Risks to Strobe Supplies Retrieved from Long Term Storage

At 05:52 PM 8/23/2007 -0700, you wrote:

> The Sept 2007 edition of LPM has an article on strobe lights. I'm curious as to how accurate the following excerpt is:
>
> "A strobe power supply that has been left "off" for long periods - weeks or months - is subject to eventual failure because the electrolytic capacitors used in the device will loose polarity formation. As a rule, a strobe that has been inactive for one year can be considered eligible for sudden failure"
>
> I have two Areoflash power supplies that were purchased new six months ago and have since been waiting for final installation. Do I need to "exercise" this strobe system to keep it from going bad?

There have been some excellent responses to this on the List so I'll offer only the following:

Articles like this are a disservice to the community because they are non-quantified. I.e., no data followed with logical deductions which lead to repeatable experiments (recipes for success). This topic has been raised many times over the years on the various aviation forums. On one occasion in years past, I scrounged around in my junk box for a high voltage electrolytic capacitor that I KNEW had not been powered up for decades.

I connected it to a supply equal to it's rated voltage (450 volts if I recall correctly). On initial power up, the capacitor did what every capacitor does . . . draw whatever current the source will deliver until equilibrium is achieved. After several seconds, the capacitor's "draw" was measured in a hand-full of milliamps and after a minute, charging was essentially complete and "leakage" was under 1 mA. After ten minutes, leakage dropped to about 100 microamps.

I then did a measurement of apparent capacity. The device was within 10% of rated value. I left the capacitor connected to the power supply for several days and measured apparent capacity again. It's increase was so tiny as to make measurement problematic.

Bottom line: In days of yore when capacitor technology and fabrication techniques were in a relative state of infancy, the devices were indeed subject to deleterious effects of long term, dormant storage.

But "modern" capacitors (meaning those built in the last 20 or so years) have exhibited great strides in operating performance and service life. An exemplar article on the topic is attached to this document.

This article addresses an expected elevation of leakage currents in the first few minutes of a long term storage but that, "no damage to the capacitor is to be expected".

This article is consistent with my own experience and in particular, with an experiment conducted on the bench. If anyone has data from an experiment arguing with the foregoing deductions, it would be interesting and useful for us to examine it for new understanding.

Bob . . .

Long-term Stability of Aluminum Electrolytic Capacitors

July 2007

Built to last

Thanks to the manufacturing process, aluminum electrolytic capacitors for automotive electronics from EPCOS offer long-term stability for both storage and operation. This is of particular benefit to automotive customers with their need for high-quality components.

These capacitors are used in a variety of automotive applications. These include engine management systems for fuel injection as well as control systems for fan and windshield-wiper motors, electronic steering systems, airbags and multimedia equipment.

Storage affects leakage current behavior

A key parameter of aluminum electrolytic capacitors is the behavior of their leakage current when they are operated immediately after storage. The leakage current is the current flowing through the capacitor on DC voltage: it remains relatively high shortly after a DC voltage is first applied to it and then drops after several days to a low current, which is known as operating leakage current. As a rule, leakage current behavior is determined by the leakage current that continues to flow through the capacitor after the DC voltage has been applied for five minutes.

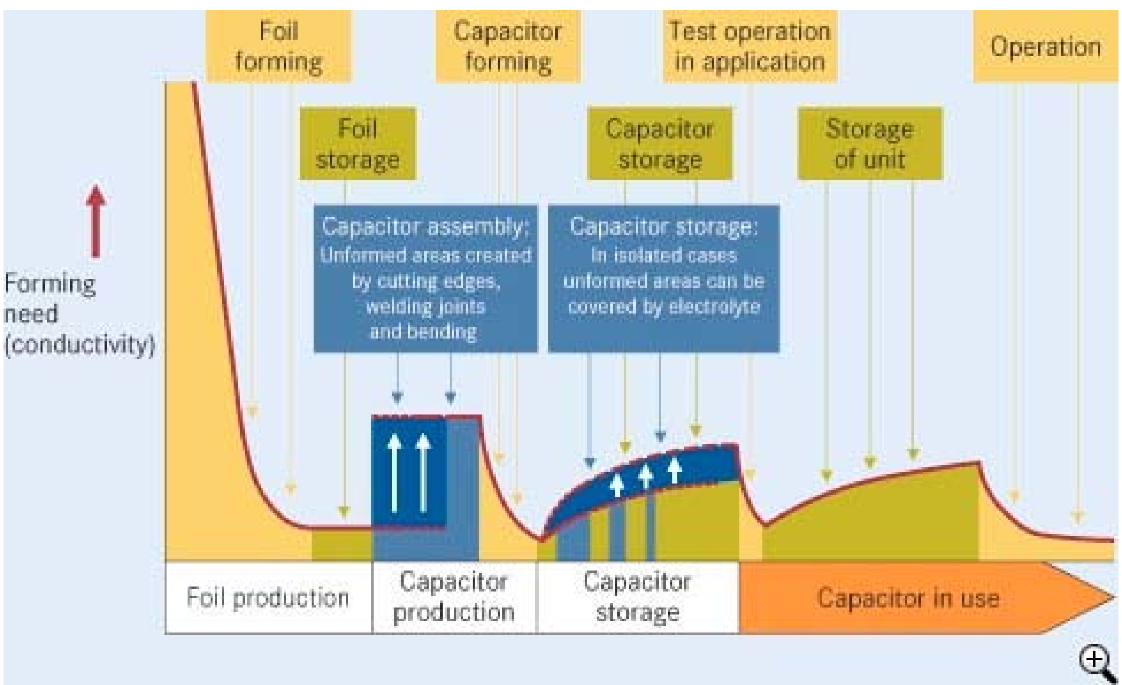


FIGURE 1: LEAKAGE CURRENT OF ALUMINUM ELECTROLYTIC CAPACITORS

The forming requirement of an aluminum electrolytic capacitor from the manufacture of the anode foil up to final operation. The reforming requirement is reflected by the leakage current value, marked here in red. When no voltage is applied (green range), the mean conductivity of the oxide layer increases again. When a voltage is subsequently applied, the increased conductivity occurs in the form of an increased leakage current that rises in line with the duration of preceding storage period.

The dielectric of an aluminum electrolytic capacitor consists of the aluminum oxide formed electrochemically on an etched aluminum foil. The quality of the oxide, which changes during the manufacture and subsequent use of the capacitor, determines the insulating properties of the dielectric. The DC conductivity of the oxide increases as a result of processing the oxide-coated anode foil during capacitor assembly and the conductivity is again lowered in the final forming process. When it is subsequently stored at zero voltage, the insulation properties of the dielectric are impaired. In order to minimize this perturbing conductivity, it is eventually necessary to repeat the forming process under voltage in order to repair and build up the oxide layer again. If the oxide has degenerated more pronouncedly, a high-forming current flows during the reforming process, thus increasing the forming requirement (Fig. 1).

Storage of aluminum electrolytic capacitors

Two different phenomena can have a negative impact on the internal insulation of an aluminum electrolytic capacitor during storage: oxide degeneration and post-impregnation effects. When a voltage is subsequently reapplied, the regeneration leakage current may initially rise again.

a) Oxide degeneration

Depending on the electrolyte class and temperature, ionic parts of the electrolyte can diffuse into the dielectric or oxide and alter the oxide crystal structure. Electrical defects and ionic charge carriers are then produced in the oxide.

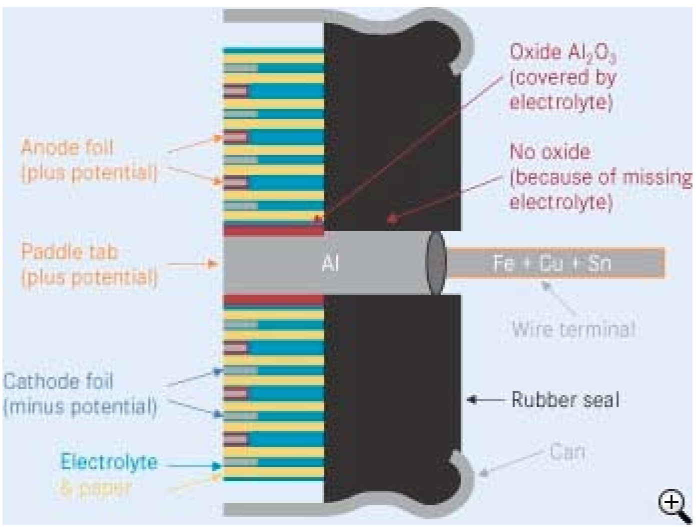
Although glycol-based electrolytes have the drawback of producing higher leakage currents, they offer the advantage of repairing defects in the oxide very effectively when current is flowing. This makes them especially well suited for high-voltage aluminum electrolytic capacitors.

In the low-voltage range, in which oxides are more homogeneous, electrolytes based on gamma butyrolactone solvents are sufficient to produce a reliable and voltage-resistant dielectric. In this case, it is advantageous when these electrolytes are almost completely unable to penetrate the oxide or break bonds, thus ensuring a well-insulating oxide even after potential-free storage lasting decades. If these electrolytes nevertheless sporadically and temporarily lead to high leakage currents after such storage, this is due to post-impregnation effects.

b) Post-impregnation effects

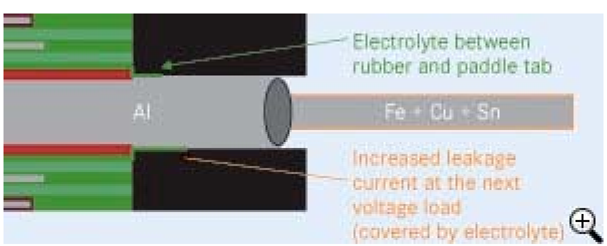
The oxide can be electrochemically formed in the component only where it is also coated with electrolyte and is connected electrically to the cathode foil via the electrolyte, thus allowing the required forming current to flow in these regions. In a new capacitor, this is the case on more than 99.9 percent of the oxide area to be formed.

In the radial capacitor shown in Fig. 2, the positive feedthrough also known as a paddle tab, was formed only in the winding element area. No oxide was able to form in the vicinity of the rubber plug where the electrolyte has not penetrated. This is not a disadvantage for the insulation because no leakage current can flow in the absence of electrolyte. However, if some electrolyte subsequently penetrates this region, a supplemental forming process must be conducted to create an isolating oxide the next time a voltage is applied (Fig. 3). This means that increased leakage current flows until the anodic aluminum surface newly wetted with electrolyte has been formed.



Example of an anode surface in the feedthrough area of a radial aluminum electrolytic capacitor not coated with electrolyte.

FIGURE 2: PARTIAL FORMING IN THE TERMINAL AREA



Example of an anode surface in a radial aluminum electrolytic capacitor with supplemental impregnation during storage.

FIGURE 3: REFORMING IN THE TERMINAL AREA

In low-voltage aluminum electrolytic capacitors with solvent electrolytes, all areas can be expected to be wetted and as a result show a very low leakage current in the long term, i.e., after the storage and transport periods and before their first operation in the application.

Supplemental reforming effects are caused by subsequent wetting and in principle also apply to high-voltage electrolytes, although they are of minor importance due to the dominant effect of oxide degeneration in high-voltage capacitors. However, test operation under voltage is also of benefit for the long-term leakage current behavior of high voltage capacitors in this electrolyte class, because each forming step makes the isolating properties of the oxide more stable.

In order to also keep the forming condition stable during storage of the equipment, larger temperature fluctuations and prolonged shocks should be avoided. Aluminum electrolytic capacitors with solvent electrolytes of the SIKOREL class can normally be stored over a period of more than 15 years without exceeding the leakage current limit specified for the new component.

In capacitors with polar electrolytes used in high-voltage capacitors made by EPCOS, the chemical interaction between electrolyte and oxide dominates the blocking behavior of the dielectric. The storage temperature for these capacitors should be as low as possible, and certainly below 25°C. This enables reaching storage periods longer than the specified two years. However, even after the permissible storage time has been exceeded, no damage to the capacitor is to be expected; there is merely an increase in the leakage current lasting several minutes.

Irrespective of the electrolyte used, the operating leakage current at equilibrium is very low. The leakage current adapts itself to the equilibrium state (voltage, temperature distribution, insertion geometry, shocks). If the equilibrium changes after long constant operation due to a higher voltage or temperature, charge carriers in the dielectric are reactivated so that a higher leakage current flows again. Under certain circumstances, equilibrium changes that make the electrolyte flow may also wet anode areas that were not effectively wetted under the old equilibrium. These anode areas may also include tiny regions with sporadic weak points that were incompletely formed. Apart from the classical production of the dielectric by formation of a non-conductive oxide, foreign inclusions may produce a defect site that continuously generates a local leakage current. These defects (Fig. 4) can apparently be corrected in equilibrium by the formation of a gas bubble. The gas generated by the local leakage current expels the electrolyte at the defect site so that the local current flow also stops.

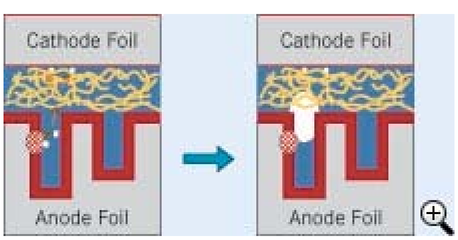


FIGURE 4: DEFECT SITES LEAD TO GASING

Every change in equilibrium that affects the gas and electrolyte quantity and its gaseous solubility can cause the leakage current to rise. This also explains the paradoxical observation that even when a capacitor cools, the leakage current can initially rise contrary to expectations.

The leakage current certainly also causes the capacitor to age by consuming some of the constituents of the electrolyte for the oxide forming or regeneration. As a rule, however, this mechanism does not determine the rate by which the capacitor ages. It should be noted that high perturbing leakage currents occur only a short time after the voltage has been applied, i.e., they can essentially be neglected during the entire operating period. In practice, a high leakage current leads to premature capacitor death only when the current cannot drop fully due to an excessive voltage or incorrect polarity, which is increased by high temperatures. The rapid gas generation then leads to bursting at the predetermined breaking point.

In applications supplied by a standard or rechargeable battery, as is typically the case in motor vehicles, there is always the concern that the high leakage current of a component could discharge the battery. This hazard is negligible with state-of-the-art electrolytic capacitors from EPCOS. This also applies for self-extinguishing high-voltage electrolytes. Undamaged aluminum electrolytic capacitors can produce high leakage currents only briefly, but never over long periods of time. Under suitable conditions of use, they may be operated over decades.

BACKGROUND: PROCESSING OF ALUMINUM ELECTROLYTIC CAPACITORS

Long storage periods for aluminum electrolytic capacitors

For the series of aluminum electrolytic capacitors listed below, which are suitable for automotive applications, EPCOS specifies in regard to the leakage current a storage period of up to 15 years at a temperature below 40°C. After the storage period, the expected leakage current is still in the order of magnitude of the original limit.

Radial series:

B41853, B41858, B41888, B41866, B41896, B41868

Axial/solder-star series:

B41684/B41784, B41691/B41791, B41692/B41792, B41693/B41793,
B41694/B41794, B41695/B41795, B41696/B41796

Snap-in and large-size series:

B41505, B41605, B41607

Screw-terminal series

B41550, B41554, B41570

If the capacitors are stored for a prolonged period, the properties of their leakage current may change and lead to errors at the final inspection. Users are recommended to insert the capacitors at an early stage and then store the completed equipment. The capacitors will then not only be optimally formed, but the soldering on the circuit board will be performed while the solder points of the component are still new. The completed equipment should be stored at a low temperature and be exposed to minimum temperature fluctuations.

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