Panasonic

EVOLVING CAPACITOR TECHNOLOGY WITH OUTSTANDING ESR VALUES

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Electrolytic Capacitors

ELECTROLYTICS PROVIDE HIGH RIPPLE CURRENT CAPABILITY TOGETHER WITH HIGH RELIABILITY AT AN EXCELLENT PRICE/PERFORMANCE RATIO

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1.0 VERSION WHITE PAPER

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INTRODUCTION

It is tempting to think that some components are so basic, so well-understood, that whatever supplier you choose or product you select – given that the CV rating is as specified on the drawing, the part will suffice. Capacitors could fall into this category of device; after all, back in 1745 it was demonstrated that a charge could be stored by connecting a high-voltage electrostatic generator by a wire to a volume of water in a hand-held glass jar; early radios used porcelain ceramic capacitors; organic capacitors followed soon after and even super-capacitors first appeared back in the 1950s. Modern devices have, of course, kept pace with industry trends of miniaturisation and today there are many suppliers competing in the market.

Electrolytic capacitors use an electrolyte to achieve a larger capacitance than other capacitor types. However, there are several drawbacks to this technology, including low rated ripple current, wide value tolerances, high ESR (equivalent series resistance) and a limited lifetime. A poorly chosen component costing cents can lead to a system failure just as surely as a complex ASIC or microprocessor. Therefore it is prudent to pay attention and give due diligence to the selection of the capacitor, just as any other component.

Although there are other technologies competing for the same market – most notably polymer and hybrid polymer capacitors - electronics design engineers feel comfortable with electrolytics. They know their characteristics and behaviour patterns and have been using them for many years. Familiarity with technology, long approval processes for qualifying a new technology and reliance on BOM-based reduction are factors for this reticence. Panasonic - as a leading capacitor manufacturer, offers diversified products across all three technology ranges. The company has developed one of the widest product ranges; available in both through hole and surface mount configurations.The company is continuing to invest in manufacturing capacity and crucially, also in product development. Therefore, the performance of electrolytic capacitors is continually improving across all the significant parameters.

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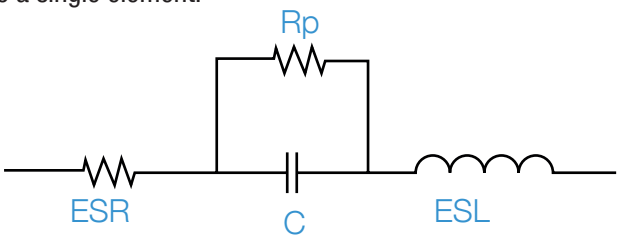
ESR - EASIER TO DEFINE THAN SPECIFY

The capacitor equivalent circuit comprises four elements (Figure 1): capacitance; equivalent series inductance (ESL) - the sum of inductive elements including leads; a high-resistance DC path (Rp) in parallel with the capacitance; and equivalent series resistance (ESR) - the series resistive effects combined into a single element.



Picture 1 - the equivalent circuit of a capacitor is made up of four apperently simple elements

ESR is frequency-dependent, temperature-dependent, and also changes as components age. It is usually only a significant consideration in selecting electrolytic capacitors.This shows that the company is expanding in several different directions, depending on the demands of the target application.For power supplies, one of the key requirements is low ESR. This because today's microprocessors need very accurately-specified support circuitry; also ESR impacts on efficiency and ultimately power consumption. With regulatory bodies around the world (ENERGY STAR, EU Code of Conduct, etc) demanding ever tighter control on energy efficiency, it's vital to consider ESR of the capacitor as one of the basic parameters alongside capacitance and voltage.

WHY IS ESR IMPORTANT?

Electrolytic capacitors are used as input buffers to supply energy when the mains input voltage is too low, store energy while an AC/DC converter adapts to a new power level, and prevent switching noise from the converter reaching the power source. On the output of a converter, they act as a filter and current sink for inductive elements and, in DC/DC conversion, function as an energy buffer when the power output demand changes.

In both cases, losses due to ESR will inhibit the ability of a capacitor to quickly source or sink charge. At the input, increasing ESR increases high frequency noise across the capacitor, decreasing filtering effectiveness. At the output, higher ESR causes more ripple, influencing the stability of the control loop.
ESR is particularly important in applications with low duty-cycle, high-frequency current pulses. Here, the ripple voltage due to the ESR will be greater than expected based on capacitance alone, although the negative correlation of ESR with temperature means that ripple decreases as the assembly warms up.

Also, the introduction of a resistive element into what designers may assume is a purely reactive circuit can lead to unexpected shifts in phase response, again affecting stability.

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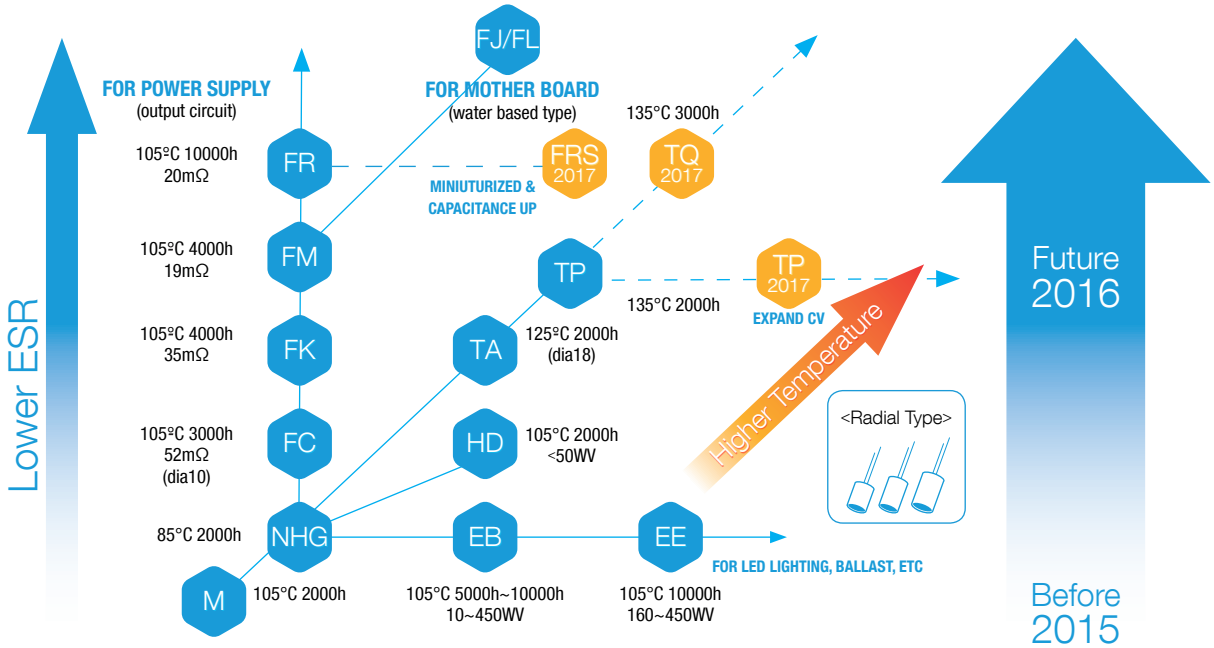

Picture 2 details the company's roadmap for throughhole technology electrolytic capacitors based on the demands of different applications

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WHAT CAN BE DONE?

Some capacitors are designed specifically for low ESR, but manufacturers of aluminium electrolytic capacitors do not specify ESR consistently. The ESR value at 25°C and 100kHz is commonly quoted with a formula provided to calculate the value at the operating frequency. Some suppliers specify at 120Hz; others leave the designer to calculate the figure at the frequency of interest from the dissipation factor (tanϑ) and specified maximum ripple current. Furthermore, for capacitors of comparable size and CV, a device with higher capacitance and lower voltage rating will have lower ESR and ESR tends to be lower for aluminium electrolytic devices with long, thin cases because the resistance of the foil is reduced. Larger overall case sizes can cut ESR too. Also, several smaller-value components can be used in parallel to achieve lower high-frequency ESR, at the expense of board space.

So we can see that high ESR values lead to greater power loss (inefficiency); also with high ESR, the internal temperature of the capacitor increases, decreasing its capacitance and reducing its lifetime. However, low ESR leads to low ripple values (often expressed as greater ripple capacity), so the device will be a much better fit for a system based on a current-generation microprocessor.

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PANASONIC & ELECTROLYTICS AND APPROPRIATE FIELDS OF APPLICATION

For automotive applications, high temperature performance is critical. Electronic systems are becoming all-pervasive in automobiles, and while some applications – entertainment systems for example – are not as critical as others, any under the hood or exposed driver-assist (parking sensors, rear vision) systems are likely to experience extremes of temperature and will need to be able to rugged enough to withstand continuous vibration. As we move into the era of the 'driverless car', the demands put upon the quality and performance of electronic systems, not only by the car manufacturers but also by insurance and public liabilities organisations, will increase hugely. Electrolytic capacitors are continually evolving to address his challenge.

Picking out one of the key series in THT technology, we can see

that leading the evolution in low ESR is the FR series, which offers ESR as low as 18 mΩ - just about the lowest available for an electrolytic capacitor on the market today. Devices are as small as 5 mm in diameter and 8 mm above board height. They have an operational life of 10,000 hours rated at 105degC. The TP series and its off-shoots suit high temperature segments for applications that require operation up to 135°C for 2000 hours. The FRS series, which will be introduced in early 2017, will bolster the higher temperature area, bringing smaller can sizes and lower ESR with high reliability and longer lifetimes at 135°C.

The EE and ED Series are high voltage, 100V to 450V devices that are smaller or the same size as capacitors with similar specifications. Both series are available in 5mm/3.5mm/7.5mm lead spacing. Panasonic ED Series capacitors are type A, radial leaded, polarized aluminium electrolytic capacitors with capacitance values ranging from 10µF to 330µF. These capacitors are the perfect solution for applications which require ultra low ESR, very high ripple current and extended life. The EE Series has an outstanding high ripple current (at high frequency) which is approximately 40% greater than that of the ED Series and guarantees 800 – 10,000 hours at 105degC.

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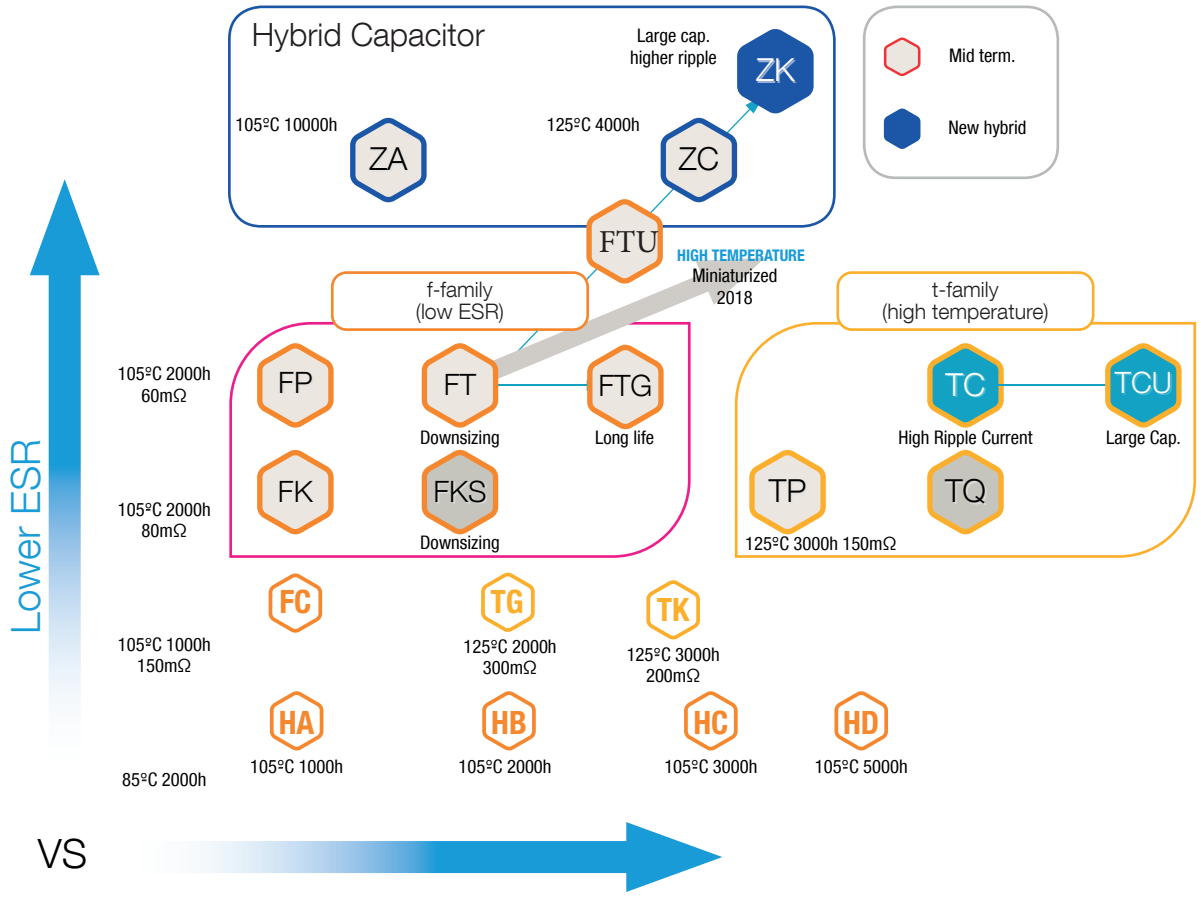
We can see that the same themes as for through-hole devices - lower ESR, longer life and miniaturisation, and a higher operating temperature – also hold true for surface mount parts. Highlighting some of the most recent developments, the F-Series addresses the lower temperature area. The FK-Series is by far the most extensive in this temperature range, because of its broad offering in terms of can sizes, low ESR and variations in soldering reflow conditions.

The H-Series and its off-shoots are rated at 105°C and are Panasonic's commodity SMD electrolytic capacitors . The FT- and FP-Series feature low ESR values down to 60mΩ in a package size measuring ø10x10 mm beginning with prefix EEET form the higher temperature spectrum from the electrolytic portfolio for 125°C.



Picture 3 details the company's roadmap for smd technology electrolytic capacitors based on the demands of different applications

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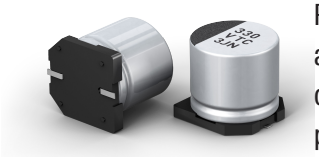
The FK-Series offers better ripple current rating in the THT line-up keeping smaller case-sizes. Between the FR and the FC series, Panasonic covers the commodity end of the market for lower voltages, while the FK-Series is designed for the upper spectrum where RCR is the decisive factor.

FKS-Series devices introduce the next generation of aluminium electrolytic capacitor technology and offer the benefits of smaller case sizes while guaranteeing the same performance as larger conventional types. Due for introduction in the first quarter of 2017, the FKS-Series will be a revolution in size and performance. Using advanced foil technology, this series contributes to the downsizing of PCB designs by delivering the same performances as legacy capacitors, but in one case size smaller. The AEC-Q200 qualification of the FKS-Series ensures these capacitors meet the most stringent quality standards in the industry. If required, Panasonic is also able to provide a vibration-proof variant for all parts with a diameter of 8mm or greater. These vibration-proof parts can withstand shocks of up to 30G (standard parts can withstand 10G maximum).



Panasonic's new V-TC and V-TCU aluminium electrolytic capacitors deliver high ripple current and capacitance while maintaining the same footprint as previous generation devices. Panasonic introduced its new TC series in the second half of 2016. Most of the new TC series parts are rated at 125°C and provide an endurance of 3000 hours. Ripple current ratings as high as 750mA ensure that the devices suit applications requiring both endurance and high levels of current.

AEC-Q200 compliance for Panasonic's entire TC-Series of aluminum electrolytic capacitors ensures optimal quality and reliability. The recently released TCU-Series of aluminium electrolytic capacitors meets the market demand for higher ripple current handling. Developed from the proven V-TP-Series components, the new V-TCU-Series benefit from 1.2 to 1.5 times higher ripple current capabilities at 125°C (V-TCU -Series 400mA for F can size, up to 750mA for G can size). In addition, V-TCU parts also offer 1.2 to 2.2 times greater capacitance values (220µF up to 680µF) while downsizing by one can size (G to F size or F to D8 size) and are currently the smallest size solution within Panasonic's electrolytic portfolio. Ideal for applications such as automotive ECU in DC/DC filtering and output ripple smoothing, the can-shape surface-mount capacitors feature footprints, ranging from 6.3mm x 7.7mm up to 10mm x 10.2mm and a lifetime of 2000 hours for smaller can sizes and 3000 hours for larger can sizes.

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Readers will see from these two roadmaps that breadth of product range is one of Panasonic's key strengths. Because the company has pushed the envelope of performance, often it is possible that a device with lower specification from within the company's portfolio will compare very favourably with a leading device from another supplier. Therefore, it is important to consider all parameters, not just CV, when specifying your required component. Some manufacturers' data sheets are written to display their parts in the best possible light – performance will be quoted at room temperature, for example, rather than a real world environment – while others, including Panasonic, tend to be more conservative. Therefore, although it is sometimes a lengthy process to compare datasheets, it pays to read the fine print. Because of its wide electrolytic portfolio, including very different product series in both through-hole and surface mount styles, Panasonic is likely to have a device that matches your requirement.

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