Si6000b Controlled Impedance Field Solver

User Guide

Polar Instruments Ltd

Polar Instruments Ltd.
Garenne Park
St. Sampson
Guernsey
Channel Islands
GY2 4AF
ENGLAND

Fax: +44 (0)1481 252476

email: mail@polarinstruments.com
http://www.polarinstruments.com

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Si6000b User Guide

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TRADEMARKS

Personal Computer Requirements

Computer	IBM PC AT or compatible
Processor	Pentium 500 or better
Operating system	Microsoft Windows 95, Windows 98 Microsoft Windows NT, Windows 2000
System memory required	128MB recommended
Hard disk space required	100MB (min.)
Video standard	SVGA (1024 x 768 min.)
CDROM drive	
Mouse	Microsoft compatible
Spreadsheet	Microsoft Excel 97 or later

Guide To The Manual

Introduction	Introduces the Polar Instruments Si6000.
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 Si6000 Quick Solver	Using the Si6000 Quick Solver for single impedance, propagation delay, inductance and capacitance calculations.
Using the Si6000 functions	Learning the Si6000 functions using the supplied sample Si6000 workbook. Using the Si6000 functions in your own applications in Si6000 expert mode.
Reference	Technical background to calculation of PCB track impedance. Discussion of field solving, Green's Functions and methods of calculation used in the Si6000.

Specifications

Supported structures

Single-ended

Surface Microstrip
Coated Microstrip
Embedded Microstrip
Symmetrical Stripline
Offset Stripline
Edge coupled Surface Microstrip
Edge coupled Coated Microstrip
Edge coupled Embedded Microstrip
Edge coupled Symmetrical Stripline
Edge coupled Offset Stripline
Broadside Coupled Stripline
Surface Coplanar Strips
Surface Coplanar Waveguide
Surface Coplanar Strips with Ground
Surface Coplanar Waveguide with Ground
Coated Coplanar Strips
Coated Coplanar Waveguide
Coated Coplanar Strips with Ground
Coated Coplanar Waveguide with Ground
Embedded Coplanar Strips
Embedded Coplanar Waveguide
Embedded Coplanar Strips with Ground
Embedded Coplanar Waveguide with Ground

Differential

Offset Coplanar Strips
Offset Coplanar Waveguide
Differential Surface Coplanar Strips
Differential Surface Coplanar Waveguide
Differential Surface Coplanar Strips with Ground
Differential Surface Coplanar Waveguide with Ground

Contents

Introduction to the Si6000

The Si6000 Controlled Impedance Field Solver

The Polar Si6000 Controlled Impedance Field Solver uses advanced field solving methods to calculate PCB trace impedance for most single-ended and differential circuit designs. Using Method of Moments, the Field Solver is able to provide rapid modelling for a wide range of microstrip, stripline and coplanar structures.

The Si6000 comprises the Si6000 Quick Solver, for rapid calculation of single PCB trace impedance values against significant PCB parameters and a comprehensive set of advanced field solving methods incorporated as user-defined functions in the popular Microsoft Excel spreadsheet to enable advanced function, e.g. sensitivity analysis.

Evaluating PCB structure behaviour

The Polar Si6000 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 Si6000 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 SI6000 incorporates field solving for single-ended and differential impedance structures. The discrete numerical analysis in the SI6000 uses Boundary Finite Element Analysis 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 evaluation of the Green's Function using Method of Moments integration 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 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.

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

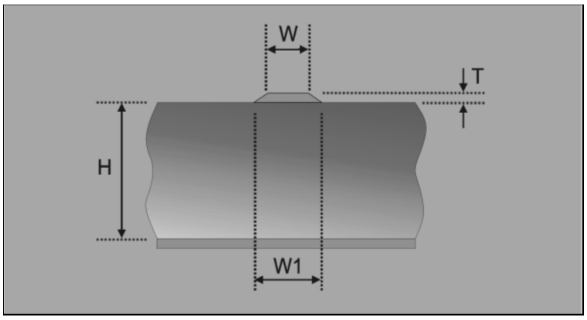
Single-ended Transmission Lines

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.

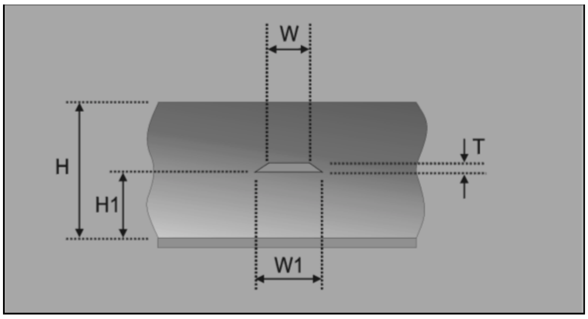
Surface Microstrip

In the diagram below (*surface*, or *exposed*, microstrip) the signal line is exposed (to air) and referenced to a power or ground plane.



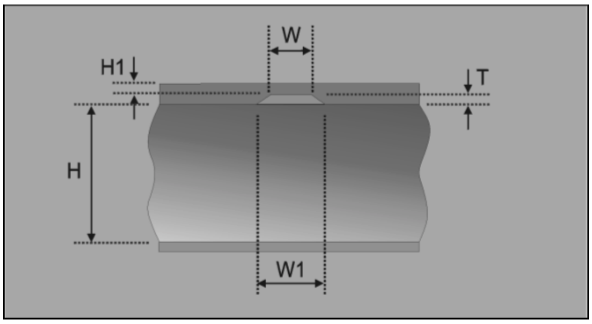
Embedded Microstrip

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



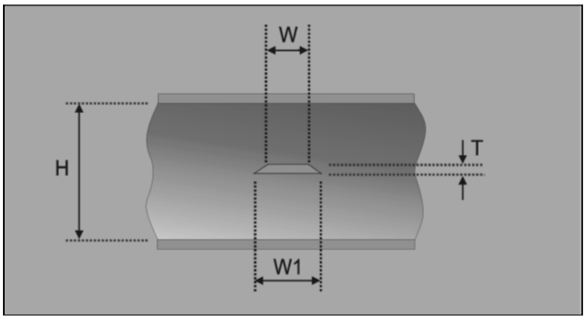
Embedding the signal line can lower the impedance by as much as 20% compared to an equivalent surface microstrip construction.

Coated Microstrip



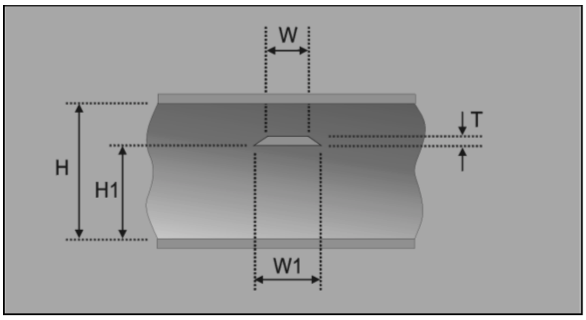
Coated microstrip is similar to the surface version, however the signal line is covered by a solder mask. This coating can lower the impedance by up to a few ohms depending on the type and thickness of the solder mask.

Symmetric Stripline



In this configuration the signal trace is sandwiched symmetrically between two planes. This is often difficult to achieve with normal manufacturing processes.

Offset Stripline



In this configuration the signal trace is sandwiched between two planes but is not 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).

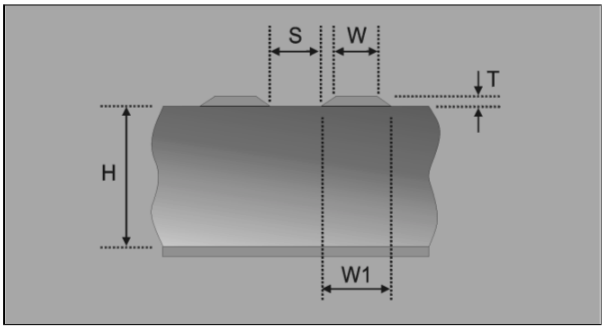
Differential Transmission Lines

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.

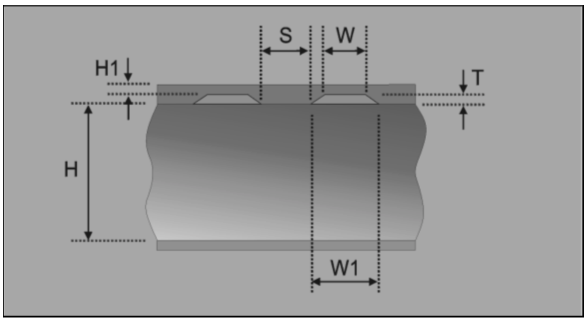
Note that in the following diagrams (except the Broadside-coupled Stripline) the traces are trapezoidal in profile and width, W, refers to the trace width nearest the upper surface, W_1 refers to the trace width nearest the lower surface.

Edge-coupled Surface Microstrip



In this construction the gap between the traces 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.

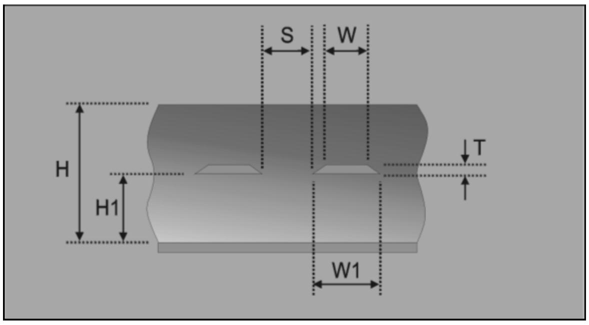
Edge-coupled Coated Microstrip



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.

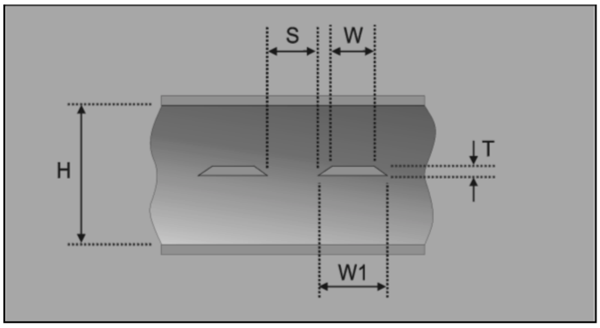
This construction is particularly sensitive to solder mask flooding with LPI (Liquid Photo Imagable) solder mask. This causes the dielectric constant in the edge coupling region to vary, depending on flood depth.

Edge-coupled Embedded Microstrip



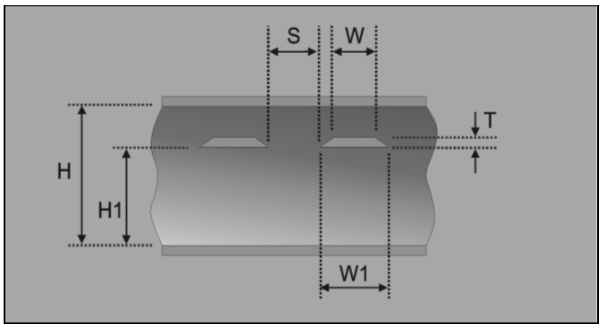
The reduced processing of internal layers makes the Edge-coupled Embedded Microstrip construction easy to fabricate with more consistent results than the equivalent surface trace structure.

Edge-coupled Symmetric Stripline



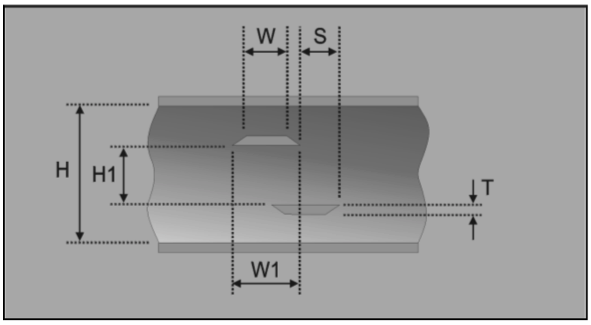
The Edge-coupled Symmetric Stripline is the simplest differential construction possible, though it may prove difficult to maintain the signal traces exactly in the centred position. Any offset from the centred position will reduce the impedance.

Edge-coupled Offset Stripline



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 are routed orthogonally to minimise layer to layer coupling and crosstalk.

Broadside-coupled Stripline



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.

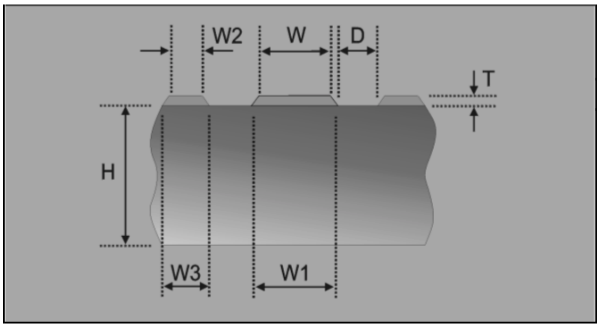
Note that in the Broadside-coupled Stripline case the traces are trapezoidal in profile and width, W, refers to the trace width nearest the surfaces, W_1 refers to the trace width nearest the Center Line.

Coplanar Lines

Most Microstrip and Stripline transmission line structures can be manufactured in a Coplanar version. Coplanar structures show only minor dispersion effects compared to microstrip lines.

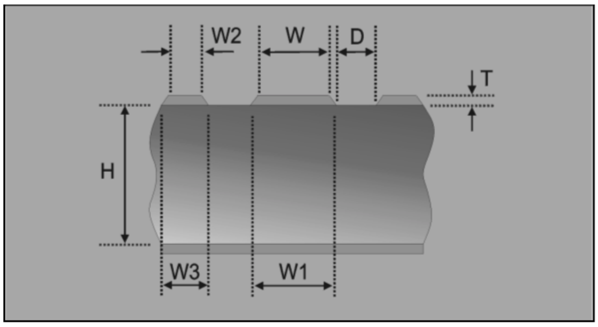
Coplanar Lines incorporate ground conductors adjacent to the controlled impedance trace(s) in the same plane as the trace(s).

Surface Coplanar Strips



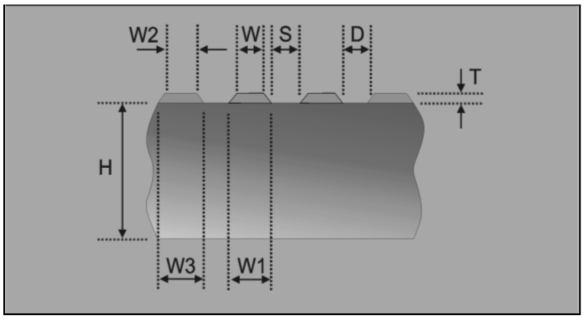
Surface Coplanar Strips with Ground

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 which will typically be used in consumer applications.

Differential Surface Coplanar Strips



Installing the Si6000 Field Solver

Activating the Si6000

Minimum system requirements

The Si6000 requires a system with the following characteristics:

IBM PC compatible

Pentium (500MHz or better recommended)

Mouse

Parallel port

100MB free hard disk space

128MB RAM recommended

Windows 95/98/ME, Windows NT 4.0/2000

Excel 97, 2000 or 2002

Installing the software key

It will be necessary to activate the Si6000 software prior to use. Insert the software key into the parallel printer port socket; if necessary, plug the printer cable into the software key.

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

Uninstalling the software

To uninstall the Si6000 software click the Windows Start button and choose Settings and Control Panel.

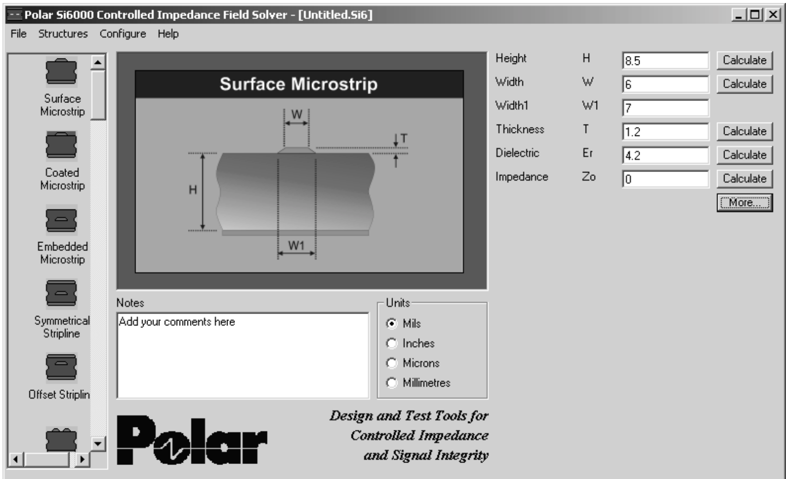
Double-click Add/Remove Programs and choose Si6000b from the list. Click Remove.

Using the Si6000 Quick Solver

The Si6000 Quick Solver

The Si6000 Quick Solver allows the operator to perform rapid single calculations of PCB trace values against significant PCB parameters. The Si6000 Quick Solver solves for impedance, propagation delay and inductance and capacitance per unit trace length.

Click the Si6000 Quick Solver icon on the desktop to start the Si6000 Quick Solver.



Si6000 Quick Solver

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 values for:

H (Height) — dielectric thickness

W and W1 (Width) — signal trace width (allowing for finished etch factor)

T (Thickness) — signal trace thickness

Er — dielectric constant

into the text boxes and press the Calculate button

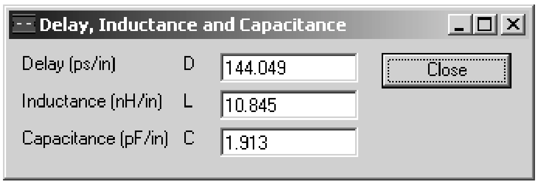
The calculated impedance will appear in the Impedance (Z_o) box.

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

Calculating propagation delay, inductance and capacitance

Click on the configuration from the Structures menu or from the Structures bar.

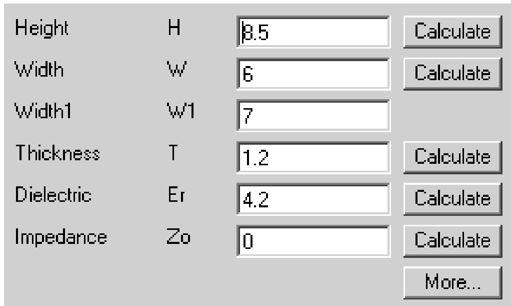
Enter the parameter values as described above into the text boxes and press the More… button.



The Si6000 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 quickly solve for board parameters given a nominal impedance value.



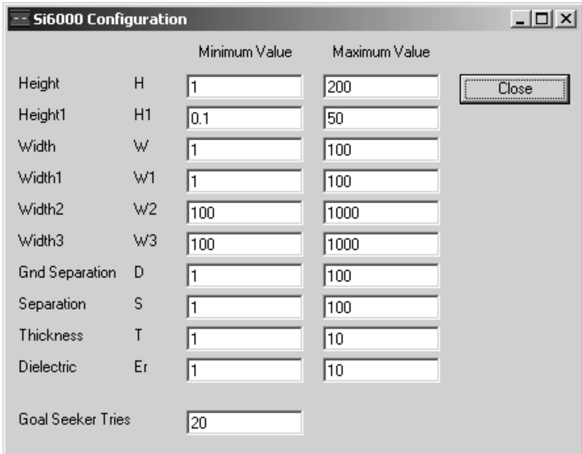
Enter the given board dimensions in their associated fields and the nominal impedance value in the Impedance field and click the Calculate button against the unknown dimension, e.g. Height, Width, etc.

Setting Si6000 parameter limits

The Si6000 is designed to work with “real world” values. If the parameter values used in calculation are beyond the Si6000 limits, the Si6000 returns a value of zero.

The user is able to control the values used by the Si6000 field solving engine during calculation.

Click the Configure menu; the Si6000 Configuration dialog is displayed.



Enter the values for minimum and maximum for each parameter and number of calculation iterations (Si6000 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.

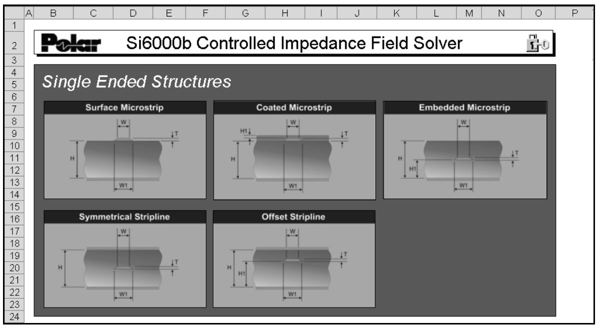
Using the Si6000 Field Solver

Starting the Field Solver

Note: the graphics displayed in this section are based on Microsoft Excel 2002. Dialog box graphics from earlier 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 Si6000b.xls and Si6000Expert.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 Si6000b.xls workbook includes pre-built sample data worksheets incorporating tables of functions and their associated parameters.

Double click the Field Solver icon on the desktop; Microsoft Excel opens the Si6000b.xls workbook at the Si6000 index sheet.



Si6000 index sheet — Single Ended Structures

Si6000 structure categories

The index sheet displays the Si6000 structure categories:

Single Ended

Differential

Surface Coplanar

Coated Coplanar

Embedded Coplanar

Offset Coplanar

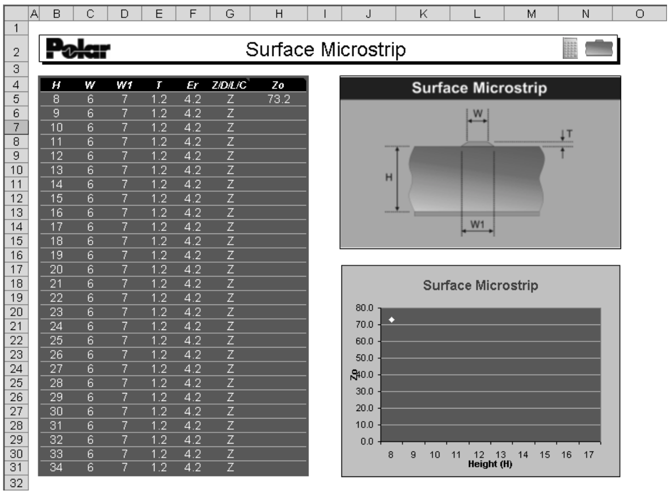
Differential Surface Coplanar

Differential Coated Coplanar

Differential Embedded Coplanar

Differential Offset Coplanar

To select a structure scroll to the category and click on its graphic. e.g. Surface Microstrip. The Si6000 selects the associated worksheet.



Surface Microstrip sample worksheet

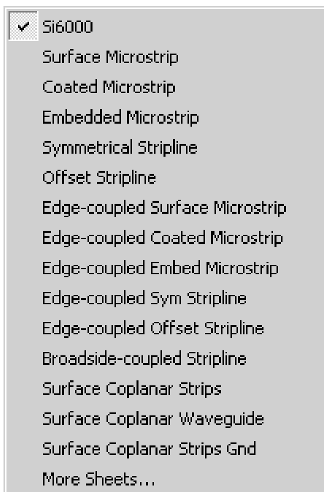
Moving through the structure sheets

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 (Z_0 is shown against a varying Height (H) in the sample chart).

4	H	W	W1	T	Er	Z/D/L/C	Zo
5	8	6	7	1.2	4.2	Z	73.2
6	9	6	7	1.2	4.2	Z	
7	10	6	7	1.2	4.2	Z	
8	11	6	7	1.2	4.2	Z	
9	12	6	7	1.2	4.2	Z	
10	13	6	7	1.2	4.2	Z	
11	14	6	7	1.2	4.2	Z	
12	15	6	7	1.2	4.2	Z	
13	16	6	7	1.2	4.2	Z	
14	17	6	7	1.2	4.2	Z	
15	18	6	7	1.2	4.2	Z	
16	19	6	7	1.2	4.2	Z	

Sample table with increasing values of H

The sheet opens with the single value of Z_0 calculated for the structure dimensions shown in row 5. The function is located in the cell labelled Z_0, the parameters for the function are contained in the associated cells labelled H, W, W1, etc.

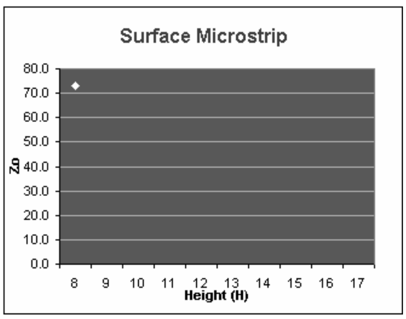
Choosing the calculation type, Z, D, L,C

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 **Z/D/L/C**), move to another cell and press the Calculate button. Re-label the results column if necessary.

H	W	W1	T	Er	Z/D/L/C	D
8	6	7	1.2	4.2	D	5680.4

Charting against varying board parameters

The Si6000 sheet opens with the value of Z_0 against H for the structure dimensions shown in row 5 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.

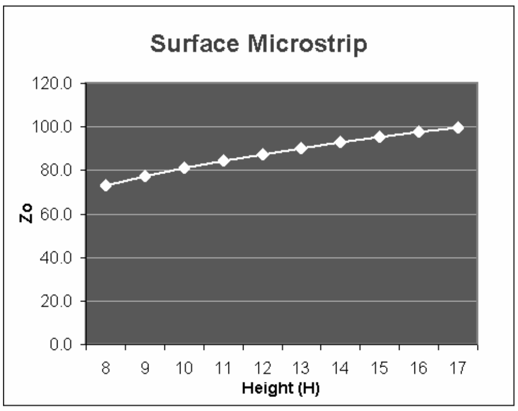
If the Fill Handle does not appear, select **Tools|Options|Edit** and tick the **Allow cell drag and drop** check box.)

Er	Z/D/L/C	D
4.2	Z	73.2
4.2	Z	
4.2	Z	
4.2	Z	
4.2	Z	
4.2	Z	
4.2	Z	
4.2	Z	
4.2	Z	
4.2	Z	
4.2	Z	
4.2	Z	

Use Excel's Fill Handle to copy the formula down

Press the Calculate button to recalculate the worksheet. (The Si6000b Workbook sets Excel's Calculation mode to Manual; see **Tools|Options|Calculation**). The Si6000 field solves for all associated rows and refreshes the chart.

H	W	W1	T	Er	Z/D/L/C	D
8	6	7	1.2	4.2	Z	73.2
9	6	7	1.2	4.2	Z	77.3
10	6	7	1.2	4.2	Z	80.9
11	6	7	1.2	4.2	Z	84.2
12	6	7	1.2	4.2	Z	87.3
13	6	7	1.2	4.2	Z	90.1
14	6	7	1.2	4.2	Z	92.7
15	6	7	1.2	4.2	Z	95.2
16	6	7	1.2	4.2	Z	97.5
17	6	7	1.2	4.2	Z	99.7
18	6	7	1.2	4.2	Z	101.8
19	6	7	1.2	4.2	Z	103.7



Plot of Z_0 as Height (H) 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 H to a single value, e.g. 8, and plot Z_0 against changes of E_r between in 0.1 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.

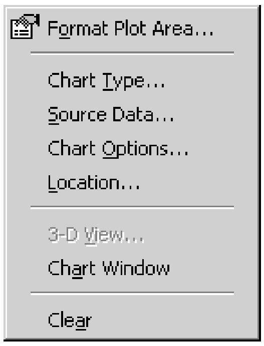
Click the Calculate icon to refresh the Z_0 column.

H	*W*	*W1*	*T*	*Er*	*Z/D/L/C*	*Z*
8	6	7	1.2	3.8	Z	76.4
8	6	7	1.2	3.85	Z	75.9
8	6	7	1.2	3.9	Z	75.5
8	6	7	1.2	3.95	Z	75.1
8	6	7	1.2	4	Z	74.7
8	6	7	1.2	4.05	Z	74.4
8	6	7	1.2	4.1	Z	74.0
8	6	7	1.2	4.15	Z	73.6
8	6	7	1.2	4.2	Z	73.2
8	6	7	1.2	4.25	Z	72.9
8	6	7	1.2	4.3	Z	72.5
8	6	7	1.2	4.35	Z	72.1

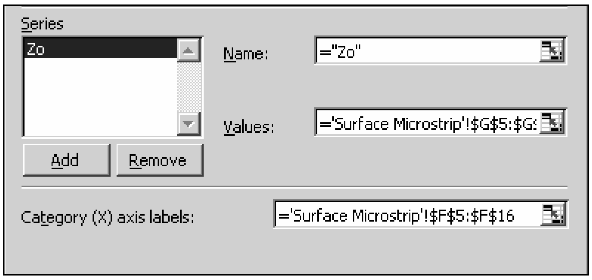
Modifying the chart

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.



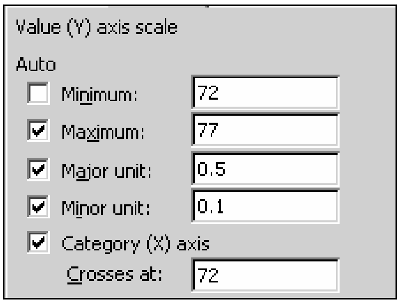
Click the Collapse Dialog button, ( ), in the Category (X) axis labels: edit box and select the range of Er values charted.

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

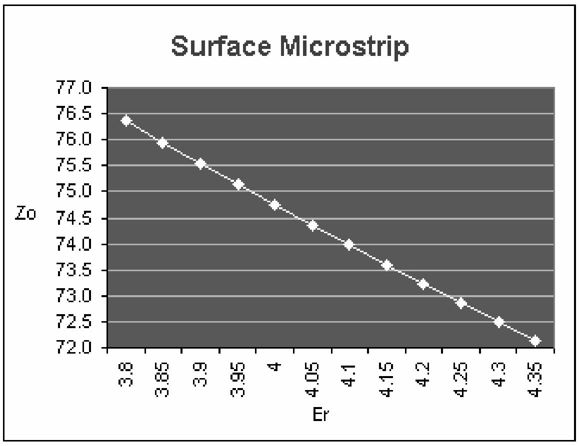
Click the Category Axis Title label and replace the H with Er.

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.



Press OK. The chart should appear as shown below.



Repeat the procedure for other parameter values.

Using the Si6000 functions in other workbooks

The Si6000b functions supplied by the Si6000 workbooks, Si6000b.xls or Si6000bExpert.xls, are available for use in other workbooks.

Prior to using any of the Si6000b functions it will be necessary to ensure the Si6000b.xls workbook or Si6000bExpert.xls is open. In this discussion the worksheet is assumed to refer to the Si6000b.xls workbook.

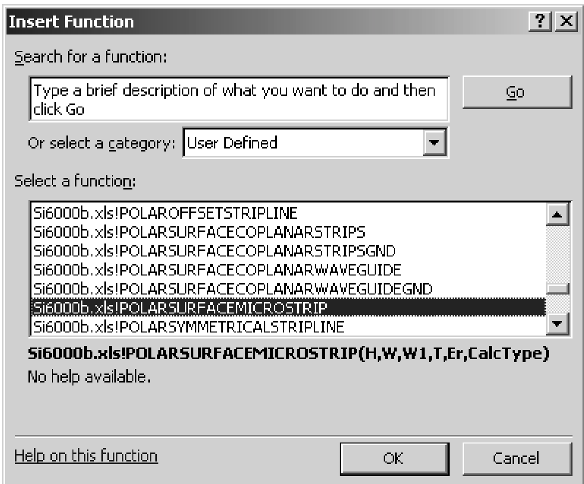
The Si6000 functions use the board parameters, H, W, E_r etc. as arguments. Parameter values can be derived from existing data in worksheet cells or inserted into the Formula Palette directly.

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 Si6000 Surface Microstrip function into cell H4.

	A	B	C	D	E	F	G	H	I
1									
2									
3		H	W	W1	T	Er	Calc Type	Zo	
4		8	6	7	1.2	3.8	Z		
5									
6									

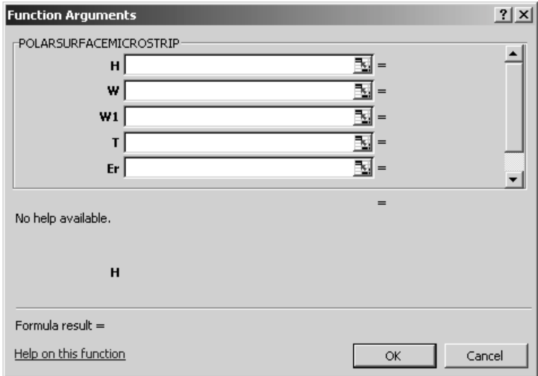
To use a function, from the **Insert** menu choose **Function…** or click the **Insert Function** button on the tool bar. The Paste Function dialog box is displayed. Choose the **User Defined** category to display the user-defined functions.



Scroll to the Si6000 functions; click the function associated with the surface microstrip structure (Si6000b.xls!POLARSURFACEMICROSTRIP() in this example) and click OK: the Formula Palette is displayed.

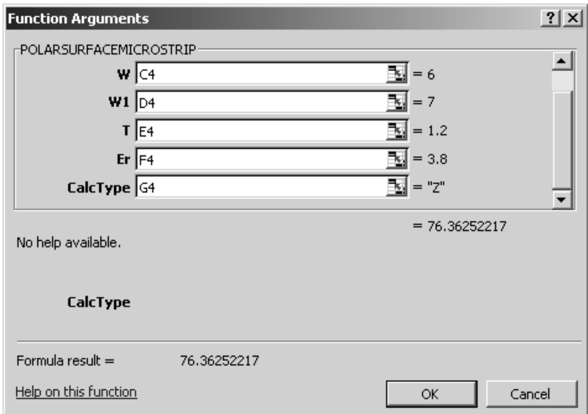
Using the Formula Palette to entering formulas

The Excel Formula Palette can help reduce errors when entering function parameters. The Formula Palette creates an edit box for each argument in the function.



Click the Collapse Dialog button ( ) in the **H** 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		**H**	**W**	**W1**	**T**	**Er**	**Calc Type**	**Zo**	
4		8	6	7	1.2	3.8	Z	76.36252	
5									
6									

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.

H	W	W1	T	Er	Calc Type	Zo
8	6	7	1.2	3.80	Z	76.36
8	6	7	1.2	3.85	Z	75.95
8	6	7	1.2	3.90	Z	75.54
8	6	7	1.2	3.95	Z	75.14
8	6	7	1.2	4.00	Z	74.74
8	6	7	1.2	4.05	Z	74.35
8	6	7	1.2	4.10	Z	73.97
8	6	7	1.2	4.15	Z	73.59
8	6	7	1.2	4.20	Z	73.22
8	6	7	1.2	4.25	Z	72.86
8	6	7	1.2	4.30	Z	72.50

Z_0 calculated for changing E_r

Charting results

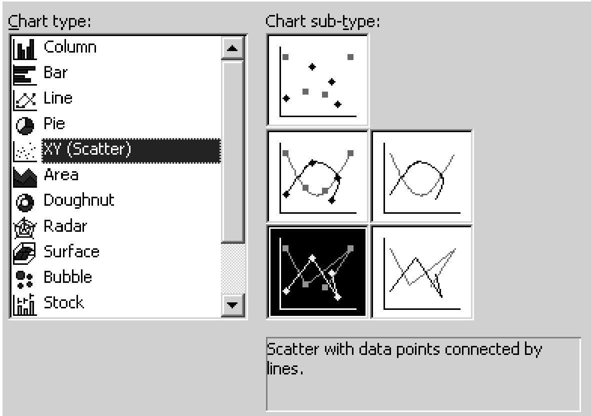
Use the Excel Chart Wizard to chart the results.

Select the area to be charted: in this example the E_r and Z_0 ranges (to select non-adjacent ranges, press Ctrl while dragging the mouse over each range).

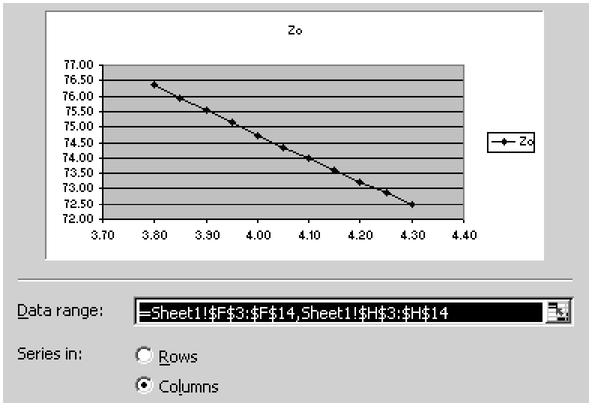
T	Er	Calc Type	Zo
1.2	3.80	Z	76.36
1.2	3.85	Z	75.95
1.2	3.90	Z	75.54
1.2	3.95	Z	75.14
1.2	4.00	Z	74.74
1.2	4.05	Z	74.35
1.2	4.10	Z	73.97
1.2	4.15	Z	73.59
1.2	4.20	Z	73.22
1.2	4.25	Z	72.86
1.2	4.30	Z	72.50

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

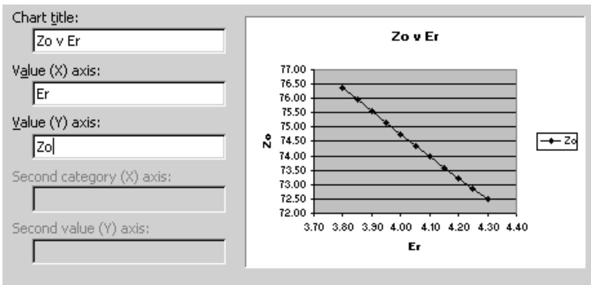


Click Next to select Step 2, Chart Source Data.

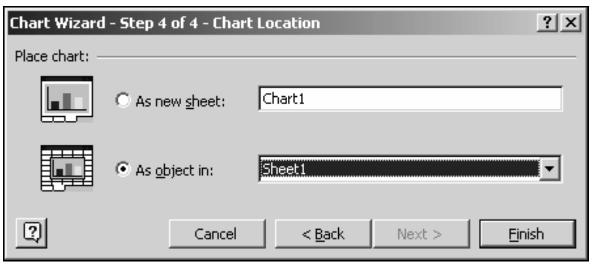


Check the Data Range: cell references are correct: leave the Series in: option set to Columns.

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



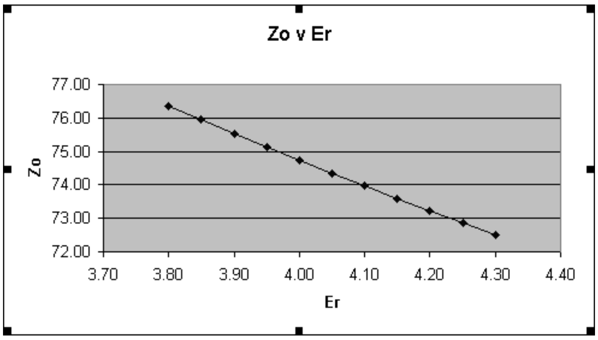
Click Next to select Step 4, Chart Location.



Use this dialog box to choose where Excel creates the chart.

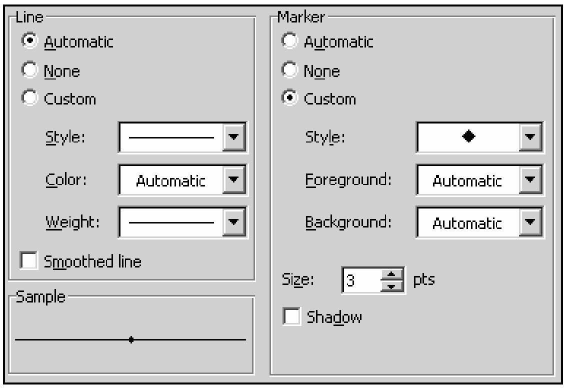
To place the chart on a new chart sheet, click **As new sheet:**, and type a name for the new chart sheet.

To embed the chart on the worksheet, click **As object in:**, select a sheet name from the As object in 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 Si6000 to plot multiple data series

Inserting the first data series

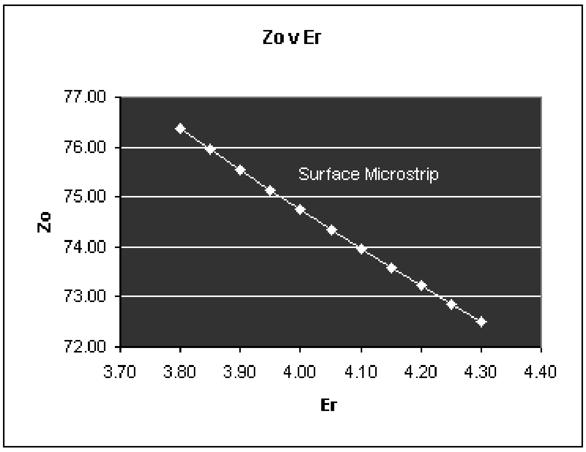
Supply the data and plot the data series for Surface Microstrip as described earlier.

Surface Microstrip

H	W	W1	T	Er	Calc Type	Zo
8	6	7	1.2	3.80	Z	76.36
8	6	7	1.2	3.85	Z	75.95
8	6	7	1.2	3.90	Z	75.54
8	6	7	1.2	3.95	Z	75.14
8	6	7	1.2	4.00	Z	74.74
8	6	7	1.2	4.05	Z	74.35
8	6	7	1.2	4.10	Z	73.97
8	6	7	1.2	4.15	Z	73.59
8	6	7	1.2	4.20	Z	73.22
8	6	7	1.2	4.25	Z	72.86
8	6	7	1.2	4.30	Z	72.50

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>; place the text as required.



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

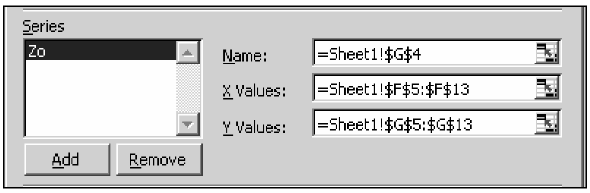
Adding the second data series

Supply the data for the Coated Microstrip structure.

Coated Microstrip

H	H1	W	W1	T	Er	Calc Type	Zo
8	1	6	7	1.2	3.80	Z	70.72
8	1	6	7	1.2	3.85	Z	70.30
8	1	6	7	1.2	3.90	Z	69.89
8	1	6	7	1.2	3.95	Z	69.48
8	1	6	7	1.2	4.00	Z	69.08
8	1	6	7	1.2	4.05	Z	68.69
8	1	6	7	1.2	4.10	Z	68.31
8	1	6	7	1.2	4.15	Z	67.93
8	1	6	7	1.2	4.20	Z	67.56
8	1	6	7	1.2	4.25	Z	67.13
8	1	6	7	1.2	4.30	Z	66.74

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 E_r column.

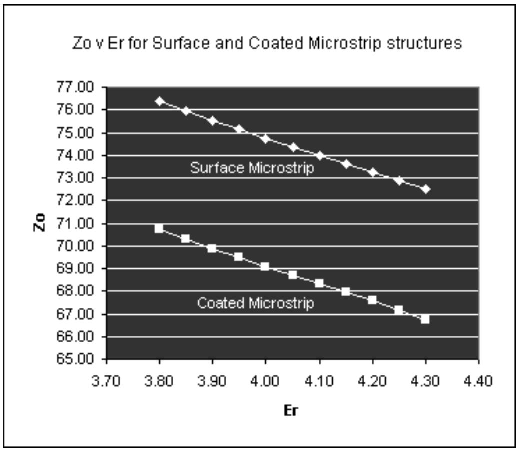
T	Er	Calc Type
1.2	3.80	Z
1.2	3.85	Z
1.2	3.90	Z
1.2	3.95	Z
1.2	4.00	Z
1.2	4.05	Z
1.2	4.10	Z
1.2	4.15	Z
1.2	4.20	Z
1.2	4.25	Z
1.2	4.30	Z

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

Er	Calc Type	Zo
3.80	Z	70.72
3.85	Z	70.30
3.90	Z	69.89
3.95	Z	69.48
4.00	Z	69.08
4.05	Z	68.69
4.10	Z	68.31
4.15	Z	67.93
4.20	Z	67.56
4.25	Z	67.13
4.30	Z	66.74

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 65 as the minimum value.



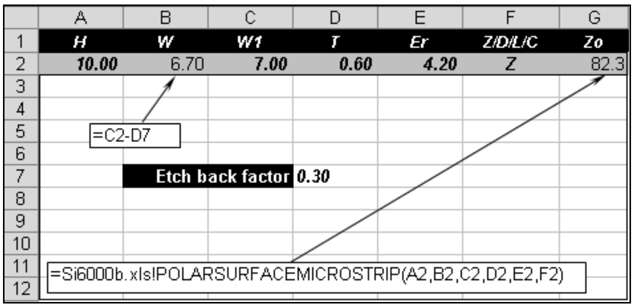
Use the Formula Bar to add explanatory text as necessary.

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 (H) and trace width (W). We use the surface microstrip structure.

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



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;

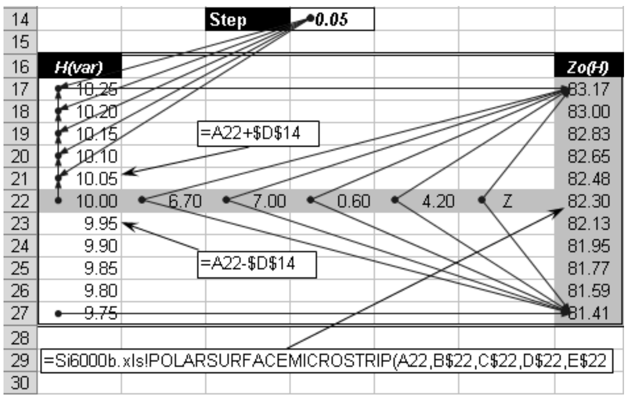
=Si6000b.xls!POLARSURFACEMICROSTRIP(A2,B2, C2,D2,E2,F2)

Press Shift-F9 to calculate.

Calculating the effect of variations in H

Next, chart the effect of varying height H in 0.05 steps. Create references to cells A2–F7 in cells A22–F22 and change each reference B22–F22 to mixed.

=
Si6000b.xls!POLARSURFACEMICROSTRIP(A22,B$2 2,C$22,D$22,E$22,F$22)



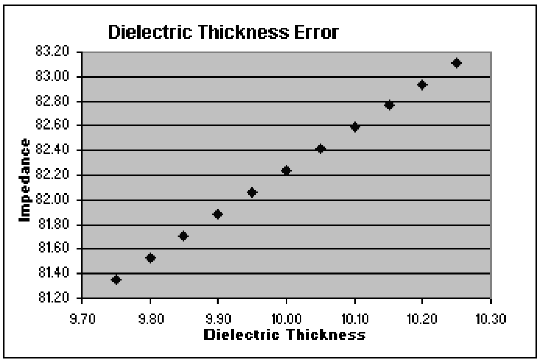
Copy the formula in G22 up to cell G17 and down to G27 as shown above

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.

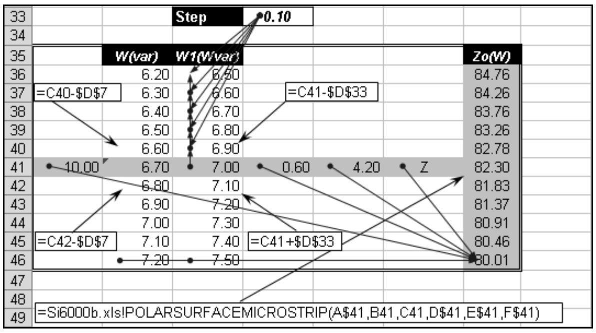
Use the Auditing Toolbar Trace Precedent and Dependent arrows to check references are as shown above. Press Shift-F9 to recalculate.

Select ranges H(var) A17:A27 and Z_0(H) 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



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

Enter the formula

=Si6000b.xls!POLARSURFACEMICROSTRIP(A$41,B41,C41,D$41,E$41,F$41)

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

Create a step value of 0.10 in cell D33.

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

Enter formula **=C41-$D$33** in cell C40 and fill up to C36.

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

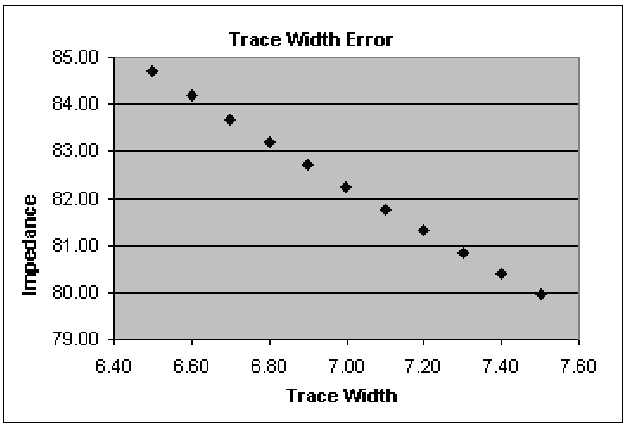
Enter formula **=C41+$D$33** in cell C42 and fill down to C46.

Use the auditing arrows to check cell precedents and dependencies.

Recalculate.

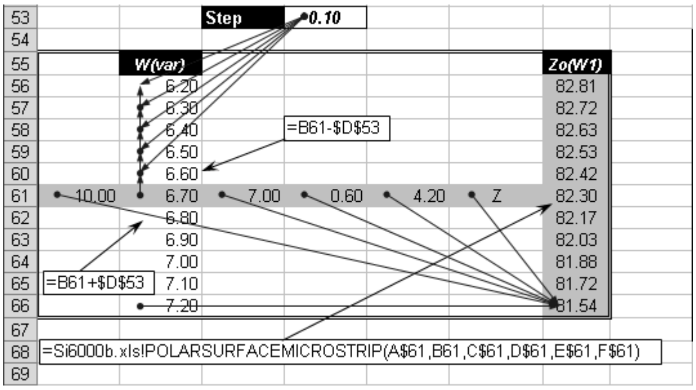
Select ranges C36:C46 and G36:G46 and chart.

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

=Si6000b.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

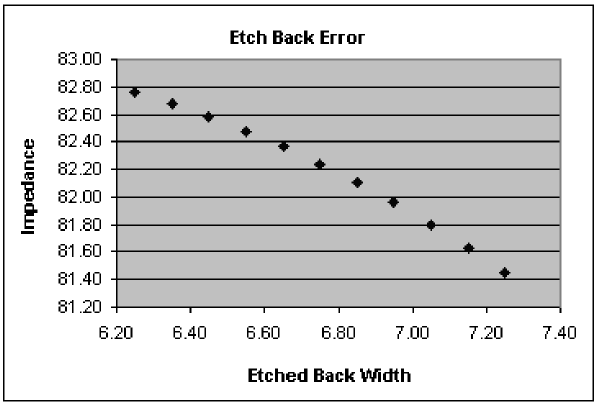
Enter the formula **=B61-$D$53** in cell B60 and fill up to B56.

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_0(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.