

1 Introduction

UltraCAD's PDS (Power Distribution System) Impedance Calculator

UltraCAD's Power Distribution System (PDS) Impedance Calculator was designed to conveniently handle the very complex calculations caused by placing a large number of capacitors in parallel. It will handle up to 500 different capacitor values, along with their inductance and ESR. The output graphs the impedance response curve against frequency and also tabulates the self-resonant frequencies and the impedance minimum and maximum values and their frequencies.

Versions 4.0 is a significant upgrade from the earlier version (UltraCAD's Bypass Capacitor Impedance Calculator, Version 3.21). It has been rewritten in VB.NET (as opposed to Visual Basic 6) and is much more user friendly. The fundamental functionality has not changed, however.

2 Operation

OPERATION

The calculator opens with a welcoming screen and license check form. The appropriate license (ucadpds.dat) must be in the same folder as the program executable (ucadpdsi.exe). If the license file exists and checks, then the user can move on the main program by selecting the "Continue" button on the form.

The screenshot shows the main window of the UltraCAD's PDS* Impedance Calculator Ver. 4. The window title is "UltraCAD's Bypass Impedance Calculator v4.0". The interface includes the UltraCAD Design, Inc. logo and the text "UltraCAD's PDS* Impedance Calculator Ver. 4 * Power Distribution System". The license information is "Licensed to: Douglas Brooks, Company: UltraCAD Design, Inc.". The interface is divided into several sections: "Input Options" with radio buttons for "Use internally defined values" (selected) and "Input values from file", and fields for "Input Filename", "Number of capacitor values" (Min = 2, Max = 500), "Number of caps for each value" (Min = 1), and "Value for ESR (Ohms)"; "Graph Control Options" with radio buttons for "Start Frequency" (10⁻⁵, 10⁻⁶, 10⁻⁷, 10⁻⁸) and "End Frequency" (10⁻⁷, 10⁻⁸, 10⁻⁹, 10⁻¹⁰), and "Frequency Step" (0.01%, 0.001%); "Output Options" with radio buttons for "Write Data to File", "Write to Default File", and "Graphical Output Only" (selected); and "Notes for each run (Optional)" with four text input fields labeled "Case1", "Case2", "Case3", and "Case4". At the bottom, there are buttons for "Start", "Clear Graph", "Print Graph", and "End", along with a "Show/Hide Printout Form" checkbox. The copyright notice at the bottom reads "Copyright 2010 UltraCAD Design, Inc., Bellevue, WA".

First, select whether you want the calculator to generate the capacitor values for you internally or whether you want to enter them from a file. The internally generated function is not particularly practical, but it provides a convenient mechanism for easily evaluating the impact of various parameters, such as the number of different capacitor values, the number of capacitors, capacitor ESR and inductance, etc, on the overall power distribution system impedance.

Internally generated capacitor values range logarithmically from .1 to .001 uF with related inductance values ranging from 10 to .1 nH. The specific code used to generate the values is:

```

user has entered nvalues, number of capacitor values
user has entered nsame, number of caps of same value
For i = 1 To nvalues
C(i) = (0.1 * ((0.01) ^ ((i - 1) / (nvalues - 1)))) * 10 ^ (-6)
L(i) = (10 * ((0.01) ^ ((i - 1) / (nvalues - 1)))) * 10 ^ (-9)
Next i
For i = 1 To nvalues
Ctotal = Ctotal + C(i) * nsame
Next I

```

The user then enters the number of desired capacitor *values*, the *number* of capacitors for each value used, and the *ESR* of the capacitors. For ease of use, it is assumed that all capacitors in the analysis have the same ESR value.

Alternatively, use the file-input dialog to enter the filename of a file containing user-defined data. This input is totally flexible. The input file contains one line (record) of comma-delimited text data for each capacitor value. Each line (record) contains (see section on coding):

```

Number of capacitors with this data
Capacitance, in uF
Inductance, in nH
ESR, in Ohms

```

A comment field can be added after the fourth data field. Comment fields are allowed at the beginning of the input file, then a line with the single phrase *startdata* must be placed immediately before the capacitor data. Duplicate records *are* allowed. User can enter up to 500 lines of input data (500 records). "Zero quantity" data is allowed. That is, you can enter an entry for a capacitor but set the quantity at zero. This allows some convenience for multiple evaluations.

Second, select whether an output option is desired. The user can enter a filename and path or browse to a filename, can accept a default filename in the application folder, or run the analysis without generating an output file at all,

Third, select a start frequency and an end frequency for the analysis.

The program samples frequencies sequentially from the start to the stop frequencies. The step between sampled frequencies is defined by the *Frequency Step* dialog. Normally, 0.01% is adequate. That represents, for example, a frequency step of 100 Hz between 1 and 10 MHz. Selecting 0.001% will achieve greater precision, but at a cost of approximately 10 times the processing time!

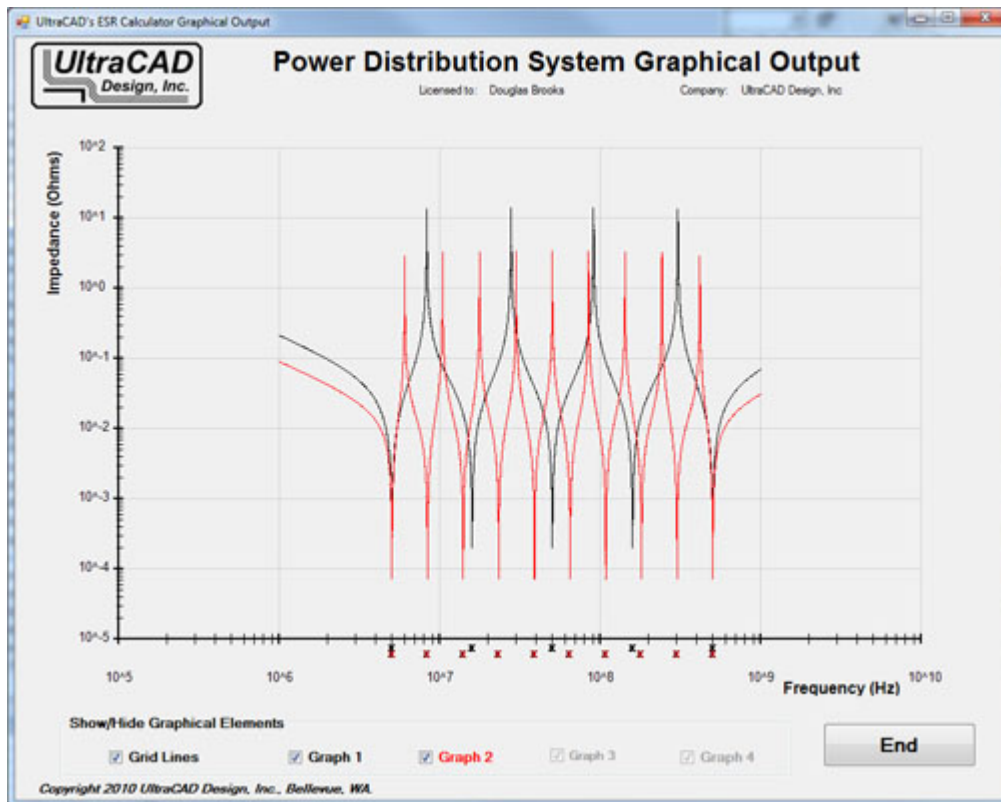
Fourth, a target impedance line can be drawn on the graph. Check the checkbox and enter the target impedance value in Ohms in the textbox.

Finally, the user can optionally enter a note describing the case being run. This note will be written to the output file (if an output file is generated) and will appear on the printout form.

Start the analysis by pressing the "Start" button. The word "Running" will appear on the button face until the

program has finished the analysis. At that point the graphical output is generated. Up to four cases can be run and the graphical outputs will be superimposed on the Graph form. After that the graph must be cleared using the "Clear Graph" button on the main form.

A "Print Graph" form is prepared in the background. This form can be viewed by checking the "Show/Hide Printout Form" checkbox. The form can be printed to the local default printer by selecting the "Print Graph" button.



The Graphical Output form displays after the program has completed. If multiple cases have been run, the resulting graphs are created in different colors. The individual graphs can be turned "On" and "Off" using the checkboxes along the bottom of the form.

The grid lines can be turned "On" or "Off" with the Grid Lines checkbox.

The line of "x's" along the Frequency axis denote the self-resonant frequencies of the individual capacitor values used in the analysis. The self-resonant frequency is given by the formula:

$$Fr = 1 / (2 * Pi * (L * C)^{.5})$$

Special Notes: *These x's are the self-resonant frequencies of the individual capacitors, not the resonant frequencies of the PDS itself. Although these two values are often very close, they are not necessarily equal. Also the relevant value of L (the inductance associated with each capacitor value) to use in the analysis is the inherent inductance of the capacitor itself PLUS any inductance associated with its leads, solder pads, etc, related to the mounting of it onto the board.*

3 Coding

CODING THE INPUT FILE

The data input file contains three components: a comments section at the beginning of the file, a "startdata" line signifying the beginning of the input data, and then the input data itself.

The user may enter as many lines of data identifying the data run as desired, although there are practical limits regarding how much data can be conveniently displayed and read on the output screens. At the end of the comments section there must be a line that contains (and *only* contains) the word *startdata*. Then the user may enter up to 500 sets of capacitor data. Each set of comma-delimited data (a record) consists of four required items of information (fields). The information, in this order, includes:

- The number of capacitors with these parameters
- Capacitance, in uF
- Inductance, in nH
- ESR, in Ohms

Each record may contain an *optional* data or description field after the fourth data field (embedded commas are allowed).

Zero-quantity data fields ARE allowed. That is, a user may have a single data file with multiple combination of capacitor values he/she might want to evaluate. Setting the quantity to zero for the values not to be used in any trial eliminates them from the calculations. Their resonant frequencies are omitted from the horizontal axis.

Then, use the dialog box to specify an output file and location.

A typical simple input file might look like this:

```
This is a sample run
date 12/31/09
startdata
1,67,4,.01
0,67,2,.001
1,1,1.1,.001, 1uF 0603, Kemet C0603C105K8PAC
20,.01,.9,.001
1,.0004,.001,.0000001, plane simulation
```

No other data, punctuation or blank lines are allowed after the startdata line. Duplicate records are allowed and are used. That is, if you entered two records for 4 each of a given capacitor, the program would calculate the impedance characteristics for the total of 8 capacitors. Zero quantities are allowed and are ignored during the calculations. (Zero quantity records do, however, count toward the 500 record limitation.)

The input file above could be for:

- 1 ea 67 uF caps with 4 nH inductance and .01 ESR
- 0 ea 67 uF caps with 2 nH inductance and .001 ESR, as an alternative to the one above (omitted in this run)
- 1 ea 1.0 uF caps with 1.1 nH inductance and .001 ESR
- 20 ea .01 uF caps with .9 nH inductance and .001 ESR
- The fourth line simulates a plane with .0004 uF capacitance.

4 Output File

OUTPUT FILE AND FORMAT

A sample output file is shown below. This is an extremely simple file to illustrate what the typical output file contains.

UltraCAD's Power Distribution System Impedance Curve Output

Run time: 8/7/2010 2:51:26 PM

Input: Internally Generated Data

Output: %App.Path% + \Temp.txt

Case Description: Test generation for an output file

Capacitor self-resonant frequencies:

<i>C(i) uF</i>	<i>L(i) nHy</i>	<i>Self-Res Freq, Mhz</i>
<i>000.100000</i>	<i>010.00000</i>	<i>5.033</i>
<i>000.001000</i>	<i>000.10000</i>	<i>503.292</i>

Impedance curve maximums and minimums.

These calculations are approximate.

They represent the next calculated value AFTER the SLOPE of the impedance curve changes sign.

Note: The precision of the calculations can be improved by setting the Frequency Step to .001.

<i>Min/maxFrequency (Mhz)</i>	<i>Impedance (Ohms)</i>
<i>Min 5.033</i>	<i>.0010001</i>
<i>Max 50.331</i>	<i>4882.7133184</i>
<i>Min 503.307</i>	<i>.0010002</i>

It starts with a heading that includes the run time. It then displays whether the input was internally generated or came from an input file, and the name and path for the output file. If this data had come from an input file, and if that input file had additional description information as a header, that information would then appear in the output file. Next is the case description (if any) that the user entered describing this case on the main form.

The next two main sections are the heart of the calculations. The first of those sections includes a list of capacitor values, their associated inductance, and the self-resonant frequency for that capacitor. Again, the self-resonant frequency for a capacitor is

$$Fr = 1 / (2 * Pi * (L * C)^.5)$$

The final section includes all the turning points in the impedance curve (the maximums and the minimums). Ideally, these correspond to the Power Distribution System resonances and anti-resonances. The system resonances are not necessarily the same as the individual capacitor self-resonant frequencies, because if the capacitor self-resonances are close together they can interact and impact the system resonances.

These values are close, but not exact. They are *not* calculated. The definition of a maximum or minimum is when the slope of the impedance curve changes sign. Thus, the detection of a change in slope is a function of the resolution of the sampling points, selected at the "Frequency Step" option on the main form. To increase this resolution, select the .001% frequency step option on the main form. BUT, this will increase the analysis time by as much as a factor of ten. Finally, if there are a large number of closely spaced capacitor values, there may be "ripples" in the impedance curve that give false indications of a change in the sign of the slope. This is adjusted for by having a "threshold" value of change that must occur before a change in slope is recognized. In rare

circumstances this may result in an output file that appears to miss many resonances. The explanation is that the changes associated with those different resonances is very minor and below the threshold.

5 Installation

INSTALLATION

The complete installation of the program consists of six files:

UcadPDSI.exe, the main executable
UCADlic.dll, a file used in the license check process
PDShelp.chm, the help file
Microsoft.VisualBasic.PowerPacks.Vs.dll, required for the PrintForm functionality
Testsample1.txt, optional sample input file
Testsample2.txt, optional sample input file

In addition you will need a license file, `ucadpds.dat`, obtained separately from UltraCAD Design, Inc.

All these files must be contained in the same folder on your system.

Note: The sample input files have been given to use by licensed users of the calculator. They have given us permission to share the files, but not to disclose their names or their companies. We do not take any position regarding the adequacy of these sample files, or whether they meet any specific parameter requirements. We offer them simply as the work of some people active in the field who found this calculator useful. We make no other representations whatever.

6 About

UltraCADs Power Distribution System Impedance Calculator

Version 4.0

Programmed by Douglas G. Brooks, PhD

Copyright 2010 by

UltraCAD Design, Inc.
Bellevue, WA. USA

Revision History:

Rev 4.0 Original release.