Modeling the frequency behavior of aluminum, ceramic, film, and tantalum, surface mount capacitors manufactured by KEMET Electronics Corp. This software is intended to work within Windows® environment and is available free from KEMET.

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(Revision 3.9.6x)
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Starting KEMET Spice

The KEMET Spice software can be activated in one of two manners, depending on the version of Windows® on your system. If the setup instructions were followed as written, then the program may be activated by the following instructions.

KEMET Spice is freeware and a freeware declaration may be downloaded from the KEMET web site. (See Appendix 8 on page 92 for more information.)

Windows 7, Vista, XP, 2000, 98, 95, ME, NT

As shown for Windows 7, select the “Start” (1) button to trigger the pop-up menu then select “All Programs”. The setup program by default creates a new program group called “KEMET” (2); select this group or the group you declared during the setup. Once selected, the “KEMET Sp” (3) program icon should be visible. Mouse-click on this item to start the program.

The setup program also puts an icon (“KEMET_Sp”) for the program on the desktop. Double click on this icon and the program will start.

Windows Vista

Windows Vista requires that the setup program be “Run as administrator” and the HELP screens may not appear. See Windows Vista discussion on page 93.

KEMET Spice

The first screen appears for only 5 seconds. This "splash" screen appears briefly only to allow the bulk of the program to load. You can eliminate the 5-second wait by clicking on the splash screen.

The initial interface screen for the operator interface is the Choose Type screen, which will appear on a dark blue, background screen.

This background screen will carry the KEMET logo or icon created for this program. The verification of the version, date, and source of this software at any time throughout the program may be activated by the pull-down menu selection of “About...” found in many of the subsequent forms, followed by a click on “Program.”

NOTE:

The Version and the KEMET name will appear on almost all of the screens in this program.

This program may be minimized to reside in an immediate call-up mode by using the minimize box selection in the upper right of the background screen. Although "Quit" is an option with many screens, the close window box selection at the upper right will also stop this program at any time.
Disclaimer

This program utilizes calculations that create responses that duplicate measured responses. The response actually fits an average of several pieces. Within that average, slight variations exist that are not randomly included with the calculated projections. As such, a disclaimer is given to denote that these responses, although the best fit to the measured data, do not define or imply a specified performance, or a maximum or minimum performance capability; but a typical or average response of the product at the time of the measurements. After reading the notes, click on the “I accept...” check box of Figure 3 and the [Continue] button will be enabled. Click on the enabled [Continue] button and the program continues as before. This opening disclaimer notice and acceptance will only appear once for each revision of the KEMET Spice program. If you quit without accepting the disclaimer, the program will not run. Once you accept and continue, the program will not repeat this routine. It is accessible in all the plots as a [NOTE: Disclaimer] button in the lower right regions of the plot displays (see Figure 18 on page 17).

Choose Type

There are six basic types of capacitors that KEMET Spice offers (Figure 4). The selections are straightforward: click on either [Aluminum/Tantalum], [Ceramic], [Film SMD], or [Film Leaded] to select the desired type of capacitor. Leaded ceramic and leaded tantalums are not yet available.

We have combined the aluminum and tantalum as a single choice because they are both electrolytic surface mount devices. The newer aluminum capacitors are available in part of the chip sizes that duplicate those of the tantalum chip, with similar voltage ratings. They are both polar types of capacitors, both constructed with an electrolytic process.

Note:

You may bypass the selection process and enter the part type(s) that you want to view in the text box, with a space delimiter for multiple part types, and no more than 10 part types (Figure 5). The part numbers must be completed with ESR codes if included in the part number. If you make any mistakes in the part numbers, the program will not include that part in the plots. After you enter these elements, press the <TAB> key, or <Enter> to resume. Shown in the illustration is two part numbers entered as: “C0805C105K9RAC T491D107M010”.

If you do enter the part numbers here, proceed to page 17, Figure 18 to read about the impedance and ESR plots.
Aluminum / Tantalum

This selection allows the operator to build the required KEMET aluminum or tantalum chip, part number to run the analysis on. Go to the “Tantalum/Aluminum Case/Style Selection” (page 13) for the next steps in the program.

Ceramic

This selection allows the operator to build the required KEMET ceramic chip part number to run the analysis on. Go to the “Ceramic Case/Style Selection” (page 11) for the next steps in the program.

Film

This selection allows the operator to build the required SMD film part number based on style (dielectric), size, voltage, and capacitance. Go to the “Film Capacitor” section on page 15.

Film_Leaded

This selection allows the operator to build the required leaded film part number based on style (dielectric), size, voltage, and capacitance. Go to the “Leaded Film Capacitors” selection on page 16.

Quit

Stop program execution. Throughout this program, quitting will be verified before the program does stop as shown in Figure 6. The [Quit] command button will appear on many forms but the verification will appear to confirm the program stoppage.

<ESC> key will not go back to “Splash” screen, but will stop at “Choose Type.”

Pull-Down Menus

*With version 1.8.x, the pull-down menus for the Choose Type form were reduced to these two: “Defaults” and “Help (F1)”, as the Help function combines the availability of the revision history and the “about” schemes.*

Help (F1)

The program now uses the F1 function key to call up an interactive help throughout the program. You can also access the contents and index for the Help files through this pull-down menu (Figure 7). Any command that is highlighted (tab to scroll through the commands within a form) may call a specific help topic to be displayed when <F1> is activated.

The <F1> key will activate a display related to the present screen, to the operator when activated. As the operator moves through the options presented, the displayed help screen can become more descriptive relating to that specific item. For example, during the view of the Capacitor Selection – Choose display, the last selection is specific to the “Choose” form. This item will change throughout the program.

Additional screens can be viewed from the Help pull-down menu including the Help Contents and Index screen, and the screens explaining the program (“About SPICE”), the revisions by date of this program (“Revision History”), and a quick view of the shortcut keys used in this program (“Keyboard Shortcut Codes”).

*“Vista” and “Windows 7” NOTE:*

*With “Vista” and “Windows 7” versions of Windows, Microsoft stopped supplying the WinHlp32.exe - see Windows Vista on page 93 for method of activating these help screens.*
Contents, Index
The context of the help file and index screen will appear to help the user through this program. The contents are the major categories involved in this program, whereas the index is a listing of each help screen available by topic.

About SPICE
Here the user can view a form that describes the program with information as to the source and author, including addresses and telephone numbers.

Revision History
The revision history of this software can be reviewed (Figure 8). A vertical scroll-bar on the right of the form will allow you to scroll through the listings.

Shown here is the listing for Revision 3.9.2. Scroll down to see all previous revisions.

![Revision History](image_url)

**Figure 8**: Revision listing (through 3.9.2) available through Help pull-down menu.
Defaults
This menu will activate the ‘Defaults’ screen, to allow some changes to the programs settings and operation.

Defaults

The purpose of the defaults screen is to allow the operator to define a range of settings that they might want that is different from the original program settings. The frequency range for each of the capacitor types can be set to all the same, or of any range, every time the operator uses the program. The number of data points created in each frequency decade is selectable.

If any of the optional selections are activated, then the red-bordered [Save Changes] command button will appear (as in the bottom-split illustration of Figure 9).

It is our recommendation that an operator not select conditions other than the default, at least until they have run the program and can see where these changes may be beneficial. In addition, all of the screens that these options call up will be shown as they appear later in the progression of this manual, and experience with these forms could be beneficial.

Return to Program

If no changes were reviewed or you want to skip the changes, this [Return to Program] command takes you back to the “Capacitor Selection” form.

Save Changes

If you made changes (a bright ride border now surrounds the [Save Changes] button as shown in bottom of Figure 9) and would like to keep these as the new default settings, then you must select the [Save Changes] command to save these settings to a default file. You can escape from this form by clicking the “Close” or “Cancel” [X] box, located at the upper right extreme of this form, but this will not save any changes made. You will be prompted to remind you to save these changes or lose them.

Change Default Frequency Ranges (Frequency Plots)

There are five frequency ranges used by this program with default settings. Each button (capacitor type or type and capacitance range) will bring up the frequency range window as shown in Figure 9, and allow the user to pre-select a starting and stopping frequency point for each of the capacitor types. The types being film, leaded film, tantalum (all), ceramic X7R, Y5V, and Z5U chips, and for the C0G ceramics, there is an option for values below 1000 pF and for values above this.

While viewing the temperature rise versus ripple current, this function behaves much differently as shown on page 34.

ASCII Data File Defaults

This applies to the parameter data output from the equivalent circuit models as depicted on page 41 (ceramic) and page 46 (tantalum). These changes include the path, arrangement of the parameters and optional headers.
**Grid Line Defaults**

For the plotted data, the program defaults to no grid lines. Here you can lock in a preference for any arrangement of the grid lines as to your preference.

**Ripple Currents at Set Frequencies**

For the plots of temperature rise for ripple currents (Figure 39 on page 31) or cumulative ripple currents (Figure 51 on page 38), the plot lines are of set frequencies that are read from these stored settings. Up to ten (10) discrete frequencies are entered as “kHz” here and stored for consistent replication.

**Skip Select Capacitor Type**

If you are using this program to check on ceramic capacitors constantly, you can skip the “Choose Type” form and immediately jump to any specific capacitor type. You can jump immediately to the ceramic capacitor selection form (Figure 11 shown on page 11), or jump to the Aluminum/Tantalum build form (Figure 13 of page 13), or jump immediately to the Film capacitor selections (Figure 16 shown on page 15). (Use <Esc> to back into this window to reselect the Defaults pull-down menu.)

**Print single plots in Landscape Mode**

The graphs created in this software can be printed on an attached printer. For singular plots (Z & ESR, or C & L, or Irms & Vrms, etc.) in the “Portrait” mode, the upper portion of the page holds the single plot while the lower portion is wasted. By selecting this check, the singular plots are rotated 90°, using the full page in “Landscape” mode.

**Keep PN Identities – do not convert**

With the ceramic capacitors, selecting any voltage will display all capacitors that would be acceptable for that voltage, including many designs with voltages that are higher than the requested voltage. For example, if 25 Vdc were the required voltage than all parts of 25, 50, 100, and 200 Vdc designs would show up in the capacitor list, with PN voltage codes of “3”, “5”, “1”, and “2”, respectively. Unless this box is checked, then the part numbers will show up with the voltage codes all switched to “3” (the requirement). Checking this box will force the part numbers to retain their design codes, and they will show up with these different codes in the subsequent plots.

**Points per Frequency Decade**

Here you may select the number of points per frequency decade that are plotted in the displays. The program defaults to 50 points for every frequency decade, but you may increase the resolution to 100 points or decrease it to 25, 20, or 10 points per decade. Be aware that because the array dimensions are limited to 600 total points for each parameter, setting the resolution to 100 points per decade will restrict the frequency range to no more than 6 decades (e.g., 100 Hz to 100 MHz, or 10 kHz to 10 GHz).

**Capacitor Types in Models Library**

During the “Choose Type” section of the program, there is an option to create models incorporated by commercial Spice software. This section added with version 3.7.x, allows a preliminary selection of the capacitor types that you would like to create. The left row of check boxes denote aluminum, ceramic, film, and tantalum as styles that will be included in the library list of files to be created for export for commercial Spice programs.

The middle section allows you to set a default for S-Parameter as either “series” or “shunt” circuit configurations. The right section of this window allows you to set the line impedance for the S-Parameter data.

**NOTE:**

*You can step back to the previous screen (stepping all the way back to “Select Type”) by touching the <ESC> key.*

*Context sensitive help is available with any of the objects presented with all screens and pop-up, “Tooltip Text” help boxes will appear with many objects by holding the mouse pointer stationary.*
Ceramic Type / Voltage / Capacitance

This window shows the version of KEMET Spice, and allows the selection of styles, voltages, and ceramic bodies.

Chip Style
The ceramic style offers chip or size selections from 0201 up to 2225. There are also listings for “Arrays”, MIL-C-PRF, Stacked Chips, High Voltage, IDC, MKS, and High Temperature styles. With revision 2.0.7, the stacked ceramics and high voltage portions were added. As of revision 3.7.4x, the high voltage devices are only partially loaded at this time, with larger chips and X7R to come.

Dielectric Type
Depending on which style or size is selected, the possibilities here change. It is possible to have up to seven dielectric types available or just one. If the dielectric is not available for the chosen style, it will appear as shadowy or “grayed out.” The character code for the dielectric is also shown (far right character for each selection), and these can vary depending on the chip style selected. For example, the X7R designation in commercial chips (0201 through 2225) is “R,” but for the MIL-C-PRF chips, the dielectric designation code is “X”.

From the bright white buttons available, click on your dielectric choice.

Rated Voltage
Just as with the dielectric, depending on style and dielectric chosen, the voltage selections may be limited here. Again, the alpha codes (shown as a character to the extreme right of the voltage value) for these voltages may vary depending on the chip style selected. Bright white buttons are available, while gray filled buttons are not. Select the desired voltage from those available.

Capacitance List
This is the most dependent listing. A scroll bar may be visible on the right side of this box to allow additional offerings in this limited space. Select the desired capacitance from this listing. You may now select multiple choices – if you hold the <Ctrl> key down, you may select randomly, and if you hold the <Shift> key down you may select a sequential series. Remember, you may only select a maximum of ten (10) part types. After your selection is complete, you can click on [Done] or touch the <Enter> key to continue. In the following illustration (Figure 12, on the left), three (3) distinct capacitance values have been selected: 10 nF, 33 nF, and 1 µF (up to ten {10} selections are possible).

By “double-clicking” on a single, desired capacitance value, the program moves on to the next screen without the need to click on [Done].

Remember that all these choices (style, body, and voltage) are increasingly dependent. If the desired capacitance is greater than the maximum offering in the list box, try a lower voltage or different dielectric type to increase the capacitance offering. If these steps cannot attain a high enough capacitance, try a larger chip style.

On the left of Figure 12, a box will appear below the capacitance listings only if any of the part numbers has a special PN code or suffix code created for this program – they are not a part of the real part number but are added here for the operator’s benefit. In the illustration below, the “#” character is added as a suffix to the last part number to create “1 µF – C0402C105K8PAC#”. This indicates that an element in the model has changed within six months of the release date for this version. In this particular case, this part had an error in the ESR seed value (a typographical error when a ‘0’ was left off and created seed value of “0.096” instead of 0.0096” – a discrepancy error of “10x”).

Other special or prefix and suffix codes include “C0402F_..” for ‘Flex Fail-Open” designs, “C0402X_.…” for flexible termination, and “+…” for a new entry (past six months).
Figure 12: Choosing multiple PNs and multiple PNs of same capacitance for same dielectric, case, and voltage.

With version 3.5.0, the list now contains the capacitances at the selected dielectric, case size, and now for all voltages that meet the selected voltage level. The left window in Figure 12 shows the three selected part types, but the first two are 16 Vdc rated, while the bottom one is rated at 10 Vdc – the “selected” voltage was 10 Vdc, and since 16 Vdc can be used at 10 Vdc, part types from both 10 and 16 Vdc are listed.

In Figure 12 on the right, there are two part types shown for 100 nF and 120 nF capacitance values. For the 100-nF pair, they are both rated at 200 Vdc (50 Vdc was criterion – as shown). The difference is in the part numbers: C1206C versus C1206F. As explained in the box below the listing, the “C1206F” prefix designates the part type is a “Flex Open” design. The 120-nF pair also shows the standard design and the flex design, but in this case the flex design is rated at 100 Vdc – still satisfies the 50 Vdc criteria.

The next group, three 150-nF part numbers, are all of the same capacitance but of three different voltage ratings: 50, 100, and 200 Vdc. In addition, the 100 Vdc design is a “Flex Open” design, whereas the others are standard designs.

Regardless of which voltage design the operator selects, the displayed part types in the plots will have the voltage code converted to the selected voltage code (“5” for 50 Vdc). For instance, if all three of the 150-nF devices shown above were chosen, they would all appear as “C1206C154K5RAC” devices, even though one is rated at 100 Vdc and the other at 200 Vdc. This type of substitution is commonplace in the industry and it is always possible to get higher rated devices marked as lower voltage devices. The difference in response shows up when applying appreciable amount of dc bias.

With the High Voltage and High Temperature part types, the displayed capacitance list will only be of the selected voltage, and the check box for keeping PN identities will be hidden.

**Keep PN identities – do NOT convert.**

If this box is checked then the design part numbers will each show up as shown in the capacitance list. If this box is not checked then the part numbers will be converted to the voltage range of your selection (all of them as “C1206C154K5RAC”). On the right side of Figure 12, three 150-nF part types could fit the three additional requirements of ‘1206’ chip size, ‘X7R’ dielectric, and 50 volts rated. In actuality, one of the part types is designed for 50 volts application, while the other two are designed for 100 Vdc and 200 Vdc – still capable of satisfying the three listed requirements. If a distributor or manufacturer has 100 Vdc or 200 Vdc sitting on the shelf, but would have to build 50 Vdc parts, then he may send you one of these higher voltages that satisfy your requirements. The major difference in performance will be with voltage coefficients (how much capacitance change at given DC bias), with a slight difference in ESR.

**Version 3.6.11 allows the operator to override the PN conversion of different capacitor voltage designs using the “Defaults” form. See page 9, for more details.**
After selecting one or more capacitance values, click on this command button to proceed. This step can be eliminated if the operator double-clicks when selecting a single capacitance value.

If you click on “Done” and nothing happens, you probably have not selected the capacitance yet. The capacitance selected will be highlighted with a dark background.

Quit the program. The program will ask for verification before ending.

To go back to select capacitor type: touch the <ESC> key.

Aluminum-Tantalum Case/Style Selection

This screen (Figure 13) is used to build the part number for the electrolytic capacitors. There are four entries to choose from the style, case size, the voltage, and finally, the capacitance. The selections are controlled by the data files - changes to these files will change selection.

Capacitor Series (or Style)

With revision 3.9.0, there are twenty-two (22) types or series of capacitors from which to choose – with the last two as preliminary. At the top is the aluminum-polymer (A700 or AO) type of capacitors. The tantalum-MnO2 series range from the facedown T428 to the high temperature (T498), and the multiple-pellet (T510). Next the conductive polymer types from the basic (T520 and T521), to the high temperature variation (T525), to the multiple pellet, extremely low ESR (T530). Product now includes the military CWR09 (T409), CWR19 (T419), and CWR29 (T429). An image of the series will appear in the center image of the window.

The resolution of your display may not be able to show all the styles in the window at one time, and if this is the case, a vertical scroll bar will appear to allow you to scroll to view all the series.

Case/Size

Once the style is selected, the available case sizes for that style will be selectable, with the un-selectable grayed out. If a previous style had a specific case chosen, and with the change in style, the case is no longer selectable, the program will seek a selectable case, starting with the smallest. The image to the right of the case selection will show the chip style in three perspectives with dimensions defined by labels. The specific measurements for these drawing labels will appear immediately below the three-perspective view. Changing the style will change the three-perspective drawing, and changing the case size selection will change the listed dimensions.
Voltage
This group is dependent on the style and the case size selected, and not all voltages will be available for every style and each case. If the voltage is not available, it will appear as “grayed out” and the button will be filled in with gray. Click on one of the white buttons to select the voltage rating desired for the part.

Capacitance
A listing of the capacitances available for the selected style, case, and voltages is shown in the box located in the top-right section of the form. From the list, select the desired capacitance by clicking on it (clicking on the selection will cause the selected row to be reverse highlighted). Once a selection is made from the capacitance listing, clicking on [Done] will activate the plotting of the frequency scan.

Again, you can now select multiple part types from the capacitance listing box. From the form shown below, there are six (6) part types of the same capacitance for the T520 part type, “V” case, and at 2.5 WVDC. The only difference among these parts is that they have different ESR ratings. After the desired part types are selected, you can click on the [Done] button or touch the <Enter> key to proceed to the plot form.

Figure 14: Illustrations of part and layouts will change with selection.

Figure 15: Selecting multiple part numbers to get plots of comparative responses.

Double-click on a single capacitance selection, and the program proceeds to the next screen without the need for clicking on the [Done] button.

C-Spec Codes
Here is an explanation of the special suffix-codes applied to the part number. Usually these represent lower ESR or special temperature capabilities. There are many other suffix-codes, but only those effecting performance are included here. This box and script will only appear if a C-Spec effects the response of the capacitor, and C-Specs that detail packaging or inspection requirements will never appear. This box will not display an explanation of the ESR code (“E###”) applied as a suffix to the part number.

Newer releases (within past six months) are designated with a plus “+” suffix (this changed as in previous versions from 3.4.0 used the asterisk “*” to designate new) and preliminary releases are designated with “(Pre)” designations as a suffix to the part number. If a change was made in any part of the model elements in the past six months, a “#” designation is used.

If the capacitance selections are completed, this button will allow the program to go to next screen. Again, this step can be eliminated by double-clicking on a single capacitance choice. If the program does not change after choosing [Done], then go back and make sure that a capacitance value is selected, and appears as highlighted on a dark background.

Quit
This selection halts the program. The program will ask for verification before ending.
Film Capacitors

With the acquisition of Evox-Rifa and Arcotronics, a new line of surface-mount film capacitors is now available. Collecting the frequency scan data and then assigning the proper seed values and relationships gives us the capability to include these models in the software. The present selection includes “boxed” and “naked” film SMD and DIL offerings (MDC, MDK, and MDS). Most recent addition is the Arcotronics “LDE” and “LDB” series.

Once a product type is selected, the dimensional outline, dimension table, and product photo may change (Figure 16). In addition, the chip size, voltage selections, and the capacitance listing may also change. Selecting another chip size may result in the voltage selections and capacitance listing to change. Changing the voltage selection will result in a changing of the capacitance listing. This form works in the same manner as the ceramic or aluminum/tantalum forms, and as such, there will be no additional instruction in the film form.

The voltage ratings are normally listed as Vdc, but with the “SMP253”, paper dielectric capacitors, the voltage rating will appear as Vac (RMS).

![Figure 16: Film capacitor selection form.](image-url)
**Leaded Film Capacitors**

This is the most recent capacitor type added to KEMET Spice. As we secure more frequency scan, temperature variation, and power capability data on these devices, this form will make more selections available. On initial release, the “C4AE” four terminal devices are the only style available.

The selection order is style, pitch length, wire diameter (if selectable), voltage, and then the desired capacitance. There may be several part types of the same style, pitch, and voltage available, and additional columns denoting the dv/dt capability, and width, height, length, and secondary pitch (if available) may also narrow the selection to one or more part types. As with the other capacitor types, you may select a sequence (Click-Shift-Click) or a discontinuous grouping (Click-Control-Click, etc.) of up to ten capacitor part numbers, to view.

![Figure 17: Leaded film capacitor selection form.](image)
Plot Impedance & ESR vs. Frequency Plot

The initial plot will show Impedance & ESR versus frequency. The default conditions are at 25°C. For tantalum capacitors, the default condition will be with ½-rated dc bias to optimize the conditions, such that the maximum AC voltage can be realized without generating reverse bias. Because the ceramics and films tolerate reverse bias, the optimum AC voltage is realized at zero Vdc bias, and this is the default condition for ceramic and film capacitors. The frequency span for tantalums is 100 Hz through 10 MHz, for ceramics it is 1 kHz through 10 GHz for all dielectrics except C0G, and 1 MHz through 10 GHz for C0G dielectric chips.

A green vertical bar will appear in the graph that will move left and right with the mouse cursor (shown here at 10 MHz), only through the range of the graph. Windows above the graph will indicate values of frequency (1.00 MHz), impedance (5.88 mOhm), and ESR (5.80 mOhm) corresponding to the horizontal position of the green line. Later you will see how to remove this indicator. The indicated values will depend on the graph type being displayed: impedance and ESR, or capacitance and inductance (possibly DF or Q), or current and voltage.

Along the top of the window, several pull-down menus can be used to manipulate the response, the graph, circuit conditions, and printing or storage of the calculated response.

You can lock the vertical bar at any horizontal position, with the key combination of <Ctrl><0> or by clicking <Mouse-Right-Button>. After the bar is locked, you can use the <Cursor-Left> and <Cursor-Right> keys to step down or up, respectively, in frequency while any mouse movements are independent of the selector. Use the <Ctrl> key in conjunction with the left and right cursors to step by decades. The <Ctrl><0> or <Mouse-Right-Button> combination toggles the lock, off and on. When turning the lock off, the vertical bar will jump to the mouse pointer only after an initial movement. These cursor keys can be used to move the selector left or right, but if the mouse makes any movement within the plot area, the selector will immediately jump to the pointer.

Figure 18: Plot of Impedance and ESR versus frequency – initial graph after part number selection.
The command button [NOTE: Disclaimer] highlighted with the red arrow at the bottom of the display was added with version 3.7.4x, and it repeats the disclaimer message shown at the beginning of this manual on page 6. This button will appear in all plot screens in this program.

*Touch the <ESC> key to go back to ceramic or tantalum part selection screens.*

The multiple selection capabilities will result in impedance plots with multiple plots as those shown below. The top plot (Figure 19) shows the five ceramic chips selected (different capacitance values), and the bottom plot (Figure 20) is of the six (6) tantalum chips selected, all of the same value with different ESR levels.

![Figure 19: Impedance and ESR versus Frequency for multiple ceramic capacitance values.](image1)

![Figure 20: Impedance and ESR versus frequency for multiple tantalum capacitors of different ESR ratings.](image2)

**File**

File associated tasks including copy to clipboard, export ASCII data, starting over, and exit.

**Copy to Clipboard**  
<Alt><Print Screen>

There are times when it may be desirable to send a captured screen to someone, enclosed in some type of electronic file. To transfer the displayed screen graph to a clipboard, this command brings up a text window that instructs the operator how to copy the active window to the clipboard at any time - and it is not restricted to this program.

![Figure 21: “File” pull-down menu.](image3)
Using the key combination of <Alt> & <Print Screen> simultaneously copies the active window to the clipboard. From the clipboard, the graphic can then be placed in much software such as spreadsheets, graphical presentation software (e.g., Power Point®, Photoshop®), or word processors. It can be copied to Microsoft’s Paint® and printed directly from Paint.

You could also print the plot to a PDF writer and send the PDF file.

| Export ASCII |
| ^E or <Ctrl><E> |

To print the calculated data points to an ASCII file. The text file is printed after selecting the delimiting feature, elements to be included in ASCII file, file extension selected. In addition, the drive, path and file name are selected by the operator (Figure 22).

This feature is included because some of the existing SPICE software can build a component based on frequency data from a text file. It also allows data transfer to commercial spreadsheet or plotting software.

The format for the file is either delimited or fixed field. Any of the parameters can be selected for output, and the file type descriptive suffix is added to the name.

Optional “header” informational lines are selectable to be included with each text file generated. This includes a line for the KEMET Spice version, part number or chips style, temperature, dc bias, a header to data delimiter (“<DATA>”), as well as a comma delimited listing of the data elements in each line.

The drive is selected as well as the directory. The file name is entered by the operator and the output is activated by the [OK] button. If the name is omitted and [OK] is touched, the program will remind the operator to enter in a proper file name.

If multiple plots were selected, then there are five options (3.4.0) available for dealing with the additional data. The data can be saved, all to one file, with <DATA> and <End> sequence delimiters added as a line prior to and after each plot’s data listing. It can also save multiple plots in individual files with designations of “-1”, “-2”, etc., added as a suffix to each file name prior to the dot and file descriptor designation (e.g., “Test-1.Txt”, “Test-2.Txt”, etc.).

You can choose to only save the highlighted or foreground plot selected in previous plot screen (“Only save C0402C105K8PAC#” in illustration). The last two options allow you to save all the data in one file, with the data arranged in sequential columns, that are delimited or of a set space. The first of these two options allows you to save the data with all elements for each piece written, followed by the next piece. The second option arranges by element first, and then by piece.

The data points are determined by the points-per-decade frequency steps. In Figure 22, the “Frequency Steps” selections start out with the programs default setting (in this illustration, 100 steps per-decade). Secondary divisions of the base step rate then are shown as 50, 25, 20, and 10 steps per decade. For these settings, the data stored will skip 0, 1, 3, 4, and 9 data points as it stores the data. Fewer points allow for smaller files, but resolution is lost.

If the 50 steps-per-decade program default setting is used, then the Frequency Steps selection will appear as in Figure 23.

Shown in Figure 24 is a short illustration of the data files, with the data ‘TAB’ delimited. The last two options allow you to save all the data in one file, with the data arranged in sequential columns, that are delimited or of a set space. The first of these two options allows you to save the data with all elements for each piece written, followed by the next piece. The second option arranges by element first, and then by piece.

The data points are determined by the points-per-decade frequency steps. In Figure 22, the “Frequency Steps” selections start out with the programs default setting (in this illustration, 100 steps per-decade). Secondary divisions of the base step rate then are shown as 50, 25, 20, and 10 steps per decade. For these settings, the data stored will skip 0, 1, 3, 4, and 9 data points as it stores the data. Fewer points allow for smaller files, but resolution is lost.

If the 50 steps-per-decade program default setting is used, then the Frequency Steps selection will appear as in Figure 23.

Shown in Figure 24 is a short illustration of the data files, with the data ‘TAB’ delimited. The last two options allow you to save all the data in one file, with the data arranged by element and then by piece. The first column in the row after “<DATA>” is the frequency, then 1st piece impedance (Z), the second piece impedance, the first piece ESR (R), and the second piece ESR. On the right is the file saved with piece priority, then by element. The impedance and ESR of piece 1 are in the 2nd and 3rd columns, while the impedance and ESR of piece 2 are in columns 4 and 5.

| Start Over |
| ^S |

Start the program initializing to the program start. This option also eliminates any multiple choices you may have made.
This goes back to the Choose Type screen (Figure 4 on page 6) and allows a choice between ceramic and aluminum/tantalum. If you have selected multiple pieces, this will only allow you to change the last piece selected.

Choose Another Ceramic  ^A or <Ctrl><A>

Or

Choose Another Alum/Tant  ^A or <Ctrl><A>

This allows you to go back to the form to select another device, the same type as the previous. If last selection was tantalum or aluminum, it will return to the Tantalum/Aluminium Case-Style form (page 13), or if ceramic was last selected go to the Ceramic Type/Voltage/Capacitance form (page 11).

Change Parameters  ^J or <Ctrl><J>

This element’s purpose is explained much later in this manual, beginning on page 55, because the operator should be familiar with the program before changes of this type are attempted.

Exit  ^X or <Ctrl><X>

This function allows the operator to quit this software. Using the key combination <Ctrl> + <X> will allow the user to quit without going through the pull-down process, when the graph form is present. The program will ask for verification before ending.

Figure 24: ASCII files with TAB delimited data, arranged by piece (Major) then by element (minor) on the left, and by element (Major) then by piece (minor) on the right.
Print Plot

These selections allow the user to print any one of the possible graphs, print all of the graphs on a single page, or change the printer set-up.

Each of the selections may be followed by a special code such as “F2” or ^ P. These key values or combinations (<Ctrl> + <Another Key>) may be activated through the keyboard, allowing a quick response to the operator without any mouse movement. Activating these functions allows the operator to use the mouse to capture a desired frequency step and activate this function carrying the selected frequency. A listing of these “hot key” keyboard combinations and their actions is on page 84 of this instructional manual.

The (Z/R) Impedance and ESR plot was shown earlier. The (C/L) capacitance and inductance plot is shown on page 22, and the current and voltage (I/V) versus frequency plot is on page 25.

I will not cover obvious, single-plot selections (e.g., “Print Z/R  F2”, “Print C/L  F3”, “Print I/V  F4”, “Print dv/dt  F6”, and “Print Cap/dt  F7”, other than to point out that only one type of response is sent to the printer on each page.

Print All Freq

With this command, all three of the frequency-related plots (Z/R, C/L, and I/V) are printed on one page, in the order as shown in this pull-down command. If the monitor function is still active, then the parameters for each graph are listed to the left of the plot for the “marked” frequency. For the Z/R graph, this listing includes the impedance and ESR at the marked frequency, plus the ESL; for C/L the listing of either capacitances (actual and measured) or inductance at the “marker”; and, for the I/V trace, a printing of the ripple current and voltage (RMS) at the marker, plus the power capability of the device. If there are more than five (5) plots per graph and printing all frequency plots, the “Measured Capacitance”, “RMS Voltage”, and “Temperature Rise” listings will not be printed (not enough room). (See Appendix 1, Appendix 2, and Appendix 3 beginning on page 85.)

Print I TempRise vs. Irip (Ripple Currents) @Mult Freqs

This menu item will create a printed plot of the temperature rise versus ripple currents for five to seven distinct frequencies for the piece highlighted or in the forefront on any of the plots. (See Figure 39 on 31, or Appendix 4, on page 88.)

Print TempRise vs. Combined Ripple Freqs/Currs

This will print the plot of the temperature rise versus the combined currents from multiple frequencies for the piece highlighted or in the forefront on any of the plots. (See Figure 55 on page 40, or Appendix 5, on page 89.)

Print S11 vs. Frequency

Print the magnitude of S11(S22) in db and the phase of S11(S22) versus frequency as a single plot. (See Appendix 6, on page 90.)

Print S12 vs. Frequency

Print the magnitude of S12(S21) in db and the phase of S12(S21) versus frequency as a single plot. (See Appendix 7, on page 91.)

Printer Setup

This command allows the operator to choose the printer and some printing features through the standard windows printer form.
Plot C/L (Capacitance and Inductance versus Frequency)

Again, the vertical bar allows a display of capacitance and inductance values at 100 kHz (Figure 26).

The plot shown below is for a T495, Low-ESR capacitor, using MnO₂ cathode system. A more recent capacitor type using a polymer cathode system could have been shown, but it does not have as severe a capacitance roll-off effect as with the MnO₂.

Two capacitance values are listed: apparent and actual. The apparent is typical of how an impedance analyzer might interpret this component as it combines the capacitive and inductive reactance and allocates all effects to the dominant, but the actual is the real capacitance stripped of inductive influence (the apparent is a false indication, the real is true indication of capacitance). At the selected frequency of 100 kHz in the display, the actual (29.3 µF), and apparent (30.1 µF) capacitances are nearly equal and unaffected by the inductive elements.

For the ceramic, if the component is C0G, the Q will be displayed. For all others, the DF will be displayed if capacitance dominates the response, and the magnitude of DF is below 100.

Temp Adj.

The response of the device versus frequency or time can be viewed for different temperature conditions (Figure 27). Temperature can affect the ESR and the Capacitance of the capacitor. There are three quick menu options to select the maximum (85°C shown here, or ^H), minimum (-55°C or ^L), or a temperature near room ambient (^R or 25°C). The fourth option here is to enter custom temperature, not equal to any of the three listed.

+125°C or +85°C or +150°C ^H or <Ctrl><H>

This represents the high temperature range of the part without any derating. For the tantalum capacitors, the maximum ambient temperature is listed as 125°C, but above 85°C, there is a voltage derating that occurs. As such, temperature listed here for the tantalum is 85°C. With the T498 series the maximum temperature is now 150°C, with the derating beginning at 85°C (no derating) to 33% derating at 175°C (rated voltage is now 67% of labeled voltage).

Factors influenced by temperature include capacitance for all devices except the C0G ceramics. The ESRs for all devices are temperature sensitive and changes are reflected through this menu. As the ESR and capacitance are factored, the maximum RMS currents and voltages allowed for these devices are also factored.

With the conductive polymer, and tantalum capacitors, temperatures above 85°C, will create a temperature dependent voltage derating (the dependence is a linear decline in rating versus temperature). From -55°C up to 85°C, the voltage rating is equal to the nameplate (catalog or stamped rating). For the T49x, T510, and T525 devices, the rating drops to 67% of the nameplate voltage at 125°C. For the T520 series, the decline begins at 85°C, and drops to 67% of nameplate voltage at 105°C. For the T498, the decline
begins at 85°C, and drops to 67% of nameplate voltage at +150°C. For the T499, the drop is 67% at 175°C. All of these compensations are automatically adjusted in the software.

The program will allow excursions beyond the maximum temperature rating of the part, but the part has its listed maximum temperature rating that we expect the customer to honor. The full operating temperature range of the tantalum capacitors is up to 125°C.

+25°C

This is the "normal" or room ambient temperature (^R), though I find 25°C rather uncomfortable.

-55°C

This denotes the minimum or low (^L) temperature rating of the part.

Custom

This entry allows the operator to enter any value for a temperature setting (Figure 25).

It will allow entries above and below maximum range, but it will warn of consequences. The entry defaults to previous temperature if none selected.

For most tantalum capacitors and temperatures above 85°C, a derating of the dc voltage is applied. If the application is in violation of this “adjusted” dc voltage rating, notice will be given to the operator and an adjustment of the application voltage may be made to allow compliance to an “adjusted” limit.

Change Allowable Temp Rise

You can change the allowable rise up to +100°C. Most of the industry uses +20°C as an arbitrary standard. Allowances for 50°C temperature rise should create no problems for all the ceramic and tantalum SMD capacitors and may be used as the absolute maximum rise; unless, this temperature is pushing the internal temperature above its maximum rating. To compare with other suppliers, a 40°C or 45°C rise can be shown to have comparisons on equal basis.

The maximum temperature rise for film capacitors is dependent on ambient temperatures and is automatically developed in the program.
Change Plot

The operator chooses what type of plot to display (Figure 30). There are three frequency domain plots for Z/R, C/L, and I/V, and these can be activated without the pull-down menus by entering a key-sequence of ‘Z’, ‘C’, and ‘I’, respectively. There are also two time-domain plots of dv, and Capacitance, that can be quickly accessed by ‘V’, and ‘U’, respectively. A plot of S21 magnitude versus frequency can be accessed by touching key <F12>, and “Plot TempRise vs. Irip @Mult Freqs” will plot temperature rise versus ripple current magnitudes for several select frequencies (“F1”). The most recent plot added with version 3.7.5 is the “Plot TempRise vs. Comb Freqs/Curr” accessed by ‘F9’ which is the temperature rise of multiple frequency currents combined.

The default or initial display is ZR, but once another type of display is selected, it remains the default until the program is ended.

- **Plot Z and R**
  ^Z or <Ctrl><Z>
  The plot data on the screen will reflect impedance (Z) and effective series resistance (ESR) versus frequency. For the tantalum chips, the frequency range will default from 100 Hz through 10 MHz. For the C0G dielectric ceramic, the frequency range default is from 1 MHz through 100 GHz, and for the other ceramics, the frequency range is from 1 kHz to 100 GHz. This graph type is depicted on page 17.

- **Plot Cap and L**
  ^C or <Ctrl><C>
  The "apparent" capacitance before self-resonance is plotted versus frequency, as well as the "apparent" ESL after self-resonance. The capacitance is shown in Farads, with suffixes indicating scientific multipliers, and the ESL is shown as Henries, again with the scientific suffixes.

  For the tantalum capacitors, since the capacitance may be decaying with frequency, the "actual" capacitance is also plotted as shown on page (Figure 26, page 22).

  For the ceramic capacitors, the actual capacitance changes slightly with frequency but a false “peaking” may occur just before the series self-resonance. The sudden rise of capacitance is not a true capacitance increase. Instead, it is how the measuring device interprets the resultant reactance without stripping the inductive reactance from the still dominant capacitive reactance. This false “peaking” also occurs with the aluminum polymer, all the film, and the T52x and T53x series tantalum capacitors.

- **Plot Current (I)**
  ^I or <Ctrl><I>
  The maximum RMS current and resulting RMS voltage-versus-frequency is plotted here (Figure 31). Each time this graph is selected a warning about the meaning of this graph will appear. This represents the plotted data for the calculated maximum RMS current at one single frequency only. (See more information on page 22.)

- **Plot dV/dT**
  ^V or <Ctrl><V>
  A plot of the voltage decay versus time from a charged capacitor is plotted as volts per ampere on the vertical axis and time on the horizontal scale. (See more information on page 27.)

- **Plot dC/dT**
  ^U or <Ctrl><U>
  A plot of the capacitance growth versus time is plotted as capacitance on the vertical axis and time on the horizontal axes. This reflects a time-domain plot of the capacitance decay in electrolytics with increasing frequency from the frequency-domain. (See page 27 for more information.)

- **Plot S11/22 or Plot S12/21**
  F11 or F12
  The magnitude and phase are plotted versus frequency for these scattering parameters. You can also change circuit connection (series or parallel – see page 28) and line impedance (50 ohm or 75 ohm – see page 28).

- **Plot Temp. Rise vs. Ripple Current**
  ↑I or <Shift><I>
  A plot of the temperature versus ripple current for several frequencies is plotted here. The cursor moves the line along the horizontal scale (current) and a readout of the temperature rise for the selected frequency plot is shown. (See page 30 for more details.)
Plot Temp. Rise vs. Combined Ripple Currents

A plot of the temperature versus the combined ripple current from several frequencies is plotted here. The cursor moves the line along the vertical axes (temperature rise) and the currents at each frequency are shown in a table in the plot, along with the power developed at each frequency. (See page 37 for more details.)

Plot Maximum RMS Current & RMS Voltage versus Frequency Plot

![Plot](image)

Figure 31: Plot of ripple current and ripple voltage versus frequency.

This plot (in red) denotes the current that would achieve maximum power dissipation of the capacitor at any frequency. This is the first method of calculating ripple used in this program whereby the defined temperature rise (20°C as shown in Figure 31) creates related power dissipation (150mW), and using that power and the ESR at ambient temperature, the ripple current (RMS) is then calculated. This calculation does not take into account that the temperature rise creates a new, higher internal temperature for the device and the ESR at this temperature could be significantly different from the ESR at the ambient temperature. If the ESR is higher at the elevated temperature, then the ripple calculation is overestimated, and if the ESR is lower, then the ripple current is underestimated. For MLCCs and tantalum capacitors, the temperature coefficient of ESR (TCR) is negative (underestimating actual ripple current), but for the film capacitors, the ESRs can be complex, containing both positive and negative TCRs. (The second method for calculating ripple current using ESRs that vary with temperature is explained under the “Plot Temperature Rise vs. Ripple Current” heading on page 30.)

If the maximum power dissipation is achieved at any single frequency then there is no more left for any other frequency. The allowable temperature rise defaults to +20°C (use <Ctrl><W> to change allowable temperature rise, see page 23), and the power to create this rise is shown in the center, above this plot (150 mW as shown). The mouse moves the vertical bar as shown in the plot, at 100 kHz, the current required to create the power dissipation is 2.63 amperes (voltage is at 59 mV).

If the resulting ripple-voltage (multiple of current and impedance) results in a peak voltage that exceeds the rated Vdc for the part, then the peak voltage will be clamped at the DC rating. In Figure 31, the voltage is clamped at 1.4 Vrms from 100 Hz up to 330 Hz, while the current decays in a linear fashion from 330 kHz down to 100 Hz. In this region, the peak voltage of 2 Vac added to the DC bias of 2 Vdc equals the rated voltage of 4-Vdc for this part type.

For film capacitors, the AC rating is not always related to the DC rating of the capacitor. Typically, the AC-RMS rating is around 63% of the DC (average sinusoidal) but with higher voltages, it can be less than 50%. The peak voltage resulting from these AC voltages is less than the DC level. For these capacitors, the peak voltage establishes the clamping level and a DC voltage at or above this level will result in an AC-RMS rating of 0Vac.

For ceramic and tantalum SMD capacitors with negative temperature coefficients of ESR (TCR), the ripple current and ripple voltage versus frequency plots (Figure 31) were adequate with a slight error because they calculated the results for a given temperature
rise (nominally +20°C) using the ambient temperature ESR and not the ESR adjusted to the internal temperature. For the negative TCR behavior, the ESR compensated for a temperature rise above ambient will be lower than the ESR at ambient. Because the error added a safety factor to the results, little concern was given to these results.

With the inclusion of film capacitors, there are dielectrics where the TCR is positive in some temperature ranges, and ignoring this could create errors in the plots versus frequency where these plots could overestimate the true capability of these devices. Because of this potential error, the ripple current and voltage plot will now display a warning if the defined temperature rise encounters a positive TCR, creating an overestimation of capabilities.

Figure 32. Warning shown when ripple current and voltage are overestimated because of positive TCR.

See the “Plot Temperature Rise vs. Ripple Current” section beginning on page 30 that details the second method for calculating ripple current and the plots of temperature rise versus applied ripple current beginning with Figure 39, on page 31. In the plot of Figure 32, the ripple current capability is shown as 7.27 Arms at 100 kHz. In using the plot of temperature rise versus applied current for this part type the ripple current at 100 kHz is 5.74 Arms for a 20°C temperature rise and above +13°C (5.66 Arms) to +20°C the response is nearly vertical.

Plot dv/dt ^V

This is a time-domain plot of dv/dt (Figure 33). This is normally current dependent, and instead of introducing another selectable variable for this program, the vertical axis is plotted as “dv/Ampere” or simply as volts per ampere. There is another variable normally associated with this plot and that is the “di/dt”. In order to keep it simple, this element of the pulse response was omitted from the display. As such, the inductive pulse portion of this voltage pulse is missing.

Figure 33: Plot of dv/Ampere versus dt. By using dv/Ampere, the third variable is accounted for.
**Plot of $dv/dt$**

This plot (Figure 33) represents cumulative voltage decay with time, for a capacitor being discharged by a constant current. As the current is not defined, the scale of voltage drop is given as “volts/ampere” or may be viewed as “mV/µA”, “µV/µA”, etc. This plot is very closely associated with power decoupling, or bus hold-up applications.

\[
dv = \sum_{i} \left( \frac{i}{C_i} \right) \times dt_i + (i \times ESR_i)
\]

This discharge is equal to the current (amperes), divided by the time dependent capacitance (farads), and then multiplied by the time (seconds). Since this discharge also creates a voltage drop across the ESR, the current times the ESR is added to the changing cap voltage.

This plot does not include an inductive voltage generated in time that is dependent on the $di/dt$, or the rate at which the current moves from zero S to the constant current. This adds another variable to this analysis and at this time was left off the plots. The calculation for this response is shown above.

*In the time-dependent plots, the <Cursor Left> and <Cursor Right> keys will extend or decrease the time scale. This is unlike the frequency-dependent plots in which these keys will move the monitor down and up the frequency scale.*

If the ESR were constant and the capacitance were constant, this plot would be a step drop in voltage (due to the ESR), then a constant voltage decay with time (with the slope of the decay inversely proportional to the capacitance). Because the capacitance for the aluminum and tantalum is represented with a RC-Ladder, the capacitance initially is very small, and it increases with time. A plot of the capacitance versus time is also available (Figure 34).

The selectable time scales for this plot are always from zero seconds, up to a selection of 1 µS, 10 µS, 100 µS, 1 mS, and 10 mS. These scales are changed with the left and right cursor keys.

---

**Plot $Cap/dt$**

The “other” time-domain plot shows the capacitance as a function of cumulative time or $dt$.

**Plot of Capacitance vs. $dt$**

With the plot shown in Figure 34 (extracted from a PDF printout to show the multiple listings for the monitored response), multiple pieces are shown with responses listed for 10 µS. The best performance is shown with the aluminum-polymer (A700), then the tantalum-polymer (T520), followed by the low-ESR and commercial versions of the tantalum-MnO2 types.

This plot highlights that multiple parts can be plotted on the same graph – a feature defined on page 50.

Figure 34: Plot of C (Capacitance) versus time for four different part types (multiple plots).
Plot of Scattering Parameters (S-Parameters)

Plot S_{11} vs. Frequency

The magnitude (red line and left vertical scale) and phase angle (blue line and right scale) are shown for the S_{11} (or S_{22}) for the ceramic capacitor in “Shunt Mode” for a 50-ohm line.

Change S-Parameter Configuration (Parallel vs. Series) \(^O\) or \(<Ctrl><O>\)

During these scattering parameter plot viewings, the operator can switch between shunt and series mode by using the \(<Ctrl><O>\) key combinations (toggles back-and-forth).

Change the S-Parameter Line Imp. (50 Ohm vs. 75 Ohm) \(^5,^7\) or \(<Ctrl><5>, <Ctrl><7>\)

Using the combination keys \(<Ctrl><5>\) sets the line impedance to 50 ohms, while \(<Ctrl><7>\) sets the line impedance at 75 ohms.

The scattering plots are based on a four-port measurement, but since the capacitors here are two-terminal devices, there is equivalence for S_{11} and S_{22}, as well as S_{12} and S_{21}. 
Figure 36: Plot of MLCC $S_{12}$ ($S_{21}$), series mode, and 75-ohm line.

This is a frequency-domain plot of the magnitude of $S_{21}$ in db, versus frequency. The line impedance used for this display is 75 $\Omega$ and the connection between ports is in the series mode configuration. This measurement is normally made using a network analyzer and a direct reading of the scattering parameters. This parameter is normally associated with high frequency networks.

**Frequency Range**

^F or <Ctrl><F>

Allows the user to extend, widen, or narrow the frequency range for the calculated response (Figure 37).

Select Start and Stop frequencies. Tantalum will only allow maximum of 100 MHz for Stop Frequency. Click on Return when completed.

**NOTE:**

This is the most frequently asked for option. It has been a part of this program since the early stages, but many users are unaware that it is possible to change the displayed frequency until this function is explained. These changes can be customized to any span desired and may remain in effect if the changes are made with the “Default” options (page /9).
Grid Lines

Light green lines can be set to extend from the major and minor indices of each axis with this form. If you would like to see the grid lines shown (and printed), activate the check in the appropriate selection box then select [Show Selection]. You may also select [Show All] if both major and minor indices of both axes are to be shown. In a like manner, you may also use a single button to choose [Show None] and no lines will be shown.

Plot Temperature Rise vs. Ripple Current

This plot will show temperature rise (°C) versus applied ripple current for any single piece at set frequencies. This plot represents the second method of calculating ripple current in this program. Set, incremental temperature rises are applied and the powers required creating this increase along with the ESRs for each frequency, at the new or elevated temperatures (ambient plus increase), are used to calculate the ripple current at those conditions. The results achieved here are likely to be different from those using the first method of calculating ripple current (page 25), or as in the Ripple Current & Voltage versus Frequency plots (Figure 31, page 25).

If a single piece had been selected, then the ripple plot can only pertain to that piece, but if multiple pieces or multiple conditions (bias or temperature) have been selected, then this plot will pertain to that piece in the forefront of the previous plots. This plot has a linear vertical scale of temperature rise from 0°C to 100°C. The horizontal axis is a log scale showing the ripple current. For this plot, the temperature rise is applied to the ambient temperature (25°C in Figure 39). The program has nine default frequencies at which the ripple currents and temperatures are plotted: 1, 3, 10, 30, 100, 300 kHz, plus 1, 3, and 10 MHz. Each listed frequency can be selected as the forefront of the display (use the mouse to click on desired frequency or use the <Up> and <Down> cursor keys to select another frequency). The forefront plot becomes bold for that frequency (as shown in Figure 39 for 10 kHz) and the ripple current and voltage as well as temperature are displayed immediately above the chart pertain to that frequency. The mouse moves the vertical green line cursor along the current axis, and the voltage and temperature rise and applied current are displayed for that piece.

There are up to five temperature regions defined. For the X7R plotted in Figure 39, there are normally four regions plotted because at an ambient of 25°C and a temperature rise of +100°C, the top of the plot defines the maximum usage temperature (125°C) for that dielectric. In order to show the five regions, the ambient was set at 35°C so from +90°C to +100°C (internal temperature >125°C), the “out of spec” region could be shown.

The first region is the “catalog specification region” from +0°C to +20°C rise (where the ripple capability for the device is specified by convention and listed in manufacturers’ catalogs). The second region from a 20°C to a 50°C rise (considered a “Safe” operating region for the capacitor) is where the device can operate with no special considerations. The third region, “Ramp-up Required” from 50°C to 70°C is where the device should be ramped up to these current levels gradually (2 to 5 minutes ramp) to prevent internal-to-external temperature gradients within the capacitor. The fourth region from above 70°C rise to the maximum temperature for the part is not recommended. The fifth region is above the operating conditions for the part type, or above the maximum temperature.
In Figure 40, the ambient temperature is changed to 25°C to show that normally for this X5R device (maximum use temperature is 85°C), there are only four regions shown.

The frequency selection can be changed with a mouse click, and by using the <Up>, or <Down> cursor keys. The selected frequency is highlighted in the selection box at the top-left region of the form, and the plotted response is thicker and bolder in the graph. In Figure 40, the 3k Hertz selection is highlighted and the red trace is wider in the plot. In these plots, a vertical bar is controlled by the mouse or <Right>, <Left> cursor keys, as a positioning guide along the horizontal or current axis. Readout of the current axis position is shown above the top, left position of the plot. In Figure 41, the cursor is positioned to a temperature rise of 20°C, revealing a current of 2.55 Arms, and the resulting voltage of 13.64 Vrms.
The plots for each frequency will be shown until an Over Voltage (“OvrVlt”) or Reverse Voltage (“RevVlt”) condition is met, or the maximum allowable temperature is met, or until +100°C is achieved. Over voltage occurs when the Peak AC voltage added to the DC bias voltage, is at or above the voltage rating of this capacitor. Reverse voltage occurs for a polar capacitor when the negative peak voltage added to the DC bias voltage results in a negative voltage peak greater than negative 15% of the rated voltage.

In Figure 41, the 1 kHz and 3k Hz plots stop in mid range indicating that an overvoltage condition occurred. The other frequency plots continue until the 60°C rise is achieved (85°C internal), creating the maximum allowable temperature for this device.

![Figure 41. Cursor position of the vertical bar shows current, temperature rise, and voltage for the selected frequency.](image)

The position of the vertical line can be controlled by the mouse, but a tighter movement and smaller increments can be created by using <Alt><Right> or <Alt><Left> keyboard combinations.

In Figure 42, the cursor is positioned at the maximum point of the 3 kHz trace, showing a delta temperature of +27.98°C, a current of 3.21 Arms, and a resulting voltage of 17.18 Vrms (24.3 Vp). Because this plot is created with set incremental temperature steps, the acceptable temperature step of 28°C resulted in allowable calculations, but the next step of 30°C resulted in peak voltage greater than the rated voltage (25V) of the part type.
Moving to the left of the first point plotted will display “<+0.1°C” temperature rise. If no point is plotted (current at +0.1°C, the first point calculated) it would mean that even at this current level, the peak voltage is approaching the rated voltage of the capacitor. Moving to the right of the last point plotted will show an over voltage or over temperature condition as in Figure 43 (“OvrVlt”). The highest valid current read will be retained, but his value may be factored by how fast the cursor transitions above the last point. Going slow allows the program to capture the highest current level (3.21 Arms in this instance).

In this plot, you can add to the basic frequencies plotted with a maximum frequency count of 10. If the basic frequencies are the first nine then there is an allowance for one additional frequency to be selected by the operator. If a SMPS is running at 500 kHz, it may be desirable to see what the temperature rise versus ripple current at that frequency is.
To access the frequency selections, cursor down past the last frequency listed. Once past the last, a pop-up window will allow you to enter the next frequency (be aware that the entry is in kHz). The frequency will appear in place of the original entry and it will be checked. When returning to the temperature rise versus current plot, the frequencies will be ordered.

You can also add, delete, or modify the frequency selections by using the pull-down menus ([Change Plot] [Frequency Range]), or use the special key code (<Ctrl><F>), and the form as in the upper left of Figure 44 will appear. Click on an unchecked entry enter the desired frequency (for 500 kHz, just enter “500”). To change an existing frequency, click on a checked frequency to clear that selection, and click again on that cleared frequency to enter a new frequency.

You can also change the default frequencies so that your selections appear every time by using the “Defaults” form of Figure 9, on page 9.

Figure 44: Adding 500 kHz as another line in temperature rise versus ripple current plots.

With film capacitors, there are only two or three regions defined in their ripple current versus temperature plots. In Figure 45, the “allowable” region (A) is limited by where “hot spot” temperatures within the capacitor begin. In this case, the MKS capacitor type utilizes a PPS dielectric, and at an ambient temperature of 25°C, the safe region in which this capacitor may operate is with a rise of 30°C. The “hot spot” temperatures are derived experimentally, and in Table 1, a listing is shown for various dielectrics and ambient temperatures.

Figure 45: Ripple current versus temperature rise for film capacitor showing two distinct regions: acceptable and unacceptable.
With some film dielectrics, these defined temperature regions are not the only consideration for safe operation. Figure 46 is a Photoshop compilation of three ambient temperatures for an “MDK10 106K50A57P7”, PPS dielectric film capacitor with ambient conditions of 25°C, 40°C, and 60°C. The slopes of ESR versus temperature rise appear to be similar in the lower temperature ranges, but changes dramatically as the temperature rise increases. In Figure 46, the temperature rise versus applied ripple current for the 60°C ambient has an abrupt change at +15°C. At this point, the temperature rise is creating an increasing ESR, creating a higher temperature, increasing the ESR, etc. Based on this response, the safe condition for this capacitor at an ambient temperature of 60°C is not to +30°C because that rise is already in the vertical response (might be defined as a “thermal runaway” condition), but more, like +10°C as this is still in a controlled region of the response. In Figure 47, a plot of ESR Multiplier versus ambient temperature is shown and the positive inflection of the TCR is occurring near 75°C ambient.

Figure 46. Creating maximum ripple limits below the “hot spot” allowance.

Figure 47. ESR Multiplier versus ambient temperature for PPS dielectric.
Table 1: Listing of allowable temperature rise versus ambient temperatures, by dielectric.

<table>
<thead>
<tr>
<th>Ambient</th>
<th>PET</th>
<th>PEN</th>
<th>PPS</th>
<th>Paper</th>
<th>PP</th>
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The operator may now change the ambient temperature (<Ctrl>T) or the bias conditions (<Ctrl>B) while viewing the temperature versus ripple plot.

A printout of this plot is shown in Appendix 4, on page 88. A listing of the frequencies and associated ripple currents for the cursor position is created in the upper left region of the printout, such that at that specific ripple current, the corresponding temperature rise is indicated for each of the temperatures.

The method of calculating this ripple capability is different from that used to plot ripple current versus frequency (Figure 31, page 25), and the results may differ. In the ripple current versus time calculation, the calculation is first attempted using the ambient temperature ESR at each frequency, and knowing the power capability of the device calculating the RMS current at each frequency. The power capability is normally specified as the power dissipation creating a +20°C temperature rise (a rating establishing conformity among manufacturers). The RMS current for the defined power dissipation is dependent on the ESR at each frequency.

If the product of the peak current and the impedance results in a peak voltage that is higher than the rated voltage minus the dc bias voltage, then the current is recalculated. The recalculated uses the voltage difference between the rated voltage and the dc bias voltage as the maximum peak voltage allowable at that frequency. The peak current is then calculated using the peak voltage and the impedance of the device at that frequency. The RMS current at this point is limited by the ripple voltage.

For the temperature rise versus ripple current (Figure 39, page 31), the ESR at each frequency is adjusted by the temperature rise (for MLCCs and MnO2 devices, this results in a diminished ESR as the temperature coefficient of resistance is negative). The power dissipated is then calculated by using the power per Celsius degree (W/°C) times the set temperature rise. The RMS current is then calculated from the power and ESR. If the product of the peak current and the impedance results in a peak voltage that is higher than the rated voltage minus the dc bias voltage, then the current is recalculated. The recalculated uses the voltage difference between the rated voltage and the dc bias voltage as the maximum peak voltage allowable at that frequency. The peak current is then calculated using the peak voltage and the impedance of the device at that frequency. The RMS current at this point is limited by the ripple voltage.

Both of the methods used in these two plot formats represent compromises. For the plot of ripple current versus frequency, the ESR is not adjusted by temperature rise, although it is evident that this takes place. We accept the error here as additional safeguard to the derived currents (This was an added safety factor for Tantalum and MLCC capacitors with consistent negative TCRs.). Additionally, as the temperature increases, the impedance changes, but we do not apply these, as these changes are small over a +20°C increase, which is used to establish the power capability in this plot.

In the plot of temperature rise versus ripple current, we use 43 distinct temperature steps to calculate the ESR change from the ambient conditions, and then calculate the ripple based on the W/°C rating of the device. When we check to make sure the impedance times the peak current is within acceptable levels, we modify the impedance by the ESR change. Though this change may be small at +20°C in the frequency plots, we are calculating the effects up to +100°C in this plot.
Plot Temperature Rise vs. Combined Multiple Frequencies/Currents

With some filtering applications, the AC signal across the capacitor is complex, containing multiple frequencies and current levels. Using Fourier analysis, the main frequency components with their associated current levels may be distinguished. The power dissipations of these multiple frequency signals combine to create a summary power dissipation and resultant temperature rise. So far, all the analysis or ripple current in this program has been to show temperature rise for a singular frequency component and not a combined effect. That capability is now presented here.

From the pull-down menu selection under “Change Plot” (Figure 30 on page 24), a selection of “Plot TempRise vs. Comb Freqs/Currs” exists and selecting this item will allow the operator to specify multiple frequencies, current levels at those frequencies, and the summary power and temperature rise for the combination. This process can also be activated with the keyboard combination of the two keys, <Ctrl><F9>.

Once this plot selection is made, a file selection box will appear (Figure 48) to allow the user to load saved frequency and current combinations. These files are kept in the program directory with the file type designation of “*.FqCurr”. Four initial files included with the program should show up in the program directory: “Power Conditions A.FqCurr”, plus conditions labeled “B”, “C”, and “Z”. Because every application could present unique combinations, any new combinations may be saved, creating additional “FqCurr” files.

Power conditions in “Z” were added once the power film capacitors were included.

A summary power is calculated (48.72mW) and based on the power dissipated and the thermal resistance of the device, a temperature rise (3.9°C), and internal temperature (23.9°C) are calculated.

The initial table calculations conform to the first method of calculating ripple current used in KEMET Spice for power calculations in that the temperature of the part will increase with the power dissipated, but the first method does not compensate the ESR for this adjusted temperature. If the ESR is lower at the final elevated temperature, then the power dissipation will be lower than calculated; and if the ESR is higher, then the power dissipated will be higher than shown.
The frequency and current entries may be selected from data listings accessed by clicking the down arrow immediately to the right of each value (Figure 50). You can select a listed entry such as the “120 Hz” selection for “No. 1” or if the exact value is not in the listing, you can enter a value such as “95.0 mA” as shown for “No. 2”. When you do enter an unlisted value, be sure to add a space before you use any labels. Acceptable labels for frequency entries include “Hz”, “kHz”, “MHz”, and “GHz”. Acceptable labels for current include “A”, “mA”, “μA”, and “pA”. DO NOT use labels other than these. Omitting any label assumes the base label (“Hz” for frequency, and “A” for current). Any activity involving the frequency, current, color, or check box entries will activate the [SAVE Entries] button, to allow storing new entries in another CURR file.

**Figure 50: Pull-down**

Clicking on the color box will allow you to change the color of the line. If the check box has a check, it will be included in the summary power calculation, the temperature rise, and the subsequent plots. Clearing the check box will omit that frequency from the calculations and plots.

The **second method for calculating ripple** will first incrementally increase the temperature of the component. That incremental temperature will relate to specific power dissipation and based on that power and the ESR adjusted to the elevated temperature, the current is then calculated. The second method is initiated with the [Continue] button on the frequency/current entry table.

The full plot shown in Figure 51 has a horizontal red line that is manipulated by the mouse, and the current readings for each frequency plotted are then displayed in the table at the top left corner of the plot. Along with the currents, the power developed is also given for each frequency. Pressing <Ctrl><1> (numeric one) will cause the horizontal line to snap to the current levels as entered in Figure 49, and lock in that position. Right clicking the mouse or using <Ctrl><0> (numeric zero) will toggle the line between locked and unlocked pertaining to subsequent mouse movements.

The lines will continue until a maximum temperature level is achieved, regardless of the voltage being generated. If the indicated currents generate a voltage above the capacitor’s capability, it too will appear with a red background if overvoltage and white background if voltage is acceptable.

**NOTE:** These voltages at each frequency are calculated independently and although there may be instances where the peak voltages from multiple frequencies become additive, the program does not look for these instances.
In Figure 51, eight lines appear although nine frequency/current combinations were selected. Because the current levels for the 720 Hz and 1.8 kHz entries were the same 120 mA, the plots are on top of one another. Slight variation of the current levels will separate these two creating two distinct current plots. The plotted lines adhere to the color designations in the frequency, current, and power table, and these can be changed in the “Ripple Current/Frequency Table” of Figure 49.

Using the varying ESR in this calculation, the power calculation is now 43.89mW (compared to 48.72mW in Figure 49) and the temperature rise is 3.51°C (compared to 3.9°C). Manipulating the cursor to 30°C (partial plot of Figure 52), which is the allowable temperature rise for this part type, shows that although the current levels create an allowable temperature rise, the ripple voltages generated in seven of the frequencies are now generating over voltage conditions.

Over voltage is as unacceptable as over temperature. There are a couple of methods that can be used to eliminate the over voltage conditions. The first is to select a part type with greater voltage rating. From the original 50Vdc rating in Figure 49, a similar part of the same capacitance at 100Vdc rating was selected (MDK10 105K100A2P3) but this part still showed over voltage with 60mA at 120Hz, although it eliminated the over voltage for the 360Hz current. Selecting the same style and capacitance rated at 250V eliminated all over voltage conditions (MDK10 105K250A5P7).

The total power dissipated as shown in Figure 53 is the same 48.72mW as the 50Vdc part, but the temperature rise is now 2.7°C compared to 3.9°C. In order to create an over voltage with this 250Vdc rated part, the current at 120 Hz would have to be greater than 133mA and the current at 360Hz would have to exceed 379mA.

Another method to eliminate the overvoltage would be to try a higher capacitance. In Figure 54 the part type was changed from 1µF to 2.7 µF (MDK10 275K50A2P3) and the 120 Hz and 360 Hz current entries now generate voltages below the 50V rating for the capacitor. The higher capacitance allows for lower ESR, and lower impedance. The power generated is reduced from the 48.72 mW (3.9°C) in Figure 49 down to 18.25 mW (1.5°C). The threshold for the 120 Hz and 360 Hz currents are now close to 72 mA and 216 mA, respectively.
If the capacitance is at or near the maximum allowable for that part type, another way of increasing capacitance and eliminating the overvoltage would be to use parallel pieces. This allows the currents to divide among the capacitors, and each capacitor receives a fraction of the specified current. This reduction in current affords a reduction in the ripple voltage.

The printout from this plot (<Shift><F9>) is as shown in Appendix 5, on page 89. The listing of the frequencies, currents, and powers are in the upper left region of the page. A filled circle and the text color for each frequency line correspond to the line color in the plot. Any frequency and current combination that creates an overvoltage condition results with an asterisk (*) designation after the power listing. Any of the lines resulting in an overvoltage will also result in the printout of “Conditions Result in Over Voltage” explanation below the listed values. Also included in the printout is a listing of the power developed (Total Power = 43.89mW), temperature rise (3.51°C), and the percent total power (100%). As indicated in the printout, 100% power occurs at that power dissipation or temperature rise where the currents are exactly equal to those entered in Figure 49.

Everything demonstrated so far for this plot has been generated for PET film capacitors at 20°C ambient. In this region up to about 70°C, the TCR for the ESR is negative, but begins a positive trend after that. In Figure 55, the same plot as in Figure 51 is shown but the ambient temperature is now 60°C. Because of the positive inflection of the TCR, the temperature rise appears to be vertical above plus 15°C. Although the allowable temperature rise for this component at an ambient of 60°C is given as plus 22°C, using that temperature rise would put the part in an unstable situation. In fact, using the part above plus 15°C gets the part into the beginning of the vertical jump and its application should be restricted to plus 15°C or lower. Because the ESR at 60°C is considerably lower at 20°C ambient, the delta temperature (0.86°C) for the applied currents will also be lower than at 25°C (3.9°C).

The currents listed in the table in the plot above do not match the entry currents exactly, except for the first (60 mA at 120 Hz). This is because the search for the entry-level currents only looks at the first frequency for an exact match, and all other currents are derived as the same fraction of the difference between plotted current points for the other frequencies. Near the very beginning of the plots as the values are very low, the resolution of the point values causes some minor error of interpolation. For the second frequency the current is listed as 96.21 mA instead of the 95 mA as entered (an error of +1.3%), the third as 121.86 mA instead of 120 mA (an error of +1.55%), and so on. The largest error is 1.69% for the 2.04 kHz current of 91.52 mA versus then entry-current of 90 mA.
Monitor XY

- **Monitor Freq.**

  The default for the monitor effect is “ON.” The actual values of the graph are difficult to interpret especially when log type graphs are used. This menu allows the user to view the data as the cursor is moved across the screen graph. Data windows will appear across the top of the graph and these display the positional (vertical marker) values of Frequency, Impedance, and ESR, for the Z/R graph. The frequency or time will be displayed in the other plots, but the positional values of the vertical axis will depend on the plot type.

  For the C/L graph, the monitored data includes Cap (apparent capacitance) when below the self-resonance, and Inductance (L-apparent) when above. The tantalums will also show "Actual" capacitance, while the ceramics will also show "DF." For the C0G ceramics, "Q" is also displayed.

  For the I/V graph, the maximum RMS currents and voltages are displayed during monitor.

  The monitor function is toggled on and off by clicking on "Monitor" or the keyboard combination (^M). If the monitor is active, the data windows appear and there is a check mark in front of the pull-down menu "Monitor Freq."

  The values in the data boxes displayed on the screen are sent to the printer when printing these graphs. When printed, the values appear in the center of each graph, instead of in boxes along the top.

  The graphs can be captured along with the entire graph for clipboard transfer to another application or to the Paint® program (as in Figure 55). With this capture technique, the data, as it appears on the screen, can be transferred to print or distribution.

Lock the Frequency Monitor

- **^0 or <Mouse-Right-Click>**

  The frequency (or time) monitored will change with the movement of the mouse. If you want to view a specific frequency (time) and still use the mouse to go to a pull-down option, it can become very tricky keeping the selected frequency. The solution is to lock the frequency once you have selected it, and the mouse movements will no longer cause the monitored frequency to change. You can lock the displayed frequency (time) by right clicking the mouse button or with the key combinations of <Control><0>. Once locked, the <Cursor Left> and <Cursor Right> keys will incrementally step down or up in frequency steps (the cursor keys are used to change the time scale in the time dependent plots). Use the <Control> key in conjunction with the cursor keys and the steps are up and down by decade values.

  Using the [Mouse-Right-Click ] button (or <Ctrl><0> key combination) toggles the lock between on and off.

Model Display

- **^D or <Ctrl><D>**

  You can view the circuit model for the capacitor at the monitored frequency once this menu selection is triggered. The monitor function must be active (“On” or checked) for this function to work. It would be best to use the {^D} key combination to activate the circuit model, as this allows you to keep the frequency selection by not moving the mouse, or if you lock the monitored frequency of time, you can use the mouse to move to this pull-down menu selection.

  The basic ceramic model (Figure 57) shows the values of the 7 elements with 6 nodes, connecting to the external circuit at nodes 1 and 6. The circuit shows the parallel resistance (R3), an external element of the ESL (L1) and the dominating RLC elemental values L2, R1, and C1, which will control most of the response. The series connection of R2 and C2 are in parallel with the dominating L2, R1, and C1 series combination. As listed below the drawing, this drawing pertains to the part “C1201C105K5RAC” with the elements listed in the first column to the left of the drawing and the actual values of these elements listed in the column on the far right.
Depending on the capacitor type, up to six different models can appear. This includes two for ceramics, two for tantalum or aluminum, and two for tantalum or aluminum with ESLs of 500 pH or lower. These three groups each have versions with and without external resistive and inductive elements.

If an external connection resistance and inductance were added to the device then the model would assume the connections as depicted in Figure 58. Here there are two elements added to the model and the number of nodes increases. R1 and L1 now represent that external resistance and inductance. The other elements take on new identities, and their associated values are again listed in the two columns to the right of the drawing.

This sub-circuit or netlist can be input to most SPICE software as the listing of the element values can be exported to an ASCII list file by activating the [Output List] command. If these models are being exported, then for the sake of simplicity and consistency, the operator should always leave the external resistance and inductance values as “0”, or inactive to keep the element and node counts to a minimum.

There is additional information in a text box to the right of the part number. This box defines the center frequency where this model was loaded, the ambient temperature and the applied dc bias. The flatness of the impedance response at this center frequency will indicate how well these elements apply to surrounding frequencies – normally ‘lossy’ devices will have less frequency variations. The temperature coefficient about the ambient temperature will define how relative the model is for wide variations in temperature (the dielectric stability in C0G defines very small variations, but with Y5V there are large variations). Variations due to dc bias are again reflective of the stability of the dielectric to these forces. The models you create should be reflective of the applications where you plan to use them. If there are large variations, then you can create models for the same device, but stored in subdirectories for large variations in temperature, bias, or frequency ranges.

**Quit Model**

This command will allow the operator to return to the previously displayed plot.

**Output List**

The element values from this model can be exported to an ASCII text file, that may in turn, be read or attached to a sub-circuit model created for a true SPICE simulation program (Figure 59). The file created is an ASCII file with the part number as its name and “.CKT” file type added to the file name shown in the text box (“T520V337M2R5ATE4R5.CKT”).

The operator may manipulate the file name and change the file type, but these conditions are the defaults created with the software. The drive and path in which this file will be stored is also electable.
With version 3.7.2x, you now have capability of creating ASCII files (*.CKT) that conform to Ansoft, Mentor (*.SP), Sigrity, Simplis, NetList (with “.END” or “.ENDS” closing lines, S-Parameter (Shunt or Series), and Touchstone Impedance formats. By clicking on one of these specific file types, the File Type Suffix selections are muted, and the suffix and file makeup is controlled by the requirements of the specific file type.

You may also include the bias, temperature, and center frequency conditions of the model within the model name. In Figure 60, this model was created for an ambient temperature of 55°C, with 1.25 Vdc bias applied, and frequency monitor at 100 kHz. Since it will export a file for Ansoft import, it will be named as follows:

“T520V337M2R5ATE4R5_55°C_1.25Vdc_100.000kHz.CKT”

If the software you are using will not allow periods in the file name except before the file type, you can replace the periods in “1.25Vdc” and “100.000kHz” with an underscore (“1_25Vdc”) and an omission (“100kHz”). You could also simply name the file as “T520V337M2R5ATE4R5” by removing the check from the “Include Conditions” check box and save the file to a directory specifically set up for the 55°C and 1.25 Vdc conditions.

Save List Form – Exporting Lists as ASCII or EDA Models

A sample of the ASCII file created is shown in Figure 61. The first line defines this as a sub circuit for the 1210 device with connection nodes to the external circuit at 1 and 6 (see Figure 57). The second line is a comment line (preceded by “*”) that defines the ambient temperature, dc bias, and center frequency (500 kHz) for this model. The second comment line defines the drawing (a JPEG file) that establishes the element connections for this model (“RLC Cerm.JPG”) and the version of the KEMET Spice program.

Each element is listed per line (space delimited) with its identity (R#, L#, C#), and the nodes (2nd and third columns) that each element connects to in the circuit. Finally, on each element’s line is the value of the device (ohms for resistance, farads for capacitance, and henrys for inductance). The listing is then terminated with the “.END” line.

If there is added external resistance or inductance, the number of nodes and elements will increase to accommodate these added elements.

There is a selection group in the lower section of Figure 60, which creates model listings to fit prescribed syntax required by commercial Spice software. These include Ansoft, Ansys, Cadence, Mentor, Multisim, Sigrity, Simplis, and Sigtry. A generic version of these file, known as “NetList” files is also selectable. There are commercial Spice programs that can also import frequency scan data as S-Parameter or Touchstone Impedance data, and these files are available. In this section, one file may be created for one part type, but in a section labeled “External Spice Model Creations (EDA Models/Libraries)” beginning an page 60, there is a capability for the program to create multiple files for many part types. It is in that section that the details of the different EDA models are discussed.

File Name

Enter the file name for the created ASCII listing in this test box. It will allow you to put any file descriptor suffix that you desire, as well as the file name. If you make no entry in this box and attempt to save the file, a warning will appear and return you to the form to make this entry.

Drive and Directory

Allows you to browse your system for an existing path establishing a location where the output list file will exist.

Reorder Sequence

You can arrange the order of the elements and their values. Click on any element of either list box and use the arrow-up and arrow-down elements on the display to rearrange the list. Shown on the right, is the same listing from above but ordered by component type.
Save List

Activates the creation and writing of the ASCII file, and quits this form. This command becomes active only after you have entered a file name as the destination for this listing. It will return you to the model form. A view for two files is shown as opened with Notepad® (shown below reordered list). The first line (optional) contains the header information.

Quit Output

This command returns the program back to model display without storing the data list.

Exporting Multiple Piece Models [n]

The model created normally represents a single piece, but there are times when many capacitors are used in parallel to achieve the desired response. For the commercial Spice software, this multiplicity can be accomplished by importing 50 models of a 0805 capacitor to duplicate the design, but these elements will slow down the software and extend the calculation times required for signal analysis. The KEMET Spice software can create a single model representing these fifty 0805s. In this software, multiple pieces (n) are always designated with brackets ([n]) enclosing the multiplier, and these brackets and the multiplier are then added as a suffix on to the part number designation of the mode (see page 53 for more information on creating multiple pieces).

First, look at ASCII files created from the singular part type (on the left) as shown in Figure 62, with a model created at these same conditions, but representing four (4) of these capacitors in parallel (right portion of Figure 62). The capacitance elements of the single piece on the left ("T520V337M2R5ATE4R5 55°C 0Vdc 100kHz") adds up to 348.56 µF while the model of four on the right adds up to 1394.25 µF ("T520V337M2R5ATE4R5[4] 55°C 1.25Vdc 100kHz" or 4 x 348.56 = 1394.24). The single piece on the left has no DC bias whereas the model of four on the right has a bias of 1.25 Vdc applied – DC bias has no measurable effect on tantalum capacitors. The single piece’s capacitance is higher than the 330-µF nominal value because the ambient is at 55°C – allowing the capacitance to rise from the nominal 330 µF at 25°C. In the same manner, the four capacitors are higher than the summation of nominal 1,320 µF.

In the case of the fifty 0805 capacitors, the external resistance and inductance can be assumed to be the same for all pieces, or the fifty could be divided into 5 rings of 10 capacitors each with increasing inductance and resistance as the ring’s radius to the center increases. If we assumed that the resistance to the inner ring capacitors is 200 µΩ and 200 pH of inductance, we could then assume that with each successive ring, the resistance and inductance is added to the next ring, and so forth. In the plots of Figure 63, the fifty 0805s were plotted as five groups of ten (10) pieces with each successive group having increased series resistance and inductance (on the right) and as 50 devices in parallel, each with 500 µΩ of external resistance and 0.5 nH of external inductance (on the left). There is little difference in these and using the model of fifty capacitors (50) is more beneficial and less time consuming than creating the five (5) bands of ten capacitors.

With Simplis export, the brackets "[ ]" are not allowed, as well as other characters and spaces. The last file’s name would appear as “T520V337M2R5ATE4R5_x4_55C_1.25Vdc_100kHz.CKT”
The ASCII models are shown below. The top five models arranged across the page all possess the same header, different R1 and L1 elements (External R and L divided by ten (10) parallel connections), and then identical elements L2 through R4. The main capacitance element, C1, for all fifty (10x5) pieces adds up to only 760 µF – well below the expected 1,100 µF because of the elevated temperature (80°C) and the DC bias (1.2Vdc). The bottom model centered in the page, represents all 50 capacitors with an average of the external R and L added (500 µΩ and 500 pH for each capacitor paralleled fifty (50) times equaling 10 µΩ and 10 pH). Again, the capacitance for these fifty 22 µF capacitors adds up to only 760 µF because of temperature and voltage.

![Figure 63: Fifty 0805 Impedance/ESR plots (Fifty on left, combined 5 bands of ten 0805s on right).](image1)

![Figure 64: Netlist models for 5 bands of 10 capacitors (each band unique Rx and Lx) versus one model for 50 capacitors (all with same Rx and Lx (R1 and L1)).](image2)
Aluminum/Tantalum Model

The tantalum model in the illustration on the right (Figure 65) has 20 distinct elements in its circuit, with 12 circuit nodes. It is built to mimic the capacitance loss with increasing frequency measured in the actual frequency scans of the components. Two additional elements, \((R_x)\), and \((L_x)\) would appear if external series resistive and inductive elements were added, creating a model with 22 elements, and 14 circuit nodes. It is rare to have this many elements in the model and these are limited to lower capacitance and higher ESR values.

The original and more prevalent model would stop the RC-Ladder after C5 (Figure 66). This model reduces the element count to twelve (12) and the node count to eight (8).

Most of the aluminum and tantalum capacitors are modeled with this structure. If an external resistance of inductance were added, then two more elements and nodes would be added to the 5RC-Ladder model.

With version 3.4.0, the one element, \(R_1\) of Figure 65, now replaces two resistor values from previous versions. The reason for separating these two elements is that with the polymer capacitors we started detecting a near zero, or slightly positive coefficient of resistance. We attribute this to the fact that the resistance from the conductive elements (tantalum, leadframe, conductive epoxy) has a positive coefficient of resistance while the semiconductive elements have a negative coefficient of resistance. For modeling purposes, the combination of these two resistances into one reduces elements and nodes in the model.

For very low ESL (version 3.5.5 with ESL<1.2 nH), a shorter model is used that stops after C3, but includes an RL network in place of L1 to mimic decaying ESL with increasing frequency. The RL network was added to enhance the accuracy of the impedance near and just above self-resonance, as a decaying inductance with increasing frequency was measured. In order to accommodate the added RL elements, the RC elements were reduced – this model can only work for lower ESR devices as the capacitance decay begins to take effect just before the device goes into self-resonance.
Aluminum/Tantalum Output List

The “Output List” form for the electrolytic capacitors is the same as with the ceramics, but the elements change. As illustrated previously in Figure 59, the output form shows two columns of data on the right of the form. These elements can be ordered in any fashion. In Figure 68, the netlist generated for a tantalum capacitor is shown as a Notebook® file. This file was created as a “Mentor” netlist file (uses the “.SP” file type designation, the filename is a combination of “KEMET”, and underscore character, and the part number, and the file terminates with “.ENDS” as the last line).

Bias Change

The selection of a dc bias option may have an impact on the graphs. With the polar electrolytic capacitors, 50% of the rated voltage is selected as a default dc bias because if an AC ripple voltage is offset by this value, then in the low frequencies, the maximum peak-to-peak voltage could create an instantaneous bias ranging from the rated voltage down to zero volts. If zero Vdc bias is selected for the tantalum, a calculation of ripple current that allows 5% of rated to be “reversed” is calculated. (You should not allow this to exist in your circuitry.)

For the electrolytic capacitors (aluminum, conductive polymer, and tantalum), the only performance affected by the dc bias setting are the calculation of RMS current and voltage. No other parameters are affected by the dc bias. With ceramics, the dc bias can affect the capacitance and the ESR. The dc bias suppresses both the capacitance and the ESR depending on the stress, or voltage per unit of dielectric thickness, as well as the dielectric type.

In addition, with ceramics being non-polar, the maximum excursion of peak-to-peak voltage capability in low frequencies would be created at a dc bias of zero (0) Vdc. This is the default bias when selecting a ceramic device, but when plotting multiple devices the tantalum or aluminum will dominate choice. Choosing multiple electrolytics may also alter the default bias to maintain that no device is over stressed.

The selected dc bias is checked. Options include "Custom" which allows any user input not exceeding the rating of the part.

| Custom | ^B or <Ctrl><B> |

A bias not covered by the listed percentages can be entered here (Figure 70). Once this menu item is selected, an input screen for any positive bias entry is allowed. It will not allow full application of the rated voltage, as this would also relegate the allowable ripple to zero (0) VRMS. If you make no entry, it will carry the previous setting.

Add RL

This menu allows the user to add a series resistance or series inductance as external elements to the capacitor. These external elements are added to each part type, and when multiple (n) pieces are used, the parallel impact decreases the total by 1/n.

| Add Ext. Res |

Input box appears to allow an entry of an external series resistance in Ohms (Ω). Enter the proper value then click on [OK]. Enter zero (0) if you wish to remove any added external resistance.
Add Ext. Induct.

Again, allows the user to specify an inductance in series with the capacitor, but external to it. This entry is in nanoHenries (nH). Enter zero (0) if you wish to remove any added inductance. This can be used to signify trace inductance from the PCB.

About...

Program

The “About … Program” will display the form with a listing of the program revision. A brief description of the software follows, along with identity of the author – this is the same program information found in many Windows® based programs.

There is also a link to view the system information here.

ESL Explanation

There are no standards for measuring ESL. Most of the difference in ESL between manufacturers is wrapped in the differences in measurement technique, and pull from marketing and sales departments. If someone is claiming that, his or her 0805 is much lower ESL than everyone else’s is – it probably is not but it is probably measured well above self-resonance.

Across all manufacturers, an X7R, 0805, 1 µF will all have approximately the same ESL at self-resonance.
Mult Plots

Multiple plots can be viewed at one time to enable comparisons. A multiple piece plot has already been shown in this manual (page 18, Figure 19 and Figure 20). These plots may contain multiple capacitors, temperatures, or bias voltages. Up to ten (10) plots can be appear on the graph at one time.

The first time this selection is activated (while viewing a single plot), the type of multiple plots must be selected (Figure 76). You can view multiple part types, multiple temperatures or multiple bias conditions for one part, or create a plot representing maximum and minimum impedances for a single part.

Additional plots (up to ten) can be added but once the method of multiplicity is selected, subsequent requests for additional plots will maintain the same method, until all multiples are eliminated and a single plot exists. The program will immediately prepare for the next part type, temperature, or bias entry. You cannot mix the selection criteria. If you already selected another part number, temperature, or bias, than any call to adding more plots will automatically be of the same selection type.

Multiple Pieces at same DC, and Temperature

With multiple pieces, you can cross chip sizes, as well as capacitor types: aluminum, ceramic, film, and tantalum. Selecting this method for multiple plots will cause the program to jump to the “Choose Type” form, shown in Figure 4 on page 6, where you select among aluminum, ceramic, film, film-leded, and tantalum capacitor types. For each subsequent part type you desire, once you again choose [AddPlot] or <Shift><Ins>, the program will again jump to the “Choose Type” form for each new part type. Unlike multiple temperatures and bias voltages, multiple part types have to added one at a time, or by selecting multiple part types from a single listing of capacitance values as in Figure 12 on page 12.

Multiple Temperatures for same piece.

With multiple temperatures, you can set the ambient conditions from -55°C to the maximum allowable temperature for each part’s operating range. Once “Multiple Temperatures” is selected from the form of Figure 76, the form of Figure 77 will appear. In this form you will enter the temperature in the text box (25, -55, -25, 0, 50, 85, and 125 are shown in the figure) and when you press <TAB> or <Enter> key, the check box will show checked for each entry. Before the plot appears, the temperatures will be arranged in ascending order.

Note that Figure 77 specifies “Multiple temperature entries from -55°C to 85°C”, but one entry is 125°C. When you click on [Save Temp Entries], the pop-up window shown in Figure 78 appears to warn the operator that the “Entry 125°C is above 85°C” and is about to be removed from the list.
Multiple DC Voltages for same piece.

Multiple biases allow observation under various bias conditions to the same part type. The film and tantalum capacitor types will show no response to bias voltages, as is true for the C0G ceramics. The non-C0G ceramics may show dramatic shifts in capacitance, ESR, and impedance. Once this method of multiplicity is selected, the form shown in Figure 79 will appear, and its heading allows multiple bias entries from 0 Vdc through 25 Vdc. In this form, a series of up to ten (10) voltages may be entered. The text boxes here show entries of 0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, and 20 Vdc. The check box adjacent to each voltage denotes that that voltage is active. After all entries are made, the bias voltages will be arranged in ascending order. Non-numeric text entries, negative voltages, and voltages above the rated voltage of the device will be flagged and eliminated after pressing the “Save” command button.

Create PNs at Max-Min Impedance levels.

Applying ± limits (last option of Figure 76) to the nominal response will create duplicate part types of maximum and minimum impedance levels. This method will use the defined capacitance tolerance in the part number to set a high and low capacitance. The low capacitance is used in the second plot (high impedance), and the high capacitance is used in the third plot (maximum impedance). The nominal ESR is adjusted by ±20% with the high ESR applied to the second plot (maximum impedance) and the low ESR applied to the third plot (minimum impedance). These adjustments result in three plots: the nominal impedance, the high impedance variation, and the low impedance variation, in that order. This is the only multiple plot that will not add additional plots, and activating this selection while the impedance variations already exist will only allow retaining those plots or cancelling them (Figure 80).

Multiple Plots Summary

Because you have already defined the method of the multiple plots with the second plot, for any subsequent plot the program will assume that the same method for the third through tenth plots will be the same (multiple PNs, temperatures, and bias).

- If you already picked multiple part numbers, when you request to “Add Plots” the program will jump to “Choose Type” and any additional PNs will be added to the previous list as long as you do not exceed 10 part types in total.
- If you already picked multiple temperatures or bias conditions, when you request to “Add Plots” the program will jump to multiple temperature or multiple voltage forms.
- If you selected the creation of multiple PNs of ± impedance tolerances, when you request to “Add Plots” or “Delete Plots” the program will ask to keep or deselect the created deviants and leave you with the single part number, with nominal impedance levels.
- Because there are check boxes that activate each plot in the add plot forms for voltage and temperature, you can eliminate all but one of the selections to effectively delete the plots in the add plots form.
- If you select to delete one of the multiple Part Numbers, temperatures, or bias levels, when you request to “Delete Plots”, a listing of the plots and check boxes will appear, allowing you to uncheck any of the plot identities (see Figure 83 on page 52.

Once you have multiples part types, then you can specify the multiples of each part type as well as view the total impact of all of these devices in parallel.
**Plot of Max-Min Impedance Levels**

![Plot of Max-Min Impedance Levels](image)

Figure 81: Application of ±Tolerance to impedance and ESR response.

This plot is created by applying the full ± tolerance to the capacitance, and a ±20% tolerance (‘M’ tolerance code) to the ESR. This adjustment does not restrict the ESR to the specified limit but allows excursions above this limit. In the plot of Figure 81, the application of ±20% to the nominal ESR results in an ESR that is above the 70 mΩ limit (78.17 mΩ), but in this release the ESR limit is being ignored. This will be corrected in future version and it will allow the operator to change the default capacitance tolerance as well as conforming to the ESR limit or ignoring it.

The second plot in the graph is the “High Impedance” variation of nominal (the first plot) and designated with “_HiZ” suffix to the part number. The third plot is the “Low Impedance” variation of nominal and designated with “_LoZ” suffix added to part number.
Plot of Multiple Part Types

In the plot shown (Figure 82), three capacitor types, all of 15-µF capacitance, are compared for impedance and ESR. The part number highlighted in the upper right portion of the plot area is represented by the solid, bold (red) line and bold, dashed (blue) lines of the graph. Using the up and down cursor keys allows you to choose the part you desire to be highlighted. All other plots are shown as a light gray or light green plots in the background.

Deleting one or more of the multiple plots

Once multiple plots exist, they can be selectively deleted. The program cannot allow a reduction in the number of plots below one. If you uncheck all boxes, a warning will appear and return you to the Multiple Plot Removal window to re-select and leave one box checked. In Figure 83, deselecting all but one of the bias levels will create a single plot of that part type at the remaining bias level.

Remember that for polar capacitors, a bias of 0 Vdc means that the negative AC volt excursions will create a negative polarization on this capacitor, and optimal AC voltage is achieved when the part is biased at 1/2 of the rated voltage.

In the same manner, a bias of 0 Vdc creates an optimum AC voltage effect for non-polar (ceramic and film) capacitors.

Figure 82: Here are three distinct part types plotted (T491B156M004, T520T156M006, C1210C156K9PAC).

Figure 83: Selecting (deleting) plots.
**Specifying multiples for each of the part types**

Multiply each piece

↑M or <Shift><M>

To review the effect of multiple pieces of each part type select this option by using the key combination of <Shift> <M> or click on the pull-down menu item (Multiple Parts / Multiple Each Piece). For each of the part types involved, enter the multiplier in the box to the left of the part number listing. A zero or blank entry will default to “1”. Click on [Continue] when completed.

As shown on the right in Figure 84, there are four 0805, X5R, 25V part types listed. The first part, the ‘474’ (or 0.47 µF) part, response is for eight (8) of these pieces in parallel. For the 684 (0.68-µF) part, there are three (3) of these parts in parallel. Plus there are seven (7) of the ‘105’ (1.0 µF) and five (5) of the ‘475’ (4.7 µF) parts.

Once the plot is created after this, the list box of part types in the upper right corner of the plot shows the count for each part type, enclosed in brackets at the end of the part type (shown in box with red-dashed outline, magnified in Figure 85).

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**Figure 84**: Multiples of each part type.

![Figure 84](image)

**Figure 85**: Plot for 18 C0805C226PAC and 10 C0805C106PAC devices.

![Figure 85](image)
Specifying the cumulative effects for all the pieces

Combined Impedance

The last element required in the analysis of multiple part types, and multiples of each of the part types is to see the combined impedance and effects for all of these pieces reacting together. Once this effect is created, then the impacts of bias voltage and temperature can be seen immediately. To activate the combined effect, use the two key combination of <Shift><C>, or click on the pull-down menu (Mult Plots / Combine Impedance).

Plot Combined Impedances

In Figure 86, there are six (6) part types shown, with multiple counts for each and the combined impedance is in the foreground. The attempt here was to create a filter with impedance below 1.5 mΩ, from 80 kHz through 15 MHz. With the series resonant points creating dips and parallel resonances creating peaks, the combination of four (4) conductive polymers (T520V477M2R5ATE007), and ceramic chip combinations including six (6) 0805 chips (C0802C226K9PAC), eighteen (18) 0603 chips (C0603C475K9PAC), and forty (40) 0402 chips (C0402C105K9PAC x16, C0402C474K9PAC x 12, C0402C224K9PAC x12) allows for this response. The impedance dips below 1.5 mΩ near 60 kHz, peaks to 1.45 mΩ at 4.89 MHz, and rises above 1.5 mΩ just above 20 MHz.

When creating multiple element filters, it may be desireable to look at responses for different bias voltages or for different temperatures. Consider the filter response in Figure 86, the desirable impedance between 1 MHz and 200 Mhz may be listed as 1.5 mΩ, and based on the response shown, this filter would meet the requirement. What happens when the temperature changes. We know that the capacitance will not vary dramatically, but the ESR will change considerably. In the plot at the top of Figure 87, this filter will continue to meet the requirements at -40°C (actually better than at 25°C), but would fail the requirements at 85°C (bottom half ). The capacitors are less lossy, have higher “Q”, sharper series resonance valleys, and the parallel resonances result in much higher impedance peaks.
The program includes the ability to change the seed parameters in the models to create variations of the product not available with the standard piece listings. **These changes are best made with an actual frequency scan of impedance and ESR versus frequency, and capacitance versus frequency.** For instance, if the lowest ESR for a specific tantalum device is listed as eight (8) mΩ, but we are working on a 6-mΩ version, you can manipulate the seed values here to see the 6-mΩ part. The existing part has an ESR of 6.81 mΩ at 100 kHz. The parameter/seed listing can be viewed by entering the two key combination of <Ctrl><J>, or with the pull-down menu under “File” listed as “Change Parameters”, as shown in Figure 88.

Figure 87: Combined impedance at -45°C (top response) and at 85°C (bottom).

**Change Parameters**

**Tantalum/Aluminum Seed Parameters**

The program includes the ability to change the seed parameters in the models to create variations of the product not available with the standard piece listings. **These changes are best made with an actual frequency scan of impedance and ESR versus frequency, and capacitance versus frequency.** For instance, if the lowest ESR for a specific tantalum device is listed as eight (8) mΩ, but we are working on a 6-mΩ version, you can manipulate the seed values here to see the 6-mΩ part. The existing part has an ESR of 6.81 mΩ at 100 kHz. The parameter/seed listing can be viewed by entering the two key combination of <Ctrl><J>, or with the pull-down menu under “File” listed as “Change Parameters”, as shown in Figure 88.

Figure 88: Pull-down menu to Change Parameters.
What appears next is a form that lists the seed parameters for that part type as shown in Figure 89, and this is the form, as it would appear for a tantalum or aluminum part.

**Items A and B** manipulate the shape of the impedance response. Increasing the value of “A” causes the low frequency portion of the impedance curve to turn up more abruptly and lowering this value causes the low frequency portion of the impedance curve to flatten out. Increasing the value of “B” causes the high frequency portion of the impedance curve to flatten out, and lowering this value causes that portion of the curve to turn up more abruptly.

If you have a measured frequency response in front of you, you can manipulate these values to match the shape of the measured response perfectly. Unless you do not have an actual, measured frequency response in front of you, do not change these values.

**Item C** is the power dissipation capability for this case, which will result in a 20°C temperature rise. Unless given a new, measured capability, do not manipulate this value.

Items D and E determine the ESR value of the capacitor. Item D is attributed to the leadframe and silver elements of the device and have a positive temperature coefficient of resistance (resistance rises with increasing temperature). Item E is attributed to the semiconductive element in the cathode system and has a negative temperature coefficient of resistance (resistance decreases as temperature rises). The impact of item D becomes important only in the very low ESR ranges, and is set to zero (0) for most of the high ESR MnO2 devices, because the effects from item E are so dominant in the high ESR devices. As such, item E should not be changed.

Item G is grayed out as this element only applies to ceramic capacitors. For this device to be offered as a 6-mΩ device, the ESR at 100 kHz will have to be below 6 mΩ - close to 5.3 or 5.6 mΩ. It is also apparent that the summation of these resistances does not equal the final ESR at 100 kHz of 6.81 mΩ, because the manipulation of these seed values creates multiples of that value. This means that in order to lower the 100 kHz ESR to 5.3 mΩ will require an entry and check method. If one manipulates item E to be 0.00100, the resulting ESR at 100 kHz will be 5.36 mΩ – close enough to the desired value of 5.3 mΩ. You could then print out the response, but the part type would be listed as “T528Z337M2R5ATE008(Pre)” which would be wrong because “(Pre)” (as well as “+”, “*”, and “#”) is a reserved suffix. You should change this part type by calling up the parameter review and changing the part number (item J) to “T528X337M2R5ATE006(JP)” – notice I designated this part type as “JP” in the parenthesis.

Never use brackets ([ ]) to set a special designation because these are used for multiple pieces indications of the part type.

Item N was added in version 3.5.0. This allows the user to select the number of RC branches in the RC-Ladder, selecting among 9, 5 (default), and 3.

The changed items, E and J, appear in the Seed Parameter review form as shown in Figure 90.

Returning to the plot will now show that the title has changed (monitor lock must not be enabled), and the response has changed to indicate the ESR at 100 kHz is now 5.36 mΩ, as shown in the truncated plot in Figure 91.
At this point, I could add another plot, and plot the original part type against the new part type as shown in Figure 92. The new part type is in red (Z) and blue (ESR) and the original (8 mΩ) is in green.

**Figure 92:** Changed part type (6 mΩ ESR) vs. original (8 mΩ).

**NOTE:**
*When changing the part number to designate this as a modified PN, do not use brackets ([ ]) as these are used to designate the multiplier of the PN.*

**Ceramic Seed Parameters**

The seed values for ceramics are very different from those for tantalum and aluminum. The seed values of items A through D are grayed out; items E and F are shown (Figure 93), item G is added, and H through J are shown as with the tantalum; and items L and M are added. Item L pertains to those ceramics where a leadframe is attached to the chip to protect the device in the mounted state from flex cracks (i.e., L1XN20B395KS).

The ESR seed value here is much closer to the minimum ESR value of the plot, but there is not an absolute correlation. When manipulating this element, you must make the change, and then go to the Z/R plot to verify. If the change is not correct, you need to repeat the changes until the desired ESR is achieved.

**Figure 93:** Seed Parameter form for ceramic (Items A-D truncated – deal with Ta).
Consider that a 33-µF part is being designed for this size (1210), dielectric (X5R), and voltage rating (6.3 VDC). There are pieces which bracket this value (22 µF as shown and 47 µF), and these pieces have significant changes in their parameters. The ESR seed value (item E) is 3.62 mΩ for the 22 µF and 3.05 mΩ for the 47-µF part. It would be acceptable to project the ESR for the 33 µF to near 3.35 mΩ (0.00335 Ω). The coefficients of thermal transfer for the 22 µF and 47 µF are given as 42°C/W and 45°C/W. Again, the 33 µF could arguably be assigned a value of 43°C/W. The ESLs are close for the two bracketing pieces at 0.90 nH for the 47 µF and 0.99 nH for the other. An assignment of 0.95 nH would be used for the 33-µF part.

The big difference between these bracketing part types is with the voltage coefficients. The 47 µF needs only 2.6 VDC to lose 20% of its capacitance, while the 22 µF needs 7 VDC. Assuming that the 22 µF is maximum capacitance at this thickness, the capacitance for the 47-µF device is achieved with appreciably thinner dielectric and increased layer count. It would be safe to assume that the 33 µF would also have to use this thinner dielectric and have a similar voltage where 20% of capacitance is lost.

With higher capacitance values being released, the final ESRs will not drop below 3 mΩ, but the voltage coefficients will get worse. Be careful in adding ceramic part types. Unless you are given the frequency scans and VCC tests results, any created part types will be guesses – some educated and some wild. Some guesses may be very good, while others could be very bad.

**NOTE:**
To change the part number to designate this as a modified PN, do not use brackets ([ ]), as these are used to designate the multiplier of the PN.
Film Seed Parameters

With film capacitors, the seed parameters are similar to the ceramic seed parameters with some exceptions. The ESR for these capacitors is independent of the self-resonant frequency. Its minimum level is obtained at a recorded frequency, and the log (base 10) value of that frequency is given as “L - Log10 ESR Resonance.” These devices also appear to have an inconsistent width to the inverted parabolic shape and that factor is stored in “N - ESR Resonance Width Factor.” These values are derived to allow the resulting ESR and DF factors to match those measured for these devices.

The Coefficient of Thermal Transfer (“G”) has been derived empirically for each case size, and is case size dependent. The ESL is derived in a like manner and these are case size dependent as well.

NOTE:
To change the part number to designate this as a modified PN, do not use brackets ([ ]), as these are used to designate the multiplier of the PN.

Figure 96: Seed parameters for Film Capacitors.
External Spice Model Creations (EDA Models/Libraries)

With version 3.6.0, the ability to create ASCII files that can be read by other SPICE software is now available. Specifically, you can create Ansoft, Mentor, NetList (previously shown in Figure 58 and Figure 68, pages 42 and 47, respectively), S-Parameter, Sigrity, Simplis, and Touchstone Impedance models as well as creating Cadence and Linear types of model files or libraries. It is important to realize that these models may have dependencies on bias voltage, frequency, and temperature that could factor response, and since the KEMET Spice software compensates for all of these, application specific or environment specific models can be quickly created.

*Warning: Once | Create Model Lists | is selected and an Excel file is opened, the program will not return to the Choose Type form of Figure 97 without restarting. The program closes when the [Quit] command is executed from the Models Creation form (Figure 98) if an Excel file has been opened.*

Access to these models is from the “Choose Type” form (Figure 97). Along the bottom of the form there are three command buttons: the large one on the left is grayed out and not selectable at this time, the one on the right will stop the program, and the one in the center will allow the operator to move into the model creation form.

![Figure 97: Select |Create Model Lists| button to access models form.](image1)

![Figure 98: Create SPICE support files form.](image2)
The model creation form at this time will allow specific models to be created as import files for standard types as well as specific Spice softwares. There are eight types listed with a black background (“NetList”, “Library of NetList”, “Touchstone”, “S-Parameter”, “Ansoft”, “Mentor”, “Sigrity”, and “Simplis”) that are available every time this form appears. The two file types listed with a blue background (“Cadence”, and “Linear”) are only available after the “Touchstone” files are created because the creation of these files creates a data file of self-resonant data required for the “Cadence” and “Linear” files.

We’ll start off the model discussions using the generic or “NetList” models. These are normally created with a “CKT” file type, but could also be created as “CIR” file types. The ending statement is normally “.ENDS” to close the file, but the initial models contained a closing line of “.END” and this capability is still maintained.

Because the descriptions here are carried over to the other model types, if you plan on using other model types, it may be beneficial to read the NetList form description as some of these items will appear with other model type but not explained.

### NetList Files (CKT, CIR Files)

The form change after NetList file type is selected as shown in Figure 99. A brief explanation of the indicated items on the form is as follows:

(Figure 99, Item 1) Create NetList CKT Model Files
This heading at the form’s top changes to indicate which of the file types you’ve selected because once you select a file type, these selection buttons are no longer available. If you selected the wrong file type, then select the [Stop] button to go back and enable the file type buttons.

(Figure 99, Item 2) Use “Spice_Seed” Data files as source listing (Go to Page 77 for using “PartList.XLS”)
Every part type that is able to be created in the KEMET Spice program is contained within data files that carry seed values on which the program manipulates seed values to create the frequency, temperature, and in some cases voltage, effects duplicating the measured responses for that device. At the time of the release of this program (version 3.6.4), there are over 7,000 part numbers included with seed data files in the program. By using all or a restricted group of these part types, the NetList files are created.

**NOTE:** Toggling between using KEMET Spice seed data and “Part List.XLS” will automatically reset the default storage path shown in item 12.

(Figure 99, Item 3) Overwrite existing files in Path
When the files are created in the designated path, unless this option is selected (checked), the file will not overwrite an existing file of the same name. If you need to create the EDA models for all part types, then by checking this box, all files will be recorded.
(Figure 99, Item 4) File Type descriptor or file name suffix
With the NetList files, you have the option of creating files with the “.CKT” file descriptor or the “.CIR” file type descriptor. The Linear Spice program will open the “.CIR” file types, although the “.CKT” file type is more common.

(Figure 99, Item 5) File terminating descriptor as “.END” or “.ENDS”
The most common terminating line in the NetList files is “.ENDS”, but there are a couple of EDA programs that use “.END” as the terminating line. Some softwares will allow either descriptor.

(Figure 99, Item 6) Ambient Temperature entry (degrees Celsius)
The models created reflect the responses at a specific ambient temperature. Most models are created based on 25°C conditions, but the applications could be anywhere from -40°C to 105°C. Changing the temperature impacts the ESR on all components (aluminum, ceramic, film and tantalum) and this will impact the impedance created. For multiple capacitors utilized to create a broad frequency filter, the reduction of ESRs at higher frequencies increases the parallel resonance peaks encountered here which could lead to noise creation.

The changing temperature also affects the leakage resistance and in most cases, the capacitance (the exception being the COG ceramics and minimal effects for film capacitors). Since the operator designates the path for the created models, it is possible to create additional subdirectories for additional ambient temperature conditions.

If the entered temperature is greater than the maximum temperature of the part type, no model file will be created.

(Figure 99, Item 7) Bias conditions (Vdc)
Most models are created with zero Vdc applied, but the dc bias can significantly affect capacitance as well as ESR. This effect is most noticeable for the higher CV ceramic capacitors, especially the downsized devices. Applying rated voltage to some X5R devices can reduce the capacitance to 25% of its original value and reducing the ESR to nearly 30% of its original. Since both of these conditions are compensated for in KEMT Spice, specifying a dc bias here will result in models that reflect those changes. Specifying the dc bias here results in all models created at this bias condition. Leaving this entry blank will allow the KEMET Spice program to invoke its default conditions of zero Vdc for all ceramic and film, and a dc bias equal to ½ the rated voltage for the aluminum and tantalum. The zero Vdc bias for the ceramics and the ½ rated bias for the electrolytic capacitors (no impact on impedance, capacitance, or ESR for electrolytics) does allow the highest ripple current capability, which is not an element in the created models.

It is important to realize if the bias voltage entered here that is greater than the rated voltage of the capacitor, it will NOT generate the intended model file.

(Figure 99, Item 8) Frequency conditions
In Figure 99, there are three frequency boxes shown. Although the reactive elements may dominate the impedance response and the capacitive and inductive elements can reflect most of this effect, there is a substantial impact on ESR with frequency that cannot be compensated for in the simple models. There are also cases where capacitance and inductance have a frequency dependence (this is severe in electrolytic capacitors but the models are created with RC elements to compensate for most of this).

For all NetList, NetList Library, Ansoft, Ansoft Library, and Cadence model creations, the model is a network arrangement of resistive, capacitive, and inductive elements reflecting the performance of that specific device for a specific frequency; but because it is a network, the models will change the response as frequency changes. With these types of networks, the center frequency is specified for COG ceramics, all other MLCCs, and for the electrolytics. These frequency points can be changed to suit each operator’s applications.

For the Touchstone and S-Parameter files, these files develop a listed response versus frequency for a specified frequency range. For the Touchstone and S-Parameter files, these elements will define the stop frequencies based on dielectric type and capacitance value. The user can change these settings.

(Figure 99, Item 9) Capacitor Types
Instead of generating models for all types of capacitors, you can select the capacitor types that you use in your designs. This allows the choices to be reduced among the aluminum, ceramic, film, and tantalum capacitor offerings. Once the box is checked, then all of the available series for that capacitor type will appear in the “library” listing as in Item 10, of Figure 99.

(Figure 99, Item 10) Capacitor family or series types
To reduce the model types created further, you have the capability of restricting which capacitor series of each type of capacitor models being created. For the aluminum capacitor types, there is only one series available, the “A700” series. For ceramic capacitors, you may restrict the models created to eleven distinct chip sizes, from 0201 up to 2225. Again, if your usage of ceramic capacitors is restricted to only the smaller case sizes, then you can create models only for those chip sizes. The selection from this list may be multiple items in consecutive order or multiple series that are not consecutive in this list. To capture multiple items that are in consecutive order within the list, hold the <Shift> key after the first selection, and then click the last selection and all items between the first selection and the last will be highlighted or “selected”. To capture multiple items that
are not consecutive in the list, hold the <Ctrl> key after the first selection, and any other selection clicked on will be added to the highlighted or “selected”. Only those selections highlighted will generate models.

(Figure 99, Item 11 and 12) Select storage drive and path
The models will be created as files and stored in a specific drive and path. The program will default to a path representative of the model type of file created. Since the source of the part numbers is the seed data files for the program and the type of file in this discussion is “NetList”, then the path selected would default to “C:\Program Files\KEMET Spice\CKTs\NetList\Seed”.

(Figure 99, Item 13) Select a new or unlisted path
You may desire to create additional directories separating the models you may desire for different conditions of DC bias and temperature. Clicking on this box when you are at the directory level where you need to create another branch. A pop-up text box will ask what the new directory is to be named, and the program will create that directory as a subdirectory of the highlighted item in the “Path to save Files” listing.

(Figure 99, Item 14) Path for Saved File
Once the path is set using items 11 through 13, the full path description will appear in the text box of item 14.

(Figure 99, Items 15 through 18) Activate “Create NetList Files” command button, and monitored files, elapsed time
Clicking on this box will activate the program's creation of the NetList files, and the file number and name will appear in the text boxes of item 16 and 17, respectively. In the text box of item 18, the elapsed time for the files created will be shown.

NOTE Excel required for “Part List.XLS”
In order to utilize the Excel file, you must have a operating version Excel loaded on your system and the Part List.XLS file in the proper directory.

NOTE on substitution:
There may be a 50 Vdc design in KEMET Spice, with a part number specific to that 50 Vdc rating, but that same part could be labeled as 25, 16, 10, or 6.3 Vdc in the Excel listing. Unless there is an actual design available for these lower voltages, the KEMET Spice program may use one voltage design for several part types of lower voltages. The part numbers in KEMET Spice default to ±20% for the electrolytic or larger capacitance types, and ±10% for most of the ceramic capacitance types. This program projects results based on nominal capacitance values, regardless of tolerance. The Excel listing could include part numbers of multiple tolerances, but these will generate models exactly alike except for their file name or designations, reflecting the tolerance differences. Considering that there are 3,700 base elements in KEMET Spice, the part list could be more than 5 times that number considering variations of tolerance, C-Spec designations, and voltage substitutions.

---

1 Optional file from KEMET Spice web page
The one substitution that this program will not perform is dielectric substitutions. As an example, if a 1206 ceramic chip of 150 pF is required and the dielectric is specified as X7R (i.e., C1206C151K5RAC), we may actually send a C0G (i.e., C1206C151KGAC) as C0G does meet X7R requirements, and building this low of a capacitance in X7R presents problems. These different dielectrics result in dramatically different frequency, temperature, and bias responses. In addition, the manner in which the program works is restrictive because it searches for a style, capacitance, and voltage capability within a data file that is defined by its dielectric. It would have to “research” another dielectric data file for the same style, capacitance, and voltage capability if it missed on the first search, and at this time it will not do that. If the capability is not found in the primary data file search, there will be no file created for that part type.

The optional Excel file “Part List.XLS” is intended to be modified from the original list of 645 part types to something more representative of the users capacitor types usage. The smaller this list becomes, the smaller number of model files will be generated, in much smaller time-frames, and will take up less storage space. This file may be downloaded from the same page as the KEMET Spice web page. When using the Excel file (“Part List.XLS”) as a source list for the created models, Excel must be available on the computer and accessible by the user. Once this file is opened, the program will terminate when clicking on the [Quit] command button, and not allow a return to the “Choose Capacitor Type” form. In this case, the program will have to be restarted.

Because this form is a slight variation of the form in , the items explained will be reduced to the new selections available with using the Excel file as list to create the model files.

(Figure 100, Item 1) Use “Part List.XLS” as source list.

Instead of creating models for all part types available from the KEMET Spice program’s data files, you could create models to only those part types that you use in your circuits. The details of this Excel file are discussed in Part List.XLS, on page 77.

(Figure 100, Item 2) Include PNs with C-Spec suffix codes. (Visible only when “Part List.XLS” selected as source.)

The listing of part numbers in the Excel file, any include part numbers with C-Spec suffix codes. The models created will be exactly the same as those for a part number without the C-Spec code, it depends on your preference weather you want these models created with PNs that vinclude the C-Spec codes. If this button is not filled, then once the program encounters a PN with the C-Spec code, it will skip that part number.

(Figure 100, Item 3) NetList/Seed Files in Part List.XLS (Visible only when “Part List.XLS” selected as source.)

Once a model file is created for the part number in the Excel file, that file name will be posted in the Excel file, along with the date of the addition. The workbook will contain separate worksheets for Ansoft, Cadence, Mentor, NetList, NetList Library, Sigrity, Simplis, S-Parameter, and Touchstone files. If this radio button is not selected, then the model’s file name will not be written to the Excel file.

(Figure 100, Items 4 and 5) Path for Saved Files

Because you selected the Excel files as the source list, the files in this example would be stored in the “C:\Program Files\KEMET Spice\CKTs\NetList\PartList” directory by default. You can change to another directory, or create a new directory.

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1 Optional file from KEMET Spice web page
Create NetList Files

Click button to create Netlist Files selected.

NetList File Breakdown

The model or file created is an ASCII type file as shown in Figure 101. The format for the first line is required with a heading of “.SUBCKT”, followed with a space-delimited description of the part type as “GMC10.2_105K50A31” followed with the connection circuit nodes, space delimited. In this part type, an underscore character (“_”) is used to replace the normal space in this part number to eliminate any confusion with the connection nodes, “1”, and “6”. The file is titled “GMC10.2 105K50A31.CKT” with the space included in the part number, as found in the film SMT catalog.

Comment lines are preceded with an asterisk (“*”), and then the elements of the circuit are given as an element per line. In this file there are two comment lines, the first details the ambient temperature, DC bias, and center frequency of the model, while the second line details that this model may be viewed pictorially as a “RLC Cerm.jpg” graphic file (Figure 102), and that the version of KEMET Spice generating the model was version “3.7.12”.

The element is followed by its circuit connection nodes and value, all space delimited. The value depends on the element type, where C denotes Farads (capacitance), L denotes Henries (inductance), and R denotes Ohms (resistance). The first element given is “L1” connected at nodes “1” and “2”, and having a value of 175 picohenries. Six other elements are specified and these correlate to the elements in the circuit diagram give in Figure 102.

Closing the file, is the ending statement shown as “.END”, but again, you have the option of defining this statement as “.ENDS”.

The model or file created is an ASCII type file as shown in Figure 101. The format for the first line is required with a heading of “.SUBCKT”, followed with a space-delimited description of the part type as “GMC10.2_105K50A31” followed with the connection circuit nodes, space delimited. In this part type, an underscore character (“_”) is used to replace the normal space in this part number to eliminate any confusion with the connection nodes, “1”, and “6”. The file is titled “GMC10.2 105K50A31.CKT” with the space included in the part number, as found in the film SMT catalog.

Comment lines are preceded with an asterisk (“*”), and then the elements of the circuit are given as an element per line. In this file there are two comment lines, the first details the ambient temperature, DC bias, and center frequency of the model, while the second line details that this model may be viewed pictorially as a “RLC Cerm.jpg” graphic file (Figure 102), and that the version of KEMET Spice generating the model was version “3.7.12”.

The element is followed by its circuit connection nodes and value, all space delimited. The value depends on the element type, where C denotes Farads (capacitance), L denotes Henries (inductance), and R denotes Ohms (resistance). The first element given is “L1” connected at nodes “1” and “2”, and having a value of 175 picohenries. Six other elements are specified and these correlate to the elements in the circuit diagram give in Figure 102.

Closing the file, is the ending statement shown as “.END”, but again, you have the option of defining this statement as “.ENDS”.

Figure 101: NetList file for SMD Film capacitor of 1 µF and 50 WVDC.

Figure 102: Diagram of “RLC Cerm.jpg” subcircuit diagram.
Selection of the source list, overwrite, frequencies, ambient temperature, DC bias, storage paths, etc., are all the same as discussed for the NetList files in Figure 99 and Figure 100 on pages 61 and 63.

By combining common style and dielectrics, a listing of several models can be included in a single ASCII file. Shown below in Figure 103, are two 0201, X5R chip capacitors. The source of the part types for this limited library was “PartList.XLS”, and the number of 0201 pieces was limited to two (2) pieces. The library file contains a comment-defined header detailing the date of creation, style, declaration, and finally a listing of part types in the library. The first is a “C0201C103K4PAC” (10 nF at 16 Vdc) and the second is “C0201C104K9PAC” (100 nF at 6.3 Vdc). The subcircuit description for each part type is actually the NetList ASCII file listing for each part type in successive order, following the header comments. The arrangement of these successive files is ordered by an alphanumeric sorting of their part numbers. Each circuit spells out its corresponding circuit diagram and these can vary within a library. Each subcircuit closes with a “.END” statement and the library file closes with a “.ENDS” statement.

The initial library file shows the circuit conditions as a temperature of 25°C and a DC bias of 0Vdc, while a second NetList Library file was created (in dashed border) at 85°C and 3.3 Vdc. In the initial library file, the main capacitance of each device (C1) drops by 9% from the nominal value as these devices are showing a center frequency of 1 MHz and the nominal capacitance is measured as 1 kHz – there is a small drop in capacitance due to frequency.

Another library file was created but for this new file, the ambient temperature was 85°C and the bias voltage was 3.3 Vdc (the results are shown as a bordered insert of Figure 103, on the right). As before, the center frequency is still at 1 MHz, but the capacitance (C1) is now -30% below nominal for the first (10nF), and -53% for the second (100nF). The difference is that the first is rated at 16 Vdc, and the second at 6.3 Vdc and these new changes are related to the voltage coefficients. The temperature coefficients are the same as each dielectric is the same type but the voltage coefficients are different because the dielectric thicknesses are different, with the lower design voltage having a thinner dielectric and greater strain (V/µm) leading to a greater loss of capacitance.

Because many models are created in a single file, the size taken up with a few of these files is considerably smaller than the space taken up with many more files that are individual. The library concept allows fewer files, but requires a basic knowledge of the capacitors to search the right library.

Figure 103: NetList Library file containing two devices (insert same devices at 85°C and 3.3 Vdc).
The KEMET Spice software allows you to create a singular model representing several capacitors. Distinguishing these multiple models from singular models is created by including the number of pieces in parallel enclosed in brackets, "[ ]" at the end of the part number, before the file type suffix. The format is “Part_Number[Ps].Type”. For an Ansoft File of 20 A700D107M006ATE015 capacitors in parallel ("A700D107M006ATE015[20].ckt"):

```
.SUBCKT A700D107M006ATE015[20] 1 8
* Temp@ 25°C, Bias@ 0Vdc , Center Freq@ 300.000kHz [x20 Pcs. in Parallel]
* KEMET Model RLC Tant5RC.JPG / Spice Version 3.7.30
L1 1 2 92.50E-12
R6 2 8 10.00E+03
R1 2 3 327.04E-06
C1 3 8 64.52E-06
R2 3 4 81.92E-06
C2 4 8 129.03E-06
R3 4 5 81.92E-06
C3 5 8 258.06E-06
R4 5 6 81.92E-06
C4 6 8 516.13E-06
R5 6 7 81.92E-06
C5 7 8 1.03E-03
.ENDS
```

The number of pieces in parallel is also spelled out in the second comment line as “[x20 Pcs. In Parallel]”
Ansys Files

These are the NetList files created for Ansys; which Ansys translated to their models.

Cadence Files

Selection of the source list, overwrite, frequencies, ambient temperature, DC bias, storage paths, etc., are all the same as discussed for the NetList files in Figure 99 and Figure 100 on pages 61 and 63.

The Cadence files are based on an overly simplified RLC circuit, with values loaded for these elements from three file types. The “TXT” files are ASCII files defining the model package, with each part having its own text file. The “DCL” or collection of ASCII files for a group of capacitors all from KEMET, all X7R dielectric, and all of “0805” chip size. The third file type is the “DML” file, which defines the electrical models for all of the part types listed in the “DCL” file. These are arranged in sequential order, the same order as in the “DCL” file. Each part type in the “DCM” file begins with the line “(part number) (e.g., “(c0508c104k5rac” as shown in Figure 105), and each part type ends with the line “)” after the “Pin Connections” definition.

The Cadence files require parasitic information for ESR and ESL based on the self-resonance of the part types. Since self-resonance can be impacted by ambient temperature and DC bias conditions, the Cadence files require this information but not before these files can be created. Since this information is collected when Touchstone Impedance files (page 75) are created, the Cadence option is only valid after the Touchstone files are created. Since the temperature and bias settings factor the Touchstone file data, these settings are not offered here but duplicate those Touchstone settings.

The “DCL” files (top left in Figure 105) are divided by chip size and dielectric. Shown here is the file for all the 0805 chip sizes with X7R dielectric arranged by part number (The source list for this file was using “Part List.XLS” which has a much smaller listing than would be created using KEMET Spice program as the source.). Because of this ordered arrangement and the use of a capacitance code, the pieces are not listed in order of capacitance. In this listing, the first four part types have capacitance codes of “102”, “102”, “103”, and “104”, which represent capacitance values of 1 nF, 1 nF, 10 nF, and 100 nF, respectively.

Figure 105: Three file types created for Cadence models: (Top Left) TXT file for part type for C0805C104K5rac; (Bottom Left) DCL collection file for all caps, KEMET, X7R dielectric, and 0805 chip size; (Right) DML file type containing model parametric values for RLC.
The “dml” file is a collection of the part numbers, arranged in alpha-numeric order by the part number, defining capacitance, intrinsic ESL, extrinsic ESL, ESR, and leakage resistance for an “ESpice” subcircuit.

There are Cadence files for ceramic and film type capacitors, but not for tantalum and aluminum electrolytic capacitors. The ceramic and film capacitors can be accurately modeled in this simple RLC model variation. The exclusion of the tantalum and aluminum is because the error created in trying to model these devices with a simple RLC model. These capacitors require a more complex model in which extended RC ladder elements duplicate the effect of capacitance loss with increasing frequency, and the errors produced with the simple RLC model are excessive.

The ceramic Cadence models are broken into dielectric and chip size groups (e.g. the C0G 0201, X5R 0201, C0G 0805, X7R 0805, etc.). The film capacitors are broken into dielectrics (PEN, PET, PPS, and Paper), and then by capacitor series or part number prefix (e.g., GMC, GMW, MMC, MDC, SMW, etc.)

### Linear Tech Files (Excel Library, or CIR files)

Selection of the source list, overwrite, frequencies, ambient temperature, DC bias, storage paths, etc., are all the same as discussed for the NetList files in Figure 99 and Figure 100 on pages 61 and 63.

The NetList files created with the CIR suffix, can be read by Linear’s “SwCad III” software. The models used in Linear Technologies software are initially embedded in an Excel spreadsheet, and the software adds this sheet as an accessible library. It is limited to values of 1 µF or higher, and moderately stable dielectrics, eliminating the Y5V and Z5U ceramic types.

Because the Linear models are created based on the Touchstone data files, there is no option for changing the temperature or DC bias as these conditions factor the creation of the Touchstone data files.

The generation of this file type is dependent on the data created in the Touchstone impedance files creation. As these files are being created, regardless if the frequency of self-resonance is inserted in the data files, the self-resonance is determined and the parameters measured here are stored in a data file. This selection will not appear as accessible if the data files do not exist so you may have to follow Touchstone the process listed on page 75 to have the capability of creating this Excel file.

This excel file is independent of the Part List.XLS file, although it was initially intended as a worksheet within this file.

**NOTE: It should be obvious that if you do not have Microsoft’s Excel program loaded on your system, that selecting this format may crash the program.**

Once the Touchstone dependent data file is created, this option uses those files included in that data file to look for all values equal to or greater than 1 µF in capacitance and creates the Linear.XLS file (Figure 106). The 1st column (“A”) represent the capacitance value (µF), the second column (“B”) specifies the manufacturer (KEMET in this case), and the 3rd column (“C”) shows the part number. The 4th column (“D”) signifies the dielectric type, the 5th column (“E”) denotes the rated voltage, and the 6th column (“F”) represents the maximum ripple current at self-resonance. The 7th and 8th columns (“G” & “H”) denote the ESR and ESL for the device at self-resonance, although I do not believe that the new Linear models use the ESL value. The “Parts per Package” and “MTBF” values are set to “1” as requested by Linear.

A limited view of this spreadsheet is shown in Figure 106.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
<th>L</th>
<th>M</th>
<th>N</th>
<th>O</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
<td>13</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>1</td>
<td>Capacitance (µF)</td>
<td>Voltage (Volts)</td>
<td>Ripple Current (mA)</td>
<td>Leakage (µA)</td>
<td>Parts/Per</td>
<td>N/A</td>
<td>N/A</td>
<td>13</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
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<td>C00501005MH5AC</td>
<td>10V</td>
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<td>16V</td>
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<td>C00501005MH5AC</td>
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<td>10.20%</td>
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<td>C00501005MH5AC</td>
<td>90V</td>
<td>10.20%</td>
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<td>C00501005MH5AC</td>
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<td>C00501005MH5AC</td>
<td>100V</td>
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</tr>
</tbody>
</table>

**Figure 106: Excel worksheet “Linear.XLS” created for transfer into Linear’s “SwCad III” software.**
Mentor Files

Selection of the source list, overwrite, frequencies, ambient temperature, DC bias, storage paths, etc., are all the same as discussed for the NetList files in Figure 99 and Figure 100 on pages 61 and 63.

The Mentor files are another variation of the NetList file in Figure 101 as shown on page 65. They will have the unique file descriptor “SP”, and the file name consists of “KEMET_” preceding the part number. These files will be created and stored in a subdirectory of the application path “/KEMET_Spice/CKTs/Mentor”.

Figure 107: Mentor netlist file for a 1206 chip capacitor, of X5R dielectric, 1 µF and rated at 6.3 Vdc.

Mentor file types are indicated with "SP" suffix. They also require "KEMET_" as a prefix to the part number in the file name.

Mentor File ("KEMET_C1206C105K5RAC.sp"):

```
.SUBCKT C1206C105K5RAC 1 6
* Temp@ 25°C, Bias@ 0Vdc, Center Freq@ 1.000MHz
* KEMET Model RLC Cerm.jpg / Spice Version 3.7.22
L1 1 2 1.07E-12
L2 2 3 2.03E-09
R1 3 4 1.21E-03
C1 4 6 9.10E-09
R2 2 5 1.22
C2 5 6 4.20E-12
R3 1 6 1.000E+09
.ENDS
```

Mentor File ("KEMET_T520C107M010ATE025.sp"):

```
.SUBCKT T520C107M010ATE025 1 8
* Temp@ 25°C, Bias@ 0Vdc, Center Freq@ 300.000kHz
* KEMET Model RLC Tant5RC.jpg / Spice Version 3.7.22
L1 1 2 2.20E-09
R6 2 8 2.00E+03
R1 2 3 3.27E-06
C1 3 8 6.45E-06
R2 3 4 8.19E-06
C2 4 8 1.29E-06
R3 4 5 8.19E-06
C3 5 8 2.58E-06
R4 5 6 8.19E-06
C4 6 8 5.16E-06
R5 6 7 1.94E-03
C5 7 8 5.16E-06
.ENDS
```

Mentor File ("KEMET_A700D107M006ATE015[20].sp"): [20 x A700D107M006ATE015 capacitors in parallel]

```
.SUBCKT A700D107M006ATE015[20] 1 8
* Temp@ 25°C, Bias@ 0Vdc, Center Freq@ 300.000kHz [x20 Pcs. in Parallel]
* KEMET Model RLC Tant5RC.jpg / Spice Version 3.7.30
L1 1 2 9.25E-12
R6 2 8 1.00E+03
R1 2 3 327.04E-06
C1 3 8 64.52E-06
R2 3 4 8.19E-06
C2 4 8 129.03E-06
R3 4 5 8.19E-06
C3 5 8 258.06E-06
R4 5 6 8.19E-06
C4 6 8 516.13E-06
R5 6 7 81.92E-06
C5 7 8 1.03E-03
.ENDS
```
Multisim Models

The models generated with this program are a preliminary or transitional model for this EDA tool. The models are sent to National Instrument where they are finalized and offered by them.

S-Parameter Files

We used the Touchstone format for the S-Parameter files. As we generated shunt as well as series connections, we included an in-line circuit diagram for each.

![S-Parameter Model files generation form.](image)

(Figure 108, Item 1) Creating S-Parameter Model Files

Once this file type is selected, the form displays the “Create S-Parameter Model Files” heading on the form. Additional elements include a selection for “Series Mode” and adjusting the line impedance.

(Figure 108, Item 2) Choose between KEMET Spice Data or Part List.XLS as source list for models

You again have a choice between using the Excel (Part List.XLS) file as a guide to the part numbers you desire or from the internal capability of the KEMET Spice program.

(Figure 108, Item 3) Choose between “Shunt” and “Serial” connection of capacitor measurement

The program defaults to the shunt connection of the capacitor in the 2-port measurement system, but this box will allow you to force the program to use a series connection method. The option to change connection mode is also available during the KEMET Spice viewing of the S-Parameter plots. Whatever you set or change the line impedance here will also show up during the S-Parameter plots. You may change the program’s default condition using the “Default” form (Figure 9, on page 9).

(Figure 108, Item 4) Frequency Ranges

The program will allow the operator to vary the stop frequencies of the data. Because there is a six-decade difference between star and stop frequencies, changing the stop frequency will change the start frequency. From the default settings, the stop frequency for the MLC capacitors below 100 pF is 10 GHz, with a start frequency of 10 kHz. For the two other ranges listed, specifying stop frequencies of 1 GHz and 100 MHz, creates start frequencies of 1 kHz and 100 Hz, respectively.

(Figure 108, Item 5)

The S-Parameter data is based on a line impedance of either 50 ohms (default), or 75 ohms selectable with this control. The option to change line impedances is also available during the KEMET Spice viewing of the S-Parameter plots. Whatever you set or change the line impedance here will also show up during the S-Parameter plots. You may change the program’s default condition using the “Default” form (Figure 9, on page 9).

---

Optional file from KEMET Spice web page
File conversion updates are shown in these text boxes. If the Excel file 1 is being used as the source, then the row and value being read from the Excel file will be displayed here. If the internal seed values for this program are being used to create the model files, then only the files for the created part numbers will be shown here.

Using the internal seed values of the KEMET Spice program will eliminate items referring to the Excel file, such as the second row indicating part numbers being read from Excel (Item 8).

The ASCII files created are similar to that shown in Figure 109. A diagram of the S-Parameter, 2-Port capacitor connection is included in the comment lines. The first line is required in the Touchstone format: “! 2-port, S-Parameter, multiple frequency points”. The comment lines also detail the nominal capacitance, ESR and ESL at self-resonance, as well as the self-resonant frequency (phase shift).

There is also a note of the temperature and DC bias voltage applied to the device during the test (25°C and 0 Vdc shown here).

The required line showing “# Hz S DB R 50” defining the data as frequency (freq) determined, expressed in decibel (DB) and the reference resistance (R 50), as 50 ohms in this case.

The next comment line “!freq dbS11 angS11 dbS21 angS21 dbS12 angS12 dbS22 andS22” defines the 9 headings of the succeeding data columns. The data is shown beginning at 1 kHz and running to 1 GHz for this C0805C103KRAC ceramic chip capacitor.

The same piece from Figure 109 is shown in Figure 110, but the device’s connection is changed from series as in the former to a shunt connection as in the latter. There are enormous differences in these two results and this selection is critical.
Sigrity Files

Selection of the source list, overwrite, frequencies, ambient temperature, DC bias, storage paths, etc., are all the same as discussed for the NetList files in Figure 99 and Figure 100 on pages 61 and 63.

The files created here are the same format as the NetList files described on page 61. For the sake of order, these files are specifically created in the “CKTs/Sigrity” directory. They can be created from the Excel Part List file\(^1\), which contains a “Sigrity” worksheet listing of Part Numbers, or the internal part numbers from KEMET Spice may be used to create the desired files. Again, since the files can be created through this program, the user may specify ambient temperature and bias conditions reflecting specific circuit operation to create models with minimal errors.

Sigrity File ("T409A105M010AH4250.ckt"):

```
.SUBCKT T409A105M010AH4250 1 8
* Temp@25°C, Bias@0Vdc , Center Freq@500000Hz
* KEMET Model RLC Tant5RC.JPG / Spice Version 3.6.0
L1 1 2 1.50E-09
R6 2 8 50.000E+06
R1 2 3 811.22E-03
C1 3 8 32.26E-09
R2 3 4 325.61E-03
C2 4 8 64.52E-09
R3 4 5 325.61E-03
C3 5 8 129.03E-09
R4 5 6 325.61E-03
C4 6 8 258.06E-09
R5 6 7 325.61E-03
C5 7 8 516.13E-09
.END
```

Sigrity File ("A700D107M006ATE015[20]ckt"): {20 x A700D107M006ATE015 capacitors in parallel}

```
.SUBCKT A700D107M006ATE015[20] 1 8
* Temp@ 25°C, Bias@ 0Vdc , Center Freq@ 300.000kHz [x20 Pcs. in Parallel]
* KEMET Model RLC Tant5RC.JPG / Spice Version 3.7.30
L1 1 2 92.50E-12
R6 2 8 10.00E+03
R1 2 3 327.04E-06
C1 3 8 64.52E-06
R2 3 4 81.92E-06
C2 4 8 129.03E-06
R3 4 5 81.92E-06
C3 5 8 258.06E-06
R4 5 6 81.92E-06
C4 6 8 516.13E-06
R5 6 7 81.92E-06
C5 7 8 1.03E-03
.END
```

\(^1\) Optional file from KEMET Spice web page
Simplis (Simplex/Simetrix)

Selection of the source list, overwrite, frequencies, ambient temperature, DC bias, storage paths, etc., are all the same as discussed for the NetList files in Figure 99 and Figure 100 on pages 61 and 63.

For the SIMplex/Simplis design software, a specific line has to appear as the second comment line in the ASCII file. This comment line (preceded by an ‘*’) defines the device as a capacitor that is either polar or non-polar.

In Figure 111, the second line is "**#ASSOC Symbol=cap_polar_us category=capacitors simulators=simetrix|simplis" defines this sub circuit as representative a polar capacitor (tantalum-polymer, electrolytic is polar). In Figure 112, the second line states "**#ASSOC Symbol=cap category=capacitors simulators=simetrix|simplis" which defines this sub circuit as a capacitor (non-polar unless explicitly defined) for the Simetrix/Simplis EDA software. All of these files end with “.ENDS” statement.

Beginning with version 3.7.5, the Simplis files have character restrictions not found in the other file types. The degrees symbol (°) has been removed, and all spaces have been replaced with underscore (“_”) characters. For multiple pieces the piece multiplier is normally set within brackets after the part number (e.g., 1206C105K5RAC[5].CKT represents a model of five (5) 1 µF capacitors), but with Simplis, the brackets are not allowed and the piece multiplier follow and underscore and small “x” (e.g., C1206C105K5RAC_x5.CKT represents a model of five (5) 1 µF capacitors in parallel).
Selecting the “Create Touchstone” files from the main models form (Figure 98, page 60) changes the form’s appearance to that shown in Figure 113. A highlight of the eight selection items available with this form are as follows.

(Figure 113, Item 1) Create Touchstone Model Files
Once the file type selection is made, all the buttons are disabled and the actual selection is shown at the top of the form. If this is not the type of files desired, click on the [Stop] button and the file types will again be enabled.

(Figure 113, Item 2) Use “PartList.XLS”\(^1\) for source listing
You can use either the Part List.XLS\(^1\) Excel file as a listing of files to be converted or you can select that all the part types capable within KEMET Spice be used as a listing of the part types to be used to create the Touchstone data files. The left portion of Figure 90 shows the form if the Excel file is selected as the source, and the right portion shows the form if the seed values are selected as the source listing.

(Figure 113, Item 3) Create ‘Touchstone_PartList.Dat’ file
Because the creation of Touchstone files requires defining the impedance and phase through the self-resonant frequency, a data file is created using recording the self-resonant frequency and the impedance, capacitance, ESR, and ESL at these self-resonant frequencies. These elements are necessary when creating the Cadence and Linear model data. When this file is created, the Linear and Cadence model file creations will become selectable.

When all the styles (item 11) are selected, this selection is automatically checked. If only a partial selection of styles is made, this check box is unselected, and you will have to check this box to create the data file based on a limited series selection. Remember, what you put into this data file determines what you can create for Cadence or Linear models. The conditions you select (temperature and bias voltage) also factor the data for this file and will influence the Cadence and Linear Tech data file models.

(Figure 113, Item 4) Include SR Freq Point
KEMET Spice will create 50 frequency points per decade of frequencies for the range defined and these frequency points will be recorded in a serial fashion in the ASCII “z1p” file. It is probable that the self-resonant frequency will occur in between these set frequency steps. When reviewing the impedance versus frequency, the impedance will never reach its minimum if it does not include a frequency step exactly at the self-resonant frequency.

By selecting this check box, the self-resonant frequency will be included, adding one more frequency point and data line. This non-standard, arbitrary insertion of a data line in the ASCII file may negate the possibility of comparing the impedance magnitudes in a side-by-side comparison for two part types as the frequency points may be shifted at different points in the files.

---
\(^1\) Optional file from KEMET Spice web page
(Figure 113, Item 5) Stop Frequency points
The files created are frequency driven, and all the files will list the impedance and phase angle for six frequency decades. Depending on the capacitor type, the upper usage regions vary and are selectable here. The default is MLCCs less than 100 pF up to 10 GHz, up to 1 GHz for all other MLCCs, and up to 100 MHz for all other types.

(Figure 113, Item 6) Flashing text and time counter
As the files are being created, the part number being read is shown, and if the Excel “PartList.XLS” file is being read and updated, the Excel part number being posted will appear here. The elapsed time keeps count of the time to create all the files selected.

(Figure 113, Item 7) Use “KEMET Spice” seed data for generating part numbers
Instead of using the limited part numbers of the Excel file, you can use all the part numbers that are contained within the program to generate these models. Once selected, you will be able to select which capacitor types and then which series to use.

(Figure 113, Item 8) Flashing text and time counter
These boxes show the files created and an elapsed time counter.

Create Touchstone Files

This command button activates the creation of the Touchstone files.

These files are very much like S-Parameter files but they allow for a single-port measurement of impedance and phase. After all, these devices are two-terminal, single-port devices as they respond in the circuit. Because this data is impedance from a single-port measurement, the file descriptor for these files is “.z1p”. The files comment lines are preceded by an exclamation mark (!), with the opening lines as defined below (as in Figure 114):

1. “! 1-port Z-parameter file, multiple frequency points”
   (Required) The first line denoting the ports and parameter of measurement and that the following data listing represents “multiple frequencies”.
2. “! Capacitance 10.0pF, ESR 878.66mOhm, ESL 564.00pH”
   (Not Required) Defines the capacitance, ESR, and ESL for the device.
3. “! Temperature 25 °C, Bias @ 0 Vdc”
   (Not Required) Defines the Ambient temperature and Vdc bias.
4. “# HZ Z MA R 50”
   (Required) “#” precedes line defining columns and condition: (1st Column Label – “Hz”) (2nd Column Label – “Z”) (3rd Column Label – MA {Magnitude Angle}) (Line Impedance – 50 Ohm)
5. “! freq magZ angZ”
   (Required) defining three elements per data line (Frequency, Magnitude of Z, Angle of Z°)
6. Remaining lines (Required)
   a. Space separated columns
   b. Through 356 lines (beginning and end shown for brevity).

Again, these values may be factored by the ambient temperature and Vdc bias applied to the component.

---

1 Optional file from KEMET Spice web page
By using the data files supplied with KEMET Spice as a source of part numbers in creating the model files, the number of files created exceeds 9,000. The time required to create 9,000 files of any model type is close to two and a half minutes. A breakdown of the elapsed times for each model type and by capacitor type is shown in Table 2. This time is not excessive if you consider that you may only need to create one set of models once, but the net list type of files is temperature, bias, and frequency dependent. If you need to develop a set of models for multiple conditions, then two and a half minutes might be a problem, and a lot of time is being spent on part types you will never use in your production.

Table 2. Elapsed times to create files for each of the EDA formats, by capacitor type.

<table>
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<th>Software</th>
<th>Alum-Poly</th>
<th>Ceram Comm.</th>
<th>Film SMD</th>
<th>Tant-Comm</th>
<th>MIL-Cerm</th>
<th>MIL-Tant</th>
<th>Total</th>
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<td>0:23</td>
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<td>0:34</td>
<td>0:33</td>
<td>0:06</td>
<td>0:23</td>
<td>2:20</td>
</tr>
<tr>
<td>Netlist [ENDS]</td>
<td>0:02</td>
<td>0:42</td>
<td>0:34</td>
<td>0:33</td>
<td>0:06</td>
<td>0:23</td>
<td>2:20</td>
</tr>
<tr>
<td>Netlist Lib</td>
<td>0:02</td>
<td>0:46</td>
<td>0:33</td>
<td>0:36</td>
<td>0:07</td>
<td>0:20</td>
<td>2:24</td>
</tr>
<tr>
<td>Signity</td>
<td>0:02</td>
<td>0:49</td>
<td>0:37</td>
<td>0:39</td>
<td>0:07</td>
<td>0:30</td>
<td>2:44</td>
</tr>
<tr>
<td>Simplis(Simplex)</td>
<td>0:02</td>
<td>0:49</td>
<td>0:31</td>
<td>0:32</td>
<td>0:07</td>
<td>0:22</td>
<td>2:23</td>
</tr>
<tr>
<td>S-Param (Shunt)</td>
<td>0:01</td>
<td>0:43</td>
<td>0:40</td>
<td>0:48</td>
<td>0:07</td>
<td>0:19</td>
<td>2:38</td>
</tr>
<tr>
<td>S-Param (Series)</td>
<td>0:01</td>
<td>0:43</td>
<td>0:40</td>
<td>0:48</td>
<td>0:08</td>
<td>0:16</td>
<td>2:36</td>
</tr>
<tr>
<td>Touchstone</td>
<td>0:01</td>
<td>0:49</td>
<td>0:36</td>
<td>0:38</td>
<td>0:08</td>
<td>0:34</td>
<td>2:46</td>
</tr>
<tr>
<td>Software</td>
<td>2,959 files</td>
<td>3,272 files</td>
<td>1,037 files</td>
<td>458 files</td>
<td>125 files</td>
<td>9,132 files</td>
<td></td>
</tr>
<tr>
<td>Linear (C=5uF)</td>
<td>121 PNs</td>
<td>290 PNs</td>
<td>262 PNs</td>
<td>2,099 PNs</td>
<td>0 PNs</td>
<td>1,140 PNs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3,921 PNs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

As an alternative, you can create a reduced listing of those capacitors that you are using in your production. The PartList.XLS file is an Excel file created for this effort. This file is located on the KEMET web site, on the same page as the KEMET Spice setup program. It is intended to allow each customer to customize the list of the models created, to conform to a limited number of part types that they use from KEMET. Although the seeds in KEMET Spice generates a response for one tolerance for each part number, using the part list will allow models to be created for each tolerance, although the models will be exactly alike except for the tolerance code. For 1 µF capacitors of 10% and 20% tolerance, these devices would have unique part numbers, but their expected responses and models should be the exactly same except for the part number.
Figure 115 shows a partial view of the “KEMET_PartNo” worksheet in “Part List.XLS”, being the first of eleven (11) worksheets contained within this Excel workbook. In column “A”, the part numbers are listed in alphanumeric order. In column ‘B’, the number of pieces may be specified (no number results in one {1} being the multiplier) allowing the user to create a single model in place of multiple models or many models (Revision 3.7.3). In this illustration, part numbers that are repeated to create different multiple piece models are highlighted in color groupings (color separation does not need to occur in actual PartList file). Once all changes to the lists of part numbers and multiple pieces are complete, a macro triggered by clicking on [Update Lists] will reorder the listing, and copy this source listing to the other ten (10) spreadsheets. Do not leave any row empty, as an empty cell in column A will stop the ordering and duplication. The KEMET Spice program creates models based on the copied part number listing on the appropriate worksheet for the model types being exported.

In Figure 115, the first part types appears once (rows 2 through 7), while the next part type (“A700107M006ATE015” in row 8) is duplicated for the next three rows (to row 11). The first time that part type appears, the multiple piece count is set to one (1), followed by five (5), then ten (10), and finally to twenty (20). These multiples are arbitrary selections made only to allow you to see the potential for creating a model of multiple parts. There will be four distinct models created for each part type: a model for a single piece (A700107M006ATE015), a model for five (5) pieces (A700107M006ATE015[5]), a model for ten (10) pieces (A700107M006ATE015[10]), and a model for twenty (20) pieces (A700107M006ATE015[20]). This series of four multiple levels for the same part type is followed by two more series from row 12 through row 15, and from row 16 through row 19.

The text box located in column F through column M, repeats the instructions here. The listing of part numbers begins on row 2 and continues until a cell in column “A” is left blank. The Part Numbers listing must be continuous – do not leave any row blank or the entire list will not be copied to the other worksheets.

The remaining worksheets (“Ansoft”, “Ansys”, “Cadence”, “Mentor”, “Multisim”, “NetList”, “S-Parameter”, “Sigrity”, “Simplis”, and “Touchstone” will be used to determine what part numbers will have corresponding models, and it is possible to record the filename of the model created (Item 5 of Figure 116). Once the [Update List] macro is completed, you have to close this worksheet or the KEMET Spice program will not be able to open and edit it.

When creating the models in KEMET Spice for this reduced listing, click on “Use ‘Part List.XLS’ as source listing (Item 3 of Figure 116). Click on the “NetList Filenames in `PartList.XLS” if you want the program to write the model files to the Excel file (Item 5 of Figure 116). Depending on which model you’ve selected, “NetList” will be replaced in this selection.

The “NetList” worksheet has three columns for three different models created: CKT files (the standard), CIR files (may be read by some EDA tools), and LIB files which are library files or collections of NetList Files. With the library files, you will see that many part numbers are collected into some common library files. The 03028 models for the part numbers in rows 2 through 5 are collected in the library file “KEMET 03028_X7R-NetList.LIB”, the 03029 models (rows 6 and 7) are collected in “KEMET 03029_X7R-NetList.LIB”, etc.
Shown in Figure 117, the “Touchstone” worksheet has the files created for the specific part numbers of column “A” listed in column “B”. The first listed part number (03028BR103AKZC) has “03028BR103AKZC.z1p” listed in column B denoting that the model file name for that device. Contact the factory if “—No File—” response is generated; it is likely because the part number is incorrect or the part number is not included in KEMET Spice. The multiple pieces discussed in Column ‘B’ of Figure 115, will be copied to column ‘E’ of each model worksheet. In the existing 545 part numbers in the Part List workbook, there are no wrong part numbers included.

The elapsed times for creating 545 model files for the different EDA formats is shown in Table 3. These times are considerably shorter than those required for all part numbers in KEMET Spice’s data files (over 9,000).

Table 3: Table of elapsed times to search 545 PNs, create the files, and post file names in “Part List.XLS” file.

Possible substitutions may include the following:
- Lower ESR than specified in PN
- Higher voltage than specified by the PN
- Any tolerance substitution (tolerance is ignored for typical response of a part number)

The remainder of the list shows the corresponding model file for each part number. The spreadsheet is updated with a time stamp in cell “L2” for the date and time of last entries. The number of bad files or “No File” count is shown in cell “J2”. The table beginning at “I7” is a table of pointers to the row where each part type begins: “A700” part type begins at row 8, “C0201” begins at row 26, “C2225” begins at row 137, etc. Each model’s spreadsheet, except for “Linear” will have this table duplicated on that spreadsheet.
Ordering Samples  \textcolor{red}{<Ctrl><K>}

Beginning with version 3.7.4, there is a capability for ordering samples through the “myKEMET” web site with a quick link from the KEMET Spice program. While viewing the frequency response form, you can use the pull-down menu “Order Sample” (Figure 118) or use the key combination of \textcolor{red}{<Ctrl><K>} to enter the sample request routine.

![Figure 118: Order samples pull-down menu.](image)

If you used the pull-down menu, click on the menu item “Place Order Ctrl+K” and the sample order preliminary form of Figure 119, shows up. The actual form is contained within the windows form of the upper left, and the part type is carried from the previous form (with multiple piece plots, it will represent the highlighted or foreground plot piece from that form). The sample pieces required is selectable and restricted by the part type. You cannot order samples for the stacked ceramic part types.

With this version of Visual Basic there is no quick internet interface, but to overcome this a URL statement is created that will connect to the sample request web page and carry the part identification data and sample size to that page.

![Figure 119: Preliminary order form and the URL text highlighted and magnified.](image)

Once the URL statement is created and adjusted for the correct sample size, use the mouse to highlight the entire statement. Click at the beginning (before “http”), hold the left mouse button, and move the mouse pointer to the end of the statement (after “Mount&qty=10”), then release the button, and the entire statement should be highlighted. Copy that statement to the clipboard (you can use \textcolor{red}{<Ctrl><C>} to copy).

Open up your web explorer program (e.g., Windows “Explorer”) and paste (use \textcolor{red}{<Ctrl><V>}) that URL statement in the address block of the web browser (Figure 120).

![Figure 120: Paste URL statement in address bar of web browser.](image)

Touch the <Enter> key or click on the [Go] button and the browser will go to the sample order page (Figure 121). The circled entries are those entries carried in the URL statement concerning the “Part Number”, “Part Description”, “Family, Type”, and “Sample Quantity”. Delivery of the sample will require delivery on contact information. Since this form was entered without any ID established, you must first log in or register. If you have to register, you do you will be assigned a user name and password.
Once you have logged in, the delivery and contact information are filled in, but there are still three (3) more entries to be made (Figure 123). Give an estimate of annual usage, a description of the “end product”, and select a purpose for this sample. At this point all required entries are complete and along the lower left of the form, there is a button labeled “Submit Part(s) Request” – click on that button and the order should be processed.
Figure 123: Last three entries to be filled in, and submitting request for samples.

At this point, you can close the web browser, or switch back to the KEMET Spice program window. The preliminary order form of Figure 119 should still be apparent and you can click on the [Exit Order Form] button to return to the frequency scan.

HELP

*With “Vista” version of Windows, Microsoft stopped supplying the WinHlp32.exe - see Windows Vista on page 93 for method of activating these help screens.*

The pull-down menus here may change throughout the program. The short-cut keys talked about in this manual can be quickly referenced here (Figure 124), and are fully detailed on page 83.

Figure 124: HELP pull-down menu, “Shortcut Keys.”

If the multiple plots are multiple dc bias conditions or multiple temperatures, then this box will reflect those elements as the choice selections. If the selection item is checked, it will be plotted, or if it is unchecked, it will not be plotted.
A full listing of the short-cut keys may be seen on page 84 of this document.

Figure 125: The shortcut key listing is available through the HELP menu and can be viewed in program.
Short-cut Key Combinations  (These are active when the graph is on screen.)

### Frequency Plots
- **→ (Cursor Right)**: Higher frequency point [<Ctrl> x10]  Next Highest Time Scale  Higher Currents
- **← (Cursor Left)**: Lower frequency point [<Ctrl> x10]  Next Lowest Time Scale  Lower Currents
- **Mouse-Right-Click**: Toggles Frequency Selector Hold (On/Off)
- **<Esc>**: Steps back in program. (e.g., {Plot Graph} back to {Capacitor Selection} back to {Choose Type}, etc.)

### Time-scaled plots
- **↑ (Cursor Right)**: Higher Currents
- **↓ (Cursor Left)**: Lower Currents
- **Mouse-Right-Click**: Toggles Time Selector Hold (On/Off)

### Ripple Current Plots
- **<Esc>**: Steps back in program. (e.g., {Plot Graph} back to {Capacitor Selection} back to {Choose Type}, etc.)

### Cursor Up-Down - During Multiple-plot Graphs
- **↑ (Cursor Up)**: Highlight previous (Higher) Part/Temperature/DC bias from list
- **↓ (Cursor Down)**: Highlight next (Lower) Part/Temperature/DC bias from list
- **<Alt>↑ (Larger Steps)**
- **<Alt>↓ (Smaller Steps)**

### Cursor Up-Down - During Temp Rise vs. Cumulative Frequency Currents Plot
- **↑ (Cursor Up)**: Highlight previous (Higher) Temperature
- **↓ (Cursor Down)**: Highlight next (Lower) Temperature
- **<Alt>↑ (Larger Steps)**
- **<Alt>↓ (Smaller Steps)**

### ^0 (Zero)**: Hold Frequency/Time/Temperature Rise selector position (Mouse Right-Click) – Toggles On/Off
### ^1 Snap to Entered Current Levels (only during “Temperature Rise vs. Combined Ripple Frequency Currents” Plots)
### ^5 S-Parameters based on 50-Ohm Line (Only during S-Parameter Plots)
### ^7 S-Parameters based on 75-Ohm line (Only during S-Parameter Plots)
### ^A Run Another (Ceramic, Film or Tantalum depending on what's been run (for Multiple Pieces, last selection only)
### ^B Custom bias Entry
### ^C Plot Capacitance and Inductance vs. Frequency
### ^C Create Combined Impedance effects
### ^D Show model circuit with parameter values
### ^E Export data to ASCII file
### ^F Change frequency range (any Frequency Plots), Define Frequency Plots (“Temperature Rise vs. Ripple Current”)
### ^G Add/Change grid-lines in charts
### ^H High Ambient Temperature (125°C, 105°C, or 85°C, depending on part type)
### ^I Plot Maximum RMS Current and RMS Voltage vs. Freq.
### ↑ ^I Plot Temperature Rise vs. RMS Current at Multiple Freq.
### ↑ ^J Change Parameter (Seed) values used in model creation
### ^K Put in request for sample
### ^L Low Temp (minimum ambient temperature, typically -55°C)
### ^M Create Multiples of each PN
### ^O Change S-Parameter Shunt/Series configurations – Alternates Shunt/Series (Only during S-Parameter Plots)
### ^P Print All (Z/R, C/L, and I/V) Frequency Graphs to system printer on single page
### ^R Room Ambient Temp (+25°C)
### ^S Start over (eliminates multiple selections)
### ^T Custom Temperature Entry
### ^U Plot Cap vs. dt
### ^V Plot dv vs. dt
### ^W Change allowable temperature rise for RMS current and power dissipation calculations
### ^X Exit Program
### ^Z Plot Impedance and ESR vs. Frequency
### F1 Help – context sensitive
### F2 Print Z/R vs. Frequency Plot – Single Plot / Single Sheet
### F3 Print C/L vs. Frequency Plot – Single Plot / Single Sheet
### F4 Print I /V vs. Frequency Plot – Single Plot / Single Sheet
### F5 Restart capacitor style selection process
### F6 Print dv vs. dt Plot – Single Plot / Single Sheet
### F7 Print Cap vs. dt Plot – Single Plot / Single Sheet
### F8 Print dv vs. dt and Cap vs. dt Plots – Two Plots / Single Sheet
### F11 Plot S11/S22 vs. Frequency
### F12 Print S21/S12 vs. Frequency
### ↑F1 Print Temp Rise vs. Ripple Current Plot – Single Plot / Single Sheet
### ↑F2 25% Rated dc bias
### ↑F3 50% Rated dc bias
### ↑F4 75% Rated dc bias
### ↑F5 Print Temp Rise vs. Combined Ripple Currents Plot – Single Plot / Single Sheet
### ↑F6 Print S11/S22 vs. Frequency Plot – Single Plot / Single Sheet
### ↑F7 Print S21/S12 vs. Frequency Plot – Single Plot / Single Sheet
### ↑<Ins> Add another plot
### ↑<Del> Remove plot(s)
Appendix 1: Printing all three frequency plots on one page (^P).
Appendix 2: Printout of Frequency Plots for multiple tantalum plots (Same PN with changing ESR levels).
Appendix 3: Printout of Frequency Plots for Multiple Ceramic Parts @ 25°C and with 0 Vdc bias.

Impedance and ESR (Ohms)

Freq = 100,000 kHz
Impedance:
- C1210C155K9PAC 168.82 mOhm
- C1210C155K9PAC 114.17 mOhm
- C1210C226K9PAC 77.67 mOhm
- C1210C478K9PAC 36.18 mOhm
- C1210C103K9PAC * 15.64 mOhm
ESR:
- C1210C156K9PAC 7.32 mOhm
- C1210C156K9PAC 5.81 mOhm
- C1210C226K9PAC 4.56 mOhm
- C1210C478K9PAC 3.59 mOhm
- C1210C103K9PAC * 3.19 mOhm

Capacitance and Inductance vs. Freq.

Freq = 100,000 kHz

Meas. Capacitance (F)
- Actual:
  - C1210C155K9PAC 8.434 uF
  - C1210C125K9PAC 13.956 uF
  - C1210C226K9PAC 20.527 uF
  - C1210C478K9PAC 44.235 uF
  - C1210C103K9PAC * 95.644 uF

Meas. Inductance (H)
- Actual:
  - C1210C156K9PAC 8.4 uH
  - C1210C156K9PAC 13.879 uH
  - C1210C226K9PAC 20.376 uH
  - C1210C478K9PAC 43.487 uH
  - C1210C103K9PAC * 82.526 uH

Max I & V vs. Freq.

Max. Current (ARMS)
- Max. RMS Current:
  - C1210C156K9PAC 7.95A
  - C1210C125K9PAC 5.23A
  - C1210C226K9PAC 10.22A
  - C1210C478K9PAC 12.69A
  - C1210C103K9PAC * 15.83A

Max. AC Voltage (VRMS)
- Max. RMS Voltage:
  - C1210C156K9PAC 1.19V
  - C1210C125K9PAC 0.876 mV
  - C1210C226K9PAC 0.744 mV
  - C1210C478K9PAC 0.483 mV
  - C1210C103K9PAC * 0.08 mV

Temp Rise = 20.0°C
Appendix 4: Printout of “Temperature Rise versus Ripple Current” at Constant Frequencies at +40°C ambient.
Appendix 5: Printout of “Temperature Rise versus Combined Multiple Frequencies and Currents” at +20°C ambient.

Temperature Rise vs. Combined Currents (Multiple Freq.)
MDK10 105K50A02P3 @ 20°C with 0VDC

Temperature Rise (°C)

- +100.0°C
- +90.0°C
- +80.0°C
- +70.0°C
- +60.0°C
- +50.0°C
- +40.0°C
- +30.0°C
- +20.0°C
- +10.0°C
- +0.0°C
- -5.0°C
- -15.0°C
- -25.0°C
- -35.0°C
- -40.0°C
- -50.0°C
- -60.0°C
- -70.0°C
- -80.0°C
- -90.0°C
- -100.0°C

Total Power = 43.09 mW
Percent Power = 100.0%
Temperature at 3.5°C
100% Power is above current levels
(same Freq/Curr Table earlier)

Temp Rise is Critical - not allowed above +30°C
Specified Power @ +30°C

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Appendix 6: Printout of $S_{11}$ (Magnitude and Phase) versus Frequency (series mode).

T520V227M2R5ATE007 @ 25°C with 1.25VDC [Series Mode / 50 Ohm Line]

**Frequency (Hz)**

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Appendix 7: Printout of S12 (Magnitude and Phase) versus Frequency (shunt mode).

T520V227M2R5ATE007 @ 25°C with 1.25VDC [Shunt Mode / 50 Ohm Line]

Freq = 238 MHz
S12/S21 Mag = -70.2 db
S12/S21 Ang = -0.2°
Appendix 8: Freeware declaration

"KEMET Spice" is free software that can be downloaded from the KEMET web site (http://www.kemet.com/kemet/web/homepage/kechome.nsf/weben/kemsoft). It is intended to be a guide to KEMET's customers in evaluating typical capacitor performance versus frequency plus application effects related to voltage and temperature. It is "freeware" with no licensing or user fees attached. All associated files created during download and setup are also freeware, and without any fees.

John D. Prymak
Director Advanced Applications
Author - KEMET Spice Software
“Windows Vista” and “Windows 7”

All help files that have the .HLP file type use WinHlp32.exe to display the help screens created for these programs. Since WinHelp32 has not changed since Windows 3.1, they decided that Windows Vista would not include it. This is all explained in Technical Article 917607 at:

http://support.microsoft.com/kb/917607/en-us

You can load a version of WinHlp32.exe from Microsoft's web site, but it varies for Windows Vista, Windows 7, and Windows Server 2008. Use this link to determine which download you need.

http://support.microsoft.com/kb/917607

Microsoft will first need to verify that you have a valid copy of Windows and then allow you to download the programs required to utilize the help screens contained within KEMET Spice. Once loaded, the help screens created in KEMET Spice will be available.

Windows Vista KEMET Spice Installation

Download the setup program to your computer. To run the setup program as administrator, right-click on the downloaded setup icon. A pop-up menu will appear (as on the right), and you will have to click on the “Run as administrator” selection.

March 14, 2008

KEMET Spice Software Freeware Declaration

"KEMET Spice" is free software that can be downloaded from the KEMET web site (http://www.kemet.com/kemet/web/homepage/kechome.nsf/weben/kemsoft). It is intended to be a guide to KEMET's customers in evaluating typical capacitor performance versus frequency plus application effects related to voltage and temperature. It is "freeware" with no licensing or user fees attached. All associated files created during download and setup are also freeware, and without any fees.

A signed copy of this declaration in PDF format is available at the download site.

(See Appendix 8 on page 92)