Build4 Scale

U.S. Department of Energy

Design for Manufacturing, Assembly, and Reliability

Module 3F Manufacturing Electronic Components

Motivation

Why is this module important?

- Module 3D outlines general design for manufacturing and assembly processes (DFMA). This module focuses on insights relating specifically to electronics assembly.

Key points, mentioned in 3D, that are relevant here:

- DFMA can determine how much you pay for production tooling and how much it costs to assemble your product
- DFMA can affect:
  - —Manufacturing cost and quality
  - —Production cycle time-and-fixture costs
  - —Production and supply-chain complexity
  - —Production personnel morale

Module Outline

- Learning objectives
- Design for manufacturing (DFM) and assembly process for electronics
  - —Process Flow
  - —Type of Circuit Boards
  - —Bill of material (BOM): List of parts
  - —Schematic Diagram: Placement of parts
  - —Design for X, unique to electronics
    - Assembly
    - Excellence
    - Operating conditions

Learning Objectives

- LO1. Understand fundamentals of electronics assembly
- LO2. Understand reliability aspects that must be taken into consideration when manufacturing electronics

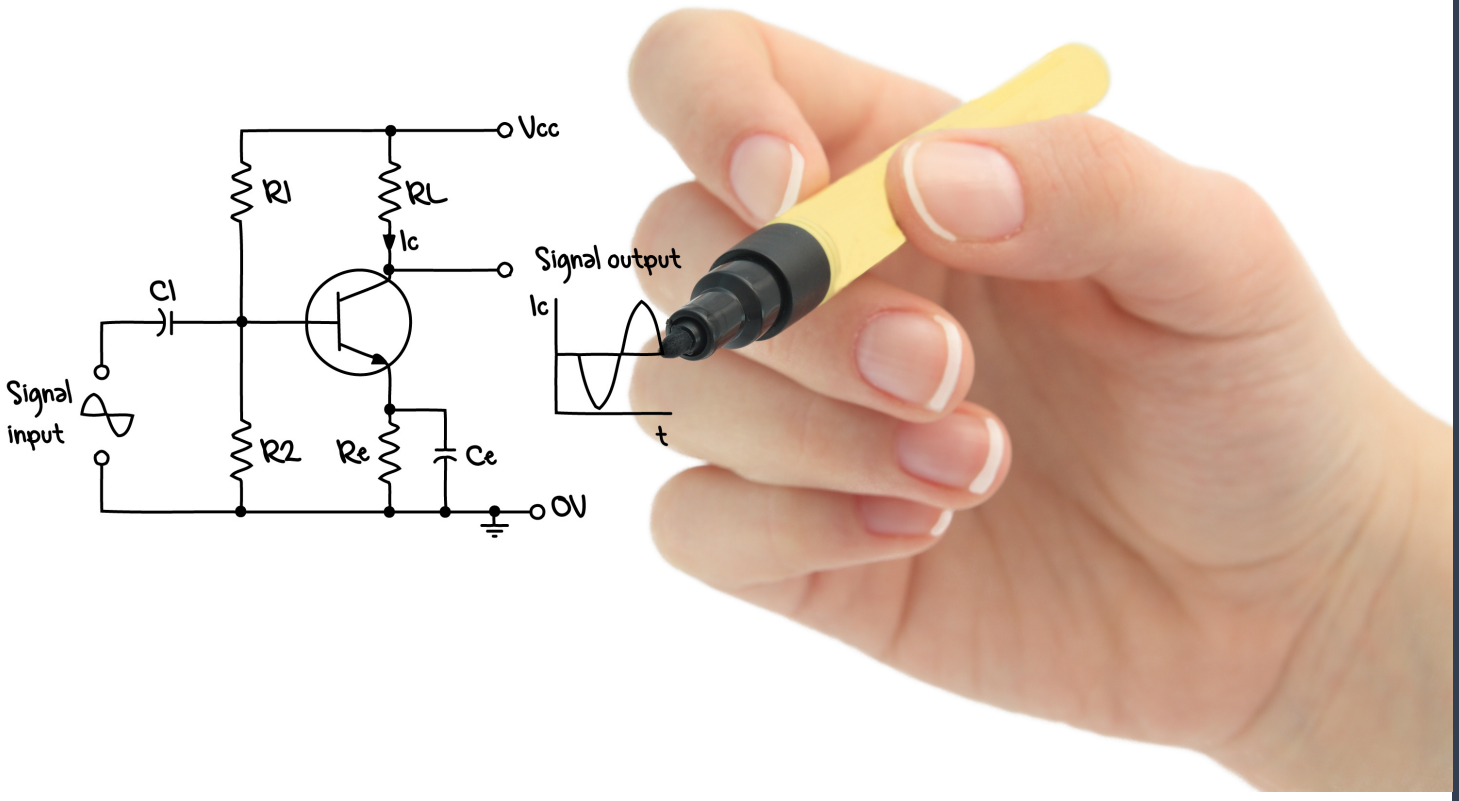
Manufacturing Electronics

Process flow

Block Diagram

Basics

- A basic figure indicating all the components included and their connections



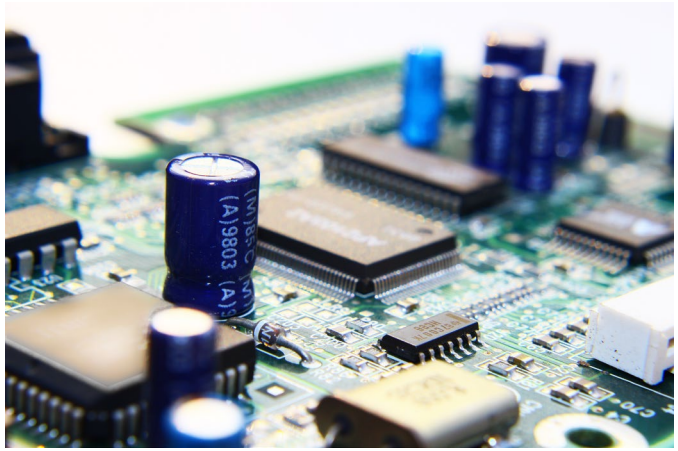
Circuit Boards

Types

Solderless:

- Uses Breadboards as base to connect circuits
- Becomes very messy for more complicated circuit
- Less cost
- Mainly used in prototyping and testing

Quantity	Cost per unit[2]
1–9	$5.95
10–99	$5.36
100+	$4.76



Circuit Boards

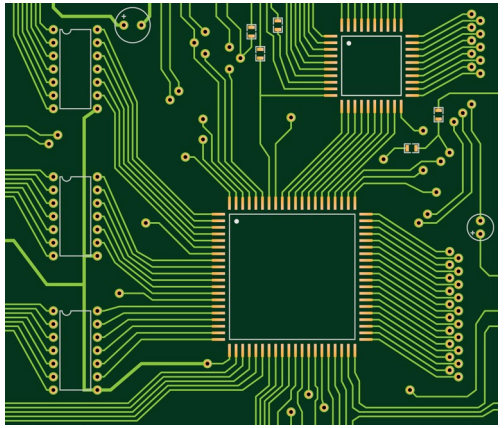
Types (cont.)

Soldering:

- Uses printed circuit boards (PCB) as base
- Widely used replacing breadboards in all applications
- Costlier
- Sturdier and more reliable design

Quantity	Cost per unit[2]
1–9	$8.95
10–99	$8.06
100+	$7.16

Printed Circuit Board



Bill Of Materials

Basics

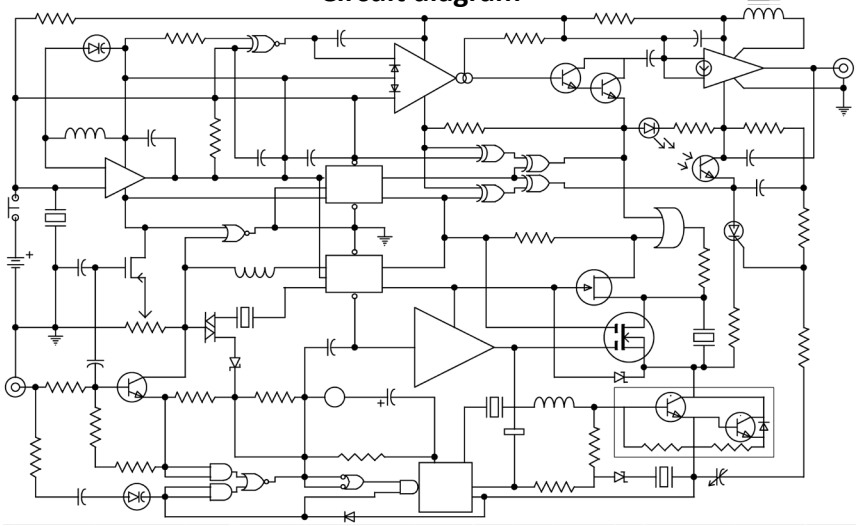
- Similar to their mechanical analogs, electronic boards have a BOM as well
- It is a list of all the parts required to make the end product
  - —Boards
  - —Semi-conductors (diodes, resistors etc.)
  - —Passives
  - —Microcontrollers

Schematic Diagram

Basics

- Explains the placement of each part on the board
- Has all the information about board dimensions, parts, and their positions as well as the assembly methods
- Called **Gerber files**, in the market, are used as communication between the customers and manufacturers

Circuit diagram



Design For X

Design for excellence

While designing the layout, many things have to be considered for successful conversion of an idea into a marketable product

Design for manufacturability:

- DFM are guidelines to make the manufacturing process of the product as easy, cost and time efficient in the design process
- This allows the designer to be aware of manufacturing tolerances and technological challenges in production while designing

Design For X

Design for excellence (cont.)

Design for assembly:

- DFA ensures that the system design facilitates the process of system assembly
- This focuses on designing a system that allocates the minimum required rotations for assembly and minimum possibility of incorrect assembly
- These systems are best for easier, quicker, and error-free parts insertion
  - —The feature of early detection of errors makes the DFA approach valuable for time and cost saving

Design For X

Design for excellence (cont.)

Design for performance:

- For a product to perform to its best, operating conditions play a key role
- It is best to consider the environment of its operation early in the design stage

Design For X

Operating conditions and effects

Moisture:

- Humidity interrupts with flow of current in form of condensation, decreases resistance of capacitors, increases losses in transistor and often results in short circuits
- Can be avoided by use of packaging with material of low water vapor transmission rate (polypropylene) and desiccant (silica gel)

Vibration:

- Electronic products are subject to a range of vibrations based on the applications—
  One example of heavy vibration and shock are in racing cars
- To overcome the physical wear and defects isolators, enclosure frames, stiffeners and braces can be used

Design For X

Operating conditions and effects (cont.)

Dust:

- Small particles mixed with water vapor can get accumulated on the circuit board
- Main consequences are short circuits and dust combustion
- Can be avoided with enclosures and clean environment

Design For X

Operating conditions and effects (cont.)

Temperature:

- Many times a high temperature tolerance is expected of the electronics in fields like automotive
- By adopting temperature tolerant fabricating technology of Silicon on Insulator (SOI) the values can be increased up to 380°C from 150°C
- But when system requirement go beyond these numbers, cooling systems can be used

Design For X

Operating conditions and effects (cont.)

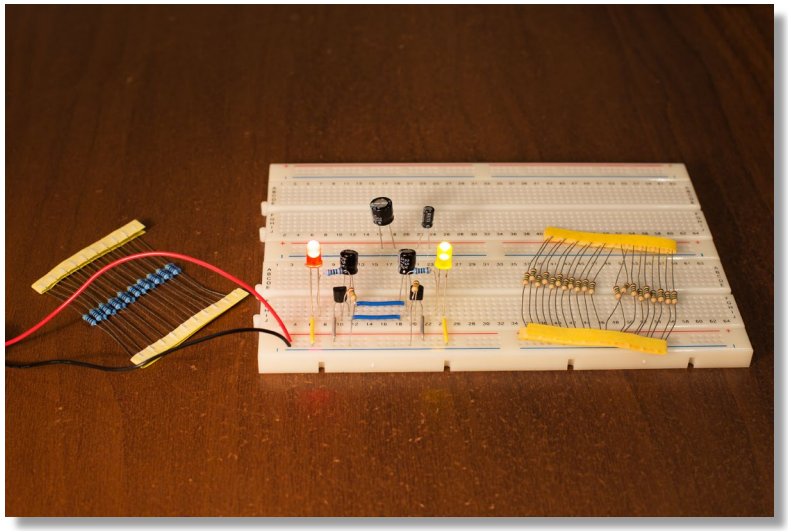
A variety of thermal management options are available such as:

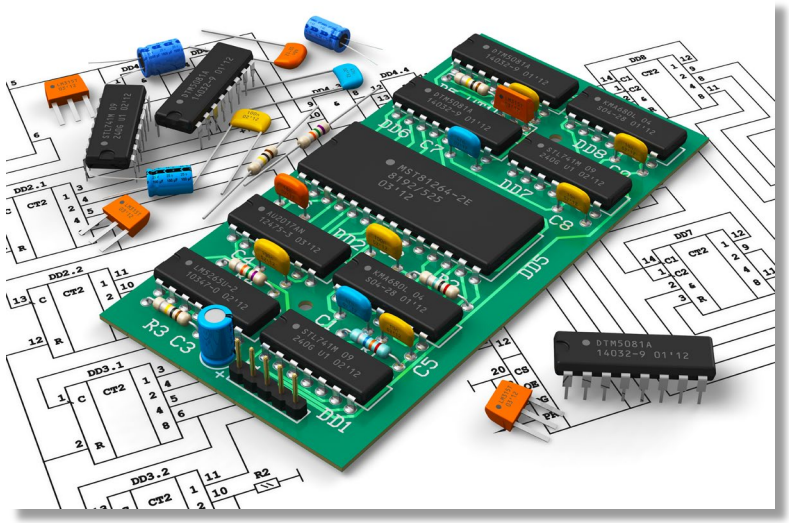
- **Active Cooling**: Achieved by introduction of external force such as a fan or coolant to bring the temperature to operational range
- **Passive Cooling**: The processors are slowed down in order to match the temperature standards

Soldering/Connecting

Considerations

- All the appropriate connections have to be made in chosen way
- This can be done in-house, but requires skilled labor and technology (machines) especially for the soldering type





Soldering/Connecting

Considerations (cont.)

- Lot of vendors available in market for fabrication given the Gerber files

Examples: Bittele, Barebones PCB, etc.

- Cost mostly depends on the quantity to be produced and technology required
- Getting quotes from multiple vendors helps in determining cost efficient way for a certain application

Quantity	Cost per Unit
1–25 (Prototype)	$15–$22
100+(Small scale)	$7–$12

References

- Hobbyprojects [n.d.] Blog post
  http://www.hobbyprojects.com/block_diagrams/block_diagrams.html
- Adafruit Products Retail
  https://www.adafruit.com/product/239
- Cost estimate as given by bittele
  http://www.7pcb.com/PCB-Assembly-Quote.php?d3=0&d5=1&c6=100&c8=2&c11=0&c13=1&c18=1&c20=1&c23=2&c25=0&send=Calculate&x=0&y=0#
- Popular Science [n.d.] Blogpost
  http://www.popsci.com/diy/article/2009-09/getting-your-circuit-boards-professionally-printed

List Of Terms

In glossary

- **Block Diagram** is a diagram of a system in which the principal parts or functions are represented by blocks connected by lines that show the relationships of the blocks
- **Schematic Diagram** is a representation of the elements of a system using abstract, graphic symbols rather than realistic pictures.
- **Soldering** is a process in which two or more items (usually metal) are joined together by melting and putting a filler metal (solder) into the joint, the filler metal having a lower melting point than the adjoining metal.
- **Gerber Files** is an open ASCII vector format for 2D binary images. It is the de facto standard used by printed circuit board (PCB) industry software to describe the printed circuit board images: copper layers, solder mask, legend, etc.
- **Active Cooling** is a design approach that uses fans and other auxiliary assistance to cool a component, such as a processor.
- **Passive Cooling** is a design approach that uses natural cooling through slowing the speed at which a component, such as a processor is operating and through ventilation without auxiliary assistance.