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Guide for the application of aluminium electrolytic capacitors

Guide pour l'utilisation de condensateurs électroytiques à l'aluminium

Leitfaden für die Anwendung von Aluminium-Elektrolyt-Kondensatoren

This CENELEC Report was prepared by EECA ETC WG1 "Aluminium Electrolytic Capacitors" and was submitted to the Technical Committee CENELEC TC 40XA, Capacitors. It was endorsed by the CENELEC Technical Board on 1997-10-01.

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CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

This document was prepared by EECA ETC WG1 "Aluminium Electrolytic Capacitors" and was submitted to the Technical Committee CENELEC/TC 40XA "Capacitors".

It is based, wherever possible, on the Publications of the International Electrotechnical Commission (IEC).

It was approved by CENELEC as R040-001 on 1997-10-01.

Secretariat Note

This guide was prepared by the working group on aluminium electrolytic capacitors, EECA ETC WG1, and the recommendation was given to TC/CECC SC 40XA to make the document available to the users in order to ease the application of aluminium electrolytic capacitors.

The proposal was discussed on the meetings of TC/CECC SC 40XA in Milan (1996) and Brussels (1997) as a guide to the Sectional Specifications EN 130300 for aluminium electrolytic capacitors with solid and non-solid electrolyte and EN 137100 for fixed aluminium electrolytic a.c. capacitors with non-solid electrolyte for use with motors.

As stated in the corresponding meeting documents TC/CECC SC 40XA(Parsons)13, item 13, and TC/CECC SC 40XA(Parsons)27, item 12, it was decided to submit the proposal – after implementation of some editorial amelioration – to CENELEC for publication.

Contents

1 Scope

This guide applies to components as described in the scope of the following Sectional Specifications.

EN 130300: Aluminium electrolytic capacitors with solid or non-solid electrolyte (primarily intended for d.c. applications for use in electronic equipment)

EN 137100: Fixed aluminium electrolytic a.c. capacitors with non-solid electrolyte for motor starter applications

The information given in these documents apply to capacitors with non-solid electrolyte but may, in its appropriate clauses, apply to capacitors with solid electrolyte as well.

In cases of doubt, the application of this document shall be discussed between the user and the manufacturer of the components.

2 Object

Electrolytic capacitors in general – and aluminium electrolytic capacitors in particular – are an exception in the capacitor field because of the components close interaction of physics and chemistry. Therefore, aluminium electrolytic capacitors show, in various aspects, a technical behaviour unaccustomed to the user. That could easily lead to misapplications and even to endangering of persons and goods. The aim of this application guide is to minimize these risks by providing detailed information on the specific peculiarities of the component.

3 Normative references

This guide incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this guide only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 130000: 1993	Harmonized system of quality assessment for electronic components Generic specification: fixed capacitors
EN 130300: 1998	Aluminium electrolytic capacitors with solid or non-solid electrolyte
EN 137000: 1995	Fixed aluminium electrolytic a.c. capacitors with non-solid electrolyte for use with motors; Generic Specification
EN 137100: 1995	Fixed aluminium electrolytic a.c. capacitors with non-solid electrolyte for motor starter applications (Qualification Approval); Sectional Specification

4 Terms and definitions

The main elements of aluminium electrolytic capacitors are as follows:

4.1 Positive electrode (anode)

Aluminium (preferably aluminium foil) of extreme purity which is etched in most cases in order to increase the electrodes surface and, consequently, the capacitors capacitance yield.

4.2 Negative electrode (cathode)

Working electrolyte which is a conductive liquid in the case of capacitors with non-solid electrolyte or a layer of manganese dioxide MnO_2, conductive organic salt (e.g. TCNQ) or conductive polymer (e.g. polypyrrole) in the case of capacitors with solid electrolyte.

4.3 Dielectric

Aluminium oxide Al_2O_3 which is formed on the anode's surface by an anodizing process.

4.4 Contact element for the negative electrode

A high-purity aluminium foil ("cathode foil") in the case of capacitors with non-solid electrolyte or silver epoxy on graphite or other conductive connections in the case of capacitors with solid electrolyte.

4.5 Separator

Layers (preferably of special paper) which separate the anode foil from the "cathode foil" in the case of capacitors with non-solid electrolyte. The other purpose of these layers is to retain the working electrolyte.

4.6 External insulation

The metallic case of capacitors with non-solid electrolyte is not insulated against internal capacitor elements as the case may be connected e.g. through the conductive working electrolyte. Therefore, the capacitors need an external insulation sleeve if electrical insulation is required.

4.7 Polarity

Electrolytic capacitors are, on principle, polarized components. For special purposes, so-called non-polar (bipolar) capacitors may be provided. Such special types consist in principle of an internal back-to-back connection of two basically polarized elements. Note: Motorstart capacitors are bipolar (see clauses 13.4 and 18).

4.8 Sealing

The internal element of a non-solid electrolytic capacitor is normally encapsulated in an aluminium case closed with a sealing material which is never perfectly gas-tight. Because of using a non-solid electrolyte, of which ,some constituents are slowly diffusing through the sealing, the electrical characteristics of the capacitor are changing gradually over its entire life.

5 Protection measures

5.1 Handling and Transport

Capacitors are generally housed in a 99,5 % aluminium case giving rise to low mechanical strength. Shocks must be avoided and manufacturer's packaging must always be used to transport capacitors.

5.2 Insulation

Capacitors may be either completely or partially insulated with sleeving. It should be noted that the capacitor case is not insulated from the cathode terminal.

Axial leaded capacitors have a direct contact between case and cathode terminal. Radial leaded capacitors have an undefined contact through electrolyte or other parts inside the case. Dummy pins shall be left potential-free or may be connected to the potential of the negative terminal. Metal parts other than terminals should never make contact to conducting tracks or metal parts of other components.

6 General Application Limits

6.1 Polarity - Reverse voltage

Electrolytic capacitors for d.c. applications require polarization.

The polarity of each capacitor is to be checked both in circuit design and in mounting. Polarity is clearly indicated on the capacitor. For short periods a limited reverse voltage is allowed as specified in the relevant specification or by the manufacturer (e.g. 1 V for capacitors with non-solid electrolyte). Exceeding the specified reverse voltage can induce damage by causing overheating, over-pressure and dielectric breakdown and may be associated with open circuit or short circuit conditions – it is the most severe failure mechanism with aluminium electrolytic capacitors. There could even be a destruction of the capacitor. Protections are to be used if there are reverse voltage risks (see clause 11).

6.2 Voltage

Exceeding the capacitors specified voltage limits may cause premature damage (e.g. by breakdown with open or short circuit) affecting the useful life. Even destruction of the capacitor may be the consequence.

6.2.1 Rated voltage

The rated voltage U_R given in the relevant specification or by the manufacturer is the value permitted for continuous operation in the rated temperature range.

6.2.2 Surge voltage

For short periods the voltage may be increased up to the surge voltage value according to EN 130300, clause 4.14, and to manufacturer specification.

6.2.3 Transient voltages

The surge voltage value may be exceeded for very short periods or short pulses when in accordance with the relevant specification or as specified by the manufacturer. A test method is given in an amendment to EN 130300; at present document CECC(Secretariat)3498.

6.3 Temperature range

The capacitors are to be used within specified temperature range.

Applicable temperature ranges are given in the relevant specifications and/or in manufacturer's data. A general principle is: lower ambient temperature means longer life. Therefore, electrolytic capacitors should be placed at the coolest positions wherever possible.

Exceeding the permitted temperature causes overheating and over-pressure which can affect the useful life.

6.4 Ripple current

The sum of d.c. voltage and maximum amplitude of ripple voltage shall remain within rated voltage and 0 V.

Electrolytic capacitors are not normally designed for a.c. application (see clauses 1 and 18).

No excessive ripple current must be allowed to pass. Exceeding the ripple current specification reduces life and can induce overheating and over-pressure. Even destruction of the capacitor may be the consequence.

The useful life of the capacitor is a function of the r.m.s ripple current. Temperature, frequency and cooling conditions are other influences on the useful life.

6.5 Charge - discharge

Under the conditions defined in EN 130300, clause 4.20, or in manufacturers specifications, frequent charge / discharge operation is allowed.

Exceeding charge / discharge frequency leads to a high ripple current and induces damage by overheating and overpressure or breakdown with open circuit or short circuit, leading to a reverse voltage risk (see clause 6.1). Even destruction of the capacitor may be the consequence.

7 Storage

Capacitors should be stored at room temperature, normal atmospheric pressure, low humidity, and in manufacturers packaging. (See for more details in EN 130000, clause 4.2.)

Storage at elevated temperature (higher than 40 to 50 °C) has a negative influence to leakage current inducing increases up to 10 times the maximum limit where the capacitors are off duty (see EN 130300).

High humidity and/or high temperature may impair solderability and taping accuracy as well as the leakage current of the capacitors.

Storage at conditions defined above has a negligible effect on capacitance, tangent of loss angle or equivalent series resistance, and impedance.

Manufacturers recommendations (reforming procedures etc.) shall be considered because long storage may influence the leakage current to increase beyond a reasonable level.

8 External Pressure

(not relevant for capacitors with solid electrolyte)

8.1 Low air pressure

Minimum air pressure is 8 kPa for short periods in accordance with EN 130300, clause 4.

8.2 High air pressure

The maximum operating pressure is dependant upon size and style of the capacitor. It should be specified by the manufacturer on request. Exceeding the specified value may damage the capacitor (e.g. destroyed cases, open pressure relief device, short circuit etc.).

9 Self-recharge Phenomenon (Dielectric Absorption)

Even if aluminium electrolytic capacitors are totally discharged, these components may afterwards develop some voltage without external influence. This self-recharge phenomenon is known as dielectric absorption or as dielectric relaxation.

The capacitor is a non-ohmic conductor and has, therefore, a non-uniform distribution of the electric field. This is correlated with electric space charges within the dielectric layer. In the case of open terminals, an increasing voltage is built up in the course of the electric charges relaxation.

Depending on the capacitor type and its designed voltage, such self-recharge may result in values (even several tens of volts) which could represent some risk: damage of semiconductor devices, sparking when by-passing the terminals, and so on.

Therefore, appropriate measures are advisable if such risks are to be avoided. In particular for capacitors of high capacitance and high electric charge, it is recommended, for instance, to keep the terminals shorted or to repeat the discharge before mounting them.

10 Flammability (Passive and Active)

Aluminium electrolytic capacitors contain materials which may inflame under the influence of external fire (passive flammability) or in case of a defect of the component (active flammability). Such flammable parts of the capacitor are for instance: plastic parts, insulation sleeve, moulding compounds, paper of the capacitors winding element, in some cases working electrolytes.

10.1 Passive flammability

Under the influence of high external energy, such as fire or electricity, the flammable parts may ignite. Clause 38 of the relevant Specification EN 130000 refers to IEC 60695-2-2 (Needle Flame Test) for testing the passive flammability of capacitors. And in EN 130000, clause 4.38, the severities and requirements for different categories of flammability are listed. Most aluminium electrolytic capacitors meet the requirements of category B or C as given in the relevant specifications or by the manufacturer.

10.2 Active flammability

In rare cases the component may ignite caused by heavy overload or some capacitor defect. One reason could be that during the operation of an aluminium electrolytic capacitor with non-solid electrolyte, there is a small quantity of hydrogen developed in the component. Under normal conditions, this gas permeates easily out of the capacitor. But under exceptional circumstances, higher gas amounts may develop and may catch fire if sparking occurs at the same time.

As explained above a fire occurrence cannot be totally excluded. Therefore, it is recommended to use special measures in critical applications (e.g. additional encapsulation of the equipment for mining applications).

11 Internal Pressure and Pressure Relief Device

(not relevant for capacitors with solid electrolyte)

During the operation of the aluminium electrolytic capacitor with non-solid electrolyte, some gas develops in the component. Under normal conditions, this small amount permeates without any problems slowly out of the capacitor. But cases like an overload, application of reverse voltage, or a malfunction of the capacitor may cause a higher gas production which cannot be covered by the normal permeation and leads to a considerable overpressure in the component.

This high internal pressure can lead to the rupture of capacitor body/casing. That is not too dramatic as long as small capacitors are concerned because the pneumatic energy is low. For larger types, the relevant detail specifications will indicate that the capacitor is equipped with a specific pressure relief device ("safety vent") which opens at a relatively low pressure and, therefore, limits the above mentioned risk of rupture.

The test of the proper function of this pressure relief device is specified in clause 4.28 of EN 130000. The test methods described therein prove whether the pressure relief device covers the majority of the fault events where the pressure increase is not too extreme.

In rare cases, such as extreme overload or ignition of gas inside the capacitor (through sparking caused by breakdown), a fully functioning pressure relief device may not react in time. Therefore, capacitors exposed to such limit conditions must be shielded. The same apply in case of testing the pressure relief device.

When using the capacitors, care has to be taken that the proper function of the pressure relief device is not impaired for instance by mounting measures such as clamps or glue and potting compounds.

12 Working Electrolytes and Contact With an Electrolyte

(not relevant for capacitors with solid electrolyte)

Capacitors with non-solid electrolyte contain high purity aluminium foils and papers that are impregnated with a suitable electrolyte. To give the electrolytic capacitor a long and stable life the ingredients must be very pure. Impurities such as chloride or metals are not allowed.

The electrolyte is a biodegradable liquid based on a stable solvent with a high boiling point as the main ingredient. (Common solvents are γ-butyrolactone or ethylene glycol.) Furthermore the electrolyte consists of an acid base system and other added chemicals that are dissolved in it. The electrolyte is chemically neutral and contains no PCBs or other halogenated compounds. It has a low toxicity but prolonged inhalation of vapours should be avoided.

However it is advisable to avoid contact with the skin or the eyes. Exposure of electrolyte on the skin shall immediately be treated by rinsing with water. Exposure to the eyes shall be flushed for 10 minutes by rinsing with water. Medical attention should be sought if problems persist. Inhalation of electrolyte vapours or dust particles from electrolyte shall be avoided. If vapour of electrolyte is present the air in the room must be ventilated. Smoke from burning electrolyte is irritating but does not contain dioxins or similar highly toxic substances. If electrolyte gets on cloth it can be washed with water.

13 Parallel and Series Connection

13.1 Parallel and series connection of capacitors

Connection of aluminium electrolytic capacitors in series / parallel banks gives rise to the following considerations:

13.1.1 Voltage sharing between devices

This factor is influenced by the leakage current difference between the individual capacitors in the chain. It is very important that the leakage current differences are compensated for at the design stage as fairly small differences can cause problems.

This is normally evidenced at turn on as an overvoltage condition on the components with the lowest leakage currents and can lead to premature failure.

Depending on the circuit configuration of the bank and failure mode other components which were initially unaffected could at this stage be subjected to voltages considerably in excess of the ratings and will also fail.

This leakage current difference is normally controlled by the use of resistors across each of the individual components or in the case of a common centre connection by only two resistors.

13.1.2 Circuit configuration

There are two major configurations to consider when constructing a series / parallel bank of capacitors. The advantages and disadvantages of each are outlined below but the final choice must be made by the equipment designer.