

Chapter 885

Response Surface Designs

Introduction

Response-surface designs are the only designs provided that allow for more than two levels. There are two general types of response-surface designs. The central-composite designs give five levels to each factor. The Box-Behnken designs give three levels to each factor.

An introduction to experimental design is presented in Chapter 881 on Two-Level Factorial Designs and will not be repeated here.

The Central-Composite designs build upon the two-level factorial designs by adding a few center points and star points. A factor's five values are: $-a$, -1 , 0 , 1 , and a . The value of a is determined by the number of factors in such a way that the resulting design is orthogonal. For example, if you are going to use either four or five factors, the value of a is 2.00.

The actual values of the levels are determined from these five values as follows:

1. The low-level value is assigned to -1 .
2. The high-level value is assigned to 1 .
3. The average of these two values is assigned to 0 .
4. The values of $-a$ and a are used to find the minimum and the maximum values.

For example, suppose we entered 50 for the low-level and 60 for the high level. Further, suppose there were four factors in the experiment. The levels would be

<u>Coded Level</u>	<u>Actual Level</u>
$-a$	45
-1	50
0	55
1	60
a	65

The values of a depend on the number of factors in the design:

<u>Factors</u>	<u>Value of a</u>
2	1.41
3	1.73
4	2.00
5	2.00
6	2.24

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The Box-Behnken designs have two differences from the central-composite designs. First, they usually use fewer runs. Second, they only use three levels while the central-composite designs use five.

The actual values of the levels are determined in the same manner as the central-composite designs, except that the value of a is ignored.

Procedure Options

This section describes the options available in this procedure.

Design Tab

This panel specifies the parameters that will be used to create the design values.

Experimental Setup

Design Type

Specify whether to generate a *central-composite* or a *Box-Behnken* design. This selection controls the number of runs generated as well as the block size (if a blocking variable is present).

Sort Order

The order of the generated rows. The rows may be in random or standard order.

- **Random**

The rows are randomly ordered (random blocks and random rows within blocks). Use this option when the order of application to experimental units is governed by the row number.

- **Standard**

The rows are not randomly ordered. Instead, they are placed in standard order. Use this option when you want to quickly see the structure of the design.

Experimental Setup – Factor Values

Factor Values

Each factor has three or five possible values (levels). The values associated with -1 and 1 are entered here.

If a Box-Behnken design was selected, the resulting three values will be -1,0,1. For example, if you entered 10 20 here, the resulting values would be 10, 15, and 20.

If a central-composite design was selected, the resulting five values will be $-a$, -1, 0, 1, a . For example, if you had four factors and entered 50 60 here, the resulting values would be 45, 50, 55, 60, and 65.

These are the values that will be written to the database. You can only use numeric values.

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Data Storage to Spreadsheet

Store Data on Spreadsheet

Check this box to generate the design data on the spreadsheet. The spreadsheet data will be identical to the design data generated on the output window.

Block Column

The variable to contain the block identification numbers. The blocks are numbered from one to B, where B is the number of blocks. This column is optional. If this option is left blank, no blocks will be generated.

First Factor Column

This is where the group of columns that is to contain your design begins. The K-1 columns after this column are also filled with data. The number of variables used is determined by the number of Factor Values boxes that contain data.

Warning: The program fills these columns with data, so any previous data will be lost.

Example 1 – Response Surface Design

This section presents an example of how to generate an experimental design using this program. **CAUTION: since the purpose of this routine is to generate data, you should always begin with an empty output spreadsheet.**

In this example, we will show you how to generate a three-factor central composite design with blocks.

Setup

This section presents the values of each of the parameters needed to run this example. First, from the PASS Home window, load the **Response Surface Designs** procedure window by expanding **Design of Experiments**, then clicking on **Experimental Design**, and then clicking on **Response Surface Designs**. You may then make the appropriate entries as listed below, or open **Example 1** by going to the **File** menu and choosing **Open Example Template**.

1 Specify the design parameters.

- Select **Central-Composite** in the **Design Type** list box.
- Select **Standard** in the **Sort Order** list box.
- Set three of the **Factor Values** boxes equal to **-1 1**.
- Check the **Store Data on Spreadsheet** box.
- Enter **1** in the **Block Column** box.
- Enter **2** in the **First Factor Column** box.

2 Run the procedure.

- From the Run menu, select **Start Calculation**. Alternatively, just click the Calculate button.

Three-Factor Response-Surface Design

Experimental Design: Central-Composite

Row	Block	Factor 1	Factor 2	Factor 3
1	1	-1	-1	-1
2	1	1	-1	-1
3	1	-1	1	-1
4	1	1	1	-1
5	1	-1	-1	1
6	1	1	-1	1
7	1	-1	1	1
8	1	1	1	1
9	1	0	0	0
10	1	0	0	0
11	1	0	0	0
12	2	-1.73	0	0
13	2	1.73	0	0
14	2	0	-1.73	0
15	2	0	1.73	0
16	2	0	0	-1.73
17	2	0	0	1.73
18	2	0	0	0
19	2	0	0	0
20	2	0	0	0

The block and factor values were also produced on the spreadsheet.

These values are also generated on the spreadsheet. Note that there are three replicates of the center points in each block. Note the star points represented by -1.73 and 1.73.