

glucat

0.8.2

Generated by Doxygen 1.8.14

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Chapter 1

Namespace Index

1.1 Namespace List

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glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >	101
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glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >	220
toClifford	
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glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >	222
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Chapter 3

Class Index

3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

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glucat::bool_to_type< truth_value >	82
Bool to type	
PyClical.clifford	83
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glucat::compare_types< LHS_T, RHS_T >	
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glucat::compare_types< T, T >	113
glucat::control_t	
Parameters to control tests	113
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glucat::numeric_traits< Scalar_T >::demoted<>	
Demoted type for long double	119
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glucat::framed_multi< Scalar_T, LO, HI >	
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A matrix_multi<Scalar_T,LO,HI> is a matrix approximation to a multivector	177
std::numeric_limits< glucat::framed_multi< Scalar_T, LO, HI > >	
Numeric limits for framed_multi inherit limits for the corresponding scalar type	194

std::numeric_limits< glucat::matrix_multi< Scalar_T, LO, HI > >	
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Sorted range for use with output	218
glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >	220
glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis	
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glucat::framed_multi< Scalar_T, LO, HI >::var_term	
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4.1 File List

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Chapter 5

Namespace Documentation

5.1 cga3 Namespace Reference

Definitions for 3D Conformal Geometric Algebra [DL].

Functions

- `template<typename Multivector_T >`
`Multivector_T cga3 (const Multivector_T &x)`
Convert Euclidean 3D vector to Conformal Geometric Algebra null vector [DL (10.50)].
- `template<typename Multivector_T >`
`Multivector_T cga3std (const Multivector_T &X)`
Convert CGA3 null vector to standard Conformal Geometric Algebra null vector [DL (10.52)].
- `template<typename Multivector_T >`
`Multivector_T agc3 (const Multivector_T &X)`
Convert CGA3 null vector to Euclidean 3D vector [DL (10.50)].

5.1.1 Detailed Description

Definitions for 3D Conformal Geometric Algebra [DL].

5.1.2 Function Documentation

5.1.2.1 agc3()

```
template<typename Multivector_T >
Multivector_T cga3::agc3 (
    const Multivector_T & X ) [inline]
```

Convert CGA3 null vector to Euclidean 3D vector [DL (10.50)].

Definition at line 138 of file PyClical.h.

References `cga3std()`, `PyClical::cl`, and `PyClical::ist`.

5.1.2.2 cga3()

```
template<typename Multivector_T >
Multivector_T cga3::cga3 (
    const Multivector_T & x ) [inline]
```

Convert Euclidean 3D vector to Conformal Geometric Algebra null vector [DL (10.50)].

Definition at line 115 of file PyClical.h.

References PyClical::cl, PyClical::ist, and PyClical::ninf3.

5.1.2.3 cga3std()

```
template<typename Multivector_T >
Multivector_T cga3::cga3std (
    const Multivector_T & X ) [inline]
```

Convert CGA3 null vector to standard Conformal Geometric Algebra null vector [DL (10.52)].

Definition at line 126 of file PyClical.h.

References PyClical::cl, PyClical::ist, and PyClical::ninf3.

Referenced by agc3().

5.2 glucat Namespace Reference

Namespaces

- [gen](#)
- [matrix](#)
- [timing](#)

Classes

- class [basis_table](#)
Table of basis elements used as a cache by basis_element()
- class [bool_to_type](#)
Bool to type.
- class [clifford_algebra](#)
clifford_algebra<> declares the operations of a Clifford algebra
- class [compare_types](#)
Type comparison.
- class [compare_types< T, T >](#)
- class [control_t](#)
Parameters to control tests.
- struct [CTAssertion](#)

- *Compile time assertion.*
- struct [CTAssertion< true >](#)
- class [error](#)
- *Specific exception class.*
- class [framed_multi](#)
- *A framed_multi<Scalar_T,LO,HI> is a framed approximation to a multivector.*
- class [glucat_error](#)
- *Abstract exception class.*
- class [index_set](#)
- *Index set class based on std::bitset<> in Gnu standard C++ library.*
- class [index_set_hash](#)
- class [matrix_multi](#)
- *A matrix_multi<Scalar_T,LO,HI> is a matrix approximation to a multivector.*
- class [numeric_traits](#)
- *Extra traits which extend numeric limits.*
- class [random_generator](#)
- *Random number generator with single instance per Scalar_T.*
- class [sorted_range](#)
- *Sorted range for use with output.*
- class [sorted_range< Sorted_Map_T, Sorted_Map_T >](#)
- struct [tuning](#)
- *Tuning policy.*

Typedefs

- typedef int [index_t](#)
- *Size of index_t should be enough to represent LO, HI.*
- typedef unsigned long [set_value_t](#)
- *Size of set_value_t should be enough to contain index_set<LO,HI>*
- typedef int(* [intfn](#)) ()
- *For exception catching: pointer to function returning int.*
- typedef int(* [intintfn](#)) (int)
- *For exception catching: pointer to function of int returning int.*

Enumerations

- enum [precision_t](#) { [precision_demoted](#), [precision_same](#), [precision_promoted](#) }
- *Precision policy.*

Functions

- template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>
bool [operator!=](#) (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)
- *Test for inequality of multivectors.*
- template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
bool [operator!=](#) (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)
- *Test for inequality of multivector and scalar.*

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`bool operator!= (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Test for inequality of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator+ (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Geometric sum of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator+ (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Geometric sum of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator+ (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Geometric sum.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator- (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Geometric difference of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator- (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Geometric difference of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator- (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Geometric difference.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator* (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Product of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator* (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Product of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator* (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Geometric product.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator^ (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Outer product.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator & (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Inner product.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator% (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Left contraction.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T star (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Hestenes scalar product.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator/ (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Quotient of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator/ (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Quotient of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator/ (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Geometric quotient.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator| (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Transformation via twisted adjoint action.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > inv (const Multivector< Scalar_T, LO, HI > &val)`
Geometric multiplicative inverse.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > pow (const Multivector< Scalar_T, LO, HI > &lhs, int rhs)`
Integer power of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > pow (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Multivector power of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > outer_pow (const Multivector< Scalar_T, LO, HI > &lhs, int rhs)`
Outer product power of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T scalar (const Multivector< Scalar_T, LO, HI > &val)`
Scalar part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T real (const Multivector< Scalar_T, LO, HI > &val)`
Real part: synonym for scalar part.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T imag (const Multivector< Scalar_T, LO, HI > &val)`
Imaginary part: deprecated (always 0)
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > pure (const Multivector< Scalar_T, LO, HI > &val)`
Pure part.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > even (const Multivector< Scalar_T, LO, HI > &val)`
Even part.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > odd (const Multivector< Scalar_T, LO, HI > &val)`
Odd part.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const std::vector< Scalar_T > vector_part (const Multivector< Scalar_T, LO, HI > &val)`
Vector part of multivector, as a vector_t with respect to frame()
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > involute (const Multivector< Scalar_T, LO, HI > &val)`
Main involution, each {i} is replaced by -{i} in each term, eg. {1}{2} -> (-{2})*(-{1})*
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > reverse (const Multivector< Scalar_T, LO, HI > &val)`
Reversion, eg. {1}{2} -> {2}*{1}.*
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > conj (const Multivector< Scalar_T, LO, HI > &val)`
Conjugation, rev o invo == invo o rev.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T quad (const Multivector< Scalar_T, LO, HI > &val)`
*Scalar_T quadratic form == (rev(x)*x)(0)*
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T norm (const Multivector< Scalar_T, LO, HI > &val)`
Scalar_T norm == sum of norm of coordinates.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T abs (const Multivector< Scalar_T, LO, HI > &val)`
Absolute value == sqrt(norm)
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T max_abs (const Multivector< Scalar_T, LO, HI > &val)`
Maximum of absolute values of components of multivector: multivector infinity norm.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > complexifier (const Multivector< Scalar_T, LO, HI > &val)`

Square root of -1 which commutes with all members of the frame of the given multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > elliptic (const Multivector< Scalar_T, LO, HI > &val)`

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > sqrt (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`

Square root of multivector with specified complexifier.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > sqrt (const Multivector< Scalar_T, LO, HI > &val)`

Square root of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > clifford_exp (const Multivector< Scalar_T, LO, HI > &val)`

Exponential of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > log (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`

Natural logarithm of multivector with specified complexifier.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > log (const Multivector< Scalar_T, LO, HI > &val)`

Natural logarithm of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > cos (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`

Cosine of multivector with specified complexifier.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > cos (const Multivector< Scalar_T, LO, HI > &val)`

Cosine of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > acos (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`

Inverse cosine of multivector with specified complexifier.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > acos (const Multivector< Scalar_T, LO, HI > &val)`

Inverse cosine of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > cosh (const Multivector< Scalar_T, LO, HI > &val)`

Hyperbolic cosine of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > acosh (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`

Inverse hyperbolic cosine of multivector with specified complexifier.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > acosh (const Multivector< Scalar_T, LO, HI > &val)`
Inverse hyperbolic cosine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > sin (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Sine of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > sin (const Multivector< Scalar_T, LO, HI > &val)`
Sine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > asin (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Inverse sine of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > asin (const Multivector< Scalar_T, LO, HI > &val)`
Inverse sine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > sinh (const Multivector< Scalar_T, LO, HI > &val)`
Hyperbolic sine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > asinh (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Inverse hyperbolic sine of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > asinh (const Multivector< Scalar_T, LO, HI > &val)`
Inverse hyperbolic sine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > tan (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Tangent of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > tan (const Multivector< Scalar_T, LO, HI > &val)`
Tangent of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > atan (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Inverse tangent of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > atan (const Multivector< Scalar_T, LO, HI > &val)`
Inverse tangent of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > tanh (const Multivector< Scalar_T, LO, HI > &val)`
Hyperbolic tangent of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > atanh (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Inverse hyperbolic tangent of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > atanh (const Multivector< Scalar_T, LO, HI > &val)`
Inverse hyperbolic tangent of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > operator & (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Inner product.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`static void check_complex (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Check that i is a valid complexifier for val.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > operator* (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI > &rhs)`
Geometric product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > operator^ (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI > &rhs)`
Outer product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > operator & (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI > &rhs)`
Inner product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > operator% (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI > &rhs)`
Left contraction.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T star (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI > &rhs)`
Hestenes scalar product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > operator/ (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI > &rhs)`
Geometric quotient.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > operator| (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI > &rhs)`
Transformation via twisted adjoint action.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::istream & operator>> (std::istream &s, framed_multi< Scalar_T, LO, HI > &val)`
Read multivector from input.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::ostream & operator<< (std::ostream &os, const framed_multi< Scalar_T, LO, HI > &val)`

Write multivector to output.

- `template<typename Scalar_T , const index_t LO, const index_t HI>
std::ostream & operator<< (std::ostream &os, const std::pair< const index_set< LO, HI >, Scalar_T > &term)`

Write term to output.

- `template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > exp (const framed_multi< Scalar_T, LO, HI > &val)`

Exponential of multivector.

- `template<typename Scalar_T , const index_t LO, const index_t HI>
static Scalar_T crd_of_mult (const std::pair< const index_set< LO, HI >, Scalar_T > &lhs, const std::pair< const index_set< LO, HI >, Scalar_T > &rhs)`

Coordinate of product of terms.

- `template<typename Scalar_T , const index_t LO, const index_t HI>
const std::pair< const index_set< LO, HI >, Scalar_T > operator* (const std::pair< const index_set< LO, HI >, Scalar_T > &lhs, const std::pair< const index_set< LO, HI >, Scalar_T > &rhs)`

Product of terms.

- `template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > sqrt (const framed_multi< Scalar_T, LO, HI > &val, const framed_multi< Scalar_T, LO, HI > &i, bool prechecked)`

Square root of multivector with specified complexifier.

- `template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > log (const framed_multi< Scalar_T, LO, HI > &val, const framed_multi< Scalar_T, LO, HI > &i, bool prechecked)`

Natural logarithm of multivector with specified complexifier.

- `template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > operator & (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI > &rhs)`

Inner product.

- `template<typename Scalar_T , const index_t LO, const index_t HI>
static Scalar_T crd_of_mult (const std::pair< const index_set< LO, HI >, Scalar_T > &lhs, const std::pair< const index_set< LO, HI >, Scalar_T > &rhs)`

Coordinate of product of terms.

- `_GLUCAT_CTAssert (std::numeric_limits< unsigned char >::radix==2, CannotDetermineBitsPerChar) const index_t BITS_PER_CHAR`

If radix of unsigned char is not 2, we can't easily determine number of bits from sizeof.

- `_GLUCAT_CTAssert (_GLUCAT_BITS_PER_ULONG==BITS_PER_SET_VALUE, BitsPerULongDoesNotMatchSetValueT) const index_t DEFAULT_LO`

Default lowest index in an index set.

- `template<typename LHS_T , typename RHS_T >
LHS_T pos_mod (LHS_T lhs, RHS_T rhs)`

Modulo function which works reliably for lhs < 0.

- `template<const index_t LO, const index_t HI>
const index_set< LO, HI > operator^ (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`

Symmetric set difference: exclusive or.

- `template<const index_t LO, const index_t HI>
const index_set< LO, HI > operator & (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`

Set intersection: and.

- `template<const index_t LO, const index_t HI>
const index_set< LO, HI > operator| (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`

Set union: or.

- `template<const index_t LO, const index_t HI>
int compare (const index_set< LO, HI > &a, const index_set< LO, HI > &b)`

"lexicographic compare" eg. {3,4,5} is less than {3,7,8}

- `_GLUCAT_CTAssert` (`sizeof(set_value_t) >= sizeof(std::bitset< DEFAULT_HI-DEFAULT_LO >)`), Default↔
`_index_set_too_big_for_value` template< const `index_t` LO
Size of set_value_t should be enough to contain bitset<DEFAULT_HI-DEFAULT_LO>
- const `index_t` HI std::ostream & `operator<<` (std::ostream &os, const `index_set`< LO, HI > &ist)
Write out index set.
- template<const `index_t` LO, const `index_t` HI>
std::istream & `operator>>` (std::istream &s, `index_set`< LO, HI > &ist)
Read in index set.
- int `sign_of_square` (`index_t` j)
Square of generator {j}.
- template<const `index_t` LO, const `index_t` HI>
`index_t` min_neg (const `index_set`< LO, HI > &ist)
Minimum negative index, or 0 if none.
- template<const `index_t` LO, const `index_t` HI>
`index_t` max_pos (const `index_set`< LO, HI > &ist)
Maximum positive index, or 0 if none.
- template<const `index_t` LO, const `index_t` HI>
const `index_set`< LO, HI > `operator &` (const `index_set`< LO, HI > &lhs, const `index_set`< LO, HI > &rhs)
Set intersection: and.
- static unsigned long `inverse_reversed_gray` (unsigned long x)
Inverse reversed Gray code.
- static unsigned long `inverse_gray` (unsigned long x)
Inverse Gray code.
- template<typename Scalar_T , const `index_t` LO, const `index_t` HI>
const `matrix_multi`< Scalar_T, LO, HI > `operator*` (const `matrix_multi`< Scalar_T, LO, HI > &lhs, const
`matrix_multi`< Scalar_T, LO, HI > &rhs)
Geometric product.
- template<typename Scalar_T , const `index_t` LO, const `index_t` HI>
const `matrix_multi`< Scalar_T, LO, HI > `operator^` (const `matrix_multi`< Scalar_T, LO, HI > &lhs, const
`matrix_multi`< Scalar_T, LO, HI > &rhs)
Outer product.
- template<typename Scalar_T , const `index_t` LO, const `index_t` HI>
const `matrix_multi`< Scalar_T, LO, HI > `operator &` (const `matrix_multi`< Scalar_T, LO, HI > &lhs, const
`matrix_multi`< Scalar_T, LO, HI > &rhs)
Inner product.
- template<typename Scalar_T , const `index_t` LO, const `index_t` HI>
const `matrix_multi`< Scalar_T, LO, HI > `operator%` (const `matrix_multi`< Scalar_T, LO, HI > &lhs, const
`matrix_multi`< Scalar_T, LO, HI > &rhs)
Left contraction.
- template<typename Scalar_T , const `index_t` LO, const `index_t` HI>
Scalar_T star (const `matrix_multi`< Scalar_T, LO, HI > &lhs, const `matrix_multi`< Scalar_T, LO, HI > &rhs)
Hestenes scalar product.
- template<typename Scalar_T , const `index_t` LO, const `index_t` HI>
const `matrix_multi`< Scalar_T, LO, HI > `operator/` (const `matrix_multi`< Scalar_T, LO, HI > &lhs, const
`matrix_multi`< Scalar_T, LO, HI > &rhs)
Geometric quotient.
- template<typename Scalar_T , const `index_t` LO, const `index_t` HI>
const `matrix_multi`< Scalar_T, LO, HI > `operator|` (const `matrix_multi`< Scalar_T, LO, HI > &lhs, const
`matrix_multi`< Scalar_T, LO, HI > &rhs)
Transformation via twisted adjoint action.
- template<typename Scalar_T , const `index_t` LO, const `index_t` HI>
std::istream & `operator>>` (std::istream &s, `matrix_multi`< Scalar_T, LO, HI > &val)
Read multivector from input.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::ostream & operator<< (std::ostream &os, const matrix_multi< Scalar_T, LO, HI > &val)`
Write multivector to output.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const index_set< LO, HI > reframe (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs, matrix_multi< Scalar_T, LO, HI > &lhs_reframed, matrix_multi< Scalar_T, LO, HI > &rhs_reframed)`
Find a common frame for operands of a binary operator.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > sqrt (const matrix_multi< Scalar_T, LO, HI > &val, const matrix_multi< Scalar_T, LO, HI > &i, bool prechecked)`
Square root of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > matrix_sqrt (const matrix_multi< Scalar_T, LO, HI > &val, const matrix_multi< Scalar_T, LO, HI > &i)`
Square root of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > log (const matrix_multi< Scalar_T, LO, HI > &val, const matrix_multi< Scalar_T, LO, HI > &i, bool prechecked)`
Natural logarithm of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > matrix_log (const matrix_multi< Scalar_T, LO, HI > &val, const matrix_multi< Scalar_T, LO, HI > &i)`
Natural logarithm of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > exp (const matrix_multi< Scalar_T, LO, HI > &val)`
Exponential of multivector.
- `index_t offset_level (const index_t p, const index_t q)`
Determine the log2 dim corresponding to signature p, q.
- `template<typename Matrix_Index_T , const index_t LO, const index_t HI>`
`static Matrix_Index_T folded_dim (const index_set< LO, HI > &sub)`
Determine the matrix dimension of the fold of a subalegebra.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > operator & (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs)`
Inner product.
- `template<typename Multivector_T , typename Matrix_T , typename Basis_Matrix_T >`
`static Multivector_T fast (const Matrix_T &X, index_t level)`
Inverse generalized Fast Fourier Transform.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static const matrix_multi< Scalar_T, LO, HI > pade_approx (const int array_size, const Scalar_T a[], const Scalar_T b[], const matrix_multi< Scalar_T, LO, HI > &X)`
Pade' approximation.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static void db_step (matrix_multi< Scalar_T, LO, HI > &M, matrix_multi< Scalar_T, LO, HI > &Y)`
Single step of product form of Denman-Beavers square root iteration.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static const matrix_multi< Scalar_T, LO, HI > db_sqrt (const matrix_multi< Scalar_T, LO, HI > &val)`
Product form of Denman-Beavers square root iteration.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static const matrix_multi< Scalar_T, LO, HI > pade_log (const matrix_multi< Scalar_T, LO, HI > &val)`
Pade' approximation of log.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static const matrix_multi< Scalar_T, LO, HI > cascade_log (const matrix_multi< Scalar_T, LO, HI > &val)`

- Incomplete square root cascade and Pade' approximation of log.*
 • `template<typename Scalar_T >`
 `Scalar_T log2 (const Scalar_T &x)`
 Log base 2 of scalar.
- `template<typename Scalar_T >`
 `numeric_traits< Scalar_T >::promoted::type to_promote (const Scalar_T &val)`
 Cast to promote.
- `template<typename Scalar_T >`
 `numeric_traits< Scalar_T >::demoted::type to_demote (const Scalar_T &val)`
 Cast to demote.
- `int try_catch (intfn f)`
 Exception catching for functions returning int.
- `int try_catch (intintfn f, int arg)`
 Exception catching for functions of int returning int.

Variables

- `const double MS_PER_S = 1000.0`
 Timing constant: deprecated here - moved to [test/timing.h](#).
- `const index_t BITS_PER_SET_VALUE = std::numeric_limits<set_value_t>::digits`
 Number of bits in set_value_t.
- `const index_t DEFAULT_HI = index_t(BITS_PER_SET_VALUE / 2)`
 Default highest index in an index set.
- `const double DEFAULT_TRUNCATION = std::numeric_limits<float>::epsilon()`
 Default for truncation.
- `const unsigned int DEFAULT_Mult_Matrix_Threshold = 8`
- `const unsigned int DEFAULT_Div_Max_Steps = 4`
- `const unsigned int DEFAULT_Sqrt_Max_Steps = 256`
- `const unsigned int DEFAULT_Log_Max_Outer_Steps = 256`
- `const unsigned int DEFAULT_Log_Max_Inner_Steps = 32`
- `const unsigned int DEFAULT_Basis_Max_Count = 12`
- `const unsigned int DEFAULT_Fast_Size_Threshold = 1 << 6`
- `const unsigned int DEFAULT_Inv_Fast_Dim_Threshold = 1 << 3`
- `const unsigned int DEFAULT_Products_Size_Threshold = 1 << 22`
- `const precision_t DEFAULT_Function_Precision = precision_same`
- `static const long double l_pi = 3.1415926535897932384626433832795029L`
- `static const long double l_ln2 = 0.6931471805599453094172321214581766L`

5.2.1 Typedef Documentation

5.2.1.1 index_t

```
typedef int glucat::index_t
```

Size of `index_t` should be enough to represent LO, HI.

Definition at line 77 of file `global.h`.

5.2.1.2 intfn

```
typedef int (* glucat::intfn) ()
```

For exception catching: pointer to function returning int.

Definition at line 37 of file try_catch.h.

5.2.1.3 intintfn

```
typedef int (* glucat::intintfn) (int)
```

For exception catching: pointer to function of int returning int.

Definition at line 40 of file try_catch.h.

5.2.1.4 set_value_t

```
typedef unsigned long glucat::set_value_t
```

Size of set_value_t should be enough to contain index_set<LO,HI>

Definition at line 79 of file global.h.

5.2.2 Enumeration Type Documentation

5.2.2.1 precision_t

```
enum glucat::precision_t
```

Precision policy.

Enumerator

precision_demoted	
precision_same	
precision_promoted	

Definition at line 117 of file global.h.

5.2.3 Function Documentation

5.2.3.1 `_GLUCAT_CTAssert()` [1/3]

```
glucat::_GLUCAT_CTAssert (
    std::numeric_limits< unsigned char >::radix  == 2,
    CannotDetermineBitsPerChar ) const
```

If radix of unsigned char is not 2, we can't easily determine number of bits from sizeof.

Number of bits per char is used to determine number of bits in `set_value_t`

5.2.3.2 `_GLUCAT_CTAssert()` [2/3]

```
glucat::_GLUCAT_CTAssert (
    _GLUCAT_BITS_PER_ULONG  == BITS_PER_SET_VALUE,
    BitsPerUlongDoesNotMatchSetValueT ) const
```

Default lowest index in an index set.

5.2.3.3 `_GLUCAT_CTAssert()` [3/3]

```
glucat::_GLUCAT_CTAssert (
    sizeof(set_value_t) >= sizeof(std::bitset< DEFAULT_HI-DEFAULT_LO > ) ,
    Default_index_set_too_big_for_value ) const
```

Size of `set_value_t` should be enough to contain `bitset<DEFAULT_HI-DEFAULT_LO>`

Write out index set

5.2.3.4 `abs()`

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↔
_T , const index_t LO, const index_t HI>
Scalar_T glucat::abs (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Absolute value == `sqrt(norm)`

Definition at line 491 of file `clifford_algebra_imp.h`.

References `glucat::numeric_traits< Scalar_T >::sqrt()`.

Referenced by `PyClical.clifford::abs()`, `acos()`, `asin()`, `glucat::matrix::classify_eigenvalues()`, `clifford_to_str()`, `glucat::framed_multi< Scalar_T, LO, HI >::framed_multi()`, `matrix_log()`, and `matrix_sqrt()`.

5.2.3.5 `acos()` [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::acos (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Inverse cosine of multivector with specified complexifier.

Definition at line 798 of file `clifford_algebra_imp.h`.

References `abs()`, `acosh()`, `check_complex()`, and `PyClical::i`.

Referenced by `glucat::numeric_traits< Scalar_T >::acos()`, and `acos()`.

5.2.3.6 `acos()` [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::acos (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Inverse cosine of multivector.

Definition at line 818 of file `clifford_algebra_imp.h`.

References `acos()`, and `complexifier()`.

5.2.3.7 `acosh()` [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::acosh (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Inverse hyperbolic cosine of multivector with specified complexifier.

Definition at line 738 of file `clifford_algebra_imp.h`.

References `check_complex()`, `PyClical::i`, `log()`, `norm()`, and `sqrt()`.

Referenced by `acos()`, and `acosh()`.

5.2.3.8 `acosh()` [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::acosh (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Inverse hyperbolic cosine of multivector.

Definition at line 758 of file `clifford_algebra_imp.h`.

References `acosh()`, and `complexifier()`.

5.2.3.9 `asin()` [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::asin (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Inverse sine of multivector with specified complexifier.

Definition at line 905 of file `clifford_algebra_imp.h`.

References `abs()`, `asinh()`, `check_complex()`, and `PyClical::i`.

Referenced by `glucat::numeric_traits< Scalar_T >::asin()`, and `asin()`.

5.2.3.10 `asin()` [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::asin (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Inverse sine of multivector.

Definition at line 925 of file `clifford_algebra_imp.h`.

References `asin()`, and `complexifier()`.

5.2.3.11 asinh() [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::asinh (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Inverse hyperbolic sine of multivector with specified complexifier.

Definition at line 845 of file `clifford_algebra_imp.h`.

References `check_complex()`, `PyClical::i`, `log()`, `norm()`, and `sqrt()`.

Referenced by `asin()`, and `asinh()`.

5.2.3.12 asinh() [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::asinh (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Inverse hyperbolic sine of multivector.

Definition at line 865 of file `clifford_algebra_imp.h`.

References `asinh()`, and `complexifier()`.

5.2.3.13 atan() [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::atan (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Inverse tangent of multivector with specified complexifier.

Definition at line 1005 of file `clifford_algebra_imp.h`.

References `atanh()`, `check_complex()`, `PyClical::i`, and `scalar()`.

Referenced by `glucat::numeric_traits< Scalar_T >::atan()`, and `atan()`.

5.2.3.14 atan() [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::atan (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Inverse tangent of multivector.

Definition at line 1025 of file clifford_algebra_imp.h.

References atan(), and complexifier().

5.2.3.15 atanh() [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::atanh (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Inverse hyperbolic tangent of multivector with specified complexifier.

Definition at line 952 of file clifford_algebra_imp.h.

References check_complex(), PyClical::i, log(), and norm().

Referenced by atan(), and atanh().

5.2.3.16 atanh() [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::atanh (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Inverse hyperbolic tangent of multivector.

Definition at line 969 of file clifford_algebra_imp.h.

References atanh(), and complexifier().

5.2.3.17 cascade_log()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
static const matrix_multi<Scalar_T,LO,HI> glucat::cascade_log (
    const matrix_multi< Scalar_T, LO, HI > & val ) [static]
```

Incomplete square root cascade and Pade' approximation of log.

Definition at line 1976 of file matrix_multi_imp.h.

References db_step(), glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan(), glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::log_max_inner_steps, glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::log_max_outer_steps, norm(), pade_log(), and pow().

Referenced by matrix_log().

5.2.3.18 check_complex()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
static void glucat::check_complex (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline], [static]
```

Check that i is a valid complexifier for val.

Definition at line 566 of file clifford_algebra_imp.h.

References complexifier(), and PyClical::i.

Referenced by acos(), acosh(), asin(), asinh(), atan(), atanh(), cos(), log(), sin(), sqrt(), and tan().

5.2.3.19 clifford_exp()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::clifford_exp (
    const Multivector< Scalar_T, LO, HI > & val )
```

Exponential of multivector.

Definition at line 604 of file clifford_algebra_imp.h.

References exp(), log2(), pow(), and scalar().

Referenced by exp().

5.2.3.20 compare()

```
template<const index_t LO, const index_t HI>
int glucat::compare (
    const index_set< LO, HI > & a,
    const index_set< LO, HI > & b ) [inline]
```

"lexicographic compare" eg. {3,4,5} is less than {3,7,8}

Lexicographic ordering of two sets: -1 if $a < b$, +1 if $a > b$, 0 if $a == b$.

Definition at line 573 of file index_set_imp.h.

References glucat::index_set< LO, HI >::lex_less_than().

5.2.3.21 complexifier()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::complexifier (
    const Multivector< Scalar_T, LO, HI > & val )
```

Square root of -1 which commutes with all members of the frame of the given multivector.

Definition at line 506 of file clifford_algebra_imp.h.

References pos_mod().

Referenced by acos(), acosh(), asin(), asinh(), atan(), atanh(), check_complex(), cos(), elliptic(), log(), sin(), sqrt(), and tan().

5.2.3.22 conj()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::conj (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Conjugation, $rev \circ inv == inv \circ rev$.

Definition at line 467 of file clifford_algebra_imp.h.

5.2.3.23 cos() [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::cos (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false )
```

Cosine of multivector with specified complexifier.

Definition at line 765 of file `clifford_algebra_imp.h`.

References `check_complex()`, `exp()`, `PyClical::i`, `PyClical::pi`, and `scalar()`.

Referenced by `glucat::numeric_traits< Scalar_T >::cos()`, `cos()`, and `tan()`.

5.2.3.24 cos() [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::cos (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Cosine of multivector.

Definition at line 789 of file `clifford_algebra_imp.h`.

References `complexifier()`, and `cos()`.

5.2.3.25 cosh()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::cosh (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Hyperbolic cosine of multivector.

Definition at line 720 of file `clifford_algebra_imp.h`.

References `exp()`, and `scalar()`.

Referenced by `glucat::numeric_traits< Scalar_T >::cosh()`, and `tanh()`.

5.2.3.26 `crd_of_mult()` [1/2]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
static Scalar_T glucat::crd_of_mult (
    const std::pair< const index\_set< LO, HI >, Scalar_T > & lhs,
    const std::pair< const index\_set< LO, HI >, Scalar_T > & rhs ) [inline], [static]
```

Coordinate of product of terms.

Referenced by operator &(), operator%(), operator*(), and operator^().

5.2.3.27 `crd_of_mult()` [2/2]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
static Scalar_T glucat::crd_of_mult (
    const std::pair< const index\_set< LO, HI >, Scalar_T > & lhs,
    const std::pair< const index\_set< LO, HI >, Scalar_T > & rhs ) [inline], [static]
```

Coordinate of product of terms.

Definition at line 1906 of file `framed_multi_imp.h`.

5.2.3.28 `db_sqrt()`

```
template<typename Scalar_T , const index_t LO, const index_t HI>
static const matrix\_multi<Scalar_T,LO,HI> glucat::db_sqrt (
    const matrix\_multi< Scalar_T, LO, HI > & val ) [static]
```

Product form of Denman-Beavers square root iteration.

Definition at line 1375 of file `matrix_multi_imp.h`.

References `db_step()`, `norm()`, `pow()`, and `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::sqrt_max_steps`.

Referenced by `matrix_sqrt()`.

5.2.3.29 `db_step()`

```
template<typename Scalar_T , const index_t LO, const index_t HI>
static void glucat::db_step (
    matrix\_multi< Scalar_T, LO, HI > & M,
    matrix\_multi< Scalar_T, LO, HI > & Y ) [inline], [static]
```

Single step of product form of Denman-Beavers square root iteration.

Definition at line 1362 of file `matrix_multi_imp.h`.

References `inv()`.

Referenced by `cascade_log()`, and `db_sqrt()`.

5.2.3.30 elliptic()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::elliptic (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Square root of -1 which commutes with all members of the frame of the given multivector The name "elliptic" is now deprecated: use "complexifier" instead.

Definition at line 557 of file clifford_algebra_imp.h.

References complexifier().

5.2.3.31 even()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::even (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Even part.

Definition at line 427 of file clifford_algebra_imp.h.

5.2.3.32 exp() [1/2]

```
template<typename Scalar_T, const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::exp (
    const framed_multi< Scalar_T, LO, HI > & val )
```

Exponential of multivector.

Definition at line 1947 of file framed_multi_imp.h.

References clifford_exp(), glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::frame(), glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::function_precision, glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::isnan(), glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::mult_matrix_threshold, precision_demoted, precision_promoted, and scalar().

Referenced by clifford_exp(), cos(), cosh(), glucat::numeric_traits< Scalar_T >::exp(), exp(), matrix_log(), matrix_sqrt(), pow(), PyClical.clifford::pow(), sin(), and sinh().

5.2.3.33 exp() [2/2]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::exp (
    const matrix_multi< Scalar_T, LO, HI > & val )
```

Exponential of multivector.

Definition at line 2140 of file matrix_multi_imp.h.

References `clifford_exp()`, `exp()`, `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::function_precision`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan()`, `precision_demoted`, `precision_promoted`, and `scalar()`.

5.2.3.34 fast()

```
template<typename Multivector_T , typename Matrix_T , typename Basis_Matrix_T >
static Multivector_T glucat::fast (
    const Matrix_T & X,
    index_t level ) [static]
```

Inverse generalized Fast Fourier Transform.

Definition at line 1083 of file matrix_multi_imp.h.

References `glucat::matrix::signed_perm_nork()`.

5.2.3.35 folded_dim()

```
template<typename Matrix_Index_T , const index_t LO, const index_t HI>
static Matrix_Index_T glucat::folded_dim (
    const index_set< LO, HI > & sub ) [inline], [static]
```

Determine the matrix dimension of the fold of a subalgebra.

Definition at line 91 of file matrix_multi_imp.h.

References `glucat::index_set< LO, HI >::count_neg()`, `glucat::index_set< LO, HI >::count_pos()`, and `offset_level()`.

5.2.3.36 imag()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar←
_T , const index_t LO, const index_t HI>
Scalar_T glucat::imag (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Imaginary part: deprecated (always 0)

Definition at line 411 of file clifford_algebra_imp.h.

Referenced by glucat::matrix::classify_eigenvalues().

5.2.3.37 inv()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar←
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::inv (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Geometric multiplicative inverse.

Definition at line 321 of file clifford_algebra_imp.h.

Referenced by db_step(), matrix_log(), and matrix_sqrt().

5.2.3.38 inverse_gray()

```
static unsigned long glucat::inverse_gray (
    unsigned long x ) [inline], [static]
```

Inverse Gray code.

Definition at line 861 of file index_set_imp.h.

Referenced by glucat::index_set< LO, HI >::sign_of_mult().

5.2.3.39 inverse_reversed_gray()

```
static unsigned long glucat::inverse_reversed_gray (
    unsigned long x ) [inline], [static]
```

Inverse reversed Gray code.

Definition at line 844 of file index_set_imp.h.

Referenced by glucat::index_set< LO, HI >::sign_of_mult().

5.2.3.40 involute()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::involute (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Main involution, each {i} is replaced by -{i} in each term, eg. {1}*{2} -> (-{2})*(-{1})

Main involution, each {i} is replaced by -{i} in each term, eg. {1} -> -{1}.

Definition at line 451 of file clifford_algebra_imp.h.

5.2.3.41 log() [1/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::log (
    const matrix_multi< Scalar_T, LO, HI > & val,
    const matrix_multi< Scalar_T, LO, HI > & i,
    bool prechecked )
```

Natural logarithm of multivector with specified complexifier.

Definition at line 2023 of file matrix_multi_imp.h.

References `check_complex()`, `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::function_precision`, `PyClical::i`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan()`, `matrix_log()`, `precision_demoted`, and `precision_promoted`.

5.2.3.42 log() [2/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::log (
    const framed_multi< Scalar_T, LO, HI > & val,
    const framed_multi< Scalar_T, LO, HI > & i,
    bool prechecked )
```

Natural logarithm of multivector with specified complexifier.

Definition at line 1997 of file framed_multi_imp.h.

References `check_complex()`, `PyClical::i`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::isnan()`, `log()`, `PyClical::pi`, and `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::scalar()`.

5.2.3.43 log() [3/4]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::log (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Natural logarithm of multivector with specified complexifier.

Definition at line 704 of file clifford_algebra_imp.h.

References PyClical::i.

Referenced by acosh(), asinh(), atanh(), glucat::numeric_traits< Scalar_T >::log(), log(), matrix_log(), glucat↵
::numeric_traits< Scalar_T >::NaN(), pow(), and PyClical.clifford::pow().

5.2.3.44 log() [4/4]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::log (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Natural logarithm of multivector.

Definition at line 712 of file clifford_algebra_imp.h.

References complexifier(), and log().

5.2.3.45 log2()

```
template<typename Scalar_T >
Scalar_T glucat::log2 (
    const Scalar_T & x ) [inline]
```

Log base 2 of scalar.

Definition at line 302 of file scalar.h.

References glucat::numeric_traits< Scalar_T >::log2().

Referenced by clifford_exp().

5.2.3.46 `matrix_log()`

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::matrix_log (
    const matrix_multi< Scalar_T, LO, HI > & val,
    const matrix_multi< Scalar_T, LO, HI > & i )
```

Natural logarithm of multivector with specified complexifier.

Definition at line 2064 of file `matrix_multi_imp.h`.

References `abs()`, `glucat::matrix::both_eig_case`, `cascade_log()`, `glucat::matrix::classify_eigenvalues()`, `exp()`, `PyClicl::i`, `inv()`, `glucat::matrix::isnan()`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan()`, `log()`, `glucat::matrix::eig_genus< Matrix_T >::m_eig_case`, `glucat::matrix::eig_genus< Matrix_T >::m_safe_arg`, `glucat::matrix::negative_eig_case`, `norm()`, `PyClicl::pi`, and `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::scalar()`.

Referenced by `log()`.

5.2.3.47 `matrix_sqrt()`

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::matrix_sqrt (
    const matrix_multi< Scalar_T, LO, HI > & val,
    const matrix_multi< Scalar_T, LO, HI > & i )
```

Square root of multivector with specified complexifier.

Definition at line 1645 of file `matrix_multi_imp.h`.

References `abs()`, `glucat::matrix::both_eig_case`, `glucat::matrix::classify_eigenvalues()`, `db_sqrt()`, `exp()`, `PyClicl::i`, `inv()`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan()`, `glucat::matrix::eig_genus< Matrix_T >::m_eig_case`, `glucat::matrix::eig_genus< Matrix_T >::m_safe_arg`, `glucat::matrix::negative_eig_case`, `norm()`, `pade_approx()`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::scalar()`, and `sqrt()`.

Referenced by `sqrt()`.

5.2.3.48 `max_abs()`

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
Scalar_T glucat::max_abs (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Maximum of absolute values of components of multivector: multivector infinity norm.

Definition at line 499 of file `clifford_algebra_imp.h`.

5.2.3.49 max_pos()

```
template<const index_t LO, const index_t HI>
index_t glucat::max_pos (
    const index_set< LO, HI > & ist ) [inline]
```

Maximum positive index, or 0 if none.

Definition at line 974 of file index_set_imp.h.

References PyClical::ist.

5.2.3.50 min_neg()

```
template<const index_t LO, const index_t HI>
index_t glucat::min_neg (
    const index_set< LO, HI > & ist ) [inline]
```

Minimum negative index, or 0 if none.

Definition at line 967 of file index_set_imp.h.

References PyClical::ist.

5.2.3.51 norm()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
Scalar_T glucat::norm (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Scalar_T norm == sum of norm of coordinates.

Definition at line 483 of file clifford_algebra_imp.h.

Referenced by acosh(), asinh(), atanh(), cascade_log(), glucat::matrix::classify_eigenvalues(), db_sqrt(), matrix_↵log(), and matrix_sqrt().

5.2.3.52 odd()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::odd (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Odd part.

Definition at line 435 of file clifford_algebra_imp.h.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fast().

5.2.3.53 offset_level()

```
index_t glucat::offset_level (
    const index_t p,
    const index_t q ) [inline]
```

Determine the log2 dim corresponding to signature p, q.

Definition at line 76 of file matrix_multi_imp.h.

References pos_mod().

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::basis_element(), and folded_dim().

5.2.3.54 operator &() [1/8]

```
template<const index_t LO, const index_t HI>
const index_set<LO,HI> glucat::operator& (
    const index_set< LO, HI > & lhs,
    const index_set< LO, HI > & rhs ) [inline]
```

Set intersection: and.

Definition at line 186 of file index_set_imp.h.

5.2.3.55 operator &() [2/8]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi<Scalar_T,LO,HI> glucat::operator& (
    const matrix_multi< Scalar_T, LO, HI > & lhs,
    const matrix_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Inner product.

Definition at line 616 of file matrix_multi_imp.h.

5.2.3.56 operator &() [3/8]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi<Scalar_T,LO,HI> glucat::operator& (
    const framed_multi< Scalar_T, LO, HI > & lhs,
    const framed_multi< Scalar_T, LO, HI > & rhs )
```

Inner product.

Definition at line 601 of file framed_multi_imp.h.

References _GLUCAT_HASH_SIZE_T, crd_of_mult(), glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::frame(), and glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::products_size_threshold.

5.2.3.57 operator &() [4/8]

```
template<const index_t LO, const index_t HI>
const index_set<LO,HI> glucat::operator& (
    const index_set< LO, HI > & lhs,
    const index_set< LO, HI > & rhs ) [inline]
```

Set intersection: and.

Definition at line 186 of file index_set_imp.h.

5.2.3.58 operator &() [5/8]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector<Scalar_T,LO,HI> glucat::operator& (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Inner product.

Definition at line 228 of file clifford_algebra_imp.h.

5.2.3.59 operator &() [6/8]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector<Scalar_T,LO,HI> glucat::operator& (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Inner product.

Definition at line 228 of file clifford_algebra_imp.h.

5.2.3.60 operator &() [7/8]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi<Scalar_T,LO,HI> glucat::operator& (
    const framed_multi< Scalar_T, LO, HI > & lhs,
    const framed_multi< Scalar_T, LO, HI > & rhs )
```

Inner product.

Definition at line 601 of file framed_multi_imp.h.

References `_GLUCAT_HASH_SIZE_T`, `crd_of_mult()`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::frame()`, and `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::products_size_threshold`.

5.2.3.61 operator &() [8/8]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi<Scalar_T,LO,HI> glucat::operator& (
    const matrix_multi< Scalar_T, LO, HI > & lhs,
    const matrix_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Inner product.

Definition at line 616 of file matrix_multi_imp.h.

5.2.3.62 operator!=(()) [1/3]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
bool glucat::operator!=( (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Test for inequality of multivectors.

Definition at line 78 of file clifford_algebra_imp.h.

5.2.3.63 operator!=(()) [2/3]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
bool glucat::operator!=( (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const Scalar_T & scr ) [inline]
```

Test for inequality of multivector and scalar.

Definition at line 86 of file clifford_algebra_imp.h.

5.2.3.64 operator!=(()) [3/3]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
bool glucat::operator!=( (
    const Scalar_T & scr,
    const Multivector< Scalar_T, LO, HI > & rhs ) [inline]
```

Test for inequality of scalar and multivector.

Definition at line 94 of file clifford_algebra_imp.h.

5.2.3.65 operator%() [1/3]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::operator% (
    const matrix_multi< Scalar_T, LO, HI > & lhs,
    const matrix_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Left contraction.

Definition at line 635 of file matrix_multi_imp.h.

5.2.3.66 operator%() [2/3]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::operator% (
    const framed_multi< Scalar_T, LO, HI > & lhs,
    const framed_multi< Scalar_T, LO, HI > & rhs )
```

Left contraction.

Definition at line 719 of file framed_multi_imp.h.

References `_GLUCAT_HASH_SIZE_T`, `crd_of_mult()`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::frame()`, and `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_↵_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_↵Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::products_size_threshold`.

5.2.3.67 operator%() [3/3]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator% (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Left contraction.

Definition at line 243 of file clifford_algebra_imp.h.

5.2.3.68 operator*() [1/6]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix\_multi< Scalar_T, LO, HI > glucat::operator* (
    const matrix\_multi< Scalar_T, LO, HI > & lhs,
    const matrix\_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Geometric product.

Definition at line 547 of file `matrix_multi_imp.h`.

References `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan()`, `glucat::matrix_multi< Scalar_T, LO, HI >::m_frame`, `glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix`, and `re-frame()`.

5.2.3.69 operator*() [2/6]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed\_multi< Scalar_T, LO, HI > glucat::operator* (
    const framed\_multi< Scalar_T, LO, HI > & lhs,
    const framed\_multi< Scalar_T, LO, HI > & rhs )
```

Geometric product.

Definition at line 400 of file `framed_multi_imp.h`.

References `_GLUCAT_HASH_SIZE_T`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::frame()`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::isnan()`, and `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::mult_matrix_threshold`.

5.2.3.70 operator*() [3/6]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator* (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const Scalar_T & scr ) [inline]
```

Product of multivector and scalar.

Definition at line 172 of file `clifford_algebra_imp.h`.

5.2.3.71 operator*() [4/6]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator* (
    const Scalar_T & scr,
    const Multivector< Scalar_T, LO, HI > & rhs ) [inline]
```

Product of scalar and multivector.

Definition at line 183 of file clifford_algebra_imp.h.

5.2.3.72 operator*() [5/6]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T, const index_t LO,
const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator* (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Geometric product.

Definition at line 198 of file clifford_algebra_imp.h.

5.2.3.73 operator*() [6/6]

```
template<typename Scalar_T, const index_t LO, const index_t HI>
const std::pair< const index_set< LO, HI >, Scalar_T > glucat::operator* (
    const std::pair< const index_set< LO, HI >, Scalar_T > & lhs,
    const std::pair< const index_set< LO, HI >, Scalar_T > & rhs ) [inline]
```

Product of terms.

Definition at line 1914 of file framed_multi_imp.h.

References `crd_of_mult()`.

5.2.3.74 operator+() [1/3]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator+ (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const Scalar_T & scr ) [inline]
```

Geometric sum of multivector and scalar.

Definition at line 102 of file clifford_algebra_imp.h.

5.2.3.75 operator+() [2/3]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator+ (
    const Scalar_T & scr,
    const Multivector< Scalar_T, LO, HI > & rhs ) [inline]
```

Geometric sum of scalar and multivector.

Definition at line 113 of file clifford_algebra_imp.h.

5.2.3.76 operator+() [3/3]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator+ (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Geometric sum.

Definition at line 127 of file clifford_algebra_imp.h.

5.2.3.77 operator-() [1/3]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator- (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const Scalar_T & scr ) [inline]
```

Geometric difference of multivector and scalar.

Definition at line 138 of file clifford_algebra_imp.h.

5.2.3.78 operator-() [2/3]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator- (
    const Scalar_T & scr,
    const Multivector< Scalar_T, LO, HI > & rhs ) [inline]
```

Geometric difference of scalar and multivector.

Definition at line 149 of file clifford_algebra_imp.h.

5.2.3.79 operator-() [3/3]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator- (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Geometric difference.

Definition at line 161 of file clifford_algebra_imp.h.

5.2.3.80 operator/() [1/5]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::operator/ (
    const matrix_multi< Scalar_T, LO, HI > & lhs,
    const matrix_multi< Scalar_T, LO, HI > & rhs )
```

Geometric quotient.

Definition at line 668 of file matrix_multi_imp.h.

References glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::div_max_steps, glucat::matrix::isnan(), glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan(), glucat::matrix_multi< Scalar_T, LO, HI >::m_frame, and reframe().

5.2.3.81 operator/() [2/5]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::operator/ (
    const framed_multi< Scalar_T, LO, HI > & lhs,
    const framed_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Geometric quotient.

Definition at line 914 of file framed_multi_imp.h.

References glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::frame().

5.2.3.82 operator/() [3/5]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator/ (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const Scalar_T & scr ) [inline]
```

Quotient of multivector and scalar.

Definition at line 269 of file clifford_algebra_imp.h.

5.2.3.83 operator/() [4/5]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator/ (
    const Scalar_T & scr,
    const Multivector< Scalar_T, LO, HI > & rhs ) [inline]
```

Quotient of scalar and multivector.

Definition at line 280 of file clifford_algebra_imp.h.

5.2.3.84 operator/() [5/5]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator/ (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Geometric quotient.

Definition at line 295 of file clifford_algebra_imp.h.

5.2.3.85 operator<<() [1/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
std::ostream & glucat::operator<< (
    std::ostream & os,
    const matrix\_multi< Scalar_T, LO, HI > & val ) [inline]
```

Write multivector to output.

Definition at line 1025 of file matrix_multi_imp.h.

5.2.3.86 `operator<<()` [2/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
std::ostream & glucat::operator<< (
    std::ostream & os,
    const framed_multi< Scalar_T, LO, HI > & val )
```

Write multivector to output.

Definition at line 1366 of file framed_multi_imp.h.

References `glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_begin`, and `glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_end`.

5.2.3.87 `operator<<()` [3/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
std::ostream & glucat::operator<< (
    std::ostream & os,
    const std::pair< const index_set< LO, HI >, Scalar_T > & term )
```

Write term to output.

Definition at line 1398 of file framed_multi_imp.h.

References `pow()`, and `glucat::numeric_traits< Scalar_T >::to_double()`.

5.2.3.88 `operator<<()` [4/4]

```
std::ostream & glucat::operator<< (
    std::ostream & os,
    const index_set< LO, HI > & ist )
```

Write out index set.

Definition at line 611 of file index_set_imp.h.

References `PyClical::i`, and `PyClical::ist`.

5.2.3.89 `operator>>()` [1/3]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
std::istream & glucat::operator>> (
    std::istream & s,
    matrix_multi< Scalar_T, LO, HI > & val ) [inline]
```

Read multivector from input.

Definition at line 1035 of file matrix_multi_imp.h.

5.2.3.90 operator>>() [2/3]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
std::istream & glucat::operator>> (
    std::istream & s,
    framed_multi< Scalar_T, LO, HI > & val )
```

Read multivector from input.

Definition at line 1436 of file framed_multi_imp.h.

References PyClical::ist.

5.2.3.91 operator>>() [3/3]

```
template<const index_t LO, const index_t HI>
std::istream & glucat::operator>> (
    std::istream & s,
    index_set< LO, HI > & ist )
```

Read in index set.

Definition at line 633 of file index_set_imp.h.

References PyClical::i, PyClical::ist, and glucat::index_set< LO, HI >::set().

5.2.3.92 operator^() [1/4]

```
template<const index_t LO, const index_t HI>
const index_set< LO, HI > glucat::operator^ (
    const index_set< LO, HI > & lhs,
    const index_set< LO, HI > & rhs ) [inline]
```

Symmetric set difference: exclusive or.

Definition at line 161 of file index_set_imp.h.

5.2.3.93 operator^() [2/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::operator^ (
    const matrix_multi< Scalar_T, LO, HI > & lhs,
    const matrix_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Outer product.

Definition at line 597 of file matrix_multi_imp.h.

5.2.3.94 `operator^()` [3/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::operator^ (
    const framed_multi< Scalar_T, LO, HI > & lhs,
    const framed_multi< Scalar_T, LO, HI > & rhs )
```

Outer product.

Definition at line 501 of file framed_multi_imp.h.

References `_GLUCAT_HASH_SIZE_T`, `crd_of_mult()`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::frame()`, and `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::products_size_threshold`.

5.2.3.95 `operator^()` [4/4]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator^ (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Outer product.

Definition at line 213 of file clifford_algebra_imp.h.

5.2.3.96 `operator" |()` [1/4]

```
template<const index_t LO, const index_t HI>
const index_set< LO, HI > glucat::operator| (
    const index_set< LO, HI > & lhs,
    const index_set< LO, HI > & rhs ) [inline]
```

Set union: or.

Definition at line 211 of file index_set_imp.h.

5.2.3.97 `operator" |()` [2/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::operator| (
    const matrix_multi< Scalar_T, LO, HI > & lhs,
    const matrix_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Transformation via twisted adjoint action.

Definition at line 777 of file matrix_multi_imp.h.

References `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::involute()`.

5.2.3.98 operator" | () [3/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::operator| (
    const framed_multi< Scalar_T, LO, HI > & lhs,
    const framed_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Transformation via twisted adjoint action.

Definition at line 940 of file framed_multi_imp.h.

References glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::involute().

5.2.3.99 operator" | () [4/4]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::operator| (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Transformation via twisted adjoint action.

Definition at line 310 of file clifford_algebra_imp.h.

5.2.3.100 outer_pow()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::outer_pow (
    const Multivector< Scalar_T, LO, HI > & lhs,
    int rhs )
```

Outer product power of multivector.

Definition at line 384 of file clifford_algebra_imp.h.

5.2.3.101 pade_approx()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
static const matrix_multi<Scalar_T,LO,HI> glucat::pade_approx (
    const int array_size,
    const Scalar_T a[],
    const Scalar_T b[],
    const matrix_multi< Scalar_T, LO, HI > & X ) [inline], [static]
```

Pade' approximation.

Definition at line 1302 of file matrix_multi_imp.h.

References glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan().

Referenced by matrix_sqrt(), and pade_log().

5.2.3.102 pade_log()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
static const matrix_multi<Scalar_T,LO,HI> glucat::pade_log (
    const matrix_multi< Scalar_T, LO, HI > & val ) [static]
```

Pade' approximation of log.

Definition at line 1955 of file matrix_multi_imp.h.

References glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan(), and pade_approx().

Referenced by cascade_log().

5.2.3.103 pos_mod()

```
template<typename LHS_T , typename RHS_T >
LHS_T glucat::pos_mod (
    LHS_T lhs,
    RHS_T rhs ) [inline]
```

Modulo function which works reliably for lhs < 0.

Definition at line 187 of file global.h.

Referenced by complexifier(), glucat::matrix_multi< Scalar_T, LO, HI >::fast_framed_multi(), glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi(), glucat::gen::generator_table< Matrix_T >::gen_vector(), offset_level(), and glucat::gen::generator_table< Matrix_T >::operator().

5.2.3.104 pow() [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::pow (
    const Multivector< Scalar_T, LO, HI > & lhs,
    int rhs )
```

Integer power of multivector.

Definition at line 328 of file clifford_algebra_imp.h.

Referenced by cascade_log(), clifford_exp(), db_sqrt(), operator<<(), and glucat::numeric_traits< Scalar_T >::pow().

5.2.3.105 pow() [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::pow (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Multivector power of multivector.

Definition at line 361 of file clifford_algebra_imp.h.

References `exp()`, and `log()`.

5.2.3.106 pure()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::pure (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Pure part.

Definition at line 419 of file clifford_algebra_imp.h.

5.2.3.107 quad()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
Scalar_T glucat::quad (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Scalar_T quadratic form == (rev(x)*x)(0)

Definition at line 475 of file clifford_algebra_imp.h.

5.2.3.108 real()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
Scalar_T glucat::real (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Real part: synonym for scalar part.

Definition at line 400 of file clifford_algebra_imp.h.

Referenced by `glucat::matrix::classify_eigenvalues()`.

5.2.3.109 reframe()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const index_set< LO, HI > glucat::reframe (
    const matrix_multi< Scalar_T, LO, HI > & lhs,
    const matrix_multi< Scalar_T, LO, HI > & rhs,
    matrix_multi< Scalar_T, LO, HI > & lhs_reframed,
    matrix_multi< Scalar_T, LO, HI > & rhs_reframed ) [inline]
```

Find a common frame for operands of a binary operator.

Definition at line 350 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_frame.

Referenced by operator*(), and operator/().

5.2.3.110 reverse()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↔
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::reverse (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Reversion, eg. {1}*{2} -> {2}*{1}.

Definition at line 459 of file clifford_algebra_imp.h.

5.2.3.111 scalar()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↔
_T , const index_t LO, const index_t HI>
Scalar_T glucat::scalar (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Scalar part.

Definition at line 392 of file clifford_algebra_imp.h.

Referenced by atan(), clifford_exp(), cos(), cosh(), exp(), glucat::framed_multi< Scalar_T, LO, HI >::fast(), sin(), sinh(), tan(), and tanh().

5.2.3.112 `sign_of_square()`

```
int glucat::sign_of_square (
    index_t j ) [inline]
```

Square of generator {j}.

Square of generator index j.

Definition at line 960 of file `index_set_imp.h`.

5.2.3.113 `sin()` [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↔
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::sin (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false )
```

Sine of multivector with specified complexifier.

Definition at line 872 of file `clifford_algebra_imp.h`.

References `check_complex()`, `exp()`, `PyClical::i`, `PyClical::pi`, and `scalar()`.

Referenced by `glucat::numeric_traits< Scalar_T >::sin()`, `sin()`, and `tan()`.

5.2.3.114 `sin()` [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↔
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::sin (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Sine of multivector.

Definition at line 896 of file `clifford_algebra_imp.h`.

References `complexifier()`, and `sin()`.

5.2.3.115 sinh()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::sinh (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Hyperbolic sine of multivector.

Definition at line 826 of file `clifford_algebra_imp.h`.

References `exp()`, and `scalar()`.

Referenced by `glucat::numeric_traits< Scalar_T >::sinh()`, and `tanh()`.

5.2.3.116 sqrt() [1/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::sqrt (
    const matrix_multi< Scalar_T, LO, HI > & val,
    const matrix_multi< Scalar_T, LO, HI > & i,
    bool prechecked )
```

Square root of multivector with specified complexifier.

Definition at line 1600 of file `matrix_multi_imp.h`.

References `check_complex()`, `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::function_precision`, `PyClical::i`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::isnan()`, `matrix_sqrt()`, `precision_demoted`, and `precision_promoted`.

5.2.3.117 sqrt() [2/4]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::sqrt (
    const framed_multi< Scalar_T, LO, HI > & val,
    const framed_multi< Scalar_T, LO, HI > & i,
    bool prechecked )
```

Square root of multivector with specified complexifier.

Definition at line 1924 of file `framed_multi_imp.h`.

References `check_complex()`, `PyClical::i`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::isnan()`, `glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::scalar()`, and `sqrt()`.

5.2.3.118 `sqrt()` [3/4]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::sqrt (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Square root of multivector with specified complexifier.

Definition at line 589 of file `clifford_algebra_imp.h`.

References `PyClical::i`.

Referenced by `acosh()`, `asinh()`, `matrix_sqrt()`, `glucat::framed_multi< Scalar_T, LO, HI >::random()`, and `sqrt()`.

5.2.3.119 `sqrt()` [4/4]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::sqrt (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Square root of multivector.

Definition at line 597 of file `clifford_algebra_imp.h`.

References `complexifier()`, and `sqrt()`.

5.2.3.120 `star()` [1/3]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
Scalar_T glucat::star (
    const matrix_multi< Scalar_T, LO, HI > & lhs,
    const matrix_multi< Scalar_T, LO, HI > & rhs ) [inline]
```

Hestenes scalar product.

Definition at line 654 of file `matrix_multi_imp.h`.

5.2.3.121 `star()` [2/3]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
Scalar_T glucat::star (
    const framed_multi< Scalar_T, LO, HI > & lhs,
    const framed_multi< Scalar_T, LO, HI > & rhs )
```

Hestenes scalar product.

Definition at line 855 of file `framed_multi_imp.h`.

5.2.3.122 star() [3/3]

```
template<template< typename, const index_t, const index_t > class Multivector, template<
typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO,
const index_t HI>
Scalar_T glucat::star (
    const Multivector< Scalar_T, LO, HI > & lhs,
    const RHS< Scalar_T, LO, HI > & rhs ) [inline]
```

Hestenes scalar product.

Definition at line 258 of file clifford_algebra_imp.h.

5.2.3.123 tan() [1/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::tan (
    const Multivector< Scalar_T, LO, HI > & val,
    const Multivector< Scalar_T, LO, HI > & i,
    const bool prechecked = false ) [inline]
```

Tangent of multivector with specified complexifier.

Definition at line 977 of file clifford_algebra_imp.h.

References check_complex(), cos(), PyClical::i, scalar(), and sin().

Referenced by glucat::numeric_traits< Scalar_T >::tan(), and tan().

5.2.3.124 tan() [2/2]

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::tan (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Tangent of multivector.

Definition at line 996 of file clifford_algebra_imp.h.

References complexifier(), and tan().

5.2.3.125 tanh()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>
const Multivector< Scalar_T, LO, HI > glucat::tanh (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Hyperbolic tangent of multivector.

Definition at line 933 of file clifford_algebra_imp.h.

References cosh(), scalar(), and sinh().

Referenced by glucat::numeric_traits< Scalar_T >::tanh().

5.2.3.126 to_demote()

```
template<typename Scalar_T >
numeric_traits<Scalar_T>::demoted::type glucat::to_demote (
    const Scalar_T & val ) [inline]
```

Cast to demote.

Definition at line 134 of file scalar_imp.h.

References glucat::numeric_traits< Scalar_T >::to_scalar_t().

5.2.3.127 to_promote()

```
template<typename Scalar_T >
numeric_traits<Scalar_T>::promoted::type glucat::to_promote (
    const Scalar_T & val ) [inline]
```

Cast to promote.

Definition at line 124 of file scalar_imp.h.

References glucat::numeric_traits< Scalar_T >::to_scalar_t().

5.2.3.128 try_catch() [1/2]

```
int glucat::try_catch (
    intfn f )
```

Exception catching for functions returning int.

Definition at line 49 of file try_catch.h.

References PyClical::e().

Referenced by glucat::control_t::call().

5.2.3.129 try_catch() [2/2]

```
int glucat::try_catch (
    intintfn f,
    int arg )
```

Exception catching for functions of int returning int.

Definition at line 64 of file try_catch.h.

References PyClical::e().

5.2.3.130 vector_part()

```
template<template< typename, const index_t, const index_t > class Multivector, typename Scalar↵
_T , const index_t LO, const index_t HI>
const std::vector< Scalar_T > glucat::vector_part (
    const Multivector< Scalar_T, LO, HI > & val ) [inline]
```

Vector part of multivector, as a vector_t with respect to frame()

Definition at line 443 of file clifford_algebra_imp.h.

5.2.4 Variable Documentation**5.2.4.1 BITS_PER_SET_VALUE**

```
const index_t glucat::BITS_PER_SET_VALUE = std::numeric_limits<set_value_t>::digits
```

Number of bits in set_value_t.

Definition at line 103 of file global.h.

5.2.4.2 DEFAULT_Basis_Max_Count

```
const unsigned int glucat::DEFAULT_Basis_Max_Count = 12
```

Definition at line 130 of file global.h.

5.2.4.3 DEFAULT_Div_Max_Steps

```
const unsigned int glucat::DEFAULT_Div_Max_Steps = 4
```

Definition at line 126 of file global.h.

5.2.4.4 DEFAULT_Fast_Size_Threshold

```
const unsigned int glucat::DEFAULT_Fast_Size_Threshold = 1 << 6
```

Definition at line 131 of file global.h.

5.2.4.5 DEFAULT_Function_Precision

```
const precision_t glucat::DEFAULT_Function_Precision = precision_same
```

Definition at line 134 of file global.h.

5.2.4.6 DEFAULT_HI

```
const index_t glucat::DEFAULT_HI = index_t(BITS_PER_SET_VALUE / 2)
```

Default highest index in an index set.

Definition at line 111 of file global.h.

5.2.4.7 DEFAULT_Inv_Fast_Dim_Threshold

```
const unsigned int glucat::DEFAULT_Inv_Fast_Dim_Threshold = 1 << 3
```

Definition at line 132 of file global.h.

5.2.4.8 DEFAULT_Log_Max_Inner_Steps

```
const unsigned int glucat::DEFAULT_Log_Max_Inner_Steps = 32
```

Definition at line 129 of file global.h.

5.2.4.9 DEFAULT_Log_Max_Outer_Steps

```
const unsigned int glucat::DEFAULT_Log_Max_Outer_Steps = 256
```

Definition at line 128 of file global.h.

5.2.4.10 DEFAULT_Mult_Matrix_Threshold

```
const unsigned int glucat::DEFAULT_Mult_Matrix_Threshold = 8
```

Definition at line 125 of file global.h.

5.2.4.11 DEFAULT_Products_Size_Threshold

```
const unsigned int glucat::DEFAULT_Products_Size_Threshold = 1 << 22
```

Definition at line 133 of file global.h.

5.2.4.12 DEFAULT_Sqrt_Max_Steps

```
const unsigned int glucat::DEFAULT_Sqrt_Max_Steps = 256
```

Definition at line 127 of file global.h.

5.2.4.13 DEFAULT_TRUNCATION

```
const double glucat::DEFAULT_TRUNCATION = std::numeric_limits<float>::epsilon()
```

Default for truncation.

Definition at line 114 of file global.h.

5.2.4.14 l_ln2

```
const long double glucat::l_ln2 = 0.6931471805599453094172321214581766L [static]
```

Definition at line 41 of file long_double.h.

Referenced by glucat::numeric_traits< Scalar_T >::ln_2().

5.2.4.15 `l_pi`

```
const long double glucat::l_pi = 3.1415926535897932384626433832795029L [static]
```

Definition at line 40 of file `long_double.h`.

Referenced by `glucat::numeric_traits< Scalar_T >::pi()`.

5.2.4.16 `MS_PER_S`

```
const double glucat::MS_PER_S = 1000.0
```

Timing constant: deprecated here - moved to [test/timing.h](#).

Definition at line 83 of file `global.h`.

5.3 glucat::gen Namespace Reference

Classes

- class [generator_table](#)
Table of generators for specific signatures.

Typedefs

- typedef `std::pair< index_t, index_t >` [signature_t](#)
A signature is a pair of indices, p , q , with $p == \text{frame.max}()$, $q == -\text{frame.min}()$

Variables

- static const [index_t](#) [offset_to_super](#) [] = {0,-1, 0,-1,-2, 3, 2, 1}
Offsets between the current signature and that of the real superalgebra.

5.3.1 Typedef Documentation

5.3.1.1 `signature_t`

```
typedef std::pair<index\_t, index\_t> glucat::gen::signature_t
```

A signature is a pair of indices, p , q , with $p == \text{frame.max}()$, $q == -\text{frame.min}()$

Definition at line 43 of file `generation.h`.

5.3.2 Variable Documentation

5.3.2.1 offset_to_super

```
const index_t glucat::gen::offset_to_super[] = {0,-1, 0,-1,-2, 3, 2, 1} [static]
```

Offsets between the current signature and that of the real superalgebra.

Definition at line 81 of file generation.h.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::fast_framed_multi(), glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi(), and glucat::gen::generator_table< Matrix_T >::operator()().

5.4 glucat::matrix Namespace Reference

Classes

- struct [eig_genus](#)
Structure containing classification of eigenvalues.

Enumerations

- enum [eig_case_t](#) { [safe_eig_case](#), [negative_eig_case](#), [both_eig_case](#) }
Classification of eigenvalues of a matrix.

Functions

- template<typename LHS_T, typename RHS_T >
const RHS_T [kron](#) (const LHS_T &lhs, const RHS_T &rhs)
Kronecker tensor product of matrices - as per Matlab kron.
- template<typename LHS_T, typename RHS_T >
const RHS_T [mono_kron](#) (const LHS_T &lhs, const RHS_T &rhs)
Sparse Kronecker tensor product of monomial matrices.
- template<typename LHS_T, typename RHS_T >
const RHS_T [nork](#) (const LHS_T &lhs, const RHS_T &rhs, const bool mono=true)
Left inverse of Kronecker product.
- template<typename LHS_T, typename RHS_T >
const RHS_T [signed_perm_nork](#) (const LHS_T &lhs, const RHS_T &rhs)
Left inverse of Kronecker product where lhs is a signed permutation matrix.
- template<typename Matrix_T >
Matrix_T::size_type [nnz](#) (const Matrix_T &m)
Number of non-zeros.
- template<typename Matrix_T >
bool [isnan](#) (const Matrix_T &m)
Not a Number.

- `template<typename Matrix_T >`
`const Matrix_T unit (const typename Matrix_T::size_type n)`
Unit matrix - as per Matlab eye.
- `template<typename LHS_T , typename RHS_T >`
`const RHS_T::expression_type mono_prod (const ublas::matrix_expression< LHS_T > &lhs, const ublas::matrix_expression< RHS_T > &rhs)`
Product of monomial matrices.
- `template<typename LHS_T , typename RHS_T >`
`const RHS_T::expression_type sparse_prod (const ublas::matrix_expression< LHS_T > &lhs, const ublas::matrix_expression< RHS_T > &rhs)`
Product of sparse matrices.
- `template<typename LHS_T , typename RHS_T >`
`const RHS_T::expression_type prod (const ublas::matrix_expression< LHS_T > &lhs, const ublas::matrix_expression< RHS_T > &rhs)`
Product of matrices.
- `template<typename Scalar_T , typename LHS_T , typename RHS_T >`
`Scalar_T inner (const LHS_T &lhs, const RHS_T &rhs)`
*Inner product: $\sum(x(i,j)*y(i,j))/x.nrows()$*
- `template<typename Matrix_T >`
`Matrix_T::value_type norm_frob2 (const Matrix_T &val)`
Square of Frobenius norm.
- `template<typename Matrix_T >`
`Matrix_T::value_type trace (const Matrix_T &val)`
Matrix trace.
- `template<typename Matrix_T >`
`ublas::vector< std::complex< double > > eigenvalues (const Matrix_T &val)`
Eigenvalues of a matrix.
- `template<typename Matrix_T >`
`eig_genus< Matrix_T > classify_eigenvalues (const Matrix_T &val)`
Classify the eigenvalues of a matrix.
- `template<typename LHS_T , typename RHS_T >`
`void nork_range (RHS_T &result, const typename LHS_T::const_iterator2 lhs_it2, const RHS_T &rhs, const typename RHS_T::size_type res_s1, const typename RHS_T::size_type res_s2)`
Utility routine for nork: calculate result for a range of indices.
- `template<typename Matrix_T >`
`static ublas::matrix< double, ublas::column_major > to_lapack (const Matrix_T &val)`
Convert matrix to LAPACK format.

5.4.1 Enumeration Type Documentation

5.4.1.1 eig_case_t

enum `glucat::matrix::eig_case_t`

Classification of eigenvalues of a matrix.

Enumerator

<code>safe_eig_case</code>	
<code>negative_eig_case</code>	
<code>both_eig_case</code>	

Definition at line 127 of file matrix.h.

5.4.2 Function Documentation

5.4.2.1 classify_eigenvalues()

```
template<typename Matrix_T >
eig_genus< Matrix_T > glucat::matrix::classify_eigenvalues (
    const Matrix_T & val )
```

Classify the eigenvalues of a matrix.

Definition at line 526 of file matrix_imp.h.

References glucat::abs(), both_eig_case, eigenvalues(), glucat::imag(), glucat::matrix::eig_genus< Matrix_T >::m_eig_case, glucat::matrix::eig_genus< Matrix_T >::m_safe_arg, negative_eig_case, glucat::norm(), glucat::numeric_traits< Scalar_T >::pi(), PyClical::pi, glucat::real(), and safe_eig_case.

Referenced by glucat::matrix_log(), and glucat::matrix_sqrt().

5.4.2.2 eigenvalues()

```
template<typename Matrix_T >
ublas::vector< std::complex< double > > glucat::matrix::eigenvalues (
    const Matrix_T & val )
```

Eigenvalues of a matrix.

Definition at line 493 of file matrix_imp.h.

References to_lapack().

Referenced by classify_eigenvalues().

5.4.2.3 inner()

```
template<typename Scalar_T , typename LHS_T , typename RHS_T >
Scalar_T glucat::matrix::inner (
    const LHS_T & lhs,
    const RHS_T & rhs )
```

Inner product: $\sum(x(i,j)*y(i,j))/x.nrows()$

Inner product: $\sum(lhs(i,j)*rhs(i,j))/lhs.nrows()$

Definition at line 391 of file matrix_imp.h.

5.4.2.4 isnan()

```
template<typename Matrix_T >
bool glucat::matrix::isnan (
    const Matrix_T & m )
```

Not a Number.

Definition at line 292 of file matrix_imp.h.

Referenced by glucat::matrix_log(), and glucat::operator/().

5.4.2.5 kron()

```
template<typename LHS_T , typename RHS_T >
const RHS_T glucat::matrix::kron (
    const LHS_T & lhs,
    const RHS_T & rhs )
```

Kronecker tensor product of matrices - as per Matlab kron.

Definition at line 73 of file matrix_imp.h.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fast().

5.4.2.6 mono_kron()

```
template<typename LHS_T , typename RHS_T >
const RHS_T glucat::matrix::mono_kron (
    const LHS_T & lhs,
    const RHS_T & rhs )
```

Sparse Kronecker tensor product of monomial matrices.

Definition at line 116 of file matrix_imp.h.

Referenced by glucat::gen::generator_table< Matrix_T >::gen_from_pm1_qm1().

5.4.2.7 mono_prod()

```
template<typename LHS_T , typename RHS_T >
const RHS_T::expression_type glucat::matrix::mono_prod (
    const ublas::matrix_expression< LHS_T > & lhs,
    const ublas::matrix_expression< RHS_T > & rhs )
```

Product of monomial matrices.

Definition at line 326 of file matrix_imp.h.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::basis_element(), glucat::gen::generator_table< Matrix_T >::gen_from_pm4_qp4(), glucat::gen::generator_table< Matrix_T >::gen_from_pp4_qm4(), and glucat::gen::generator_table< Matrix_T >::gen_from_qp1_pm1().

5.4.2.8 nnz()

```
template<typename Matrix_T >
Matrix_T::size_type glucat::matrix::nnz (
    const Matrix_T & m )
```

Number of non-zeros.

Definition at line 269 of file matrix_imp.h.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::framed_multi().

5.4.2.9 nork()

```
template<typename LHS_T , typename RHS_T >
const RHS_T glucat::matrix::nork (
    const LHS_T & lhs,
    const RHS_T & rhs,
    const bool mono = true )
```

Left inverse of Kronecker product.

Definition at line 188 of file matrix_imp.h.

References norm_frob2().

5.4.2.10 nork_range()

```
template<typename LHS_T , typename RHS_T >
void glucat::matrix::nork_range (
    RHS_T & result,
    const typename LHS_T::const_iterator2 lhs_it2,
    const RHS_T & rhs,
    const typename RHS_T::size_type res_s1,
    const typename RHS_T::size_type res_s2 )
```

Utility routine for nork: calculate result for a range of indices.

Definition at line 155 of file matrix_imp.h.

References glucat::numeric_traits< Scalar_T >::to_scalar_t().

5.4.2.11 norm_frob2()

```
template<typename Matrix_T >
Matrix_T::value_type glucat::matrix::norm_frob2 (
    const Matrix_T & val )
```

Square of Frobenius norm.

Definition at line 413 of file matrix_imp.h.

Referenced by nork().

5.4.2.12 prod()

```
template<typename LHS_T , typename RHS_T >
const RHS_T::expression_type glucat::matrix::prod (
    const ublas::matrix_expression< LHS_T > & lhs,
    const ublas::matrix_expression< RHS_T > & rhs ) [inline]
```

Product of matrices.

Definition at line 373 of file matrix_imp.h.

5.4.2.13 signed_perm_nork()

```
template<typename LHS_T , typename RHS_T >
const RHS_T glucat::matrix::signed_perm_nork (
    const LHS_T & lhs,
    const RHS_T & rhs )
```

Left inverse of Kronecker product where lhs is a signed permutation matrix.

Definition at line 237 of file matrix_imp.h.

Referenced by glucat::fast().

5.4.2.14 sparse_prod()

```
template<typename LHS_T , typename RHS_T >
const RHS_T::expression_type glucat::matrix::sparse_prod (
    const ublas::matrix_expression< LHS_T > & lhs,
    const ublas::matrix_expression< RHS_T > & rhs ) [inline]
```

Product of sparse matrices.

Definition at line 362 of file matrix_imp.h.

5.4.2.15 to_lapack()

```
template<typename Matrix_T >
static ublas::matrix<double, ublas::column_major> glucat::matrix::to_lapack (
    const Matrix_T & val ) [static]
```

Convert matrix to LAPACK format.

Definition at line 461 of file matrix_imp.h.

Referenced by eigenvalues().

5.4.2.16 trace()

```
template<typename Matrix_T >
Matrix_T::value_type glucat::matrix::trace (
    const Matrix_T & val )
```

Matrix trace.

Definition at line 437 of file matrix_imp.h.

References glucat::numeric_traits< Scalar_T >::NaN().

5.4.2.17 unit()

```
template<typename Matrix_T >
const Matrix_T glucat::matrix::unit (
    const typename Matrix_T::size_type n ) [inline]
```

Unit matrix - as per Matlab eye.

Definition at line 317 of file matrix_imp.h.

5.5 glucat::timing Namespace Reference

Functions

- static double [elapsed](#) (clock_t cpu_time)
Elapsed time in milliseconds.

Variables

- const double [MS_PER_SEC](#) = 1000.0
Timing constant: milliseconds per second.
- const double [MS_PER_CLOCK](#) = [MS_PER_SEC](#) / double(CLOCKS_PER_SEC)
Timing constant: milliseconds per clock.
- const int [EXTRA_TRIALS](#) = 2
Timing constant: trial expansion factor.

5.5.1 Function Documentation

5.5.1.1 elapsed()

```
static double glucat::timing::elapsed (  
    clock_t cpu_time ) [inline], [static]
```

Elapsed time in milliseconds.

Definition at line 51 of file timing.h.

References `MS_PER_CLOCK`.

5.5.2 Variable Documentation

5.5.2.1 EXTRA_TRIALS

```
const int glucat::timing::EXTRA_TRIALS = 2
```

Timing constant: trial expansion factor.

Definition at line 45 of file timing.h.

5.5.2.2 MS_PER_CLOCK

```
const double glucat::timing::MS_PER_CLOCK = MS\_PER\_SEC / double(CLOCKS_PER_SEC)
```

Timing constant: milliseconds per clock.

Definition at line 42 of file timing.h.

Referenced by `elapsed()`.

5.5.2.3 MS_PER_SEC

```
const double glucat::timing::MS_PER_SEC = 1000.0
```

Timing constant: milliseconds per second.

Definition at line 39 of file timing.h.

5.6 PyClical Namespace Reference

Classes

- class [clifford](#)
- class [index_set](#)

Functions

- def [index_set_hidden_doctests](#) ()
- def [clifford_hidden_doctests](#) ()
- def [e](#) (obj)
- def [istpq](#) (p, q)
- def [_test](#) ()

Variables

- string [__version__](#) = "0.8.2"
- [obj](#)
- [i](#)
- [ixt](#)
- [fill](#)
- float [tau](#) = atan([clifford](#)(1.0)) * 8.0
- float [pi](#) = [tau](#) / 2.0
- [cl](#) = [clifford](#)
- [ist](#) = [index_set](#)
- def [ninf3](#) = [e](#)(4) + [e](#)(-1)
- def [nbar3](#) = [e](#)(4) - [e](#)(-1)

5.6.1 Function Documentation

5.6.1.1 [_test\(\)](#)

```
def PyClical._test ( ) [private]
```

Definition at line 1913 of file PyClical.pyx.

5.6.1.2 clifford_hidden_doctests()

```
def PyClical.clifford_hidden_doctests ( )
```

Tests for functions that Doctest cannot see.

For clifford.__cinit__: Construct an object of type clifford.

```
>>> print clifford(2)
2
>>> print clifford(2L)
2
>>> print clifford(2.0)
2
>>> print clifford(1.0e-1)
0.1
>>> print clifford("2")
2
>>> print clifford("2{1,2,3}")
2{1,2,3}
>>> print clifford(clifford("2{1,2,3}"))
2{1,2,3}
>>> print clifford("-{1}")
-{1}
>>> print clifford(2,index_set({1,2}))
2{1,2}
>>> print clifford([2,3],index_set({1,2}))
2{1}+3{2}
>>> print clifford([1,2])
Traceback (most recent call last):
...
TypeError: Cannot initialize clifford object from <type 'list'>.
>>> print clifford(None)
Traceback (most recent call last):
...
TypeError: Cannot initialize clifford object from <type 'NoneType'>.
>>> print clifford(None,[1,2])
Traceback (most recent call last):
...
TypeError: Cannot initialize clifford object from (<type 'NoneType'>, <type 'list'>).
>>> print clifford([1,2],[1,2])
Traceback (most recent call last):
...
TypeError: Cannot initialize clifford object from (<type 'list'>, <type 'list'>).
>>> print clifford("")
Traceback (most recent call last):
...
ValueError: Cannot initialize clifford object from invalid string ''.
>>> print clifford("{")
Traceback (most recent call last):
...
ValueError: Cannot initialize clifford object from invalid string '{'.
>>> print clifford("{1}")
Traceback (most recent call last):
...
ValueError: Cannot initialize clifford object from invalid string '{1'.
>>> print clifford("{+")
Traceback (most recent call last):
...
ValueError: Cannot initialize clifford object from invalid string '{+'.
>>> print clifford("-")
Traceback (most recent call last):
...
ValueError: Cannot initialize clifford object from invalid string '-'.
>>> print clifford("{1}+")
Traceback (most recent call last):
...
ValueError: Cannot initialize clifford object from invalid string '{1}+'.

```

For clifford.__richcmp__: Compare objects of type clifford.

```

>>> clifford("{1}") == clifford("1{1}")
True
>>> clifford("{1}") != clifford("1.0{1}")
False
>>> clifford("{1}") != clifford("1.0")
True
>>> clifford("{1,2}") == None
False
>>> clifford("{1,2}") != None
True
>>> None == clifford("{1,2}")
False
>>> None != clifford("{1,2}")
True

```

Definition at line 1243 of file PyClicl.pyx.

5.6.1.3 e()

```

def PyClicl.e (
    obj )

```

Abbreviation for `clifford(index_set(obj))`.

```

>>> print e(1)
{1}
>>> print e(-1)
{-1}
>>> print e(0)
1

```

Definition at line 1887 of file PyClicl.pyx.

Referenced by `glucat::matrix_multi< Scalar_T, LO, HI >.basis_element()`, `clifford_to_str()`, `glucat::framed_multi< Scalar_T, LO, HI >.framed_multi()`, `glucat::matrix_multi< Scalar_T, LO, HI >.matrix_multi()`, and `glucat.try_catch()`.

5.6.1.4 index_set_hidden_doctests()

```

def PyClicl.index_set_hidden_doctests ( )

```

Tests for functions that Doctest cannot see.

For `index_set.__cinit__`: Construct `index_set`.

```

>>> print index_set(1)
{1}
>>> print index_set({1,2})
{1,2}
>>> print index_set(index_set({1,2}))
{1,2}
>>> print index_set({1,2})
{1,2}
>>> print index_set({1,2,1})
{1,2}
>>> print index_set({1,2,1})
{1,2}

```

```

>>> print index_set("")
{}
>>> print index_set("{}")
Traceback (most recent call last):
...
ValueError: Cannot initialize index_set object from invalid string '{}'.
>>> print index_set("{1}")
Traceback (most recent call last):
...
ValueError: Cannot initialize index_set object from invalid string '{1}'.
>>> print index_set("{1,2,100}")
Traceback (most recent call last):
...
ValueError: Cannot initialize index_set object from invalid string '{1,2,100}'.
>>> print index_set({1,2,100})
Traceback (most recent call last):
...
IndexError: Cannot initialize index_set object from invalid set([1, 2, 100]).
>>> print index_set([1,2])
Traceback (most recent call last):
...
TypeError: Cannot initialize index_set object from <type 'list'>.

For index_set.__richcmp__: Compare two objects of class index_set.

>>> index_set(1) == index_set({1})
True
>>> index_set({1}) != index_set({1})
False
>>> index_set({1}) != index_set({2})
True
>>> index_set({1}) == index_set({2})
False
>>> index_set({1}) < index_set({2})
True
>>> index_set({1}) <= index_set({2})
True
>>> index_set({1}) > index_set({2})
False
>>> index_set({1}) >= index_set({2})
False
>>> None == index_set({1,2})
False
>>> None != index_set({1,2})
True
>>> None < index_set({1,2})
False
>>> None <= index_set({1,2})
False
>>> None > index_set({1,2})
False
>>> None >= index_set({1,2})
False
>>> index_set({1,2}) == None
False
>>> index_set({1,2}) != None
True
>>> index_set({1,2}) < None
False
>>> index_set({1,2}) <= None
False
>>> index_set({1,2}) > None
False
>>> index_set({1,2}) >= None
False

```

Definition at line 404 of file PyClical.pyx.

5.6.1.5 istpq()

```
def PyClical.istpq (
    p,
    q )
```

Abbreviation for `index_set({-q,...p})`.

```
>>> print istpq(2,3)
{-3,-2,-1,1,2}
```

Definition at line 1900 of file PyClical.pyx.

5.6.2 Variable Documentation

5.6.2.1 __version__

```
string PyClical.__version__ = "0.8.2" [private]
```

Definition at line 32 of file PyClical.pyx.

5.6.2.2 cl

```
PyClical.cl = clifford
```

Definition at line 1859 of file PyClical.pyx.

Referenced by `cga3.agc3()`, `cga3.cga3()`, and `cga3.cga3std()`.

5.6.2.3 fill

```
PyClical.fill
```

Definition at line 1815 of file PyClical.pyx.

Referenced by `glucat::matrix_multi< Scalar_T, LO, HI >.random()`, and `glucat::framed_multi< Scalar_T, LO, HI >.random()`.

5.6.2.4 i

```
PyClical.i
```

Definition at line 1542 of file PyClical.pyx.

Referenced by `glucat.acos()`, `glucat.acosh()`, `glucat.asin()`, `glucat.asinh()`, `glucat.atan()`, `glucat.atanh()`, `glucat.check_complex()`, `glucat.cos()`, `glucat.log()`, `glucat.matrix_log()`, `glucat.matrix_sqrt()`, `glucat.operator<<()`, `glucat.operator>>()`, `glucat.sin()`, `glucat.sqrt()`, and `glucat.tan()`.

5.6.2.5 ist

```
PyClical.ist = index_set
```

Definition at line 1879 of file PyClical.pyx.

Referenced by `cga3.agc3()`, `glucat::matrix_multi< Scalar_T, LO, HI >.basis_element()`, `glucat::framed_multi< Scalar_T, LO, HI >.centre_pm4_qp4()`, `glucat::framed_multi< Scalar_T, LO, HI >.centre_pp4_qm4()`, `glucat::framed_multi< Scalar_T, LO, HI >.centre_qp1_pm1()`, `cga3.cga3()`, `cga3.cga3std()`, `glucat::framed_multi< Scalar_T, LO, HI >.divide()`, `glucat::framed_multi< Scalar_T, LO, HI >.framed_multi()`, `index_set_to_repr()`, `index_set_to_str()`, `glucat::matrix_multi< Scalar_T, LO, HI >.matrix_multi()`, `glucat.max_pos()`, `glucat.min_neg()`, `glucat.operator<<()`, and `glucat.operator>>()`.

5.6.2.6 ixt

```
PyClical.ixt
```

Definition at line 1815 of file PyClical.pyx.

5.6.2.7 nbar3

```
def PyClical.nbar3 = e(4) - e(-1)
```

Definition at line 1910 of file PyClical.pyx.

5.6.2.8 ninf3

```
def PyClical.ninf3 = e(4) + e(-1)
```

Definition at line 1909 of file PyClical.pyx.

Referenced by `cga3.cga3()`, and `cga3.cga3std()`.

5.6.2.9 obj

`PyClical.obj`

Definition at line 1542 of file `PyClical.pyx`.

5.6.2.10 pi

```
float PyClical.pi = tau / 2.0
```

Definition at line 1857 of file `PyClical.pyx`.

Referenced by `glucat::matrix.classify_eigenvalues()`, `glucat.cos()`, `glucat.log()`, `glucat.matrix_log()`, and `glucat.sin()`.

5.6.2.11 tau

```
float PyClical.tau = atan(clifford(1.0)) * 8.0
```

Definition at line 1856 of file `PyClical.pyx`.

5.7 std Namespace Reference

Classes

- struct `numeric_limits< glucat::framed_multi< Scalar_T, LO, HI > >`
Numeric limits for framed_multi inherit limits for the corresponding scalar type.
- struct `numeric_limits< glucat::matrix_multi< Scalar_T, LO, HI > >`
Numeric limits for matrix_multi inherit limits for the corresponding scalar type.

Chapter 6

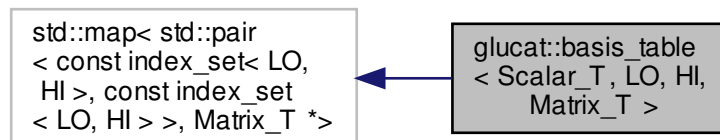
Class Documentation

6.1 `glucat::basis_table< Scalar_T, LO, HI, Matrix_T >` Class Template Reference

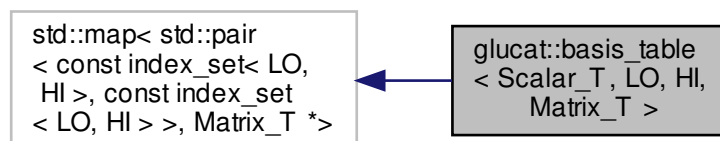
Table of basis elements used as a cache by `basis_element()`

```
#include <matrix_multi_imp.h>
```

Inheritance diagram for `glucat::basis_table< Scalar_T, LO, HI, Matrix_T >`:



Collaboration diagram for `glucat::basis_table< Scalar_T, LO, HI, Matrix_T >`:



Static Public Member Functions

- static [basis_table](#) & [basis](#) ()
Single instance of basis table.

Private Member Functions

- [basis_table](#) ()
- [~basis_table](#) ()
- [basis_table](#) (const [basis_table](#) &)
- [basis_table](#) & [operator=](#) (const [basis_table](#) &)

Friends

- class [friend_for_private_destructor](#)

6.1.1 Detailed Description

```
template<typename Scalar_T, const index_t LO, const index_t HI, typename Matrix_T>
class glucat::basis_table< Scalar_T, LO, HI, Matrix_T >
```

Table of basis elements used as a cache by [basis_element](#)()

Definition at line 1218 of file [matrix_multi_imp.h](#).

6.1.2 Constructor & Destructor Documentation

6.1.2.1 [basis_table](#)() [1/2]

```
template<typename Scalar_T , const index_t LO, const index_t HI, typename Matrix_T >
glucat::basis_table< Scalar_T, LO, HI, Matrix_T >::basis_table ( ) [inline], [private]
```

Definition at line 1228 of file [matrix_multi_imp.h](#).

6.1.2.2 [~basis_table](#)()

```
template<typename Scalar_T , const index_t LO, const index_t HI, typename Matrix_T >
glucat::basis_table< Scalar_T, LO, HI, Matrix_T >::~basis_table ( ) [inline], [private]
```

Definition at line 1229 of file [matrix_multi_imp.h](#).

6.1.2.3 basis_table() [2/2]

```
template<typename Scalar_T , const index_t LO, const index_t HI, typename Matrix_T >
glucat::basis_table< Scalar_T, LO, HI, Matrix_T >::basis_table (
    const basis_table< Scalar_T, LO, HI, Matrix_T > & ) [private]
```

6.1.3 Member Function Documentation

6.1.3.1 basis()

```
template<typename Scalar_T , const index_t LO, const index_t HI, typename Matrix_T >
static basis_table& glucat::basis_table< Scalar_T, LO, HI, Matrix_T >::basis ( ) [inline],
[static]
```

Single instance of basis table.

Definition at line 1224 of file matrix_multi_imp.h.

6.1.3.2 operator=()

```
template<typename Scalar_T , const index_t LO, const index_t HI, typename Matrix_T >
basis_table& glucat::basis_table< Scalar_T, LO, HI, Matrix_T >::operator= (
    const basis_table< Scalar_T, LO, HI, Matrix_T > & ) [private]
```

6.1.4 Friends And Related Function Documentation

6.1.4.1 friend_for_private_destructor

```
template<typename Scalar_T , const index_t LO, const index_t HI, typename Matrix_T >
friend class friend_for_private_destructor [friend]
```

Friend declaration to avoid compiler warning: "... only defines a private destructor and has no friends" Ref: Carlos O'Ryan, ACE <http://doc.ece.uci.edu>

Definition at line 1236 of file matrix_multi_imp.h.

The documentation for this class was generated from the following file:

- glucat/[matrix_multi_imp.h](#)

6.2 glucat::bool_to_type< truth_value > Class Template Reference

Bool to type.

```
#include <global.h>
```

Private Types

- enum { [value](#) = truth_value }

6.2.1 Detailed Description

```
template<bool truth_value>  
class glucat::bool_to_type< truth_value >
```

Bool to type.

Definition at line 69 of file global.h.

6.2.2 Member Enumeration Documentation

6.2.2.1 anonymous enum

```
template<bool truth_value>  
anonymous enum [private]
```

Enumerator

value	
-------	--

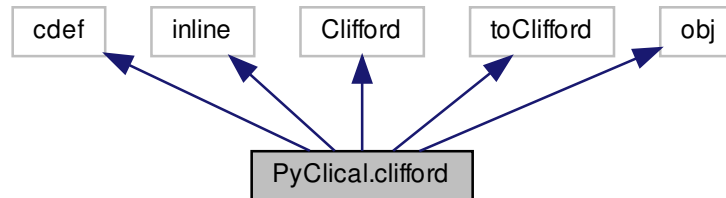
Definition at line 72 of file global.h.

The documentation for this class was generated from the following file:

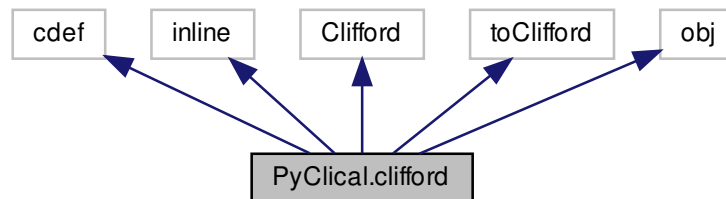
- glucat/[global.h](#)

6.3 PyClical.clifford Class Reference

Inheritance diagram for PyClical.clifford:



Collaboration diagram for PyClical.clifford:



Public Member Functions

- def `__cinit__` (self, other=0, `ixt`=None)
- def `__dealloc__` (self)
- def `__contains__` (self, x)
- def `__iter__` (self)
- def `reframe` (self, `ixt`)
- def `__richcmp__` (lhs, rhs, int, op)
- def `__getitem__` (self, `ixt`)
- def `__neg__` (self)
- def `__pos__` (self)
- def `__add__` (lhs, rhs)
- def `__iadd__` (self, rhs)
- def `__sub__` (lhs, rhs)
- def `__isub__` (self, rhs)
- def `__mul__` (lhs, rhs)
- def `__imul__` (self, rhs)
- def `__mod__` (lhs, rhs)
- def `__imod__` (self, rhs)

- def `__and__` (lhs, rhs)
- def `__iand__` (self, rhs)
- def `__xor__` (lhs, rhs)
- def `__ixor__` (self, rhs)
- def `__div__` (lhs, rhs)
- def `__idiv__` (self, rhs)
- def `inv` (self)
- def `__or__` (lhs, rhs)
- def `__ior__` (self, rhs)
- def `__pow__` (self, m, dummy)
- def `pow` (self, m)
- def `outer_pow` (self, m)
- def `__call__` (self, grade)
- def `scalar` (self)
- def `pure` (self)
- def `even` (self)
- def `odd` (self)
- def `vector_part` (self, frm=None)
- def `involute` (self)
- def `reverse` (self)
- def `conj` (self)
- def `quad` (self)
- def `norm` (self)
- def `abs` (self)
- def `max_abs` (self)
- def `truncated` (self, limit)
- def `isnan` (self)
- def `frame` (self)
- def `__repr__` (self)
- def `__str__` (self)

Public Attributes

- `instance`

6.3.1 Detailed Description

Python class `clifford` wraps C++ class `Clifford`.

Definition at line 532 of file `PyClical.pyx`.

6.3.2 Member Function Documentation

6.3.2.1 `__add__()`

```
def PyClical.clifford.__add__ (
    lhs,
    rhs )

Geometric sum.

>>> print clifford(1) + clifford("{2}")
1+{2}
>>> print clifford("{1}") + clifford("{2}")
{1}+{2}
```

Definition at line 739 of file PyClical.pyx.

6.3.2.2 `__and__()`

```
def PyClical.clifford.__and__ (
    lhs,
    rhs )

Inner product.

>>> print clifford("{1}") & clifford("{2}")
0
>>> print clifford(2) & clifford("{2}")
0
>>> print clifford("{1}") & clifford("{1}")
1
>>> print clifford("{1}") & clifford("{1,2}")
{2}
```

Definition at line 835 of file PyClical.pyx.

6.3.2.3 `__call__()`

```
def PyClical.clifford.__call__ (
    self,
    grade )

Pure grade-vector part.

>>> print clifford("{1}") (1)
{1}
>>> print clifford("{1}") (0)
0
>>> print clifford("1+{1}+{1,2}") (0)
1
>>> print clifford("1+{1}+{1,2}") (1)
{1}
>>> print clifford("1+{1}+{1,2}") (2)
{1,2}
>>> print clifford("1+{1}+{1,2}") (3)
0
```

Definition at line 1019 of file PyClical.pyx.

References `PyClical.index_set.instance`, and `PyClical.clifford.instance`.

6.3.2.4 `__cinit__()`

```
def PyClical.clifford.__cinit__ (
    self,
    other = 0,
    ixt = None )
```

Construct an object of type clifford.

```
>>> print clifford(2)
2
>>> print clifford(2L)
2
>>> print clifford(2.0)
2
>>> print clifford(1.0e-1)
0.1
>>> print clifford("2")
2
>>> print clifford("2{1,2,3}")
2{1,2,3}
>>> print clifford(clifford("2{1,2,3}"))
2{1,2,3}
>>> print clifford("-{1}")
-{1}
>>> print clifford(2,index_set ({1,2}))
2{1,2}
>>> print clifford([2,3],index_set ({1,2}))
2{1}+3{2}
```

Definition at line 563 of file PyClical.pyx.

6.3.2.5 `__contains__()`

```
def PyClical.clifford.__contains__ (
    self,
    x )
```

Not applicable.

```
>>> x=clifford(index_set ({-3,4,7})); -3 in x
Traceback (most recent call last):
...
TypeError: Not applicable.
```

Definition at line 626 of file PyClical.pyx.

6.3.2.6 `__dealloc__()`

```
def PyClical.clifford.__dealloc__ (
    self )
```

Clean up by deallocating the instance of C++ class Clifford.

Definition at line 620 of file PyClical.pyx.

References `PyClical.index_set.instance`, and `PyClical.clifford.instance`.

6.3.2.7 `__div__()`

```
def PyClical.clifford.__div__ (
    lhs,
    rhs )
```

Geometric quotient.

```
>>> print clifford("{1}") / clifford("{2}")
{1,2}
>>> print clifford(2) / clifford("{2}")
2{2}
>>> print clifford("{1}") / clifford("{1}")
1
>>> print clifford("{1}") / clifford("{1,2}")
-{2}
```

Definition at line 895 of file PyClical.pyx.

6.3.2.8 `__getitem__()`

```
def PyClical.clifford.__getitem__ (
    self,
    ixt )
```

Subscripting: map from index set to scalar coordinate.

```
>>> clifford("{1}") [index_set(1)]
1.0
>>> clifford("{1}") [index_set({1})]
1.0
>>> clifford("{1}") [index_set({1,2})]
0.0
>>> clifford("2{1,2}") [index_set({1,2})]
2.0
```

Definition at line 706 of file PyClical.pyx.

References `PyClical.index_set.instance`, and `PyClical.clifford.instance`.

6.3.2.9 `__iadd__()`

```
def PyClical.clifford.__iadd__ (
    self,
    rhs )
```

Geometric sum.

```
>>> x = clifford(1); x += clifford("{2}"); print x
1+{2}
```

Definition at line 750 of file PyClical.pyx.

6.3.2.10 __iand__()

```
def PyClical.clifford.__iand__ (
    self,
    rhs )
```

Inner product.

```
>>> x = clifford("{1}"); x &= clifford("{2}"); print x
0
>>> x = clifford(2); x &= clifford("{2}"); print x
0
>>> x = clifford("{1}"); x &= clifford("{1}"); print x
1
>>> x = clifford("{1}"); x &= clifford("{1,2}"); print x
{2}
```

Definition at line 850 of file PyClical.pyx.

6.3.2.11 __idiv__()

```
def PyClical.clifford.__idiv__ (
    self,
    rhs )
```

Geometric quotient.

```
>>> x = clifford("{1}"); x /= clifford("{2}"); print x
{1,2}
>>> x = clifford(2); x /= clifford("{2}"); print x
2{2}
>>> x = clifford("{1}"); x /= clifford("{1}"); print x
1
>>> x = clifford("{1}"); x /= clifford("{1,2}"); print x
-{2}
```

Definition at line 910 of file PyClical.pyx.

6.3.2.12 __imod__()

```
def PyClical.clifford.__imod__ (
    self,
    rhs )
```

Contraction.

```
>>> x = clifford("{1}"); x %= clifford("{2}"); print x
0
>>> x = clifford(2); x %= clifford("{2}"); print x
2{2}
>>> x = clifford("{1}"); x %= clifford("{1}"); print x
1
>>> x = clifford("{1}"); x %= clifford("{1,2}"); print x
{2}
```

Definition at line 820 of file PyClical.pyx.

6.3.2.13 `__imul__()`

```
def PyClical.clifford.__imul__ (
    self,
    rhs )
```

Geometric product.

```
>>> x = clifford(2); x *= clifford("{2}"); print x
2{2}
>>> x = clifford("{1}"); x *= clifford("{2}"); print x
{1,2}
>>> x = clifford("{1}"); x *= clifford("{1,2}"); print x
{2}
```

Definition at line 792 of file PyClical.pyx.

6.3.2.14 `__ior__()`

```
def PyClical.clifford.__ior__ (
    self,
    rhs )
```

Transform left hand side, using right hand side as a transformation.

```
>>> x=clifford("{1,2}") * pi/2; y=clifford("{1}"); y|=x; print y
-{1}
>>> x=clifford("{1,2}") * pi/2; y=clifford("{1}"); y|=exp(x); print y
-{1}
```

Definition at line 949 of file PyClical.pyx.

6.3.2.15 `__isub__()`

```
def PyClical.clifford.__isub__ (
    self,
    rhs )
```

Geometric difference.

```
>>> x = clifford(1); x -= clifford("{2}"); print x
1-{2}
```

Definition at line 770 of file PyClical.pyx.

6.3.2.16 `__iter__()`

```
def PyClical.clifford.__iter__ (
    self )
```

Not applicable.

```
>>> for a in clifford(index_set({-3,4,7})): print a,
Traceback (most recent call last):
...
TypeError: Not applicable.
```

Definition at line 637 of file PyClical.pyx.

6.3.2.17 `__ixor__()`

```
def PyClical.clifford.__ixor__ (
    self,
    rhs )
```

Outer product.

```
>>> x = clifford("{1}"); x ^= clifford("{2}"); print x
{1,2}
>>> x = clifford(2); x ^= clifford("{2}"); print x
2{2}
>>> x = clifford("{1}"); x ^= clifford("{1}"); print x
0
>>> x = clifford("{1}"); x ^= clifford("{1,2}"); print x
0
```

Definition at line 880 of file PyClical.pyx.

6.3.2.18 `__mod__()`

```
def PyClical.clifford.__mod__ (
    lhs,
    rhs )
```

Contraction.

```
>>> print clifford("{1}") % clifford("{2}")
0
>>> print clifford(2) % clifford("{2}")
2{2}
>>> print clifford("{1}") % clifford("{1}")
1
>>> print clifford("{1}") % clifford("{1,2}")
{2}
```

Definition at line 805 of file PyClical.pyx.

6.3.2.19 `__mul__()`

```
def PyClical.clifford.__mul__ (
    lhs,
    rhs )
```

Geometric product.

```
>>> print clifford("{1}") * clifford("{2}")
{1,2}
>>> print clifford(2) * clifford("{2}")
2{2}
>>> print clifford("{1}") * clifford("{1,2}")
{2}
```

Definition at line 779 of file PyClical.pyx.

6.3.2.20 `__neg__()`

```
def PyClical.clifford.__neg__ (
    self )
```

Unary `-`.

```
>>> print -clifford("{1}")
-{1}
```

Definition at line 721 of file PyClical.pyx.

References `PyClical.index_set.instance`, and `PyClical.clifford.instance`.

6.3.2.21 `__or__()`

```
def PyClical.clifford.__or__ (
    lhs,
    rhs )
```

Transform left hand side, using right hand side as a transformation.

```
>>> x=clifford("{1,2}") * pi/2; y=clifford("{1}"); print y|x
-{1}
>>> x=clifford("{1,2}") * pi/2; y=clifford("{1}"); print y|exp(x)
-{1}
```

Definition at line 938 of file PyClical.pyx.

6.3.2.22 __pos__()

```
def PyClical.clifford.__pos__ (
    self )
```

Unary +.

```
>>> print +clifford("{1}")
{1}
```

Definition at line 730 of file PyClical.pyx.

6.3.2.23 __pow__()

```
def PyClical.clifford.__pow__ (
    self,
    m,
    dummy )
```

Power: self to the m.

```
>>> x=clifford("{1}"); print x ** 2
1
>>> x=clifford("2"); print x ** 2
4
>>> x=clifford("2+{1}"); print x ** 0
1
>>> x=clifford("2+{1}"); print x ** 1
2+{1}
>>> x=clifford("2+{1}"); print x ** 2
5+4{1}
>>> i=clifford("{1,2}");print exp(pi/2) * (i ** i)
1
```

Definition at line 960 of file PyClical.pyx.

References PyClical.clifford.pow().

6.3.2.24 __repr__()

```
def PyClical.clifford.__repr__ (
    self )
```

The "official" string representation of self.

```
>>> clifford("1+3{-1}+2{1,2}+4{-2,7}").__repr__()
'clifford("1+3{-1}+2{1,2}+4{-2,7}")'
```

Definition at line 1225 of file PyClical.pyx.

References clifford_to_repr().

6.3.2.25 `__richcmp__()`

```
def PyClical.clifford.__richcmp__ (
    lhs,
    rhs,
    int,
    op )
```

Compare objects of type clifford.

```
>>> clifford("{1}") == clifford("1{1}")
True
>>> clifford("{1}") != clifford("1.0{1}")
False
>>> clifford("{1}") != clifford("1.0")
True
>>> clifford("{1,2}") == None
False
>>> clifford("{1,2}") != None
True
>>> None == clifford("{1,2}")
False
>>> None != clifford("{1,2}")
True
```

Definition at line 671 of file PyClical.pyx.

6.3.2.26 `__str__()`

```
def PyClical.clifford.__str__ (
    self )
```

The “informal” string representation of self.

```
>>> clifford("1+3{-1}+2{1,2}+4{-2,7}").__str__()
'1+3{-1}+2{1,2}+4{-2,7}'
```

Definition at line 1234 of file PyClical.pyx.

References `clifford_to_str()`.

6.3.2.27 `__sub__()`

```
def PyClical.clifford.__sub__ (
    lhs,
    rhs )
```

Geometric difference.

```
>>> print clifford(1) - clifford("{2}")
1-{2}
>>> print clifford("{1}") - clifford("{2}")
{1}-{2}
```

Definition at line 759 of file PyClical.pyx.

6.3.2.28 `__xor__()`

```
def PyClical.clifford.__xor__ (
    lhs,
    rhs )
```

Outer product.

```
>>> print clifford("{1}") ^ clifford("{2}")
{1,2}
>>> print clifford(2) ^ clifford("{2}")
2{2}
>>> print clifford("{1}") ^ clifford("{1}")
0
>>> print clifford("{1}") ^ clifford("{1,2}")
0
```

Definition at line 865 of file PyClical.pyx.

6.3.2.29 `abs()`

```
def PyClical.clifford.abs (
    self )
```

Absolute value: square root of norm.

```
>>> clifford("1+{-1}+{1,2}+{1,2,3}").abs()
2.0
```

Definition at line 1174 of file PyClical.pyx.

References `glucat.abs()`.

6.3.2.30 `conj()`

```
def PyClical.clifford.conj (
    self )
```

Conjugation, reverse o involute == involute o reverse.

```
>>> print (clifford("{1}")).conj()
-1
>>> print (clifford("{2}") * clifford("{1}")).conj()
{1,2}
>>> print (clifford("{1}") * clifford("{2}")).conj()
-1,2
>>> print clifford("1+{1}+{1,2}").conj()
1-{1}-{1,2}
```

Definition at line 1137 of file PyClical.pyx.

References `PyClical.index_set.instance`, and `PyClical.clifford.instance`.

6.3.2.31 even()

```
def PyClical.clifford.even (
    self )
```

Even part of multivector, sum of even grade terms.

```
>>> print clifford("1+{1}+{1,2}").even()
1+{1,2}
```

Definition at line 1060 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.32 frame()

```
def PyClical.clifford.frame (
    self )
```

Subalgebra generated by all generators of terms of given multivector.

```
>>> print clifford("1+3{-1}+2{1,2}+4{-2,7}").frame()
{-2,-1,1,2,7}
>>> s=clifford("1+3{-1}+2{1,2}+4{-2,7}").frame(); type(s)
<type 'PyClical.index_set'>
```

Definition at line 1214 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.33 inv()

```
def PyClical.clifford.inv (
    self )
```

Geometric multiplicative inverse.

```
>>> x = clifford("{1}"); print x.inv()
{1}
>>> x = clifford(2); print x.inv()
0.5
>>> x = clifford("{1,2}"); print x.inv()
-{1,2}
```

Definition at line 925 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.34 involute()

```
def PyClicl.clifford.involute (
    self )
```

Main involution, each {i} is replaced by -{i} in each term,
eg. clifford("{1}") -> -clifford("{1}").

```
>>> print clifford("{1}").involute()
-{1}
>>> print (clifford("{2}") * clifford("{1}")).involute()
-{1,2}
>>> print (clifford("{1}") * clifford("{2}")).involute()
{1,2}
>>> print clifford("1+{1}+{1,2}").involute()
1-{1}+{1,2}
```

Definition at line 1106 of file PyClicl.pyx.

References PyClicl.index_set.instance, and PyClicl.clifford.instance.

6.3.2.35 isnan()

```
def PyClicl.clifford.isnan (
    self )
```

Check if a multivector contains any IEEE NaN values.

```
>>> clifford().isnan()
False
```

Definition at line 1205 of file PyClicl.pyx.

References PyClicl.index_set.instance, and PyClicl.clifford.instance.

6.3.2.36 max_abs()

```
def PyClicl.clifford.max_abs (
    self )
```

Maximum of absolute values of components of multivector: multivector infinity norm.

```
>>> clifford("1+{-1}+{1,2}+{1,2,3}").max_abs()
1.0
>>> clifford("3+2{1}+{1,2}").max_abs()
3.0
```

Definition at line 1183 of file PyClicl.pyx.

References PyClicl.index_set.instance, and PyClicl.clifford.instance.

6.3.2.37 norm()

```
def PyClical.clifford.norm (
    self )
```

Norm == sum of squares of coordinates.

```
>>> clifford("1+{1}+{1,2}").norm()
3.0
>>> clifford("1+{-1}+{1,2}+{1,2,3}").norm()
4.0
```

Definition at line 1163 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.38 odd()

```
def PyClical.clifford.odd (
    self )
```

Odd part of multivector, sum of odd grade terms.

```
>>> print clifford("1+{1}+{1,2}").odd()
{1}
```

Definition at line 1069 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.39 outer_pow()

```
def PyClical.clifford.outer_pow (
    self,
    m )
```

Outer product power.

```
>>> x=clifford("2+{1}"); print x.outer_pow(0)
1
>>> x=clifford("2+{1}"); print x.outer_pow(1)
2+{1}
>>> x=clifford("2+{1}"); print x.outer_pow(2)
4+4{1}
>>> print clifford("1+{1}+{1,2}").outer_pow(3)
1+3{1}+3{1,2}
```

Definition at line 1003 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.40 pow()

```
def PyClical.clifford.pow (
    self,
    m )

Power: self to the m.

>>> x=clifford("{1}"); print x.pow(2)
1
>>> x=clifford("2"); print x.pow(2)
4
>>> x=clifford("2+{1}"); print x.pow(0)
1
>>> x=clifford("2+{1}"); print x.pow(1)
2+{1}
>>> x=clifford("2+{1}"); print x.pow(2)
5+4{1}
>>> print clifford("1+{1}+{1,2}").pow(3)
1+3{1}+3{1,2}
>>> i=clifford("{1,2}");print exp(pi/2) * i.pow(i)
1
```

Definition at line 979 of file PyClical.pyx.

References `glucat.exp()`, `PyClical.index_set.instance`, `PyClical.clifford.instance`, and `glucat.log()`.

Referenced by `PyClical.clifford.__pow__()`.

6.3.2.41 pure()

```
def PyClical.clifford.pure (
    self )

Pure part.

>>> print clifford("1+{1}+{1,2}").pure()
{1}+{1,2}
>>> print clifford("{1,2}").pure()
{1,2}
```

Definition at line 1049 of file PyClical.pyx.

References `PyClical.index_set.instance`, and `PyClical.clifford.instance`.

6.3.2.42 quad()

```
def PyClical.clifford.quad (
    self )

Quadratic form == (rev(x)*x)(0).

>>> print clifford("1+{1}+{1,2}").quad()
3.0
>>> print clifford("1+{-1}+{1,2}+{1,2,3}").quad()
2.0
```

Definition at line 1152 of file PyClical.pyx.

References `PyClical.index_set.instance`, and `PyClical.clifford.instance`.

6.3.2.43 reframe()

```
def PyClical.clifford.reframe (
    self,
    ixt )
```

Put self into a larger frame, containing the union of self.frame() and index set ixt. This can be used to make multiplication faster, by multiplying within a common frame.

```
>>> clifford("2+3{1}").reframe(index_set({1,2,3}))
clifford("2+3{1}")
>>> s=index_set({1,2,3});t=index_set({-3,-2,-1});x=random_clifford(s); x.reframe(t).frame() == (s|t);
True
```

Definition at line 648 of file PyClical.pyx.

6.3.2.44 reverse()

```
def PyClical.clifford.reverse (
    self )
```

Reversion, eg. clifford("{1}")*clifford("{2}") -> clifford("{2}")*clifford("{1}").

```
>>> print clifford("{1}").reverse()
{1}
>>> print (clifford("{2}") * clifford("{1}")).reverse()
{1,2}
>>> print (clifford("{1}") * clifford("{2}")).reverse()
-{1,2}
>>> print clifford("1+{1}+{1,2}").reverse()
1+{1}-{1,2}
```

Definition at line 1122 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.45 scalar()

```
def PyClical.clifford.scalar (
    self )
```

Scalar part.

```
>>> clifford("1+{1}+{1,2}").scalar()
1.0
>>> clifford("{1,2}").scalar()
0.0
```

Definition at line 1038 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.46 truncated()

```
def PyClical.clifford.truncated (
    self,
    limit )
```

Remove all terms of self with relative size smaller than limit.

```
>>> clifford("1e8+{1}+1e-8{1,2}").truncated(1.0e-6)
clifford("100000000")
>>> clifford("1e4+{1}+1e-4{1,2}").truncated(1.0e-6)
clifford("10000+{1}")
```

Definition at line 1194 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.2.47 vector_part()

```
def PyClical.clifford.vector_part (
    self,
    frm = None )
```

Vector part of multivector, as a Python list, with respect to frm.

```
>>> print clifford("1+2{1}+3{2}+4{1,2}").vector_part()
[2.0, 3.0]
>>> print clifford("1+2{1}+3{2}+4{1,2}").vector_part(index_set({-1,1,2}))
[0.0, 2.0, 3.0]
```

Definition at line 1078 of file PyClical.pyx.

References PyClical.index_set.instance, and PyClical.clifford.instance.

6.3.3 Member Data Documentation

6.3.3.1 instance

PyClical.clifford.instance

Definition at line 592 of file PyClical.pyx.

Referenced by PyClical.clifford.__call__(), PyClical.clifford.__dealloc__(), PyClical.clifford.__getitem__(), PyClical.clifford.__neg__(), PyClical.clifford.conj(), PyClical.clifford.even(), PyClical.clifford.frame(), PyClical.clifford.inv(), PyClical.clifford.involute(), PyClical.clifford.isnan(), PyClical.clifford.max_abs(), PyClical.clifford.norm(), PyClical.clifford.odd(), PyClical.clifford.outer_pow(), PyClical.clifford.pow(), PyClical.clifford.pure(), PyClical.clifford.quad(), PyClical.clifford.reverse(), PyClical.clifford.scalar(), PyClical.clifford.truncated(), and PyClical.clifford.vector_part().

The documentation for this class was generated from the following file:

- [pyclical/PyClical.pyx](#)

6.4 glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T > Class Template Reference

clifford_algebra<> declares the operations of a Clifford algebra

```
#include <clifford_algebra.h>
```

Public Types

- typedef Scalar_T [scalar_t](#)
- typedef Index_Set_T [index_set_t](#)
- typedef Multivector_T [multivector_t](#)
- typedef std::pair< const [index_set_t](#), Scalar_T > [pair_t](#)
- typedef std::vector< Scalar_T > [vector_t](#)

Public Member Functions

- virtual [~clifford_algebra](#) ()
- virtual bool [operator==](#) (const [multivector_t](#) &val) const =0
Test for equality of multivectors.
- virtual bool [operator==](#) (const Scalar_T &scr) const =0
Test for equality of multivector and scalar.
- virtual [multivector_t](#) & [operator+=](#) (const [multivector_t](#) &rhs)=0
Geometric sum.
- virtual [multivector_t](#) & [operator+=](#) (const Scalar_T &scr)=0
Geometric sum of multivector and scalar.
- virtual [multivector_t](#) & [operator-=](#) (const [multivector_t](#) &rhs)=0
Geometric difference.
- virtual const [multivector_t](#) [operator-](#) () const =0
Unary -.
- virtual [multivector_t](#) & [operator*=](#) (const Scalar_T &scr)=0
Product of multivector and scalar.
- virtual [multivector_t](#) & [operator*=](#) (const [multivector_t](#) &rhs)=0
Geometric product.
- virtual [multivector_t](#) & [operator%=>](#) (const [multivector_t](#) &rhs)=0
Contraction.
- virtual [multivector_t](#) & [operator &=](#) (const [multivector_t](#) &rhs)=0
Inner product.
- virtual [multivector_t](#) & [operator^=](#) (const [multivector_t](#) &rhs)=0
Outer product.
- virtual [multivector_t](#) & [operator/=](#) (const Scalar_T &scr)=0
Quotient of multivector and scalar.
- virtual [multivector_t](#) & [operator/=](#) (const [multivector_t](#) &rhs)=0
Geometric quotient.
- virtual [multivector_t](#) & [operator|=](#) (const [multivector_t](#) &rhs)=0
Transformation via twisted adjoint action.
- virtual const [multivector_t](#) [inv](#) () const =0
Geometric multiplicative inverse.
- virtual const [multivector_t](#) [pow](#) (int m) const =0

- **this to the m*
- virtual const [multivector_t](#) [outer_pow](#) (int m) const =0
Outer product power.
- virtual const [index_set_t](#) [frame](#) () const =0
Subalgebra generated by all generators of terms of given multivector.
- virtual [index_t](#) [grade](#) () const =0
Maximum of the grades of each term.
- virtual Scalar_T [operator\[\]](#) (const [index_set_t](#) ist) const =0
Subscripting: map from index set to scalar coordinate.
- virtual const [multivector_t](#) [operator\(\)](#) ([index_t](#) grade) const =0
Pure grade-vector part.
- virtual Scalar_T [scalar](#) () const =0
Scalar part.
- virtual const [multivector_t](#) [pure](#) () const =0
Pure part.
- virtual const [multivector_t](#) [even](#) () const =0
Even part of multivector, sum of even grade terms.
- virtual const [multivector_t](#) [odd](#) () const =0
Odd part of multivector, sum of odd grade terms.
- virtual const [vector_t](#) [vector_part](#) () const =0
Vector part of multivector, as a vector_t with respect to [frame\(\)](#)
- virtual const [vector_t](#) [vector_part](#) (const [index_set_t](#) frm, const bool prechecked) const =0
Vector part of multivector, as a vector_t with respect to frm.
- virtual const [multivector_t](#) [involute](#) () const =0
Main involution, each {i} is replaced by -{i} in each term, eg. {1} -> -{1}.
- virtual const [multivector_t](#) [reverse](#) () const =0
Reversion, eg. {1}{2} -> {2}*{1}.*
- virtual const [multivector_t](#) [conj](#) () const =0
Conjugation, reverse o involute == involute o reverse.
- virtual Scalar_T [quad](#) () const =0
*Scalar_T quadratic form == (rev(x)*x)(0)*
- virtual Scalar_T [norm](#) () const =0
Scalar_T norm == sum of norm of coordinates.
- virtual Scalar_T [max_abs](#) () const =0
Maximum of absolute values of components of multivector: multivector infinity norm.
- virtual const [multivector_t](#) [truncated](#) (const Scalar_T &limit=Scalar_T(DEFAULT_TRUNCATION)) const =0
Remove all terms with relative size smaller than limit.
- virtual bool [isnan](#) () const =0
Check if a multivector contains any IEEE NaN values.
- virtual void [write](#) (const std::string &msg="") const =0
Write formatted multivector to output.
- virtual void [write](#) (std::ofstream &ofile, const std::string &msg="") const =0
Write formatted multivector to file.

Static Public Member Functions

- static const std::string [classname](#) ()

6.4.1 Detailed Description

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
class glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >
```

clifford_algebra<> declares the operations of a Clifford algebra

Definition at line 42 of file clifford_algebra.h.

6.4.2 Member Typedef Documentation

6.4.2.1 index_set_t

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
typedef Index_Set_T glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::index_set_t
```

Definition at line 46 of file clifford_algebra.h.

6.4.2.2 multivector_t

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
typedef Multivector_T glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::multivector_t
```

Definition at line 47 of file clifford_algebra.h.

6.4.2.3 pair_t

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
typedef std::pair< const index_set_t, Scalar_T > glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::pair_t
```

Definition at line 48 of file clifford_algebra.h.

6.4.2.4 scalar_t

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
typedef Scalar_T glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::scalar_t
```

Definition at line 45 of file clifford_algebra.h.

6.4.2.5 vector_t

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
typedef std::vector<Scalar_T> glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T
>::vector_t
```

Definition at line 49 of file clifford_algebra.h.

6.4.3 Constructor & Destructor Documentation

6.4.3.1 ~clifford_algebra()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::~~clifford_algebra (
) [inline], [virtual]
```

Definition at line 53 of file clifford_algebra.h.

6.4.4 Member Function Documentation

6.4.4.1 classname()

```
template<typename Scalar_T , typename Index_Set_T , typename Multivector_T >
const std::string glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::classname
( ) [static]
```

Definition at line 66 of file clifford_algebra_imp.h.

6.4.4.2 conj()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::conj ( ) const [pure virtual]
```

Conjugation, reverse o involute == involute o reverse.

6.4.4.3 even()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::even ( ) const [pure virtual]
```

Even part of multivector, sum of even grade terms.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi().

6.4.4.4 frame()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const index_set_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::frame ( ) const [pure virtual]
```

Subalgebra generated by all generators of terms of given multivector.

6.4.4.5 grade()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual index_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::grade ( )
const [pure virtual]
```

Maximum of the grades of each term.

6.4.4.6 inv()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::inv ( ) const [pure virtual]
```

Geometric multiplicative inverse.

6.4.4.7 involute()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::involute ( ) const [pure virtual]
```

Main involution, each {i} is replaced by -{i} in each term, eg. {1} -> -{1}.

6.4.4.8 isnan()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual bool glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::isnan ( ) const
[pure virtual]
```

Check if a multivector contains any IEEE NaN values.

6.4.4.9 max_abs()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual Scalar_T glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::max_abs ( )
const [pure virtual]
```

Maximum of absolute values of components of multivector: multivector infinity norm.

6.4.4.10 norm()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual Scalar_T glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::norm ( )
const [pure virtual]
```

Scalar_T norm == sum of norm of coordinates.

6.4.4.11 odd()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::odd ( ) const [pure virtual]
```

Odd part of multivector, sum of odd grade terms.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi().

6.4.4.12 operator &=()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator&= (
    const multivector_t & rhs ) [pure virtual]
```

Inner product.

6.4.4.13 operator%=()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator%= (
    const multivector_t & rhs ) [pure virtual]
```

Contraction.

6.4.4.14 operator()()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator() (
    index_t grade ) const [pure virtual]
```

Pure grade-vector part.

6.4.4.15 operator*=() [1/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator*= (
    const Scalar_T & scr ) [pure virtual]
```

Product of multivector and scalar.

6.4.4.16 operator*=() [2/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator*= (
    const multivector_t & rhs ) [pure virtual]
```

Geometric product.

6.4.4.17 operator+=() [1/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator+= (
    const multivector_t & rhs ) [pure virtual]
```

Geometric sum.

6.4.4.18 operator+=() [2/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator+= (
    const Scalar_T & scr ) [pure virtual]
```

Geometric sum of multivector and scalar.

6.4.4.19 operator-()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator- ( ) const [pure virtual]
```

Unary -.

6.4.4.20 operator-=()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator-= (
    const multivector_t & rhs ) [pure virtual]
```

Geometric difference.

6.4.4.21 operator/=() [1/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator/= (
    const Scalar_T & scr ) [pure virtual]
```

Quotient of multivector and scalar.

6.4.4.22 operator/=() [2/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::operator/= (
    const multivector_t & rhs ) [pure virtual]
```

Geometric quotient.

6.4.4.23 operator==([1/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual bool glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::operator== (
    const multivector_t & val ) const [pure virtual]
```

Test for equality of multivectors.

6.4.4.24 operator==([2/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual bool glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::operator== (
    const Scalar_T & scr ) const [pure virtual]
```

Test for equality of multivector and scalar.

6.4.4.25 operator[]()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual Scalar_T glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::operator[]
(
    const index_set_t ist ) const [pure virtual]
```

Subscripting: map from index set to scalar coordinate.

6.4.4.26 operator^=()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::operator^= (
    const multivector_t & rhs ) [pure virtual]
```

Outer product.

6.4.4.27 operator" |=()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual multivector_t& glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::operator|= (
    const multivector_t & rhs ) [pure virtual]
```

Transformation via twisted adjoint action.

6.4.4.28 outer_pow()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::outer_pow (
    int m ) const [pure virtual]
```

Outer product power.

6.4.4.29 pow()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::pow (
    int m ) const [pure virtual]
```

*this to the m

6.4.4.30 pure()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::pure ( ) const [pure virtual]
```

Pure part.

6.4.4.31 quad()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual Scalar_T glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::quad ( )
const [pure virtual]
```

Scalar_T quadratic form == (rev(x)*x)(0)

6.4.4.32 reverse()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↔
::reverse ( ) const [pure virtual]
```

Reversion, eg. {1}*{2} -> {2}*{1}.

6.4.4.33 scalar()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual Scalar_T glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::scalar ( )
const [pure virtual]
```

Scalar part.

6.4.4.34 truncated()

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const multivector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::truncated (
    const Scalar_T & limit = Scalar_T(DEFAULT_TRUNCATION) ) const [pure virtual]
```

Remove all terms with relative size smaller than limit.

6.4.4.35 vector_part() [1/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const vector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::vector_part ( ) const [pure virtual]
```

Vector part of multivector, as a vector_t with respect to [frame\(\)](#)

6.4.4.36 vector_part() [2/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual const vector_t glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >↵
::vector_part (
    const index_set_t frm,
    const bool prechecked ) const [pure virtual]
```

Vector part of multivector, as a vector_t with respect to frm.

6.4.4.37 write() [1/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual void glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::write (
    const std::string & msg = "" ) const [pure virtual]
```

Write formatted multivector to output.

6.4.4.38 write() [2/2]

```
template<typename Scalar_T, typename Index_Set_T, typename Multivector_T>
virtual void glucat::clifford\_algebra< Scalar_T, Index_Set_T, Multivector_T >::write (
    std::ofstream & ofile,
    const std::string & msg = "" ) const    [pure virtual]
```

Write formatted multivector to file.

The documentation for this class was generated from the following files:

- [glucat/clifford_algebra.h](#)
- [glucat/clifford_algebra_imp.h](#)

6.5 [glucat::compare_types](#)< LHS_T, RHS_T > Class Template Reference

Type comparison.

```
#include <global.h>
```

Public Types

- enum { [are_same](#) = false }

6.5.1 Detailed Description

```
template<typename LHS_T, typename RHS_T>
class glucat::compare\_types< LHS_T, RHS_T >
```

Type comparison.

Definition at line 54 of file [global.h](#).

6.5.2 Member Enumeration Documentation

6.5.2.1 anonymous enum

```
template<typename LHS_T , typename RHS_T >
anonymous enum
```

Enumerator

are_same	
--------------------------	--

Definition at line 57 of file global.h.

The documentation for this class was generated from the following file:

- [glucat/global.h](#)

6.6 glucat::compare_types< T, T > Class Template Reference

```
#include <global.h>
```

Public Types

- enum { [are_same](#) = true }

6.6.1 Detailed Description

```
template<typename T>
class glucat::compare_types< T, T >
```

Definition at line 60 of file global.h.

6.6.2 Member Enumeration Documentation

6.6.2.1 anonymous enum

```
template<typename T >
anonymous enum
```

Enumerator

are_same	
--------------------------	--

Definition at line 63 of file global.h.

The documentation for this class was generated from the following file:

- [glucat/global.h](#)

6.7 glucat::control_t Class Reference

Parameters to control tests.

```
#include <control.h>
```

Public Member Functions

- int [call](#) ([intfn](#) f) const
Call a function that returns int.
- int [call](#) ([intintfn](#) f, int arg) const
Call a function of int that returns int.

Static Public Member Functions

- static const [control_t](#) & [control](#) (int argc, char **argv)
- static bool [verbose](#) ()
Produce more detailed output from tests.

Private Member Functions

- bool [valid](#) () const
- bool [catch_exceptions](#) () const
- [control_t](#) (int argc, char **argv)
Constructor from program arguments.
- [control_t](#) ()
- [~control_t](#) ()
- [control_t](#) (const [control_t](#) &)
- [control_t](#) & [operator=](#) (const [control_t](#) &)

Private Attributes

- bool [m_valid](#)
Test parameters are valid.
- bool [m_catch_exceptions](#)
Catch exceptions.

Static Private Attributes

- static bool [m_verbose_output](#) = false
Produce more detailed output from tests.

Friends

- class [friend_for_private_destructor](#)

6.7.1 Detailed Description

Parameters to control tests.

Definition at line 39 of file control.h.

6.7.2 Constructor & Destructor Documentation

6.7.2.1 control_t() [1/3]

```
glucat::control_t::control_t (
    int argc,
    char ** argv ) [private]
```

Constructor from program arguments.

Test control constructor from program arguments.

Definition at line 89 of file control.h.

References GLUCAT_PACKAGE_NAME, GLUCAT_VERSION, m_catch_exceptions, m_valid, m_verbose_output, and valid().

6.7.2.2 control_t() [2/3]

```
glucat::control_t::control_t ( ) [inline], [private]
```

Definition at line 59 of file control.h.

6.7.2.3 ~control_t()

```
glucat::control_t::~~control_t ( ) [inline], [private]
```

Definition at line 60 of file control.h.

6.7.2.4 control_t() [3/3]

```
glucat::control_t::control_t (
    const control_t & ) [private]
```

6.7.3 Member Function Documentation

6.7.3.1 `call()` [1/2]

```
int glucat::control_t::call (
    intfn f ) const [inline]
```

Call a function that returns int.

Definition at line 137 of file control.h.

References `catch_exceptions()`, `glucat::try_catch()`, and `valid()`.

6.7.3.2 `call()` [2/2]

```
int glucat::control_t::call (
    intintfn f,
    int arg ) const [inline]
```

Call a function of int that returns int.

Definition at line 151 of file control.h.

References `catch_exceptions()`, `glucat::try_catch()`, and `valid()`.

6.7.3.3 `catch_exceptions()`

```
bool glucat::control_t::catch_exceptions ( ) const [inline], [private]
```

Definition at line 49 of file control.h.

References `m_catch_exceptions`.

Referenced by `call()`.

6.7.3.4 `control()`

```
static const control_t& glucat::control_t::control (
    int argc,
    char ** argv ) [inline], [static]
```

Single instance Ref: Scott Meyers, "Effective C++" Second Edition, Addison-Wesley, 1998.

Definition at line 71 of file control.h.

6.7.3.5 operator=()

```
control_t& glucat::control_t::operator= (
    const control_t & ) [private]
```

6.7.3.6 valid()

```
bool glucat::control_t::valid ( ) const [inline], [private]
```

Definition at line 44 of file control.h.

References m_valid.

Referenced by call(), and control_t().

6.7.3.7 verbose()

```
static bool glucat::control_t::verbose ( ) [inline], [static]
```

Produce more detailed output from tests.

Definition at line 80 of file control.h.

References m_verbose_output.

6.7.4 Friends And Related Function Documentation

6.7.4.1 friend_for_private_destructor

```
friend class friend_for_private_destructor [friend]
```

Friend declaration to avoid compiler warning: "... only defines a private destructor and has no friends" Ref: Carlos O'Ryan, ACE <http://doc.ece.uci.edu>

Definition at line 67 of file control.h.

6.7.5 Member Data Documentation

6.7.5.1 m_catch_exceptions

```
bool glucat::control_t::m_catch_exceptions [private]
```

Catch exceptions.

Definition at line 48 of file control.h.

Referenced by `catch_exceptions()`, and `control_t()`.

6.7.5.2 m_valid

```
bool glucat::control_t::m_valid [private]
```

Test parameters are valid.

Definition at line 43 of file control.h.

Referenced by `control_t()`, and `valid()`.

6.7.5.3 m_verbose_output

```
bool glucat::control_t::m_verbose_output = false [static], [private]
```

Produce more detailed output from tests.

Definition at line 53 of file control.h.

Referenced by `control_t()`, and `verbose()`.

The documentation for this class was generated from the following file:

- [test/control.h](#)

6.8 glucat::CTAssertion< bool > Struct Template Reference

Compile time assertion.

```
#include <global.h>
```


6.8.1 Detailed Description

```
template<bool>
struct glucat::CTAssertion< bool >
```

Compile time assertion.

Definition at line 46 of file global.h.

The documentation for this struct was generated from the following file:

- [glucat/global.h](#)

6.9 glucat::CTAssertion< true > Struct Template Reference

```
#include <global.h>
```

6.9.1 Detailed Description

```
template<>
struct glucat::CTAssertion< true >
```

Definition at line 47 of file global.h.

The documentation for this struct was generated from the following file:

- [glucat/global.h](#)

6.10 glucat::numeric_traits< Scalar_T >::demoted<> Struct Template Reference

Demoted type for long double.

```
#include <long_double.h>
```

Public Types

- typedef long double [type](#)
- typedef float [type](#)

6.10.1 Detailed Description

```
template<typename Scalar_T>
template<>
struct glucat::numeric_traits< Scalar_T >::demoted<>
```

Demoted type for long double.

Demoted type.

Definition at line 47 of file long_double.h.

6.10.2 Member Typedef Documentation

6.10.2.1 type [1/2]

```
template<typename Scalar_T >
typedef long double glucat::numeric_traits< Scalar_T >::demoted<>::type
```

Definition at line 49 of file long_double.h.

6.10.2.2 type [2/2]

```
template<typename Scalar_T >
typedef float glucat::numeric_traits< Scalar_T >::demoted<>::type
```

Definition at line 147 of file scalar.h.

The documentation for this struct was generated from the following files:

- glucat/long_double.h
- glucat/scalar.h

6.11 glucat::matrix::eig_genus< Matrix_T > Struct Template Reference

Structure containing classification of eigenvalues.

```
#include <matrix.h>
```

Public Types

- typedef Matrix_T::value_type [Scalar_T](#)

Public Attributes

- [eig_case_t m_eig_case](#)
What kind of eigenvalues does the matrix contain?
- [Scalar_T m_safe_arg](#)
Argument such that $\exp(\pi \cdot m_safe_arg)$ lies between arguments of eigenvalues.

6.11.1 Detailed Description

```
template<typename Matrix_T>
struct glucat::matrix::eig_genus< Matrix_T >
```

Structure containing classification of eigenvalues.

Definition at line 131 of file matrix.h.

6.11.2 Member Typedef Documentation

6.11.2.1 Scalar_T

```
template<typename Matrix_T>
typedef Matrix_T::value_type glucat::matrix::eig_genus< Matrix_T >::Scalar_T
```

Definition at line 133 of file matrix.h.

6.11.3 Member Data Documentation

6.11.3.1 m_eig_case

```
template<typename Matrix_T>
eig_case_t glucat::matrix::eig_genus< Matrix_T >::m_eig_case
```

What kind of eigenvalues does the matrix contain?

Definition at line 135 of file matrix.h.

Referenced by glucat::matrix::classify_eigenvalues(), glucat::matrix_log(), and glucat::matrix_sqrt().

6.11.3.2 m_safe_arg

```
template<typename Matrix_T>
Scalar_T glucat::matrix::eig_genus< Matrix_T >::m_safe_arg
```

Argument such that $\exp(\pi m_safe_arg)$ lies between arguments of eigenvalues.

Definition at line 137 of file matrix.h.

Referenced by glucat::matrix::classify_eigenvalues(), glucat::matrix_log(), and glucat::matrix_sqrt().

The documentation for this struct was generated from the following file:

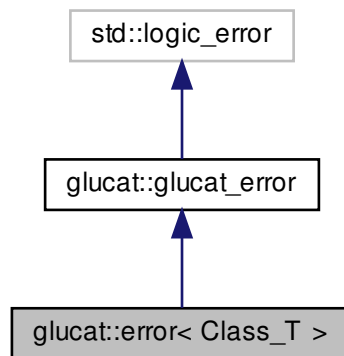
- glucat/matrix.h

6.12 glucat::error< Class_T > Class Template Reference

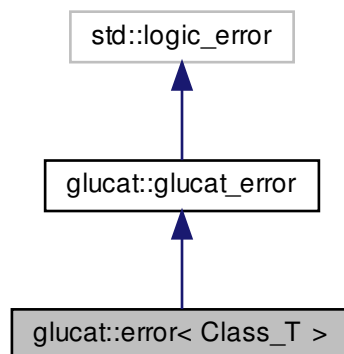
Specific exception class.

```
#include <errors.h>
```

Inheritance diagram for glucat::error< Class_T >:



Collaboration diagram for glucat::error< Class_T >:



Public Member Functions

- [error](#) (const std::string &msg)
Specific exception class.
- [error](#) (const std::string &context, const std::string &msg)
- virtual const std::string [heading](#) () const throw ()
- virtual const std::string [classname](#) () const throw ()
- virtual void [print_error_msg](#) () const

Additional Inherited Members

6.12.1 Detailed Description

```
template<class Class_T>
class glucat::error< Class_T >
```

Specific exception class.

Definition at line 57 of file errors.h.

6.12.2 Constructor & Destructor Documentation

6.12.2.1 error() [1/2]

```
template<class Class_T >
glucat::error< Class_T >::error (
    const std::string & msg )
```

Specific exception class.

Definition at line 39 of file errors_imp.h.

6.12.2.2 error() [2/2]

```
template<class Class_T >
glucat::error< Class_T >::error (
    const std::string & context,
    const std::string & msg )
```

Definition at line 45 of file errors_imp.h.

6.12.3 Member Function Documentation

6.12.3.1 classname()

```
template<class Class_T >
const std::string glucat::error< Class_T >::classname ( ) const throw ( ) [virtual]
```

Implements [glucat::glucat_error](#).

Definition at line 58 of file errors_imp.h.

6.12.3.2 heading()

```
template<class Class_T >
const std::string glucat::error< Class_T >::heading ( ) const throw ( ) [virtual]
```

Implements [glucat::glucat_error](#).

Definition at line 52 of file errors_imp.h.

6.12.3.3 print_error_msg()

```
template<class Class_T >
void glucat::error< Class_T >::print_error_msg ( ) const [virtual]
```

Implements [glucat::glucat_error](#).

Definition at line 64 of file errors_imp.h.

The documentation for this class was generated from the following files:

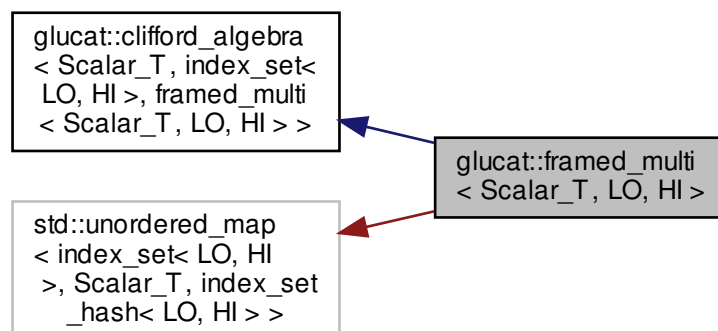
- [glucat/errors.h](#)
- [glucat/errors_imp.h](#)

6.13 glucat::framed_multi< Scalar_T, LO, HI > Class Template Reference

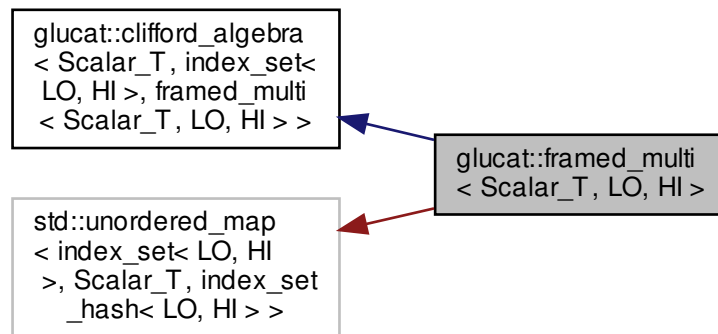
A framed_multi<Scalar_T,LO,HI> is a framed approximation to a multivector.

```
#include <framed_multi.h>
```

Inheritance diagram for glucat::framed_multi< Scalar_T, LO, HI >:



Collaboration diagram for glucat::framed_multi< Scalar_T, LO, HI >:



Classes

- class [hash_size_t](#)
- class [var_term](#)

Variable term.

Public Types

- typedef [framed_multi](#) [multivector_t](#)
- typedef [multivector_t](#) [framed_multi_t](#)
- typedef [Scalar_T](#) [scalar_t](#)
- typedef [index_set< LO, HI >](#) [index_set_t](#)
- typedef std::pair< const [index_set_t](#), [Scalar_T](#) > [term_t](#)
- typedef std::vector< [Scalar_T](#) > [vector_t](#)
- typedef [error< multivector_t >](#) [error_t](#)
- typedef [matrix_multi< Scalar_T, LO, HI >](#) [matrix_multi_t](#)

Public Member Functions

- [~framed_multi](#) ()
Destructor.
- [framed_multi](#) ()
Default constructor.
- template<typename Other_Scalar_T >
[framed_multi](#) (const [framed_multi](#)< Other_Scalar_T, LO, HI > &val)
Construct a multivector from a multivector with a different scalar type.
- template<typename Other_Scalar_T >
[framed_multi](#) (const [framed_multi](#)< Other_Scalar_T, LO, HI > &val, const [index_set_t](#) frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a given multivector.
- [framed_multi](#) (const [framed_multi_t](#) &val, const [index_set_t](#) frm, const bool prechecked=false)

- Construct a multivector, within a given frame, from a given multivector.*
- `framed_multi` (const `index_set_t` ist, const `Scalar_T` &crd=`Scalar_T`(1))
Construct a multivector from an index set and a scalar coordinate.
- `framed_multi` (const `index_set_t` ist, const `Scalar_T` &crd, const `index_set_t` frm, const bool prechecked=false)
Construct a multivector, within a given frame, from an index set and a scalar coordinate.
- `framed_multi` (const `Scalar_T` &scr, const `index_set_t` frm=`index_set_t`())
Construct a multivector from a scalar (within a frame, if given)
- `framed_multi` (const int scr, const `index_set_t` frm=`index_set_t`())
Construct a multivector from an int (within a frame, if given)
- `framed_multi` (const `vector_t` &vec, const `index_set_t` frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a given vector.
- `framed_multi` (const std::string &str)
Construct a multivector from a string: eg: "3+2{1,2}-6.1e-2{2,3}".
- `framed_multi` (const std::string &str, const `index_set_t` frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a string: eg: "3+2{1,2}-6.1e-2{2,3}".
- `framed_multi` (const char *str)
Construct a multivector from a char: eg: "3+2{1,2}-6.1e-2{2,3}".*
- `framed_multi` (const char *str, const `index_set_t` frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a char: eg: "3+2{1,2}-6.1e-2{2,3}".*
- template<typename Other_Scalar_T >
`framed_multi` (const `matrix_multi`< Other_Scalar_T, LO, HI > &val)
Construct a multivector from a matrix_multi_t.
- template<typename Other_Scalar_T >
const `matrix_multi`< Other_Scalar_T, LO, HI > `fast_matrix_multi` (const `index_set_t` frm) const
Use generalized FFT to construct a matrix_multi_t.
- const `framed_multi_t` `fast_framed_multi` () const
Use inverse generalized FFT to construct a framed_multi_t.
- `_GLUCAT_CLIFFORD_ALGEBRA_OPERATIONS` unsigned long `nbr_terms` () const
Number of terms.
- `multivector_t` & `operator+=` (const `term_t` &term)
Add a term, if non-zero.

Static Public Member Functions

- static const std::string `classname` ()
Class name used in messages.
- static const `framed_multi_t` `random` (const `index_set_t` frm, `Scalar_T` fill=`Scalar_T`(1))
Random multivector within a frame.

Private Types

- typedef class `var_term` `var_term_t`
- typedef `matrix_multi_t::matrix_t` `matrix_t`
- typedef std::map< `index_set_t`, `Scalar_T`, std::less< const `index_set_t` > > `sorted_map_t`
- typedef std::unordered_map< `index_set_t`, `Scalar_T`, `index_set_hash`< LO, HI > > `map_t`
- typedef std::pair< const `multivector_t`, const `multivector_t` > `framed_pair_t`
- typedef map_t::size_type `size_type`
- typedef map_t::iterator `iterator`
- typedef map_t::const_iterator `const_iterator`

Private Member Functions

- `framed_multi` (const `hash_size_t` &hash_size)
Private constructor using hash_size.
- `multivector_t fold` (const `index_set_t` frm) const
Subalgebra isomorphism: fold each term within the given frame.
- `multivector_t unfold` (const `index_set_t` frm) const
Subalgebra isomorphism: unfold each term within the given frame.
- `multivector_t & centre_pm4_qp4` (`index_t` &p, `index_t` &q)
Subalgebra isomorphism: $R_{\{p,q\}}$ to $R_{\{p-4,q+4\}}$.
- `multivector_t & centre_pp4_qm4` (`index_t` &p, `index_t` &q)
Subalgebra isomorphism: $R_{\{p,q\}}$ to $R_{\{p+4,q-4\}}$.
- `multivector_t & centre_qp1_pm1` (`index_t` &p, `index_t` &q)
Subalgebra isomorphism: $R_{\{p,q\}}$ to $R_{\{q+1,p-1\}}$.
- const `framed_pair_t divide` (const `index_set_t` ist) const
Divide multivector into part divisible by `index_set` and remainder.
- const `matrix_t fast` (const `index_t` level, const bool odd) const
Generalized FFT from `framed_multi_t` to `matrix_t`.

Friends

- template<typename Other_Scalar_T , const `index_t` Other_LO, const `index_t` Other_HI>
class `matrix_multi`
- template<typename Other_Scalar_T , const `index_t` Other_LO, const `index_t` Other_HI>
class `framed_multi`
- const `framed_multi_t operator*` (const `framed_multi_t` &lhs, const `framed_multi_t` &rhs)
- const `framed_multi_t operator^` (const `framed_multi_t` &lhs, const `framed_multi_t` &rhs)
- const `framed_multi_t operator &` (const `framed_multi_t` &lhs, const `framed_multi_t` &rhs)
- const `framed_multi_t operator%` (const `framed_multi_t` &lhs, const `framed_multi_t` &rhs)
- `Scalar_T star` (const `framed_multi_t` &lhs, const `framed_multi_t` &rhs)
- const `framed_multi_t operator/` (const `framed_multi_t` &lhs, const `framed_multi_t` &rhs)
- const `framed_multi_t operator|` (const `framed_multi_t` &lhs, const `framed_multi_t` &rhs)
- `std::istream & operator>>` (`std::istream` &s, `multivector_t` &val)
- `std::ostream & operator<<` (`std::ostream` &os, const `multivector_t` &val)
- `std::ostream & operator<<` (`std::ostream` &os, const `term_t` &term)
- const `framed_multi_t exp` (const `framed_multi_t` &val)

6.13.1 Detailed Description

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
class glucat::framed_multi< Scalar_T, LO, HI >
```

A `framed_multi<Scalar_T,LO,HI>` is a framed approximation to a multivector.

Definition at line 65 of file `framed_multi.h`.

6.13.2 Member Typedef Documentation

6.13.2.1 const_iterator

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef map_t::const_iterator glucat::framed_multi< Scalar_T, LO, HI >::const_iterator [private]
```

Definition at line 196 of file framed_multi.h.

6.13.2.2 error_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef error<multivector_t> glucat::framed_multi< Scalar_T, LO, HI >::error_t
```

Definition at line 155 of file framed_multi.h.

6.13.2.3 framed_multi_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef multivector_t glucat::framed_multi< Scalar_T, LO, HI >::framed_multi_t
```

Definition at line 150 of file framed_multi.h.

6.13.2.4 framed_pair_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef std::pair< const multivector_t, const multivector_t > glucat::framed_multi< Scalar_T,
LO, HI >::framed_pair_t [private]
```

Definition at line 193 of file framed_multi.h.

6.13.2.5 index_set_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef index_set<LO,HI> glucat::framed_multi< Scalar_T, LO, HI >::index_set_t
```

Definition at line 152 of file framed_multi.h.

6.13.2.6 iterator

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef map_t::iterator glucat::framed_multi< Scalar_T, LO, HI >::iterator [private]
```

Definition at line 195 of file framed_multi.h.

6.13.2.7 map_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef std::unordered_map< index_set_t, Scalar_T, index_set_hash<LO,HI> > glucat::framed_multi<
Scalar_T, LO, HI >::map_t [private]
```

Definition at line 175 of file framed_multi.h.

6.13.2.8 matrix_multi_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef matrix_multi<Scalar_T,LO,HI> glucat::framed_multi< Scalar_T, LO, HI >::matrix_multi_t
```

Definition at line 156 of file framed_multi.h.

6.13.2.9 matrix_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef matrix_multi_t::matrix_t glucat::framed_multi< Scalar_T, LO, HI >::matrix_t [private]
```

Definition at line 165 of file framed_multi.h.

6.13.2.10 multivector_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef framed_multi glucat::framed_multi< Scalar_T, LO, HI >::multivector_t
```

Definition at line 149 of file framed_multi.h.

6.13.2.11 scalar_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef Scalar_T glucat::framed_multi< Scalar_T, LO, HI >::scalar_t
```

Definition at line 151 of file framed_multi.h.

6.13.2.12 size_type

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef map_t::size_type glucat::framed_multi< Scalar_T, LO, HI >::size_type [private]
```

Definition at line 194 of file framed_multi.h.

6.13.2.13 sorted_map_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef std::map< index_set_t, Scalar_T, std::less<const index_set_t> > glucat::framed_multi<
Scalar_T, LO, HI >::sorted_map_t [private]
```

Definition at line 172 of file framed_multi.h.

6.13.2.14 term_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef std::pair<const index_set_t, Scalar_T> glucat::framed_multi< Scalar_T, LO, HI >↵
::term_t
```

Definition at line 153 of file framed_multi.h.

6.13.2.15 var_term_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef class var_term glucat::framed_multi< Scalar_T, LO, HI >::var_term_t [private]
```

Definition at line 164 of file framed_multi.h.

6.13.2.16 vector_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef std::vector<Scalar_T> glucat::framed_multi< Scalar_T, LO, HI >::vector_t
```

Definition at line 154 of file framed_multi.h.

6.13.3 Constructor & Destructor Documentation

6.13.3.1 ~framed_multi()

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
glucat::framed_multi< Scalar_T, LO, HI >::~~framed_multi ( ) [inline]
```

Destructor.

Definition at line 202 of file framed_multi.h.

6.13.3.2 framed_multi() [1/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi ( )
```

Default constructor.

Definition at line 67 of file framed_multi_imp.h.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::framed_multi().

6.13.3.3 framed_multi() [2/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const hash_size_t & hash_size ) [private]
```

Private constructor using hash_size.

Definition at line 74 of file framed_multi_imp.h.

6.13.3.4 framed_multi() [3/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const framed_multi< Other_Scalar_T, LO, HI > & val )
```

Construct a multivector from a multivector with a different scalar type.

Definition at line 82 of file framed_multi_imp.h.

6.13.3.5 framed_multi() [4/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const framed_multi< Other_Scalar_T, LO, HI > & val,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a given multivector.

Definition at line 97 of file framed_multi_imp.h.

6.13.3.6 framed_multi() [5/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const framed_multi_t & val,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a given multivector.

Definition at line 112 of file framed_multi_imp.h.

6.13.3.7 framed_multi() [6/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const index_set_t ist,
    const Scalar_T & crd = Scalar_T(1) )
```

Construct a multivector from an index set and a scalar coordinate.

Definition at line 120 of file framed_multi_imp.h.

References PyClical::ist.

6.13.3.8 framed_multi() [7/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const index_set_t ist,
    const Scalar_T & crd,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from an index set and a scalar coordinate.

Definition at line 130 of file framed_multi_imp.h.

References PyClical::ist.

6.13.3.9 framed_multi() [8/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const Scalar_T & scr,
    const index_set_t frm = index_set_t() )
```

Construct a multivector from a scalar (within a frame, if given)

Definition at line 143 of file framed_multi_imp.h.

6.13.3.10 framed_multi() [9/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const int scr,
    const index_set_t frm = index_set_t() )
```

Construct a multivector from an int (within a frame, if given)

Definition at line 153 of file framed_multi_imp.h.

6.13.3.11 framed_multi() [10/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const vector_t & vec,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a given vector.

Definition at line 163 of file framed_multi_imp.h.

References glucat::index_set< LO, HI >::count(), glucat::index_set< LO, HI >::max(), and glucat::index_set< LO, HI >::min().

6.13.3.12 framed_multi() [11/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const std::string & str )
```

Construct a multivector from a string: eg: "3+2{1,2}-6.1e-2{2,3}".

Definition at line 186 of file framed_multi_imp.h.

6.13.3.13 framed_multi() [12/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const std::string & str,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a string: eg: "3+2{1,2}-6.1e-2{2,3}".

Definition at line 202 of file framed_multi_imp.h.

6.13.3.14 framed_multi() [13/15]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const char * str ) [inline]
```

Construct a multivector from a char*: eg: "3+2{1,2}-6.1e-2{2,3}".

Definition at line 238 of file framed_multi.h.

References glucat::framed_multi< Scalar_T, LO, HI >::framed_multi().

6.13.3.15 framed_multi() [14/15]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const char * str,
    const index_set_t frm,
    const bool prechecked = false ) [inline]
```

Construct a multivector, within a given frame, from a char*: eg: "3+2{1,2}-6.1e-2{2,3}".

Definition at line 241 of file framed_multi.h.

References glucat::framed_multi< Scalar_T, LO, HI >::framed_multi().

6.13.3.16 framed_multi() [15/15]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
glucat::framed_multi< Scalar_T, LO, HI >::framed_multi (
    const matrix_multi< Other_Scalar_T, LO, HI > & val )
```

Construct a multivector from a matrix_multi_t.

Definition at line 215 of file framed_multi_imp.h.

References _GLUCAT_HASH_SIZE_T, glucat::abs(), glucat::matrix_multi< Scalar_T, LO, HI >::basis_element(), glucat::index_set< LO, HI >::count(), PyClical::e(), glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::frame(), glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::inv_fast_dim_threshold, PyClical::ist, glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix, glucat::matrix::nnz(), and glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, matrix_multi< Scalar_T, LO, HI > >::norm().

6.13.4 Member Function Documentation

6.13.4.1 centre_pm4_qp4()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
framed_multi< Scalar_T, LO, HI > & glucat::framed_multi< Scalar_T, LO, HI >::centre_pm4_qp4 (
    index_t & p,
    index_t & q ) [private]
```

Subalgebra isomorphism: $R_{\{p,q\}}$ to $R_{\{p-4,q+4\}}$.

Definition at line 1655 of file framed_multi_imp.h.

References PyClical::ist.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::fast_framed_multi(), and glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi().

6.13.4.2 centre_pp4_qm4()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
framed_multi< Scalar_T, LO, HI > & glucat::framed_multi< Scalar_T, LO, HI >::centre_pp4_qm4 (
    index_t & p,
    index_t & q ) [private]
```

Subalgebra isomorphism: $R_{\{p,q\}}$ to $R_{\{p+4,q-4\}}$.

Definition at line 1700 of file framed_multi_imp.h.

References PyClical::ist.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::fast_framed_multi(), and glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi().

6.13.4.3 centre_qp1_pm1()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
framed_multi< Scalar_T, LO, HI > & glucat::framed_multi< Scalar_T, LO, HI >::centre_qp1_pm1 (
    index_t & p,
    index_t & q ) [private]
```

Subalgebra isomorphism: $R_{\{p,q\}}$ to $R_{\{q+1,p-1\}}$.

Definition at line 1745 of file framed_multi_imp.h.

References PyClical::ist.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::fast_framed_multi(), and glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi().

6.13.4.4 classname()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const std::string glucat::framed_multi< Scalar_T, LO, HI >::classname ( ) [static]
```

Class name used in messages.

Definition at line 53 of file framed_multi_imp.h.

6.13.4.5 divide()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const std::pair< const framed_multi< Scalar_T, LO, HI >, const framed_multi< Scalar_T, LO, HI > >
glucat::framed_multi< Scalar_T, LO, HI >::divide (
    const index_set_t ist ) const [private]
```

Divide multivector into part divisible by [index_set](#) and remainder.

Divide multivector into quotient with terms divisible by index set, and remainder.

Definition at line 1781 of file framed_multi_imp.h.

References PyClical::ist.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fast().

6.13.4.6 fast()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI >::matrix_t glucat::framed_multi< Scalar_T, LO, HI >↵
::fast (
    const index_t level,
    const bool odd ) const [private]
```

Generalized FFT from framed_multi_t to matrix_t.

Definition at line 1800 of file framed_multi_imp.h.

References glucat::framed_multi< Scalar_T, LO, HI >::divide(), glucat::framed_multi< Scalar_T, LO, HI >::fast(), glucat::matrix::kron(), glucat::odd(), and glucat::scalar().

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fast(), and glucat::framed_multi< Scalar_T, LO, HI >↵::fast_matrix_multi().

6.13.4.7 fast_framed_multi()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::framed_multi< Scalar_T, LO, HI >::fast_↵
framed_multi ( ) const [inline]
```

Use inverse generalized FFT to construct a framed_multi_t.

Definition at line 1898 of file framed_multi_imp.h.

6.13.4.8 fast_matrix_multi()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
const matrix_multi< Other_Scalar_T, LO, HI > glucat::framed_multi< Scalar_T, LO, HI >::fast_↵
_matrix_multi (
    const index_set_t frm ) const
```

Use generalized FFT to construct a matrix_multi_t.

Definition at line 1866 of file framed_multi_imp.h.

References glucat::framed_multi< Scalar_T, LO, HI >::centre_pm4_qp4(), glucat::framed_multi< Scalar_T, LO, HI >::centre_pp4_qm4(), glucat::framed_multi< Scalar_T, LO, HI >::centre_qp1_pm1(), glucat::index_set< L↵O, HI >::count_neg(), glucat::index_set< LO, HI >::count_pos(), glucat::clifford_algebra< Scalar_T, Index_Set↵_T, Multivector_T >::even(), glucat::framed_multi< Scalar_T, LO, HI >::fast(), glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >::odd(), glucat::gen::offset_to_super, and glucat::pos_mod().

6.13.4.9 fold()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
framed_multi< Scalar_T, LO, HI > glucat::framed_multi< Scalar_T, LO, HI >::fold (
    const index_set_t frm ) const [private]
```

Subalgebra isomorphism: fold each term within the given frame.

Definition at line 1614 of file framed_multi_imp.h.

References glucat::index_set< LO, HI >::is_contiguous().

6.13.4.10 nbr_terms()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
unsigned long glucat::framed_multi< Scalar_T, LO, HI >::nbr_terms ( ) const
```

Number of terms.

Definition at line 1545 of file framed_multi_imp.h.

6.13.4.11 operator+=()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
framed_multi< Scalar_T, LO, HI > & glucat::framed_multi< Scalar_T, LO, HI >::operator+= (
    const term_t & term ) [inline]
```

Add a term, if non-zero.

Insert a term into a multivector, add terms with same index set.

Geometric sum.

Geometric sum of multivector and scalar.

Definition at line 329 of file framed_multi_imp.h.

6.13.4.12 random()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const framed_multi< Scalar_T, LO, HI > glucat::framed_multi< Scalar_T, LO, HI >::random (
    const index_set_t frm,
    Scalar_T fill = Scalar_T(1) ) [static]
```

Random multivector within a frame.

Definition at line 1273 of file framed_multi_imp.h.

References glucat::index_set< LO, HI >::count(), PyClical::fill, and glucat::sqrt().

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::random().

6.13.4.13 `unfold()`

```
template<typename Scalar_T , const index_t LO, const index_t HI>
framed_multi< Scalar_T, LO, HI > glucat::framed_multi< Scalar_T, LO, HI >::unfold (
    const index_set_t frm ) const [private]
```

Subalgebra isomorphism: unfold each term within the given frame.

Definition at line 1634 of file framed_multi_imp.h.

References `glucat::index_set< LO, HI >::is_contiguous()`.

Referenced by `glucat::matrix_multi< Scalar_T, LO, HI >::fast_framed_multi()`.

6.13.5 Friends And Related Function Documentation

6.13.5.1 `exp`

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
const framed_multi_t exp (
    const framed_multi_t & val ) [friend]
```

6.13.5.2 `framed_multi`

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
friend class framed_multi [friend]
```

Definition at line 160 of file framed_multi.h.

6.13.5.3 `matrix_multi`

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
friend class matrix_multi [friend]
```

Definition at line 158 of file framed_multi.h.

6.13.5.4 operator &

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const framed_multi_t operator& (
    const framed_multi_t & lhs,
    const framed_multi_t & rhs ) [friend]
```

6.13.5.5 operator%

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const framed_multi_t operator% (
    const framed_multi_t & lhs,
    const framed_multi_t & rhs ) [friend]
```

6.13.5.6 operator*

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const framed_multi_t operator* (
    const framed_multi_t & lhs,
    const framed_multi_t & rhs ) [friend]
```

6.13.5.7 operator/

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const framed_multi_t operator/ (
    const framed_multi_t & lhs,
    const framed_multi_t & rhs ) [friend]
```

6.13.5.8 operator<< [1/2]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
std::ostream& operator<< (
    std::ostream & os,
    const multivector_t & val ) [friend]
```

6.13.5.9 operator<< [2/2]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
std::ostream& operator<< (
    std::ostream & os,
    const term\_t & term ) [friend]
```

6.13.5.10 operator>>

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
std::istream& operator>> (
    std::istream & s,
    multivector\_t & val ) [friend]
```

6.13.5.11 operator^

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const framed\_multi\_t operator^ (
    const framed\_multi\_t & lhs,
    const framed\_multi\_t & rhs ) [friend]
```

6.13.5.12 operator" |

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const framed\_multi\_t operator| (
    const framed\_multi\_t & lhs,
    const framed\_multi\_t & rhs ) [friend]
```

6.13.5.13 star

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
Scalar_T star (
    const framed\_multi\_t & lhs,
    const framed\_multi\_t & rhs ) [friend]
```

The documentation for this class was generated from the following files:

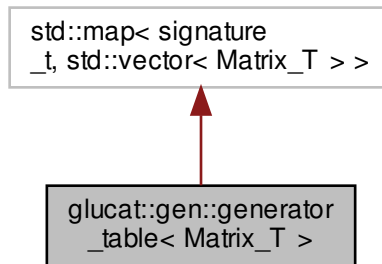
- [glucat/framed_multi.h](#)
- [glucat/framed_multi_imp.h](#)

6.14 glucat::gen::generator_table< Matrix_T > Class Template Reference

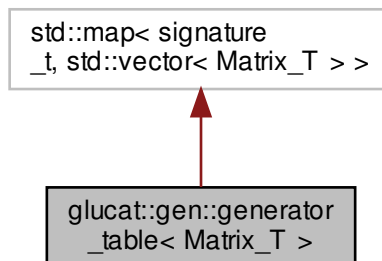
Table of generators for specific signatures.

```
#include <generation.h>
```

Inheritance diagram for glucat::gen::generator_table< Matrix_T >:



Collaboration diagram for glucat::gen::generator_table< Matrix_T >:



Public Member Functions

- `const Matrix_T * operator()` (const `index_t` p, const `index_t` q)
Pointer to generators for a specific signature.

Static Public Member Functions

- static `generator_table< Matrix_T > & generator` ()
Single instance of generator table.

Private Member Functions

- `const std::vector< Matrix_T > & gen_vector` (const `index_t` p, const `index_t` q)
Construct a vector of generators for a specific signature.
- `void gen_from_pm1_qm1` (const std::vector< Matrix_T > &old, const `signature_t` sig)
Construct generators for p,q given generators for p-1,q-1.
- `void gen_from_pm4_qp4` (const std::vector< Matrix_T > &old, const `signature_t` sig)
Construct generators for p,q given generators for p-4,q+4.
- `void gen_from_pp4_qm4` (const std::vector< Matrix_T > &old, const `signature_t` sig)
Construct generators for p,q given generators for p+4,q-4.
- `void gen_from_qp1_pm1` (const std::vector< Matrix_T > &old, const `signature_t` sig)
Construct generators for p,q given generators for q+1,p-1.
- `generator_table` ()
- `~generator_table` ()
- `generator_table` (const `generator_table` &)
- `generator_table & operator=` (const `generator_table` &)

Friends

- class `friend_for_private_destructor`

6.14.1 Detailed Description

```
template<class Matrix_T>
class glucat::gen::generator_table< Matrix_T >
```

Table of generators for specific signatures.

Definition at line 47 of file generation.h.

6.14.2 Constructor & Destructor Documentation

6.14.2.1 generator_table() [1/2]

```
template<class Matrix_T>
glucat::gen::generator_table< Matrix_T >::generator_table ( ) [inline], [private]
```

Definition at line 69 of file generation.h.

6.14.2.2 ~generator_table()

```
template<class Matrix_T>
glucat::gen::generator_table< Matrix_T >::~~generator_table ( ) [inline], [private]
```

Definition at line 70 of file generation.h.

6.14.2.3 generator_table() [2/2]

```
template<class Matrix_T>
glucat::gen::generator_table< Matrix_T >::generator_table (
    const generator_table< Matrix_T > & ) [private]
```

6.14.3 Member Function Documentation

6.14.3.1 gen_from_pm1_qm1()

```
template<class Matrix_T >
void glucat::gen::generator_table< Matrix_T >::gen_from_pm1_qm1 (
    const std::vector< Matrix_T > & old,
    const signature_t sig ) [private]
```

Construct generators for p,q given generators for p-1,q-1.

Definition at line 127 of file generation_imp.h.

References glucat::matrix::mono_kron().

6.14.3.2 gen_from_pm4_qp4()

```
template<class Matrix_T >
void glucat::gen::generator_table< Matrix_T >::gen_from_pm4_qp4 (
    const std::vector< Matrix_T > & old,
    const signature_t sig ) [private]
```

Construct generators for p,q given generators for p-4,q+4.

Definition at line 164 of file generation_imp.h.

References glucat::matrix::mono_prod().

6.14.3.3 gen_from_pp4_qm4()

```
template<class Matrix_T >
void glucat::gen::generator_table< Matrix_T >::gen_from_pp4_qm4 (
    const std::vector< Matrix_T > & old,
    const signature_t sig ) [private]
```

Construct generators for p,q given generators for p+4,q-4.

Definition at line 195 of file generation_imp.h.

References glucat::matrix::mono_prod().

6.14.3.4 gen_from_qp1_pm1()

```
template<class Matrix_T >
void glucat::gen::generator_table< Matrix_T >::gen_from_qp1_pm1 (
    const std::vector< Matrix_T > & old,
    const signature_t sig ) [private]
```

Construct generators for p,q given generators for q+1,p-1.

Definition at line 225 of file generation_imp.h.

References glucat::matrix::mono_prod().

6.14.3.5 gen_vector()

```
template<class Matrix_T >
const std::vector< Matrix_T > & glucat::gen::generator_table< Matrix_T >::gen_vector (
    const index_t p,
    const index_t q ) [private]
```

Construct a vector of generators for a specific signature.

Definition at line 80 of file generation_imp.h.

References glucat::pos_mod().

6.14.3.6 generator()

```
template<class Matrix_T >
generator_table< Matrix_T > & glucat::gen::generator_table< Matrix_T >::generator ( ) [static]
```

Single instance of generator table.

Definition at line 50 of file generation_imp.h.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::basis_element().

6.14.3.7 operator>()

```
template<class Matrix_T >
const Matrix_T * glucat::gen::generator_table< Matrix_T >::operator() (
    const index_t p,
    const index_t q ) [inline]
```

Pointer to generators for a specific signature.

Definition at line 59 of file generation_imp.h.

References glucat::gen::offset_to_super, and glucat::pos_mod().

6.14.3.8 operator=()

```
template<class Matrix_T>
generator_table& glucat::gen::generator_table< Matrix_T >::operator= (
    const generator_table< Matrix_T > & ) [private]
```

6.14.4 Friends And Related Function Documentation

6.14.4.1 friend_for_private_destructor

```
template<class Matrix_T>
friend class friend_for_private_destructor [friend]
```

Friend declaration to avoid compiler warning: "... only defines a private destructor and has no friends" Ref: Carlos O'Ryan, ACE <http://doc.ece.uci.edu>

Definition at line 77 of file generation.h.

The documentation for this class was generated from the following files:

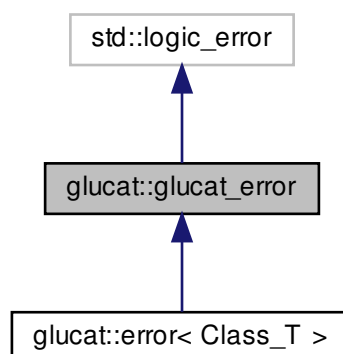
- [glucat/generation.h](#)
- [glucat/generation_imp.h](#)

6.15 glucat::glucat_error Class Reference

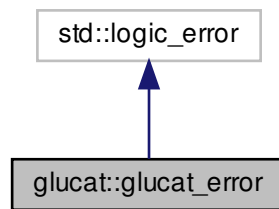
Abstract exception class.

```
#include <errors.h>
```

Inheritance diagram for glucat::glucat_error:



Collaboration diagram for glucat::glucat_error:



Public Member Functions

- [glucat_error](#) (const std::string &context, const std::string &msg)
- [~glucat_error](#) () throw ()
- virtual const std::string [heading](#) () const =0 throw ()
- virtual const std::string [classname](#) () const =0 throw ()
- virtual void [print_error_msg](#) () const =0

Public Attributes

- std::string [name](#)

6.15.1 Detailed Description

Abstract exception class.

Definition at line 41 of file errors.h.

6.15.2 Constructor & Destructor Documentation

6.15.2.1 glucat_error()

```
glucat::glucat_error::glucat_error (  
    const std::string & context,  
    const std::string & msg ) [inline]
```

Definition at line 44 of file errors.h.

6.15.2.2 ~glucat_error()

```
glucat::glucat_error::~~glucat_error ( ) throw )    [inline]
```

Definition at line 47 of file errors.h.

6.15.3 Member Function Documentation

6.15.3.1 classname()

```
virtual const std::string glucat::glucat_error::classname ( ) const throw )    [pure virtual]
```

Implemented in [glucat::error< Class_T >](#).

6.15.3.2 heading()

```
virtual const std::string glucat::glucat_error::heading ( ) const throw )    [pure virtual]
```

Implemented in [glucat::error< Class_T >](#).

6.15.3.3 print_error_msg()

```
virtual void glucat::glucat_error::print_error_msg ( ) const    [pure virtual]
```

Implemented in [glucat::error< Class_T >](#).

6.15.4 Member Data Documentation

6.15.4.1 name

```
std::string glucat::glucat_error::name
```

Definition at line 52 of file errors.h.

The documentation for this class was generated from the following file:

- [glucat/errors.h](#)

6.16 glucat::framed_multi< Scalar_T, LO, HI >::hash_size_t Class Reference

Public Member Functions

- [hash_size_t](#) (size_t hash_size)
- [size_t operator\(\)](#) () const

Private Attributes

- [size_t n](#)

6.16.1 Detailed Description

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
class glucat::framed_multi< Scalar_T, LO, HI >::hash_size_t
```

Definition at line 180 of file framed_multi.h.

6.16.2 Constructor & Destructor Documentation

6.16.2.1 hash_size_t()

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
glucat::framed_multi< Scalar_T, LO, HI >::hash_size_t::hash_size_t (
    size_t hash_size ) [inline]
```

Definition at line 183 of file framed_multi.h.

6.16.3 Member Function Documentation

6.16.3.1 operator()()

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
size_t glucat::framed_multi< Scalar_T, LO, HI >::hash_size_t::operator() () const [inline]
```

Definition at line 186 of file framed_multi.h.

References [glucat::framed_multi< Scalar_T, LO, HI >::hash_size_t::n](#).

6.16.4 Member Data Documentation

6.16.4.1 n

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
size_t glucat::framed_multi< Scalar_T, LO, HI >::hash_size_t::n [private]
```

Definition at line 189 of file framed_multi.h.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::hash_size_t::operator()().

The documentation for this class was generated from the following file:

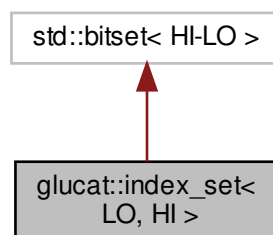
- glucat/[framed_multi.h](#)

6.17 glucat::index_set< LO, HI > Class Template Reference

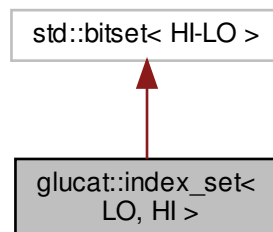
Index set class based on std::bitset<> in Gnu standard C++ library.

```
#include <index_set.h>
```

Inheritance diagram for glucat::index_set< LO, HI >:



Collaboration diagram for glucat::index_set< LO, HI >:



Classes

- class [reference](#)
Index set member reference.

Public Types

- typedef [index_set](#) [index_set_t](#)
- typedef std::pair< [index_t](#), [index_t](#) > [index_pair_t](#)

Public Member Functions

- [index_set](#) ()
Default constructor creates an empty set.
- [index_set](#) (const [bitset_t](#) bst)
Constructor from [bitset_t](#).
- [index_set](#) (const [index_t](#) idx)
Constructor from [index](#).
- [index_set](#) (const [set_value_t](#) folded_val, const [index_set_t](#) frm, const bool prechecked=false)
Constructor from set value of an index set folded within the given frame.
- [index_set](#) (const [index_pair_t](#) &range, const bool prechecked=false)
Constructor from range of indices from range.first to range.second.
- [index_set](#) (const std::string &str)
Constructor from string.
- bool [operator==](#) (const [index_set_t](#) rhs) const
Equality.
- bool [operator!=](#) (const [index_set_t](#) rhs) const
Inequality.
- [index_set_t](#) [operator~](#) () const
Set complement: not.
- [index_set_t](#) & [operator^](#) = (const [index_set_t](#) rhs)
Symmetric set difference: exclusive or.
- [index_set_t](#) & [operator &](#) = (const [index_set_t](#) rhs)
Set intersection: and.
- [index_set_t](#) & [operator|](#) = (const [index_set_t](#) rhs)
Set union: or.
- bool [operator\[\]](#) (const [index_t](#) idx) const
Subscripting: Test idx for membership: test value of bit idx.
- bool [test](#) (const [index_t](#) idx) const
Test idx for membership: test value of bit idx.
- [index_set_t](#) & [set](#) ()
Include all indices except 0: set all bits except 0.
- [index_set_t](#) & [set](#) (const [index_t](#) idx)
Include idx: Set bit at idx if idx != 0.
- [index_set_t](#) & [set](#) (const [index_t](#) idx, const int val)
Set membership of idx to val if idx != 0: Set bit at idx to val if idx != 0.
- [index_set_t](#) & [reset](#) ()
Make set empty: Set all bits to 0.
- [index_set_t](#) & [reset](#) (const [index_t](#) idx)
Exclude idx: Set bit at idx to 0.

- `index_set_t & flip ()`
Set complement, except 0: flip all bits, except 0.
- `index_set_t & flip (const index_t idx)`
Complement membership of idx if idx != 0: flip bit at idx if idx != 0.
- `index_t count () const`
Cardinality: Number of indices included in set.
- `index_t count_neg () const`
Number of negative indices included in set.
- `index_t count_pos () const`
Number of positive indices included in set.
- `index_t min () const`
Minimum member.
- `index_t max () const`
Maximum member.
- `bool operator< (const index_set_t rhs) const`
Less than operator used for comparisons, map, etc.
- `bool is_contiguous () const`
Determine if the index set is contiguous, ie. has no gaps.
- `const index_set_t fold () const`
Fold this index set within itself as a frame.
- `const index_set_t fold (const index_set_t frm, const bool prechecked=false) const`
Fold this index set within the given frame.
- `const index_set_t unfold (const index_set_t frm, const bool prechecked=false) const`
Unfold this index set within the given frame.
- `set_value_t value_of_fold (const index_set_t frm) const`
The set value of the fold of this index set within the given frame.
- `int sign_of_mult (const index_set_t ist) const`
Sign of geometric product of two Clifford basis elements.
- `int sign_of_square () const`
Sign of geometric square of a Clifford basis element.
- `size_t hash_fn () const`
Hash function.
- `reference operator[] (index_t idx)`
Subscripting: Element access.

Static Public Member Functions

- `static const std::string classname ()`

Static Public Attributes

- `static const index_t v_lo = LO`
- `static const index_t v_hi = HI`

Private Types

- `typedef std::bitset< HI-LO > bitset_t`
- `typedef error< index_set > error_t`

Private Member Functions

- `BOOST_STATIC_ASSERT` ((LO<=0) &&(0<=HI) &&(LO< HI) &&(-LO< _GLUCAT_BITS_PER_ULONG) &&(HI< _GLUCAT_BITS_PER_ULONG) &&(HI-LO<=_GLUCAT_BITS_PER_ULONG))
- `bool lex_less_than` (const `index_set_t` rhs) const
*Lexicographic ordering of two sets: *this < rhs.*

Friends

- class `reference`
- const `index_set_t` `operator^` (const `index_set_t` &lhs, const `index_set_t` &rhs)
- const `index_set_t` `operator &` (const `index_set_t` &lhs, const `index_set_t` &rhs)
- const `index_set_t` `operator|` (const `index_set_t` &lhs, const `index_set_t` &rhs)
- int `compare` (const `index_set_t` &lhs, const `index_set_t` &rhs)

6.17.1 Detailed Description

```
template<const index_t LO, const index_t HI>
class glucat::index_set< LO, HI >
```

Index set class based on `std::bitset<>` in Gnu standard C++ library.

Definition at line 45 of file `index_set.h`.

6.17.2 Member Typedef Documentation

6.17.2.1 `bitset_t`

```
template<const index_t LO, const index_t HI>
typedef std::bitset<HI-LO> glucat::index_set< LO, HI >::bitset_t [private]
```

Definition at line 81 of file `index_set.h`.

6.17.2.2 `error_t`

```
template<const index_t LO, const index_t HI>
typedef error<index_set> glucat::index_set< LO, HI >::error_t [private]
```

Definition at line 82 of file `index_set.h`.

6.17.2.3 index_pair_t

```
template<const index_t LO, const index_t HI>
typedef std::pair<index_t, index_t> glucat::index_set< LO, HI >::index_pair_t
```

Definition at line 85 of file index_set.h.

6.17.2.4 index_set_t

```
template<const index_t LO, const index_t HI>
typedef index_set glucat::index_set< LO, HI >::index_set_t
```

Definition at line 84 of file index_set.h.

6.17.3 Constructor & Destructor Documentation

6.17.3.1 index_set() [1/6]

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::index_set ( ) [inline]
```

Default constructor creates an empty set.

Definition at line 92 of file index_set.h.

6.17.3.2 index_set() [2/6]

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::index_set (
    const bitset_t bst )
```

Constructor from bitset_t.

Definition at line 61 of file index_set_imp.h.

6.17.3.3 index_set() [3/6]

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::index_set (
    const index_t idx )
```

Constructor from index.

Constructor from index value.

Definition at line 55 of file index_set_imp.h.

6.17.3.4 index_set() [4/6]

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::index_set (
    const set_value_t folded_val,
    const index_set_t frm,
    const bool prechecked = false )
```

Constructor from set value of an index set folded within the given frame.

Definition at line 68 of file index_set_imp.h.

References glucat::index_set< LO, HI >::count(), glucat::index_set< LO, HI >::fold(), glucat::index_set< LO, HI >::min(), and glucat::index_set< LO, HI >::unfold().

6.17.3.5 index_set() [5/6]

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::index_set (
    const index_pair_t & range,
    const bool prechecked = false )
```

Constructor from range of indices from range.first to range.second.

Definition at line 82 of file index_set_imp.h.

6.17.3.6 index_set() [6/6]

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::index_set (
    const std::string & str )
```

Constructor from string.

Definition at line 102 of file index_set_imp.h.

6.17.4 Member Function Documentation

6.17.4.1 BOOST_STATIC_ASSERT()

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::BOOST_STATIC_ASSERT (
    (LO<=0) && (0<=HI) && (LO< HI) && (-LO< _GLUCAT_BITS_PER_ULONG) && (HI< _GLUCAT_BITS_PER_ULONG) && (HI-LO<=_GLUCAT_BITS_PER_ULONG) ) [private]
```

6.17.4.2 classname()

```
template<const index_t LO, const index_t HI>
const std::string glucat::index_set< LO, HI >::classname ( ) [inline], [static]
```

Definition at line 49 of file index_set_imp.h.

6.17.4.3 count()

```
template<const index_t LO, const index_t HI>
index_t glucat::index_set< LO, HI >::count ( ) const [inline]
```

Cardinality: Number of indices included in set.

Definition at line 344 of file index_set_imp.h.

Referenced by glucat::index_set< LO, HI >::count_neg(), glucat::index_set< LO, HI >::count_pos(), glucat::framed_multi< Scalar_T, LO, HI >::framed_multi(), glucat::index_set< LO, HI >::index_set(), glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi(), glucat::index_set< LO, HI >::operator<(), and glucat::framed_multi< Scalar_T, LO, HI >::random().

6.17.4.4 count_neg()

```
template<const index_t LO, const index_t HI>
index_t glucat::index_set< LO, HI >::count_neg ( ) const [inline]
```

Number of negative indices included in set.

Definition at line 364 of file index_set_imp.h.

References glucat::index_set< LO, HI >::count().

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi(), and glucat::folded_dim().

6.17.4.5 count_pos()

```
template<const index_t LO, const index_t HI>
index_t glucat::index_set< LO, HI >::count_pos ( ) const [inline]
```

Number of positive indices included in set.

Definition at line 376 of file index_set_imp.h.

References glucat::index_set< LO, HI >::count().

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fast_matrix_multi(), and glucat::folded_dim().

6.17.4.6 flip() [1/2]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::flip ( ) [inline]
```

Set complement, except 0: flip all bits, except 0.

Definition at line 319 of file index_set_imp.h.

6.17.4.7 flip() [2/2]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::flip (
    const index_t idx ) [inline]
```

Complement membership of idx if idx != 0: flip bit at idx if idx != 0.

Definition at line 330 of file index_set_imp.h.

6.17.4.8 fold() [1/2]

```
template<const index_t LO, const index_t HI>
const index_set< LO, HI > glucat::index_set< LO, HI >::fold ( ) const [inline]
```

Fold this index set within itself as a frame.

Definition at line 748 of file index_set_imp.h.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::basis_element(), glucat::index_set< LO, HI >::index_set(), and glucat::index_set< LO, HI >::value_of_fold().

6.17.4.9 fold() [2/2]

```
template<const index_t LO, const index_t HI>
const index_set< LO, HI > glucat::index_set< LO, HI >::fold (
    const index_set_t frm,
    const bool prechecked = false ) const
```

Fold this index set within the given frame.

Definition at line 756 of file index_set_imp.h.

References glucat::index_set< LO, HI >::max(), glucat::index_set< LO, HI >::min(), glucat::index_set< LO, HI >::set(), and glucat::index_set< LO, HI >::test().

6.17.4.10 hash_fn()

```
template<const index_t LO, const index_t HI>
size_t glucat::index_set< LO, HI >::hash_fn ( ) const [inline]
```

Hash function.

Definition at line 948 of file index_set_imp.h.

Referenced by glucat::index_set_hash< LO, HI >::operator()().

6.17.4.11 is_contiguous()

```
template<const index_t LO, const index_t HI>
bool glucat::index_set< LO, HI >::is_contiguous ( ) const [inline]
```

Determine if the index set is contiguous, ie. has no gaps.

Determine if the index set is contiguous, ie. has no gaps when 0 is included.

Definition at line 732 of file index_set_imp.h.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::fold(), and glucat::framed_multi< Scalar_T, LO, HI >::unfold().

6.17.4.12 lex_less_than()

```
template<const index_t LO, const index_t HI>
bool glucat::index_set< LO, HI >::lex_less_than (
    const index_set_t rhs ) const [inline], [private]
```

Lexicographic ordering of two sets: *this < rhs.

Definition at line 588 of file index_set_imp.h.

Referenced by glucat::compare().

6.17.4.13 max()

```
template<const index_t LO, const index_t HI>
index_t glucat::index_set< LO, HI >::max ( ) const
```

Maximum member.

Maximum member, or 0 if none.

Definition at line 550 of file index_set_imp.h.

Referenced by PyClical.index_set::__iter__(), glucat::matrix_multi< Scalar_T, LO, HI >::basis_element(), glucat::index_set< LO, HI >::fold(), glucat::framed_multi< Scalar_T, LO, HI >::framed_multi(), glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi(), and glucat::index_set< LO, HI >::unfold().

6.17.4.14 min()

```
template<const index_t LO, const index_t HI>
index_t glucat::index_set< LO, HI >::min ( ) const
```

Minimum member.

Minimum member, or 0 if none.

Definition at line 461 of file index_set_imp.h.

Referenced by PyClical.index_set::__iter__(), glucat::matrix_multi< Scalar_T, LO, HI >::basis_element(), glucat::index_set< LO, HI >::fold(), glucat::framed_multi< Scalar_T, LO, HI >::framed_multi(), glucat::index_set< LO, HI >::index_set(), glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi(), glucat::index_set< LO, HI >::unfold(), and glucat::index_set< LO, HI >::value_of_fold().

6.17.4.15 operator &=()

```
template<const index_t LO, const index_t HI>
index_set_t& glucat::index_set< LO, HI >::operator&= (
    const index_set_t rhs )
```

Set intersection: and.

6.17.4.16 operator!=(=)

```
template<const index_t LO, const index_t HI>
bool glucat::index_set< LO, HI >::operator!= (
    const index_set_t rhs ) const [inline]
```

Inequality.

Definition at line 130 of file index_set_imp.h.

6.17.4.17 operator<()

```
template<const index_t LO, const index_t HI>
bool glucat::index_set< LO, HI >::operator< (
    const index_set_t rhs ) const [inline]
```

Less than operator used for comparisons, map, etc.

Definition at line 597 of file index_set_imp.h.

References glucat::index_set< LO, HI >::count().

6.17.4.18 operator==()

```
template<const index_t LO, const index_t HI>
bool glucat::index_set< LO, HI >::operator== (
    const index_set_t rhs ) const [inline]
```

Equality.

Definition at line 119 of file index_set_imp.h.

6.17.4.19 operator[]() [1/2]

```
template<const index_t LO, const index_t HI>
bool glucat::index_set< LO, HI >::operator[] (
    const index_t idx ) const [inline]
```

Subscripting: Test idx for membership: test value of bit idx.

Definition at line 232 of file index_set_imp.h.

6.17.4.20 operator[]() [2/2]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI >::reference glucat::index_set< LO, HI >::operator[] (
    index_t idx ) [inline]
```

Subscripting: Element access.

Definition at line 224 of file index_set_imp.h.

6.17.4.21 operator^=()

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::operator^= (
    const index_set_t rhs ) [inline]
```

Symmetric set difference: exclusive or.

Definition at line 149 of file index_set_imp.h.

6.17.4.22 operator" |=()

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::operator|= (
    const index_set_t rhs ) [inline]
```

Set union: or.

Definition at line 199 of file index_set_imp.h.

6.17.4.23 operator~()

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > glucat::index_set< LO, HI >::operator~ ( ) const [inline]
```

Set complement: not.

Definition at line 141 of file index_set_imp.h.

6.17.4.24 reset() [1/2]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::reset ( ) [inline]
```

Make set empty: Set all bits to 0.

Definition at line 294 of file index_set_imp.h.

6.17.4.25 reset() [2/2]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::reset (
    const index_t idx ) [inline]
```

Exclude idx: Set bit at idx to 0.

Definition at line 305 of file index_set_imp.h.

6.17.4.26 set() [1/3]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::set ( ) [inline]
```

Include all indices except 0: set all bits except 0.

Definition at line 255 of file index_set_imp.h.

Referenced by glucat::index_set< LO, HI >::fold(), glucat::operator>>(), and glucat::index_set< LO, HI >↵::unfold().

6.17.4.27 set() [2/3]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::set (
    const index_t idx ) [inline]
```

Include idx: Set bit at idx if idx != 0.

Definition at line 266 of file index_set_imp.h.

6.17.4.28 set() [3/3]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI > & glucat::index_set< LO, HI >::set (
    const index_t idx,
    const int val ) [inline]
```

Set membership of idx to val if idx != 0: Set bit at idx to val if idx != 0.

Definition at line 280 of file index_set_imp.h.

6.17.4.29 sign_of_mult()

```
template<const index_t LO, const index_t HI>
int glucat::index_set< LO, HI >::sign_of_mult (
    const index_set_t ist ) const
```

Sign of geometric product of two Clifford basis elements.

Definition at line 879 of file index_set_imp.h.

References glucat::inverse_gray(), and glucat::inverse_reversed_gray().

6.17.4.30 sign_of_square()

```
template<const index_t LO, const index_t HI>
int glucat::index_set< LO, HI >::sign_of_square ( ) const [inline]
```

Sign of geometric square of a Clifford basis element.

Definition at line 928 of file index_set_imp.h.

6.17.4.31 test()

```
template<const index_t LO, const index_t HI>
bool glucat::index_set< LO, HI >::test (
    const index_t idx ) const [inline]
```

Test idx for membership: test value of bit idx.

Definition at line 240 of file index_set_imp.h.

Referenced by glucat::index_set< LO, HI >::fold(), and glucat::index_set< LO, HI >::unfold().

6.17.4.32 unfold()

```
template<const index_t LO, const index_t HI>
const index_set< LO, HI > glucat::index_set< LO, HI >::unfold (
    const index_set_t frm,
    const bool prechecked = false ) const
```

Unfold this index set within the given frame.

Definition at line 794 of file index_set_imp.h.

References glucat::index_set< LO, HI >::max(), glucat::index_set< LO, HI >::min(), glucat::index_set< LO, HI >::set(), and glucat::index_set< LO, HI >::test().

Referenced by glucat::index_set< LO, HI >::index_set().

6.17.4.33 value_of_fold()

```
template<const index_t LO, const index_t HI>
set_value_t glucat::index_set< LO, HI >::value_of_fold (
    const index_set_t frm ) const [inline]
```

The set value of the fold of this index set within the given frame.

Definition at line 828 of file index_set_imp.h.

References glucat::index_set< LO, HI >::fold(), and glucat::index_set< LO, HI >::min().

6.17.5 Friends And Related Function Documentation

6.17.5.1 compare

```
template<const index_t LO, const index_t HI>
int compare (
    const index_set_t & lhs,
    const index_set_t & rhs ) [friend]
```

6.17.5.2 operator &

```
template<const index_t LO, const index_t HI>
const index_set_t operator& (
    const index_set_t & lhs,
    const index_set_t & rhs ) [friend]
```

6.17.5.3 operator^

```
template<const index_t LO, const index_t HI>
const index_set_t operator^ (
    const index_set_t & lhs,
    const index_set_t & rhs ) [friend]
```

6.17.5.4 operator" |

```
template<const index_t LO, const index_t HI>
const index_set_t operator| (
    const index_set_t & lhs,
    const index_set_t & rhs ) [friend]
```

6.17.5.5 reference

```
template<const index_t LO, const index_t HI>
friend class reference [friend]
```

Definition at line 173 of file index_set.h.

6.17.6 Member Data Documentation

6.17.6.1 v_hi

```
template<const index_t LO, const index_t HI>
const index_t glucat::index_set< LO, HI >::v_hi = HI [static]
```

Definition at line 88 of file index_set.h.

6.17.6.2 v_lo

```
template<const index_t LO, const index_t HI>
const index_t glucat::index_set< LO, HI >::v_lo = LO [static]
```

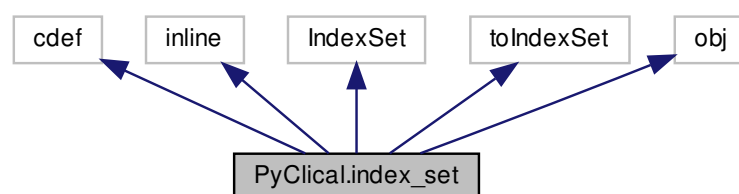
Definition at line 87 of file index_set.h.

The documentation for this class was generated from the following files:

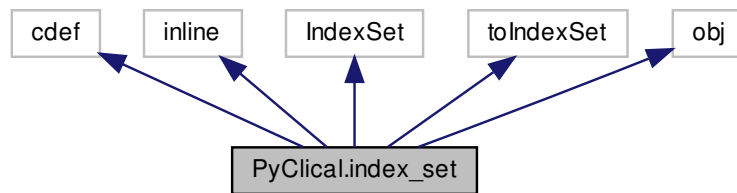
- glucat/index_set.h
- glucat/index_set_imp.h

6.18 PyClical.index_set Class Reference

Inheritance diagram for PyClical.index_set:



Collaboration diagram for PyClical.index_set:



Public Member Functions

- `def __cinit__(self, other=0)`
- `def __dealloc__(self)`
- `def __richcmp__(lhs, rhs, int, op)`
- `def __setitem__(self, idx, val)`
- `def __getitem__(self, idx)`
- `def __contains__(self, idx)`
- `def __iter__(self)`
- `def __invert__(self)`
- `def __xor__(lhs, rhs)`
- `def __ixor__(self, rhs)`
- `def __and__(lhs, rhs)`
- `def __iand__(self, rhs)`
- `def __or__(lhs, rhs)`
- `def __ior__(self, rhs)`
- `def count(self)`
- `def count_neg(self)`
- `def count_pos(self)`
- `def min(self)`
- `def max(self)`
- `def hash_fn(self)`
- `def sign_of_mult(self, rhs)`
- `def sign_of_square(self)`
- `def __repr__(self)`
- `def __str__(self)`

Public Attributes

- `instance`

6.18.1 Detailed Description

Return the C++ `IndexSet` instance wrapped by `index_set(obj)`.

Python class `index_set` wraps C++ class `IndexSet`.

Definition at line 39 of file `PyClical.pyx`.

6.18.2 Member Function Documentation

6.18.2.1 `__and__()`

```
def PyClical.index_set.__and__ (
    lhs,
    rhs )
```

Set intersection: and.

```
>>> print index_set({1}) & index_set({2})
{}
>>> print index_set({1,2}) & index_set({2})
{2}
```

Definition at line 269 of file PyClical.pyx.

6.18.2.2 `__cinit__()`

```
def PyClical.index_set.__cinit__ (
    self,
    other = 0 )
```

Construct an object of type index_set.

```
>>> print index_set(1)
{1}
>>> print index_set({1,2})
{1,2}
>>> print index_set(index_set({1,2}))
{1,2}
>>> print index_set({1,2})
{1,2}
>>> print index_set({1,2,1})
{1,2}
>>> print index_set("{1,2,1}")
{1,2}
>>> print index_set("")
{}
```

Definition at line 73 of file PyClical.pyx.

6.18.2.3 `__contains__()`

```
def PyClical.index_set.__contains__ (
    self,
    idx )
```

Check that an `index_set` object contains the index `idx`: `idx` in `self`.

```
>>> 1 in index_set({1})
True
>>> 2 in index_set({1})
False
>>> -1 in index_set({2})
False
>>> 1 in index_set({2})
False
>>> 2 in index_set({2})
True
>>> 33 in index_set({2})
False
```

Definition at line 208 of file `PyClical.pyx`.

References `PyClical.index_set.instance`.

6.18.2.4 `__dealloc__()`

```
def PyClical.index_set.__dealloc__ (
    self )
```

Clean up by deallocating the instance of C++ class `IndexSet`.

Definition at line 114 of file `PyClical.pyx`.

References `PyClical.index_set.instance`.

6.18.2.5 `__getitem__()`

```
def PyClical.index_set.__getitem__ (
    self,
    idx )
```

Get the value of an `index_set` object at an index.

```
>>> index_set({1})[1]
True
>>> index_set({1})[2]
False
>>> index_set({2})[-1]
False
>>> index_set({2})[1]
False
>>> index_set({2})[2]
True
>>> index_set({2})[33]
False
```

Definition at line 189 of file `PyClical.pyx`.

References `PyClical.index_set.instance`.

6.18.2.6 __iand__()

```
def PyClical.index_set.__iand__ (
    self,
    rhs )

Set intersection: and.

>>> x = index_set({1}); x &= index_set({2}); print x
{}
>>> x = index_set({1,2}); x &= index_set({2}); print x
{2}
```

Definition at line 280 of file PyClical.pyx.

6.18.2.7 __invert__()

```
def PyClical.index_set.__invert__ (
    self )

Set complement: not.

>>> print ~index_set({-16,-15,-14,-13,-12,-11,-10,-9,-8,-7,-6,-5,-4,-3,-2,-1,1,2,3,4,5,6,7,8,9,10,11,12,13,14,
{-32,-31,-30,-29,-28,-27,-26,-25,-24,-23,-22,-21,-20,-19,-18,-17,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,
```

Definition at line 238 of file PyClical.pyx.

References `PyClical.index_set.instance`.

6.18.2.8 __ior__()

```
def PyClical.index_set.__ior__ (
    self,
    rhs )

Set union: or.

>>> x = index_set({1}); x |= index_set({2}); print x
{1,2}
>>> x = index_set({1,2}); x |= index_set({2}); print x
{1,2}
```

Definition at line 302 of file PyClical.pyx.

6.18.2.9 `__iter__()`

```
def PyClical.index_set.__iter__ (
    self )
```

Iterate over the indices of an `index_set`.

```
>>> for i in index_set({-3,4,7}): print i,
-3 4 7
```

Definition at line 227 of file `PyClical.pyx`.

References `glucat::index_set< LO, HI >.max()`, `PyClical.index_set.max()`, `glucat::index_set< LO, HI >.min()`, and `PyClical.index_set.min()`.

6.18.2.10 `__ixor__()`

```
def PyClical.index_set.__ixor__ (
    self,
    rhs )
```

Symmetric set difference: exclusive or.

```
>>> x = index_set({1}); x ^= index_set({2}); print x
{1,2}
>>> x = index_set({1,2}); x ^= index_set({2}); print x
{1}
```

Definition at line 258 of file `PyClical.pyx`.

6.18.2.11 `__or__()`

```
def PyClical.index_set.__or__ (
    lhs,
    rhs )
```

Set union: or.

```
>>> print index_set({1}) | index_set({2})
{1,2}
>>> print index_set({1,2}) | index_set({2})
{1,2}
```

Definition at line 291 of file `PyClical.pyx`.

6.18.2.12 `__repr__()`

```
def PyClical.index_set.__repr__ (
    self )
```

The “official” string representation of self.

```
>>> index_set({1,2}).__repr__()
'index_set({1,2})'
>>> repr(index_set({1,2}))
'index_set({1,2})'
```

Definition at line 382 of file `PyClical.pyx`.

References `index_set_to_repr()`.

6.18.2.13 `__richcmp__()`

```
def PyClical.index_set.__richcmp__ (
    lhs,
    rhs,
    int,
    op )
```

Compare two objects of class `index_set`.

```
>>> index_set(1) == index_set({1})
True
>>> index_set({1}) != index_set({1})
False
>>> index_set({1}) != index_set({2})
True
>>> index_set({1}) == index_set({2})
False
>>> index_set({1}) < index_set({2})
True
>>> index_set({1}) <= index_set({2})
True
>>> index_set({1}) > index_set({2})
False
>>> index_set({1}) >= index_set({2})
False
```

Definition at line 120 of file `PyClical.pyx`.

6.18.2.14 `__setitem__()`

```
def PyClical.index_set.__setitem__ (
    self,
    idx,
    val )
```

Set the value of an `index_set` object at index `idx` to value `val`.

```
>>> s=index_set({1}); s[2] = True; print s
{1,2}
>>> s=index_set({1,2}); s[1] = False; print s
{2}
```

Definition at line 177 of file `PyClical.pyx`.

References `PyClical.index_set.instance`.

6.18.2.15 `__str__()`

```
def PyClical.index_set.__str__ (
    self )
```

The “informal” string representation of self.

```
>>> index_set({1,2}).__str__()
' {1,2} '
>>> str(index_set({1,2}))
' {1,2} '
```

Definition at line 393 of file PyClical.pyx.

References `index_set_to_str()`.

6.18.2.16 `__xor__()`

```
def PyClical.index_set.__xor__ (
    lhs,
    rhs )
```

Symmetric set difference: exclusive or.

```
>>> print index_set({1}) ^ index_set({2})
{1,2}
>>> print index_set({1,2}) ^ index_set({2})
{1}
```

Definition at line 247 of file PyClical.pyx.

6.18.2.17 `count()`

```
def PyClical.index_set.count (
    self )
```

Cardinality: Number of indices included in set.

```
>>> index_set({-1,1,2}).count()
3
```

Definition at line 313 of file PyClical.pyx.

References `PyClical.index_set.instance`.

6.18.2.18 count_neg()

```
def PyClical.index_set.count_neg (
    self )
```

Number of negative indices included in set.

```
>>> index_set({-1,1,2}).count_neg()
1
```

Definition at line 322 of file PyClical.pyx.

References `PyClical.index_set.instance`.

6.18.2.19 count_pos()

```
def PyClical.index_set.count_pos (
    self )
```

Number of positive indices included in set.

```
>>> index_set({-1,1,2}).count_pos()
2
```

Definition at line 331 of file PyClical.pyx.

References `PyClical.index_set.instance`.

6.18.2.20 hash_fn()

```
def PyClical.index_set.hash_fn (
    self )
```

Hash function.

Definition at line 358 of file PyClical.pyx.

References `PyClical.index_set.instance`.

6.18.2.21 max()

```
def PyClical.index_set.max (
    self )
```

Maximum member.

```
>>> index_set({-1,1,2}).max()
2
```

Definition at line 349 of file PyClical.pyx.

References PyClical.index_set.instance.

Referenced by PyClical.index_set.__iter__().

6.18.2.22 min()

```
def PyClical.index_set.min (
    self )
```

Minimum member.

```
>>> index_set({-1,1,2}).min()
-1
```

Definition at line 340 of file PyClical.pyx.

References PyClical.index_set.instance.

Referenced by PyClical.index_set.__iter__().

6.18.2.23 sign_of_mult()

```
def PyClical.index_set.sign_of_mult (
    self,
    rhs )
```

Sign of geometric product of two Clifford basis elements.

```
>>> s = index_set({1,2}); t=index_set({-1}); s.sign_of_mult(t)
1
```

Definition at line 364 of file PyClical.pyx.

References PyClical.index_set.instance.

6.18.2.24 sign_of_square()

```
def PyClical.index_set.sign_of_square (
    self )
```

Sign of geometric square of a Clifford basis element.

```
>>> s = index_set({1,2}); s.sign_of_square()
-1
```

Definition at line 373 of file PyClical.pyx.

References PyClical.index_set.instance.

6.18.3 Member Data Documentation

6.18.3.1 instance

PyClical.index_set.instance

Definition at line 94 of file PyClical.pyx.

Referenced by PyClical.clifford.__call__(), PyClical.index_set.__contains__(), PyClical.index_set.__dealloc__(), PyClical.clifford.__dealloc__(), PyClical.index_set.__getitem__(), PyClical.clifford.__getitem__(), PyClical.index_set.__invert__(), PyClical.clifford.__neg__(), PyClical.index_set.__setitem__(), PyClical.clifford.conj(), PyClical.index_set.count(), PyClical.index_set.count_neg(), PyClical.index_set.count_pos(), PyClical.clifford.even(), PyClical.clifford.frame(), PyClical.index_set.hash_fn(), PyClical.clifford.inv(), PyClical.clifford.involute(), PyClical.clifford.isnan(), PyClical.index_set.max(), PyClical.clifford.max_abs(), PyClical.index_set.min(), PyClical.clifford.norm(), PyClical.clifford.odd(), PyClical.clifford.outer_pow(), PyClical.clifford.pow(), PyClical.clifford.pure(), PyClical.clifford.quad(), PyClical.clifford.reverse(), PyClical.clifford.scalar(), PyClical.index_set.sign_of_mult(), PyClical.index_set.sign_of_square(), PyClical.clifford.truncated(), and PyClical.clifford.vector_part().

The documentation for this class was generated from the following file:

- [pyclical/PyClical.pyx](#)

6.19 glucat::index_set_hash< LO, HI > Class Template Reference

```
#include <framed_multi.h>
```

Public Types

- typedef [index_set](#)< LO, HI > [index_set_t](#)

Public Member Functions

- `size_t operator() (index_set_t val) const`

6.19.1 Detailed Description

```
template<const index_t LO, const index_t HI>
class glucat::index_set_hash< LO, HI >
```

Definition at line 126 of file framed_multi.h.

6.19.2 Member Typedef Documentation

6.19.2.1 index_set_t

```
template<const index_t LO, const index_t HI>
typedef index_set<LO,HI> glucat::index_set_hash< LO, HI >::index_set_t
```

Definition at line 129 of file framed_multi.h.

6.19.3 Member Function Documentation

6.19.3.1 operator()()

```
template<const index_t LO, const index_t HI>
size_t glucat::index_set_hash< LO, HI >::operator() (
    index_set_t val ) const [inline]
```

Definition at line 130 of file framed_multi.h.

References `glucat::index_set< LO, HI >::hash_fn()`.

The documentation for this class was generated from the following file:

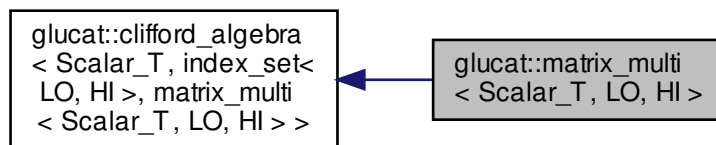
- `glucat/framed_multi.h`

6.20 glucat::matrix_multi< Scalar_T, LO, HI > Class Template Reference

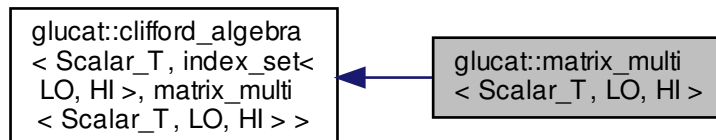
A matrix_multi<Scalar_T,LO,HI> is a matrix approximation to a multivector.

```
#include <framed_multi.h>
```

Inheritance diagram for glucat::matrix_multi< Scalar_T, LO, HI >:



Collaboration diagram for glucat::matrix_multi< Scalar_T, LO, HI >:



Public Types

- typedef [matrix_multi](#) [multivector_t](#)
- typedef [multivector_t](#) [matrix_multi_t](#)
- typedef [Scalar_T](#) [scalar_t](#)
- typedef [index_set< LO, HI >](#) [index_set_t](#)
- typedef std::pair< const [index_set_t](#), [Scalar_T](#) > [term_t](#)
- typedef std::vector< [Scalar_T](#) > [vector_t](#)
- typedef [error< multivector_t >](#) [error_t](#)
- typedef [framed_multi< Scalar_T, LO, HI >](#) [framed_multi_t](#)

Public Member Functions

- [~matrix_multi](#) ()
Destructor.
- [matrix_multi](#) ()
Default constructor.
- `template<typename Other_Scalar_T >`
[matrix_multi](#) (const [matrix_multi](#)< Other_Scalar_T, LO, HI > &val)
Construct a multivector from a multivector with a different scalar type.
- `template<typename Other_Scalar_T >`
[matrix_multi](#) (const [matrix_multi](#)< Other_Scalar_T, LO, HI > &val, const [index_set_t](#) frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a given multivector.
- [matrix_multi](#) (const [multivector_t](#) &val, const [index_set_t](#) frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a given multivector.
- [matrix_multi](#) (const [index_set_t](#) ist, const Scalar_T &crd=Scalar_T(1))
Construct a multivector from an index set and a scalar coordinate.
- [matrix_multi](#) (const [index_set_t](#) ist, const Scalar_T &crd, const [index_set_t](#) frm, const bool prechecked=false)
Construct a multivector, within a given frame, from an index set and a scalar coordinate.
- [matrix_multi](#) (const Scalar_T &scr, const [index_set_t](#) frm=[index_set_t](#)())
Construct a multivector from a scalar (within a frame, if given)
- [matrix_multi](#) (const int scr, const [index_set_t](#) frm=[index_set_t](#)())
Construct a multivector from an int (within a frame, if given)
- [matrix_multi](#) (const [vector_t](#) &vec, const [index_set_t](#) frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a given vector.
- [matrix_multi](#) (const std::string &str)
Construct a multivector from a string: eg: "3+2{1,2}-6.1e-2{2,3}".
- [matrix_multi](#) (const std::string &str, const [index_set_t](#) frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a string: eg: "3+2{1,2}-6.1e-2{2,3}".
- [matrix_multi](#) (const char *str)
Construct a multivector from a char: eg: "3+2{1,2}-6.1e-2{2,3}".*
- [matrix_multi](#) (const char *str, const [index_set_t](#) frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a char: eg: "3+2{1,2}-6.1e-2{2,3}".*
- `template<typename Other_Scalar_T >`
[matrix_multi](#) (const [framed_multi](#)< Other_Scalar_T, LO, HI > &val)
Construct a multivector from a framed_multi_t.
- `template<typename Other_Scalar_T >`
[matrix_multi](#) (const [framed_multi](#)< Other_Scalar_T, LO, HI > &val, const [index_set_t](#) frm, const bool prechecked=false)
Construct a multivector, within a given frame, from a framed_multi_t.
- const [matrix_multi_t](#) [fast_matrix_multi](#) (const [index_set_t](#) frm) const
Use generalized FFT to construct a matrix_multi_t.
- `template<typename Other_Scalar_T >`
const [framed_multi](#)< Other_Scalar_T, LO, HI > [fast_framed_multi](#) () const
Use inverse generalized FFT to construct a framed_multi_t.
- [_GLUCAT_CLIFFORD_ALGEBRA_OPERATIONS](#) [multivector_t](#) & [operator=](#) (const [multivector_t](#) &rhs)
Assignment operator.
- [multivector_t](#) & [operator+=](#) (const [term_t](#) &rhs)
Add a term, if non-zero.

Static Public Member Functions

- static const std::string [classname](#) ()
Class name used in messages.
- static const [matrix_multi_t](#) [random](#) (const [index_set_t](#) frm, Scalar_T fill=Scalar_T(1))
Random multivector within a frame.

Private Types

- typedef ublas::row_major [orientation_t](#)
- typedef ublas::compressed_matrix< int, [orientation_t](#) > [basis_matrix_t](#)
- typedef ublas::compressed_matrix< Scalar_T, [orientation_t](#) > [matrix_t](#)
- typedef matrix_t::size_type [matrix_index_t](#)

Private Member Functions

- template<typename Matrix_T >
[matrix_multi](#) (const Matrix_T &mtx, const [index_set_t](#) frm)
Construct a multivector within a given frame from a given matrix.
- [matrix_multi](#) (const [matrix_t](#) &mtx, const [index_set_t](#) frm)
Construct a multivector within a given frame from a given matrix.
- const [basis_matrix_t](#) [basis_element](#) (const [index_set](#)< LO, HI > &ist) const
Create a basis element matrix within the current frame.

Private Attributes

- [index_set_t](#) [m_frame](#)
Index set representing the frame for the subalgebra which contains the multivector.
- [matrix_t](#) [m_matrix](#)
Matrix value representing the multivector within the folded frame.

Friends

- template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
class [framed_multi](#)
- template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
class [matrix_multi](#)
- const [matrix_multi_t](#) operator* (const [matrix_multi_t](#) &lhs, const [matrix_multi_t](#) &rhs)
- const [matrix_multi_t](#) operator^ (const [matrix_multi_t](#) &lhs, const [matrix_multi_t](#) &rhs)
- const [matrix_multi_t](#) operator & (const [matrix_multi_t](#) &lhs, const [matrix_multi_t](#) &rhs)
- const [matrix_multi_t](#) operator% (const [matrix_multi_t](#) &lhs, const [matrix_multi_t](#) &rhs)
- Scalar_T star (const [matrix_multi_t](#) &lhs, const [matrix_multi_t](#) &rhs)
- const [matrix_multi_t](#) operator/ (const [matrix_multi_t](#) &lhs, const [matrix_multi_t](#) &rhs)
- const [matrix_multi_t](#) operator| (const [matrix_multi_t](#) &lhs, const [matrix_multi_t](#) &rhs)
- std::istream & operator>> (std::istream &s, [multivector_t](#) &val)
- std::ostream & operator<< (std::ostream &os, const [multivector_t](#) &val)
- std::ostream & operator<< (std::ostream &os, const [term_t](#) &term)

- `template<typename Other_Scalar_T, const index_t Other_LO, const index_t Other_HI>`
`const index_set< Other_LO, Other_HI > reframe (const matrix_multi< Other_Scalar_T, Other_LO, Other_HI`
`> &lhs, const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > &rhs, matrix_multi< Other_Scalar_↵`
`T, Other_LO, Other_HI > &lhs_reframed, matrix_multi< Other_Scalar_T, Other_LO, Other_HI > &rhs_↵`
`reframed)`
- `template<typename Other_Scalar_T, const index_t Other_LO, const index_t Other_HI>`
`const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > matrix_sqrt (const matrix_multi< Other_↵`
`Scalar_T, Other_LO, Other_HI > &val, const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > &i)`
- `template<typename Other_Scalar_T, const index_t Other_LO, const index_t Other_HI>`
`const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > matrix_log (const matrix_multi< Other_↵`
`Scalar_T, Other_LO, Other_HI > &val, const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > &i)`

6.20.1 Detailed Description

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
class glucat::matrix_multi< Scalar_T, LO, HI >
```

A `matrix_multi<Scalar_T,LO,HI>` is a matrix approximation to a multivector.

Definition at line 68 of file `framed_multi.h`.

6.20.2 Member Typedef Documentation

6.20.2.1 `basis_matrix_t`

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef ublas::compressed_matrix< int, orientation\_t > glucat::matrix\_multi< Scalar_T, LO, HI
>::basis_matrix_t [private]
```

Definition at line 152 of file `matrix_multi.h`.

6.20.2.2 `error_t`

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef error<multivector\_t> glucat::matrix\_multi< Scalar_T, LO, HI >::error_t
```

Definition at line 142 of file `matrix_multi.h`.

6.20.2.3 framed_multi_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef framed_multi<Scalar_T,LO,HI> glucat::matrix_multi< Scalar_T, LO, HI >::framed_multi_t
```

Definition at line 143 of file matrix_multi.h.

6.20.2.4 index_set_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef index_set<LO,HI> glucat::matrix_multi< Scalar_T, LO, HI >::index_set_t
```

Definition at line 139 of file matrix_multi.h.

6.20.2.5 matrix_index_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef matrix_t::size_type glucat::matrix_multi< Scalar_T, LO, HI >::matrix_index_t [private]
```

Definition at line 159 of file matrix_multi.h.

6.20.2.6 matrix_multi_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef multivector_t glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi_t
```

Definition at line 137 of file matrix_multi.h.

6.20.2.7 matrix_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef ublas::compressed_matrix< Scalar_T, orientation_t > glucat::matrix_multi< Scalar_T,
LO, HI >::matrix_t [private]
```

Definition at line 157 of file matrix_multi.h.

6.20.2.8 multivector_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef matrix_multi glucat::matrix_multi< Scalar_T, LO, HI >::multivector_t
```

Definition at line 136 of file matrix_multi.h.

6.20.2.9 orientation_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef ublas::row_major glucat::matrix_multi< Scalar_T, LO, HI >::orientation_t [private]
```

Definition at line 150 of file matrix_multi.h.

6.20.2.10 scalar_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef Scalar_T glucat::matrix_multi< Scalar_T, LO, HI >::scalar_t
```

Definition at line 138 of file matrix_multi.h.

6.20.2.11 term_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef std::pair<const index_set_t, Scalar_T> glucat::matrix_multi< Scalar_T, LO, HI >↵
::term_t
```

Definition at line 140 of file matrix_multi.h.

6.20.2.12 vector_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAU↵
LT_HI>
typedef std::vector<Scalar_T> glucat::matrix_multi< Scalar_T, LO, HI >::vector_t
```

Definition at line 141 of file matrix_multi.h.

6.20.3 Constructor & Destructor Documentation

6.20.3.1 ~matrix_multi()

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
glucat::matrix_multi< Scalar_T, LO, HI >::~~matrix_multi ( ) [inline]
```

Destructor.

Definition at line 165 of file matrix_multi.h.

6.20.3.2 matrix_multi() [1/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi ( )
```

Default constructor.

Definition at line 97 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi().

6.20.3.3 matrix_multi() [2/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const matrix_multi< Other_Scalar_T, LO, HI > & val )
```

Construct a multivector from a multivector with a different scalar type.

Definition at line 106 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix.

6.20.3.4 matrix_multi() [3/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const matrix_multi< Other_Scalar_T, LO, HI > & val,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a given multivector.

Definition at line 128 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_frame, and glucat::matrix_multi< Scalar_T, LO, HI >↔::m_matrix.

6.20.3.5 matrix_multi() [4/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const multivector_t & val,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a given multivector.

Definition at line 156 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_frame, and glucat::matrix_multi< Scalar_T, LO, HI >↔::m_matrix.

6.20.3.6 matrix_multi() [5/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const index_set_t ist,
    const Scalar_T & crd = Scalar_T(1) )
```

Construct a multivector from an index set and a scalar coordinate.

Definition at line 168 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_frame, and glucat::matrix_multi< Scalar_T, LO, HI >↔::m_matrix.

6.20.3.7 matrix_multi() [6/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const index_set_t ist,
    const Scalar_T & crd,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from an index set and a scalar coordinate.

Definition at line 180 of file matrix_multi_imp.h.

References PyClical::ist, and glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix.

6.20.3.8 matrix_multi() [7/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const Scalar_T & scr,
    const index_set_t frm = index_set_t() )
```

Construct a multivector from a scalar (within a frame, if given)

Definition at line 194 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix.

6.20.3.9 matrix_multi() [8/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const int scr,
    const index_set_t frm = index_set_t() )
```

Construct a multivector from an int (within a frame, if given)

Definition at line 206 of file matrix_multi_imp.h.

6.20.3.10 matrix_multi() [9/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const vector_t & vec,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a given vector.

Definition at line 212 of file matrix_multi_imp.h.

References glucat::index_set< LO, HI >::count(), glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix, glucat::index_set< LO, HI >::max(), and glucat::index_set< LO, HI >::min().

6.20.3.11 `matrix_multi()` [10/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const std::string & str )
```

Construct a multivector from a string: eg: "3+2{1,2}-6.1e-2{2,3}".

Definition at line 239 of file `matrix_multi_imp.h`.

6.20.3.12 `matrix_multi()` [11/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const std::string & str,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a string: eg: "3+2{1,2}-6.1e-2{2,3}".

Definition at line 245 of file `matrix_multi_imp.h`.

6.20.3.13 `matrix_multi()` [12/17]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const char * str ) [inline]
```

Construct a multivector from a char*: eg: "3+2{1,2}-6.1e-2{2,3}".

Definition at line 196 of file `matrix_multi.h`.

References `glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi()`.

6.20.3.14 `matrix_multi()` [13/17]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const char * str,
    const index_set_t frm,
    const bool prechecked = false ) [inline]
```

Construct a multivector, within a given frame, from a char*: eg: "3+2{1,2}-6.1e-2{2,3}".

Definition at line 199 of file `matrix_multi.h`.

References `glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi()`.

6.20.3.15 matrix_multi() [14/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const framed_multi< Other_Scalar_T, LO, HI > & val )
```

Construct a multivector from a framed_multi_t.

Definition at line 252 of file matrix_multi_imp.h.

References PyClical::e(), glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::fast_size_threshold, glucat::matrix_multi< Scalar_T, LO, HI >::m_frame, and glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix.

6.20.3.16 matrix_multi() [15/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const framed_multi< Other_Scalar_T, LO, HI > & val,
    const index_set_t frm,
    const bool prechecked = false )
```

Construct a multivector, within a given frame, from a framed_multi_t.

Definition at line 279 of file matrix_multi_imp.h.

References PyClical::e(), glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::fast_size_threshold, and glucat::clifford_algebra< Scalar_T, index_set< LO, HI >, framed_multi< Scalar_T, LO, HI > >::frame().

6.20.3.17 matrix_multi() [16/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Matrix_T >
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const Matrix_T & mtx,
    const index_set_t frm ) [private]
```

Construct a multivector within a given frame from a given matrix.

Definition at line 307 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix.

6.20.3.18 matrix_multi() [17/17]

```
template<typename Scalar_T , const index_t LO, const index_t HI>
glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi (
    const matrix_t & mtx,
    const index_set_t frm ) [private]
```

Construct a multivector within a given frame from a given matrix.

Definition at line 328 of file matrix_multi_imp.h.

6.20.4 Member Function Documentation

6.20.4.1 basis_element()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI >::basis_matrix_t glucat::matrix_multi< Scalar_T, LO, HI
>::basis_element (
    const index_set< LO, HI > & ist ) const [private]
```

Create a basis element matrix within the current frame.

Definition at line 1243 of file matrix_multi_imp.h.

References glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >::basis_max_count, PyClical::e(), glucat::index_set< LO, HI >::fold(), glucat::gen::generator_table< Matrix_T >::generator(), PyClical::ist, glucat::index_set< LO, HI >::max(), glucat::index_set< LO, HI >::min(), glucat::matrix::mono_prod(), and glucat::offset_level().

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::framed_multi().

6.20.4.2 classname()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const std::string glucat::matrix_multi< Scalar_T, LO, HI >::classname ( ) [static]
```

Class name used in messages.

Definition at line 69 of file matrix_multi_imp.h.

6.20.4.3 fast_framed_multi()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
template<typename Other_Scalar_T >
const framed_multi< Other_Scalar_T, LO, HI > glucat::matrix_multi< Scalar_T, LO, HI >::fast↵
_framed_multi ( ) const
```

Use inverse generalized FFT to construct a framed_multi_t.

Definition at line 1166 of file matrix_multi_imp.h.

References glucat::framed_multi< Scalar_T, LO, HI >::centre_pm4_qp4(), glucat::framed_multi< Scalar_T, LO, HI >::centre_pp4_qm4(), glucat::framed_multi< Scalar_T, LO, HI >::centre_qp1_pm1(), glucat::gen::offset_to_↵super, glucat::pos_mod(), and glucat::framed_multi< Scalar_T, LO, HI >::unfold().

6.20.4.4 fast_matrix_multi()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::matrix_multi< Scalar_T, LO, HI >::fast↵
matrix_multi (
    const index_set_t frm ) const [inline]
```

Use generalized FFT to construct a matrix_multi_t.

Definition at line 1153 of file matrix_multi_imp.h.

6.20.4.5 operator+=()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
matrix_multi< Scalar_T, LO, HI > & glucat::matrix_multi< Scalar_T, LO, HI >::operator+= (
    const term_t & rhs ) [inline]
```

Add a term, if non-zero.

Geometric sum.

Geometric sum of multivector and scalar.

Definition at line 470 of file matrix_multi_imp.h.

6.20.4.6 operator=()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
matrix_multi< Scalar_T, LO, HI > & glucat::matrix_multi< Scalar_T, LO, HI >::operator= (
    const multivector_t & rhs )
```

Assignment operator.

Definition at line 336 of file matrix_multi_imp.h.

References glucat::matrix_multi< Scalar_T, LO, HI >::m_frame, and glucat::matrix_multi< Scalar_T, LO, HI >↵::m_matrix.

6.20.4.7 random()

```
template<typename Scalar_T , const index_t LO, const index_t HI>
const matrix_multi< Scalar_T, LO, HI > glucat::matrix_multi< Scalar_T, LO, HI >::random (
    const index_set_t frm,
    Scalar_T fill = Scalar_T(1) ) [static]
```

Random multivector within a frame.

Definition at line 996 of file matrix_multi_imp.h.

References PyClical::fill, and glucat::framed_multi< Scalar_T, LO, HI >::random().

6.20.5 Friends And Related Function Documentation

6.20.5.1 framed_multi

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
friend class framed_multi [friend]
```

Definition at line 145 of file matrix_multi.h.

6.20.5.2 matrix_log

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
const matrix_multi<Other_Scalar_T,Other_LO,Other_HI> matrix_log (
    const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > & val,
    const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > & i ) [friend]
```

6.20.5.3 matrix_multi

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
friend class matrix_multi [friend]
```

Definition at line 147 of file matrix_multi.h.

6.20.5.4 matrix_sqrt

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
const matrix_multi<Other_Scalar_T,Other_LO,Other_HI> matrix_sqrt (
    const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > & val,
    const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > & i ) [friend]
```

6.20.5.5 operator &

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const matrix_multi_t operator& (
    const matrix_multi_t & lhs,
    const matrix_multi_t & rhs ) [friend]
```

6.20.5.6 operator%

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const matrix_multi_t operator% (
    const matrix_multi_t & lhs,
    const matrix_multi_t & rhs ) [friend]
```

6.20.5.7 operator*

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const matrix_multi_t operator* (
    const matrix_multi_t & lhs,
    const matrix_multi_t & rhs ) [friend]
```

6.20.5.8 operator/

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const matrix_multi_t operator/ (
    const matrix_multi_t & lhs,
    const matrix_multi_t & rhs ) [friend]
```

6.20.5.9 operator<< [1/2]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
std::ostream& operator<< (
    std::ostream & os,
    const multivector_t & val ) [friend]
```

6.20.5.10 operator<< [2/2]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
std::ostream& operator<< (
    std::ostream & os,
    const term_t & term ) [friend]
```

6.20.5.11 operator>>

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
std::istream& operator>> (
    std::istream & s,
    multivector_t & val ) [friend]
```

6.20.5.12 operator^

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const matrix_multi_t operator^ (
    const matrix_multi_t & lhs,
    const matrix_multi_t & rhs ) [friend]
```

6.20.5.13 operator" |

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
const matrix_multi_t operator| (
    const matrix_multi_t & lhs,
    const matrix_multi_t & rhs ) [friend]
```

6.20.5.14 reframe

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
template<typename Other_Scalar_T , const index_t Other_LO, const index_t Other_HI>
const index_set<Other_LO,Other_HI> reframe (
    const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > & lhs,
    const matrix_multi< Other_Scalar_T, Other_LO, Other_HI > & rhs,
    matrix_multi< Other_Scalar_T, Other_LO, Other_HI > & lhs_reframed,
    matrix_multi< Other_Scalar_T, Other_LO, Other_HI > & rhs_reframed ) [friend]
```

6.20.5.15 star

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
Scalar_T star (
    const matrix_multi_t & lhs,
    const matrix_multi_t & rhs ) [friend]
```

6.20.6 Member Data Documentation

6.20.6.1 m_frame

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
index_set_t glucat::matrix_multi< Scalar_T, LO, HI >::m_frame [private]
```

Index set representing the frame for the subalgebra which contains the multivector.

Definition at line 275 of file matrix_multi.h.

Referenced by glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi(), glucat::operator*(), glucat::operator/(), glucat::matrix_multi< Scalar_T, LO, HI >::operator=(), and glucat::reframe().

6.20.6.2 m_matrix

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
matrix_t glucat::matrix_multi< Scalar_T, LO, HI >::m_matrix [private]
```

Matrix value representing the multivector within the folded frame.

Definition at line 277 of file matrix_multi.h.

Referenced by glucat::framed_multi< Scalar_T, LO, HI >::framed_multi(), glucat::matrix_multi< Scalar_T, LO, HI >::matrix_multi(), glucat::operator*(), and glucat::matrix_multi< Scalar_T, LO, HI >::operator=().

The documentation for this class was generated from the following files:

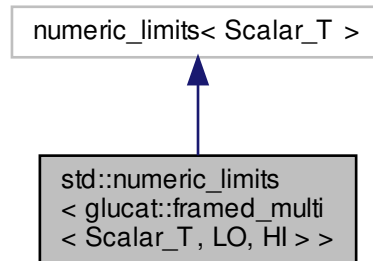
- glucat/framed_multi.h
- glucat/matrix_multi.h
- glucat/matrix_multi_imp.h

6.21 `std::numeric_limits< glucat::framed_multi< Scalar_T, LO, HI > >` Struct Template Reference

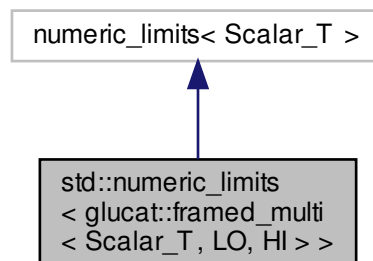
Numeric limits for `framed_multi` inherit limits for the corresponding scalar type.

```
#include <framed_multi.h>
```

Inheritance diagram for `std::numeric_limits< glucat::framed_multi< Scalar_T, LO, HI > >`:



Collaboration diagram for `std::numeric_limits< glucat::framed_multi< Scalar_T, LO, HI > >`:



6.21.1 Detailed Description

```
template<typename Scalar_T, const glucat::index_t LO, const glucat::index_t HI>
struct std::numeric_limits< glucat::framed_multi< Scalar_T, LO, HI > >
```

Numeric limits for `framed_multi` inherit limits for the corresponding scalar type.

Definition at line 374 of file `framed_multi.h`.

The documentation for this struct was generated from the following file:

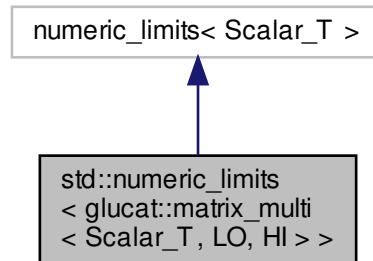
- [glucat/framed_multi.h](#)

6.22 std::numeric_limits< glucat::matrix_multi< Scalar_T, LO, HI > > Struct Template Reference

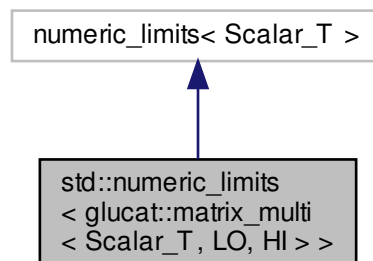
Numeric limits for matrix_multi inherit limits for the corresponding scalar type.

```
#include <matrix_multi.h>
```

Inheritance diagram for std::numeric_limits< glucat::matrix_multi< Scalar_T, LO, HI > >:



Collaboration diagram for std::numeric_limits< glucat::matrix_multi< Scalar_T, LO, HI > >:



6.22.1 Detailed Description

```
template<typename Scalar_T, const glucat::index_t LO, const glucat::index_t HI>
struct std::numeric_limits< glucat::matrix_multi< Scalar_T, LO, HI > >
```

Numeric limits for matrix_multi inherit limits for the corresponding scalar type.

Definition at line 293 of file matrix_multi.h.

The documentation for this struct was generated from the following file:

- glucat/[matrix_multi.h](#)

6.23 glucat::numeric_traits< Scalar_T > Class Template Reference

Extra traits which extend numeric limits.

```
#include <scalar.h>
```

Classes

- struct [demoted](#)
Demoted type for long double.
- struct [promoted](#)
Promoted type.

Public Member Functions

- `template<>`
`long double pi ()`
Pi for long double.
- `template<>`
`long double ln_2 ()`
log(2) for long double
- `template<>`
`float to_scalar_t (const Other_Scalar_T &val)`
Extra traits which extend numeric limits.
- `template<>`
`double to_scalar_t (const Other_Scalar_T &val)`
Cast to double.
- `template<>`
`long double to_scalar_t (const dd_real &val)`
Cast to long double.
- `template<>`
`long double to_scalar_t (const qd_real &val)`
Cast to long double.
- `template<>`
`dd_real to_scalar_t (const long double &val)`
Cast to dd_real.
- `template<>`
`dd_real to_scalar_t (const qd_real &val)`
Cast to dd_real.
- `template<>`
`qd_real to_scalar_t (const long double &val)`
Cast to qd_real.
- `template<>`
`qd_real to_scalar_t (const dd_real &val)`
Cast to qd_real.

Static Public Member Functions

- static bool [isInf](#) (const Scalar_T &val)
Smart isinf.
- static bool [isNaN](#) (const Scalar_T &val)
Smart isnan.
- static bool [isNaN_or_isInf](#) (const Scalar_T &val)
Smart isnan or isinf.
- static Scalar_T [NaN](#) ()
Smart NaN.
- static int [to_int](#) (const Scalar_T &val)
Cast to int.
- static double [to_double](#) (const Scalar_T &val)
Cast to double.
- template<typename Other_Scalar_T >
static Scalar_T [to_scalar_t](#) (const Other_Scalar_T &val)
Cast to Scalar_T.
- static Scalar_T [fmod](#) (const Scalar_T &lhs, const Scalar_T &rhs)
Modulo function for scalar.
- static Scalar_T [conj](#) (const Scalar_T &val)
Complex conjugate of scalar.
- static Scalar_T [real](#) (const Scalar_T &val)
Real part of scalar.
- static Scalar_T [imag](#) (const Scalar_T &val)
Imaginary part of scalar.
- static Scalar_T [abs](#) (const Scalar_T &val)
Absolute value of scalar.
- static Scalar_T [pi](#) ()
Pi.
- static Scalar_T [ln_2](#) ()
log(2)
- static Scalar_T [pow](#) (const Scalar_T &val, int n)
Integer power.
- static Scalar_T [sqrt](#) (const Scalar_T &val)
Square root of scalar.
- static Scalar_T [exp](#) (const Scalar_T &val)
Exponential.
- static Scalar_T [log](#) (const Scalar_T &val)
Logarithm of scalar.
- static Scalar_T [log2](#) (const Scalar_T &val)
Log base 2.
- static Scalar_T [cos](#) (const Scalar_T &val)
Cosine of scalar.
- static Scalar_T [acos](#) (const Scalar_T &val)
Inverse cosine of scalar.
- static Scalar_T [cosh](#) (const Scalar_T &val)
Hyperbolic cosine of scalar.
- static Scalar_T [sin](#) (const Scalar_T &val)
Sine of scalar.
- static Scalar_T [asin](#) (const Scalar_T &val)
Inverse sine of scalar.

- static Scalar_T [sinh](#) (const Scalar_T &val)
Hyperbolic sine of scalar.
- static Scalar_T [tan](#) (const Scalar_T &val)
Tangent of scalar.
- static Scalar_T [atan](#) (const Scalar_T &val)
Inverse tangent of scalar.
- static Scalar_T [tanh](#) (const Scalar_T &val)
Hyperbolic tangent of scalar.

Static Private Member Functions

- static bool [isInf](#) (const Scalar_T &val, [bool_to_type](#)< false >)
Smart isinf specialised for Scalar_T without infinity.
- static bool [isInf](#) (const Scalar_T &val, [bool_to_type](#)< true >)
Smart isinf specialised for Scalar_T with infinity.
- static bool [isNaN](#) (const Scalar_T &val, [bool_to_type](#)< false >)
Smart isnan specialised for Scalar_T without quiet NaN.
- static bool [isNaN](#) (const Scalar_T &val, [bool_to_type](#)< true >)
Smart isnan specialised for Scalar_T with quiet NaN.

6.23.1 Detailed Description

```
template<typename Scalar_T>
class glucat::numeric_traits< Scalar_T >
```

Extra traits which extend numeric limits.

Definition at line 46 of file scalar.h.

6.23.2 Member Function Documentation

6.23.2.1 [abs\(\)](#)

```
template<typename Scalar_T >
static Scalar_T glucat::numeric\_traits< Scalar_T >::abs (
    const Scalar_T & val ) [inline], [static]
```

Absolute value of scalar.

Definition at line 181 of file scalar.h.

References [UBLAS_ABS](#).

6.23.2.2 acos()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::acos (
    const Scalar_T & val ) [inline], [static]
```

Inverse cosine of scalar.

Definition at line 244 of file scalar.h.

References glucat::acos().

6.23.2.3 asin()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::asin (
    const Scalar_T & val ) [inline], [static]
```

Inverse sine of scalar.

Definition at line 265 of file scalar.h.

References glucat::asin().

6.23.2.4 atan()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::atan (
    const Scalar_T & val ) [inline], [static]
```

Inverse tangent of scalar.

Definition at line 286 of file scalar.h.

References glucat::atan().

6.23.2.5 conj()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::conj (
    const Scalar_T & val ) [inline], [static]
```

Complex conjugate of scalar.

Definition at line 160 of file scalar.h.

6.23.2.6 cos()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::cos (
    const Scalar_T & val ) [inline], [static]
```

Cosine of scalar.

Definition at line 237 of file scalar.h.

References glucat::cos().

6.23.2.7 cosh()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::cosh (
    const Scalar_T & val ) [inline], [static]
```

Hyperbolic cosine of scalar.

Definition at line 251 of file scalar.h.

References glucat::cosh().

6.23.2.8 exp()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::exp (
    const Scalar_T & val ) [inline], [static]
```

Exponential.

Definition at line 216 of file scalar.h.

References glucat::exp().

6.23.2.9 fmod()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::fmod (
    const Scalar_T & lhs,
    const Scalar_T & rhs ) [inline], [static]
```

Modulo function for scalar.

Definition at line 153 of file scalar.h.

6.23.2.10 imag()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::imag (
    const Scalar_T & val ) [inline], [static]
```

Imaginary part of scalar.

Definition at line 174 of file scalar.h.

6.23.2.11 isInf() [1/3]

```
template<typename Scalar_T >
static bool glucat::numeric_traits< Scalar_T >::isInf (
    const Scalar_T & val,
    bool_to_type< false > ) [inline], [static], [private]
```

Smart isinf specialised for Scalar_T without infinity.

Definition at line 53 of file scalar.h.

Referenced by glucat::numeric_traits< Scalar_T >::isInf(), and glucat::numeric_traits< Scalar_T >::isNaN_or_isInf().

6.23.2.12 isInf() [2/3]

```
template<typename Scalar_T >
static bool glucat::numeric_traits< Scalar_T >::isInf (
    const Scalar_T & val,
    bool_to_type< true > ) [inline], [static], [private]
```

Smart isinf specialised for Scalar_T with infinity.

Definition at line 60 of file scalar.h.

References _GLUCAT_ISINF.

6.23.2.13 isInf() [3/3]

```
template<typename Scalar_T >
static bool glucat::numeric_traits< Scalar_T >::isInf (
    const Scalar_T & val ) [inline], [static]
```

Smart isinf.

Definition at line 82 of file scalar.h.

References glucat::numeric_traits< Scalar_T >::isInf().

6.23.2.14 isNaN() [1/3]

```
template<typename Scalar_T >
static bool glucat::numeric_traits< Scalar_T >::isNaN (
    const Scalar_T & val,
    bool_to_type< false > ) [inline], [static], [private]
```

Smart isnan specialised for Scalar_T without quiet NaN.

Definition at line 67 of file scalar.h.

Referenced by glucat::numeric_traits< Scalar_T >::isNaN(), and glucat::numeric_traits< Scalar_T >::isNaN_or_isInf().

6.23.2.15 isNaN() [2/3]

```
template<typename Scalar_T >
static bool glucat::numeric_traits< Scalar_T >::isNaN (
    const Scalar_T & val,
    bool_to_type< true > ) [inline], [static], [private]
```

Smart isnan specialised for Scalar_T with quiet NaN.

Definition at line 74 of file scalar.h.

References _GLUCAT_ISNAN.

6.23.2.16 isNaN() [3/3]

```
template<typename Scalar_T >
static bool glucat::numeric_traits< Scalar_T >::isNaN (
    const Scalar_T & val ) [inline], [static]
```

Smart isnan.

Definition at line 92 of file scalar.h.

References glucat::numeric_traits< Scalar_T >::isNaN().

6.23.2.17 isNaN_or_isInf()

```
template<typename Scalar_T >
static bool glucat::numeric_traits< Scalar_T >::isNaN_or_isInf (
    const Scalar_T & val ) [inline], [static]
```

Smart isnan or isinf.

Definition at line 102 of file scalar.h.

References glucat::numeric_traits< Scalar_T >::isInf(), and glucat::numeric_traits< Scalar_T >::isNaN().

6.23.2.18 `ln_2()` [1/2]

```
template<>
long double glucat::numeric_traits< long double >::ln_2 ( ) [inline]
```

`log(2)` for long double

Definition at line 83 of file `long_double.h`.

References `glucat::l_ln2`.

6.23.2.19 `ln_2()` [2/2]

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::ln_2 ( ) [inline], [static]
```

`log(2)`

Definition at line 195 of file `scalar.h`.

Referenced by `glucat::numeric_traits< Scalar_T >::log2()`.

6.23.2.20 `log()`

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::log (
    const Scalar_T & val ) [inline], [static]
```

Logarithm of scalar.

Definition at line 223 of file `scalar.h`.

References `glucat::log()`.

Referenced by `glucat::numeric_traits< Scalar_T >::log2()`.

6.23.2.21 `log2()`

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::log2 (
    const Scalar_T & val ) [inline], [static]
```

Log base 2.

Definition at line 230 of file `scalar.h`.

References `glucat::numeric_traits< Scalar_T >::ln_2()`, and `glucat::numeric_traits< Scalar_T >::log()`.

Referenced by `glucat::log2()`.

6.23.2.22 NaN()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::NaN ( ) [inline], [static]
```

Smart NaN.

Definition at line 114 of file scalar.h.

References glucat::log().

Referenced by glucat::matrix::trace().

6.23.2.23 pi() [1/2]

```
template<>
long double glucat::numeric_traits< long double >::pi ( ) [inline]
```

Pi for long double.

Definition at line 75 of file long_double.h.

References glucat::l_pi.

6.23.2.24 pi() [2/2]

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::pi ( ) [inline], [static]
```

Pi.

Definition at line 188 of file scalar.h.

Referenced by glucat::matrix::classify_eigenvalues().

6.23.2.25 pow()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::pow (
    const Scalar_T & val,
    int n ) [inline], [static]
```

Integer power.

Definition at line 202 of file scalar.h.

References glucat::pow().

6.23.2.26 real()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::real (
    const Scalar_T & val )    [inline], [static]
```

Real part of scalar.

Definition at line 167 of file scalar.h.

6.23.2.27 sin()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::sin (
    const Scalar_T & val )    [inline], [static]
```

Sine of scalar.

Definition at line 258 of file scalar.h.

References glucat::sin().

6.23.2.28 sinh()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::sinh (
    const Scalar_T & val )    [inline], [static]
```

Hyperbolic sine of scalar.

Definition at line 272 of file scalar.h.

References glucat::sinh().

6.23.2.29 sqrt()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::sqrt (
    const Scalar_T & val )    [inline], [static]
```

Square root of scalar.

Definition at line 209 of file scalar.h.

References UBLAS_SQRT.

Referenced by glucat::abs().

6.23.2.30 tan()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::tan (
    const Scalar_T & val ) [inline], [static]
```

Tangent of scalar.

Definition at line 279 of file scalar.h.

References glucat::tan().

6.23.2.31 tanh()

```
template<typename Scalar_T >
static Scalar_T glucat::numeric_traits< Scalar_T >::tanh (
    const Scalar_T & val ) [inline], [static]
```

Hyperbolic tangent of scalar.

Definition at line 293 of file scalar.h.

References glucat::tanh().

6.23.2.32 to_double()

```
template<typename Scalar_T >
static double glucat::numeric_traits< Scalar_T >::to_double (
    const Scalar_T & val ) [inline], [static]
```

Cast to double.

Definition at line 132 of file scalar.h.

Referenced by glucat::operator<<(), and glucat::numeric_traits< Scalar_T >::to_scalar_t().

6.23.2.33 to_int()

```
template<typename Scalar_T >
static int glucat::numeric_traits< Scalar_T >::to_int (
    const Scalar_T & val ) [inline], [static]
```

Cast to int.

Definition at line 125 of file scalar.h.

6.23.2.34 to_scalar_t() [1/9]

```
template<>
float glucat::numeric_traits< float >::to_scalar_t (
    const Other_Scalar_T & val ) [inline]
```

Extra traits which extend numeric limits.

Cast to float

Definition at line 52 of file scalar_imp.h.

References glucat::numeric_traits< Scalar_T >::to_double().

6.23.2.35 to_scalar_t() [2/9]

```
template<>
double glucat::numeric_traits< double >::to_scalar_t (
    const Other_Scalar_T & val ) [inline]
```

Cast to double.

Definition at line 61 of file scalar_imp.h.

References glucat::numeric_traits< Scalar_T >::to_double().

6.23.2.36 to_scalar_t() [3/9]

```
template<>
long double glucat::numeric_traits< long double >::to_scalar_t (
    const dd_real & val ) [inline]
```

Cast to long double.

Definition at line 71 of file scalar_imp.h.

6.23.2.37 to_scalar_t() [4/9]

```
template<>
long double glucat::numeric_traits< long double >::to_scalar_t (
    const qd_real & val ) [inline]
```

Cast to long double.

Definition at line 80 of file scalar_imp.h.

6.23.2.38 to_scalar_t() [5/9]

```
template<>
dd_real glucat::numeric_traits< dd_real >::to_scalar_t (
    const long double & val ) [inline]
```

Cast to dd_real.

Definition at line 89 of file scalar_imp.h.

6.23.2.39 to_scalar_t() [6/9]

```
template<>
dd_real glucat::numeric_traits< dd_real >::to_scalar_t (
    const qd_real & val ) [inline]
```

Cast to dd_real.

Definition at line 98 of file scalar_imp.h.

6.23.2.40 to_scalar_t() [7/9]

```
template<>
qd_real glucat::numeric_traits< qd_real >::to_scalar_t (
    const long double & val ) [inline]
```

Cast to qd_real.

Definition at line 107 of file scalar_imp.h.

6.23.2.41 to_scalar_t() [8/9]

```
template<>
qd_real glucat::numeric_traits< qd_real >::to_scalar_t (
    const dd_real & val ) [inline]
```

Cast to qd_real.

Definition at line 116 of file scalar_imp.h.

6.23.2.42 `to_scalar_t()` [9/9]

```
template<typename Scalar_T >
template<typename Other_Scalar_T >
static Scalar_T glucat::numeric\_traits< Scalar\_T >::to\_scalar\_t (
    const Other_Scalar_T & val ) [inline], [static]
```

Cast to `Scalar_T`.

Definition at line 140 of file `scalar.h`.

Referenced by `glucat::matrix::nork_range()`, `glucat::to_demote()`, and `glucat::to_promote()`.

The documentation for this class was generated from the following file:

- [glucat/scalar.h](#)

6.24 `glucat::numeric_traits< Scalar_T >::promoted` Struct Reference

Promoted type.

```
#include <scalar.h>
```

Public Types

- typedef double [type](#)

6.24.1 Detailed Description

```
template<typename Scalar_T>
struct glucat::numeric_traits< Scalar_T >::promoted
```

Promoted type.

Definition at line 144 of file `scalar.h`.

6.24.2 Member Typedef Documentation

6.24.2.1 `type`

```
template<typename Scalar_T >
typedef double glucat::numeric\_traits< Scalar\_T >::promoted::type
```

Definition at line 144 of file `scalar.h`.

The documentation for this struct was generated from the following file:

- [glucat/scalar.h](#)

6.25 glucat::random_generator< Scalar_T > Class Template Reference

Random number generator with single instance per Scalar_T.

```
#include <random.h>
```

Public Member Functions

- Scalar_T [uniform](#) ()
- Scalar_T [normal](#) ()

Static Public Member Functions

- static [random_generator](#) & [generator](#) ()
Single instance of Random number generator.

Private Member Functions

- [random_generator](#) (const [random_generator](#) &)
- [random_generator](#) & [operator=](#) (const [random_generator](#) &)
- [random_generator](#) ()
- [~random_generator](#) ()

Private Attributes

- std::mt19937 [uint_gen](#)
- std::uniform_real_distribution< double > [uniform_dist](#)
- std::normal_distribution< double > [normal_dist](#)

Static Private Attributes

- static const unsigned long [seed](#) = 19590921UL

Friends

- class [friend_for_private_destructor](#)

6.25.1 Detailed Description

```
template<typename Scalar_T>  
class glucat::random_generator< Scalar_T >
```

Random number generator with single instance per Scalar_T.

Definition at line 47 of file random.h.

6.25.2 Constructor & Destructor Documentation

6.25.2.1 random_generator() [1/2]

```
template<typename Scalar_T >
glucat::random_generator< Scalar_T >::random_generator (
    const random_generator< Scalar_T > & ) [private]
```

6.25.2.2 random_generator() [2/2]

```
template<typename Scalar_T >
glucat::random_generator< Scalar_T >::random_generator ( ) [inline], [private]
```

Definition at line 83 of file random.h.

References glucat::random_generator< Scalar_T >::seed.

6.25.2.3 ~random_generator()

```
template<typename Scalar_T >
glucat::random_generator< Scalar_T >::~~random_generator ( ) [inline], [private]
```

Definition at line 87 of file random.h.

6.25.3 Member Function Documentation

6.25.3.1 generator()

```
template<typename Scalar_T >
static random_generator& glucat::random_generator< Scalar_T >::generator ( ) [inline], [static]
```

Single instance of Random number generator.

Definition at line 51 of file random.h.

6.25.3.2 normal()

```
template<typename Scalar_T >
Scalar_T glucat::random_generator< Scalar_T >::normal ( ) [inline]
```

Definition at line 93 of file random.h.

References glucat::random_generator< Scalar_T >::normal_dist.

6.25.3.3 operator=()

```
template<typename Scalar_T >
random_generator& glucat::random_generator< Scalar_T >::operator= (
    const random_generator< Scalar_T > & ) [private]
```

6.25.3.4 uniform()

```
template<typename Scalar_T >
Scalar_T glucat::random_generator< Scalar_T >::uniform ( ) [inline]
```

Definition at line 91 of file random.h.

References glucat::random_generator< Scalar_T >::uniform_dist.

6.25.4 Friends And Related Function Documentation

6.25.4.1 friend_for_private_destructor

```
template<typename Scalar_T >
friend class friend_for_private_destructor [friend]
```

Friend declaration to avoid compiler warning: "... only defines a private destructor and has no friends" Ref: Carlos O'Ryan, ACE <http://doc.ece.uci.edu>

Definition at line 56 of file random.h.

6.25.5 Member Data Documentation

6.25.5.1 normal_dist

```
template<typename Scalar_T >
std::normal_distribution<double> glucat::random_generator< Scalar_T >::normal_dist [private]
```

Definition at line 81 of file random.h.

Referenced by glucat::random_generator< Scalar_T >::normal().

6.25.5.2 seed

```
template<typename Scalar_T >
const unsigned long glucat::random_generator< Scalar_T >::seed = 19590921UL [static], [private]
```

Definition at line 59 of file random.h.

Referenced by glucat::random_generator< Scalar_T >::random_generator().

6.25.5.3 uint_gen

```
template<typename Scalar_T >
std::mt19937 glucat::random_generator< Scalar_T >::uint_gen [private]
```

Definition at line 79 of file random.h.

6.25.5.4 uniform_dist

```
template<typename Scalar_T >
std::uniform_real_distribution<double> glucat::random_generator< Scalar_T >::uniform_dist
[private]
```

Definition at line 80 of file random.h.

Referenced by glucat::random_generator< Scalar_T >::uniform().

The documentation for this class was generated from the following file:

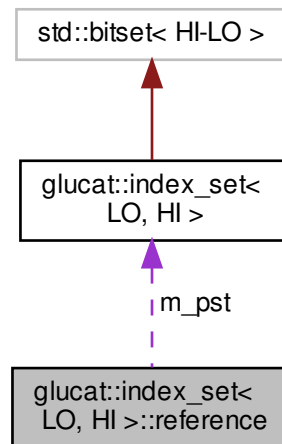
- [glucat/random.h](#)

6.26 glucat::index_set< LO, HI >::reference Class Reference

Index set member reference.

```
#include <index_set.h>
```

Collaboration diagram for glucat::index_set< LO, HI >::reference:



Public Member Functions

- [reference](#) ([index_set_t](#) &ist, [index_t](#) idx)
index_set reference
- [~reference](#) ()
- [reference](#) & [operator=](#) (const bool x)
for b[i] = x;
- [reference](#) & [operator=](#) (const [reference](#) &j)
for b[i] = b[j];
- bool [operator~](#) () const
Flips a bit.
- [operator bool](#) () const
for x = b[i];
- [reference](#) & [flip](#) ()
for b[i].flip();

Private Member Functions

- [reference](#) ()
Private default constructor is left undefined.

Private Attributes

- [index_set_t](#) * m_pst
- [index_t](#) m_idx

Friends

- class [index_set](#)

6.26.1 Detailed Description

```
template<const index_t LO, const index_t HI>
class glucat::index_set< LO, HI >::reference
```

Index set member reference.

Definition at line 177 of file [index_set.h](#).

6.26.2 Constructor & Destructor Documentation

6.26.2.1 [reference\(\)](#) [1/2]

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::reference::reference ( ) [private]
```

Private default constructor is left undefined.

6.26.2.2 [reference\(\)](#) [2/2]

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::reference::reference (
    index_set_t & ist,
    index_t idx ) [inline]
```

[index_set](#) reference

Definition at line 983 of file [index_set_imp.h](#).

6.26.2.3 ~reference()

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::reference::~reference ( ) [inline]
```

Definition at line 184 of file index_set.h.

6.26.3 Member Function Documentation

6.26.3.1 flip()

```
template<const index_t LO, const index_t HI>
index_set< LO, HI >::reference & glucat::index_set< LO, HI >::reference::flip ( ) [inline]
```

for b[i].flip();

Definition at line 1036 of file index_set_imp.h.

References glucat::index_set< LO, HI >::reference::flip().

Referenced by glucat::index_set< LO, HI >::reference::flip().

6.26.3.2 operator bool()

```
template<const index_t LO, const index_t HI>
glucat::index_set< LO, HI >::reference::operator bool ( ) const [inline]
```

for x = b[i];

Definition at line 1028 of file index_set_imp.h.

6.26.3.3 operator=() [1/2]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI >::reference & glucat::index_set< LO, HI >::reference::operator= (
    const bool x ) [inline]
```

for b[i] = x;

Definition at line 993 of file index_set_imp.h.

6.26.3.4 operator=() [2/2]

```
template<const index_t LO, const index_t HI>
index_set< LO, HI >::reference & glucat::index_set< LO, HI >::reference::operator= (
    const reference & j ) [inline]
```

for b[i] = b[j];

Definition at line 1007 of file index_set_imp.h.

References glucat::index_set< LO, HI >::reference::m_idx, and glucat::index_set< LO, HI >::reference::m_pst.

6.26.3.5 operator~()

```
template<const index_t LO, const index_t HI>
bool glucat::index_set< LO, HI >::reference::operator~ ( ) const [inline]
```

Flips a bit.

flips the bit

Definition at line 1021 of file index_set_imp.h.

6.26.4 Friends And Related Function Documentation**6.26.4.1 index_set**

```
template<const index_t LO, const index_t HI>
friend class index_set [friend]
```

Definition at line 178 of file index_set.h.

6.26.5 Member Data Documentation**6.26.5.1 m_idx**

```
template<const index_t LO, const index_t HI>
index_t glucat::index_set< LO, HI >::reference::m_idx [private]
```

Definition at line 198 of file index_set.h.

Referenced by glucat::index_set< LO, HI >::reference::operator=().

6.26.5.2 m_pst

```
template<const index_t LO, const index_t HI>
index_set_t* glucat::index_set< LO, HI >::reference::m_pst [private]
```

Definition at line 197 of file index_set.h.

Referenced by glucat::index_set< LO, HI >::reference::operator=().

The documentation for this class was generated from the following files:

- glucat/index_set.h
- glucat/index_set_imp.h

6.27 glucat::sorted_range< Map_T, Sorted_Map_T > Class Template Reference

Sorted range for use with output.

```
#include <framed_multi_imp.h>
```

Public Types

- typedef Map_T [map_t](#)
- typedef Sorted_Map_T [sorted_map_t](#)
- typedef Sorted_Map_T::const_iterator [sorted_iterator](#)

Public Member Functions

- [sorted_range](#) (Sorted_Map_T &sorted_val, const Map_T &val)

Public Attributes

- [sorted_iterator](#) [sorted_begin](#)
- [sorted_iterator](#) [sorted_end](#)

6.27.1 Detailed Description

```
template<typename Map_T, typename Sorted_Map_T>
class glucat::sorted_range< Map_T, Sorted_Map_T >
```

Sorted range for use with output.

Definition at line 1326 of file framed_multi_imp.h.

6.27.2 Member Typedef Documentation

6.27.2.1 map_t

```
template<typename Map_T, typename Sorted_Map_T>
typedef Map_T glucat::sorted_range< Map_T, Sorted_Map_T >::map_t
```

Definition at line 1329 of file framed_multi_imp.h.

6.27.2.2 sorted_iterator

```
template<typename Map_T, typename Sorted_Map_T>
typedef Sorted_Map_T::const_iterator glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_iterator
```

Definition at line 1331 of file framed_multi_imp.h.

6.27.2.3 sorted_map_t

```
template<typename Map_T, typename Sorted_Map_T>
typedef Sorted_Map_T glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_map_t
```

Definition at line 1330 of file framed_multi_imp.h.

6.27.3 Constructor & Destructor Documentation

6.27.3.1 sorted_range()

```
template<typename Map_T, typename Sorted_Map_T>
glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_range (
    Sorted_Map_T & sorted_val,
    const Map_T & val ) [inline]
```

Definition at line 1333 of file framed_multi_imp.h.

References glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_begin, and glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_end.

6.27.4 Member Data Documentation

6.27.4.1 sorted_begin

```
template<typename Map_T, typename Sorted_Map_T>
sorted_iterator glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_begin
```

Definition at line 1343 of file framed_multi_imp.h.

Referenced by glucat::operator<<(), and glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_range().

6.27.4.2 sorted_end

```
template<typename Map_T, typename Sorted_Map_T>
sorted_iterator glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_end
```

Definition at line 1344 of file framed_multi_imp.h.

Referenced by glucat::operator<<(), and glucat::sorted_range< Map_T, Sorted_Map_T >::sorted_range().

The documentation for this class was generated from the following file:

- glucat/framed_multi_imp.h

6.28 glucat::sorted_range< Sorted_Map_T, Sorted_Map_T > Class Template Reference

```
#include <framed_multi_imp.h>
```

Public Types

- typedef Sorted_Map_T [map_t](#)
- typedef Sorted_Map_T [sorted_map_t](#)
- typedef Sorted_Map_T::const_iterator [sorted_iterator](#)

Public Member Functions

- [sorted_range](#) (Sorted_Map_T &sorted_val, const Sorted_Map_T &val)

Public Attributes

- [sorted_iterator](#) [sorted_begin](#)
- [sorted_iterator](#) [sorted_end](#)

6.28.1 Detailed Description

```
template<typename Sorted_Map_T>
class glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >
```

Definition at line 1348 of file framed_multi_imp.h.

6.28.2 Member Typedef Documentation

6.28.2.1 map_t

```
template<typename Sorted_Map_T >
typedef Sorted_Map_T glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >::map_t
```

Definition at line 1351 of file framed_multi_imp.h.

6.28.2.2 sorted_iterator

```
template<typename Sorted_Map_T >
typedef Sorted_Map_T::const_iterator glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >↔
::sorted_iterator
```

Definition at line 1353 of file framed_multi_imp.h.

6.28.2.3 sorted_map_t

```
template<typename Sorted_Map_T >
typedef Sorted_Map_T glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >::sorted_map_t
```

Definition at line 1352 of file framed_multi_imp.h.

6.28.3 Constructor & Destructor Documentation

6.28.3.1 sorted_range()

```
template<typename Sorted_Map_T >
glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >::sorted_range (
    Sorted_Map_T & sorted_val,
    const Sorted_Map_T & val ) [inline]
```

Definition at line 1355 of file framed_multi_imp.h.

6.28.4 Member Data Documentation

6.28.4.1 sorted_begin

```
template<typename Sorted_Map_T >
sorted_iterator glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >::sorted_begin
```

Definition at line 1359 of file framed_multi_imp.h.

6.28.4.2 sorted_end

```
template<typename Sorted_Map_T >
sorted_iterator glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >::sorted_end
```

Definition at line 1360 of file framed_multi_imp.h.

The documentation for this class was generated from the following file:

- [glucat/framed_multi_imp.h](#)

6.29 glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision > Struct Template Reference

Tuning policy.

```
#include <global.h>
```

Public Types

- enum { [mult_matrix_threshold](#) = Mult_Matrix_Threshold }
Minimum index count needed to invoke matrix multiplication algorithm.
- enum { [div_max_steps](#) = Div_Max_Steps }
Maximum steps of iterative refinement in division algorithm.
- enum { [sqrt_max_steps](#) = Sqrt_Max_Steps }
Maximum number of steps in square root iteration.
- enum { [log_max_outer_steps](#) = Log_Max_Outer_Steps }
Maximum number of incomplete square roots in cascade log algorithm.
- enum { [log_max_inner_steps](#) = Log_Max_Inner_Steps }
Maximum number of steps in incomplete square root within cascade log algorithm.
- enum { [basis_max_count](#) = Basis_Max_Count }
Maximum index count of folded frames in basis cache.
- enum { [fast_size_threshold](#) = Fast_Size_Threshold }
Minimum map size needed to invoke generalized FFT.
- enum { [inv_fast_dim_threshold](#) = Inv_Fast_Dim_Threshold }
Minimum matrix dimension needed to invoke inverse generalized FFT.
- enum { [products_size_threshold](#) = Products_Size_Threshold }
Minimum size needed for to invoke faster products algorithms.

- static const [precision_t function_precision](#) = Function_Precision
Precision used for exp, log and sqrt functions.

6.29.1 Detailed Description

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int Div_Max_Steps = DEFAULT_
Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps, unsigned int Log_Max_Outer_Steps = DEFAULT_
Log_Max_Outer_Steps, unsigned int Log_Max_Inner_Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count =
DEFAULT_Basis_Max_Count, unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_
_Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_Products_Size_Threshold,
precision_t Function_Precision = DEFAULT_Function_Precision>
struct glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps,
Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_Threshold, Products_Size_Threshold, Function_Precision >
```

Tuning policy.

Definition at line 151 of file global.h.

6.29.2 Member Enumeration Documentation

6.29.2.1 anonymous enum

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int
Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps,
unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_
Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count,
unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_
Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_
Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum
```

Minimum matrix dimension needed to invoke inverse generalized FFT.

Enumerator

inv_fast_dim_threshold	
------------------------	--

Definition at line 174 of file global.h.

6.29.2.2 anonymous enum

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int
Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps,
```

```

unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_↵
Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count,
unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_↵
Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_↵
Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum

```

Minimum size needed for to invoke faster products algorithms.

Enumerator

products_size_threshold	
-------------------------	--

Definition at line 177 of file global.h.

6.29.2.3 anonymous enum

```

template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int
Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps,
unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_↵
Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count,
unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_↵
Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_↵
Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum

```

Minimum index count needed to invoke matrix multiplication algorithm.

Enumerator

mult_matrix_threshold	
-----------------------	--

Definition at line 155 of file global.h.

6.29.2.4 anonymous enum

```

template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int
Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps,
unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_↵
Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count,
unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_↵
Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_↵
Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum

```

Maximum steps of iterative refinement in division algorithm.

Enumerator

div_max_steps	
---------------	--

Definition at line 158 of file global.h.

6.29.2.5 anonymous enum

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps, unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count, unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum
```

Maximum number of steps in square root iteration.

Enumerator

sqrt_max_steps	
----------------	--

Definition at line 161 of file global.h.

6.29.2.6 anonymous enum

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps, unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count, unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum
```

Maximum number of incomplete square roots in cascade log algorithm.

Enumerator

log_max_outer_steps	
---------------------	--

Definition at line 164 of file global.h.

6.29.2.7 anonymous enum

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int
Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps,
unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_↵
Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count,
unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_↵
Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_↵
Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum
```

Maximum number of steps in incomplete square root within cascade log algorithm.

Enumerator

log_max_inner_steps	
---------------------	--

Definition at line 166 of file global.h.

6.29.2.8 anonymous enum

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int
Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps,
unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_↵
Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count,
unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_↵
Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_↵
Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum
```

Maximum index count of folded frames in basis cache.

Enumerator

basis_max_count	
-----------------	--

Definition at line 169 of file global.h.

6.29.2.9 anonymous enum

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int
Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps,
unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_↵
Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count,
unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_↵
Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_↵
Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
anonymous enum
```

Minimum map size needed to invoke generalized FFT.

Enumerator

fast_size_threshold	
---------------------	--

Definition at line 172 of file global.h.

6.29.3 Member Data Documentation

6.29.3.1 function_precision

```
template<unsigned int Mult_Matrix_Threshold = DEFAULT_Mult_Matrix_Threshold, unsigned int
Div_Max_Steps = DEFAULT_Div_Max_Steps, unsigned int Sqrt_Max_Steps = DEFAULT_Sqrt_Max_Steps,
unsigned int Log_Max_Outer_Steps = DEFAULT_Log_Max_Outer_Steps, unsigned int Log_Max_Inner_↵
Steps = DEFAULT_Log_Max_Inner_Steps, unsigned int Basis_Max_Count = DEFAULT_Basis_Max_Count,
unsigned int Fast_Size_Threshold = DEFAULT_Fast_Size_Threshold, unsigned int Inv_Fast_Dim_↵
Threshold = DEFAULT_Inv_Fast_Dim_Threshold, unsigned int Products_Size_Threshold = DEFAULT_↵
Products_Size_Threshold, precision_t Function_Precision = DEFAULT_Function_Precision>
const precision_t glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_↵
_Max_Outer_Steps, Log_Max_Inner_Steps, Basis_Max_Count, Fast_Size_Threshold, Inv_Fast_Dim_↵
_Threshold, Products_Size_Threshold, Function_Precision >::function_precision = Function_↵
Precision [static]
```

Precision used for exp, log and sqrt functions.

Definition at line 180 of file global.h.

Referenced by glucat::exp(), glucat::log(), and glucat::sqrt().

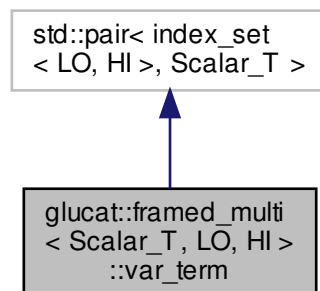
The documentation for this struct was generated from the following file:

- [glucat/global.h](#)

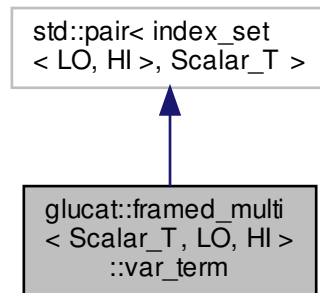
6.30 glucat::framed_multi< Scalar_T, LO, HI >::var_term Class Reference

Variable term.

Inheritance diagram for glucat::framed_multi< Scalar_T, LO, HI >::var_term:



Collaboration diagram for `glucat::framed_multi< Scalar_T, LO, HI >::var_term`:



Public Types

- typedef `std::pair< index_set< LO, HI >, Scalar_T >` `var_pair_t`

Public Member Functions

- `~var_term ()`
Destructor.
- `var_term ()`
Default constructor.
- `var_term (const index_set_t ist, const Scalar_T &crd=Scalar_T(1))`
Construct a variable term from an index set and a scalar coordinate.
- `var_term_t & operator*= (const term_t &rhs)`
Product of variable term and term.

Static Public Member Functions

- static const `std::string classname ()`
Class name used in messages.

6.30.1 Detailed Description

```
template<typename Scalar\_T = double, const index\_t LO = DEFAULT\_LO, const index\_t HI = DEFAULT\_HI>
class glucat::framed_multi< Scalar\_T, LO, HI >::var_term
```

Variable term.

Definition at line 308 of file `framed_multi.h`.

6.30.2 Member Typedef Documentation

6.30.2.1 var_pair_t

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
typedef std::pair<index_set<LO,HI>, Scalar_T> glucat::framed_multi< Scalar_T, LO, HI >::var_term::var_pair_t
```

Definition at line 312 of file framed_multi.h.

6.30.3 Constructor & Destructor Documentation

6.30.3.1 ~var_term()

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
glucat::framed_multi< Scalar_T, LO, HI >::var_term::~~var_term ( ) [inline]
```

Destructor.

Definition at line 318 of file framed_multi.h.

6.30.3.2 var_term() [1/2]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
glucat::framed_multi< Scalar_T, LO, HI >::var_term::var_term ( ) [inline]
```

Default constructor.

Definition at line 320 of file framed_multi.h.

6.30.3.3 var_term() [2/2]

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
glucat::framed_multi< Scalar_T, LO, HI >::var_term::var_term (
    const index_set_t ist,
    const Scalar_T & crd = Scalar_T(1) ) [inline]
```

Construct a variable term from an index set and a scalar coordinate.

Definition at line 324 of file framed_multi.h.

6.30.4 Member Function Documentation

6.30.4.1 `classname()`

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
static const std::string glucat::framed\_multi< Scalar_T, LO, HI >::var_term::classname ( )
[inline], [static]
```

Class name used in messages.

Definition at line 315 of file `framed_multi.h`.

6.30.4.2 `operator*=()`

```
template<typename Scalar_T = double, const index_t LO = DEFAULT_LO, const index_t HI = DEFAULT_HI>
LT_HI>
var\_term\_t& glucat::framed\_multi< Scalar_T, LO, HI >::var_term::operator*= (
    const term\_t & rhs ) [inline]
```

Product of variable term and term.

Definition at line 328 of file `framed_multi.h`.

The documentation for this class was generated from the following file:

- [glucat/framed_multi.h](#)

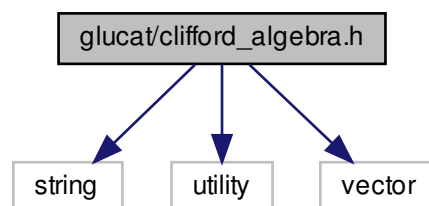
Chapter 7

File Documentation

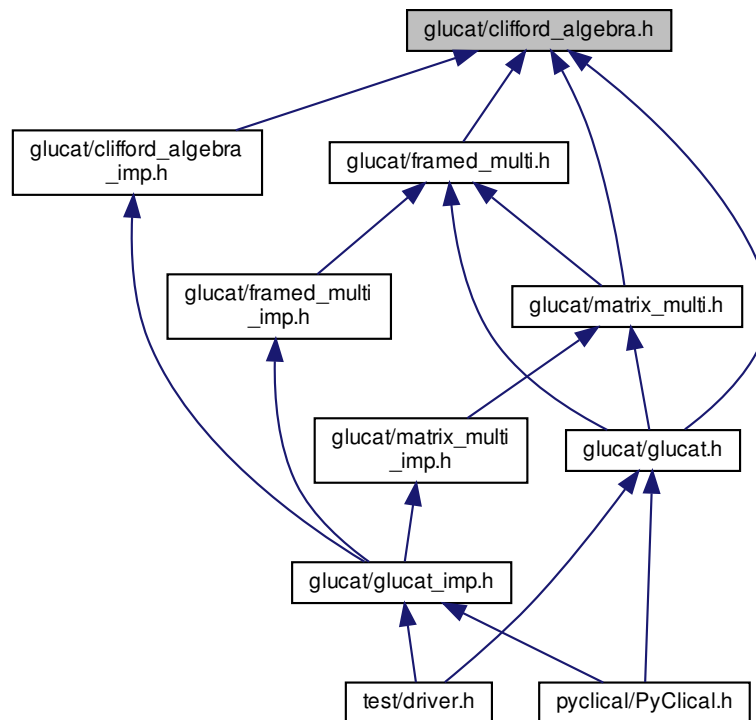
7.1 glucat/clifford_algebra.h File Reference

```
#include <string>
#include <utility>
#include <vector>
```

Include dependency graph for clifford_algebra.h:



This graph shows which files directly or indirectly include this file:



Classes

- class `glucat::clifford_algebra< Scalar_T, Index_Set_T, Multivector_T >`
clifford_algebra<> declares the operations of a Clifford algebra

Namespaces

- `glucat`

Macros

- `#define _GLUCAT_CLIFFORD_ALGEBRA_OPERATIONS`

Functions

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T, const index_t LO, const index_t HI>`
`bool glucat::operator!= (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Test for inequality of multivectors.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`bool glucat::operator!= (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Test for inequality of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`bool glucat::operator!= (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Test for inequality of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator+ (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Geometric sum of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator+ (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Geometric sum of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator+ (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Geometric sum.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator- (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Geometric difference of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator- (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Geometric difference of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator- (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Geometric difference.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator* (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Product of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator* (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Product of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator* (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Geometric product.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator^ (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Outer product.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator & (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Inner product.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator% (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Left contraction.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::star (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Hestenes scalar product.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator/ (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`

Quotient of multivector and scalar.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator/ (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`

Quotient of scalar and multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator/ (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Geometric quotient.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator| (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Transformation via twisted adjoint action.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::inv (const Multivector< Scalar_T, LO, HI > &val)`

Geometric multiplicative inverse.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::pow (const Multivector< Scalar_T, LO, HI > &lhs, int rhs)`

Integer power of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::pow (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Multivector power of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::outer_pow (const Multivector< Scalar_T, LO, HI > &lhs, int rhs)`

Outer product power of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`Scalar_T glucat::scalar (const Multivector< Scalar_T, LO, HI > &val)`

Scalar part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`Scalar_T glucat::real (const Multivector< Scalar_T, LO, HI > &val)`

Real part: synonym for scalar part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`Scalar_T glucat::imag (const Multivector< Scalar_T, LO, HI > &val)`

Imaginary part: deprecated (always 0)

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`const Multivector< Scalar_T, LO, HI > glucat::pure (const Multivector< Scalar_T, LO, HI > &val)`

Pure part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`const Multivector< Scalar_T, LO, HI > glucat::even (const Multivector< Scalar_T, LO, HI > &val)`

Even part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`const Multivector< Scalar_T, LO, HI > glucat::odd (const Multivector< Scalar_T, LO, HI > &val)`

Odd part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`const std::vector< Scalar_T > glucat::vector_part (const Multivector< Scalar_T, LO, HI > &val)`

Vector part of multivector, as a vector_t with respect to frame()

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`const Multivector< Scalar_T, LO, HI > glucat::involute (const Multivector< Scalar_T, LO, HI > &val)`

Main involution, each {i} is replaced by -{i} in each term, eg. {1}{2} -> (-{2})*(-{1})*

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`const Multivector< Scalar_T, LO, HI > glucat::reverse (const Multivector< Scalar_T, LO, HI > &val)`

Reversion, eg. {1}{2} -> {2}*{1}.*

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`const Multivector< Scalar_T, LO, HI > glucat::conj (const Multivector< Scalar_T, LO, HI > &val)`

Conjugation, rev o invo == invo o rev.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`Scalar_T glucat::quad (const Multivector< Scalar_T, LO, HI > &val)`

*Scalar_T quadratic form == (rev(x)*x)(0)*

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`Scalar_T glucat::norm (const Multivector< Scalar_T, LO, HI > &val)`

Scalar_T norm == sum of norm of coordinates.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`

`Scalar_T glucat::abs (const Multivector< Scalar_T, LO, HI > &val)`

Absolute value == sqrt(norm)

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 Scalar_T glucat::max_abs (const Multivector< Scalar_T, LO, HI > &val)
Maximum of absolute values of components of multivector: multivector infinity norm.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::complexifier (const Multivector< Scalar_T, LO, HI > &val)
Square root of -1 which commutes with all members of the frame of the given multivector.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::elliptic (const Multivector< Scalar_T, LO, HI > &val)`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::sqrt (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)
Square root of multivector with specified complexifier.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::sqrt (const Multivector< Scalar_T, LO, HI > &val)
Square root of multivector.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::clifford_exp (const Multivector< Scalar_T, LO, HI > &val)
Exponential of multivector.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::log (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)
Natural logarithm of multivector with specified complexifier.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::log (const Multivector< Scalar_T, LO, HI > &val)
Natural logarithm of multivector.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::cos (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)
Cosine of multivector with specified complexifier.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::cos (const Multivector< Scalar_T, LO, HI > &val)
Cosine of multivector.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::acos (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)
Inverse cosine of multivector with specified complexifier.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::acos (const Multivector< Scalar_T, LO, HI > &val)
Inverse cosine of multivector.`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>
 const Multivector< Scalar_T, LO, HI > glucat::cosh (const Multivector< Scalar_T, LO, HI > &val)
Hyperbolic cosine of multivector.`

- Generated by Doxygen

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::atan (const Multivector< Scalar_T, LO, HI > &val)`
Inverse tangent of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::tanh (const Multivector< Scalar_T, LO, HI > &val)`
Hyperbolic tangent of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::atanh (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Inverse hyperbolic tangent of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::atanh (const Multivector< Scalar_T, LO, HI > &val)`
Inverse hyperbolic tangent of multivector.

7.1.1 Macro Definition Documentation

7.1.1.1 _GLUCAT_CLIFFORD_ALGEBRA_OPERATIONS

```
#define _GLUCAT_CLIFFORD_ALGEBRA_OPERATIONS
```

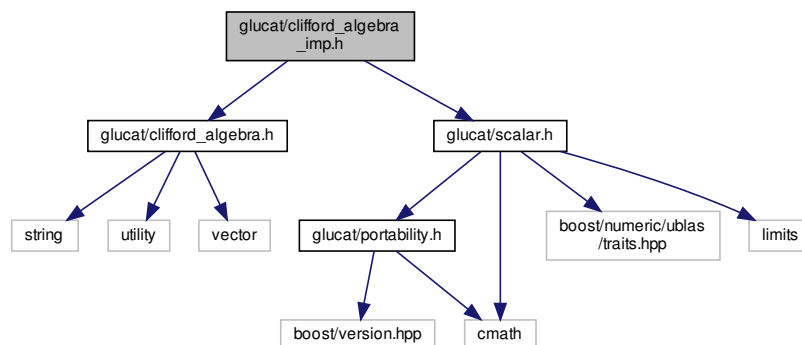
Definition at line 134 of file `clifford_algebra.h`.

7.2 `glucat/clifford_algebra_imp.h` File Reference

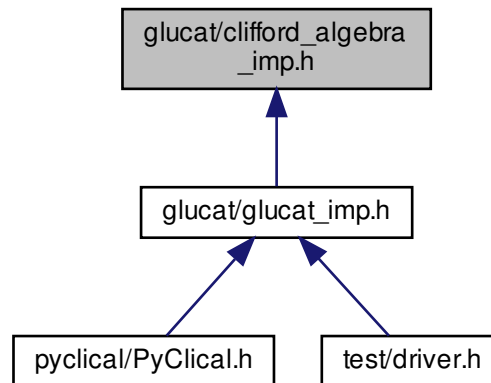
```
#include <glucat/clifford_algebra.h>
```

```
#include <glucat/scalar.h>
```

Include dependency graph for `clifford_algebra_imp.h`:



This graph shows which files directly or indirectly include this file:



Namespaces

- [glucat](#)

Functions

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T, const index_t LO, const index_t HI>`
`bool glucat::operator!= (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`
Test for inequality of multivectors.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>`
`bool glucat::operator!= (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Test for inequality of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>`
`bool glucat::operator!= (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Test for inequality of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator+ (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`
Geometric sum of multivector and scalar.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T, const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator+ (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`
Geometric sum of scalar and multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T, const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator+ (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Geometric sum.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator- (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`

Geometric difference of multivector and scalar.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator- (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`

Geometric difference of scalar and multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator- (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Geometric difference.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator* (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`

Product of multivector and scalar.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator* (const Scalar_T &scr, const Multivector< Scalar_T, LO, HI > &rhs)`

Product of scalar and multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator* (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Geometric product.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator^ (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Outer product.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator & (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Inner product.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator% (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Left contraction.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t > class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::star (const Multivector< Scalar_T, LO, HI > &lhs, const RHS< Scalar_T, LO, HI > &rhs)`

Hestenes scalar product.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator/ (const Multivector< Scalar_T, LO, HI > &lhs, const Scalar_T &scr)`

Quotient of multivector and scalar.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator/ (const Scalar_T &scr, const Multivector< Scalar_T,`
`LO, HI > &rhs)`

Quotient of scalar and multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t >`
`class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator/ (const Multivector< Scalar_T, LO, HI > &lhs, const`
`RHS< Scalar_T, LO, HI > &rhs)`

Geometric quotient.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t >`
`class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::operator| (const Multivector< Scalar_T, LO, HI > &lhs, const`
`RHS< Scalar_T, LO, HI > &rhs)`

Transformation via twisted adjoint action.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t`
`HI>`
`const Multivector< Scalar_T, LO, HI > glucat::inv (const Multivector< Scalar_T, LO, HI > &val)`

Geometric multiplicative inverse.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t`
`HI>`
`const Multivector< Scalar_T, LO, HI > glucat::pow (const Multivector< Scalar_T, LO, HI > &lhs, int rhs)`

Integer power of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, template< typename, const index_t, const index_t >`
`class RHS, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::pow (const Multivector< Scalar_T, LO, HI > &lhs, const RHS<`
`Scalar_T, LO, HI > &rhs)`

Multivector power of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t`
`HI>`
`const Multivector< Scalar_T, LO, HI > glucat::outer_pow (const Multivector< Scalar_T, LO, HI > &lhs, int`
`rhs)`

Outer product power of multivector.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t`
`HI>`
`Scalar_T glucat::scalar (const Multivector< Scalar_T, LO, HI > &val)`

Scalar part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t`
`HI>`
`Scalar_T glucat::real (const Multivector< Scalar_T, LO, HI > &val)`

Real part: synonym for scalar part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t`
`HI>`
`Scalar_T glucat::imag (const Multivector< Scalar_T, LO, HI > &val)`

Imaginary part: deprecated (always 0)

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t`
`HI>`
`const Multivector< Scalar_T, LO, HI > glucat::pure (const Multivector< Scalar_T, LO, HI > &val)`

Pure part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t`
`HI>`
`const Multivector< Scalar_T, LO, HI > glucat::even (const Multivector< Scalar_T, LO, HI > &val)`

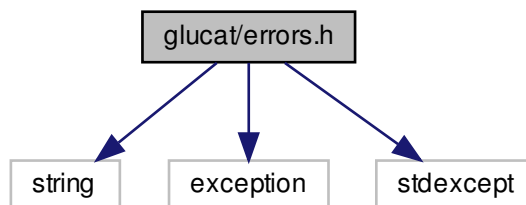
Even part.

- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::odd (const Multivector< Scalar_T, LO, HI > &val)`
Odd part.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const std::vector< Scalar_T > glucat::vector_part (const Multivector< Scalar_T, LO, HI > &val)`
Vector part of multivector, as a vector_t with respect to frame()
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::involute (const Multivector< Scalar_T, LO, HI > &val)`
Main involution, each {i} is replaced by -{i} in each term, eg. {1}{2} -> (-{2})*(-{1})*
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::reverse (const Multivector< Scalar_T, LO, HI > &val)`
Reversion, eg. {1}{2} -> {2}*{1}.*
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::conj (const Multivector< Scalar_T, LO, HI > &val)`
Conjugation, rev o invo == invo o rev.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::quad (const Multivector< Scalar_T, LO, HI > &val)`
*Scalar_T quadratic form == (rev(x)*x)(0)*
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::norm (const Multivector< Scalar_T, LO, HI > &val)`
Scalar_T norm == sum of norm of coordinates.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::abs (const Multivector< Scalar_T, LO, HI > &val)`
Absolute value == sqrt(norm)
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::max_abs (const Multivector< Scalar_T, LO, HI > &val)`
Maximum of absolute values of components of multivector: multivector infinity norm.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::complexifier (const Multivector< Scalar_T, LO, HI > &val)`
Square root of -1 which commutes with all members of the frame of the given multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::elliptic (const Multivector< Scalar_T, LO, HI > &val)`
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`static void glucat::check_complex (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Check that i is a valid complexifier for val.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::sqrt (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Square root of multivector with specified complexifier.

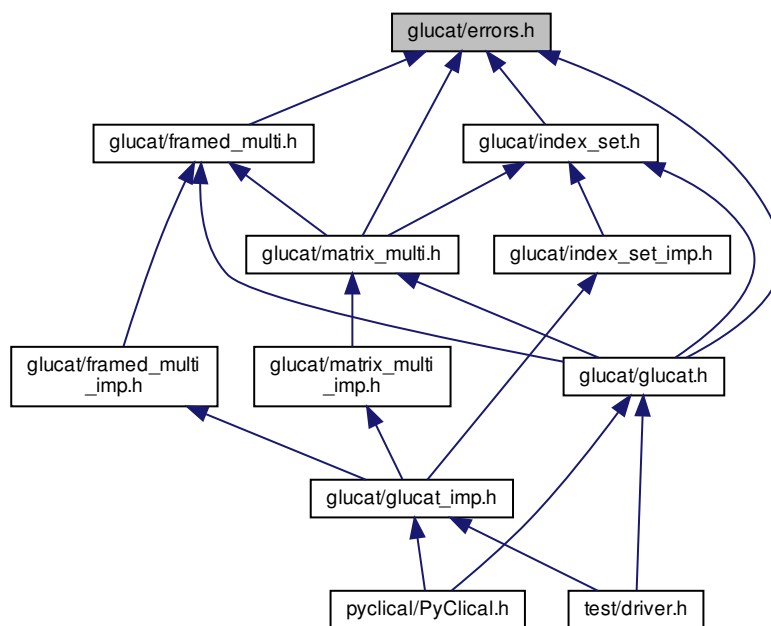
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::sqrt (const Multivector< Scalar_T, LO, HI > &val)`
Square root of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::clifford_exp (const Multivector< Scalar_T, LO, HI > &val)`
Exponential of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::log (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Natural logarithm of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::log (const Multivector< Scalar_T, LO, HI > &val)`
Natural logarithm of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::cosh (const Multivector< Scalar_T, LO, HI > &val)`
Hyperbolic cosine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::acosh (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Inverse hyperbolic cosine of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::acosh (const Multivector< Scalar_T, LO, HI > &val)`
Inverse hyperbolic cosine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::cos (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Cosine of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::cos (const Multivector< Scalar_T, LO, HI > &val)`
Cosine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::acos (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`
Inverse cosine of multivector with specified complexifier.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::acos (const Multivector< Scalar_T, LO, HI > &val)`
Inverse cosine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::sinh (const Multivector< Scalar_T, LO, HI > &val)`
Hyperbolic sine of multivector.
- `template<template< typename, const index_t, const index_t > class Multivector, typename Scalar_T , const index_t LO, const index_t HI>`
`const Multivector< Scalar_T, LO, HI > glucat::asinh (const Multivector< Scalar_T, LO, HI > &val, const Multivector< Scalar_T, LO, HI > &i, const bool prechecked=false)`

7.3 glucat/errors.h File Reference

```
#include <string>
#include <exception>
#include <stdexcept>
Include dependency graph for errors.h:
```



This graph shows which files directly or indirectly include this file:



Classes

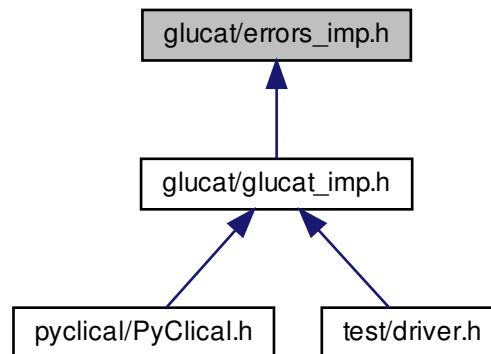
- class [glucat::glucat_error](#)
Abstract exception class.
- class [glucat::error< Class_T >](#)
Specific exception class.

Namespaces

- [glucat](#)

7.4 glucat/errors_imp.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- [glucat](#)

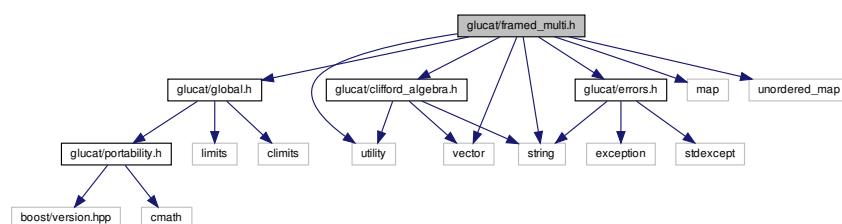
7.5 glucat/framed_multi.h File Reference

```

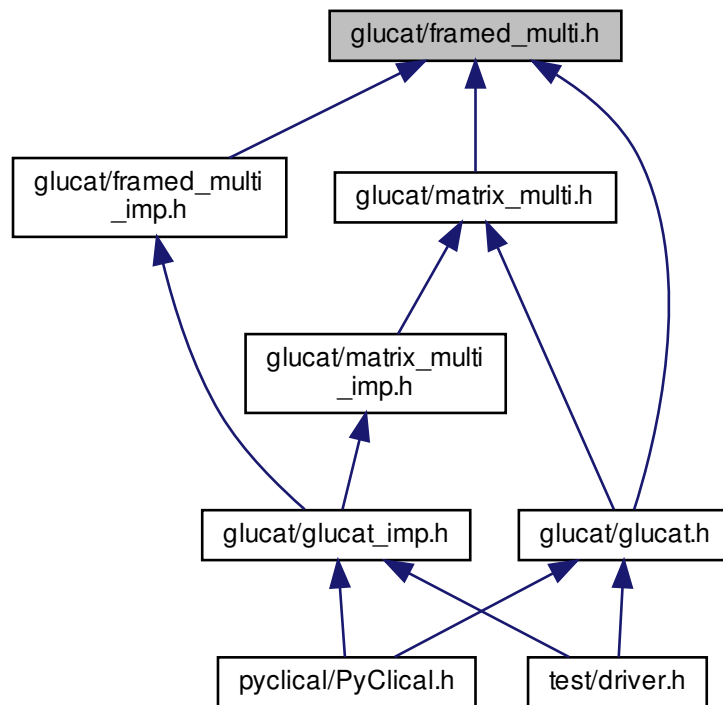
#include "glucat/global.h"
#include "glucat/errors.h"
#include "glucat/clifford_algebra.h"
#include <string>
#include <utility>
#include <map>
#include <vector>
#include <unordered_map>

```

Include dependency graph for `framed_multi.h`:



This graph shows which files directly or indirectly include this file:



Classes

- class [glucat::framed_multi< Scalar_T, LO, HI >](#)
A *framed_multi< Scalar_T, LO, HI >* is a framed approximation to a multivector.
- class [glucat::matrix_multi< Scalar_T, LO, HI >](#)
A *matrix_multi< Scalar_T, LO, HI >* is a matrix approximation to a multivector.
- class [glucat::index_set_hash< LO, HI >](#)
- class [glucat::framed_multi< Scalar_T, LO, HI >](#)
A *framed_multi< Scalar_T, LO, HI >* is a framed approximation to a multivector.
- class [glucat::framed_multi< Scalar_T, LO, HI >::hash_size_t](#)
- class [glucat::framed_multi< Scalar_T, LO, HI >::var_term](#)
Variable term.
- struct [std::numeric_limits< glucat::framed_multi< Scalar_T, LO, HI > >](#)
Numeric limits for *framed_multi* inherit limits for the corresponding scalar type.

Namespaces

- [glucat](#)
- [std](#)

Macros

- `#define _GLUCAT_MAP_IS_HASH`

Functions

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator* (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Geometric product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator^ (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Outer product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator & (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Inner product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator% (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Left contraction.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::star (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI`
`> &rhs)`
Hestenes scalar product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator/ (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Geometric quotient.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator| (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Transformation via twisted adjoint action.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::istream & glucat::operator>> (std::istream &s, framed_multi< Scalar_T, LO, HI > &val)`
Read multivector from input.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::ostream & glucat::operator<< (std::ostream &os, const framed_multi< Scalar_T, LO, HI > &val)`
Write multivector to output.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::ostream & glucat::operator<< (std::ostream &os, const std::pair< const index_set< LO, HI >, Scalar_T`
`> &term)`
Write term to output.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::exp (const framed_multi< Scalar_T, LO, HI > &val)`
Exponential of multivector.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static Scalar_T glucat::crd_of_mult (const std::pair< const index_set< LO, HI >, Scalar_T > &lhs, const`
`std::pair< const index_set< LO, HI >, Scalar_T > &rhs)`
Coordinate of product of terms.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const std::pair< const index_set< LO, HI >, Scalar_T > glucat::operator* (const std::pair< const index_↵`
`set< LO, HI >, Scalar_T > &lhs, const std::pair< const index_set< LO, HI >, Scalar_T > &rhs)`

Product of terms.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::sqrt (const framed_multi< Scalar_T, LO, HI > &val, const framed_multi< Scalar_T, LO, HI > &i, bool prechecked)`

Square root of multivector with specified complexifier.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::log (const framed_multi< Scalar_T, LO, HI > &val, const framed_multi< Scalar_T, LO, HI > &i, bool prechecked)`

Natural logarithm of multivector with specified complexifier.

7.5.1 Macro Definition Documentation

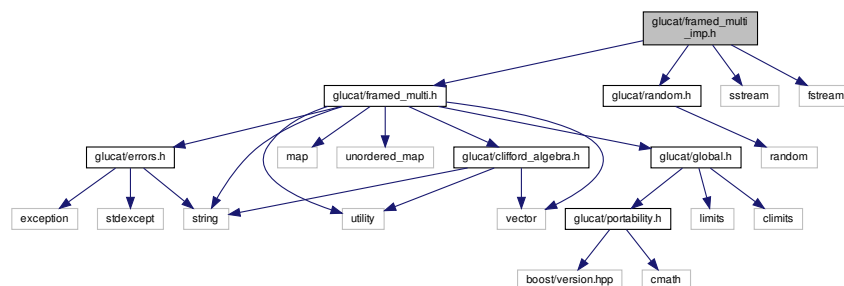
7.5.1.1 _GLUCAT_MAP_IS_HASH

```
#define _GLUCAT_MAP_IS_HASH
```

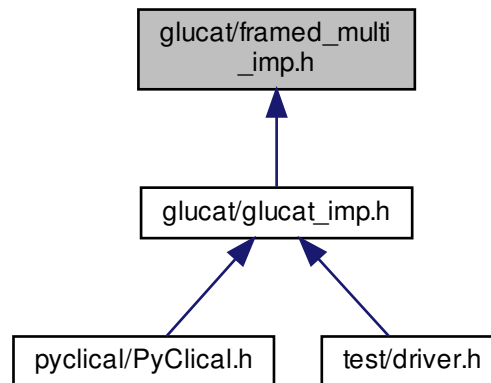
Definition at line 55 of file framed_multi.h.

7.6 glucat/framed_multi_imp.h File Reference

```
#include "glucat/framed_multi.h"
#include "glucat/random.h"
#include <sstream>
#include <fstream>
Include dependency graph for framed_multi_imp.h:
```



This graph shows which files directly or indirectly include this file:



Classes

- class [glucat::sorted_range< Map_T, Sorted_Map_T >](#)
Sorted range for use with output.
- class [glucat::sorted_range< Sorted_Map_T, Sorted_Map_T >](#)

Namespaces

- [glucat](#)

Macros

- [#define _GLUCAT_HASH_N\(x\)](#)
- [#define _GLUCAT_HASH_SIZE_T\(x\)](#)

Functions

- [template<typename Scalar_T , const index_t LO, const index_t HI>](#)
const framed_multi< Scalar_T, LO, HI > [glucat::operator*](#) (const framed_multi< Scalar_T, LO, HI > &lhs,
const framed_multi< Scalar_T, LO, HI > &rhs)
Geometric product.
- [template<typename Scalar_T , const index_t LO, const index_t HI>](#)
const framed_multi< Scalar_T, LO, HI > [glucat::operator^](#) (const framed_multi< Scalar_T, LO, HI > &lhs,
const framed_multi< Scalar_T, LO, HI > &rhs)
Outer product.
- [template<typename Scalar_T , const index_t LO, const index_t HI>](#)
const framed_multi< Scalar_T, LO, HI > [glucat::operator &](#) (const framed_multi< Scalar_T, LO, HI > &lhs,
const framed_multi< Scalar_T, LO, HI > &rhs)
Inner product.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator% (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Left contraction.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::star (const framed_multi< Scalar_T, LO, HI > &lhs, const framed_multi< Scalar_T, LO, HI`
`> &rhs)`
Hestenes scalar product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator/ (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Geometric quotient.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::operator| (const framed_multi< Scalar_T, LO, HI > &lhs,`
`const framed_multi< Scalar_T, LO, HI > &rhs)`
Transformation via twisted adjoint action.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::ostream & glucat::operator<< (std::ostream &os, const framed_multi< Scalar_T, LO, HI > &val)`
Write multivector to output.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::ostream & glucat::operator<< (std::ostream &os, const std::pair< const index_set< LO, HI >, Scalar_T`
`> &term)`
Write term to output.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::istream & glucat::operator>> (std::istream &s, framed_multi< Scalar_T, LO, HI > &val)`
Read multivector from input.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static Scalar_T glucat::crd_of_mult (const std::pair< const index_set< LO, HI >, Scalar_T > &lhs, const`
`std::pair< const index_set< LO, HI >, Scalar_T > &rhs)`
Coordinate of product of terms.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const std::pair< const index_set< LO, HI >, Scalar_T > glucat::operator* (const std::pair< const index_↔`
`set< LO, HI >, Scalar_T > &lhs, const std::pair< const index_set< LO, HI >, Scalar_T > &rhs)`
Product of terms.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::sqrt (const framed_multi< Scalar_T, LO, HI > &val, const`
`framed_multi< Scalar_T, LO, HI > &i, bool prechecked)`
Square root of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::exp (const framed_multi< Scalar_T, LO, HI > &val)`
Exponential of multivector.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const framed_multi< Scalar_T, LO, HI > glucat::log (const framed_multi< Scalar_T, LO, HI > &val, const`
`framed_multi< Scalar_T, LO, HI > &i, bool prechecked)`
Natural logarithm of multivector with specified complexifier.

7.6.1 Macro Definition Documentation

7.6.1.1 _GLUCAT_HASH_N

```
#define _GLUCAT_HASH_N(  
    x )
```

Definition at line 60 of file framed_multi_imp.h.

7.6.1.2 _GLUCAT_HASH_SIZE_T

```
#define _GLUCAT_HASH_SIZE_T(  
    x )
```

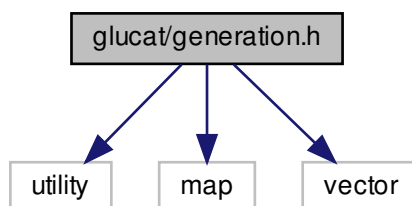
Definition at line 61 of file framed_multi_imp.h.

Referenced by `glucat::framed_multi< Scalar_T, LO, HI >::framed_multi()`, `glucat::operator &()`, `glucat::operator%()`, `glucat::operator*()`, and `glucat::operator^()`.

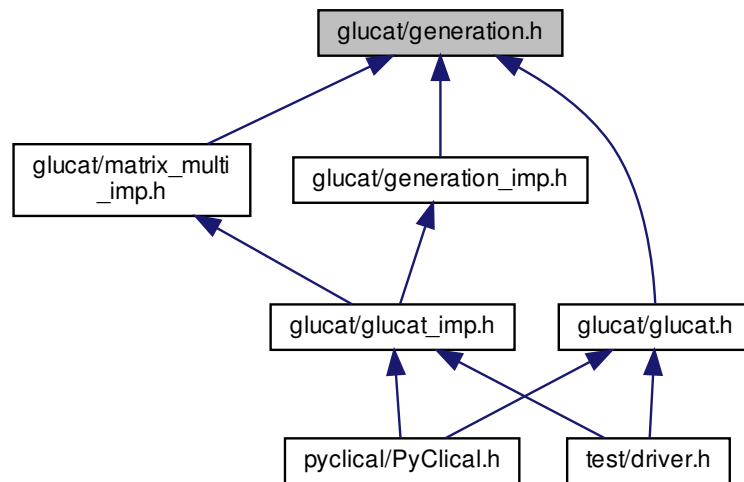
7.7 glucat/generation.h File Reference

```
#include <utility>  
#include <map>  
#include <vector>
```

Include dependency graph for generation.h:



This graph shows which files directly or indirectly include this file:



Classes

- class [glucat::gen::generator_table< Matrix_T >](#)

Table of generators for specific signatures.

Namespaces

- [glucat](#)
- [glucat::gen](#)

Typedefs

- typedef std::pair< index_t, index_t > [glucat::gen::signature_t](#)

A signature is a pair of indices, p, q, with p == frame.max(), q == -frame.min()

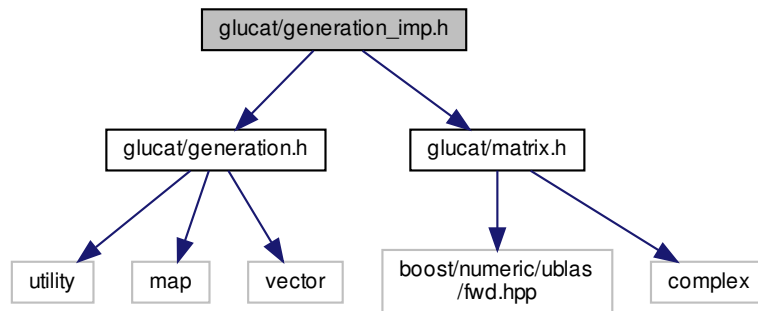
Variables

- static const index_t [glucat::gen::offset_to_super](#) [] = {0,-1, 0,-1,-2, 3, 2, 1}

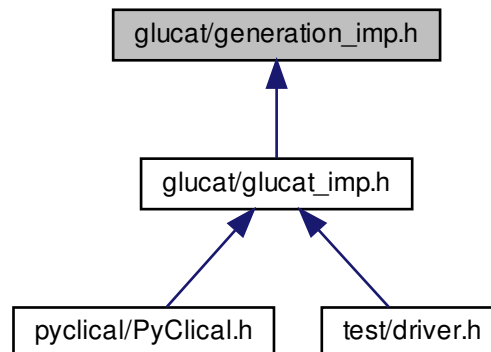
Offsets between the current signature and that of the real superalgebra.

7.8 glucat/generation_imp.h File Reference

```
#include "glucat/generation.h"
#include "glucat/matrix.h"
Include dependency graph for generation_imp.h:
```



This graph shows which files directly or indirectly include this file:



Namespaces

- [glucat](#)
- [glucat::gen](#)

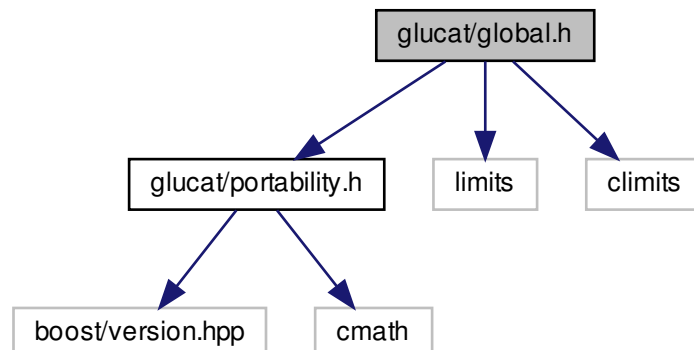
7.9 glucat/global.h File Reference

```
#include "glucat/portability.h"
#include <limits>
```

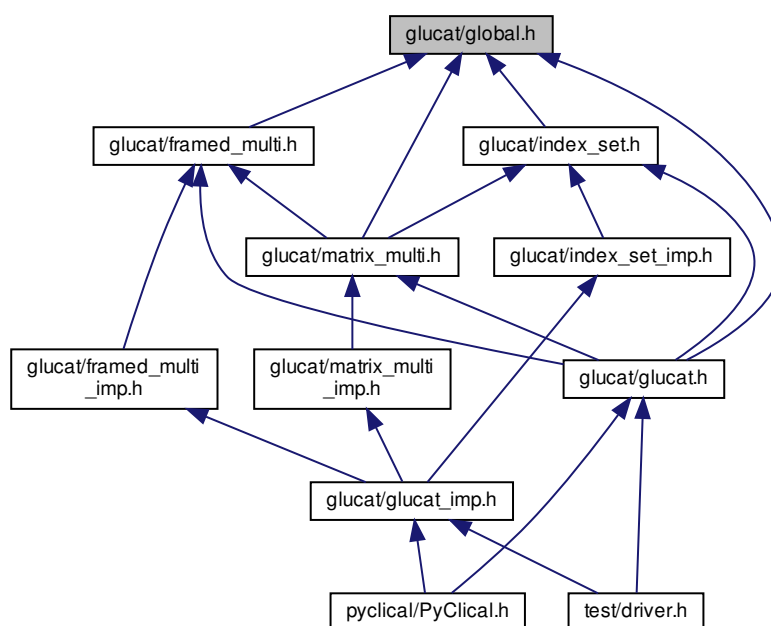


```
#include <climits>
```

Include dependency graph for global.h:



This graph shows which files directly or indirectly include this file:



Classes

- struct [glucat::CTAssertion](#)< bool >
Compile time assertion.
- struct [glucat::CTAssertion](#)< true >

- class `glucat::compare_types< LHS_T, RHS_T >`
Type comparison.
- class `glucat::compare_types< T, T >`
- class `glucat::bool_to_type< truth_value >`
Bool to type.
- struct `glucat::tuning< Mult_Matrix_Threshold, Div_Max_Steps, Sqrt_Max_Steps, Log_Max_Outer_Steps, Log_Max_Inner_Steps >`
Tuning policy.

Namespaces

- `glucat`

Macros

- `#define _GLUCAT_CTAssert(expr, msg) namespace { struct msg { glucat::CTAssertion<(expr)> ERROR↵
_##msg; }; }`

Typedefs

- typedef int `glucat::index_t`
Size of index_t should be enough to represent LO, HI.
- typedef unsigned long `glucat::set_value_t`
Size of set_value_t should be enough to contain index_set<LO,HI>

Enumerations

- enum `glucat::precision_t` { `glucat::precision_demoted`, `glucat::precision_same`, `glucat::precision_promoted` }
Precision policy.

Functions

- `glucat::_GLUCAT_CTAssert` (std::numeric_limits< unsigned char >::radix==2, CannotDetermineBitsPer↵
Char) const index_t BITS_PER_CHAR
If radix of unsigned char is not 2, we can't easily determine number of bits from sizeof.
- `glucat::_GLUCAT_CTAssert` (_GLUCAT_BITS_PER_ULONG==BITS_PER_SET_VALUE, BitsPerULong↵
DoesNotMatchSetValueT) const index_t DEFAULT_LO
Default lowest index in an index set.
- template<typename LHS_T, typename RHS_T >
LHS_T `glucat::pos_mod` (LHS_T lhs, RHS_T rhs)
Modulo function which works reliably for lhs < 0.

Variables

- const double `glucat::MS_PER_S` = 1000.0
Timing constant: deprecated here - moved to [test/timing.h](#).
- const index_t `glucat::BITS_PER_SET_VALUE` = std::numeric_limits<set_value_t>::digits
Number of bits in set_value_t.
- const index_t `glucat::DEFAULT_HI` = index_t(BITS_PER_SET_VALUE / 2)
Default highest index in an index set.
- const double `glucat::DEFAULT_TRUNCATION` = std::numeric_limits<float>::epsilon()
Default for truncation.
- const unsigned int `glucat::DEFAULT_Mult_Matrix_Threshold` = 8
- const unsigned int `glucat::DEFAULT_Div_Max_Steps` = 4
- const unsigned int `glucat::DEFAULT_Sqrt_Max_Steps` = 256
- const unsigned int `glucat::DEFAULT_Log_Max_Outer_Steps` = 256
- const unsigned int `glucat::DEFAULT_Log_Max_Inner_Steps` = 32
- const unsigned int `glucat::DEFAULT_Basis_Max_Count` = 12
- const unsigned int `glucat::DEFAULT_Fast_Size_Threshold` = 1 << 6
- const unsigned int `glucat::DEFAULT_Inv_Fast_Dim_Threshold` = 1 << 3
- const unsigned int `glucat::DEFAULT_Products_Size_Threshold` = 1 << 22
- const precision_t `glucat::DEFAULT_Function_Precision` = precision_same

7.9.1 Macro Definition Documentation

7.9.1.1 _GLUCAT_CTAssert

```
#define _GLUCAT_CTAssert(  
    expr,  
    msg ) namespace { struct msg { glucat::CTAssertion<(expr)> ERROR_##msg; }; }
```

Definition at line 48 of file global.h.

7.10 glucat/glucat.h File Reference

```
#include "glucat/portability.h"  
#include "glucat/global.h"  
#include "glucat/errors.h"  
#include "glucat/index_set.h"  
#include "glucat/scalar.h"  
#include "glucat/long_double.h"  
#include "glucat/qd.h"  
#include "glucat/clifford_algebra.h"  
#include "glucat/framed_multi.h"  
#include "glucat/generation.h"  
#include "glucat/matrix.h"
```


Macros

- `#define GLUCAT_HAVE_INTTYPES_H 1`
- `#define GLUCAT_HAVE_MEMORY_H 1`
- `#define GLUCAT_HAVE_STDINT_H 1`
- `#define GLUCAT_HAVE_STDLIB_H 1`
- `#define GLUCAT_HAVE_STRINGS_H 1`
- `#define GLUCAT_HAVE_STRING_H 1`
- `#define GLUCAT_HAVE_SYS_STAT_H 1`
- `#define GLUCAT_HAVE_SYS_TYPES_H 1`
- `#define GLUCAT_HAVE_UNISTD_H 1`
- `#define GLUCAT_PACKAGE "glucat"`
- `#define GLUCAT_PACKAGE_BUGREPORT ""`
- `#define GLUCAT_PACKAGE_NAME "glucat"`
- `#define GLUCAT_PACKAGE_STRING "glucat 0.8.2"`
- `#define GLUCAT_PACKAGE_TARNAME "glucat"`
- `#define GLUCAT_PACKAGE_URL ""`
- `#define GLUCAT_PACKAGE_VERSION "0.8.2"`
- `#define GLUCAT_STDC_HEADERS 1`
- `#define GLUCAT_VERSION "0.8.2"`

7.11.1 Macro Definition Documentation

7.11.1.1 GLUCAT_HAVE_INTTYPES_H

```
#define GLUCAT_HAVE_INTTYPES_H 1
```

Definition at line 10 of file `glucat_config.h`.

7.11.1.2 GLUCAT_HAVE_MEMORY_H

```
#define GLUCAT_HAVE_MEMORY_H 1
```

Definition at line 18 of file `glucat_config.h`.

7.11.1.3 GLUCAT_HAVE_STDINT_H

```
#define GLUCAT_HAVE_STDINT_H 1
```

Definition at line 23 of file `glucat_config.h`.

7.11.1.4 GLUCAT_HAVE_STDLIB_H

```
#define GLUCAT_HAVE_STDLIB_H 1
```

Definition at line 28 of file `glucat_config.h`.

7.11.1.5 GLUCAT_HAVE_STRING_H

```
#define GLUCAT_HAVE_STRING_H 1
```

Definition at line 38 of file `glucat_config.h`.

7.11.1.6 GLUCAT_HAVE_STRINGS_H

```
#define GLUCAT_HAVE_STRINGS_H 1
```

Definition at line 33 of file `glucat_config.h`.

7.11.1.7 GLUCAT_HAVE_SYS_STAT_H

```
#define GLUCAT_HAVE_SYS_STAT_H 1
```

Definition at line 43 of file `glucat_config.h`.

7.11.1.8 GLUCAT_HAVE_SYS_TYPES_H

```
#define GLUCAT_HAVE_SYS_TYPES_H 1
```

Definition at line 48 of file `glucat_config.h`.

7.11.1.9 GLUCAT_HAVE_UNISTD_H

```
#define GLUCAT_HAVE_UNISTD_H 1
```

Definition at line 53 of file `glucat_config.h`.

7.11.1.10 GLUCAT_PACKAGE

```
#define GLUCAT_PACKAGE "glucat"
```

Definition at line 58 of file glucat_config.h.

7.11.1.11 GLUCAT_PACKAGE_BUGREPORT

```
#define GLUCAT_PACKAGE_BUGREPORT ""
```

Definition at line 63 of file glucat_config.h.

7.11.1.12 GLUCAT_PACKAGE_NAME

```
#define GLUCAT_PACKAGE_NAME "glucat"
```

Definition at line 68 of file glucat_config.h.

Referenced by glucat::control_t::control_t().

7.11.1.13 GLUCAT_PACKAGE_STRING

```
#define GLUCAT_PACKAGE_STRING "glucat 0.8.2"
```

Definition at line 73 of file glucat_config.h.

7.11.1.14 GLUCAT_PACKAGE_TARNAME

```
#define GLUCAT_PACKAGE_TARNAME "glucat"
```

Definition at line 78 of file glucat_config.h.

7.11.1.15 GLUCAT_PACKAGE_URL

```
#define GLUCAT_PACKAGE_URL ""
```

Definition at line 83 of file glucat_config.h.

7.11.1.16 GLUCAT_PACKAGE_VERSION

```
#define GLUCAT_PACKAGE_VERSION "0.8.2"
```

Definition at line 88 of file `glucat_config.h`.

7.11.1.17 GLUCAT_STDC_HEADERS

```
#define GLUCAT_STDC_HEADERS 1
```

Definition at line 93 of file `glucat_config.h`.

7.11.1.18 GLUCAT_VERSION

```
#define GLUCAT_VERSION "0.8.2"
```

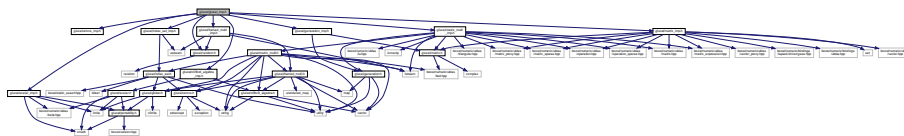
Definition at line 98 of file `glucat_config.h`.

Referenced by `glucat::control_t::control_t()`.

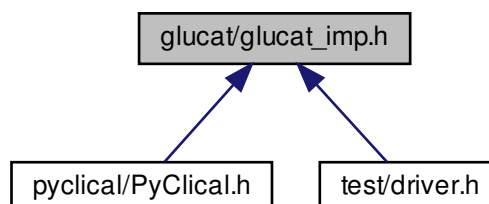
7.12 glucat/glucat_imp.h File Reference

```
#include "glucat/errors_imp.h"
#include "glucat/index_set_imp.h"
#include "glucat/scalar_imp.h"
#include "glucat/clifford_algebra_imp.h"
#include "glucat/random.h"
#include "glucat/framed_multi_imp.h"
#include "glucat/matrix_imp.h"
#include "glucat/generation_imp.h"
#include "glucat/matrix_multi_imp.h"
```

Include dependency graph for `glucat_imp.h`:



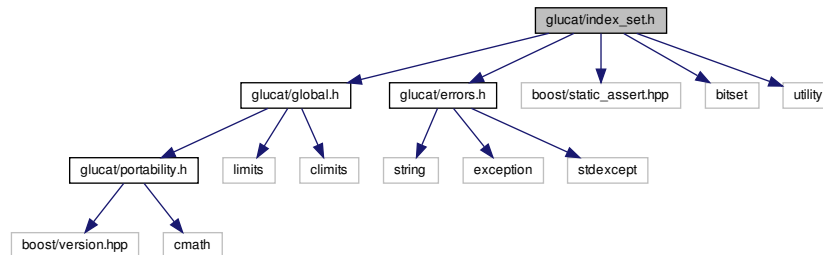
This graph shows which files directly or indirectly include this file:



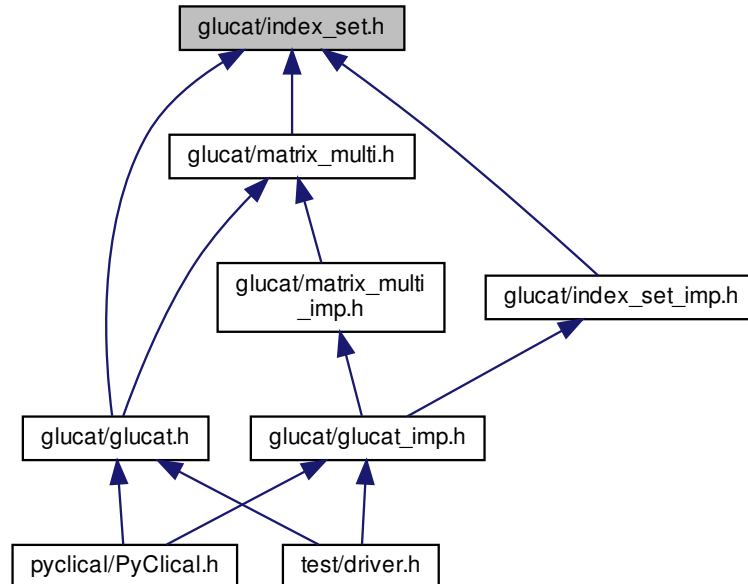
7.13 glucat/index_set.h File Reference

```
#include "glucat/global.h"
#include "glucat/errors.h"
#include <boost/static_assert.hpp>
#include <bitset>
#include <utility>
```

Include dependency graph for index_set.h:



This graph shows which files directly or indirectly include this file:



Classes

- class [glucat::index_set< LO, HI >](#)

Index set class based on `std::bitset<>` in Gnu standard C++ library.

- class [glucat::index_set< LO, HI >](#)
Index set class based on `std::bitset<>` in Gnu standard C++ library.
- class [glucat::index_set< LO, HI >::reference](#)
Index set member reference.

Namespaces

- [glucat](#)

Functions

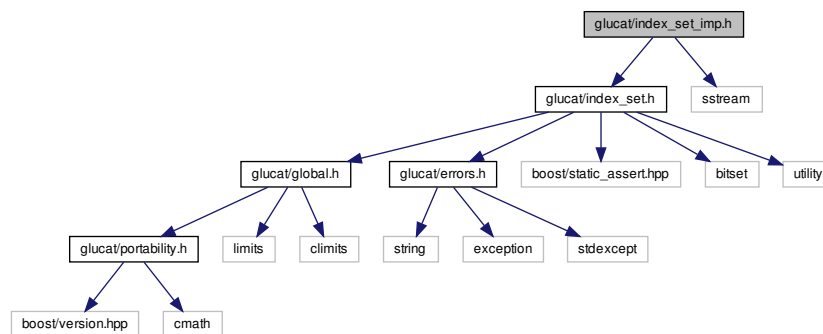
- `template<const index_t LO, const index_t HI>`
`const index_set< LO, HI > glucat::operator^ (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`
Symmetric set difference: exclusive or.
- `template<const index_t LO, const index_t HI>`
`const index_set< LO, HI > glucat::operator & (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`
Set intersection: and.
- `template<const index_t LO, const index_t HI>`
`const index_set< LO, HI > glucat::operator| (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`
Set union: or.
- `template<const index_t LO, const index_t HI>`
`int glucat::compare (const index_set< LO, HI > &a, const index_set< LO, HI > &b)`
"lexicographic compare" eg. {3,4,5} is less than {3,7,8}
- `glucat::GLUCAT_CTAssert (sizeof(set_value_t) >=sizeof(std::bitset< DEFAULT_HI-DEFAULT_LO >), Default_index_set_too_big_for_value) template< const index_t LO`
Size of `set_value_t` should be enough to contain `bitset<DEFAULT_HI-DEFAULT_LO>`
- `const index_t HI std::ostream & glucat::operator<< (std::ostream &os, const index_set< LO, HI > &ist)`
Write out index set.
- `template<const index_t LO, const index_t HI>`
`std::istream & glucat::operator>> (std::istream &s, index_set< LO, HI > &ist)`
Read in index set.
- `int glucat::sign_of_square (index_t j)`
Square of generator {j}.
- `template<const index_t LO, const index_t HI>`
`index_t glucat::min_neg (const index_set< LO, HI > &ist)`
Minimum negative index, or 0 if none.
- `template<const index_t LO, const index_t HI>`
`index_t glucat::max_pos (const index_set< LO, HI > &ist)`
Maximum positive index, or 0 if none.

7.14 glucat/index_set_imp.h File Reference

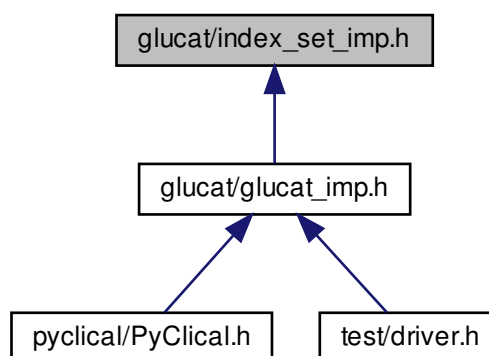
```
#include "glucat/index_set.h"
```

```
#include <sstream>
```

Include dependency graph for index_set_imp.h:



This graph shows which files directly or indirectly include this file:



Namespaces

- [glucat](#)

Functions

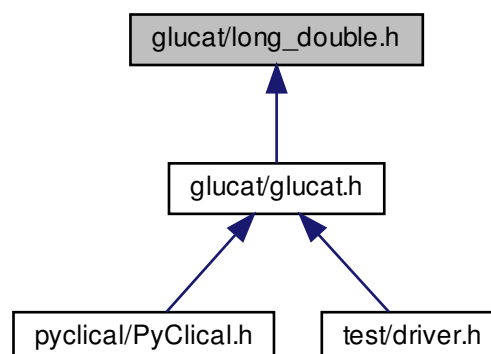
- `template<const index_t LO, const index_t HI>`
`const index_set< LO, HI > glucat::operator^ (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`

Symmetric set difference: exclusive or.

- `template<const index_t LO, const index_t HI>`
`const index_set< LO, HI > glucat::operator & (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`
Set intersection: and.
- `template<const index_t LO, const index_t HI>`
`const index_set< LO, HI > glucat::operator | (const index_set< LO, HI > &lhs, const index_set< LO, HI > &rhs)`
Set union: or.
- `template<const index_t LO, const index_t HI>`
`int glucat::compare (const index_set< LO, HI > &a, const index_set< LO, HI > &b)`
"lexicographic compare" eg. {3,4,5} is less than {3,7,8}
- `const index_t HI std::ostream & glucat::operator << (std::ostream &os, const index_set< LO, HI > &ist)`
Write out index set.
- `template<const index_t LO, const index_t HI>`
`std::istream & glucat::operator >> (std::istream &s, index_set< LO, HI > &ist)`
Read in index set.
- `static unsigned long glucat::inverse_reversed_gray (unsigned long x)`
Inverse reversed Gray code.
- `static unsigned long glucat::inverse_gray (unsigned long x)`
Inverse Gray code.
- `int glucat::sign_of_square (index_t j)`
Square of generator {j}.
- `template<const index_t LO, const index_t HI>`
`index_t glucat::min_neg (const index_set< LO, HI > &ist)`
Minimum negative index, or 0 if none.
- `template<const index_t LO, const index_t HI>`
`index_t glucat::max_pos (const index_set< LO, HI > &ist)`
Maximum positive index, or 0 if none.

7.15 glucat/long_double.h File Reference

This graph shows which files directly or indirectly include this file:



Classes

- struct `glucat::numeric_traits< Scalar_T >::demoted<>`
Demoted type for long double.

Namespaces

- `glucat`

Variables

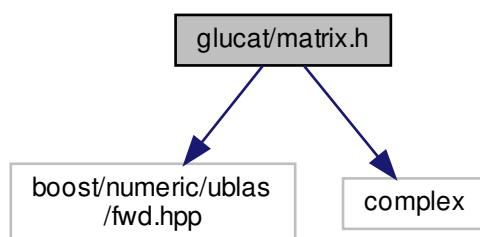
- static const long double `glucat::l_pi` = 3.1415926535897932384626433832795029L
- static const long double `glucat::l_ln2` = 0.6931471805599453094172321214581766L

7.16 glucat/matrix.h File Reference

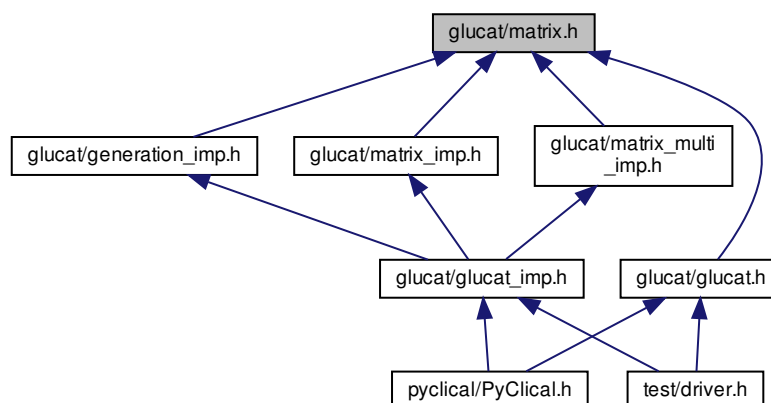
```
#include <boost/numeric/ublas/fwd.hpp>
```

```
#include <complex>
```

Include dependency graph for matrix.h:



This graph shows which files directly or indirectly include this file:



Classes

- struct [glucat::matrix::eig_genus](#)< [Matrix_T](#) >
Structure containing classification of eigenvalues.

Namespaces

- [glucat](#)
- [glucat::matrix](#)

Enumerations

- enum [glucat::matrix::eig_case_t](#) { [glucat::matrix::safe_eig_case](#), [glucat::matrix::negative_eig_case](#), [glucat::matrix::both_eig_case](#) }
Classification of eigenvalues of a matrix.

Functions

- template<typename LHS_T , typename RHS_T >
const RHS_T [glucat::matrix::kron](#) (const LHS_T &lhs, const RHS_T &rhs)
Kronecker tensor product of matrices - as per Matlab kron.
- template<typename LHS_T , typename RHS_T >
const RHS_T [glucat::matrix::mono_kron](#) (const LHS_T &lhs, const RHS_T &rhs)
Sparse Kronecker tensor product of monomial matrices.
- template<typename LHS_T , typename RHS_T >
const RHS_T [glucat::matrix::nork](#) (const LHS_T &lhs, const RHS_T &rhs, const bool mono=true)
Left inverse of Kronecker product.
- template<typename LHS_T , typename RHS_T >
const RHS_T [glucat::matrix::signed_perm_nork](#) (const LHS_T &lhs, const RHS_T &rhs)
Left inverse of Kronecker product where lhs is a signed permutation matrix.
- template<typename Matrix_T >
Matrix_T::size_type [glucat::matrix::nnz](#) (const Matrix_T &m)
Number of non-zeros.
- template<typename Matrix_T >
bool [glucat::matrix::isnan](#) (const Matrix_T &m)
Not a Number.
- template<typename Matrix_T >
const Matrix_T [glucat::matrix::unit](#) (const typename Matrix_T::size_type n)
Unit matrix - as per Matlab eye.
- template<typename LHS_T , typename RHS_T >
const RHS_T::expression_type [glucat::matrix::mono_prod](#) (const ublas::matrix_expression< LHS_T > &lhs, const ublas::matrix_expression< RHS_T > &rhs)
Product of monomial matrices.
- template<typename LHS_T , typename RHS_T >
const RHS_T::expression_type [glucat::matrix::sparse_prod](#) (const ublas::matrix_expression< LHS_T > &lhs, const ublas::matrix_expression< RHS_T > &rhs)
Product of sparse matrices.
- template<typename LHS_T , typename RHS_T >
const RHS_T::expression_type [glucat::matrix::prod](#) (const ublas::matrix_expression< LHS_T > &lhs, const ublas::matrix_expression< RHS_T > &rhs)
Product of matrices.

- `template<typename Scalar_T, typename LHS_T, typename RHS_T >`
`Scalar_T glucat::matrix::inner (const LHS_T &lhs, const RHS_T &rhs)`
*Inner product: $\sum(x(i,j)*y(i,j))/x.nrows()$*
- `template<typename Matrix_T >`
`Matrix_T::value_type glucat::matrix::norm_frob2 (const Matrix_T &val)`
Square of Frobenius norm.
- `template<typename Matrix_T >`
`Matrix_T::value_type glucat::matrix::trace (const Matrix_T &val)`
Matrix trace.
- `template<typename Matrix_T >`
`ublas::vector< std::complex< double > > glucat::matrix::eigenvalues (const Matrix_T &val)`
Eigenvalues of a matrix.
- `template<typename Matrix_T >`
`eig_genus< Matrix_T > glucat::matrix::classify_eigenvalues (const Matrix_T &val)`
Classify the eigenvalues of a matrix.

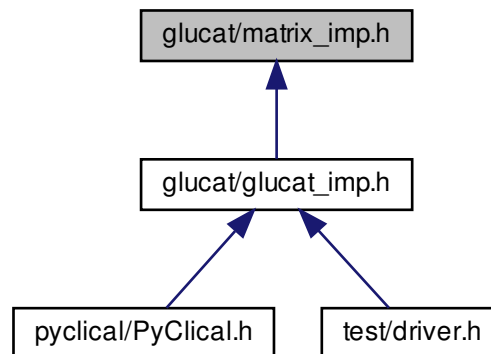
7.17 glucat/matrix_imp.h File Reference

```
#include "glucat/matrix.h"
#include <boost/numeric/ublas/vector.hpp>
#include <boost/numeric/ublas/vector_proxy.hpp>
#include <boost/numeric/ublas/matrix.hpp>
#include <boost/numeric/ublas/matrix_expression.hpp>
#include <boost/numeric/ublas/matrix_proxy.hpp>
#include <boost/numeric/ublas/matrix_sparse.hpp>
#include <boost/numeric/ublas/operation.hpp>
#include <boost/numeric/ublas/operation_sparse.hpp>
#include <boost/numeric/bindings/lapack/driver/gees.hpp>
#include <boost/numeric/bindings/ublas.hpp>
#include <set>
```

Include dependency graph for matrix_imp.h:



This graph shows which files directly or indirectly include this file:



Namespaces

- [glucat](#)
- [glucat::matrix](#)

Functions

- `template<typename LHS_T , typename RHS_T >`
`const RHS_T glucat::matrix::kron (const LHS_T &lhs, const RHS_T &rhs)`
Kronecker tensor product of matrices - as per Matlab kron.
- `template<typename LHS_T , typename RHS_T >`
`const RHS_T glucat::matrix::mono_kron (const LHS_T &lhs, const RHS_T &rhs)`
Sparse Kronecker tensor product of monomial matrices.
- `template<typename LHS_T , typename RHS_T >`
`void glucat::matrix::nork_range (RHS_T &result, const typename LHS_T::const_iterator2 lhs_it2, const RHS_T &rhs, const typename RHS_T::size_type res_s1, const typename RHS_T::size_type res_s2)`
Utility routine for nork: calculate result for a range of indices.
- `template<typename LHS_T , typename RHS_T >`
`const RHS_T glucat::matrix::nork (const LHS_T &lhs, const RHS_T &rhs, const bool mono=true)`
Left inverse of Kronecker product.
- `template<typename LHS_T , typename RHS_T >`
`const RHS_T glucat::matrix::signed_perm_nork (const LHS_T &lhs, const RHS_T &rhs)`
Left inverse of Kronecker product where lhs is a signed permutation matrix.
- `template<typename Matrix_T >`
`Matrix_T::size_type glucat::matrix::nnz (const Matrix_T &m)`
Number of non-zeros.
- `template<typename Matrix_T >`
`bool glucat::matrix::isnans (const Matrix_T &m)`
Not a Number.
- `template<typename Matrix_T >`
`const Matrix_T glucat::matrix::unit (const typename Matrix_T::size_type n)`

Unit matrix - as per Matlab eye.

- `template<typename LHS_T, typename RHS_T >`
`const RHS_T::expression_type glucat::matrix::mono_prod (const ublas::matrix_expression< LHS_T > &lhs,`
`const ublas::matrix_expression< RHS_T > &rhs)`

Product of monomial matrices.

- `template<typename LHS_T, typename RHS_T >`
`const RHS_T::expression_type glucat::matrix::sparse_prod (const ublas::matrix_expression< LHS_T >`
`&lhs, const ublas::matrix_expression< RHS_T > &rhs)`

Product of sparse matrices.

- `template<typename LHS_T, typename RHS_T >`
`const RHS_T::expression_type glucat::matrix::prod (const ublas::matrix_expression< LHS_T > &lhs, const`
`ublas::matrix_expression< RHS_T > &rhs)`

Product of matrices.

- `template<typename Scalar_T, typename LHS_T, typename RHS_T >`
`Scalar_T glucat::matrix::inner (const LHS_T &lhs, const RHS_T &rhs)`

*Inner product: $\text{sum}(x(i,j)*y(i,j))/x.\text{nrows}()$*

- `template<typename Matrix_T >`
`Matrix_T::value_type glucat::matrix::norm_frob2 (const Matrix_T &val)`

Square of Frobenius norm.

- `template<typename Matrix_T >`
`Matrix_T::value_type glucat::matrix::trace (const Matrix_T &val)`

Matrix trace.

- `template<typename Matrix_T >`
`static ublas::matrix< double, ublas::column_major > glucat::matrix::to_lapack (const Matrix_T &val)`

Convert matrix to LAPACK format.

- `template<typename Matrix_T >`
`ublas::vector< std::complex< double > > glucat::matrix::eigenvalues (const Matrix_T &val)`

Eigenvalues of a matrix.

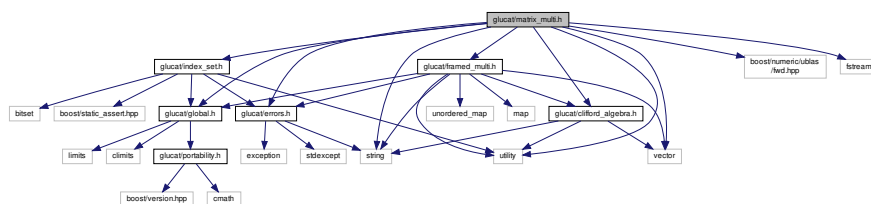
- `template<typename Matrix_T >`
`eig_genus< Matrix_T > glucat::matrix::classify_eigenvalues (const Matrix_T &val)`

Classify the eigenvalues of a matrix.

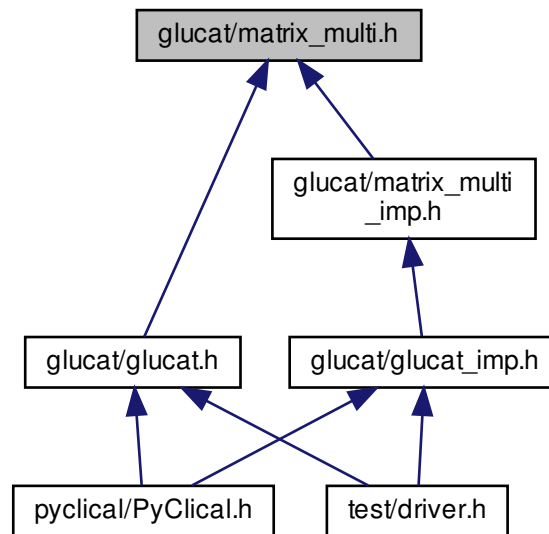
7.18 glucat/matrix_multi.h File Reference

```
#include "glucat/global.h"
#include "glucat/errors.h"
#include "glucat/index_set.h"
#include "glucat/clifford_algebra.h"
#include "glucat/framed_multi.h"
#include <boost/numeric/ublas/fwd.hpp>
#include <fstream>
#include <string>
#include <utility>
#include <vector>
```

Include dependency graph for matrix_multi.h:



This graph shows which files directly or indirectly include this file:



Classes

- class [glucat::framed_multi< Scalar_T, LO, HI >](#)
A *framed_multi< Scalar_T, LO, HI >* is a framed approximation to a multivector.
- class [glucat::matrix_multi< Scalar_T, LO, HI >](#)
A *matrix_multi< Scalar_T, LO, HI >* is a matrix approximation to a multivector.
- class [glucat::matrix_multi< Scalar_T, LO, HI >](#)
A *matrix_multi< Scalar_T, LO, HI >* is a matrix approximation to a multivector.
- struct [std::numeric_limits< glucat::matrix_multi< Scalar_T, LO, HI > >](#)
Numeric limits for *matrix_multi* inherit limits for the corresponding scalar type.

Namespaces

- [glucat](#)
- [std](#)

Functions

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator* (const matrix_multi< Scalar_T, LO, HI > &lhs,`
`const matrix_multi< Scalar_T, LO, HI > &rhs)`
Geometric product.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator^ (const matrix_multi< Scalar_T, LO, HI > &lhs,`
`const matrix_multi< Scalar_T, LO, HI > &rhs)`

Outer product.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator & (const matrix_multi< Scalar_T, LO, HI > &lhs,`
`const matrix_multi< Scalar_T, LO, HI > &rhs)`

Inner product.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator% (const matrix_multi< Scalar_T, LO, HI > &lhs,`
`const matrix_multi< Scalar_T, LO, HI > &rhs)`

Left contraction.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`Scalar_T glucat::star (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI >`
`&rhs)`

Hestenes scalar product.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator/ (const matrix_multi< Scalar_T, LO, HI > &lhs, const`
`matrix_multi< Scalar_T, LO, HI > &rhs)`

Geometric quotient.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator| (const matrix_multi< Scalar_T, LO, HI > &lhs, const`
`matrix_multi< Scalar_T, LO, HI > &rhs)`

Transformation via twisted adjoint action.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::istream & glucat::operator>> (std::istream &s, matrix_multi< Scalar_T, LO, HI > &val)`

Read multivector from input.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`std::ostream & glucat::operator<< (std::ostream &os, const matrix_multi< Scalar_T, LO, HI > &val)`

Write multivector to output.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const index_set< LO, HI > glucat::reframe (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_↔`
`multi< Scalar_T, LO, HI > &rhs, matrix_multi< Scalar_T, LO, HI > &lhs_reframed, matrix_multi< Scalar_T,`
`LO, HI > &rhs_reframed)`

Find a common frame for operands of a binary operator.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::sqrt (const matrix_multi< Scalar_T, LO, HI > &val, const`
`matrix_multi< Scalar_T, LO, HI > &i, bool prechecked)`

Square root of multivector with specified complexifier.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::matrix_sqrt (const matrix_multi< Scalar_T, LO, HI > &val,`
`const matrix_multi< Scalar_T, LO, HI > &i)`

Square root of multivector with specified complexifier.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::log (const matrix_multi< Scalar_T, LO, HI > &val, const`
`matrix_multi< Scalar_T, LO, HI > &i, bool prechecked)`

Natural logarithm of multivector with specified complexifier.

- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::matrix_log (const matrix_multi< Scalar_T, LO, HI > &val,`
`const matrix_multi< Scalar_T, LO, HI > &i)`

Natural logarithm of multivector with specified complexifier.

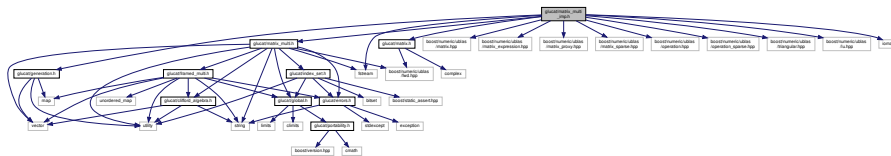
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::exp (const matrix_multi< Scalar_T, LO, HI > &val)`

Exponential of multivector.

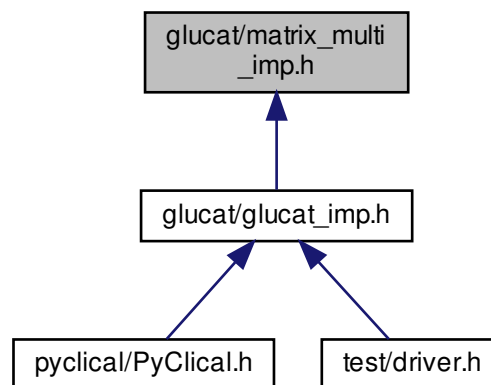
7.19 glucat/matrix_multi_imp.h File Reference

```
#include "glucat/matrix_multi.h"
#include "glucat/matrix.h"
#include "glucat/generation.h"
#include <boost/numeric/ublas/matrix.hpp>
#include <boost/numeric/ublas/matrix_expression.hpp>
#include <boost/numeric/ublas/matrix_proxy.hpp>
#include <boost/numeric/ublas/matrix_sparse.hpp>
#include <boost/numeric/ublas/operation.hpp>
#include <boost/numeric/ublas/operation_sparse.hpp>
#include <boost/numeric/ublas/triangular.hpp>
#include <boost/numeric/ublas/lu.hpp>
#include <fstream>
#include <iomanip>
```

Include dependency graph for matrix_multi_imp.h:



This graph shows which files directly or indirectly include this file:



Classes

- class [glucat::basis_table< Scalar_T, LO, HI, Matrix_T >](#)
Table of basis elements used as a cache by basis_element()

Namespaces

- [glucat](#)

Functions

- `index_t glucat::offset_level` (const index_t p, const index_t q)
Determine the log2 dim corresponding to signature p, q.
- `template<typename Matrix_Index_T, const index_t LO, const index_t HI>`
`static Matrix_Index_T glucat::folded_dim` (const index_set< LO, HI > &sub)
Determine the matrix dimension of the fold of a subalgebra.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`const index_set< LO, HI > glucat::reframe` (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs, matrix_multi< Scalar_T, LO, HI > &lhs_reframed, matrix_multi< Scalar_T, LO, HI > &rhs_reframed)
Find a common frame for operands of a binary operator.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator*` (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs)
Geometric product.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator^` (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs)
Outer product.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator &` (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs)
Inner product.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator%` (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs)
Left contraction.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`Scalar_T glucat::star` (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs)
Hestenes scalar product.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator/` (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs)
Geometric quotient.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::operator|` (const matrix_multi< Scalar_T, LO, HI > &lhs, const matrix_multi< Scalar_T, LO, HI > &rhs)
Transformation via twisted adjoint action.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`std::ostream & glucat::operator<<` (std::ostream &os, const matrix_multi< Scalar_T, LO, HI > &val)
Write multivector to output.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`std::istream & glucat::operator>>` (std::istream &s, matrix_multi< Scalar_T, LO, HI > &val)
Read multivector from input.
- `template<typename Multivector_T, typename Matrix_T, typename Basis_Matrix_T>`
`static Multivector_T glucat::fast` (const Matrix_T &X, index_t level)
Inverse generalized Fast Fourier Transform.
- `template<typename Scalar_T, const index_t LO, const index_t HI>`
`static const matrix_multi< Scalar_T, LO, HI > glucat::pade_approx` (const int array_size, const Scalar_T a[], const Scalar_T b[], const matrix_multi< Scalar_T, LO, HI > &X)
Pade' approximation.

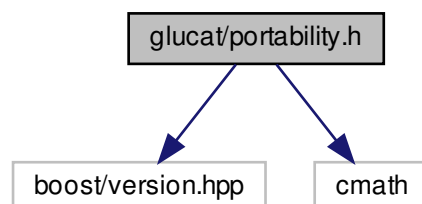
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static void glucat::db_step (matrix_multi< Scalar_T, LO, HI > &M, matrix_multi< Scalar_T, LO, HI > &Y)`
Single step of product form of Denman-Beavers square root iteration.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static const matrix_multi< Scalar_T, LO, HI > glucat::db_sqrt (const matrix_multi< Scalar_T, LO, HI > &val)`
Product form of Denman-Beavers square root iteration.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::sqrt (const matrix_multi< Scalar_T, LO, HI > &val, const matrix_multi< Scalar_T, LO, HI > &i, bool prechecked)`
Square root of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::matrix_sqrt (const matrix_multi< Scalar_T, LO, HI > &val, const matrix_multi< Scalar_T, LO, HI > &i)`
Square root of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static const matrix_multi< Scalar_T, LO, HI > glucat::pade_log (const matrix_multi< Scalar_T, LO, HI > &val)`
Pade' approximation of log.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`static const matrix_multi< Scalar_T, LO, HI > glucat::cascade_log (const matrix_multi< Scalar_T, LO, HI > &val)`
Incomplete square root cascade and Pade' approximation of log.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::log (const matrix_multi< Scalar_T, LO, HI > &val, const matrix_multi< Scalar_T, LO, HI > &i, bool prechecked)`
Natural logarithm of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::matrix_log (const matrix_multi< Scalar_T, LO, HI > &val, const matrix_multi< Scalar_T, LO, HI > &i)`
Natural logarithm of multivector with specified complexifier.
- `template<typename Scalar_T , const index_t LO, const index_t HI>`
`const matrix_multi< Scalar_T, LO, HI > glucat::exp (const matrix_multi< Scalar_T, LO, HI > &val)`
Exponential of multivector.

7.20 `glucat/portability.h` File Reference

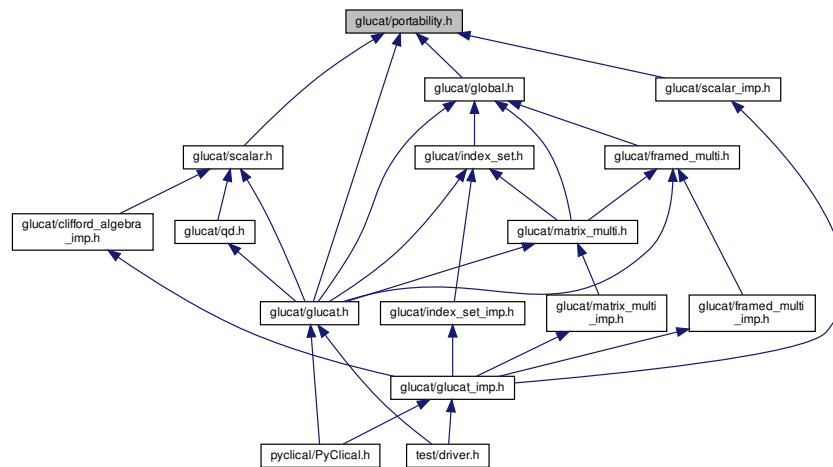
```
#include <boost/version.hpp>
```

```
#include <cmath>
```

Include dependency graph for `portability.h`:



This graph shows which files directly or indirectly include this file:



Macros

- `#define _GLUCAT_ISNAN(x) (x != x)`
- `#define _GLUCAT_ISINF(x) (!_GLUCAT_ISNAN(x) && _GLUCAT_ISNAN(x-x))`
- `#define UBLAS_ABS abs`
- `#define UBLAS_SQRT sqrt`

7.20.1 Macro Definition Documentation

7.20.1.1 _GLUCAT_ISINF

```
#define _GLUCAT_ISINF(
    x ) ( !_GLUCAT_ISNAN(x) && _GLUCAT_ISNAN(x-x) )
```

Definition at line 48 of file portability.h.

Referenced by `glucat::numeric_traits< Scalar_T >::isInf()`.

7.20.1.2 _GLUCAT_ISNAN

```
#define _GLUCAT_ISNAN(
    x ) ( x != x )
```

Definition at line 47 of file portability.h.

Referenced by `glucat::numeric_traits< Scalar_T >::isNaN()`.

7.20.1.3 UBLAS_ABS

```
#define UBLAS_ABS abs
```

Definition at line 56 of file portability.h.

Referenced by `glucat::numeric_traits< Scalar_T >::abs()`.

7.20.1.4 UBLAS_SQRT

```
#define UBLAS_SQRT sqrt
```

Definition at line 57 of file portability.h.

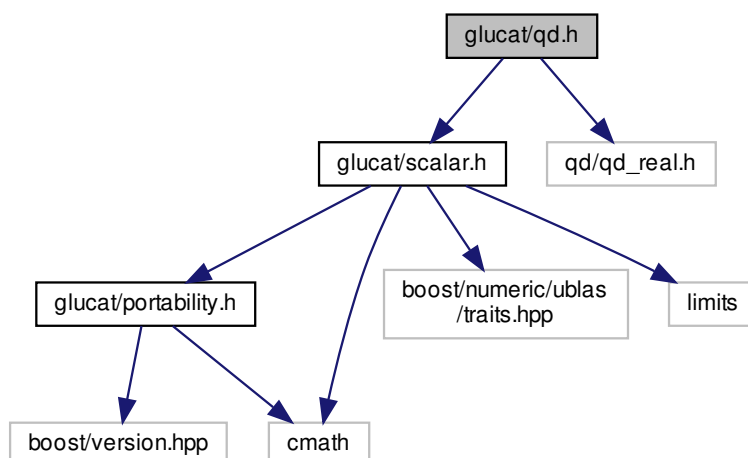
Referenced by `glucat::numeric_traits< Scalar_T >::sqrt()`.

7.21 glucat/qd.h File Reference

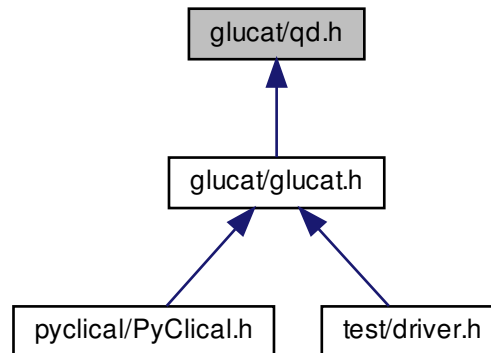
```
#include "glucat/scalar.h"
```

```
#include <qd/qd_real.h>
```

Include dependency graph for qd.h:



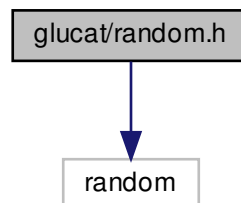
This graph shows which files directly or indirectly include this file:



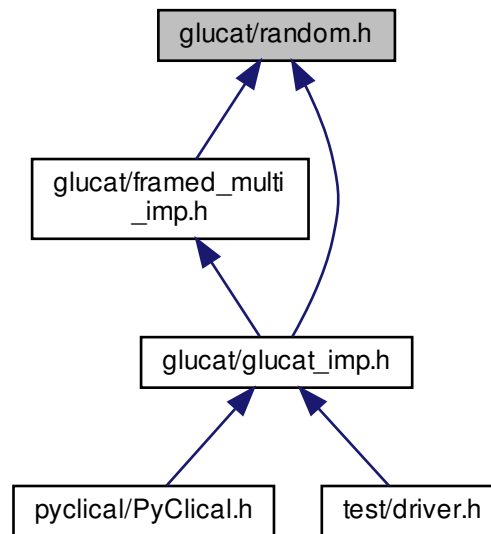
7.22 glucat/random.h File Reference

```
#include <random>
```

Include dependency graph for random.h:



This graph shows which files directly or indirectly include this file:



Classes

- class [glucat::random_generator< Scalar_T >](#)
Random number generator with single instance per Scalar_T.

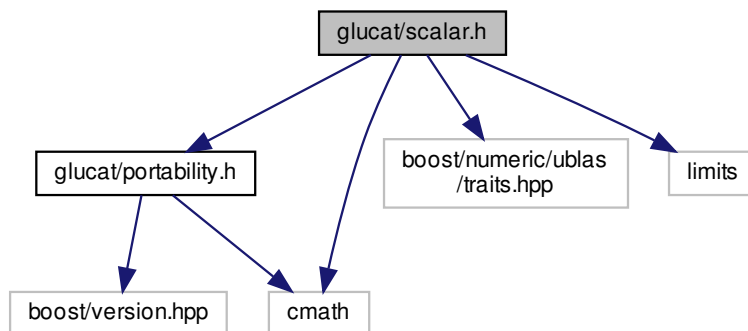
Namespaces

- [glucat](#)

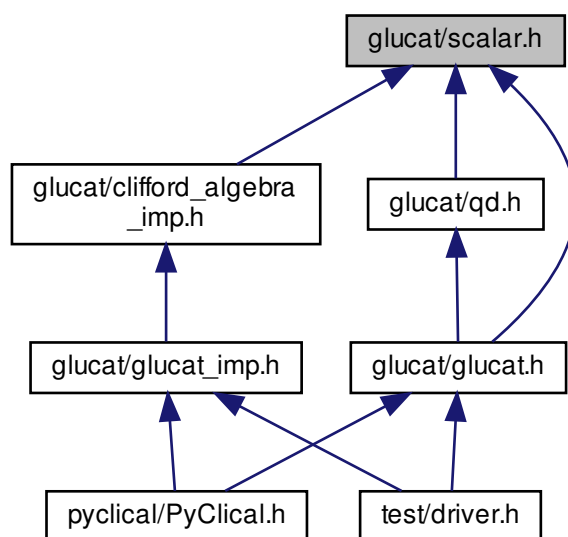
7.23 glucat/scalar.h File Reference

```
#include "glucat/portability.h"  
#include <boost/numeric/ublas/traits.hpp>  
#include <cmath>  
#include <limits>
```

Include dependency graph for scalar.h:



This graph shows which files directly or indirectly include this file:



Classes

- class `glucat::numeric_traits< Scalar_T >`
Extra traits which extend numeric limits.
- struct `glucat::numeric_traits< Scalar_T >::promoted`
Promoted type.
- struct `glucat::numeric_traits< Scalar_T >::demoted<>`
Demoted type for long double.

Namespaces

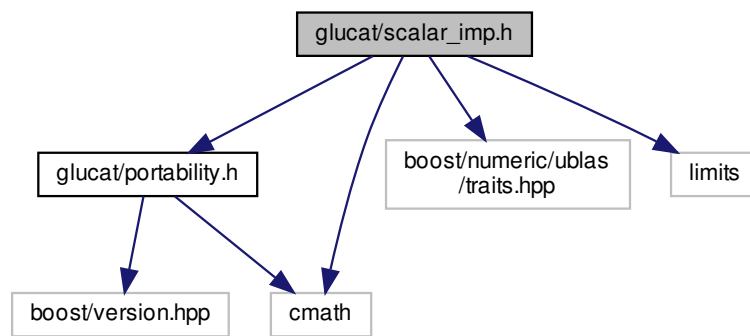
- [glucat](#)

Functions

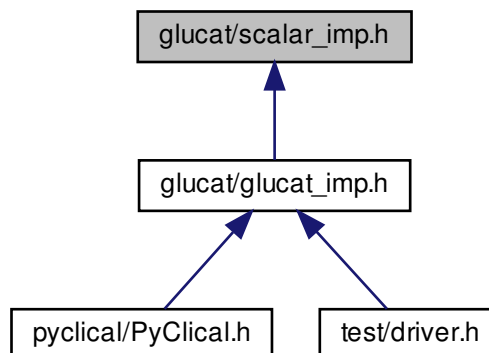
- `template<typename Scalar_T >`
`Scalar_T glucat::log2 (const Scalar_T &x)`
Log base 2 of scalar.

7.24 glucat/scalar_imp.h File Reference

```
#include "glucat/portability.h"
#include <boost/numeric/ublas/traits.hpp>
#include <cmath>
#include <limits>
Include dependency graph for scalar_imp.h:
```



This graph shows which files directly or indirectly include this file:



Namespaces

- [glucat](#)

Functions

- `template<typename Scalar_T >`
`numeric_traits< Scalar_T >::promoted::type` [glucat::to_promote](#) (const Scalar_T &val)
Cast to promote.
- `template<typename Scalar_T >`
`numeric_traits< Scalar_T >::demoted::type` [glucat::to_demote](#) (const Scalar_T &val)
Cast to demote.

7.25 pyclical/glucat.pxd File Reference

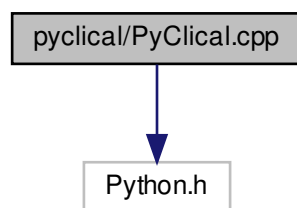
Namespaces

- [glucat](#)

7.26 pyclical/PyClical.cpp File Reference

```
#include "Python.h"
```

Include dependency graph for PyClical.cpp:



Macros

- `#define` [PY_SSIZE_T_CLEAN](#)

7.26.1 Macro Definition Documentation

7.26.1.1 PY_SSIZE_T_CLEAN

```
#define PY_SSIZE_T_CLEAN
```

Definition at line 57 of file PyClical.cpp.

7.27 pyclical/PyClical.h File Reference

```
#include "glucat/glucat.h"
#include "glucat/glucat_imp.h"
#include <iostream>
#include <sstream>
#include <iomanip>
```

Include dependency graph for PyClical.h:



Namespaces

- [cga3](#)
Definitions for 3D Conformal Geometric Algebra [DL].

Typedefs

- typedef [glucat::tuning](#)< [glucat::DEFAULT_Mult_Matrix_Threshold](#), [glucat::DEFAULT_Div_Max_Steps](#), [glucat::DEFAULT_Sqrt_Max_Steps](#), [glucat::DEFAULT_Log_Max_Outer_Steps](#), [glucat::DEFAULT_Log_Max_Inner_Steps](#), [glucat::DEFAULT_Basis_Max_Count](#), [glucat::DEFAULT_Fast_Size_Threshold](#), [glucat::DEFAULT_Inv_Fast_Dim_Threshold](#), [glucat::DEFAULT_Products_Size_Threshold](#), [glucat::precision_promoted](#) > [Tune_P](#)
- typedef std::string [String](#)
- typedef [index_set](#)< [lo_ndx](#), [hi_ndx](#) > [IndexSet](#)
- typedef double [scalar_t](#)
- typedef [matrix_multi](#)< [scalar_t](#) > [Clifford](#)

Functions

- template<typename [Scalar_T](#) >
[PyObject](#) * [PyFloat_FromDouble](#) ([Scalar_T](#) v)
- template<typename [Index_Set_T](#) >
[String](#) [index_set_to_repr](#) (const [Index_Set_T](#) &ist)
The "official" string representation of [Index_Set_T](#) ist.
- template<typename [Index_Set_T](#) >
[String](#) [index_set_to_str](#) (const [Index_Set_T](#) &ist)
The "informal" string representation of [Index_Set_T](#) ist.
- template<typename [Multivector_T](#) >
[String](#) [clifford_to_repr](#) (const [Multivector_T](#) &mv)

The "official" string representation of `Multivector_T` mv.

- template<typename `Multivector_T`>
[String clifford_to_str](#) (const `Multivector_T` &mv)

The "informal" string representation of `Multivector_T` mv.

- template<typename `Multivector_T`>
`Multivector_T` [cga3::cga3](#) (const `Multivector_T` &x)

Convert Euclidean 3D vector to Conformal Geometric Algebra null vector [DL (10.50)].

- template<typename `Multivector_T`>
`Multivector_T` [cga3::cga3std](#) (const `Multivector_T` &X)

Convert CGA3 null vector to standard Conformal Geometric Algebra null vector [DL (10.52)].

- template<typename `Multivector_T`>
`Multivector_T` [cga3::agc3](#) (const `Multivector_T` &X)

Convert CGA3 null vector to Euclidean 3D vector [DL (10.50)].

Variables

- const [index_t lo_ndx](#) = DEFAULT_LO
- const [index_t hi_ndx](#) = DEFAULT_HI

7.27.1 Typedef Documentation

7.27.1.1 Clifford

```
typedef matrix\_multi<scalar\_t> Clifford
```

Definition at line 160 of file `PyClical.h`.

7.27.1.2 IndexSet

```
typedef index\_set<lo\_ndx,hi\_ndx> IndexSet
```

Definition at line 157 of file `PyClical.h`.

7.27.1.3 scalar_t

```
typedef double scalar\_t
```

Definition at line 159 of file `PyClical.h`.

7.27.1.4 String

```
typedef std::string String
```

Definition at line 65 of file PyClical.h.

7.27.1.5 Tune_P

```
typedef glucat::tuning< glucat::DEFAULT_Mult_Matrix_Threshold, glucat::DEFAULT_Div_Max_Steps,
glucal::DEFAULT_Sqrt_Max_Steps, glucat::DEFAULT_Log_Max_Outer_Steps, glucat::DEFAULT_Log_Max_Inner_Steps,
glucat::DEFAULT_Basis_Max_Count, glucat::DEFAULT_Fast_Size_Threshold, glucat::DEFAULT_Inv_Fast_Dim_Threshold,
glucat::DEFAULT_Products_Size_Threshold, glucat::precision_promoted > Tune_P
```

Definition at line 49 of file PyClical.h.

7.27.2 Function Documentation

7.27.2.1 clifford_to_repr()

```
template<typename Multivector_T >
String clifford_to_repr (
    const Multivector_T & mv ) [inline]
```

The "official" string representation of Multivector_T mv.

Definition at line 87 of file PyClical.h.

Referenced by PyClical.clifford::__repr__().

7.27.2.2 clifford_to_str()

```
template<typename Multivector_T >
String clifford_to_str (
    const Multivector_T & mv ) [inline]
```

The "informal" string representation of Multivector_T mv.

Definition at line 98 of file PyClical.h.

References glucat::abs(), and PyClical::e().

Referenced by PyClical.clifford::__str__().

7.27.2.3 index_set_to_repr()

```
template<typename Index_Set_T >
String index_set_to_repr (
    const Index_Set_T & ist ) [inline]
```

The "official" string representation of Index_Set_T ist.

Definition at line 69 of file PyClical.h.

References PyClical::ist.

Referenced by PyClical.index_set::__repr__().

7.27.2.4 index_set_to_str()

```
template<typename Index_Set_T >
String index_set_to_str (
    const Index_Set_T & ist ) [inline]
```

The "informal" string representation of Index_Set_T ist.

Definition at line 78 of file PyClical.h.

References PyClical::ist.

Referenced by PyClical.index_set::__str__().

7.27.2.5 PyFloat_FromDouble()

```
template<typename Scalar_T >
PyObject* PyFloat_FromDouble (
    Scalar_T v ) [inline]
```

Create a PyFloatObject object from Scalar_T v. Needed because Scalar_T might not be the same as double.

Definition at line 59 of file PyClical.h.

7.27.3 Variable Documentation

7.27.3.1 hi_ndx

```
const index_t hi_ndx = DEFAULT_HI
```

Definition at line 156 of file PyClical.h.

7.27.3.2 lo_ndx

```
const index_t lo_ndx = DEFAULT_LO
```

Definition at line 155 of file PyClical.h.

7.28 pyclical/PyClical.pxd File Reference

Namespaces

- [PyClical](#)

7.29 pyclical/PyClical.pyx File Reference

Classes

- class [PyClical.index_set](#)
- class [PyClical.index_set](#)
- class [PyClical.clifford](#)
- class [PyClical.clifford](#)

Namespaces

- [PyClical](#)

Functions

- def [PyClical.index_set_hidden_doctests](#) ()
- def [PyClical.clifford_hidden_doctests](#) ()
- def [PyClical.e](#) (obj)
- def [PyClical.istpq](#) (p, q)
- def [PyClical._test](#) ()

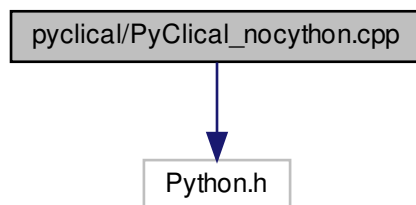
Variables

- string [PyClical.__version__](#) = "0.8.2"
- [PyClical.obj](#)
- [PyClical.i](#)
- [PyClical.ixt](#)
- [PyClical.fill](#)
- float [PyClical.tau](#) = atan(clifford(1.0)) * 8.0
- float [PyClical.pi](#) = tau / 2.0
- [PyClical.cl](#) = clifford
- [PyClical.ist](#) = index_set
- def [PyClical.ninf3](#) = e(4) + e(-1)
- def [PyClical.nbar3](#) = e(4) - e(-1)

7.30 pyclical/PyClical_nocython.cpp File Reference

```
#include "Python.h"
```

Include dependency graph for PyClical_nocython.cpp:



Macros

- `#define PY_SSIZE_T_CLEAN`

7.30.1 Macro Definition Documentation

7.30.1.1 PY_SSIZE_T_CLEAN

```
#define PY_SSIZE_T_CLEAN
```

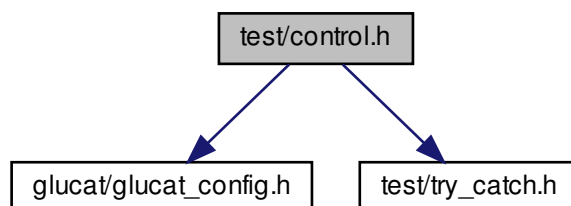
Definition at line 52 of file PyClical_nocython.cpp.

7.31 test/control.h File Reference

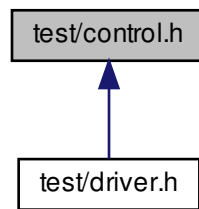
```
#include "glucat/glucat_config.h"
```

```
#include "test/try_catch.h"
```

Include dependency graph for control.h:



This graph shows which files directly or indirectly include this file:



Classes

- class [glucat::control_t](#)
Parameters to control tests.

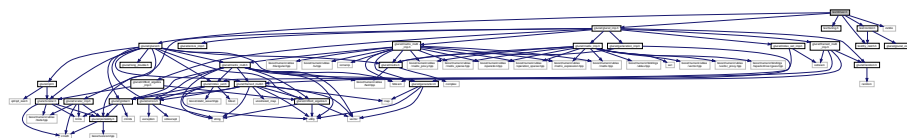
Namespaces

- [glucat](#)

7.32 test/driver.h File Reference

```
#include "glucat/glucat.h"
#include "test/tuning.h"
#include "glucat/glucat_imp.h"
#include "test/try_catch.h"
#include "test/control.h"
#include <cstdio>
```

Include dependency graph for driver.h:



7.33 test/timing.h File Reference

Namespaces

- [glucat](#)
- [glucat::timing](#)

Functions

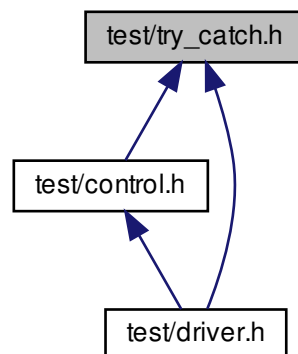
- static double `glucat::timing::elapsed` (clock_t cpu_time)
Elapsed time in milliseconds.

Variables

- const double `glucat::timing::MS_PER_SEC` = 1000.0
Timing constant: milliseconds per second.
- const double `glucat::timing::MS_PER_CLOCK` = MS_PER_SEC / double(CLOCKS_PER_SEC)
Timing constant: milliseconds per clock.
- const int `glucat::timing::EXTRA_TRIALS` = 2
Timing constant: trial expansion factor.

7.34 test/try_catch.h File Reference

This graph shows which files directly or indirectly include this file:



Namespaces

- `glucat`

Typedefs

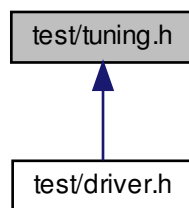
- typedef int(* `glucat::intfn`) ()
For exception catching: pointer to function returning int.
- typedef int(* `glucat::intintfn`) (int)
For exception catching: pointer to function of int returning int.

Functions

- int [glucat::try_catch](#) (intfn f)
Exception catching for functions returning int.
- int [glucat::try_catch](#) (intintfn f, int arg)
Exception catching for functions of int returning int.

7.35 test/tuning.h File Reference

This graph shows which files directly or indirectly include this file:



Macros

- `#define __TEST_TUNING_DEFAULT_CONSTANT(SUFFIX) const unsigned int Test_Tuning_##SUFFIX = glucat::DEFAULT_##SUFFIX`

Typedefs

- typedef [glucat::precision_t](#) [precision_t](#)
- typedef [glucat::tuning](#) < Test_Tuning_Mult_Matrix_Threshold, Test_Tuning_Div_Max_Steps, Test_Tuning_Sqrt_Max_Steps, Test_Tuning_Log_Max_Outer_Steps, Test_Tuning_Log_Max_Inner_Steps, Test_Tuning_Basis_Max_Count, Test_Tuning_Fast_Size_Threshold, Test_Tuning_Inv_Fast_Dim_Threshold, Test_Tuning_Products_Size_Threshold, [Test_Tuning_Function_Precision](#) > [Tune_P](#)
Tuning policy.

Functions

- [_GLUCAT_CTAssert](#) (std::numeric_limits< unsigned int >::radix==2, CannotSetThresholds) const unsigned int Test_Tuning_Int_Digits
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Mult_Matrix_Threshold)
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Div_Max_Steps)
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Sqrt_Max_Steps)
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Log_Max_Outer_Steps)
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Log_Max_Inner_Steps)
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Basis_Max_Count)
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Fast_Size_Threshold)
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Inv_Fast_Dim_Threshold)
- [__TEST_TUNING_DEFAULT_CONSTANT](#) (Products_Size_Threshold)

Variables

- const unsigned int `Test_Tuning_Max_Threshold` = 1 << `Test_Tuning_Int_Digits`
- const `precision_t` `Test_Tuning_Function_Precision` = `glucat::DEFAULT_Function_Precision`

7.35.1 Macro Definition Documentation

7.35.1.1 __TEST_TUNING_DEFAULT_CONSTANT

```
#define __TEST_TUNING_DEFAULT_CONSTANT(  
    SUFFIX ) const unsigned int Test_Tuning_##SUFFIX = glucat::DEFAULT_##SUFFIX
```

Definition at line 41 of file tuning.h.

7.35.2 Typedef Documentation

7.35.2.1 precision_t

```
typedef glucat::precision_t precision_t
```

Definition at line 39 of file tuning.h.

7.35.2.2 Tune_P

```
typedef glucat::tuning< Test_Tuning_Mult_Matrix_Threshold, Test_Tuning_Div_Max_Steps, Test_↵  
_Tuning_Sqrt_Max_Steps, Test_Tuning_Log_Max_Outer_Steps, Test_Tuning_Log_Max_Inner_Steps,  
Test_Tuning_Basis_Max_Count, Test_Tuning_Fast_Size_Threshold, Test_Tuning_Inv_Fast_Dim_↵  
Threshold, Test_Tuning_Products_Size_Threshold, Test_Tuning_Function_Precision > Tune_P
```

Tuning policy.

Definition at line 126 of file tuning.h.

7.35.3 Function Documentation

7.35.3.1 __TEST_TUNING_DEFAULT_CONSTANT() [1/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Mult_Matrix_Threshold )
```

7.35.3.2 __TEST_TUNING_DEFAULT_CONSTANT() [2/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Div_Max_Steps )
```

7.35.3.3 __TEST_TUNING_DEFAULT_CONSTANT() [3/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Sqrt_Max_Steps )
```

7.35.3.4 __TEST_TUNING_DEFAULT_CONSTANT() [4/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Log_Max_Outer_Steps )
```

7.35.3.5 __TEST_TUNING_DEFAULT_CONSTANT() [5/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Log_Max_Inner_Steps )
```

7.35.3.6 __TEST_TUNING_DEFAULT_CONSTANT() [6/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Basis_Max_Count )
```

7.35.3.7 __TEST_TUNING_DEFAULT_CONSTANT() [7/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Fast_Size_Threshold )
```


7.35.3.8 `__TEST_TUNING_DEFAULT_CONSTANT()` [8/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Inv_Fast_Dim_Threshold )
```

7.35.3.9 `__TEST_TUNING_DEFAULT_CONSTANT()` [9/9]

```
__TEST_TUNING_DEFAULT_CONSTANT (
    Products_Size_Threshold )
```

7.35.3.10 `_GLUCAT_CTAssert()`

```
_GLUCAT_CTAssert (
    std::numeric_limits< unsigned int >::radix  = 2,
    CannotSetThresholds ) const
```

7.35.4 Variable Documentation

7.35.4.1 `Test_Tuning_Function_Precision`

```
const precision_t Test_Tuning_Function_Precision = glucat::DEFAULT_Function_Precision
```

Definition at line 110 of file tuning.h.

7.35.4.2 `Test_Tuning_Max_Threshold`

```
const unsigned int Test_Tuning_Max_Threshold = 1 << Test_Tuning_Int_Digits
```

Definition at line 37 of file tuning.h.

7.36 test/undefine.h File Reference

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