```
/* x5_4.sas */
/* Purpose:  */

title1 'Example 5.4.';

data a;
input b1d1 b1d2 b2d1 b2d2 b3d1 b3d2 b4d1 b4d2 b5d1 b5d2;
cards;
1890 2057 1925 2112 1988 1932 1967 1980 2000 2110
1863 2028 1903 2083 1876 1862 2021 2025 1769 1983
1927 1964 2043 2096 1874 1863 2014 1983 1885 2098
1830 1955 1957 2078 1914 1927 2019 1862 2004 2084
1803 1976 1946 2031 1882 1907 2002 2041 1904 2015
1951 1996 1940 2084 1774 1763 2128 2001 1865 1978
1995 2057 1916 2017 1872 1841 1949 1970 1927 2098
1967 1979 1967 2035 1822 1914 1904 2053 1972 2124
1934 2010 1958 1978 1891 1837 2029 1978 1886 2077
1897 2037 1879 2045 1855 1911 1989 1940 2019 2036
1869 2013 1995 2002 1809 1866 2052 1980 1884 2060
1847 1990 1980 2078 1894 1797 2042 1921 1990 2141
1882 2015 1934 2118 1870 1983 1835 2002 1884 2075
1965 1975 1990 2017 1910 1873 1970 1969 1938 2074
1954 1934 1906 2107 1970 1907 2028 1849 1950 2003
1973 2074 1985 2005 1980 1923 2000 2030 1999 2077
1870 2071 2000 2094 1885 1962 2041 2006 1987 2110
1894 1993 1951 1993 1775 1859 2033 1999 1823 2061
1927 1943 1979 2020 1871 1993 1996 2006 1951 2099
;

proc print data=a;
title2 'List of data.';

proc means data=a;
title2 'Simple statistics of data.';

data b; set a;
  batch=1; day=1; yards=b1d1; output;
  batch=1; day=2; yards=b1d2; output;
  batch=2; day=1; yards=b2d1; output;
  batch=2; day=2; yards=b2d2; output;
  batch=3; day=1; yards=b3d1; output;
  batch=3; day=2; yards=b3d2; output;
  batch=4; day=1; yards=b4d1; output;
  batch=4; day=2; yards=b4d2; output;
  batch=5; day=1; yards=b5d1; output;
  batch=5; day=2; yards=b5d2; output;
keep batch day yards;

proc print data=b;
title2 'List of reorganised data';

proc glm;
  class batch day;
  model yards=batch day(batch) / solution;
  random day(batch) /test;
  means batch;
title2 'Analysis of model with random "day". using proc glm.';

proc anova;
  class batch day;
  model yards=batch day(batch);
  means batch;
```



```
title2 'Analysis of model with systematic "day" using proc anova.';

proc varcomp method=type1;
  class batch day;
  model yards=batch day(batch) /fixed=1;
title2 'Alternative assessment of variance components.';

run;
```

Example 5.4. 1
List of data.

Obs	b1d1	b1d2	b2d1	b2d2	b3d1	b3d2	b4d1	b4d2	b5d1	b5d2
1	1890	2057	1925	2112	1988	1932	1967	1980	2000	2110
2	1863	2028	1903	2083	1876	1862	2021	2025	1769	1983
3	1927	1964	2043	2096	1874	1863	2014	1983	1885	2098
4	1830	1955	1957	2078	1914	1927	2019	1862	2004	2084
5	1803	1976	1946	2031	1882	1907	2002	2041	1904	2015
6	1951	1996	1940	2084	1774	1763	2128	2001	1865	1978
7	1995	2057	1916	2017	1872	1841	1949	1970	1927	2098
8	1967	1979	1967	2035	1822	1914	1904	2053	1972	2124
9	1934	2010	1958	1978	1891	1837	2029	1978	1886	2077
10	1897	2037	1879	2045	1855	1911	1989	1940	2019	2036
11	1869	2013	1995	2002	1809	1866	2052	1980	1884	2060
12	1847	1990	1980	2078	1894	1797	2042	1921	1990	2141
13	1882	2015	1934	2118	1870	1983	1835	2002	1884	2075
14	1965	1975	1990	2017	1910	1873	1970	1969	1938	2074
15	1954	1934	1906	2107	1970	1907	2028	1849	1950	2003
16	1973	2074	1985	2005	1980	1923	2000	2030	1999	2077
17	1870	2071	2000	2094	1885	1962	2041	2006	1987	2110
18	1894	1993	1951	1993	1775	1859	2033	1999	1823	2061
19	1927	1943	1979	2020	1871	1993	1996	2006	1951	2099

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Example 5.4. 2
Simple statistics of data.

The MEANS Procedure

Variable	N	Mean	Std Dev	Minimum	Maximum
b1d1	19	1907.26	53.2362054	1803.00	1995.00
b1d2	19	2003.53	42.2681498	1934.00	2074.00
b2d1	19	1955.47	40.0782130	1879.00	2043.00
b2d2	19	2052.26	44.6813932	1978.00	2118.00
b3d1	19	1879.58	59.5121984	1774.00	1988.00
b3d2	19	1890.53	59.4328458	1763.00	1993.00
b4d1	19	2001.00	61.1909579	1835.00	2128.00
b4d2	19	1978.68	54.0473585	1849.00	2053.00
b5d1	19	1928.26	67.9017608	1769.00	2019.00
b5d2	19	2068.58	46.3960197	1978.00	2141.00

Example 5.4. 3
List of reorganised data

Obs	batch	day	yards
1	1	1	1890
2	1	2	2057
3	2	1	1925
4	2	2	2112
5	3	1	1988
6	3	2	1932
7	4	1	1967
8	4	2	1980
9	5	1	2000
10	5	2	2110
11	1	1	1863
12	1	2	2028
13	2	1	1903
14	2	2	2083
15	3	1	1876
16	3	2	1862
17	4	1	2021
18	4	2	2025
19	5	1	1769
20	5	2	1983
21	1	1	1927
22	1	2	1964
23	2	1	2043
24	2	2	2096
25	3	1	1874
26	3	2	1863
27	4	1	2014
28	4	2	1983
29	5	1	1885
30	5	2	2098
31	1	1	1830
32	1	2	1955
33	2	1	1957
34	2	2	2078
35	3	1	1914
36	3	2	1927
37	4	1	2019
38	4	2	1862
39	5	1	2004
40	5	2	2084
41	1	1	1803
42	1	2	1976
43	2	1	1946
44	2	2	2031
45	3	1	1882
46	3	2	1907
47	4	1	2002
48	4	2	2041
49	5	1	1904
50	5	2	2015
51	1	1	1951
52	1	2	1996
53	2	1	1940
54	2	2	2084
55	3	1	1774
56	3	2	1763
57	4	1	2128

58	4	2	2001
59	5	1	1865
60	5	2	1978

Example 5.4. 4
List of reorganised data

Obs	batch	day	yards
61	1	1	1995
62	1	2	2057
63	2	1	1916
64	2	2	2017
65	3	1	1872
66	3	2	1841
67	4	1	1949
68	4	2	1970
69	5	1	1927
70	5	2	2098
71	1	1	1967
72	1	2	1979
73	2	1	1967
74	2	2	2035
75	3	1	1822
76	3	2	1914
77	4	1	1904
78	4	2	2053
79	5	1	1972
80	5	2	2124
81	1	1	1934
82	1	2	2010
83	2	1	1958
84	2	2	1978
85	3	1	1891
86	3	2	1837
87	4	1	2029
88	4	2	1978
89	5	1	1886
90	5	2	2077
91	1	1	1897
92	1	2	2037
93	2	1	1879
94	2	2	2045
95	3	1	1855
96	3	2	1911
97	4	1	1989
98	4	2	1940
99	5	1	2019
100	5	2	2036
101	1	1	1869
102	1	2	2013
103	2	1	1995
104	2	2	2002
105	3	1	1809
106	3	2	1866
107	4	1	2052
108	4	2	1980
109	5	1	1884
110	5	2	2060
111	1	1	1847
112	1	2	1990
113	2	1	1980
114	2	2	2078
115	3	1	1894
116	3	2	1797
117	4	1	2042

118	4	2	1921
119	5	1	1990
120	5	2	2141

Example 5.4. 5
List of reorganised data

Obs	batch	day	yards
121	1	1	1882
122	1	2	2015
123	2	1	1934
124	2	2	2118
125	3	1	1870
126	3	2	1983
127	4	1	1835
128	4	2	2002
129	5	1	1884
130	5	2	2075
131	1	1	1965
132	1	2	1975
133	2	1	1990
134	2	2	2017
135	3	1	1910
136	3	2	1873
137	4	1	1970
138	4	2	1969
139	5	1	1938
140	5	2	2074
141	1	1	1954
142	1	2	1934
143	2	1	1906
144	2	2	2107
145	3	1	1970
146	3	2	1907
147	4	1	2028
148	4	2	1849
149	5	1	1950
150	5	2	2003
151	1	1	1973
152	1	2	2074
153	2	1	1985
154	2	2	2005
155	3	1	1980
156	3	2	1923
157	4	1	2000
158	4	2	2030
159	5	1	1999
160	5	2	2077
161	1	1	1870
162	1	2	2071
163	2	1	2000
164	2	2	2094
165	3	1	1885
166	3	2	1962
167	4	1	2041
168	4	2	2006
169	5	1	1987
170	5	2	2110
171	1	1	1894
172	1	2	1993
173	2	1	1951
174	2	2	1993
175	3	1	1775
176	3	2	1859
177	4	1	2033

178	4	2	1999
179	5	1	1823
180	5	2	2061

Example 5.4. 6
List of reorganised data

Obs	batch	day	yards
181	1	1	1927
182	1	2	1943
183	2	1	1979
184	2	2	2020
185	3	1	1871
186	3	2	1993
187	4	1	1996
188	4	2	2006
189	5	1	1951
190	5	2	2099

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Example 5.4. 7
Analysis of model with random "day". using proc glm.

The GLM Procedure

Class Level Information

Class	Levels	Values
batch	5	1 2 3 4 5
day	2	1 2

Number of Observations Read 190
Number of Observations Used 190

```
                               Example 5.4.                                    8
           Analysis of model with random "day". using proc glm.

                            The GLM Procedure

Dependent Variable: yards

                                          Sum of
 Source                      DF          Squares     Mean Square    F Value    Pr > F

 Model                        9       739194.821       82132.758      28.59    <.0001

 Error                      180       517068.632        2872.604

 Corrected Total            189      1256263.453


              R-Square     Coeff Var      Root MSE    yards Mean

              0.588407      2.725464      53.59667      1966.516


 Source                      DF        Type I SS     Mean Square    F Value    Pr > F

 batch                        4      369253.8211      92313.4553      32.14    <.0001
 day(batch)                   5      369941.0000      73988.2000      25.76    <.0001


 Source                      DF      Type III SS     Mean Square    F Value    Pr > F

 batch                        4      369253.8211      92313.4553      32.14    <.0001
 day(batch)                   5      369941.0000      73988.2000      25.76    <.0001


                                                 Standard
    Parameter                Estimate               Error    t Value    Pr > |t|

    Intercept            2068.578947 B        12.29592039     168.23      <.0001
    batch      1          -65.052632 B        17.38905738      -3.74      0.0002
    batch      2          -16.315789 B        17.38905738      -0.94      0.3494
    batch      3         -178.052632 B        17.38905738     -10.24      <.0001
    batch      4          -89.894737 B        17.38905738      -5.17      <.0001
    batch      5            0.000000 B          .               .          .
    day(batch) 1 1        -96.263158 B        17.38905738      -5.54      <.0001
    day(batch) 2 1          0.000000 B          .               .          .
    day(batch) 1 2        -96.789474 B        17.38905738      -5.57      <.0001
    day(batch) 2 2          0.000000 B          .               .          .
    day(batch) 1 3        -10.947368 B        17.38905738      -0.63      0.5298
    day(batch) 2 3          0.000000 B          .               .          .
    day(batch) 1 4         22.315789 B        17.38905738       1.28      0.2010
    day(batch) 2 4          0.000000 B          .               .          .
    day(batch) 1 5       -140.315789 B        17.38905738      -8.07      <.0001
    day(batch) 2 5          0.000000 B          .               .          .

NOTE: The X'X matrix has been found to be singular, and a generalized inverse
      was used to solve the normal equations.  Terms whose estimates are
      followed by the letter 'B' are not uniquely estimable.
```



```
                               Example 5.4.                                    9
           Analysis of model with random "day". using proc glm.

                            The GLM Procedure

   Source                     Type III Expected Mean Square

   batch                      Var(Error) + 19 Var(day(batch)) + Q(batch)

   day(batch)                 Var(Error) + 19 Var(day(batch))

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                               Example 5.4.                                   10
           Analysis of model with random "day". using proc glm.

                            The GLM Procedure
          Tests of Hypotheses for Mixed Model Analysis of Variance

Dependent Variable: yards

 Source                      DF     Type III SS     Mean Square    F Value    Pr > F

 batch                        4          369254           92313       1.25    0.3985

 Error                        5          369941           73988
 Error: MS(day(batch))


 Source                      DF     Type III SS     Mean Square    F Value    Pr > F

 day(batch)                   5          369941           73988      25.76    <.0001

 Error: MS(Error)           180          517069     2872.603509

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                               Example 5.4.                                   11
           Analysis of model with random "day". using proc glm.

              Level of            ------------yards------------
              batch          N             Mean          Std Dev

              1             38       1955.39474       68.0232629
              2             38       2003.86842       64.4826275
              3             38       1885.05263       58.9250313
              4             38       1989.84211       58.0561361
              5             38       1998.42105       91.3530815

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                               Example 5.4.                                   12
        Analysis of model with systematic "day" using proc anova.

                           The ANOVA Procedure

                         Class Level Information

                      Class         Levels    Values

                      batch              5    1 2 3 4 5

                      day                2    1 2
```

```
                    Number of Observations Read         190
                    Number of Observations Used         190
```



```
                                 Example 5.4.                                 13
          Analysis of model with systematic "day" using proc anova.

                             The ANOVA Procedure

Dependent Variable: yards

                                        Sum of
 Source                      DF        Squares     Mean Square    F Value    Pr > F

 Model                        9     739194.821       82132.758      28.59    <.0001

 Error                      180     517068.632        2872.604

 Corrected Total            189    1256263.453


              R-Square     Coeff Var      Root MSE    yards Mean

              0.588407      2.725464      53.59667      1966.516


 Source                      DF        Anova SS     Mean Square    F Value    Pr > F

 batch                        4    369253.8211      92313.4553      32.14    <.0001
 day(batch)                   5    369941.0000      73988.2000      25.76    <.0001

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                                 Example 5.4.                                 14
          Analysis of model with systematic "day" using proc anova.

                             The ANOVA Procedure

              Level of            ------------yards------------
              batch         N             Mean          Std Dev

              1            38       1955.39474       68.0232629
              2            38       2003.86842       64.4826275
              3            38       1885.05263       58.9250313
              4            38       1989.84211       58.0561361
              5            38       1998.42105       91.3530815
```

```
                      Example 5.4.                                15
          Alternative assessment of variance components.

             Variance Components Estimation Procedure

                     Class Level Information

                Class         Levels    Values

                batch              5    1 2 3 4 5

                day                2    1 2


             Number of Observations Read         190
             Number of Observations Used         190


                   Dependent Variable:    yards


                   Type 1 Analysis of Variance

                                           Sum of
       Source                  DF         Squares     Mean Square

       batch                    4          369254           92313
       day(batch)               5          369941           73988
       Error                  180          517069     2872.603509
       Corrected Total        189         1256263               .

                   Type 1 Analysis of Variance

     Source             Expected Mean Square

     batch              Var(Error) + 19 Var(day(batch)) + Q(batch)
     day(batch)         Var(Error) + 19 Var(day(batch))
     Error              Var(Error)
     Corrected Total    .


                         Type 1 Estimates

                Variance Component        Estimate

                Var(day(batch))             3742.9
                Var(Error)                  2872.6
```