

Real Circuit Elements

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Overview

1 Resistors

2 Capacitors

3 Inductors

Resistors

Real Resistor

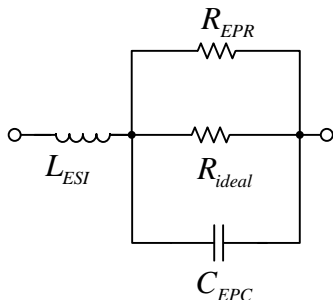


Figure: Real resistor model.

- Parasitic resistance, capacitance, and **inductance** elements
- Dependency on **temperature**, frequency, voltage, current, ...
- Limitation on **power**, voltage, current, temperature, ...

Resistor Types

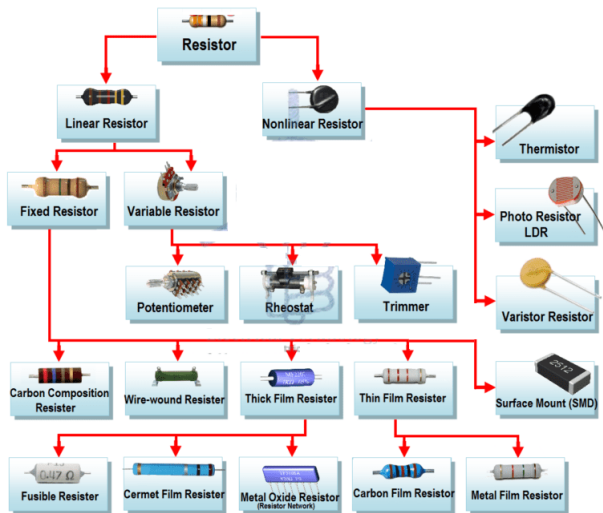


Figure: Classification of resistors in terms of application, construction, size,

Resistor Symbols

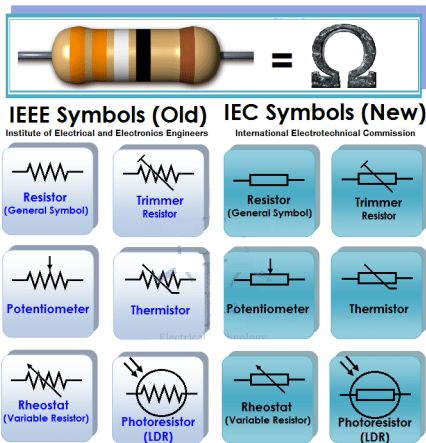


Figure: IEEE and IEC symbols of different types of resistors.

Carbon Composition Resistor

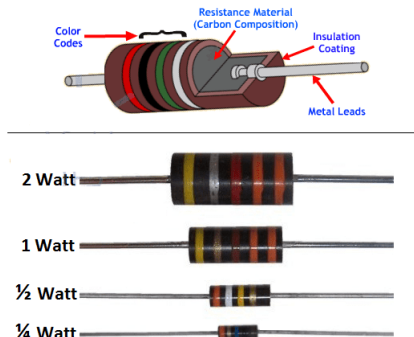


Figure: Carbon composition resistors.

- 1 Ω to 25 M Ω , 0.25, 0.5, 1, 2 W
- 2 Cheap, small size, reliable, available
- 3 High temperature coefficient, high noise, high tolerance
- 4 Used in simple circuits

Carbon composition resistors

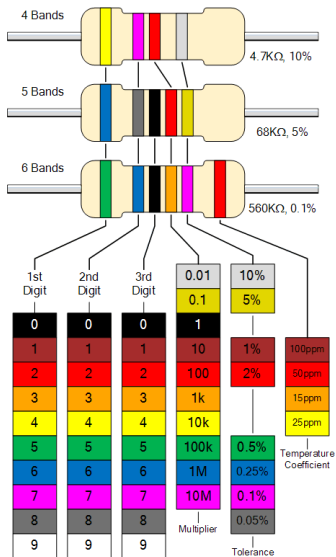


Figure: Resistor color code.

Carbon composition resistors

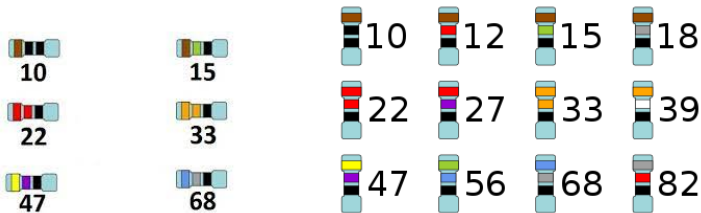


Figure: A decade of the *E12* values with 10% tolerance and *E6* values with 20% tolerance.

Wire Wound Resistors

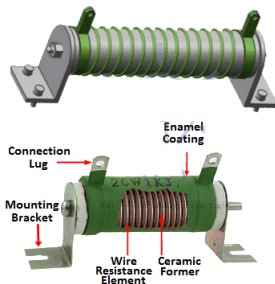


Figure: Wire wound resistors.

- 1 0.1Ω to $200 \text{ k}\Omega$, and $2 - 500 \text{ W}$
- 2 Reliable, available, low noise, high power, high temperature (350°C)
- 3 Expensive , low frequency
- 4 Used in measuring and/or high power devices

Carbon Thin Film Resistors

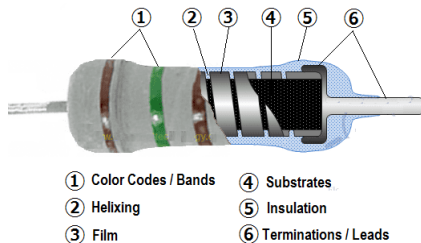


Figure: Carbon thin film resistors.

- ① 0.1Ω to $10 \text{ M}\Omega$, and $0.125, 0.25, 0.5, 1, 2 \text{ W}$
- ② Reliable, available, cheap, low noise
- ③ Low power
- ④ Used in typical electronic circuits

Metal Thin Film Resistors

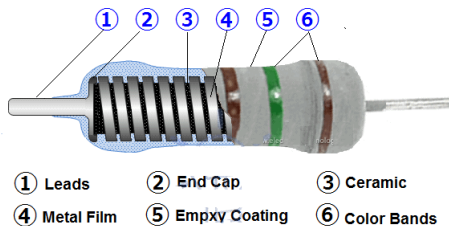


Figure: Metal thin film resistors.

- ① 0.1Ω to $10 \text{ M}\Omega$, and $0.25 - 4 \text{ W}$
- ② Reliable, available, low noise, cheap and low temperature coefficient ($\pm 2 \text{ ppm}/^\circ\text{C}$)
- ③ Low power
- ④ Used in low-noise electronic circuits

Metal Oxide Thick Film Resistors

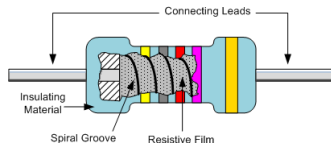


Figure: Metal oxide thick film resistors.

- 1 0.1Ω to $10 \text{ M}\Omega$, and $0.25 - 4 \text{ W}$
- 2 Reliable, available, low noise, high temperature, high voltage
- 3 High temperature coefficient
- 4 Used in high endurance circuits

Cermet Oxide Thick Film Resistors

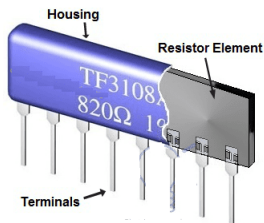


Figure: Cermet oxide thick film resistors (network resistor).

- 1 $10\ \Omega$ to $100\ \text{k}\Omega$, and $0.25 - 4\ \text{W}$
- 2 Reliable, high temperature, cheap, compact
- 3 Low power
- 4 Used in compact circuits

Fusible Resistors

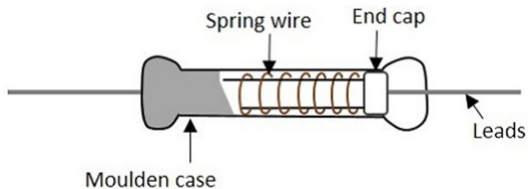


Figure: Fusible resistor.

- 1 Used in protection circuits

Potentiometers

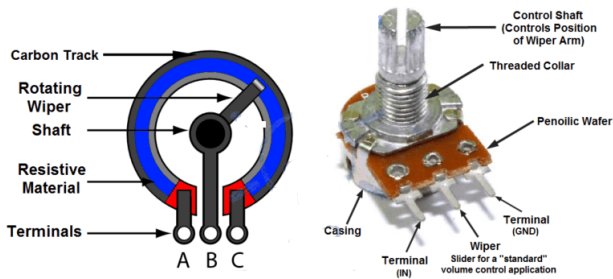


Figure: Potentiometer.

- 1 Used as voltage divider and/or volume control

Rheostats

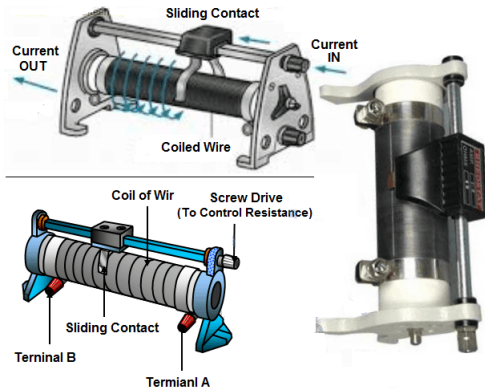


Figure: Rheostat.

- 1 Used as current limiter in power circuits

Trimmers

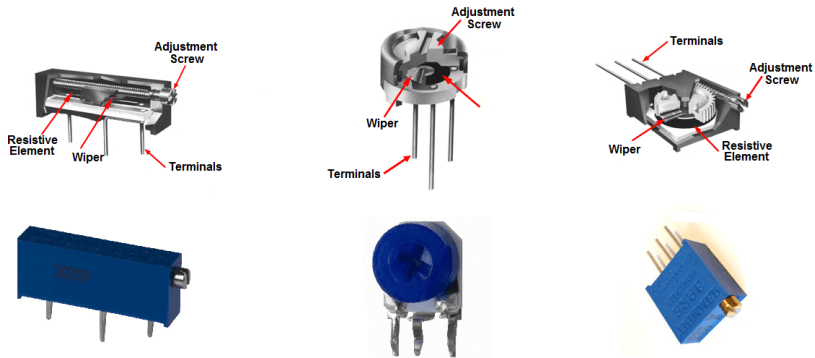


Figure: Trimmer.

- 1 Used for internal tuning of circuits

Thermistors

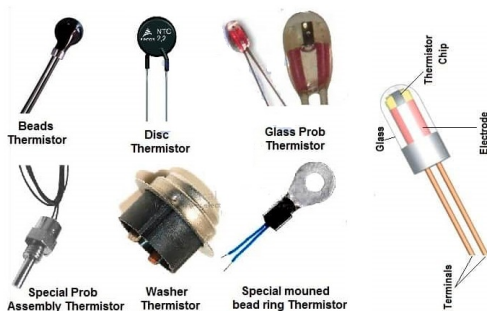


Figure: Thermistor.

- 1 Used as temperature sensor



Figure: Voltage dependent resistor (VDR) or varistor.

- 1 Used for high voltage surge protection

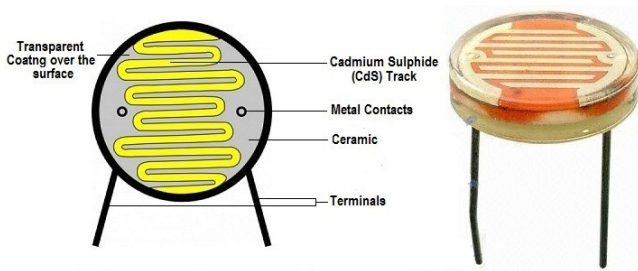


Figure: Light dependent resistor (LDR) or photo-resistor.

- 1 Used as light sensor

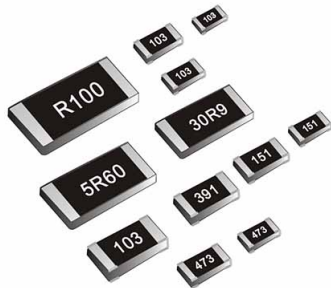


Figure: Surface-mounted device (SMD) resistor.

- ① Used in surface-mounted technology (SMT)

Package type	Size in inches	Size in mm	Power rating
0201	0.024" × 0.012"	0.6 mm × 0.3 mm	1/20W
0402	0.04" × 0.02"	1.0 mm × 0.5 mm	1/32W 1/16W
0603	0.063" × 0.031"	1.6 mm × 0.8 mm	1/16W
0805	0.08" × 0.05"	2.0 mm × 1.25 mm	1/10W
1206	0.126" × 0.063"	3.2 mm × 1.6 mm	1/8W
1210	0.12" × 0.10"	3.2 mm × 2.6 mm	1/4W
2020	0.20" × 0.20"	5.08 mm × 5.08 mm	1/2W
2512	0.25" × 0.12"	6.35 mm × 3.0 mm	1W

Figure: SMD package size.

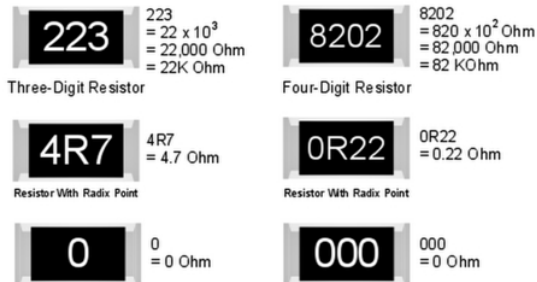


Figure: SMD codes.

Code	Ohms	Code	Ohms	Code	Ohms	Code	Ohms	Code	Ohms	Code	Ohms
01	100	17	147	33	215	49	316	65	464	81	681
02	102	18	150	34	221	50	324	66	475	82	698
03	105	19	154	35	226	51	332	67	487	83	715
04	107	20	158	36	232	52	340	68	499	84	732
05	110	21	162	37	237	53	348	69	511	85	750
06	113	22	165	38	243	54	357	70	523	86	768
07	115	23	169	39	249	55	365	71	536	87	787
08	118	24	174	40	255	56	374	72	549	88	806
09	121	25	178	41	261	57	383	73	562	89	825
10	124	26	182	42	267	58	392	74	576	90	845
11	127	27	187	43	274	59	402	75	590	91	866
12	130	28	191	44	280	60	412	76	604	92	887
13	133	29	196	45	287	61	422	77	619	93	909
14	137	30	200	46	294	62	432	78	634	94	931
15	140	31	205	47	301	63	442	79	649	95	953
16	143	32	210	48	309	64	453	80	665	96	976

Letter	Meaning
R or Y	Multiply the value (ohms) by 0.01
S or X	Multiply the value (ohms) by 0.1
A	Add no zeros to value
B	Add 1 zero to value x10
C	Add 2 zeros to value x100
D	Add 3 zeros to value x1000
E	Add 4 zeros to value x10,000
F	Add 5 zeros to value x100,000

01Y $100 \times 0,01 = 1 \Omega$

12X $130 \times 0,1 = 13\Omega$

01A $100 \times 1 = 100 \Omega$

18B $150 \times 10 = 1,5K$

Figure: SMD codes.

Capacitors

Real Capacitor

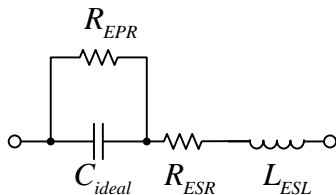


Figure: Real capacitor model.

- Parasitic **resistance**, capacitance, and inductance elements
- Dependency on temperature, **frequency**, voltage, current, ...
- Limitation on power, **voltage**, current, temperature, ...

Capacitor Symbols

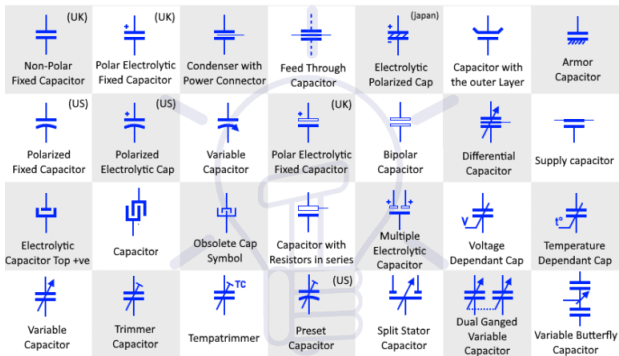


Figure: Symbols of different types of capacitors.

Ceramic Capacitors

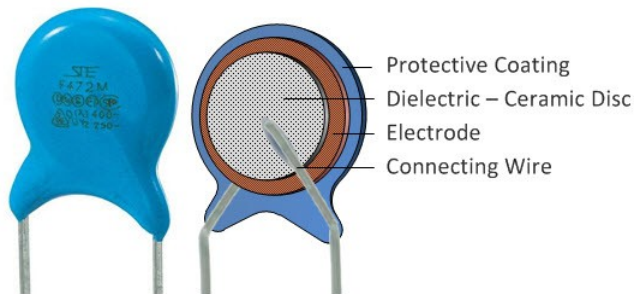


Figure: Ceramic capacitors. The value of the ceramic capacitors is denoted by a code like 153K, which means $15 \times 10^3 \pm 10\%$ pF.

- 1 Stable, unpolarized, low temperature coefficient
- 2 Low capacitance
- 3 Used for coupling, decoupling, analog filters, ...

SMD Capacitors

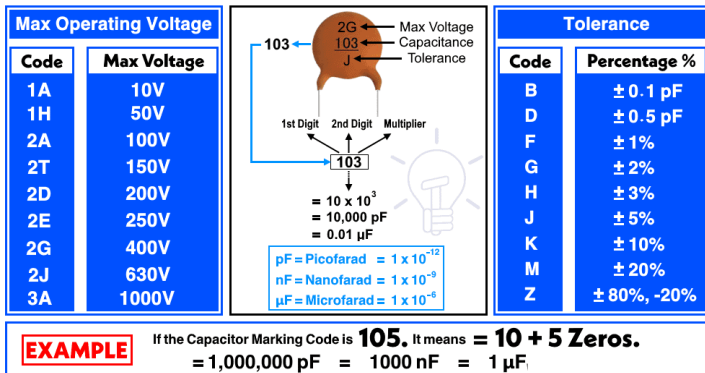


Figure: Capacitor codes.

Electrolytic Capacitors

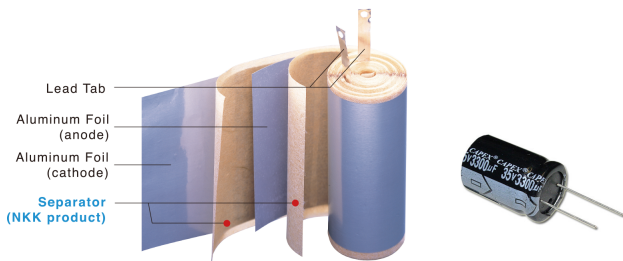


Figure: Electrolytic capacitors. The capacitance, voltage polarity, and maximum tolerable voltage of the electrolytic capacitor are written on its package.

- 1 Available, cheap, small size, high capacitance
- 2 Low voltage, voltage polarity, low frequency, low temperature
- 3 Used for coupling, decoupling, smoothing, storage, ...

Tantalum Capacitors

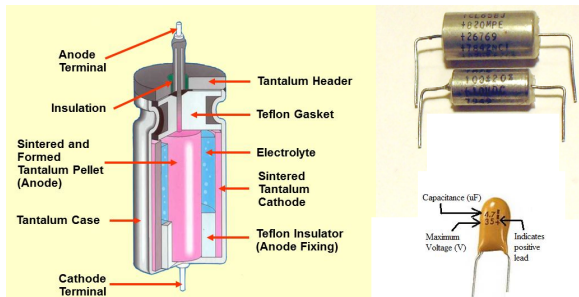


Figure: Tantalum capacitors. The capacitance, voltage polarity, and maximum tolerable voltage of the tantalum capacitor are written on its package.

- 1 Available, cheap, small size, high capacitance
- 2 Low voltage, voltage polarity
- 3 Used for coupling, decoupling, smoothing, ...

Mica Capacitors

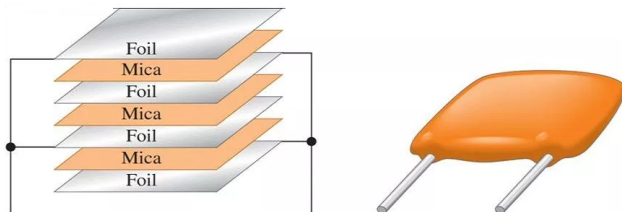


Figure: Mica capacitors.

- 1 Stable, high frequency
- 2 Low capacitance
- 3 Used for high frequency circuits

Polyester Capacitors

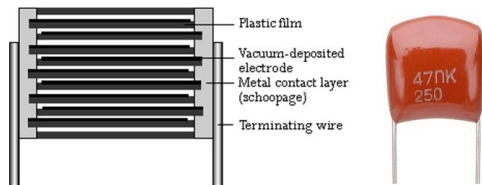


Figure: Polyester capacitors.

- 1 Stable, unpolarized, high voltage, high temperature
- 2 Low frequency
- 3 Used for filtering, DC/AC circuits, audio application

Super Capacitors



Figure: Super capacitors.

- 1 Used for storage and rapid charge/discharge applications

Trimmer Capacitors



Figure: Trimmer capacitors.

- 1 Used for internal tuning of circuits

Variable Capacitors



Figure: Variable capacitors.

- 1 Used in tunable filters, radios, ...

Varactor

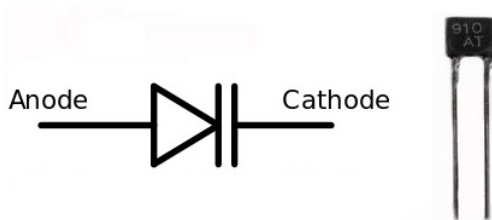


Figure: **Varactor** or voltage-dependent capacitor.

- 1 Used in voltage-controlled oscillators, parametric amplifiers, and frequency multipliers

SMD Capacitors



Figure: Surface-mounted device (SMD) capacitor.

- 1 Used in surface-mounted technology (SMT)

Inductors

Real Inductor

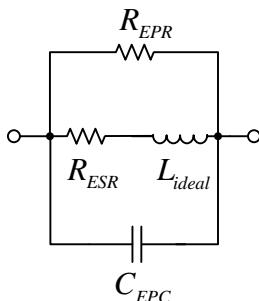


Figure: Real inductor model.

- Parasitic **resistance**, capacitance, and inductance elements
- Dependency on temperature, **frequency**, voltage, current, ...
- Limitation on power, voltage, **current**, temperature, ...

Inductor Symbols

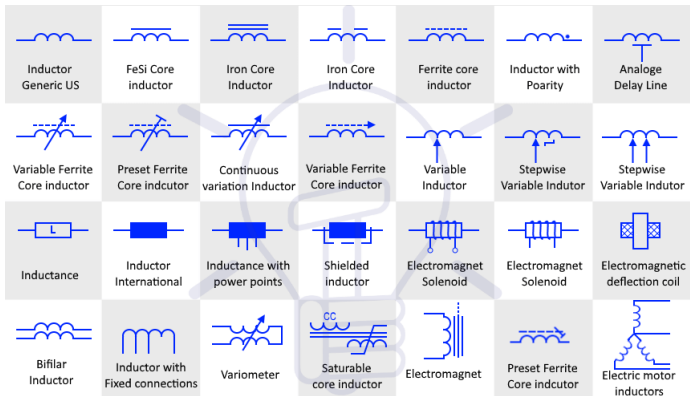


Figure: Symbols of different types of inductors.

Solenoid

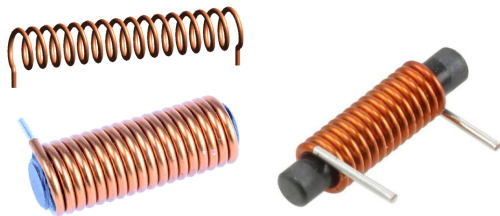


Figure: Solenoid.

- 1 Air core, iron core, ferrite core, hand-wound
- 2 High interference, large size, weak mechanical strength
- 3 Used in oscillators, filters, relay, ...

Toroidal Core Inductor



Figure: Toroidal core inductor.

- 1 Iron core, ferrite core, hand-wound, low interference, high mechanical strength
- 2 Large size, hard winding
- 3 Used in oscillators, filters, relay, regulators, ...

Bobbin Based Inductor



Figure: Bobbin based inductor.

- 1 Vertical mounting on PCBs



Figure: Axial inductor.

- 1 Horizontal mounting on PCBs

Variable Inductor

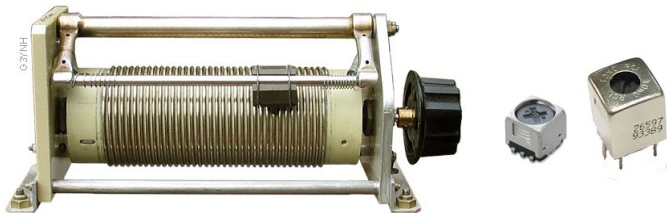


Figure: Variable inductor.

- 1 Used for tuning

SMD Film Inductor

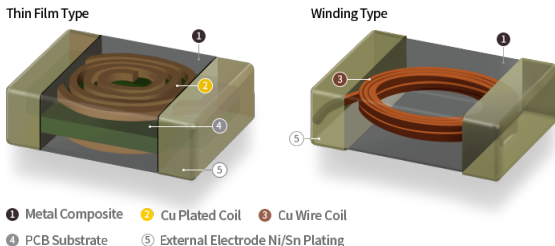


Figure: SMD film inductor.

- 1 Used in surface-mounted technology (SMT)

Shielded SMD Inductor

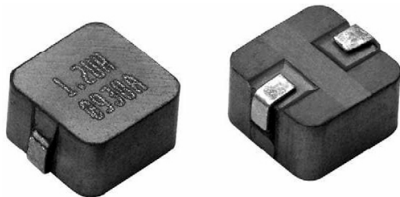


Figure: Shielded SMD inductor.

- 1 Used in surface-mounted technology (SMT)

Coupled Inductor

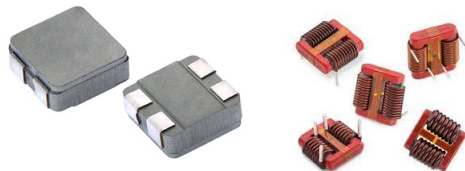


Figure: Coupled inductor.

- ① Used as isolator, DC remover, voltage transformer, ...

Transformer

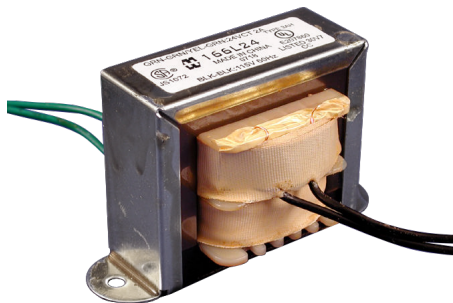


Figure: Transformers.

- 1 Used as voltage transformer, current transformer, ...

Relay



Figure: Relays.

- 1 Used as switch

The End