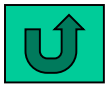
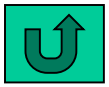
INTRODUCTION TO HIGH-SPEED PCB DESIGN

Signal Integrity and Electromagnetic Interference Considerations



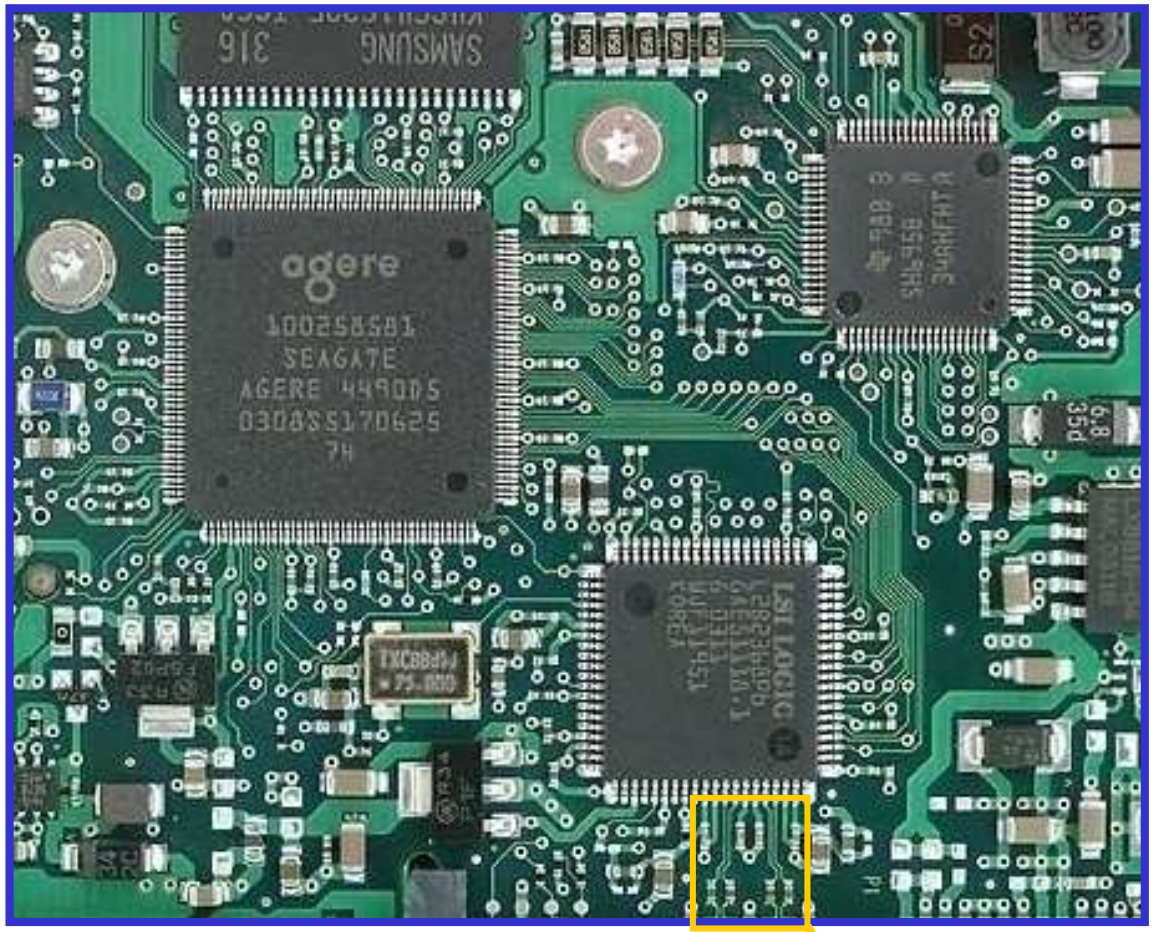
PART 1 – Introduction to Multi-Layers Printed Circuit Board Structures

Characteristics of Printed Circuit Board (PCB) Assembly

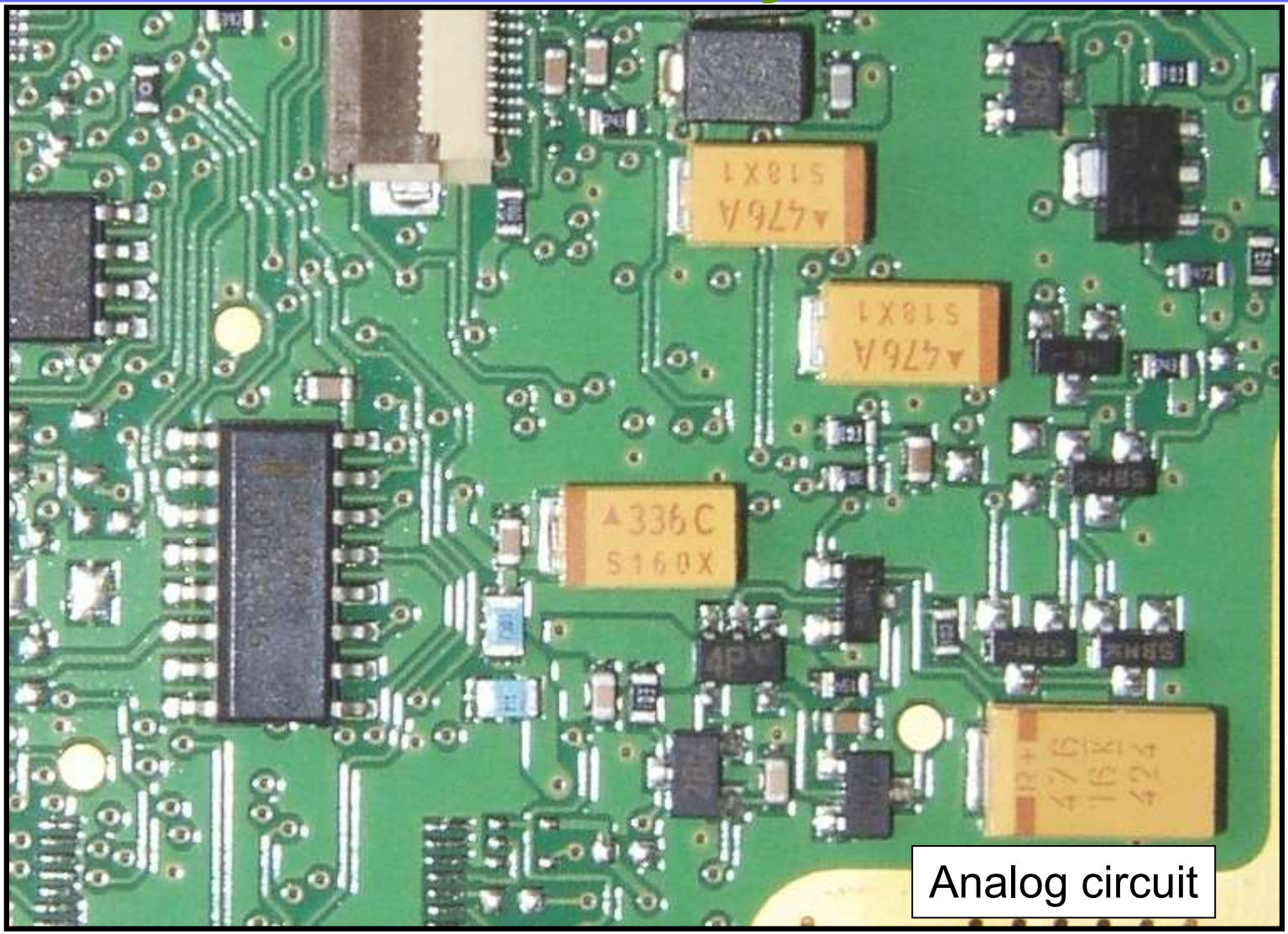


An Example of PCB Assembly

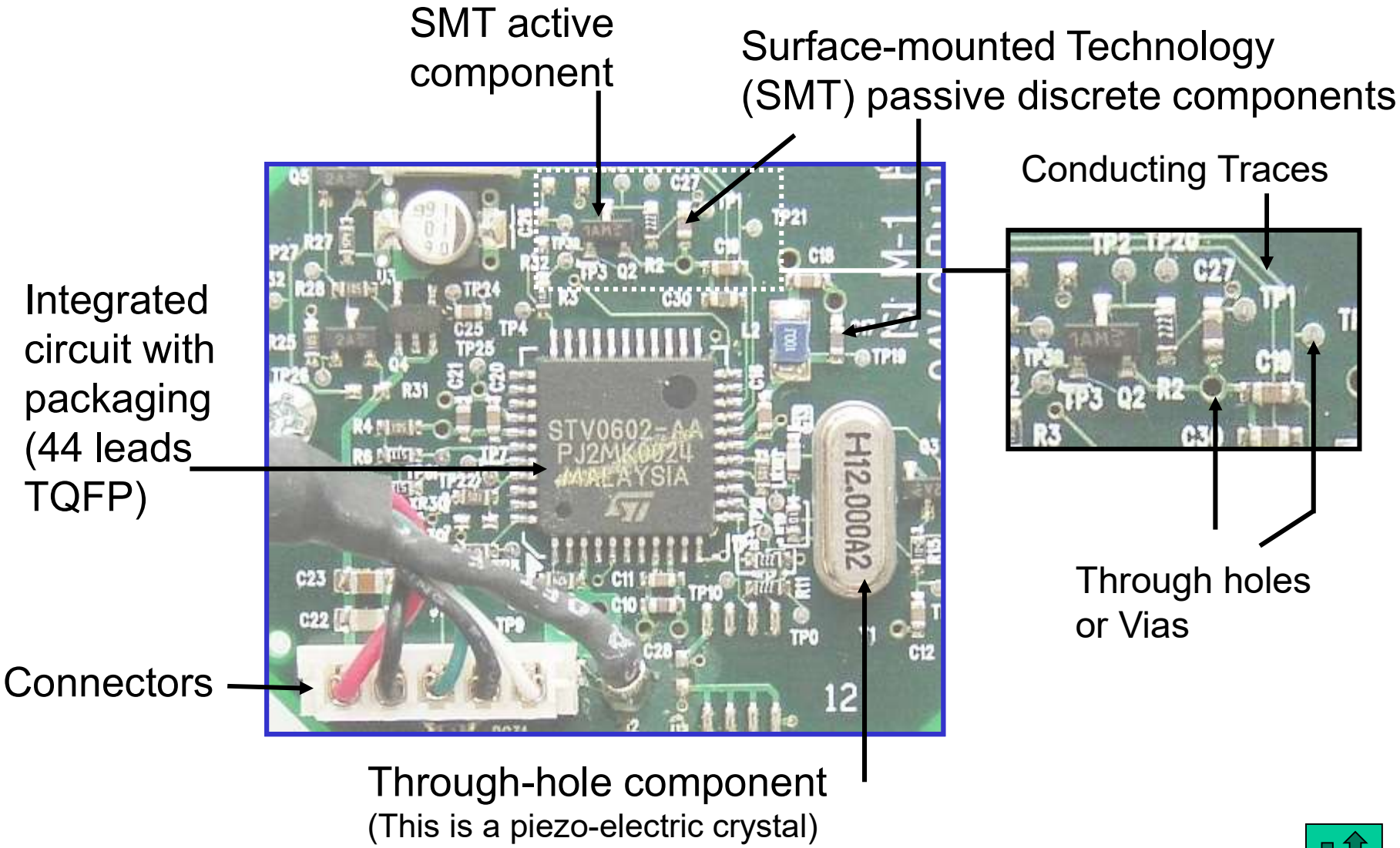
- A snapshot of a modern PCB assembly (Digital circuit).



Close-up View of Another PCB Assembly

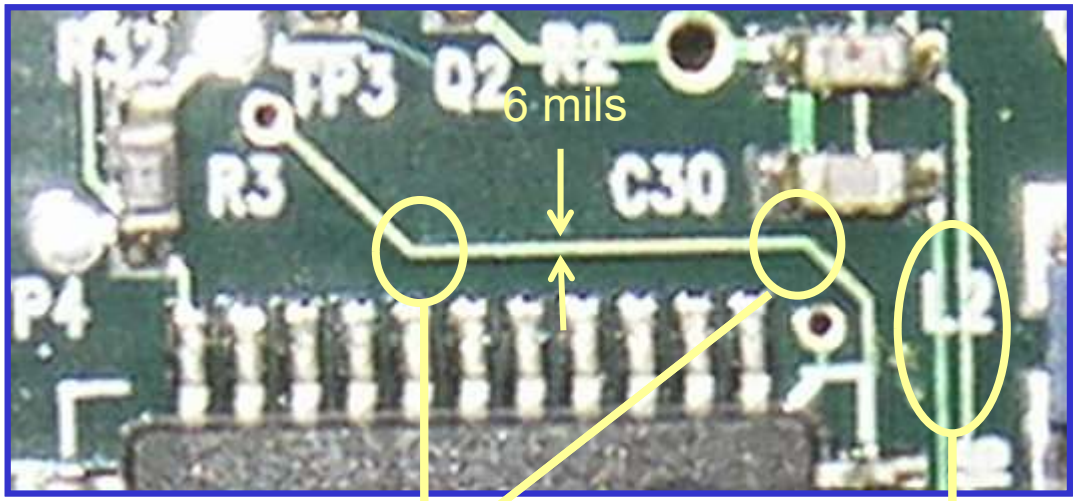


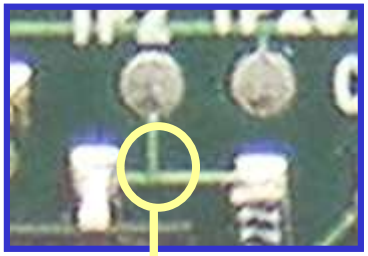
Structures on PCB Assembly (1)



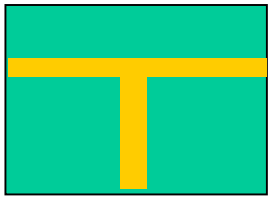
Structures on PCB Assembly (2)

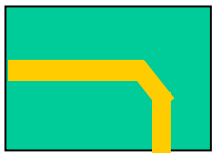
- If we were to examine the conducting traces closely:





Junction





Bends

Close proximity traces
(coupled traces)

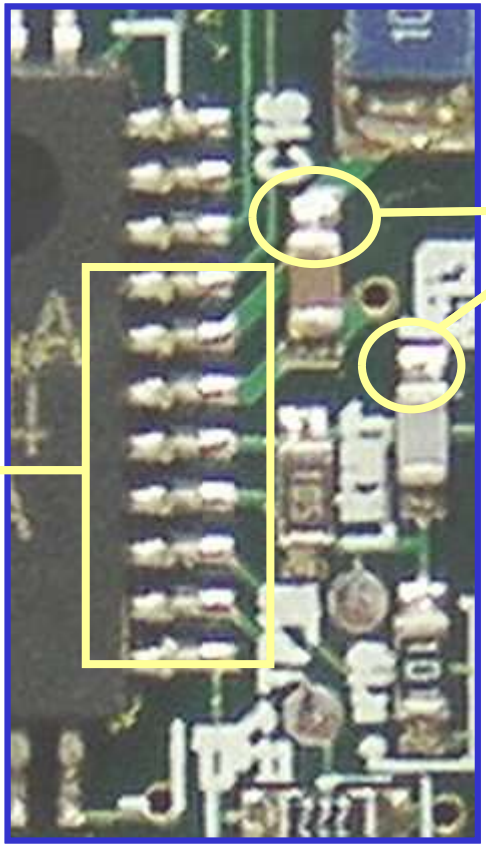
- The conducting traces are typically very fine, with trace width of 3 - 8 mils (≅ 0.08 - 0.21mm).

Structures on PCB Assembly (3)

- If we were to examine the components closely:

1. Close proximity of package pins, < 10 mils for some cases, for example in TSSOP and BGA packages.

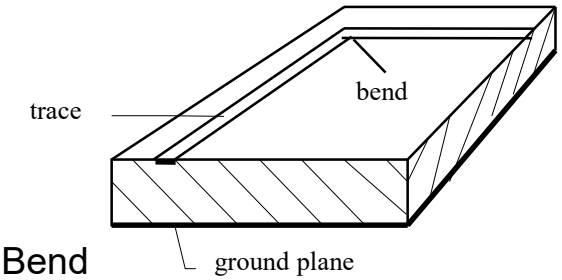
2. Transition between trace and pins.



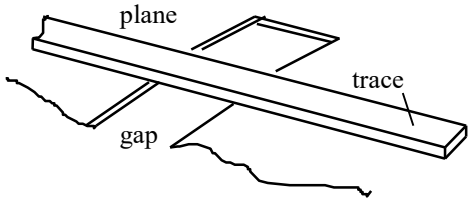
Component pads

Structures on PCB Assembly (4)

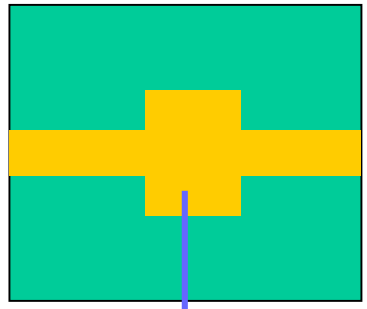
- There are many more structures to be found:



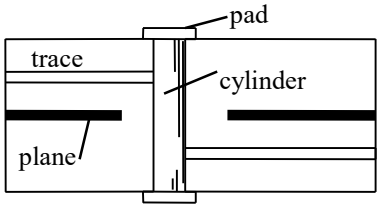
Bend



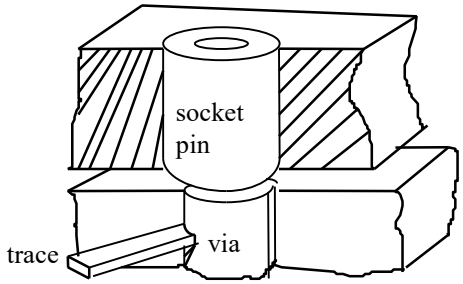
Ground plane gap



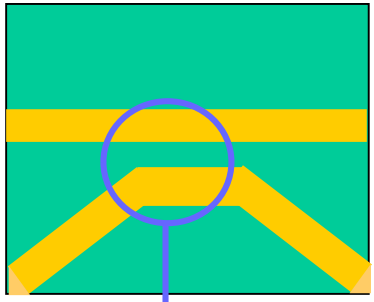
Pad or Stub



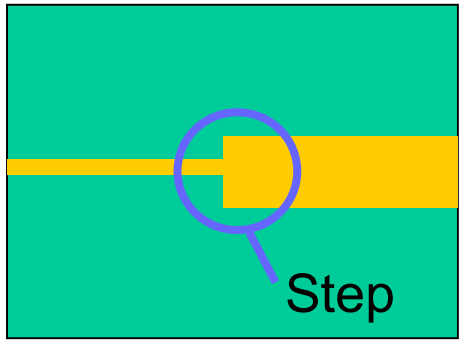
Via or Through -hole



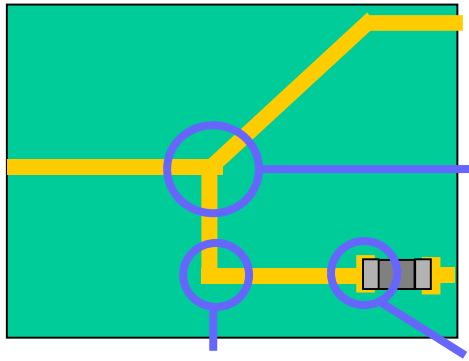
Socket-trace interconnection



Coupled lines



Step



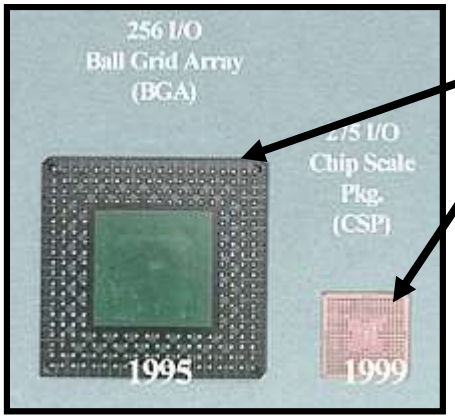
Junction

Line to Component Interface

Bend

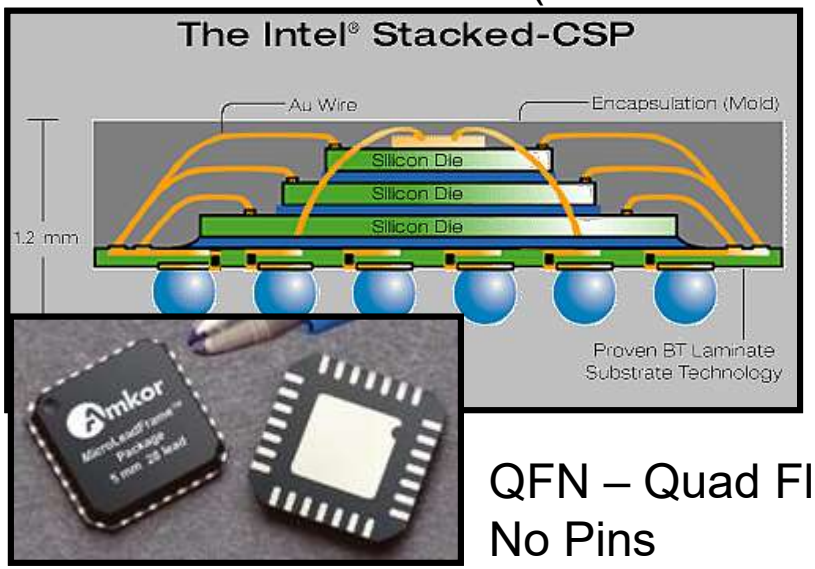
Structures on PCB Assembly (5)

- Common component packages:



BGA – Ball Grid Array
CSP – Chip Scale Packaging

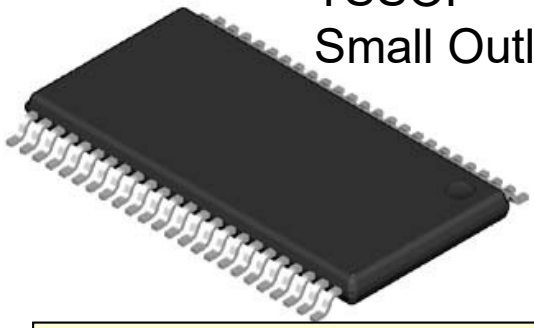
Example of cross-section View of CSP package (also known as flip-chip)



QFN – Quad Flat No Pins

TQFP – Thin Quad Flat Pack

TSSOP – Tiny-Scale Small Outline Package



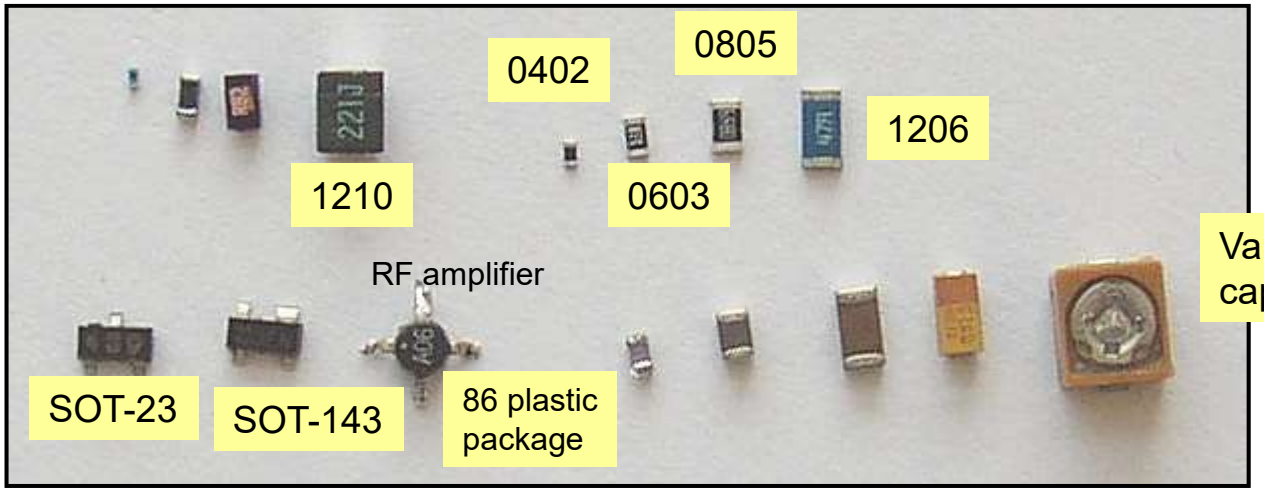
Visit JEDEC Solid State Technology Association (formerly known as Joint Electron Device Engineering Council) homepage for more Information: www.jedec.org

Structures on PCB Assembly (6)

- Common component packages:

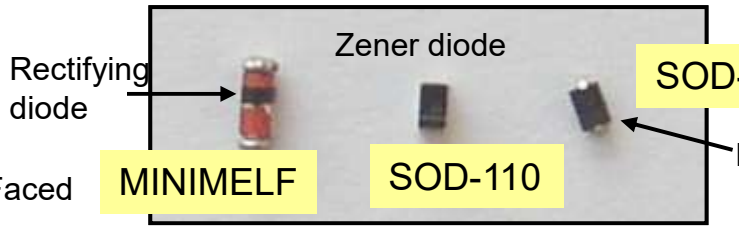
Inductors

Thick/thin film Resistors



Transistors and MMIC (monolithic microwave integrated circuit)

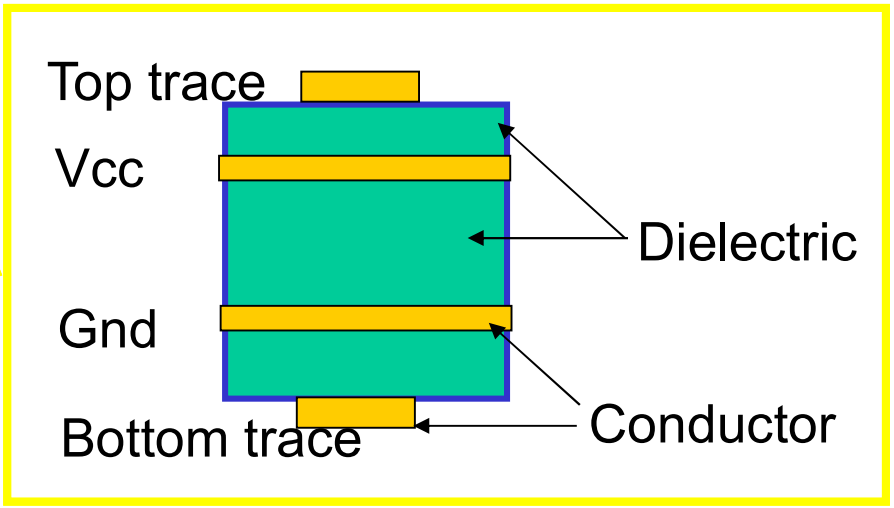
Various types of capacitors



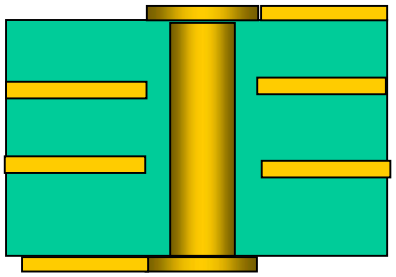
Various types of diodes

Structures on PCB Assembly (7)

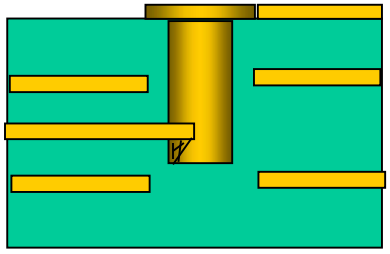
- Moreover if we examine the layers within the PCB:



- 6 - 12 layers board being the norm nowadays for compact devices (here layers refer to the number of conducting layers).



Cross section of a normal Via



Cross section of a buried Via

Structures on PCB Assembly (8)

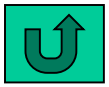
- Photomicrograph of a 4 layer PCB cross section at 60X magnification.

Structures on PCB Assembly (9)

- Examples of PCB material:

Material Tradename	Composition	Dielectric constant (ε_r) @ 1.0GHz	Dielectric constant (ε_r) @ 10.0GHz	Loss tangent @ 1.0GHz	Loss tangent @ 10.0GHz	Glass Transition temperature T_g (^oC)
FR4	Epoxy resin/glass fiber	4.2-4.6	4.2-4.6	0.02	0.04	140 (180 for high T_g variant)
GETEK	Epoxy resin/glass	3.6-4.1		0.0130		180
N7000-2 (Park/Nelco)	Polyimide	3.8	3.5	0.015	0.015	260
RO4000 (Rogers)	Hydrocarbon/Ceramic/glass	3.38-3.48	3.38-3.48	0.002-0.003	0.0027-0.0037	>280
Diclad 870 (Arlon)	Glass/PTFE	2.33	2.33	0.0009	0.0013	NA

Note: the above values are only rough approximation and dependent on processes.



Example of Modern PCB Manufacturing Rules

- An example of a typical PCB manufacturer 'Standard' capability:

Feature	Max	Min	Unit
Board thickness	200	8	mils about 0.2 to 5mm
Panel dimension	21x24	0.2x0.4	inches
Internal trace width (0.5oz copper)		4	mils
External trace width (0.5oz copper)		4 0.1mm	mils
Copper thickness	4	0.25	oz/feet^2
Through drill hole diameter		8	Mils
Micro-via drilling diameter		4	mils
Internal annular ring (circular copper pad to drill difference)		10	mils
External annular ring		1	mils
Trace to trace spacing (internal & external)		4	mils
Surface finishing: Hot-air leveling solder thickness Immersion gold thickness Immersion silver thickness	 5 0.1 0.2	 1 0.05 0.2	micron

Summary of the Characteristics of Modern Digital PCB (1)

Mechanical:

- Usually multi-layer by design.
- Good quality dielectric is used (tight electrical and mechanical specs).
- Very narrow conducting trace width.
- High density, components and traces are packed closely.
- High quality component packaging is used (small foot-print and form factor, robust construction, good isolation from external environment, good electrical connection from die to package pin).

Required for compact system

Electrical:

- Typically low voltage (1.8V or less), uses digital logic family with low logic swing voltage and large sink/source current ability.
- Rapid transition rate for logic signal, e.g. small rise/fall time of digital pulse waveforms (<1.0nsec).
- Differential signaling for improve

These factors enable high frequency or high data rate in pulses.

Summary of the Characteristics of Modern Digital PCB (2)

Other Attributes:

- Because of the density of conducting structures and components on a modern PCB assembly, electrical interference between components and circuits occurs easily if the system is not properly designed – Low isolation.
- Interference here is defined as the unintentional transfer of electrical energy between circuits due to interaction of electromagnetic (EM) fields in the system.
- Interference is aggravated by the presence of high-frequency (HF) and high-speed (HS) signals on the system.
- There is a subtle difference between high-frequency and high-speed signal, we will clarify this later.
- We will loosely use the term HS-PCB for high-speed/high frequency PCB. More precise definition will be given later at the end of this part.