# SAS MACRO FOR GENERATION OF HALF REPLICATE OF A $2^{k}$ FACTORIAL RUN ORDER WITH MINIMUM LEVEL CHANGES 

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Factorial experiments are experiments where two or more factors are used simultaneously. When the number of combinations of factorial designs becomes too large to be logistically feasible, one can use fractional factorial designs by carefully choosing a fraction of the full factorial designs. Both factorial and fractional factorial designs found profound applications in agricultural and industrial research. Factorial and fractional factorial run orders with minimum level changes are important when experiments involve hard-to-change factors for which it is very difficult to change levels [Bhowmik et al. $(2015,2017,2020)]$. Here, a SAS macro has been developed to generate half replicate of $2^{\mathrm{k}}$ factorial run order with minimum level changes based on the methods proposed by Bhowmik et al. (2015). The method of construction of half replicate of 2level factorial with minimum level changes as given by Bhowmik et al. (2015) is as follows:

Let, there are k factors each at 2 level. In order to construct half replicate of $2^{\mathrm{k}}$ factorial with minimum number of changes, where the identity group of contrast will be the highest order interaction effect, the following steps are required:

Step I: Construct a $2^{\mathrm{k}-1}$ factorial with minimum changes in run sequences
Step II: Generate a new factor by taking the product of all the k-1 factor in the developed $2^{\mathrm{k}-1}$ factorial with minimum changes in run sequences

The total number of changes will be the sum of factor wise level changes of individual factors.

For generation of half replicate of $2^{\mathrm{k}}$ factorial with minimum level changes through the use of the developed SAS macro, user only need to enter the value of $\mathbf{k}$ where $\mathbf{k}$ is the number of factor. Once user run the macro after entering the value of $\mathbf{k}$, the SAS Macro will generate the layout under the heading Minimally changed run sequences for half replicate of 2-level factorial experiment along with Factor-wise number of changes in the run sequence and Total number of changes in the run sequence respectively under two different arrays.

## CODE

options nodate nonumber;
\%let $\mathrm{k}=5 ; / *$ Enter the number of factors*/
ods rtf file $=$ 'output.rtf' startpage $=$ no;
proc iml;
sss=j(\&k,1,2);
$\mathrm{s}=\mathrm{j}($ nrow(sss)-1,1,0);/* 2 level for fractional factorial*/
do $\mathrm{i}=1$ to $\operatorname{nrow}(\mathrm{s})$;
$s[i]=,s s s[i$,$] ;$
end;
If $\& \mathrm{k}<3$ then do;
print 'The number factor should be $>=3$ ';
end;
else do;
$\mathrm{a}=\mathrm{j}(\max (\mathrm{s}), \operatorname{nrow}(\mathrm{s}), 0)$;
do $\mathrm{kk}=1$ to $\operatorname{nrow}(\mathrm{s})$;
$\mathrm{m}=\bmod (\mathrm{s}[\mathrm{kk}], 2$,$) ;$
do $\mathrm{i}=1$ to $\mathrm{s}[\mathrm{kk}$,$] ;$
do $j=i$ to $s[k k$,$] ;$
if $m=1$ then
do;
$\mathrm{a}[\mathrm{j}, \mathrm{kk}]=-((\mathrm{s}[\mathrm{kk}]-1) / 2)+,(\mathrm{i}-1)$;
end;
else
do;
if $-(\mathrm{s}[\mathrm{kk}] / 2)+,(\mathrm{i}-1)<0$ then do;
$\mathrm{a}[\mathrm{j}, \mathrm{kk}]=-(\mathrm{s}[\mathrm{kk}] / 2)+,(\mathrm{i}-1)$;
end;
else do;
$\mathrm{a}[\mathrm{j}, \mathrm{kk}]=-(\mathrm{s}[\mathrm{kk}] / 2)+$,i ;
end;
end;
end;
end;
end;
*print a;
$\mathrm{aa}=\mathrm{j}(\mathrm{s}[1], 1,0$,$) ;$
do $\mathrm{i}=1$ to $\mathrm{s}[1$,$] ;$
aa[i, $]=a[i, 1]$;
end;
*print aa;
sum=1;
do $\mathrm{j}=1$ to $\operatorname{nrow}(\mathrm{s})-1$;
do $\mathrm{i}=1$ to $\operatorname{nrow}(\mathrm{aa})$;
$\mathrm{kk}=$ repeat $(\mathrm{aa}[\mathrm{i}],, \mathrm{s}[\mathrm{j}+1], 1$,$) ;$
if $i=1$ then do;
aaa=kk;
end;else do;
aaa=aaa//kk;
end; end;

```
*print aaa;
sum=sum*s[j, ];
if mod(sum,2)=0 then do;
ggg=j(s[j+1, ],1,0);
do i=1 to s[j+1, ];
ggg[i,]=a[i,j+1];
end;
ggg1=ggg*-1;
ggg2=ggg//ggg1;
hh=repeat(ggg2,sum/2,1);
aa=aaa|\hh;
end;
else do;
ggg=j(s[j+1, ],1,0);
do i=1 to s[j+1, ];
ggg[i,]=a[i,j+1];
end;
ggg1=ggg*-1;
ggg2=ggg//ggg1;
hh1=repeat(ggg2,(sum-1)/2,1);
hh=hh1//ggg;
aa=aaa||hh;
end;
end;
aa1=j(nrow(aa),1,0);/* Generator by multiplying the columns of aa*/
do k=1 to nrow(aa);
s=1;
do ii=1 to ncol(aa);
aa1[k,]=s*aa[k,ii];
s=aa1[k,];
end;
end;
*print aa1;
aa=aa||aa1;
print 'Minimally changed run sequences for factorial experiment';
Run_Sequence=aa;
print Run_sequence;
Factor_Change=j(1,ncol(Run_Sequence),0);
do k=1 to ncol(Run_Sequence);
do l=2 to nrow(Run_Sequence);
if Run_Sequence[l-1,k]^=Run_Sequence[l,k] then do;
Factor_Change[1,k]=Factor_Change[1,k]+1;
end;
end;
end;
print 'Factor-wise number of changes in the run sequence';
print Factor_Change;
Total_change=sum(Factor_Change);
print 'Total number of changes in the run sequence';
print Total_change;
end; run; ods rtf close; quit;
```

SAS output for generation of a half replicate of a $2^{5}$ factorial with minimum changes in run

## sequences

The SAS System
Minimally changed run sequences for factorial experiment

| Run_Sequence |  |  |  |  |
| ---: | ---: | ---: | ---: | ---: |
| -1 | -1 | -1 | -1 | 1 |
| -1 | -1 | -1 | 1 | -1 |
| -1 | -1 | 1 | 1 | 1 |
| -1 | -1 | 1 | -1 | -1 |
| -1 | 1 | 1 | -1 | 1 |
| -1 | 1 | 1 | 1 | -1 |
| -1 | 1 | -1 | 1 | 1 |
| -1 | 1 | -1 | -1 | -1 |
| 1 | 1 | -1 | -1 | 1 |
| 1 | 1 | -1 | 1 | -1 |
| 1 | 1 | 1 | 1 | 1 |
| 1 | 1 | 1 | -1 | -1 |
| 1 | -1 | 1 | -1 | 1 |
| 1 | -1 | 1 | 1 | -1 |
| 1 | -1 | -1 | 1 | 1 |
| 1 | -1 | -1 | -1 | -1 |

Factor-wise number of changes in the run sequence
Factor_Change

| 1 | 2 | 4 | 8 | 15 |
| :--- | :--- | :--- | :--- | :--- |

Total number of changes in the run sequence


## References

Bhowmik, A., Varghese, E., Jaggi, S. and Varghese, C. (2015). Factorial experiments with minimum changes in run sequences. Journal of Indian Society of Agricultural Statistics, 69(3), 243- 255.
Bhowmik, A., Varghese, E., Jaggi, S., and Varghese, C. (2017). Minimally changed run sequences in factorial experiments. Communication in Statistics -Theory and Methods, 46(15), 7444-7459.
Bhowmik, A., Varghese, E., Jaggi, S., and Varghese, C. (2020). On the generation of factorial designs with minimum level changes. Communication in Statistics -Simulation and Computation. DOI: 10.1080/03610918.2020.1720244.

