DERATING

The derating guidelines for each of the major classes of capacitors are addressed separately, beginning in this section. Capacitors are derated by limiting applied voltage and operating temperature.

Table 1. Derating Requirements of Capacitors in Tabular Form (Summary)[3]

Capacitor Style	Derating Parameter		
	Voltage (Max % of Rated max)	Max Temperature	Reverse Voltage
Fixed, Paper, Film	55%	T_{MAX} - 10°C	N/A
Fixed, Plastic, Film	55%	T_{MAX} - 10°C	N/A
Fixed, Metallized Paper-Plastic	55%	T_{MAX} - 10°C	N/A
Fixed, Mica, Conventional	70%	T_{MAX} - 25°C	N/A
Fixed, Mica, Button	55%	T_{MAX} - 10°C	N/A
Fixed, Glass	60%	T_{MAX} - 15°C	N/A
Fixed, Ceramic, General Purpose	60%	T_{MAX} - 15°C	N/A
Fixed, Ceramic, Temp. Comp.	60%	T_{MAX} - 10°C	N/A
Fixed, Ceramic, Chip	60%	T_{MAX} - 10°C	N/A
Fixed, Tantalum, Chip	60%	T_{MAX} - 10°C	N/A
Fixed, Electrolytic, Tantalum, Solid	60%	T_{MAX} - 10°C	2% of Forward
Fixed, Electrolytic, Tantalum, Non-Solid (Wet and Foil)	60%	T_{MAX} - 10°C	2% of Forward
Fixed, Electrolytic, Aluminum	70%	T_{MAX} - 10°C	N/A
Fixed, Electrolytic (Dry), Aluminum (Polarized)	70%	T_{MAX} - 10°C	N/A
Variable, Ceramic	60%	T_{MAX} - 10°C	N/A
Variable, Piston	60%	T_{MAX} - 15°C	N/A
Variable, Air Trimmer	60%	T_{MAX} - 10°C	N/A
Variable and Fixed, Gas or Vacuum	60%	T_{MAX} - 10°C	N/A

Additional derating is necessary for ripple current for capacitor styles that substantially degrade due to the temperature effects of high ripple current. The derating guidelines for some capacitor styles is very complex due to a non-linear relationship between failure rate and stress level (e.g., film/foil styles). For convenience to the user, the derating requirements for all capacitors are also presented in Table 1. Care must be taken when using this table because it does not show linear derating between T_S to T_D. Consult individual sections for linear derating requirements.

Capacitors, Fixed, Paper Film

This is a low cost capacitor designed for circuits requiring high insulation resistance, low dielectric absorption, and where the ac component of voltage is small in respect to dc voltage rating. Available in medium capacitance values (0.001 μf – 100 μf).

Construction

This film/foil capacitor style is composed of a metal foil (usually aluminum) with paper serving as the dielectric. The leads are welded directly to the metal foil.

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[3] Note: This table is only intended to serve as a convenient summary of the derating requirements for capacitors. The actual derating requirements are contained in Figures 1 through 18.

Derating Requirements

Voltage: Derate voltage to 55% of maximum rated voltage when below 0^{o}C. Linearly derate from 55% at 0^{o}C to 50% at T_S as shown in Figure 1, where $T_S = T_{MAX} - 35^O C$. Linearly derate from 50% at T_S to 30% at T_D, where $T_D = T_{MAX} - 10^O C$. Do not use within 10^{o}C of maximum rated operating temperature.[4]

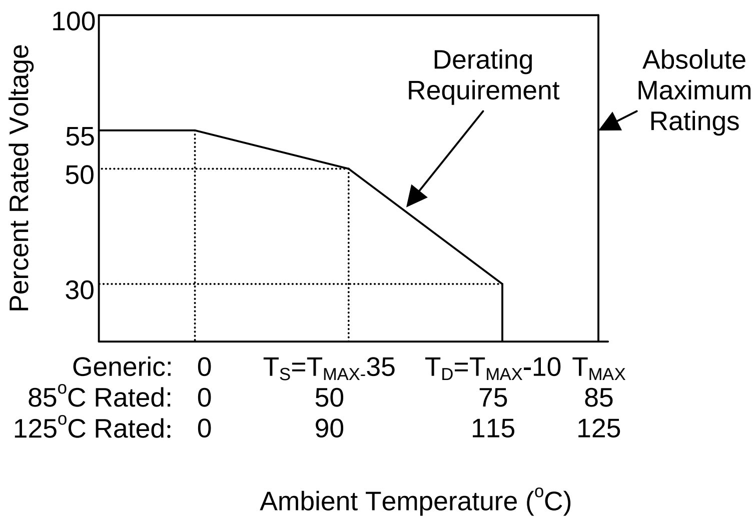

Figure 1. Derating Requirement for Fixed, Paper Film Capacitor

Application Information

Reliability: Reliability is considered poor in comparison to other capacitor styles, especially in high humidity applications because paper dielectric tends to absorb moisture. Paper films are capable of withstanding higher voltages than metallized paper styles due to the increased heat sinking capability of a thicker electrode foil. The most common failure mode is a catastrophic short or an open circuit.

Tolerance/Aging: Typical purchased tolerance is 5 and 10%. Stability is considered good except in high humidity conditions. Design is recommended to be able to tolerate an additional 2% change in capacitance value to assure long life. Because the capacitor lacks self-healing capabilities, it tends to fail prior to substantial drift in capacitance.

Frequency Characteristics: This capacitor is available across a wide range of common operating frequencies.

Military Considerations

Figure 1 specifies the temperature derating requirements for capacitors conforming to MIL-C-25 (Style CP), MIL-C-12889 (Style CA), and MIL-C-11693 (Style CZ and CZR).

Capacitors, Fixed, Plastic Film

These are a broad class of plastic and paper-plastic film/foil styles with similar failure characteristics and modes. This style is generally intended for high voltage applications where the AC component of voltage is small in comparison to the DC component.

Construction

This capacitor is similar in construction to paper styles, except a plastic replaces paper as the dielectric. It is subdivided into several types and classified according to plastic dielectric.

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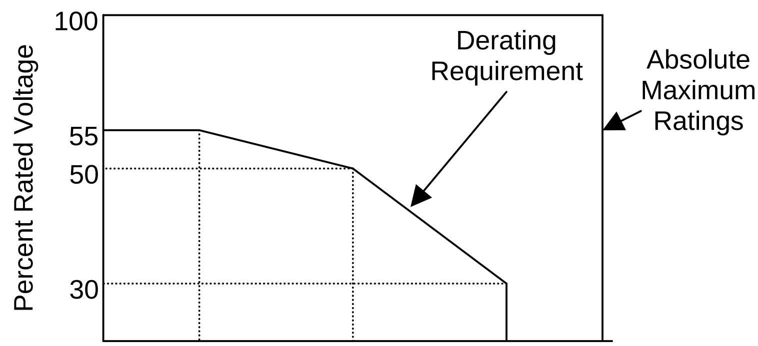
[4] Note: Derating of all film/foil capacitors is identical due to similar failure characteristics. This includes paper-plastic, plastic, and metallized paper-plastic styles.

Derating Requirements

Voltage: Derate voltage to 55% of maximum rated voltage when below 0^oC. Linearly derate from 55% at 0^oC to 50% at T_S as shown in Figure 2, where $T_S = T_{MAX} - 35^O C$. Linearly derate from 50% at T_S to 30% at T_D, where $T_D = T_{MAX} - 10^O C$. Do not use within 10^oC of maximum rated operating temperature.



Generic:	0	$T_S=T_{MAX}$ -35	$T_D=T_{MAX}$-10	T_{MAX}
65^oC Rated:	0	30	55	65
85^oC Rated:	0	50	75	85
125^oC Rated:	0	90	115	125
170^oC Rated:	0	135	160	170

Ambient Temperature (^oC)

Figure 2. Derating Requirement for Fixed Paper and Plastic Film Capacitor

Application Information

Table 2 identifies the major type categories of plastic capacitors and typical working voltages and capacitance ranges for each. Cost and performance characteristics of each type vary and the details are too complex to discuss here. Plastic styles are generally intended for higher temperature applications and harsher environmental conditions than paper styles. In addition, plastic styles generally exhibit high insulation resistance at high temperature.

Table 2. Plastic Dielectric Capacitor Types

Type	Typical Capacitance Range	Typical Working Voltage
Polyester	1nf – 15μf	50V – 6KV
Polycarbonate	100pf - 15μf	63V – 1KV
Polypropylene	100pf - 10μf	63V – 2KV
Polystyrene	10pf – 47nf	30V – 630V

Reliability: The reliability varies with type, but plastic capacitor reliability is generally higher (by ≈10X) than paper styles, especially in high humidity conditions.

Tolerance/Aging: The purchased variance and temperature sensitivity varies between types. Polycarbonate (Q Style) types are particularly insensitive to temperature (typically, +100ppm/^oC).

Frequency Characteristics: This style has similar frequency characteristics to paper styles. It can generally be used across the entire common frequency range (as shown in Figure 2 of the Capacitor Packaging section).

Military Considerations

Figure 2 specifies temperature-derating requirements for capacitors conforming to MIL-PRF-19978 (Style CQR, paper and polyethylene terephthalate).

Capacitors, Fixed, Metallized Paper-Plastic Film

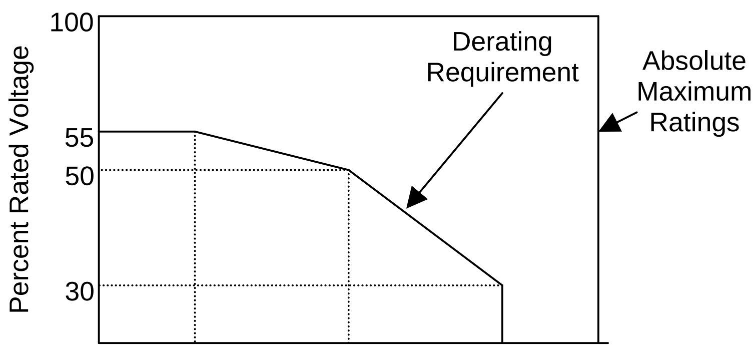
This film/foil style capacitor is intended for applications similar to paper and plastic styles, but where increased capacitance is needed for the same volume. It exhibits higher reliability and less sensitivity to environmental conditions than non-metallized styles. It generally is not intended for high impedance, low voltage applications.

Construction

The basic structure is similar to paper and plastic styles, except the electrode is a thin layer of vacuum deposited metal (onto the dielectric film) instead of an independent conductive foil. The metallization thickness varies with manufacturer and dielectric type. The lead is welded to a metal sprayed on each end of the capacitor section.

Derating Requirements

Voltage: Derate voltage to 55% of maximum rated voltage when below 0°C. Linearly derate from 55% at 0°C to 50% at T_S as shown in Figure 3, where $T_S = T_{MAX} - 35^O C$. Linearly derate from 50% at T_S to 30% at T_D, where $T_D = T_{MAX} - 10^O C$. Do not use within 10°C of maximum rated operating temperature.



Generic:	0	T_S=T_{MAX} -35	T_D=T_{MAX}-10	T_{MAX}
85°C Rated:	0	50	75	85
125°C Rated:	0	90	115	125

Ambient Temperature (°C)

Figure 3. Derating Requirement for Fixed, Metallized Paper, Paper-Plastic, and Plastic Capacitor

Application Information

The unique metallization process and thinner electrode film will increase capacitive efficiency for this capacitor style. This results in higher capacitance over non-metallized film/foil styles for a given size (typically 75% of the volume). Properties will vary with the type of paper-plastic used as the dielectric.

Reliability: This capacitor style exhibits higher reliability than non-metallized styles (by ≈10X). The metallization process gives the capacitor self-healing properties that increase capacitor life at the expense of decreased stability.

Tolerance/Aging: This capacitor is available over a wide range of purchased tolerances from 0.25 to 10%. The self-healing process burns pinholes in the dielectric and damages electrodes, resulting in decreased stability over non-metallized styles. It should only be used in applications capable of withstanding momentary dielectric breakdowns. The increased metallization thickness provides increased protection against long term aging effects.

Frequency Characteristics: It generally is useful over the entire common frequency range, with each paper-plastic material exhibiting unique frequency characteristics.

Military Considerations

Figure 3 specifies temperature derating requirements for capacitors conforming to MIL-C-39022 (Style CHR, metallized paper and polyethylene terephthalate), MIL-C-18312 (Style CH), MIL-C-83421 (Style CRH, metallized polycarbonate), and MIL-PRF-55514 (Style CFR).

Capacitors, Fixed, Mica, Conventional

This is a film/foil capacitor style with low capacitance values (1 pf – 1.5 μf) and good high frequency characteristics. It is intended for use in circuits requiring precise filtering, bypassing, and coupling. This capacitor is small and inexpensive, but relatively uncommon.

Construction

This capacitor is constructed with a mica dielectric between a tin-lead foil and is usually formed by a silvered mica process. The capacitor is enclosed in a molded case that is typically made of a polyester material.

Derating Requirements

Voltage: Derate voltage to 70% of maximum full rated voltage below T_S, where $T_S = T_{MAX} - 70^o C$. Linearly derate from 70% at T_S to 30% at T_D, where $T_D = T_{MAX} - 25^O C$. See Figure 4. Do not operate within 25^{o}C of maximum rated operating temperature.

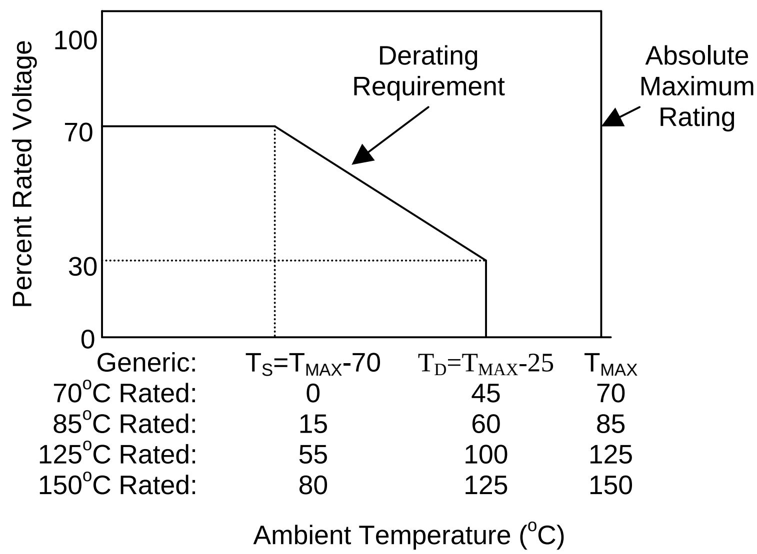


Figure 4. Derating Requirement for Fixed Value, Mica, and Conventional Capacitor

Application Information

Reliability: The inherent properties of the mica dielectric create a highly stable, highly reliable capacitor. It has a strong tendency to fail in the short circuit mode.

Tolerance/Aging: This capacitor is typically used where close impedance limits are essential with respect to temperature, frequency, and aging. Standard purchased tolerances is ±1, ±2, and ±5%. The design should be able to tolerate an additional ±0.5% change in capacitance value over lifetime. The temperature coefficient is typically between 0 and 100 ppm/^{o}C. This capacitor style is more resistant to high humidity conditions than most other capacitor styles.

Frequency Characteristics: This capacitor style is designed for use in circuits requiring precise high frequency filtering. Good high frequency characteristics (typically up to 500 MHz).

Military Considerations

Figure 4 specifies temperature derating requirements for capacitors conforming to MIL-PRF-39001 (Style CMR) and MIL-C-5 (Style CM).

Capacitors, Fixed, Mica, Button

This capacitor is a small-sized, low capacitance value (1pf – 0.1μf), high frequency capacitor style. Typical uses are in tuned circuits and in coupling and bypassing high frequency applications. The style is relatively uncommon.

Construction

A stack of silvered-mica sheets is connected in parallel, encased in metal, and sealed in either a resin or hermetic glass seal. The package is designed to provide the shortest RF current path between the center terminal and chassis to lower inductance and increase high frequency performance.

Derating Requirements

Voltage: Derate voltage to 55% of maximum full rated voltage below T_S, where $T_S = T_{MAX} - 60^O C$. Linearly derate from 55% at T_S to 40% at T_D as shown in Figure 5, where $T_D = T_{MAX} - 10^O C$. Do not operate within 10°C of maximum rated operating temperature.

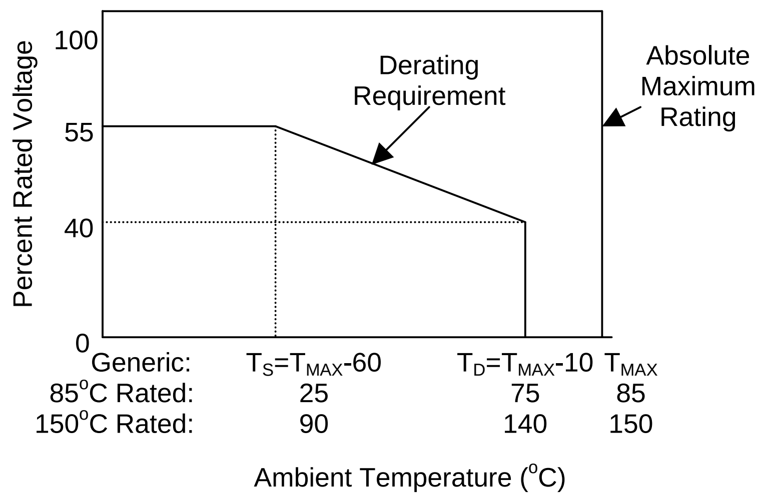


Figure 5. Derating Requirement for Fixed Value, Mica, Button Style Capacitor

Application Information

Reliability: Reliability for this capacitor style is considered poor in comparison to other capacitor styles. The failure rate model is significantly different from the non-button type mica capacitor.

Tolerance/Aging: Capacitor stability is very good with time and highly reliable in circuits where ambient conditions can be closely controlled. It is prone to failure from silver-ion migration when used under DC voltage stress in high humidity and high temperature environments.

Frequency Characteristics: The capacitor is intended for use up to 500 MHz.

Military Considerations

Figure 5 specifies temperature-derating requirements for capacitors conforming to MIL-C-10950 (Style CB).

Capacitors, Fixed, Glass

This capacitor is a small-sized, low capacitance value (1pf – 0.1 μf) style, with good high frequency characteristics. The package is rugged and able to withstand high temperatures. It is intended for applications where high insulation resistance, low dielectric absorption, and fixed temperature coefficients are important.

Construction

This capacitor is composed of alternating layers of glass ribbon and electrode material (pressurized sealed) monolithic block. It is not always hermetically sealed because thermal expansion of case often does not match that of leads.

Derating Requirements

Voltage: Derate voltage to 60% of maximum rated voltage when below T_S, where $T_S = T_{MAX} - 40^O C$. Linearly derate from 60% at T_S to 30% at T_D, as shown in Figure 6, where $T_D = T_{MAX} - 15^O C$. Do not operate within 15°C of maximum rated operating temperature.

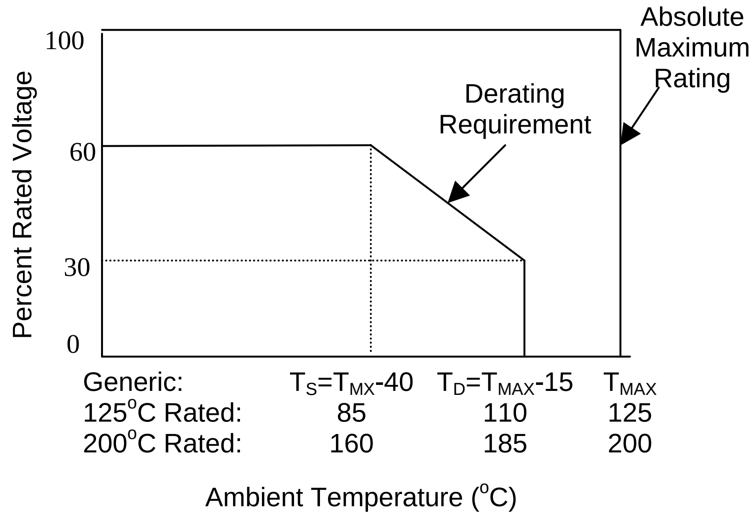


Figure 6. Derating Requirement for Fixed Value, Glass Capacitor

Application Information

Reliability: This is a highly reliable capacitor style, especially at high temperatures. It generally has the lowest failure rate of any capacitor style. This capacitor has a strong tendency to fail in the short circuit mode.

Tolerance/Aging: This capacitor is very good at withstanding extreme environmental conditions such as high shock, vibration, acceleration, moisture, and vacuum. Its temperature coefficient is typically between 85 and 165 PPM/°C. It is highly stable with time, but in a severe operating environment, the design should be able to withstand an additional 1% change in capacitance value over a lifetime.

Frequency Characteristics: The high frequency performance characteristics are superior to most other capacitor styles. It exhibits a much higher Q factor than other capacitor styles.

Military Considerations

None.

Capacitors, Fixed, Ceramic, General Purpose

This is a capacitor designed for applications where a small physical size with comparatively large electrical capacitance and high insulation resistance is required. Its primary drawback is poor tolerance and stability over time.

Construction

Stacked layers of a ceramic dielectric with a thin metallic film (usually silver) are fired onto the ceramic at high temperatures. Terminal leads are attached by pressure contact or soldering. The package is encapsulated to provide electrical insulation and environmental protection. It is also called a ceramic disk.

Derating Requirements

Voltage: Derate voltage to 60% of maximum rated voltage. Ambient operating temperature should be limited to 15°C below maximum rated operating temperature (T_{MAX}), as shown in Figure 7.

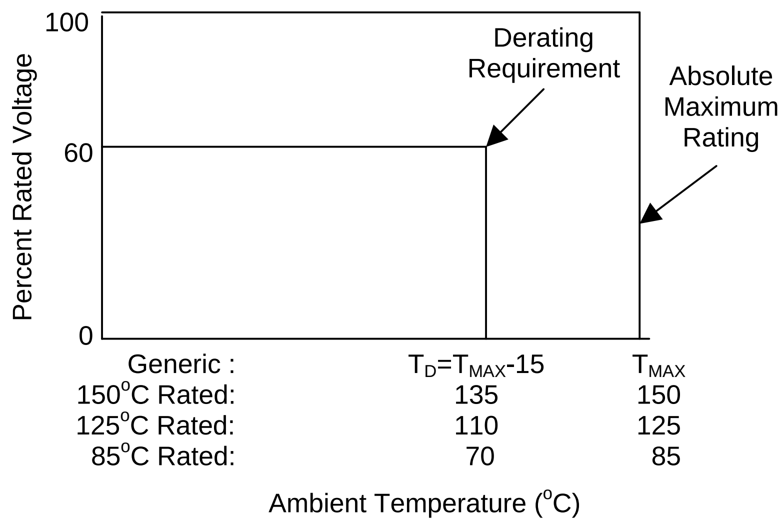


Figure 7. Derating Requirement for Fixed Value, General Purpose Ceramic Capacitor

Application Information

The package is smaller than paper or mica units of the same capacitance and voltage rating. It has the largest capacitance-to-size ratios of all high-resistance dielectrics.

Reliability: The failure rate is very stable with temperature. It is capable of withstanding high moisture conditions due to relative impermeability of ceramic to moisture. The most common failure mode is a short circuit, but open circuits and parameter drift are nearly as common.

Tolerance/Aging: The tolerance of this capacitor varies with grade of dielectric. This capacitor is generally recommended only where large variations in capacitance value can be tolerated (up to ±20% through the life of capacitor). The cumulative effect of high voltage and temperature tends to decrease capacitance value and dielectric constant with time. It is relatively insensitive to moisture due to the non-hydrostropic nature of ceramic. Storage under high humidity conditions may cause silver migration problems and result in high leakage currents.

Frequency Characteristics: Suitable as by-pass, filter, and non-critical coupling elements in high frequency applications where moderate variations due to temperature, voltage, and frequency will not affect proper functioning of the circuit. Typical operating frequency range is 1kHz to 300MHz.

Military Considerations

Figure 7 shows the derating temperature requirements for capacitors conforming to MIL-PRF-39014 (Style CKR) and MIL-C-11015 (Style CK).

Capacitors, Fixed, Ceramic, Temperature Compensating

This is a capacitor used to compensate for temperature induced variance from other circuit elements. It is used for highly accurate circuits where change in capacitance value cannot be tolerated.

Construction

It is constructed with multiple layers of conductive material sandwiched between ceramic dielectric.

Derating Requirements

Voltage: Derate voltage to 60% of maximum rated voltage below T_S, where $T_S = T_{MAX} - 40^O C$. Linearly derate from 60% at T_S to 40% at T_D as shown in Figure 8, where $T_D = T_{MAX} - 10^O C$. Do not operate within 10°C of maximum rated operating temperature.

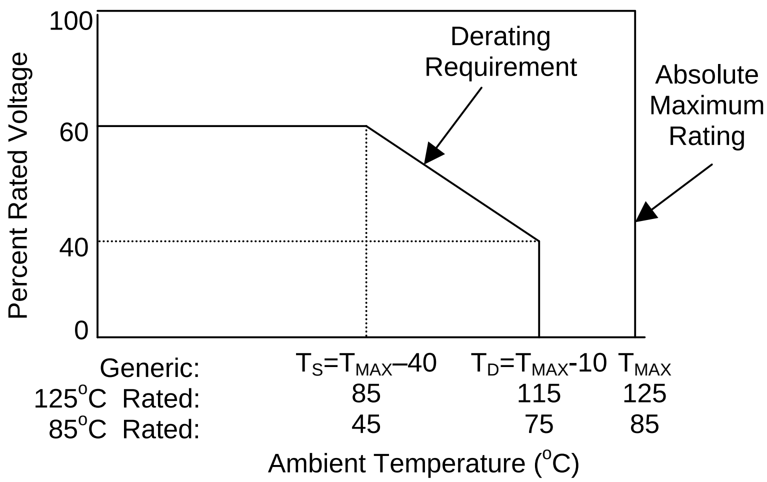


Figure 8. Derating Requirement for Fixed Value, Ceramic, Temperature Compensating Capacitor

Application Information

Reliability: This capacitor is highly reliable in high humidity conditions due to relatively non-hydrotropic nature of ceramic, but insulation resistance may vary with humidity and organic contamination on the ceramic chip surface. Electrical leakage across the chip can occur due to silver migration under simultaneous application of high humidity and high dc voltage conditions.

Tolerance/Aging: The individual capacitor specification must be consulted for detailed temperature coefficient and linearity information. One can expect this capacitor to remain within tolerance throughout life, except in severe environments, where they should be able to tolerate an additional ±1% change in capacitance value over lifetime.

Frequency Characteristics: This capacitor style is typically intended for frequencies between 1kHz and 300MHz.

Military Considerations

Figure 8 shows the derating temperatures for capacitors conforming to MIL-PRF-20 (Style CC and CCR).

Capacitors, Fixed, Ceramic, Chip

This capacitor package is intended for surface mount applications where a variation in capacitance with respect to temperature, voltage, and life can be tolerated.

Construction

Multiple layers of conductive material are sandwiched between ceramic dielectric material.

Derating Requirements

Voltage: Derate voltage to 60% of maximum rated voltage below T_S, where $T_S = T_{MAX} - 40^O C$. Linearly derate from 60% at T_S to 40% at T_D as shown in Figure 9, where $T_D = T_{MAX} - 10^O C$. Do not operate within 10°C of maximum rated operating temperature.

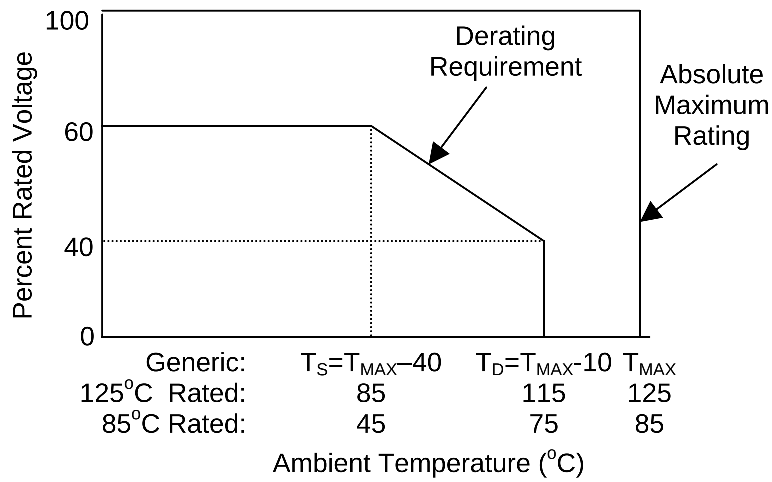


Figure 9. Derating Requirement for Fixed Value, Ceramic Chip Capacitor

Application Information

Reliability: This capacitor is highly reliable in high humidity conditions due to the relatively non-hydrotropic nature of ceramic, but insulation resistance may vary with humidity and organic contamination on the ceramic chip surface. It is historically prone to electrical leakage across the chip due to silver migration under simultaneous application of high humidity and high DC voltage conditions. However, special-manufacturing techniques can be used by the vendor to retard the problem (i.e., addition of 20% palladium to the silver or completely overcovering the silver terminations by tin-lead bonding).

Tolerance/Aging: This capacitor is available with many different tolerances (typically ±1 to 10%). One can expect the capacitor to remain within tolerance throughout life, except in severe environments where the capacitor should be able to tolerate an additional ±1% change in capacitance value.

Frequency Characteristics: This capacitor is typically intended for frequencies between 1kHz and 300MHz.

Military Considerations

Figure 9 shows the derating temperatures for capacitors conforming to MIL-PRF-55681 (Style CDR).

Capacitors, Fixed, Tantalum, Chip

This is a small-sized, medium capacitance value (0.068 to 100 μF) chip capacitor intended for surface mount applications, including hybrid circuits. It is designed to be mounted with reflow soldering equipment and typically available with maximum voltage rating below 50V.

Construction

The surface is a porous tantalum slab (anode) that is electrochemically converted to an oxide of tantalum (dielectric) and then coated with an oxide semiconductor (solid electrolyte).

Derating Requirements

Voltage: Derate voltage to 60% of maximum rated voltage below T_S, where $T_S = T_{MAX} - 40^O C$.

Linearly derate from 60% at T_S to 50% at T_D as shown in Figure 10, where $T_D = T_{MAX} - 10^O C$. Do not operate within 10^oC of maximum rated operating temperature.

Reverse Voltage: For polarized capacitors, derate reverse voltage to 2% of maximum (forward) rated DC voltage (maximum allowable reverse voltage is typically 15% of rated DC voltage).

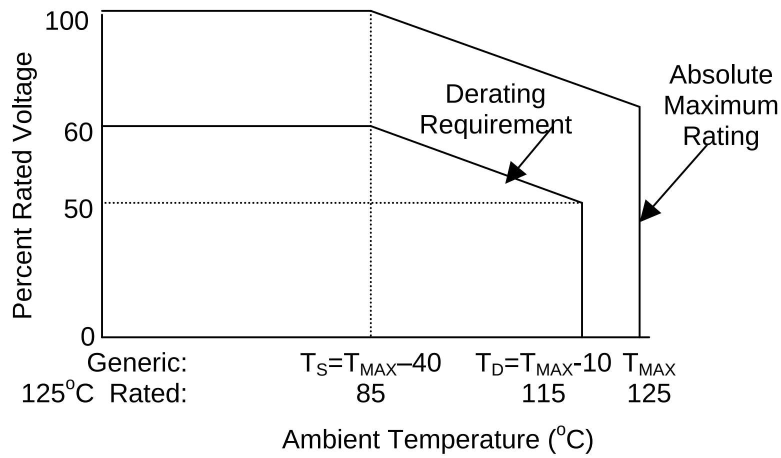


Figure 10. Derating Requirement for Fixed Value, Tantalum Chip Capacitor

Application Information

Reliability: This is a highly reliable style with a failure rate slightly lower than an equivalent ceramic chip capacitor. It has a relatively constant failure rate with stress level.

Tolerance/Aging: This capacitor is typically purchased with tolerances of 10 and 20%. Its stability is considered good. Further recommend designing with a series impedance of at least 1 Ω/V (or limit maximum current to 330 mA) to protect against excess damage to the dielectric during self-healing process. This capacitor has excellent high temperature characteristics with low capacitance-temperature characteristic.

Frequency Characteristics: This capacitor can be used over a wide range of operating frequencies.

Special Considerations: None.

Military Considerations

Figure 10 shows the derating temperatures for capacitors conforming to MIL-PRF-55365 (Style CWR).

Capacitors, Fixed, Electrolytic, Tantalum, Solid

This style is a general purpose tantalum capacitor that is package in a leaded, metal/glass hermetic package. Commercial versions of this part are also available in molded and dipped plastic packages. It is available in high capacitance values (0.047 – 3000 μf). The cost is generally higher than other electrolytic capacitors, and it has a low reverse voltage tolerance.

Construction

The surface of a tantalum pellet or wire (anode) is electrochemically converted to an oxide to create a dielectric. The result is coated with manganese dioxide and a metal film to serve as the cathode. It is available in lower voltage rating (typically 50V) than aluminum electrolytics.

Derating Requirements

Voltage: Derate voltage to 60% of maximum full rated voltage below T_S, where $T_S = T_{MAX} - 40^O C$. Linearly derate from 60% at T_S to 10% at T_D as shown in Figure 11, where $T_D = T_{MAX} - 10^O C$. Do not operate within 10°C of maximum rated operating temperature.

Reverse Voltage: For polarized capacitors, derate reverse voltage to 2% of maximum (forward) rated DC voltage (maximum allowable reverse voltage is typically 15% of rated DC voltage).

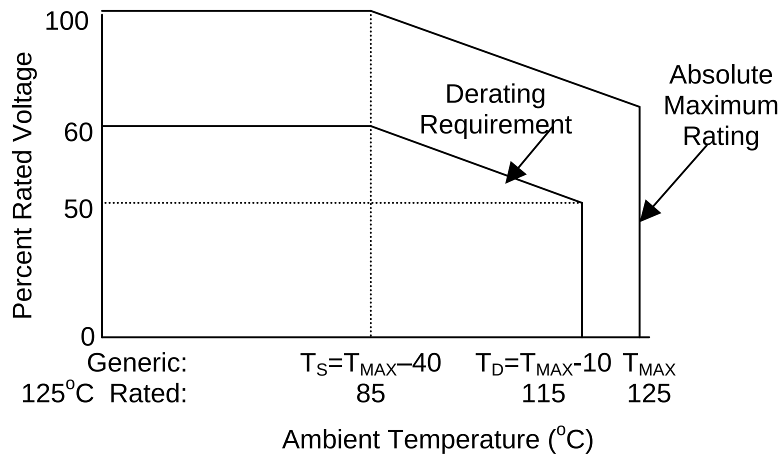


Figure 11. Derating Requirement for Fixed Value, Solid Tantalum Capacitor

Application Information

Reliability: This is the most reliable of the electrolytic capacitor styles. The capacitor has a self-healing dielectric, but its capacitance decreases and leakage current increases with age due to reformation of dielectric during the self-healing process. Compared to aluminum electrolytics, it has a longer shelf life, superior low temperature characteristics, freedom from electrolyte leakage, and higher operating temperatures. It is capable of withstanding high ripple currents for short periods, until heat-dissipation limit is reached.

Tolerance/Aging: This capacitor is typically purchased with tolerances of 10 and 20%. Its stability is considered good. Further recommend designing with a series impedance of at least 1 Ω/V (or limit maximum current to 330 mA) to protect against excess damage to the dielectric during self-healing process. This capacitor has excellent high temperature characteristics with low capacitance-temperature characteristic.

Frequency Characteristics: This capacitor can be used over a wide range of operating frequencies.

Military Considerations

Figure 11 shows derating temperature requirements for capacitors conforming to MIL-PRF-39003 (Style CSR).

Capacitors, Fixed, Electrolytic, Tantalum, Non-Solid (Wet and Foil)

This is a capacitor that normally exhibits a high capacitance value (0.1 µf to 3000 µf). It is primarily used in low frequency filtering applications where high capacitance density is needed but where wide tolerances can be tolerated. This style has a high leakage current that increases with age. This category is intended to cover plain foil, etched foil, and sintered slug types. This capacitor style is not recommended for airborne applications.

Construction

In foil types, tantalum foil acts as the anode and electrolyte acts as the cathode. The foil is electrochemically treated to form a tantalum oxide, which acts as the dielectric. Etched foil styles are similar, but foil is etched to increase surface area and capacitive density. In sintered slug styles, a sintered slug serves as the anode. Solderable leads are welded to tantalum lead wires in all styles.

Derating Requirements

Voltage: Derate voltage to 60% of maximum full rated voltage below ambient temperature of T_S, where $T_S = T_{MAX} - 60^O C$. Linearly derate from 60% at T_S to 10% at T_D as shown in Figure 12, where $T_D = T_{MAX} - 10^O C$. Do not operate within 10°C of maximum rated operating temperature.

Reverse Voltage: Derate reverse voltage to 2% of maximum (forward) rated DC voltage.

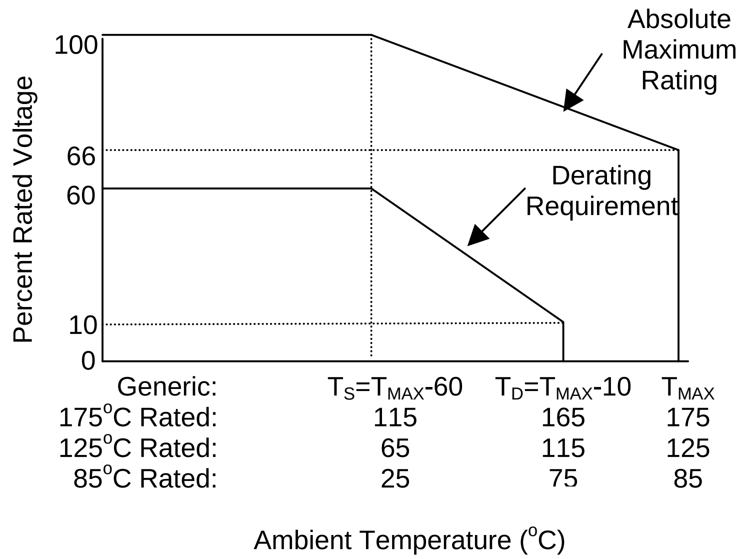


Figure 12. Derating Requirement for Fixed Value, Non-Solid Tantalum Electrolytic Capacitor

Application Information

This category covers three non-solid tantalum capacitor types, discussed as follows:

Foil: The most versatile of all electrolytic capacitors. It has the advantage of high ripple current, good capacitance-tolerance characteristics, and a low power factor. Packages available in both polarized and non-polarized versions.

Etched Foil: Capacitance density is up to 10X the capacitance/area of plain foil style, but the capacitance values are highly variable.

Sintered Slug: Use is limited to low voltage applications.

Reliability: Reliability is better than aluminum electrolytic styles, but less reliable than similar value dry slug tantalum capacitor. Shelf life characteristics are considered excellent. Because this capacitor style is often used in power rectification application, attention must be paid to the effect of ambient temperature rise of nearby components.

Tolerance/Aging: The typical purchased tolerance is 20%, but designs should be capable of withstanding an additional 10% tolerance through life. Etched foil styles can have purchased tolerances as high as +75%.

Frequency Characteristics: This capacitor style is not intended for high frequency characteristics. It is generally designed to be used below 1KHz, although special processing techniques can increase high frequency performance.

Special Considerations: Compared to aluminum electrolytics, tantalums have higher capacitance per unit area due to higher dielectric constant of tantalum oxide (≈24) over aluminum oxide (≈8). Wet slug tantalum capacitors should not be used in airborne systems.

Military Considerations

Figure 12 shows temperature derating requirements for capacitors conforming to MIL-PRF-39006 (Style CLR) and MIL-C-3965 (Style CL). Style CLR is rated at 125°C, and Style CL can be rated at either 85, 125, or 175°C, depending on the style.

Capacitors, Fixed, Electrolytic, Aluminum, General Purpose

This capacitor possesses high capacitance density, high voltmetric efficiency, low cost, and low frequency filtering capacitor. This is the most common electrolytic capacitor style. It is not recommended for airborne applications.

Construction

Similar to electrolytic aluminum style capacitors, except it is considered a higher grade and made with higher quality materials.

Derating Requirements

Voltage: Derate voltage to 70% of maximum rated voltage below T_S, where $T_S = T_{MAX} - 30^O C$. Linearly derate from 70% at T_S to 40% at T_{D1} as shown in Figure 13, where $T_{D1} = T_{MAX} - 20^O C$. Linearly derate from 40% at T_{D1} to 20% at T_{D2}, where $T_{D2} = T_{MAX} - 10^O C$. Do not operate within 10°C of maximum rated operating temperature. Apply additional derating in applications where high voltage surges are known to occur so maximum voltage surge will remain below the maximum voltage rating.

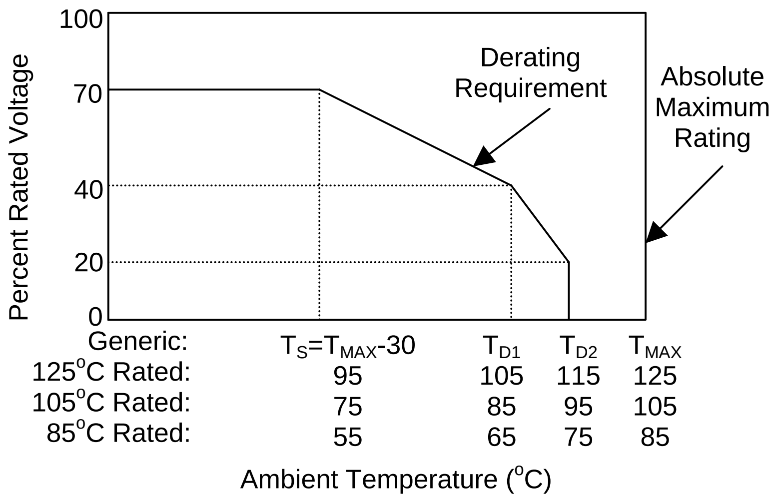


Figure 13. Derating Requirement for Fixed Value, Aluminum Electrolytic, General Purpose, and Capacitor

Application Information

Reliability: This style is less reliable than tantalum styles, as it is susceptible to oxide breakdown at small reverse biased voltages. A wear out failure mechanism, resulting in decreased capacitance and increased equivalent series resistance, is caused by electrolyte evaporation.

Tolerance/Aging: The initial purchased tolerance is high in comparison to non-electrolytic styles. Aging, storage, and environmental effects will cause further tolerance buildup. Low temperatures may cause capacitance to decrease (20% to 50% at -40°C) and series resistance to increase. High working voltage causes capacitance to decrease due to growth in the thickness of the oxide layer. Long periods in storage without applied voltage causes increase in leakage current (although low leakage electrolytic capacitors can be purchased).

Frequency Characteristics: This capacitor is not intended for high frequency applications.

Special Considerations: This capacitor is not recommended for airborne applications. A safety vent hole is incorporated into the capacitor case and is designed to open at dangerous pressure. Low barometric pressures may cause safety vent hole to release and result in electrolyte dry out. Electrolyte is corrosive and can cause damage to surrounding components and copper board traces if vent hole releases. Explosion can result due to spark ignition or pressure buildup of free oxygen and hydrogen liberated at the electrode.

Military Considerations

Figure 13 shows the temperature derating requirements for capacitors conforming to MIL-PRF-39018 (Style CU).

Capacitors, Fixed, Electrolytic, Aluminum (Dry)

This capacitor style is similar to an aluminum electrolytic capacitor GP, except with lower grade materials. The derating requirements are similar, but T_{D1} is 15°C less than T_{MAX} (rather than 20°C). A non-aqueous electrolyte is used, thus the reference to “dry electrolyte capacitor”. This capacitor style is not recommended for airborne applications.

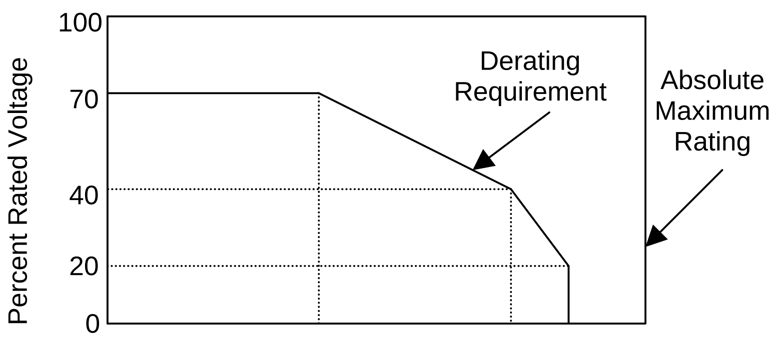
A wear out failure mechanism results in decreased capacitance, and increased equivalent series resistance caused by electrolyte evaporation.

Construction

An aluminum foil is rolled onto a porous space with impregnated electrolyte solution of ammonium borate, boric acid, and glycol in a porous spacer. The aluminum plate is etched to increase surface area and capacitance volume. A vent hole is incorporated into the case as a safety precaution.

Derating Requirements

Voltage: Derate voltage to 70% of maximum rated voltage below T_S, where $T_S = T_{MAX} - 30^O C$. Linearly derate from 70% at T_S to 40% at T_{D1} as shown in Figure 14, where $T_{D1} = T_{MAX} - 15^O C$. Linearly derate from 40% at T_{D1} to 20% at T_{D2}, where $T_{D2} = T_{MAX} - 10^O C$. Do not operate within 10°C of maximum rated operating temperature. Apply additional derating in applications where high voltage surges are known to occur, such that the maximum voltage surge will remain below the maximum voltage rating of the capacitor.



Generic:	$T_S=T_{MAX}$-30	T_{D1}	T_{D2}	T_{MAX}
125°C Rated:	95	110	115	125
105°C Rated:	75	90	95	105
85°C Rated:	55	70	75	85

Ambient Temperature (°C)

Figure 14. Derating Requirement for Fixed Value, Aluminum Electrolytic, Dry, Capacitor

Application Information

Reliability: This style is less reliable than tantalum styles. It is susceptible to oxide breakdown at small reverse biased voltages. A wear out failure mechanism, resulting in decreased capacitance and increased equivalent series resistance, is caused by electrolyte evaporation.

Tolerance/Aging: The initial purchased tolerance is high in comparison to non-electrolytic styles. Aging, storage, and environmental effects will cause further tolerance buildup. Low temperatures cause capacitance to decrease (20% to 50% at -40°C) and series resistance to increase. High working voltage causes capacitance to decrease due to growth in the thickness of the oxide layer. Long periods in storage without applied voltage causes increase in leakage current (although low leakage electrolytic capacitors can be purchased).

Frequency Characteristics: This style is not intended for high frequency applications.

Special Considerations: This capacitor is not recommended for airborne applications. A safety vent hole is incorporated into the capacitor case and designed to open at dangerous pressure. Low barometric pressures may cause the safety vent hole to release and may result in electrolyte dry out. Electrolyte is corrosive and can cause damage to surrounding components and copper board traces if vent hole releases. Explosion can result due to spark ignition or pressure buildup of free oxygen and hydrogen liberated at the electrode.

Military Considerations

Figure 14 shows temperature-derating requirements for capacitors conforming to MIL-C-62 (Style CE).

Capacitors, Variable, Ceramic

This is a non-linearly adjustable, small-sized trimmer capacitor designed for applications where fine-tuning is periodically required during the life of an equipment.

Construction

The package consists of stator with silver fired on surface and rotor. The rotor is usually made of titanium dioxide. The overlap of stator and rotor determines capacitance value.

Derating Requirements

Voltage: Derate to 60% of maximum rated voltage below T_S, where $T_S = T_{MAX} - 60^O C$. Linearly derate from 60% at T_S to 40% at T_D as shown in Figure 15, where $T_D = T_{MAX} - 60^O C$. Do not operate within 10°C of maximum rated operating temperature.

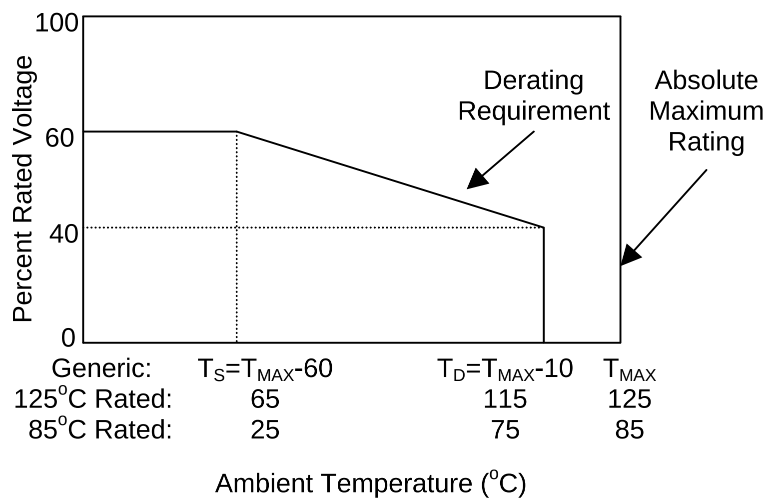


Figure 15. Derating Requirement for Variable, Ceramic Capacitor

Application Information

Reliability: As with all variable capacitors, reliability is considered poor.

Tolerance/Aging: This style should generally not be used in applications that will experience large temperature variations because capacitance value stability is non-linear and varies considerably with the quality of the capacitor. It is relatively stable against shock and vibration due to low mass, but not as stable as air trimmer variables. Capacitance drift with age is generally less than 0.5 pf. This style is not recommended for temperature compensation applications because capacitance value is non-linear with temperature and varies greatly between units.

Frequency Characteristics: Breakdown voltage remains steady up to about 2.5 MHz and then decreases with increased frequency (decreases by about 10% at 30 MHz).

Military Considerations

Figure 15 shows the temperature derating limits for capacitors conforming to MIL-PRF-81 (Style CV).

Capacitors, Variable, Piston Style

This is a linearly adjustable, small-sized trimmer capacitor designed for applications where fine tuning is periodically required during the life of equipment. The package is able to withstand higher ambient temperatures than variable ceramic style.

Construction

Capacitance is achieved by interleaving concentric cylindrical metal sleeves. Capacitance is varied by adjusting the penetration of one set of sleeves into the other. Construction materials will vary.

Derating Requirements

Voltage: Derate to 60% of maximum rated operating voltage at ambient temperature below T_S, where $T_S = T_{MAX} - 85^O C$. Linearly derate from 60% at T_S to 20% at T_{D1} as shown in Figure 16, where $T_{D1} = T_{MAX} - 25^O C$. Above T_{D1}, linearly derate to T_{D2}, where $T_{D2} = T_{MAX} - 15^O C$.

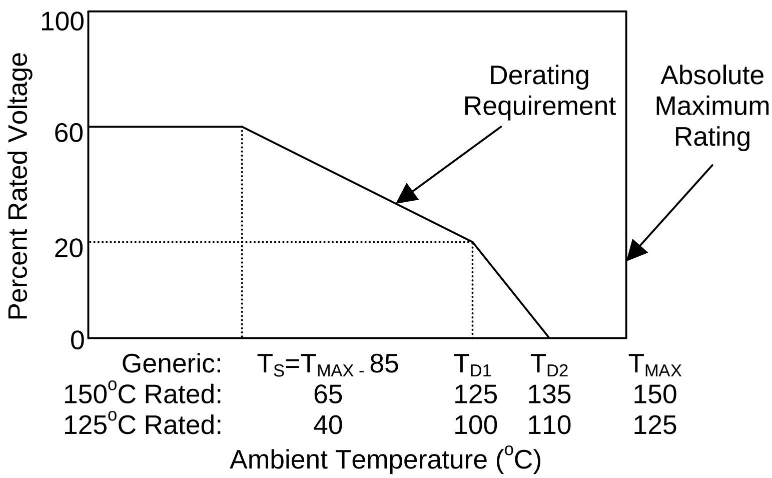


Figure 16. Derating Requirement for Variable, Ceramic, Piston Style Capacitor

Application Information

Reliability: This style exhibits the best reliability among the variable capacitor styles, but is considerably worse than equivalent valued fixed capacitor. Its most common failure mode is parameter drift.

Tolerance/Aging: This style is relatively stable against shock and vibration due to low mass. Capacitance change is linear with respect to rotation to about ±10%.

Frequency Characteristics: This capacitor is capable of being used across a wide range of operating frequencies up to RF.

Military Considerations

Figure 16 gives the temperature derating requirements for capacitors conforming to MIL-C-14409 (Style PC).

Capacitors, Variable, Air Trimmer

This is a large capacitor intended for line rectification applications.

Construction

The overlap of stator and rotor determines capacitance value.

Derating Requirements

Voltage: Derate to 60% of maximum rated operating voltage at ambient temperature below T_S, where $T_S = T_{MAX} - 60^O C$. Linearly derate from 60% at T_S to 20% at T_D as shown in Figure 17, where $T_S = T_{MAX} - 10^O C$. Do not operate within 10°C of maximum rated operating temperature.

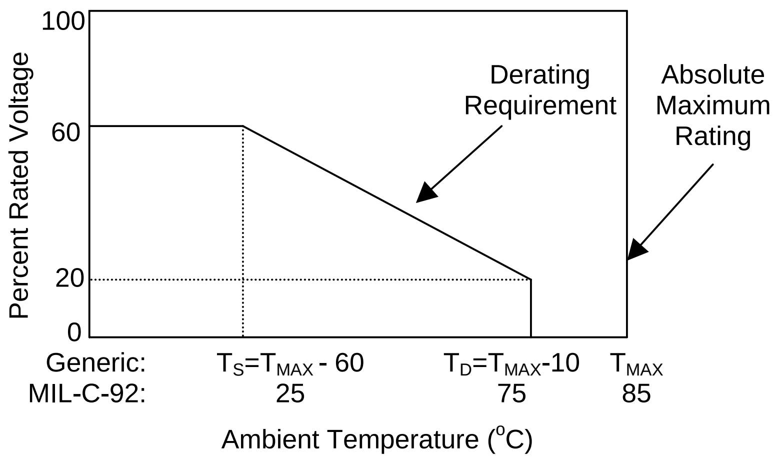


Figure 17. Derating Requirement for Variable, Air Trimmer Capacitor

Application Information

Reliability: As with all variable capacitors, reliability is considered very low.

Frequency Characteristics: This capacitor is intended for low frequency applications only.

Military Considerations

Figure 17 shows the temperature derating requirements for capacitors conforming to MIL-C-92 (Style CT).

Capacitors, Variable and Fixed, Gas or Vacuum

This is a non-linear fixed or variable capacitor intended for high power applications.

Construction

A heavy copper construction minimizes stray inductance and provides an excellent heat sink.

Derating Requirements

Voltage: Derate 60% of maximum rated voltage at ambient temperatures below 25°C. Linearly derate from 60% at 25°C to 40% at T_D as shown in Figure 18, where $T_D = T_{MAX} - 10^O C$.

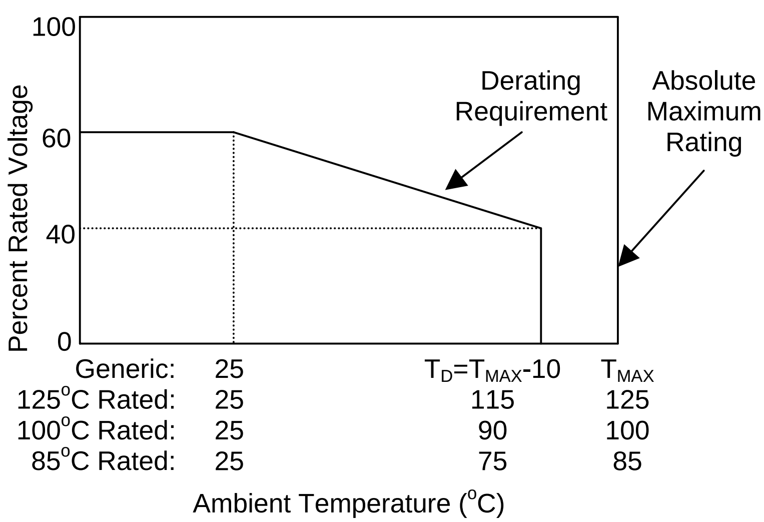


Figure 18. Derating Requirement for Variable and Fixed, Gas or Vacuum Capacitor

Application Information

Reliability: As with all variable capacitors, reliability is considered relatively poor. The package is able to withstand repeated, heavy current overloads. The heat dissipation factor is very low.

Frequency Characteristics: This style will handle exceptionally high currents at very high frequencies. Breakdown voltage is stable to about 2.5MHz, before decreasing.

Military Considerations

Figure 18 shows temperature-derating requirements for capacitors conforming to MIL-C-23183 (Style CG).