The New ADX Interface for Design and Analysis of Experiments

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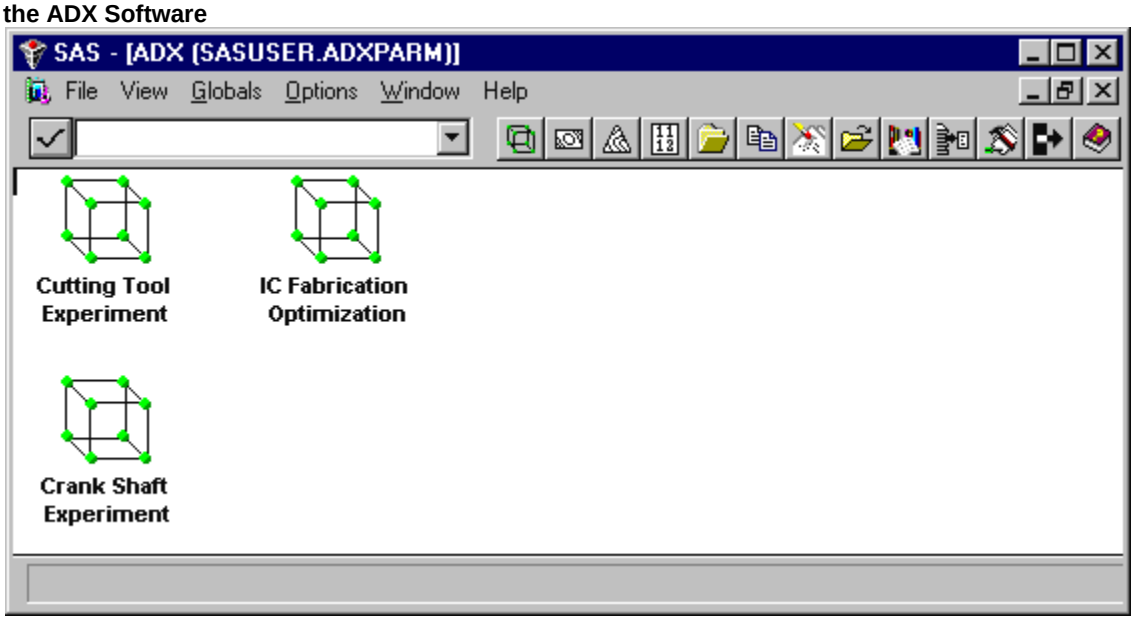
Introduction

The ADX environment provides a point-and-click interface for designing and analyzing standard experiments that is intended primarily for quality engineers, researchers, and other non-statisticians. Support is provided for construction of two-level designs, response surface designs, designs for Taguchi applications, mixture designs, and optimal designs. The new interface described in this presentation is more intuitive, offers greater customization of results, and provides a desktop for viewing and organizing designs, as well as a journaling facility. Interactive graphics have been added to facilitate analysis and optimization, and new plotting techniques such as profile plots have been incorporated. For more advanced users, the new ADX interface offers direct interfaces to the FACTEX and OPTEX procedures.

Invoking the ADX Software



When you invoke the ADX interface you first see the ADX desktop with the icons representing any designs that you previously constructed and saved. The ADX desktop provides a placeholder to organize and view the designs. You can copy a design, view a design summary, or export a design to a data set from the desktop. The following example illustrates how a design is constructed and analyzed using the ADX interface.

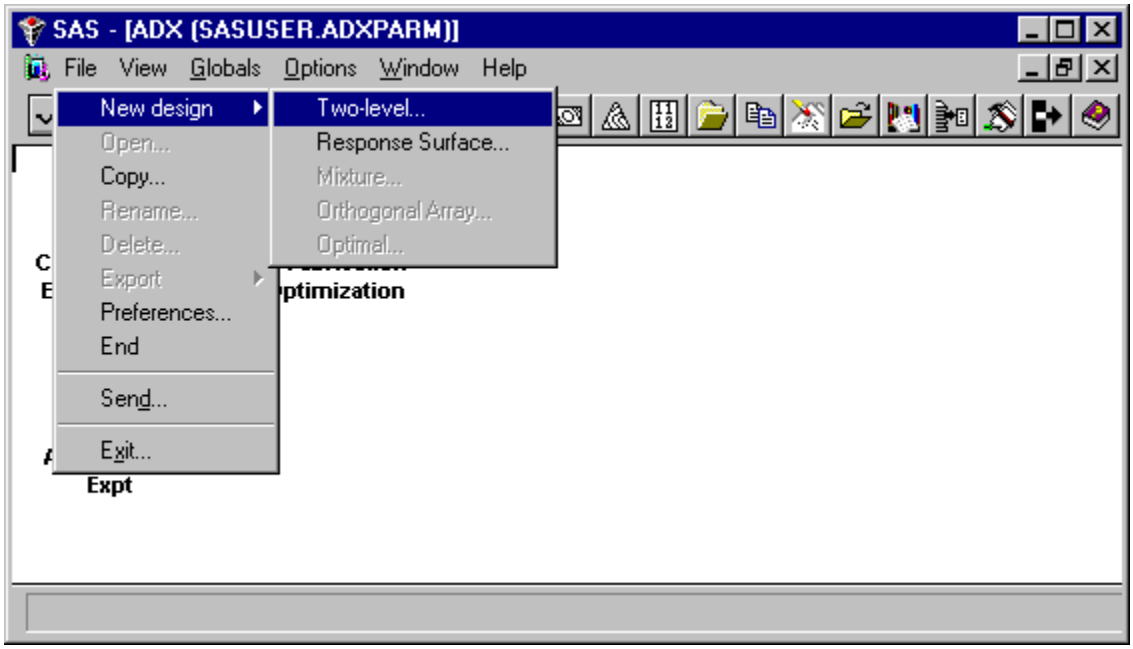
Example

This example comes from a wafer production facility in the semiconductor industry. The objective of the experiment is to improve the process of growing an epitaxial layer on polished silicon wafer used in IC fabrication. Five factors that affect the process performance were selected, and two levels of each factor were chosen. The response variables are layer thickness (THCKNESS) and layer resitivity (RESTIVTY).

Factor Name	Factor Label	Low Level	High Level
TEMP	Deposition Temperature (deg C)	1210	1220
FLOW	Arsenic Flow Rate (%)	55	60
TIME	Deposition Time (sec)	10	16
ETCH	Etch Temperature (deg C)	1180	1200
ACID	Acid Flow Rate (%)	8	14

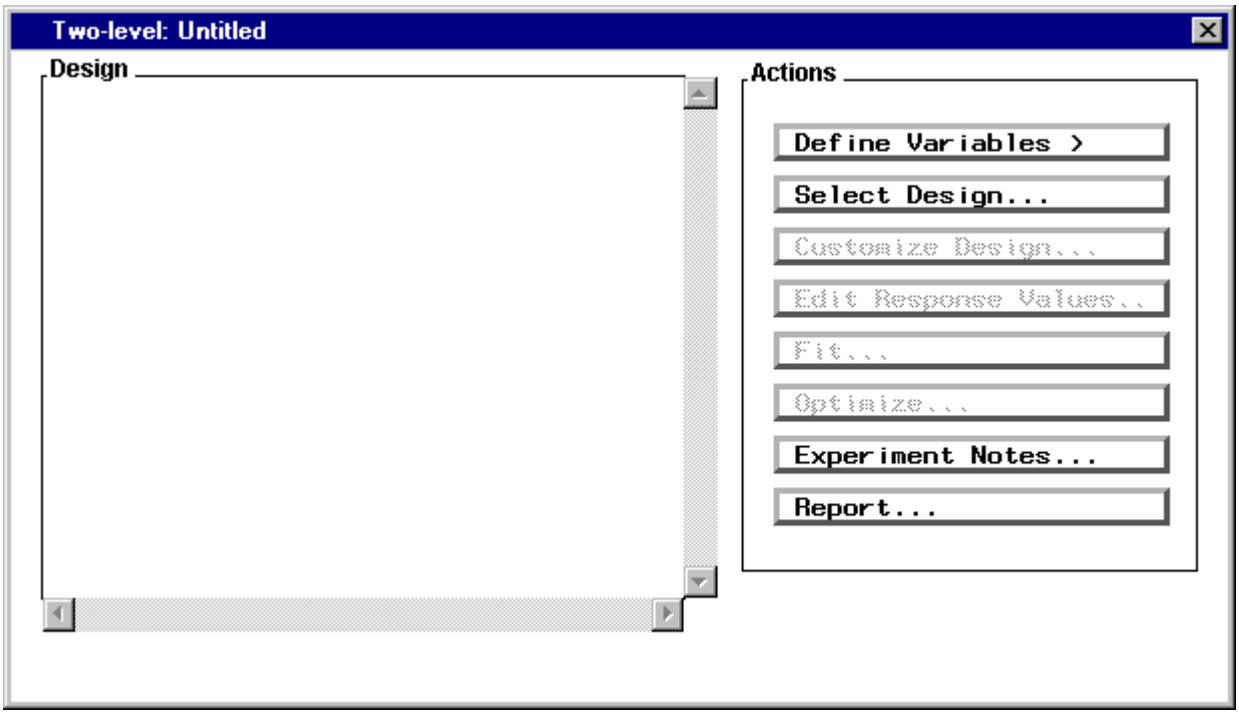
Creating a New Design

To create a new design, select **File** from the pull-down menu in the ADX desktop window, click **New Design** and choose the type of design that you want to construct from the available choices: Two-level, Response Surface, Mixture, Orthogonal Array, and Optimal design. For this example, choose the item **Two-level**. To open an existing design, you would double click the appropriate design icon on the desktop. Either way takes you to the main ADX window.



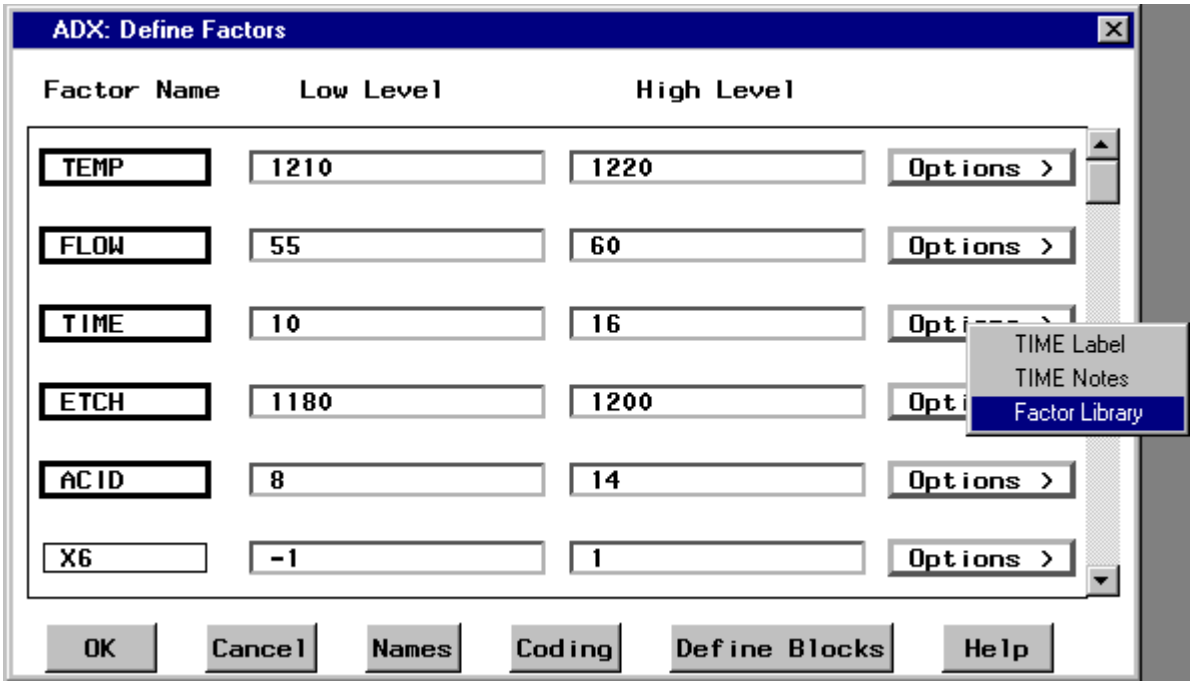
Main ADX Window

The main window guides you through the design and analysis of an experiment. The **Actions** buttons on the right side are organized in the logical sequence that an experimenter follows to construct and analyze a design. You typically start at the top and work your way down as the design construction progresses.

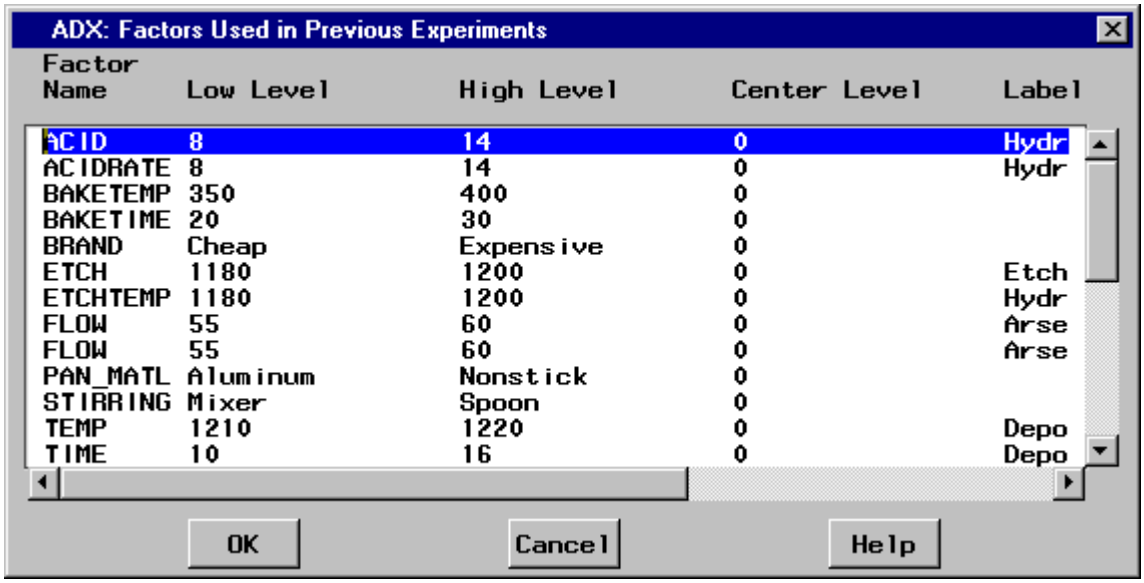


To begin specifying a new design, you can either enter factor names and levels or select a design. When you press the **Define Variables >** button and select **Factors and Levels...** item you get the Factor and Block definition screen.

Factor Definition
Enter the names and levels for the five factors. Optionally you can provide factor information such as units, label, and background information.

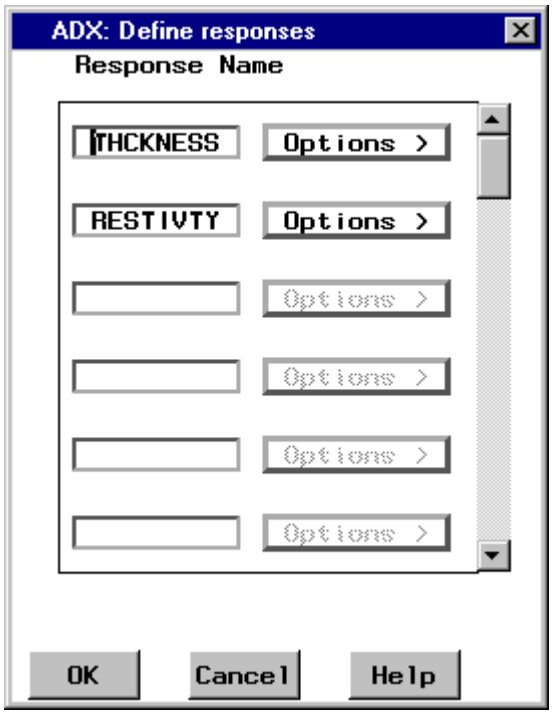


From the Factor Definition window, you can select **Factor Library** by clicking on the **Options >** button available on each row in the factor list. ADX memorizes the factor names and levels used in the previous experiments and displays them in the **Factor Library**. This is a convenient way to specify factor names and levels without having to retype the information.



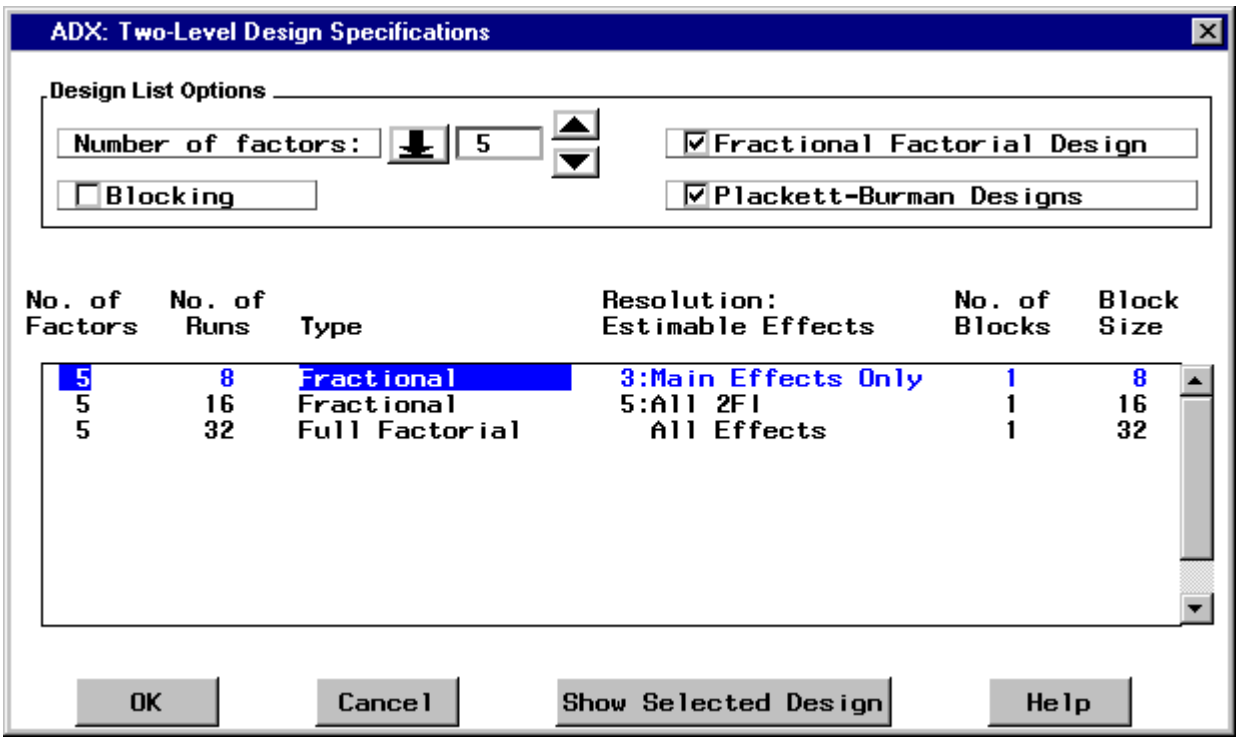
Response Definition

Next, select the **Define Variables >** button in the main window and choose **Responses...**. This takes you to the Response definition screen. Fill in the information for the two response variables THCKNESS and RESTVITY.



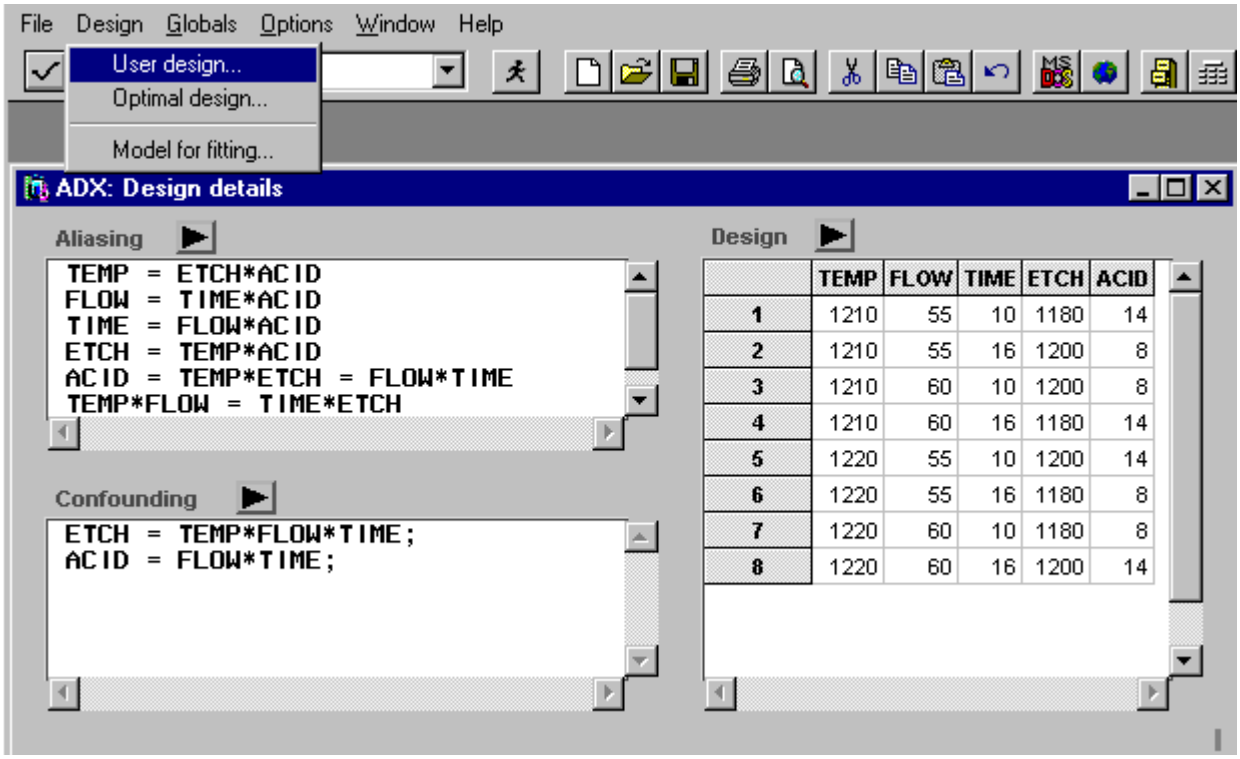
Design Selection

Now that you have entered the factor and response information, you need to choose a design that meets the objective of the experiment. Press the **Select Design...** button in the main window to go to the design selection screen. You can choose a two-level design up to 50 factors from a wide range of fractional factorial and Plackett-Burman designs available with or without blocking. Each line in the list below represents a different design.



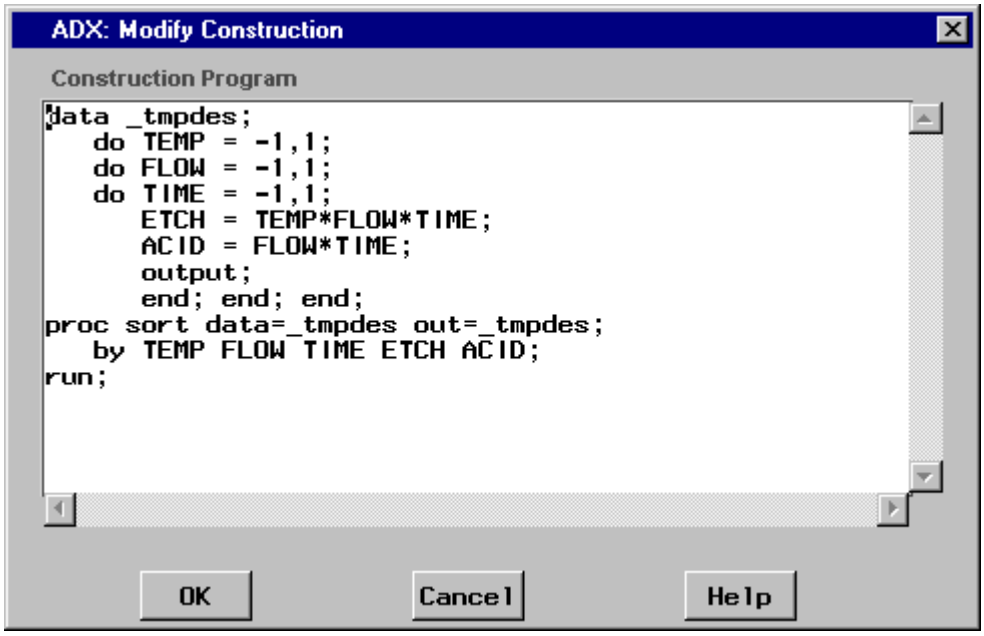
To examine the characteristics of a design, double-click a design row in the list. For instance when you point the mouse to the five-factor design in 8 runs and double click, you see the design details as displayed in the following screen.

Design Details
Design points and characteristics of the selected design such as alias structure and confounding rules is shown below.



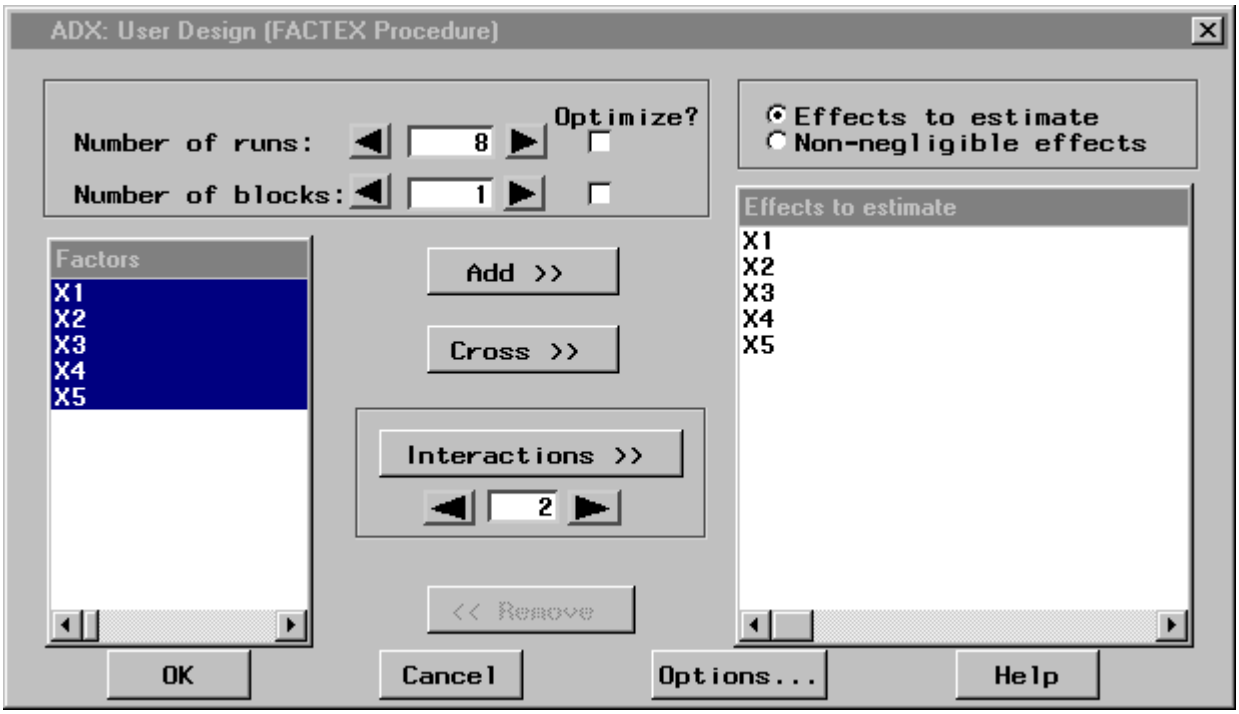
If a standard design does not meet your experiment objectives you can build a *user design*. Typically this step would not be necessary.

User Design: Modify Confounding Rules
To produce a design with a different confounding rule, press the arrow next to **Confounding** in the Design Details window. This takes you to a window where you can modify the confounding rules. You can now edit the SAS code to build a *user design* to suit your requirements.



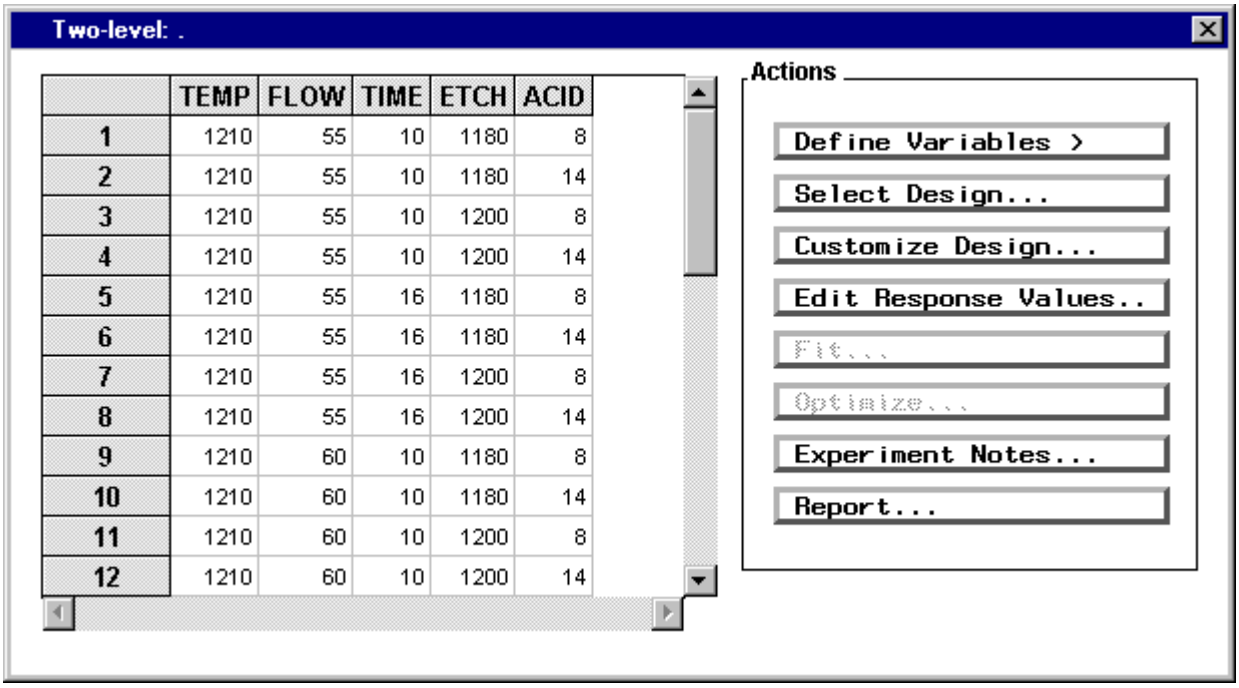
User Design: Specify Construction Model

Alternatively, you can construct a *user design* by specifying a model using an interface to the FACTEX procedure. Select **Design** from the pull-down menu in the Design Details window and choose **User Design**. This takes you to the FACTEX procedure window. You can specify the effects you want the design to estimate and the non-negligible effects.



Main Window (with a design selected)

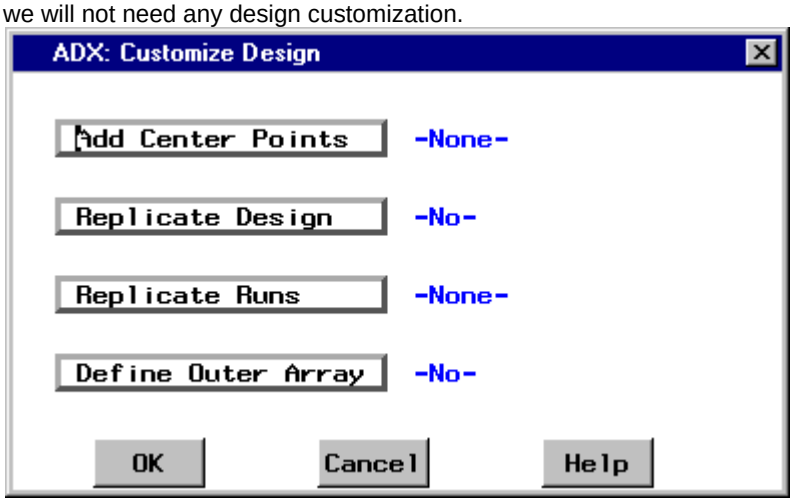
Now suppose we are interested in a design that can estimate all the effects. Go back to the design selection window, select a standard five-factor design in 32 runs. When you press the OK button the design is constructed and displayed in the main window as shown below. Note that since a design has now been selected, the two buttons beneath the **Select Design...** button that were inactive before are now ungrayed.



	TEMP	FLOW	TIME	ETCH	ACID
1	1210	55	10	1180	8
2	1210	55	10	1180	14
3	1210	55	10	1200	8
4	1210	55	10	1200	14
5	1210	55	16	1180	8
6	1210	55	16	1180	14
7	1210	55	16	1200	8
8	1210	55	16	1200	14
9	1210	60	10	1180	8
10	1210	60	10	1180	14
11	1210	60	10	1200	8
12	1210	60	10	1200	14

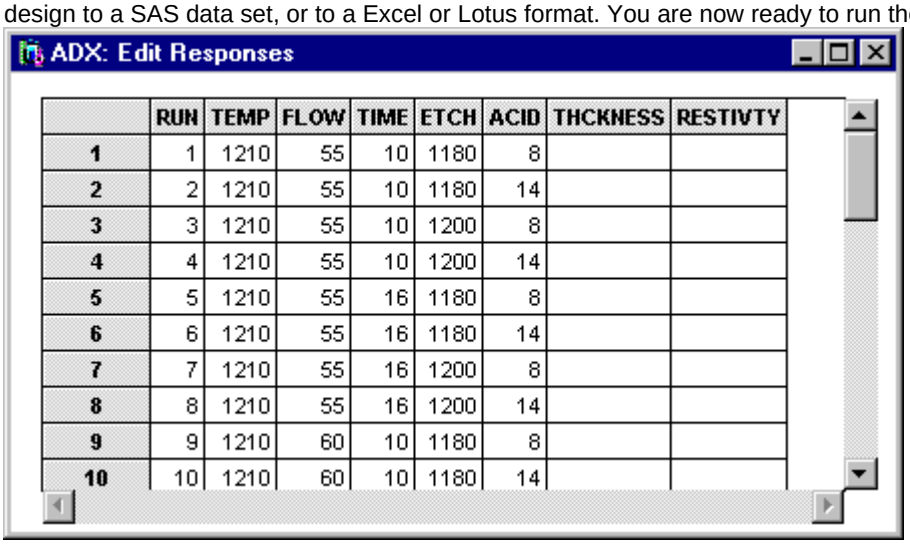
Customizing A Design

To customize a selected design, press the **Customize Design...** button in the main window. You can add center points, replicate an entire design, fold-over a design, replicate certain points in the design, and/or define an outer array for the noise factors. For our example, we will not need any design customization.



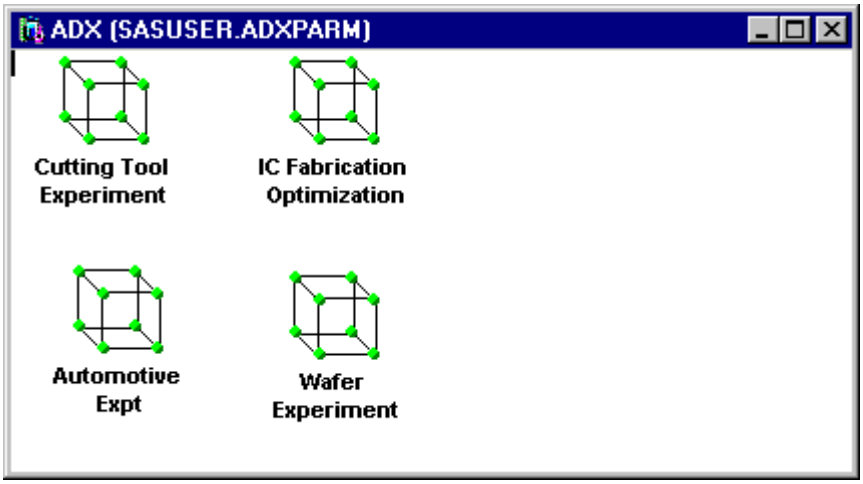
Collecting the Data

Press the **Edit Responses...** button in the main window to go to the data entry window. From this window you can print the design or export the design to a SAS data set, or to a Excel or Lotus format. You are now ready to run the experiment.



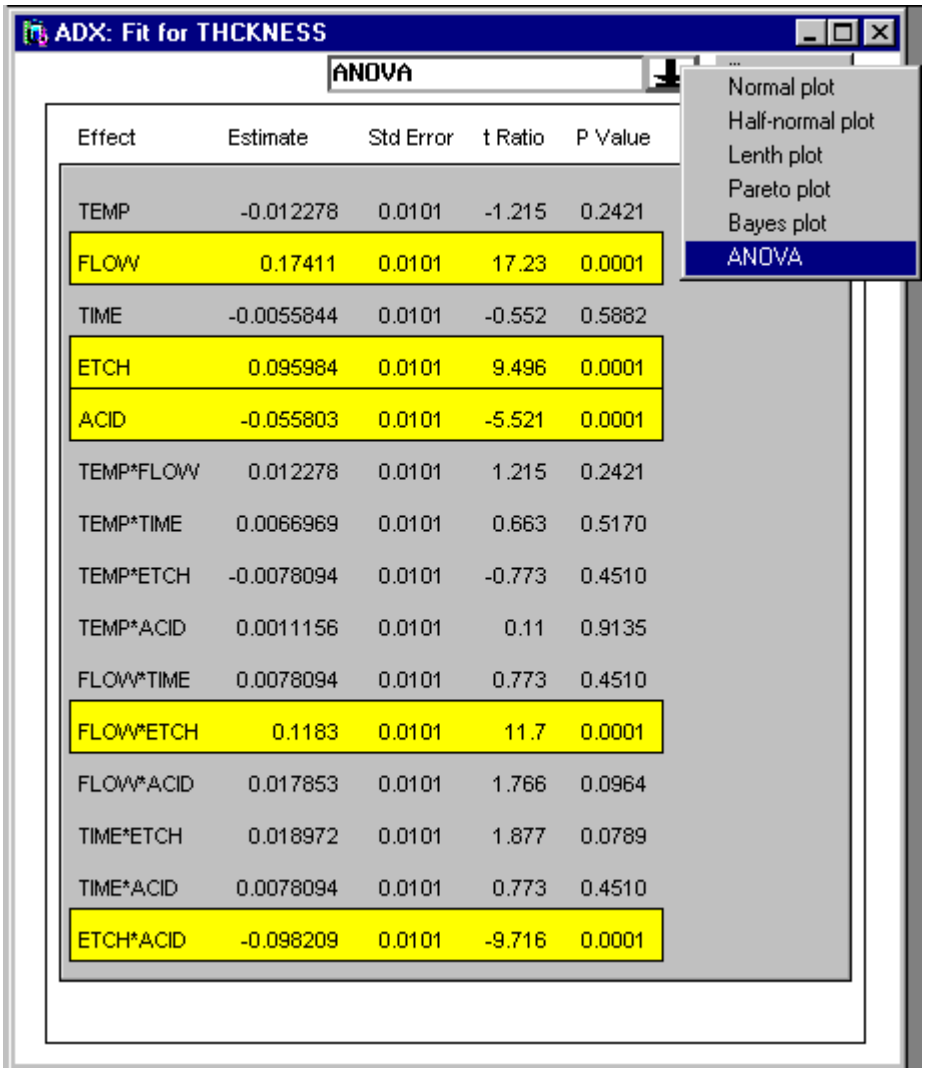
	RUN	TEMP	FLOW	TIME	ETCH	ACID	THCKNESS	RESTIVTY
1	1	1210	55	10	1180	8		
2	2	1210	55	10	1180	14		
3	3	1210	55	10	1200	8		
4	4	1210	55	10	1200	14		
5	5	1210	55	16	1180	8		
6	6	1210	55	16	1180	14		
7	7	1210	55	16	1200	8		
8	8	1210	55	16	1200	14		
9	9	1210	60	10	1180	8		
10	10	1210	60	10	1180	14		

If you close the ADX session at this point the design will be stored on the ADX desktop. Notice the design in our example is saved as *Wafer Experiment* on the desktop. Once the experiment has been carried out and you are ready to enter the response values, double click *the Wafer Experiment* icon and go to the data entering window by pressing the **Edit Responses...** button in the main window.



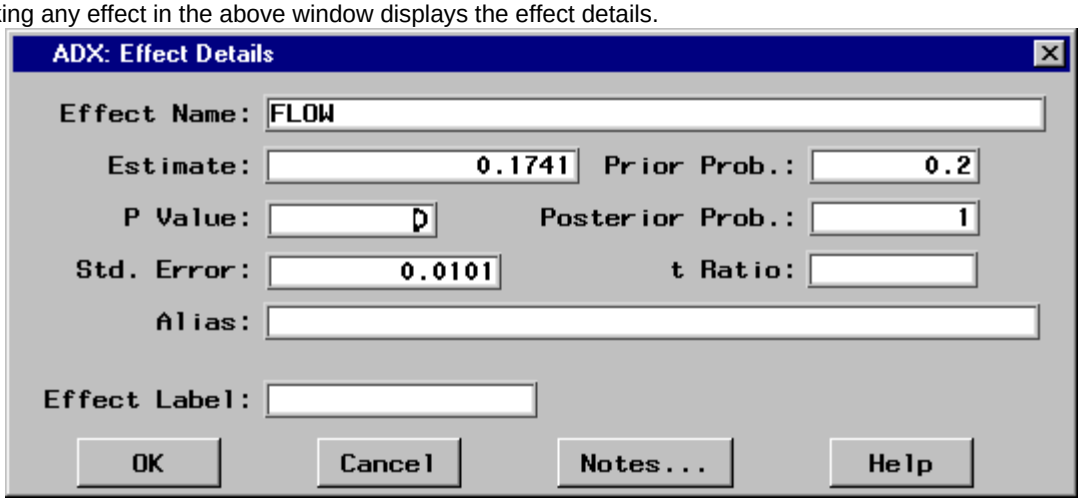
Fit Window

Once the responses values are entered you are ready to fit a model and analyze the design. Press the **Fit...** button in the main window and choose the response you want to analyze. You can view the effects using a normal plot, half-normal plot, ANOVA, Lenth plot, Pareto chart or Bayes plot. In our example since the design is not saturated an ANOVA display is the default. Five effects stand out as active, and are highlighted automatically.



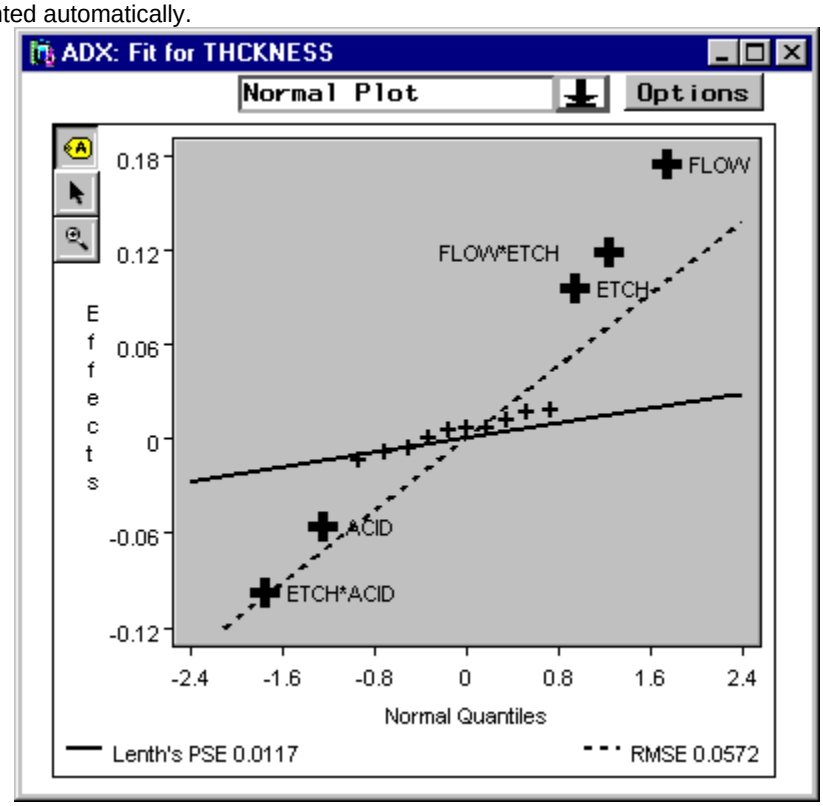
Effect	Estimate	Std Error	t Ratio	P Value
TEMP	-0.012278	0.0101	-1.215	0.2421
FLOW	0.17411	0.0101	17.23	0.0001
TIME	-0.0055844	0.0101	-0.552	0.5882
ETCH	0.095984	0.0101	9.496	0.0001
ACID	-0.055803	0.0101	-5.521	0.0001
TEMP*FLOW	0.012278	0.0101	1.215	0.2421
TEMP*TIME	0.0066969	0.0101	0.663	0.5170
TEMP*ETCH	-0.0078094	0.0101	-0.773	0.4510
TEMP*ACID	0.0011156	0.0101	0.11	0.9135
FLOW*TIME	0.0078094	0.0101	0.773	0.4510
FLOW*ETCH	0.1183	0.0101	11.7	0.0001
FLOW*ACID	0.017853	0.0101	1.766	0.0964
TIME*ETCH	0.018972	0.0101	1.877	0.0789
TIME*ACID	0.0078094	0.0101	0.773	0.4510
ETCH*ACID	-0.098209	0.0101	-9.716	0.0001

Double-clicking any effect in the above window displays the effect details.



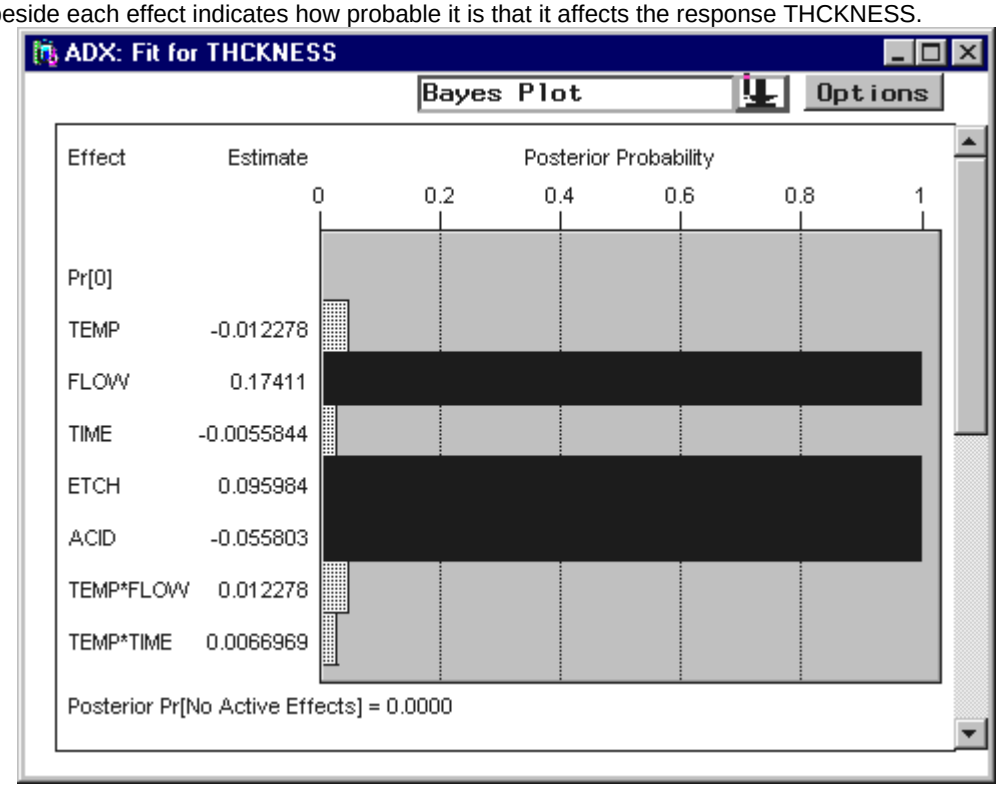
Normal Plot

You can request a normal plot by pressing the down arrow in the Fit window and choosing Normal plot. If all effects are due to random noise, they follow a straight line with slope equal to the standard error. Significant effects deviate from the line and are labeled and highlighted automatically.



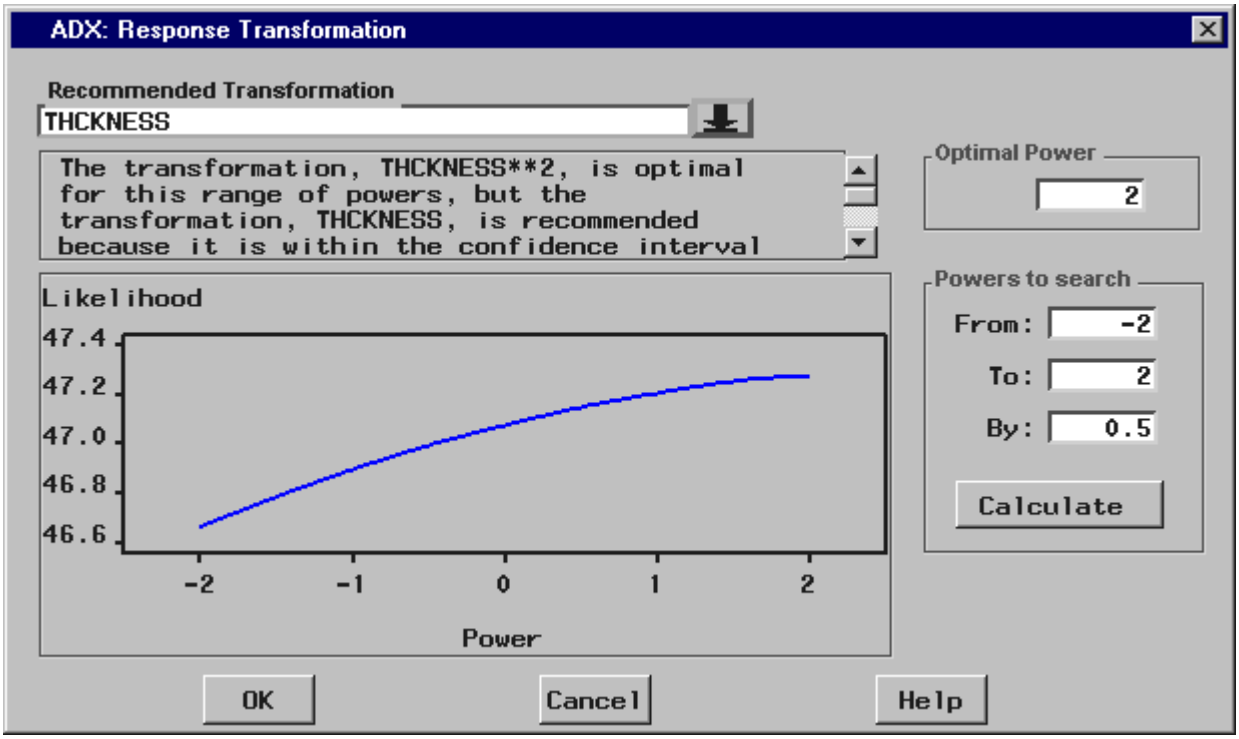
Bayes Plot

You can request a Bayes plot by pressing the down arrow in the Fit window and choosing Bayes plot. The length of the horizontal bar beside each effect indicates how probable it is that it affects the response THCKNESS.

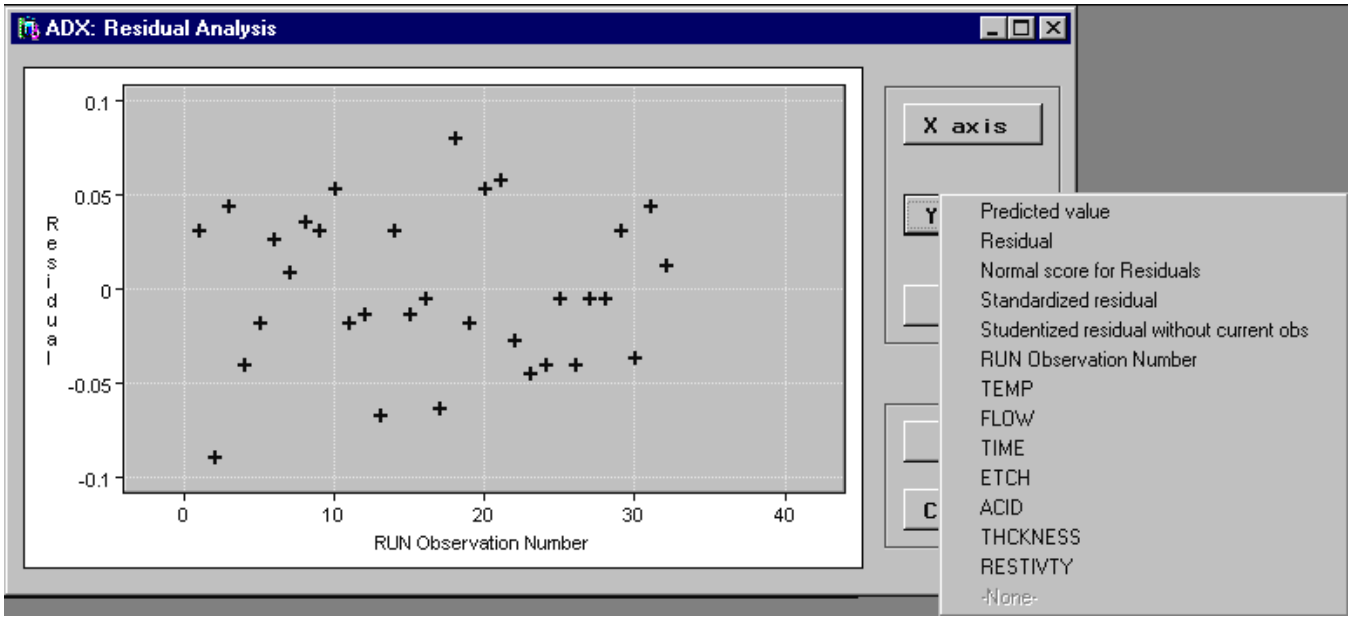


Checking Assumptions

Sometimes a transformation on the response is needed to improve the model fit. To examine the need for a transformation go to the Box-Cox transformation plot by selecting **Assumptions** and choosing **Response scaling**...from the pull-down menu in the Fit window. No transformation is needed for the response THCKNESS.

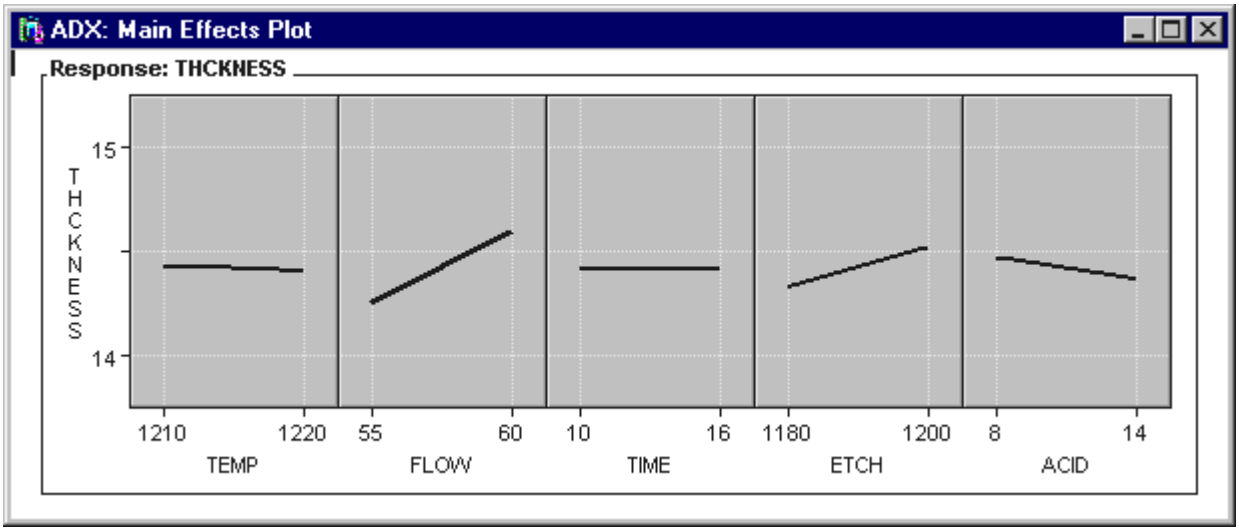


To perform a residual analysis, select the item **Assumptions** from the pull-down menu in the Fit window and choose **Residual analysis**....You can change the X and Y axis by pressing the axis button and selecting an item from the pop-up menu as shown below.

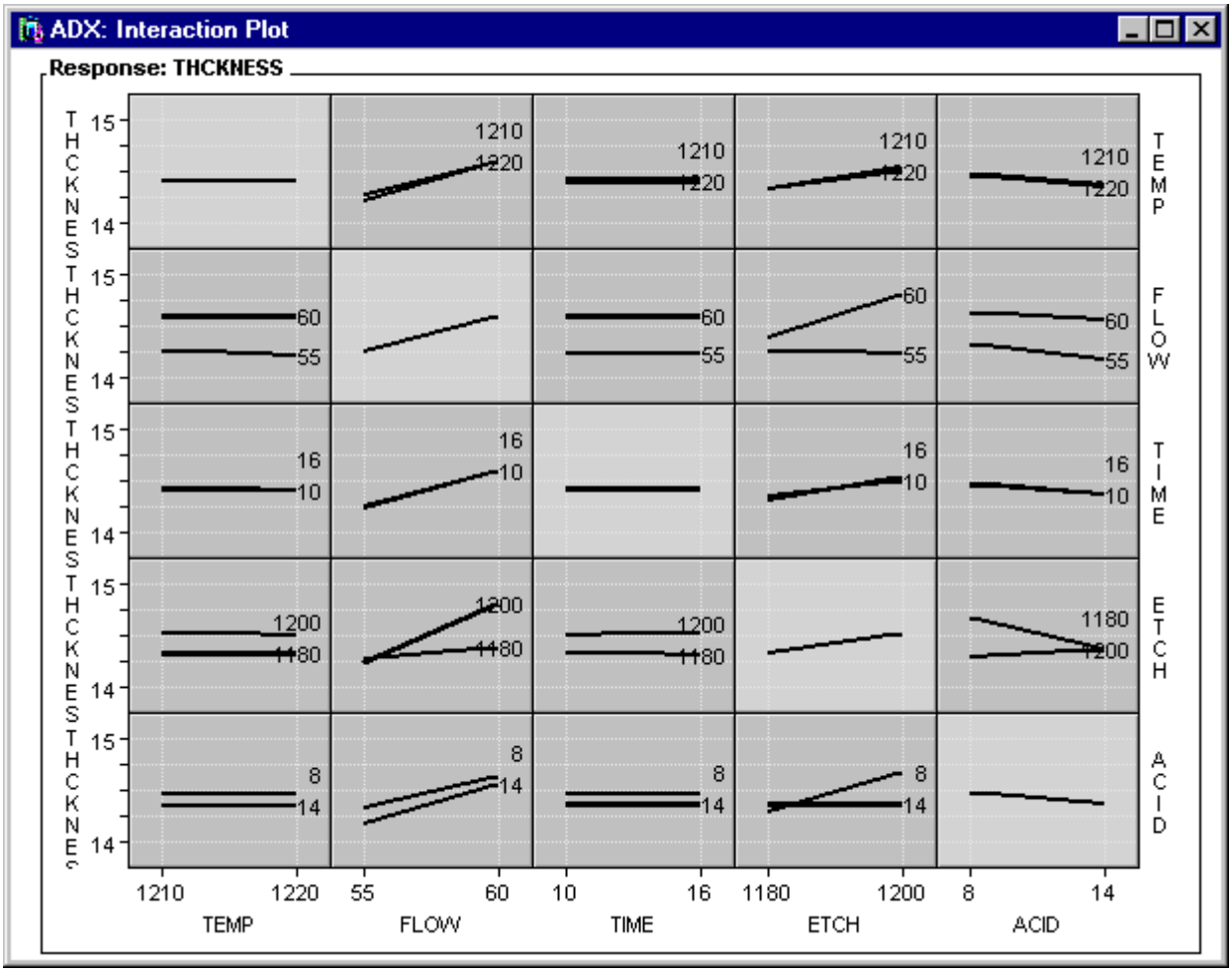


Effect Plots

To look at a main effects plot, select the item **EffectPlots** from the pull-down menu in the Fit window and choose the item **Main effects plot...**. This plot helps you identify the effect of a factor on the response when the factor is varied from the low level to the high level. A flat line indicates that the main effect is inactive. This plot indicates that the factors FLOW, ETCH and ACID as significant.

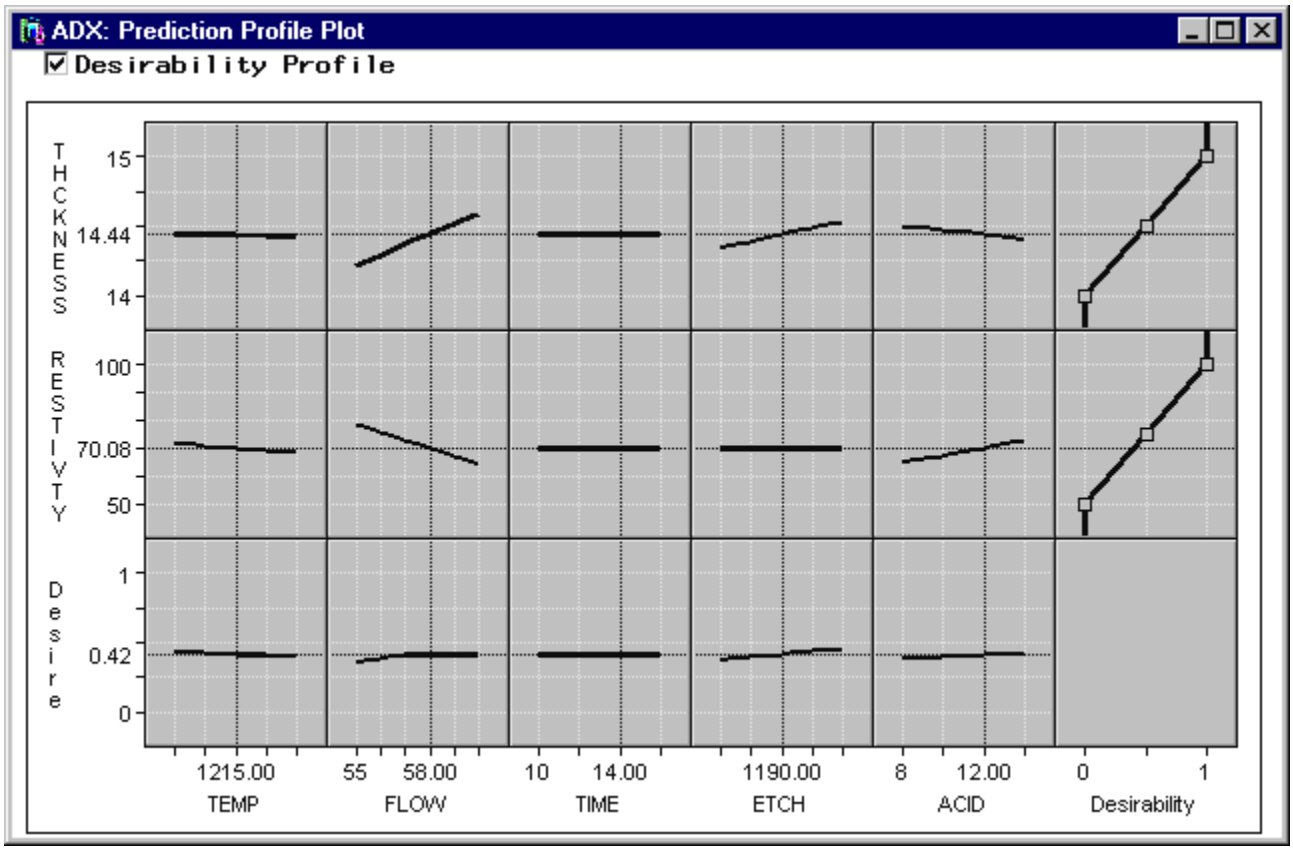


To look at an interaction plot, select the item **EffectPlots** from to the pull-down menu in the Fit window and choose the item **Interaction plot...**. This plot helps you examine interaction effects between two factors. Non-parallel lines indicate an interaction.



Prediction Profile Plot

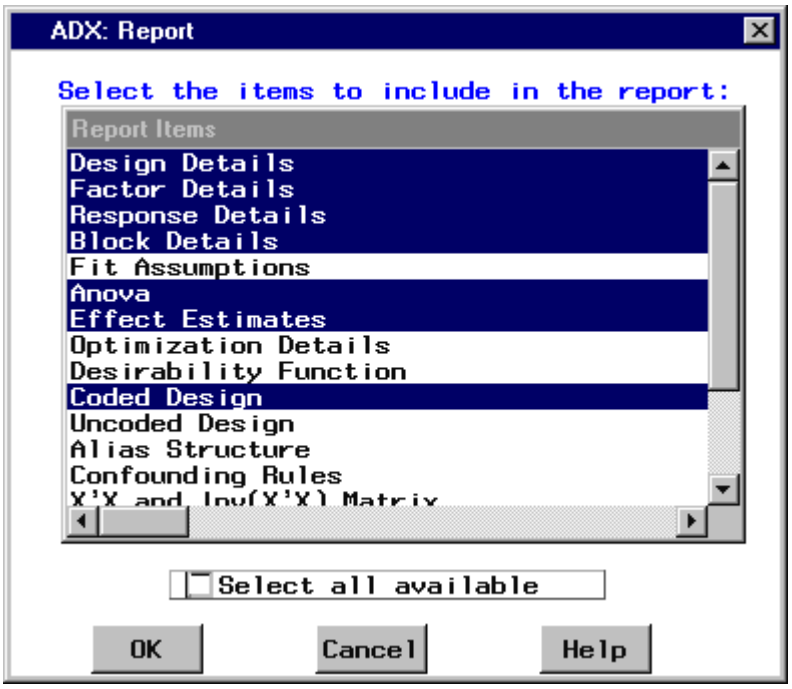
Press the **Optimize...** button in the main window and select the responses that you want to optimize. The prediction profile plot displays the predicted response as one variable is changed while the others are held constant. The vertical line represents the current value of the factor and the horizontal line indicates the predicted response at the current factor settings. You can study the effect of changing one factor at a time on the predicted response. To change a factor value, you simple drag the vertical line to a new factor setting. This recomputes the trace and displays the new predicted response values.



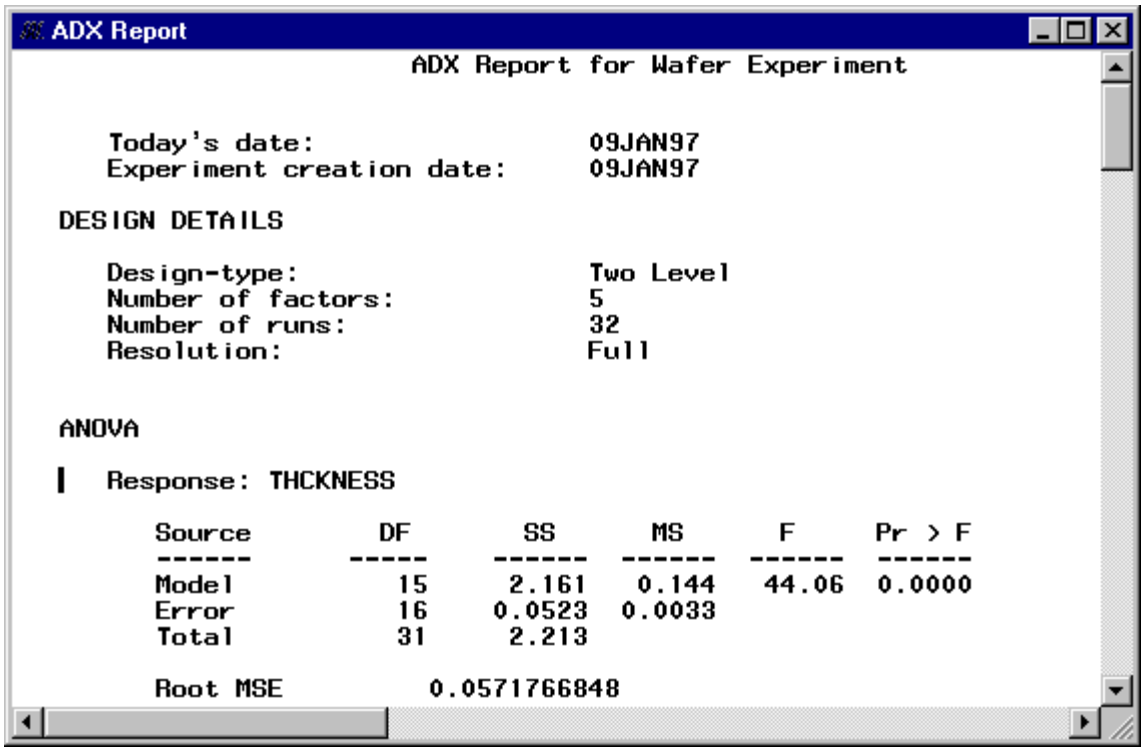
For experiments with multiple responses the most desirable outcome may depend on all the responses. You may want to maximize one response, minimize another or have the response close to a target value. You can achieve this by specifying a desirability function (see the last column in the above plot). The desirability of each factor is displayed in the bottom row and the overall desirability (the geometric mean of the individual desirabilities) is indicated on the bottom vertical-axis.

Experiment Report

To generate an experiment report, press the **Report...** button in the main window. Choose from the list, the items that you want to include in the report and click OK.



A report is created that you can edit and/or save as a file.



For more up-to-date information about the new ADX interface, please visit us at http://www.sas.com/rnd.