HRP Training Aid

Capacitors

Description	ECCN
Capacitors	30A001.e.2, 3A201.a
Capacitors, mica paper	3A611.y.5
Energy storage capacitors	3A001.e.2
High-energy storage capacitors	3A001.e.2
High-voltage capacitors	3A999.c

Key Terms

- ***Capacitance:*** A measure of how much energy a capacitor can store in farads (F).
- ***Capacitor:*** An electronic device that has the capacity to store electrical energy in the form of an electric charge. Unlike a battery, it can discharge its entire charge in a fraction of a second.
- ***Charge time:*** The amount of time required for the capacitor to become charged.
- ***Cycle life:*** The life of a capacitor is defined as the expected number of shots before a specified amount of degradation occurs (e.g., overheats due to increase in series resistance).
- ***Dielectric:*** The electrically insulating material between the conductive plates of a capacitor.
- ***Discharge time:*** The amount of time it takes for the capacitor to discharge.
- ***Inductance:*** A measure of capacitor operating speed in henry (H).
- ***Repetition rate:*** The number of charge–discharge cycles (shots) per second, expressed in hertz (Hz). When the repetition rate is very small or the capacitor is not fired often, the operating condition is known as *single shot*.
- ***Shot:*** A charge–discharge cycle.

Capacitors

- A common component of practically all electronic and electrical systems
- The vast majority (over 99%) of capacitors are not controlled
- Consists of two electrical conductors, called *plates,* separated by a dielectric insulator
  - o Leads are attached to each plate and a coating or other case is placed around the capacitor.
  - o The plates and the dielectric can be made from a variety of different materials, so different types of capacitors have different qualities and uses.
- In a normal application, the capacitor is charged slowly, is discharged rapidly, and undergoes a set number of discharge cycles per unit time.

Capacitance

- Size analogy: A 1 F capacitor would be the size of a can of tuna or a 1 L bottle.
- Most capacitors used in electronics have capacitances in the microfarad (6–10 μF) range.

ECCN 3A001.e.2
High-Energy Storage Capacitors

Review the capacitor's label or manufacturer's data sheets to identify the controlled items described below.

Single-shot capacitors

- Repetition rate of **<10 Hz** and having **all** of the following:
  - o A voltage rating ≥5 kV
  - o An energy density ≥250 J/kg
  - o A total energy ≥25 kJ

Repetition-rated capacitors

- Repetition rate of **≥10 Hz** and having **all** of the following:
  - o A voltage rating ≥5 kV
  - o An energy density ≥50 J/kg
  - o A total energy ≥100 J
  - o A charge–discharge cycle life ≥10,000

Useful formula

Use the following formula to calculate energy under ECCN 3A001.e.2:

$$\text{Capacitor energy } (J) = \tfrac{1}{2} CV^2,$$

where J is the energy in joules, C is the capacitance in farads, and V is the voltage across the capacitor in volts.

High-Energy Discharge Capacitors

- Very high repetition rates
- Optimized for very high current discharges and high-reliability performance

Performance:

- Rated voltage: 2–60 kV
- Peak current: Up to 20 kA
- Frequency range: ≤1,000
- Standard life: 1,000,000 discharges

Standard design features:

- Case shape: Cylindrical or plane-parallel
- Case material: Phenolic resin, laminate paper, Bakelite, PVC, metal
- Terminals: Axial leads in brass, thread rods, or screw holes with contact plates

Applications:

- Very fast energy restitution
- Generation of normalized lightning waves
- Lithotripsy
- Pulse-forming networks

Controlled: ECCN 3A001.e.2

ECCN 3A201.a
Pulse Discharge Capacitors

Appearance

- Two terminals
- If a case is used as one terminal, only one terminal may be visible
- Many uncontrolled capacitors are very small (made to fit on circuit boards)
- Pulse discharge capacitors that meet export control specifications will be larger and typically square or rectangular
  - o Sizes range from a small box of matches to a tall trash can
  - o Weights will range up to several kilograms

Special Characteristics

- Low inductance is often (but not always) indicated by flat plate terminals
- May be marketed using the following terms:
  - o Low-inductance capacitor
  - o Advanced high-energy capacitor
  - o High-voltage pulse capacitor
  - o Pulsed power capacitor

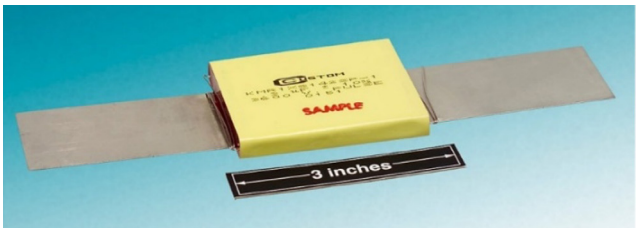
Technical Specifications of Controlled Items

- Voltage rating >1.4 kV, energy storage >10 J, capacitance >0.5 µF, and series inductance <50 nH **or**
- Voltage rating >750 V, capacitance >0.25 µF, and series inductance <10 nH

Note: *Inductance is a measure of how fast a capacitor operates in henry (H). Inductance will never be on the label. Always contact the manufacturer to request this information. Watch for capacitors with very low inductance (<50 nH).*

Applications

- Weapons of mass destruction
  - o Used in firing sets for detonation of nuclear weapons
  - o Used in firing sets for detonation of all explosive payloads
- Commercial
  - o Engine ignition systems
  - o Pulsed radars and lasers

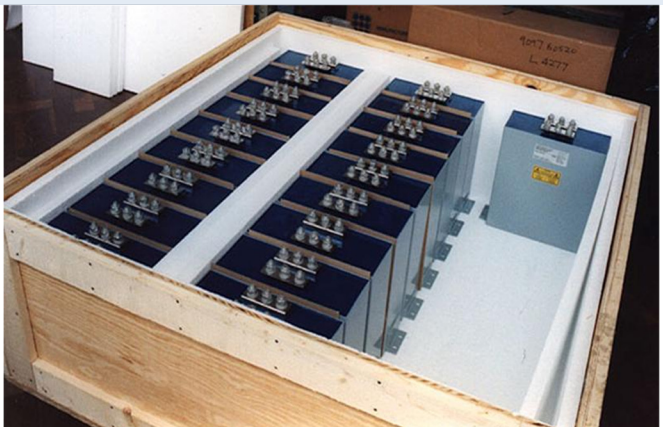


(Left) A 3 in. pulse discharge capacitor

Packaging and Handling

- Packaging provides protection from shock and vibration, such as plastic bags, packing foam inside cardboard, or wooden boxes
- Capacitors can store electrical charge sufficient to cause a lethal shock
  - o Terminals and electrical leads should be shorted to prevent electrical shock
  - o Avoid contact with all capacitor oils (older devices may contain polychlorinated biphenyls, which are highly carcinogenic chemical compounds that were formerly used in industrial and consumer products)
- Special markings
  - o Directly labeled with voltage (V or kV)
  - o Directly labeled with capacitance
  - o Other labels may list the model number, serial number, or manufacturer
  - o High-voltage warning labels

Note: *Farad is a unit of capacitance. Capacitors will usually be marked with either microfarads (μF), picofarads (pF), or nanofarads (nF).*



Filter capacitors packed for shipping.
Note the metal shunts across the leads.

Filter capacitors packed for shipping.
Note the wires shorting the terminals.

Snubbers

- Simple energy-absorbing circuits used to eliminate, or "snub," voltage spikes when a switch opens. Snubbers are typically found in high-power AC circuits.
- The most popular snubber circuit is a capacitor and a series resistor connected across a switch.
- Capacitors typically used.
  - o Capacitance ≤0.01 μF: Dipped mica capacitors.
  - o Higher capacitance values: Polypropylene film/foil capacitors.
- Some snubber capacitors meet the control specifications of **ECCN 3A201.a**

Snubber capacitors used in high-power AC circuits.

ECCN 3A999
High-Voltage Capacitors

This ECCN controls exports to North Korea for antiterrorism reasons specific to processing equipment (including item c. below) not elsewhere specified in the Commerce Control List.

c. All flash X-ray machines, and parts or components of pulsed power systems designed thereof, including Marx generators, high-power pulse-shaping networks, high-voltage capacitors, and triggers.

High-Voltage Capacitors

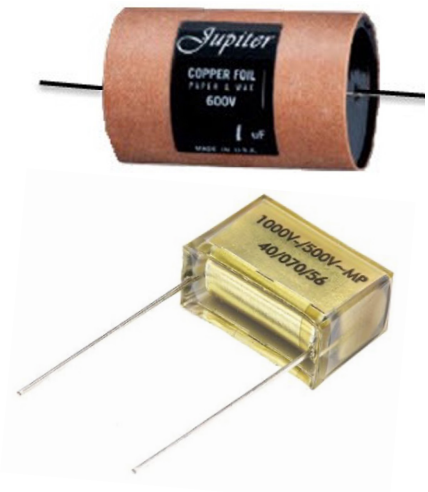
- The term *high-voltage capacitor* refers to capacitors that can safely withstand hundreds or thousands of volts as opposed to the few volts typical of many common electronic applications.
- Such high-voltage capacitors have thicker dielectrics, among other design features.

High-voltage pulse capacitor, 20 kV; 10 nF
4 in. long × 1 in. diameter

Other Types of Capacitors

Paper Capacitor

- Primitive but still found in electronic equipment.
- Made by placing a paper soaked with mineral oil between two strips of aluminum foil, rolling the assembly, attaching wire leads, and enclosing in a cylindrical container or case.
- Capacitances 0.001–0.1 μF.
- Voltages up to ~1,000 V.
- Not controlled.



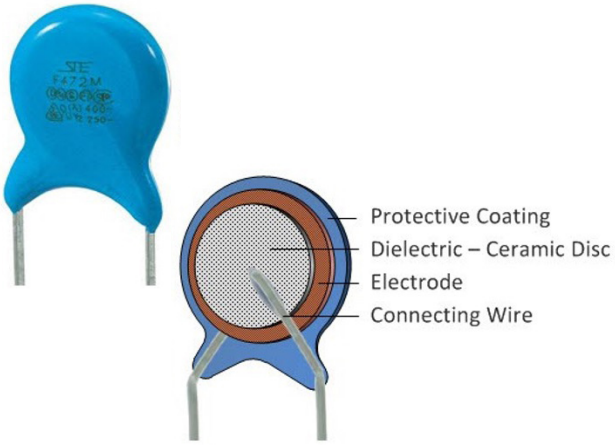
Mica Capacitor

- Mica is a naturally occurring transparent substance that flakes off in thin sheets. This material makes an excellent dielectric for capacitors.
- Main applications: Radio receivers, radio transmitters.
- Capacitances: Lower than paper capacitor, ranging from a few tens of picofarads (10^{-12} F) to ~0.05 µF.

Note: *Mica paper capacitors "specially designed" for a commodity subject to control in a 600 series ECCN (e.g., military electronics) or a defense article is export-controlled under* **ECCN 3A611.y.5**

Ceramic Capacitor

- Made of porcelain, which also works well as a dielectric.
  - o Disk-ceramic capacitor (one layer of disk-shaped ceramic) for low capacitance.
  - o Tubular capacitor (a tube or cylinder of ceramic).
- Capacitances from a few picofarads (10^{-12} F) to ~0.5 µF.
- Not controlled.



Plastic-Film Capacitor

- Different plastics make good dielectrics for the manufacture of capacitors.
- Polyethylene, polyester (Mylar), and polystyrene are commonly used.
- Found in several different shapes and geometries.
- Capacitances: 50 pF to several tens of microfarads.
- Not controlled.

Electrolytic Capacitor

- Also known as *aluminum capacitors.*
- Made by rolling up aluminum foil strips, separated by a paper (dielectric), saturated with an electrolyte liquid, and tightly sealed in an aluminum cylindrical can.
- Polarized—has positive and negative polarity.
- High capacitance per unit volume.
- **Applications:** Audio frequency circuits, photoflash for photography, strobe lighting, DC power supplies.
- **Capacitances:** Up to thousands of microfarads. Some units can handle thousands of volts.
- Not controlled.

Tantalum Capacitor

- Another type of electrolytic capacitor using tantalum pentoxide rather than aluminum.
- Tantalum can be a foil or take the form of a porous pellet—the irregular surface provides a large area in a small volume.
- High reliability, excellent efficiency, smaller in size, and lighter than aluminum capacitor.
- Often used in military applications because of its low failure rate.

Semiconductor Capacitor

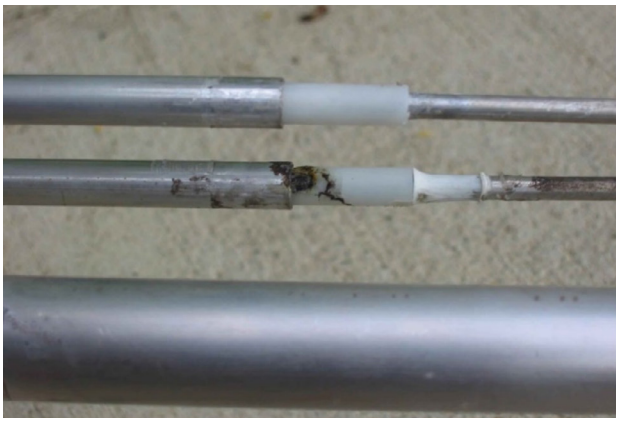
- Also called *MIS capacitor,* which stands for metal–insulator–semiconductor.
- Formed from a layer of metal, a layer of insulating material, and a layer of semiconductor material of an integrated circuit.
- Physically tiny; look like little boxes or cylinders with many pins.
- Miniaturization makes them extremely common in electronic equipment (e.g., a personal computer will have several dozen).
- Small values of capacitance; can handle only low voltages.
- Not controlled.

Trimmer Capacitor

- Consists of two plates, mounted on a ceramic base and separated by a sheet of Mylar, mica, or other dielectric material.
- The plates are "springy" and can be moved relative to each other by means of a screw.
- **Capacitances:** A few picofarads to 200 pF; can handle low to moderate voltages.
- Not controlled.

Coaxial Capacitor

- Telescoping sections of tubing used to create a capacitor in transmission lines
- A sleeve of plastic dielectric is placed between the sections of tubing, creating an effective surface area
- Used in radio-frequency applications, particularly in antenna systems
- **Capacitances:** A few picofarads to 100 pF
- Not controlled.



DOE/NNSA High Risk Property

https://hrp.doe.gov

https://ecap.doe.gov

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