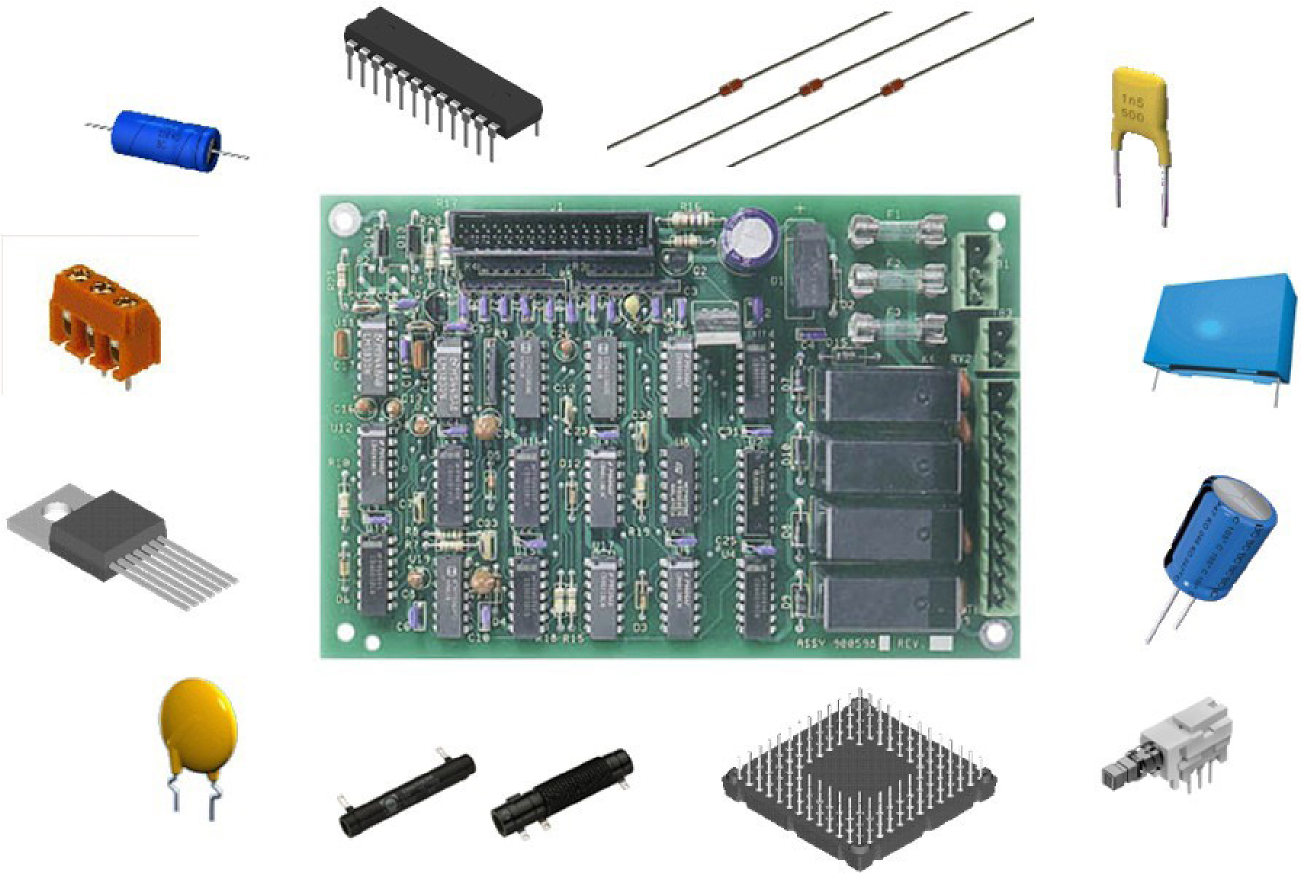
Design and Production Viewpoints of Electronic Products



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UNIVERSITY OF PÉCS

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1. Introduction

In today's world, we do almost all of our steps and actions by means of an electronic or electrical device. We can think about the tools that are initially appearing to make work and travel considerably easier, as well as the media and communication tools later on. Without these devices today's life would be almost impossible. Spread of communication and media tools did not stop.

Electric devices that exist in enormous quantities and in different forms of appearance have become more eco-conscious thinking. Because of the high content of hazardous substances of these devices and equipment, environmental considerations must be taken into account when designing. We can also face during manufacturing and during creation of manufacturing prototypes with events that justify re-thinking and re-designing the product. Without a thoughtful, all-in-one planning and manufacturing preparation, the lifetime and environmental aspects of the product will be less or no effect at all. Legislative decisions should also be taken into account when choosing the process materials and the plug-in components of the product.

In many cases, it may seem obvious, but it is worthwhile to carefully clarify the goal to be achieved, the task you want our future tool to accomplish. Inadequate *specification* of the task may result in unsuitable or unexpected operation of the final product. Such unnecessarily manufactured products are unnecessarily burdensome for our environment. When selecting the through-hole devices and surface mounted components and process materials into the product, the issue of service life and economy must be kept in mind.

You will get acquainted with the *Failure Mode and Effect Analysis (FMEA), Flowchart (FC), Control Plan (CP)* concepts when making any mistakes during production and the proper execution of production. There is a need for a simplified flowchart, even if only one prototype is produced. Failure Mode and Effect Analysis, and Control Plan to minimize scrap generated by mass production, eliminate the problems that arise, and make production economical and environmentally conscious.

In the *Manufacturing Documentation* section, you can get acquainted with the various types of documents that are essential for *low volume* or *high volume* electronics *production*. Though it is not a goal for the curriculum to present the reader with specific *PCB design programs*, the main aspects are presented. Based on the basic presentation of the *EAGLE software*, the understanding of other similar programs is easier.

In the design of small series, perhaps at home, as well as in the design and preparation of prototypes, we have to behave differently according to mass production conditions. References to these aspects can be found in the sections on *prototype* *making* and *production under mass production conditions*. A comprehensive understanding of the *state of the art production lines* is indispensable for starting planning tailored to mass production conditions.

Product Development and Productivity Improvement considerations focus on the aspects that can be used to adapt our product to user requirements and to make new modifications to the *product* or *process* by correcting the *manufacturing problems*.

The last, *environmental protection, lead-free soldering, RoHS* chapter provides insights into the most important environmental laws and regulations that arise in the manufacture of electronic products and makes recommendations beyond the rules for possible aspects of preserving our environment.

2. Assignment of task specifications and requirements list

The first step in the design of all equipment, electronic devices, is to set up the exact *task specification and requirement list*. Unqualified or obscure set of requirements will most likely undermine the end-product's usability, but even the most detailed requirement list does not guarantee that the product or manufacturing process will not undergo numerous *engineering modifications* during the life of the product.

2.1 Indirect and direct task specification

During the *task specification*, the customer formulates his expectations regarding the product. Where appropriate - and perhaps more typical in today's world - expectations are not expressed by the end-user, but by a marketing group, so the product may include services that the end-user did not explicitly request or did not know about. The main reason for this kind of *indirect task specification* is the growing battle between manufacturing and design companies, mammoth companies. By integrating the various extra services, companies are trying to ensure that they stay on the market. An example of this is the Philips Ambien Light module introduced on LCD and Plasma TVs, which illuminates the wall from the back in similar colors that are on the same screen on the television screen at a given moment. Thus, on the left side of a sea-side image, reddish-colored sand reflects the red light of the left light source to the blue ocean on its right side and the right side light source lightens the wall in blue. With this effect, engineers also wanted to increase the perceived size of the screen size. Similarly, we do not have a lot of expectations for the end user in almost every electrical appliance for the above mentioned reasons.

An interesting question is how the reliability of the product is influenced by the virtually unnecessarily built-in function, such as the frequently mistaken Follow Me Home feature for cars, which performs its task (illuminating the footpath on the way home), in many cases keeps turned on the headlights, discharged in the morning makes the car indecisive.

For this reason, the design team is responsible for deciding whether to follow a minimal concept or trying to get as many features as possible into the device at any cost. Indirect, not end-user-defined product specifications are the most popular range of entertainment electronics and communication media devices such as mobile phones. On a software side, a similar phenomenon can be observed, as hardware with increasing computing capacity is often unnecessarily large, unreliable, and slowly operating software that contains many of the features to which the end-user does not need or just the rarest need. For specific equipment that designed for a special purpose, the above indirect formulation is less typical.

2.2 Definition of Task Specification

As a general rule we can say that the task specification is characterized by the fact that the customer formulates his expectations regarding the final product. It collects its own expectations, which in many cases are subject to safety requirements, technical requirements, functional requirements, forms, etc. attached to the job specification as an attachment. Specific attention is given to the communication, negotiation, task specification, testing, and iteration steps with the customer. The protocols generated during the communication and afterwards from a professional point of view, and the designs, diagrams and diagrams generated by the CASE tool, are also part of the requirement list. The job specification includes the technology we want to use, and the requirements for connecting to other systems.

2.3 Concept of design, example

The following example shows the expected features and design concepts of a real, completed system. The task specification of devices with more complex tasks or with complicated logic functions is much larger than the example below and includes several aspects. As a general insight, however, it is worth looking into the design concept of the "Professional Audio Digital-Analog Convertor" below.

"In the introduction, it has already been mentioned how much the sound of digital audio is dependent on the players and the D / A converters. It was also rumored that devices that provide good sound are often not affordable for everyone because of their high price levels. For this reason, the D / A converter, designed to connect with the CD player, is carefully designed with high quality components and can significantly improve the quality of our home audio system.

When designing the DAC-122, there were basically two aspects: good sound and low price. However, it is important to note that the good quality of the two aspects was of higher priority because of the unambiguous deterioration of the excessive cost reduction that can’t be allowed. Of course, other considerations had to be taken into consideration when designing:

- Minimum duplicate over-sampling and 24-bit resolution
- Possibility to connect linear PCM systems (e.g. DVD) with sampling rate and resolution other than the CD

- Existence of optical and coaxial digital inputs
- Conventional and symmetrical analogue outputs
- Reduce the interplay between each circuit
- Capable for mass production: This means, on the one hand, the use of tools and components that are available in larger quantities over the longer term. On the other hand, the design of the circuits should ensure fast, easy construction and few errors in manufacturing.
- Convenience Considerations: It is important, for example, to have easy access to the controls or to enter the in- switch off, or noise, disturbances, transients caused by faulty digital information do not get to the output.
- Aesthetics: Aesthetic is as important as technical content. This is true not only for the outside of the device, but also for the interior design, from the layout to the printed circuit boards"(1)

3. Component knowledge, through hole components and surface-mounted parts, enclosures

After the task specification and design concept has been cleansed, we have to decide on the assembly technology and the components of the given task. To select the right technology, you need to know the types, the enclosures, and the main features of the parts. A common design flaw is that, apart from the complete manufacturing process, a through-hole-mounted component is designed to be in a location where otherwise the surface mounted component would be more favorable. An example of this is a board made of almost completely surface-mounted components, where one or two connectors were unnecessarily through-hole-mounted. This makes the production process considerably more expensive and longer. In the opposite direction, we can be mistakenly designing a surface-mounted component close to the base of a connector that is to be soldered by a wave solder, which is most likely to be wavering during the manufacturing process. This includes a long line of components designed for inadequate tolerance, economy or negligence, which significantly reduces the life and reliability of the end product.

3.1 Classifying of parts (2)

Parts can be *classified* according to different aspects. The aspects of grouping may be*: circuit function, operating principle, base material, manufacturing technology, inserting method.*

3.2 Classification by function principle

According to their operating principle, *electronic*, *optoelectronic, electromechanical, mechanical* and *other* groups can be defined.

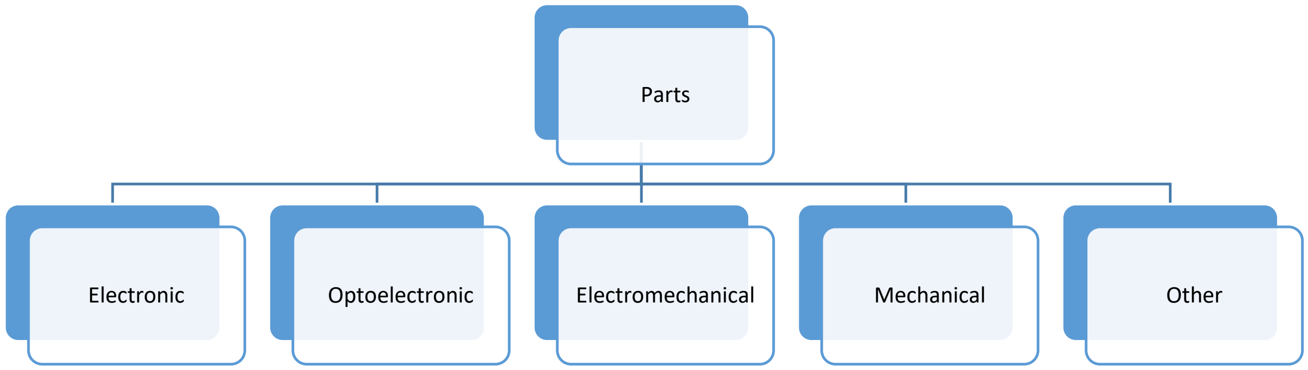


Figure 3.1

- *Electronic*: resistors, capacitors, coils, diodes, transistors, ICs, etc.
- *Optoelectronic*: bulbs, LEDs, displays (segmented, LCD, VFD), opto-couplers etc.
- *Electromechanical*: relays, switches, motors, connectors, loudspeakers, microphones, etc.
- *Mechanical*: supporting and bracing elements (houses, boxes, cases, spacers, clamps, bolts, etc.)
- *Others*: antennas, magnetic sensors (Hall sensors, reed relays, etc.)

3.3 Classification by insertion methods

The installation method of the parts will affect the assembly technology. Most manufacturers give you the option to choose, for example, for an integrated circuit, you can purchase the same job in three different enclosures. For example: NE5532 can be purchased in both SOIC (D), SOP (PS) and PDIP (P) enclosures.

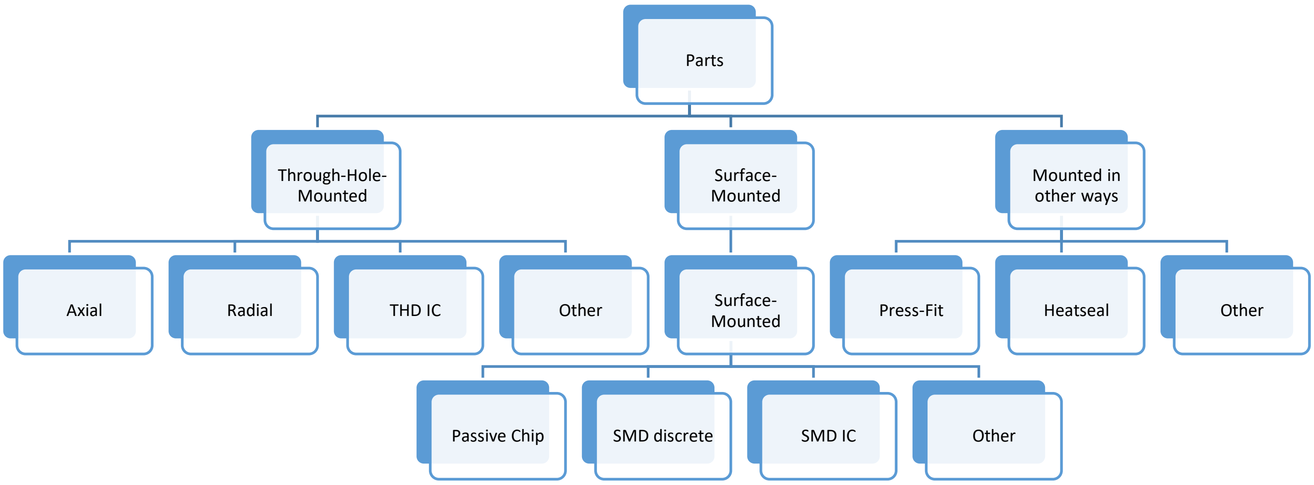


Figure 3.2

The "traditional", through-hole-mounted parts are called Through-Hole Devices (THD), and technology is called Through-Hole Technology (THT)

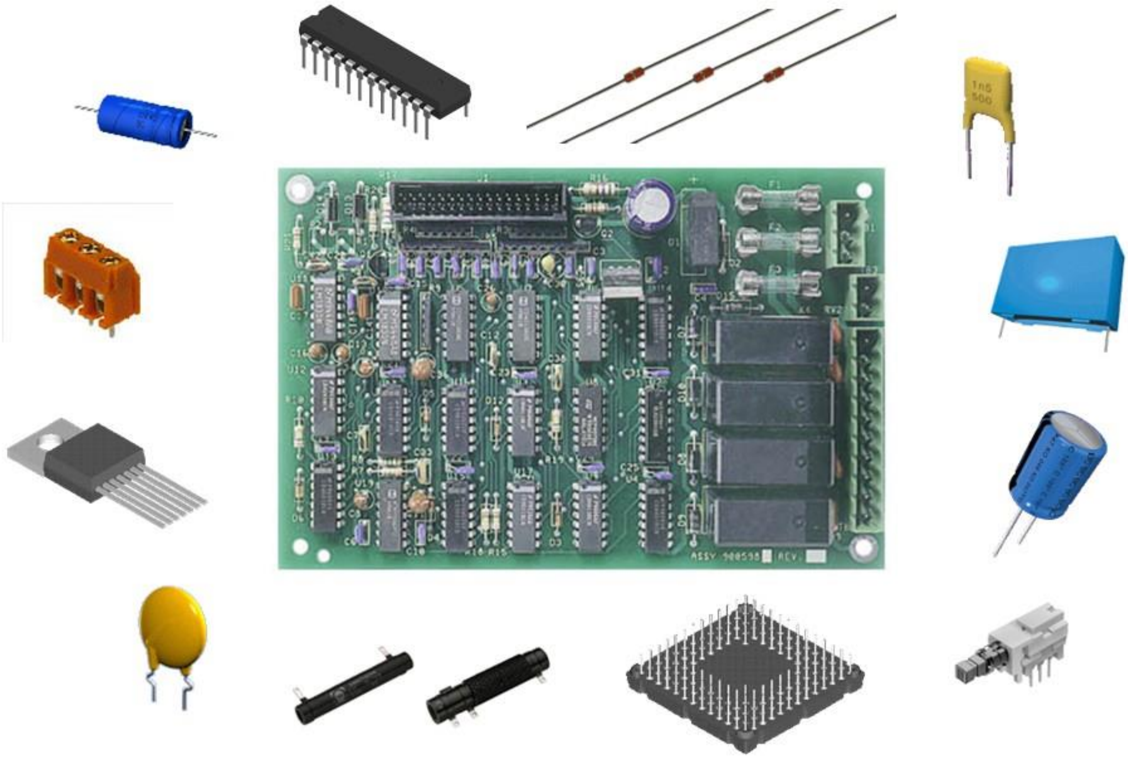


Figure 3.3: *THD-THT*

The nowadays used surface-mounted components name is *Surface Mount Devices (SMD)*, and the technology is called *Surface Mount Technology (SMT)*:

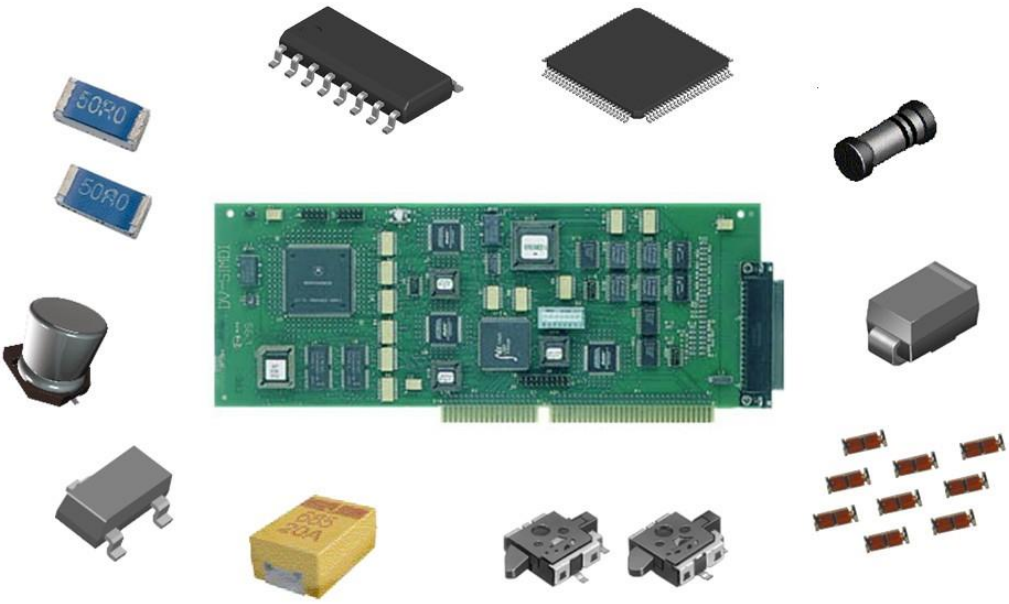


Figure 3.4: *SMD-SMT*

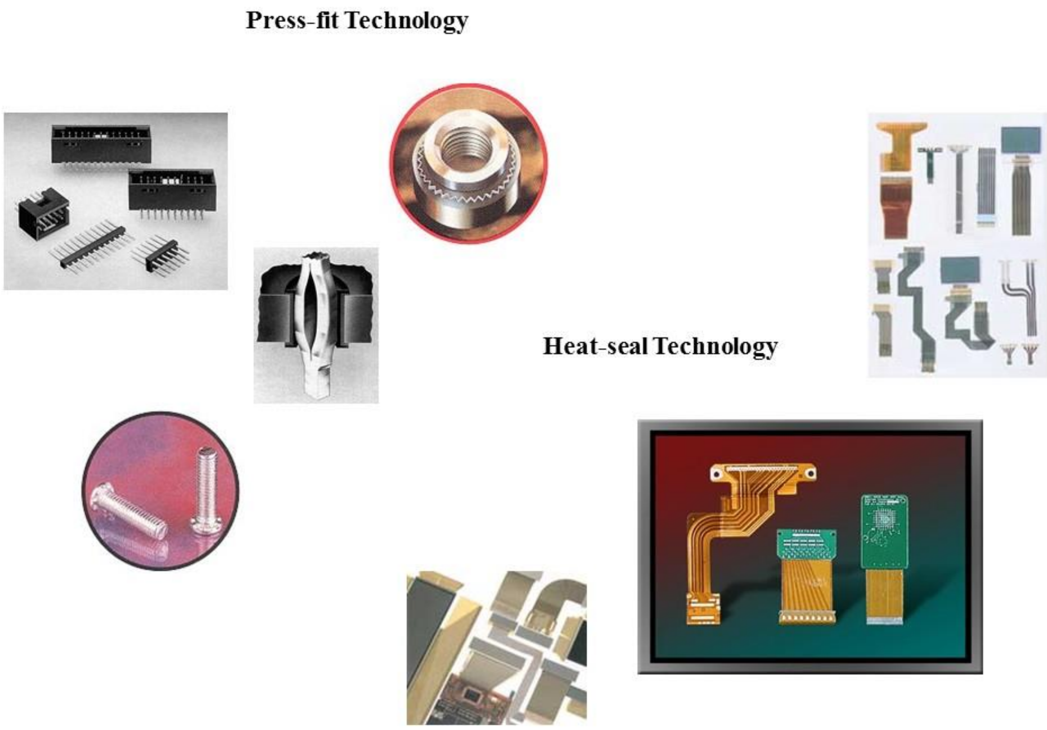


Figure 3.5: *Press-Fit and Heat-Seal Technologies*

3.4 Grouping of electronic components in terms of complexity

From the point of view of complexity, the components can be grouped into discrete elements and integrated circuits (Integrated Circuit - IC)

- *Discrete elements:* resistors, capacitors, inductances, diodes, transistors, accumulators, crystals, etc.
- *Integrated Circuit (IC):* Memory, MCU, AD / DA Converters, Operational Amplifiers, etc.

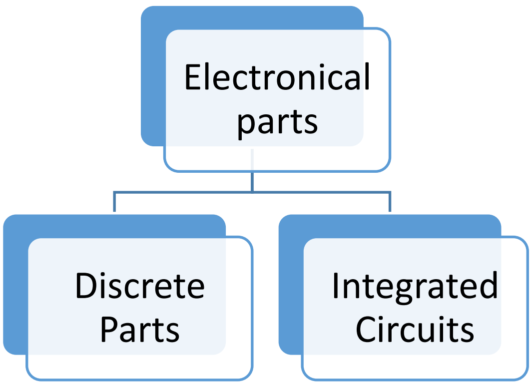


Figure 3.6

3.5 Traditional grouping of electronic components

The following grouping is most commonly used, with the above grouping considerations being substantially mixed.

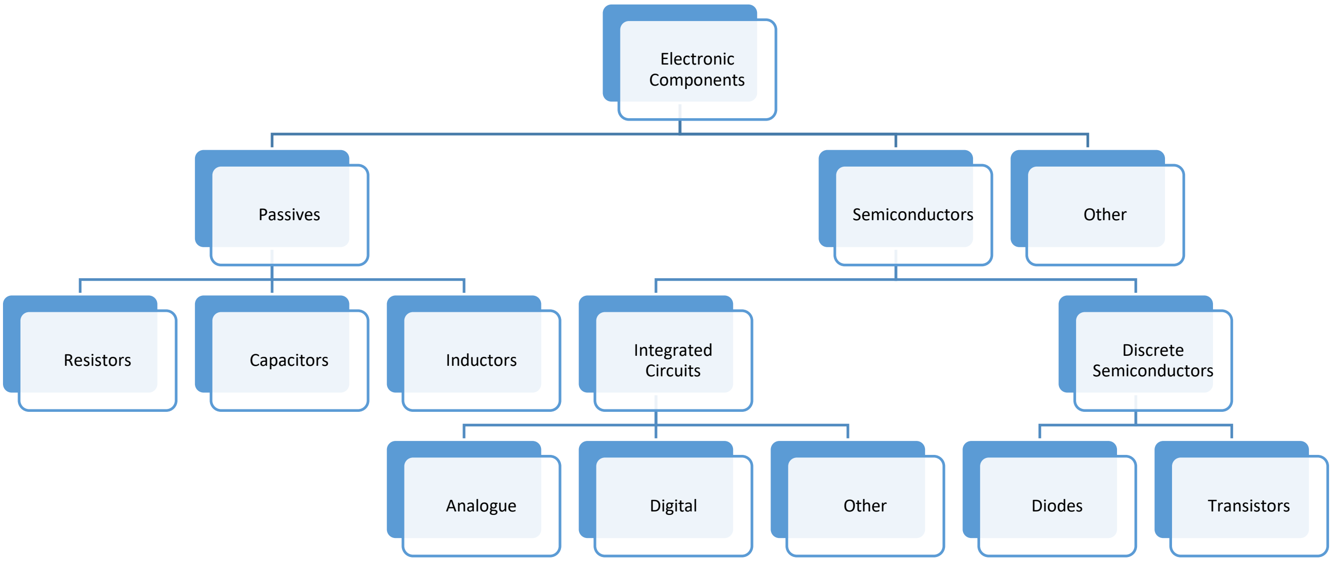


Figure 3.7

3.6 Resistors

We know the many types and forms of resistors. Essentially, electrical conductivity is impeded in the material, depending on the resistance value. They can be of constant value or can be changeable types. The carbon layer resistor consists of aluminum oxide ceramic substrate and a shielded thin film. At the metal layer resistance, the aluminum oxide support is coated with a thin layer of thin film or a pressed thick layer. The wire resistance features a single layer coil on a ceramic substrate. SMD resistors are typically formatted by the small cylindrical body, with two-sided leads. The protective layer has a resistance code. Values can be added according to standard EIA values, with the addition of tolerances and power. These parameters should also be kept in mind when selecting. The color coding for THT axial resistors is shown in the figure below.

Color-coding of Resistors

Colors	Value-bands			Multiplier Ω	Tolerance ±%
Silver				x10^{-2} = 10m	10
Gold				x10^{-1} = 100m	5
Black		0	0	x10^{0} = 1	1
Brown	1	1	1	x10^{1} = 10	2
Red	2	2	2	x10^{2} = 100	
Orange	3	3	3	x10^{3} = 1k	
Yellow	4	4	4	x10^{4} = 10k	
Green	5	5	5	x10^{5} = 100k	0,5
Blue	6	6	6	x10^{6} = 1M	0,25
Purple	7	7	7	x10^{7} = 10M	0,1
Grey	8	8	8	x10^{8} = 100M	
White	9	9	9	x10^{9} = 1G	

Figure 3.8

Resistors can be grouped according to their function:

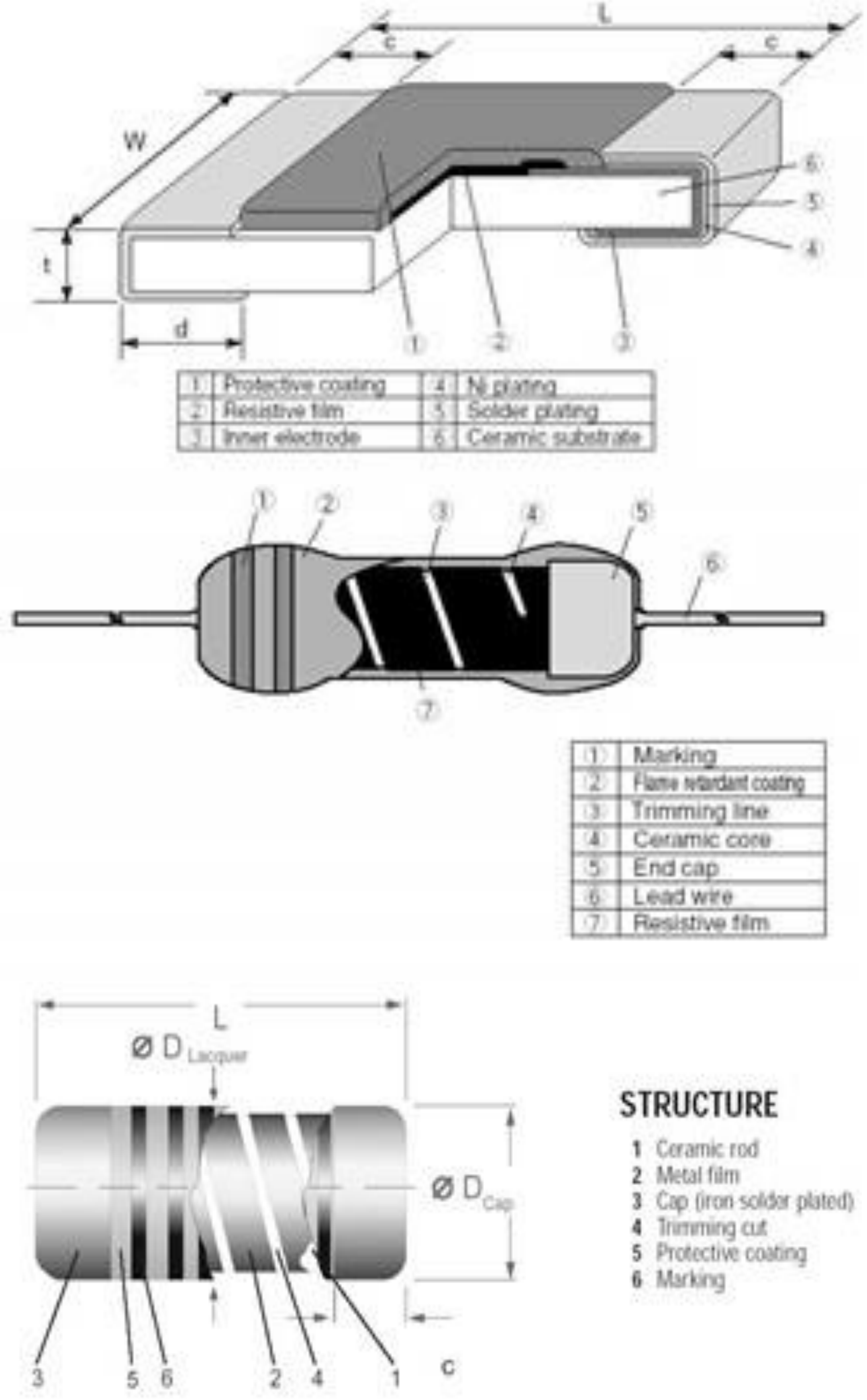
1. Linear resistors

  1.1 fixed value

  1.2 variable (potentiometers)

2. Nonlinear resistors: thermistors (NTC, PTC), varistors

The types of Linear Fixed Resistors:
1. CC - carbon composite
2. CF-carbon film
3. MF - metal film (e.g. TNF - thin film)
4. MOX - metal oxide (e.g. TKF - thick film)
5. WW – wire-wound



L
c
c
W
t
d
1 Protective coating
2 Resistive film
3 Inner electrode
4 Ni plating
5 Solder plating
6 Ceramic substrate
1 Marking
2 Flame retardant coating
3 Trimming line
4 Ceramic core
5 End cap
6 Lead wire
7 Resistive film
L
Ø D Lacquer
Ø D Cap
c
STRUCTURE
1 Ceramic rod
2 Metal film
3 Cap (iron solder plated)
4 Trimming cut
5 Protective coating
6 Marking

Figure 3.9

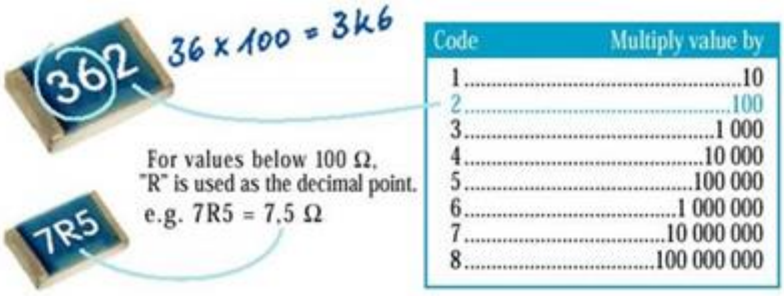
Based on mechanical characteristics:
1 Chip resistors (EIA standard classes)
2. Axial resistors (non-standardized standard classes)
3. Radial resistors (no standards)

Resistance value and tolerance: Their value is derived from the mΩ - MΩ range in the E24, E48, and E96 series. The E-series shows a series of values within a decade (e.g. 10Ω to 100Ω). They are classified into standard tolerance classes according to their production spread.

E48	E24	E12	E6	E3	E48	E24	E12	E6	E3
100	10	10	10	10	316	33	33	33	
105					332				
110	11				348	36			
115					365				
121	12	12			383	39	39		
127					402				
133	13				422	43			
140					442				
147	15	15	15		464	47	47	47	47
154					487				
162	16				511	51			
169					536				
178	18	18			562	56	56		
187					590				
196	20				619	62			
205					649				
215	22	22	22	22	681	68	68	68	
226					715				
237	24				750	75			
249					787				
261	27	27			825	82	82		
274					866				
287	30				909	91			
301					953				

Figure 3.10: E-series

Multiply Units and *Value Encoding*: Due to the small size of SMD resistors, a 3 or 4 digit coding method has been developed:



Multiplier	Letter	Meaning
10^{-12} = 0.000000000001	p	piko
10^{-9} = 0.000000001	n	nano
10^{-6} = 0.000001	u	mikro
10^{-3} = 0.001	m	mili
10^{0} = 1	-	-
10^{3} = 1000	k	kilo
10^{6} = 1000000	M	mega
10^{9} = 1000000000	G	giga
10^{12} = 1000000000000	T	terra

3-digit Value Coding:

4R7	4,7
100	$10 * 10^0 = 10$
101	$10 * 10^1 = 100$
272	$27 * 10^2 = 2700$

4-digit Value Coding:

6R81	6,81
5110	$511 * 10^0 = 511$
7502	$750 * 10^2 = 75000$
3304	$330 * 10^4 = 3300000$

Figure 3.11

Temperature coefficient: Their value changes by 10-1000ppm / ° C due to temperature change.

Power (dissipated power): Depending on size and type, the value may be in the range mW - kW.

The name of some resistor manufacturing companies: KOA, Yageo - Phycomp, Yageo - Vitrohm, Rohm, Kamaya, Matsushita - Panasonic, Vishay - Draloric, Vishay - Dale, BCComponents, Samsung Electro-Mechanics

Variable Resistors

They can be potentiometers or trimmer potentiometers. Mechanically adjustable resistance value. Typically, they have a cylindrical or block body, with a lower leg and at the front a control unit. They have standard values, tolerances and power.

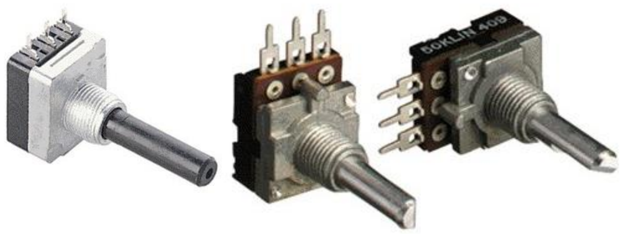


Figure 3.12: Potentiometers

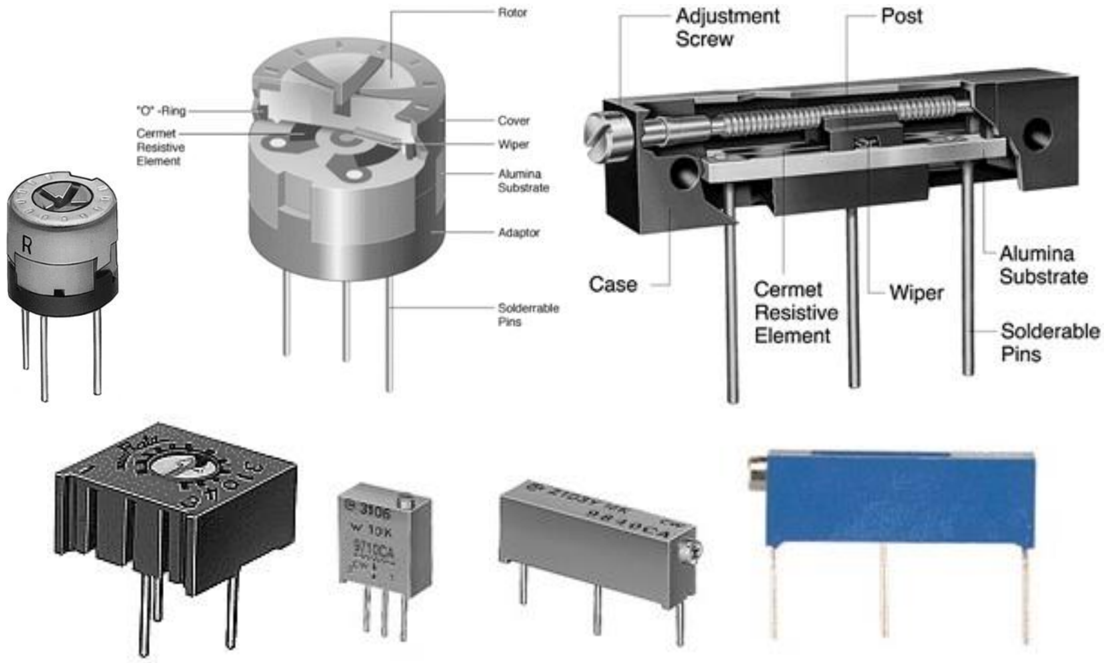


Figure 3.13: Trimmer Potentiometers and their Internal Structure

Surface-mounted resistors

The constant-value SM (Surface Mounted) resistors are characterized by their small size, flat panel design. One of the tabs is the resistance layer, the contacts are located on both edges. Insulating glass or ceramic carrier. Foam thin film, pressed and burnt thick layer contains the resistance. They cover the upper bobbin side with a protective layer, which is most often referred to as standard (standard). Their characteristics are the load capacity (maximum dissipated power) given on the datasheet, which should not be exceeded.

Figure 3.14: Surface-Mounted fix value resistors

Figure 3.15: Internal Structure of Surface-Mounted fix value resistors

Fixed Value Surface Mounted Resistance Networks

Surface mounted resistance networks are characterized by small space requirements and are easy to insert. It is most commonly used in digital circuits to load the same functions. This can be the cooling of the buses' wiring or the function of the pull-up resistor. It requires less space on the panel than if it had been implemented from separate resistors and the probability of faulty insertion is lower.

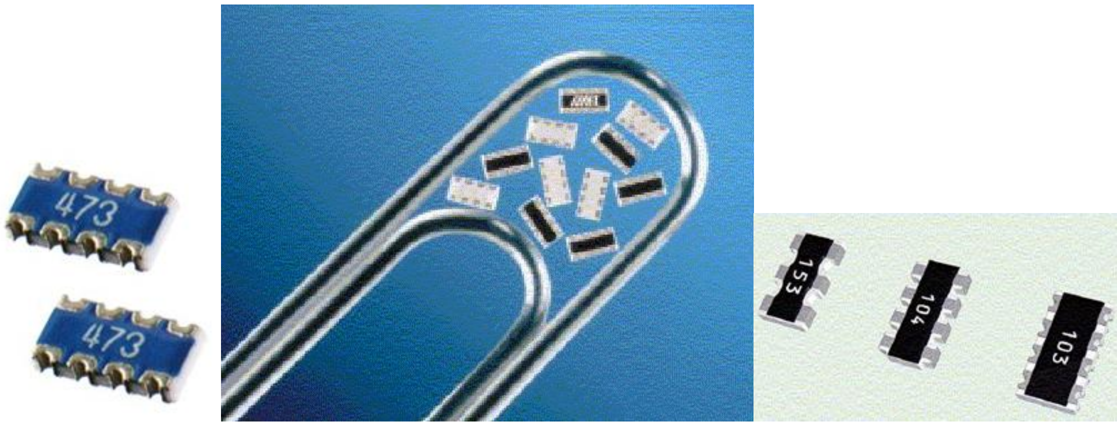


Figure 3.16: Fixed Value Surface Mounted Resistance Networks

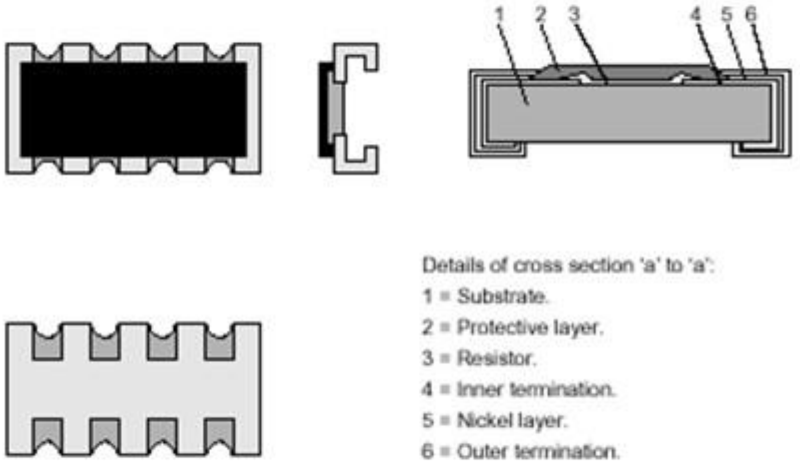


Figure 3.17: Internal Structure of Fixed Value Surface Mounted Resistance Networks

Variable value SM resistors

With surface-mounted technology, we can create variable resistors as well as through-hole technology. Consideration should be given to the limits of the possibilities provided by surface-mounted technology, i.e. mechanical strength, the mechanical strength of the implantation will be lower than THT.

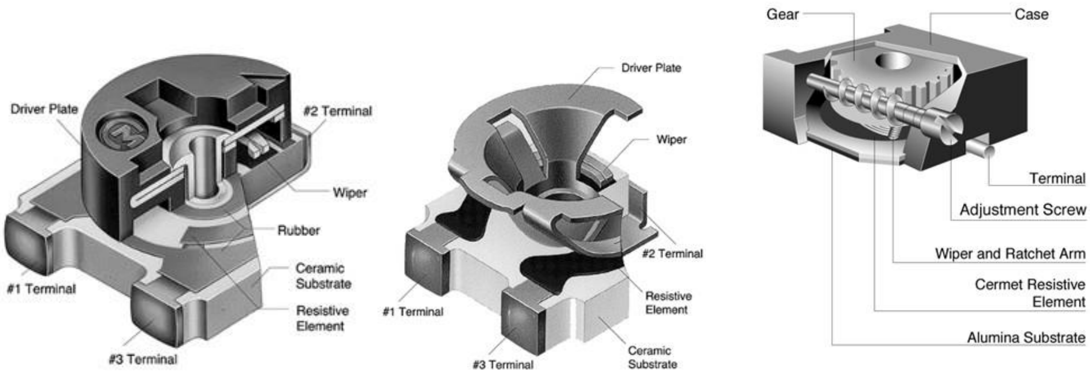


Figure 3.18: Internal Structure of Variable value SM resistors

3.6 Capacitors

A *capacitor*, is a passive two-terminal electrical component that stores potential energy in an electric field. The effect of a capacitor is known as capacitance. While some capacitance exists between any two electrical conductors in proximity in a circuit, a capacitor is a component designed to add capacitance to a circuit. The capacitor was originally known as a condenser or condensator. The original name is still widely used in many languages, but not in English.

The physical form and construction of practical capacitors vary widely and many capacitor types are in common use. Most capacitors contain at least two electrical conductors often in the form of metallic plates or surfaces separated by a dielectric medium. A conductor may be a foil, thin film, sintered bead of metal, or an electrolyte. The non-conducting dielectric acts to increase the capacitor's charge capacity. Materials commonly used as dielectrics include glass, ceramic, plastic film, paper, mica, and oxide layers. Capacitors are widely used as parts of electrical circuits in many common electrical devices. Unlike a resistor, an ideal capacitor does not dissipate energy.

The main *characteristics* of the condenser are:

- Capacity;
- Rated voltage;
- Tolerance (accuracy);
- Temperature factor;
- Frequency range;
- Polarized or Non-Polarized (NP) (interchangeability of terminals);
- Maximum alternating voltage.

Capacitor (Condenser) types:

Ceramic Capacitors 1 (MLCC, disc)

1.1 Class 1 dielectrics (C0G = NP0, U2J = N750 etc.)

1.2 Class 2 dielectrics (X7R, Z5V, etc.)

2. Electrolytic capacitors (wet, dry)

2.1 Aluminum electrolyte

2.2 Tantalum electrolyte

3. Plastic film / film capacitors (wound, stacked)

3.1 Polyester (KT, MKT, MFT)

3.2 Polypropylene (KP, MKP, MFP)

4. Paper capacitors

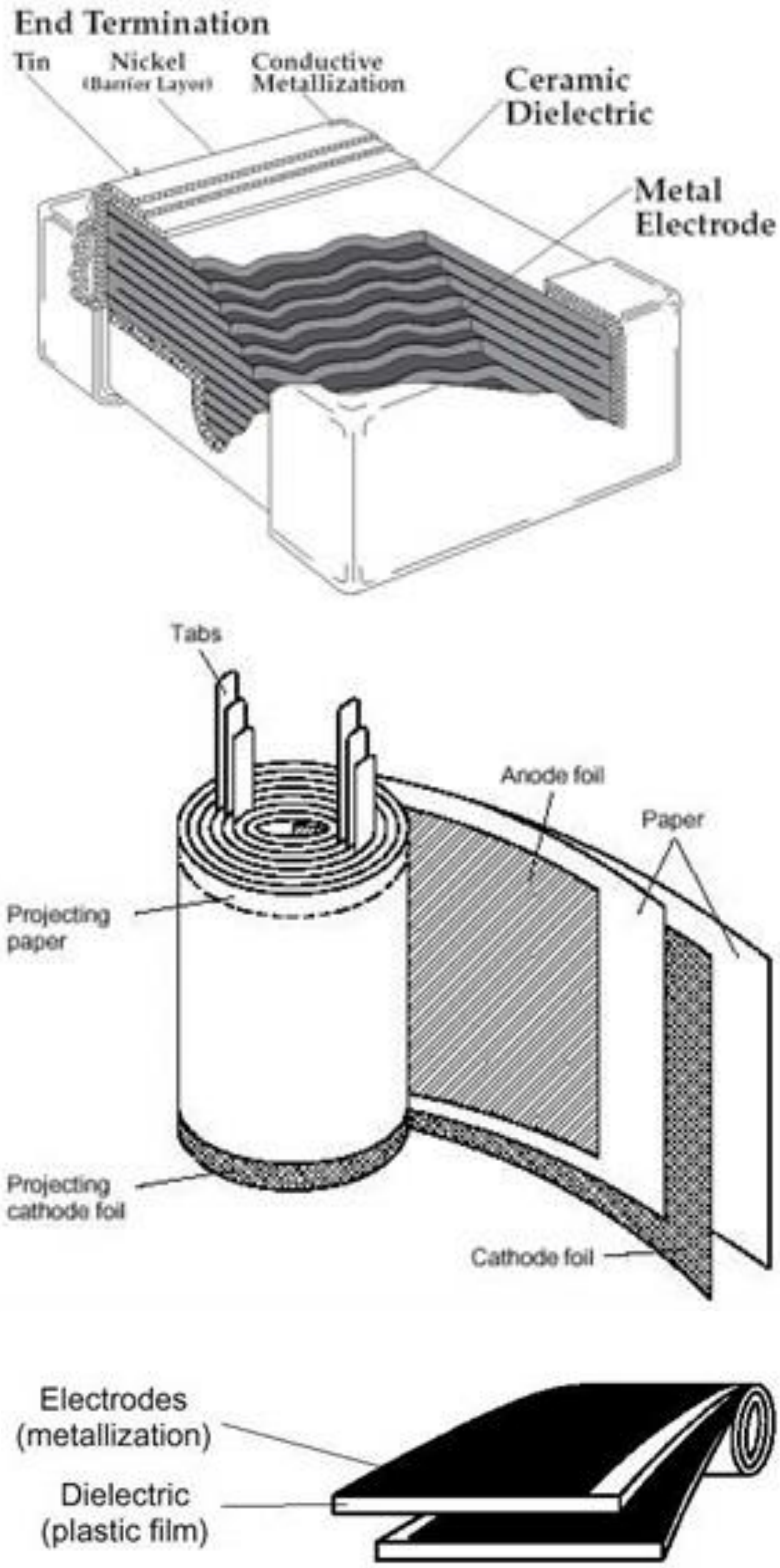

End Termination
Tin
Nickel
(Barrier Layer)
Conductive
Metallization
Ceramic
Dielectric
Metal
Electrode
Tabs
Anode foil
Paper
Projecting
paper
Projecting
cathode foil
Cathode foil
Electrodes
(metallization)
Dielectric
(plastic film)

Figure 3.19

Mechanical features:

- Chip capacitors (EIA standard classes)
- Axial capacitors (no standards)
- Radial capacitors (no standards)

Capacity and Tolerance:

- Their value is taken from the pF-mF range in the E6, E12, and E24 series.
- They are classified into standard tolerance classes according to their production scattering.

Maximum operating voltage:

Some V and some kV values. SM capacitors do not have a mark on this, but are shown on larger capacitors. In addition to given parameters, it is inversely proportional to the maximum capacity available.

Type-dependent properties:

- Ceramic Capacitors: The type of dielectric characterizes the temperature coefficient.
- Electrolytic capacitors: Typical operating temperature range, lifetime, maximum ripple current (leakage current, creates warming)
- Film Capacitors: Typical parameter is the dielectric loss

Capacitor Manufacturers:

Murata, Epcos, AVX - Kyocera, Yageo - Phycomp, Rohm, Kemet, Vishay - Sprague, Vishay - Roederstein, BCComponents, Evox-Rifa, Arcotronics, TDK, Nichicon, Rubycon, Samsung Electro-Mechanics

Ceramic capacitors

The ceramic capacitor is a small, metallized ceramic plate capacitor. The simplest ones consist of a piece of disc-shaped ceramic plate that vaporizes on the two sides of a few microns of silver reinforcements. In the case of a precision version, the exact capacity values are set by post machining, and finally coated. Ceramic capacitors from a few pF to approx. up to 100 nF. According to the values, they can add capacitance values (standard), their voltage values are also specified.

Figure 3.20: Ceramic Capacitors

Foil Capacitors - Block Capacitors

The film capacitor is most often made in blocks or rolls. The scattered inductance of the array design and its equivalent serial resistance are lower, so it can be better used at higher frequencies. The coiled version is simpler to manufacture and therefore costs lower. In modern foil capacitors, the terminals connect two sides to the entire surface, so low-inductance and low-resistance capacitors can be manufactured. Depending on the material used, it can be optimized for different properties.

- *Polystyrene*: Condenser with relatively low capacitance, with limited temperature tolerance. Due to its aging properties it is used in precision analog electronics. Its loss factor is low.
- *Polypropylene*: smaller price, good electrical properties and are particularly good at impulse operation. They can be used at temperatures above PS, even at +85 degrees. Their uniqueness is self-healing: short-term overloading, short-circuit electrical energy is locally evaporated by the plates, which isolates the fault location. After a break, it continues to work with unchanged properties. (4)
- *Polyester*: Recommended for high-voltage applications. Its loss factor is relatively high and is therefore not used at high frequencies.
- *Polyamide*: similar to polyester, but higher operating temperature.
- *Polycarbonate*: Due to its excellent insulation properties it is popular with high voltages.
- *Teflon*: It has very favorable high frequency properties and is therefore often used in microwave or radio frequency applications. It has good stability, high breakthrough strength and low loss factor even at high temperatures. Its disadvantage is that due to its low dielectric constant, its specific capacity is low and very expensive.

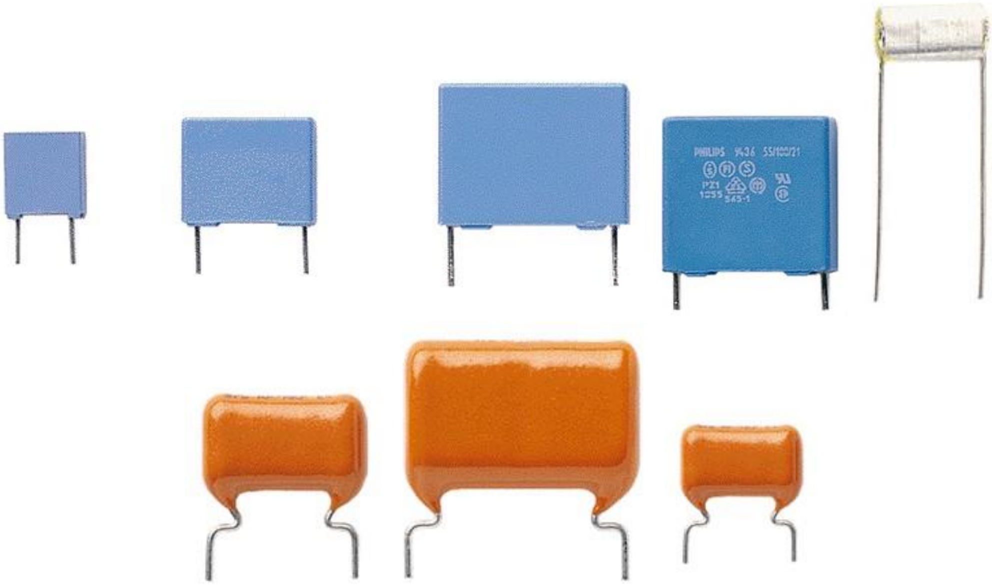


Figure 3.21: Foil Capacitors - Block Capacitors

Surface-Mounted (SM) Ceramic Capacitors

These capacitors have a ceramic dielectric (insulator) located between the electrodes as shown. They are small in size and have a flat column. Contacts are located on the two edges. The protective layer is the dielectric itself. Their capacity can be recorded according to the values (standard), their characteristic data is the voltage value.

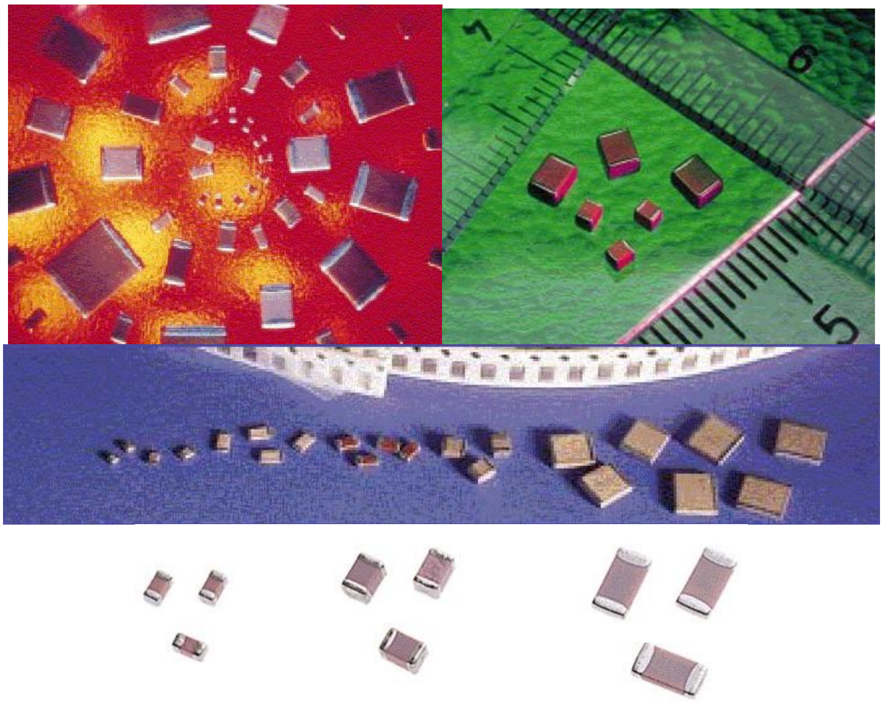


Figure 3.22: Surface-Mounted (SM) Ceramic Capacitors

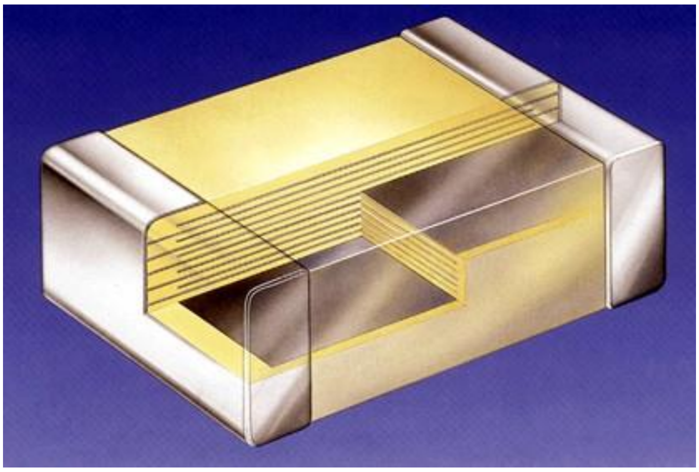


Figure 3.23: Internal Structure of Surface-Mounted (SM) Ceramic Capacitors

Based on dielectrics, ceramic surface mounted capacitors can be classified into standard classes. Taking into account the needs of specific applications, we have to select the appropriate dielectric quality capacitor from the manufacturer's data sheet to the appropriate position.

EIA standard coding

digits of TC		TC value multiplyer		TC tolerance	
ppm/°C	lettercode	multiplyer	num. cod.	ppm/°C	lettercode
0.0	C	-1	0	±30	G
0.3	B	-10	1	±60	H
0.9	A	-100	2	±120	J
1.0	M	-1000	3	±250	K
1.5	P	-10000	4	±500	L
2.2	R				
3.3	S				
4.7	T				
7.5	U				

Other wide-spread coding

TC presage	TC value (ppm/°C)
N/P - negative / positive	0(±30)
	150(±60)
	220(±60)
	330(±60)
	470(±60)
	750(±120)

C0G = NP0 - TC = 0±30ppm/°C
P2H = N150 - TC = -150±60ppm/°C
S2H = N330 - TC = -330±60ppm/°C
U2J = N750 - TC = -750±120ppm/°C

Figure 3.24: I. Class Dielectric Coding (Temperature Compensating Type)

EIA Standard Coding

Lower Temp. Limit		Higher Temp. Limit		Max. Capacity Change	
°C	Lettercode	°C	Numbercode	%	Lettercode
+10	Z	+45	2	±1.0	A
-30	Y	+65	4	±1.5	B
-55	X	+85	5	±2.2	C
		+105	6	±3.3	D
		+125	7	±4.7	E
		+150	8	±7.5	F
		+200	9	±10.0	P
				±15.0	R
				±22.0	S
				+22/-33	T
				+22/-56	U
				+22/-82	V

X7R - TC = 15% (-55°C - +125°C)
X5R - TC = 15% (-55°C - +85°C)
Y5V - TC = +22/-82% (-30°C - +85°C)
Z5U - TC = +22/-56% (+10°C - +85°C)

Figure 3.25: II. and III. Class Dielectric Coding (High Dielectric Constant Type)

Block Capacitor Networks

Their construction is identical to SM ceramic capacitors. Equal capacitors are built into a case, so you can save space on the expensive panel, and the chance of wrong insertion is also lower. It is used when performing the same functions, such as when cooling or connecting bus lines.

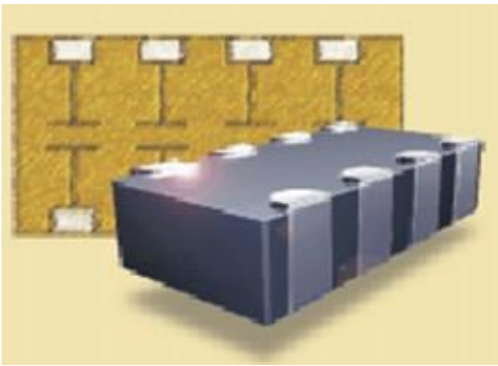



Figure 3.26: SM Block Capacitor Networks (Ceramic)

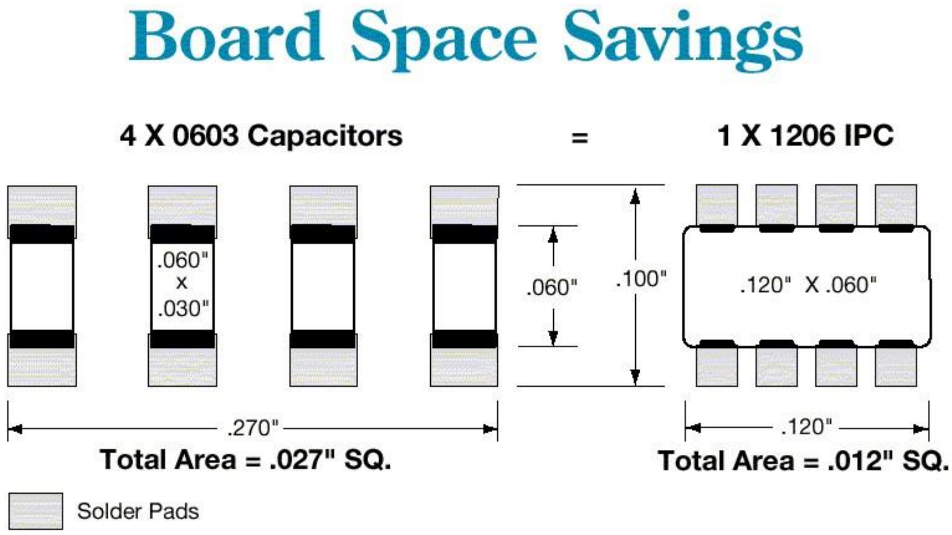


Figure 3.27: Less space requirements for block capacitor networks

Electrolytic capacitors

Electrolytic capacitors can be made in aluminum and tantalum. An aluminum foil electrolytic capacitor is an oxidized surface aluminum, where aluminum oxide acts as a dielectric. Thus, one of the plates in the condenser is aluminum and the other is the electrolyte (liquid or gel). With a small volume, it has a large capacity: from 0.5 μF (microfarad) to up to 100 F. Losses, however, may be significant. The capacitance of the electrolytic capacitor changes with temperature (decreasing temperature decreases capacity, increasing temperature increases capacity). The most important field of use of the electrolytic capacitor is the stabilization of rectified DC voltages in the alternating voltage in the power supply units and the filtering of the low frequency alternating current components as a filter condenser. In general it can be said that its high frequency properties are bad, its loss factor is relatively high, its value is uncertain (only with high dispersion, can be inaccurately manufactured), but its relative capacity is high.

The major disadvantage is its polarity sensitivity, because it results in an inversion of polarity due to intense gas formation. They are relatively small, cylindrical. The radial contacts are located at the bottom with two sides in axial design. The protective layer is the aluminum housing itself, and in most cases the plastic covering layer. They can have capacitance values according to standard values, their main characteristic being the voltage value (permissible maximum voltage), which should not be exceeded. When designing the voltage tolerance, the 12V capacitor must not be designed for a 12V supply line! Smaller electrolytic capacitors are provided with a diffuser to prevent explosion, while the industrial electrolytic capacitors are equipped with a safety valve. There are alternating current variants, both of which have an oxide layer on both metal plates. Their specific capacity is half for the same size. For example, they are used in less expensive crossovers. In sound engineering applications, their applications are not recommended, but they are widely used in commercial entertainment electronics because of its low price and small size. Its features can be improved by applying a parallel-connected lower capacity film capacitor.

Figure 3.28: Aluminum Electrolytic capacitors

Tantalum Capacitors

Its properties are similar to aluminum electrolytic capacitors. Its relative capacity is even higher and its high frequency properties are much better. Less aging and wider temperature range. The price is higher and the use requires careful attention. Tantalum capacitors may explode in reverse polarity, overvoltage, or high current. On the tantalum condensers the "+" mark indicates the positive-pole terminal. There is a Tantalum dielectric between Tantalum electrodes. Small in size, with drop shape. Leads are located at the bottom. The protective layer includes capacity values that can be of standard values, and the maximum voltage value.

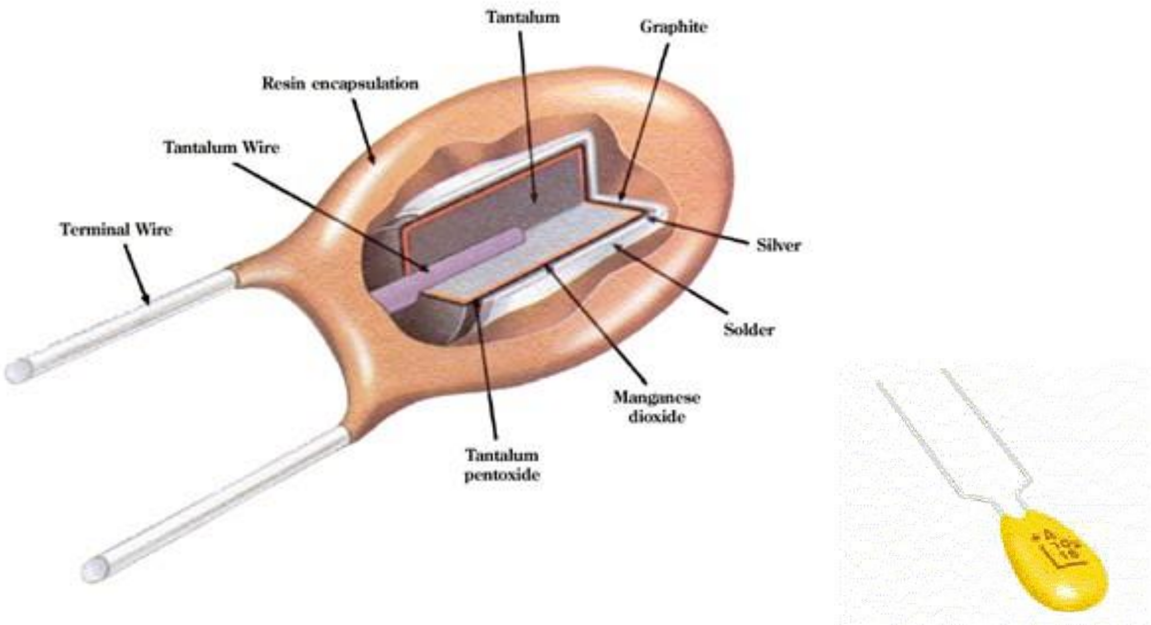


Figure 3.29: Tantalum Capacitor, Internal Structure, Markings

SM Electrolytic Capacitors

Their interior design and characteristics has the same as the through-hole mounted versions. Designed for surface-mounted technology.

Figure 3.30: SM Electrolytic Capacitors

SM tantalum capacitors

Tantalum capacitors are also manufactured in surface mounted designs. They have a small column shape and the contacts are located on the two sides. Protective layers are plastic housing. They can have capacitance values according to standard values, their main characteristic being the voltage value (permissible maximum voltage), which should not be exceeded.

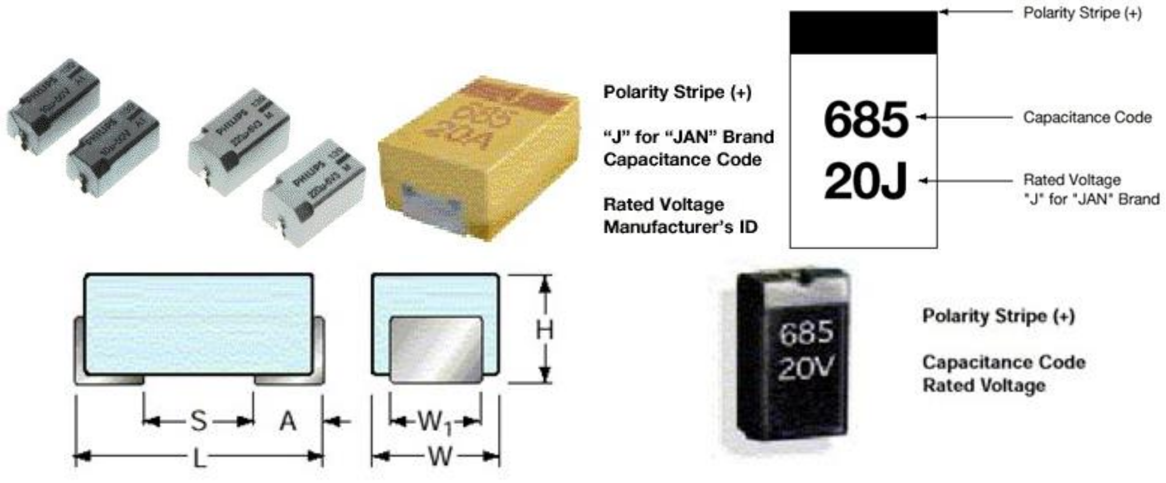


Figure 3.31: SM tantalum capacitors

SM trimmer capacitors

They have two terminals, relatively low and variable capacitance, and surface-mounted design.

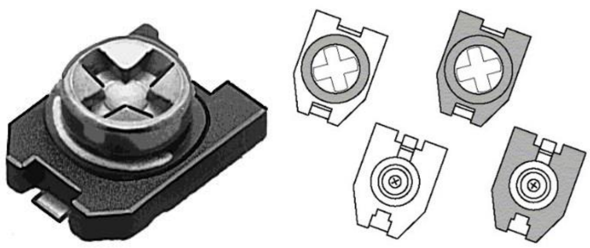


Figure 3.32: SM trimmer capacitors

3.7 Resistance, capacitor dimensions, tolerance codes

Tolerance Codes for Resistors and Capacitors

The following tolerance table shows how much the actual component value (resistance or capacity) due to manufacturing can differ from the nominal value for a given mark. When designing, we also need to consider economics as the more accurate parts are more expensive. There are circuitry details where spare parts with little tolerance are unnecessary, but in some cases this is desirable. Tolerances A, B, C and D used only for below 10pF condensers.

Tolerance Code	Tolerance Value Resistors	Tolerance Value Capacitors
A	-	±0.05pF
B	±0.1%	±0.1pF
C	±0.25%	±0.25pF
D	±0.5%	±0.5pF
F	±1%	±1%
G	±2%	±2%
J	±5%	±5%
K	±10%	±10%
M	±20%	±20%
Y	-	+10%/-20%
Z	-	+80%/-20%

Figure 3.33: Tolerance Codes for Resistors and Capacitors

Dimensions of axial parts

The various dimension data that is included on each datasheet is especially important when designing a PCB. In many cases, it is free to choose whether or not the application is implemented from through-hole mounted or surface-mounted parts.

Size Code	0204	0207	0411	0617	0922
D - Diameter (mm)	≈1.7	≈2.5	≈3.5	≈6	≈9
L - Length (mm)	≈3.5	≈6.5	≈10	≈16.5	≈20

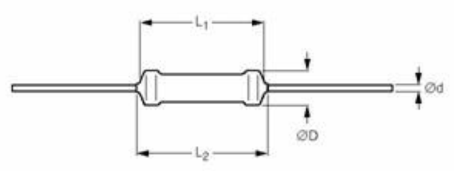


Figure 3.34: Standard size codes used by many manufacturers of axial resistors

Dimensions of radial parts

F = e = P = pitch (leads distance)

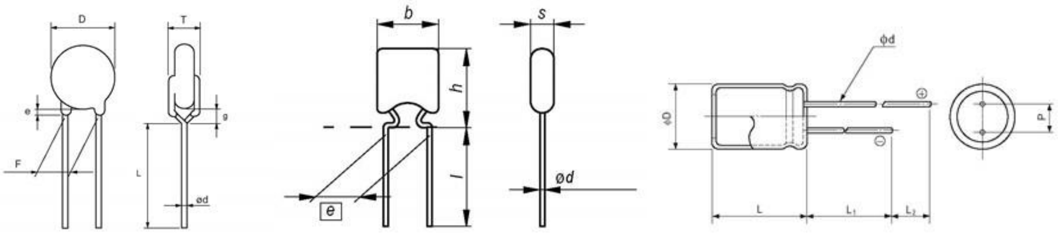


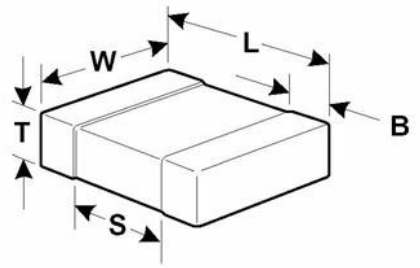
Figure 3.35: Dimensions of radial parts

Passive chip parts size codes

For passive chip components, we mean surface mounted capacitors and resistors. They are commonly called "chicken food" components. Length and width values may differ by ± 0.1mm per manufacturer. Some special sizes:

- **0805 -** size used for resistors and capacitors
- 2512 - used only for resistors
- 1812 - used only for capacitors

EIA code (inch-based)	EIA code (meter-based)	L - Length (mm)	W - Width (mm)
0201	0603	0,6	0,3
0402	1005	1,0	0,5
0603	1608	1,6	0,8
0805	2012	2,0	1,25
1206	3216	3,2	1,6
1210	3225	3,2	2,5
2010	5025	5,0	2,5
1218	3245	3,2	4,5
1812	*4532*	*4,5*	*3,2*
1825	*4564*	*4,5*	*6,4*
2512	6432	6,4	3,2
2220	5750	5,7	5,0
2225	*5664*	*5,6*	*6,4*



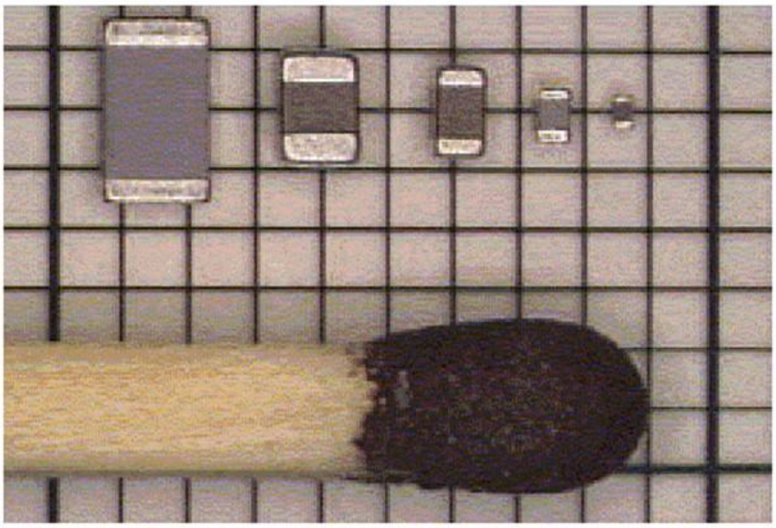


Figure 4 - Capacitors Ranging from 1206, 0805, 0603, 0402 and 0201

Figure 3.36: Passive chip parts size codes, illustrations

Size Codes of Chip Tantalum Capacitors

The surface-mounted tantalum capacitors are different from the SM ceramic capacitors in terms of size, so they can identify their type immediately. Letter numbers may differ from manufacturer except for bold **A, B, C, D** – these are manufacturerindependent size codes. There is a polarity mark ("+") on the surface, since the tantalum capacitors should not be charged with an opposing polarity voltage.

Letter Code	EIA Code (meter based)	L - Length (mm)	W - Width (mm)
P	2012	2,0	1,25
A	**3216**	**3,2**	**1,6**
S	3216L	3,2	1,6
B	**3528**	**3,4**	**2,8**
T	3528L	3,4	2,8
C	**6032**	**6,0**	**3,2**
U	6032L	6,0	3,2
D	**7343**	**7,3**	**4,3**
V	7343L	7,3	4,3
X	7343H	7,3	4,3
E	7260	7,2	6,0

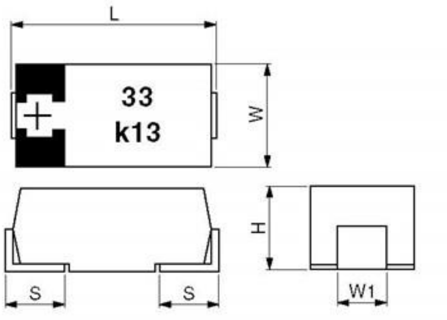


Figure 3.37: Size Codes of Chip Tantalum Capacitors

MELF Resistor Size Codes

MELF (**M**etal **E**lectrode **L**eadless **F**ace) resistors are cylindrical, unlike conventional ones. Micromelf: can be planted in a hole. Their implantation and handling difficulties are compensated for their high reliability, precision, long-term stability, high sensitivity to moisture and high temperature operating range. Because of these properties, they are mainly used in precision devices and are not popular in commercial electronics. The length and diameter values may differ by ± 0.1mm per manufacturer.

Name	Size Code	D - Diameter (mm)	L - Length (mm)
microMELF	0102	1.2	2.1
miniMELF	0204	1.4	3.5
MELF	0207	2.2	5.8

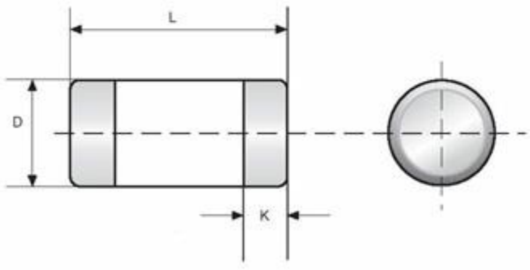


Figure 3.38: MELF Resistor Size Codes

3.8 Diodes

The diode is an electronic component, usually two-lead, mostly used for rectification, for telecommunication purposes (e.g. for demodulation in radio transmitters) or for simpler gate circuits. There are different power (small or high current diodes) or diode bridges containing 4 diodes in one case (Graetz bridge).

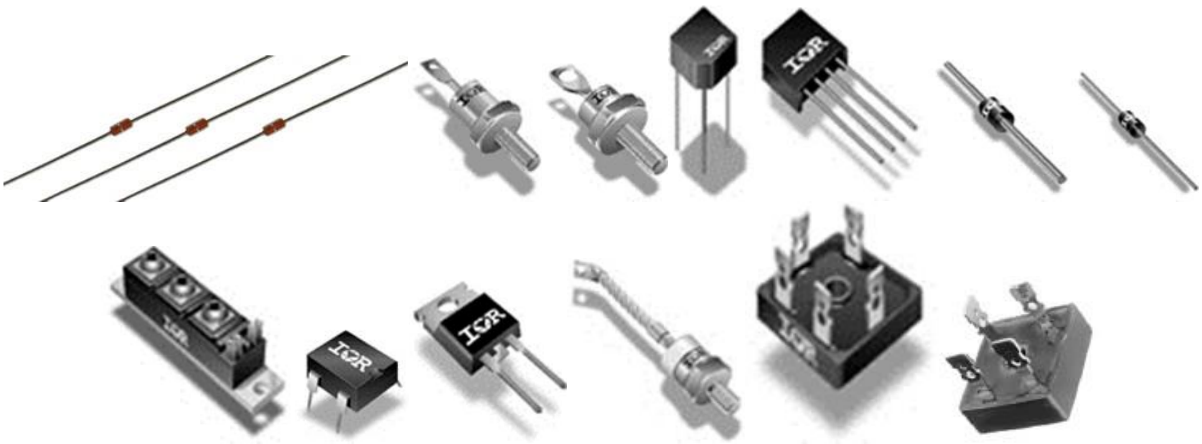


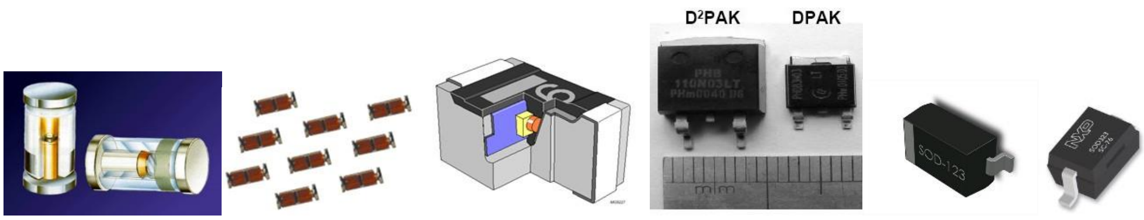
Figure 3.38: Diodes

Surface Mounted Diodes

SM diodes are widely used in today's electronic equipment. Generally they have two terminals. SOD = Small Outline Diode

The most widespread enclosures are:

- MELF (SOD-80)
- SOD-110
- D-PAK
- D2-PAK
- SOD 123, SOD 323
- SM LED-ek



MELF (SOD-80) SOD-110 D2-PAK,D-PAK SOD 123, SOD 323

Figure 3.40: SM Diodes

Types of diodes:

- Switching diodes
- Rectifier diodes
- Schottky diodes
- Zener diodes
- TVS diodes
- Capacity diodes

Mechanical features:
Standard diode and transistor enclosures include various mechanical characteristics, measurements, and size tolerances.

Type markings:
1. Pro Electron standard:
- BA(.)xx – signal processing diode
- BY(.)xx – rectifier diode
- BZ(.)xx – Zener diode
- BC(.)xx – AF, small power transistor
- BD(.)xx – AF, power transistor
- BS(.)xx – small power switching transistor
- etc.

2. JEDEC standard:
- 1Nxxxx - Diodes
- 2Nxxxx – Bipolar Transistors, JFETs
- 3Nxxxx - MOSFETs, other

3. JIS standard:
- 1SSxxxx - signal processing diode
- 1SRxxxx - rectifier diode
- 2SCxxxx - NPN transistor
- 2SKxxxx - N-channel FET
- etc.

Examples: BAS316, BYD57, BZD27, BC847, 1N4148, 1SS355, 2SK1413

Diode and Transistor Manufacturers:
Philips Semi, Fairchild Semi, ST Micro, ON Semi, Infineon, Eupec, Toshiba, Diodes, Rohm, International Rectifier, Vishay - Telefunken, Vishay - General Semi, National Semi

3.9 Transistors

The transistor is a three-layer semiconductor device that is predominantly used for amplification of weak electrical signals, for signal switching or voltage stabilization. The three layers are chemically differently doped (contaminated) containing two p-n transitions. The transistor is the basic element of modern electronics, it is manufactured as a stand-alone component and as an integral part of integrated circuits. Generally they have three terminals.

Types of Transistors:
1. Bipolar Transistors
   1.1 NPN
   1.2 PNP
2. Field Effect Transistors (FET)
   2.1 JFET
   2.2 MOSFET (IGFET)
3. IGBTs

Widely used THT packages are:

- TO-3
- TO-39
- TO-220
- TO-92
- TO-247, etc.

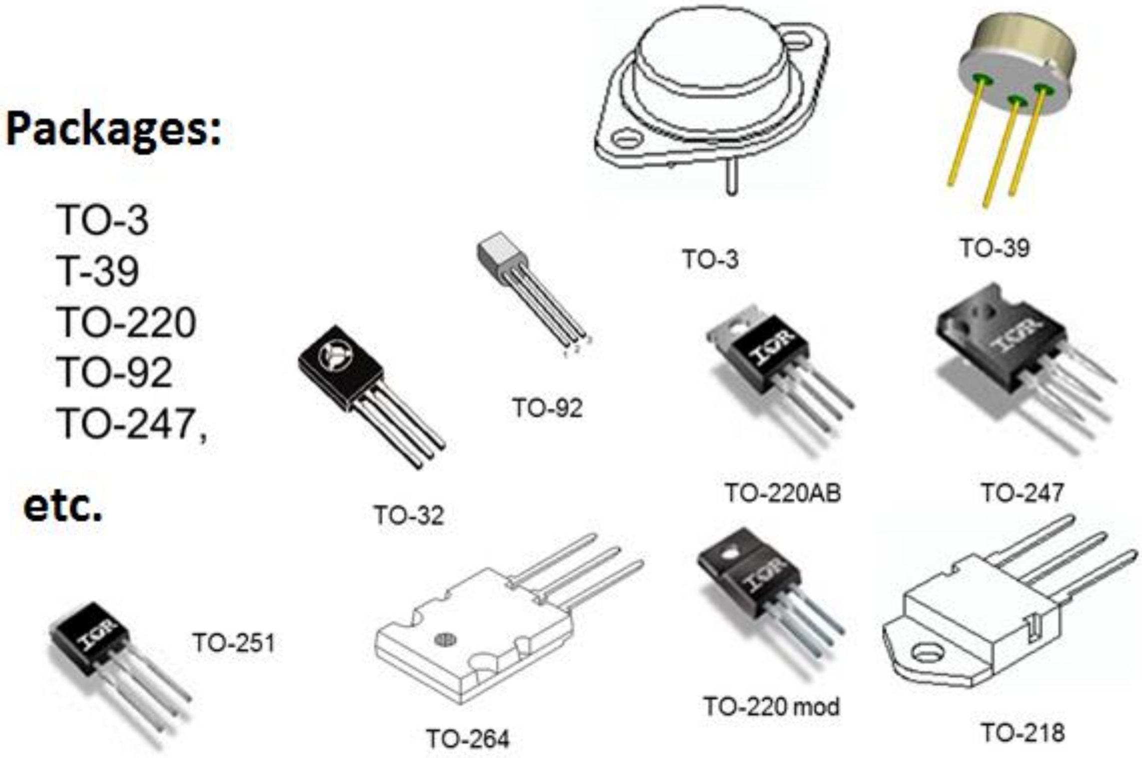


Figure 3.41: THT Transistor Packages

Surface Mounted Transistors

Generally they have three terminals. The description of the enclosure also includes: SOT=**S**mall **O**utline **T**ransistor.

Their internal structure is illustrated by the following figure:

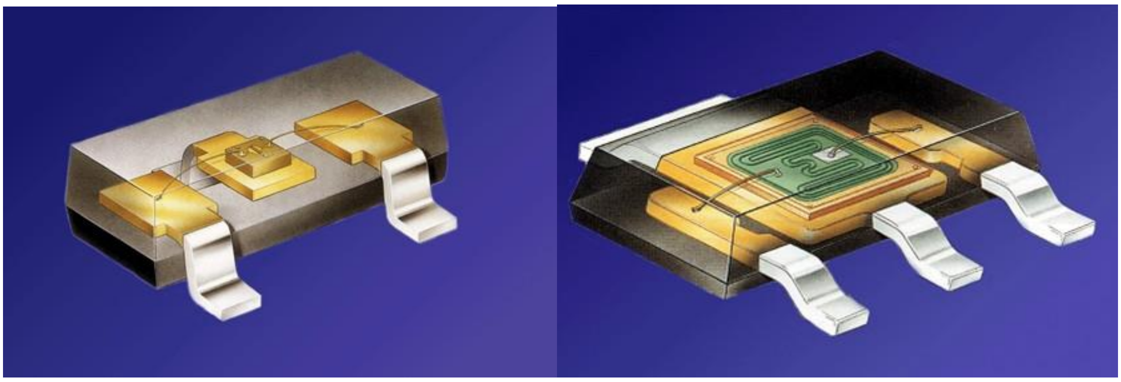


Figure 3.42: Internal Structure of SM Transistors

More widespread packages are the following:

- SOT-23
- SOT-223
- SOT-490
- SOT-89

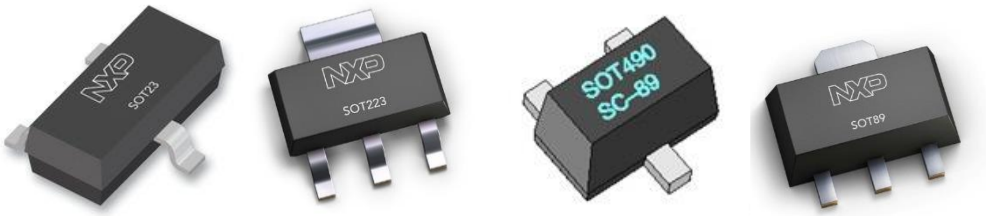


Figure 3.43: SOT23, SOT223, SOT490, SOT89 SM Transistor Packages

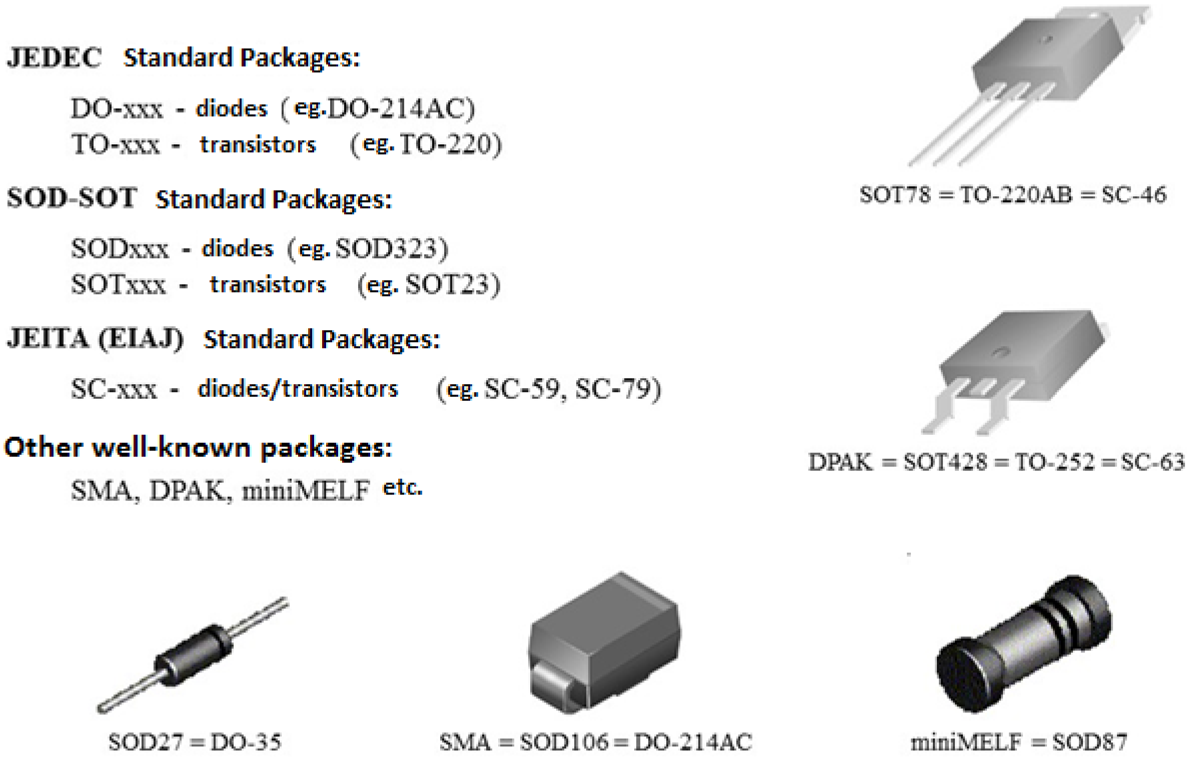


Figure 3.44: Grouping of discrete semiconductor packages, different names, standards

3.10 Integrated Circuits

An integrated circuit or monolithic integrated circuit (also referred to as an IC, a chip, or a microchip) is a set of electronic circuits on one small flat piece (or "chip") of semiconductor material, normally silicon. The integration of large numbers of tiny transistors into a small chip results in circuits that are orders of magnitude smaller, cheaper, and faster than those constructed of discrete electronic components. The IC's mass production capability, reliability and building-block approach to circuit design has ensured the rapid adoption of standardized ICs in place of designs using discrete transistors. ICs are now used in virtually all electronic equipment and have revolutionized the world of electronics. Computers, mobile phones, and other digital home appliances are now inextricable parts of the structure of modern societies, made possible by the small size and low cost of ICs.

This category also includes multichip modules, which contain multiple chips in a single case. The first integrated circuit was made by Jack Kilby, Texas Instruments engineer in 1958. Advantages of a circuit implemented in an integrated form against a conventional circuit that performs the same function:

- Greater reliability
- Compact design with high density in small spaces
- Greater speed
- Lower consumption
- More economical mass production (5)

Functional classification:

- Analog circuits: linear circuits (amplifiers, comparators, filters), regulator ICs, etc.
- Digital circuits: logic gates, counters, flip-flops, memories, CPUs / MCUs, etc.
- Other circuits: AD / DA converters, timers, oscillators, etc.

Integrated Circuits Properties:

- Function - The IC manufacturer code is usually begins with the function describing letters
- Enclosure - generally referred to as the last letter of the manufacturer's code (except where the packing code is indicated - TR)
- Operating temperature range - if not knit, usually there is reference to the enclosure in the manufacturer's code
- Many other attributes that are specific to each type

Their interior design:

- Circuit board (silicon chip: *Up to millions of parts!*)
- Joints for legs with gold wirings
- Package - there are many types

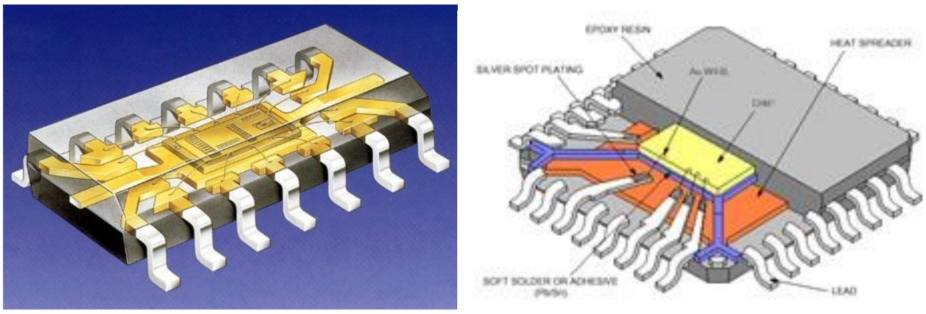


Figure 3.45: Internal Structure of Integrated Circuits

Classification of IC Packages:

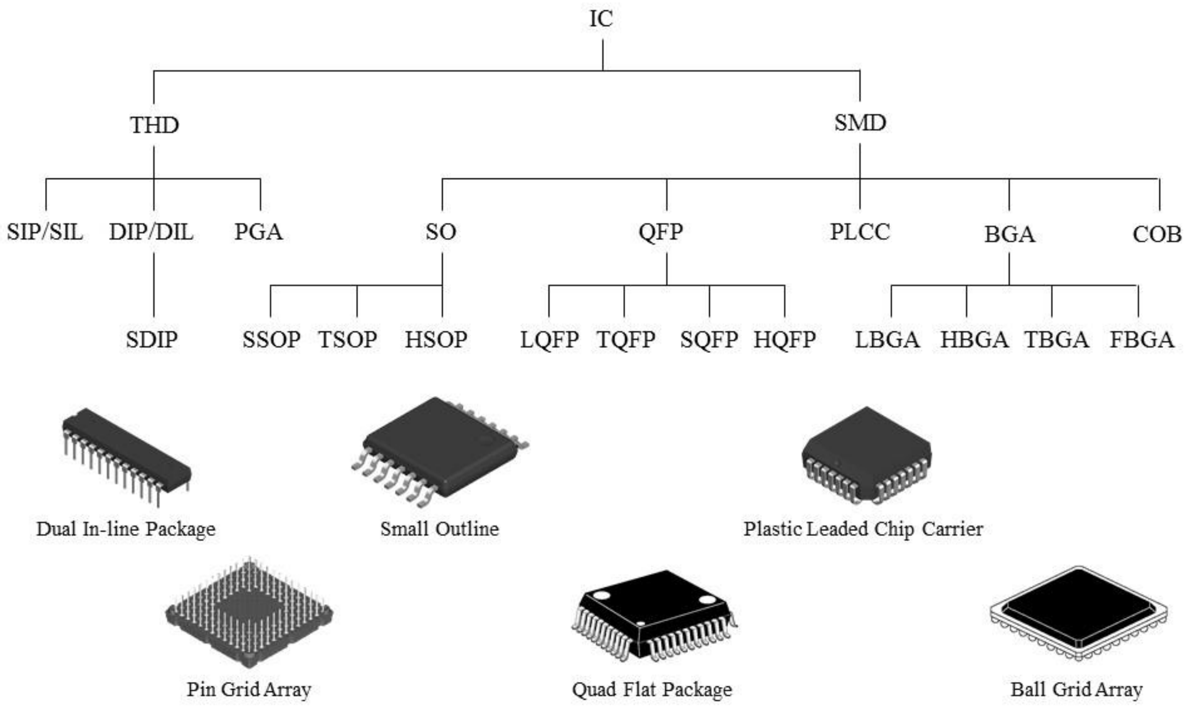


Figure 3.46: Classification of IC Packages

Packages of Integrated Circuits

Due to the variety of integration levels and functions as well as the different manufacturing needs, many standard encapsulation forms have emerged. Today, higher integrity levels, fine-pitch or BGA encapsulation are widespread. When designing, it should be taken into account that using these components makes our manufacturing process more problematic and requires more precision. However, after reaching a certain degree of integration, only these forms of encapsulation can be selected.

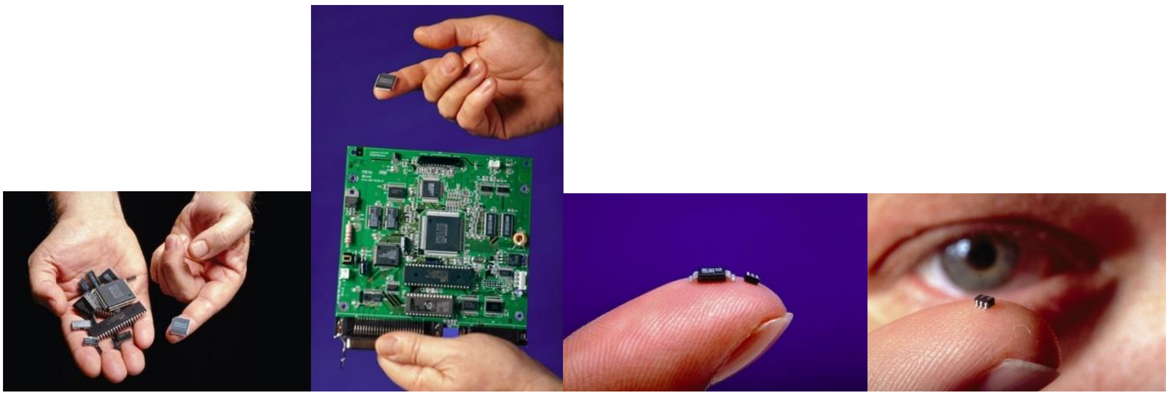


Figure 3.47: IC packages

DIP

DIP: **D**ual **I**n-line **P**ackage, with conventional THT enclosures. **PDIP**: **P**lastic **D**ual **I**n-line **P**ackage Terminals on two sides, bent in the direction of the plastic casing, in one direction, manufactured from 1965, can be inserted into the IC socket it has, line spacing: 0.3 "; 0.5"; 0.6 "; 0.9". Number of leads: 4 - 64, Distance of leads: 2.54 mm (6).

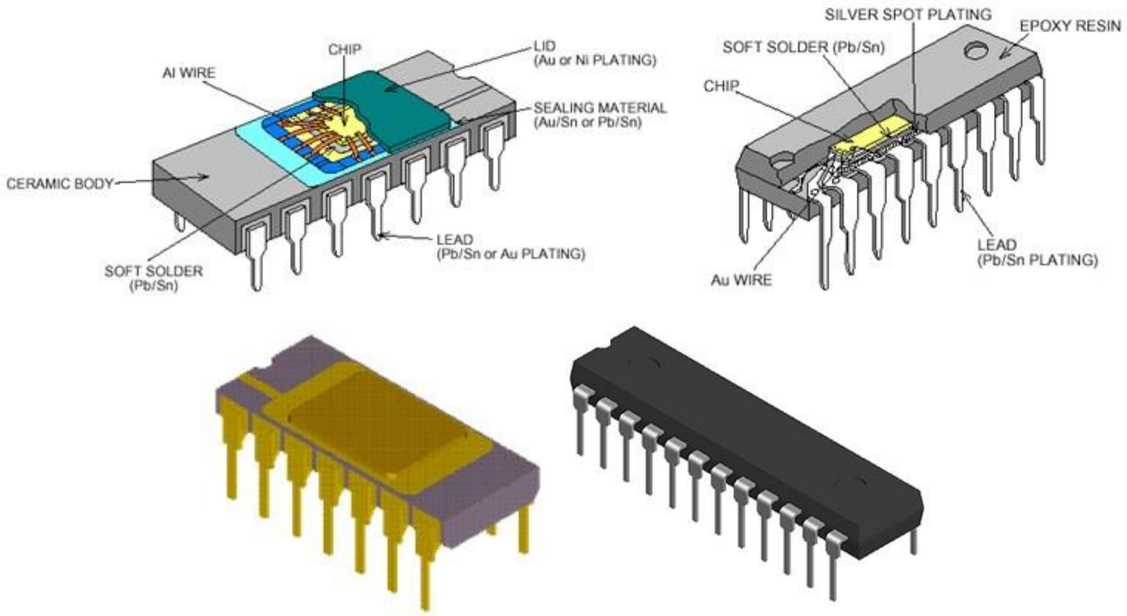


Figure 3.48: DIP

TO220, Clipwatt, Felxiwatt, Heptawatt packages

These THT enclosures are used primarily for power amplifiers and power supplies. Because they have to dissipate high power, they need to be fitted to a heat sink by using the appropriate thermal insulation paste and electrical insulation (mica plate, insulating ring). In addition to surface-mounted technology, it is used with blended manufacturing technology or exclusively with THT technology.

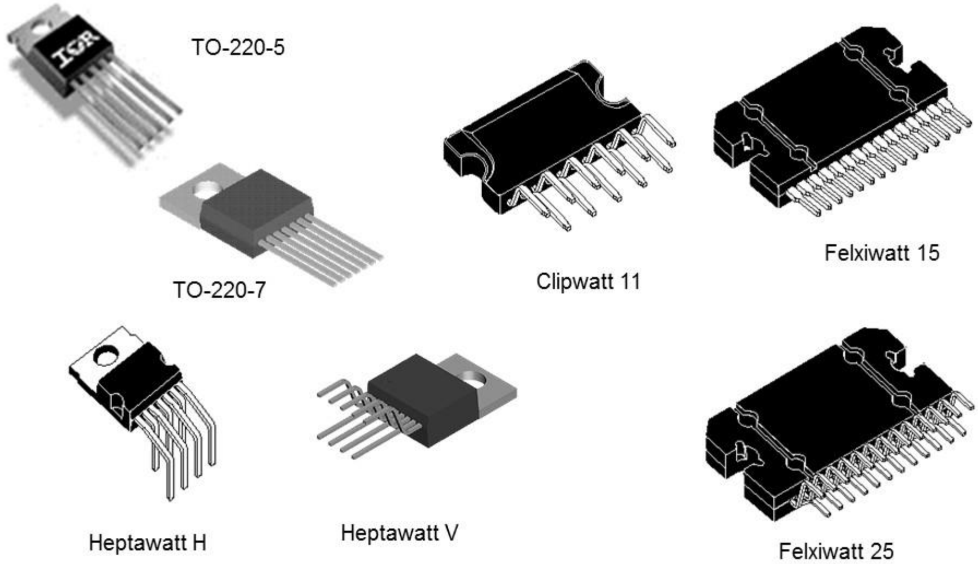


Figure 3.49: TO-220, Clipwatt, Felxiwatt, Heptawatt packages

SOP, **SOIC** package

SO and **SOP** SM IC packages: **S**mall **O**utline **P**ackage English initials are the abbreviation of the abbreviation. **SOIC**: **S**mall **O**utline **IC**. Surface mounted, terminals on two sides, bent on the housing, bent in one direction, thickness: 1.5 - 3 mm; Width: 0.15..0.65 "Number of leads: 6 to 90, Distance between the leads: 0.5, 0.65, 0.8, 1, 1.27 mm

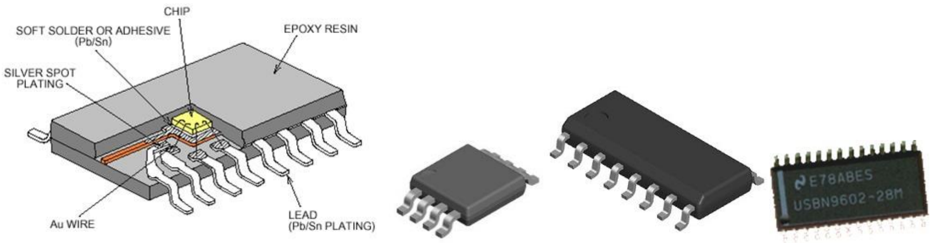


Figure 3.50: SOP

SSOP

SSOP: **S**hrink **S**mall **O**utline **P**ackage. "Shrunk" SOP. Surface mounted, terminals on two sides, bent at one end of the enclosure. Number of leads: 8 to 96, Distance of leads: 0.4; 0.5; 0.65 mm

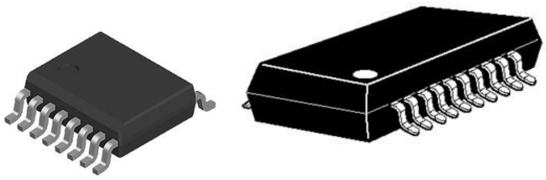


Figure 3.51: SSOP

Fine pitch ICs

Under *Fine pitch* ICs, we mean high-density integrated circuits. The insertion of these parts is particularly problematic, and it is difficult to find the right manufacturing conditions, since when using a bit more solder, it will be a solder-ball, with little less solder, there will be insufficient wetting/run up. Insufficient wetting/running up results in unreliable operation and a lower life expectancy, and solder balls cause short-circuits, resulting in a malfunctioning or non-working product. The pitch is below the distance between the leads, measured from the middle of the foot to the middle of the foot. Fine pitch ICs are those whose pitch value is:

- 0.5 mm
- 0.4 mm
- 0.3 mm

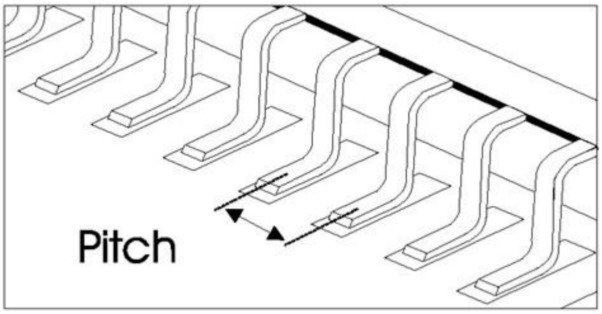


Figure 3.52: Measurement of Pitch

TSOP

TSOP stands for the initial letters of the English **T**hin **S**mall **O**utline **P**ackage. "Thin" SOP. Surface mounted, terminals on two sides, bent at one end of the enclosure. Number of leads: 8 - 86, Distance of leads: 0.4; 0.5; 0.65; 0.8; 1.27 mm

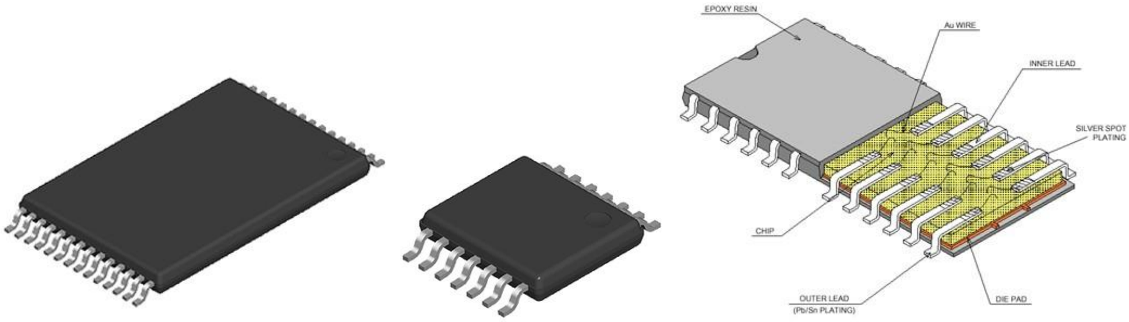


Figure 3.53: TSOP

SOJ package

The **SOJ** abbreviation is derived from the initials of the English **S**mall **O**utline **J**-leaded package. Surface-mount, **J**-shaped terminals on two sides, bent at one end of the enclosure. Number of leads: 14 - 70, Distance of leads: 0.8; 1.27 mm. It was developed mainly because of easier insertion and removal into IC sockets. It is also used without IC sockets, in this case special attention should be paid to the wetting/running up of the legs during insertion.

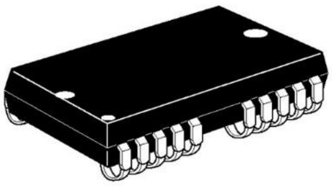


Figure 3.54: SOJ

QFP

QFP stands for the initials of the English **Q**uad **F**lat **P**ackage. Square ceramic case with four-sided contacts. "Square-shaped flat package".

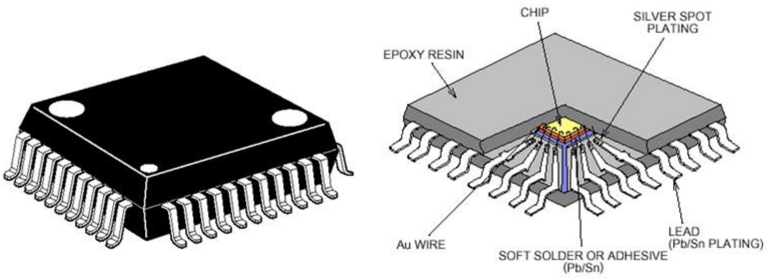


Figure 3.55: QFP

LQFP

The abbreviation **LQFP** comes from the initial letters of the English **L**ow-profile **Q**uad **F**lat **P**ackage. Square or rectangular plastic case with four-bolted terminals, thickness: 1.4 mm. Number of leads: 20 - 256, Distance of leads: 0.4; 0.5; 0.65; 0.8; 1 mm. *In most cases fine pitch ICs!*

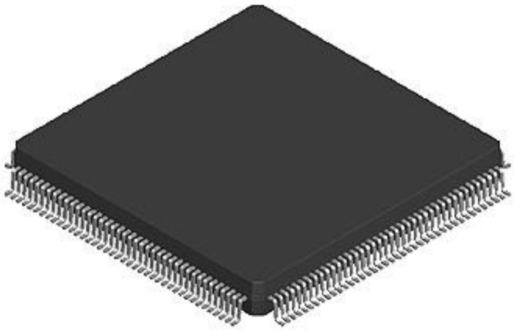


Figure 3.56: LQFP

TQFP

The abbreviation **TQFP** comes from the initial letters of the English **T**hin **Q**uad **F**lat **P**ackage. Square or rectangular plastic case with four-bent castings, thickness: 1 mm "Slim rectangular flat case". Number of leads: 20 - 256, Distance of leads: 0.4; 0.5; 0.65; 0.8; 1 mm. *In most cases fine pitch ICs!*

Figure 3.57: TQFP

HQFP

The abbreviation **HQFP** comes from the initials of the English **Q**uad **F**lat **P**ackage with **H**eatsink. It is a QFP enclosure that has a cooling surface due to the dissipation requirement of the electronics in it. Conducts the heat to the well-designed pads or copper islands on the PCB.

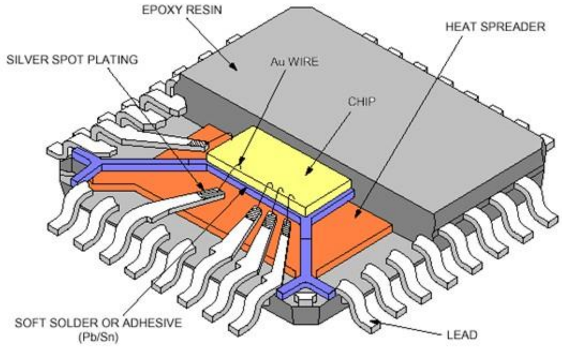


Figure 3.58: HQFP

QFJ, PLCC package

QFJ stands for the initials of the English **Q**uad **F**lat **J**-leaded package. The abbreviation **PLCC** is derived from the initials of the English **P**lastic **L**eaded **C**hip **C**arrier. Square or rectangular plastic case with four J-shaped terminals. Number of leads: 18 - 124, Distance of leads: 1.27 mm. It was developed mainly because of easier insertion and removal into IC sockets. It is also used without IC sockets, in this case special attention should be paid to the wetting / running up of the leads during insertion. Various types of memory, EEPROMs, are commonly used, since they store the boot software on the devices, which may occasionally need replacement or external reprogramming.

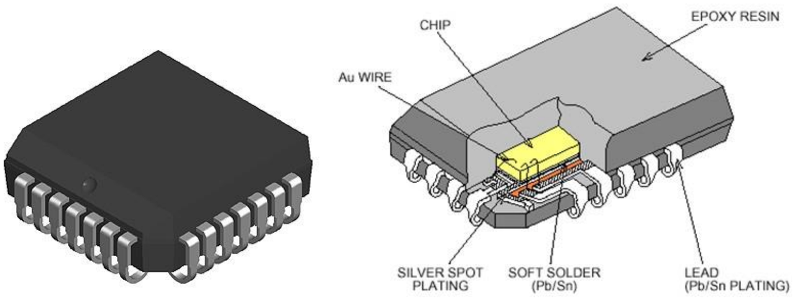


Figure 3.59: QFJ, PLCC package

BGA package

The **BGA** abbreviation comes from the initial letters of the English **B**all **G**rid **A**rray. A surface mounted package for integrated circuits. Devices for final insertion, such as microprocessors. With the BGA layout, you get more connectivity than DIP or flat packages. The complete lower surface can be exploited, unlike the previous ones, where only the edges of the case were used. In addition, the terminals are shorter than the previous packages, which is why the features at high speed are better. The insertion requires precision equipment, which is why it is used only for automatic insertion. BGA packaged ICs are not suitable for socket connection. There is a problem with debugging in case of incorrect insertion, as only the extreme balls are visible. We have to make an X-ray for the test. In the case of rework, re-balling should be performed with special equipment and a re-soldering with a specially designed equipment must be carried out with a strictly respected heat profile. With lead-free soldering, their reliability is in many cases smaller than for other types of packages, since balls can crack or detach from one side after many warm-ups / cool-downs. This can result in unreliable operation, at a certain temperature and humidity.

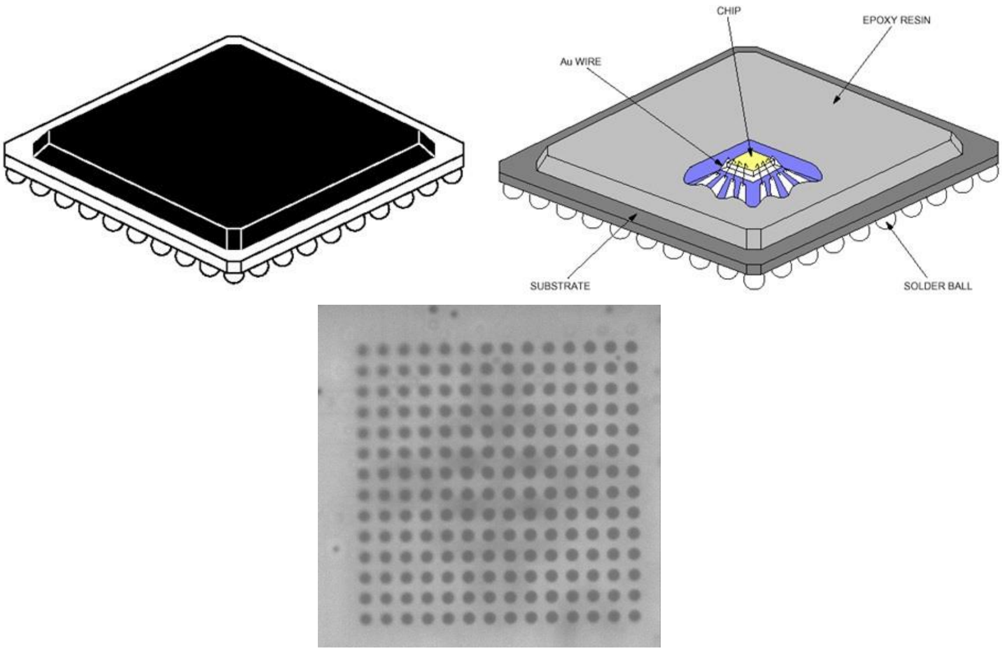


Figure 3.60: BGA package, Internal Structure, X-Ray picture

CDBGA package

The **CDBGA** abbreviation is derived from the initials of the English **C**avity-**D**own **BGA**. Cavity-Down BGA packages are most often connected to high performance and high-speed devices. Its excellent heat conducting channel makes it suitable for encapsulating processors and other high performance power circuits.

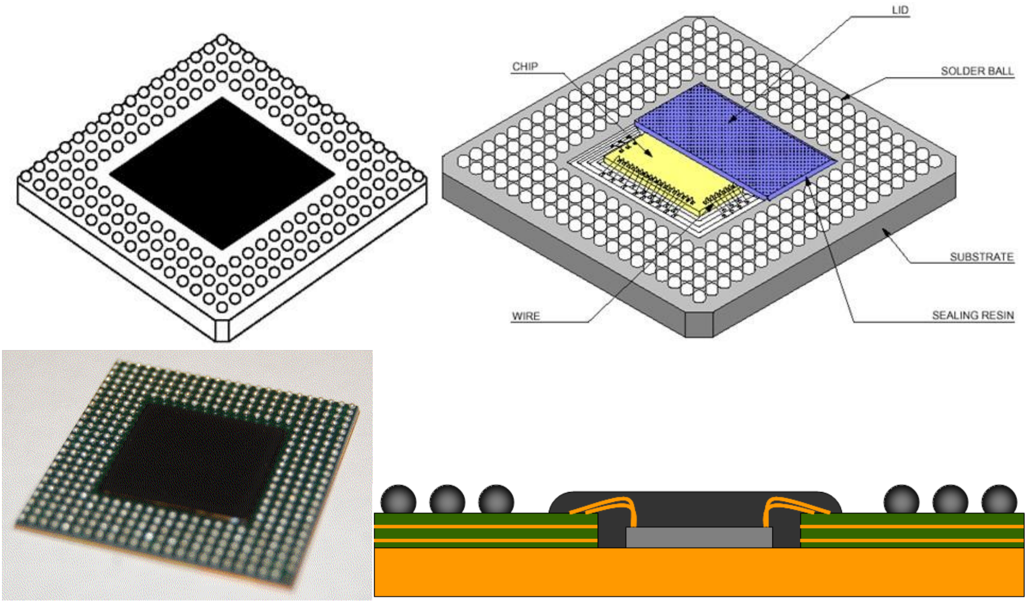


Figure 3.61: CDBGA package, Internal Structure, cross-section

FBGA package

The **FBGA** abbreviation is derived from the initials of the English **F**ine-Pitch **B**all **G**rid **A**rray. Square or rectangular ceramic casing, with a lower rounded circle with several spherical contacts, thickness: 1.3 - 5.5 mm. Number of leads: 24 - **4624**, Distance of leads: 0.4; 0.5; 0.65; 0.75; 0.8 mm. Another name is **μBGA**.

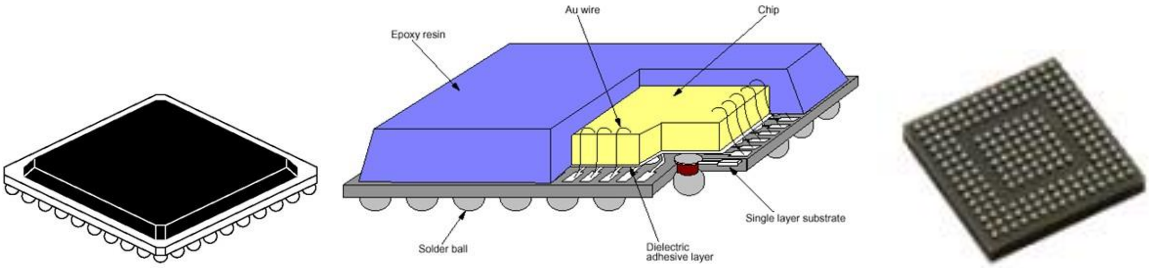


Figure 3.62: FBGA package, Internal Structure

MCSP

The **MCSP** abbreviation is derived from the initials of the English **M**olded **C**hip **S**cale **P**ackage. Compared to earlier forms of package, MCSP reduced the height of the case by 50%, and significantly improved the robustness of the case due to the cast material used, which pours the chip into a capsule. Due to a significant improvement in quality indicators, it is ideal for the latest ultra-portable devices such as smartphones, tablet PCs, ultra-books, and other handheld mobile devices. The MCSP can choose traditional CSPs with the same layout, pitch, ultra-rugged, thinner enclosures. The molding compound used is halogen-free, green technology that allows the thinner and more robust case to overcome the chips and implantation difficulties typical of CSPs.

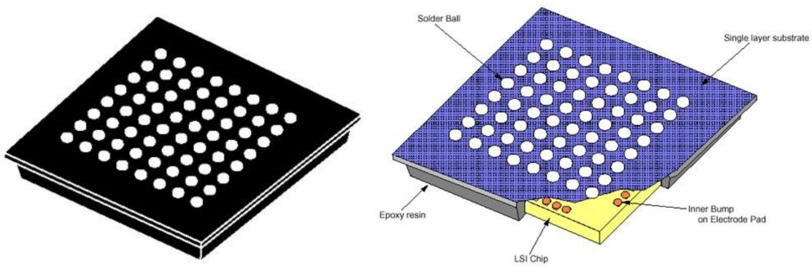


Figure 3.63: MCSP, Internal Structure, Advantages

QTP

The abbreviation **QTP** comes from the initials of the English **Q**uad **T**ape Carrier **P**ackage.

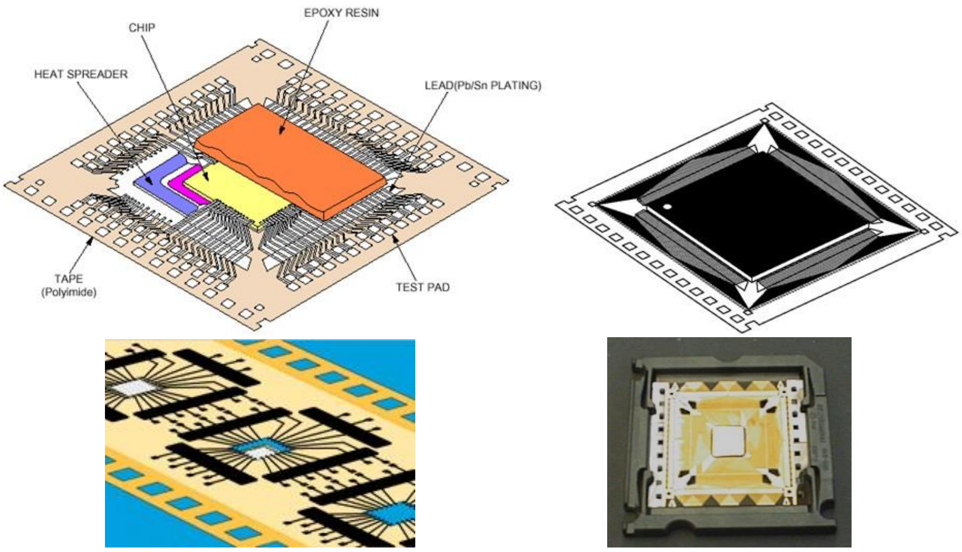


Figure 3.64: QTP, Internal Structure

3.11 Other Parts

Crystal oscillators, quartz crystals, resonators

The crystal oscillator is an electronic oscillator whose base is the piezoelectric phenomenon (piezoelectricity). Mechanical vibrations are converted into frequencies in the crystal. The crystal oscillator is used to produce accurate and stable frequencies (digital clocks, clocks for computers, radio transmitters / receivers, etc.). The most commonly used piezoelectric resonator is quartz crystal, but other piezoelectric materials can be used, such as polycrystalline ceramics. Quartz crystals are made from several kilohertz to several MHz frequencies. They produce over 2 billion crystals per year in watches, watches, mobile phones, computers, radios. Quartz crystals are part of the instruments such as oscilloscopes, calculators, signal generators, measuring devices. (7) There are exist THT and SM versions. They are provided with metal enclosures for shielding.

Figure 3.65: Crystal oscillators with THT package

Figure 3.66: Crystal oscillators with SM package

Mechanical Components: IC Sockets, Connectors

The quality requirements for mechanical components are high, because in case of poor quality connections, the entire circuit will become inoperative. (Connectors, for example: Battery Connector, SIM Card Connector, Antenna Connector) Pay particular attention to quality control, incoming material check for these components. In most cases visual inspection is sufficient.

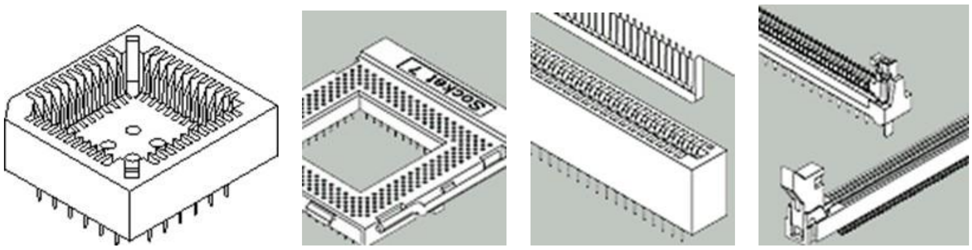


Figure 3.67: IC Sockets, Connectors

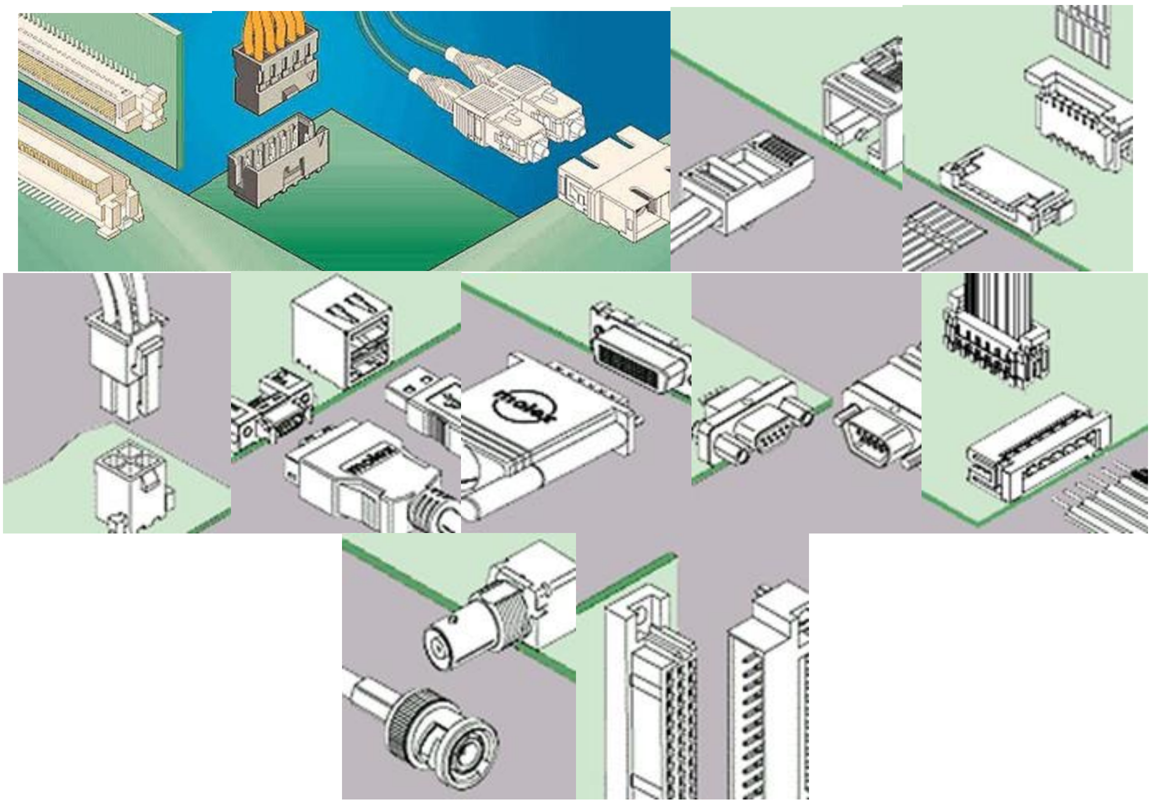


Figure 3.68: Connectors

Electromechanical components, Switches, Push Buttons

The above-described quality control is also required, as it is a critical part exposed to high stress. In areas with higher mechanical stress, only THT components are used.

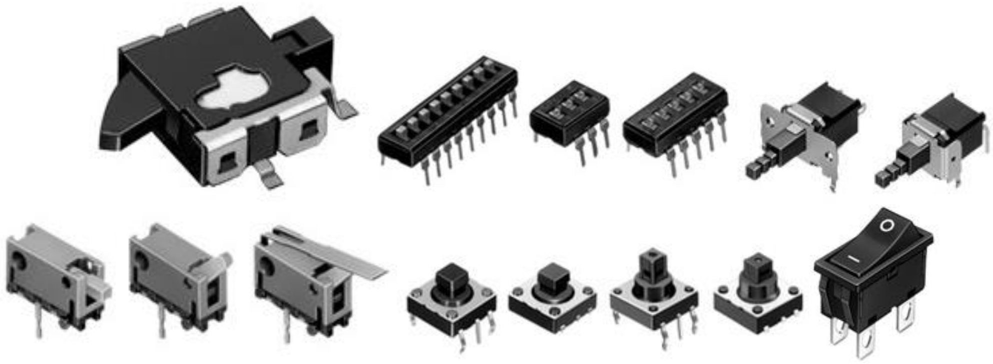


Figure 3.69: Switches, Push Buttons

Displays

There are LEDs and liquid crystal displays. When designing, it must be taken into account that liquid crystal displays are not readable under sunlight without background illumination. The renaissance is coming by using the Nixie tubes (what used in the 1960s), which can be readable digits and provide strong light and good readability, but a special drive circuit (140V anode voltage) is required for their use.

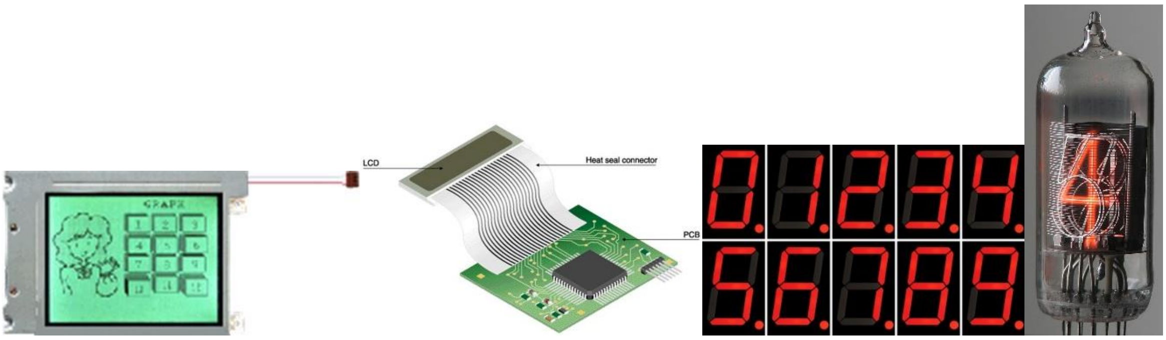


Figure 3.70: Liquid Crystal, LED, Nixie tubes

4. The process and principles of design and development

4.1 The origin of the product idea

Every new product starts with an idea. The steps from the idea state to the production of the new product are shown in the following figure: (8)

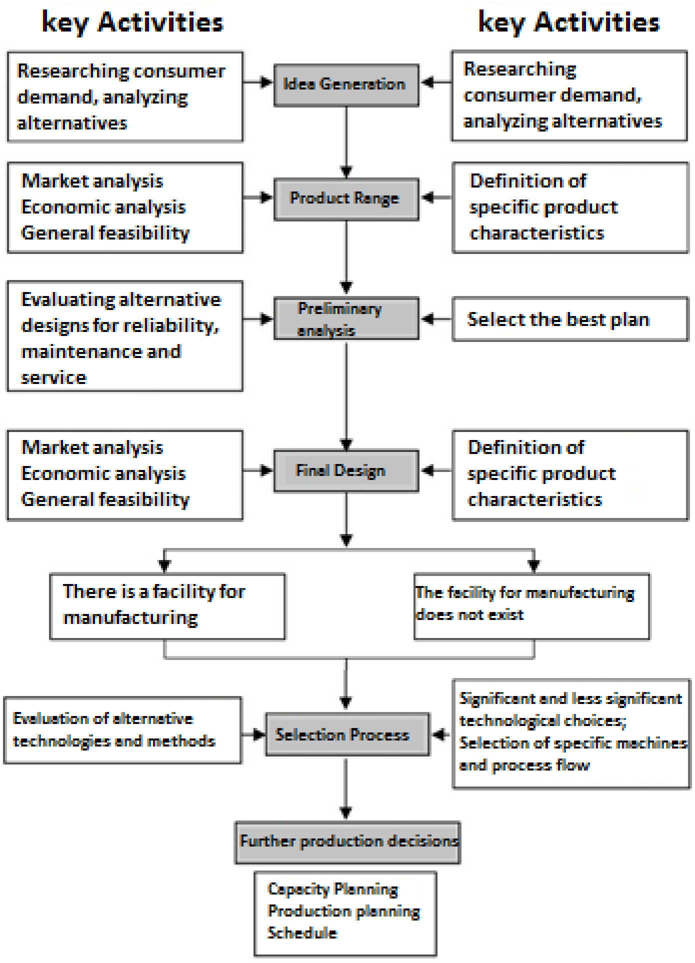


Figure 4.1: The product design and development process

In excellent companies, new product ideas originate mainly from paying attention to the buyer. This awareness can take several forms: managers and engineers visit the consumers of existing company products; they are involved in the production of innovations and prototypes of products developed by users (of course, with the cooperation of users); traditional market research. Such companies have extensive R & D activities and encourage their employees to find new products and to contribute to the development they are pursuing. For example, in Hewlett-Packard, product design engineers leave them on the table they work on if others come to think about it.

4.2 Product Design

Since the initial period of industrial production, the technical possibilities of manufacture determine the design of the products. Initially, the problem was the technological way in which the new construction could be created. The next stage of industrial production was characterized by the turbulent development of new manufacturing processes and materials, at the same time, many solutions were available.

The development of the *methodology of value analysis and engineering design* opened the third stage of development. By systematically analyzing the criteria, you can consistently select the most valuable solution. This makes it possible to closely associate the manufacturing and technological design process with the simultaneous consideration of manufacturing and assembly aspects.

From these considerations, the design and structure of the products should be discussed. Product design is actually the export documentation itself (e.g. various drawings, bills of parts, etc.). However, since there is a need to produce a single product, but rather a constantly changing range of products, it is becoming increasingly important to know the available structural units and work pieces. The number of products, the depth of production (the verticality) and the speed of the change are ultimately a decisive factor in manufacturing and assembly, so it is advisable to discuss these factors together.

Over the past 10 to 15 years, the question of whether a market requires a product manufactured by a company and the ability to produce it competitively in terms of costs and delivery times has become increasingly important during the economic analysis of the various products. It turned out that product design - commonly called editing - is becoming more and more important. Costs incurred by business departments, as opposed to the manufacturing costs determined by the work of each department, show that the design and construction work related to product design is up to 10% of the production cost. However, the materials, dimensions, tolerances and surface quality standards set out in the dossier are largely influenced or even clearly defined by the choice of the material, as well as the manufacturing and installation process and thus the production costs are approx. 70%. The manufacturing and assembly process controllers should therefore be aware of the design of the product design in order to provide timely suggestions to help create the most suitable construction and assembly requirements.

The editing process has long been seen as a complex intellectual-creative and manual activity, which can’t be rationalized and can’t be automated. Basically, it still exists today. It was recognized, however, that this applies primarily to the conceptual design of the construction and the design phase of the concept. In parallel with the gradual concretization of the design of the product, however, it is possible to develop a more rational workflow. To stimulate the different areas of research and practice, the VDI Edit Methodical Committee has developed a general product design scheme that summarizes existing knowledge and is valid for any technical product. This is illustrated in the following figure.

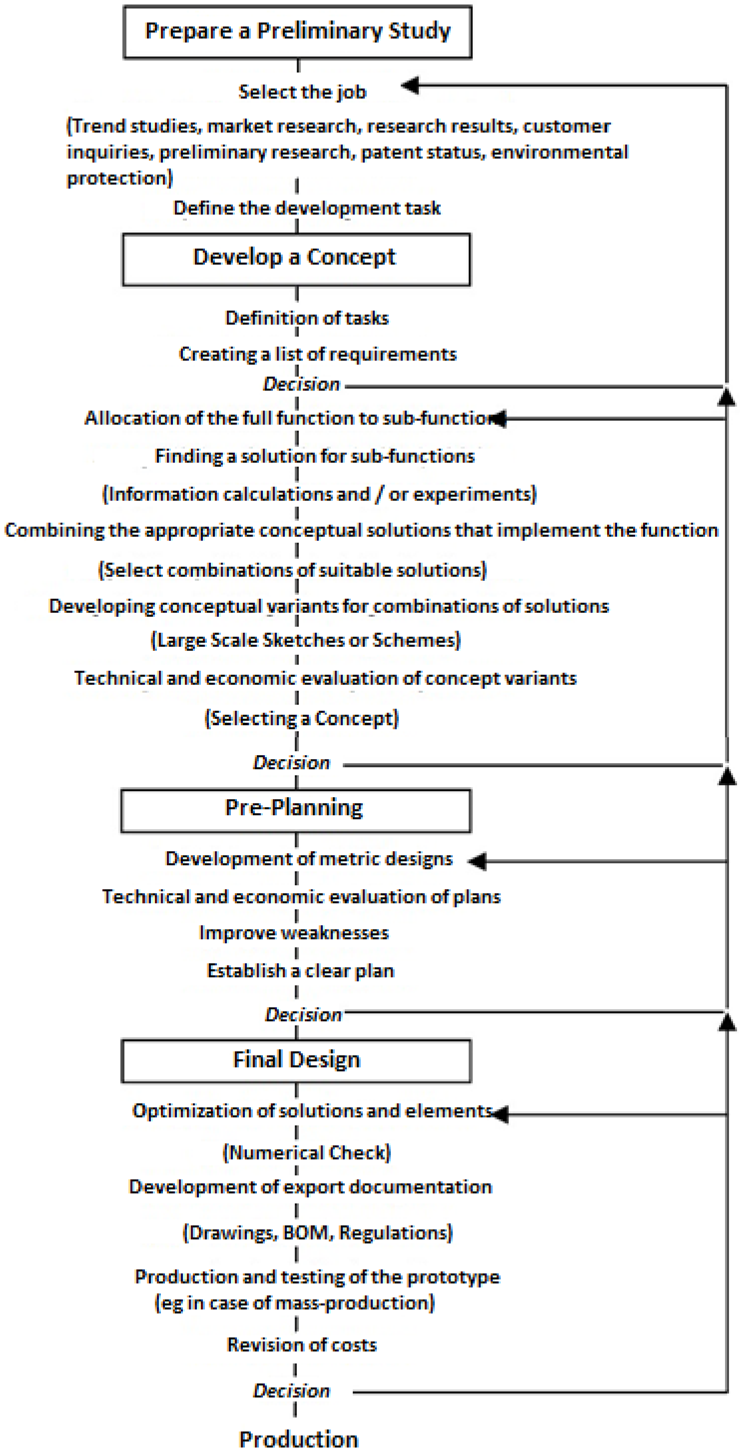


Figure 4.2: The Way of Product Design

The scheme starts with four consecutive phases of the product design process. By step-by-step in each phase, technical and economic criteria can systematically narrow down the otherwise overwhelming multitude of solutions.

The first phase - the ***Preliminary Study*** - is to clarify the requirements of the market for the product to be developed from the point of view of the market or the customer. In the product development plan this operation, performance, number of pieces, production time, etc. in its wording.

The second phase - the ***Design of the Concept***. This is in the form of a requirement list, starting with further clarification of tasks that include the set and minimum requirements, requirements and allowed production costs.

The importance of the *requirement list* can't be emphasized enough. This is the most important documentation in *product development*, as it is only in terms of its conditions that the benefits and disadvantages of different ideas and suggestions can be objectively assessed. The next step is to divide the desired functions into sub-functions. For each of the sub-functions, a variety of conceptual solutions can be conceived, which must be selected and summarized by criteria of the criteria list. There are also several ways to solve these issues (e.g., the next step is the various conceptions developed in the form of a large-scale sketch).

To select the *right concept* requires technical-economic considerations that go beyond editorial knowledge. It is a good idea to create a team of evaluators, in which besides the editorial and purchasing department, there is also a place for the production and assembly representative (!). The head of the Manufacturing Preparation Department is often involved in the working group. As a result, later surprises can be avoided.

In the ***third phase*** - in the ***Preparation of the Pre-plan*** - the elaboration of the scale plan begins, in which the different structural elements are strength, deformation, we can find calculations. Once the structural elements have been dimensioned, they have to be redesigned and evaluated with the value analysis method. This gives the conditions for developing the component drawings. This point also includes the simulation of electronic circuits, which can be done for example with the Hungarian-developed *TINA (Toolkit for Interactive Network Analysis) software*.

In the ***fourth (last) phase*** - during the ***Final Design*** process - the selected determinant elements must first be optimized. Meanwhile, it refers to the functional or cost-relevant parts of the structural unit (e.g. bearing locations, gaskets, controls, etc.). The value analysis method at this point can also be useful. During the simulation of electronic circuits, the optimized eigenvalues can be incorporated into the final design plan at this stage.

You can then draw up the export documentation (e.g. drawings, BOM, and any special manufacturing, assembly or receipt specifications). In doing so, special attention must be paid to the reuse of existing components and the use of standards.

Based on the above, it can be seen that the influence of production technology on the product begins before the detail design begins in the concept development phase, and concretizes the design plan in parallel with an increasingly detailed evaluation.

Finally, in connection with the design of the product, a brief overview of the methods available for the technical and economic evaluation of different concepts and designs in these phases is given. The decisive element of design is that the manufactured product is foreseeable to be able to utilize the existing manufacturing and installation options or to expand and adapt them.

Technical-economical editing primarily covers the technological criteria to evaluate alternative solutions.

Value analysis, on the other hand, focuses on a functional approach, thus allowing for objectively examining the purpose of structural units and components. Knowing the two methods is therefore an important prerequisite for the useful cooperation of manufacturing and assembly and product design.

4.3 Choice between alternative products

The idea-gathering process - if properly done - often leads to more ideas than is practicable. That is why an election process is needed to help un-corporate unrealizable ideas. The essence of each such process is to make ideas comparable in some respects (cost, time, weighted average of features, etc.). The definitive selection of the new product is a complicated result of market analysis, corporate product strategy and fact sheet analysis. The method also provides business case studies as they analyze the direct and indirect financial effects of alternatives and their impact on corporate strategy. However, bureaucracy in companies often frustrates even the most well-founded cases.

4.4 Preliminary design

From the point of view of the product manager, the most important result of the product design activity is the detailed description of the product. These detailed descriptions provide the basis for production decisions that managers have to make, including the purchase of a product, the selection of machines, the position of workers, and often the size and equipment of the production facility.

In the preliminary design, alternative product designs conforming to the imagined properties of the selected product will be developed. For example, if a refrigeration company decides to manufacture deep freezers, their shape, storage capacity, engine size, and so on. This is going to end in this phase. Here you decide on the main product features of reliability, maintenance and service times. For a deep freezer, these include decisions on breakdown frequency (reliability), ease of repair and maintenance (sustainability), and forecasted useful operating time (service time).

4.5 Final Design

During the *Final Design* phase, product prototypes are developed, eliminating hidden errors so that the product is engineered to be flawless. The final result of the final design is the final specification of the product, its parts and assembly drawings, which provide the basis for full series production.

At this stage, consideration should be given to the effectiveness of alternative plans compared to their cost implications. This confrontation leads to necessary compromises. This is especially true for selecting the configuration and material for the batch items. The complexity of these conversions can easily be seen by considering that even a relatively less complicated product such as a freezer has roughly 500 parts, all of which can be perceived as an alternative cost analysis object. Compatibility and simplification are to be considered in the analysis.

Compatibility refers to the suitability and fit-ability of each component during the operation. Problems of compatibility arise not only in parts that have to be connected, such as those of the freezer door locks, but also those that have to respond similarly to the conditions of use. The components of the elevator-bridge, of course, must fit together, and even their tensile strength must be similar to equalizing the strong wind; they should also have similar expansion coefficients to adapt to temperature changes.

Simplification refers to the elimination of features that increase production costs. The lack of simplification is evident if seemingly innocuous circumstances - such as edging or non-standard hole sizes - produce bottlenecks in production or cause problems during the product's subsequent use.

In addition to the above design activities, many companies carry out rather formalized product testing programs or re-design activities at the final design stage. Product testing may take the form of a marketing test for consumer goods or a gunshot test weaponry in the army. In both cases, extensive design is required before testing. Product recalculation is usually done during prototype testing. If the extent of the re-design is greater, the product may return to the preliminary planning phase if the change is smaller, the product is likely to be in production. It should be noted, however, that there are minor changes and "minor changes" - in some cases a seemingly slight modification on some parts can substantially alter the whole product!

4.6 Selection of the Process

Process selection is perhaps the most important area of production and logistics strategy, which has the most complex and deeper impact on the functioning of the value creation process. There are two pure basic types of installed production processes: the ***Flow Shop*** and the ***Job Shop***. In the ***Flow Shop*** system, the product is produced on a *coherent chain*, often through a conveyor belt. In other words, each step of the production process follows each other in space, as required by the manufacturing or assembly steps of the product. On the other hand, in the ***Job Shop*** system, machines or people carrying out the same operations are housed in a workshop. In other words, the product flows between the workshops practically in the same way as production, assembly or service requires.

4.7 Manufacturing Technologies

Manufacturing operations can be divided into three types of processes in general, when converting inputs into outputs. ***Continuous Production*** should be carried out 24 hours a day to avoid expensive shifts and restarts. Typical representatives of these are process industries, e.g. steel, plastics, chemicals, beer and oil.

In the case of ***Duplicate Production***, the items are produced in bulk, performing the same operations on them. This is a typical way of conveyor belt mass production in industries such as car manufacturing, assembly, electronic component, garment clothes or toy production.

During ***Series Production***, the products are manufactured in small mass or in small batches, often according to the customer's needs. Workshops are characterized by such serial production, custom orders go through different machining paths, requiring frequent launches and shutdowns. Improvement services, production equipment production and dressage after size are typical examples of series production. The series production also includes ***Individual Production***, which refers to "one type of one" or the manufacture of one-off products. A typical example of individual production is the production of large turbines, aircraft and ships, as well as major projects, construction work.

Process decisions generally have fewer choices because of the process selector decision, as technology generally is more like a large machine than connecting multiple separate machines. However, serial production and some repetitive manufacturing processes can be split into separate machining steps and as a result provide multiple manufacturing alternatives.

4.8 Product-Process Matrix

The relationship between processes and products depends on quantity, as shown in Figure 4.3. This matrix also indicates that a normal development of an organization is down the diagonal, from low volume production to continuous production of large volumes. The company, which occupies above the diagonal in the matrix, maintains flexibility for new products and process variability, so that it can adjust production volume to market changes. Companies under the diagonal focus on lower costs with higher capital investment. The matrix, therefore, essentially demonstrates the conversion between the processes' elasticity and economies of scale. The validity of this conversion has now become open to us by the latest developments in the automation of production. Automation makes it possible to efficiently and quickly produce low-volume, consumer-specific products, i.e. products traditionally produced in a workshop can move horizontally to the right.

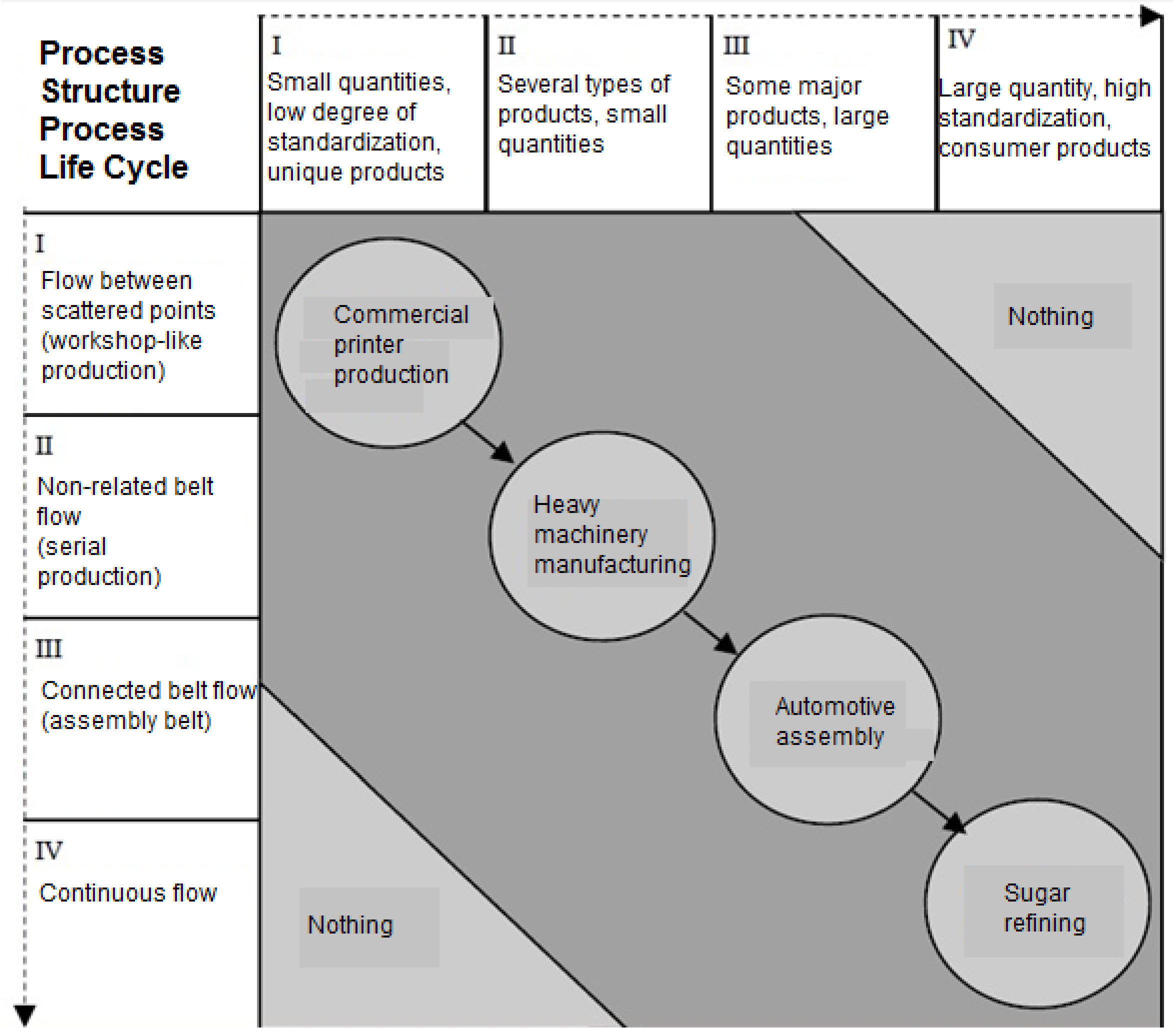


Figure 4.3: Relationship between the main stages of product and process life cycles

4.9 Machine Selection

The choice of the general type of manufacturing technology is followed by the selection of specific machines. Of course, for an existing plant, the evaluation of new machines is a temporary decision. Figure 4.4 shows some key factors that need to be considered when deciding.

Decision Variable	***Factors To Consider***
Initial investment	Price Manufacturer Used models availability Need of Space Need for additional / support machines
Emission rate	Actual and stated capacity
Finished product quality	Compliance with specifications Scrap Rate
Operational requirements	Difficulty in use Safety Impact on humans
Labor requirements	Direct and indirect labor force ratio Qualification requirement and training
Flexibility	General or special purpose machine Special tooling
Changeover Requirements	Complexity Conversion speed
Maintenance	Complexity Frequency
Obsolescence	Standard equipment Conversion-ability to other activities
Semi-finished product buffer	Timing and volume of security buffer
Entire system effect	Switching to a functioning production system Regulatory activity Compliance with production strategy

Figure 4.4: The decision variables of the machine selection

One company can have general purpose and special purpose equipment. For example, a machine shop may have lathes, drilling machines and transport equipment. An electronics company can have a one-party tester, which is a type of test and multifunction tester that simultaneously performs several tests. With the spread of computer-based technology, the general goal / special goal difference is blurred, as a general purpose machine can produce as efficiently as many special purposes.

4.10 Automation

Automation has been one of the typical trends in the development of production in recent years. Although this term is known to most manufacturers, it has not been possible to find a generally accepted definition. Some argue that automation is a completely new set of concepts that relate to automatic operation of production processes; others are seen as the degree of organic development of the technology, in which machines perform part or all of the process control functions. They are of the opinion that automation is first to *replace automated human surveillance of machines*, and secondly, this substitution requires a *closed-loop control and feedback*. Feedback enables the machine or process to control power at any moment by providing data to an "automatic" control unit performing the activity review. Accordingly, a new inventory of automation (regulatory) concepts, which is organic in the sense that it is a logical and foreseeable step in the development of machines and processes.

The latest developments in the manufacturing automation are under the heading of ***CAM** (**C**omputer **A**ided **M**anufacturing)*, which includes machine Manufacturing Centers, industrial robots, and flexible manufacturing systems.

Machine Manufacturing Centers do not only control the machine automatically, but also perform the necessary tool changes automatically. For example, a machine can be equipped with two movable worktables that can be folded and rolled into the machine. While the machine is doing the work on the first table, the next piece can be set on the other table. When the machining is finished on the first table, they are taken off the road and started to work the second part in the machine.

Industrial robots are essentially mechanical arms that can be fitted with fingers, pliers, vacuum caps, or a wrench similar to the hand. They are capable of executing a number of factory operations from machining to simple assembling.

The ***Flexible Manufacturing System*** combines the elements of machine manufacturing centers and robotic computerized material handling to create an automated system. Combined with the CAD model, manufacturers have the opportunity to design from the initials to the full production stage overnight. The application of this capability opens up wide prospects, especially since one of the features of our time is the spread of small-scale production: the assembly of products is increasingly being tailored to specific customer orders to meet the special market segments. The ability of the manufacturing system to deliver a wide range of products is called *Economies of Scale* contrary to the *Economies of Volume*.

Computer Aided Manufacturing (CAM) integrates all elements of production into an automated system. Product design, testing, machining, assembly, quality control and material handling can be automated on their own but only become integrated with the computer when the classroom communication is automated. Full automation results in greater efficiency, more transparent organization and lower labor costs.

4.11 Process Flow Design

Process Flow Planning focuses on specific lines that are followed by raw materials, components, and sub-units as they pass through the plant. Many production management tools are used in process flow planning; most common are assembly drawings, assembly diagrams, route sheets, and flow diagrams. It should be noted that each of these diagrams is also a useful diagnostic tool, and therefore it is also used to develop activities for existing systems. The first step in analyzing any production system is to "discover processes and operations" by using one of these techniques. These are the "organizational charts" of the production system.

The ***Assembly Drawing*** shows a given product in drawing form, broken down into parts, for example in a table, its four legs, its top cover, and the connecting bolts. The ***Assembly or Gozinto Diagram*** uses the assembly drawing information and determines how the parts are connected, what is the order of assembly, and often shows the whole flow process scheme. The ***Action or Route Sheet*** shows the operation and path of a particular part. It carries information such as type of machine, tooling method, and operations required to complete the item.

The ***Flowchart*** uses standard **ASME** (**A**merican **S**ociety of **M**echanical **E**ngineers) symbols to show what happens to the product as it passes through the production system. As a rule we can say that the fewer the waiting and the storage in the process, the better the flow, though there are exceptions. For example, if you would not expect any wait of a single product, it would mean that the system is not running at full capacity, as there is always a machine and manpower available.

5. Failure Mode and Effect Analysis (FMEA), Flowchart (FC), Control Plan (CP)

This chapter describes the most important documents produced during the design phase of the manufacturing process and are under continuous development (***CI****: **C**ontinuous **I**mprovement*), all of which are important both in engineering and in quality control. These documents are important primarily under mass production conditions, but small series production must also be clarified, even if they are not invested in *Flowchart (FC), Failure Mode and Effect Analysis (FMEA) and Control Plan CP*.

For these documents, a *cross-functional team* is responsible, with experts in all key areas, engineers responsible for quality control, production scheduler, incoming quality control engineer, representative for the procurement department, and managers responsible for starting / organizing the production.

5.1 Flowchart

Flowchart is a diagram that displays the production process in algorithm, with visual elements. Image elements are shapes that illustrate different process steps and connect them with different types of lines or arrows.

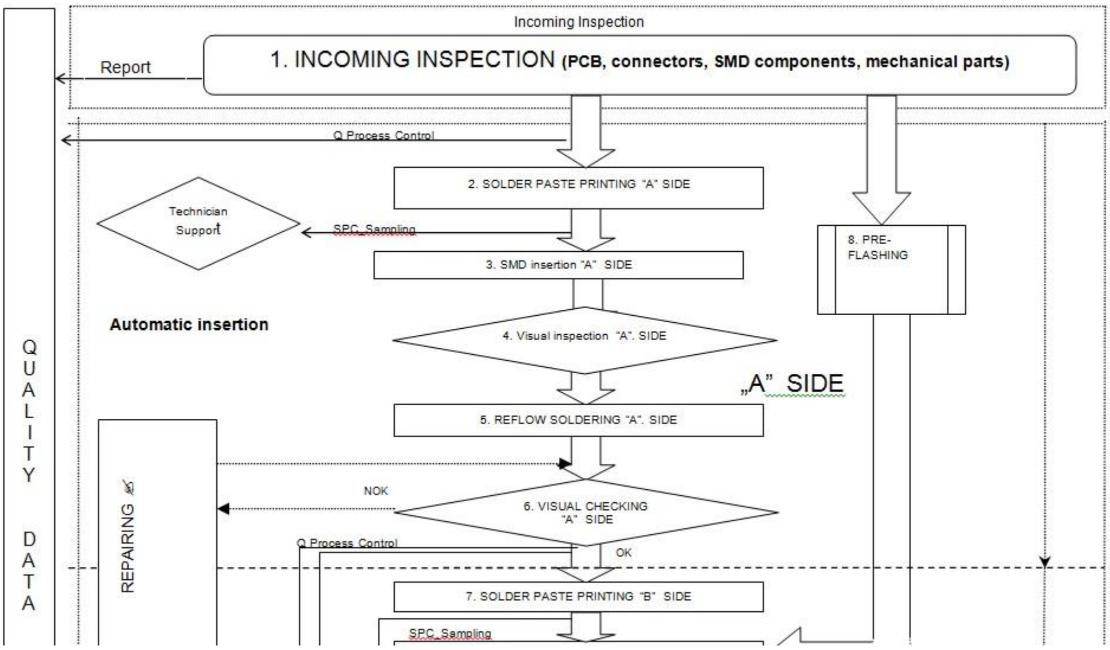


Figure 5.1: Flowchart section (9)

The flowchart should include a list of relevant products, including designations and their factory and general (customer) codes. Beside the document engineer responsible for the document and the cross-functional group, it is important for the number of documents, for identification, as well as the validity of the document and the name of the approved quality control engineer. After the document is undergoing continuous development and development, it is very important to keep track of version and keep up-to-date the correct version of the in-house documents as a document that has been lost in a particular workstation can cause a production stoppage or a defective product. For this reason, a separate documentation department is responsible for the approval, upkeep of the documents and the placement on the production lines.

Different objects may have different meanings, but generally the diamond shape is a step where a decision process takes place and as a result the flow of the product proceeds in one or another direction. In the example, the manufacturing processes are indicated by a square or rectangular shape, the flow of products between the processes with thick arrows and the sampling with thin arrows. A complete flow chart can be seen in Figure 5.2.

Figure 5.2: Process Flowchart (complete)

5.2 Failure Mode and Effect Analysis (FMEA)

Creating a Flowchart must precede the creation of *FMEA*, as we will take the steps in the process steps in the Flowchart. Creating a correct FMEA is a time-consuming process, but many possible failures can be eliminated even before they are created. This can reduce scraps, increase profits, and meet environmental requirements.

Failure Mode and Effect Analysis was the first systematic error analysis technique developed by reliability engineers at the end of the 1940s to investigate possible defects in the failure of military equipment. (10). FMEA is most often the first document to be taken into consideration during a reliability study. It includes all possible process steps, components and subsystems so that you can have the greatest insight into the possible defects, the causes and their effects. The components and process steps are recorded on an FMEA worksheet.

FMEA basically performs a quality analysis. A successful FMEA process helps to identify possible errors based on the experience *gained in the production of similar products* and the common logic of the physical appearance of the errors. The logic of FMEA is fully *inductive (forward logic)*, although probability estimation of occurrences of errors and their reduction can only be possible after understanding the occurrence mechanism of errors. Ideally, the occurrence probability of errors should be reduced to nearly zero by eliminating the root causes of the errors. For this reason, it is very important for the FMEA to include the potential causes of the errors with sufficient depth of information (*deductive logic*).

Mostly, a "*Criticality Analysis*" follows the creation of FMEA. In this case, FMEA is called *FMECA*, labeled "*Criticality Analysis*: *CA*". FMEA / FMECA is a live document that we have to create during design, as it may affect the design of a particular product during the product design process, and in extreme cases, we may even decide to discard the product. If the document is created because of the production of another product, we may have very little influence on design - which is a common case for EMS manufacturing companies - but we have fewer modification suggestions for product designers:

Engineering Change Request (***ECR***). FMECA's greatest importance is in designing the product, as it is possible to eliminate possible catastrophic failures before manufacturing can be avoided by avoiding enormous amounts of waste and pollutants (environmental aspects).

Process Function / Requirements	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s)/ Mechanism(s) of Failure	Occur	Current Process Controls	Detec	R.P.N.	Recommended action(s)	Responsibility, Target Date	Action Results: Action Taken	Sev	Occ	Det	R.P.N.
	Missing or faulted test steps	Functional faults	8	-	Improper Test system setting,	3	Performing First Piece Off	5	120	Apply reference sample to the IC Tester to check the proper test system setting.	T. Török Week 432					
17. Functional Test (FNT)	Failed board pass the test	Functional fault	8		Carelessness work	2	Continuous training For the FT operator	4	64							
	Good board does not pass	Delivery accuracy	8		Defected tester	3	Regular maintenance	2	48							
	Missing or faulted test steps	Functional faults	8	-	Improper Test system setting,	3	Performing First Piece Off and OB Audit	5	120	Apply reference sample to the tester to check the proper test system setting.	**T. Török** Week 427					
	Missing or faulted test steps	Functional faults	8	-	Careless work	2	Continuous training for the Functional test operator Define in the work instruction the self-checking Performing First Piece Off	3	48							

Figure 5.3: FMEA section, Functional Test (FNT) (11)

***P**robability (P), or **O**ccurrence (O)*: It is important to determine the causes of the failure mode and its probability of occurrence. This estimate can be made using different quality assurance methods and based on observed values of similar processes or products.

***S**everity (S):* Determines the severity and impact of the worst possible output. Based on a predetermined list of severity, fault codes can be categorized, such as: inoperative product, partially functional product, product start-up later on, aesthetic error, etc.

***D**etection (D)*: Determines the extent to which it can be detected by the error operator or test device. You can add values based on a predetermined table, just like the previous two variables.

After the determination of the above variables, a multiplication was performed by the method of R.P.N. value. (Priority Number: RPN = P (O) * S * D) Setting a certain limit value (for example, RPN> 120) for the product value that exceeds it, an action must be created to defeat the given error mode by setting a responsible and a time limit. After the deadline has expired, the values must be re-determined and the document must be updated.

PQ-FM-2900 FMEA SSB_top.doc

Figure 5.4: FMEA (complete)

5.3 Control Plan (CP)

The purpose of creating a Process Control Plan (CP) is to regulate the product's characteristic variables and process step variables so that the desired production volume can be achieved and the product remains reliable after long periods of time. The CP provides a written summary of how our process steps can be kept at the right level to achieve optimal production in a well-established, well-functioning system. This includes training, various actions, and process improvement measures. The goal of the CP is therefore to keep the ongoing development of the project team sustainable with the time progressed. Like the previous documents, the CP is also created by a cross-functional group under the direction of the process control engineer. As a live document, if a change occurs in the process, CP needs to be upgraded.

Advantages:

- It summarizes the knowledge base of the process
- The necessary settings and goals for the various processes are visible for all the coated functional areas
- Specifies the indicators that indicate the quality of our process steps (process and / or qualitative indicators)
- Specifies what control step should be taken when or after how many products are produced to maintain production quality and to avoid mistakes, who is responsible for the task, etc.
- Specifies who is responsible for the process (notification).

Part/ Process Number	Process Name / Operation Description	Machine, Device, Jig, Tools For Mfg.	Characteristics			Spec. Char. Class	Methods					Reaction Plan
			No.	Product	Process		Product/Process Specification/ Tolerance	Evaluation Measurement Technique	Sample Size	Sample Freq.	Control Method	
7	Solder Paste printing B. side	MPM No: 9168	14		Amount, placement	SC	Work instruction: PT-PR-0008	2D Built –in camera	100 %	Continuous	Program stops under adjusted limit. Electronic form.	Stencil and settings checking. PT-PR-0003
		Laser microscope LSM300 S/N: 3021	15		Paste -existence -hight		Form PF-PR-0053 PT-PR-0001 PT-PR-0018 PT-PR-0019	3D	1pc	1 hour	Sampling inspection Electronic form.	Stencil and settings checking. PF-PR-0034

Figure 5.5: Control Plan section (12)

Preparation of the Control Plan needs an existing and complete, up-to-date Flowchart. The quality control department, especially the department responsible for internal processes, plays a key role in the preparation of the CP. The process steps are based on the flowchart, but are complemented by other steps that are not visible. After defining the test equipment with a general or specific type, it is necessary to specify that a process step or a certain part of the product is checked. In the next section, you will need to detail the method of performing the check that is most commonly available in the form of a work instruction for the person performing the process.

The CP should only refer to the work instruction’s number and keep it up to date. An external specification or standard specifies the setting values that are appropriate, either in the appropriate "Product / Process Specification / Tolerance" column of the CP or referenced to the standard document’s number. The size of the sample gives you how many percentages of a given production volume should be examined. For example, when testing incoming material, specific standards apply according to the AQL methodology. Sampling frequency gives the sampling concurrency, such as 2 sampling per shift. The last "Reaction plan" column contains the notification organizational chart that tells you who should be notified and who is the supervisor in case of a problem.

PQ-CP-4326 Control
Plan SSB Top.doc

Figure 5.6: Control Plan (complete)

6. Manufacturing Documentation

In the manufacturing documentation, we mean all the documents necessary to produce the specific product or version. In the narrow sense, these documents are not part of the FC / FMEA / CP package, as they can be different depending on the manufacturing conditions of the particular factory. The manufacturing documentation package for EMS is provided by the buyer, usually by the designer (company). These documents are primarily the Bill Of Material (BOM), the Gerber package and its parts, the coordinate file, the insertion diagram (s), the wiring diagram (s), and the mechanical assembly instructions.

6.1 Bill Of Material: BOM

The major product-specific manufacturing documentation defining the product is a list of parts whose English language designation and abbreviation is ***B****ill* ***O****f* ***M****aterial,* ***BOM***. BOM is a vital document for tracking a live document, version, and therefore keeping it up to date. From the design of a product to its runway, there are countless modifications, and for entertainment electronics it is often over 100. The primary task of the manufacturing department's documentation department is to keep the BOM up-to-date for all product versions in the company's information system. Nowadays, dual information storage is common, that is, the BOM is digitally stored in the IT system of the manufacturing company and simultaneously places an authenticated *hard copy* at the appropriate locations.

For EMS, the design and manufacturing team of the product is separate because the design is carried out by the buyer's specialized department and the production is often EMS manufacturing company located in another country. Each company has an ***E****nterprise* ***R****esource* ***P****lanning (****ERP****)*, which can include *BOM management*.

```
Factory Steering Information for Initial BOM                     Imported: 2004-09-20, 13:05
                                                             FSI Creation: 2004-09-20, 13:07
==============================================================================================

Plant:                          ELCTEQ
Concept:                        ECM2_FTV ENTRY 2K4 42"
Assembly 12NC:                  3104 328 29786
Assembly Description:           SSB PDP STEP A EU 42"FHP
Owning Organisation:            Brugge - TV
Critical Component:             N      (Supply chain restriction)
CP Reference Number:            BA008894

Content Variant:                0
Process Variant:                0
Purchasing Variant:             1

Adoption Date Reference CP:     2004-09-20
Promised introduction date:
Realised introduction date:

----------------------------------------------------------------------------------------------
PARTSLIST
Itm#|S|Qty    |Unit of Measure
    | |       |    |Critical for supply chain
    | |       |    | |Child12NC    |$|Description / Remark                  |Pcod|Organisation |
0001| |01.000|PCE|N|310431360034|$|SPB LCD/PDP 2004 EU                    |00B |Brugge - TV  |
0101| |01.000|PCE|N|310430797161| |PROCESS BOX PA GENERAL                 |29  |Brugge - TV  |
0600| |01.000|PCE|N|310430926442| |OPTION CODE01 FTV 2004                 |00 S|Brugge - TV  |
0600|R|      |   | |            | |Item 7011 to be programmed with this ...
0601| |01.000|PCE|N|310431707411| |ROM TC58FVM5 TX21EU_2.1_07411          |00 S|Brugge - TV  |
0601|R|      |   | |            | |Item 7006 to be programmed with this ...
0602| |01.000|PCE|N|310431707871| |ROM EPCS R_FTV2004_48_47               |00 S|Brugge - TV  |
0602|R|      |   | |            | |Item 7V01 to be programmed with this ...
0603| |01.000|PCE|N|310431706601| |ROM 24C02 EDID EMG2004 EUPDP           |00 S|Brugge - TV  |
0603|R|      |   | |            | |Item 7I19 to be programmed with this ...
0604| |01.000|PCE|N|310431706044| |ROM M24C64 PDP FHP 2K4 EU V4           |00 S|Brugge - TV  |
0604|R|      |   | |            | |Item 7011 to be programmed with this ...
0605| |01.000|PCE|N|310431747621| |SOFTW.ASSY 310431707621                |00 S|Brugge - TV  |
0605|R|      |   | |            | |Item 7711 to be progammed with this file
1000| |01.000|PCE|N|242208611092| |FUSE SM    F 500MA 50V  UL   R         |None|Philips      |
1001| |01.000|PCE|Y|242254389022| |RES XTL SM 6M000   20P CX-5F R         |04B |Philips      |
1305| |01.000|PCE|N|242254301184| |RES XTL 4M433619  20P HC49/U A         |00B |Philips      |
1308| |01.000|PCE|N|242254301183| |RES XTL 3M579545  16PHC49/U A          |00B |Philips      |
1404| |01.000|PCE|N|242212700543| |SWI SLID 1P 2POS SM SSSS811* R         |05A |Philips      |
1407| |01.000|PCE|N|242254944324| |FIL CER SM 5M5/5M74 TPWKA5M50B         |05A |Philips      |
1408| |01.000|PCE|N|242254944372| |FIL SAW SM 38MHZ9 OFWK3953L  R         |05B |Philips      |
1409| |01.000|PCE|N|242254944369| |FIL SAW SM 38MHZ9 OFWK9656L  R         |05A |Philips      |
1702| |01.000|PCE|N|242254098456| |RES CER SM 12MHZ CSTCV*MTJ0C R         |04B |Philips      |
1A00| |01.000|PCE|N|242254389019| |RES XTL SM 18M432  12P CX-5F R         |04A |Philips      |
1D01| |01.000|PCE|N|242203300515| |SOC DVI H 29P F         DVI-I Y        |00B |Philips      |
1E02| |01.000|PCE|N|242202517274| |CON V 10P M 2.54 SM   147279 R         |05B |Philips      |
```

Figure 6.1: BOM (section) (13)

The BOM may contain other important information, including the name of the product and the design code of the product, such as the number of changes recently introduced, the date of issue and the name of the manufacturer. It is common for BOMs to be hierarchically interlinked, for example, for a TV, a separate BOM can be described for the final assembly parts and may receive a separate BOM for parts of a specific built-in panel.

Item number, Position

The position of the insert, in English item number or position, specifies which position of the particular component is to be automatically or manually inserted. The inserting positions are often found on the panel's silk layer, but for SM components it would be impossible to designate all the positions, which is why they are located in the insertion drawings and in the coordinate file. Frequently four-digit, encoding with letters and numbers, such as 1E02.

Quantity

The amount of insertion, the English quantity column most often shows one piece if a row of BOM can contain an insertion position. However, there are BOMs that contain a row of parts per type of component (instead of per insertion position), so that a commonly used filter capacitor can be inserted into the product up to 150 times, so the quantity column shows 150.

Component code

It is common that the design company uses different component coding than the manufacturing company. For example, Philips, where all parts and semi-finished products come with a 12-digit numeric code (12NC), but the EMS company, Elcoteq Magyarország Kft., Uses its own 8-digit coding. For this reason, the parts have to be matched to each other, which is often unclear. In some cases, the designer leaves the opportunity to order the part from a number of licensed suppliers with a broader technical specification. These components are provided with *collective coding*. Under each collective code, specific parts of the specific suppliers can be found and these are individually provided with dedicated codes.

However, in most positions in the BOM, there are *dedicated codes* that represent a specific part of a particular manufacturer. Already in planning, it is a separate engineering task to ensure the availability of parts, as there is a lack of a specific component in the case of dedicated coding, production may stop. For this reason, in some cases, the design company allows the *alternative code* to be used in addition to the collective codes, which means that the other components of one or more other manufacturers with the same technical specifications of the BOM specified in given inserting positions. Taking these alternative options for a company with another component coding can be almost an unsolvable task and may necessarily cause differences between the designer (buyer) BOM and the EMS BOM. For smaller companies or prototype manufacturing, it is therefore recommended to use the part list of the buyer (designer) without modification, without being recoded, if the management system of the manufacturing company can handle it.

Description of the part

This column contains the text description of the part, but it should never be based on it, since several different parts may have the same part description.

Manufacturing number of the part

In most cases manuf.number or manufacturing number is not indicated in the BOM, as a separate document contains the customer's (designer) code below which specific parts of the manufacturer. The manufacturer code specifically identifies a particular component of a particular manufacturer, in many cases even the packaging mode, most often listed at the end of the manufacturer's code (e.g. reel, tape or reel, etc.). Manufacturer codes can be found on the manufacturer's website. Each manufacturer uses its own encoding, the corresponding numbers and letters carry a proper meaning in the correct position, and this encoding method can always be found in the manufacturer's website download part specification, but often on the website, in an online useable form. You can always find the manufacturer code for that part number in the company's information system, under the part code in the BOM or on the code separately. Using a collective coding, multiple vendor codes are allowed for a component, and the purchasing department of the manufacturing company may decide which part of the component is being used to observe the availability of parts.

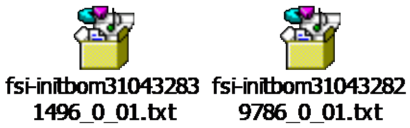


Figure 6.2: BOMs, complete

6.2 *Gerber-package, Gerber-files*

Gerber is a vector graphic file format that is the world's number one standard for ***P**rinted **C**ircuit **B**oard (**PCB**)* manufacturing. It consists of copper layers, solder masks, legends, and so on. Extending most .gbr or .GBR, but other extensions (such as .gbx) are also in use.

Photo plotters used in the manufacture of PCBs are most often used in Gerber files and printers used to print labels, but such files are used as standard inputs by Automated Optical Inspection machines (AOI). It also contains a stencil layer that is used to deliver soldering paste to the correct place in production. In the Philips system, the files marked with 070 report the Gerber files.

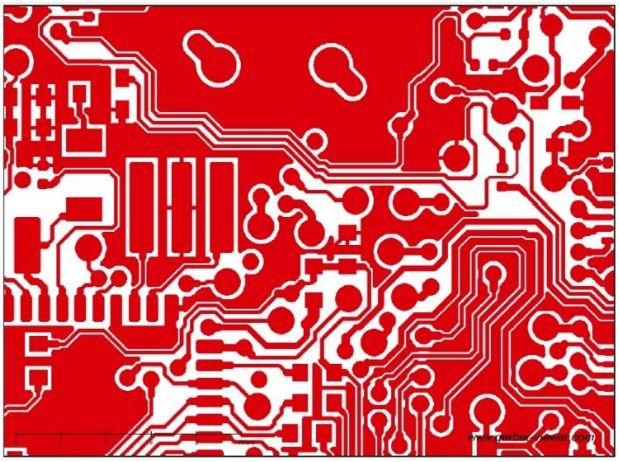


Figure 6.3: one layer of the Gerber-package, section

6.3 *Coordinate-file*

The coordinate file is essentially a complement to the Gerber package as part of it. Also common is the DAT file name. It contains all the insert positions and other points on the panel, so it is not a product, but a PCB-specific file, just like the Gerber package. In addition to the insert positions, there are vias, and test points and subtitles in the DAT file. For all possible positions, the X (Horizontal) and Y (Vertical) positions are measured in mm or inches. The third data for each position is the angle of rotation, which is usually 90° integer multiple. In the Philips system, 060 represents the coordinate file.

%QB	1612	2IC0	214.025	209.650	180	1	6s20120
%QB	1613	2IC0	217.675	209.650	180	1	6s20120
%QB	1614	2IC1	222.375	209.700	180	1	6s20120
%QB	1615	2IC1	226.025	209.700	180	1	6s20120
%QB	1616	2IC2	197.525	209.800	180	1	6s20120
%QB	1617	2IC2	201.175	209.800	180	1	6s20120
%QB	1618	2IC8	293.800	174.600	180	1	6s20029
%QB	1619	2IC8	295.700	174.600	180	1	6s20029
%QB	1620	2IC9	117.700	219.800	90	1	6s20004
%QB	1621	2IC9	117.700	218.300	90	1	6s20004
%QB	1622	2IE1	291.450	174.600	270	1	6s20004
%QB	1623	2IE1	291.450	176.100	270	1	6s20004
%QB	1624	2IE2	267.000	169.500	0	1	6s20004
%QB	1625	2IE2	265.500	169.500	0	1	6s20004
%QB	1626	2IE3	264.300	180.000	0	1	6s20029
%QB	1627	2IE3	262.400	180.000	0	1	6s20029
%QB	1628	2IE4	262.650	178.350	90	1	6s20004
%QB	1629	2IE4	262.650	176.850	90	1	6s20004
%QB	1630	2IE5	285.500	160.950	180	1	6s20004
%QB	1631	2IE5	287.000	160.950	180	1	6s20004
%QB	1632	2IE6	279.550	161.100	180	1	6s20004
%QB	1633	2IE6	281.050	161.100	180	1	6s20004
%QB	1634	2IE7	283.200	158.000	90	1	6s20029
%QB	1635	2IE7	283.200	156.100	90	1	6s20029
%QB	1636	2IE8	289.950	159.050	180	1	6s20029

Figure 6.4: Coordinate-file, section

6.4 *Insertion drawings*

On the panel, it is impossible to indicate any position of insertions, as in SMD 4 cm^2 is common for 30 parts as well. For mixed technology, we can talk about SMD insertion drawings and THT or manual insertion drawings. For SMD, it is common to have the Top and Bottom sides, so we need to look at two separate SMD insertion drawings when looking for an insert position on the panel. Mostly, it is a vector graphics file, so it has the ability to zoom without loss of quality. In the Philips system, the 132-tagged files represent the insertion drawings. The drawing also includes the X-Y region position used for maps and a list of which position to be searched for in Section X-Y.

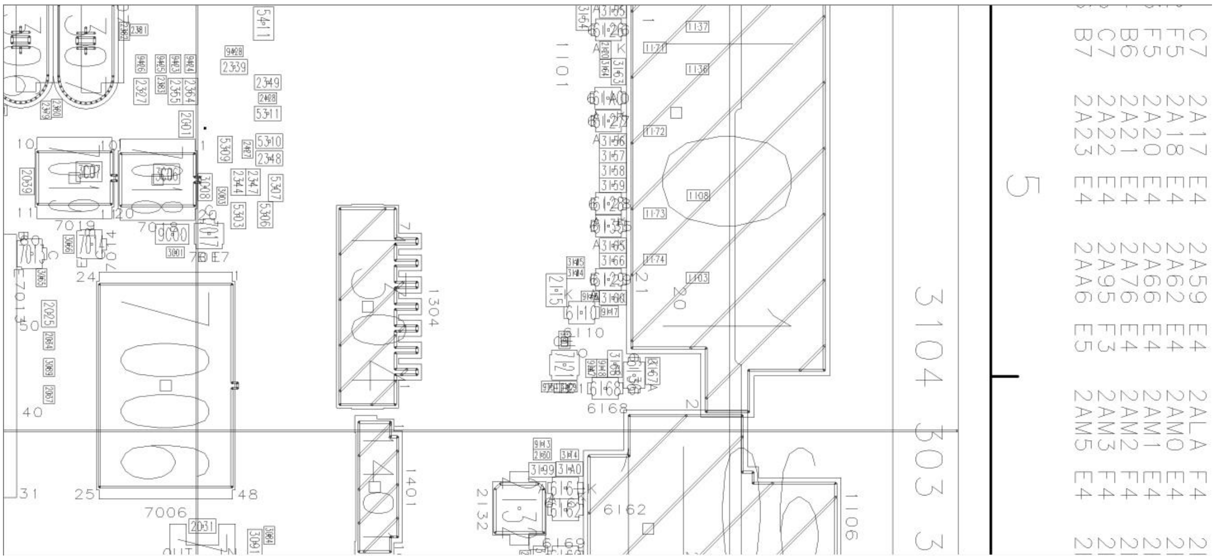


Figure 6.5: Insertion drawing, section (14)

3104_303_38947_13 2-04.tif

Figure 6.6: Insertion drawing, complete

6.5 *Schematic diagram*

It is also a PCB specific file, that is, a circuit diagram of all the products that can be built on that PCB. This may often be more than ten different products, due to the integration of different functions and the different needs of the countries and regions (US, EU, AP). In case of deviations, the wiring diagrams are displayed, e.g.: EU only. There are also product-specific wiring diagrams, in this case markings can be omitted, but separate versions of each version must be attached.

Overall, we can say that the specific version is determined by the BOM and not the universal wiring diagram. For a manufacturing company, wiring diagrams are important when setting up test equipment or repairing defective products. Multiple pages of circuit diagrams for more complex products are provided, and sub frames with different functions are placed on separate pages, labeled (for example, Audio Amplifier Part). These details can be in separate files or in a large multi-page file. The Service Manual also includes the wiring diagram, but may also provide information, flow charts, measuring aids, voltage levels and signal forms for repairs.

In the wiring diagram, you can search the X-Y region plots as in the insertion drawing. In the Philips system, the code for the wiring diagrams was 130.

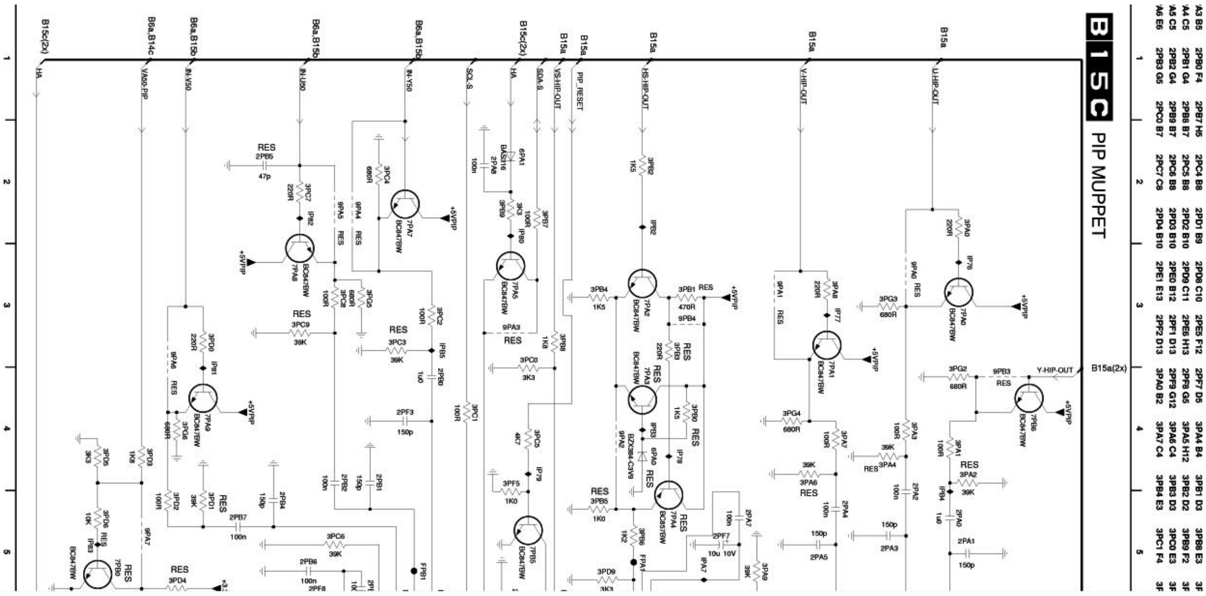


Figure 6.7: Schematic diagram, section

3104_313_60037_130-99.pdf

Figure 6.8: Schematic diagram, complete

6.6 *Mechanical Assembly Instructions*

A product-specific document that specifies assembly information that is not available in BOM or insertion drawings. These may include ways of draining and securing hand-wound cables, tightening torques and arrangement of screws, assembly methods for shielding plates. These are essentially job descriptions from the designer, but the manufacturing company has to make their own work instructions based on them, placing them on the given workstation in a controlled, version-tracked form.

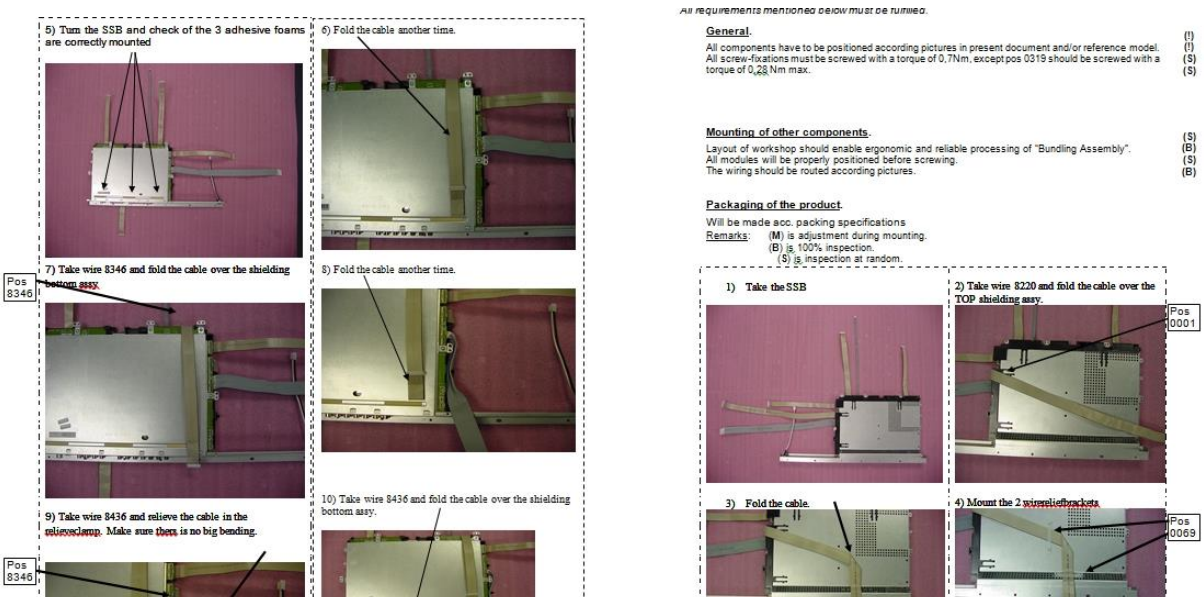


Figure 6.9: Mechanical Assembly Instruction, section (15)

Figure 6.10: Mechanical Assembly Instruction, complete

6.7 *Engineering Change Order, ECO*

The ***E****ngineering* ***C****hange* ***O****rder*, abbreviated as ***ECO***, is a document in which a product design team describes some changes to the product manufacturer in a controlled form. It runs through a strict approval process through an ECO, both on the designer (buyer) side and on the manufacturer's side.

Even after the product has been developed, there are aspects that will make the introduction of a certain change important. This can be the case if a certain defect is discovered only later or when a certain function is further developed by the design engineers during the production of the product based on market feedback. Due to the ever increasing demand for new products on the market, it is a common phenomenon that the product should be further developed due to malfunction or unreliability. Fortunately, this is a less common phenomenon, but the need to make changes due to the lack of parts is more common. In this case, the design team should consider to allow the available but possibly inferior quality component to the product or not.

The introduction of ECOs is a very complex process, affecting the whole production line, but in general terms, from the supply chain to the delivery process to the whole production. An ECO introduced by an incorrect or inappropriate timing may result in a large number of scrap products or production stoppages. This is also to be avoided from an *environmental point of view*, as various process materials, such as soldered materials, can be as scrap as irreparable products.

ECO is similar to the BOM, but the positions indicate which part is to be deleted and which part is added. Various categories have been developed for the introduction timing of the ECO, which may also include the reworking of finished products also, but may include the recall of finished products in the supply chain. In a milder but urgent case, it is necessary to move immediately to the new definition in the production. In the easiest case, only ECO should be introduced if the old part is out of stock to prevent the warehouse from getting stuck.

Each introduced ECO results in a *new revision* in the BOM, both on the designer and the manufacturer side. If the two are different, it may be difficult to retrospect the various manufactured products during a repair process. In some important cases, a *distinct mark* on the outside of the product or on the panel is used to visually recognize the advent of that change.

```
Factory Steering Information for Parts list changes              Created: 2004-06-01, 14:13
                                                             FSI Creation: 2004-06-01, 14:13
==============================================================================================

Plant:                        ELCTEQ
Concept:                      ECM2_FTV TOP 2K4
CP Number:                    EHBRBA001823
CP Intro Type:                2 : Urgent change (not required to change finished products in stock)
CP Maturity Level:            Stage 2

Target introduction date:     2004-05-20
Promised introduction date:
Realised introduction date:

Endorser Comment:

Cost Consequenses:              no EUR

Process Consequences:
  no

Tooling Consequences:
  no

Service Consequences:
  no
----------------------------------------------------------------------------------------------
Reasons for Changes:
     R =  Quality Improvement
          avoid safety problems.

----------------------------------------------------------------------------------------------
PARTSLIST AND REMARK CHANGES
   |Variant Code
   |Content
   | |Process
   | | |Purchase            |Critical for supply chain                               |Reference       |Stage
Act| | | |Itm#|S|QTY     |UOM| |Par/Chld12NC|$|Description / Remark        |PCod| |Organisation | |
.P |0|0| |    | |        |   | |310432831083| |SSB LCD 32"SHARP 2K4 EU     |    | |             |2|
 O |0|0|1|5T02| |01.000|PCE|N|319801890080| |FXDIND 0805  100MHZ 600R COL R |None| |Coding Group |0|
 C |0|0|1|5T02|P|01.000|PCE|N|319801890060| |FXDIND 0805  100MHZ  30R COL R |None| |Philips      |0|
 O |0|0|1|5T04| |01.000|PCE|N|319801890080| |FXDIND 0805  100MHZ 600R COL R |04A | |Coding Group |0|
 C |0|0|1|5T04|P|01.000|PCE|N|319801890060| |FXDIND 0805  100MHZ  30R COL R |04A | |Philips      |0|
 O |0|0|1|5T20| |01.000|PCE|N|319801890080| |FXDIND 0805  100MHZ 600R COL R |None| |Coding Group |0|
 C |0|0|1|5T20|P|01.000|PCE|N|319801890060| |FXDIND 0805  100MHZ  30R COL R |None| |Philips      |0|
 O |0|0|1|5T22| |01.000|PCE|N|319801890080| |FXDIND 0805  100MHZ 600R COL R |None| |Coding Group |0|
 C |0|0|1|5T22|P|01.000|PCE|N|319801890060| |FXDIND 0805  100MHZ  30R COL R |None| |Philips      |0|
   | | | |    | |        |   | |            | |                            |    | |             | |
.P |0|0| |    | |        |   | |310432831093| |SSB LCD 42/37"LPL 2K4 EU    |    | |             |2|
 O |0|0|1|5T02| |01.000|PCE|N|319801890080| |FXDIND 0805  100MHZ 600R COL R |None| |Coding Group |0|
 C |0|0|1|5T02|P|01.000|PCE|N|319801890060| |FXDIND 0805  100MHZ  30R COL R |None| |Philips      |0|
```

Figure 6.11: ECO, section (16)

fsi-EHBRBA001823_1
389_OK.txt

Figure 6.12: ECO, complete

7. PCB Design Software

7.1 Basics of PCB design

Designing a printed circuit board is about the technically convenient and cost-effective arrangement of components in the wiring diagram. Prior to this task, expensive tools were needed, but the well-functioning, yet free software, such as the DesignSpark PCB, and the widespread use of templates significantly accelerated the work of designers. (17)

The best way is to use *best practices* to avoid money-consuming mistakes over time. Ignoring them, may be very costly to repair faults caused by the electromagnetic disturbances, or even to redesign the original layout, which may hinder the implementation of the project for months.

The first problem that designers face is the *component layout.* This is to a certain extent determined by the *wiring diagram*, as some parts are logically aligned. However, a number of *secondary circumstances* are important at the same time. For example, temperature-sensitive elements, including sensors, should be farther away from the heat-supplying components, including, in particular, voltage converters. If the circuit needs various power-supply voltages, the components that convert the 12V voltage to 5V at different points on the circuit board may have placed. These components produce heat and electromagnetic noise, which negatively affects the performance of other components, or even the reliability and performance of the entire system.

Such components affect the electromagnetic performance of the entire equipment, which is important not only for operation and energy consumption, but also for licensing the device. All equipment sold in Europe must obtain the CE marking, one of which is the condition that the equipment does not cause interference in other systems. The most common cause of interference is the switching power supply, but can be caused by many other elements, such as DC / DC converters on the panel, and even high-speed data converters. Electromagnetic radiation can be perceived by the conductors of the printed circuits and can be sent out as small antennas, which, depending on the design of the circuitry, can cause unwanted and unusual frequencies distortions.

Problems caused by remote interference can be solved by shielding and metal covers, but careful selection of interference-causing components on the circuit board can reduce total cost as cheaper covers can be used.

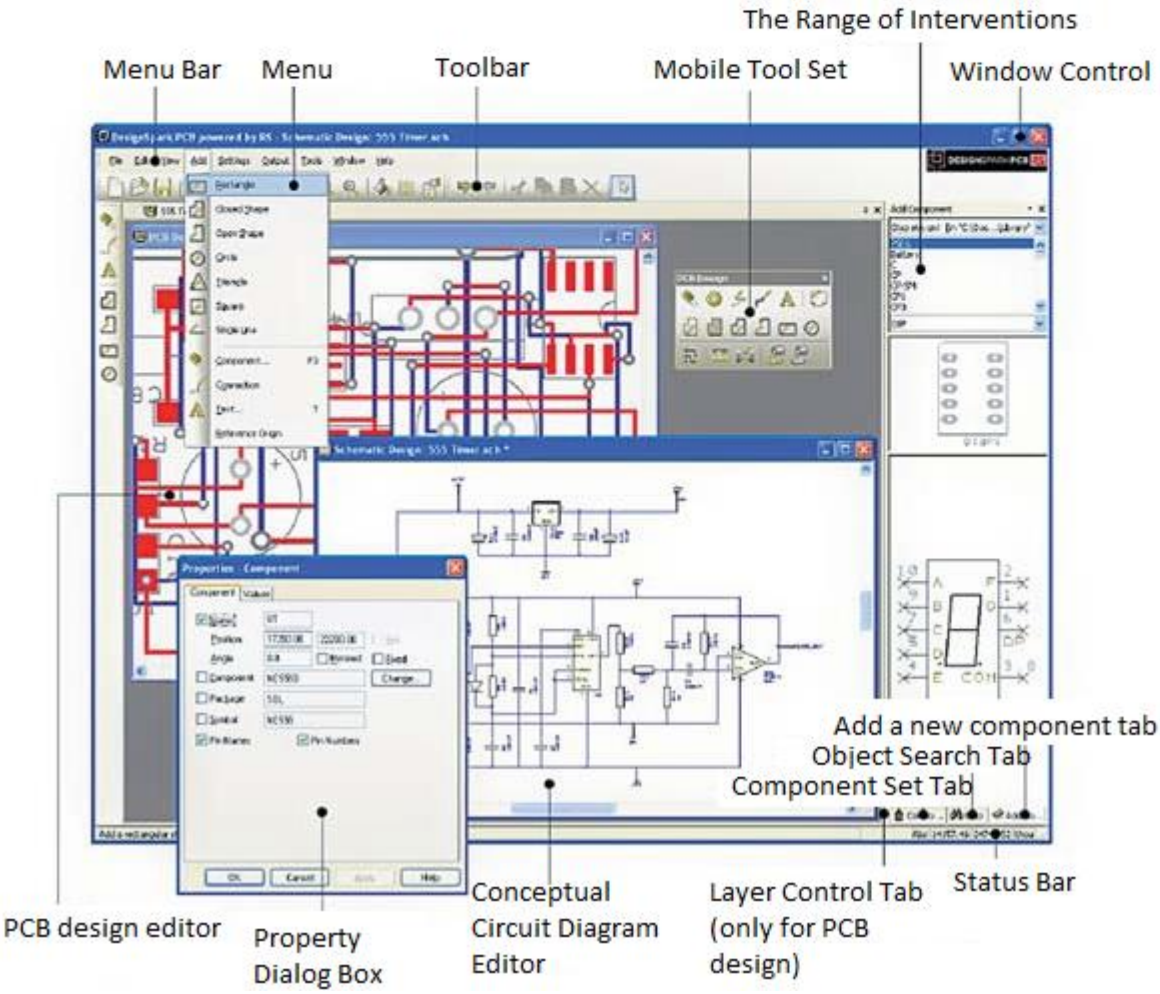


Figure 7.1: Using DesignSpark PCB

Electromagnetic interference may also cause problems within the circuit board. The circuit boards of the circuit board can lead to *inductive coupling*, which reduces the signal to noise ratio, thus reducing the performance of the entire device. In the case of excessive noise, the signal may be completely lost and more expensive components such as amplifiers may be needed, although the problem can be prevented by careful selection of important signal paths. In this case, the template designs are less useful as the different components in the design circuitry have different thermal and electromagnetic properties in different locations.

Capacity design is also an important factor in designing printed circuits as it slows down signals and increases energy consumption. A *capacitive coupling* between the parallel and the conducting paths disposed in the different layers can occur. This can be relatively easily avoided by not allowing the driving paths to run for too long, but turning them into one of them. However, it is also important to take into account the design guidelines that make it easy for the circuit to be manufactured and do not include "sharp" bends that increase the noise. Signal ways may be too close to each other and this may cause a short circuit between the tracks, especially in places where needle crystals can develop over time (Figure 7.2). When controlling the design rules, it is usually possible to discover sites where this is more likely than usual.

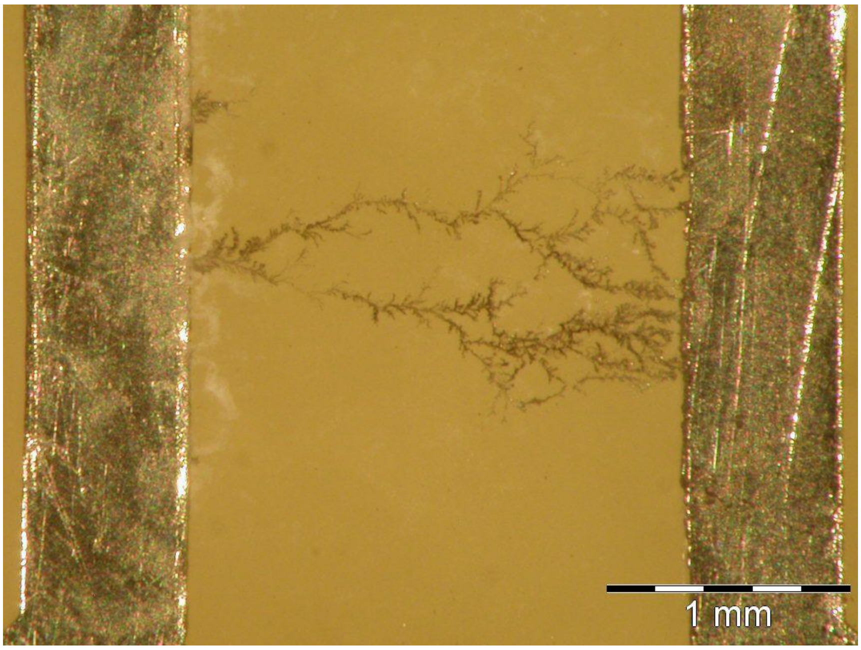


Figure 7.2: Tin Dendrite (metal thread)

The problem is particularly pronounced in the case of ground plates. In this case, a single coextensive metal layer will form a capacitive coupling with all of the underlying and overlying guide paths. Although the ground is effectively shielding the paths, it also builds its own *parasitic capacity*, which reduces line speed and increases energy consumption.

Forming the gap between the layers (via: hole galvanized joints) is one of the most important problems for multilayer circuit boards, as this may cause problems during manufacturing. Improperly crafted vias reduce the signal performance and the reliability of the finished product, so their use should be carefully considered.

Various techniques can be used to answer the different challenges of PCB planning. Some, such as noise reduction with differential signaling, should be *validated in the plan itself*, while others are *designed in the arrangement* of circuit components. These design techniques can be implemented *automatically by design tools*, but the ability to *manually correct* automatic layout and part placement can greatly improve design quality. During these processes, design control checks ensure that circuit technology files meet the manufacturer's requirements.

Layer splitting can reduce parasitic capacity, but it can increase the number of layers, and meet the costs and the challenges you face in designing the vias. By virtue of perpendicular conduction of power and ground, two-layer circuit boards can also provide an impact similar to the ground plane, reducing capacity and simplifying production, but often the price of a circuit board size increases.

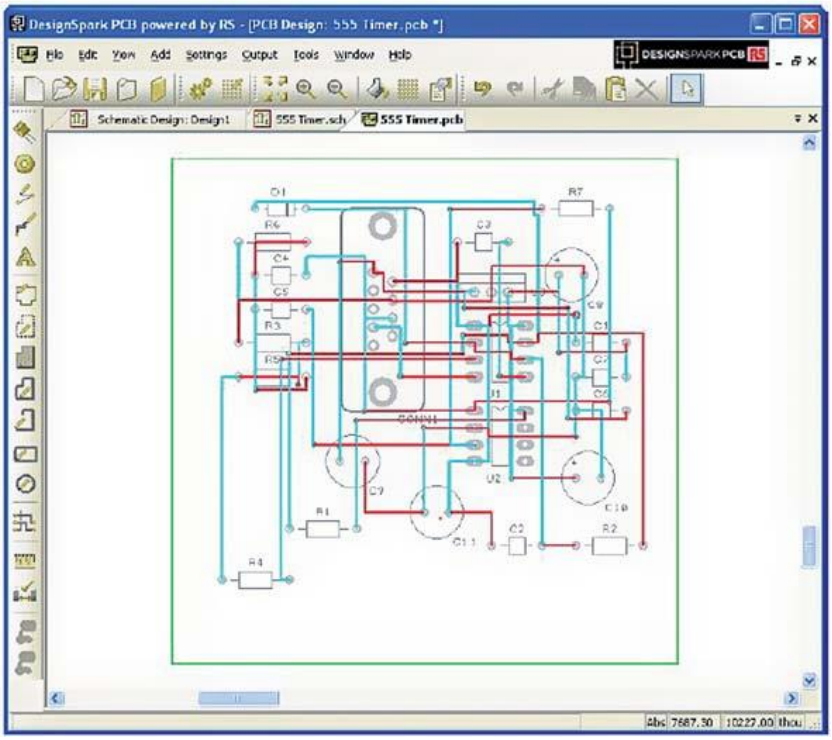


Figure 7.3: Arrangement of a 555 timer circuit board

Using DesignSpark PCBs and similar design tools some of these problems can be solved from the very beginning of the design, but it is absolutely necessary to know the basic requirements of PCB design. For example, a PCB designer SW automatically creates several layers, such as two signal conductors, one earth and one power supply layer. Automated component placement is a very useful feature that allows the designer to spend more time on details that require more careful consideration, such as performance tools close to sensitive signal controllers or higher heat output areas. Similarly, most of the problems can be avoided by automatic positioning of signal lines, but some analysis and manual intervention in high risk areas can significantly improve the quality of the PCB design by increasing output and reducing costs.

Checking design rules is also a very useful tool to find out, among other things, that signal tracks are not too close to each other (i.e. there is no risk of short-circuiting), and also provides for economical design. It is also possible to scan and edit power and ground plates to avoid large surface areas causing parasitic capacity.

These tools help to produce "outputs" for the final product, such as *Gerber files* for signal paths and soldering surfaces, and the production of *Excellon files* for drilling automation. These must fit the technology files of the circuit board manufacturer.

During PCB design, a number of problems have to be considered, most of which can be effectively solved with DesignSpark PCB-like software. Using some of the best practices, designers can develop cost-effective, reliable circuit boards that conform to system specifications and do not cause extensive and costly problems during the certification process.

7.2 EAGLE PCB design software package

The software called EAGLE is powerful, easy to use and free to try. Electronic design practice has long been an "art" anymore. It has become an industry whose performance can be accurately measured with the cost of time and the time it takes to produce a marketable product. Consequently everything that can be mechanized during the design work should be mechanized. That is why it is extremely important to know all the tools - including CAD software tools - that can improve the efficiency of design work. This is also the EAGLE PCB designer who has been marketed by Farnell. (18)

As the CAD tools of the electronics industry are pushing to offer a machine-assisted solution to the problems of circuit design, the ever-increasing efficiency of **EDA** (**E**lectronic **D**esign **A**utomation) software packages, such as EAGLE. The EAGLE code is small, targeted and of good quality. It comes with a PDF manual and documentation that helps you learn basic features, but also contains an extensive and detailed help feature. PDF files are intended for pre-reading, and online Help gives users access to on-line quick online help. The documentation and help system is easy to "take over" and in less than a day the user can go to a certain degree of usage, i.e. you can work - instead of "figuring out" the complex and mysterious functions and ways of using the CAD software package. EAGLE's code is also highly reliable and of good quality, since the development of the EAGLE has been the same team for decades. Thus, there was enough time for the team to improve code and have been able to develop a process for tracking changes that could keep up the high quality level. The team does not allow code without thorough beta testing.

Engineers who specially design specialized cards, such as the signal conduction used with highly differential or predetermined impedance, need expensive CAD software tools. These users often have to purchase features that they may never use, and a significant part of the price is the license fees that are required to maintain the compatibility of all design work. EAGLE, on the other hand, focuses on the most commonly occurring PCB design work, and the entry level price is also affordable for individuals.

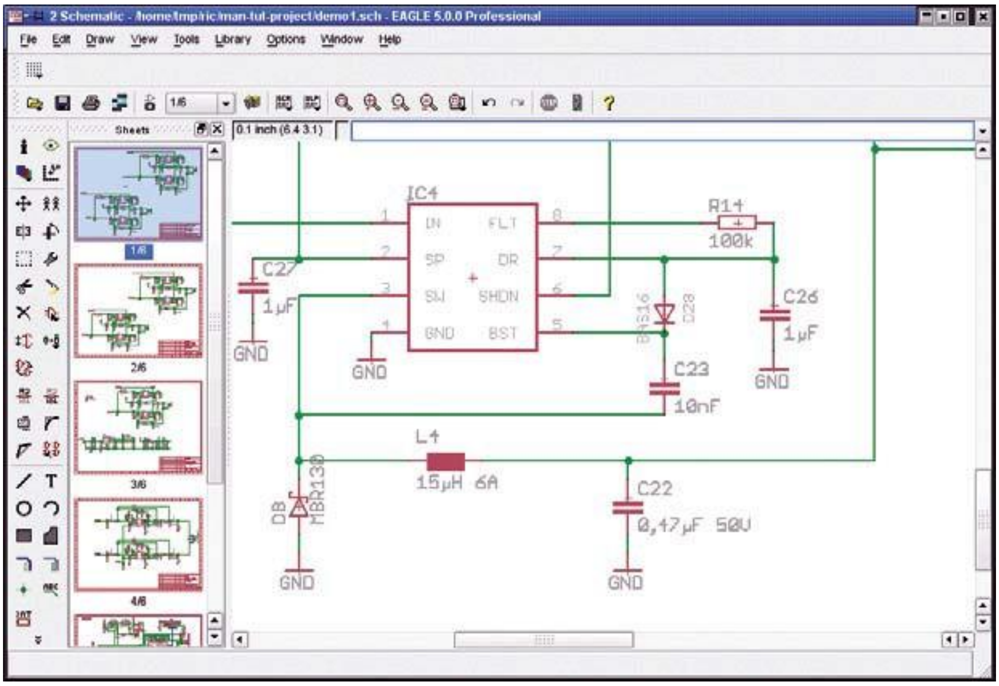


Figure 7.4: EAGLE Schematic Editor

The structure of EAGLE

EAGLE consists of 3 functional modules:

- Schematic Editor - for editing the schematic diagram
- Layout Editor – for modifying the existing layout
- Auto router - to automatically design the signal paths of the printed circuit.

These modules are available in a variety of licensing combinations, so there is an appropriate service solution for any financial opportunity. Licenses also determine the operating parameters of the program modules. For example, Standard License 99 conceptual wiring diagrams, 6-ply and Europe-wide (160 × 100 mm) printed circuit boards are used. The Professional licensing variant, on the other hand, handles 999 conceptual wiring diagrams, 16-layer printing, and 1.6 x 1.6 m PCBs. All licensing variants have a uniform resolution of 0.0001 mm.

Auto router

In addition to the full automatic route tracking of the entire card, the EAGLE Auto router module can be used in semi-automatic mode, which means that the manual tracking is "behind" in the background. There are two semi-automatic modes: one shows the path proposed by the program from the mouse cursor to the closer connection point of the currently designed wire and the other mode to the two ends of the planned track. While moving the mouse, the track is recalculated and displayed continuously. The recommended path is accepted with a single mouse click. This eliminates the most boring part of the trail planning, while remaining complete control over the planned trail remains. Additionally, EAGLE comes with a C-like user programming language that allows the operation to be "customizable" and adapted to the unique features of the application.

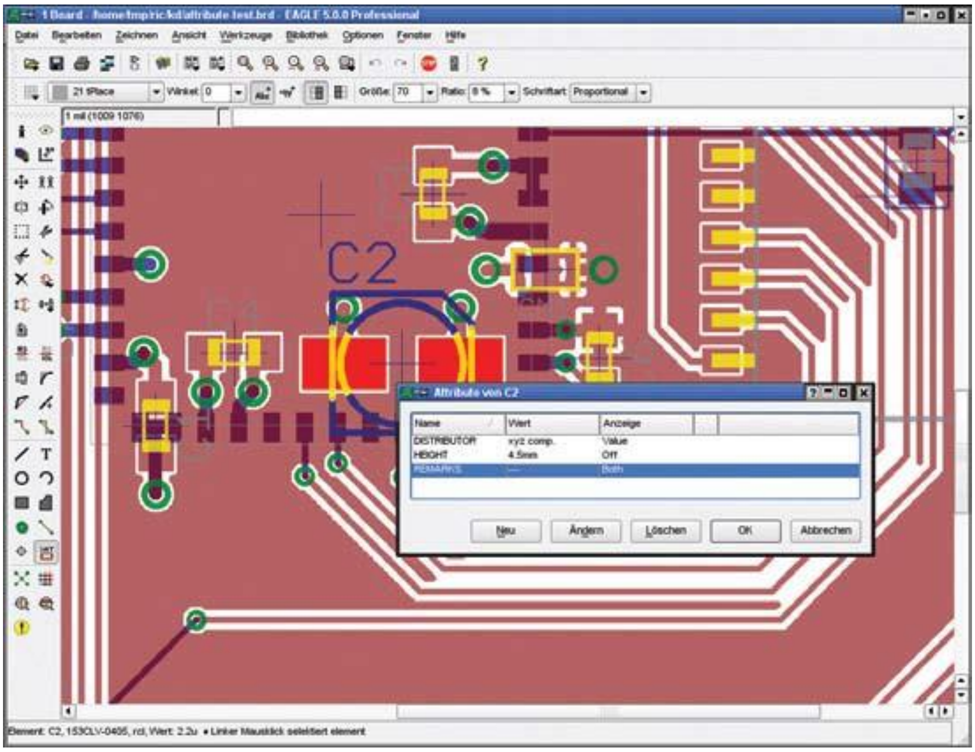


Figure 7.5: EAGLE Layout Editor

EAGLE releases

EAGLE is available in various configurations. This gives users the opportunity to first get acquainted with the program, the evaluation software that can be used to evaluate, and as the complexity of the developed circuits increases, the fuller versions can be used to track changes in priorities and projects. The version change method allows developers to switch over to more powerful software versions, but they do not require any new training time and costs, which is often required in other software.

Freemium release

Since the acquisition of CadSoft by Premier Farnell, it has introduced a more powerful free version that is named Freemium. This will allow developers to evaluate how they can use EAGLE in their applications. This is a licensed limited-time license with capabilities close to Standard editions. It supports 4-layer printing with 4 conceptual sketches and half a European-card size PCB. The Freemium license is valid for 60 days and the activation code can be downloaded from the Farnell element14 portal (www.element-14.com/eagle-freemium). To download a "reverence copy" for evaluation, you need to register on this page. The use of the evaluation program instance is restricted to one PC and a single e-mail address.

Www.element-14.com is a new, informative professional portal and electronic community site for electronics development engineers. Provides product data sheets, design tools, and technology information - embedded in Web2.0 functionality that allows users to interact, communicate, collaborate, and share information with their colleagues around the world. Design engineers can consult experts, recognize trends, and publish blogs, articles, and posts at this worldwide forum.

8. The aspects of prototype making

8.1 Definition of Prototype

The prototype is an early sample, model or product release that is built on checking the functionality of the product or concept. After manufacturing the prototype, either the production of replicas or a further product development phase follows. The purpose of prototype building is therefore to control the new design by users and system analysts. The prototype is a real, working tool, not just a theoretical model.

In some workflow models, prototype making is called materialization, which is between formalization and idea evolution steps.

The prototype word comes from the Greek word πρωτότυπον prototypon, meaning primitive or simple form.

8.2 Prototype categories

There is no general agreement on what exactly is the concept of prototype and is often used alternately with the word "model", which in many cases may cause confusion. Usually, the term "prototype" refers to the following five categories:

a. *„Proof-of-concept" Prototype:* in electronics, this is often a prototype for a probe or "bread board". The Proof-of-concept prototype is designed to control design, without any later design, material selection or manufacturing process testing. These prototypes, therefore, are designed to prove the design idea, and are often used to find out what features are working and which require further improvements.

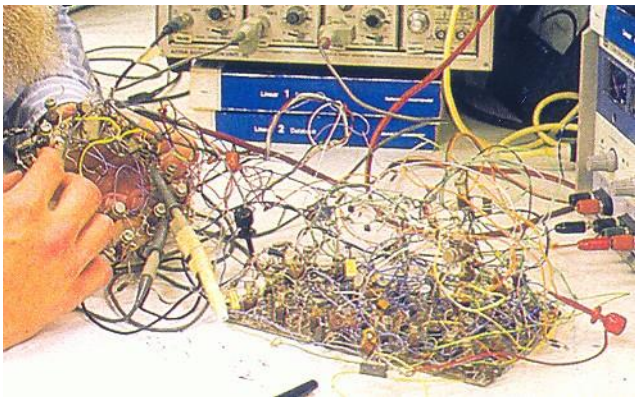


Figure 8.1: „Proof-of-concept" Prototype

b. *„Form Study" Prototype (model):* this prototype variety is used to control the physical realization, dimensions and appearance of the product, without the functionality being realized in it. Helps the designer controlling the ergonomic factors and the final look of the product. Form Study models are most often made of hand-carved or machine-readable material (e.g. polyurethane foam). The end product is color, texture, surface, not formed, only its shape. Thanks to the easy-to-work, but non-abrasive material used, this model is designed solely for internal decision making and is not strong enough to be subjected to testing for end-users.

Figure 8.2: checking „Form Study" Prototype

c. *„User Experience" Prototype (model):* This prototype is primarily used to observe human intervention, most often in user-focused studies. The design of the ultimate look is not a goal, but here are the small details and formal features of the final product. With these prototypes, you can evaluate how the user will perform the actions while using the product, handling the various components, and how much it corresponds to the pre-script or can be evaluated by the later user experience. As these prototypes have been handled for manual testing, robust design is an important aspect. They are often made of plywood or "RENshape" technology or with CNC machines.

Figure 8.3: „User Experience" and Visual Prototypes

d. *Visual Prototype (model):* conforms to the ultimate aesthetic design, simulates the intended color and surface texture but does not have functionality. Visual prototypes are used for market research, management review and approval, packing samples, and brochure photos.

e. *Functional Prototype (model):* another name is the working prototype. This has the greatest practical benefit as it simulates the ultimate design, aesthetics, materials, and planned functionality. The functional prototype is sometimes scaled down, because of the cost reduction. By designing a full-sized prototype and complete concept design, design engineers have the latest opportunity to fix any mistakes before mass production starts.

8.2 Difference between the prototype and the production piece

Generally speaking, the prototype differs from the end product in series production in three basic ways.

Raw materials: Materials used in mass production involve higher costs than those that are practically used for prototypes. For this reason, engineers and prototype specialists use substitutes that have similar properties and simulate the intended final material.

Processes: Often, special machines are required to produce a new design for a new product, which is very expensive and time-consuming. When manufacturing prototypes, they often make compromises and use standard, readily-replaceable manufacturing methods, often with inadequate testing that does not reach the maturity level of standard equipment.

Lower Accuracy: The finished product that is present in production is often used to group huge resources to produce accurate details. These details on the prototype may be missing, as they have not yet reached their final shape, they can still be modified. Often, very low detail is built on prototypes compared to the final product intended for production, which, however, runs through a rigorous testing process and a statistical process control.

8.3 Limitation of Prototypes

Prototype specialists and engineers are paramount to be aware of the limitations of prototypes when they are trying to simulate the intended idea.

It is important to accept that prototypes, in terms of the entire design documentation, represent, in many ways, a compromise over the production part. Protocols that differ from raw materials, processes, and accuracy may not work well in a place where the production piece is flawless. By contrast, the prototype may work where the production piece is bankrupt, because the materials and processes used to make a prototype may overshoot the mass production conditions.

In general, the expected cost of prototypes significantly outweighs the cost of the production end product because of the low efficiency processes and materials. Prototypes are often designed to revise the design, the primary purpose of which is to reduce costs, optimize and process improvement steps.

Testing prototypes can reduce the chances that the final product may not work as planned, but the overall risk cannot be ruled out. There are practical reasons why prototypes can limit the design of the end product to a limited extent. Mostly, engineering permits and decisions are needed to move on to the design of a working production piece.

Accurate construction of a complete design is often a time-consuming and very expensive solution, especially if we have to do it more than once - building the complete design, fixing errors, and then rebuilding a whole new design. As an alternative to this, *rapid prototyping* or *rapid application development* techniques are used for the introductory phase, but not for full product design. This enables engineers to quickly and cost-effectively build critical parts of the product (where it is most likely to experience errors), correct problems, and then build the overall design.

By the contrary, it is the fastest way to build something if we first build something else. Telescopic Rule or Thomson's Principle for the first telescope makers: "It's quicker to make a 6 inches mirror when you first make a 4 inch, and then go for 6 inches." In fact, the knowledge base that is created when solving the minor problem gives you the basics to solve the bigger problem.

Figure 8.4: Beskid 106 Polish prototype from 1983

8.4 Prototypes in electronics

In the electronics, prototype making is the construction of a circuit that can control the functionality of the original theoretical principle and provide a physical platform for bug fixing if it does not work. Prototypes are often constructed using wire wrap techniques or Vero boards (probe-PCBs) or breadboard (protoboards), which electronically implement a correct circuit, but differ from the intended final product in physical appearance.

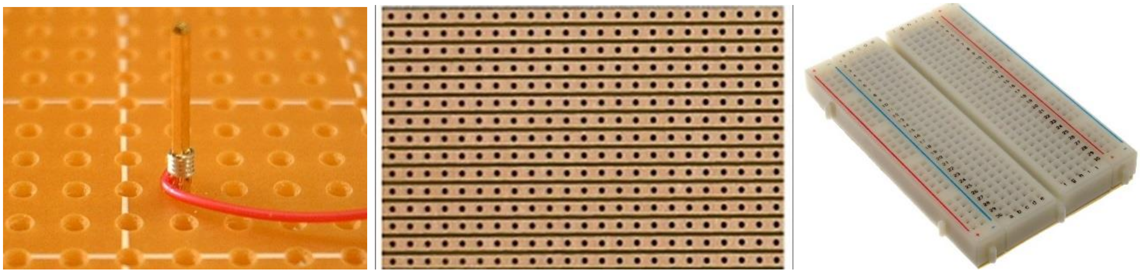


Figure 8.5: Wire Wrap, Vero board, Breadboard

Open source applications are available to implement the documentation of electronic prototypes (mainly built on the breadboard) and promote the way to production. Such applications include Fritzing and Arduino.

By these methods, a technician can build a prototype much faster and make the necessary modifications, though it is much cheaper to produce large quantities of unique PCB than to produce prototypes with such techniques. The principle is similar to writing a poem for one or two people with easier freehand, but if you need hundreds of thousands of copies, it's easier to publish in the newspaper.

With rapid, short-term PCB manufacturing companies and insertion companies, rapid prototyping was available. It has now become possible to include the smallest passive components and the fine pitch ICs with a few days' time to complete the prototype with insertion.

8.5 Null series (Pre-Series)

Null series (Pre-Series) are a stage in the product development process and the final status of the technical product development process. During the previous period (unique, experimental), the prototype of the new product is produced. After the prototype has been evaluated, preparations for serial production begin. The serial production license is a prerequisite for the small series of zero-series production. At this point most of the new products are manufactured in a small series, based on technology. It is then decided whether the new product is suitable for serial production. (19)

Stations of the technical development process

- Idea, objective
- Plan-Target Jury
- Planning
- Enabling prototype production
- Prototype production and evaluation
- Enabling the production of Null series and technology.
- Technologization, tool design, tool manufacturing
- Null series production
- Null series rating
- Entire technology and tool manufacturing
- Enable serial production
- Serial production

9. Production under mass production conditions, state of the art production lines

9.1 Mass production experience and error finding, repair

There are completely different aspects of mass production conditions than during the design phase of the product and during prototype production and control. Effective yields, low scrap percentages, cost efficiency, and manufacturing speed are all new concepts that are not or are less typical of earlier product life.

It is common that, despite the careful prototype control, there is no evidence of a lot of development opportunities for minor errors that can only be found in mass production conditions. The most common defects that are not related to the operation of the product, but also the manufacturability, such as a SM component designed near a pin solder to be soldered by a wave-solder, may be the omission of the technology frame. Many design or raw material defects include the initial product definition, which will only be discovered later when thousands of products are produced. The statistical error analysis method only yields measurable results after a higher number of outputs, and less spectacular defects that are immediately out of the production line can be hidden in the null series.

However, companies with high manufacturing experience and specialists may notice these design shortcomings even after the first zero-series production of the product, based on their experience of manufacturing other similar products over the last few years. This is done by the ***Start-Up Review***, which was held before the launch of the null-series, which includes managers besides the cross-functional team, indicating the expected failures of the design team and deciding on the production of the product and the expected risk assumption.

9.2 Elements of modern production lines

Whether it is ***O**riginal **E**quipment **M**anufacturer (**OEM**)*, which has its own production line, either from an ***EMS** (**E**lectronic **M**anufacturing **S**ervices)* company, manufacturing processes and materials are significantly different from those used in prototype manufacturing or at home.

The high degree of automation, precision, high output, speed and low scraping properties of modern production lines make these factories suitable for manufacturing more 10,000 products per shift, depending on the complexity. Despite the high number of pieces produced, the ***field reject*** (end-user error) may remain low, often under 200 ***PPM** (**P**arts **P**er **M**illion).*

The Flow Chart discussed above already included the elements we use under mass production conditions:

- *Solder Paste Printer*
- *SMD Inserter*
- *Reflow Oven*
- *Manual Insertion*
- *(Selective) Wave Soldering Machine*
- *In Circuit Tester- ICT*
- *Functional Tester – FNT*
- *Monitor Tester – MON*
- *Visual Inspection*
- *Automated Optical Inspection – AOI*
- *Conveyor Belt*
- *Off-line programmer*

Solder Paste Printer

They will not be disclosed separately, but other stations may be in front of the pasting machine. The Incoming Inspection station is often located away from the production line, even in the storage area, as inappropriate materials are not already taken to the manufacturing plant. Inbound material control can be automated or manually, according to a specific Acceptable Quality Level (AQL) exception rule. This determines the number of pieces of product that should be checked and the frequency at which the AQL level is to be controlled. A separate engineering and quality control task is the definition of the control method and the definition of acceptable and unacceptable levels. Critical is the quality control of the materials and components used, as many of the ultimate root cause of user error can be traced back to this.

Before the paste machine, there is usually an intermediate device for filling empty cassettes for bare PCBs. Loader is the English name for this unit.

It is the duty of the pasting machine to dispense the appropriate amount of solder (paste) in the pads under controlled conditions.

Figure 9.1: Solder Paste Printer

This is accomplished by using a stencil placed in the machine. The stencil is a thin, high wear-resistant metal plate that holds in a stencil frame. In the right places where you want to create soldering later, there are stencil holes, in other words, apertures. Stencils are created by growth technique or laser cutting. First of all, the thickness of the stencil will determine the amount of solder paste, but the machine's adjusted characteristics (pasting speed) also affect the paste height. The solder paste on the stencil is uniformly dispersed by the Squeegee, its coagulation must be checked at regular intervals, as is the clogging of the stencil apertures. Each PCB has a separate stencil, but a bare PCB can have multiple product versions.

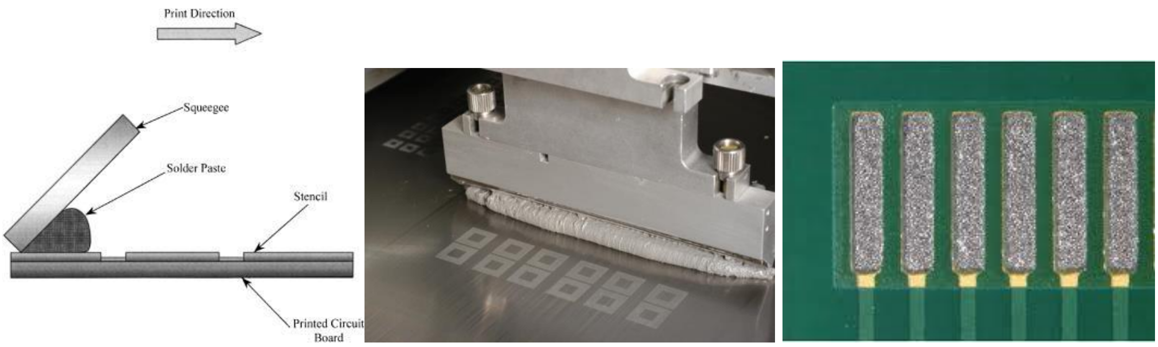


Figure 9.2: The process of pasting, soldering paste before Owen

SMD Inserter

The task of the automatic SMD inserter is to insert SMD components into the bare PCB, which already contains solder-paste. For small SMD components, it is almost impossible to install the parts with the correct precision so automation is needed above a certain level of complexity or for fine-pitch components.

Figure 9.3: SMD Inserter machine

The SMD inserter program is written by a specialized engineer or technician based on the previously discussed DAT file (coordinate file) and product BOM. Thus, all the information was provided to make it clear to which machine what kind of component was to be placed in X and Y positions by the given rotating value (Z).

Various optimization procedures can also help the technician to automatically designate the shortest path to SMD inserter head. Parts are picked up on reels and trays by the machine Separate dispensers are available for the rolls, and the trays also require a special receiving unit. The inserter works out of the coil or tray with the help of pipettes, and the inserter head moves on a quick servomotor to plant the panel. It is a very common solution that parts used in many positions (e.g. filter capacitors) are rolled up in several reels, since a single reel would run off very quickly. Prior to the first insertion, the SMD technician or engineer will make a sticky board with adhesive sticker to check whether all parts have been inserted in the right place.

The most common SMD inserter manufacturers are Panasonic, Siemens and Fuji.

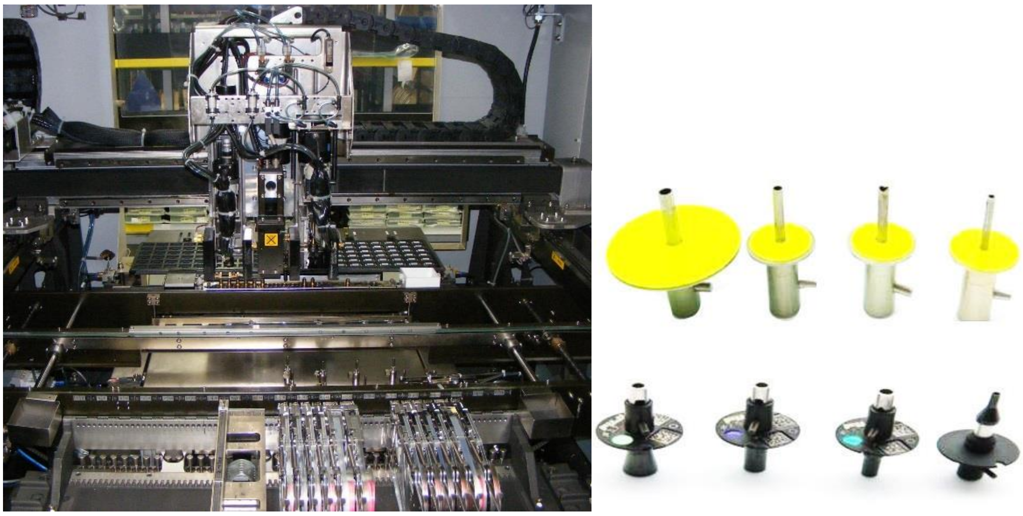


Figure 9.4: SMD inserter head, pipettes

Reflow oven

The next stage of successful plotting and SMD insertion is often a visual inspection, but a well-functioning insertion line can be followed immediately by the reflow oven. The conveyor belts at specified speed here and fills the given time in the respective ***zones*** of the ***reflow-Owen***. Different zones operate at different temperatures, so there is a way to control them. The professional setting of a computer-controlled reflow oven is an engineering task, and we also need to consider the component manufacturers' recommendations because high temperatures require the soldering of a lead-free solder, but components will not tolerate this high temperature for a long time. The time-temperature graph is called the ***heat profile***. A common solution is that for two-sided PCBs, the first page containing smaller SMD components will be installed, and the second one containing larger ones. If reverse order was used, high-weight (control and CPU, MCU) ICs could easily dampen when the second side was soldered.

Figure 9.5: Reflow Owen

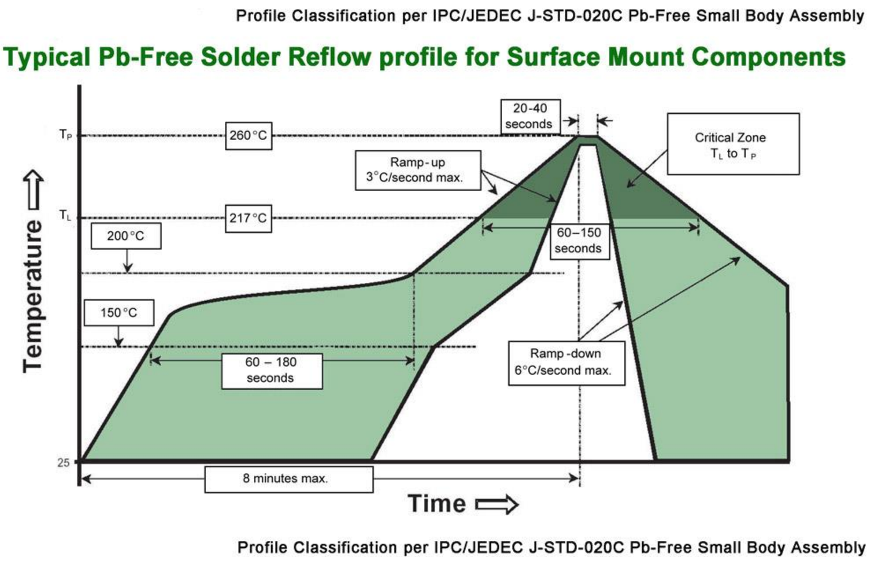


Figure 9.6: Reflow Owen's heat profile for lead-free soldering

Manual Insertion

In most cases, the ***SMD and THT departments*** are separated, as the two departments require completely different technology, and in many cases the speed of the two is not the same. As THT components are often hand-picked, the line speed may be smaller, even with much less inserted parts.

There are ***axial and radial automatic inserters***, but their significance is decreasing due to the spread of SMD components. In addition, these automatic THT inserters transfer high mechanical vibration to the PCB already containing SMD components, which makes them easily damaged.

The task of the design team is to decide whether to create a complete SMD product or THT. For full SMD, the manual insertion section - and thus many defect possibilities - can be omitted, however, the mechanical stability of an SMD connector does not reach the THT, as it is only soldered on the surface but is not secured by the through hole on the PCB.

In case of manual insertion plays a major role in the on-line, live-documented, constantly updated insertion work instruction. At a given station this includes the insertion positions of the parts, names, codes, and diagrams of the parts to be inserted. In a line with multiple manual insert stations, it is advisable to distribute the components so that connectors of the same shape, but differently colored, or parts that can be easily mixed can be stacked separately, thus reducing the chance of misalignment.

Figure 9.7: Manual Insertion

(Selective) Wave Soldering Machine

Manual insertion is usually done in a special ***frame*** (called: ***jig***)-mounted panel. The conveyor belt moves the jig and moves it to the wave solder after insertion. The function of the wave solder is to properly solder the THT parts. The solder material is present in the melted state of the wave solder bath, whose physical and chemical control is a continuous task. The wave formed from of the molten solder is created by a special circulating pump. The inserted panel in the jig passes above the wave and the THT parts are soldered in the free holes. For two-sided SMD panels it is selective, while for single-sided panels or components with adhesive, normal wave soldering is required.

Figure 9.8: Wave Soldering Machine

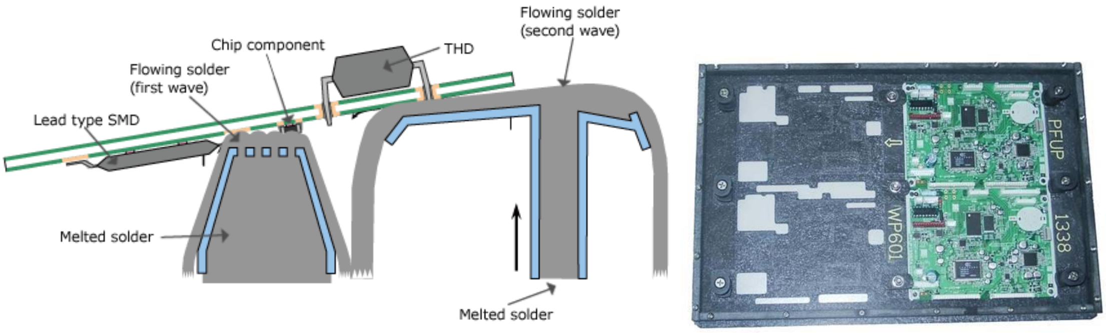


Figure 9.9: wave soldering process, selective wave soldering frame (jig)

In Circuit Tester- ICT

After the wave soldering, the solder repairer repairs the typical faults immediately or sends it to a repair team in a separate block.

The stuffed board with all components is, in principle, operational, but it is through a multi-step test process. For a product with a power supply, the first test step is the ***H**igh **V**oltage **T**ester (**HVT**)* or High Pot Tester that monitors the leakage current at the output by high voltage to exclude the primary and secondary side shorts that could otherwise cause life-threatening electric shocks, even during the later stages of the test line.

However, in the case of a board that does not have a power supply, the first test step is the ***I**n **C**ircuit **T**ester (**ICT**)*. ICT focuses on the existing and correct values of passive components. A special jig is holding the panel, which is fed from the bottom of the test points with golden plated test pins. The needles of the tester are called bed of nails. Through the connections, the various circuitry details can be checked, similar to a multimeter measurement.

The design team also usually has a recommended test program where tolerances for different components and test regions are provided. When programming ICT, these values should be based on. If the values measured at the product test points meet these tolerances, the product gets a “Pass” result if the measured value is outside the error limit for a test point and then performs “Fail”. In this case, a paper on a cash register tape is also provided with an error list showing the measured values and the acceptable tolerance in that test point. The defective products are placed at the repair station where the incorrectly installed, missing or rotated parts can be detected based on test points on the wiring diagram.

ICT efficiency is very limited, as parallel components, and in some cases capacitors and active components, cannot be adequately controlled by this method. In the case of a panel of high complexity, it is impossible to design a separate test point for each component on the board, so it is not possible to control all the components, but the features of a component group can be inferred from the tolerance of the parts within it.

Due to the relatively high ratio of first-rate (false positive) and second-type (false negative) errors, ICT is not used as a stand-alone test device, but is complemented by other test equipment.

The Flying Probe Tester also operates on the ICT principle, which is more flexible for quick product variations and small series production, as it does not use special and very expensive jigs as well as product-specific bed of nails but moves a fast robot arm to the appropriate points and performs a two point component check. Flying Probe is much slower than the needle layout due to its operating principle, and is therefore used primarily for prototypes and null series production.

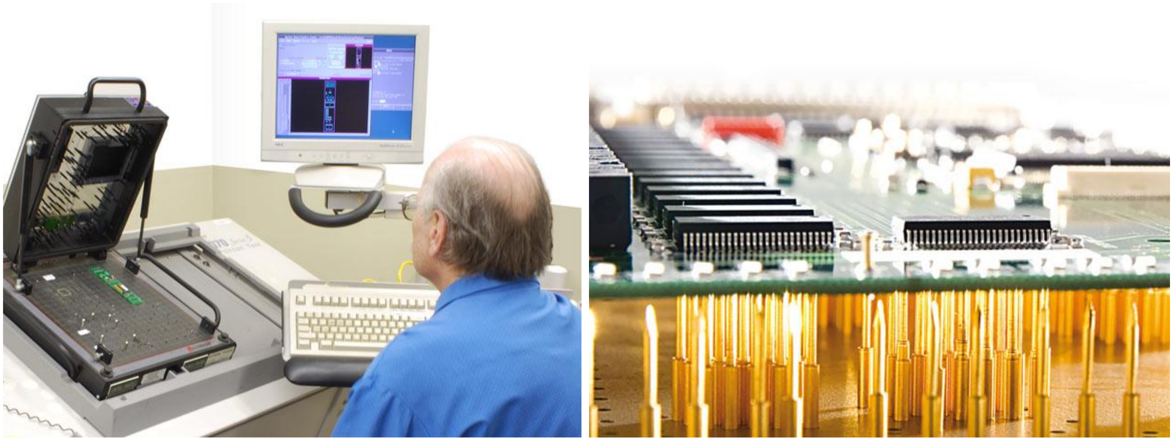


Figure 9.10: ICT (In Circuit Tester), ICT's bed of nails

Functional Tester – FNT

The post-ICT test step is in most cases the ***Functional Tester (FNT)***. At this test step, we can check not only the passive characteristics of the circuit but also the active operation. The various circuitry details must have an output specified by supplying an appropriate supply voltage and an input signal. The FNT performs this with the needles and jig like the ICT, which means that it is looking for expected outputs for active certain inputs.

It is almost impossible to check the full functionality of the product, since the automated equipment cannot be checked for all the features that are possible during operation, but the type of software that is typically used in the built-in software is typically tested in this test step.

FNT also provides ***Pass*** or ***Fail*** results, and in the second case, provides a bug list that facilitates error correction work.

In many cases, ICT and FNT already provide sufficient test coverage, but more complex equipment requires additional test steps.

Figure 9.11: Functional Tester – FNT

Monitor Tester – MON

The *__Mon__itor Tester (__MON__)* is used for controlling products where previous ICT and FNTs do not provide sufficient test coverage or are verifiable with the product monitor. These are the motherboards of today's televisions that can be controlled with an LCD or LED display and with appropriate inputs. Here, we do not have a needles connection, but we use the connectors on the product, but the connection can be facilitated by various auto-jigs. In this test step, various features that can be evaluated by visual and image processing can be checked, such as RGB values of color or contrast, saturation.

It can also query the versions of the SW version of the product, including some of its built-in software, in this test step, but we can also specify a subtype of this product by entering codes that can be used in factory. Here, it is possible to simulate the end-user operation of the product with end-user input devices (DVDs, aerials, etc.). However, in many cases there are also signal generators or some image samples that can be evaluated by a special test software. The output of the test step similar to the previous one is Pass or Fail, but the role of the operator is greater than the previous test steps, since fewer features are automatically evaluated and more are assigned to humanity (e.g. product version number, correct software version checking.)

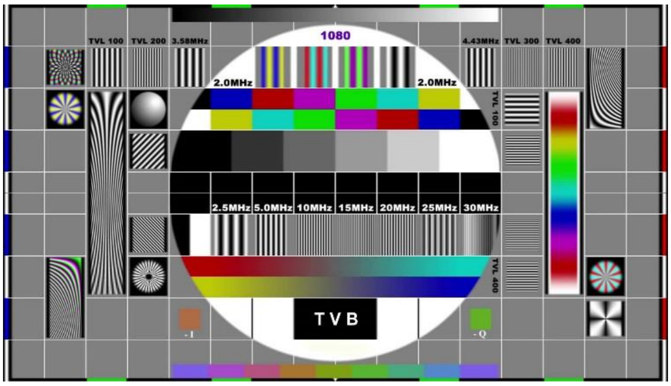


Figure 9.12: picture used for the monitor test

Visual Inspection

Visual inspection or control is used in several stages of the manufacturing process. Often, after SMD insertion, they perform a visual check on both sides, after soldering, but also before packaging the product. Of course, the various process steps need to focus on different details, for example after wave soldering, to tin-bridges often formed at the terminals of connectors or not enough to rise-up. Visual inspection uses special microscopes, but in most cases, magnifying lamps are used. When packed, the product is checked without any microscope. Any faults detected during visual inspections are either repaired immediately by the operator (such as a solder repair / visual check after wave soldering) or faulty products repaired by the repair team.

Figure 9.13: visual control and its tools

Automated Optical Inspection – AOI

Automated equivalent of the visual inspection is Automated Optical Inspection (AOI). For AOI, we are relying on a program that automatically detects errors, but the final error evaluation is still the task of the operator, since the best-configured AOI cannot function without falsity. Programming AOI is an engineering task, a product's Gerber package, and a properly stuffed sample board (golden board) is the basic information on which the first program is to be completed. The program can be continuously improved during production by fixing errors that are occurring in the program. Similar to the testers, this is a bug list for the defective product, to facilitate the repair work.

The Automatic Optical Inspection (AOI) can be located at:

- post-print inspection, Solder Paste Inspection
- post-place inspection, Automatic Placement Inspection
- post-reflow inspection

Today, 99% of LED light sources are used. The camera system is characterized by resolution and field of vision (FoV), which determines the speed of control and the AOI permeability.

Figure 9.14: Automated Optical Inspection – AOI

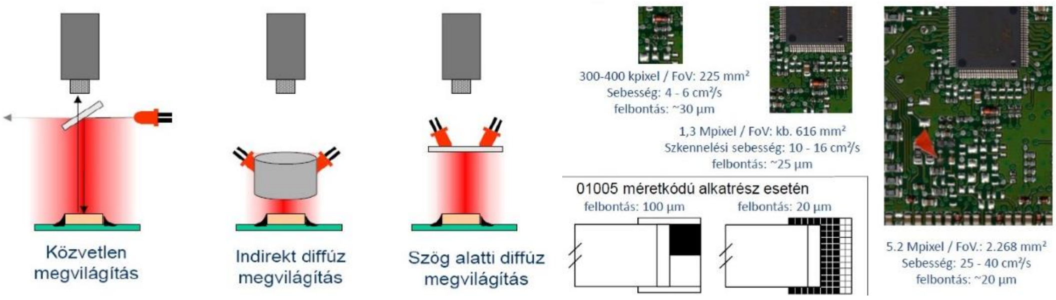


Figure 9.15: AOI lighting system, resolution and permeability

Conveyor Belt

In most cases the *Conveyor Belt* does not constitute a separate production step, but it composes a bridge between the steps. One or more conveyor belts integrated into each-other operate in homogenous parts of the production line, however at the end of the given department products have to be collected into cassettes with the help of an *unloader* for enabling the compensation of the different cycle periods of the different departments (e.g. SMD and manual department). Because of different cycle periods an SMD department can often serve two or more manual lines. Speed of the conveyor belts can be adjusted and the belts are protected against electrostatic charging.

Fig. 9.16: Conveyor belt

The off-line programmer

Most of complex products contain more software packages responsible for the control of part procedures apart from the basic program of the product. During mass production it is highly important to have these software packages most possible soon loaded into the appropriate EEPROMs. Software packages of the product can be loaded into the operating, assembled board as well at the functional test station, however this a time consuming procedure, therefore in most cases – especially in case of large software packages – the so called *Off-line programmer* is used. The off-line programmer programs EEPROMs (flash memories) with mainly TSSOP or PLCC (QFJ) casing before their installation in special sockets.

This machine contains several parallel operating sockets, thus cycle period can be reduced. Art of input and output packaging can be chosen, the machine accepts reel or tray packaging arts and the output can be chosen as well. Using the appropriate labelling or coding is of high importance, since a wide pallet of products results numerous different software versions and the IC containing the appropriate software has to be installed into the appropriate hardware on the SMD lines. Off-line programming cannot completely replace software downloads in case of test appliances, since several small-scale software packages exist, the download of which into test appliances (mainly on FNT) is more economic because of their small size. Such a software is e.g. the EDID SW containing the appropriate monitor dimensioning's and it is a rather small-scale software.

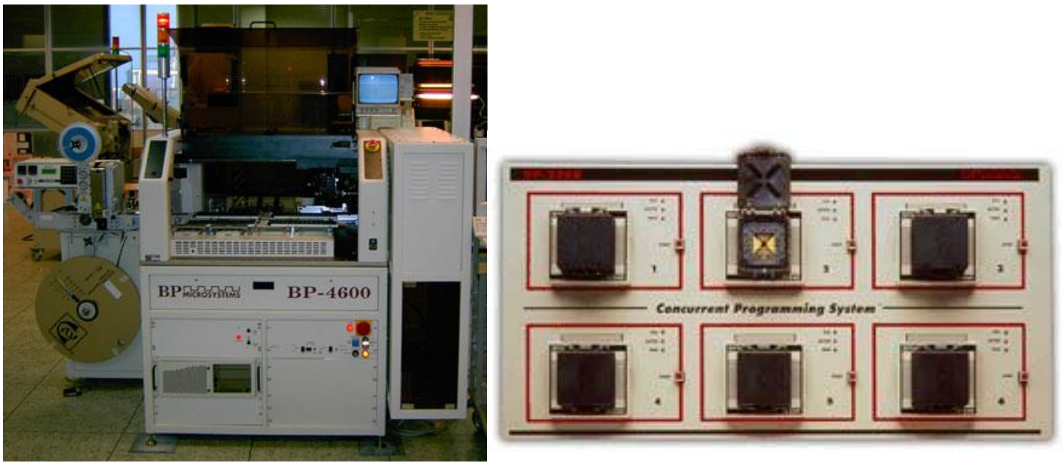


Fig. 9.17: Off-line programming machine (BP Microsystems BP-4600) and the programming sockets

10. Aspects of product development and manufacturing efficiency, Lean

When using the production line elements listed in the previous chapter, we can choose between lots of setting options, however for achieving the appropriate, *optimum production quality and quantity*, parameters can vary only between very narrow boundaries. In spite of the above there is still an opportunity of ***C****ontinuous* ***I****mprovement* – ***CI*** and of making more perfect the process settings.

Most EMS companies integrate the CI processes intentionally into the price of the product already during its pilot series and develop a pricing accordingly for the customers. This is frequently an expressed expectation from the customers' side as well, which means that the customer buys the product against a continuously decreasing price because of the increasing number of pieces and the know-how developing in the factory, i.e. because of the CI processes, since the resources expended to the production decrease. As time passes the amount of refuse decreases as well, thus enhancing the *environment protection* indexes in turn.

10.1 Start-up review

Before launching the pilot production the manufacturer company performs a so-called *Start-up review* with the cooperation of the cross-function group (head of all engineering departments and internal and external quality insurance engineers, specialists) and managers. If the design team is separate from the production – typical OEM – EMS connection – then a knowledge base, know-how develops at the place of the production which has a feedback onto the product development as well.

Before the Start-up review preliminary flowchart, FMEA and CP are developed on the basis of which production and quality problems possibly arising during the production of the given product can be evaluated step-by-step. Apart from the above documents a physical *prototype* helps the work of those taking part on the meeting, which prototype can be inspected and evaluated by them. Such an example has less importance for the design team, however during the manufacture the backwardness of the production frame from the PCB is inevitable, or an SMD part with 0402 dimensions designed too close to the pin of the THT connector to be soldered with wave soldering. However parts with low quality features are frequently used as well, e.g. textile-Bakelite panel used for high voltage circuits or neglecting the electromagnetic disturbances.

An outcome of the Start-up review can be the refusal of the manufacture of the product, however this happens very rarely. But frequently happens when the review calls attention to product development aspects, which can be remedied by the design engineers already before launching the mass production.

It is advisable to perform a smaller scale Start-up review-t even if the product is not manufactured under mass production circumstances, since even in case of low piecemeal can *typical failures* occur by the prevention of which refuse can be prevented and the environment can be protected.

10.2 Experiences collected during pilot production

After a successful Start-up Review the management can decide for the pilot production having the expressed objective to verify the aspects formulated before and to collect experiences related to the manufacture of the product.

During pilot production new problems can arise having been covered during the preliminary Start-up Review also in case of manufacturers with highest manufacturing competences. The design team has to be announced without delay about the detected design failures. Controlled form of this announcement is the Engineering Change Request – ECR. Mostly design failures of certain parts appear, but problems concerning the process can arise as well. If design failures of the base PCB occur then this composes a more problematic case, since the redesign of this part is a greater task and concerns more documentations. If several thousands of empty PCB boards have already been produced, then the management can decide for the production of a product with smaller failure including its manual repair (rework).

10.3 Continuous Improvement

Even after the pilot production during normal manufacture of the product under mass production circumstances the product can often be altered either by the design engineers (ECO) or on the basis of proposals made by those taking part in the production (ECR).

A regular task of quality engineers is the review of quality indicators and accordingly the development of a continuous action plan continuously varying on the bases of the current tasks. Based on the failures occurring in the factory and at the end users (*field reject*) and of the refuse having been built up, a priority list is determined, on the basis of which action plans are prepared for the heads of the different production departments. Thus the quality indicators of the product can be enhanced continuously.

Economical aspects have often to be taken into account as well and an unnecessary process step or part can be left out from the product if this makes the indicators better.

CI activity has a high significance for factory managements and it can become an indicator of competitiveness of a prosperous company. Therefore engineers or other employees working in the production and giving really successful development proposals can be rewarded even with financial benefits of material gifts. However for leading engineers of different departments it is an expressed prescription to perform CI activity above a limit measured in a certain financial amount for a given period.

10.4 Lean

Lean Manufacturing is a production philosophy. Its objective is to ensure the satisfaction of customer expectations on a highest possible level with making the operation of the factory continuously more perfect: eliminates losses found in the acquisition chain, eliminates failures and ensures the continuous flow of raw materials. (20)

Objective of Lean

Objective of Lean Manufacturing is to produce the highest quality product within the *shortest possible time period* for *minimum costs* (a dream of every manufacturer).

Why to introduce Lean production?

This manufacturing system requires less manpower, less production space, less capital investment, material and time than the traditional mass production. James P. Womack and Daniel T. Jones conducted an international research to determine the sources of competitive advantage in the field of car manufacturing. Results of this research are summarized in their book "The Machine That Changed The World" having been become a bestseller meanwhile. These result were shocking, since they pointed out, that the *productivity* of *Toyota* company is about twice as high and its *quality* is 100 times higher than those of western car manufacturers of that time.

The term Lean denotes in fact the best practices applied at the company *Toyota* and thus this term can be used as a synonym of the ***T**oyota **P**roduction **S**ystem (**TPS**)* or with a newer approach as a synonym of ***T**hinking **P**eople **S**ystem*. TPS was introduced in the 1950-eth years on the basis of the work of Taylor, Gilbreth, Smiles, Miles and Gantt and of the results achieved at Ford until that time.

Lean organization is able to react on customers' requirements quickly and flexibly using its resources in a most possible effective way at the same time. In case of Lean the term *buyer* covers not only the buyers and future customer of the company (they are the *external buyers*), but the co-workers of departments, divisions inside the company (they are the *internal buyers*), who further deals with the products, services produced by another departments, divisions before these products/services reach their external buyers.

Lean model

Means of Lean production are composed by proven elements like *("Value Stream Analysis"*), the basis of which the values acknowledged by the customer can be determined and by uncovering trade processes determining *how the company meets customer needs*. Uncovering a process expands from the acceptance of raw materials to the analysis of certain manufacturing procedures containing ***V**alue **A**dded – **VA*** as well as ***N**ot **V**alue **A**dded – **NVA*** procedures. It is important to have an *overview on* *the procedures as a whole* and to optimize the whole instead of trying repairing part procedures meanwhile becoming lost in the details.

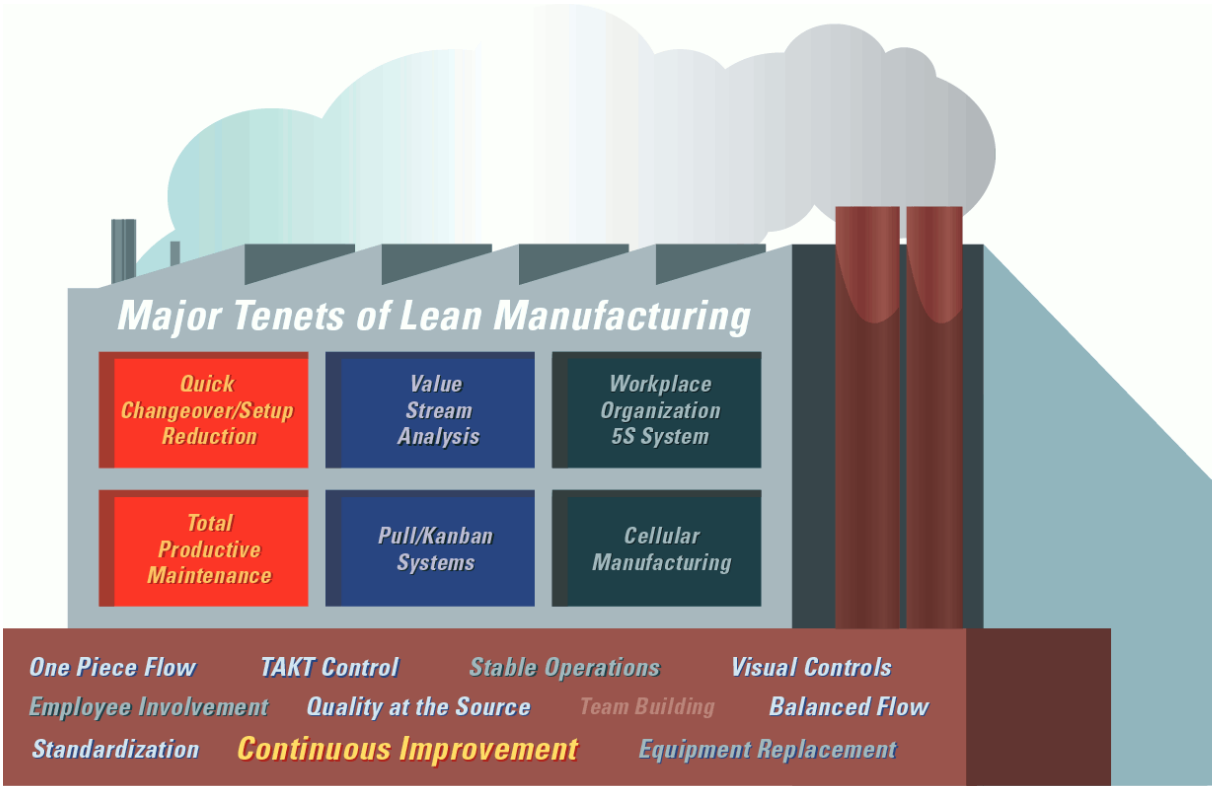


Fig. 10.1: The Lean model

Basic principles of Lean

Two main principles of Lean philosophy:

- *respect of humans* and
- *removal of losses, i.e. of steps not adding value* from every process, activities.

10.5 Lean Six Sigma methodology

The *Lean Six Sigma* methodology combines Lean principles with *Six Sigma* methods and means. The former achieves the increase of the effectiveness of work processes by *eliminating losses and wastes not adding value* for the customer, while the later aims the enhancement and development of the *quality of company procedures and outputs of procedures* apart from surveying the operation and continuous measurement of the effectiveness. (21) Thus similarly to Lean the Six Sigma *strives to a continuous development* as well, however it prefers measurement and data based analysis supported by an effective *statistical methodology*.

The Lean Six Sigma applies the so called *DMAIC methodology* from Six Sigma. This name originates from the denominations of the five stages of a process development project, i.e. the acronym DMAIC is composed from the initials of the names of the certain stages:

- ***D****efine*: Definition of the task, collecting the expectations, dealing with customer expectations with priority;
- ***M****easure*: Definition and precise measurement of the process and its indicators;
- ***A****nalyze*: Analysis of the data and activities;
- ***I****mprove*: Definition of development actions;
- ***C****ontrol*: Re-measurement and control of the new process.

11. **Environmental considerations, lead-free soldering, RoHS**

11.1 Environmental considerations

When making our production processes more perfect by applying either Lean or Six Sigma methods, *environmental considerations* have to be of highest priority. Refuse and process materials arising as a result of the high proportion of environment polluting substances applied in the electronic industry represent a serious burden on our environment.

Measurement and analysis of refused products arising during production processes compose the task of a separate expert and the remedy of process failures regularly resulting refuse is of primary importance as well. These processes have often to be analyzed in close cooperation with quality insurance engineers, since production failures can result in unrepairable refused products in some cases.

Expert disposal of refused products from the electronic industry is the task of a separate division or a separate company.

11.2 Lead-free soldering, RoHS

Objectives of the law ***W****aste* ***E****lectrical and* ***E****lectronic* ***E****quipment* – ***WEEE*** on recycling (22):

- Reduction of waste originating from electric and electronic devices,
- Reuse/recycling of waste of this art,
- Reduction of harmful impacts of cheap processes on the environment,
- Reduction of environment pollution caused by rejected devices.

The directive ***R****estriction* ***o****f Certain* ***H****azardous* ***S****ubstances* – ***RoHS)*** restricts not only the use of lead but that of other materials like e.g. mercury, cadmium, chrome derivatives and fire-proof materials containing brome as well. The RoHS [2002/95/EC] directive on replacement of lead is compulsory since July 1st of 2006 inside the European Union.

Objectives of the directive:

- Restricts the amount of dangerous materials which can be used in electric and electronic devices,
- Restricts the formation of electronic waste arisen by rejecting devices.

Exceptions:

High temperature soldering materials (HMP), since these substances have no cheap lead-free alternatives.

Certain medical electronic and automotive standards compose exceptions from the obligatory use of lead-free soldering.

Outside of the *European Union* different directives are valid, e.g. *USA* is conservative, *the EC directive is partly refused there* (e.g. NASA refuses it), *Japan* is environment conscious *the directive is used there, China uses it for a proportion of 50%* (in case of EU export yes, else not).

The companies Intel and AMD uses exclusively lead-free technology.

Problems to be solved in case of lead-free soldering:

- Quality reduction because of the replacement of leaded soldering material
- More rapid wear of the product, more frequent replacement cycles
- More dangerous waste arise.

Requirements against lead-free soldering materials

- Precise melting point: $217°C \leq T \leq 227°C$
- High conductivity: $0{,}017\ \Omega * mm^2/m \leq \varrho \leq 0{,}020\ \Omega * mm^{2/}m$
- Good mechanical features
- Long lifetime
- Good dampening on surfaces of regular metals (Cu, Zn, Ag, Au, and alloys of these).
- High quality attachments in case of regular soldering technologies

Lead-free alloys applied

- Tin-copper alloys
  Typical: 99,3% Sn, 0,7% Cu
  Melting point: 227°C
- Tin-silver alloys
  Typical: 96,5% Sn, 3,5% Ag
  Melting point: 221°C
- Tin-silver-copper alloys
  Typical: 95,5% Sn, 3,8 % Ag, 0,7% Cu
  Melting point: 217°C

Since *the technological window is narrower* in case of lead-free soldering materials, the heat profile can be set more difficult, however environmental prescriptions can be met, i.e. the environment is polluted to a less extent in case of the same production amount and refuse proportion.

Fig. 11.1: RoHS conformity signs

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