UltraCAD Design, Inc. PCB Trace Calculator v. 4.2

This manual covers the major operating features of version 4.0. This is the latest version of UltraCAD's popular PCB Trace Calculator. Version 4.0 is updated from version 3.3 in two very important ways:

1. The calculations for trace currents/temperatures result in values much closer to the IPC 2152 values;
2. The fusing temperature calculations now offer results for "real world" traces, besides just the Onderdonk calculated values.

This calculator is heavily based on two papers available on the UltraCAD website [1], [2]. We highly recommend you read these two papers for a much better understanding of the capabilities and limitations of the calculator.

Licensing:

The calculator requires a license file to operate. A license file can be obtained from this site: http://www.ultracad.com/ucadpcblic.htm. Version 4 is a free upgrade for current licensees of versions 3.x.

Place the license file (ucadpcb3.dat or ucadpcb4.dat) in one of three places:
1. The root directory of the system drive (probably in c:\), or
2. In a specially prepared folder under the root folder named \ucadpcb (probably c:\ucadpcb\)
3. The same folder as the executable.

If you have an UltraCAD Universal license, place the executable in the same folder as the old executable.

System Requirements:

The program is written in Visual Basic version 6.0. It will run under any version of Windows starting with NT. You may or may not have the support files required for the program to run already installed in your system:
　　The Visual Basic Run Time Library
　　The Visual Basic controls mscomctl.ocx and msflxgrd.ocx

If you do not already have these files, an error message will display when you start the program. Included in your download package (ucadpcb4.0.zip) are the two controls and a run-time file named vbrun60sp4.exe. (These files are also available at http://www.ultracad.com/calc.htm if you have misplaced them.) If necessary, execute vbrun60sp4.exe and copy the control files to the \Windows\system32 folder.

　* 　**Special note for users of 64 bit systems:**

 Windows x64 (at least some systems) apparently protects itself from additions to the System32 folder. In such cases, do this:

1. Place the DLL or OCX file in a convenient folder (it will probably have to stay there)
    (I will use msstdfmt.dll in the root folder, c:\, as an example.)
2. Open the Command Prompt as Administrator (it is in the Accessories folder.)
      (Right-click and select Run as Administrator.)
3. Navigate to C:\Windows\System32 directory (assuming Windows is installed on the C drive.)
4. Enter regsvr32.exe c:\msstdfmt.dll and hit return (Don't overlook the space.)
      (Be sure to enter the complete path to the DLL or OCX file)
5. You should get a message that the control has been registered.

You may have to do this for two or three dlls/controls, depending on which calculators you have.
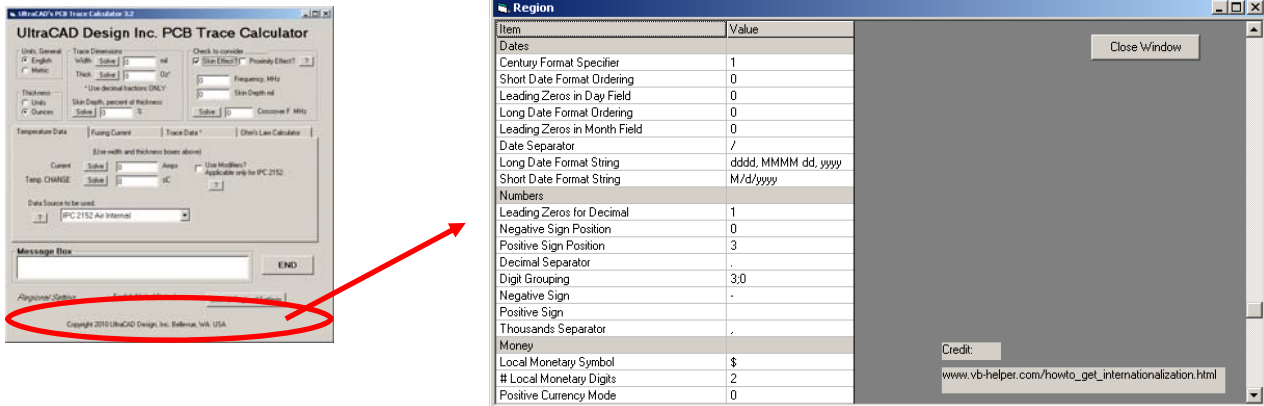
Starting the Program:

When you first start the program, the information included in the license file will be displayed. If the license is not found, an error message will say so. Following that a disclaimer screen will open. You must agree to the disclaimer to operate the program.
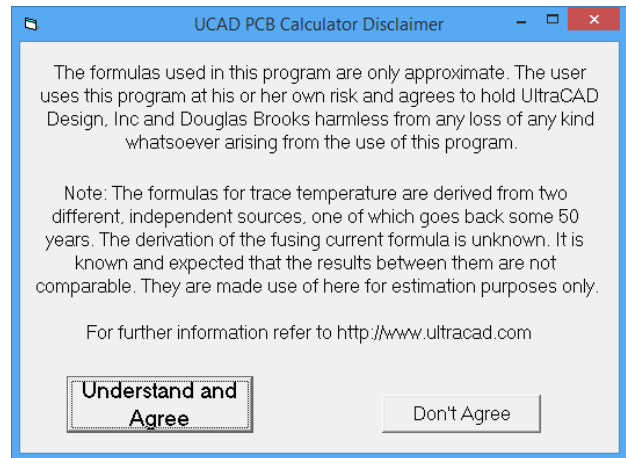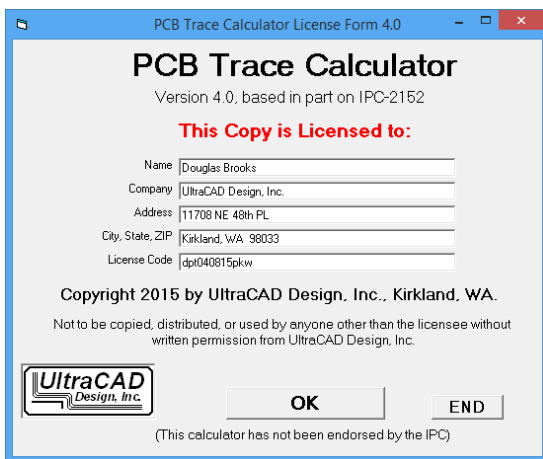
After you agree to the disclaimer, the main program window opens:
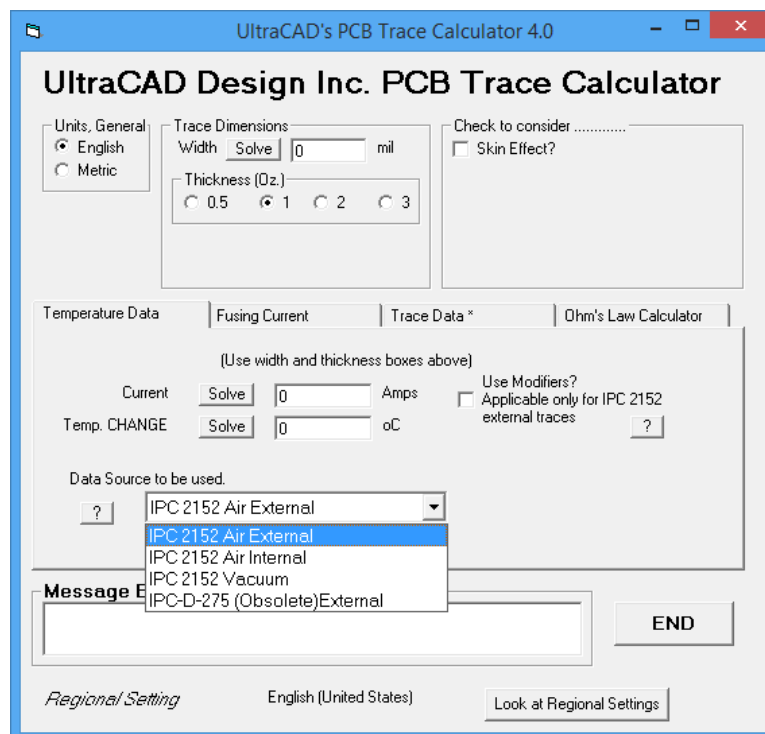
Regional Settings:

The program is "region aware." That means it should understand, and automatically adjust for (among other things), the local conventions for the decimal and thousands separators. The local regional setting for your computer is shown near the bottom of the window, and clicking on the "Look at Regional Settings" command button will open another window showing all of the settings in effect for your region.

Skin Effect Settings:

The calculator can compensate for high-frequency skin effect. For example, suppose we enter a frequency of 30 MHz and a trace thickness of 1 Oz into the calculator. The skin depth for a 30 MHz signal is .4747 mils. As long as the skin depth is deeper than 1/2 the trace thickness, the skin effect will not limit the current. If the skin depth is shallower than 1/2 the trace thickness, it will begin to impact the current flow. For a 1 Oz. trace, the thickness is about 1.35 mils (and 1/2 the thickness is about .675 mils). Therefore, in this example the skin effect is limiting the current flow. The calculator shows that the skin effect is extending into each half of the trace thickness by 70.3% (.4747 mils is 70.3% of 1/2 the 1.35 mil trace thickness.) We can also see that the cross-over frequency for a 1 Oz trace (where the frequency just begins to impact the trace current) is 14.8 MHz.
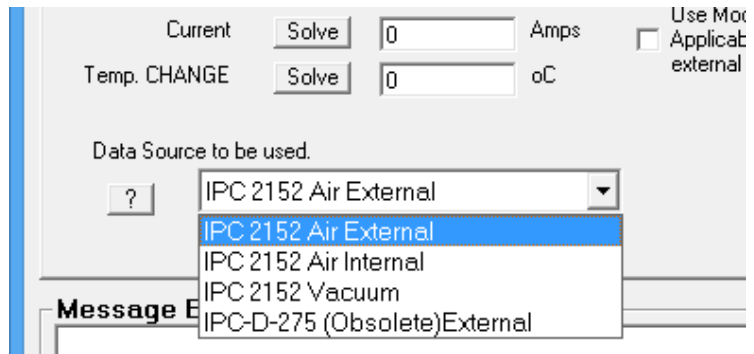

For more information on skin effect, see [3].

Temperature Data Calculations:

First, select the data source you would like to use. The four sources are

IPC 2152 Air External trace
IPC 2152 Air Internal trace
ICP 2152 (external traces in a) Vacuum
IPC-D-275 Older standard, now obsolete

Notes:

1. The new standard, perhaps surprisingly, states that internal traces cool *better* (more efficiently) than do external traces. This is because the thermal conductivity of the board material is better than that of air.
2. There is no difference between External and Internal for Vacuum.
3. For more information on how formulas are derived see [1].
4. Prior versions of the calculator used to provide an option for data from an article that appeared in Design News in 1968. We have determined that that data was unreliable and we no longer offer that option.

You must select a trace thickness in ounces. Then enter any two of the remaining three variables, Trace Width, Trace Current, and the Change in Trace Temperature (above 20 ^{o}C ambient) and solve for the third. You can use either English or metric units. In the illustration shown, for external traces, the increase in temperature for a 100 mil wide trace carrying 10 Amps is 79.9 ^{o}C.
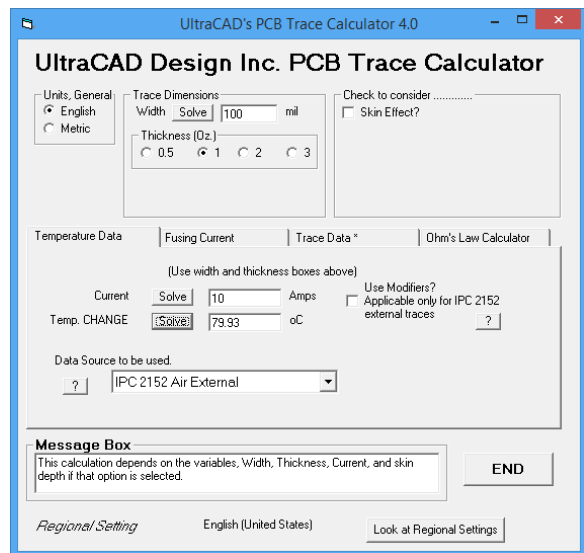
But, if we want to consider the impact of skin effect for a 30 MHz signal, check the "Skin Effect?" box. The skin effect would reduce the effective cross-sectional area of the trace. Therefore, the temperature would increase to the value shown, 113.7 ^{o}C. A message highlights the fact that the skin effect is impacting the calculated result.

If we now entered a maximum desired temperature increase of only 60 degrees into the "Temp CHANGE" window, and solved for a new width, the result would be over 174 mils.
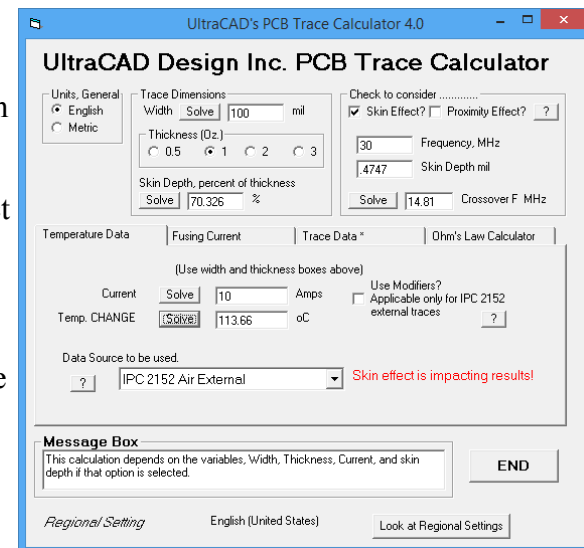
Calculation Modifiers:

These modifiers are courtesy of Jack Olson [4].The Appendix in IPC 2152 [5] includes some very brief guidelines on how to adjust the results from the curves for specific special conditions. The most important of these, by far, is the proximity to an adjacent plane (Section A.4.6). Also important is board thickness (Section A.4.2). The calculator offers a method for incorporating very rough estimates of these effects by checking the "Use Modifiers?" check box.

(Note: The results obtained, while useful, are very approximate and should be used with caution.)

Using the results from the previous page, (without frequency effects) suppose we checked the "Use Modifiers?" checkbox. The window on the right would open. We calculated, on the previous page, that a trace width of 100 mils of 1 Oz copper carrying 10 Amps would result in a temperature rise of 79.9 ^oC.

Suppose now we consider that that trace is 20 mils above a 2 Oz plane, that the plane has an area larger than 25 in^2, and that the board is 65 mils thick. If we enter this information in the appropriate places in the window, we calculate that the ***actual*** (modified) temperature rise will be only 29.6 ^oC (Column A). This shows the impact of the plane (primarily) as well as the other factors.

But suppose we can tolerate a temperature change of 25 ^oC, and so we want to calculate the increased width that the modified results will require. Enter 25 ^oC in the top box of Column B (and click the "TOTAL Factor" button.) The new modified temperature is 67.5 ^oC. If we enter this temperature back into the calculator and then solve for the width, we obtain a width of 115.8 mils. (If we then repeat the process of checking the "Use Modifiers" box, entering the same data as before, we will find that the adjusted temperature is 24.98 degrees, very close to the target.)

The buttons on the bottom row will enter the temperature data immediately above them into the "Temp. CHANGE" box in the main calculator. This is just for convenience.

Fusing Current Calculations:

Occasionally there are designs where a catastrophic failure can occur that can result in personal injury or property damage. In such cases it might be necessary for a trace to carry a very large amount of current for a very short time, perhaps until an emergency shutdown procedure can be carried out. So there may be a requirement, for example, for a trace to carry 20 Amps for 1.0 seconds, and then it doesn't matter if the trace fails (fuses) or not.

There is an important distinction between trace fusing current and a normal fuse. A fuse protects against a predictable overload and is replaceable. A fused trace results from a catastrophic event and is not replaceable. A fused trace results in a failed board which must be replaced in its entirety.

There are very few sources to work from in this area. Two individuals, W. H. Preece and I. M. Onderdonk, have published fusing current equations. They are repeated and summarized in [2]. This section of the calculator is based on Onderdonk's equations.

Assume for example, we have a 1.0 Oz trace that must carry 25 Amps for 1.0 second. The question is, how wide must it be? Using part A, Onderdonk's equation, the calculator says 98.5 mils. These calculations can/will be modified by frequency if the Skin Effect check box is checked.

Onderdonk's equation is completely different from the IPC values. And, as shown in [1], the IPC values tend to be "worst case" values. Reference [2] provides a method for estimating real-world results from Onderdonk's equation. Press the "Adjust Current" button and we see that in a real-world case for this trace, the trace is likely able to carry a minimum of 53.5 Amps for 1.0 second.

Unfortunately, it is not practical to work backwards from here. If you would like to find the minimum trace size for a 25 Amp current and 1.0 second of time, repeat the process outlined here with progressively smaller trace widths until you find a combination that results in an "Adjusted Current" of 25 Amps.

Other Features:

The remaining features of the calculator are pretty straightforward.

The **Trace Data** window will calculate the trace resistance (Ohms/in or Ohms/cm) for a trace of the given thickness, width, and temperature (operating and/or ambient —- assumed to be 20° C). It will also provide the frequency adjusted values if the Skin Effect checkbox is checked.

Effective with version 3.3 the user can now enter negative operating temperatures (in degrees C). The calculation will be approximately correct until the resistance of the conductor gets to almost zero. At this point the conductor can become superconductive (at approximately $-245\ ^oC$, depending on what assumptions are made.) The calculator is not intended to calculate the point of superconductivity. If the calculated resistance becomes negative the calculator will continue to show zero resistance.

The **Ohm's Law Calculator** provides a basic calculational capability between various trace aspects of resistance/unit length, trace length, current and voltage drop (along the trace.) The values in this section do not carry over from prior sections. They must be entered or pasted manually. The results here are NOT adjusted for skin effect.

References:

1. Brooks, Douglas and Adam, Johannes, "Trace Currents and Temperatures Revisited" available in the articles section at www.ultracad.com.
2. Brooks, Douglas and Adam, Johannes, "Fusing Currents in Traces," www.ultracad.com.
3. Brooks, Douglas, "Skin Effect," www.ultracad.com
4. Olson, Jack, "Determining Circuit Board Current Carrying Capacity," www.frontdoor.biz/PCBportal/HowTo2152.pdf
5. IPC-2152, "Standard for Determining Current Carrying Capacity in Printed Board Design," August, 2009, www.ipc.org