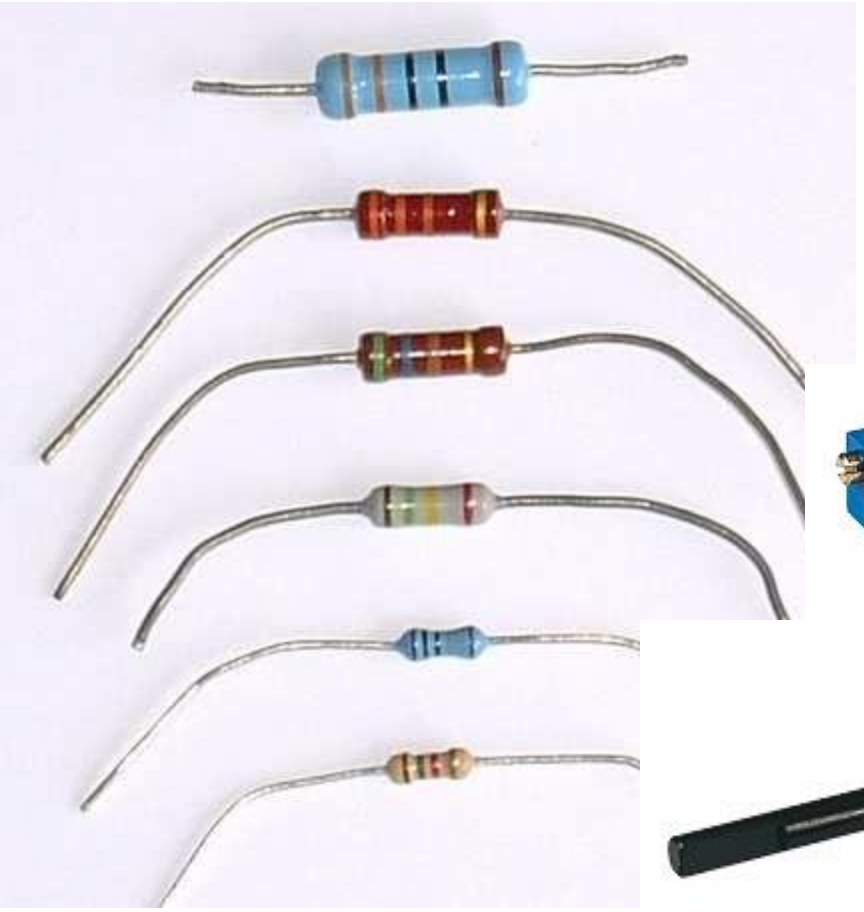
Introduction to Passive Electronic Components

- Resistors (R), Capacitors (C), Inductors (L)

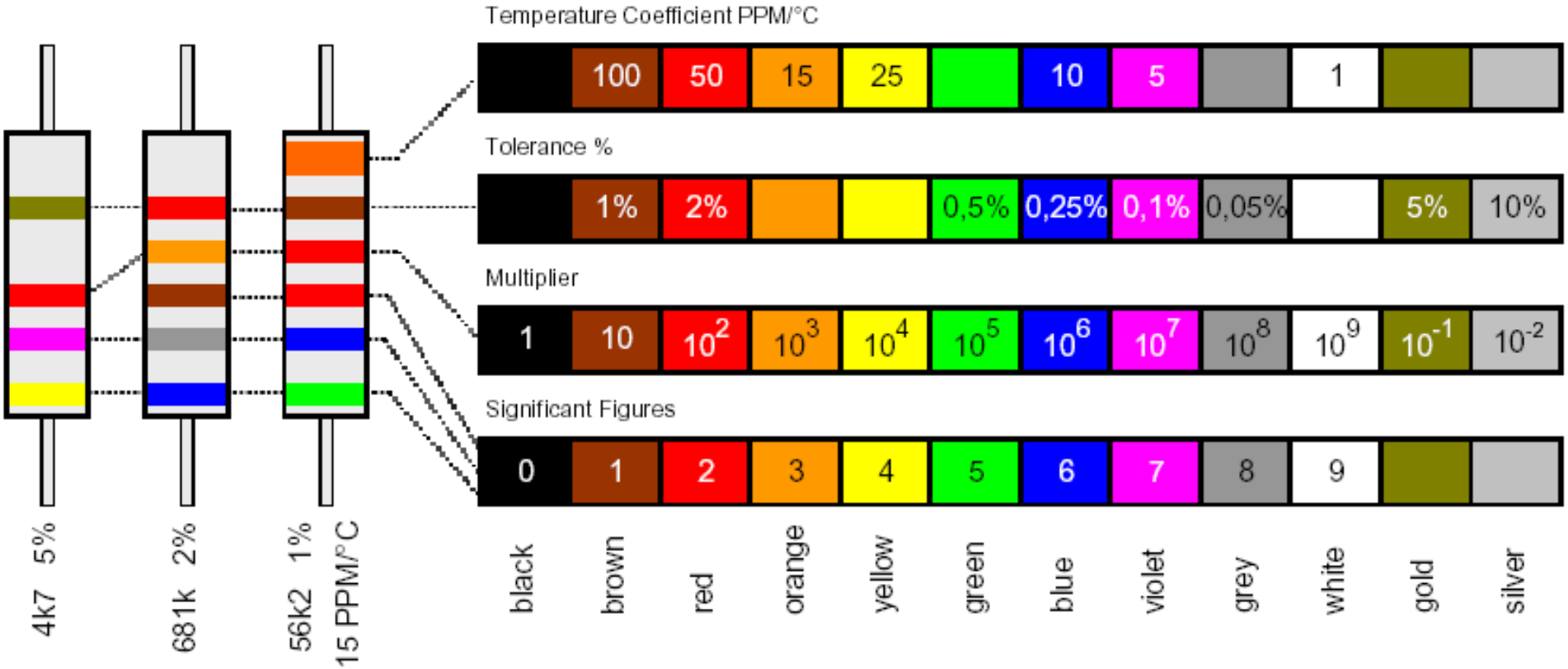
	Resistor	Capacitor	Inductor
Units	Ohm (Ω)	Farad (F)	Henry (H)
Typical Values	Fraction of ohms to tens of Mega-ohm	Few pico-Farad To thousands of micro-Farad	Few nano-Henry to tens of milli-Henry
Other Specifications	▪ Power (Watt) ▪ Tolerance (%) ▪ Package ▪ Voltage ▪ Material/Type	▪ Voltage (Volt) ▪ Tolerance (%) ▪ Package ▪ Temperature ▪ Material/Type	▪ Current (A) ▪ Tolerance (%) ▪ Package ▪ Material/Type

Resistors

- Through-hole, surface-mount
- Film, wire-wound; fixed or variable



Resistor Value Code (usually for resistors of 2W or less)



- The 4 band code is most common with 5% and 10% tolerance, and the 5 band code is used with 2% and better.

Standard Resistor Values

Electronic Industries Association (EIA) Standard E12, or E24, and more:

Normally Standard E24 specifies resistors based on 5% tolerance, and Standard E12 specifies resistors based on 10% tolerance

E12	1.0	1.2	1.5	1.8	2.2	2.7	3.3	3.9	4.7	5.6	6.8	8.2

12 Values per Decade

E24	1.0	1.1	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.7	3.0
	3.3	3.6	3.9	4.3	4.7	5.1	5.6	6.2	6.8	7.5	8.2	9.1

24 Values per Decade

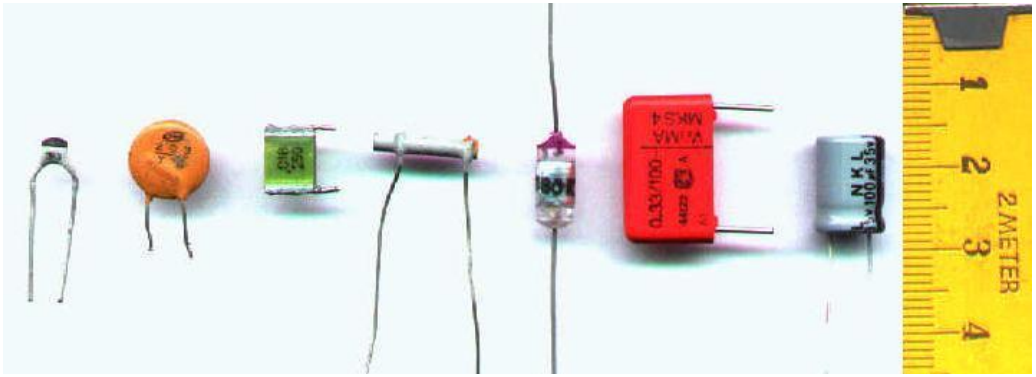
- Need to use parallel or series resistors for non-standard values

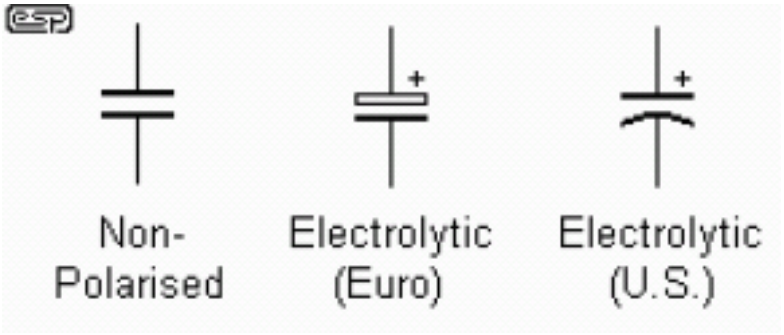
Resistor Materials

- **Carbon Composition:** Low to medium power. Comparatively poor tolerance and stability. Inexpensive.
- **Carbon Film:** Low power. Reasonable tolerance and stability. Inexpensive.
- **Metal Film:** Low to medium power. Very good tolerance and stability. – Normally higher quality than carbon resistors.
- **Wire-wound:** High to very high power. Acceptable to very good tolerance, good stability. Expensive. May be inductive → for low freq appl.

Capacitors

- Through-hole, surface-mount
- Film, ceramic; electrolytic, tantalum (polarized)
- Fixed or variable

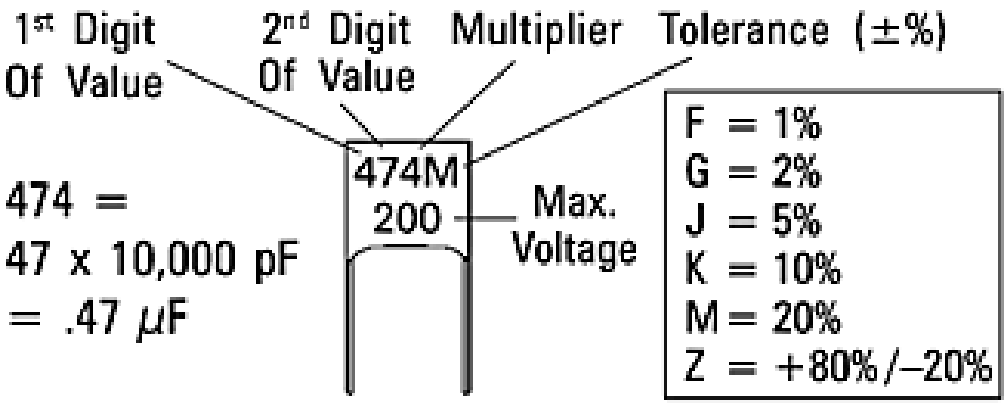




Capacitor Value Code

CAPACITOR GUIDE

The Result of Capacitor Code is Given in pF



On some capacitors the value is shown as a straight number (4.7pF). On others the decimal point is replaced with the first letter of the prefix (4p7 = 4.7pF).

Prefix	Abbr.	Multiplier
pico	p	10^{-12}
nano	n	10^{-9}
micro	μ (R)	10^{-6}

1000 pico = 1 nano
1 nano = .001 micro
1000 nano = 1 micro

EXAMPLES:

223J = 22 x 10^3pF = 22nF = 0.022μF 5%

151K = 15 x 10^1pF = 150pF 10%

4R7 = 4.7 μF 4N7 = 4.7 nF 4P7 = 4.7 pF

Standard Capacitor Values (Examples)

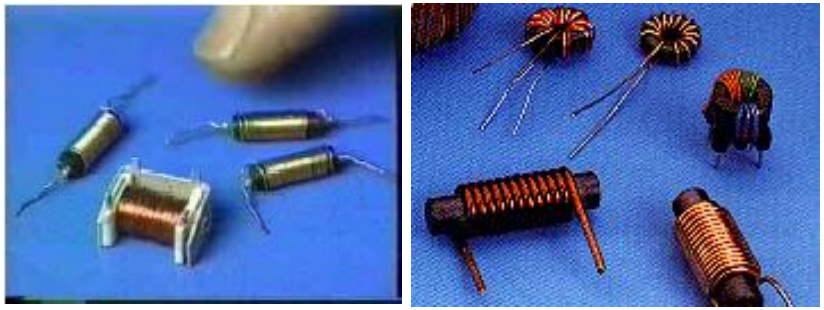
Standard Capacitor Values (±10%)						
10pF	100pF	1000pF	.010μF	.10μF	1.0μF	10μF
12pF	120pF	1200pF	.012μF	.12μF	1.2μF	
15pF	150pF	1500pF	.015μF	.15μF	1.5μF	
18pF	180pF	1800pF	.018μF	.18μF	1.8μF	
22pF	220pF	2200pF	.022μF	.22μF	2.2μF	22μF
27pF	270pF	2700pF	.027μF	.27μF	2.7μF	
33pF	330pF	3300pF	.033μF	.33μF	3.3μF	33μF
39pF	390pF	3900pF	.039μF	.39μF	3.9μF	
47pF	470pF	4700pF	.047μF	.47μF	4.7μF	47uF
56pF	560pF	5600pF	.056μF	.56μF	5.6μF	
68pF	680pF	6800pF	.068μF	.68μF	6.8μF	
82pF	820pF	8200pF	.082μF	.82μF	8.2μF	

Capacitor Materials

- **Silvered Mica:** Probably the most linear low value capacitor, commonly used in RF applications
- **Polystyrene:** Very good electrical properties. Very linear and stable, but physically large.
- **Ceramic:** Excellent high frequency performance, but not stable with temperature.
- **Monolithic Ceramic:** Designed as bypass capacitors, these are physically small.
- **Polyester:** One of the most popular types. Stable and reliable, generally low voltage (up to 100V).
- **Mylar:** Another popular cap, suitable for high frequency applications, as well as bypass for power amps and op-amps.
- **Polypropylene:** Available in relatively large values.
- **PET**: (Polyethylene Terephthalate) - Used in many different types of plastic film caps, often replacing polyester or mylar
- **Electrolytic:** Using plates of aluminium and an electrolyte to provide conductivity, these caps use an extremely thin layer of aluminium oxide (created by anodising) as the dielectric. This gives very high capacitance per unit volume, and are used as coupling capacitors, power filters etc. – low frequency applications.
- **Tantalum:** Very high capacitance per unit volume, better quality than electrolytic. More expensive than electrolytic caps.
- **Oil/ Paper:** These are mainly for power applications as motor start and power factor correction capacitors. They are extremely rugged, and are self-healing. They do not fail as a short circuit - any arc is extinguished by the oil, and the cap can continue to function normally after the excess voltage is removed.

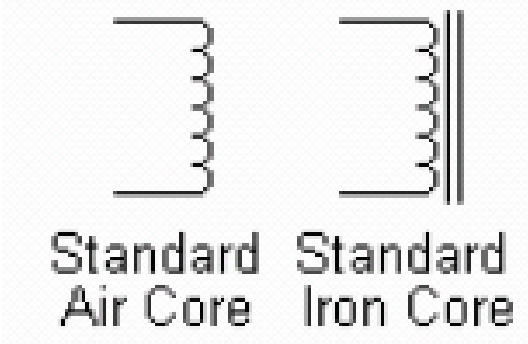
Inductor Examples

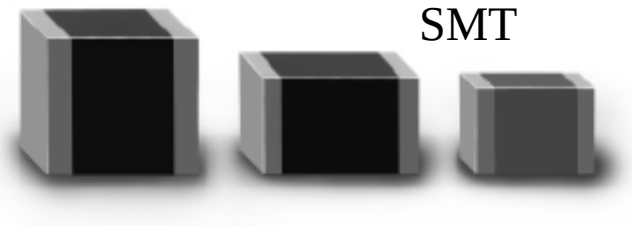
- Through-hole, surface-mount
- Air-core, iron-core
- Fixed, variable

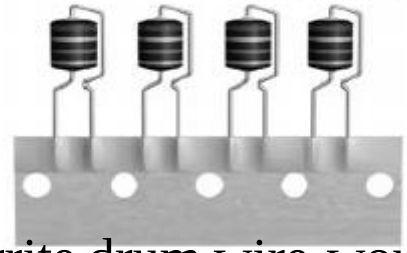


Wire-wound Inductors

http://www.wordiq.com/definition/Inductor







Ferrite drum wire-wound

http://www.epcos.com/inf/30/db/emc_00/01810183.pdf

For More:
http://www.cambion.co.uk/Main/catalogue_inductive.htm

Inductor Value Code

INDUCTOR COLOR GUIDE

Result Is In µH

4-BAND-CODE  270µH ± 5%

COLOR	1st BAND	2nd BAND	MULTIPLIER	TOLERANCE
BLACK	0	0	1	± 20%
BROWN	1	1	10	Military ± 1%
RED	2	2	100	Military ± 2%
ORANGE	3	3	1,000	Military ± 3%
YELLOW	4	4	10,000	Military ± 4%
GREEN	5	5		
BLUE	6	6		
VIOLET	7	7		
GREY	8	8		
WHITE	9	9		
NONE				Military ± 20%
GOLD			0.1 / Mil. Dec. Pt.	Both ± 5%
SILVER			0.01	Both ±10%

Military Identifier  6.8µH ± 10% MILITARY CODE

Electronix Express / RSR
http://www.elexp.com

1-800-972-2225
In NJ 732-381-8020

http://www.elexp.com/t_induct.htm

PCB Design Software

Electronic Design Automation (EDA)

Features:

- Schematic editing
- Circuit simulation, FPGA simulation/synthesis
- Design rule check
- PCB layout editing
- Auto-placement
- Auto-router
- PCB design rule check
- Documentation generation
- Gerber file export
- …

PCB Design Software

- OrCAD (Capture, PSpice, PCB, SPECCTRA) from Cadence.
  Lite version is free.
- Allegro by Cadence
- Altium Designer
- CircuitMaker from Altium, free version
- Protel, PCAD, PADS, etc. in the old days
- Freeware / Open source / Web based

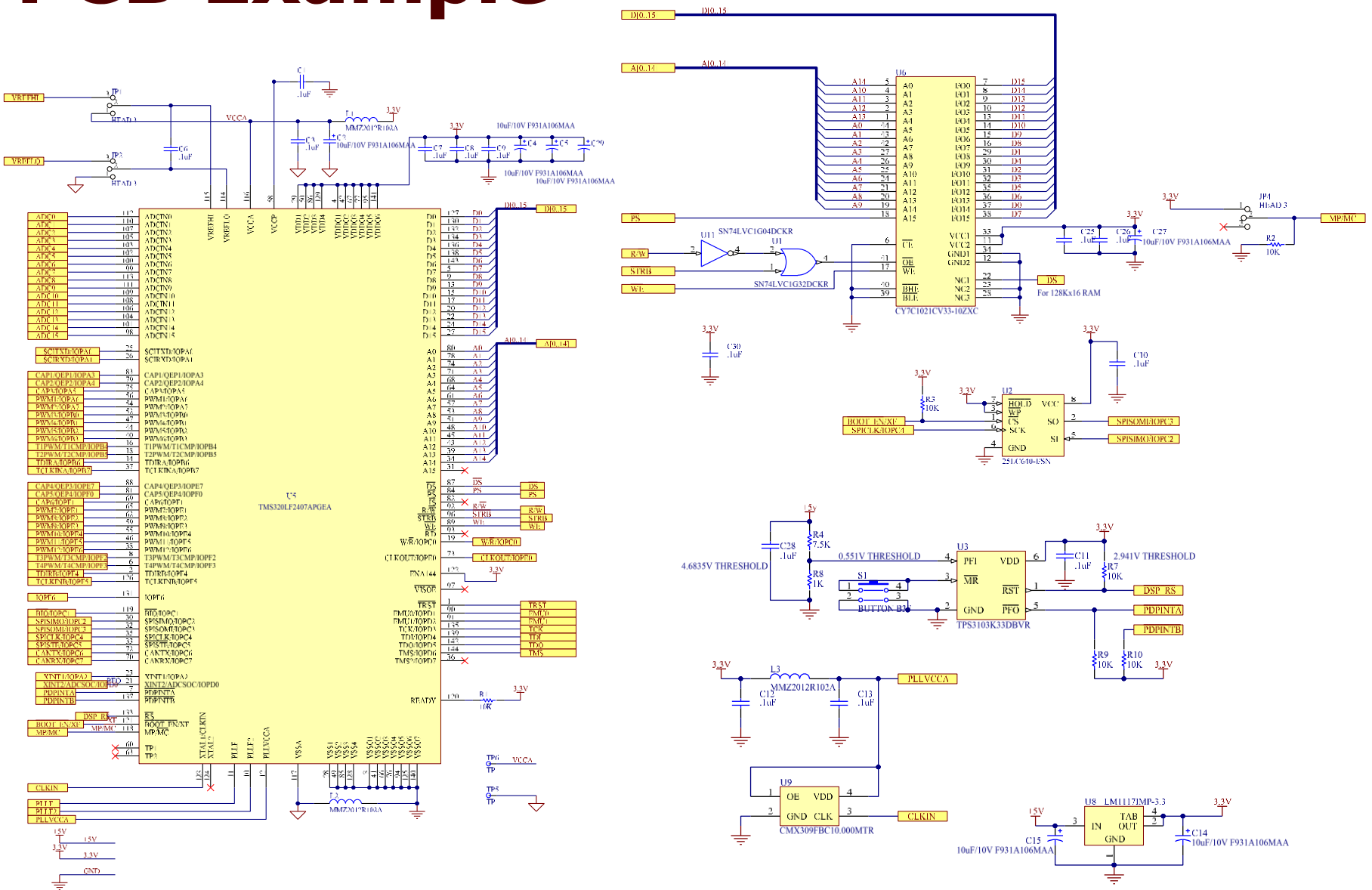
PCB Design Workflow

- Circuit schematic design
- Design check / Simulation / Review
- Netlist
- Part footprint design
- PCB outline / Mechanical design
- Place components (auto, manual)
- Route traces (auto, manual, priority)
- Design rule check (track width, clearance)
- Gerber output

PCB Test

- Soldering (proper iron tip, lead-free solder, temperature, no overheat
- Shiny, volcano shape joint
- Electrical safety and isolation (trace spacing)
- Multimeter
- Oscilloscope

PCB Example



PCB Example

(Inverter Control Board (4-layer)