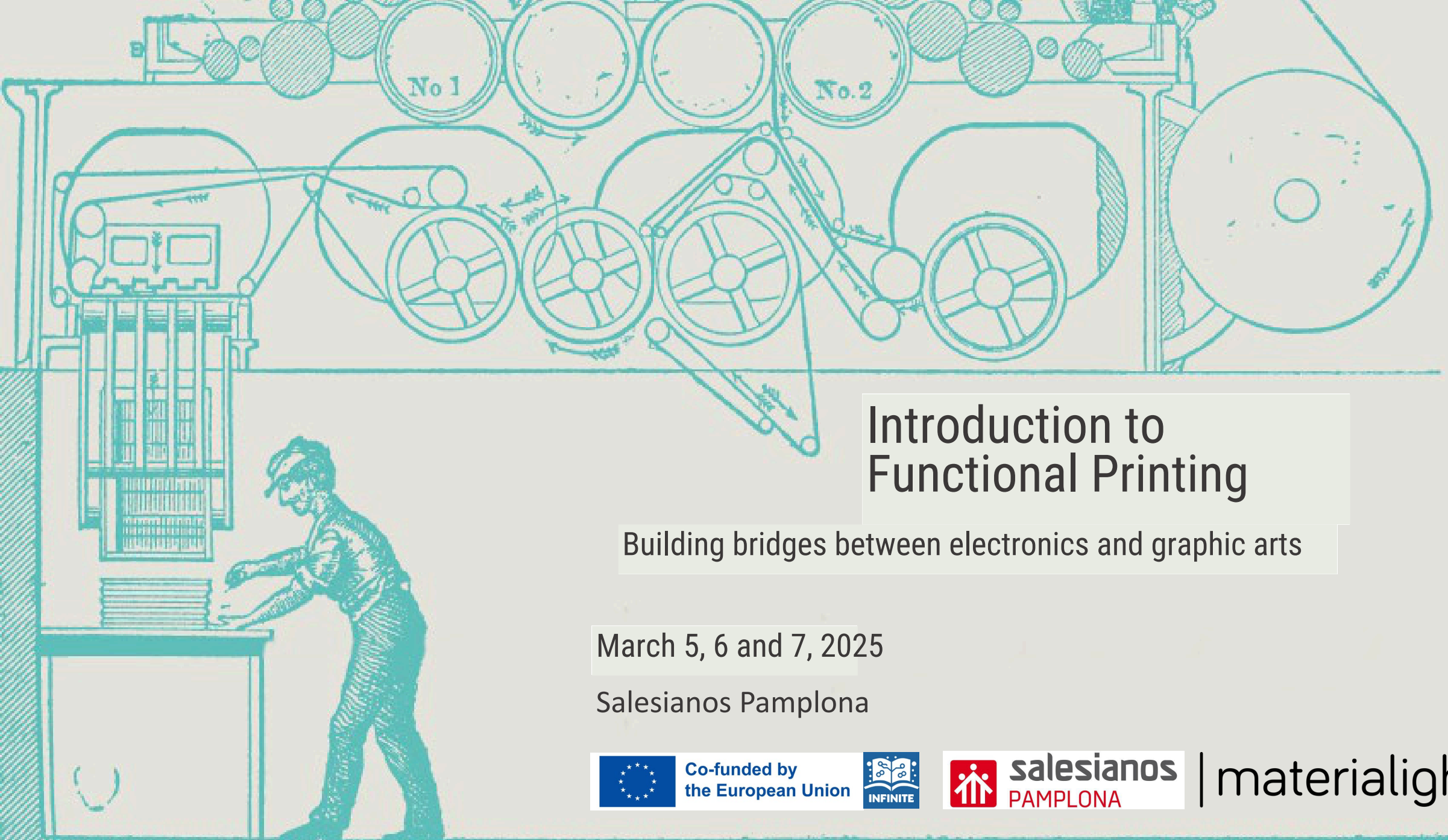




Introduction to Functional Printing

Building bridges between electronics and graphic arts

March 5, 6 and 7, 2025

Salesianos Pamplona



Co-funded by
the European Union



salesianos
PAMPLONA

| **materialight** |



Course agenda

March 5

A bit of electricity / A bit of Graphic Arts

PCB design: standards, tools and best practices.

PCB manufacturing: lithography, acid etching, drilling and via techniques.

Component assembly: SMT and through-hole technologies.

Adapting files to functional printing processes: screens, plates and engraved rollers.

8:30 - 10:45

Basic electricity / semiconductors

Current and Voltage. Insulation.

Are printed circuit boards actually printed?

First steps in electronic circuit design. KiCad.

10:45 - 11:15

Coffee break

11:15 - 13:00

Hands-on work: simple circuit in KiCad (the legendary 555)

Schematic - footprints - PCB

13:00 - 13:30

Summary and group discussion...

Questionnaire (the "EXAM" :)



Course agenda

March 6

Hybrids: half printed, half assembled

Introduction to hybrid circuits and their potential in printed electronics.
Surface-mount technology (SMT): processes, standards and equipment.
Application of conductive adhesives and low-temperature assembly techniques.
Identification and troubleshooting of mechanical defects in flexible circuits.
Alternative hybridisation technologies: crimping on flexible substrates.

8:30 - 10:45

Understanding the footprint concept better.

Making use of existing practices: adapting the workflow to Graphic Arts

Hands-on work: analysing footprints in KiCad and designing your own footprint.

Hands-on work: touch circuit with microcontroller

10:45 - 11:15

Coffee break

11:15 - 13:00

Hands-on work: touch circuit with microcontroller (continued)

Exporting files to Adobe Illustrator.

13:00 - 13:30

Summary and group discussion...

Another exam today...

A vertical strip on the left side of the slide features a technical drawing in blue ink. It depicts various mechanical components, including gears, shafts, and circular parts, some with handwritten labels like 'No 1' and 'No 2'.

Course agenda

March 7 Digital manufacturing

Introduction to digital inkjet printing: fundamentals and printhead types.
Drop-by-drop image formation and interaction with the substrate.
Printing modes: wide-format (scanning) versus single-pass.
Applications of inkjet technology in functional printing.
Advanced materials: organic and inorganic semiconductors.

8:30 - 10:45

Inkjet technology: a bit of physics
Image formation from droplets (in electronics).
Hands-on work: creating digital images from vectors.

10:45 - 11:15

Coffee break

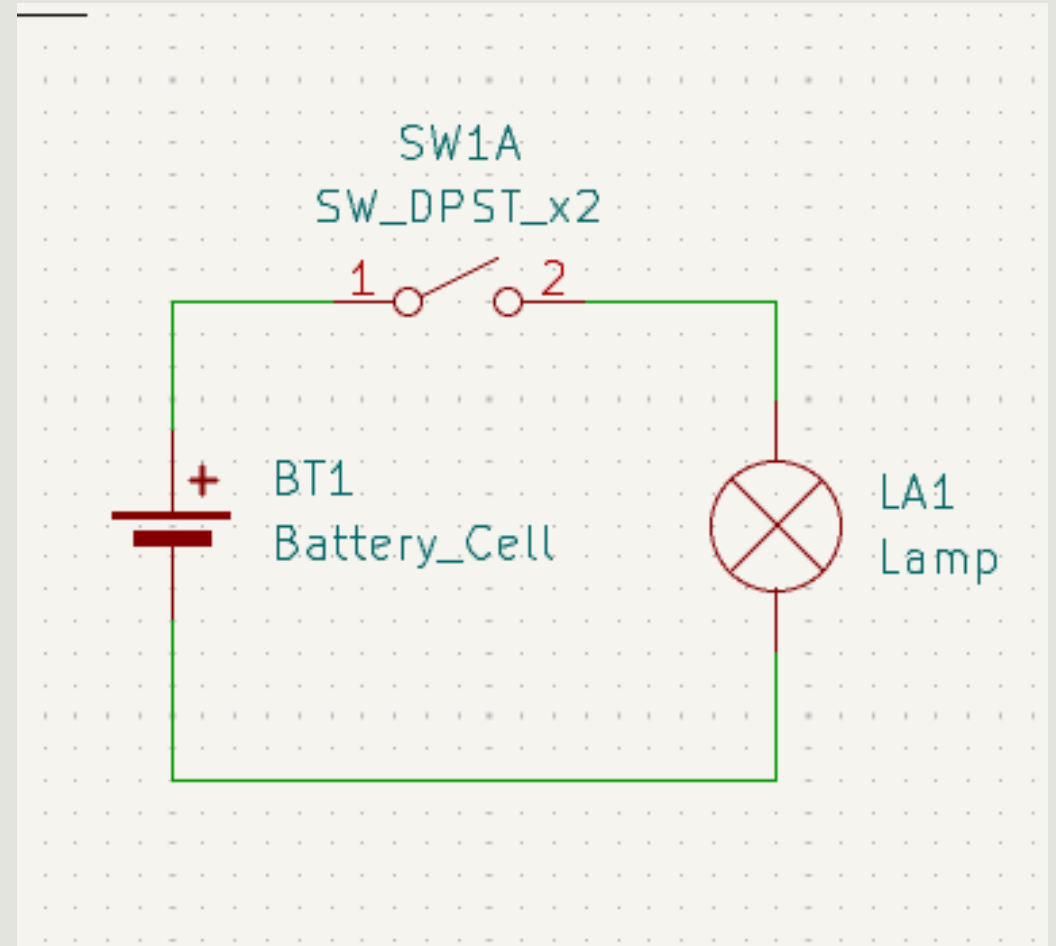
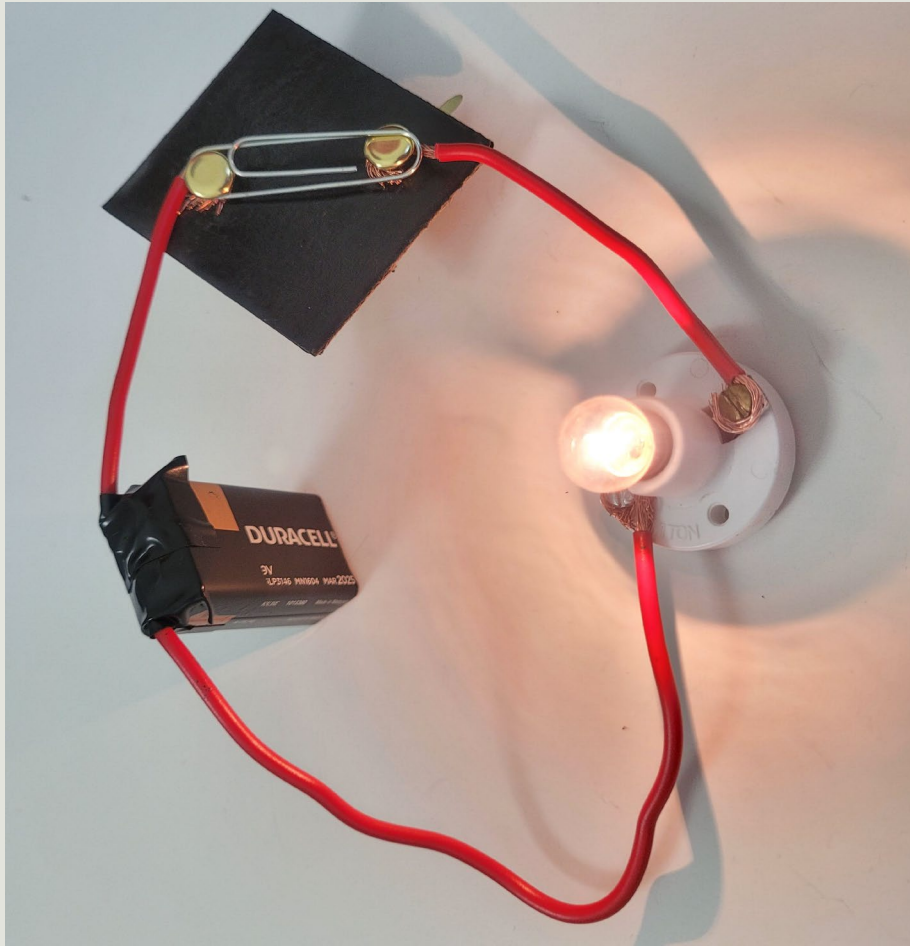
11:45 - 13:00

State of the art in inkjet printing. Industrial applications.
Case study: the LiveWall concept in industrialised construction.

13:00 - 13:30

End of course: lessons learned and advice

Basic Electricity



A vertical strip on the left side of the slide features a technical drawing of various mechanical components, including gears, shafts, and circular parts, rendered in a light blue line-art style.

“Passive” components

We can group them into three “ideal” types

Resistors	R	(resistance only, do not store charge)
Capacitors	C	(store charge only)
Inductors	L	(“oppose” changes in current)

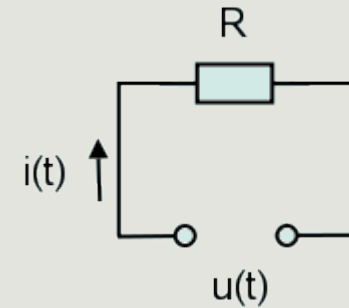
The last two only have a practical effect when there is a change in current or voltage (which is almost always)

Resistance (R)

Components are manufactured with a precise resistance value. They regulate the current flowing through a conductive path. Traces also have their own resistance, according to the formula:

$$R = \rho \frac{L}{S}$$

ρ resistivity
 L wire length
 S wire cross-sectional area

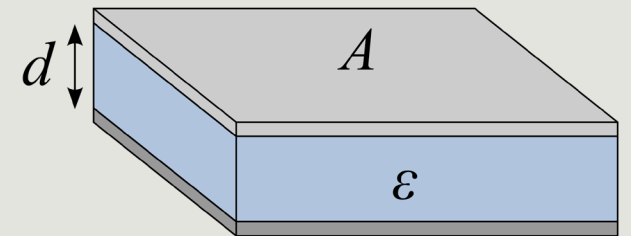


Capacitance (C)

If two conductors are placed facing each other at different electrical potentials, charges accumulate on their surfaces. These charges can move and, in some cases, act as a current source. The capacitance of parallel plates follows the formula:

ϵ permittivity
A capacitor area
d distance between plates

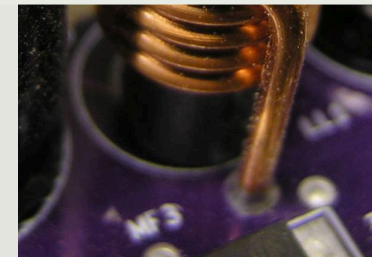
$$C = \epsilon \frac{A}{d}$$



Inductance (L)

Whenever an electric current flows, it induces a magnetic field. This effect can be used to build devices that amplify the effect. In these cases, the devices appear to “oppose” the current when it tries to change value or direction.

(And yes, this is the phenomenon behind “induction cooktops”)



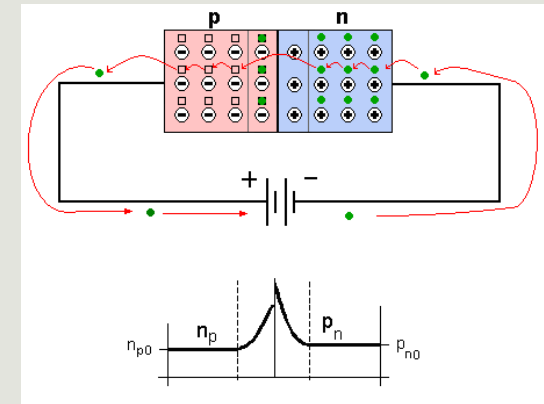
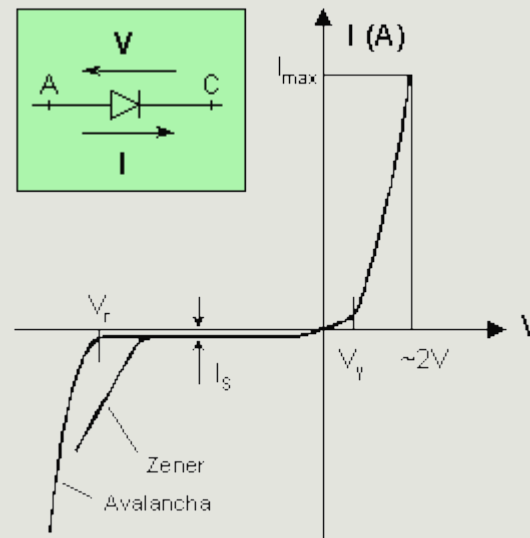
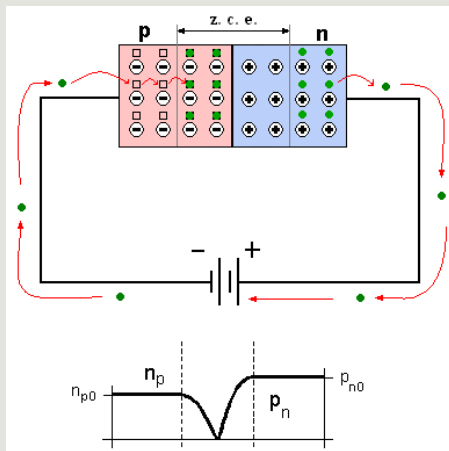
A vertical strip on the left side of the slide featuring a technical drawing of various mechanical components, including gears, shafts, and pulleys, rendered in a light blue line-art style.

Semiconductors

Not everything behaves according to Ohm's law...
Materials with very different properties have been discovered:
"semiconductors".
They have a non-linear relationship between current and voltage.
"Devices" with very special properties have been designed using these materials:
Some allow current to flow in only one direction.
Others allow one current to flow in the presence of another.

Diodes

They behave in a “strange” way: depending on how they are connected, they either allow electric current to flow or block it.





Transistor

Even stranger: it conducts electricity or not (between C and E), depending on whether a current exists at B.

For the first time, one electric current can be controlled by another electric current.

Furthermore, when used intelligently, a weaker electrical signal I_C can be amplified.

It is the greatest invention of the 20th century, and its greatest technological legacy.

I_E

Transistor

If we use a very weak signal at V_{in} , we can make V_{out} “copy” the original signal, but much more amplified.

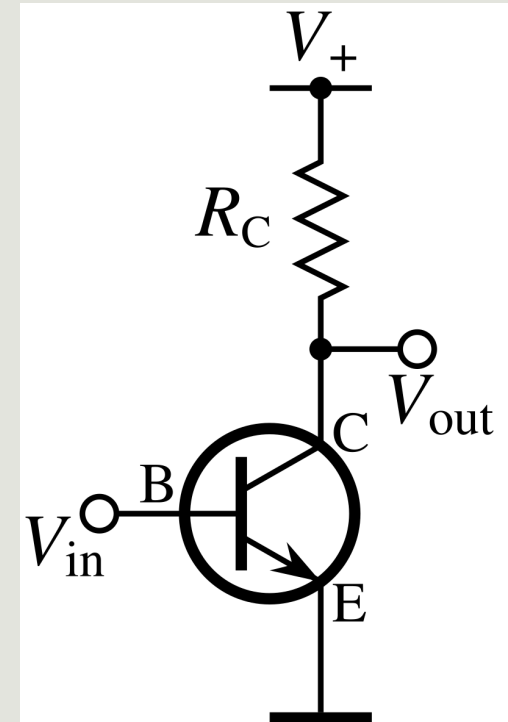
This is the basis of all electronics as we know it:

Radios, Televisions

Power supplies

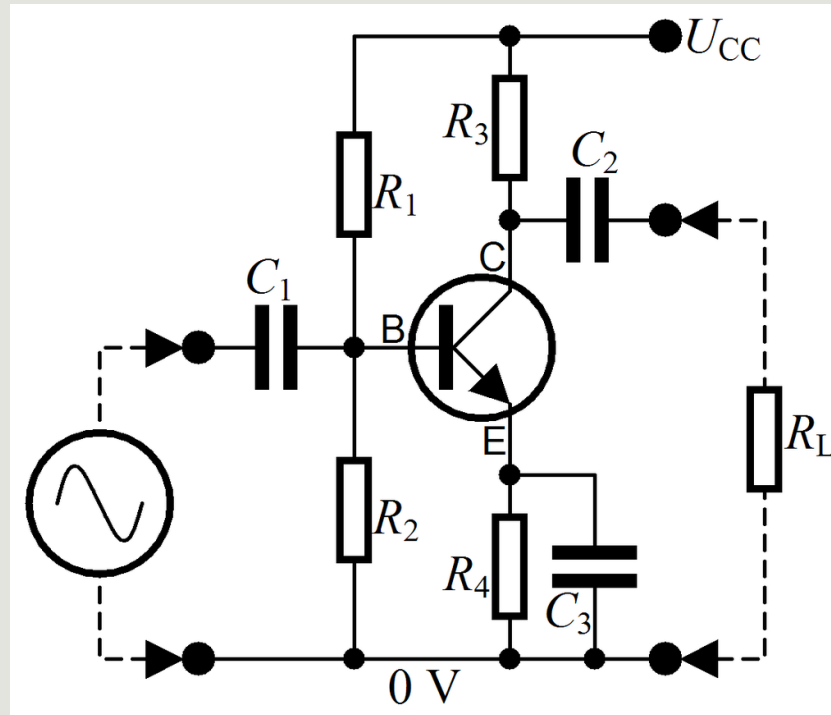
Computers

EVERYTHING



Transistor

Things can get complicated very quickly...



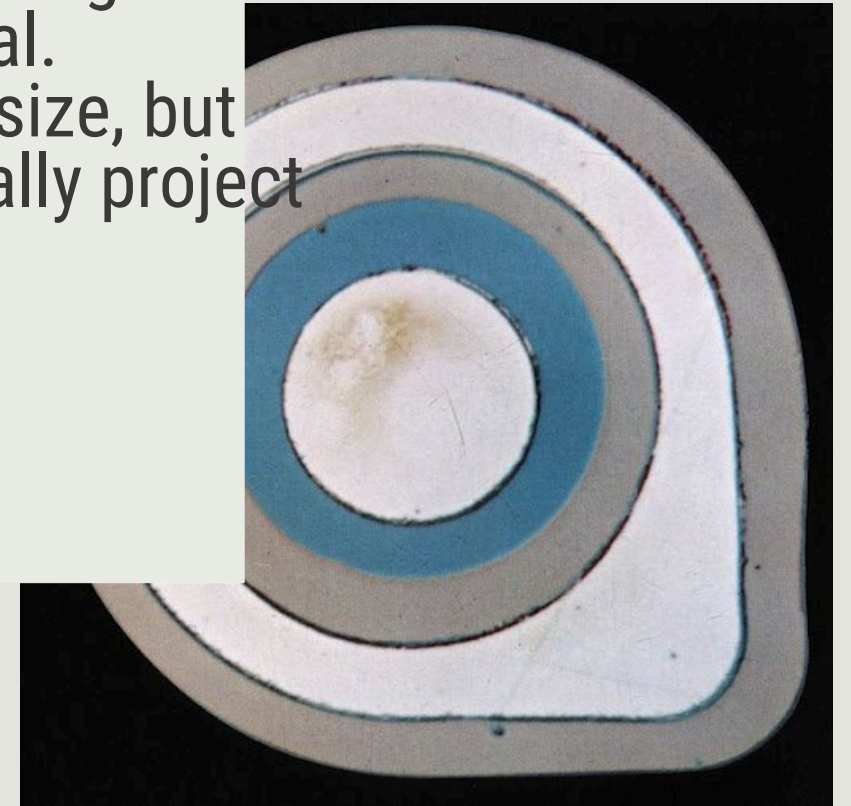
The first transistors

1947: the first transistor (a huge lump)



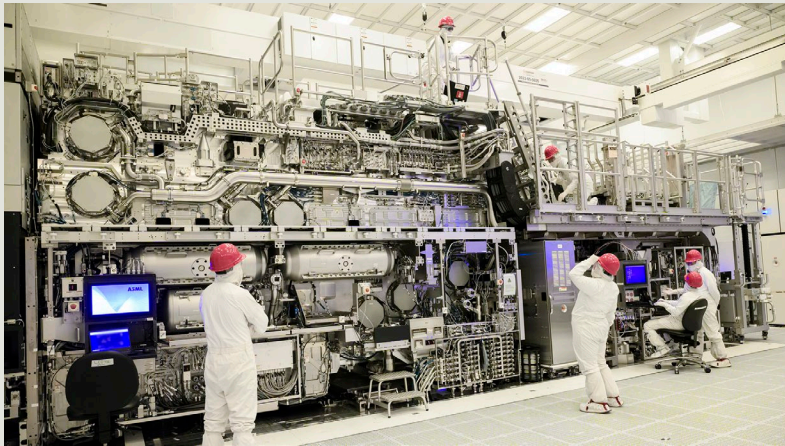
Let's "print" it

1957: first planar manufacturing processes
"Masks" were printed and used to project light and develop layers of semiconductor material.
The first one was several millimetres in size, but this technique made it possible to optically project the mask and achieve smaller formats.



Smaller, please

Today, transistors are 500 times smaller than a red blood cell (10 nm)



A vertical strip on the left side of the slide featuring a technical drawing of various mechanical components, including gears, shafts, and circular parts, rendered in a light blue line-art style.

Electronic printers

Today, printing is already a profession within the electronics industry:
PCB manufacturing: printing masks for printed circuit boards
PCB assembly: applying conductive adhesive for component assembly
Flexible circuits: keyboards, touchscreens



First steps in electronic design

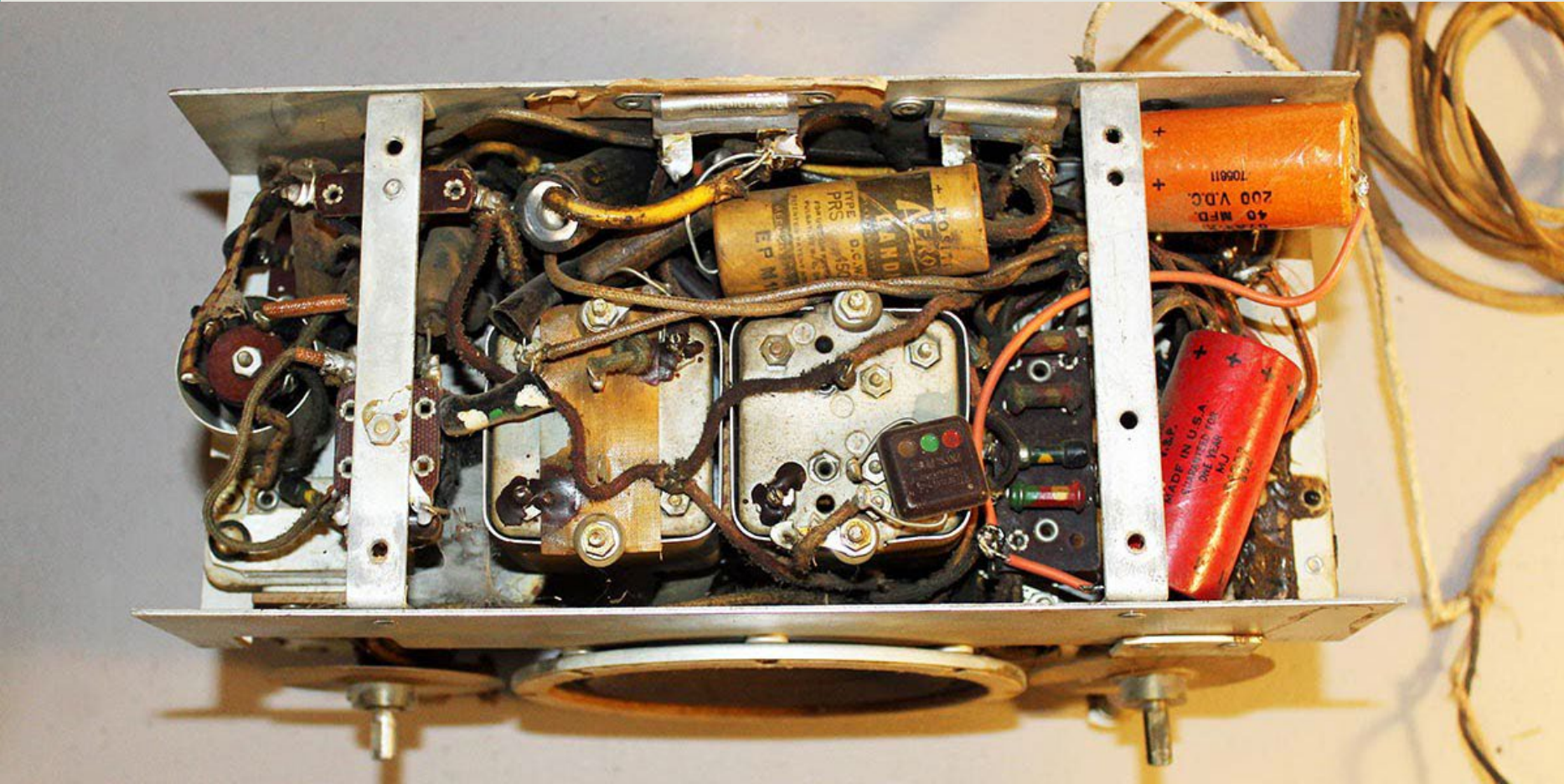
Electronic designs are now highly standardised; procedures and rules exist for almost everything.

We will introduce the basic concepts so that they can be understood:

- 1) Schematic level: the circuit is designed theoretically, using symbols and connections between symbols to achieve a function.**
- 2) Board level: the physical components are arranged, with their dimensions and connections, and physical interconnections are established between them.**

We will move from one level to the other until we obtain the final design.

A little history...



Printing comes to the aid of electronics

1936: Paul Eisler decides to replace all the wiring with a “printed” copper board (which was not actually printed, but anyway...)

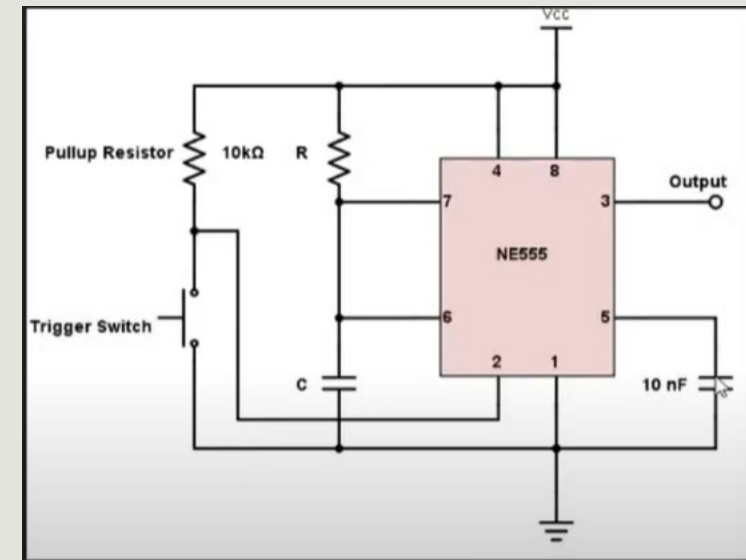


Hands-on work

Using KiCad for electronic design

We are going to create a schematic design of the following circuit:

It is an oscillator that generates a square-wave “on-off” output, with frequency and duty cycle defined by the components.



<https://www.falstad.com/circuit/e-555square.html>

<https://www.falstad.com/circuit/e-555int.html>



Hands-on work

Using KiCad for electronic design

- 1) We will choose the appropriate symbols to represent the design and connect them as shown in the reference design.
 - 2) For each symbol, we will associate a real physical component, with its dimensions and connection geometry.
 - 3) Finally, we will arrange them on a surface and try to ensure that all elements are connected as indicated in the schematic.
- KiCad, like other software tools, makes the designer's tasks easier and speeds up the product development process.

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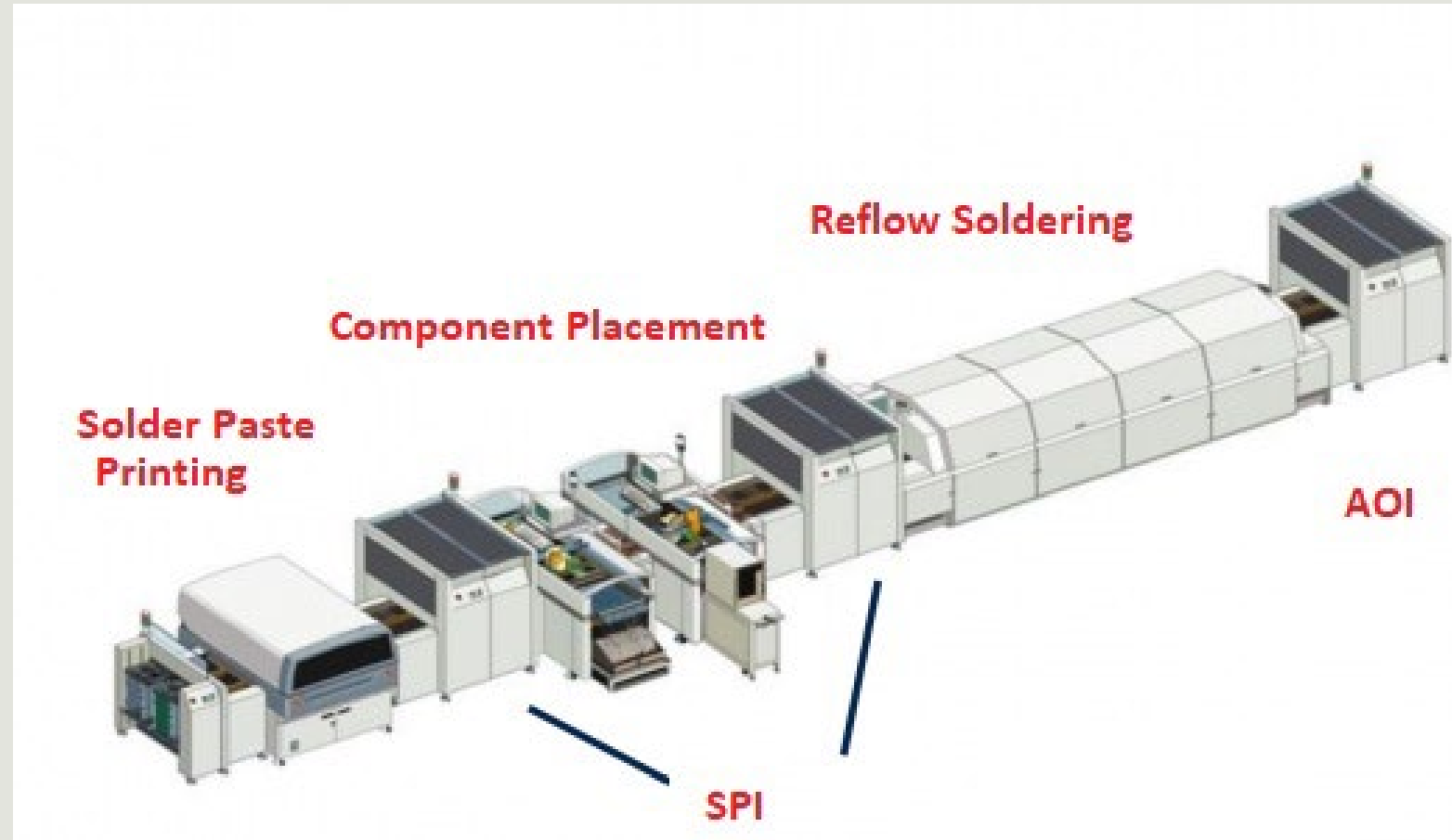
SMD Technology

This method allows components to be mounted on the surface without the need for “legs” or “holes”.

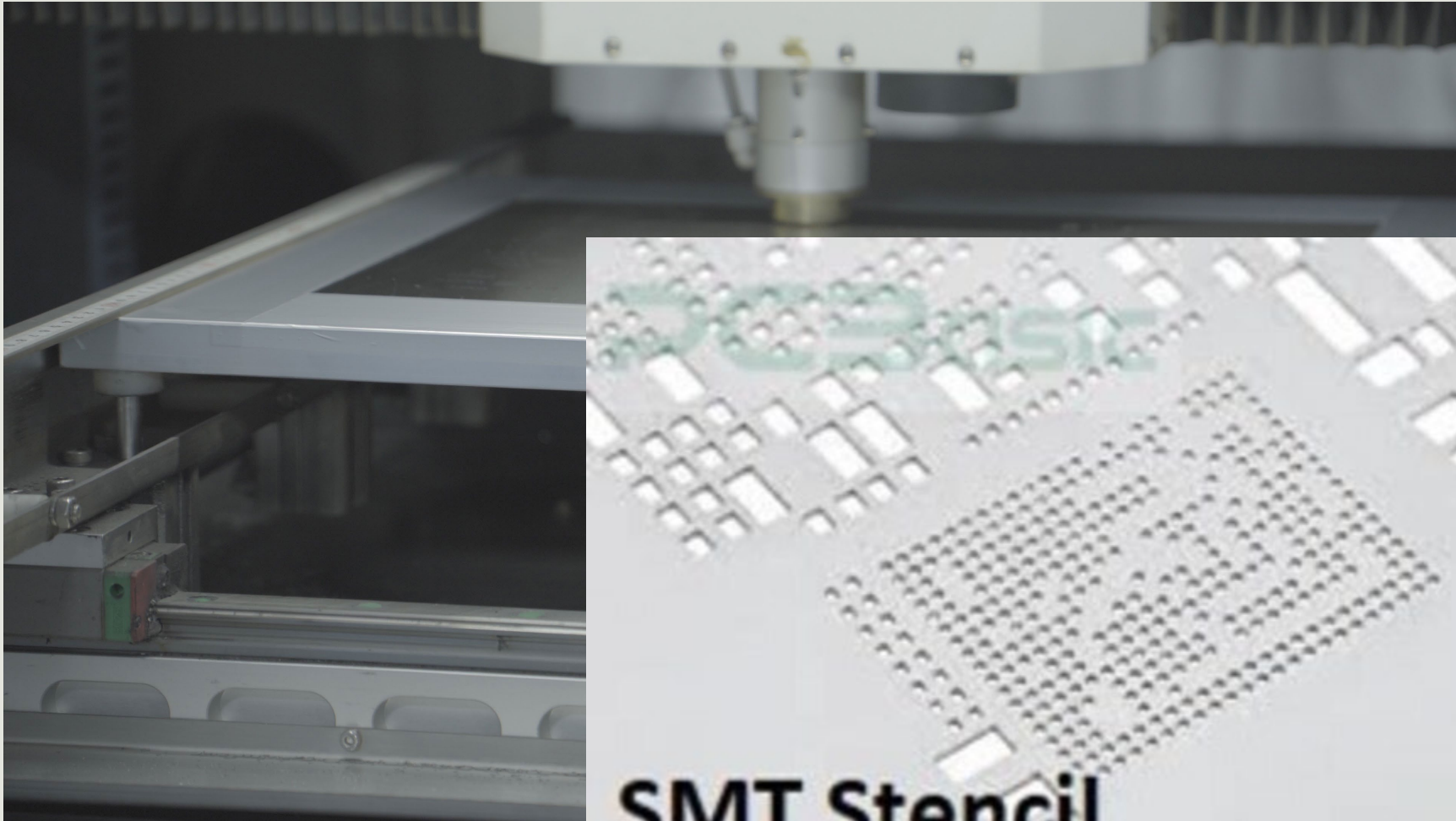
Components are placed on a “footprint”, just like THT components, except that these footprints do not have through holes.

Instead, a precise layer of conductive adhesive is deposited on the footprints and then cured in an oven.

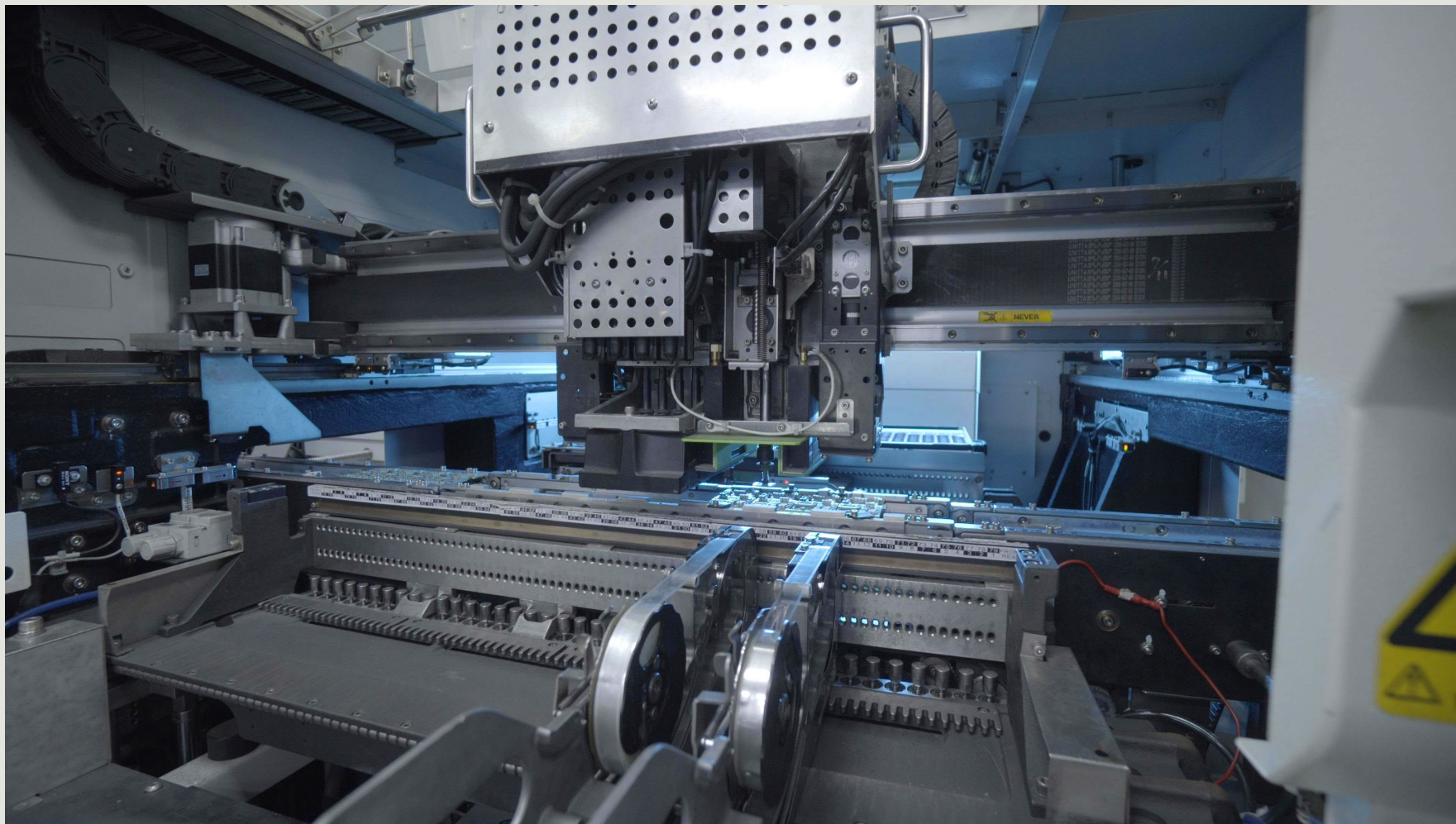
SMD Line



Stencil



Pick & Place



Reflow



SMT Sizes

<i>comparison</i>	Metric code	Imperial code	<i>comparison</i>
0.1x0.1 mm	0402	01005	0.01x0.01 in (10x10 mils)
	0603	0201	
	1005	0402	
	1608	0603	
1x1mm	2012	0805	0.1x0.1 in (100x100 mils)
	2520	1008	
	3216	1206	
	3225	1210	
	4516	1806	
1x1 cm	4532	1812	0.5x0.5in (500x500 mils)
	5025	2010	
	6332	2512	
	Actual size		



Hands-on work: touch circuit

We will imagine a demonstrator circuit for different human-machine interface (HMI) technologies.

Based on a microprocessor specialised for this purpose.
Programmable and connectable via a standard communication protocol.

The documentation can be found in the following documents:

[Infineon-PSOC4000T_datasheet-DataSheet-v11_00-EN.pdf](#) (p. 32, schematic)

[Infineon-AN85951_-_PSoC_4_and_PSoC_6_MCU_CapSense_Design_Guide-ApplicationNotes-v73_00-EN.pdf](#)

[Infineon-AN239751_Flyback_inductive_sensing_ISX_design_guide-ApplicationNotes-v02_00-EN.pdf](#)

[Infineon-AN239805-Liquid_level_sensing_PSoC4_CAPSENSE-ApplicationNotes-v04_00-EN.pdf](#)

[Infineon-AN234185_PSoC_4_CAPSENSE_touchpad_design_guide-ApplicationNotes-v02_00-EN.pdf](#)



Hands-on work: touch circuit

We will use the schematic on p. 32 as a basis for the CY8C4046LQI-T452 processor.

1) First, we will connect the common elements:

power supply

base capacitors (CMOD1, CMOD2)

programming

communications

2) Then we will start by designing a 5-element slider in CSX mode



Touch CSX Slider

The element will be designed using the documentation in the attached PDFs, and we will also take a close look at similar PCBs for “inspiration”. It can be created in Adobe Illustrator or Inkscape.

Required layers and connection pads.
We will also create a symbol to include it in the design.

A vertical strip on the left side of the slide features a technical drawing in blue lines. It depicts various mechanical components, including gears, shafts, and circular parts, some of which are labeled with 'No 1' and 'No 2'.

Touch CSX Slider

The workflow is as follows

1. We will work with the symbol in the KiCad symbol library.
2. The sensor elements will be designed in a graphics program.
3. Then both designs will be imported into the footprint editor.
4. Finally, the symbol will be used in the schematic and the footprint on the PCB.

A vertical strip on the left side of the slide features a technical drawing of various mechanical components, including gears, shafts, and circular parts, rendered in a light blue line-art style.

ISX Buttons

They are another way of detecting presence in HMIs.

They can be made on metal surfaces.
No openings or mechanisms are required.

We will proceed in the same way as for the CSX Slider:
Symbol / Design / Export / Footprint / Schematic / PCB