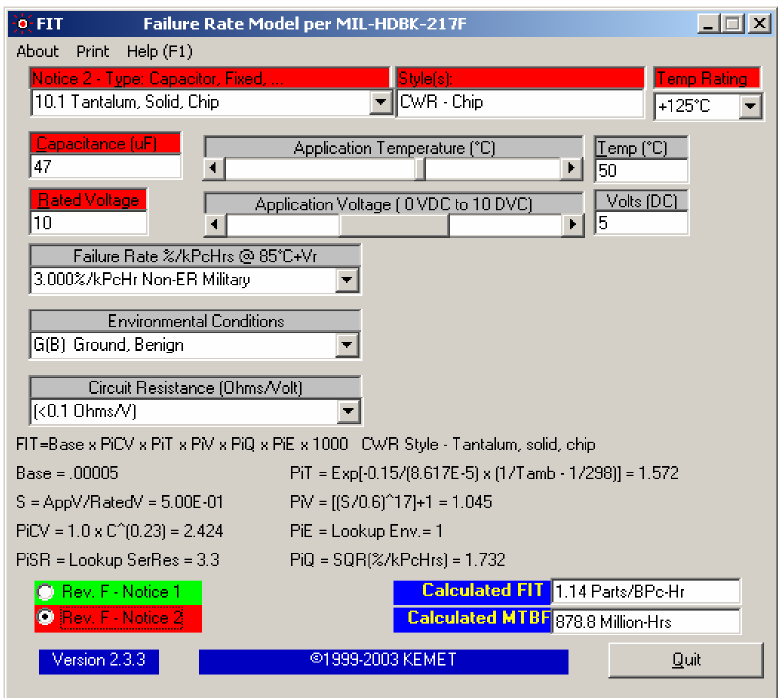
FIT Calculator Software

(version 2.3.3, and higher)



John D. Prymak – Applications Manager

KEMET Electronics Corp.

January 2003

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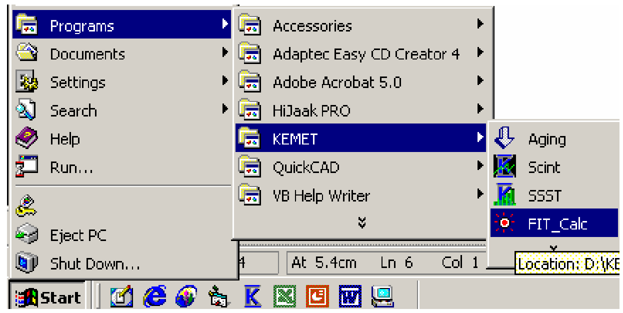
Install or Update

The update of this software will not add any other files to the system directory not already established with a previous version of FIT, or “KEMET Spice”, or “SSST Data Analysis” programs. If you already have any of these programs installed, use the ***Quick FIT*** installation program. Otherwise, you will need to run the ***Full FIT*** installation or setup program.

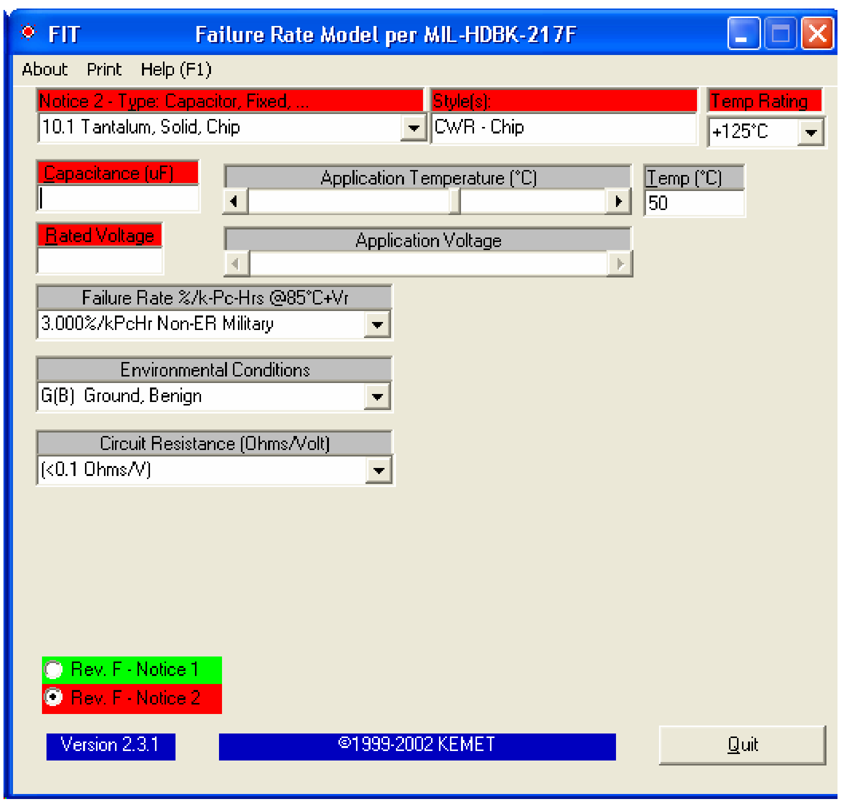
The setup program will install the calculator program in the KEMET directory of drive D:/.



Running the FIT Calculator

You activate the program by using the [Start] button of the lower left windows screen, select {Programs}, {KEMET}, then, click on the {FIT_Calc} selection. This will launch the program and the following calculator screen will appear.

Calculator Screen



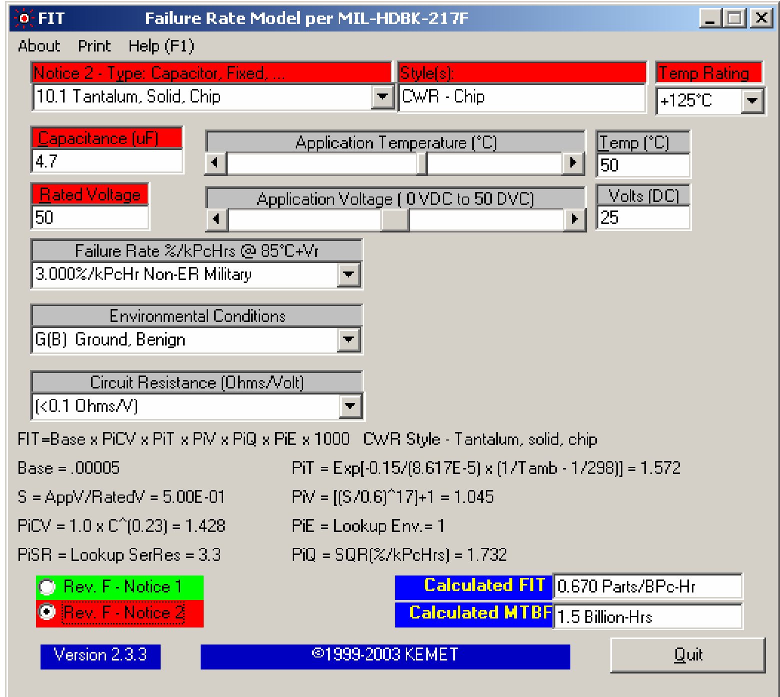
The screen initially comes up looking for an entry using the “10.1 Tantalum, Solid Chip” model of “MIL-HDBK-217F, Notice-2.” After the user enters the capacitance (in µF), and rated voltage of the part, the calculations are initialized, and a [Calculated FIT] will appear.

Initial calculations begin at 50% of rated voltage, and ambient operational temperature of 50°C. The initial Failure Rate given as 3% per Thousand-Piece-Hours at Rated voltage (Non-Military). Additionally, the environmental condition is given as Ground-Benign [G(B) or G_B – see page 6], and the series resistance (see page 7) as less than 0.1 ohms-per-volt [(<0.1 Ohms/V)]. The style is shown as “CWR – Chip.”

Once the capacitance and voltage entries are completed, the window will show the calculated FIT and the methods and formulas for this calculation.

In the MIL-HDBK-217F, there are many capacitor types available, each with unique parameters and unique calculation methods for deriving the failure rates based on application temperatures and voltages. This model will deal only with those capacitors manufactured by KEMET.

Calculator Options



A view of this form after the capacitance and voltage is entered is shown here. Once the calculator makes a FIT calculation, the base parameters and methods as specified in the handbook are listed on the form. The calculated fit appears at the lower right of the form (here shown as "0.67 Parts/BPc-Hr" and read as 0.67 Parts Per Billion-Piece-Hours. To convert this failure rate to the system failure rate, simply multiple the FIT by the number of pieces per system, and this represents the parts per system per system-hour. As an example, if 10 capacitors of this type are used per circuit, then the circuit failure rate can be calculated as 10 times the piece failure rate or 6.7 Per Billion-Circuit-Hours.

In addition to the FIT calculation, the MTBF (mean time before failure) calculation is also shown, and this is the inverse of the FIT calculation. Here the indication is that there should be 1.5 billion hours, before failure. For multiple pieces per system, this indication must be divided by the pieces per system. Again using the 10 pieces per circuit example, the MTBF for the circuit would be 150 million-hours.

FIT Calculations

The calculations displayed on the form are identical to those specified in MIL-HDBK-217F, with multiplying factors attributed to temperature, applied voltage, the capacitance of the component, the environmental conditions, and the historical failure rate of the component in life test exposures. These factors and the base calculations for deriving them are capacitor type dependent.

Base

The initial factor is the 'Base" multiplier, which is determined empirically and specified in the tables within the specification. Each capacitor type will carry its unique base multiplier.

PiT – Application temperature multiplier

The temperature factor will increase with increasing temperatures, and with this capacitor type is 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.

PiV – Application voltage multiplier

Wit this capacitor type, the multiplier for voltage stress is referenced to 60% of rated voltage. Above this stress and the multiplier grows rapidly, as the exponential factor is 17. Below this stress and the fractional ratio is added to unity, resulting in a diminishing factor approaching unity, but never fractional. At 90%, 80%, 70%, <u>60%</u>, 50%, and 40% of rated voltage, the factors become 986, 134, 14.7, <u>2</u>, 1.045, and 1.001, respectively.

PiCV – Capacitance Value multiplier

Here is the multiplier for the capacitance (in µF) of the part. This reflects an increasing probability of failure with increasing dielectric area with increasing capacitance.

PiE – Environmental conditions multiplier

The environmental conditions are detailed and explained on page 6. The multipliers range from 1 at GB, to the highest of 570 in the CL Series (Notice-2). These reflect atmospheric and mechanical stress conditions expected in the application of the capacitors. These multipliers are part type dependent.

PiQ – Reliability multipliers

These are based on the established reliability rating of the capacitor type or each specific batch (graded to indicated levels) based on failure count, pieces tested, and acceleration conditions. Many manufacturers of aluminum and tantalum parts will not release a product until it shows repeatable performance of less than 1% failures per thousand-piece-hours in life testing. For ceramics, the required failure rate is better than 0.1% per thousand-piece-hours. This factor is the square root of the % failures per thousand-piece-hours. See page 5 for additional information.

PiSR – Circuit or Series Resistance multipliers

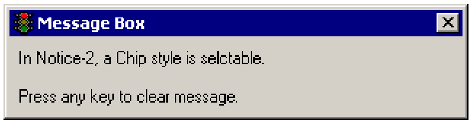
This multiplier is only used for tantalum capacitors, For all other capacitor types it is set to unity, or left out of the multiplier string. The higher the circuit resistance, the larger the multiplier and resulting FIT rate.

Notice-1 vs. Notice-2

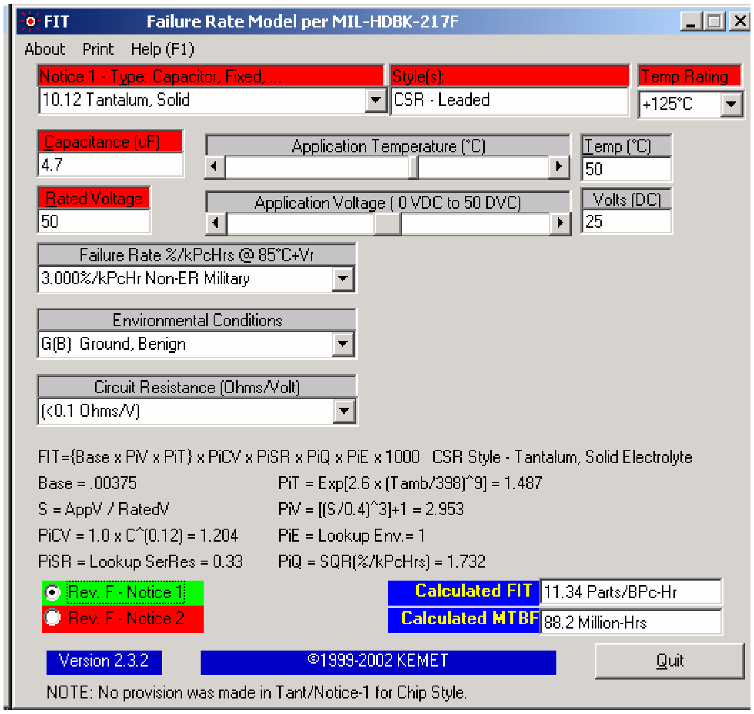
Notice-1 was released in 1992, on July 2. Notice-2 was released in 1995, on February 28. KEMET has recently converted all FIT calculations and reports to conform to Notice-2.

The option to revert back to Notice-1 was in deference to those who have questioned the changes instituted with the latest revisions. Switching the method to Notice-1 does change some of the base parameters and methods of FIT calculation; and therefore, will change the FIT results.

The following details the changes experienced when moving from Notice-2 to Notice-1 in this style ("CWR – Chip"):



The program will immediately notify the user that in Notice-1, there is no coverage for surface mount chips, and the program will revert to "CSR – Leaded" style. The base multiplier (***Base***) changes from 0.00005 up to 0.00375.

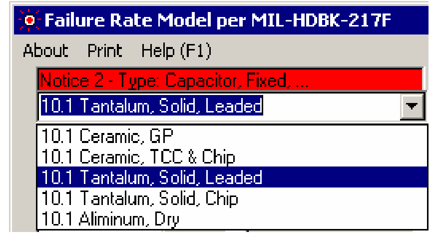


In addition, look at how the ***PiT*** (temperature factor), ***PiV*** (voltage factor), and ***PiCV*** (capacitance in µF, factor) have changed. The ***PiSR*** has decreased by a factor of 1/10 in Notice-1. The FIT calculation results move from 0.67 Parts/Billion-Piece-Hours to 11.34 Parts/Billion-Piece-Hours.

If you'll look at the ***PiV*** calculation you can see where these multipliers have exponential factors in them. In Notice-1, the exponent is 9, while in Notice-2, the exponent is 17. This places a much higher importance on the application voltage for Notice-2 then Notice-1. At 50% of rated voltage, the large exponential increase is offset by differences in the base and temperature factors. Keep this higher dependence on voltage in mind when trying to run the tantalum at application voltages closer to the rated voltage. In addition, with Notice-1 the voltage factor is fractional below 40% of rated, unity at 40% of rated, and multiples above 40% of rated. In Notice-2, the critical percentage moves up to 60% of rated.

With ***PiT***, there are many changes. In Notice-2, the factor is varied by the ratio of the ambient temperature compared to 298°K (25°C), and there is no exponential factor for this ratio. With Notice-1, the factor is based on the ratio of the ambient temperature compared to the temperature extreme of the part (398°K for 125°C), and this ratio is then raised to the 9^{th} power. Though these calculations are very different for the "CWR – Chip" of Notice-2, the ***PiT*** factor is 1.572 (@50°C and 50% rated voltage), while the same conditions and value as "CSR – Leaded" in Notice-1, results in a factor of 1.487.

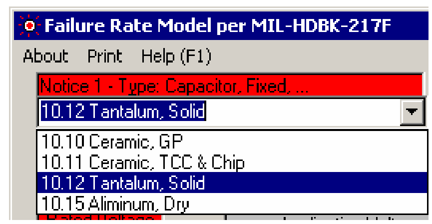
Capacitor Type and Style Selection



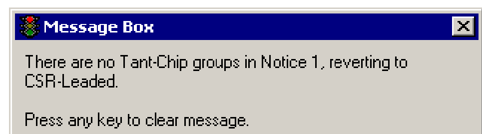
In Notice-2, there are three types of capacitors selectable (Ceramic, Tantalum, and Aluminum). There are two ceramic styles selectable (GP {General Purpose – Leaded}, and TCC {Temperature Compensating} & Chip), and two tantalum styles selectable ("CSR-Solid Leaded" and "CWR-Chip"). The aluminum listed here refers to a can type using a solid-state electrolyte (MnO_2). In all cases, these styles refer to military part types, but by using the actual FIT data generated for our components, we believe that these models work just as well for the non-military part types.

The ceramic selection of "GP" relates to the military "CK" and "CKR" designations of molded, leaded multilayer ceramic capacitors. The "TCC & Chip" selection of ceramic relate to the surface mount chips designated as "CCR, CC, and CDR" prefixed part numbers. These part types are duplications of the non-military commercial chip line.

The tantalum types referred to here are the "CSR", military equivalent of the leaded tantalum capacitors. We used this category to project the FIT for our surface-mount chips because it is the same base pellet or anode structure, and close duplication of the encapsulating material.



The aluminum type is not the same as our AO or aluminum-polymer chips, but it utilizes the same dielectric type, and in both cases, there is no wet electrolyte. They refer to a "CE" type, which is a rolled can structure (just like the 'wet'), but uses MnO_2 as the cathode connection. In the same way we use the tantalum models (with MnO_2) to FIT our tantalum-polymer calculations, we use this "CE" model to FIT our aluminum-polymer calculations.

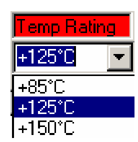


In Notice-1, the total selection list decreases by one as the tantalum chip (CWR) style is missing. By selecting the tantalum chip style in Notice-2, when switching back to Notice-1, a warning is again generated to warn the operator that the style selected will revert to the "CSR" leaded style. If you have the tantalum (CSR) selected in Notice-1, switching to Notice-2 will keep it in this style, but a notice will be shown to the operator (as detailed on the previous page).

Style(s) – Not Selectable (for information only)

Once the type of capacitor is selected, the available style(s) for that type will be displayed here. This window is not available to the operator – but is displayed for information only.

Temp Rating



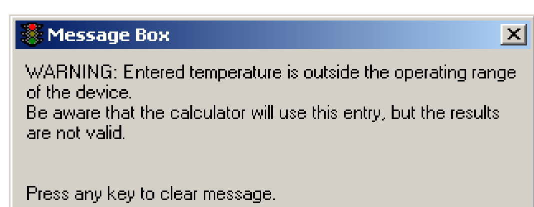
This box refers to the maximum operating temperature designated for the device. For the tantalum chip, there is only one temperature selectable here (+125°C). For the ceramic, there are three possible temperature maximums selectable. If you are dealing with an X5R chip, use the +85°C setting, and use the +125°C setting for all other dielectrics (this model is not intended for Y5V or Z5U dielectrics).

If you look in the ***PiT*** (temperature factor) calculations of Notice-1 and Notice-2, you will see that by changing this temperature setting, the calculations change in Notice-1, but not in Notice-2. With Notice-1, the maximum temperature setting is converted to °K by adding 273 to the °C setting, and this term is then used in the denominator of the ***PiT*** calculation. For a selection of 85°C or 125°C, the term that will appear will be 358°K, and 398°K, respectively.

Now looking at the ***PiT*** calculation in Notice-2, all reference temperatures are listed at 298°K, or 25°C. Notice-2 does not use the maximum temperature level in any of its calculations.

Application Temperature Entry

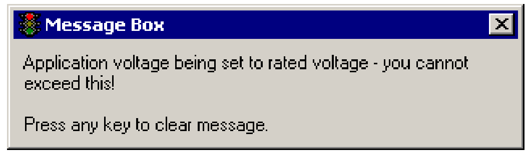
The operator can use the horizontal scroll bar to increment this setting to higher or lower temperatures, or go directly to the text box, to the right of the horizontal scroll bar, and enter a numeric value here. The initial setting is to 50°C (just like the printed FIT plots generated by the QA group). The scroll bar will stop at the maximum temperature of the part, but you can enter a temperature beyond that in the text box. If you do exceed the range, a warning will pop up to alert you of this. This program will warn you about exceeding the limits, but it will not stop you. Be careful!



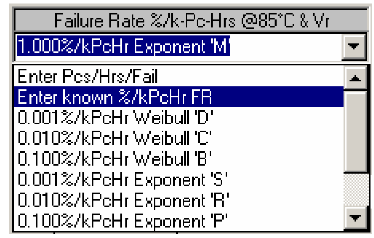
Application Voltage

Again as in the temperature selection, you can us a scroll bar or enter the setting of the application voltage. The scroll bar only allows integer changes to the application voltage, but the direct entry will allow fractional entries.

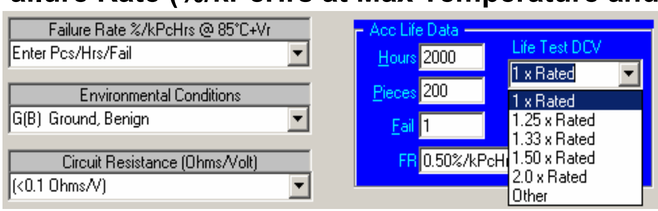
Like the temperature entry, you can exceed the maximum voltage rating of the part after a warning is issued. Because this invalidates the application, the accuracy of the calculations are very suspect.



*With the tantalum capacitor, the device is derated 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, will created a de-rated voltage, and increase the ratio (**S**) of the application to rated voltage. This in turn, will create an increasing voltage factor (**PiV**) as the temperature increases. The calculation shown on page 2 shows the **PiV** factor to be 1.045 at ½ rated voltage (**S**=0.5) and +50°C. At any temperature from -55°C to +85°C, the **PiV** factor will not change. At +105°C, the **PiV** goes to 1.967 (**S**=0.599), and at +125°C, the **PiV** goes to 41.799 (**S**=0.746). These derating factors will change with both Notice-1 and Notice-2, though not as severe with the former.*

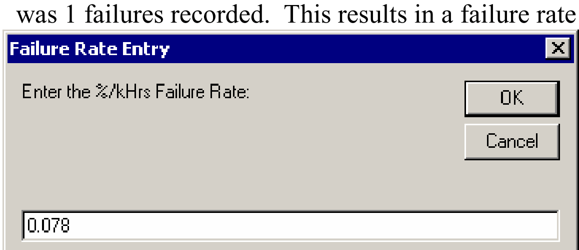


Failure Rate (%/kPcHrs at Max Temperature and RatedV)



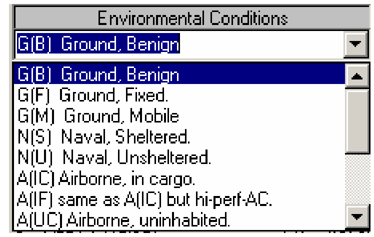
There are established reliability ratings that the military demands their parts to be tested to conform to specific failure rates. These established reliability rates might be coded as being "Weibull" grade "D" through "B" (representing failure rates of 0.001, 0.01, and 0.10 percent per thousand-piece-hours at rated voltage and at rated temperature). They can also be codes as "Exponential" graded to level "S" through "M" (representing 0.001, 0.01, 0.10, and 1.0 percent per thousand-piece-hours at rated voltage and at rated temperature). Additional fixed failure rate selections include "Non-military Established Reliability at 3%/kPcHrs" and "10%/k-Pc-Hrs for Commercial Product."

At the top of the selection list are two other choices: "Enter Pcs/Hrs/Fail" and "Enter Known (%/kPcHrs) FR." With the first selection, you must have access to the hard numbers from the FIT testing. Once this entry is selected, another box will appear on the form and require you to enter the latest hours tested, the pieces tested, and then the failed piece count. After these three entries, a failure rate is then calculated for that particular part type, and this failure rate is used in the FIT calculations the result. From the example shown, the test was for 2000 hours, there were 200 pieces involved, and there was 1 failures recorded. This results in a failure rate calculation of 0.50% per thousand-piece-hours. The latest version of the program also allows you to select the bias conditions of the life-test. It will default to normal stress levels for each capacitor type, but you can manipulate these as there is discussion concerning the bias conditions for ceramics being too high and the desire to lower them to selectable conditions or a unique condition accessed through "Other.".



The second selection the Failure Rate listing requires the calculated failure rate, again from the ongoing FIT testing. Once this selection is made, a pop-up box requires you to enter the failure rate as a percent per thousand-piece-hours entry. Make the entry, and then click on [OK] to return to the program.

Environmental Conditions



This listing refers to the relative stress experienced by the part during its application. This listing is explained in military conditions, but these can be related to non-military environments. If you do not want to make any judgments here, leave it at the top selection which is "G(B)" or 'Ground-Benign.'

Normally these designations are expressed with the letters in parenthesis as sub-text for the 1st character, but with the limitations of list text, the parenthesis are used in place of subtext (i.e., G(B) should be read as G_B).

G(B) Ground, Benign

Nonmobile, temperature and humidity controlled environments readily accessible to maintenance; includes laboratory instruments and test equipment, medical electronic equipment, business and scientific computer complexes, and missiles and support equipment in ground silos.

G(F) Ground, Fixed

Moderately controlled environments such as installation in permanent racks with adequate cooling air and possible installation in unheated buildings; includes permanent installation of air traffic control radar and communications facilities.

G(M) Ground, Mobile

Equipment installed on wheeled of tracked vehicles and equipment manually transported; includes tactical missile ground support equipment, mobile communications equipment, tactical fire direction systems, handheld communications equipment, laser designations, and range finders.

N(S) Naval, Sheltered

Includes sheltered or below deck conditions on surface ships and equipment installed in submarines.

N(U) Naval, Unsheltered

Unprotected surface shipborne equipment exposed to weather conditions and equipment immersed in salt water. Includes sonar equipment and equipment installed on hydrofoil vessels.

A(IC) Airborne, Inhabited, Cargo

Typical conditions in cargo compartments which can be occupied by an aircrew. Environment extremes of pressure, temperature, shock, and vibration are minimal. Examples include the C130, C5, B52, and C141. This category also applies to smaller aircraft such as the T38.

A(IF) Airborne, Inhabited, Fighter

Same as A(IC) but installed on high performance aircraft such as fighters and interceptors. Examples include the F15, F16, and F111, F /A 18 and A10 aircraft.

A(UC) Airborne, Uninhabited, Cargo

Environmentally uncontrolled areas which cannot be inhabited by an aircrew during flight. Environmental extremes of pressure, temperature, and shock may be severe. Examples include uninhabited areas of long mission aircraft such as the C130, C5, B52, and C141. This category also applies to uninhabited area of lower performance smaller aircraft such as the T38.

A(UF) Airborne, Uninhabited, Fighter

Same as A(UC) but installed on high performance aircraft such as fighters and interceptors. Examples include the F15, F16, F111, F/A 18 and A10 aircraft.

A(RW) Airborne, Rotary Winged

Equipment installed on helicopters. Applies to both internally and externally mounted equipment such as laser designators, fire control systems, and communications equipment.

S(F) Space, Flight

Earth orbital. Approaches benign ground conditions. Vehicle neither under powered flight nor in atmospheric reentry; includes satellite and shuttles.

M(F) Missile, Flight

Conditions related to powered flight of air breathing missiles , cruise missiles, and missiles in unpowered free flight.

M(L) Missile, Launch

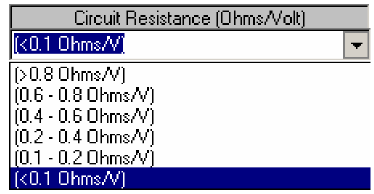
Severe conditions related to missile launch (air, ground and sea), space vehicle boost into orbit, and vehicle reentry and landing by parachute. Also applies to solid rocket motor propulsion powered flight, and torpedo and missile launch from submarines.

C(L) Cannon, Launch

Extremely severe conditions related to cannon launching of 155 mm and 5 inch guided projectiles. Conditions apply to the projectiles from launch to target impact.

Circuit Resistance (*PiSR)*

<u>(Tantalum Devices ONLY!)</u>

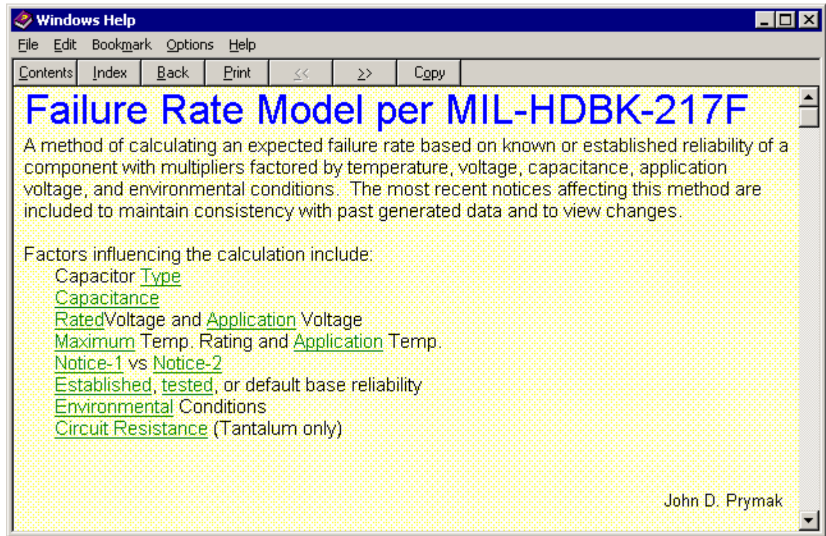


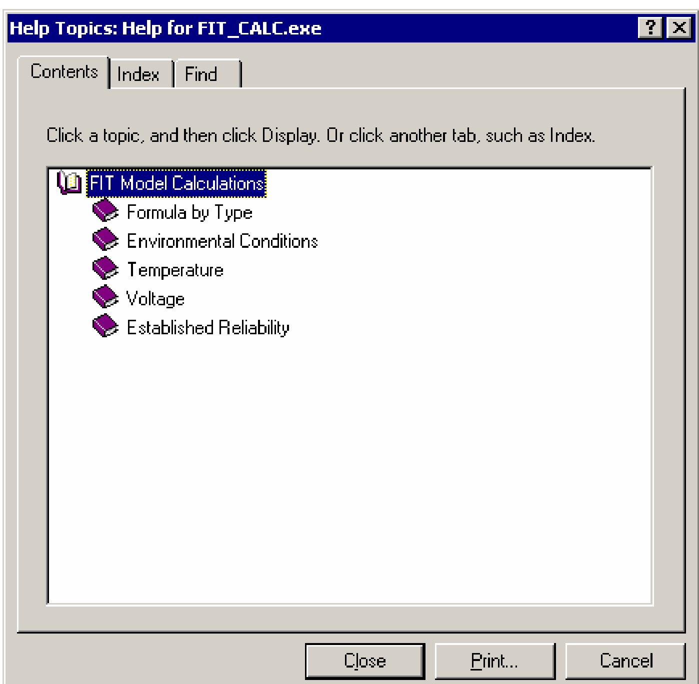
This table will only appear with the tantalum selections. It relates to an improvement in failure rate if there is added series resistance with the capacitor in application. Adding resistance is contrary to the movement to lower ESR. In most cases tahat demand low ESR, there is no series resistance added to the circuit, as it would create huge noise factors that make its inclusion impossible. As such, the default selection of 'less than 0.1 ohms per volt' will be applicable in almost all situations.

HELP

As you use this program, you will see that if the mouse pointer remains over any of the controls of the calculator from, a pop-up message will attempt to explain the control in one sentence. If further assistance is needed, click on the control, text box or list-box and then press the <F1> key for further information. The form on the right is accessed by placing the cursor in the FIT results box, then pressing <F1>.

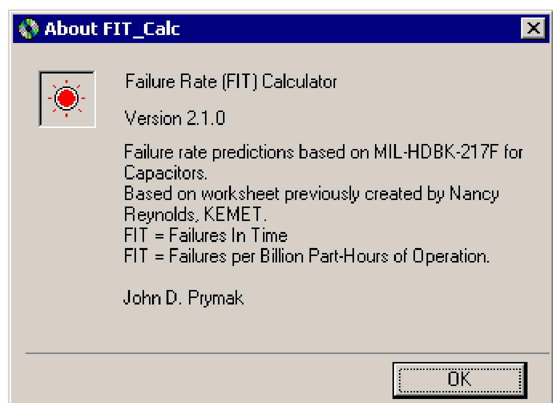
In addition, there is a pull-down menu under "Help" that will allow you to view the contents of the help file, and utilize an index to search for specific help on any topics covered with this program.





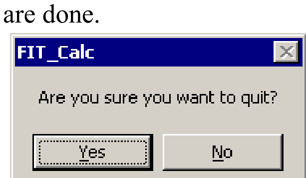
About (FIT Calculator)

There is also a pull-down menu to activate the 'About' form that gives background information on the program.



Closing the program

When you click on [Quit] in the calculator, a pop-up message box will ask you to verify your intention to quit. Click on [<u>Y</u>es] and you are done.



Revisions

2.0.0	And all previous versions – my personal use only.
2.1.0	July 2002 Added ‘Aluminum’ and ‘Ceramic’ types. Display of calculations and parameters. ‘Type’ by paragraph from 217F. All environmental conditions. Multiple maximum temperature limits.
2.2.0	Aug 2002 Multiple temperature maximums were being defeated by set temperatures in program – corrected. Messages changed from required mouse click on [OK], to touch any key.
2.3.0	August 2002 Ambient temperature in calculation at 0°C instead of 50°C – fixed. Allowed minimize of form. HELP activation context sensitive with <F1> key. Added bias conditions for Life-Test. Fixed NOTE messages for aluminum and tantalum. Fixed typo’s in help files.
2.3.1	December 2002 Added MTBF calculation. Default is Notice-2, Tantalum Chip, and 3%/kPc-Hr established Failure Rate
2.3.2	December 2002 Print FIT Form to printer instead of listing Error in ***PiQ*** listing, entered 1.5 instead of 3, and 3 instead of 10
2.3.3	January 2003 Error in voltage derating adjustment with tantalum in temperatures above +85°C. --- Derating voltage to 67% at +125°C instead of 80%. Allowed over-rated voltage and temperature applications, with warning issued.