KEMET FIT Calculator Manual

Introduction

To help customers with FIT calculations, KEMET offers a free tool called the KEMET FIT Calculator. The formulas defined in the MIL-HDBK-217F are the basis for this calculator.

The KEMET FIT Calculator has sections for User Inputs, Factors, and FIT Results. This document provides an overview of the controls in each of those sections. While the MIL-HDBK-217F describes many capacitor types, the KEMET FIT Calculator focuses only on capacitor types manufactured, previously or currently, by KEMET.

For an application example of how to use the KEMET FIT Calculator for commercial grade products, please see the KEMET Application Note: "AN1002 – Calculating Failure In Time."

User Inputs

This section describes the inputs available in the KEMET FIT Calculator.

Capacitor Type and Style Selection

There are four types of capacitors selectable: Film, Ceramic, Tantalum, and Aluminum. These styles refer to military part types. However, when using actual FIT data generated for KEMET components, these models may be usable for non-military part types.

Military Equivalent and Commercial Parts

The film selection is for Metalized Paper and Film. Ceramic has two styles selectable: Ceramic Leaded and Ceramic Chip. Tantalum has three styles selectable: Tantalum (Solid, Leaded), Tantalum (Solid-Chip) and Tantalum (Wet-Leaded). Aluminum has two styles selectable: Aluminum (Wet) and Aluminum (Wet-Leaded). "Solid" refers to a MnO_2 style cathode system while "Wet" refers to a wet-electrolyte.

KEMET has added "Tantalum (Polymer)" and "Aluminum (Polymer)" selections even though there is not, at this time, a MIL-PRF that describes them.

The ceramic selection of "Leaded" relates to the military "CK" and "CKR" designations of molded, leaded multilayer ceramic capacitors. The "Chip" selection of ceramic relate to the surface mount chips designated as "CCR, CC, and CDR" prefixed part numbers. These part types are similar, but not exact duplications of our commercial chip line.

The tantalum selection of "Leaded" relates to the military "CSR" equivalent of the leaded tantalum capacitors. The "Chip" selection of tantalum relates to the "CWR" series. The "Chip" category is very similar to the same anode (or pellet) structure and encapsulation material used in the commercial chip lines.

The aluminum selection "Dry" relates to the military "CE" equivalent of a rolled aluminum foil structure with a solid MnO_2 cathode. KEMET does not manufacture this type of capacitor.

Note: neither the Aluminum (Wet) nor Aluminum (Dry) are suitable for KEMET's aluminum polymer (AO-CAP) or can style aluminum capacitors. The dielectric style is the only similarity.

Aluminum Polymer (AO-CAP) and Tantalum Polymer (KO-CAP)

The KEMET FIT Calculator does provide dielectric quality figures for two capacitors not specified in the MIL-HDBK-217F. The Tantalum(Polymer) and Aluminum(Polymer) options have been added. Because the dielectric quality of these devices is better than the MnO_2-based systems, the KEMET FIT Calculator provides unique Application Voltage multipliers for Pi(V). For tantalum, the calculator uses 0.8 and for aluminum the calculator uses 0.9.

Style(s)

Once the type of capacitor is selected, the available style(s) for that type is displayed here. This control is not accessible to the user. It is an information only dialog.

Temp Rating

This box refers to the maximum operating temperature specified for the device. For the tantalum types, there are two selectable temperatures: +85°C and +125°C. For the ceramic types, there are three selectable temperatures: +85°C, +125°C, and +150°C.

Note: This value has no effect when using Notice-2 calculations. This value is only used for Notice-1. For more information, see the section "Changes from Notice-1 to Notice-2."

Capacitance (uF)

This input box allows for entering the capacitance of the device as microfarads (μF).

Application Temperature

The application temperature can either be entered directly in the "Temp (°C)" input box or by using the horizontal slider. The default setting is 50°C, which is the same temperature used in KEMET's FIT data.

It is possible to enter a temperature higher than the rated temperature. In Notice-2 calculations, the mismatch between rated temperature and application temperature is ignored. If a tantalum type is selected, a de-rated voltage is displayed. For more information about exceeding 85°C with tantalum parts, see the "Temperature and Derated Voltage" note in the "Application Voltage" section.

Application Voltage

The application voltage can either be entered directly in the "Volts (DC)" input box or by using the horizontal slider. For fractional voltages, the input box must be used.

Like the temperature entry, you can exceed the maximum voltage rating of the part by using the text entry box. While

the calculator produces an "S" factor based on this information, the MIL-HDBK-217F does not have provisions for these conditions. A warning dialog indicates when this happens.

Temperature and Derated Voltage

With the tantalum capacitor, the device is de-rated at temperatures above +85°C, in a linear fashion to 67% of rated voltage at +125°C. Increasing the temperature of the application above +85°C, creates a de-rated voltage and increases the ratio (S) of the application to rated voltage. This change creates an increasing voltage factor (PiV) as the temperature increases.

Failure Rate %/kPcH at Max Temperature and RatedV (FR)

This dropdown allows the user to select an established reliability rating, non-military rating, commercial rating or with data to calculate a known failure rate.

MIL-PRF specifications detail how to test and grade parts for the established reliability (ER) ratings. These ER ratings may use "Weibull" grade "D" through "B"; which represents failure rates of 0.001, 0.01, and 0.10 percent per thousand-piece-hours at rated voltage and at rated temperature. Another option is the "Exponential" graded levels "S" through "M"; which represent 0.001, 0.01, 0.10, and 1.0 percent per thousand-piece-hours at rated voltage and at rated temperature.

For commercial grade products, it is most common to use "Enter Pcs/Hrs/Fail" or "Enter Known (%/kPcHrs) FR." Please contact a KEMET field application engineer (FAE) to obtain the information necessary to use these sections.

Enter Pcs/Hrs/Fail

This entry allows direct entry of KEMET's ongoing FIT testing data. Once selected, another input box allows you to enter the hours tested, the number of pieces tested, the failed piece count and the life-test's bias condition. The failure rate is calculated based on these numbers and the selected part type.

The bias condition defaults to normal stress levels for each capacitor type. However, you can manipulate them.

Enter Known (%/kPcHrs) FR

The Failure Rate listing requires the calculated failure rate from KEMET's ongoing FIT testing. This dialog allows entering the failure rate as a percent per thousand-piece-hours.

Environmental Conditions (PiE)

The MIL-HDBK-217F allows for environmental stress factors. Refer to MIL-HDBK-217F for a detailed description of each of these conditions.

Typically the default, "G(B) Ground-Benign", can be used.

Note that the MIL-HDBK-217F displays these as letters with subscripts, e.g. G_B. The dropdown uses parenthesis to indicate the subscript letters. For example, G_B is shown as G(B) in the dropdown.

Circuit Resistance Ohms/Volt (PiSR)

The circuit resistance drop-down only appears when selecting a tantalum capacitor type.

For circuits not using a series resistor, the default "(<0.1 Ohms/V)" is suitable.

Wet Tantalum Construction Type (PiCON)

The wet tantalum construction type drop-down appears when selecting aTantalum(Wet-Leaded) capacitor type while Notice 1 calculations is enabled.

The electrolyte used in wet tantalum capacitors can interact with the case and the materials used in their construction, causing concerns for long-term reliability.

Note, KEMET previously, but no longer, manufacturers wet-type tantalum capacitors.

Factors

After a calculation is completed, the formula and factors used to calculate the FIT are displayed. This section explains each of these factors.

Base

The initial factor is the "Base" multiplier, which is determined empirically and specified in the tables within the MIL-HDBK-217F specification. Each capacitor type has a unique base multiplier.

Pi(T) or πT – Application temperature multiplier

The temperature factor increases with increasing temperatures and is typically referenced to +298°K (+25°C). At temperatures above this reference results in a multiplier that is greater than one, and lower than this temperature results in a fractional multiplier.

Pi(V) or πV – Application voltage multiplier

The application voltage multiplier works with two variables: the voltage stress, relative to rated voltage, and a multiplier. Applied voltages below this stress add the fractional ratio to unity, resulting in a diminishing factor approaching unity.

Above this voltage stress, the multiplier grows rapidly, as provided by the exponential factor.

Both the voltage stress and multiplier are defined by the capacitor type used.

Pi(CV) or πCV – Capacitance Value multiplier

The expected capacitance value is in microfarads (μF). This multiplier reflects an increasing probability of failure with increasing dielectric area as the capacitance value increases.

Pi(E) – Environmental conditions multiplier

The environmental conditions multiplier range from 1 at G_B, to the highest of 570 in the C_L Series. These reflect atmospheric and mechanical stress conditions expected in the application of the capacitors. MIL-HDBK-217F provides more information on these multipliers. Typically G_B Ground-benign is used for commercial applications.

Pi(Q) or πQ – Reliability multipliers

The established reliability rating of the capacitor type determines the reliability multipliers. Specific batch information can be used if failure count, pieces tested, and acceleration conditions are available.

For commercial grade parts or parts without established reliability or specific batch data, the following guidelines could be considered. Aluminum and tantalum parts are typically released when life testing shows repeatable performance of less than 1% failures per thousand-piece-hours. Ceramics parts are typically released when life testing shows repeatable performance of less than 0.1% per thousand-piece-hours. This factor is the square root of the % failures per thousand-piece-hours.

See the section titled "Failure Rate %/kPcH at Max Temperature and RatedV (FR)" in the User Inputs section of this document for more information.

Pi(SR) or πSR – Circuit or Series Resistance multipliers

Only tantalum capacitors use the series resistance multipliers. For all other capacitor types, it is set to unity or left out of the multiplier string. The higher the circuit resistance, the lower the multiplier, and resulting FIT rate.

Notice-1 or Notice-2

When Notice-2 was released in 1995, some calculations and factors changed. This calculator uses both methods, with the KEMET FIT Calculator defaulting to Notice-2.

For more information, see the section titled "Changes from Notice-1 to Notice-2".

FIT Results

There are two results provided by the KEMET FIT Calculator, the FIT and a mean time to failure (MTTF). Please note that the calculator displays MTBF, which doesn't apply to components.

FIT

The information supplied by the user provides The Calculated FIT.

For a system failure rate, simply multiple the FIT by the number of pieces per system. This value represents the parts per system per system-hour.

MTBF

Using the inverse of the Calculated FIT, the mean-time-to-failure MTTF is displayed.

For a system's MTBF, simply divide the MTTF by the pieces per system.

Changes from Notice-1 to Notice-2

Notice-1 was released on July 2 1992. Notice-2 was published on February 28, 1995.

KEMET suggests only using Notice-2 calculations when using the KEMET FIT Calculator. When changing to Notice-1, some

of the base parameters and methods change, causing a difference in FIT results. Below are some of the changes between Notice-1 and Notice-2 for your reference.

Changes in Capacitor Type Section

- Tantalum chip (CWR) style were added in Notice-2. If a "chip" style is selected, and then Notice-1 is selected, the style reverts to CSR leaded style.
- When selecting either aluminum or tantalum polymers, in Notice 1 a warning appears showing that the leaded MnO_2 style is being used. In Notice 2 a notice shows that the denominator of the Pi(V) calculation is being changed.

Changes in Temp Rating

- The PiT (temperature factor) calculations are only used in Notice-1. With Notice-1, the maximum temperature setting is converted to °K by adding 273 to the °C setting. This term is then utilized in the denominator of the PiT calculation.
- Notice-2 calculations only use 298°K (25°C) in the denominator of the PiT calculation.

Changes in parameters

- Pi(SR) has decreased by a factor to 1/10 of Notice-2.
- Pi(V) sees differences in both the voltage stress and exponential factors
    - The exponential factor in Notice-1 is different from Notice-2.
    - The voltage stress point in Notice-1 is different from Notice-2.
- Pi(T) handles rated and application temperatures differently.
    - Notice-1 varies the factor based on the ratio of ambient temperature compared to maximum rated temperature with an exponent. Notice-2 varies the factor by the ratio of the ambient temperature compared to 298°K (25°C) with no exponential factor.

Application Revision History

<2.0.0		Internal Use Only
2.1.0	July 2002	First public release Added: • 'Aluminum' and 'Ceramic' types. • Added display for calculations and parameters. • Added 'Type' by paragraph. • Added All environmental conditions • Added multiple maximum temperature limits
2.2.0	August 2002	Fixed: • Multiple temperature maximum bug Added: • Dialogs allow "any key" instead of mouse click
2.3.0	August 2002	Fixed: • Ambient temperature calculation • Typos in help files • Notes for Aluminum and Tantalum Added: • Application (form) minimizing • Context sensitive help • Bias conditions for life-test
2.3.1	December 2002	Added: • MTBF Calculation
2.3.2	December 2002	Fixed: • PiQ Listing (1.5 instead of 3, and 3 instead of 10) Added: • Print of entire dialog window
2.3.3	January 2003	Fixed: • Tantalum voltage derating adjustment with temps above +85°C
3.0.0	January 2004	Fixed: • Aluminum solid temperature factor (was constant at 25°C) Added: • PiQ as absolute values of 3 and 10 (correlates to 10% and 100% per thousand-piece-hour failure rates) • Help screen on Failure Rate calculation and PiQ Link
3.1.0	September 2007	Fixed: • Error in Pi(Q) calculation
3.2.0	November 2007	Fixed: • "PiQ as 10" bug • Corrected PiCV Notice 1 calculations (uF was assumed, ceramics was to be in pF)
3.3.0	March 2008	Added: • Polymer-tantalum (KO-CAP) and Polymer-aluminum (AO-CAP) to pull-down part type selections
3.3.5	June 2008	Added: • Film and Wet Aluminum types

3.5.0	June 2011	Added: • Polymer with adjusted Pi(V) denominator
3.5.31	March 2012	Fixed: • Allow tantalum temperature data to be collected at 85°C to be entered in Pi(Q) selections. • Pi(Q) selection labels for Weibull failure rate classes. Removed: • Help Screens (until new revisions are ready.)