

Design & Fabrication

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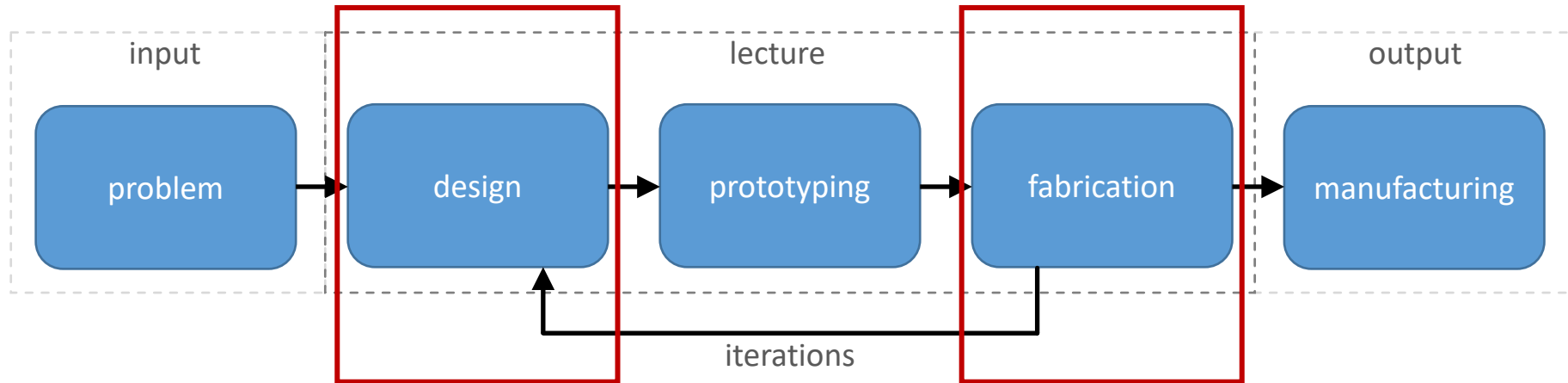
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From Design to Fabrication

Recapitulation



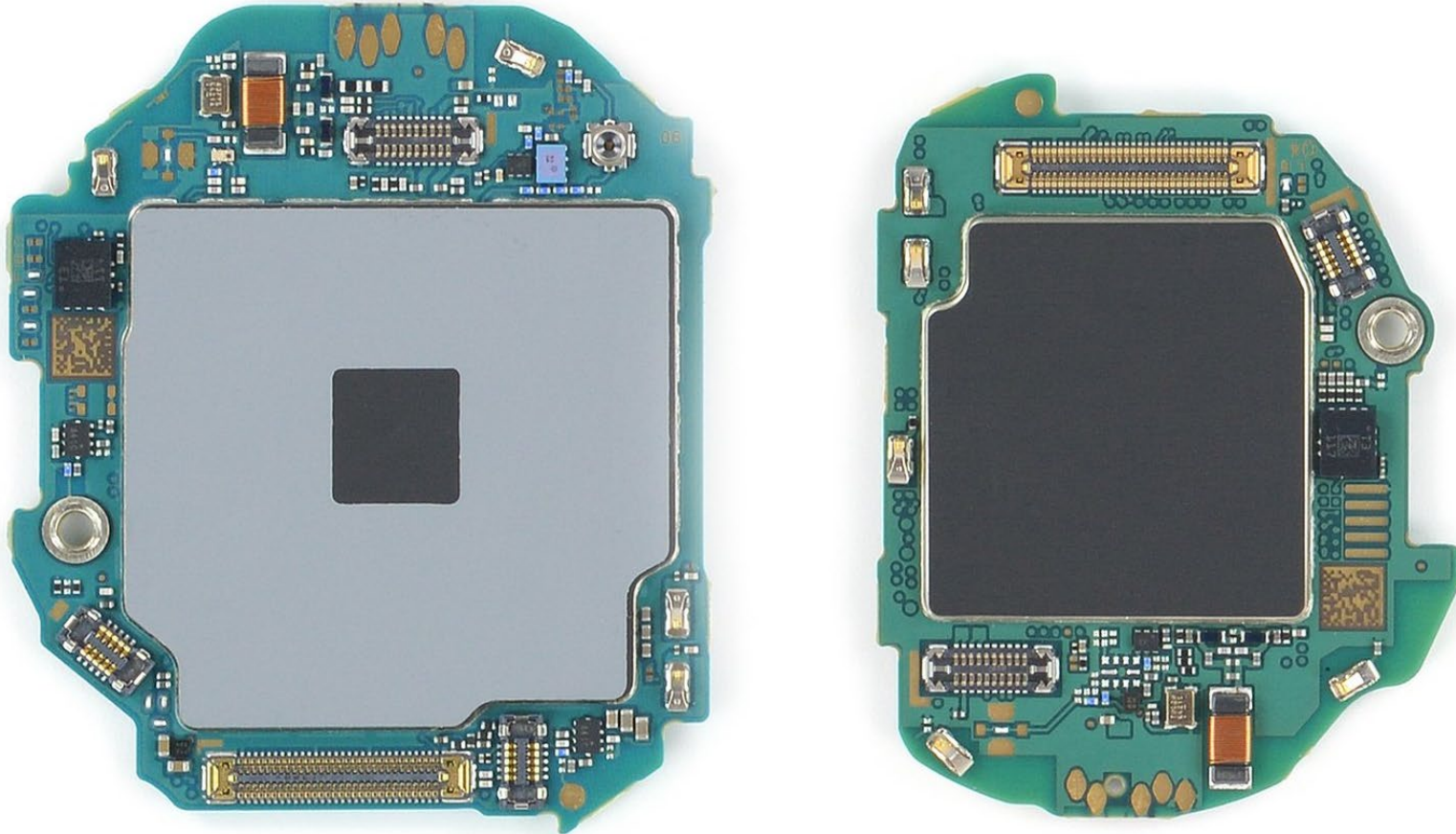
Lecture 8

Electronic Circuit Design

Electronic Circuit Design

Motivation

Samsung Galaxy Watch 4



Electronic Circuit Design

History

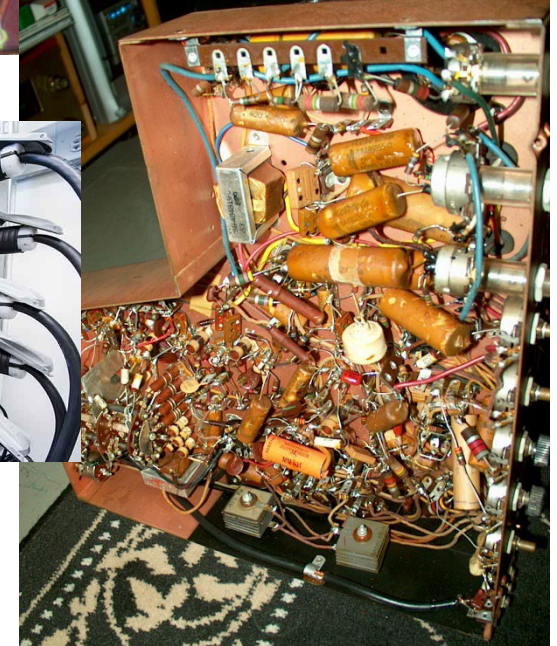
Point-to-Point Construction

- › Standard until the 1950s
- › **Wired connection** of components
- › Still normal in power electronics
- › **Prototyping**
 - › Breadboard & jump wires
 - › Stripboard (e.g. Veroboard)

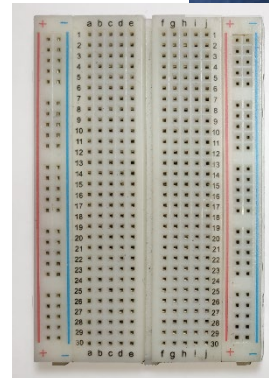
Military radio equipment



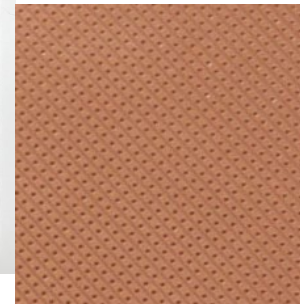
Power electronics



Underside of a Motorola TV (1948)



Breadboard



Stripboard

Electronic Circuit Design

History

Printed Circuit Boards

- › Introduced in the 1950s
- › FR4: epoxy-laminated fibers
- › Cu: Copper foil and plating



Components

Electronic Circuit Design

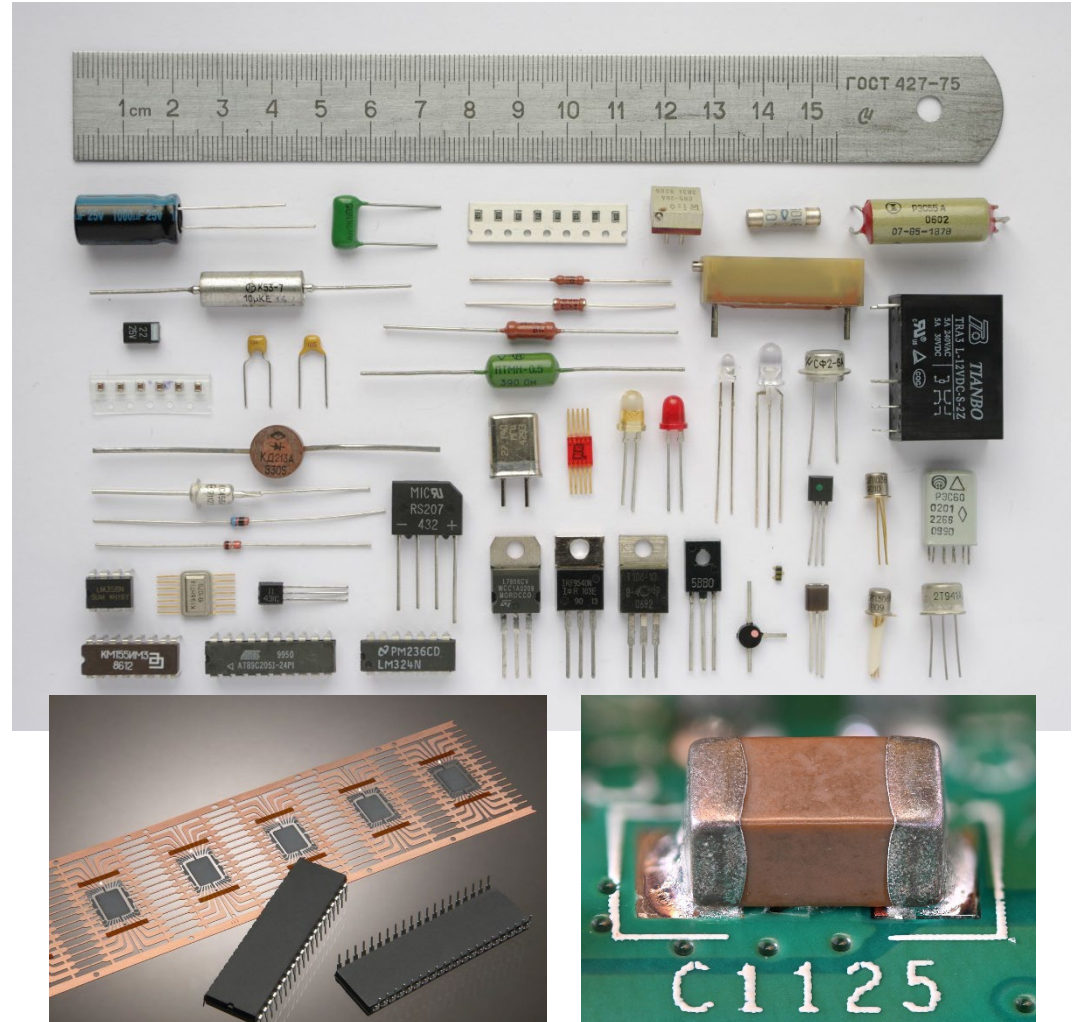
Components

Mounting Technologies

- › Through-Hole Technology (THT)
 - › Leads inserted through holes, drilled through pads on a PCB
- › Surface-Mount Technology (SMT)
 - › Mounted planarly on pads

Packages

- › Mechanical protection and fixation
- › Number of pins (lead frame)
- › Thermal dissipation / cooling



Electronic Circuit Design

Components

Classification

› Passive

- › Incapable of controlling current in a circuit
- › E.g., resistors, capacitors, inductors, transformers, ...

› Active

- › Can inject or control power in a circuit
- › E.g., power sources and semiconductors such as transistors, integrated circuits, ...

› Electromechanic

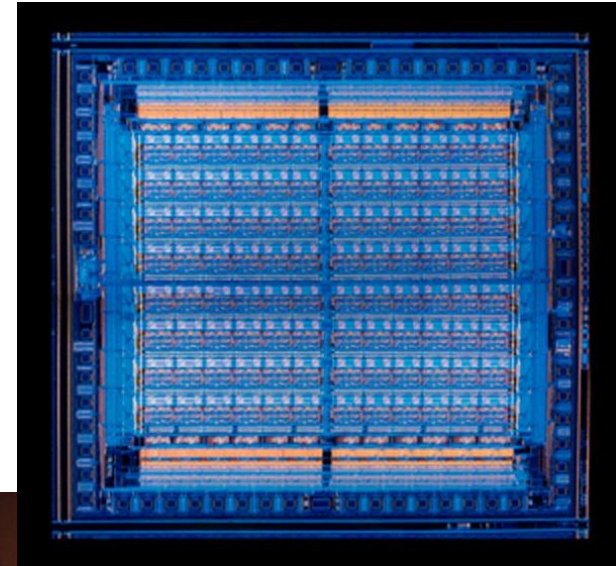
- › Carry out electrical operations by using moving parts or electrical connections
- › E.g., connectors, switches, crystal/MEMS resonators, microphones, motors, relays, ...

Electronic Circuit Design

Components

Integrated Circuits

- › Set of **miniaturized** electronic circuits on one piece of semiconductor
- › Large number of transistors and other components
- › **Higher density** results in **lower costs**, **signal delays**, and **power dissipation**



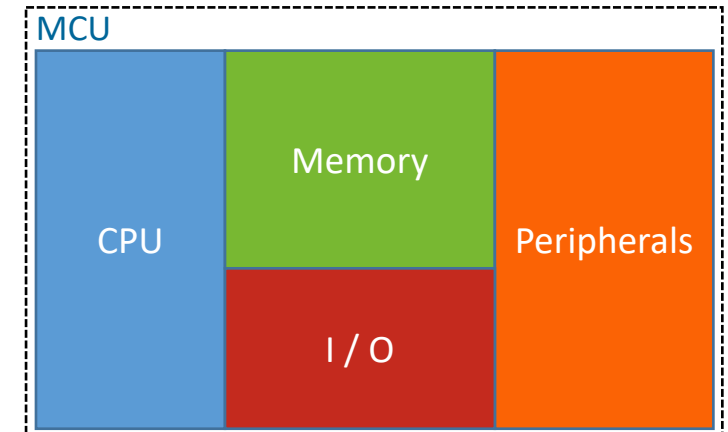
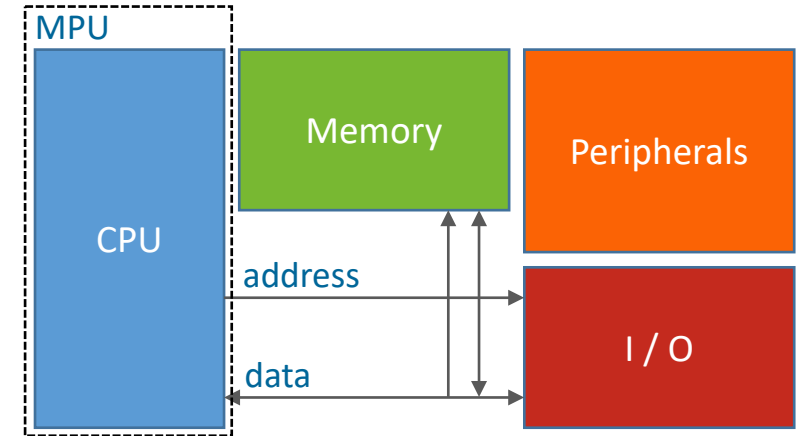
Operators hand-cut IC designs into Rubylith film, which is then optically reduced to a photolithography mask. (Intel, 1991)

Electronic Circuit Design

Components

Microprocessor vs. Microcontroller

- › Microprocessor Unit (MPU)
- › Microcontroller Unit (MCU)
- › Miniaturized computer on a **single chip**
- › **Same components** as a computer

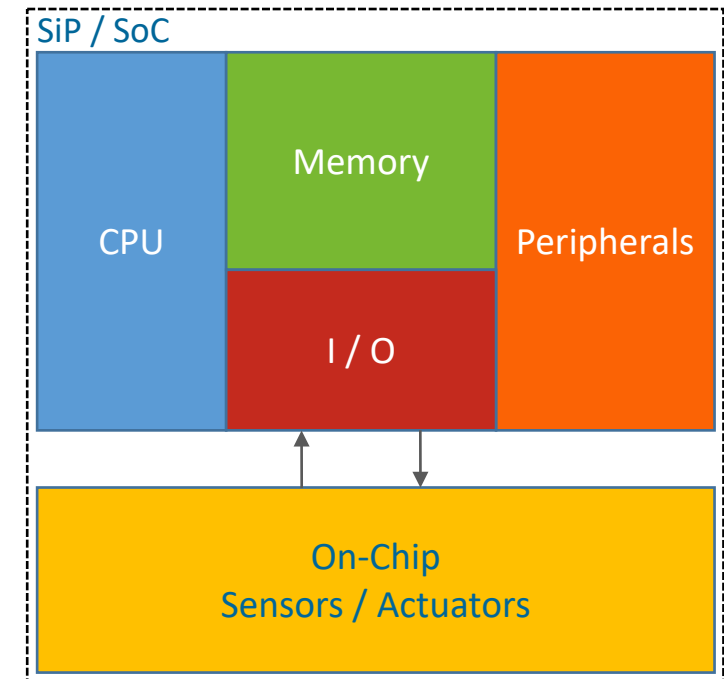


Electronic Circuit Design

Components

Fully-Integrated Systems

- › Next level of miniaturization and integration
- › System-in-Package (SiP)
- › System-on-Chip (SoC)
- › **Modularity** and versioning
- › Shorter leads, lower impedances, **less noise**
- › Precise **fine-tuning** at manufacturer (trimming)
- › Easier circuit design and prototyping

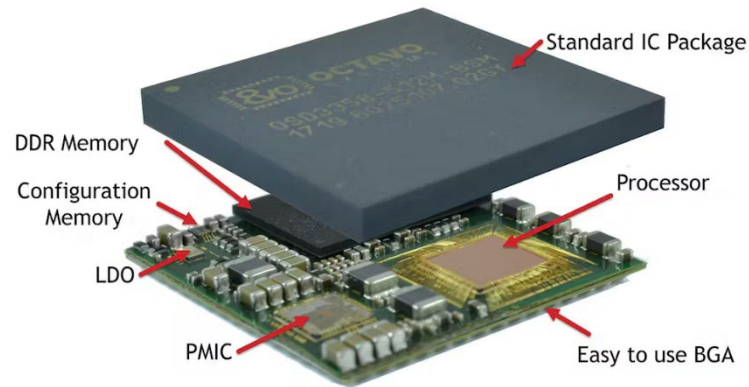


Electronic Circuit Design

Components

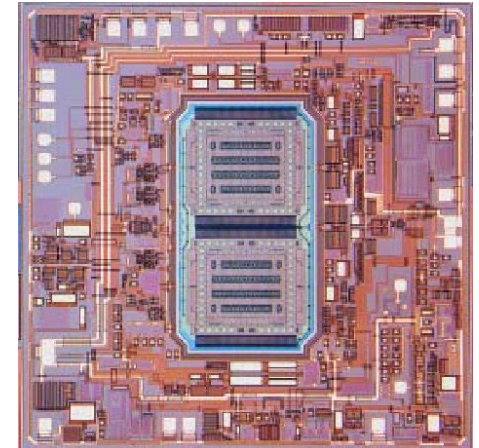
System-in-Package (SiP)

- › Multiple chips and components
- › Printed Circuit Board (PCB) or air wires
- › Example: 21 x 21 mm²



System-on-Chip (SoC)

- › Single substrate (e.g., silicon)
- › Multiple blocks / standard cells
- › Application-specific IC (ASIC)
- › Example: 7 x 7 mm²



SiP or SoC?



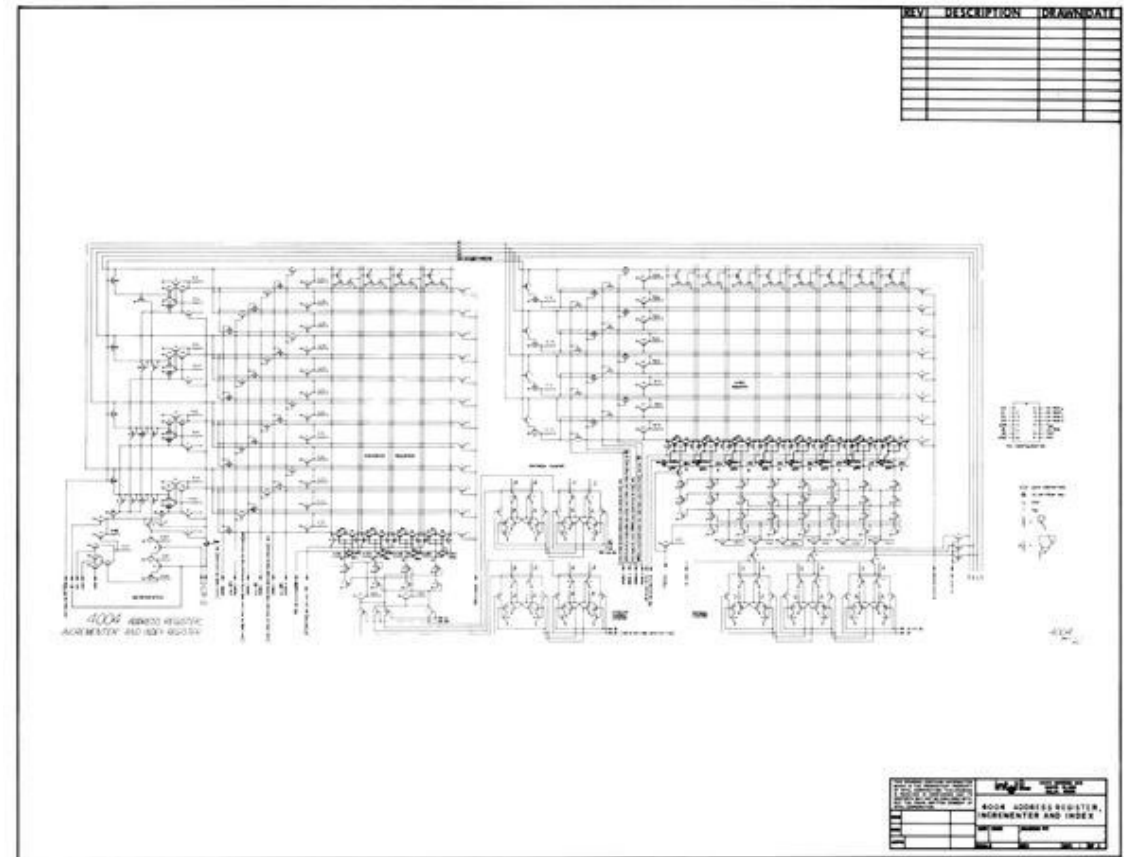
Schematics

Electronic Circuit Design

Schematics

Schematics





































































































- › Abstract representation of electronic circuits
- › Standardized symbols
- › Basis for simulation
- › Basis for PCB design



Electronic Circuit Design

Schematics

Symbols

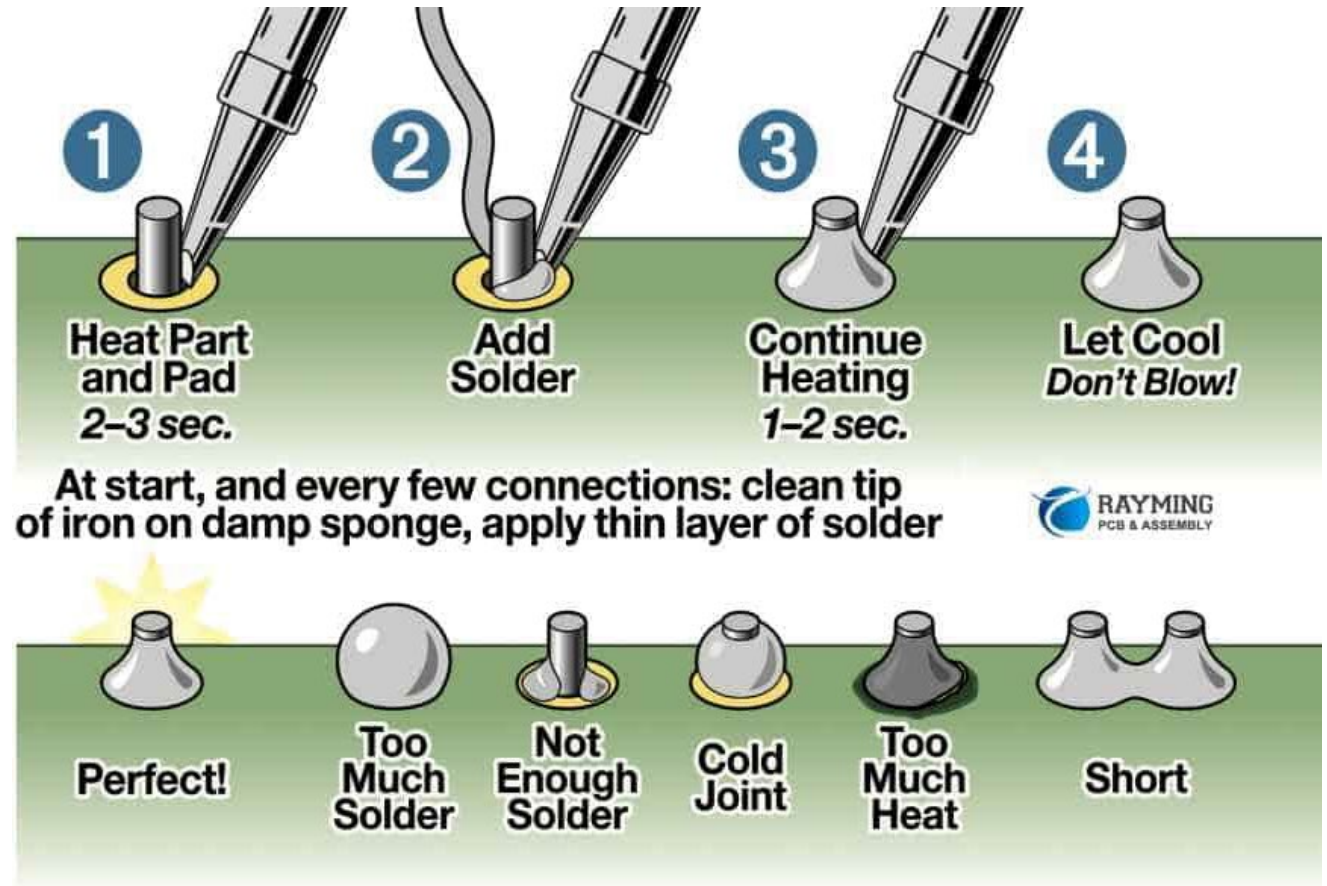
 Signal ground	 Cell	 Push switch	 NOT gate	 Fuse	 NPN transistor	 Photo Darlington	 Constant Current Diode	 Varistor	 Joined wires
 Chassis Ground	 Battery	 Push-to-break switch	 AND gate	 Crystal Oscillator	 PNP transistor	 Diode	 Laser Diode	 Magneto Resistor	 Wires
 Basic Amplifier	 DC supply	 On-off switch (SPST)	 NAND gate	 ADC	 Phototransistor	 Light Emitting Diode	 Capacitor	 Tapped resistor	 Disjointed wires
 Operational Amplifier	 AC supply	 2-way switch (SPDT)	 OR gate	 DAC	 Field Effect Transistor	 Zener Diode	 Polarised capacitor	 Attenuator	 Input bus line
 Microphone	 Constant Current Source	 Dual on-off switch (DPST)	 NOR gate	 Thermocouple	 N-channel JFET	 Photo Diode	 Variable capacitor	 Memristor	 Output bus line
 Earphone	 Controlled Current Source	 Reversing switch (DPDT)	 EX-OR gate	 Heater	 P-channel JFET	 Tunnel Diode	 Trimmer capacitor	 Voltmeter	 Terminal
 Loudspeaker	 Controlled Voltage Source	 Relay	 EX-NOR gate	 Iron Core Inductor	 N-channel Enhancement MOSFET	 Schottky Diode	 Resistor	 Ammeter	 Bus line
 Piezo- transducer	 Fuse	 Antenna	 Lamp	 Ferrite Core Inductors	 N-channel Depletion MOSFET	 Varactor Diode	 Rheostat	 Galvanometer	 Sinusoidal generator
 Bell	 Transformer	 Loop Antenna	 Light Bulb	 Center Tapped Inductors	 LDR	 Shockley Diode	 Potentiometer	 Ohmmeter	 Pulse generator
 Buzzer	 Earth	 Dipole Antenna	 Motor	 Variable Inductorsv	 Thermistor	 Thyristor	 Preset	 Oscilloscope	 Triangular wave

Soldering

Printed Circuit Boards

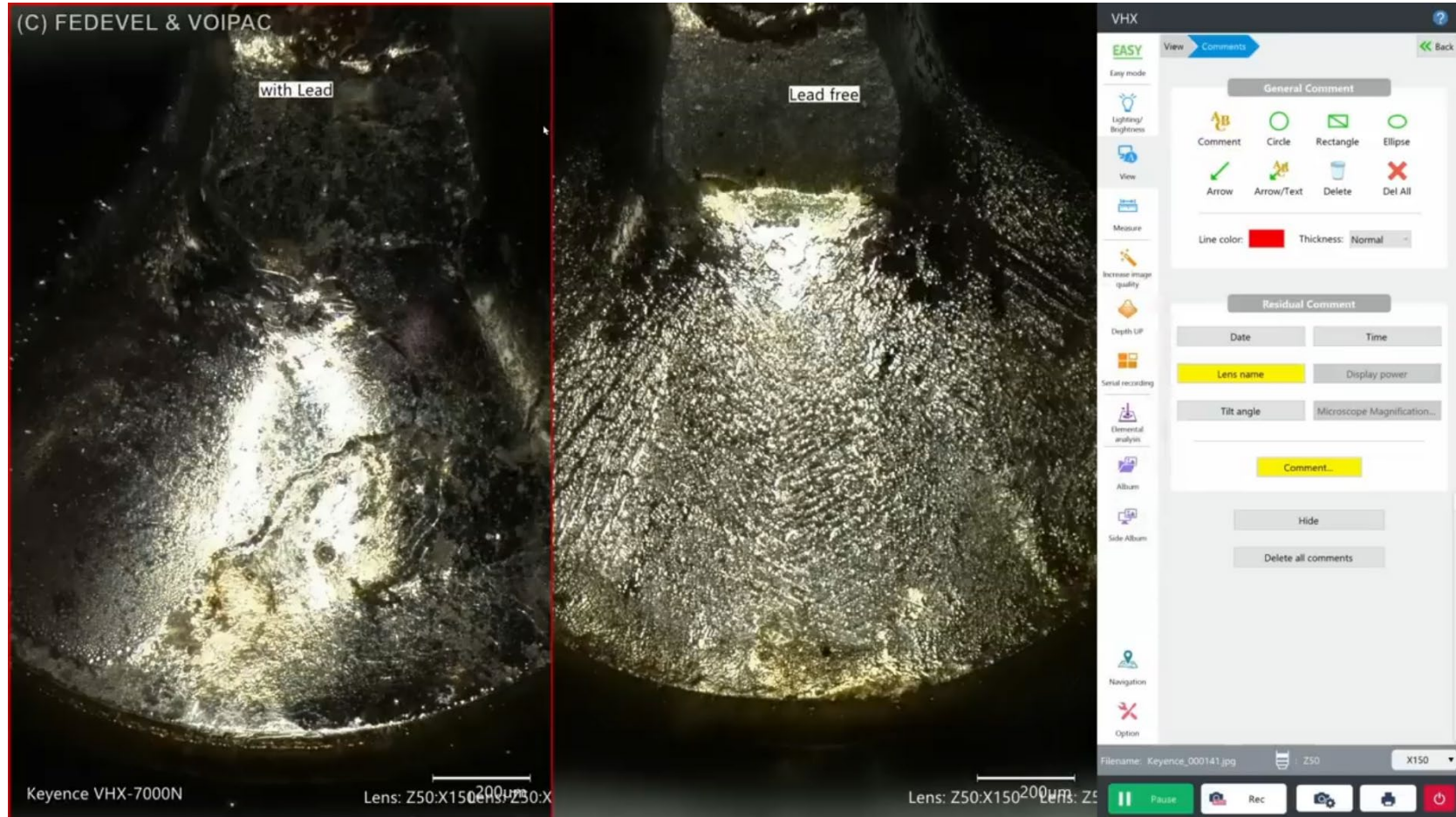
Soldering

How to Solder by Hand



Printed Circuit Boards

Soldering



Printed Circuit Boards

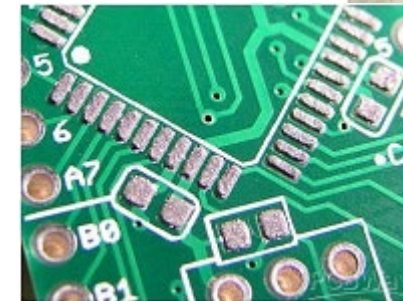
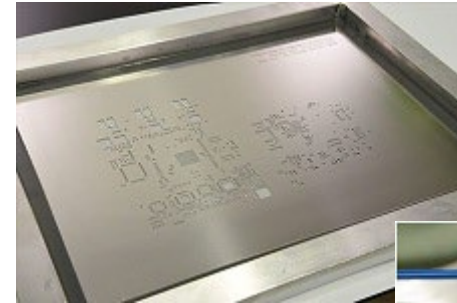
Soldering

Reflow Soldering

› Solder paste

- › Powdered solder suspended in flux paste
- › Sticky to temporarily hold components

› Stencil printing

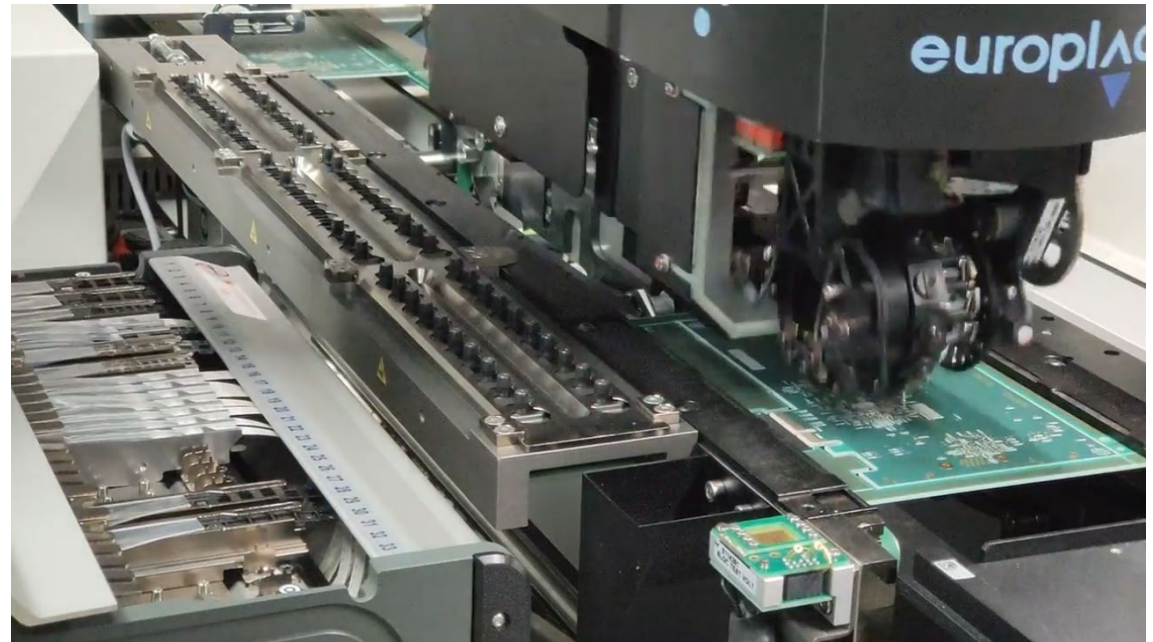


Printed Circuit Boards

Soldering

Reflow Soldering

- › Solder paste
 - › Powdered solder suspended in flux paste
 - › Sticky to temporarily hold components
- › Stencil printing
- › Pick-and-Place machine

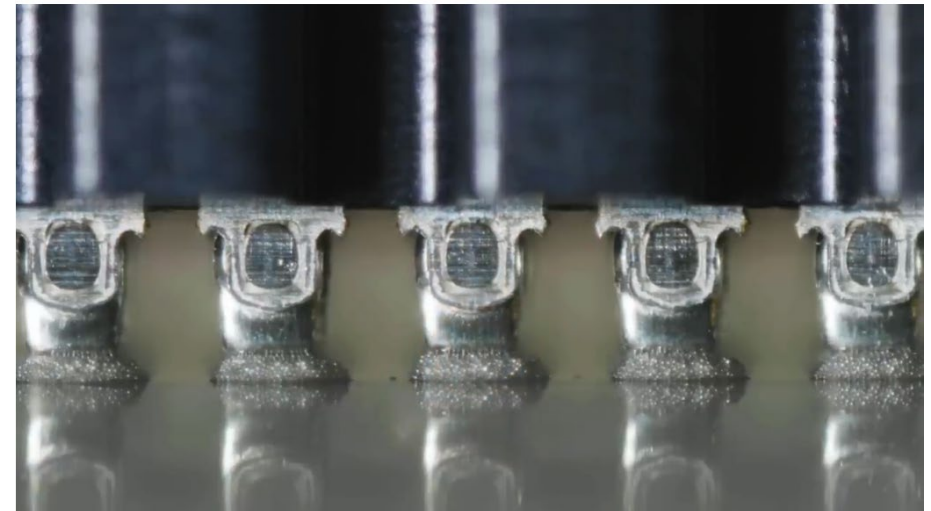
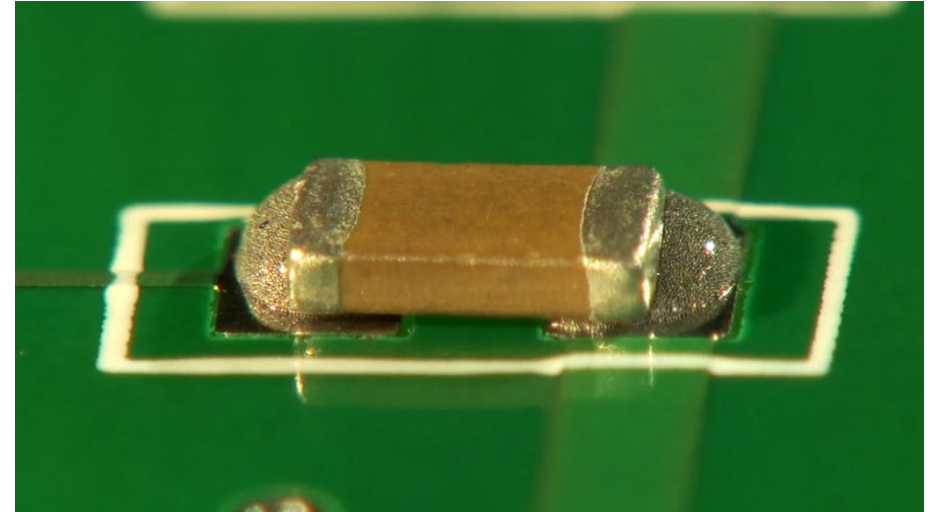


Printed Circuit Boards

Soldering

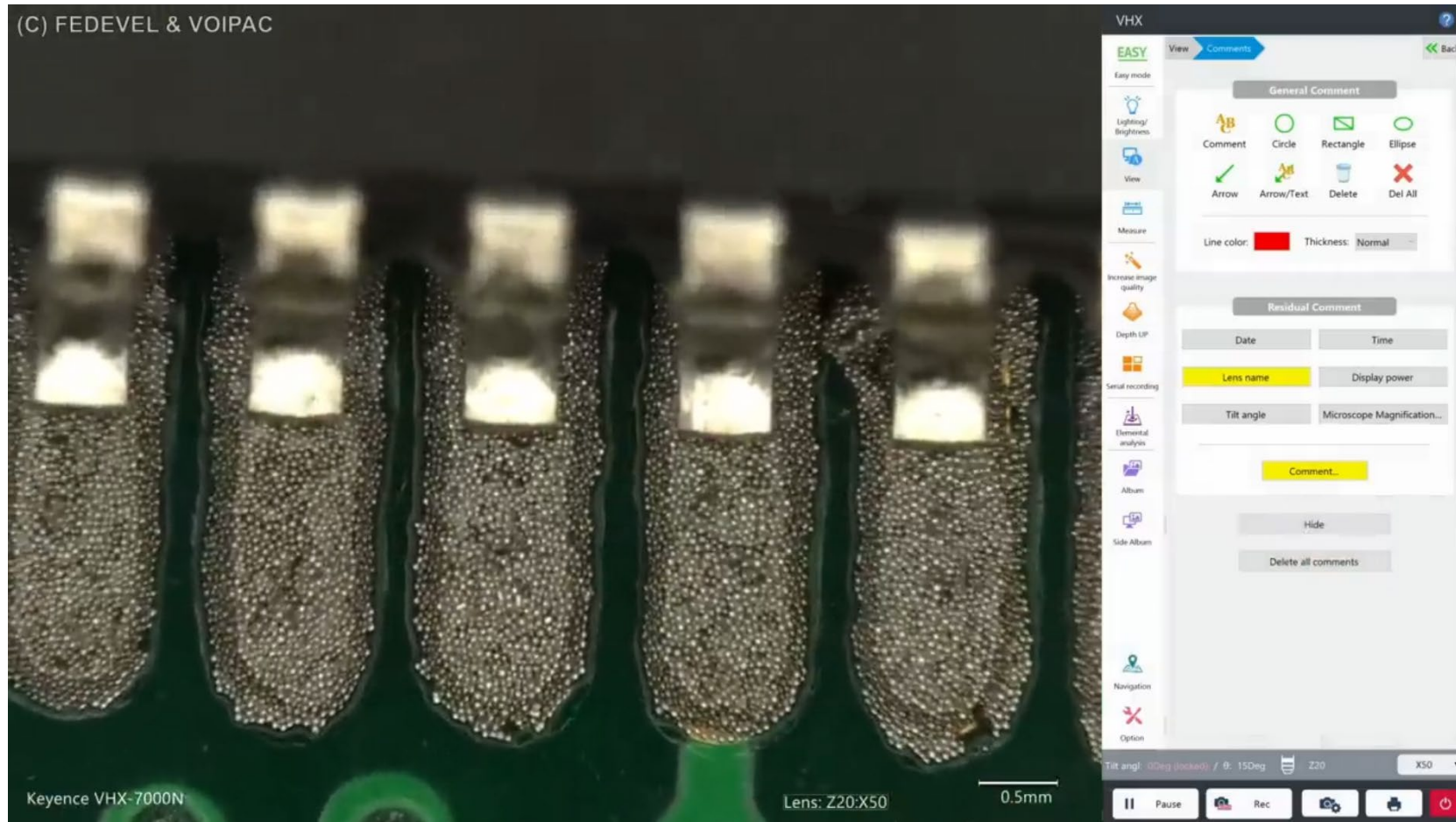
Reflow Soldering

- › Solder paste
 - › Powdered solder suspended in flux paste
 - › Sticky to temporarily hold components
- › Stencil printing
- › Pick-and-Place machine
- › Reflow oven
 - › Runs specific temperature profile



Printed Circuit Boards

Soldering



Electronic Design Automation

Printed Circuit Boards

Electronic Design Automation

Electronic Design Automation (EDA)

- › Tools for the design of
 - › Printed Circuit Boards (PCBs)
 - › Integrated Circuits (ICs)

Printed Circuit Boards

Electronic Design Automation

KiCAD

- › Created in 1992 at IUT Grenoble
- › Boosted by CERN from 2013-2018
- › Joined Linux Foundation in 2019
- › **Free EDA software**
- › Design and simulation of hardware



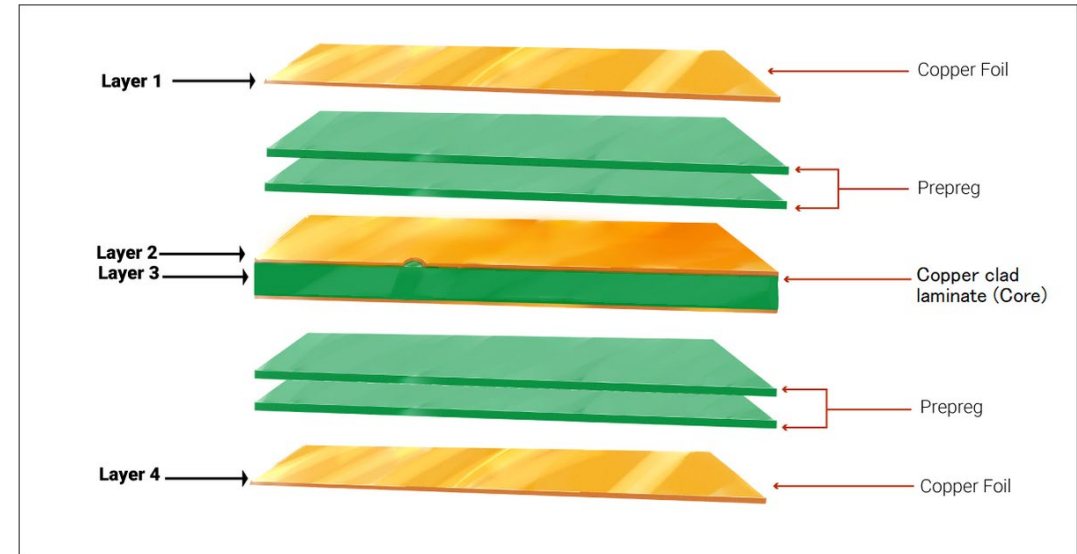
Design Guidelines

Printed Circuit Boards

Design Guidelines

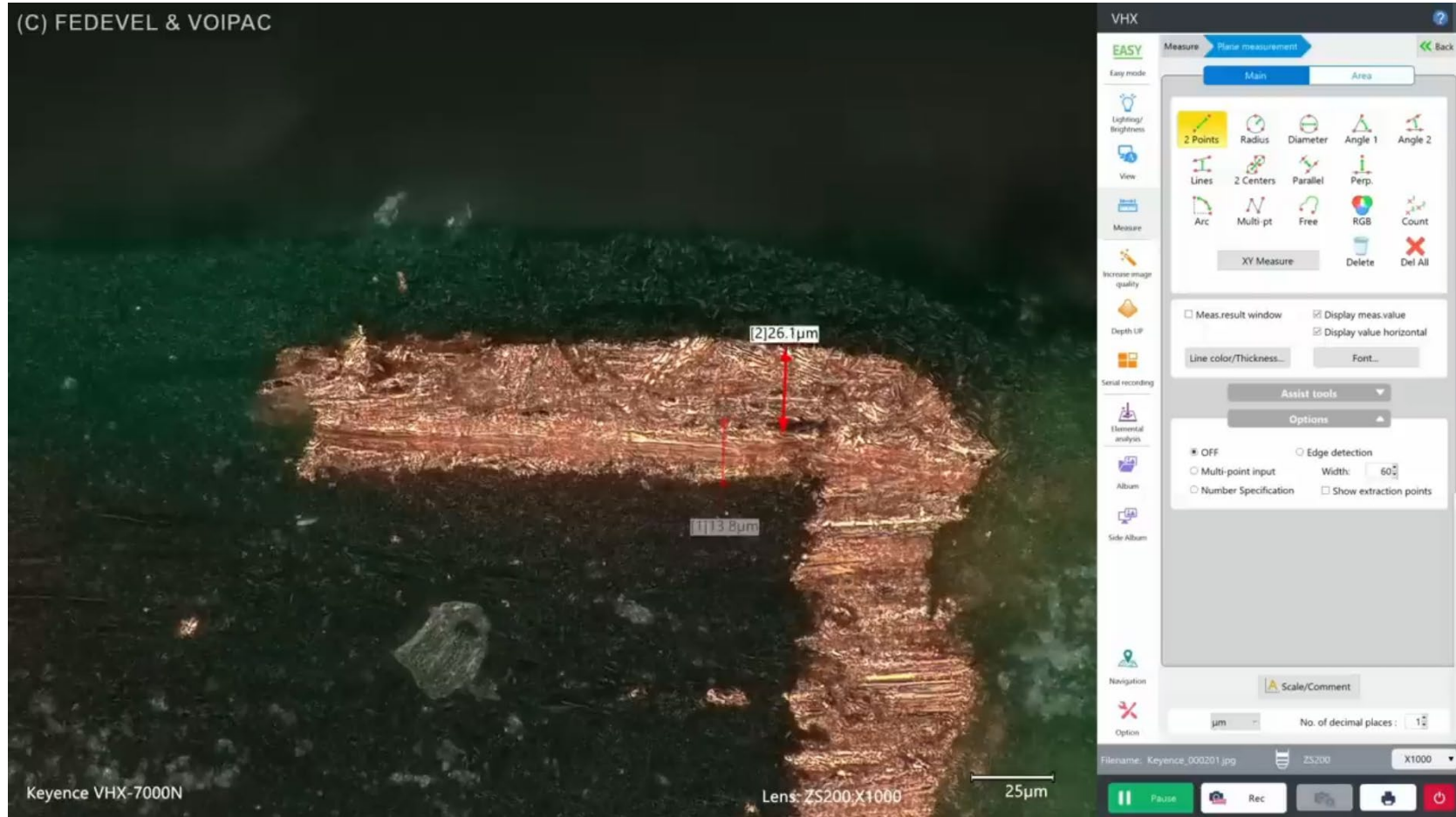
Layers

- › Single/double/multiple layers
- › FR-4 core (typ. 1.55 mm)
- › Cu foil (typ. 18 μm)
- › Outer Cu plating (typ. 23 μm)



Printed Circuit Boards

Design Guidelines



Printed Circuit Boards

Design Guidelines

Design Rules

- › Specified by manufacturer
- › Design Rule Check (DRC)

Printed Circuit Boards

Design Guidelines

Component Placement

- › Optimize density
- › Consider space for traces
- › Consider heat dissipation

Printed Circuit Boards

Design Guidelines

Bypass Capacitors

- › Noise reduction
- › Usually **100 nF** ceramic capacitor

Printed Circuit Boards

Design Guidelines

Trace Routing

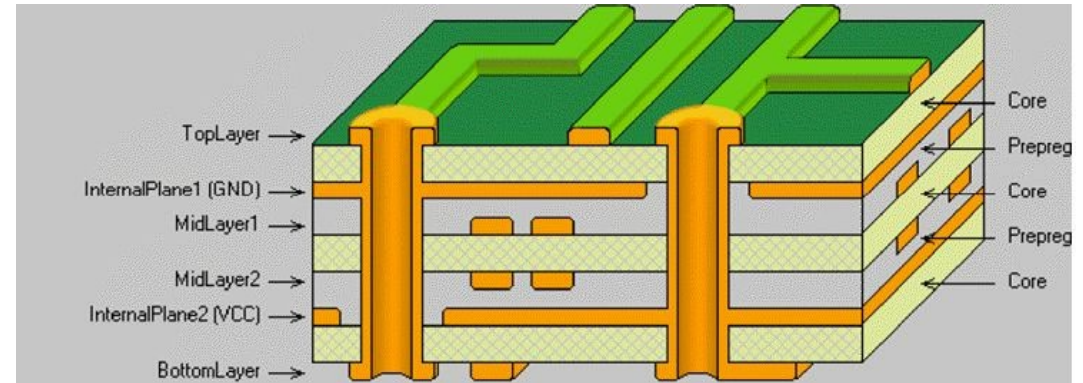
1. Local, short traces
2. Analog signals
 - › Keep them short
 - › Avoid interfering traces
 - › Avoid vias
3. Ensure power supply
 - › Use ground planes
 - › Avoid vias
4. Digital signals
 - › Separate from analog signal traces

Printed Circuit Boards

Design Guidelines

Vias

- › Plated holes
- › Connecting layers



Printed Circuit Boards

Design Guidelines

Ground Plane

- › Spanning areas or full layer
- › Shielding
- › Mutual capacitance for denoising

Live Demonstration

KiCAD

Electronic Circuit Design

Questions?



What are your questions?



Exercise 3

PCB Design

Task 1 – Astable Multivibrator (5 points)

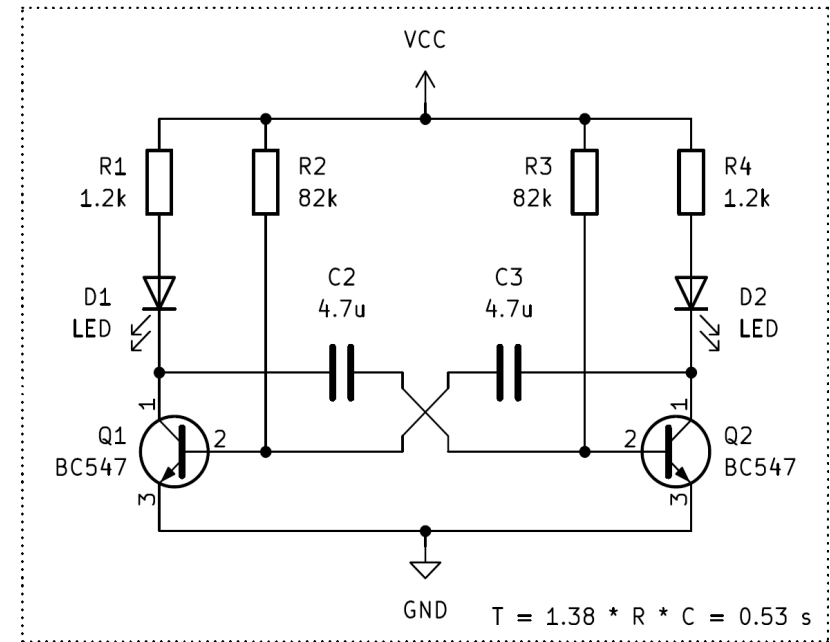
› Schematic

- › Replicate the schematic provided for the Astable Multivibrator
- › Utilize components available in the default libraries of KiCad
- › Place components and connect their pins using traces
- › Configure components with the specified values
- › Assign appropriate footprints for the components
- › Annotate the schematic and ensure all components are correctly labeled

› Printed Circuit Board

- › Create a PCB from the schematic
- › Place the components considering their intended usage and physical dimensions
- › Route the traces manually (F.Cu and B.Cu) and use vias only if necessary
- › Draw the PCB's contour (Edge.Cuts)

Astable Multivibrator



Task 2 – Microcontroller-based Running Light



Task 2 – Microcontroller-based Running Light (10 points)

- › Create an advanced microcontroller-based circuit that would be capable of generating an 8-channel running light
- › Follow the manufacturer's design rules, like those from EuroCircuits, available at <http://www.eurocircuits.com/blog/kicad-design-rules/>
- › Use the external library for the TinyPico Nano microcontroller that can be found on <https://www.tinypico.com/tinypico-nano> and <https://github.com/tinypico/tinypico-hardware>
- › Place the components thoughtfully to ensure clear routing paths and label them with appropriate values
- › Arrange 8 LEDs in a row and configure them
- › Add two buttons: one for start/stop functionality and the other to switch between different modes
- › Label the traces (e.g., VCC, GND, SIG_LED1, SIG_BUT1, ...)
- › Adjust the trace widths considering current flow and limit heat rise to $\leq 10^{\circ}\text{C}$ (using KiCAD's internal tool)
- › Route the traces to ensure signal integrity, avoid crossovers, and minimize the number of vias
- › Miniaturize the PCB (e.g., optimized trace routing, SMT, double-sided design, ...)
- › Perform the DRC to identify and resolve design violations

Submission Guidelines

Due date: January 14, 2025 at 23:59 h

Individual submission of a *.zip archive named "[family name]_exercise3.zip" to TUWEL, containing the following files:

1. Two folders for "Task1" and "Task2"
2. Both folders must contain:
 - › The KiCAD project, schematic, and board files (*.kicad_sch, *.kicad_pcb and *.kicad_pro)
 - › The exported/printed schematic and board as *.pdf
 - › Two screenshots of the PCB's 3D view, one of each side
3. A short reflection (max 1 page):
 - › Technical aspects of implementation (design rules, component placement, and trace routing)
 - › Reflect specifically on the miniaturization strategy (task 2) implemented or intended

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