

UltraCAD Design Inc.

Differential Impedance Transmission Line Calculator UCCALC.exe

Help File and Operator's Manual Version 2.01

1 Welcome

Thank you for using UltraCAD's Differential Impedance Calculator.

This is a follow-on calculator to UltraCAD's highly popular ULTRACLC Transmission Line Impedance Calculator, introduced many years ago. That calculator has been downloaded and used by countless designers all over the world. But it did not calculate differential impedance. This new version does. And this new version is substantially more accurate.

This version still calculates single-ended impedances without cost to the user. A nominal license fee and USB dongle are required for differential calculations. See the section on licensing if you would like to obtain one, and for information on how to administer a license once it is obtained.

We hope you like it.

2 Installation

2.1 System Requirements

UltraCAD's Differential Impedance Calculator runs on

Win98/ME/2000/XP

It does NOT run on NT because the dongle USB system files are not supported by NT (NT doesn't support USB ports.)

The unlicensed (freeware) portion of the calculator should run successfully on NT.

2.2 Files and locations

NOTE: Version 2.0 changes the installation procedure (from prior versions) which in turn impacts file locations. File locations for Version 1.1 are not compatible with file locations for Version 2.0 (and vice versa).

Download UCCALC.zip to a convenient directory and unzip it. The following 10 files should be found in that directory. The program can be run from that directory.

UCCALC.exe:

This is the main program file.

UCCALC.hlp

UCCALC.cnt

The help files.

UCCALC.cxx

These are a series of 7 resource files. These files cannot be edited or they will no longer be

operational. If they are somehow damaged, replacement files may be downloaded from UltraCAD's website at www.ultracad.com. Or, contact UltraCAD at DiffCalcHelp@ultracad.com

SUPPORT FILES:

This program is written in Microsoft Visual Basic 6. It should run on any Microsoft Windows system from Win98 on. No additional support files should be needed, but it is possible you may need to install the Microsoft Visual Basic runtime library, VBRUN60-Setup.exe, which can be downloaded from many sites, including UltraCAD's.

LICENSE FILES:

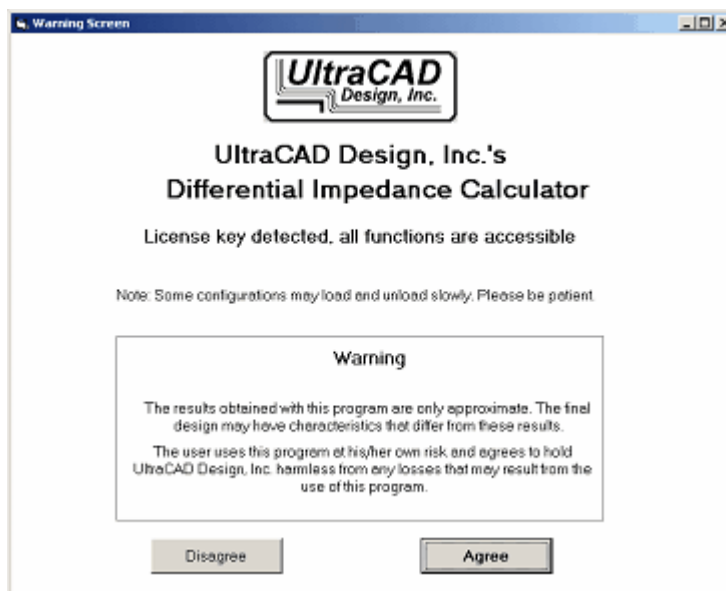
If you have purchased a license and received a USB dongle, certain USB driver files MUST be installed before the dongle is plugged into a USB port the first time. See the section on licensing for more information.

3 Operation

3.1 Starting Up

Starting Up

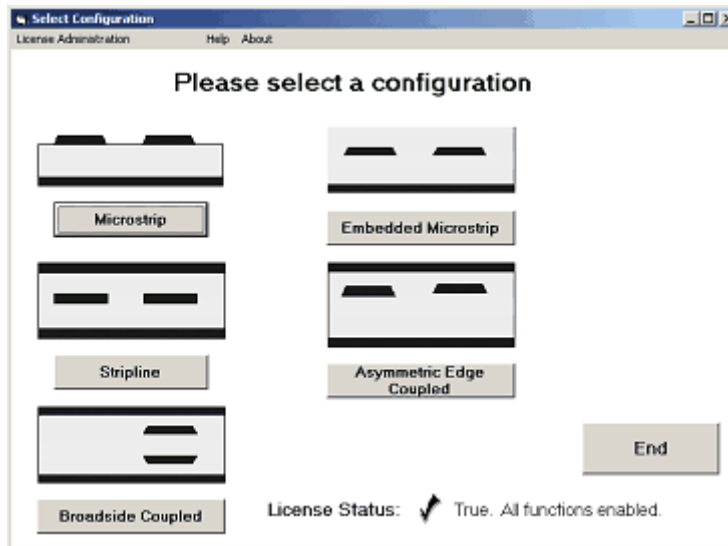
When the program first opens, there can be a delay as it goes through an initialization process. This might take a few seconds on slower computers. Please be patient. When the initialization process is complete, the opening screen is displayed:



This screen advises whether the license has been detected and contains a disclaimer. You must agree to the disclaimer to use the program.

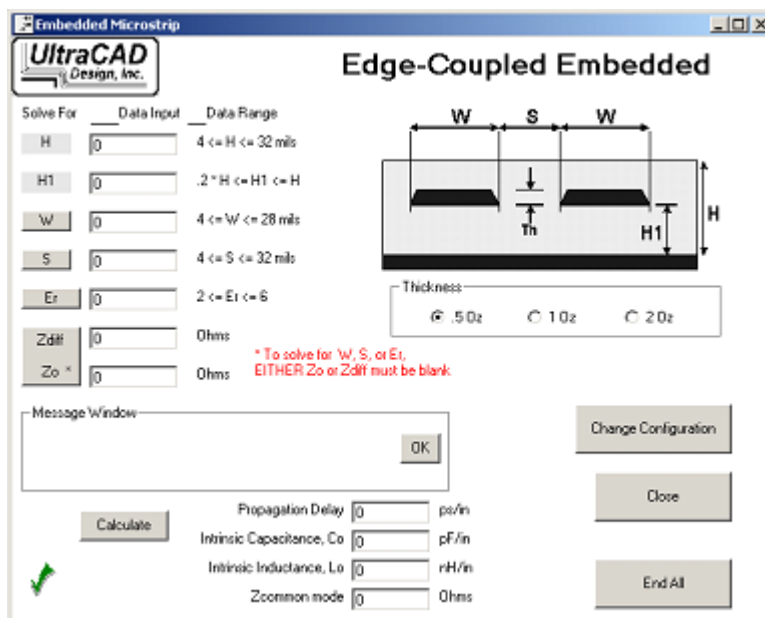
Configuration Selection Screen:

The next screen contains the configuration alternatives. This screen is always active, and all configurations can be active at the same time. Note that this screen contains a visual indication of whether the license is currently active (or whether the dongle might have been unplugged.) The "End" button on this screen closes all windows and terminates the program.

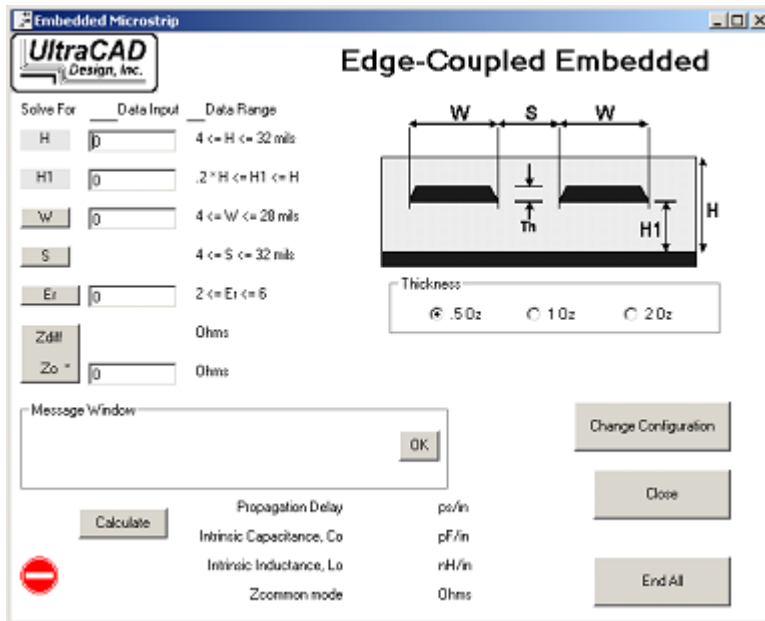


Individual Configuration Screens:

When you select a specific configuration, its window will open. A typical one is shown below:



Embedded Microstrip with license active



Embedded Microstrip with license not active

The user enters the desired values in the text boxes, and selects the desired trace thickness button. The allowable ranges for the values are indicated beside the text box. A command button exists beside the text box for any variable the computer can solve for (note that in this specific configuration it cannot solve for H or H1; see the section on formulas.) If data values fall outside the allowable ranges, a message to that effect will be displayed in the message window. Solving for any variable other than Zo and Zdiff requires that the user set either Zo or Zdiff to zero (otherwise, the calculator does not know which value to use!)

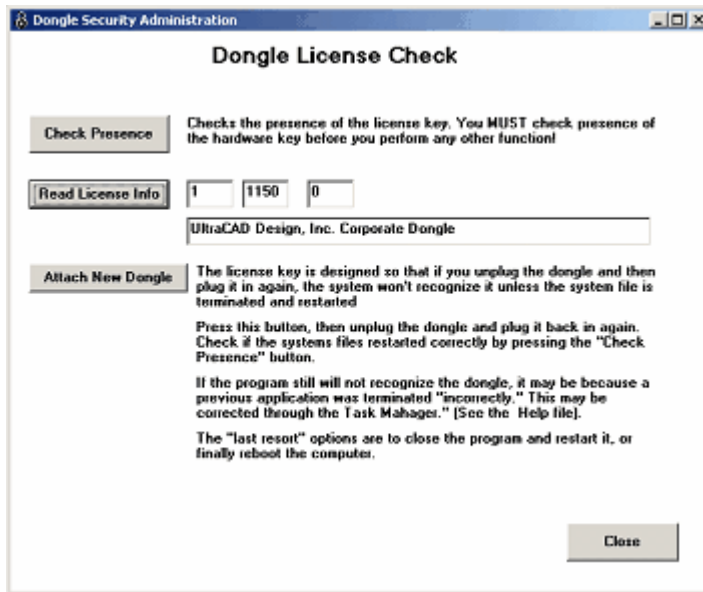
Select the "Calculate" button to calculate Propagation time, Co and Lo.

Note: The calculator checks for a dongle every time the Zdiff calculation is made.

Use the "Close" button to close a specific configuration window. Use the "Change Configuration" button to return to the Configuration Selection Screen. Use the "End All" button to terminate the entire program.

License Administration Window:

The License Administration Window is accessed from the menu on the Configuration Selection screen. It appears below:



The "Check Presence" button confirms the presence or absence of the dongle. The "Read License Info" button will display the license information for the particular dongle that is attached to the system. If your system is having trouble recognizing the dongle (perhaps because you unplugged it) the "Attach New Dongle" button may help you re-acquire it. See the section on "Licensing:Checking/Troubleshooting."

3.2 Formulas

Formulas Used:

Zo, Zdiff and related:

The formulas used for the calculation of Zo and Zdiff, and for the other variables that depend on Zo and Zdiff, are proprietary. They may be described as "successive approximation."

Propagation Time, Co and Lo:

Stripline: The propagation time in any homogeneous stripline configuration is well known to be derived as follows:

Propagation speed is the speed of light divided by the square root of the relative dielectric coefficient. The Propagation time is simply the inverse of the propagation speed:

$$\text{Propagation Time} = (Er)^{.5} / 11.8 \text{ ns/in}$$

The formulas for Co and Lo follow from these two relationships:

$$\begin{aligned} \text{Propagation Time} &= (Co * Lo)^{.5}, \text{ and} \\ Zo &= (Lo / Co)^{.5} \end{aligned}$$

From these we can derive that:

$$Co = \text{Propagation Time} / Zo$$

$$Lo = Co * Zo^2$$

Microstrip: The formula for Propagation Time in microstrip is complicated by the fact that the trace is not in a homogeneous environment. There is a dielectric beneath the trace and (typically) air above it. Brooks has shown that the generally accepted correction factor for this is deficient. The formula for propagation Time in microstrip can be found in:

Brooks, Douglas, Signal Integrity Issues and Printed Circuit Board Design, Prentice Hall, 2003, p. 31, and in

Brooks, Douglas, "Microstrip Propagation Times: Slower Than We Think," available for download at www.mentor.com/pcb/tech_papers.cfm

Then, having solved for Propagation Time, the values for Co and Lo are found as before:

$$Co = \text{Propagation Time} / Zo$$

$$Lo = Co * Zo^2$$

Embedded Microstrip: The technique used for calculating Propagation Time in embedded microstrip is proprietary. Having made the calculation, the calculations for Co and Lo are as above.

Common Mode: Beginning with version 2.01, UCCALC also calculates the common mode impedance. Given the differential impedance, Zdiff, the common mode impedance can be calculated as follows:

Since: $Z_{diff} = 2 * Zo(1-k)$

And $Z_{com} = .5 * Zo(1+k)$

It therefore follows that $Z_{com} = Zo - .25 * Z_{diff}$

3.3 Special Situations

Special Situations:

There are a few special situations that exist with the calculator. These are summarized below:

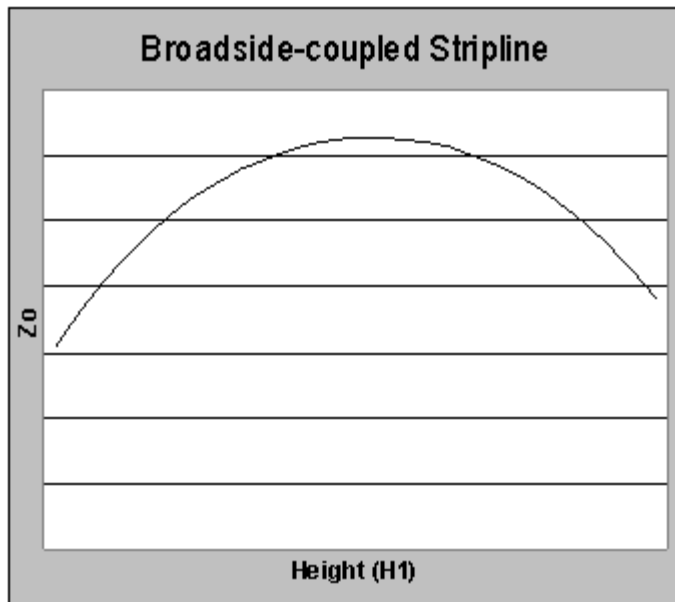
Embedded Microstrip:

The calculator does not solve for H or H1. That is because the two values in embedded microstrip configurations interrelate very strongly together. The solution to either one is VERY sensitive to the value of the other, and disquieting results are obtained we one tries to calculate either. On the other hand, this configuration is very stable with respect to the *ratio* of H1 to H.

Broadside Coupled Stripline:

The calculator does not solve for H1. It turns out, in broadside configurations, given the other variables, there are generally *two* values for H1 that can meet the conditions (that is, if there are any values that do!) See the figure below. The value for H1 that maximizes differential impedance is usually

approximately $.5*H$. Rather than deal with this anomaly, we have simply removed this option. The user can approach a solution using a sequential approximation approach if desired.



3.4 Internal Consistency

Internal Consistency:

We would normally expect a calculational tool to be perfectly consistent. That is, if we set up a problem for the solution, for example, of Z_{diff} , and then use that solution to solve for one of the other variables (S for example) we would expect to get the same value for S we started with. This is usually the case with this calculator.

But it sometimes happens that there is a small difference in the values of some of the other variables when we do this. These differences are explained by one of the following reasons.

1. This calculator (as is the case with most calculators) is subject to round-off errors. Thus, if you solve for Z_{diff} using a set of variables, and then use that value of Z_{diff} to solve for any of the other values, the calculator may be internally rounding the value of Z_{diff} , causing a slight inconsistency.
2. These types of inconsistencies are more prevalent at points where small variations in some variables are related to large variations in other variables. This can happen in some cases where traces are very close to planes or to each other.
3. Z_{diff} is $2 * Z_0 * (1 - \text{some coupling factor})$. If the coupling factor is low, then Z_{diff} is approximately $2 * Z_0$. Under this condition, large changes in the value of some variables cause very small changes in Z_{diff} , and vice-versa. When you are concerned about apparent inconsistencies in the results, always check the value of Z_{diff} to see if it is nearly $2 * Z_0$.

If you solve for Z_{diff} and then see a change when you work backwards and solve for one of the other variables, resolve for Z_{diff} . Chances are very good you will find that Z_{diff} is not very sensitive to that particular variable under this set of conditions.

4 Licensing

4.1 Installation

Installation

The license system files are contained within the ZIP archive UCCALCLic.zip

This file should unzip to a directory containing the following files:

```
UCAD.exe
usbkey.sys
usbkey98.inf
usbkey2k.inf
kl2dll32.dll
Readme.txt
InstallUSB.bat
```

RUN THE INSTALLUSB.bat FILE BEFORE PLUGGING IN THE USB DONGLE FOR THE FIRST TIME. (Note: Do **NOT** run UCAD.exe. This file is called, with the proper switch, from the install batch file.) Microsoft OS's become very confused if you don't do this in the right order!

The Install program will install the correct files based on your operating system.

In case of problem

If the USB key was inserted before running the INSTALL utility the dongle may require user intervention to find the driver each time it is inserted or the dongle may not work correctly. To correct this problem follow these steps:

- 1) Open the device manager
- 2) Remove the dongle
- 3) Delete the following files to force the internal Windows Driver Database to be rebuilt.

Windows 95/98/ME:

```
Windows\inf\drvdata.bin
Windows\inf\drvidx.bin
```

Windows 2000/XP:


```
SystemRoot\inf\usbkey2k.PNF
SystemRoot\inf\oemX.pnf (where X is a system generated number.)
```

To determine which file is the correct inf file, open it and verify line 3 is "Class=USB Dongle"

4.2 Checking/Troubleshooting

Startup:

When the program first starts, it checks for the presence of a dongle. A message is displayed on the opening screen regarding whether the dongle was found or not. The next screen ("Select Configuration") also displays the license status along with an icon (check or crossbar). These icons are displayed on all subsequent screens.

License present  License not detected 

Program Check:

The program checks for the presence of the dongle every time it performs certain operations. Failure to detect the dongle at any time cancels the license for that session (see "unplugging the Dongle, below.")

Checking Status:

The "Select Configuration" screen also has a Menu item labeled "License Administration." That opens a "Dongle License Check" window. Here you can check:

- A. To see if the system recognizes the dongle at that moment
- B. Read the license information programmed into the dongle. (You must check for the presence, first.)
- C. Reset or attach a new dongle (see below)

Unplugging the dongle:

The dongle is designed such that if it is unplugged after the program has started, the system won't recognize it again if it is reinserted back into the computer. In order for the dongle to be recognized again, the dongle system files must be stopped and then restarted. This may or may not be easy to accomplish! *Note: As you become familiar with the dongle, it may emit a sound on your system as it is plugged in and unplugged. There may be a distinctive sound when it is plugged in and recognized.*

1. Press the "Attach New Dongle" button, then unplug and replug in the dongle. Press the "Check Presence" button to see if the dongle is recognized. If not, proceed to step 2.
2. If step 1 does not work, it may be that you have two sessions of the calculator running or that you exited a prior session with the calculator "ungracefully"! Always exit the calculator using the "End" or "End All" command. If you use the "x" at the upper right corner of the window, the window may close but the program may still reside in memory. Then if a second session opens, there may be a conflict with the dongle driver. If a session still resides in memory, it may be closed using the Task Manager (see Windows Help).
3. If for some reason, the dongle is still not recognized, terminate the program and restart it.
4. Finally, as a last resort, it might be necessary to reboot the computer to completely stop the systems files. The dongle should be recognized when the computer reboots.

4.3 Obtaining a License

To obtain a license and a dongle, please:

1. Visit UltraCAD's web site at www.ultracad.com
2. Send an e-mail to diffcalc@ultracad.com
3. Or call us at 425-450-9708 (USA)

5 Specifications

5.1 System Requirements

UltraCAD's Differential Impedance Calculator runs on

Win98/ME/2000/XP

It does NOT run on NT, because the dongle USB system files are not supported by NT
(NT doesn't support USB ports.)

The unlicensed (freeware) portion of the calculator should run successfully on NT.

5.2 Specifications

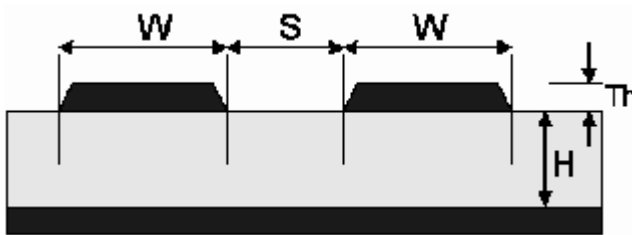
Ranges and Specifications:

(All data in mils unless otherwise specified.)

Common to all configurations:

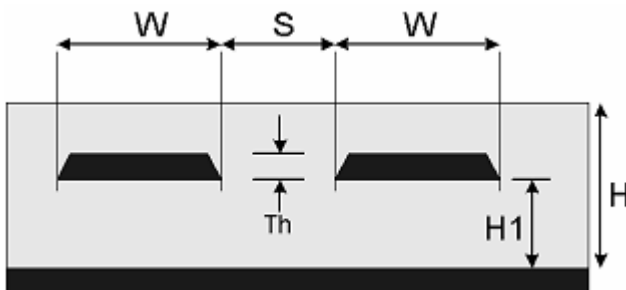
Variable	Data Range	Can solve for?	Requires license? *
Er	- 6		
Th	.5, 1. 2 Oz		
Zo	1	2	
Zdiff	1		
Prop. Delay	1	4	
Co, Lo	1	Note 5	

Microstrip:



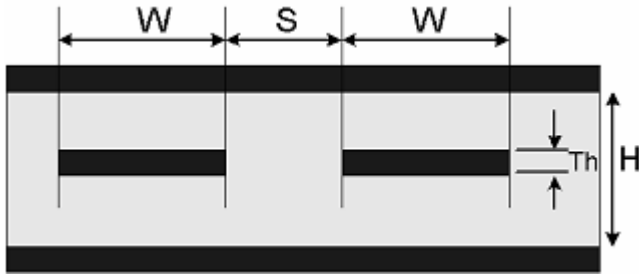
Variable	Range	Solve for?	License?
H	- 32		
W	- 28		
S	- 33	6	

Embedded Microstrip:

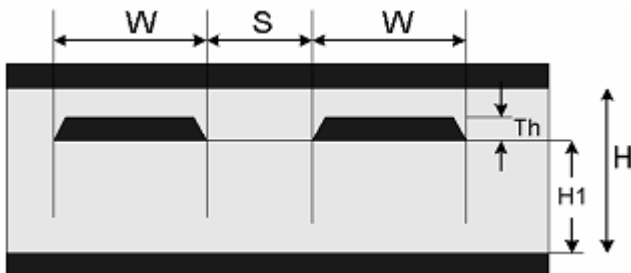


Variable	Range	Can Solve For?	Requires License?
H	- 32		
H1	.2H - H		

W	- 28	
S	- 32	6

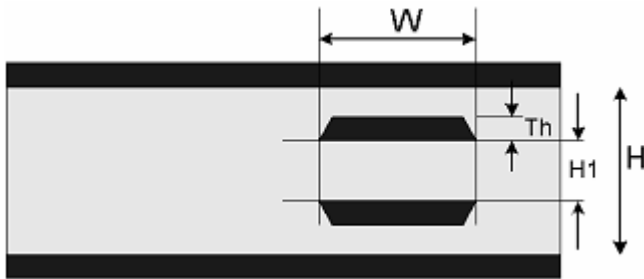
Stripline:

Variable License?	Data Range	Can Solve For?	Requires
H	- 32		
W	- 28		
S	- 33	6	

Edge-Coupled Asymmetric Stripline:

Variable License?	Data Range	Can Solve For?	Requires
H	- 32		
H1	.5H - .95H		
W	- 28		
S	- 32	6	

Broadside Coupled Stripline:



Variable License?	Data Range	Can Solve For?		Requires
H	- 32	3		
H1	.2H - .8H		3, 6	
W	- 28	3		

Notes:

1. Data range is determined by the range of the other variables.
2. Calculations related to Z_o and other single-ended parameters do not require a license. Calculations related to Z_{diff} and other differential impedance parameters do require a license.
3. If there is no license, then Z_o here is the same as Z_o for Edge Coupled Asymmetric Stripline. Use that configuration instead.
4. Propagation times are calculated based on the value of Z_o and other values as necessary for the respective calculations. See the section on formulas for additional information. A license is required for the calculation of propagation time for the embedded microstrip configuration.
5. C_o and L_o are calculated based on the value for Z_o and on the value for the propagation time. See the section on formulas for more details. Calculation of C_o and L_o require a license.
6. These variables do not apply to the single-ended configuration, only to the differential configuration.

5.3 Accuracy

Accuracy:

The accuracy of the results of any impedance calculator, especially a differential impedance calculator, is difficult to specify because it is difficult to obtain "actual" results to compare it to. We approach that question for this calculator from two standpoints.

Comparisons with other tools:

We have compared the results of this calculator with other respected tools currently available. The results compare favorably, generally within a percent or two. We will happily make a copy of the

calculator available to a credible organization for the purposes of evaluating calculational accuracy.

Fabrication Tolerances:

It is generally agreed that the current state-of-the-art allows fabricators to hit within about 5% of a single-ended impedance requirement. It is harder to hit a differential impedance target. We believe the tolerance of this calculator is much tighter than current fabrication techniques can achieve.

6 Version Info

6.1 Version Info

UltraCAD Design, Inc.'s Differential Impedance Calculator

Version 2.01

Written by: Douglas G. Brooks
Copyright 2003 by: Douglas G. Brooks
Distributed under License by
UltraCAD Design, Inc
Bellevue, WA. USA

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6.2 Version History

Version 2.01

If UCCALC was called from a shortcut and the system default directory was not the program directory, the support and Help files were not found. This fix corrected that.
Also, beginning with version 2.01 the program calculates the common mode impedance, Zcommon mode.

Version 2.0

Changed the installation procedure. The most significant impact of this change is that some file locations are changed. All files are now contained within the program folder. None are placed in the c:\ (root) folder.

This also fixed a problem where a very small percentage of users received a message that MSSTDFMT.DLL was not found.

Version 1.1

Corrected a calculation error

Version 1.0

Original release.