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**Si8000 Controlled Impedance Field Solver**

# **User Guide**

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MAN 193-0308



## Si8000 User Guide

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## Personal Computer Requirements

Computer	IBM PC AT or compatible
Processor	Pentium 500 (1GHz or better recommended)
Operating system	Microsoft Windows 95, Windows 98 Microsoft Windows NT, Windows 2000/XP
System memory required	128MB recommended
Hard disk space required	100MB (min.)
Video standard	SVGA (1024 x 768 min.)
CDROM drive	
Mouse	Microsoft compatible
Software key port	Parallel port/USB port
Spreadsheet	Microsoft Excel 2000 or later

## Guide To The Manual

Introduction	Introduces the Polar Instruments Si8000.
Introduction to controlled impedance PCBs	Brief discussion of the requirement for controlled impedance, impedance matching and calculation methods.
Transmission line structures	Brief discussion of the PCB structures used for controlled impedance.
Installation/set up	Hardware and software requirements and instructions for installing and uninstalling the software.
Using the Si8000 Quick Solver	Using the Si8000 Quick Solver for single impedance, propagation delay, inductance and capacitance calculations.
Using the Si8000 functions	Learning the Si8000 functions using the supplied sample Si8000 workbook. Using the Si8000 functions in your own applications in Si8000 expert mode.

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# Introduction to the Si8000

## The Si8000 Controlled Impedance Field Solver

The Polar Si8000 Controlled Impedance Field Solver uses advanced field solving methods to calculate PCB trace impedance for most single-ended and differential circuit designs. Based on boundary element analysis, the Field Solver is able to provide rapid modelling for a wide range of microstrip, stripline and coplanar structures.

### Multiple dielectric builds

The Si8000 features advanced modelling to predict the finished impedance of multiple dielectric PCB builds and also takes into account the local variations in dielectric constant on close spaced differential structures (e.g. areas of high resin concentration between differential pairs).

### Surface coating modelling

The Si8000 models the resist thickness adjacent to, above and between surface traces. This offers an elegant solution to modelling surface coating which can be tailored to the particular resist application method in use. The new Si8000 also extracts even and common mode impedance. It is becoming increasingly necessary to control these characteristics on high speed systems such as USB2.0 and LVDS.

The Si8000 comprises the Quick Solver for single impedance and parameter calculations and a comprehensive set of advanced field solving

methods incorporated as user-defined functions in the popular Microsoft Excel spreadsheet format.

### **Si8000 Quick Solver**

The Quick Solver provides for rapid calculation of single PCB trace impedance values against significant PCB parameters (e.g. trace height and thickness, dielectric constant, etc.) Given a target impedance the Si8000 allows the user to calculate circuit parameter values to achieve the desired impedance. For situations with structure dimensional constraints, the Field Solver Tolerance fields allow the designer and board fabricator easily to calculate the effects of variations in supplier material dimensions.

### **Si8000 spreadsheet functions**

The Si8000 functions included in Excel format enable advanced functions, e.g. sensitivity analysis, graphing the effects of a range of parameter value changes. The Si8000 supports single or multiple dielectric builds in a comprehensive range of trace and dielectric configurations. The Si8000 provides models for structures with dielectric layers above and below traces, soldermask modelling and includes compensation for resin rich areas between traces.

### **Evaluating PCB structure behaviour**

The Polar Si8000 runs within the Microsoft Windows environment. The Field Solver uses the familiar Microsoft Excel for Windows interface for easy graphing and data sharing. Using Excel's powerful Autofill and Chart Wizard features, the Si8000 can rapidly chart  $Z_0$  against a varying parameter, providing easy comparison and evaluation of the behaviour of most popular controlled impedance structures.

# Introduction to Controlled Impedance PCBs

## Controlled impedance

The increase in processor clock speed and component switching speed on modern PCBs means that the interconnecting paths between components (i.e. PCB tracks) can no longer be regarded as simple conductors.

At fast switching speeds or high frequencies (i.e. for digital edge speeds faster than 1ns or analog frequencies greater than 300MHz) PCB tracks must be treated as *transmission lines*; i.e. for stable and predictable high speed operation the electrical characteristics of PCB traces and the dielectric of the PCB must be controlled.

One critical parameter is the *characteristic impedance* of the PCB track (the ratio of voltage to current of a wave moving down the signal transmission line); this will be a function of the physical dimensions of the track (e.g. track width and thickness) and the dielectric constant of the PCB substrate material and dielectric thickness. The impedance of a PCB track will be determined by its inductive and capacitive reactance, resistance and conductance. PCB impedances will typically range from 25Ω to 120Ω.

In practice a PCB transmission line typically consists of a line conductor trace, one or more reference planes and a dielectric material. The transmission line, i.e. the trace and planes, form the *controlled impedance*.

The PCB will frequently be multi-layer in fabrication and the controlled impedance can be constructed in several ways. However, whichever method is used the value of the impedance will be determined by its physical construction and electrical characteristics of the dielectric material:

- The width and thickness of the signal trace

- The height of the core or pre-preg material either side of the trace

- The configuration of trace and planes

- The dielectric constant of the core and pre-preg material

## Impedance matching

Components themselves exhibit characteristic impedance so the impedance of the PCB tracks must be chosen to match the characteristic impedance of the logic family in use.

If the impedance of the PCB tracks does not match the device characteristic impedance multiple reflections will occur on the line before the device can settle. This can result in increased switching times or random errors in high-speed digital systems. The value and tolerance of impedance will be specified by the circuit design engineer and the PCB designer, however, it will be left to the PCB manufacturer to conform to the designer's specification and verify the finished boards meet the specification.

## Calculation methods

The Si8000 incorporates field solving for single-ended and differential impedance structures. The discrete numerical analysis in the Si8000 uses the Boundary Element Method to evaluate the

residual field. A piecewise linear approximation is used with a weighted sub-division of the perimeter of the trace cross-section to predict the surface charge distribution on the trace. Knowing the boundary voltage conditions and the charge distribution allows the Boundary Element Method to predict the capacitance of the structure. This in turn allows the impedance of the structure to be calculated.

# Transmission Line Structures

## Microstrip and Stripline Transmission Lines

Controlled impedance PCBs are usually produced using *microstrip and/or stripline transmission lines* in single-ended (unbalanced) or differential (balanced) configurations.

A micro strip line consists of controlled width conductive traces on a low-loss dielectric (in practice the dielectric may be constructed from a single dielectric or multiple dielectric layers) mounted on a conducting ground plane. The dielectric is usually made of glass-reinforced epoxy such as FR-4. For very high frequencies PTFE may be used. Other reinforcement/resin systems are also available.

For close spaced differences on woven glass reinforced dielectrics, refer to application note AP139 on the Polar Instruments web site, [www.polarinstruments.com](http://www.polarinstruments.com)

There are several configurations of PCB transmission line:

- Exposed, or surface, microstrip
- Coated microstrip (coating usually solder mask)
- Buried, or embedded, microstrip
- Centred stripline
- Dual (offset) stripline
- Coplanar strips and waveguides

The structures above can be constructed with single or multiple dielectrics.



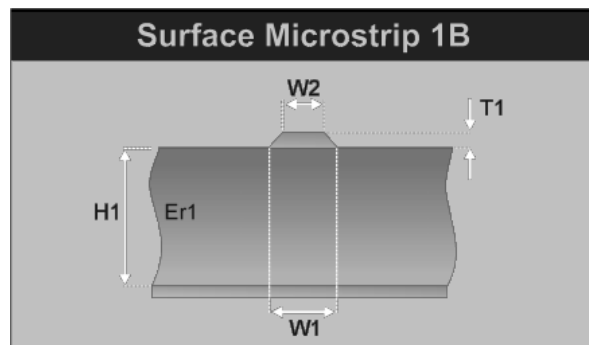
## Single-ended Transmission Lines

Single-ended transmission lines are the commonest way to connect two devices (i.e. a single conductor connects the source of a device to the load of another device). The reference (ground) plane provides the return path.

*Note that in the diagrams the trace is trapezoidal in profile and width,  $W$ , refers to the trace width nearest the upper surface,  $W_1$  refers to the trace width nearest the lower surface.*

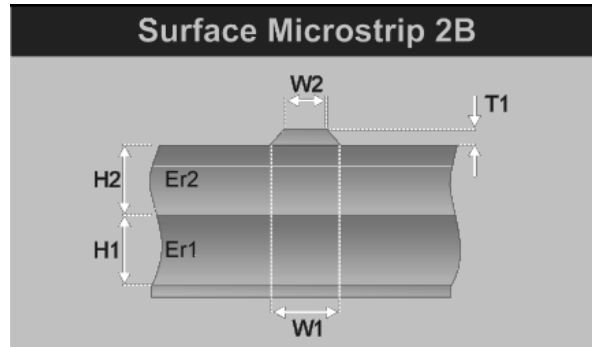
### Surface Microstrip

In the diagram below (*surface*, or *exposed*, microstrip) the signal line is exposed (to air) and referenced to a power or ground plane. In the Si8000 structures are categorised according to the arrangement of the dielectric with respect to the trace (below or above the trace). The diagram below shows the surface microstrip structure using a single dielectric layer below the signal trace (designated 1B)



Surface microstrip with single dielectric below the trace

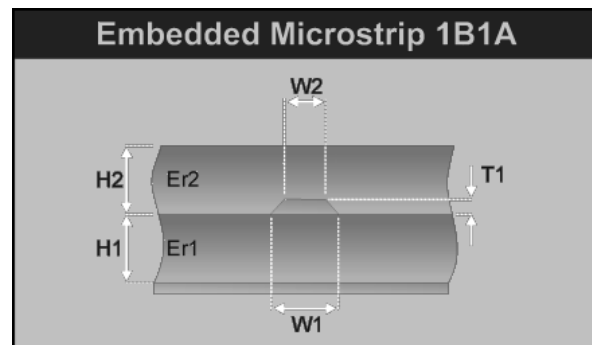
The diagram below shows the surface microstrip structure using two dielectric layers below the trace (designated 2B).



Surface microstrip with two dielectric layers below the trace

### *Embedded Microstrip*

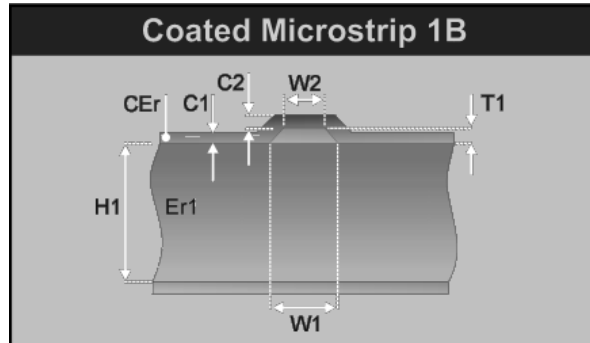
Embedded, or buried, microstrip is similar to the surface version, however the signal line is embedded between two dielectrics and located a known distance from the reference plane.



Embedded microstrip with two dielectric layers, one below and one above the trace

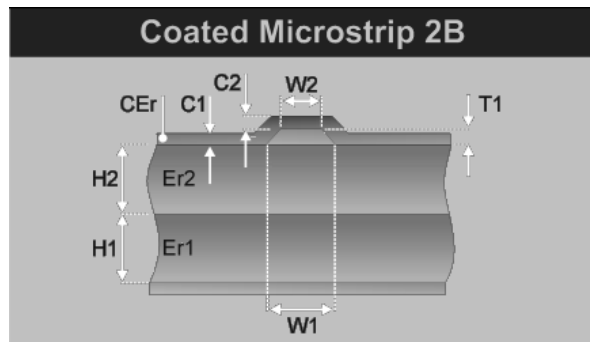
In this structure the two dielectrics are arranged one below and one above the trace (designated 1B1A). Embedding the signal line can lower the impedance by as much as 20% compared to an equivalent surface microstrip construction.

#### Coated Microstrip



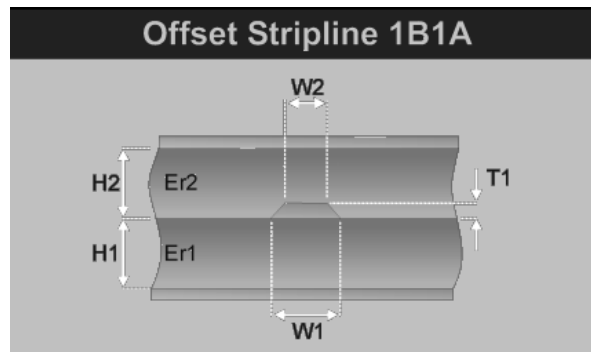
Coated microstrip with single dielectric below the trace

Coated microstrip is similar to the surface version, however the signal line is covered by a solder mask. This coating can lower the impedance by up to a few ohms depending on the type and thickness of the solder mask.



Coated microstrip with two dielectrics below the trace

### Offset Stripline



In this configuration the signal trace is sandwiched between two planes and may or may not be equally spaced between the two planes. This construction is often referred to as Dual Stripline.

A second mirror trace will be positioned  $H_1$  from the top ground plane. These two signal layers will be routed orthogonally (crossing at right angles so as to minimise the crossing area).

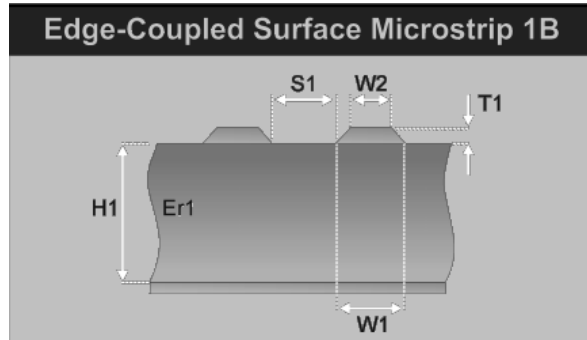
## Differential Transmission Lines

The differential configuration (often referred to as a *balanced line*) is used when better noise immunity and improved timing are required. In differential mode the signal and its logical complement are applied to the load.

The balanced line thus has *two* signal conductors and an associated reference plane or planes as in the equivalent single-ended (unbalanced) case. Fields generated in the balanced line will tend to cancel each other, so EMI and RFI will be lower than with the unbalanced line. External noise will be "common-moded out" as it will be equally sensed by both signal lines.

Note that in the following diagrams (except the Broadside-coupled Stripline) the traces are trapezoidal in profile and width,  $W$ , refers to the trace width nearest the upper surface,  $W_1$  refers to the trace width nearest the lower surface.

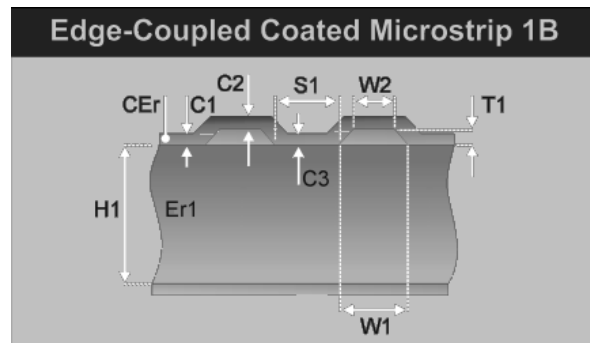
#### Edge-coupled Surface Microstrip



Edge-coupled surface microstrip with single dielectric below the trace

In this construction the gap between the traces,  $S_1$ , defines the coupling factor and hence the differential impedance. The etch factor, plating density and undercut will make this construction simple to manufacture, but with a wider tolerance due to the extra processing required on external layers.

### Edge-coupled Coated Microstrip

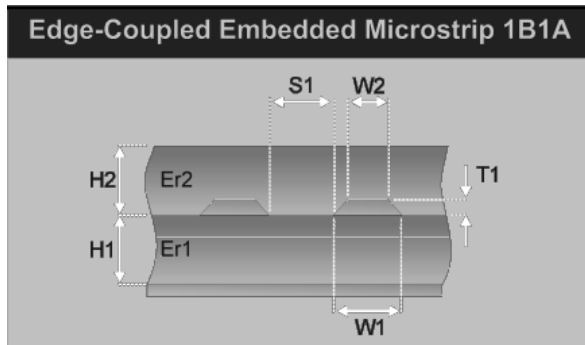


Edge-coupled coated microstrip with single dielectric below the trace

As in the case of the Surface Microstrip this construction is simple to fabricate, but the extra process of adding solder mask coating can cause impedance variations. The Si8000 enables the operator to specify the thickness of the coating outside, above and between the traces to allow for variations in the board fabricating process.

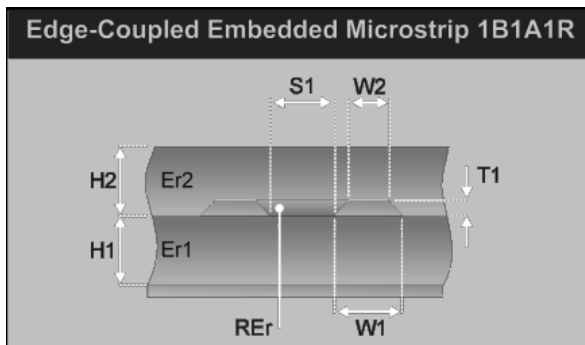
This construction is particularly sensitive to solder mask flooding with LPI (Liquid Photo Imagable) solder mask. This causes the dielectric constant in the edge coupling region to vary, depending on flood depth.

### Edge-coupled Embedded Microstrip



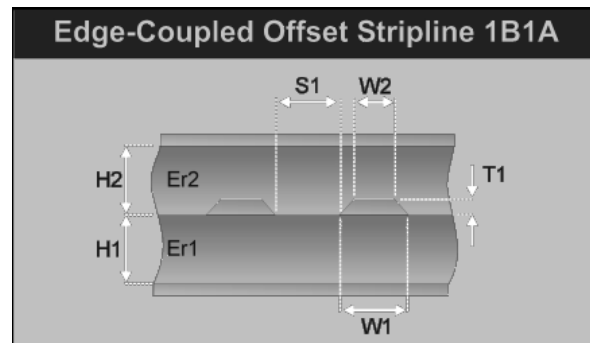
Edge-coupled embedded microstrip with one dielectric below and one above the traces

The reduced processing of internal layers makes the Edge-coupled Embedded Microstrip construction easy to fabricate with more consistent results than the equivalent surface trace structure. During the manufacturing process resin will be forced in between the traces resulting in a resin-rich region (shown as  $R_{Er}$  in the 1B1A1R model below) between the two traces. This region will result in a dielectric with  $Er$  different from the rest of the structure.



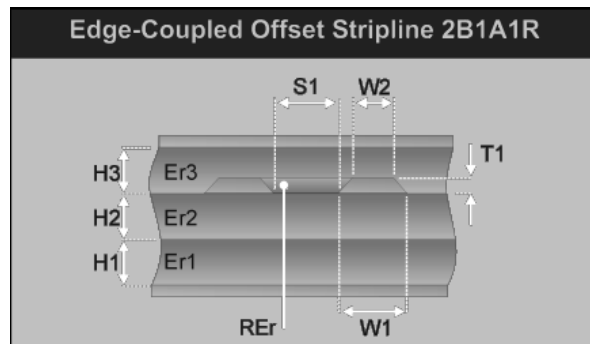
Edge-coupled embedded microstrip with resin-rich region between the traces

### Edge-coupled Offset Stripline



Edge-coupled offset stripline with one dielectric below and one above the traces

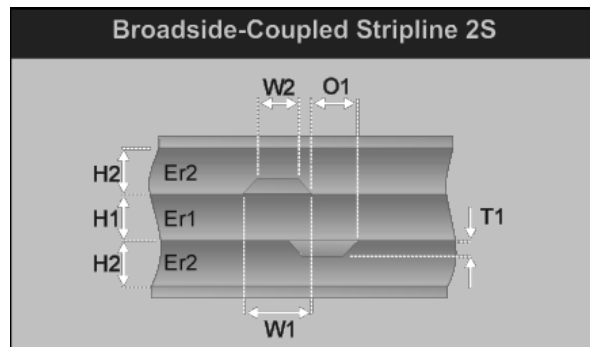
As in the case of the single-ended Offset Stripline construction this structure can be made up as a dual construction with a mirrored edge-coupled differential pair set a distance  $H_1$  from the upper reference plane. The lower pair is routed orthogonal to the upper to minimise layer to layer coupling and cross-talk. The model below shows a structure with two layers below the traces and one above and includes the resin rich region between the traces



Edge-coupled offset stripline structure modelling the resin-rich region between the traces



### Broadside-coupled Stripline

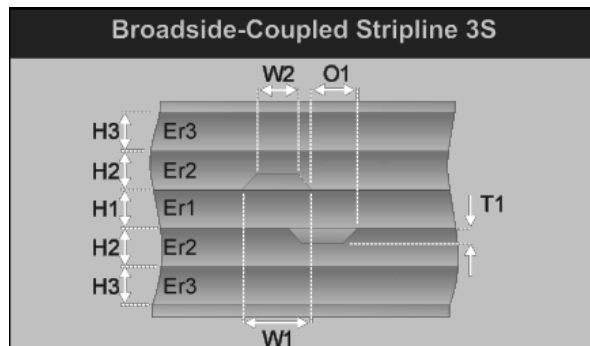


Broadside-coupled offset stripline with two substrate dielectrics, H1 and H2

This apparently simple construction is actually one of the most difficult to fabricate to produce consistent impedance results.

Despite having internal layers with minimal processing, the most common structure is that with both traces overlaid for maximum coupling.

Inner-layer mis-registration and slight offsets and differences in etching combine to make this more difficult to achieve consistent results, particularly if the traces are fine-line.



Broadside-coupled offset stripline with three substrate dielectrics, H1, H2 and H3

The Si8000 broadside-coupled model assumes symmetry of dielectric in the two H2 and H3 layers — the two layers will normally be fabricated from the same material, i.e. with the same dielectric constant.

*Note that in the Broadside-coupled Stripline case the traces are trapezoidal in profile and width,  $W$ , refers to the trace width nearest the surfaces,  $W_1$  refers to the trace width nearest the center.*

## Coplanar Lines

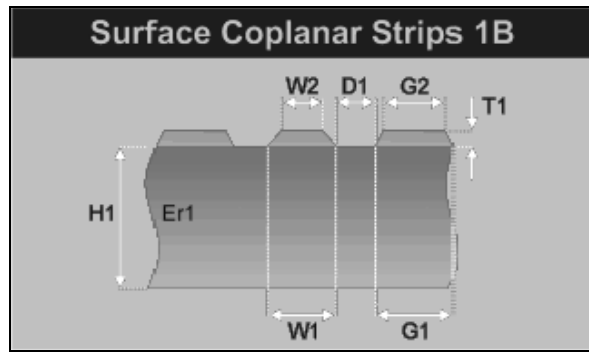
Most Microstrip and Stripline transmission line structures can be manufactured in a Coplanar version.

Coplanar structures have the advantage of single-sided construction with the signal line and ground on the same plane. Components can be grounded on the same plane as the signal line; this means the coplanar configuration is ideally suited for surface mounted devices.

In addition, the coplanar configuration shows only minor dispersion effects compared to microstrip lines.

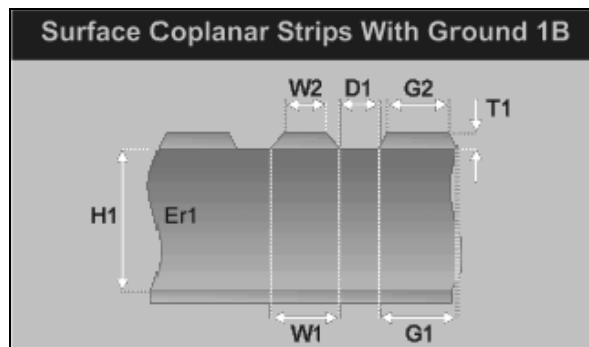
Coplanar Lines incorporate ground conductors adjacent to the controlled impedance trace(s) in the same plane as the trace(s).

### Surface Coplanar Strips



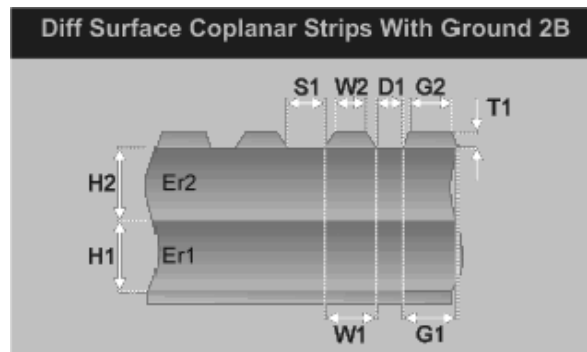
### Surface Coplanar Strips with Ground

Coplanar Lines may be constructed with or without a ground plane underneath the controlled impedance trace(s).



This structure is an example of a controlled impedance trace on a single sided board that will typically be used in consumer applications.

*Differential Surface Coplanar Strips*



The diagram above shows a differential surface coplanar structure with strips and a lower ground plane fabricated using two dielectric layers

# Installing the Si8000 Field Solver

## Activating the Si8000

Note: The structures available will depend on the license purchased. It will be necessary to activate the product license prior to performing calculations with the Si8000.

The Si8000 is licensed using the FLEXlm License Manager or a software key connected to either the parallel port (typically LPT1) or a USB port

The FLEXlm licensing files should be installed and running on a locally accessible server. The server must be running to manage licensing.

### Licensing the Si8000 using FLEXlm

When the first calculation is performed the Si8000 FLEXlm License finder asks for the name of the License Server or License File.



Ensure the **Specify the license Server** option is selected and press **Next**.

Enter the name of the License Server and press **Next**.



The name will normally be the Network Identification name of the computer acting as the Licensing Server.

The Si8000 will perform calculations within the terms of the license purchased.

#### **Installing the software key**

If a software key is used insert the key into the parallel printer port or USB port; if required, plug the printer cable into the software key.

*Note: If installing the software key on a Microsoft Windows NT or Windows 2000/XP system it will be necessary to be logged on as Administrator.*

#### **Uninstalling the software**

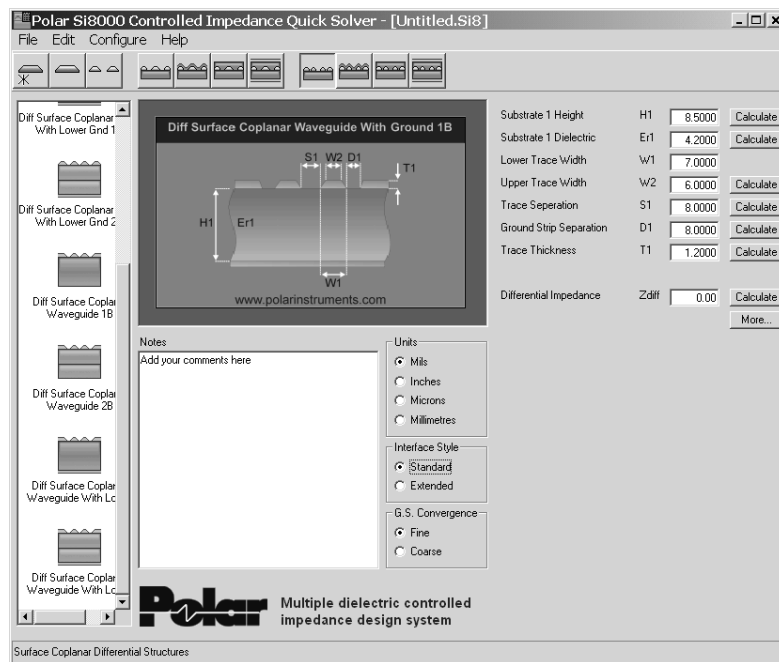
To uninstall the Si8000 software click the Windows Start button and choose Settings and Control Panel.

Double-click Add/Remove Programs and choose Si8000 from the list. Click Remove.

# Using the Si8000 Quick Solver

## The Si8000 Quick Solver

The Si8000 Quick Solver allows the operator to perform rapid single calculations of PCB trace values against significant PCB parameters. The Si8000 Quick Solver solves for impedance, propagation delay and inductance and capacitance per unit trace length. Click the Si8000 Quick Solver icon on the desktop to start the Si8000 Quick Solver.



Si8000 Quick Solver – Standard Interface

To specify dimensional values click the parameter in the diagram or select the associated text box.

### Calculating impedance

Click on the configuration from the Structures menu or from the Structures Bar. Select the dimension units (mils, inches, microns or millimetres) from the Units option group. Enter the parameter values in the associated text boxes. For example, the Surface Microstrip structure uses:

- H1 (Height) — dielectric thickness
- W1 and W2 (Width) — signal trace width (allowing for finished etch factor)
- T1 (Thickness) — signal trace thickness
- Er1 — dielectric constant

Other structures will use additional parameters; press the Impedance **Calculate** button. The calculated impedance will appear in the Impedance ( $Z_0$ ) box.

Add explanatory notes on your particular construction, if necessary, in the Notes text box.

### Specifying Goal Seeking convergence

The convergence values used during goal seeking are specified in the Configuration screen (see **Setting Si8000 parameter limits**). Choose between fine convergence to derive parameters whose values may be infinitely variable (e.g. trace width) and coarse convergence for parameters whose values may be fixed by supplier (e.g. height).

Typically the user will enter all the known parameters and goal seek for the desired impedance on the dielectric height. Using the coarse convergence option can speed up goal seeking on complex structures. The trace width can then be derived using fine convergence.



### Calculating propagation delay, inductance and capacitance

Click on the configuration from the **Structures** menu or from the Structures Bar. Enter the parameter values as described above into the text boxes and press the **More...** button.

The Si8000 displays the results of propagation delay, inductance and capacitance in the selected units. Press **Close** to exit.

### Quick solving for board parameters

The Quick Solver can solve for board parameters given a nominal impedance value.

Substrate 1 Height	H1	<input type="text" value="8.4360"/>	<input type="button" value="Calculate"/>
Substrate 1 Dielectric	Er1	<input type="text" value="4.2000"/>	<input type="button" value="Calculate"/>
Lower Trace Width	W1	<input type="text" value="7.0000"/>	<input type="button" value="Calculate"/>
Upper Trace Width	W2	<input type="text" value="6.0000"/>	<input type="button" value="Calculate"/>
Trace Thickness	T1	<input type="text" value="1.2000"/>	<input type="button" value="Calculate"/>
Impedance	Zo	<input type="text" value="75.00"/>	<input type="button" value="Calculate"/>
			<input type="button" value="More..."/>

Enter the given board dimensions in their associated fields and the nominal impedance value in the Impedance field and click the **Calculate** button against the unknown dimension, e.g. Substrate Height, Width, etc.

### Using the Extended Interface

Selecting the Extended Interface Style displays additional fields, Tolerance, Minimum and Maximum allowing the user to specify a range of values for each parameter and observe the effect of manufacturing process variations.

			Tolerance	Minimum	Maximum	
Substrate 1 Height	H1	<input type="text" value="8.5000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="8.5000"/>	<input type="text" value="8.5000"/>	<input type="button" value="Calculate"/>
Substrate 1 Dielectric	Er1	<input type="text" value="4.2000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="4.2000"/>	<input type="text" value="4.2000"/>	<input type="button" value="Calculate"/>
Lower Trace Width	W1	<input type="text" value="7.0000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="7.0000"/>	<input type="text" value="7.0000"/>	
Upper Trace Width	W2	<input type="text" value="6.0000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="6.0000"/>	<input type="text" value="6.0000"/>	<input type="button" value="Calculate"/>
Trace Thickness	T1	<input type="text" value="1.2000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="1.2000"/>	<input type="text" value="1.2000"/>	<input type="button" value="Calculate"/>
Impedance	Zo	<input type="text" value="75.26"/>		<input type="text" value="75.26"/>	<input type="text" value="75.26"/>	<input type="button" value="Calculate"/>
						<input type="button" value="More..."/>

Fields which control the maximum impedance value are shown in green, fields which control the minimum impedance value are shown in orange.

In this example we specify a nominal impedance value of  $80\Omega$  and observe the effects on the nominal impedance of a manufacturing variation of  $\pm 1\text{mil}$  in the substrate height.

Select the Extended Interface, enter a value of  $80\Omega$  in the Impedance field and click the Substrate 1 Height **Calculate** button

			Tolerance	Minimum	Maximum	
Substrate 1 Height	H1	<input type="text" value="9.7542"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="9.7542"/>	<input type="text" value="9.7542"/>	<input type="button" value="Calculate"/>
Substrate 1 Dielectric	Er1	<input type="text" value="4.2000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="4.2000"/>	<input type="text" value="4.2000"/>	<input type="button" value="Calculate"/>
Lower Trace Width	W1	<input type="text" value="7.0000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="7.0000"/>	<input type="text" value="7.0000"/>	
Upper Trace Width	W2	<input type="text" value="6.0000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="6.0000"/>	<input type="text" value="6.0000"/>	<input type="button" value="Calculate"/>
Trace Thickness	T1	<input type="text" value="1.2000"/>	<input type="text" value="+/- 0.0000"/>	<input type="text" value="1.2000"/>	<input type="text" value="1.2000"/>	<input type="button" value="Calculate"/>
Impedance	Zo	<input type="text" value="80.00"/>		<input type="text" value="80.00"/>	<input type="text" value="80.00"/>	<input type="button" value="Calculate"/>
						<input type="button" value="More..."/>

The nominal Substrate 1 Height is calculated at 9.75 mil. Enter a value of 1mil in the Substrate 1 Height Tolerance field and click the Impedance **Calculate** button.

			Tolerance	Minimum	Maximum	
Substrate 1 Height	H1	9.7542	+/- 1.0000	8.7542	10.7542	Calculate
Substrate 1 Dielectric	Er1	4.2000	+/- 0.0000	4.2000	4.2000	Calculate
Lower Trace Width	W1	7.0000	+/- 0.0000	7.0000	7.0000	
Upper Trace Width	W2	6.0000	+/- 0.0000	6.0000	6.0000	Calculate
Trace Thickness	T1	1.2000	+/- 0.0000	1.2000	1.2000	Calculate
Impedance	Zo	80.00		76.27	83.40	Calculate
						More...

The Si8000 calculates the range of impedance for a 1mil variation in H1 as 76.27–83.40Ω.

Other parameter tolerances can be included as necessary. Enter a value of 0.5 in the Substrate 1 Dielectric Tolerance field and click the **Impedance Calculate** button. The impedance range should now show 72.71–87.91Ω.

## Setting Si8000 parameter limits

The Si8000 is designed to work with “real world” values. If the parameter values used in calculation are beyond the Si8000 limits, the Si8000 returns a value of zero. The user is able to control the range of values used by the Si8000 field solving engine during calculation.

Click the **Configure** menu; the Si8000 Configuration dialog is displayed.

The image shows the 'Si8000 Configuration' dialog box. It has a title bar with a close button. The main area is a table with columns for parameter names, codes, minimum values, and maximum values. There are 'Apply' and 'Cancel' buttons on the right. At the bottom, there is a section for 'Lower Trace Width Etch Factor Setting' with a text box and a note.

Units : Mils		Minimum	Maximum	
Substrate 1 Height	H1	1.0000	200.0000	Apply Cancel
Substrate 1 Dielectric	Er1	1.0000	10.0000	
Substrate 2 Height	H2	1.0000	200.0000	
Substrate 2 Dielectric	Er2	1.0000	10.0000	
Substrate 3 Height	H3	1.0000	200.0000	
Substrate 3 Dielectric	Er3	1.0000	10.0000	
Substrate 4 Height	H4	1.0000	200.0000	
Substrate 4 Dielectric	Er4	1.0000	10.0000	
Upper Trace Width	W1	2.0000	100.0000	
Lower Trace Width	W2	2.0000	100.0000	
Upper Coplanar Width	G1	2.0000	100.0000	
Lower Coplanar Width	G2	2.0000	100.0000	
Trace Separation	S1	1.0000	100.0000	
Coplanar Ground Separation	D1	1.0000	100.0000	
Trace Offset	O1	0.0000	100.0000	
Trace Thickness	T1	1.0000	10.0000	
Separation Region Dielectric	REr	1.0000	10.0000	
Coating Above Substrate	C1	0.5000	5.0000	
Coating Above Trace	C2	0.5000	5.0000	
Coating Between Traces	C3	0.5000	5.0000	
Coating Dielectric	CEr	1.0000	10.0000	
Goal Seek Tries		20		
Goal Seek Convergence - Fine		0.01		
Goal Seek Convergence - Coarse		2.00		
Lower Trace Width Etch Factor Setting				
	Lower Trace Width Etch Factor	1.0000		
[Enter a value that should be applied to the Upper Trace Width parameter to model the effect of the Etch process. + or - values accepted]				

Enter the values for minimum and maximum for each parameter and number of calculation iterations (Si8000 Quick Solver Tries).

## Saving and recalling results

Impedance calculation results for a board type or vendor, for example, may be saved to disk and recalled for future reference.

From the **File** menu choose the **Save As...** command. Choose a name and destination and press **Save**.

The program will only save calculated results.

To recall a set of results choose **Open...** from the **File** menu and choose the desired results file and press **Open**.

## Printing results

Choose Print from the File menu to print a hard copy of the Si8000 Quick Solver screen.

## Copying Quick Solver parameters to Excel

Selecting this command from the **Edit** menu takes the current parameters from the Quick Solver and places them on the Windows clipboard in Microsoft Excel format.

The parameter values may then be pasted to a suitable location in an Si8000 or Si8000Expert workbook. The values are placed horizontally beginning at the active cell location. The number of cells required depends upon the structure chosen. Ensure no important data are overwritten in the process.

The operator can now use Excel's **Paste** Function command to insert the associated Si8000 function using the pasted Quick Solver parameter values as arguments.

*(See Using the Si8000 Field Solver.)*

## Using the Si8000 Field Solver

### Starting the Field Solver

*Note: the graphics displayed in this section are based on Microsoft Excel 2000. Dialog box graphics*

*from different versions of Microsoft Excel may display slight differences from those shown here.*

The Field Solver functions for each controlled impedance structure are built into Microsoft Excel workbooks Si8000.xls and Si8000Expert.xls as user-defined functions. This allows rapid and convenient analysis of board trace characteristics such as impedance, propagation delay, inductance and capacitance against several varying board parameters.

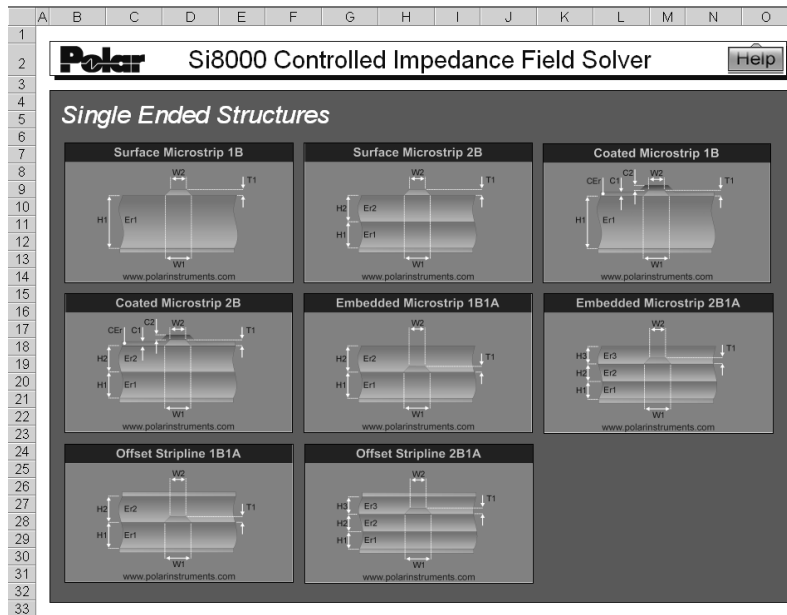
In addition to the Field Solver functions, the Si8000.xls workbook includes pre-built sample data worksheets incorporating tables of functions and their associated parameters.

If the Si8000.xls workbook opens with the warning that the workbook contains macros (Visual Basic code), click the **Enable Macros** button to allow the field solver to perform calculations. (See Excel's **Tools|Macro|Security...** command and the discussion on security levels in Excel's help file).

The workbook opens by default as read-only; this allows the operator to perform calculations but not save changes to the workbook.

The Si8000Expert.xls sheet includes the Si8000 functions but does not include the sample worksheets.

Double click the Field Solver icon on the desktop; Microsoft Excel opens the Si8000.xls workbook at the Si8000 index sheet.



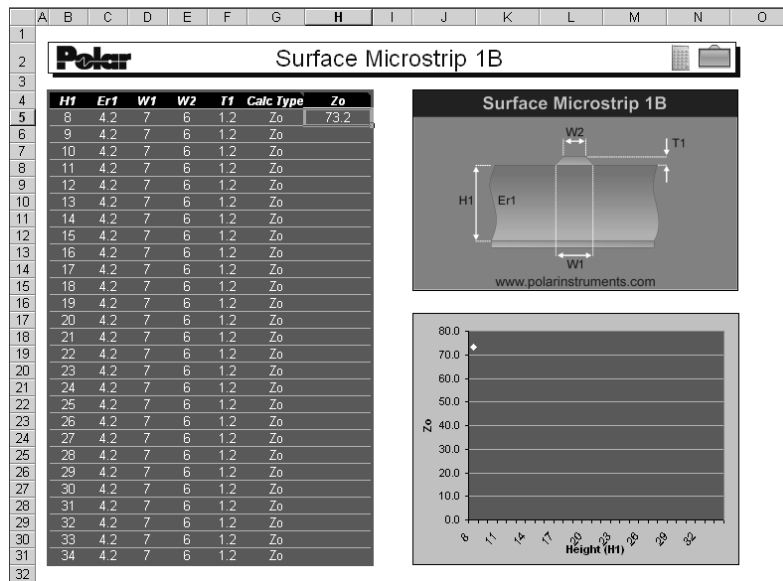
Si8000 index sheet — Single Ended Structures

## Si8000 structure categories

The index sheet displays the Si8000 structure categories; each group of structures contains the associated models

To select a structure, scroll to the category and click on its graphic, e.g. Surface Microstrip 1B. The Si8000 activates the associated worksheet.

Each worksheet comprises the graphic associated with the chosen model, a table with predefined values and an embedded chart that uses the table as its data source (typically set to chart impedance against substrate height). The user can redefine the chart source data to show results for other columns.



Surface Microstrip sample worksheet

### Moving through the structure sheets

Structure sheets may also be selected via the Tab Scrolling Buttons, .

Click the buttons to select the first, previous, next or last structure sheets.

Alternatively, use the Ctrl + Page Up/Ctrl + Page Down keys to move to the previous/next sheet.

To move directly to a structure, right click the Tab Scrolling Buttons to display the list of structure sheets.





Select the structure from the list. If necessary choose **More Sheets...** to display the complete list of structures.

### Calculating trace characteristics

Each worksheet includes a pre-built sample application, incorporating a table of typical dimensions for use with the function associated with the structure and a chart displaying the change in impedance ( $Z_0$ ), propagation delay (D), inductance (L) or capacitance (C) against structure dimensions (in the sample chart below  $Z_0$  is shown against a varying Substrate Height (H1) with other parameters fixed).

H1	Er1	W1	W2	T1	Calc Type	Zo
8	4.2	7	6	1.2	Zo	73.2
9	4.2	7	6	1.2	Zo	
10	4.2	7	6	1.2	Zo	
11	4.2	7	6	1.2	Zo	
12	4.2	7	6	1.2	Zo	
13	4.2	7	6	1.2	Zo	
14	4.2	7	6	1.2	Zo	
15	4.2	7	6	1.2	Zo	
16	4.2	7	6	1.2	Zo	
17	4.2	7	6	1.2	Zo	
18	4.2	7	6	1.2	Zo	
19	4.2	7	6	1.2	Zo	
20	4.2	7	6	1.2	Zo	

Sample table with increasing values of H

The sheet opens with the single value of  $Z_0$  calculated for the structure dimensions shown in the first row. The field solving function is located in the cell labelled  $Z_0$ , the parameters for the function are contained in the associated cells labelled H1, Er1, W1, W2, T1, etc.

### Choosing the calculation type, Z, D, L, C

To calculate other characteristics for the selected parameters, enter the value D, L or C in the associated cell in the Calc Type column (labelled **Calc Type**), move to another cell and press the

Calculate button. Re-label the results column if necessary. Differential structures include other characteristics, e.g.  $Z_{\text{even}}$ ,  $Z_{\text{odd}}$ ,  $Z_{\text{Common}}$ .

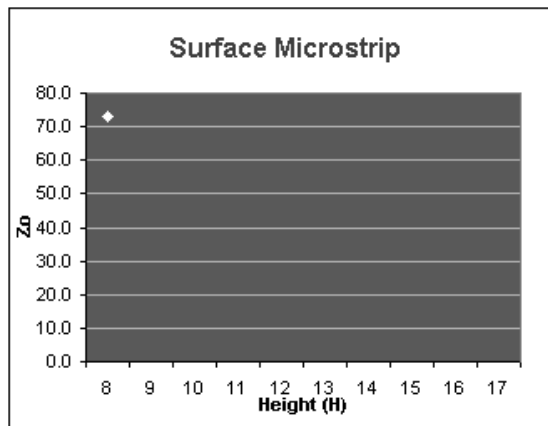
To see which characteristics are available for a structure, move the mouse over the Calc Type label to display the Note text box.

Surface Microstrip 1B			Calc Type
W2	T1	Calc Type	Acceptable values for this field are :
6	1.2	$Z_0$	Z / Z <sub>0</sub> - Impedance (Ohms)
6	1.2	$Z_0$	D - Delay (ps/m)
6	1.2	$Z_0$	L - Inductance (nH/m)
6	1.2	$Z_0$	C - Capacitance (pF/m)
6	1.2	$Z_0$	EER - Effective Er

Enter the characteristic type in the Calc Type (e.g.  $Z_{\text{even}}$ ) exactly as shown in the note.

### Charting against varying board parameters

The Si8000 sheet opens with the value of  $Z_0$  against H for the structure dimensions shown in the first row and charted as shown below.



To chart the change in  $Z_0$ , D, L, or C as H changes over a range of values, use the Excel Fill Handle to copy the function formula down into the associated cells.

(To activate the Fill Handle, move the mouse to the lower right corner of the active cell. The mouse changes to a black plus sign.)

If the Fill Handle does not appear, select **Tools|Options|Edit** and tick the **Allow cell drag and drop** check box.)

H1	Er1	W1	W2	T1	Calc Type	Zo
8	4.2	7	6	1.2	Zo	73.2
9	4.2	7	6	1.2	Zo	
10	4.2	7	6	1.2	Zo	
11	4.2	7	6	1.2	Zo	
12	4.2	7	6	1.2	Zo	
13	4.2	7	6	1.2	Zo	
14	4.2	7	6	1.2	Zo	
15	4.2	7	6	1.2	Zo	
16	4.2	7	6	1.2	Zo	
17	4.2	7	6	1.2	Zo	
18	4.2	7	6	1.2	Zo	
19	4.2	7	6	1.2	Zo	
20	4.2	7	6	1.2	Zo	
21	4.2	7	6	1.2	Zo	
22	4.2	7	6	1.2	Zo	
23	4.2	7	6	1.2	Zo	

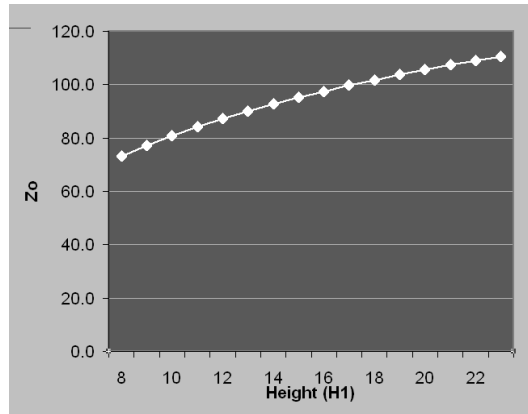
Use Excel's Fill Handle to copy the formula down

Press the **Calculate** button to recalculate the worksheet. (The Si8000 Workbook sets Excel's Calculation mode to Manual; see **Tools|Options|Calculation**).

The Si8000 field solves for the selected characteristic in all associated rows .

H1	Er1	W1	W2	T1	Calc Type	Zo
8	4.2	7	6	1.2	Zo	73.2
9	4.2	7	6	1.2	Zo	77.2
10	4.2	7	6	1.2	Zo	80.9
11	4.2	7	6	1.2	Zo	84.2
12	4.2	7	6	1.2	Zo	87.2
13	4.2	7	6	1.2	Zo	90.1
14	4.2	7	6	1.2	Zo	92.7
15	4.2	7	6	1.2	Zo	95.2
16	4.2	7	6	1.2	Zo	97.5
17	4.2	7	6	1.2	Zo	99.7
18	4.2	7	6	1.2	Zo	101.7
19	4.2	7	6	1.2	Zo	103.7
20	4.2	7	6	1.2	Zo	105.5
21	4.2	7	6	1.2	Zo	107.3
22	4.2	7	6	1.2	Zo	109.0
23	4.2	7	6	1.2	Zo	110.6

The embedded chart is refreshed with the results of the calculation.



Plot of  $Z_0$  as Height (H1) varies

### Choosing other parameters

$Z_0$ , D, L and C can be plotted against any of the function parameters.

For example, to display  $Z_0$  as  $E_r$  varies, in the example reset H1 to a single value, e.g. 8, and plot  $Z_0$  against changes of  $E_r$  between 3.8 and 4.35 in 0.05 increments.

### Changing the parameters

Select the first value in the Height column and use the Fill Handle to fill down to row 16 with the value 8.

Change the first value in the  $E_r$  column to 3.8, change the second value to 3.85 then select *both* cells.

Use the Fill Handle to fill down to row 16; Excel detects the two cell values as an incrementing sequence and fills the column accordingly with values increasing at 0.05 intervals.

Click the **Calculate** icon to refresh the  $Z_0$  column.

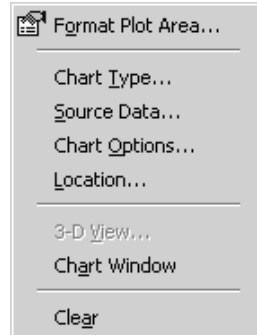
H1	Er1	W1	W2	T1	Calc Type	Zo
8	3.8	7	6	1.2	Zo	76.3
8	3.85	7	6	1.2	Zo	75.9
8	3.9	7	6	1.2	Zo	75.5
8	3.95	7	6	1.2	Zo	75.1
8	4	7	6	1.2	Zo	74.7
8	4.05	7	6	1.2	Zo	74.3
8	4.1	7	6	1.2	Zo	73.9
8	4.15	7	6	1.2	Zo	73.6
8	4.2	7	6	1.2	Zo	73.2
8	4.25	7	6	1.2	Zo	72.8
8	4.3	7	6	1.2	Zo	72.5
8	4.35	7	6	1.2	Zo	72.1

$Z_0$  against  $E_r$  with other parameters fixed

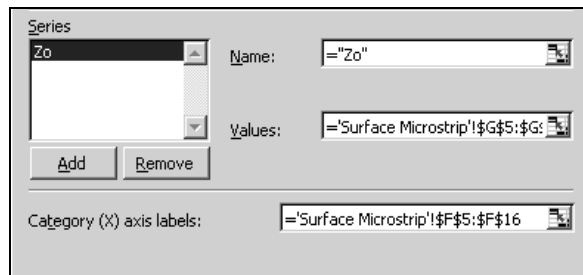
### Modifying the chart


It will be necessary to modify the chart to reflect the new scales and Category axis.

Right click the chart area and choose **Source Data...**



From the Source Data dialog box, click the **Series** tab; the Series page shows the source data cell ranges for the chart.



Click the **Collapse Dialog** button, (  ), in the Category (X) axis labels: edit box and select the range of Er values charted.

Click the button again to restore the dialog box and press **OK**.

Click the Category Axis Title label and replace the H with Er.

Right click the value axis and choose **Format Axis...**

Choose the Scale tab and change the values as necessary for Minimum and Maximum scale values.

Value (Y) axis scale

Auto

Minimum: 72

Maximum: 77

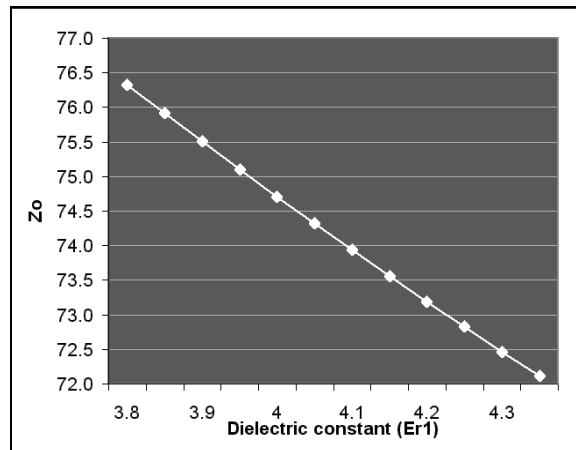
Major unit: 0.5

Minor unit: 0.1

Category (X) axis

Crosses at: 72

Press OK. The chart should appear as shown below.



Format the chart (color, scales, etc.) as required.

Repeat the procedure for other parameter values.



## Using the Si8000 functions in other workbooks

The Si8000 functions supplied by the Si8000 workbooks, Si8000.xls or Si8000Expert.xls, are available for use in other workbooks.

*Prior to using any of the Si8000 functions it will be necessary to ensure the Si8000.xls workbook or Si8000Expert.xls is open. In this discussion the worksheet is assumed to refer to the Si8000.xls workbook.*


The Si8000 functions use the board parameters, H1, W1, Er1 etc. as arguments. Parameter values can be derived from existing data in worksheet cells or inserted into the Formula Palette directly.

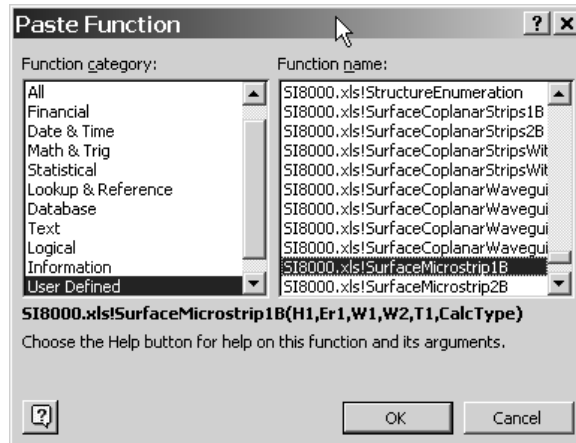
Begin a new worksheet.

In the example below the values for a Surface Microstrip structure are contained in cells B4 to G4. We insert the Si8000 Surface Microstrip function into cell H4.

	A	B	C	D	E	F	G	H	I
1									
2									
3		H1	Er1	W1	W2	T1	Calc Type	Zo	
4		8	3.8	7	6	1.2	Zo		
5									
6									
7									
8									
9									
10									

Insert Si8000 function in cell H4

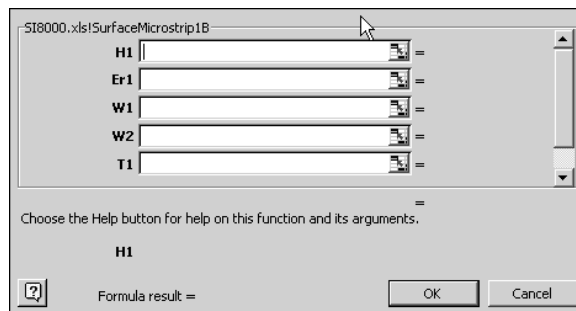
To use a function, from the **Insert** menu choose **Function...** or click the **Insert Function** button  on the tool bar. The Paste Function dialog box is displayed. Choose the **User Defined** category to display the user-defined functions.




Scroll to the Si8000 functions; click the function associated with the surface microstrip structure (SI8000.xls!SurfaceMicrostrip1B in this example) and click OK: the Formula Palette is displayed.

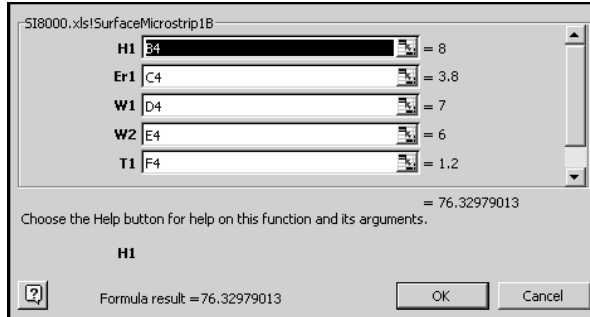
#### *Using the Formula Palette to enter formulas*

Use the Excel Formula Palette to enter function parameters. The Formula Palette creates an edit box for each argument in the function.



Click the Collapse Dialog button (  ) in the **H1** edit box and select cell B4: click the button again. Tab through the other edit boxes and repeat the procedure for each value.

As the function is entered, the Formula Palette displays the value of each of its arguments, the current result of the function, and the current result of the entire formula. When the last value is entered Excel calculates and displays the final result.



Press OK to close the Formula Palette and complete the formula.

	A	B	C	D	E	F	G	H	I
1									
2									
3		H1	Er1	W1	W2	T1	Calc Type	Zo	
4		8	3.8	7	6	1.2	Zo	76.32979	
5									



$Z_0$  calculated for a single set of values

To calculate  $Z_0$  over a range of parameter values, select the data and formula (cells B4 to H4) and use the Fill Handle to copy down as necessary.

Select each column of cells as appropriate and enter the new parameter values.

*Hint: to fill a range of cells with a single value select the range, type the value and press Shift + Enter.*

Press Shift + F9 to recalculate the sheet.

If necessary use the Increase decimal/Decrease Decimal buttons   to select the required number of decimal places.

Format as required.

H1	Er1	W1	W2	T1	Calc Type	Zo
8	3.80	7	6	1.2	Zo	76.32979
8	3.85	7	6	1.2	Zo	75.91486
8	3.90	7	6	1.2	Zo	75.50671
8	3.95	7	6	1.2	Zo	75.10516
8	4.00	7	6	1.2	Zo	74.71004
8	4.05	7	6	1.2	Zo	74.32117
8	4.10	7	6	1.2	Zo	73.93838
8	4.15	7	6	1.2	Zo	73.56152
8	4.20	7	6	1.2	Zo	73.19043
8	4.25	7	6	1.2	Zo	72.82497
8	4.30	7	6	1.2	Zo	72.46499

Z<sub>0</sub> calculated for changing E<sub>r</sub>

### Charting results

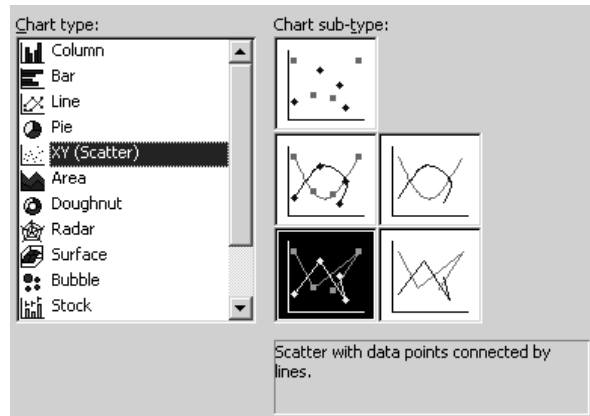
Use the Excel Chart Wizard to chart the results.

Select the area to be charted: in this example the Er1 and Z<sub>0</sub> ranges (to select non-adjacent ranges, press Ctrl while dragging the mouse over each range).

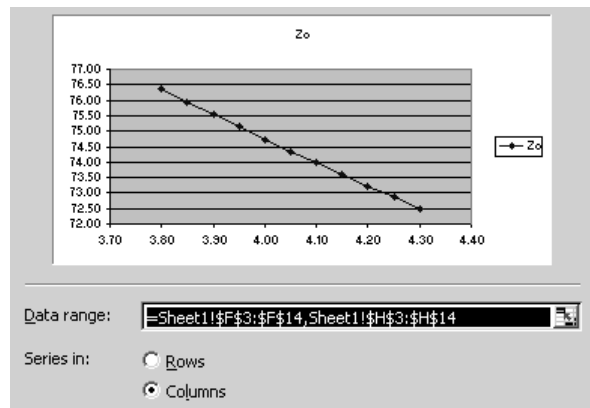
H1	Er1	W1	W2	T1	Calc Type	Zo
8	3.80	7	6	1.2	Zo	76.32979
8	3.85	7	6	1.2	Zo	75.91486
8	3.90	7	6	1.2	Zo	75.50671
8	3.95	7	6	1.2	Zo	75.10516
8	4.00	7	6	1.2	Zo	74.71004
8	4.05	7	6	1.2	Zo	74.32117
8	4.10	7	6	1.2	Zo	73.93838
8	4.15	7	6	1.2	Zo	73.56152
8	4.20	7	6	1.2	Zo	73.19043
8	4.25	7	6	1.2	Zo	72.82497
8	4.30	7	6	1.2	Zo	72.46499

Click the **Chart Wizard** button  to start the Chart Wizard.

From Step 1, Chart Type, of the Chart Wizard, choose Chart Type: XY (Scatter) type and Chart sub-type: Data points connected by lines



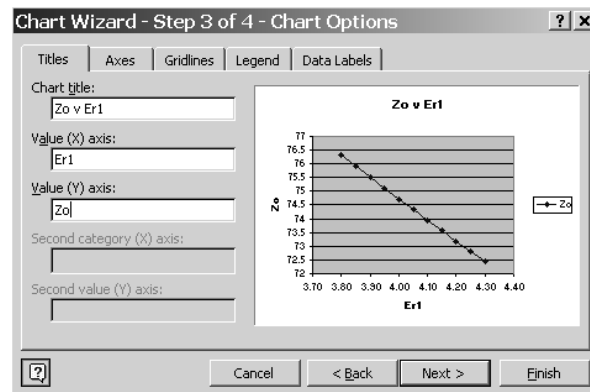
Click **Next** to select Step 2, Chart Source Data.



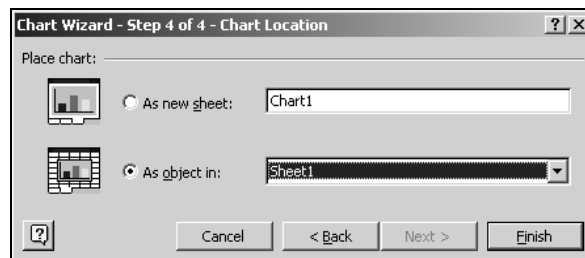
Check the **Data Range**: in this case the cell references are correct.

Leave the **Series in**: option set to **Columns**.

Click **Next** to select Step 3, Chart Options, and add titles for the chart and its axes and (optionally) remove the legend.



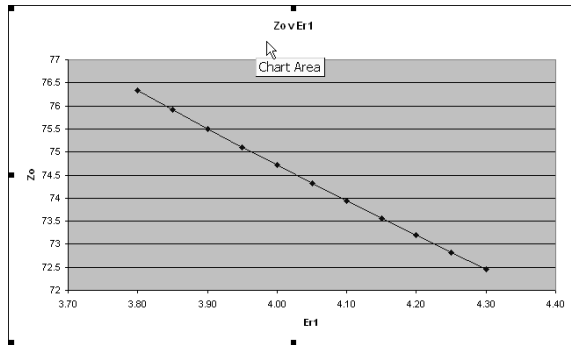
Click **Next** to select Step 4, Chart Location.



Use the Chart Location dialog box to choose where Excel creates the chart.

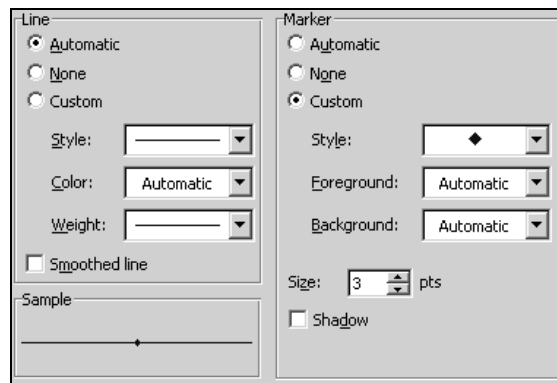
To place the chart on a new chart sheet, click **As new sheet:**, and type a name for the new chart sheet.

To embed the chart on the worksheet, click **As object in:**, select a sheet name from the As object in: list box, and click **Finish**.



Choose the **As object in:** option then drag and size the embedded chart as required on the worksheet.

To modify the data series (e.g. line weight, marker style etc.) right click the chart line and choose **Format Data Series...**



Change the series format as required.

## Using the Si8000 to plot multiple data series

### Plotting $Z_0$ for surface and coated microstrip

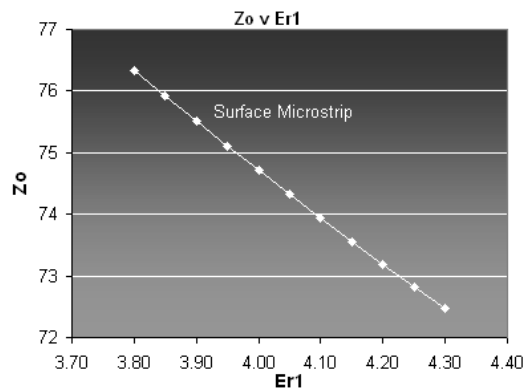
#### Inserting the first data series

Supply the data and plot the data series for Surface Microstrip as described earlier.

Surface Microstrip							
H1	Er1	W1	W2	T1	Calc Type	Zo	
8	3.80	7	6	1.2	Zo	76.32979	
8	3.85	7	6	1.2	Zo	75.91486	
8	3.90	7	6	1.2	Zo	75.50671	
8	3.95	7	6	1.2	Zo	75.10516	
8	4.00	7	6	1.2	Zo	74.71004	
8	4.05	7	6	1.2	Zo	74.32117	
8	4.10	7	6	1.2	Zo	73.93838	
8	4.15	7	6	1.2	Zo	73.56152	
8	4.20	7	6	1.2	Zo	73.19043	
8	4.25	7	6	1.2	Zo	72.82497	
8	4.30	7	6	1.2	Zo	72.46499	

In this example, plot  $Z_0$  against  $E_r$ .

To add comments, titles, etc., to the chart, click into the Excel Formula Bar, type the text and press <Return>; the text appears on the chart — place the text as required.





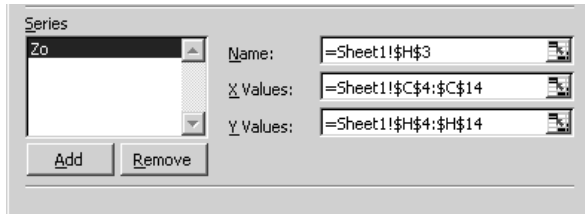
To format any chart item, right click the item and change its properties via the short cut menu.

*Adding the second data series*

Supply the data for the Coated Microstrip structure as shown below.

Coated Microstrip										
H1	Er1	W1	W2	T1	C1	C2	Cer	Calc Type	Zo	
8	3.80	7	6	1.2	1	1	3.80	Zo	72.16992	
8	3.85	7	6	1.2	1	1	3.85	Zo	71.75441	
8	3.90	7	6	1.2	1	1	3.90	Zo	71.3461	
8	3.95	7	6	1.2	1	1	3.95	Zo	70.94479	
8	4.00	7	6	1.2	1	1	4.00	Zo	70.55029	
8	4.05	7	6	1.2	1	1	4.05	Zo	70.16239	
8	4.10	7	6	1.2	1	1	4.10	Zo	69.78091	
8	4.15	7	6	1.2	1	1	4.15	Zo	69.40569	
8	4.20	7	6	1.2	1	1	4.20	Zo	69.03653	
8	4.25	7	6	1.2	1	1	4.25	Zo	68.67329	
8	4.30	7	6	1.2	1	1	4.30	Zo	68.3158	

Right click the chart and choose **Source Data...** from the menu. Click the **Series** tab.



Click the **Add** button to add a second series to the chart; in this case we use the same values for the X axis. Click the **Collapse Dialog** button and select the values in the Er1 column.

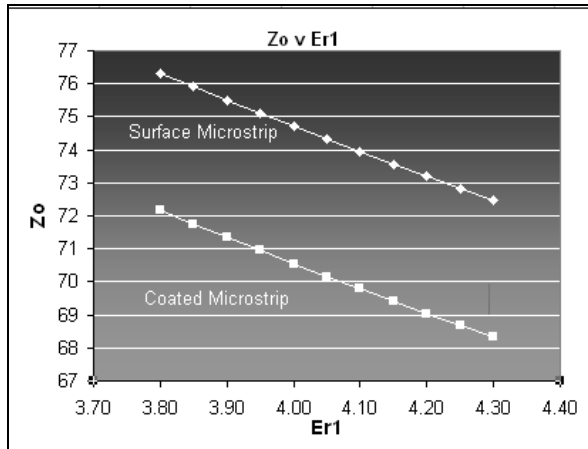
Coated Microstrip		
H1	Er1	W1
8	3.80	7
8	3.85	7
8	3.90	7
8	3.95	7
8	4.00	7
8	4.05	7
8	4.10	7
8	4.15	7
8	4.20	7
8	4.25	7
8	4.30	7

Repeat for the Y axis; select the values in the Coated Microstrip  $Z_0$  column.

Cer	Calc Type	Zo
3.80	Zo	72.16992
3.85	Zo	71.75441
3.90	Zo	71.3461
3.95	Zo	70.94479
4.00	Zo	70.55029
4.05	Zo	70.16239
4.10	Zo	69.78091
4.15	Zo	69.40569
4.20	Zo	69.03653
4.25	Zo	68.67329
4.30	Zo	68.3158

Add the name *Coated Microstrip* to the Name text box, click the  $Z_0$  series from the Series list and add the name *Surface Microstrip*; press **OK**.

Right click the Y axis and choose **Format Axis...**, choose the Scale tab and specify a suitable value (in this case 67) as the minimum value. The chart should appear as below.



Use the Formula Bar to add explanatory text as necessary (in this case the titles *Surface Microstrip* and *Coated Microstrip* were added to the chart).

### Plotting $Z_{\text{even}}$ and $Z_{\text{odd}}$ v trace separation

In this example we use the Edge Coupled Offset Stripline structure to examine the effects of decreasing trace separation on even and odd impedance.

Choose the Edge Coupled Offset Stripline structure from the Si8000 main index sheet.

Supply the values for H1 (copy the value 8 to all cells in the height column).

Supply the decreasing values for S (7.75 to 0.25 in 0.5 steps).

Change the Calc Type to  $Z_{\text{even}}$ .

Change the Formula column heading to Zeven.

Fill down the formula column with the function.

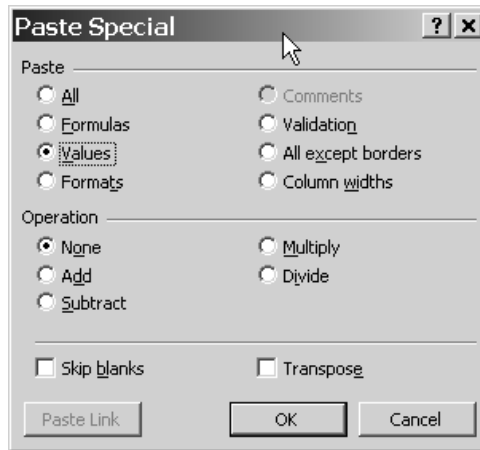
Press the **Calculate** button to display the results — partial results are shown below.

H1	Er1	H2	Er2	W1	W2	S1	T1	Calc Type	Zeven
3	4.2	3	4.2	7	6	8	1.2	Zeven	21.4
3	4.2	3	4.2	7	6	7.75	1.2	Zeven	21.4
3	4.2	3	4.2	7	6	7.5	1.2	Zeven	21.4
3	4.2	3	4.2	7	6	7.25	1.2	Zeven	21.4
3	4.2	3	4.2	7	6	7	1.2	Zeven	21.5
3	4.2	3	4.2	7	6	6.75	1.2	Zeven	21.5
3	4.2	3	4.2	7	6	6.5	1.2	Zeven	21.5
3	4.2	3	4.2	7	6	6.25	1.2	Zeven	21.5
3	4.2	3	4.2	7	6	6	1.2	Zeven	21.5
3	4.2	3	4.2	7	6	5.75	1.2	Zeven	21.6
3	4.2	3	4.2	7	6	5.5	1.2	Zeven	21.6
3	4.2	3	4.2	7	6	5.25	1.2	Zeven	21.6
3	4.2	3	4.2	7	6	5	1.2	Zeven	21.7
3	4.2	3	4.2	7	6	4.75	1.2	Zeven	21.7
3	4.2	3	4.2	7	6	4.5	1.2	Zeven	21.8
3	4.2	3	4.2	7	6	4.25	1.2	Zeven	21.8

Insert a column to the right of the formula column.

Select the formula cells, choose **Copy** and select the cell to the right of the Zeven label.

From the **Edit** menu choose **Paste Special...**



Choose the **Values** option and press **OK**.

Press **Esc** to exit Copy-Paste mode.

Change the Calc Type and the label of the formula column to **Zodd**.

Press the **Calculate** button. Partial results are shown below.

<b>H1</b>	<b>Er1</b>	<b>H2</b>	<b>Er2</b>	<b>W1</b>	<b>W2</b>	<b>S1</b>	<b>T1</b>	<b>Calc Type</b>	<b>Zodd</b>	<b>Zeven</b>
3	4.2	3	4.2	7	6	8	1.2	Zodd	21.27	21.4
3	4.2	3	4.2	7	6	7.75	1.2	Zodd	21.26	21.4
3	4.2	3	4.2	7	6	7.5	1.2	Zodd	21.24	21.4
3	4.2	3	4.2	7	6	7.25	1.2	Zodd	21.23	21.4
3	4.2	3	4.2	7	6	7	1.2	Zodd	21.22	21.5
3	4.2	3	4.2	7	6	6.75	1.2	Zodd	21.20	21.5
3	4.2	3	4.2	7	6	6.5	1.2	Zodd	21.18	21.5
3	4.2	3	4.2	7	6	6.25	1.2	Zodd	21.16	21.5
3	4.2	3	4.2	7	6	6	1.2	Zodd	21.13	21.5
3	4.2	3	4.2	7	6	5.75	1.2	Zodd	21.10	21.6
3	4.2	3	4.2	7	6	5.5	1.2	Zodd	21.07	21.6
3	4.2	3	4.2	7	6	5.25	1.2	Zodd	21.03	21.6
3	4.2	3	4.2	7	6	5	1.2	Zodd	20.98	21.7
3	4.2	3	4.2	7	6	4.75	1.2	Zodd	20.93	21.7
3	4.2	3	4.2	7	6	4.5	1.2	Zodd	20.87	21.8
3	4.2	3	4.2	7	6	4.25	1.2	Zodd	20.80	21.8

The associated chart should show the results for  $Z_{\text{odd}}$ .

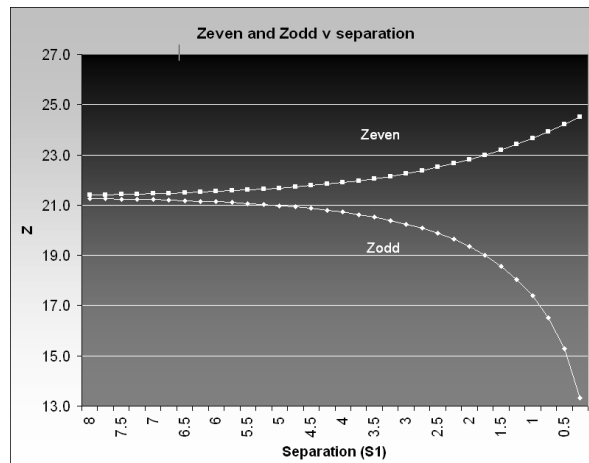
Drag the column of  $Z_{\text{even}}$  values onto the chart.

Modify the chart so the Source Data Category (X) axis labels, and Series refer to the S1,  $Z_{\text{even}}$  and  $Z_{\text{odd}}$  cell ranges.

Choose a suitable minimum value for the Value (Y) axis.

Format the axes and add text labels as required.

The results are shown below.



## Using more complex models

### Calculating the effect of etch back

In this example we consider the effect of PCB trace side-wall slope. As part of the process we chart the change in impedance due to variations in dielectric thickness and trace width. We use the surface microstrip structure.

Begin by entering the parameter values for the surface microstrip structure in cells A2:F2.

	A	B	C	D	E	F	G	H
1	<b>H1</b>	<b>Er1</b>	<b>W1</b>	<b>W2</b>	<b>T1</b>	<b>Calc Type</b>	<b>Zo</b>	
2	8	4.2	7	6.00	1.2	Z <sub>0</sub>	73.2	
3								
4								
5			=C2-D7					
6								
7		<b>Etchback factor</b>		1.00				
8								
9								
10								

The etch back factor will be a variable so assign W1 a value of **7.00**, locate the etch back factor in cell D7 and define W as C2–D7 (i.e. W1 minus etch back factor). Assign a value of **0.3** as etch back factor and insert the Surface Microstrip function into cell F6:

=Si8000.xls!SurfaceMicrostrip(A2,B2,C2,D2,E2,F2)

Press Shift-F9 to calculate.

### Calculating the effect of variations in Height

Next, chart the effect of varying height H1 in 0.05 steps. Create references to cells A2–F7 in cells A22–F22, add the surface microstrip function to G22 and change references B22–F22 to mixed as shown below (click into the formula and use the F4 key to change each reference).

= Si8000.xls!SurfaceMicrostrip1B(A22,B\$22,C\$22,D\$22,E\$22,F\$22)

14			<b>Step</b>	0.05			
15							
16	<b>H1(var)</b>					<b>Zo(H1)</b>	
17	8.25					74.2	
18	8.2			=A22+\$D\$14		74.0	
19	8.15					73.8	
20	8.1					73.6	
21	8.1					73.4	
22	8.0	-4.2	-7.0	-6.0	-1.2	Zo	73.2
23	8.0						73.0
24	7.9						72.8
25	7.85						72.5
26	7.8			=A22-\$D\$14			72.3
27	7.75						72.1
28							
29	=SI8000.xls!SurfaceMicrostrip1B(A22,B\$22,C\$22,D\$22,E\$22,F\$22)						

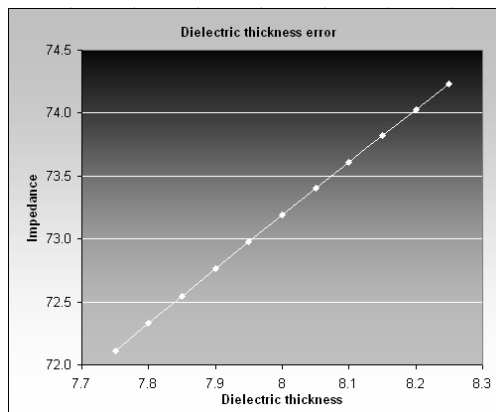
Copy the formula in G22 up to cell G17 and down to G27 as shown above

Create a step value of **0.05** in D14, enter the equation **=A22+\$D\$14** in cell A21 and fill it up to A17.

Enter the equation **=A22-\$D\$14** in cell A23 and fill it down to A27.

Use the Auditing Toolbar Trace Precedent and Dependent arrows to check references are as shown above. Press Shift-F9 to recalculate.

Select ranges H1(var) A17:A27 and Zo(H1) G17:G27 and chart; the chart should appear as below.





### Charting trace width error

Next we chart the effect of varying the trace width with a fixed trace side slope

33			<b>Step</b>	0.1		
34						
35			<b>W1(var)</b>	<b>W2(var)</b>		<b>Step</b>
36			6.5	5.5		75.5
37			6.6	5.6		75.0
38			6.7	5.7		74.6
39	=C41-\$D\$33		6.8	5.8		74.1
40			6.9	5.9	=C40-\$D\$7	73.6
41	9.0	4.2	7.0	6.0	1.2	Z0
42			7.1	6.1		72.7
43	=C41+\$D\$33		7.2	6.2	=C42-\$D\$7	72.3
44			7.3	6.3		71.9
45			7.4	6.4		71.4
46			7.5	6.5		71.0
47						
48	=SI8000.xls!SurfaceMicrostrip1B(A\$41,B\$41,C41,D41,E\$41,F\$41)					
49						

Create references to A2:F2 in cells A41:F41.

Enter the formula

**=SI8000.xls!SurfaceMicrostrip(A\$41,B\$41,C41,D\$41,E\$41,F\$41)**

in cell G41 and copy it up to G36 and down to G46 as shown. (Note that B41 and C41 are left as relative references.)

Create a step value of **0.10** in cell D33.

Enter formula **=D41-\$D\$33** in cell C40 and fill up to C36.

Enter formula **=C40-\$D\$7** in cell B40 and fill up to B36.

Enter formula **=C42-\$D\$7** in cell B42 and fill down to B46.

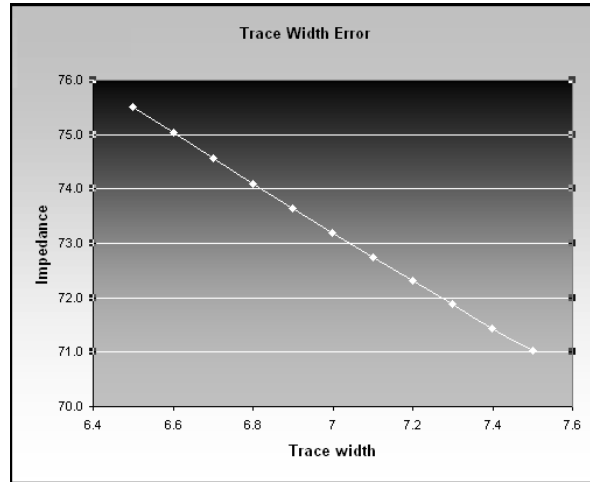
Enter formula **=C41+\$D\$33** in cell C42 and fill down to C46.

Use the auditing arrows to check cell precedents and dependencies.

Recalculate.

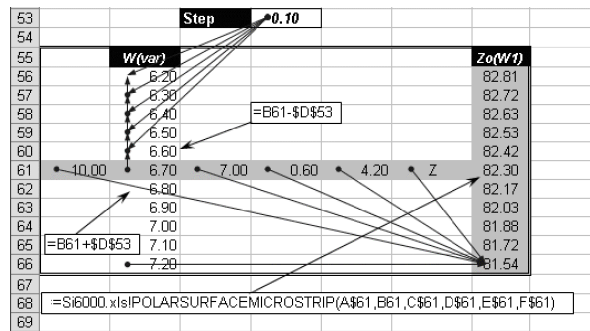
Select ranges C36:C46 and G36:G46 and chart.

The trace width error chart should appear as shown below.



### Charting etch back error

Finally, we chart the effect of etch back error.



Create references to cells A2:F2 in cells A61:F61.

Enter the function

**=Si8000.xls!POLARSURFACEMICROSTRIP(A\$61,B61,C\$61,D\$61,E\$61,F\$61)**

in cell G61. (Note the relative reference to cell B61.) Fill up to G56 and down to G66.

Create a step value of 0.10 in cell D53

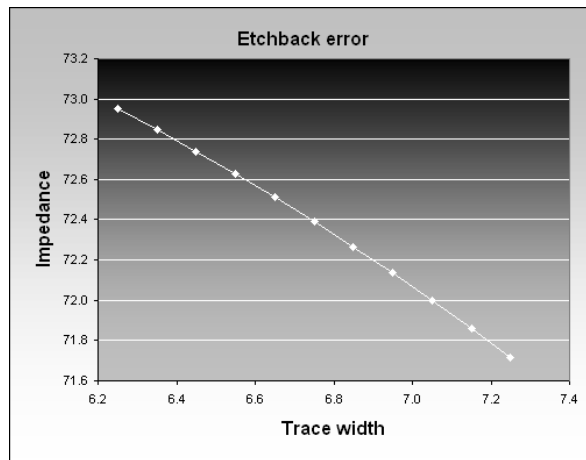
Enter the formula  $=B61-\$D\$53$  in cell B60 and fill up to B56.

Enter the formula  $=B61+\$D\$53$  in cell B62 and fill down to B56.

Audit the precedents and dependencies.

Select cell ranges W(var) B56:B66 and Z<sub>0</sub>(W1) G56:G66 and chart.

The chart for an etch back error of 0.25 appears below.



Change the etch back factor cell value in cell D7 and recalculate to observe the change in impedance of a different trace side slope.

## Appendix

For further relevant papers and application notes  
visit the Polar Instruments web site,  
[www.polarinstruments.com](http://www.polarinstruments.com).

## Terms used in this manual

AC	Alternating Current
CMOS	Complimentary Metal Oxide Silicon
DC	Direct Current
ECL	Emitter Coupled Logic
EMI	Electromagnetic Interference
FR-4	Epoxy Glass Dielectric Material
TDR	Time domain Reflectometry
TTL	Transistor-Transistor Logic
$Z_0$	Characteristic Line Impedance
$Z_0'$	Characteristic Line Impedance (Loaded)
$E_r$	Relative Permittivity (homogeneous dielectric materials)
$E_r'$	Effective Relative Permittivity (non-homogeneous dielectric materials)



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