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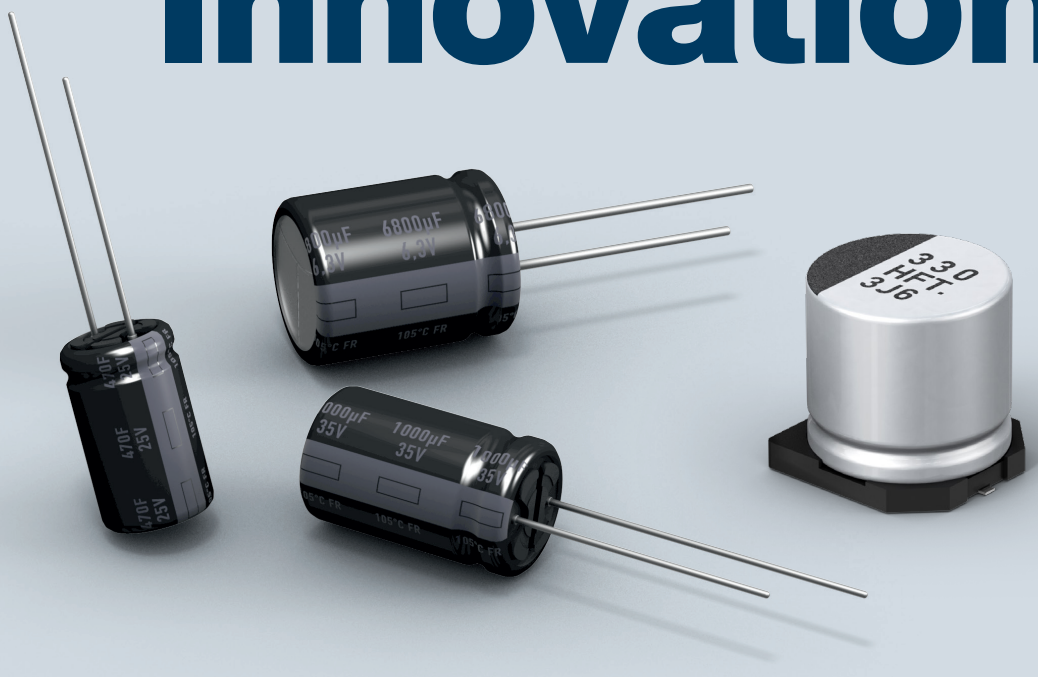
Your Committed Enabler

Evolving capacitor technology with outstanding ESR values

Electrolytics provide high ripple current capability together with high reliability at an excellent price/performance ratio

White Paper

IN Your Innovation



IN Your Future

Index

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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 handheld 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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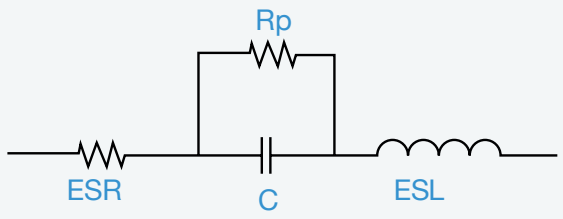
What is ESR?

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.

Figure 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 is 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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Advantages of Low ESR Capacitors

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 100 kHz is commonly quoted with a formula provided to calculate the value at the operating frequency. Some suppliers specify at 120 Hz; others leave the designer to calculate the figure at the frequency of interest from the dissipation factor (tan ∂) 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.

On the other hand, low ESR capacitors produce low ripple voltage and provide cleaner, more stable power, which is critical for the reliable operation of current-generation microprocessors. They help ensure optimal performance, efficiency, and longevity of both the power supply components and the microprocessor itself.

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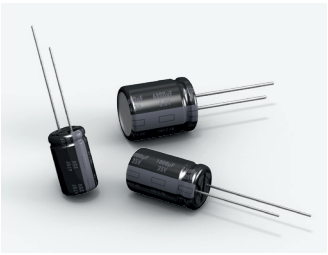
Panasonic's Low ESR Series and Its Unique Selling Points

Exploring Panasonic's Low ESR THT Solutions

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 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 this 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 impedance as low as 12mΩ (at 100kHz and 20°C) – just about the lowest available for an electrolytic capacitor on the market today. Devices are as small as 5 mm in diameter and 11 mm above board height. They have an operational life of up to 10,000 hours rated at 105 °C.

The TP series and its off-shoots suit high temperature segments for applications that require operation up to 135 °C for 2,000 hours.

The EE and ED Series are high voltage, 160 V to 450 V devices that are smaller or the same size as capacitors with similar specifications. Both series are available in 5 mm/7.5 mm lead spacing. Panasonic ED and EE Series capacitors are type A, radial leaded, polarized aluminium electrolytic capacitors with capacitance values ranging from 10 µF to 330 µF.

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 especially outstanding high ripple current (at high frequency) which is approximately 40% greater than that of the ED Series and guarantees 8000–10,000 hours at 105 °C.

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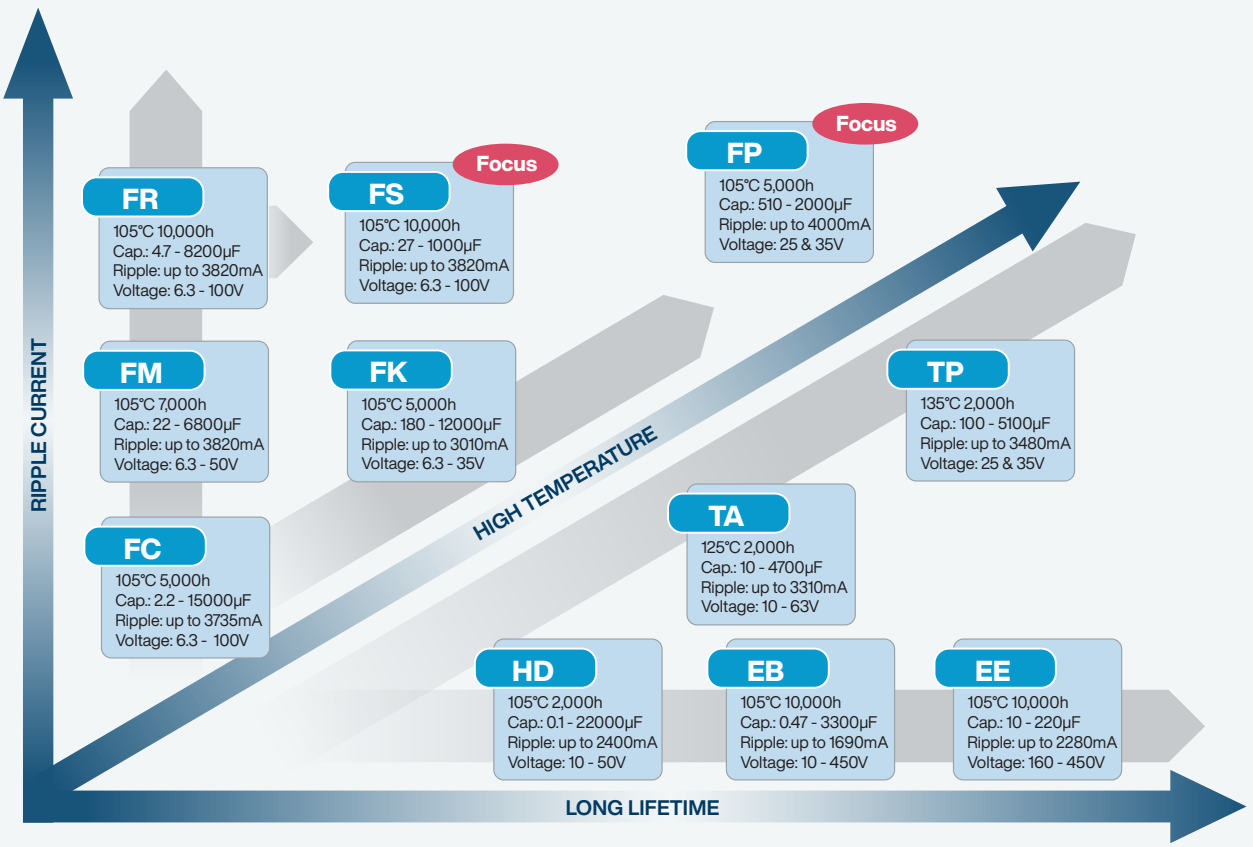
Figure 2
Electrolytic Capacitors THT Series Overview



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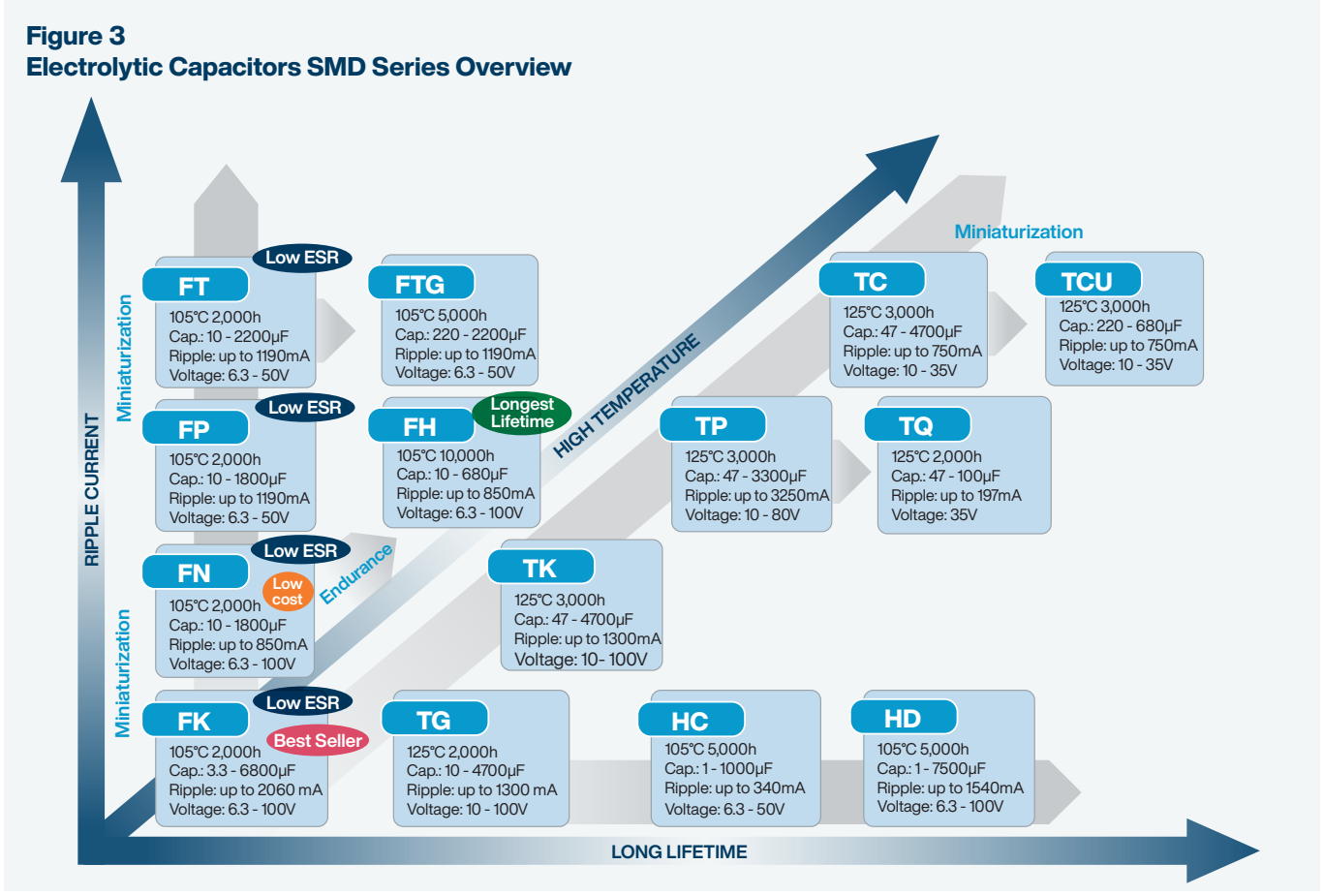
Exploring Panasonic's low ESR SMD Solutions

We can see that the same themes as for through-hole devices – lower ESR, longer life, 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 exten-sive in this temperature range, because of its broad offering in terms of capacitance, rated voltage, can sizes, low ESR, and variations in soldering reflow conditions. The low ESR values from Panasonic's FK series make this series ideal for high-performance applications where efficiency is crucial and energy loss from self-generated heating should be minimized. For even greater low-ESR performance, the FT and FP series offer exceptional values down to 60mΩ in a compact 10x10mm package, further enhancing their suitability for demanding, high-efficiency systems.

Figure 3
Electrolytic Capacitors SMD Series Overview



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Panasonic's FN-series introduces the next generation of aluminium electrolytic capacitor technology, offering the advantages of smaller case sizes while maintaining the performance levels of larger, conventional types. Utilizing advanced foil technology, the FN-Series represents a significant breakthrough in size and performance, supporting cutting-edge, miniaturized design applications.

Panasonic's higher-temperature electrolytic capacitors operating at 125°C are identified with the prefix EEET- in their part numbers, signifying their extended temperature range within the electrolytic portfolio.

For example, the V-TC and V-TCU aluminium electrolytic capacitors deliver high ripple current and capacitance while maintaining the same footprint as previous generation devices. Both the TC series (excluding case size D8) and the TCU series are rated for 125°C and provide an endurance of 3,000 hours. Their ripple current ratings are notably high, reaching up to 750mA at 125°C.

The TCU series is an upgraded version of the TC series, offering higher capacitance within the same case size thanks to advanced foil technology. This enhancement allows these capacitors to handle 1.2 to 1.5 times higher ripple currents at 125°C compared to older series, addressing the increasing demand for robust ripple current handling in the market.

Designed for applications such as automotive ECUs, DC/DC filtering, and output ripple smoothing, these can-shape surface-mount capacitors come in footprints ranging from 6.3mm x 6.1mm up to 18mm x 21.8mm. Most part numbers boast a lifetime of 3,000 hours at 125°C, ensuring reliable performance in demanding environments.

Speaking of automotive applications, all Panasonic surface-mount electrolytic capacitors are qualified to the stringent AEC-Q200 standard, ensuring they meet the highest industry demands for reliability and quality. Selected through-hole (THT) variants also adhere to these rigorous requirements, providing added assurance for your applications.

For applications subject to high mechanical stress, such as intense vibrations, Panasonic offers vibration-proof variants for surface-mount parts with a diameter of 6.3mm or greater. These vibration-proof versions can withstand shocks up to 30G, compared to the standard parts' maximum of 10G.

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The two graphs above illustrate Panasonic's extensive active series lineup, highlighting the company's key strength in offering a broad and diverse product range. By continually pushing performance boundaries, Panasonic's devices often outperform higher-rated alternatives when evaluated based on actual performance, despite lower datasheet specifications.

Therefore, when selecting components, it is crucial to consider all relevant parameters including ESR values and others — not just capacitance and voltage. Some manufacturers' datasheets may showcase their parts in the best possible light, often quoting performance at room temperature rather than under real-world conditions. In contrast, Panasonic's datasheets tend to adopt a more conservative approach, providing a realistic assessment of device capabilities.

While comparing datasheets can be a detailed process, paying close attention to the fine print is well worth the effort. Thanks to its extensive and versatile electrolytic portfolio—spanning numerous series in both through-hole and surface-mount styles—Panasonic is confident that it can supply a device perfectly suited to your specific application and requirements.

Panasonic matches your requirement thanks to it's wide electrolytic portfolio, including very different product series in both through-hole and surface mount styles.

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We are dedicated to the highest standards of global sustainability as **Your Committed Enabler**. Find out more on our website.

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11/25