

# Package ‘AsymmetricSORDs’

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**Type** Package

**Title** Asymmetric Second Order Rotatable Designs (AsymmetricSORDs)

**Version** 1.0.0

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**Description** Response surface designs (RSDs) are widely used for Response Surface Methodology (RSM) based optimization studies, which aid in exploring the relationship between a group of explanatory variables and one or more response variable(s) (G.E.P. Box and K.B. Wilson (1951), “On the experimental attainment of optimum conditions” ; M. Hemavathi, Shashi Shekhar, Eldho Varghese, Seema Jaggi, Bikas Sinha & Nripes Kumar Mandal (2022) <DOI:10.1080/03610926.2021.1944213>.”Theoretical developments in response surface designs: an informative review and further thoughts”). Second order rotatable designs are the most prominent and popular class of designs used for process and product optimization trials but it is suitable for situations when all the number of levels for each factor is the same. In many practical situations, RSDs with asymmetric levels (J.S. Mehta and M.N. Das (1968). “Asymmetric rotatable designs and orthogonal transformations” ; M. Hemavathi, Eldho Varghese, Shashi Shekhar & Seema Jaggi (2020) <DOI:10.1080/02664763.2020.1864817>.”Sequential asymmetric third order rotatable designs (SATORDs)” .) are more suitable as these designs explore more regions in the design space. This package contains functions named `Asords()`, `CCD_coded()`, `CCD_original()`, `SORD_coded()` and `SORD_original()` for generating asymmetric/symmetric RSDs along with the randomized layout. It also contains another function named `Pred.var()` for generating the variance of predicted response as well as the moment matrix based on a second order model.

**License** GPL (>= 2)

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Asords

*Asymmetric Second Order Rotatable Designs*

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### Description

This function generates ASORDs through the orthogonal transformation of central composite designs as per the procedure given by J.S. Mehta and M.N. Das (1968). It would be providing two types of asymmetric designs for a given number of treatments ( $v$ ). It requires four input parameters viz.,  $v(>2)$ ; `number_of_pairs(>0)`;  $z$ = vector of real number of length equals to `number_of_pairs`; `type="ccc"` or `"cci"` and `randomization=TRUE` or `FALSE`.

### Usage

```
Asords(v, number_of_pairs, z, type, randomization = FALSE, variance = FALSE)
```

### Arguments

<code>v</code>	Number of input factors, $v(>2)$
<code>number_of_pairs</code>	Number of pairs of input factors for which asymmetry is required
<code>z</code>	A vector of real number and its length equals to <code>number_of_pairs</code>
<code>type</code>	Type of central composite design i.e. <code>ccc</code> or <code>cci</code> . <code>"ccc"</code> is for Central Composite Circumscribed designs and <code>"cci"</code> is for Central Composite Inscribed designs
<code>randomization</code>	It is for generating the randomized layout of the design. It takes either <code>TRUE</code> or <code>FALSE</code> and by default, it is set to <code>FALSE</code>
<code>variance</code>	This is for generating the moment matrix and prediction variance of the design based on a second order model. It gives unique prediction variance along with its frequencies. It takes either <code>TRUE</code> or <code>FALSE</code> and by default, it is set to <code>FALSE</code>

### Value

Asymmetric Second Order Rotatable Designs (ASORDs) for a given  $v$ .

## References

- 1) J.S. Mehta and M.N. Das (1968). "Asymmetric rotatable designs and orthogonal transformations".
- 2) M. Hemavathi, Eldho Varghese, Shashi Shekhar & Seema Jaggi (2020) <DOI: 10.1080/02664763.2020.1864817>. "Sequential asymmetric third order rotatable designs (SATORDs)".
- 3) M. Hemavathi, Shashi Shekhar, Eldho Varghese, Seema Jaggi, Bikas Sinha & Nripes Kumar Mandal (2022) <DOI: 10.1080/03610926.2021.1944213>. "Theoretical developments in response surface designs: an informative review and further thoughts".

## Examples

```
library(AsymmetricSORDs)
Asords(5, 2, c(2, 3), "ccc", TRUE)
```

---

CCD\_coded

*Central Composite Designs (CCD) with coded levels*

---

## Description

This function generates Central Composite Designs (CCD) with coded levels for a given number of input factors ( $v$ ). The CCD constitute combinations of factorial points, axial points and center points. Three types of CCD can be generated using this function i.e. ccc or cci or ccf. "ccc" is for Central Composite Circumscribed designs, "cci" is for Central Composite Inscribed designs and "ccf" is for Central Composite Face Centered designs. It gives the randomized layout of the design along with the moment matrix and prediction variance.

## Usage

```
CCD_coded(v, type, randomization = FALSE, variance = FALSE)
```

## Arguments

<code>v</code>	Number of input factors, $v(>2)$
<code>type</code>	Type of central composite design i.e. ccc or cci or ccf. "ccc" is for Central Composite Circumscribed designs, "cci" is for Central Composite Inscribed designs and "ccf" is for Central Composite Face Centered designs
<code>randomization</code>	It is for generating the randomized layout of the design. It takes either TRUE or FALSE and by default, it is set to FALSE
<code>variance</code>	This is for generating the moment matrix and prediction variance of the design based on a second order model. It gives unique prediction variance along with its frequencies. It takes either TRUE or FALSE and by default, it is set to FALSE

## Value

Central Composite Designs (CCD) for a given number of input factors ( $v$ ) with coded levels

**Note**

Here, the factorial portion consists of  $2^v$  (full factorial) combinations and there is no upper limit for the number of input factors,  $v (>2)$ . To get a CCD with smaller runs, one may use fractional factorial (of resolution V) in place of full factorial.

**References**

- 1) G.E.P. Box and K.B. Wilson (1951). " On the experimental attainment of optimum conditions".
- 2) M. Hemavathi, Shashi Shekhar, Eldho Varghese, Seema Jaggi, Bikas Sinha & Nripes Kumar Mandal (2022)<DOI: 10.1080/03610926.2021.1944213>. "Theoretical developments in response surface designs: an informative review and further thoughts".

**Examples**

```
library(AsymmetricSORDs)
CCD_coded(5, 'ccc', FALSE, FALSE)
CCD_coded(6, "cci", FALSE, FALSE)
```

---

 CCD\_original

---

*Central Composite Designs (CCD) with original levels*


---

**Description**

This function generates Central Composite Designs (CCD) with original levels along with coded levels for a given number of input factors ( $v$ ). The CCD constitute combinations of factorial points, axial points and center points. Three types of CCDs can be generated using this function i.e. ccc or cci or ccf. "ccc" is for Central Composite Circumscribed designs, "cci" is for Central Composite Inscribed designs and "ccf" is for Central Composite Face Centered designs. It gives the randomized layout of the design along with the moment matrix and prediction variance.

**Usage**

```
CCD_original(v, type, min_L, max_L, randomization = FALSE, variance = FALSE)
```

**Arguments**

<code>v</code>	Number of input factors, $v(>2)$
<code>type</code>	Type of central composite design i.e. ccc or cci or ccf. "ccc" is for Central Composite Circumscribed designs, "cci" is for Central Composite Inscribed designs and "ccf" is for Central Composite Face Centered designs
<code>min_L</code>	A vector of minimum levels of the factors
<code>max_L</code>	A vector of maximum levels of the factors
<code>randomization</code>	It is for generating the randomized layout of the design. It takes either TRUE or FALSE and by default, it is set to FALSE

variance This is for generating the moment matrix and prediction variance of the design based on a second order model. It gives unique prediction variance along with its frequencies. It takes either TRUE or FALSE and by default, it is set to FALSE

### Value

Central Composite Designs (CCD) for a given number of input factors ( $v$ ) with original levels

### Note

Here, the factorial portion consists of  $2^v$  (full factorial) combinations and there is no upper limit for the number of input factors,  $v (>2)$ . To get a CCD with smaller runs, one may use fractional factorial (of resolution  $V$ ) in place of full factorial.

### References

- 1) G.E.P. Box and K.B. Wilson (1951). "On the experimental attainment of optimum conditions".
- 2) M. Hemavathi, Shashi Shekhar, Eldho Varghese, Seema Jaggi, Bikas Sinha & Nripes Kumar Mandal (2022) <DOI: 10.1080/03610926.2021.1944213>. "Theoretical developments in response surface designs: an informative review and further thoughts".

### Examples

```
library(AsymmetricSORDs)
CCD_original(5, 'ccc', c(10, 15, 20, 25, 30), c(15, 20, 25, 30, 35), FALSE, FALSE)
```

---

Pred.var	<i>Function for generating the moment matrix and variance of the predicted response</i>
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### Description

This function generates the moment matrix and variance of the predicted response for a given design based on a second-order model, for measuring the rotatability of the design. The input should be the specified form of a design matrix with the coefficients of the corresponding input factors. A minimum number of centre points is to be used to ensure the non-singularity of  $X'X$ .

### Usage

```
Pred.var(matrix)
```

### Arguments

matrix Design matrix with the coefficients of the corresponding input factors

**Value**

The moment matrix and the prediction variance for a given design based on a second-order model. It gives unique prediction variance along with its frequencies.

**References**

- 1) G.E.P. Box and K.B. Wilson (1951). 'On the experimental attainment of optimum conditions'.
- 2) M. Hemavathi, Shashi Shekhar, Eldho Varghese, Seema Jaggi, Bikas Sinha & Nripes Kumar Mandal (2022) <DOI: 10.1080/03610926.2021.1944213>. 'Theoretical developments in response surface designs: an informative review and further thoughts'.

**Examples**

```
## Not run:
library(AsymmetricSORDs)
Pred.var(matrix)

## End(Not run)
```

---

SORD\_coded

*Second Order Rotatable Designs with coded levels*


---

**Description**

This function generates second order rotatable designs given in Das and Narasimham (1962) for a given number of input factors,  $v$  ( $3 \leq v \leq 16$ ) with coded levels of the factors. It gives the randomized layout of the design along with the moment matrix and prediction variance. Here, all the factors are having 5-levels except for  $v=7$ , which gives a rotatable design with 3-levels for each factor.

**Usage**

```
SORD_coded(v, n0, randomization = FALSE, variance = FALSE)
```

**Arguments**

<code>v</code>	Number of input factors, $v$ ( $3 \leq v \leq 16$ )
<code>n0</code>	Number of centre points, $n_0$ ( $>0$ )
<code>randomization</code>	It is for generating the randomized layout of the design. It takes either TRUE or FALSE and by default, it is set to FALSE
<code>variance</code>	This is for generating the moment matrix and prediction variance of the design based on a second order model. It gives unique prediction variance along with its frequencies. It takes either TRUE or FALSE and by default, it is set to FALSE

**Value**

Second-Order Rotatable Designs with coded levels

## References

- 1) M. N. Das and V. L. Narasimham (1962). "Construction of rotatable designs through balanced incomplete block designs".
- 2) M. Hemavathi, Shashi Shekhar, Eldho Varghese, Seema Jaggi, Bikas Sinha & Nripes Kumar Mandal (2022)<DOI: 10.1080/03610926.2021.1944213> "Theoretical developments in response surface designs: an informative review and further thoughts".

## Examples

```
library(AsymmetricSORDs)
SORD_coded(4, 3, FALSE, FALSE)
```

---

SORD\_original

*Second Order Rotatable Designs with original levels*

---

## Description

This function generates second order rotatable designs given in Das and Narasimham (1962) for a given number of input factors ( $3 \leq v \leq 16$ ) with original levels along with coded levels of the factors. It gives the randomized layout of the design along with the moment matrix and prediction variance. Here, all the factors are having 5-levels except for  $v=7$ , which gives a rotatable design with 3-levels for each factor.

## Usage

```
SORD_original(v, n0, min_L, max_L, randomization = FALSE, variance = FALSE)
```

## Arguments

v	Number of input factors, $v(3 \leq v \leq 16)$
n0	Number of centre points, $n0(>0)$
min_L	A vector of minimum levels of the factors
max_L	A vector of maximum levels of the factors
randomization	It is for generating the randomized layout of the design. It takes either TRUE or FALSE and by default, it is set to FALSE
variance	This is for generating the moment matrix and prediction variance of the design based on a second order model. It gives unique prediction variance along with its frequencies. It takes either TRUE or FALSE and by default, it is set to FALSE

## Value

Second-Order Rotatable Designs with original levels

**References**

- 1) M. N. Das and V. L. Narasimham (1962). "Construction of rotatable designs through balanced incomplete block designs".
- 2) M. Hemavathi, Shashi Shekhar, Eldho Varghese, Seema Jaggi, Bikas Sinha & Nripes Kumar Mandal (2022)<DOI: 10.1080/03610926.2021.1944213> "Theoretical developments in response surface designs: an informative review and further thoughts".

**Examples**

```
library(AsymmetricSORDs)  
SORD_original(4,3,c(10,15,20,25),c(15,20,25,30),FALSE,FALSE)
```



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