ALUMINUM ELECTROLYTIC CAPACITORS

TECHNICAL NOTE

5 Reliability
5-1 The bathtub curve:
Aluminum electrolytic capacitors feature failure rates shown by the following bathtub curve.

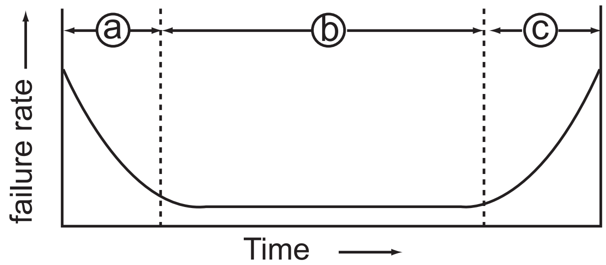

Fig. 5-1 bathrub curve

a) Infant failure period
This is a period during which failures are caused by deficiencies in design, structure, manufacturing process or severe misapplications. Such failures occur soon after the components are exposed to circuit conditions. In aluminum electrolytic capacitors, these failures are either corrected through aging process reforming or repairing a damaged oxide layer, or found by the aging process, removed by the sorting process, and thus do not reach the field.
Infant failures due to capacitor misapplication such as inappropriate ambient comditions, over-voltage, reverse voltage or excessive ripple current can be avoided with proper circuit design and installation.

b)Useful life period
This is a random failure period during which the failure rate is the lowest. These failures are not related to operating time but to application conditions. During this period, non-solid aluminum electrolytic capacitors show a slow decrease in capacitance and a slow increase in tan δ and ESR, which are caused by a small loss of electrolyte, and feature fewer catastrophic failures than semiconductors and solid tantalum capacitors.

c)Wear-out failure period
This is a period during which the properties of a component extremely deteriorate, and the failure rate increases with time. Non-solid aluminum electrolytic capacitors end their useful life during this period.

5-2 Failure types:
The two types of failures are classified as catastrophic failures and wear-out failures as follows,
① Catastrophic failure
Like a short circuit or open circuit failure, this is a failures mode which destroys the function of the capacitor.
② Wear-out failure
This is a failure mode resulted by the gradual deterioration of the capacitor electrical parameters. The criteria for judging the failures varies with application and design factors.
Capacitance decrease and tan δ increase are caused by the loss of electrolyte in the wear-out failure period. This is due primarily to loss of electrolyte by diffusion(as vapor)through the sealing material. Gas molecules can diffuse out through the material of the end seal. If the electrolyte vapor pressure within the capacitor is increased, by high temperatures for example, the diffusion rare is increased. Swelling of the seal material by electrolyte vapor pressure may also occur at elevated temperature.This swelling may further enhance diffusion and mechanically weaken the seal.

5-3 Failure modes:
Aluminum electrolytic capacitors show various failure modes in different applications.(see table below.)

5. 可靠性
5-1 浴缸曲线
铝电解电容器的失效率性可以用下图的浴缸曲线来描述。

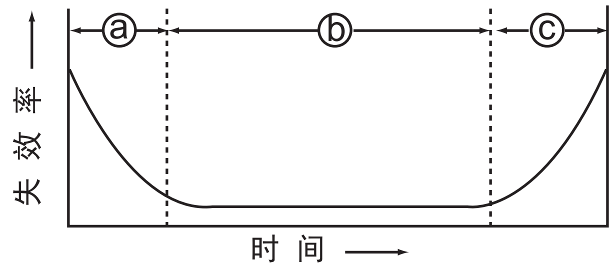

图 5-1 浴 缸 曲 线

a）早期失效阶段
早期失效阶段是由于在设计、结构、制造工艺中存在缺陷或由于严重的使用不当而造成产品失效的阶段。这种失效在元件通电后不久就会被发现。在铝电解电容器中，这种失效要么通过老化过程中对损坏的氧化膜重新化成或修补得以避免，要么在老化过程中被发现，在测试分选时被剔除，因此不会进入使用领域。
由于使用环境不当、过电压、施加反向电压或纹波电流过大等使用不当引起的早期失效，可以通过适当的电路设计和安装方法加以避免。

b）使用期阶段
这是一个随机的失效阶段，通常该阶段的失效概率很低。这种失效与工作环境有关，与工作时间无关。在此阶段，非固体电解质电容器表现为容量缓慢下降，损耗和ESR逐渐上升，这是由于电解液量逐渐减少引起的，很少会出现半导体和固体钽电容器那种致命性的失效。

c）耗损失效阶段
该阶段，元件的性能急剧恶化，失效率随时间而上升。非固体铝电解电容器在此阶段结束其使用寿命。

5-2 失效类型：
失效的类型分为两种，致命性失效和耗损性失效。
① 致命性失效
诸如短路和开路失效，这种失效模式破坏了电容器的使用功能。
② 耗损性失效
这是一种由于电容器电参数逐渐恶化而造成的失效，判断失效的标准也随应用和设计参数的改变而不同。耗损失效阶段，由于电解液的减少，容量下降，损耗角正切上升，这是由于电解液以蒸汽形式从封口材料而散失。如果由于高温等原因使电容器内部蒸汽压力上升，则扩散的速度也会上升。温度上升造成的电解液蒸汽压力也会导致封口材料的膨胀，这种膨胀可能进一步加强电解液的渗透，同时削弱密封作用。

5-3 失效模式：
铝电解电容器在不同情况下表现出不同的失效模式（见下表）