

## Applications & Cases



[Rugged aluminum electrolytic capacitors for start-stop systems](#)

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### No stress on the automotive electrical system

Stop-and-go traffic is toxic both to the climate and your wallet. Start-stop systems are designed to alleviate this problem. Their job is to switch the engine off at red lights or in a traffic jam and switch it on again as soon as the clutch is activated. The resulting savings are considerable: in a defined urban cycle over a route of seven kilometers with twelve stops, each of 15 seconds, carbon dioxide emissions and fuel consumption drop by up to

eight percent. For longer stops, the savings are greater still.

But constant stopping and restarting the engine also places high stresses on the vehicle's electrical system and the components it uses. In today's cars, the system is already overloaded by an increasing number of subsidiary electrical units. These include coolant, fuel and hydraulic pumps, fan motors as well as electronic control and braking systems. As such, these vehicles need generators with an output of up to 3.8 kW to ensure a stable supply to all systems.

Moreover, the battery is no longer stowed in the engine compartment near the generator but in the trunk for better weight distribution. Due to the high currents in the electrical system and the distance of the battery from the generator via long leads, the battery can no longer stabilize the electrical system sufficiently. In order to smooth out the associated voltage ripple, aluminum electrolytic capacitors from EPCOS have already been used for many years as EMI-suppression capacitors with high current handling capacity and low self-inductance.

#### **New aluminum electrolytic capacitors for high stresses**

Because very high charging currents of up to 300 A flow briefly when the engine is started, the new start-stop systems additionally stress the electrical systems and thus the capacitors to a great extent. Conventional capacitors reach their limits at these stresses. In order to satisfy these increased requirements, EPCOS has developed new aluminum electrolytic capacitors in cooperation with the automotive industry. They can reduce the high current ripple of the generator over the entire lifetime of the vehicle and can withstand the high stresses as well as several hundreds of thousands of engine starts and stops.

In developing these new capacitors, special attention was paid to the avoidance of hydrogen gassing and film oxidation. These can occur as a result of different potential distributions and electrical asymmetries inside the capacitor at very high charging and discharging currents.

Extremely compact capacitors with a high capacitance density react with particular sensitivity to internal asymmetries. This is because only low currents – used to equalize potential differences – flow through the thin and dense paper spacers used as separation layers in these capacitors.

An examination of the suitability of radial and axial types for start-stop systems shows that the axial variants need no redesign. The advantages of axial capacitors lie in the high symmetry of the axial construction and the narrower gaps between anode and cathode films. In order to be equipped for the even tougher demands of the future, a new specifically axial pulse design was developed and successfully tested.

EPCOS also improved the electrical symmetry of the radial types and thus minimized their internal dynamic potential differences. Some of these further developments have already been used in products and have proved their worth, for instance in electronic lamp ballasts. Because of their design, however, these measures can only reduce - but not completely - eliminate the diverse asymmetries. This is due to the cavities in these types of capacitor resulting from the two paddle tabs to the terminal.

## Applications & Cases

### Selecting capacitors in practical tests

To test the suitability of a capacitor for an application, the originally specified voltage profile must be used for the test. A standard symmetrical profile can lead to over- or underloading of the capacitor. The information as to whether the capacitor is stressed with rapid charging or rapid discharging pulses is important for design and testing, as different electrochemical processes are involved in the capacitor. The direction of the internal leakage currents is also different. Table 1 shows the effects to be expected for different charging and discharging pulses.

**TABLE 1: HYDROGEN AND OXIDE FORMATION FOR DIFFERENT CHARGING AND DISCHARGING PULSES**

| Current profile                     | Hydrogen formation  | Oxide formation   |
|-------------------------------------|---|---|
| Slow charging<br>Slow discharging   | None  | None  |
| Rapid charging<br>Slow discharging  | Only at a few points on the cathode film                      | Across the entire cathode film                                |
| Slow charging<br>Rapid discharging  | Across the entire cathode film                                | Only at a few points on the cathode film                      |
| Rapid charging<br>Rapid discharging | Across the entire cathode film and intensified at some points | Across the entire cathode film and intensified at some points |

The gas and oxide are produced by potential equalizing currents flowing along the electrolyte and cathode film. These currents, which act electrochemically as leakage currents, circulate inside the capacitor. They cannot be determined as leakage currents from the current balance (sum of the charges flowing in and out of the capacitor). The greater the difference between charging and discharging currents, the more spatially extended are the current paths in the capacitor. The same applies to the rotational directions of the currents, which depend on whether the charging or discharging current is greater.

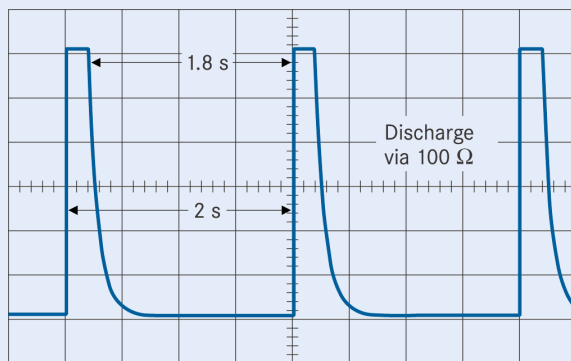
The locally intensified hydrogen production leads to chemical changes of the electrolyte at these critical points. Even where no short-circuit failures were detected at the points showing visible changes, the capacitors were internally analyzed and evaluated after a recharging test. A continuous test was conducted to identify further prior damage. All low-voltage electrolytes used at EPCOS have been tested in axial capacitors for such irregularities and, in the tests described below, no failures occurred.

In the rapid charging test, the axial capacitors were charged rapidly to 40 V at up to 470 A and discharged again slowly after 0.2 s via a 100-Ω resistor. The test was run in a two-second cycle (Fig. 1).

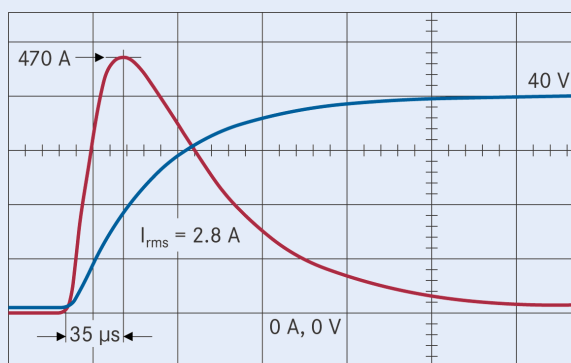
## Applications & Cases



**FIGURE 1: SYNCHRONIZED RAPID-CHARGING TEST OF AL CAPS**



Pulse diagram for synchronizing the rapid-charging test



Current and voltage curves during rapid charging

Charging test 40 V/ 85 °C

The capacitors showed no undesired gas production even after 200,000 rapid charging cycles from 0 V to 40 V at an ambient temperature of 85 °C. The key electrical data showed a capacitance reduction of only about three percent and an impedance rise of about 20 percent at 10 kHz. The reverse test with slow charging and rapid discharging led to no significant pressure rise in the capacitor either. A slight capacitance drop of one percent was noted. This measurement also covered 200,000 cycles.

These measurements confirmed that the stresses occurring during rapid charging can produce greater changes in the capacitor than the classical discharge processes, such as when using flash lamps. All tested capacitors, irrespective of the test temperature and voltage profile, were still unchanged after a further continuous test lasting 3000 h at 40 V and 125 °C and their electrical parameters were in the normal range.

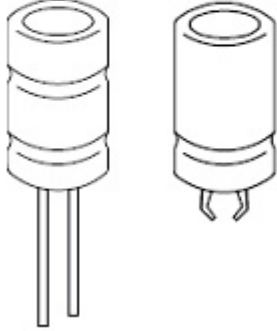
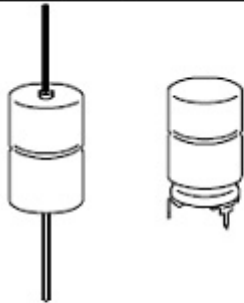
### Fit for start-stop operation

These tests show that state-of-the-art axial and compact round-can electrolytic capacitors (large size) can satisfy the high charging and discharging requirements of start-stop systems.


EPCOS offers a wide range of electrolytic capacitors for applications in automotive electronics; they are listed in the data book entitled "Aluminum Electrolytic Capacitors for Automotive Applications." These capacitors are characterized by their high ripple current capability, high temperature stability and in many cases also high mechanical ruggedness and outstanding reliability. Table two gives an overview of the most important types.

## Applications & Cases

**TABLE 2: KEY DATA OF AL CAPS FOR AUTOMOTIVE ELECTRONICS**

| Terminal style   | Series           | Temperature °C | Special features, field of application     | V <sub>R</sub><br>V DC | C <sub>R</sub><br>µF |
|--|------------------|----------------|--|------------------------|----------------------|
| <b>Large size</b><br>                     | B41605           | +125/<br>+140  | Automotive<br>up to 140 °C                 | 25 ...<br>63           | 1500 ...<br>20000    |
|  | B41607           | +125/<br>+150  | Automotive<br>up to 150 °C                 | 25 ...<br>63           | 800 ...<br>4700      |
| <b>Axial-lead and soldering star</b><br> | B41691<br>B41791 | +125/<br>+150  | Long useful life                           | 25 ...<br>63           | 100 ...<br>4000      |
|  | B41692<br>B41792 | +125/<br>+140  | Long useful life,<br>compact               | 25 ...<br>63           | 220 ...<br>6800      |
|  | B41693<br>B41793 | +125/<br>+150  | High temperature<br>capability             | 25 ...<br>75           | 100 ...<br>4000      |
|  | B41694<br>B41794 | +125/<br>+140  | Low ESR                                    | 25,<br>40              | 330 ...<br>3900      |
|  | B41695<br>B41795 | +125/<br>+140  | High temperature<br>capability,<br>compact | 25 ...<br>63           | 220 ...<br>6800      |
|  | B41696<br>B41796 | +125           | Low ESR,<br>compact                        | 25,<br>40              | 470 ...<br>6800      |
|  | B43693<br>B43793 | +125           | High voltage                               | 250                    | 22 ...<br>130        |

## Applications & Cases

| Terminal style  | Series | Temperature °C | Special features, field of application                           | V <sub>R</sub><br>V DC | C <sub>R</sub><br>μF |
|---|--------|----------------|--|------------------------|----------------------|
| Single-ended<br><br> | B41853 | +105           | High CV product, compact design                                  | 25 ...<br>50           | 470 ...<br>6800      |
|   | B41858 |                | Low ESR, low impedance, high reliability, long useful life       | 10 ...<br>100          | 22 ...<br>12000      |
|   | B41888 |                | Very low impedance, extended useful life                         | 10 ...<br>63           | 56 ...<br>12000      |
|   | B41866 | +125           | High ripple current capability at high temperature               | 10 ...<br>63           | 10 ...<br>10000      |
|   | B41896 |                | Wide temperature range, high ripple current capability,          | 10 ...<br>63           | 1 ...<br>10000       |
|   | B43896 |                | extra long useful life   | 160 ...<br>450         | 4.7 ...<br>220       |
|   | B41868 | +150           | Very high temperature capability, high ripple current capability | 10 ...<br>50           | 47 ...<br>5600       |