THE POWER TO KNOW®

SAS/STAT® 9.2 User's Guide
The PLAN Procedure
(Book Excerpt)

SAS® Documentation

Chapter 65

The PLAN Procedure

Contents

Overview: PLAN Procedure

The PLAN procedure constructs designs and randomizes plans for factorial experiments, especially nested and crossed experiments and randomized block designs. PROC PLAN can also be used for generating lists of permutations and combinations of numbers. The PLAN procedure can construct the following types of experimental designs:

- full factorial designs, with and without randomization
- certain balanced and partially balanced incomplete block designs
- generalized cyclic incomplete block designs
- Latin square designs

For other kinds of experimental designs, especially fractional factorial, response surface, and orthogonal array designs, see the FACTEX and OPTEX procedures and the ADX Interface in SAS/QC software.

PROC PLAN generates designs by first generating a selection of the levels for the first factor. Then, for the second factor, PROC PLAN generates a selection of its levels for each level of the first factor. In general, for a given factor, the PLAN procedure generates a selection of its levels for all combinations of levels for the factors that precede it.

The selection can be done in five different ways:

- randomized selection, for which the levels are returned in a random order
- ordered selection, for which the levels are returned in a standard order every time a selection is generated
- cyclic selection, for which the levels returned are computed by cyclically permuting the levels of the previous selection
- permuted selection, for which the levels are a permutation of the integers $1, \ldots, n$
- combination selection, for which the m levels are selected as a combination of the integers $1, \ldots, n$ taken m at a time

The randomized selection method can be used to generate randomized plans. Also, by appropriate use of cyclic selection, any of the designs in the very wide class of generalized cyclic block designs (Jarrett and Hall 1978) can be generated.

There is no limit to the depth to which the different factors can be nested, and any number of randomized plans can be generated.

You can also declare a list of factors to be selected simultaneously with the lowest (that is, the most nested) factor. The levels of the factors in this list can be seen as constituting the treatment to be applied to the cells of the design. For this reason, factors in this list are called *treatments*. With this list, you can generate and randomize plans in one run of PROC PLAN.

Getting Started: PLAN Procedure

Three Replications with Four Factors

Suppose you want to determine if the order in which four drugs are given affects the response of a subject. If you have only three subjects to test, you can use the following statements to design the experiment.

```
proc plan seed=27371;
   factors Replicate=3 ordered Drug=4;
run;
```

These statements produce a design with three replicates of the four levels of the factor Drug arranged in random order. The three levels of Replicate are arranged in order, as shown in Figure 65.1.

Figure 65.1 Three Replications and Four Factors

```
                          The PLAN Procedure

             Factor          Select       Levels     Order

             Replicate            3            3     Ordered
             Drug                 4            4     Random

                        Replicate      --Drug-

                                1      3 2 4 1
                                2      1 2 4 3
                                3      4 1 2 3
```

You might also want to apply one of four different treatments to each cell of this plan (for example, applying different amounts of each drug). The following additional statements create the output shown in Figure 65.2:

```
   factors Replicate=3 ordered Drug=4;
   treatments Treatment=4;
run;
```

Figure 65.2 Using the TREATMENTS Statement

```
                          The PLAN Procedure

                             Plot Factors

             Factor          Select       Levels     Order

             Replicate            3            3     Ordered
             Drug                 4            4     Random
```

Figure 65.2 *continued*

```
                          Treatment Factors

             Factor          Select       Levels      Order

             Treatment            4            4     Random

              Replicate      --Drug-      --Treatment--

                      1      3 1 2 4      2   1   3   4
                      2      4 3 2 1      4   1   2   3
                      3      3 2 4 1      1   4   2   3
```

Randomly Assigning Subjects to Treatments

You can use the PLAN procedure to design a completely randomized design. Suppose you have 12 experimental units, and you want to assign one of two treatments to each unit. Use a DATA step to store the unrandomized design in a SAS data set, and then call PROC PLAN to randomize it by specifying one factor with the default type of RANDOM, having 12 levels. The following statements produce Figure 65.3 and Figure 65.4:

```
title 'Completely Randomized Design';
/* The unrandomized design */

data Unrandomized;
   do Unit=1 to 12;
      if (Unit <= 6) then Treatment=1;
      else                Treatment=2;
      output;
   end;
run;

/* Randomize the design */

proc plan seed=27371;
   factors Unit=12;
   output data=Unrandomized out=Randomized;
run;

proc sort data=Randomized;
   by Unit;
proc print;
run;
```

Figure 65.3 shows that the 12 levels of the unit factor have been randomly reordered and then lists the new ordering.

Figure 65.3 A Completely Randomized Design for Two Treatments

```
                    Completely Randomized Design

                         The PLAN Procedure

              Factor      Select      Levels     Order

              Unit            12          12     Random

                 ----------------Unit---------------

                  8  5  1  4  6  2 12  7  3  9 10 11
```

After the data set is sorted by the unit variable, the randomized design is displayed (Figure 65.4).

Figure 65.4 A Completely Randomized Design for Two Treatments

```
                    Completely Randomized Design

                      Obs    Unit    Treatment

                        1       1        1
                        2       2        1
                        3       3        2
                        4       4        1
                        5       5        1
                        6       6        1
                        7       7        2
                        8       8        1
                        9       9        2
                       10      10        2
                       11      11        2
                       12      12        2
```

You can also generate the plan by using a TREATMENTS statement instead of a DATA step. The following statements generate the same plan.

```
proc plan seed=27371;
   factors Unit=12;
   treatments Treatment=12 cyclic (1 1 1 1 1 1 2 2 2 2 2 2);
   output out=Randomized;
run;
```

Syntax: PLAN Procedure

The following statements are available in PROC PLAN.

> **PROC PLAN** < *options* > ;
> **FACTORS** *factor-selections* < / **NOPRINT** > ;
> **OUTPUT OUT=***SAS-data-set* < *factor-value-settings* > ;
> **TREATMENTS** *factor-selections* ;

To use PROC PLAN, you need to specify the PROC PLAN statement and at least one FACTORS statement before the first RUN statement. The TREATMENTS statement, OUTPUT statement, and additional FACTORS statements can appear either before the first RUN statement or after it.

The rest of this section gives detailed syntax information for each of the statements, beginning with the PROC PLAN statement. The remaining statements are described in alphabetical order.

You can use PROC PLAN interactively by specifying multiple groups of statements, separated by RUN statements. For details, see the section "Using PROC PLAN Interactively" on page 4737.

PROC PLAN Statement

> **PROC PLAN** < *options* > ;

The PROC PLAN statement starts the PLAN procedure and, optionally, specifies a random number seed or a default method for selecting levels of factors. By default, the procedure uses a random number seed generated from reading the time of day from the computer's clock and randomly selects levels of factors. These defaults can be modified with the SEED= and ORDERED options, respectively. Unlike many SAS/STAT procedures, the PLAN procedure does not have a DATA= option in the PROC statement; in this procedure, both the input and output data sets are specified in the OUTPUT statement.

You can specify the following options in the PROC PLAN statement:

SEED=*number*

specifies an integer used to start the pseudo-random number generator for selecting factor levels randomly. If you do not specify a seed, or if you specify a value less than or equal to zero, the seed is by default generated from reading the time of day from the computer's clock.

ORDERED

selects the levels of the factor as the integers $1, 2, \ldots, m$, in order. For more detail, see "*Selection-Types*" on page 4731 and "Specifying Factor Structures" on page 4739.

FACTORS Statement

FACTORS *factor-selections* < / **NOPRINT** > **;**

The FACTORS statement specifies the factors of the plan and generates the plan. Taken together, the *factor-selections* specify the plan to be generated; more than one *factor-selection* request can be used in a FACTORS statement. The form of a *factor-selection* is

name **=** *m* < **OF** *n* > < *selection-type* > **;**

where

name	is a valid SAS name. This gives the name of a factor in the design.
m	is a positive integer that gives the number of values to be selected. If n is specified, the value of m must be less than or equal to n.
n	is a positive integer that gives the number of values to be selected from.
selection-type	specifies one of five methods for selecting m values. Possible values are COMB, CYCLIC, ORDERED, PERM, and RANDOM. The CYCLIC *selection-type* has additional optional specifications that enable you to specify an initial block of numbers to be cyclically permuted and an increment used to permute the numbers. By default, the *selection-type* is RANDOM, unless you use the ORDERED option in the PROC PLAN statement. In this case, the default *selection-type* is ORDERED. For details, see the following section, "*Selection-Types*"; for examples, see the section "Syntax Examples" on page 4732.

The following option can appear in the FACTORS statement after the slash:

NOPRINT

suppresses the display of the plan. This is particularly useful when you require only an output data set. Note that this option temporarily disables the Output Delivery System (ODS); see Chapter 20, "Using the Output Delivery System," for more information.

Selection-Types

PROC PLAN interprets *selection-type* as follows:

RANDOM	selects the m levels of the factor randomly without replacement from the integers $1, 2, \ldots, n$. Or, if n is not specified, RANDOM selects levels by randomly ordering the integers $1, 2, \ldots, m$.
ORDERED	selects the levels of the factor as the integers $1, 2, \ldots, m$, in that order.
PERM	selects the m levels of the factor as a permutation of the integers $1, \ldots m$ according to an algorithm that cycles through all $m!$ permutations. The permutations are produced in a sorted standard order; see Example 65.6.
COMB	selects the m levels of the factor as a combination of the integers $1, \ldots, n$ taken m at a time, according to an algorithm that cycles through all $n!/(m!(n-m)!)$ combinations. The combinations are produced in a sorted standard order; see Example 65.6.

CYCLIC < **(***initial-block***)** > < *increment* > selects the levels of the factor by cyclically permuting the integers $1, 2, \ldots, n$. Wrapping occurs at m if n is not specified, and at n if n is specified. Additional optional specifications are as follows.

With the *selection-type* CYCLIC, you can optionally specify an *initial-block* and an *increment*. The *initial-block* must be specified within parentheses, and it specifies the block of numbers to permute. The first permutation is the block you specify, the second is the block permuted by 1 (or by the *increment* you specify), and so on. By default, the *initial-block* is the integers $1, 2, \ldots, m$. If you specify an *initial-block*, it must have m values. Values specified in the *initial-block* do not have to be given in increasing order.

The *increment* specifies the increment by which to permute the block of numbers. By default, the *increment* is 1.

Syntax Examples

This section gives some simple syntax examples. For more complex examples and details on how to generate various designs, see "Specifying Factor Structures" on page 4739. The examples in this section assume that you use the default random selection method and do not use the ORDERED option in the PROC PLAN statement.

The following specification generates a random permutation of the numbers 1, 2, 3, 4, and 5.

```
factors A=5;
```

The following specification generates a random permutation of five of the integers from 1 to 8, selected without replacement.

```
factors A=5 of 8;
```

Adding the ORDERED *selection-type* to the two previous specifications generates an ordered list of the integers 1 to 5. The following specification cyclically permutes the integers 1, 2, 3, and 4.

```
factors A=4 cyclic;
```

Since this simple request generates only one permutation of the numbers, the procedure generates an ordered list of the integers 1 to 4. The following specification cyclically permutes the integers 5 to 8.

```
factors A=4 of 8 cyclic (5 6 7 8);
```

In this case, since only one permutation is performed, the procedure generates an ordered list of the integers 5 to 8. The following specification produces an ordered list for A, with values 1 and 2.

```
factors A=2 ordered B=4 of 8 cyclic (5 6 7 8) 2;
```

The associated factor levels for B are 5, 6, 7, 8 for level 1 of A, and 7, 8, 1, 2 for level 2 of A.

Handling More Than One *Factor-Selection*

For cases with more than one *factor-selection* in the same FACTORS statement, PROC PLAN constructs the design as follows:

1. PROC PLAN first generates levels for the first *factor-selection*. These levels are permutations of integers (1, 2, and so on) appropriate for the selection type chosen. If you do not specify a selection type, PROC PLAN uses the default (RANDOM); if you specify the ORDERED option in the PROC PLAN statement, the procedure uses ORDERED as the default selection type.
2. For every integer generated for the first *factor-selection*, levels are generated for the second *factor-selection*. These levels are generated according to the specifications following the second equal sign.
3. This process is repeated until levels for all *factor-selections* have been generated.

The following statements give an example of generating a design with two random factors:

```
proc plan;
   factors One=4 Two=3;
run;
```

The procedure first generates a random permutation of the integers 1 to 4 and then, for each of these, generates a random permutation of the integers 1 to 3. You can think of factor Two as being nested within factor One, where the levels of factor One are to be randomly assigned to 4 units.

As another example, six random permutations of the numbers 1, 2, 3 can be generated by specifying the following statements:

```
proc plan;
   factors a=6 ordered b=3;
run;
```

OUTPUT Statement

OUTPUT OUT=*SAS-data-set* < **DATA=***SAS-data-set* > < *factor-value-settings* > **;**

The OUTPUT statement applies only to the last plan generated. If you use PROC PLAN interactively, the OUTPUT statement for a given plan must be immediately preceded by the FACTORS statement (and the TREATMENTS statement, if appropriate) for the plan.

See "Output Data Sets" on page 4737 for more information about how output data sets are constructed.

You can specify the following options in the OUTPUT statement:

OUT=*SAS-data-set*

DATA=*SAS-data-set*

You can use the OUTPUT statement both to output the last plan generated and to use the last plan generated to randomize another SAS data set.

When you specify only the OUT= option in the OUTPUT statement, PROC PLAN saves the last plan generated to the specified data set. The output data set contains one variable for each factor in the plan and one observation for each cell in the plan. The value of a variable in a given observation is the level of the corresponding factor for that cell. The OUT= option is required.

When you specify both the DATA= and OUT= options in the OUTPUT statement, then PROC PLAN uses the last plan generated to randomize the input data set (DATA=), saving the results to the output data set (OUT=). The output data set has the same form as the input data set but has modified values for the variables that correspond to factors (see the section "Output Data Sets" on page 4737 for details). Values for variables not corresponding to factors are transferred without change.

factor-value-settings

specify the values input or output for the factors in the design. The form for *factor-value-settings* is different when only an OUT= data set is specified and when both OUT= and DATA= data sets are specified.

Both forms are discussed in the following section.

Factor-Value-Settings with Only an OUT= Data Set

When you specify only an OUT= data set, the form for each *factor-value-setting* specification is one of the following:

factor-name < **NVALS=***list-of-n-numbers* > < **ORDERED | RANDOM** > **;**

or

factor-name < **CVALS=***list-of-n-strings* > < **ORDERED | RANDOM** > **;**

where

factor-name	is a factor in the last FACTORS statement preceding the OUTPUT statement.
NVALS=	lists n numeric values for the factor. By default, the procedure uses NVALS=(1 2 3 $\cdots n$).
CVALS=	lists n character strings for the factor. Each string can have up to 40 characters, and each string must be enclosed in quotes. WARNING: When you use the CVALS= option, the variable created in the output data set has a length equal to the length of the longest string given as a value; shorter strings are padded with trailing blanks. For example, the values output for the first level of a two-level factor with the following two different specifications are not the same.

```
CVALS=('String 1' "String 2")

CVALS=('String 1' "A longer string")
```

The value output with the second specification is 'String 1' followed by seven blanks. In order to match two such values (for example, when merging two plans), you must use the TRIM function in the DATA step (see *SAS Language Reference: Dictionary*).

ORDERED | RANDOM specifies how values (those given with the NVALS= or CVALS= option, or the default values) are associated with the levels of a factor (the integers $1, 2, \ldots, n$). The default association type is ORDERED, for which the first value specified is output for a factor level setting of 1, the second value specified is output for a level of 2, and so on. You can also specify an association type of RANDOM, for which the levels are associated with the values in a random order. Specifying RANDOM is useful for randomizing crossed experiments (see the section "Randomizing Designs" on page 4742).

The following statements give an example of using the OUTPUT statement with only an OUT= data set and with both the NVALS= and CVALS= specifications.

```
proc plan;
   factors a=6 ordered b=3;
   output out=design a nvals=(10 to 60 by 10)
                     b cvals=('HSX' 'SB2' 'DNY');
run;
```

The DESIGN data set contains two variables, a and b. The values of the variable a are 10 when factor a equals 1, 20 when factor a equals 2, and so on. Values of the variable b are 'HSX' when factor b equals 1, 'SB2' when factor b equals 2, and 'DNY' when factor b equals 3.

Factor-Value-Settings with OUT= and DATA= Data Sets

If you specify an input data set with DATA=, then PROC PLAN assumes that each factor in the last plan generated corresponds to a variable in the input set. If the variable name is different from the name of the factor to which it corresponds, the two can be associated in the values specification by

input-variable-name = factor-name ;

Then, the NVALS= or CVALS= specification can be used. The values given by NVALS= or CVALS= specify the input values as well as the output values for the corresponding variable.

Since the procedure assumes that the collection of input factor values constitutes a plan position description (see the section "Output Data Sets" on page 4737), the values must correspond to integers less than or equal to m, the number of values selected for the associated factor. If any input values do not correspond, then the collection does not define a plan position, and the corresponding observation is output without changing the values of any of the factor variables.

The following statements demonstrate the use of *factor-value-settings*. The input SAS data set a contains variables Block and Plot, which are renamed Day and Hour, respectively.

```
proc plan;
   factors Day=7 Hour=6;
   output data=a out=b
      Block = Day  cvals=('Mon' 'Tue' 'Wed' 'Thu'
                          'Fri' 'Sat' 'Sun'      )
      Plot  = Hour;
run;
```

For another example of using both a DATA= and OUT= data set, see the section "Randomly Assigning Subjects to Treatments" on page 4728.

TREATMENTS Statement

TREATMENTS *factor-selections* **;**

The TREATMENTS statement specifies the *treatments* of the plan to generate, but it does not generate a plan. If you supply several FACTORS and TREATMENTS statements before the first RUN statement, the procedure uses only the last TREATMENTS specification and applies it to the plans generated by each of the FACTORS statements. The TREATMENTS statement has the same form as the FACTORS statement. The individual *factor-selections* also have the same form as in the FACTORS statement:

name **=** *m* < **OF** *n* > < *selection-type* > **;**

The procedure generates each *treatment* simultaneously with the lowest (that is, the most nested) factor in the last FACTORS statement. The *m* value for each *treatment* must be at least as large as the *m* for the most nested factor.

The following statements give an example of using both a FACTORS and a TREATMENTS statement. First the FACTORS statement sets up the rows and columns of a 3×3 square (factors r and c). Then, the TREATMENTS statement augments the square with two cyclic treatments. The resulting design is a 3×3 Graeco-Latin square, a type of design useful in main-effects factorial experiments.

```
proc plan;
   factors r=3 ordered c=3 ordered;
   treatments a=3 cyclic
              b=3 cyclic 2;
run;
```

The resulting Graeco-Latin square design is shown in Figure 65.5. Notice how the values of r and c are ordered (1, 2, 3) as requested.

Figure 65.5 A 3×3 Graeco-Latin Square

```
                    The PLAN Procedure

               r      --c--       --a--       --b--

               1      1 2 3       1 2 3       1 2 3
               2      1 2 3       2 3 1       3 1 2
               3      1 2 3       3 1 2       2 3 1
```

Details: PLAN Procedure

Using PROC PLAN Interactively

After specifying a design with a FACTORS statement and running PROC PLAN with a RUN statement, you can generate additional plans and output data sets without invoking PROC PLAN again.

In PROC PLAN, all statements can be used interactively. You can execute statements singly or in groups by following the single statement or group of statements with a RUN statement.

If you use PROC PLAN interactively, you can end the procedure with a DATA step, another PROC step, an ENDSAS statement, or a QUIT statement. The syntax of the QUIT statement is

```
quit;
```

When you use PROC PLAN interactively, additional RUN statements do not end the procedure but tell PROC PLAN to execute additional statements.

Output Data Sets

To understand how PROC PLAN creates output data sets, you need to look at how the procedure represents a plan. A plan is a list of values for all the factors, the values being chosen according to the *factor-selection* requests you specify. For example, consider the plan produced by the following statements:

```
proc plan seed=12345;
   factors a=3 b=2;
run;
```

The plan as displayed by PROC PLAN is shown in Figure 65.6.

Figure 65.6 A Simple Plan

```
                         The PLAN Procedure

             Factor      Select      Levels     Order

             a                3           3    Random
             b                2           2    Random

                                  a      -b-

                                  2      2 1
                                  1      1 2
                                  3      2 1
```

The first cell of the plan has a=2 and b=2, the second has a=2 and b=1, the third has a=1 and b=1, and so on. If you output the plan to a data set with the OUTPUT statement, by default the output data set contains a numeric variable with that factor's name; the values of this numeric variable are the numbers of the successive levels selected for the factor in the plan. For example, the following statements produce Figure 65.7.

```
proc plan seed=12345;
   factors a=3 b=2;
   output out=out;
proc print data=out;
run;
```

Figure 65.7 Output Data Set from Simple Plan

```
                         Obs    a    b

                          1     2    2
                          2     2    1
                          3     1    1
                          4     1    2
                          5     3    2
                          6     3    1
```

Alternatively, you can specify the values that are output for a factor with the CVALS= or NVALS= option. Also, you can specify that the internal values be associated with the output values in random order with the RANDOM option. See the section "OUTPUT Statement" on page 4733.

If you also specify an input data set (DATA=), each factor is associated with a variable in the DATA= data set. This occurs either implicitly by the factor and variable having the same name or explicitly as described in the specifications for the OUTPUT statement. In this case, the values of the variables corresponding to the factors are first read and then interpreted as describing the position of a cell in the plan. Then the respective values taken by the factors at that position are assigned to the variables in the OUT= data set. For example, consider the data set defined by the following statements.

```
data in;
   input a b;
   datalines;
1 1
2 1
3 1
;
```

Suppose you specify this data set as an input data set for the OUTPUT statement.

```
proc plan seed=12345;
   factors a=3 b=2;
   output out=out data=in;
proc print data=out;
run;
```

PROC PLAN interprets the first observation as referring to the cell in the first row and column of the plan, since a=1 and b=1; likewise, the second observation is interpreted as the cell in the second row and first column, and the third observation as the cell in the third row and first column. In the output data set, a and b have the values they have in the plan at these positions, as shown in Figure 65.8.

Figure 65.8 Output Form of Input Data Set from Simple Plan

```
Obs    a    b

  1    2    2
  2    1    1
  3    3    2
```

When the factors are random, this has the effect of randomizing the input data set in the same manner as the plan produced (see the sections "Randomizing Designs" on page 4742 and "Randomly Assigning Subjects to Treatments" on page 4728).

Specifying Factor Structures

By appropriately combining features of the PLAN procedure, you can construct an extensive set of designs. The basic tools are the *factor-selections*, which are used in the FACTORS and TREATMENTS statements. Table 65.1 summarizes how the procedure interprets various *factor-selections* (assuming that the ORDERED option is not specified in the PROC PLAN statement).

Table 65.1 *Factor-Selection* Interpretation

Form of Request	Interpretation	Example	Results
name=*m*	produce a random permutation of the integers $1, 2, \ldots, m$	`t=15`	lists a random ordering of the numbers $1, 2, \ldots, 15$
name=*m* cyclic	cyclically permute the integers $1, 2, \ldots, m$	`t=5 cyclic`	selects the integers 1 to 5. On the next iteration, selects 2,3,4,5,1; then 3,4,5,1,2; and so on.
name=*m* of *n*	choose a random sample of *m* integers (without replacement) from the set of integers $1, 2, \ldots, n$	`t=5 of 15`	lists a random selection of 5 numbers from 1 to 15. First, the procedure selects 5 numbers and then arranges them in random order.
name=*m* of *n* ordered	has the same effect as *name*=*m* ordered	`t=5 of 15 ordered`	lists the integers 1 to 5 in increasing order (same as t=5 ordered)
name=*m* of *n* cyclic	permute *m* of the *n* integers	`t=5 of 30 cyclic`	selects the integers 1 to 5. On the next iteration, selects 2,3,4,5,6; then 3,4,5,6,7; and so on. The 30th iteration produces 30,1,2,3,4; the 31st iteration produces 1,2,3,4,5; and so on.
name=*m* perm	produce a list of all permutations of *m* integers	`t=5 perm`	lists the integers 1,2,3,4,5 on the first iteration; on the second lists 1,2,3,5,4; on the 119th iteration lists 5,4,3,1,2; and on the last (120th) lists 5,4,3,2,1.
name=*m* of *n* comb	choose combinations of *m* integers from *n* integers	`t=3 of 5 comb`	lists all combinations of 5 choose 3 integers. The first iteration is 1,2,3; the second is 1,2,4; the third is 1,2,5; and so on until the last iteration 3,4,5.

Table 65.1 *continued*

Form of Request	Interpretation	Example	Results
name=*m* of *n* cyclic (*initial-block*)	permute *m* of the *n* integers, starting with the values specified in the *initial-block*	`t=4 of 30 cyclic (2 10 15 18)`	selects the integers 2,10,15,18. On the next iteration, selects 3,11,16,19; then 4,12,17,20; and so on. The thirteenth iteration is 14,22,27,30; the fourteenth iteration is 15,23,28,1; and so on.
name=*m* of *n* cyclic (*initial-block*) *increment*	permute *m* of the *n* integers. Start with the values specified in the *initial-block*, then add the *increment* to each value.	`t=4 of 30 cyclic (2 10 15 18) 2`	selects the integers 2,10,15,18. On the next iteration, selects 4,12,17,20; then 6,14,19,22; and so on. The wrap occurs at the eighth iteration. The eighth iteration is 16,24,29,2; and so on.

In Table 65.1, in order for more than one iteration to appear in the plan, another *name*=*j* factor selection (with $j > 1$) must precede the example factor selection. For example, the following statements produce six of the iterations described in the last entry of Table 65.1.

```
proc plan;
   factors c=6 ordered t=4 of 30 cyclic (2 10 15 18) 2;
run;
```

The following statements create a randomized complete block design and output the design to a data set.

```
proc plan ordered;
   factors blocks=3 cell=5;
   treatments t=5 random;
   output out=rcdb;
run;
```

Randomizing Designs

In many situations, proper randomization is crucial for the validity of any conclusions to be drawn from an experiment. Randomization is used both to neutralize the effect of any unknown systematic biases that might be involved in the design and to provide a basis for the assumptions underlying the analysis.

You can use PROC PLAN to randomize an already existing design: one produced by a previous call to PROC PLAN, perhaps, or a more specialized design taken from a standard reference such as Cochran and Cox (1957). The method is to specify the appropriate block structure in the FACTORS statement and then to specify the data set where the design is stored with the DATA= option in the OUTPUT statement. For an illustration of this method, see the section "Randomly Assigning Subjects to Treatments" on page 4728).

Two sorts of randomization are provided for, corresponding to the RANDOM factor selection and association types in the FACTORS and OUTPUT statements, respectively. Designs in which factors are completely nested (for example, block designs) should be randomized by specifying that the selection type of each factor is RANDOM in the FACTORS statement, which is the default (see Example 65.3). On the other hand, if the factors are crossed (for example, row-and-column designs), they should be randomized by one random reassignment of their values for the whole design. To do this, specify that the association type of each factor is RANDOM in the OUTPUT statement (see Example 65.4).

Displayed Output

The PLAN procedure displays the following output:

- the m value for each factor, which is the number of values to be selected
- the n value for each factor, which is the number of values to be selected from
- the selection type for each factor, as specified in the FACTORS statement
- the initial block and increment number for cyclic factors
- the *factor-value-selections* making up each plan

In addition, notes are written to the log that give the starting and ending values of the random number seed for each call to PROC PLAN.

ODS Table Names

PROC PLAN assigns a name to each table it creates. You can use these names to reference the table in the Output Delivery System (ODS) to select tables and create output data sets. These names are listed in the following table. For more information about ODS, see Chapter 20, "Using the Output Delivery System."

Table 65.2 ODS Tables Produced by PROC PLAN

ODS Table Name	Description	Statements
FInfo	General factor information	FACTORS and no TREATMENTS
PFInfo	Plot factor information	FACTORS and TREATMENTS
Plan	Computed plan	default
TFInfo	Treatment factor information	FACTORS and TREATMENTS

Examples: PLAN Procedure

Example 65.1: A Split-Plot Design

This plan is appropriate for a split-plot design with main plots forming a randomized complete block design. In this example, there are three blocks, four main plots per block, and two subplots per main plot. First, three random permutations (one for each of the blocks) of the integers 1, 2, 3, and 4 are produced. The four integers correspond to the four levels of the main plot factor a; the permutation determines how the levels of a are assigned to the main plots within a block. For each of these 12 numbers (four numbers per block for three blocks), a random permutation of the integers 1 and 2 is produced. Each two-integer permutation determines the assignment of the two levels of the subplot factor b within a main plot. The following statements produce Output 65.1.1:

```
title 'Split Plot Design';
proc plan seed=37277;
   factors Block=3 ordered a=4 b=2;
run;
```

Output 65.1.1 A Split-Plot Design

```
                         Split Plot Design

                         The PLAN Procedure

             Factor       Select       Levels      Order

             Block             3            3    Ordered
             a                 4            4    Random
             b                 2            2    Random

                        Block         a      -b-

                            1         4      2 1
                                      3      2 1
                                      1      2 1
                                      2      2 1
                            2         4      1 2
                                      3      1 2
                                      1      2 1
                                      2      1 2
                            3         4      2 1
                                      2      2 1
                                      3      2 1
                                      1      2 1
```

Example 65.2: A Hierarchical Design

In this example, three plants are nested within four pots, which are nested within three houses. The FACTORS statement requests a random permutation of the numbers 1, 2, and 3 to choose Houses randomly. The second step requests a random permutation of the numbers 1, 2, 3, and 4 for each of those first three numbers to randomly assign Pots to Houses. Finally, the FACTORS statement requests a random permutation of 1, 2, and 3 for each of the 12 integers in the second set of permutations. This last step randomly assigns Plants to Pots. The following statements produce Output 65.2.1:

```
title 'Hierarchical Design';
proc plan seed=17431;
   factors Houses=3 Pots=4 Plants=3 / noprint;
   output out=nested;
run;

proc print data=nested;
run;
```

Output 65.2.1 A Hierarchical Design

```
                 Obs    Houses    Pots    Plants

                   1       1        3        2
                   2       1        3        3
                   3       1        3        1
                   4       1        1        3
                   5       1        1        1
                   6       1        1        2
                   7       1        2        2
                   8       1        2        3
                   9       1        2        1
                  10       1        4        3
                  11       1        4        2
                  12       1        4        1
                  13       2        4        1
                  14       2        4        3
                  15       2        4        2
                  16       2        2        2
                  17       2        2        1
                  18       2        2        3
                  19       2        3        2
                  20       2        3        3
                  21       2        3        1
                  22       2        1        2
                  23       2        1        3
                  24       2        1        1
                  25       3        4        1
                  26       3        4        3
                  27       3        4        2
                  28       3        1        3
                  29       3        1        2
                  30       3        1        1
                  31       3        2        1
                  32       3        2        2
                  33       3        2        3
                  34       3        3        3
                  35       3        3        2
                  36       3        3        1
```

Example 65.3: An Incomplete Block Design

Jarrett and Hall (1978) give an example of a generalized cyclic design with good efficiency characteristics. The design consists of two replicates of 52 treatments in 13 blocks of size 8. The following statements use the PLAN procedure to generate this design in an appropriately randomized form and store it in a SAS data set GCBD. Then the design is sorted and transposed to display in randomized order. The following statements produce Output 65.3.1 and Output 65.3.2:

```
title 'Generalized Cyclic Block Design';
proc plan seed=33373;
   treatments Treatment=8 of 52 cyclic (1 2 3 4 32 43 46 49) 4;
   factors Block=13 Plot=8;
   output out=GCBD;
quit;
proc sort data=GCBD out=GCBD;
   by Block Plot;
proc transpose data= GCBD(rename=(Plot=_NAME_))
               out =tGCBD(drop=_NAME_);
   by Block;
   var Treatment;
proc print data=tGCBD noobs;
run;
```

Output 65.3.1 A Generalized Cyclic Block Design

```
                      Generalized Cyclic Block Design

                             The PLAN Procedure

                               Plot Factors

                  Factor      Select      Levels     Order

                  Block           13          13    Random
                  Plot             8           8    Random

                             Treatment Factors

   Factor          Select      Levels     Order      Initial Block / Increment

   Treatment            8          52    Cyclic      (1 2 3 4 32 43 46 49) / 4
```

Output 65.3.1 *continued*

```
                Block      ------Plot-----      -------Treatment-------

                   10      7 4 8 1 2 3 5 6       1  2  3  4 32 43 46 49
                    8      1 2 4 3 8 6 5 7       5  6  7  8 36 47 50  1
                    9      2 5 4 7 3 1 8 6       9 10 11 12 40 51  2  5
                    6      4 2 6 8 3 7 1 5      13 14 15 16 44  3  6  9
                    7      4 7 6 3 1 2 8 5      17 18 19 20 48  7 10 13
                    4      4 8 1 5 3 6 7 2      21 22 23 24 52 11 14 17
                    2      6 2 3 8 7 5 1 4      25 26 27 28  4 15 18 21
                    3      6 2 3 1 7 4 5 8      29 30 31 32  8 19 22 25
                    1      1 2 7 8 5 6 3 4      33 34 35 36 12 23 26 29
                    5      5 7 6 8 4 3 1 2      37 38 39 40 16 27 30 33
                   12      5 8 1 4 7 3 6 2      41 42 43 44 20 31 34 37
                   13      3 5 1 8 4 2 6 7      45 46 47 48 24 35 38 41
                   11      4 1 5 2 3 8 6 7      49 50 51 52 28 39 42 45
```

Output 65.3.2 A Generalized Cyclic Block Design

```
                         Generalized Cyclic Block Design

               Block     _1     _2     _3     _4     _5     _6     _7     _8

                   1     33     34     26     29     12     23     35     36
                   2     18     26     27     21     15     25      4     28
                   3     32     30     31     19     22     29      8     25
                   4     23     17     52     21     24     11     14     22
                   5     30     33     27     16     37     39     38     40
                   6      6     14     44     13      9     15      3     16
                   7     48      7     20     17     13     19     18     10
                   8      5      6      8      7     50     47      1     36
                   9     51      9     40     11     10      5     12      2
                  10      4     32     43      2     46     49      1      3
                  11     50     52     28     49     51     42     45     39
                  12     43     37     31     44     41     34     20     42
                  13     47     35     45     24     46     38     41     48
```

Example 65.4: A Latin Square Design

All of the preceding examples involve designs with completely nested block structures, for which PROC PLAN was especially designed. However, by appropriate coordination of its facilities, a much wider class of designs can be accommodated. A Latin square design is based on experimental units that have a row-and-column block structure. The following example uses the CYCLIC option for a treatment factor tmts to generate a simple 4×4 Latin square. Randomizing a Latin square design involves randomly permuting the row, column, and treatment values independently. In order to do this, use the RANDOM option in the OUTPUT statement of PROC PLAN. The example also uses *factor-value-settings* in the OUTPUT statement. The following statements produce Output 65.4.1:

```
title 'Latin Square Design';
proc plan seed=37430;
   factors Row=4 ordered Col=4 ordered / noprint;
   treatments Tmt=4 cyclic;
   output out=LatinSquare
          Row cvals=('Day 1' 'Day 2' 'Day 3' 'Day 4') random
          Col cvals=('Lab 1' 'Lab 2' 'Lab 3' 'Lab 4') random
          Tmt nvals=(      0     100     250     450) random;
quit;

proc sort data=LatinSquare out=LatinSquare;
   by Row Col;
proc transpose data= LatinSquare(rename=(Col=_NAME_))
               out =tLatinSquare(drop=_NAME_);
   by Row;
   var Tmt;
proc print data=tLatinSquare noobs;
run;
```

Output 65.4.1 A Randomized Latin Square Design

```
                    Latin Square Design

           Row      Lab_1     Lab_2     Lab_3     Lab_4

          Day 1         0       250       100       450
          Day 2       250       450         0       100
          Day 3       100         0       450       250
          Day 4       450       100       250         0
```

Example 65.5: A Generalized Cyclic Incomplete Block Design

The following statements depict how to create an appropriately randomized generalized cyclic incomplete block design for v treatments (given by the value of t) in b blocks (given by the value of b) of size k (with values of p indexing the cells within a block) with initial block ($e_1\ e_2\ \cdots\ e_k$) and increment number i.

factors b=b **p=**k **;**
treatments t=k **of** v **cyclic (**$e_1\ e_2\ \cdots\ e_k$ **)** i **;**

For example, the specification

```
proc plan seed=37430;
   factors b=10 p=4;
   treatments t=4 of 30 cyclic (1 3 4 26) 2;
run;
```

generates the generalized cyclic incomplete block design given in Example 1 of Jarrett and Hall (1978), which is given by the rows and columns of the plan associated with the treatment factor t in Output 65.5.1.

Output 65.5.1 A Generalized Cyclic Incomplete Block Design

```
                              The PLAN Procedure

                                Plot Factors

                  Factor       Select       Levels      Order

                  b                10           10     Random
                  p                 4            4     Random

                              Treatment Factors

                                                                 Initial Block
         Factor       Select       Levels       Order        / Increment

         t                 4           30      Cyclic         (1 3 4 26) / 2

                                b      ---p---      -----t-----

                                2      2 3 1 4       1  3  4 26
                                1      3 2 4 1       3  5  6 28
                                3      2 3 4 1       5  7  8 30
                               10      4 2 3 1       7  9 10  2
                                9      4 1 2 3       9 11 12  4
                                4      1 3 2 4      11 13 14  6
                                5      1 2 4 3      13 15 16  8
                                8      3 2 4 1      15 17 18 10
                                7      2 4 1 3      17 19 20 12
                                6      2 1 4 3      19 21 22 14
```

Example 65.6: Permutations and Combinations

Occasionally, you might need to generate all possible permutations of *n* things, or all possible combinations of *n* things taken *m* at a time.

For example, suppose you are planning an experiment in cognitive psychology where you want to present four successive stimuli to each subject. You want to observe each permutation of the four stimuli. The following statements use PROC PLAN to create a data set containing all possible permutations of four numbers in random order.

```
title 'All Permutations of 1,2,3,4';
proc plan seed=60359;
   factors    Subject  = 24
              Order    = 4  ordered;
   treatments Stimulus = 4  perm;
   output out=Psych;
run;

proc sort data=Psych out=Psych;
   by Subject Order;
```

```
proc transpose data= Psych(rename=(Order=_NAME_))
               out =tPsych(drop=_NAME_);
   by Subject;
   var Stimulus;
proc print data=tPsych noobs;
run;
```

The variable Subject is set at 24 levels because there are $4! = 24$ total permutations to be listed. If Subject > 24, the list repeats. Output 65.6.1 displays the PROC PLAN output. Note that the variable Subject is listed in random order.

Output 65.6.1 List of Permutations

```
                        All Permutations of 1,2,3,4

                             The PLAN Procedure

                                Plot Factors

                 Factor         Select       Levels     Order

                 Subject            24           24     Random
                 Order               4            4     Ordered

                             Treatment Factors

                Factor          Select       Levels     Order

                Stimulus             4            4     Perm

                    Subject      -Order-      -Stimulus-

                          4      1 2 3 4      1  2  3  4
                         15      1 2 3 4      1  2  4  3
                         24      1 2 3 4      1  3  2  4
                          1      1 2 3 4      1  3  4  2
                          5      1 2 3 4      1  4  2  3
                         17      1 2 3 4      1  4  3  2
                         19      1 2 3 4      2  1  3  4
                         14      1 2 3 4      2  1  4  3
                          6      1 2 3 4      2  3  1  4
                         23      1 2 3 4      2  3  4  1
                          8      1 2 3 4      2  4  1  3
                          2      1 2 3 4      2  4  3  1
                         13      1 2 3 4      3  1  2  4
                         16      1 2 3 4      3  1  4  2
                         12      1 2 3 4      3  2  1  4
                         18      1 2 3 4      3  2  4  1
                         21      1 2 3 4      3  4  1  2
                          9      1 2 3 4      3  4  2  1
                         22      1 2 3 4      4  1  2  3
                         10      1 2 3 4      4  1  3  2
                          7      1 2 3 4      4  2  1  3
                         11      1 2 3 4      4  2  3  1
                          3      1 2 3 4      4  3  1  2
                         20      1 2 3 4      4  3  2  1
```

The output data set Psych contains 96 observations of the 3 variables (Subject, Order, and Stimulus). Sorting the output data set by Subject and by Order within Subject results in all possible permutations of Stimulus in random order. PROC TABULATE displays these permutations in Output 65.6.2.

Output 65.6.2 Randomized Permutations

```
                    All Permutations of 1,2,3,4

                  Subject    _1    _2    _3    _4

                      1       1     3     4     2
                      2       2     4     3     1
                      3       4     3     1     2
                      4       1     2     3     4
                      5       1     4     2     3
                      6       2     3     1     4
                      7       4     2     1     3
                      8       2     4     1     3
                      9       3     4     2     1
                     10       4     1     3     2
                     11       4     2     3     1
                     12       3     2     1     4
                     13       3     1     2     4
                     14       2     1     4     3
                     15       1     2     4     3
                     16       3     1     4     2
                     17       1     4     3     2
                     18       3     2     4     1
                     19       2     1     3     4
                     20       4     3     2     1
                     21       3     4     1     2
                     22       4     1     2     3
                     23       2     3     4     1
                     24       1     3     2     4
```

As another example, suppose you have six alternative treatments, any four of which can occur together in a block (in no particular order). The following statements use PROC PLAN to create a data set containing all possible combinations of six numbers taken four at a time. In this case, you use ODS to create the data set.

```
title 'All Combinations of (6 Choose 4) Integers';
proc plan;
   factors Block=15 ordered
           Treat= 4 of 6 comb;
   ods output Plan=Combinations;
run;

proc print data=Combinations noobs;
run;
```

The variable Block has 15 levels since there are a total of $6!/(4!2!) = 15$ combinations of four integers chosen from six integers. The data set formed by ODS from the displayed plan has one row for each block, with the four values of Treat corresponding to four different variables, as shown in Output 65.6.3 and Output 65.6.4.

Output 65.6.3 List of Combinations

```
                    All Combinations of (6 Choose 4) Integers

                                The PLAN Procedure

                    Factor      Select      Levels     Order

                    Block           15          15    Ordered
                    Treat            4           6    Comb

                                 Block      -Treat-

                                     1      1 2 3 4
                                     2      1 2 3 5
                                     3      1 2 3 6
                                     4      1 2 4 5
                                     5      1 2 4 6
                                     6      1 2 5 6
                                     7      1 3 4 5
                                     8      1 3 4 6
                                     9      1 3 5 6
                                    10      1 4 5 6
                                    11      2 3 4 5
                                    12      2 3 4 6
                                    13      2 3 5 6
                                    14      2 4 5 6
                                    15      3 4 5 6
```

Output 65.6.4 Combinations Data Set Created by ODS

```
                    All Combinations of (6 Choose 4) Integers

                    Block    Treat1    Treat2    Treat3    Treat4

                        1       1         2         3         4
                        2       1         2         3         5
                        3       1         2         3         6
                        4       1         2         4         5
                        5       1         2         4         6
                        6       1         2         5         6
                        7       1         3         4         5
                        8       1         3         4         6
                        9       1         3         5         6
                       10       1         4         5         6
                       11       2         3         4         5
                       12       2         3         4         6
                       13       2         3         5         6
                       14       2         4         5         6
                       15       3         4         5         6
```

Example 65.7: Crossover Designs

In *crossover* experiments, the same experimental units or subjects are given multiple treatments in sequence, and the model for the response at any one period includes an effect for the treatment applied in the previous period. A good design for a crossover experiment will therefore be one which balances how often each treatment is preceded by each other treatment. Cox (1992) gives the following example of a balanced crossover experiment for paper production. In this experiment, the subjects are production runs of the mill, with the treatments being six different concentrations of pulp used in sequence. The following statements construct this design in a standard form, as shown in Output 65.7.1.

```
proc plan;
   factors Run=6 ordered Period=6 ordered;
   treatments Treatment=6 cyclic (1 2 6 3 5 4);
run;
```

Output 65.7.1 Crossover Design for Six Treatments

```
                             The PLAN Procedure

                               Plot Factors

                  Factor      Select      Levels     Order

                  Run              6           6    Ordered
                  Period           6           6    Ordered

                             Treatment Factors

                                                         Initial Block
        Factor         Select       Levels     Order     / Increment

        Treatment           6            6    Cyclic     (1 2 6 3 5 4) / 1

                        Run       ---Period--      -Treatment-

                          1       1 2 3 4 5 6      1 2 6 3 5 4
                          2       1 2 3 4 5 6      2 3 1 4 6 5
                          3       1 2 3 4 5 6      3 4 2 5 1 6
                          4       1 2 3 4 5 6      4 5 3 6 2 1
                          5       1 2 3 4 5 6      5 6 4 1 3 2
                          6       1 2 3 4 5 6      6 1 5 2 4 3
```

The construction method for this example is due to Williams (1949). The initial block for the treatment variable Treatment is defined thus for $n = 6$:

$$(1 \quad 2\ n \quad 3\ n-1 \quad \ldots \quad n/2\ n/2+2 \quad n/2)$$

This general form serves to generate a balanced crossover design for n treatments and n subjects in n periods when n is even. When n is odd, $2n$ subjects are required, with the initial blocks

$$\begin{array}{l} (1 \quad 2\ n \quad 3\ n-1 \quad \ldots \quad n/2+1\ \ n/2) \\ (n/2\ \ n/2+1 \quad \ldots \quad n-1\ \ 3 \quad n\ \ 2 \quad 1) \end{array}$$

respectively.

In order to randomize Williams' crossover designs, the following statements randomly permute the subjects and treatments:

```
proc plan seed=136149876;
   factors Run=6 ordered Period=6 ordered / noprint;
   treatments Treatment=6 cyclic (1 2 6 3 5 4);
   output out=RandomizedDesign
      Run       random
      Treatment random
      ;

/*
/ Relabel Period to obtain the same design as in Cox (1992).
/-------------------------------------------------------------------*/
data RandomizedDesign; set RandomizedDesign;
   Period = mod(Period+2,6)+1;
run;

proc sort data=RandomizedDesign;
   by Run Period;
proc transpose data=RandomizedDesign out=tDesign(drop=_name_);
   by notsorted Run;
   var Treatment;
data tDesign; set tDesign;
   rename COL1-COL6 = Period_1-Period_6;
proc print data=tDesign noobs;
run;
```

In the preceding, Run and Treatment are randomized by using the RANDOM option in the OUTPUT statement and new labels for Period are obtained in a subsequent DATA step. This Period relabeling is not necessary and might not be valid for Williams' designs in general; it is used in this example only to match results with those of Cox (1992). The SORT and TRANSPOSE steps then prepare the design to be printed in a standard form, shown in Output 65.7.2.

Output 65.7.2 Randomized Crossover Design

```
 Run    Period_1   Period_2   Period_3   Period_4   Period_5   Period_6

  1        3          6          2          5          4          1
  2        5          3          4          6          1          2
  3        1          4          5          2          6          3
  4        2          1          6          4          3          5
  5        6          5          1          3          2          4
  6        4          2          3          1          5          6
```

The analysis of a crossover experiment requires for each observation a *carryover* variable whose values are the treatment in the preceding period. The following statements add such a variable to the randomized design constructed previously, displaying the values of the carryover variable for each run and period in Output 65.7.3.

```
proc sort data=RandomizedDesign;
   by Run Period;
data RandomizedDesign; set RandomizedDesign;
   by Run period;
   LagTreatment = lag(Treatment);
   if (first.Run) then LagTreatment = .;
run;

proc transpose data=RandomizedDesign out=tDesign(drop=_name_);
   by notsorted Run;
   var LagTreatment;
data tDesign; set tDesign;
   rename COL1-COL6 = Period_1-Period_6;
proc print data=tDesign noobs;
run;
```

Output 65.7.3 Lag Treatment Effect in Crossover Design

```
Run    Period_1    Period_2    Period_3    Period_4    Period_5    Period_6

 1         .           3           6           2           5           4
 2         .           5           3           4           6           1
 3         .           1           4           5           2           6
 4         .           2           1           6           4           3
 5         .           6           5           1           3           2
 6         .           4           2           3           1           5
```

Of course, the carryover variable has no effect in the first period, which is why it is coded with a missing value in this case.

The experimental EFFECT statement in PROC GLIMMIX provides a convenient mechanism for incorporating the carryover variable into the analysis. The following statements first add the observed data to the design to create the Mills data set. Then PROC GLIMMIX is invoked and the carryover effect is defined as a multimember effect (having only a single member in this case) with the NOEFFECT option. The NOEFFECT option specifies that the columns for the carryover effect will be all zero when LagTreatment is missing. GLIMMIX is a very general procedure, so ODS is used to trim down the results to show only the parts that are usually of interest in crossover analysis. For more information about the EFFECTS statement in PROC GLIMMIX, see the section "EFFECT Statement (Experimental)" on page 2132. The carryover analysis is shown in Output 65.7.4.

```
data Responses;
   input Response @@;
datalines;
56.7 53.8 54.4 54.4 58.9 54.5
58.5 60.2 61.3 54.4 59.1 59.8
55.7 60.7 56.7 59.9 56.6 59.6
57.3 57.7 55.2 58.1 60.2 60.2
```

```
53.7 57.1 59.2 58.9 58.9 59.6
58.1 55.7 58.9 56.6 59.6 57.5
;
data Mills;
   merge RandomizedDesign Responses;
run;

proc glimmix data=Mills outdesign=d;
   class Run Period Treatment LagTreatment;
   effect CarryOver = mm(LagTreatment / noeffect);
   model Response = Run Period Treatment CarryOver / htype=1;
   lsmeans Treatment CarryOver / obsmargins diff=anom e;
   ods select Tests1 LSMeans Diffs;
run;
```

Output 65.7.4 Carryover Analysis for Crossover Experiment

```
                          The GLIMMIX Procedure

                     Type I Tests of Fixed Effects

                                Num       Den
               Effect            DF        DF    F Value    Pr > F

               Run                5        15      13.76    <.0001
               Period             5        15       7.19    0.0013
               Treatment          5        15      22.95    <.0001
               CarryOver          5        15       7.76    0.0009

                     Treatment Least Squares Means

                                           Standard
Treatment    Margins       Estimate         Error        DF    t Value    Pr > |t|

1            WORK.MILLS     57.1954        0.3220        15     177.65      <.0001
2            WORK.MILLS     57.6204        0.3220        15     178.97      <.0001
3            WORK.MILLS     59.1919        0.3220        15     183.85      <.0001
4            WORK.MILLS     59.2288        0.3220        15     183.97      <.0001
5            WORK.MILLS     57.9829        0.3220        15     180.10      <.0001
6            WORK.MILLS     55.0639        0.3220        15     171.03      <.0001

                Differences of Treatment Least Squares Means

                                                 Standard
Treatment  _Treatment  Margins     Estimate        Error      DF  t Value  Pr > |t|

1          Avg         WORK.MILLS   -0.5185       0.2948      15    -1.76    0.0990
2          Avg         WORK.MILLS  -0.09345       0.2948      15    -0.32    0.7556
3          Avg         WORK.MILLS    1.4780       0.2948      15     5.01    0.0002
4          Avg         WORK.MILLS    1.5149       0.2948      15     5.14    0.0001
5          Avg         WORK.MILLS    0.2690       0.2948      15     0.91    0.3758
6          Avg         WORK.MILLS   -2.6500       0.2948      15    -8.99    <.0001
```

Output 65.7.4 *continued*

```
                        CarryOver Least Squares Means

 Carry                              Standard
 Over      Margins       Estimate      Error        DF    t Value    Pr > |t|

 1         WORK.MILLS     Non-est          .         .          .          .
 2         WORK.MILLS     Non-est          .         .          .          .
 3         WORK.MILLS     Non-est          .         .          .          .
 4         WORK.MILLS     Non-est          .         .          .          .
 5         WORK.MILLS     Non-est          .         .          .          .
 6         WORK.MILLS     Non-est          .         .          .          .

                 Differences of CarryOver Least Squares Means

        _
Carry   Carry                                Standard
Over    Over     Margins       Estimate        Error       DF    t Value     Pr > |t|

1       Avg      WORK.MILLS      0.3726       0.3284       15       1.13       0.2743
2       Avg      WORK.MILLS     -0.2774       0.3284       15      -0.84       0.4116
3       Avg      WORK.MILLS      0.6512       0.3284       15       1.98       0.0660
4       Avg      WORK.MILLS     -1.3274       0.3284       15      -4.04       0.0011
5       Avg      WORK.MILLS      1.3976       0.3284       15       4.26       0.0007
6       Avg      WORK.MILLS     -0.8167       0.3284       15      -2.49       0.0252
```

The Type I analysis of variance indicates that all effects are significant—in particular, both the direct and the carryover effects of the treatment. In the presence of carryover effects, the LS-means need to be defined with some care. The LS-means for treatments computed using balanced margins for the carryover effect are inestimable, so the OBSMARGINS option is specified in the LSMEANS statement in order to use the observed margins instead. The observed margins take the absence of a carryover effect in the first period into account. Note that the LS-means themselves of the carryover effect are inestimable, but their differences are estimable. The LS-means of the direct effect of the treatment and the ANOM differences for the LS-means of their carryover effect match the "adjusted direct effects" and "adjusted residual effects," respectively, of Cox (1992).

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