

# **UltraCAD Design Inc.**

## **Differential Impedance Transmission Line Calculator UCCALC.exe**

### **Help File and Operator's Manual**

Version 3.11

# 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.

We introduced a newer version of that calculator in 2003 that performed differential impedance calculations. That calculator required a license dongle to operate.

Version 3.0 no longer requires a license dongle, but did require a license file to operate. This simplifies the licensing procedure significantly. See the section on Licensing to learn how to obtain and install a license file.

Version 3.1 added international awareness to data entry --- the decimal separator will be recognized based on the local language and keyboard settings of the computer.

## 2 Installation

### 2.1 System Requirements

UltraCAD's Differential Impedance Calculator runs on

Win98/ME/NT/2000/XP/Vista/Win7

### 2.2 Files and locations

**NOTE: Version 3.0 changes the installation procedure (from prior versions).**

Download UCCALC.zip to a convenient directory and unzip it. We recommend you place the files in a folder named \UCCALC under the system root folder (typically c:\uccalc ) The following 9 files should be found in that directory. The program can be run from that directory.

**UCCALC.exe:**

This is the main program file.

**UCCALC.chm**

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](http://www.ultracad.com). Or, contact UltraCAD at [DiffCalcHelp@ultracad.com](mailto: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.

The following file is **NOT** included in the ZIP file:

### **LICENSE FILE, UCADUCCALC.dat**

If you have purchased a license, the license will be emailed to you in a file named UcadUCCALC.zip. Unzip that file to obtain UcadUCCALC.dat.

This file must be placed in EITHER of these directories.

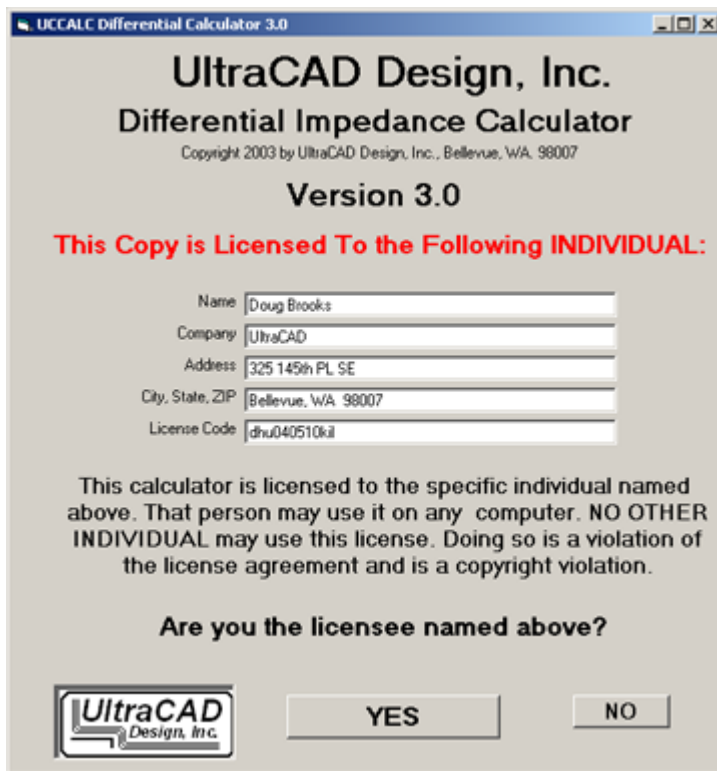
The root directory of your system drive (typically `c:\`) or a `\uccalc\` subfolder under the root directory of your system drive (typically `c:\uccalc\`)

## **3 Operation**

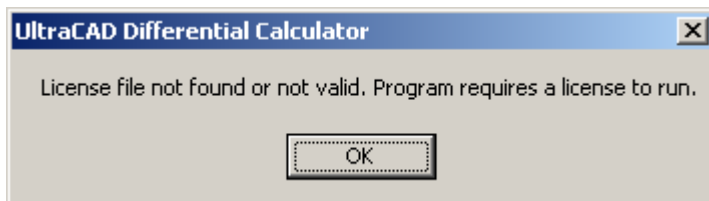
### **3.1 Starting Up**

#### **Starting Up**

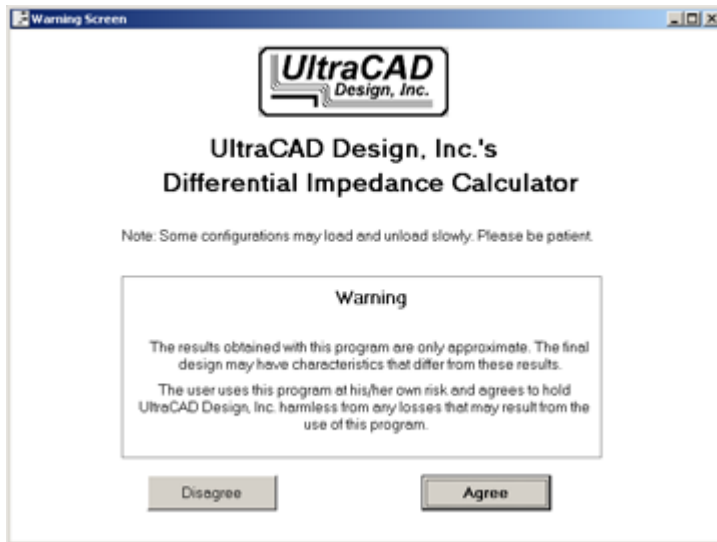
When the program first opens, there can be a delay as it goes through an initialization process. This might take a few seconds on slower computers. Please be patient. When the initialization process is complete, an opening license screen similar to this is displayed:



If the program did not find a license file, The following message is displayed:



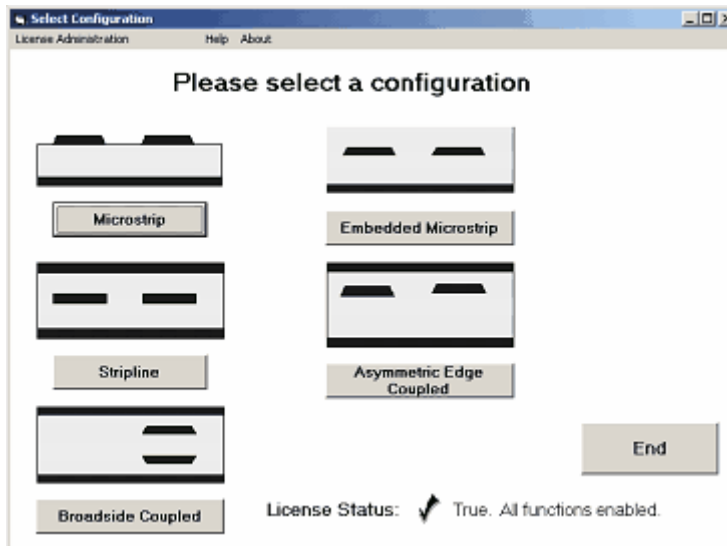
If you answer "Yes" to the opening license screen, the following disclaimer is displayed:



If you select "Agree," the configuration selection screen is displayed.

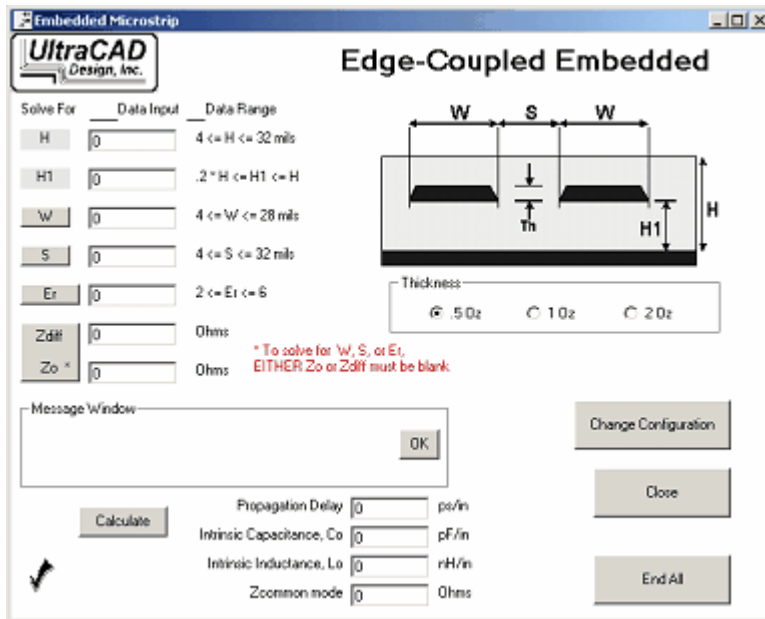
### Configuration Selection Screen:

The next screen contains the configuration alternatives. This screen is always active, and all configurations can be active at the same time. 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

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!)

**Note on International awareness:** Use the decimal separator (period (.) or comma (,)) appropriate for your country and keyboard settings. If the wrong separator is used, the program ignores it. This can lead to a "value too high" message. For example, on a US-English keyboard, a value of 4,3 will be understood to mean 43.

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

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.

## 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:

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

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

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

From these we can derive that:

$$\begin{aligned} \text{Co} &= \text{Propagation Time} / \text{Zo} \\ \text{Lo} &= \text{Co} * \text{Zo}^2 \end{aligned}$$

**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 <http://www.ultracadm.com/mentor/microstrip%20propagation.pdf>

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

$$\begin{aligned} \text{Co} &= \text{Propagation Time} / \text{Zo} \\ \text{Lo} &= \text{Co} * \text{Zo}^2 \end{aligned}$$

**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:

$$\begin{aligned} \text{Since: } Z_{\text{diff}} &= 2 * \text{Zo} (1 - k) \\ \text{And } Z_{\text{com}} &= .5 * \text{Zo} (1 + k) \end{aligned}$$

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

### 3.3 Special Situations

#### Special Situations:

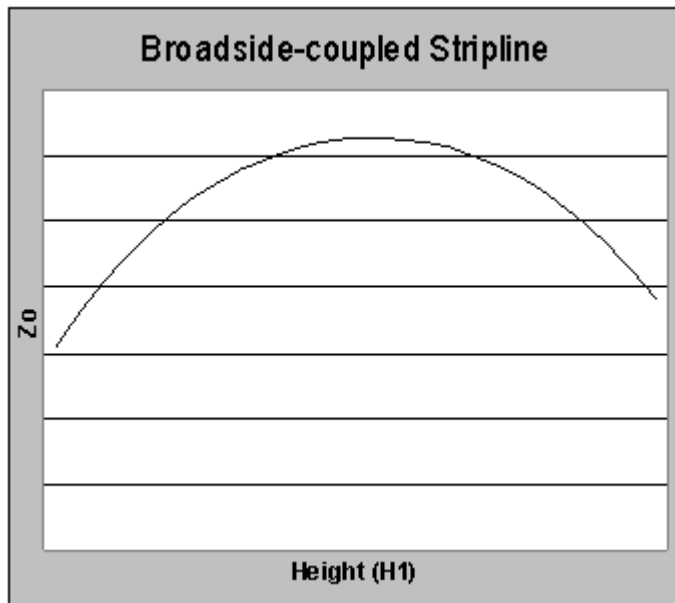
There are a few special situations that exist with the calculator. These are summarized below:

#### 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  $2 * Z_o * (1 - \text{some coupling factor})$ . If the coupling factor is low, then  $Z_{diff}$  is approximately  $2 * Z_o$ . 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  $2 * Z_o$ .

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

Beginning with Version 3.0 of the calculator, the calculator requires only a license file be obtained to operate; the dongle is no longer required.

Go to [http://www.ultracad.com/diff\\_calc\\_licensing.htm](http://www.ultracad.com/diff_calc_licensing.htm) and fill out a license form. Note: The form is not interactive. You must cut-and-paste it or otherwise copy it to an email and send it to [Doug@ultracad.com](mailto:Doug@ultracad.com). Click on the Paypal logo to make the payment for the license (or you may send a check to UltraCAD).

The license will be emailed to you in a file named `UcadUCCALC.zip`. Unzip that file to obtain `UcadUCCALC.dat`.

This file must be placed in EITHER of these directories.

The root directory of your system drive (typically c:\ ) or  
a \uccalc\ subfolder under the root directory of your system drive (typically c:\uccalc\)

Note: The program is not backward compatible. That is, versions 2.2 and before require a license dongle. Versions 3.0 and later require a license file. Versions 2.2 and before will not work with a license file, and versions 3.0 and later will not work with a license dongle.

## **5 Specifications**

### **5.1 System Requirements**

UltraCAD's Differential Impedance Calculator version 3.1 runs on  
Win98/ME/NT/2000/XP/Vista/Win7, either the 32 or 64 bit versions.

## 5.2 Specifications

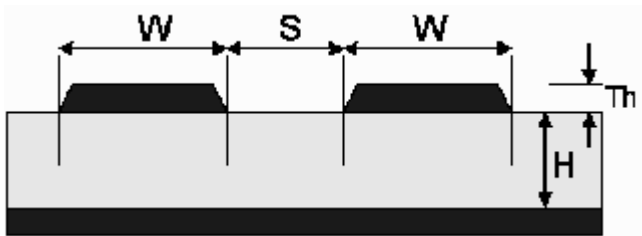
### Ranges and Specifications:

(All data in mils unless otherwise specified.)

#### Common to all configurations:

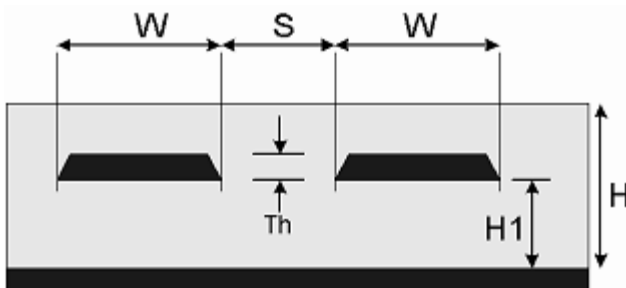
Variable	Data Range	Can solve for?	Requires license? *
Er	2-6	Y	Y
Th	.5, 1.0, 2.0	N	
Zo	1	Y	Y
Zdiff	1	Y	Y
Prop Delay	1	Y	N
Co, Lo	1	Y	Y

#### Microstrip:



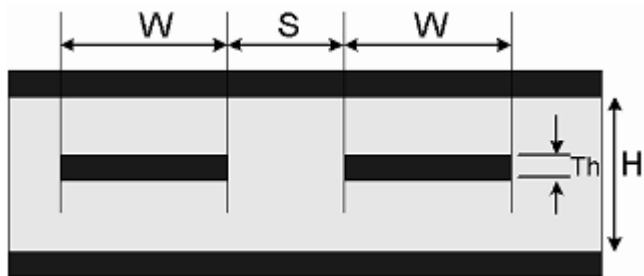
Variable	Range	Can Solve for?	Requires License?
H	4-32	Y	Y
W	4-28	Y	Y
S	3-33	Y,2	Y

#### Embedded Microstrip:



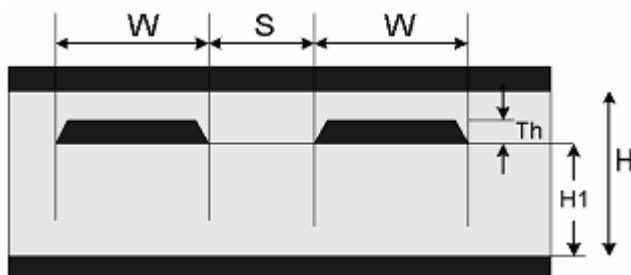
Variable	Range	Can Solve For?	Requires License?
H	4-32	N	
H1	.2H - H	N	
W	4-28	Y	Y
S	4-32	Y,2	Y

### Stripline:



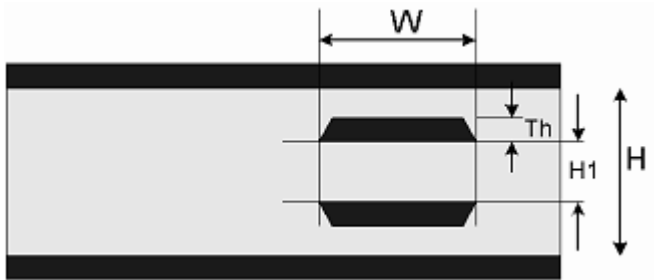
Variable	Range	Can Solve For?	Requires License?
H	4-32	Y	Y
W	4-28	Y	Y
S	3-323	Y,2	Y

### Edge-Coupled Asymmetric Stripline:



Variable	Range	Can Solve For?	Requires License?
H	8-32	Y	Y
H1	.5H - .95H	Y	Y
W	4-28	Y	Y
S	4-28	Y,2	Y

### Broadside Coupled Stripline:



Variable	Range	Can Solve For?	Requires License?
H	4-32	Y	Y
H1	.2H - .8H	Y,2	Y
W	4-28	Y	Y

#### Notes:

1. Data range is determined by the range of the other variables.
2. 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.

### 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 3.11

Written by: Douglas G. Brooks

Copyright 2003-2010 by: Douglas G. Brooks

Distributed under License by

UltraCAD Design, Inc

Bellevue, WA. USA

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### 6.2 Version History

Version 3.11

Added International language awareness for decimal separators. Also corrected some calculational errors.

\*\*\*\*\*

Version 3.0

Changed the program to work with a license file instead of a license dongle. This eliminated the freeware option of the calculator.

\*\*\*\*\*

Version 2.2

Changed the USB installation files to work with Vista.

\*\*\*\*\*

Version 2.1

In some cases the program required a valid entry for trace separation, s, for single-ended calculations even though those calculations did not depend on s. Fixed in this version.

\*\*\*\*\*

Version 2.03

Changed the color scheme. Some forms were distorted by some of the less common desktop color schemes.

\*\*\*\*\*

Version 2.01, 2.02

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.