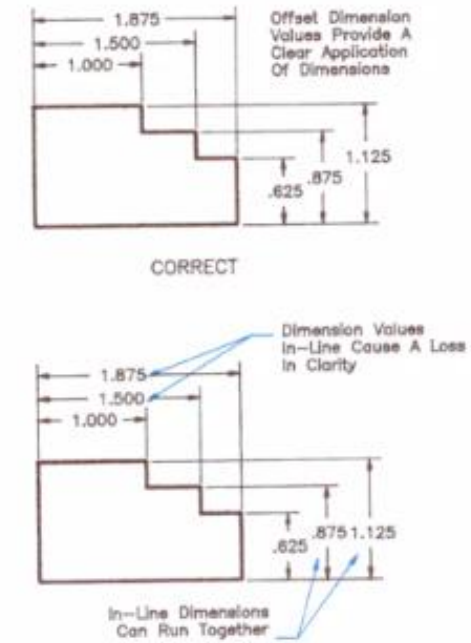
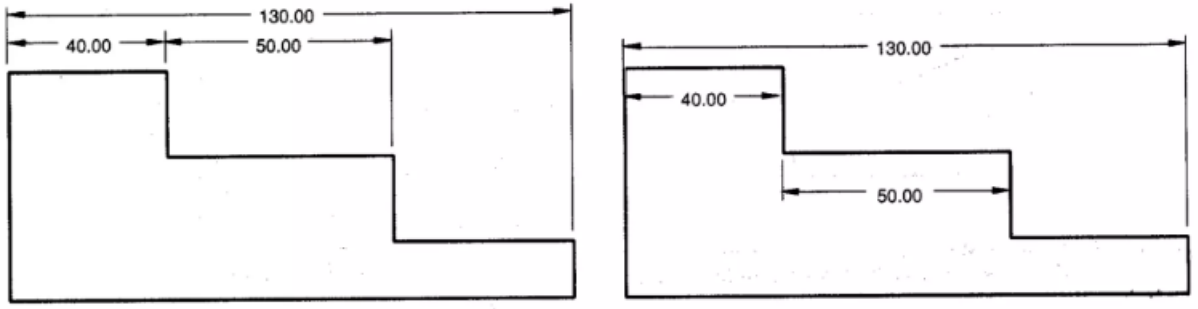


Figure 3-29. Staggered positions for dimension values make it easier to read the dimensions.

Drawings: Fundamentals
Examples of dimensions

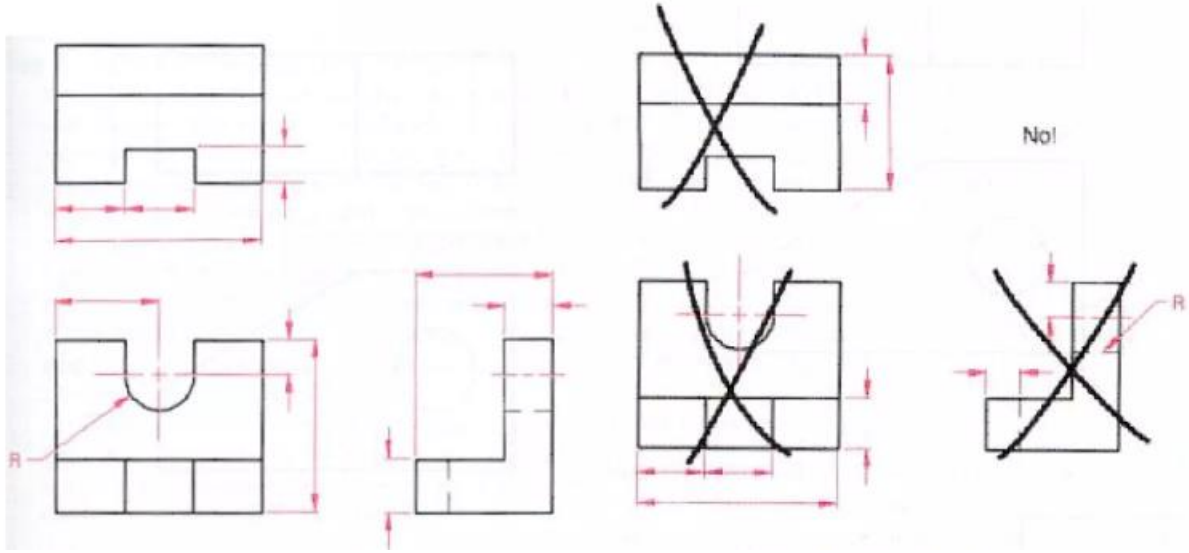
- Dimensions should always be placed outside the part



Yes

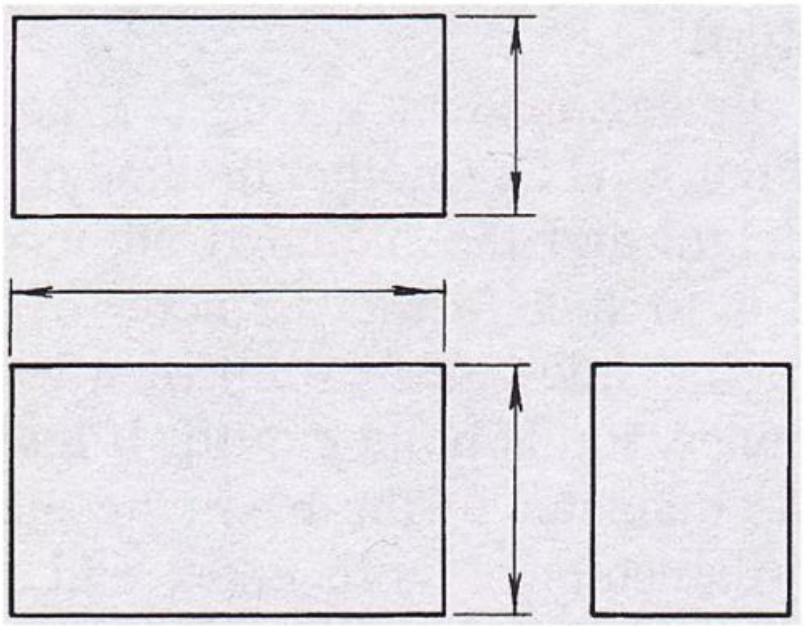
No

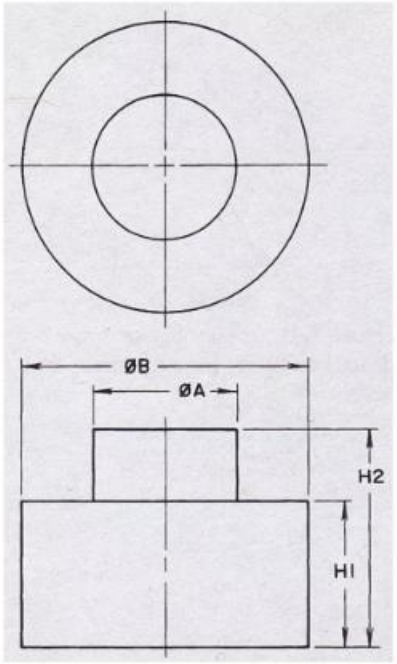
Dimensions should be placed in the view that most clearly describes the feature being dimensioned (contour (shape) dimensioning)



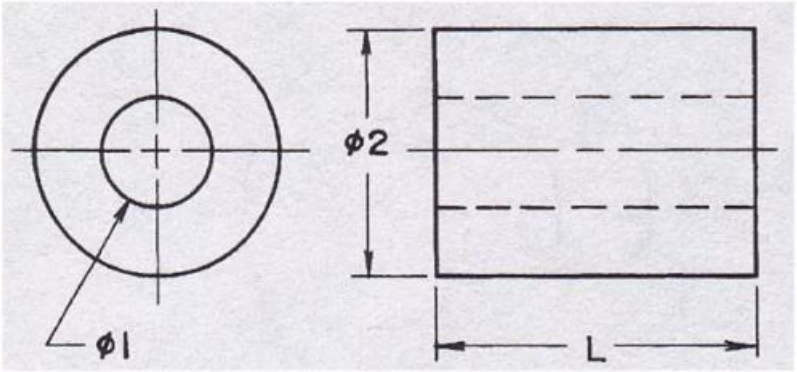
Drawings: Fundamentals
Examples of dimensions

- Rectangular Prism

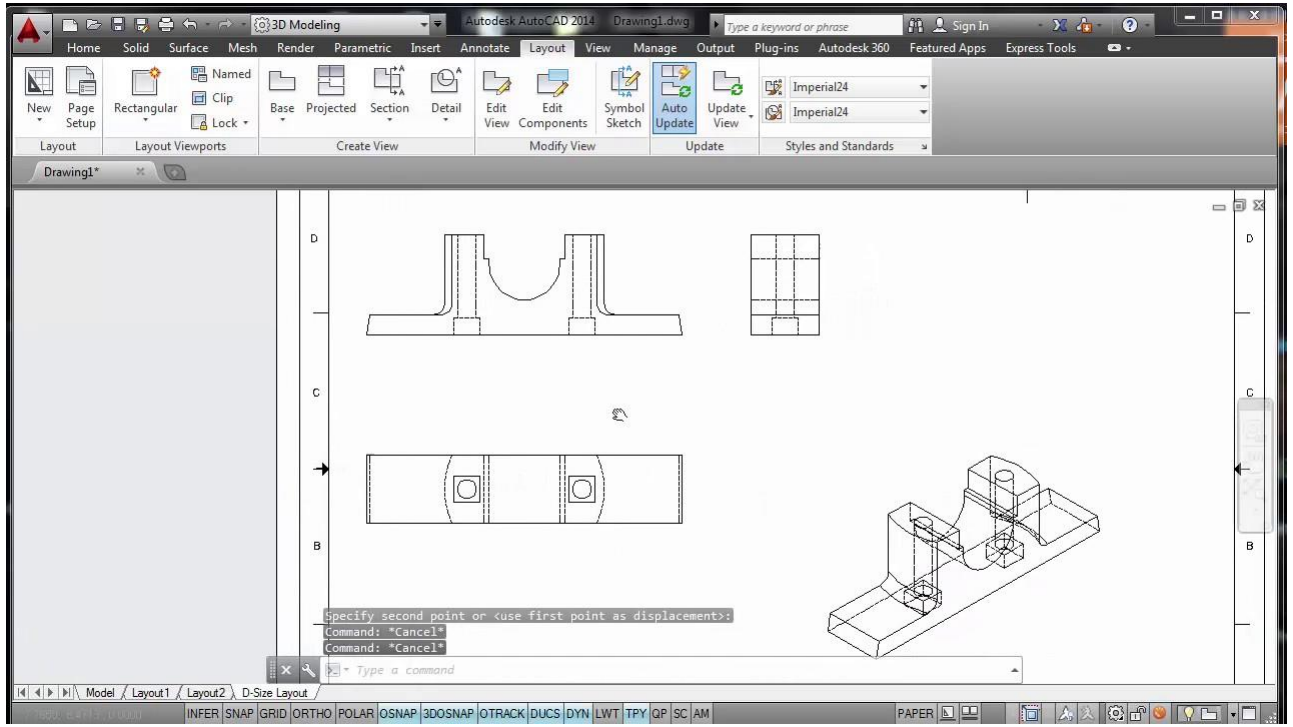




- Cylinders
  - Positive
  - Negative



Generating Drawings in CAD…



- Choose views
- Add dimensions, remove, add (rearrange after auto-generate)
- Set scale
- Remove/add lines
- Generate Bill of Materials (BoM)

Understanding the different types of engineering drawings is key to communicating design. Needed both for creating drawings, and reading from them

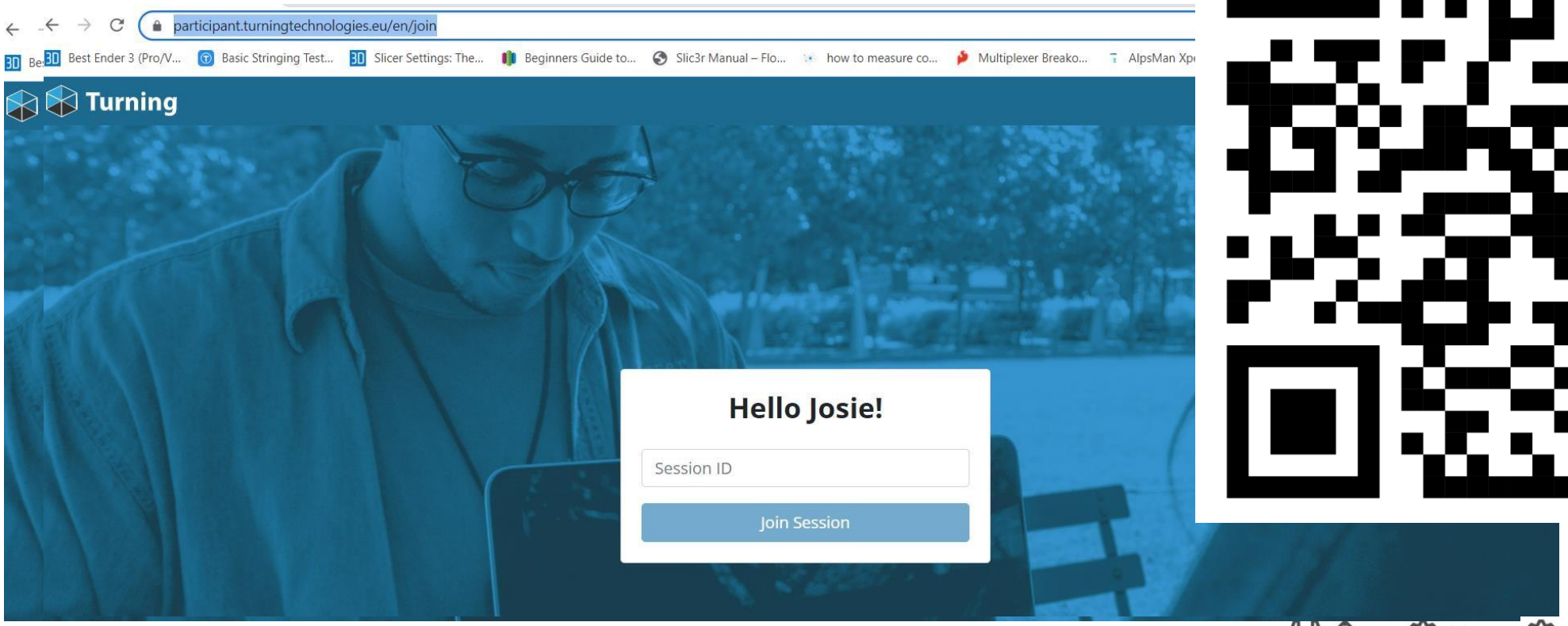
Engineering Drawings Quiz

https://participant.turningtechnologies.eu/en/join

https://participant.turningtechnologies.eu

SessionID: datadriven

https://ttpoll.eu/p/datadriven



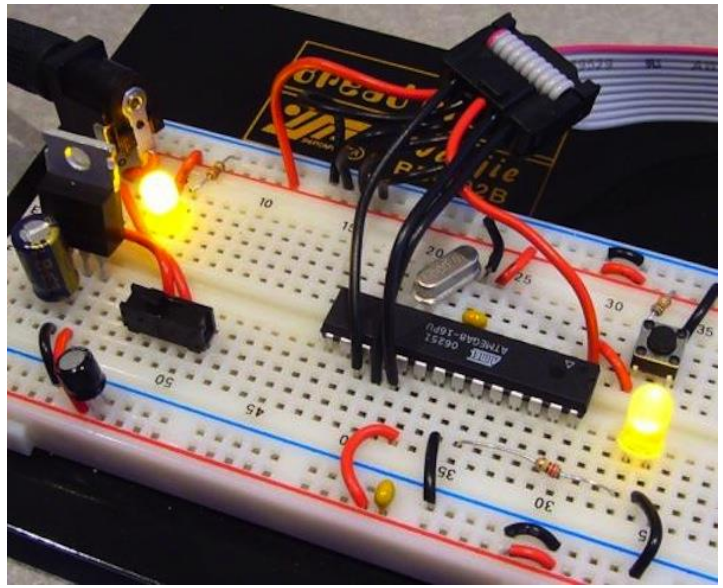
Mechanical Prototyping
CAD → Engineering Drawings

How do we evolve electronic prototypes?

How can we represent system integration & electronics?

Electronics Prototyping & Development

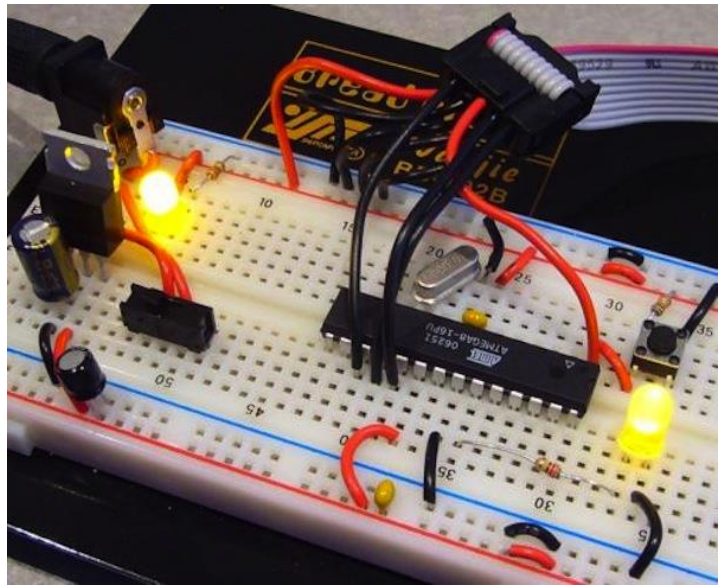
Breadboarding:
Rapid Prototyping



What have you found to be the limitations?

Electronics Prototyping & Development

Breadboarding:
Rapid Prototyping



What have you found to be the limitations?

Loose parts

Not scaleable

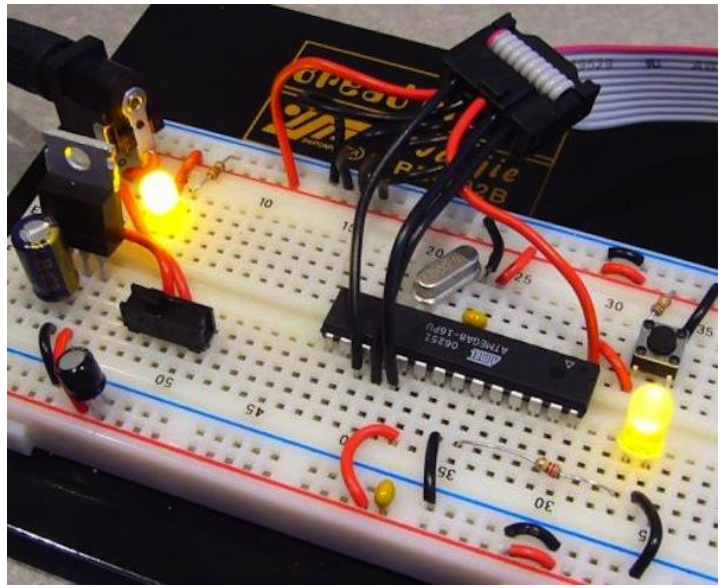
Large Size

Messy

Noisy electrical connections

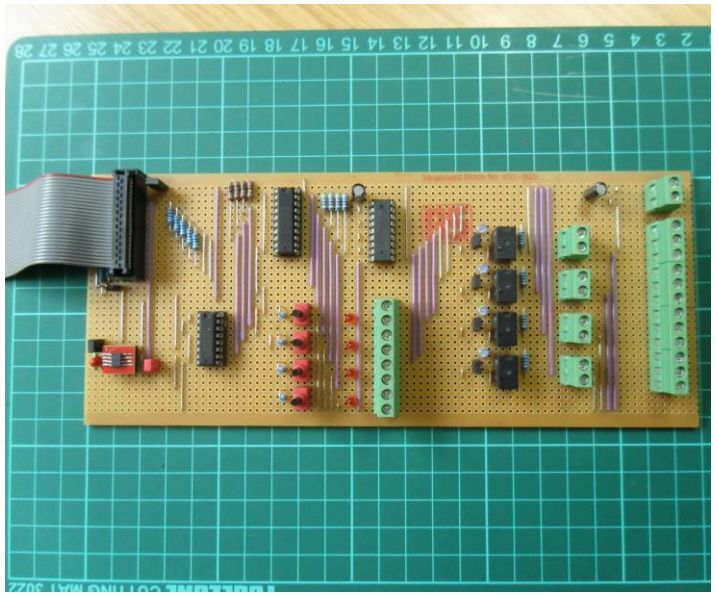
Electronics Prototyping & Development

Breadboarding:
Rapid Prototyping



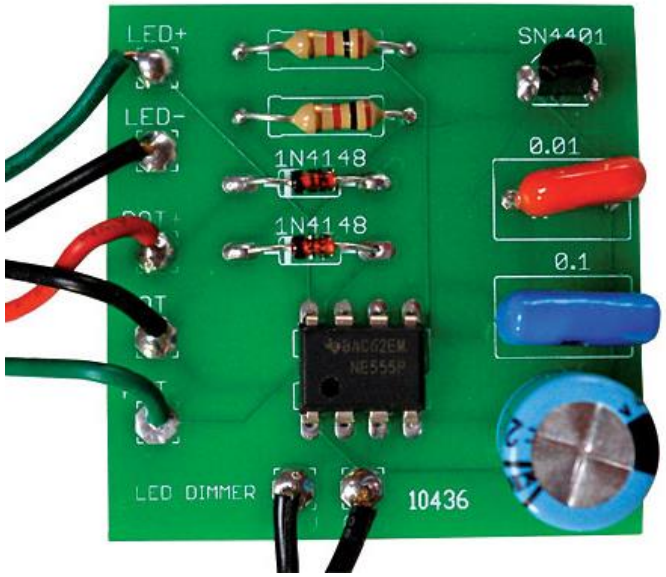
What have you found to be the limitations?

Strip-board/Veroboard:
Improved stability, less flexibility



Soldered parts
Low-cost, quick
Does not scale

PCB
Mass Manufacture

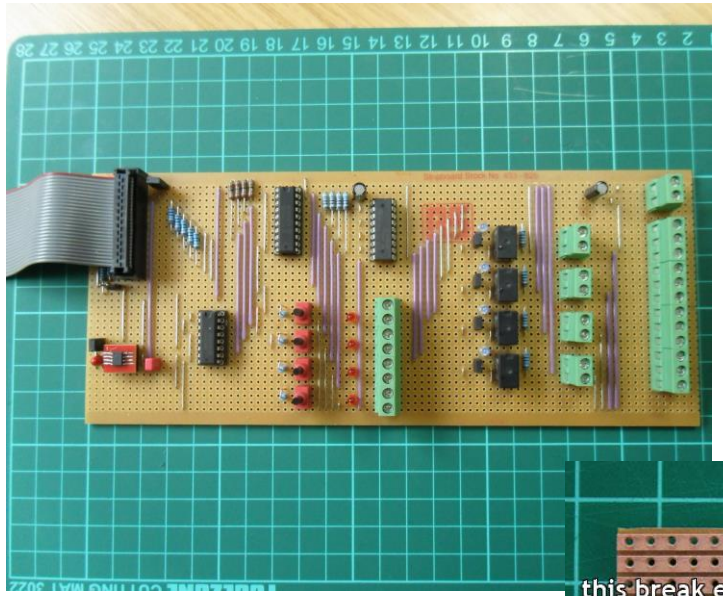


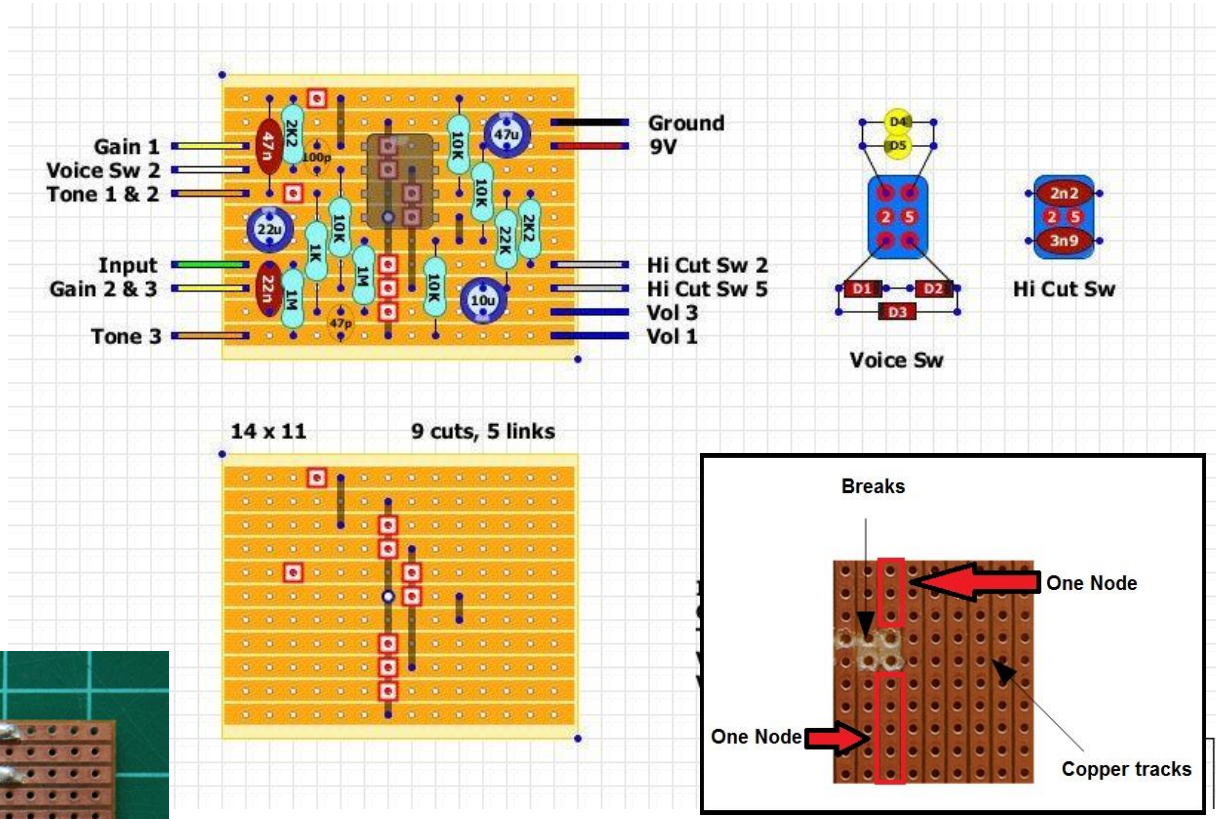
Compact (internal routing)
Mass manufacture
Takes time (design + fab)

Electronics Prototyping & Development

Strip-board/Veroboard:

Improved stability, less flexibility





Soldered parts

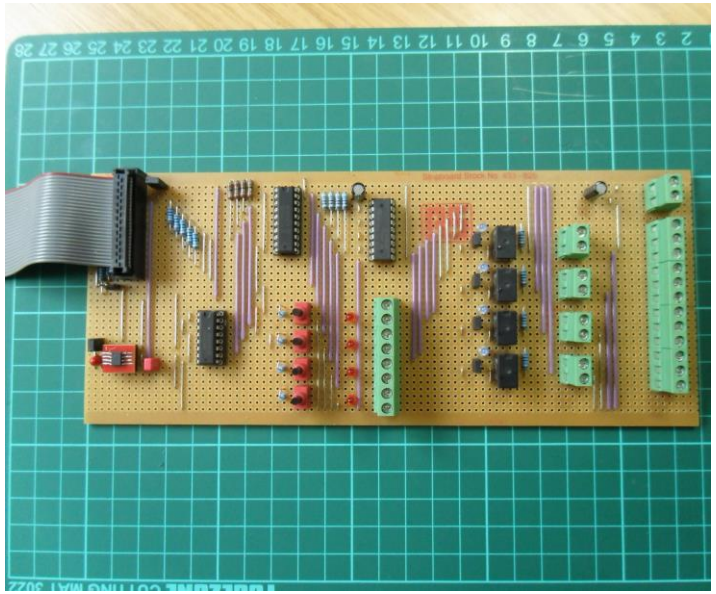
Low-cost, quick

Does not scale

- Need to fix layout
- Parts must be soldered

Electronics Prototyping & Development

Strip-board/Veroboard:
Improved stability, less flexibility



- Requires thought and planning in the layout
- Correcting mistakes is time-consuming
- Good for one-off stable electronics
  - Improved electrical connections
- Limited to through-hole components
- Still rather large foot-print
- Parts cannot be re-used
- Low cost (of verroboard)

Electronics Prototyping & Development

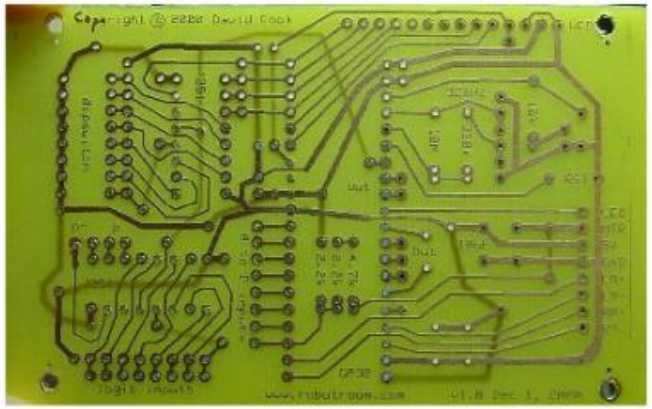
PCB

Mass Manufacture

Compact (internal routing)

Mass manufacture

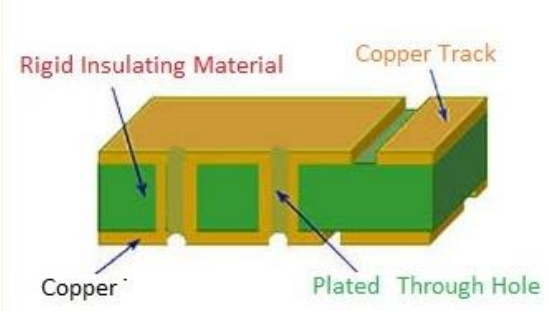
Takes time (design + fab)

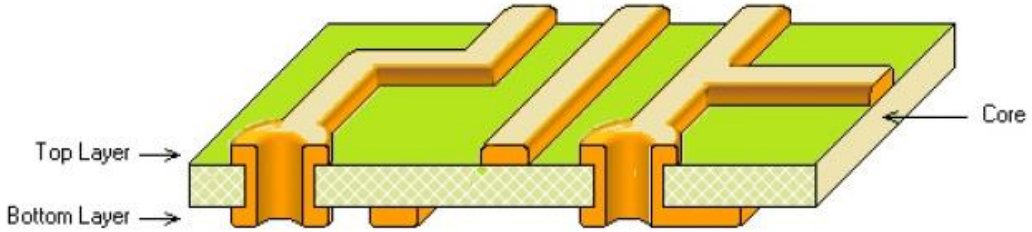


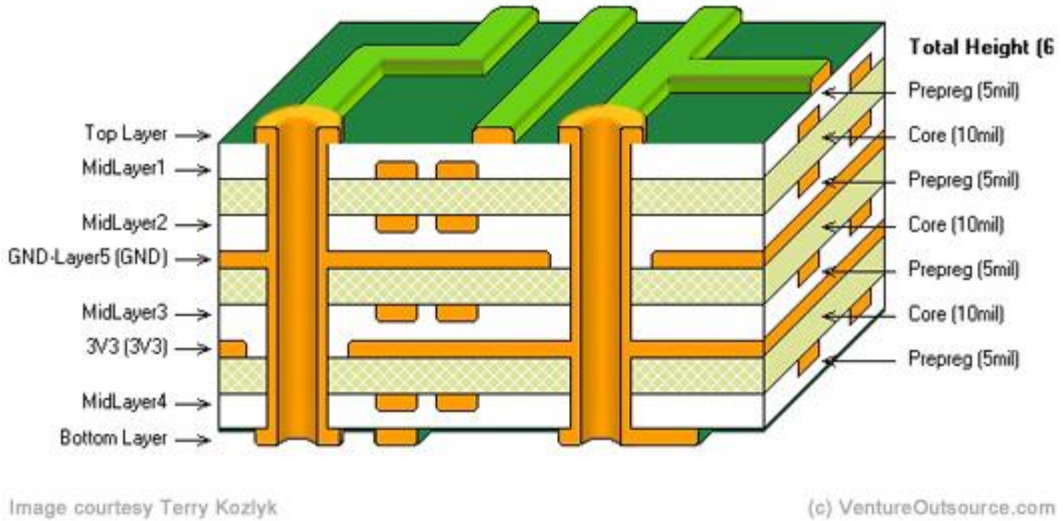
Double Sided PCB

- Etch and remove different layers
- Chemical etching to remove solder-mask and silk screen
- Mechanical drilling removing of parts

Electronics Prototyping & Development

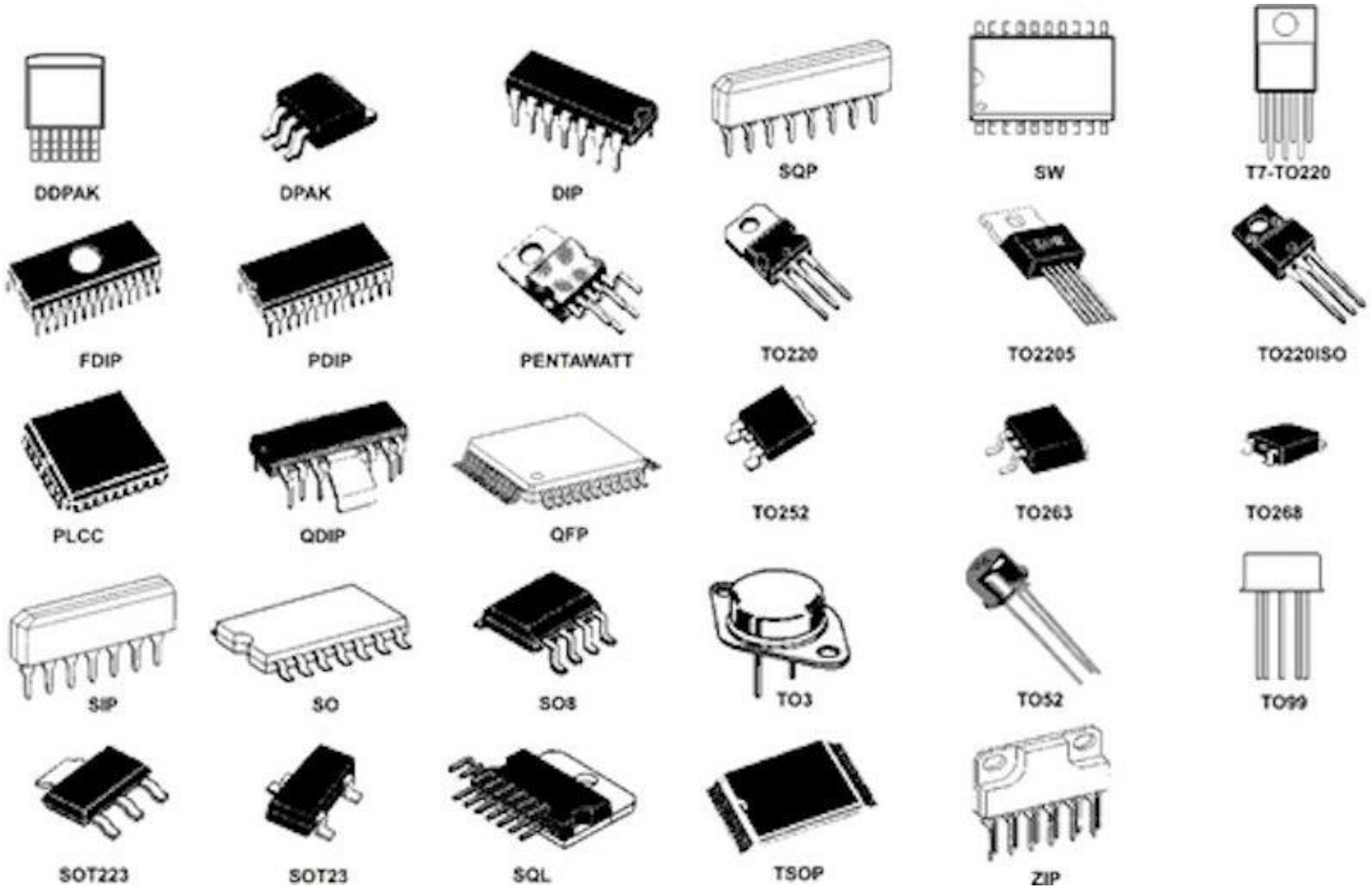


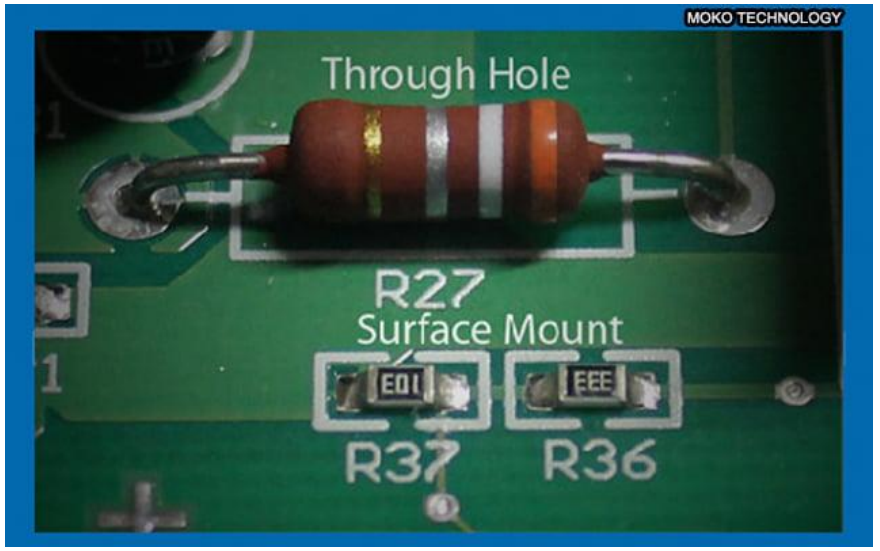




Electronics Prototyping & Development

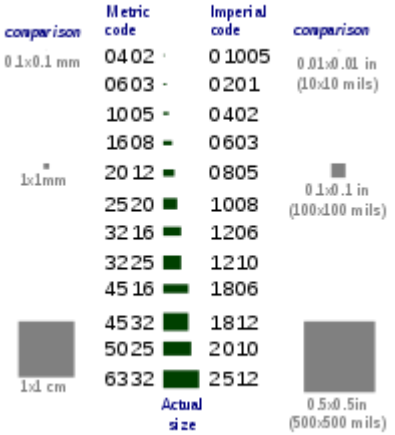
Standard Footprints





Surface mount components (SMD)

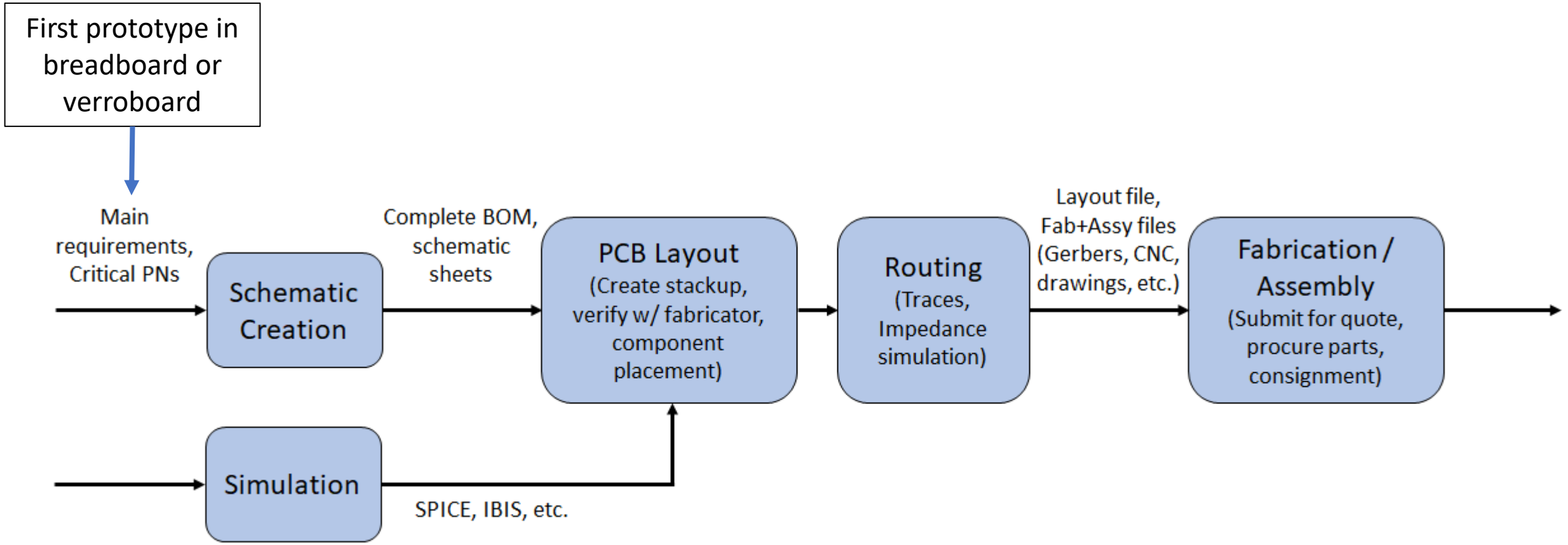
Passive components



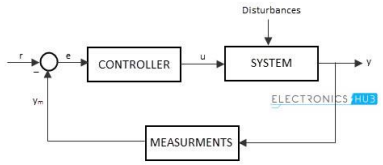
PCB Workflow

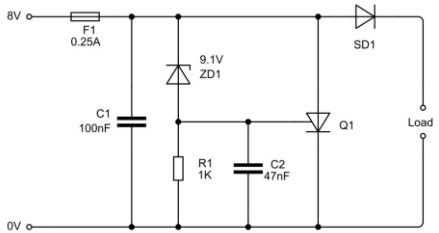
https://www.youtube.com/shorts/VrvzNFBnTDQ

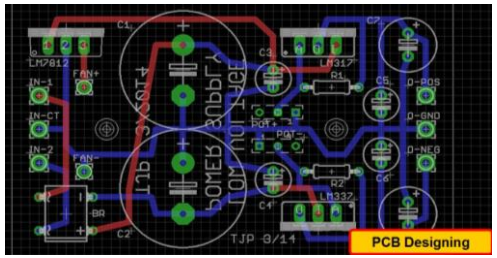
PCB Workflow



Representing Electronics & Systems







System Diagram

Schematic Diagrams

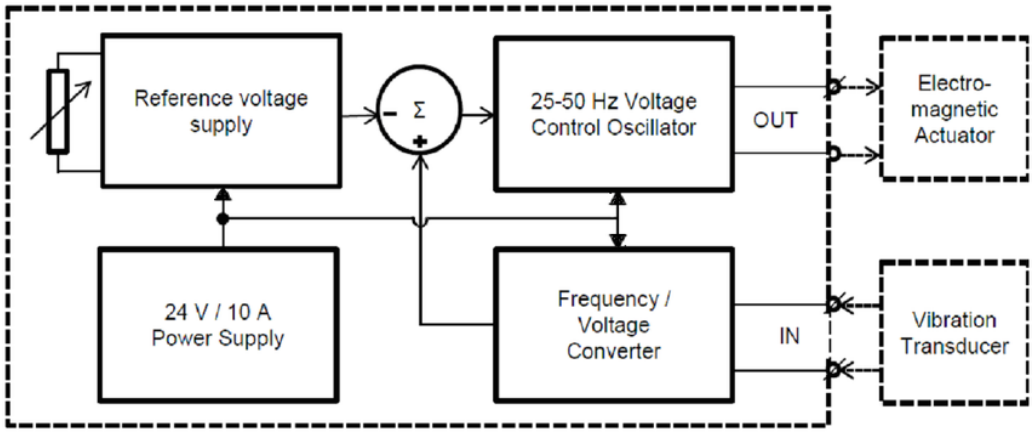
Layouts

High level systems, signals, interactions.

Electronics

Specific Layout

System Diagrams



- Key systems are included
- Signals and connections
  - Power signals
  - Data/information signals
- Direction of arrows matters!
- Indicate the different subsections

For a robot gripper with following what would our system diagram look like?

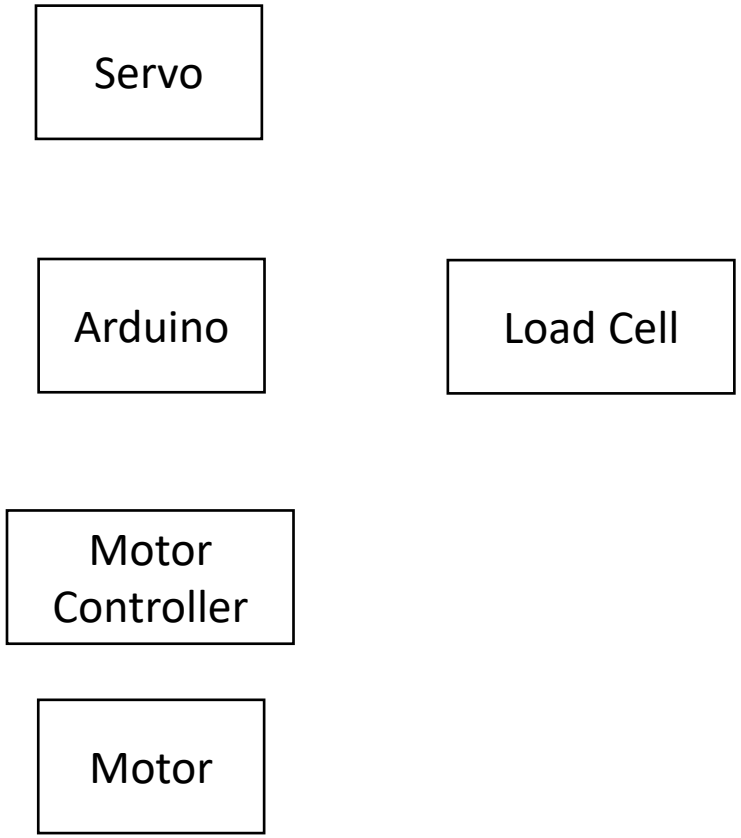
Servo, Motor, Motor Controller, Microcontroller, Load Cell

System Diagrams

For a robot gripper with following what would our system diagram look like?

Servo, Motor, Motor Controller, Microcontroller, Load Cell

What direction should the arrows go?

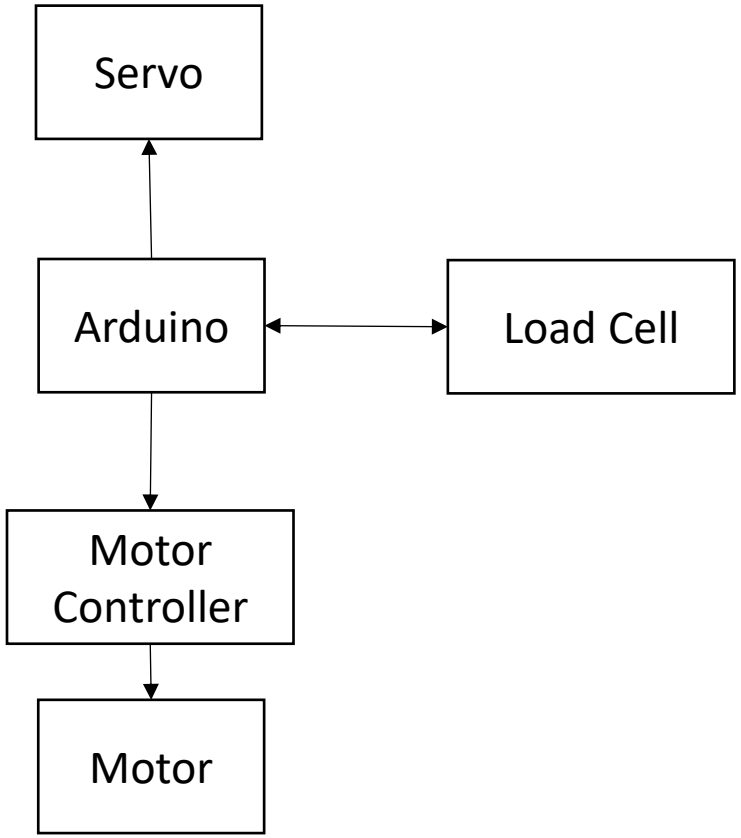


System Diagrams

For a robot gripper with following what would our system diagram look like?

Servo, Motor, Motor Controller, Microcontroller, Load Cell

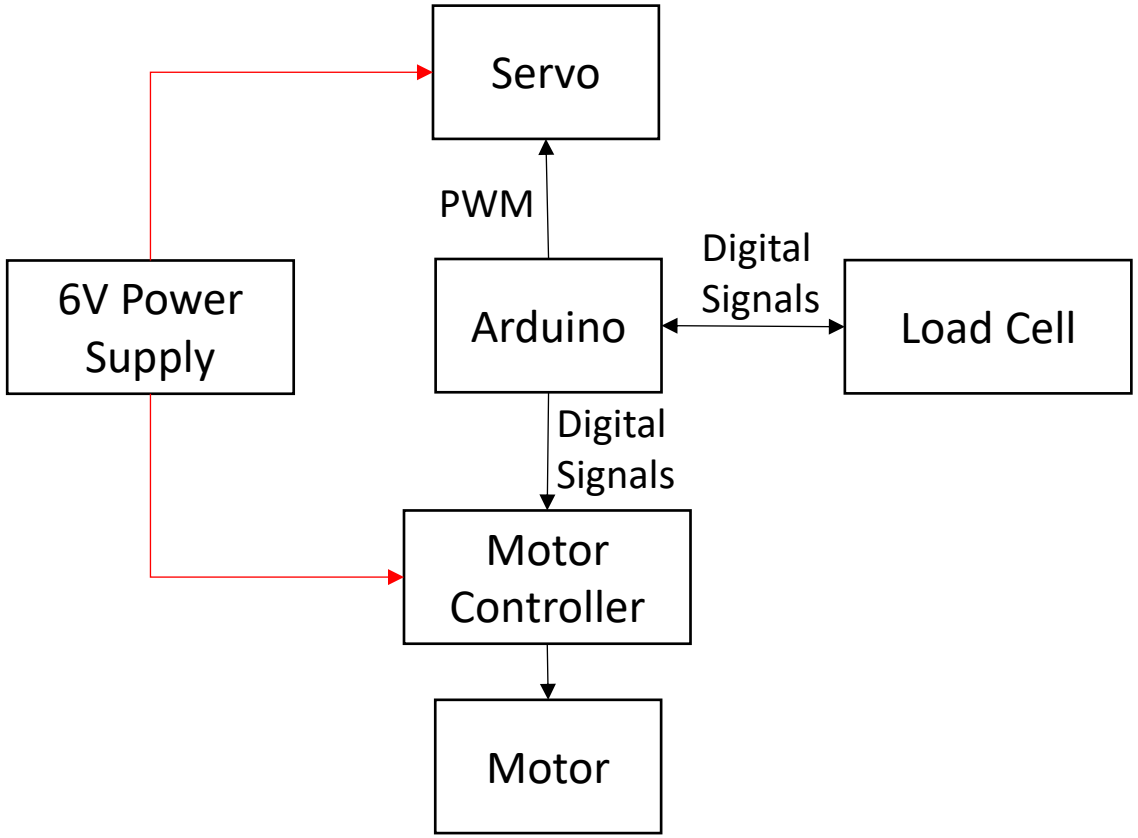
What's missing?



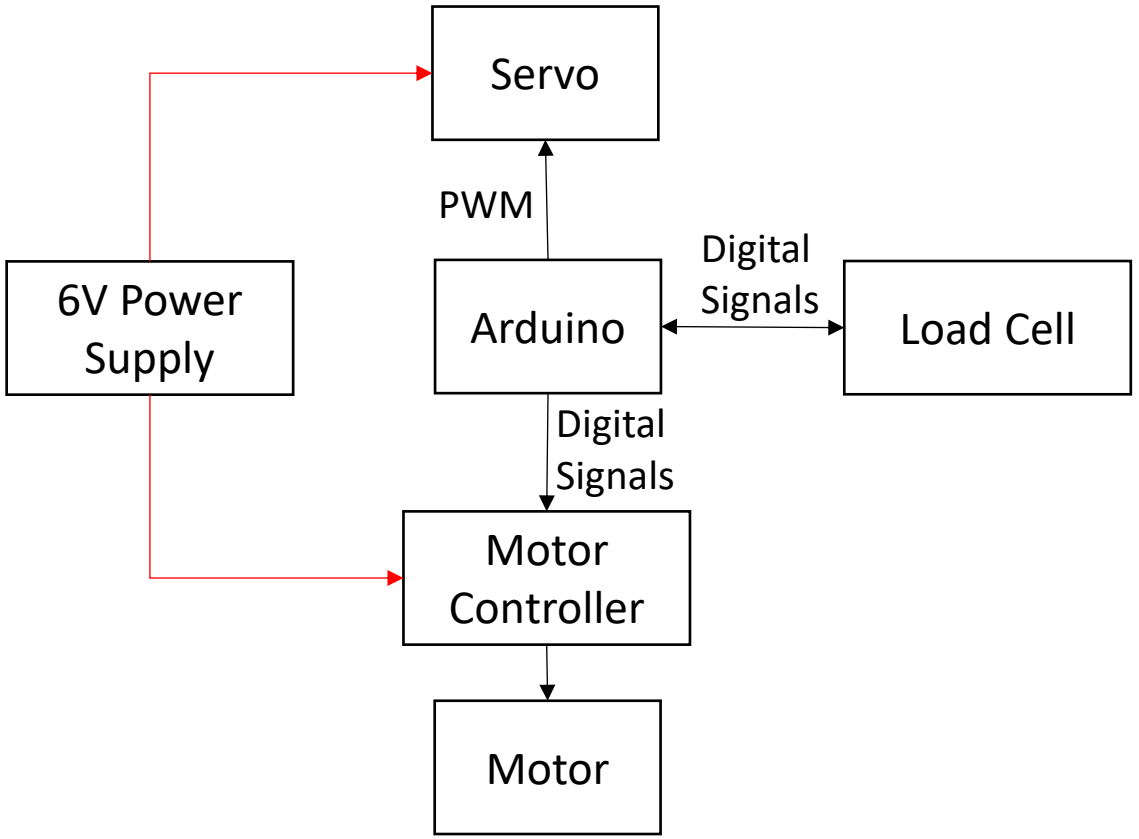
System Diagrams

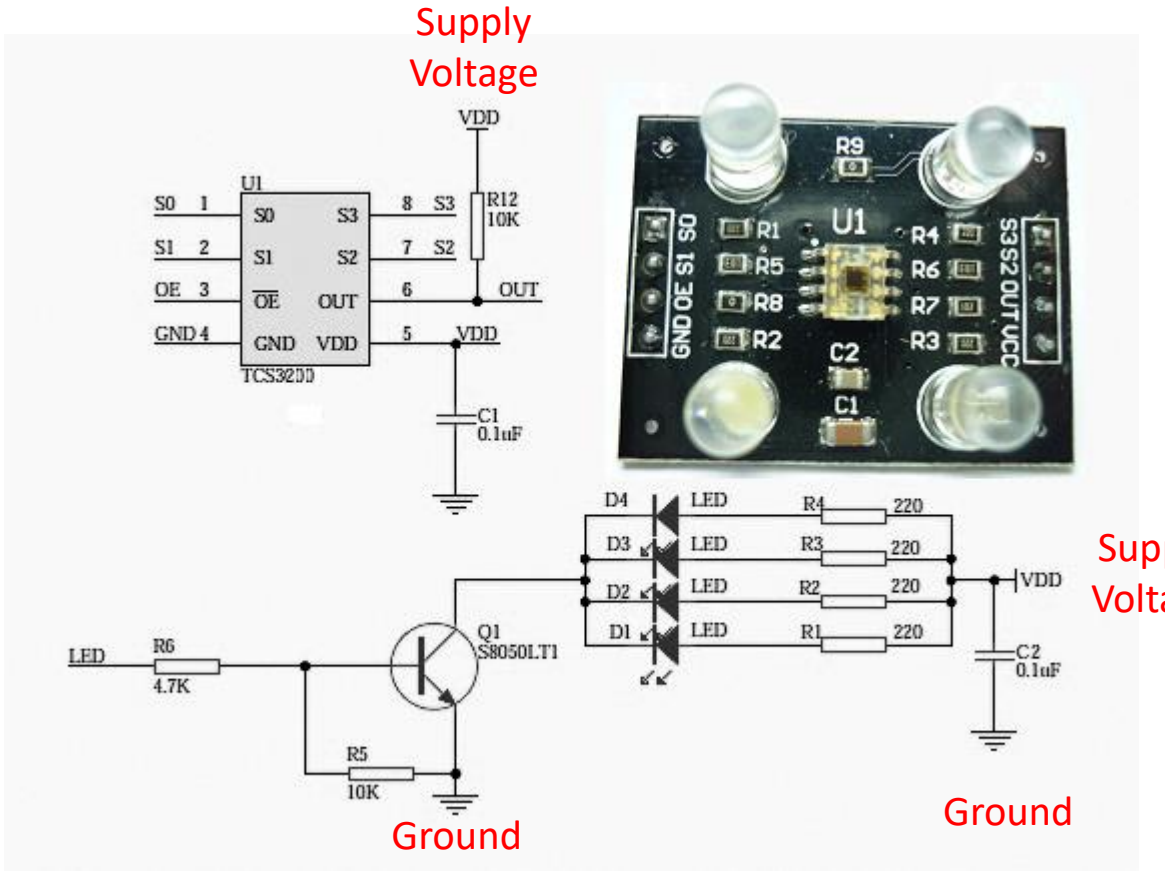
For a robot gripper with following what would our system diagram look like?

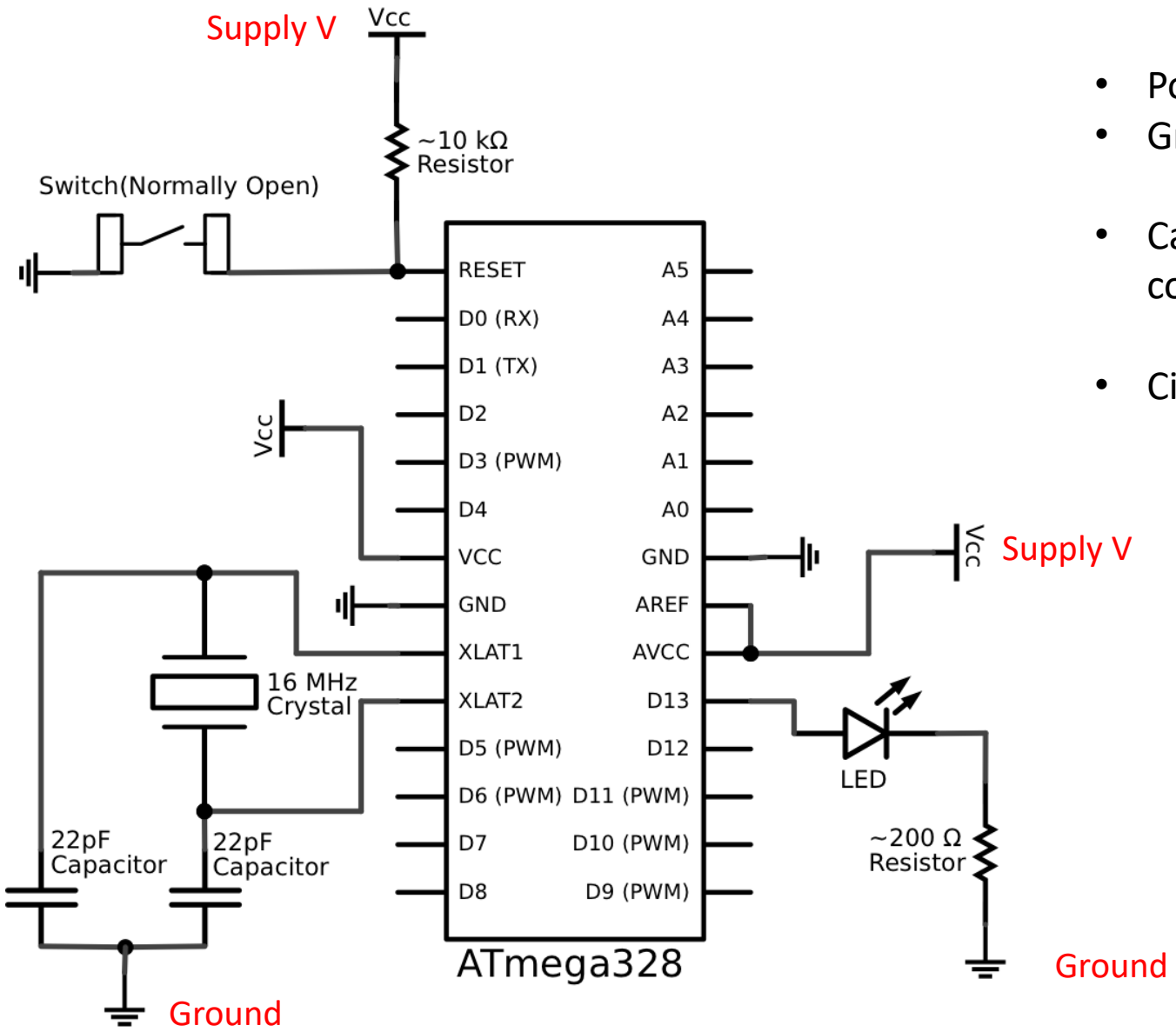
Servo, Motor, Motor Controller, Microcontroller, Load Cell



Electronics Schematics



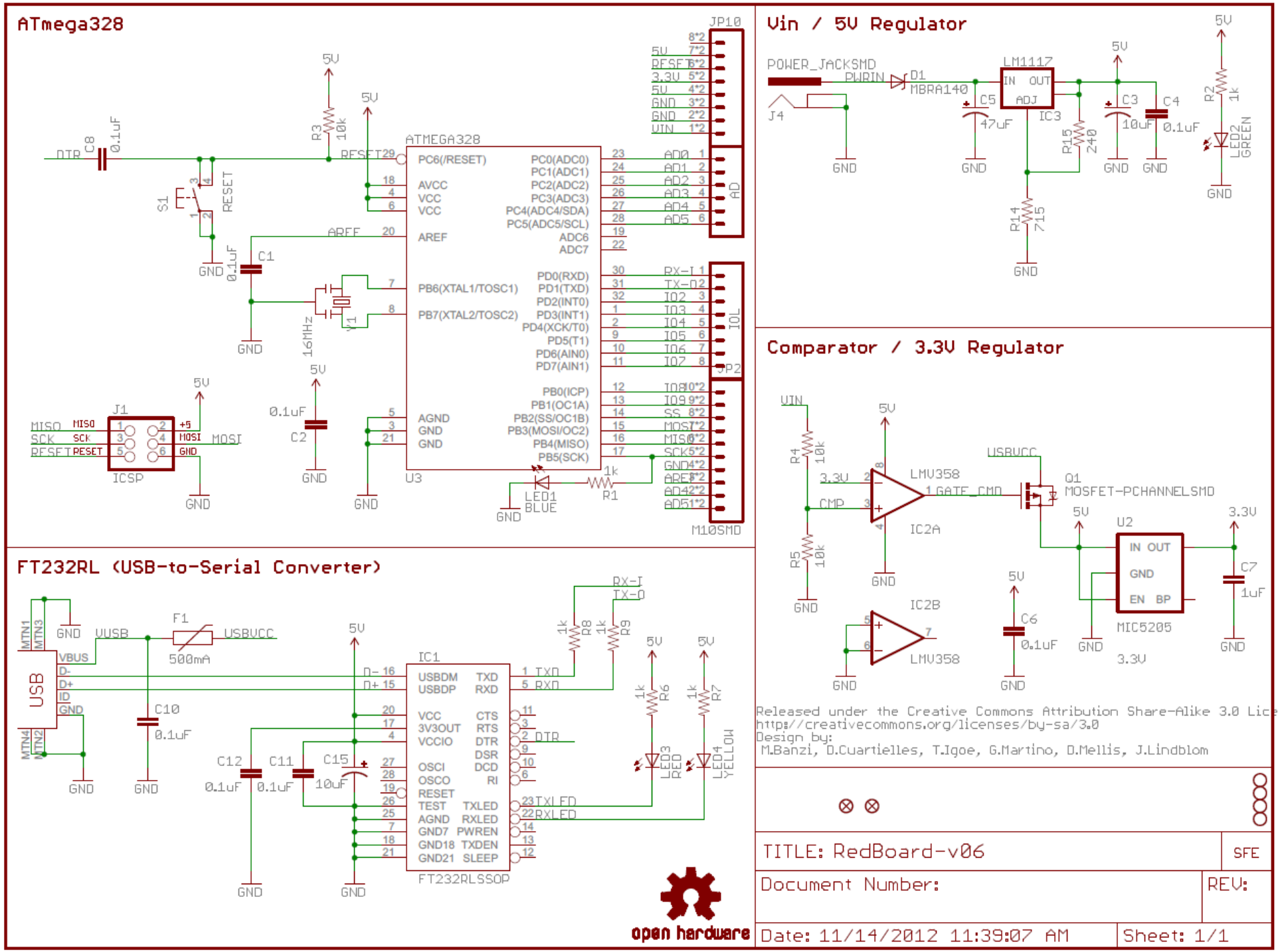




- Power Rails
- Ground Rails

- Can separate into different circuit components with common GND + VCC connections

- Circuit Symbols


ATmega328
JP10
ATMEGA328
U3
M10SMD
ICSP
J1
Vin / 5V Regulator
POWER_JACKSMD
D1
MBRA140
LM1117
IC3
Comparator / 3.3V Regulator
LMV358
IC2A
IC2B
MIC5205
U2
Q1
MOSFET-PCHANNELSMD
FT232RL (USB-to-Serial Converter)
IC1
FT232RLSSOP
F1
500mA
LED1 BLUE
LED2 GREEN
LED3 RED
LED4 YELLOW
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Design by:
M.Banzi, D.Cuartielles, T.Igoe, G.Martino, D.Mellis, J.Lindblom
TITLE: RedBoard-v06
SFE
Document Number:
REV:
Date: 11/14/2012 11:39:07 AM
Sheet: 1/1

PRODUCT & E

Layouts

- Breadboard Layouts
- Veroboard Layouts
- PCB Layouts

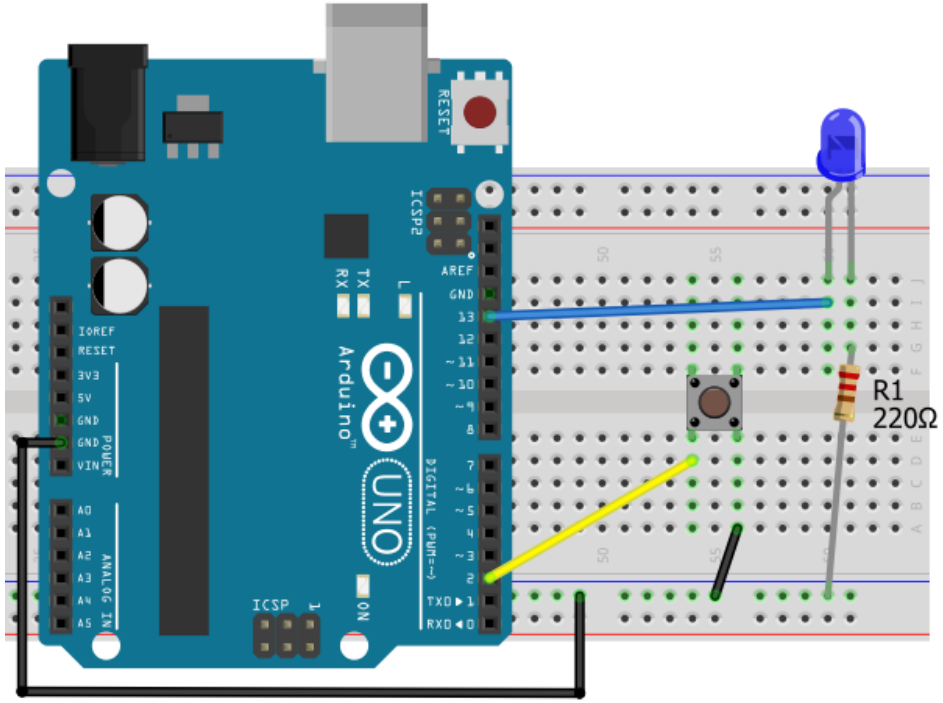
Link together

Circuit Diagram → Footprint of Components → Optimized Circuit

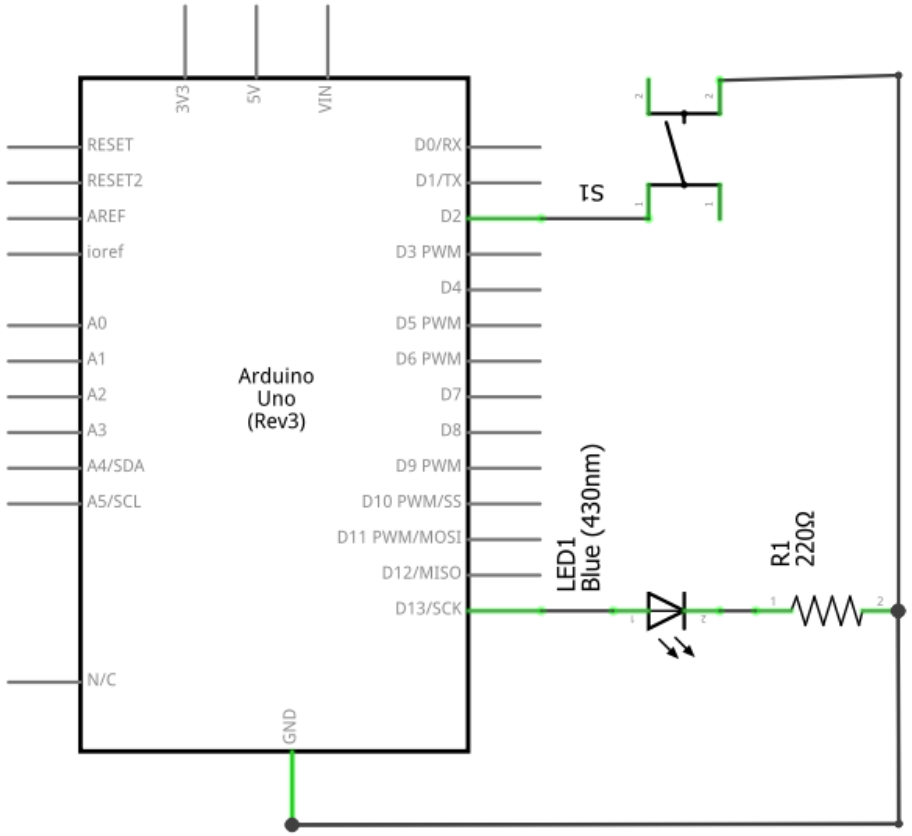
Layouts

Breadboard Layout

Breadboard View

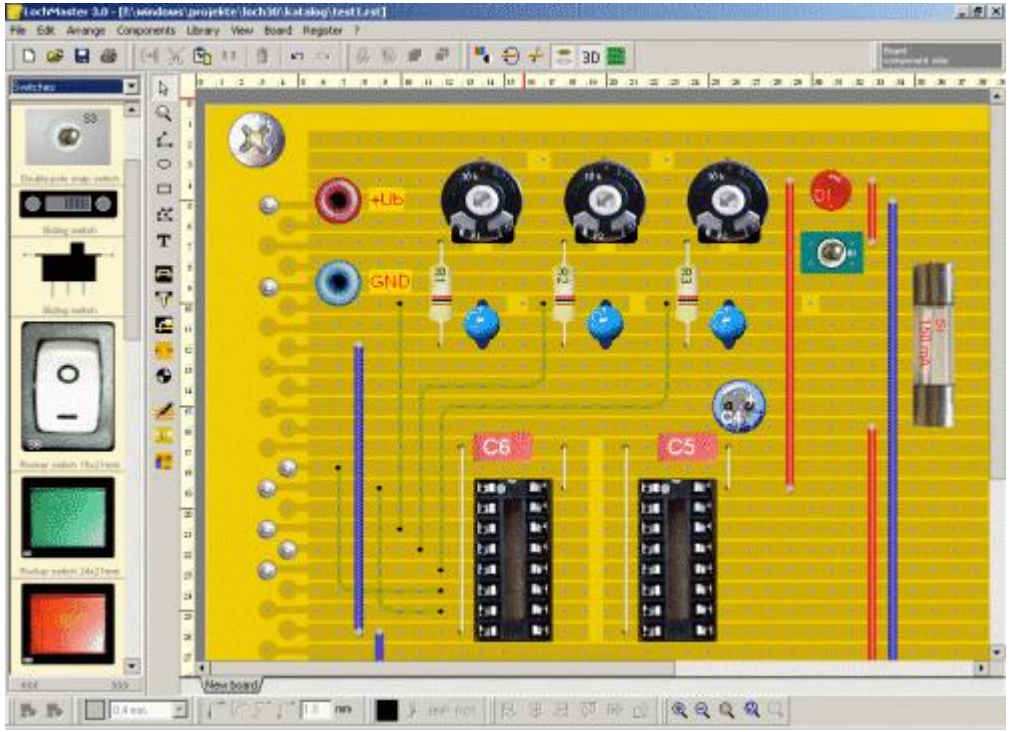


Schematic View



Layouts

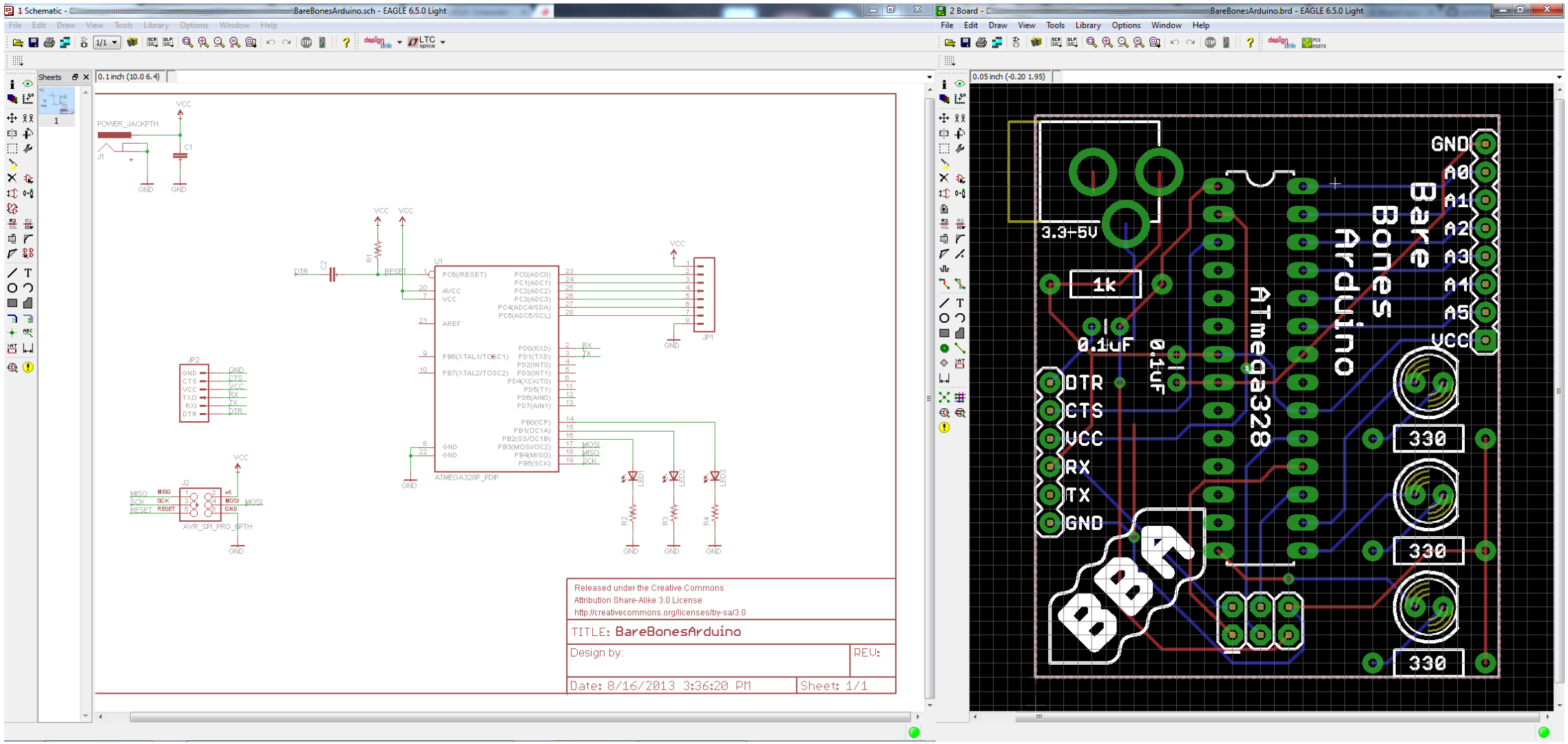
Veroboard Layout



- Footprint of different components
- Cutting/strips of wire
- Placement of components

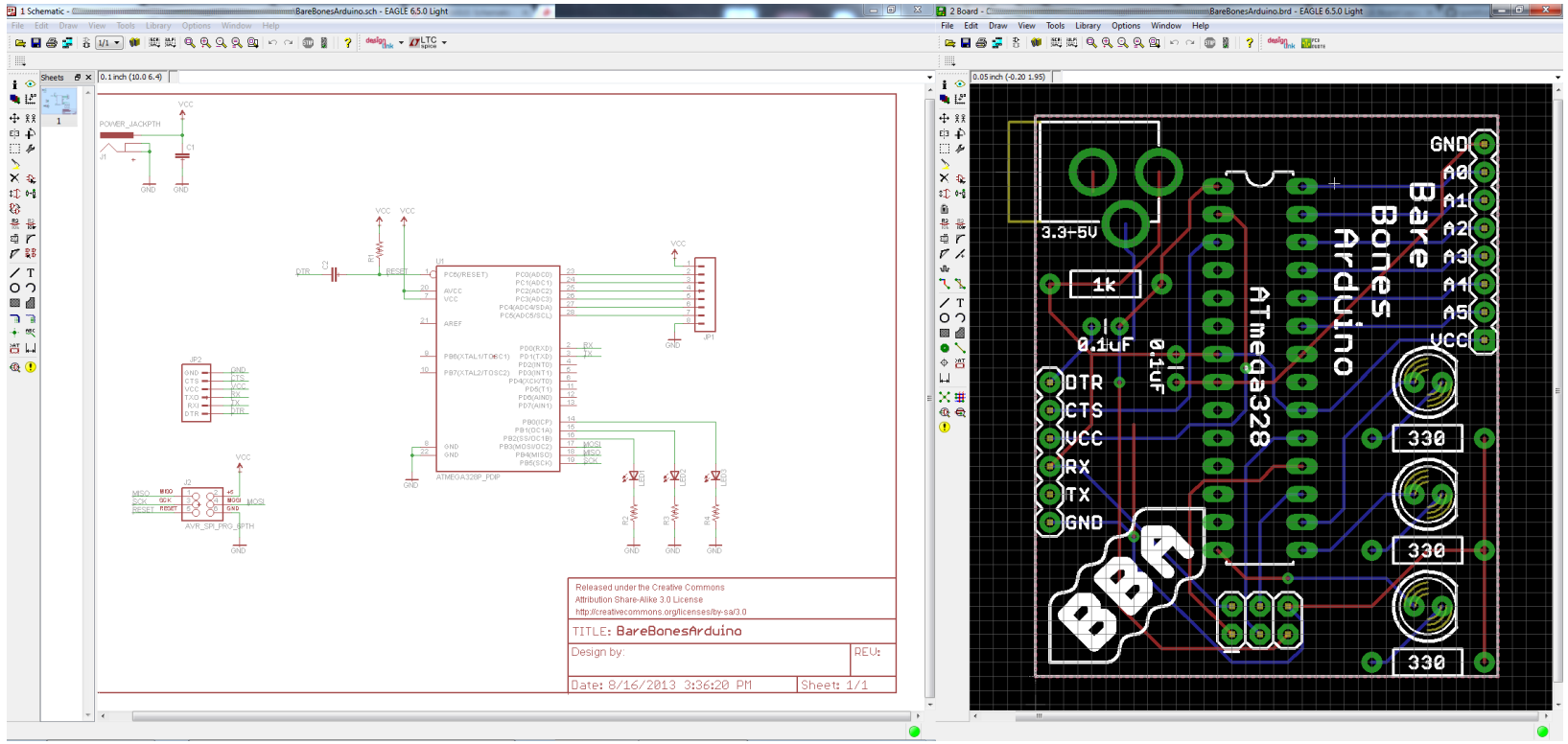
Layouts

PCB Layout



Layouts

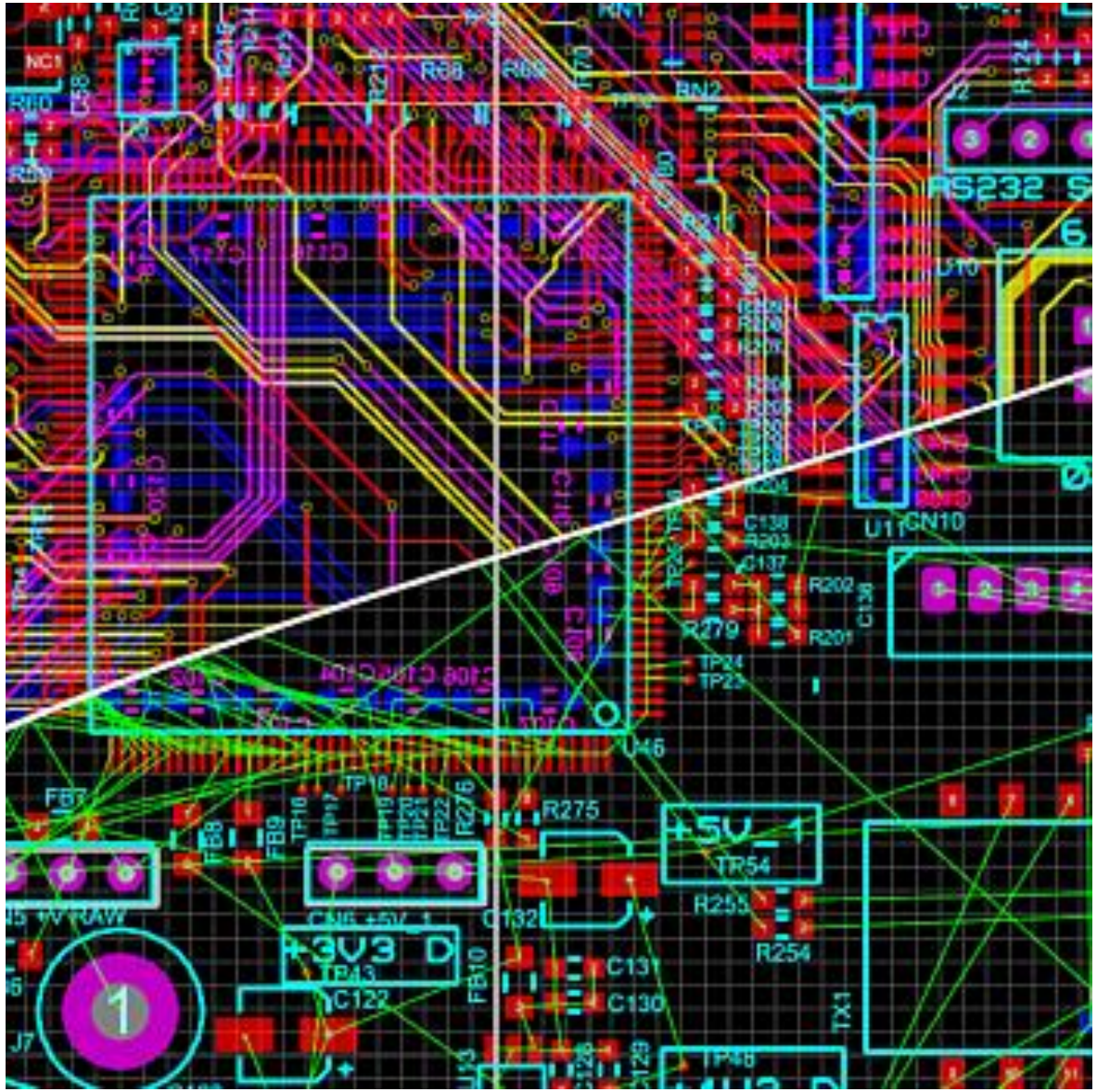
PCB Layout



- Footprint
- Manufacturing capabilities
- Routing of layers
- Ground plane

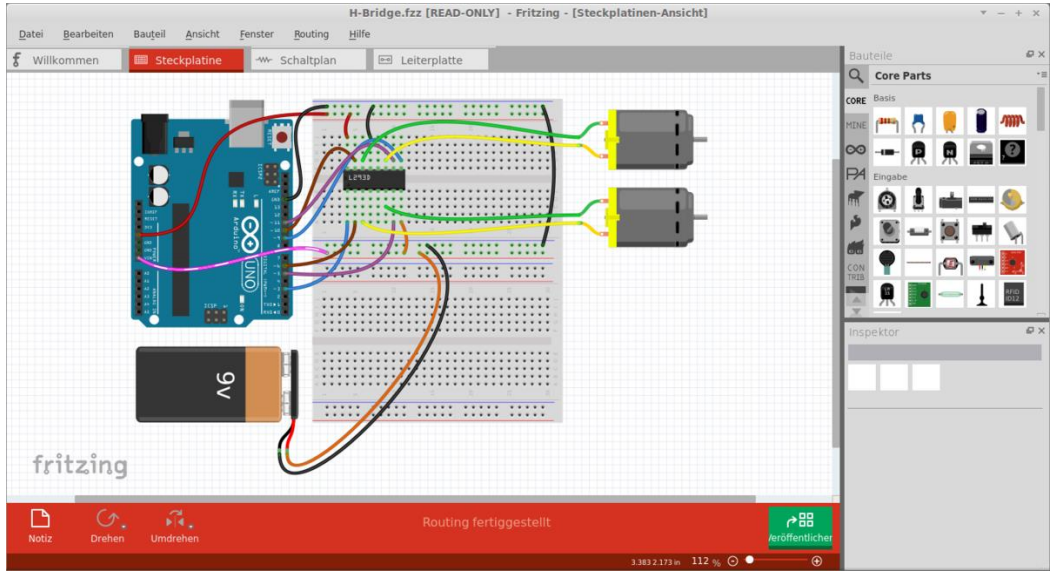
Layouts

PCB Layout



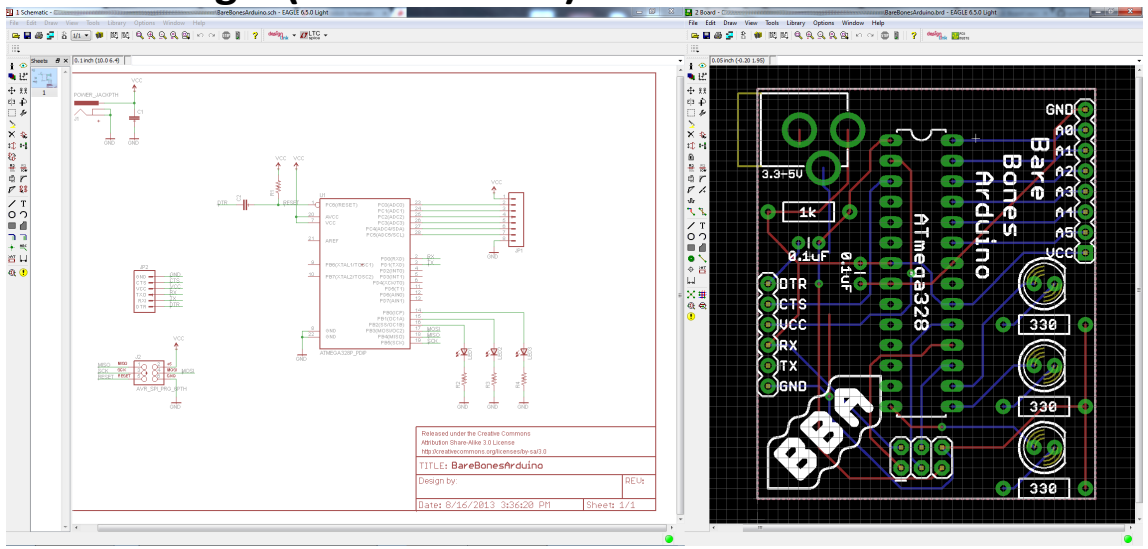
Electronics Diagrams: Available Tools

Fritzing: Online Protoyping Electronics Tool



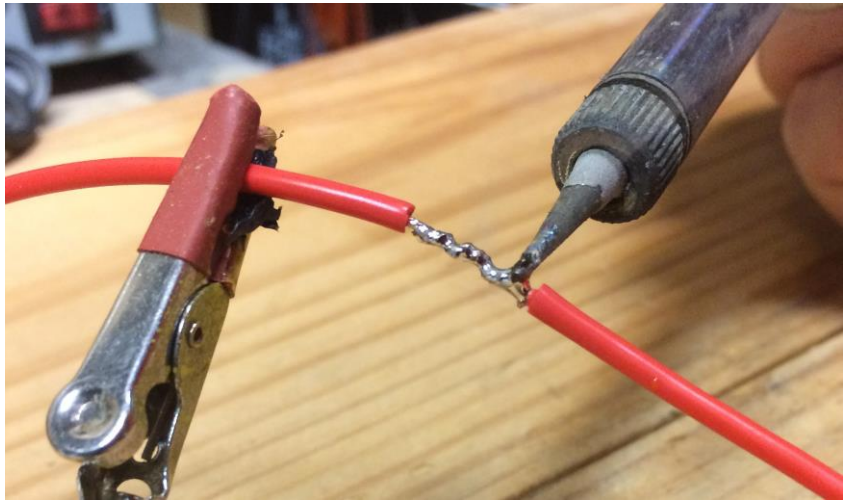
Circuit diagram, layout, PCB

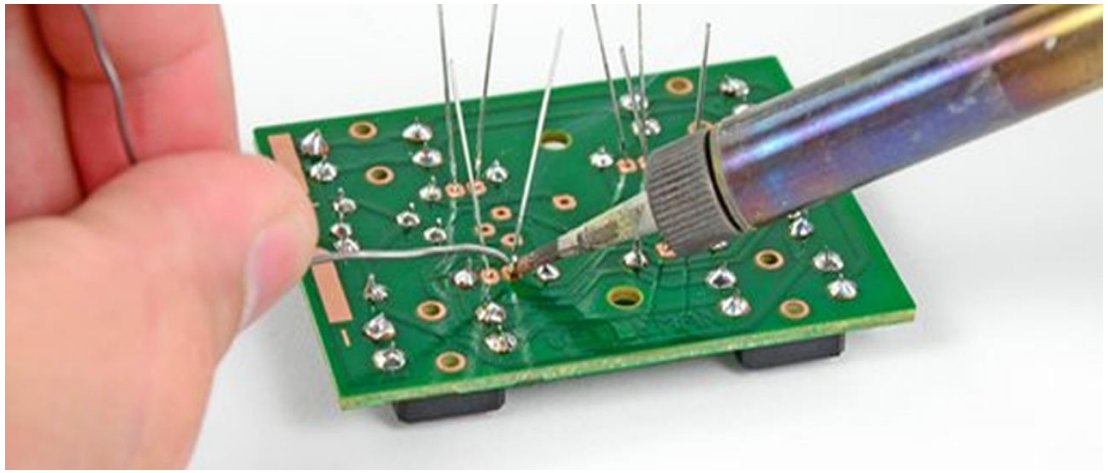
Eagle (CAD for PCBS)



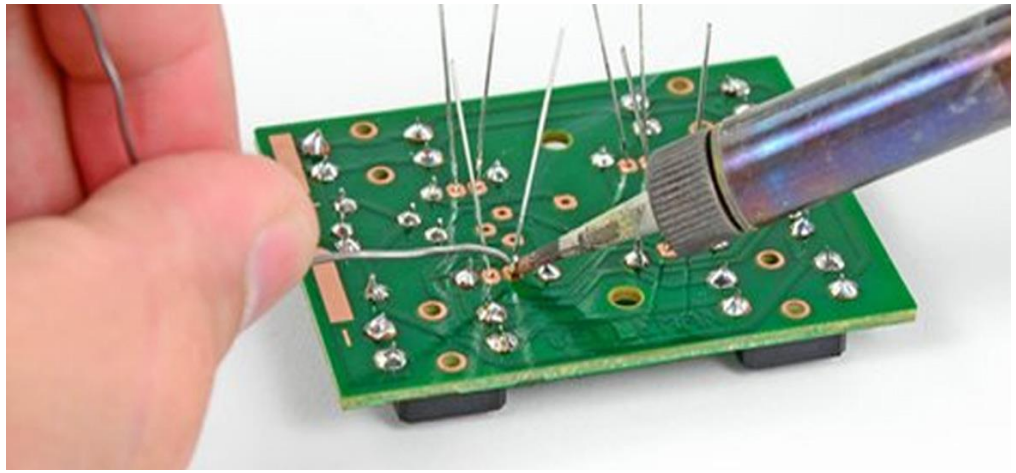
Schematic, database of parts/footprints, layout tools.

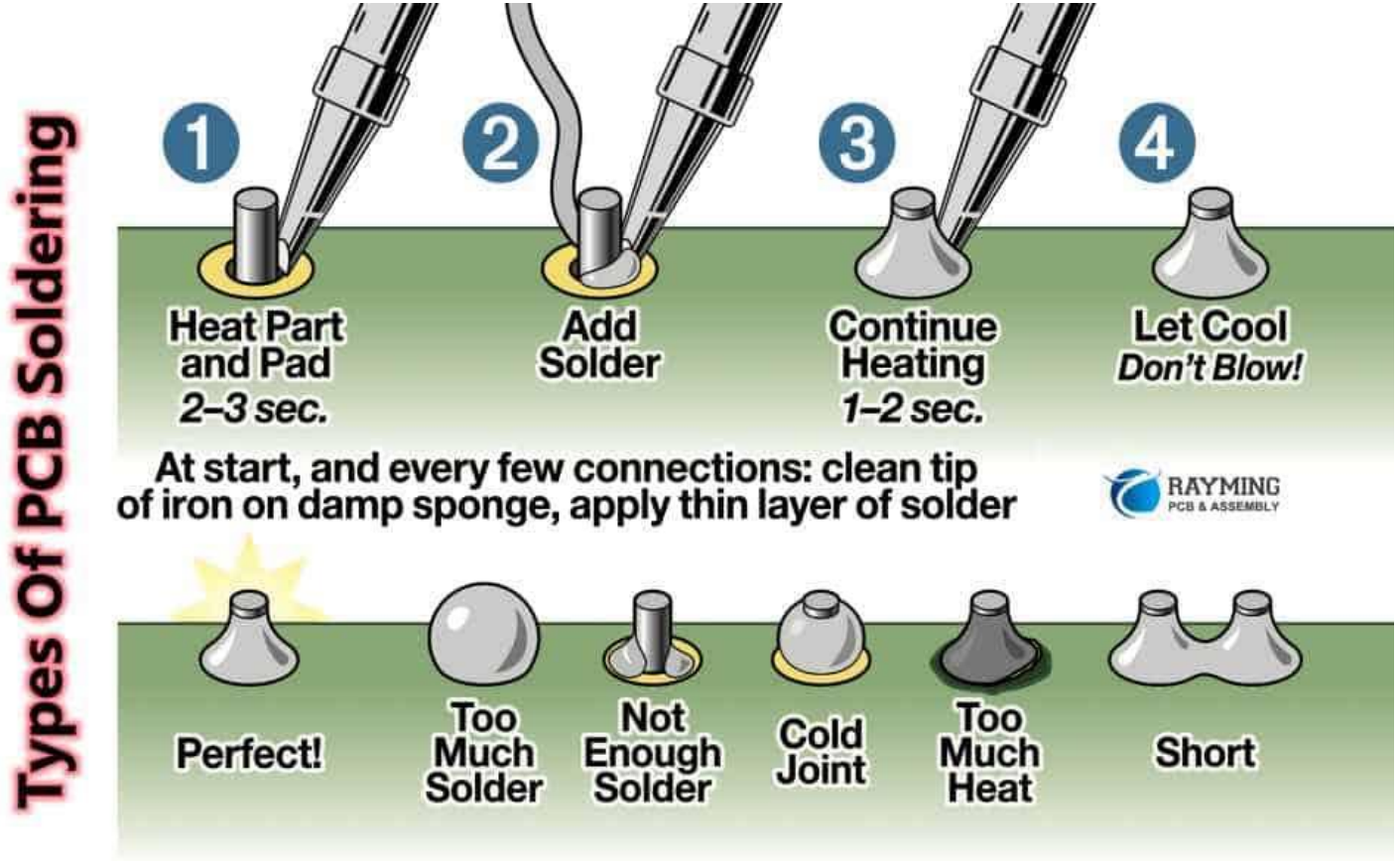
Soldering!



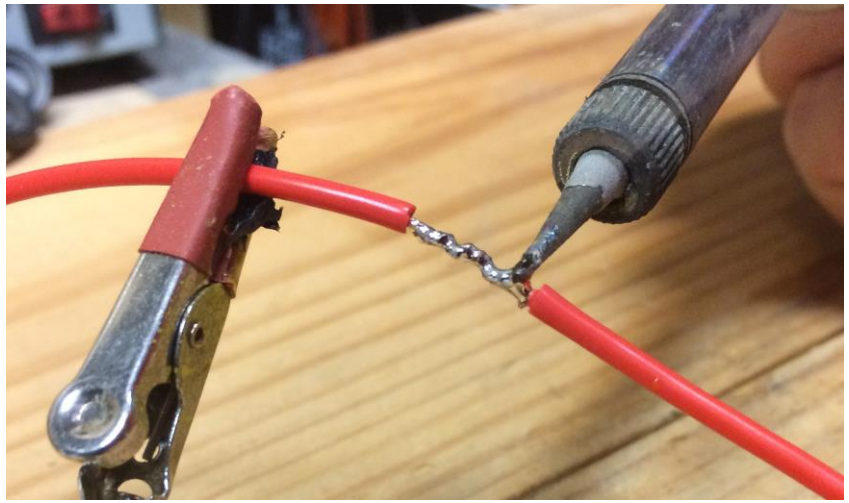


Soldering!



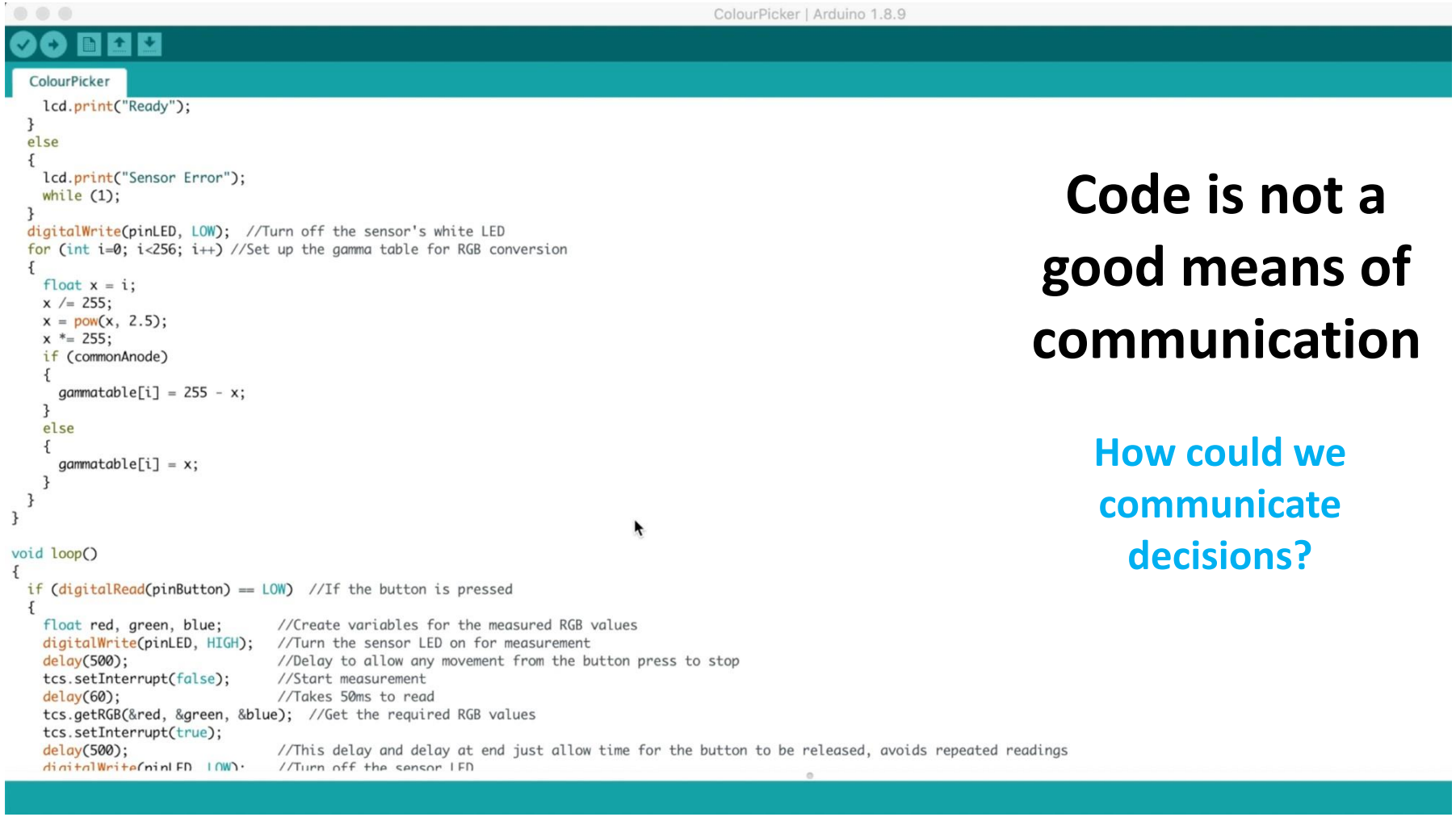

Types Of PCB Soldering
1
Heat Part and Pad
2–3 sec.
2
Add Solder
3
Continue Heating
1–2 sec.
4
Let Cool
Don't Blow!
At start, and every few connections: clean tip of iron on damp sponge, apply thin layer of solder
RAYMING
PCB & ASSEMBLY
Perfect!
Too Much Solder
Not Enough Solder
Cold Joint
Too Much Heat
Short

Soldering!



https://www.youtube.com/watch?v=-qk-ulz05J8&ab_channel=HowDoYou%3FDIY

Representing Flow/Decision Making



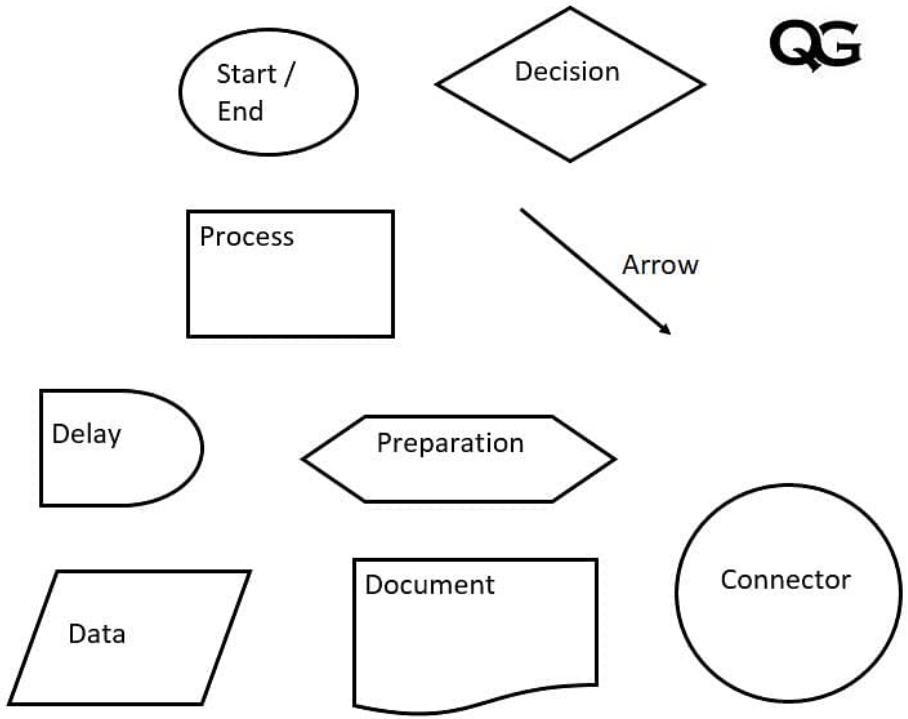
Code is not a good means of communication

How could we communicate decisions?

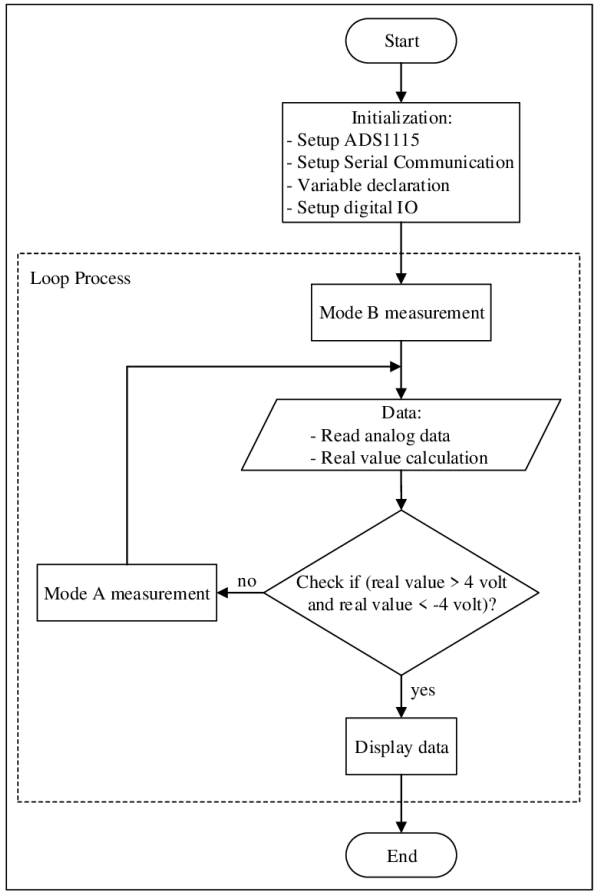
Representing Flow/Decision Making

Flow charts

Standard Symbols



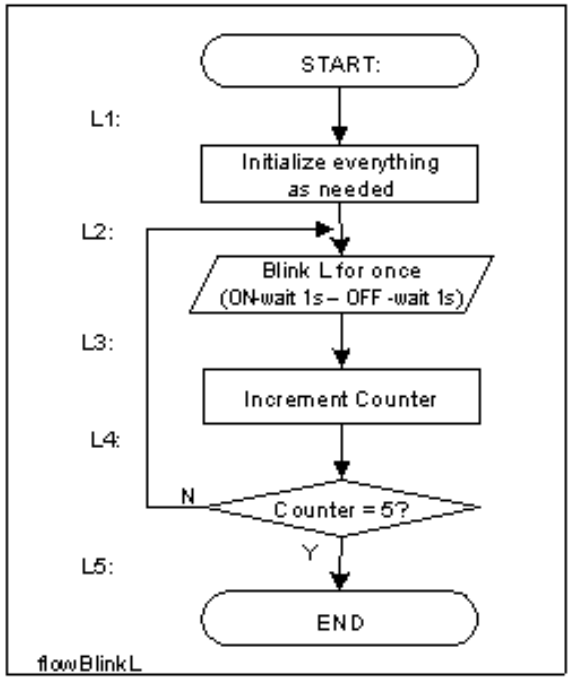
Example flow chart



Representing Flow/Decision Making

Flow charts

What does this flow chart do?



Representing Flow/Decision Making

Pseudo Code

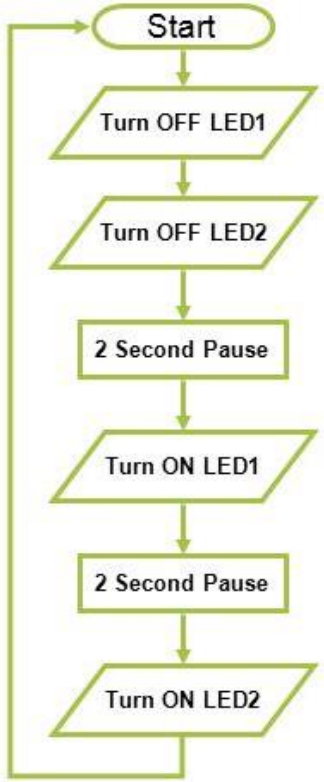
Looping Flow Example

Pseudo-Code:

Start of program

- Turn off LED 1
- Turn off LED 2
- Pause for 2 seconds
- Light LED 1
- Pause for 2 seconds
- Light LED 2
- Go back to start

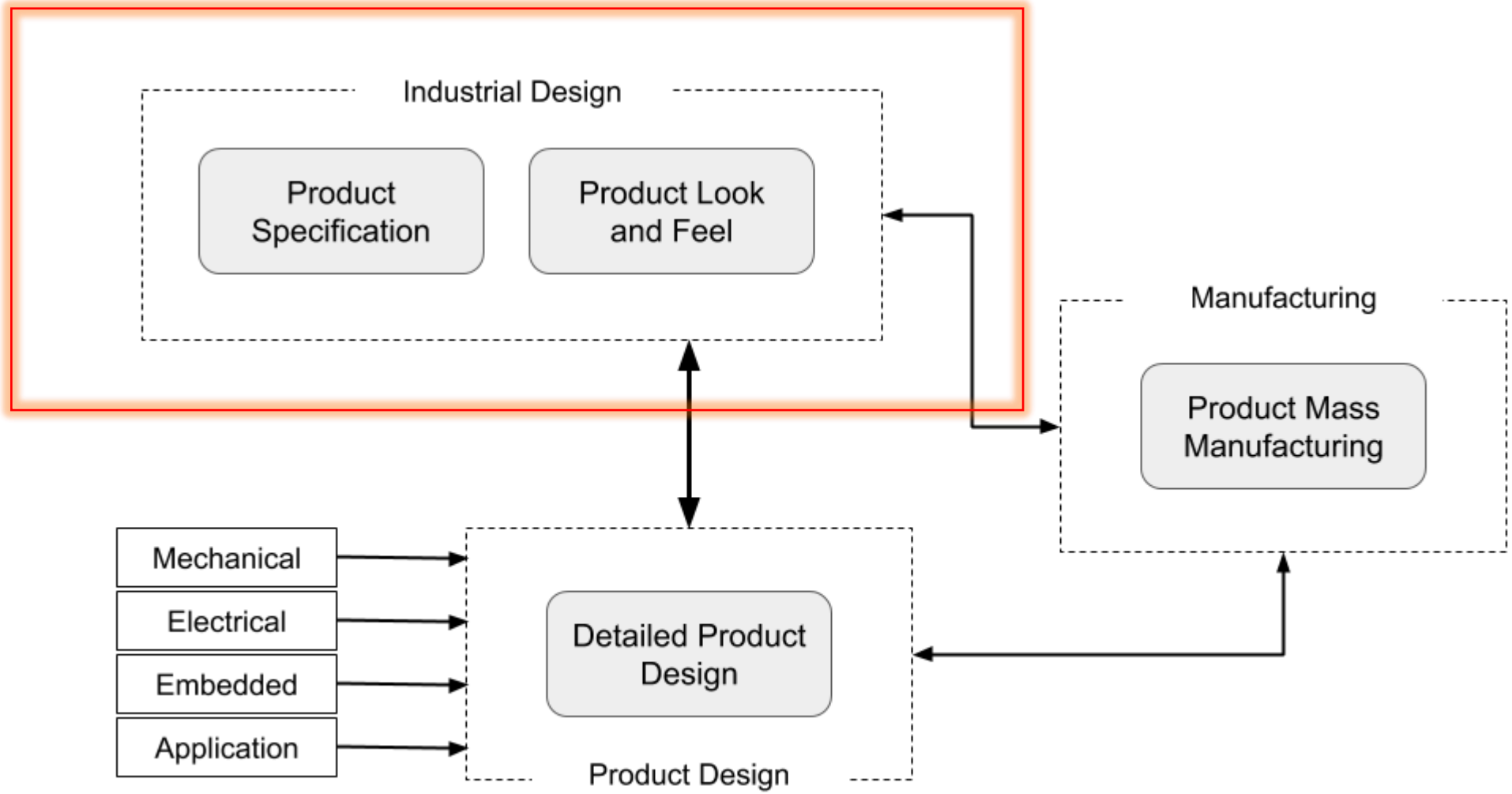
Flowchart:



- Finalized concept
- Finalized key engineering concept
- Demonstrated proof-of concept
- Work-like prototype
- Communicated concepts (drawings)

What next?

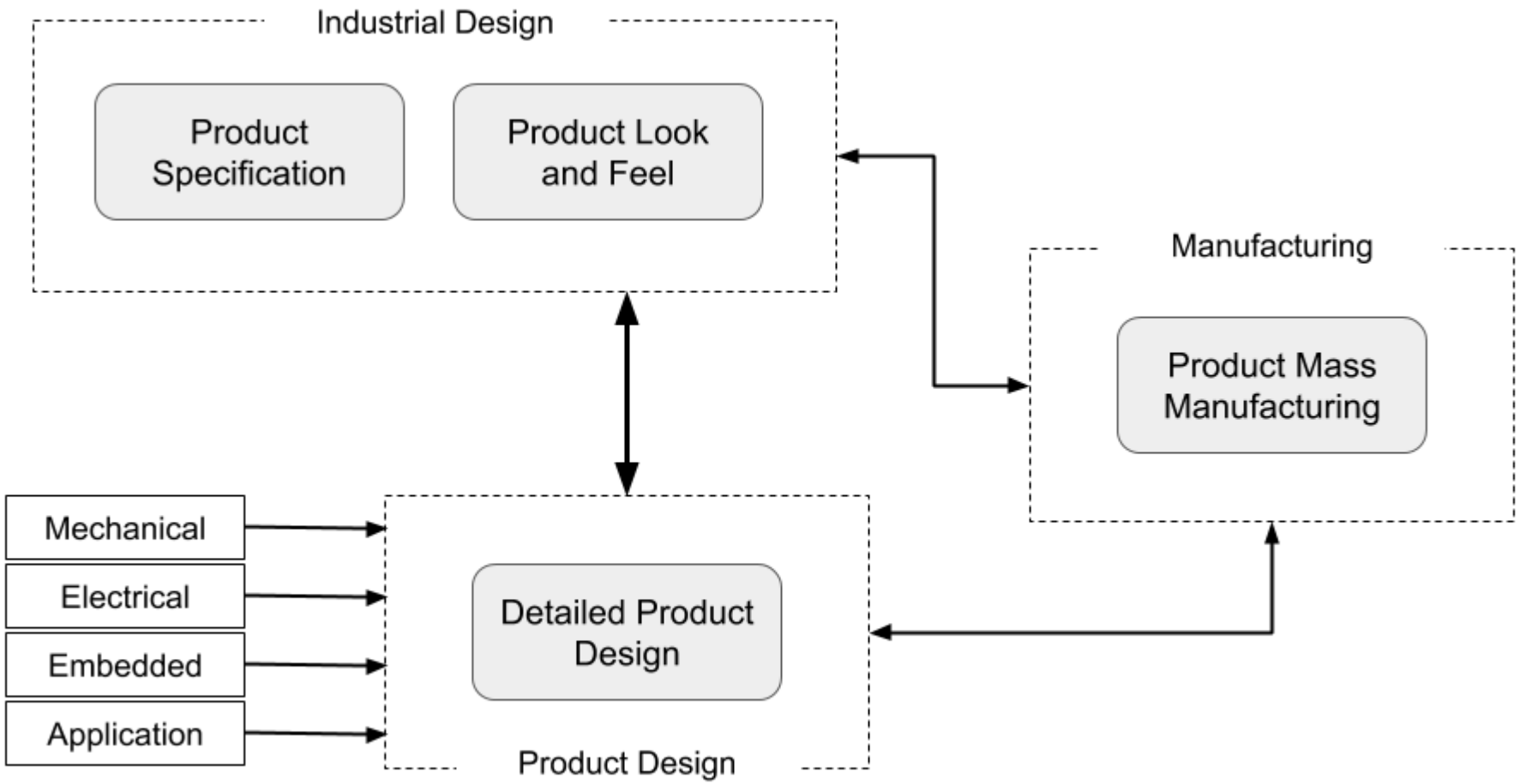
1) Industrial Design
2) Design for Manufacture


Industrial Design
Product Specification
Product Look and Feel
Manufacturing
Product Mass Manufacturing
Mechanical
Electrical
Embedded
Application
Detailed Product Design
Product Design

What is Industrial Design?

“(...) the professional service of creating and developing concepts and specifications that optimize the function, value, and appearance of products and systems for the mutual benefit of both user and manufacturer.”

Industrial Designers Society of America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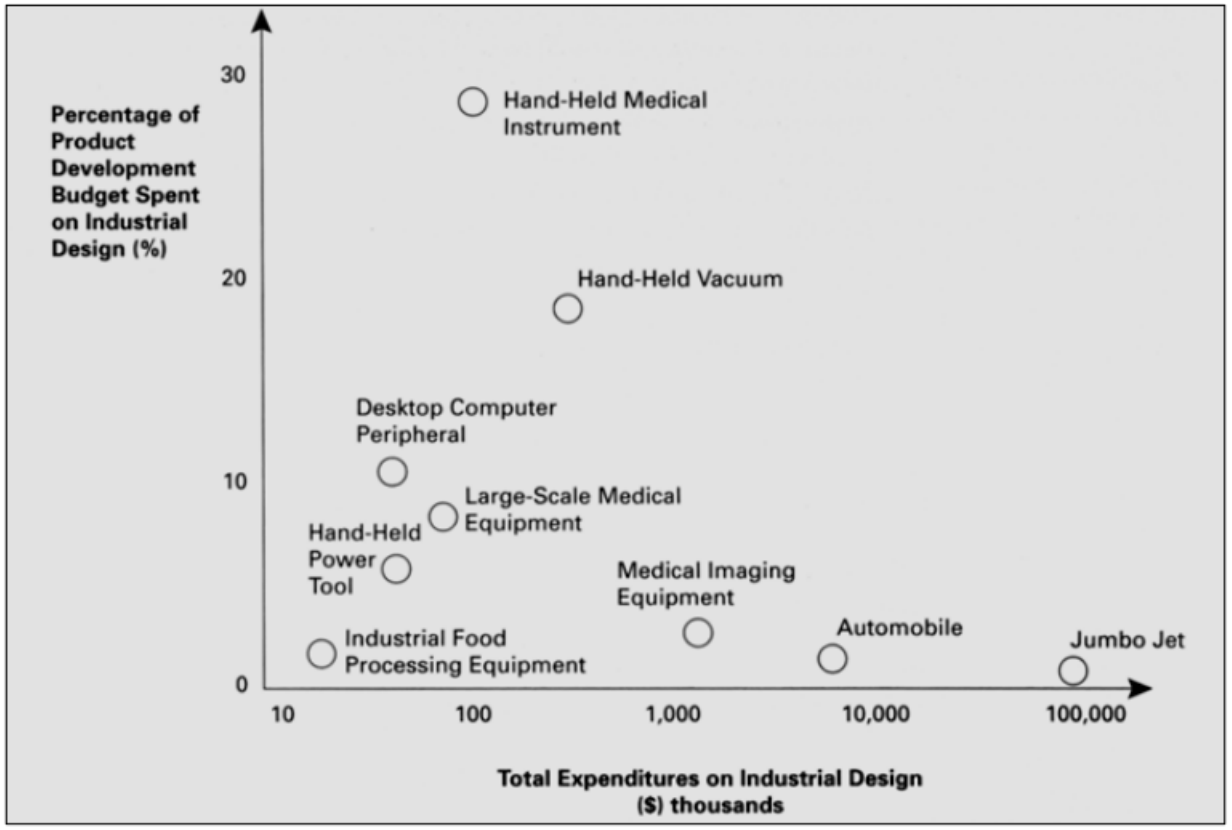
5 Goals of Industrial Design

- Utility
- Appearance
- Ease of maintenance
- Low costs
- Communication

How important is industrial design?

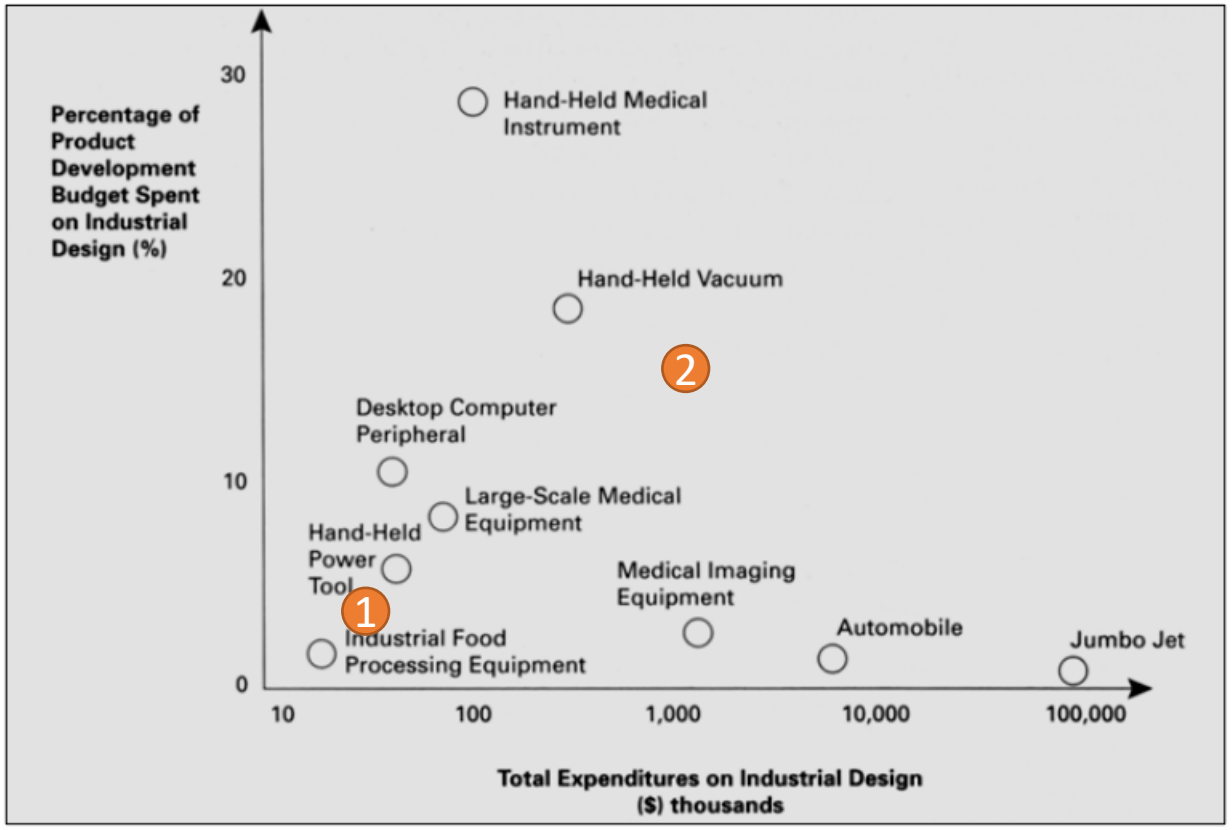


Where would you put:

1. Robot gripper for item handling
2. Mobile Phone

...varies with task

How important is industrial design?



Where would you put:

1. Robot gripper for item handling in factory
2. Mobile Phone

...varies with task

How important is industrial design?

Ergonomic needs

– How important is ease of use?
– How important is ease of maintenance?
– How many user interactions are required?
– How novel are the user interaction needs?
– What are the safety issues?

Aesthetic needs

– Is visual differentiation required?
– How important are pride of ownership, image and fashion?
– Will an aesthetic product motivate the team?

Needs	Level of Importance	Explanation of Rating
	Low Medium High	
Ergonomics		
Ease of use		Critical for a portable telephone since it may be used frequently, may be needed in emergency situations, and can be operated by motorists while driving. The product's function must be communicated through its design.
Ease of maintenance		As with many integrated electronics products there is very little maintenance required.
Quantity of user interactions		There are many important user interactions such as: changing the battery, dialing, programming the features, sending and receiving calls.
Aesthetics		
Product differentiation		There were hundreds of models of cellular pones on the market when the StarTAC was introduced. Its appearance (including its size and shape) was essential for differentiation.
Pride of ownership, fashion, or image		The StarTAC was intended to be a highly visible product used by people for business and personal communication in public areas. It had to be physically attractive for everyday use.
Team motivation		The StarTAC's novel form turned out to be an important inspiration to the development team and selling point for senior management.

StarTAC

The First Flip phone

The Impact of ID…

Is ID worth the investment?

- Direct cost
- Manufacturing cost
- Time cost

How does ID establish a corporate identity?

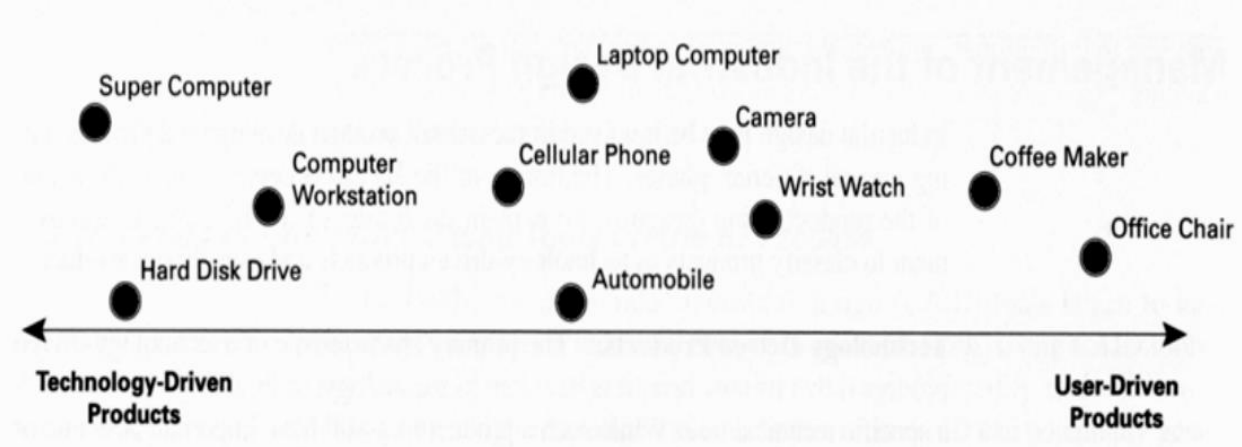
– Apple Computer, Inc.
– Rolex Watch Co.
– Braun AG
– Bang & Olufsen
– Motorola, Inc.

Iconic Examples of Industrial Design

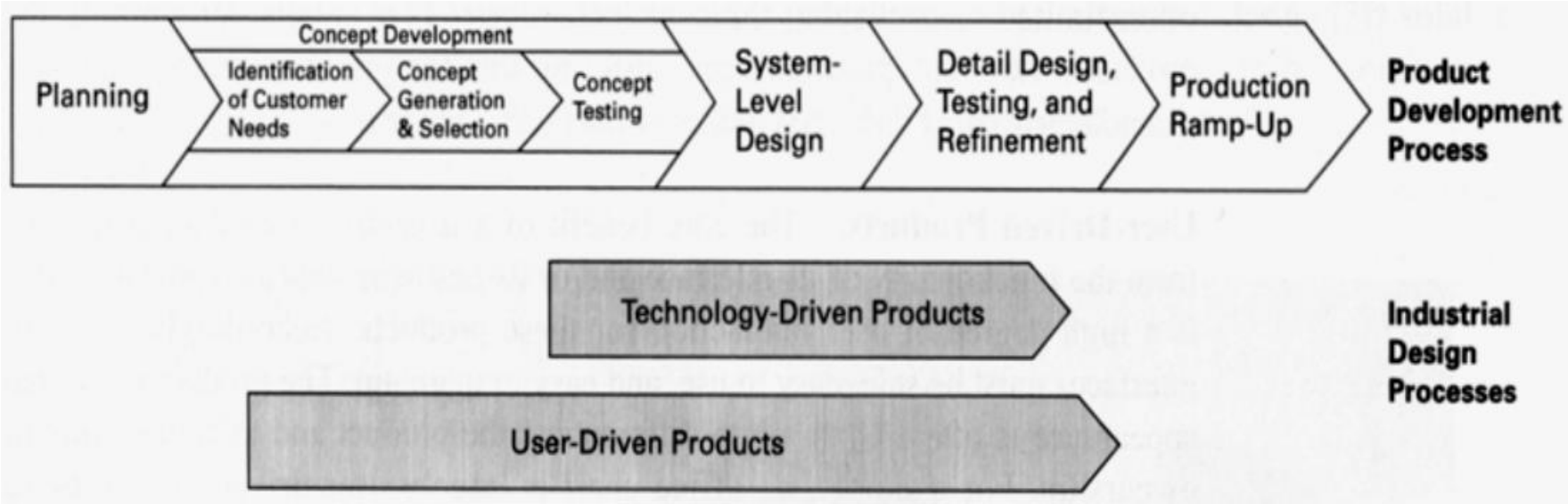
Ergonomics & Aesthetics help make these products stand out

Management of ID Process

- Technology-driven products
- User-driven products



Management of ID Process



- Can have pure product development or industrial design
- Most-likely blend and combine

Product Development Activity	Type of Product	
	Technology-Driven	**User-Driven**
Identification of Customer Needs	ID typically has no involvement	ID works closely with marketing to identify customer needs. Industrial designers participate in focus groups or one-on-one customer interviews
Concept Generation and Selection	ID works with marketing and engineering to assure that human factors and user-interface issues are addressed. Safety and maintenance issues are often of primary importance	ID generates multiple concepts according to the industrial design process flow described earlier
Concept Testing	ID helps engineering to create prototypes, which are shown to customers for feedback	ID leads in the creation of models to be tested with customers by marketing
System-Level Design	ID has typically little involvement	ID narrows down the concepts and refines the most promising approaches
Detail Design, Testing and Refinement	ID is responsible for packaging the product once most of the engineering details have been addressed. ID receives product specifications and constraints from enginering and marketing	ID selects a final concept, then coordinates with engineering, manufacturing and marketing to finalize the design

Assessing the quality of ID

Metrics for assessing ID:

- Quality of the user interfaces
- Emotional appeal
- Ability to maintain and repair the product
- Appropriate use of resources
- Product differentiation

Can be subjective…
May not appeal to all

Assessing the quality of ID

Assessment Category	Level of Importance (Low / Medium / High)	Explanation of Rating
1. Quality of the User Interfaces	High	In general, the StarTAC is both easy to use and comfortable. For example: calls can be answered by simply opening the keypad cover, numbers can be easily dialed into the keypad, and the functions are readily accessible. The StarTAC's drawbacks include that the visual display can be difficult to interpret because it mixes upper- and lower-case alphabetic characters, and that some users inadvertently remove the battery when attempting to open the phone for the first time.
2. Emotional Appeal	High	The StarTAC has a high emotional appeal which stems from its sleek appearance and tiny size.
3. Ability to Maintain and Repair the Product	Medium	Although maintenance and repair are not of primary importance to the customer, the StarTAC rates high in this category. The battery can be removed and replaced easily. Customers can install various batteries depending on their preference for size, weight, and talk time.
4. Appropriate Use of Resources	Medium	The final design includes only those features that satisfy real customer needs. Materials were selected to satisfy manufacturing constraints, to withstand extreme environmental conditions, and to meet strict appearance criteria.
5. Product Differentiation	High	The StarTAC's appearance is clearly unique. It is easily identified when viewed in a public area or next to a competitor's product.

StarTAC

The First Flip phone

Summary

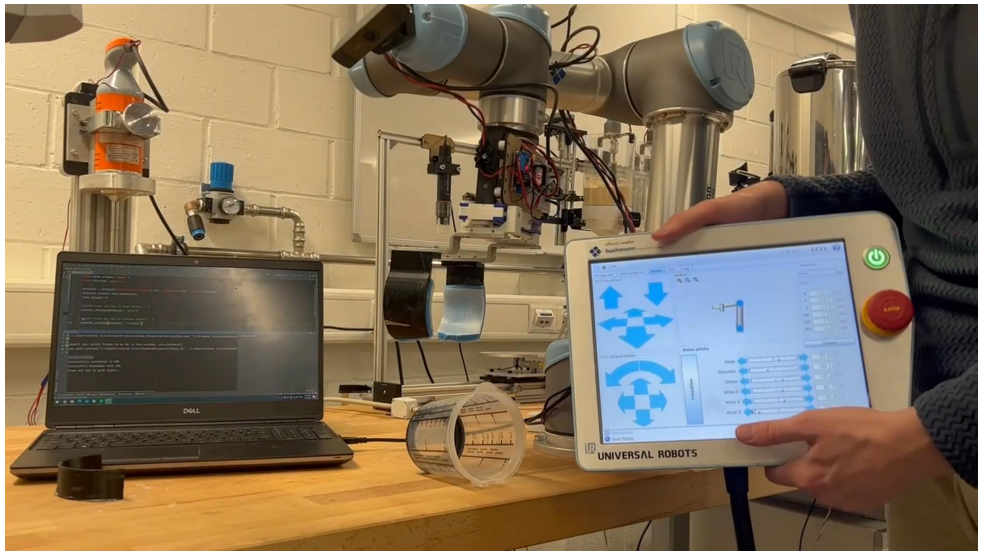
- The primary mission of ID is to design the aspects of a product that relate to the user: aesthetics and ergonomics
- Most products can benefit in some way or another from ID.
- When the success of a product relies more on technology, ID can be integrated into development process later.

Project

General Advice:

- Integrate and test early – this takes time
- Something is better than nothing
  - Taking some small scarifies in capabilities but getting a reliable system could be sensible
- Keep it simple (e.g. fewer actuators/sensors have fewer points of failure)
- Testing is super important

Controlling Program Flow

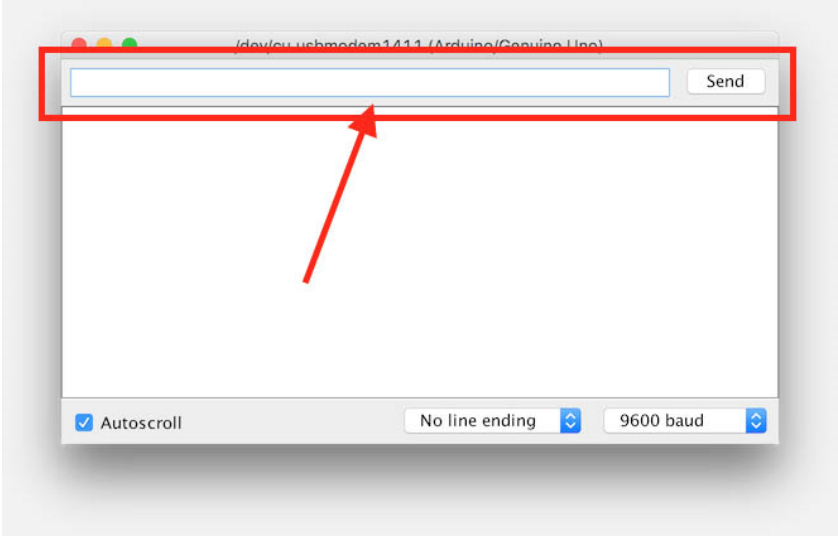


Trigger the different parts of the code

Use serial inputs to control the process flow on Arduino.

Wait for serial inputs

```
void setup() {
  Serial.begin(9600);

  Serial.println("1. Close");
  Serial.println("2. Sense");
  Serial.println("3. Open");
}

void loop() {
  Serial.println("Which process would you like to do ");

  while (Serial.available() == 0) {
  }

  int menuChoice = Serial.parseInt();

  switch (menuChoice) {
    case 1:
      // Gripper Close code
      Serial.println("Closing Gripper");
      break;

    case 2:
      // Sensing
      Serial.println("Object is xxxx");
      break;

    case 3:
      // Gripper Open
      Serial.println("Opening Gripper");
      break;


    default:
      Serial.println("Please choose a valid selection");
  }
}
```



Electronics

Generating more Male/Female connectors, or making them an arbitrary length…

DuPont Connector Kit…