

# NAG Library Function Document

## nag\_zher2k (f16zrc)

### 1 Purpose

nag\_zher2k (f16zrc) performs a rank- $2k$  update on a complex Hermitian matrix.

### 2 Specification

```
#include <nag.h>
#include <nagf16.h>

void nag_zher2k (Nag_OrderType order, Nag_UploType uplo,
                Nag_TransType trans, Integer n, Integer k, Complex alpha,
                const Complex a[], Integer pda, const Complex b[], Integer pdb,
                double beta, Complex c[], Integer pdc, NagError *fail)
```

### 3 Description

nag\_zher2k (f16zrc) performs one of the Hermitian rank- $2k$  update operations

$$C \leftarrow \alpha AB^H + \bar{\alpha}A^H + \beta C \quad \text{or} \quad C \leftarrow \bar{\alpha}A^H B + \alpha B^H A + \beta C,$$

where  $A$  and  $B$  are complex matrices,  $C$  is an  $n$  by  $n$  complex Hermitian matrix,  $\alpha$  is a complex scalar, and  $\beta$  is a real scalar.

### 4 References

Basic Linear Algebra Subprograms Technical (BLAST) Forum (2001) *Basic Linear Algebra Subprograms Technical (BLAST) Forum Standard* University of Tennessee, Knoxville, Tennessee <http://www.netlib.org/blas/blast-forum/blas-report.pdf>

### 5 Arguments

1: **order** – Nag\_OrderType *Input*

*On entry:* the **order** argument specifies the two-dimensional storage scheme being used, i.e., row-major ordering or column-major ordering. C language defined storage is specified by **order** = Nag\_RowMajor. See Section 2.3.1.3 in How to Use the NAG Library and its Documentation for a more detailed explanation of the use of this argument.

*Constraint:* **order** = Nag\_RowMajor or Nag\_ColMajor.

2: **uplo** – Nag\_UploType *Input*

*On entry:* specifies whether the upper or lower triangular part of  $C$  is stored.

**uplo** = Nag\_Upper

The upper triangular part of  $C$  is stored.

**uplo** = Nag\_Lower

The lower triangular part of  $C$  is stored.

*Constraint:* **uplo** = Nag\_Upper or Nag\_Lower.

- 3: **trans** – Nag\_TransType *Input*  
*On entry:* specifies the operation to be performed.  
**trans** = Nag\_NoTrans  

$$C \leftarrow \alpha B^H A + \bar{\alpha} B A^H + \beta C.$$
**trans** = Nag\_ConjTrans  

$$C \leftarrow \bar{\alpha} A^H B + \alpha B^H A + \beta C.$$
*Constraint:* **trans** = Nag\_NoTrans or Nag\_ConjTrans.
- 4: **n** – Integer *Input*  
*On entry:*  $n$ , the order of the matrix  $C$ ; the number of rows of  $A$  and  $B$  if **trans** = Nag\_NoTrans, or the number of columns of  $A$  and  $B$  otherwise.  
*Constraint:*  $n \geq 0$ .
- 5: **k** – Integer *Input*  
*On entry:*  $k$ , the number of columns of  $A$  and  $B$  if **trans** = Nag\_NoTrans, or the number of rows of  $A$  and  $B$  otherwise.  
*Constraint:*  $k \geq 0$ .
- 6: **alpha** – Complex *Input*  
*On entry:* the scalar  $\alpha$ .
- 7: **a**[*dim*] – const Complex *Input*  
**Note:** the dimension, *dim*, of the array **a** must be at least  
 $\max(1, \mathbf{pda} \times \mathbf{k})$  when **trans** = Nag\_NoTrans and **order** = Nag\_ColMajor;  
 $\max(1, \mathbf{n} \times \mathbf{pda})$  when **trans** = Nag\_NoTrans and **order** = Nag\_RowMajor;  
 $\max(1, \mathbf{pda} \times \mathbf{n})$  when **trans** = Nag\_ConjTrans and **order** = Nag\_ColMajor;  
 $\max(1, \mathbf{k} \times \mathbf{pda})$  when **trans** = Nag\_ConjTrans and **order** = Nag\_RowMajor.  
If **order** = Nag\_ColMajor,  $A_{ij}$  is stored in **a**[( $j - 1$ )  $\times$  **pda** +  $i - 1$ ].  
If **order** = Nag\_RowMajor,  $A_{ij}$  is stored in **a**[( $i - 1$ )  $\times$  **pda** +  $j - 1$ ].  
*On entry:* the matrix  $A$ ;  $A$  is  $n$  by  $k$  if **trans** = Nag\_NoTrans, or  $k$  by  $n$  otherwise.
- 8: **pda** – Integer *Input*  
*On entry:* the stride separating row or column elements (depending on the value of **order**) in the array **a**.  
*Constraints:*  
if **order** = Nag\_ColMajor,  
    if **trans** = Nag\_NoTrans, **pda**  $\geq$   $\max(1, \mathbf{n})$ ;  
    if **trans** = Nag\_ConjTrans, **pda**  $\geq$   $\max(1, \mathbf{k})$ .;  
if **order** = Nag\_RowMajor,  
    if **trans** = Nag\_NoTrans, **pda**  $\geq$   $\max(1, \mathbf{k})$ ;  
    if **trans** = Nag\_ConjTrans, **pda**  $\geq$   $\max(1, \mathbf{n})$ .
- 9: **b**[*dim*] – const Complex *Input*  
**Note:** the dimension, *dim*, of the array **b** must be at least  
 $\max(1, \mathbf{pda} \times \mathbf{k})$  when **trans** = Nag\_NoTrans and **order** = Nag\_ColMajor;  
 $\max(1, \mathbf{n} \times \mathbf{pda})$  when **trans** = Nag\_NoTrans and **order** = Nag\_RowMajor;  
 $\max(1, \mathbf{pda} \times \mathbf{n})$  when **trans** = Nag\_ConjTrans and **order** = Nag\_ColMajor;

$\max(1, \mathbf{k} \times \mathbf{pdb})$  when **trans** = Nag\_ConjTrans and **order** = Nag\_RowMajor.

If **order** = Nag\_ColMajor,  $B_{ij}$  is stored in  $\mathbf{b}[(j-1) \times \mathbf{pdb} + i - 1]$ .

If **order** = Nag\_RowMajor,  $B_{ij}$  is stored in  $\mathbf{b}[(i-1) \times \mathbf{pdb} + j - 1]$ .

*On entry:* the matrix  $B$ ;  $B$  is  $n$  by  $k$  if **trans** = Nag\_NoTrans, or  $k$  by  $n$  otherwise.

10: **pdb** – Integer *Input*

*On entry:* the stride separating row or column elements (depending on the value of **order**) in the array **b**.

*Constraints:*

if **order** = Nag\_ColMajor,

if **trans** = Nag\_NoTrans,  $\mathbf{pdb} \geq \max(1, \mathbf{n})$ ;

if **trans** = Nag\_ConjTrans,  $\mathbf{pdb} \geq \max(1, \mathbf{k})$ ;

if **order** = Nag\_RowMajor,

if **trans** = Nag\_NoTrans,  $\mathbf{pdb} \geq \max(1, \mathbf{k})$ ;

if **trans** = Nag\_ConjTrans,  $\mathbf{pdb} \geq \max(1, \mathbf{n})$ .

11: **beta** – double *Input*

*On entry:* the scalar  $\beta$ .

12: **c**[*dim*] – Complex *Input/Output*

**Note:** the dimension, *dim*, of the array **c** must be at least  $\max(1, \mathbf{pdc} \times \mathbf{n})$ .

*On entry:* the  $n$  by  $n$  Hermitian matrix  $C$ .

If **order** = Nag\_ColMajor,  $C_{ij}$  is stored in  $\mathbf{c}[(j-1) \times \mathbf{pdc} + i - 1]$ .

If **order** = Nag\_RowMajor,  $C_{ij}$  is stored in  $\mathbf{c}[(i-1) \times \mathbf{pdc} + j - 1]$ .

If **uplo** = Nag\_Upper, the upper triangular part of  $C$  must be stored and the elements of the array below the diagonal are not referenced.

If **uplo** = Nag\_Lower, the lower triangular part of  $C$  must be stored and the elements of the array above the diagonal are not referenced.

*On exit:* the updated matrix  $C$ . The imaginary parts of the diagonal elements are set to zero.

13: **pdc** – Integer *Input*

*On entry:* the stride separating row or column elements (depending on the value of **order**) of the matrix  $C$  in the array **c**.

*Constraint:*  $\mathbf{pdc} \geq \max(1, \mathbf{n})$ .

14: **fail** – NagError \* *Input/Output*

The NAG error argument (see Section 2.7 in How to Use the NAG Library and its Documentation).

## 6 Error Indicators and Warnings

### NE\_ALLOC\_FAIL

Dynamic memory allocation failed.

See Section 2.3.1.2 in How to Use the NAG Library and its Documentation for further information.

**NE\_BAD\_PARAM**

On entry, argument  $\langle value \rangle$  had an illegal value.

**NE\_ENUM\_INT\_2**

On entry, **trans** =  $\langle value \rangle$ , **k** =  $\langle value \rangle$ , **pda** =  $\langle value \rangle$ .  
Constraint: if **trans** = Nag-ConjTrans, **pda**  $\geq$  max(1, **k**).

On entry, **trans** =  $\langle value \rangle$ , **k** =  $\langle value \rangle$ , **pda** =  $\langle value \rangle$ .  
Constraint: if **trans** = Nag-NoTrans, **pda**  $\geq$  max(1, **k**).

On entry, **trans** =  $\langle value \rangle$ , **k** =  $\langle value \rangle$ , **pdb** =  $\langle value \rangle$ .  
Constraint: if **trans** = Nag-ConjTrans, **pdb**  $\geq$  max(1, **k**).

On entry, **trans** =  $\langle value \rangle$ , **k** =  $\langle value \rangle$ , **pdb** =  $\langle value \rangle$ .  
Constraint: if **trans** = Nag-NoTrans, **pdb**  $\geq$  max(1, **k**).

On entry, **trans** =  $\langle value \rangle$ , **n** =  $\langle value \rangle$ , **pda** =  $\langle value \rangle$ .  
Constraint: if **trans** = Nag-ConjTrans, **pda**  $\geq$  max(1, **n**).

On entry, **trans** =  $\langle value \rangle$ , **n** =  $\langle value \rangle$ , **pda** =  $\langle value \rangle$ .  
Constraint: if **trans** = Nag-NoTrans, **pda**  $\geq$  max(1, **n**).

On entry, **trans** =  $\langle value \rangle$ , **n** =  $\langle value \rangle$ , **pdb** =  $\langle value \rangle$ .  
Constraint: if **trans** = Nag-ConjTrans, **pdb**  $\geq$  max(1, **n**).

On entry, **trans** =  $\langle value \rangle$ , **n** =  $\langle value \rangle$ , **pdb** =  $\langle value \rangle$ .  
Constraint: if **trans** = Nag-NoTrans, **pdb**  $\geq$  max(1, **n**).

**NE\_INT**

On entry, **k** =  $\langle value \rangle$ .  
Constraint: **k**  $\geq$  0.

On entry, **n** =  $\langle value \rangle$ .  
Constraint: **n**  $\geq$  0.

**NE\_INT\_2**

On entry, **pdn** =  $\langle value \rangle$ , **n** =  $\langle value \rangle$ .  
Constraint: **pdn**  $\geq$  max(1, **n**).

**NE\_INTERNAL\_ERROR**

An internal error has occurred in this function. Check the function call and any array sizes. If the call is correct then please contact NAG for assistance.

An unexpected error has been triggered by this function. Please contact NAG.  
See Section 2.7.6 in How to Use the NAG Library and its Documentation for further information.

**NE\_NO\_LICENCE**

Your licence key may have expired or may not have been installed correctly.  
See Section 2.7.5 in How to Use the NAG Library and its Documentation for further information.

**7 Accuracy**

The BLAS standard requires accurate implementations which avoid unnecessary over/underflow (see Section 2.7 of Basic Linear Algebra Subprograms Technical (BLAST) Forum (2001)).

**8 Parallelism and Performance**

nag\_zher2k (f16zrc) is threaded by NAG for parallel execution in multithreaded implementations of the NAG Library.

nag\_zher2k (f16zrc) makes calls to BLAS and/or LAPACK routines, which may be threaded within the vendor library used by this implementation. Consult the documentation for the vendor library for further information.

Please consult the x06 Chapter Introduction for information on how to control and interrogate the OpenMP environment used within this function. Please also consult the Users' Note for your implementation for any additional implementation-specific information.

## 9 Further Comments

None.

## 10 Example

Perform rank- $2k$  update of complex Hermitian 4 by 4 matrix  $C$  using 4 by 2 matrices  $A$  and  $B$ ,  $C = -C + (-0.5 + 0.5i)AB^T + (-0.5 - 0.5i)BA^T$ , where

$$C = \begin{pmatrix} 4.78 + 0.00i & 2.00 + 0.30i & 2.89 + 1.34i & -1.89 - 1.15i \\ 2.00 - 0.30i & -4.11 + 0.00i & 2.36 + 4.25i & 0.04 + 3.69i \\ 2.89 - 1.34i & 2.36 - 4.25i & 4.15 + 0.00i & -0.02 - 0.46i \\ -1.89 + 1.15i & 0.04 - 3.69i & -0.02 + 0.46i & 0.33 + 0.00i \end{pmatrix},$$

$$A = \begin{pmatrix} 1.7 - 2.3i & -1.8 + 2.4i \\ 2.9 - 2.1i & 1.2 + 1.4i \\ -2.9 + 1.0i & 0.6 + 0.8i \\ 1.5 + 0.9i & -1.4 - 1.7i \\ -0.3 - 1.9i & 2.1 - 1.1i \end{pmatrix}$$

and

$$B = \begin{pmatrix} -2.4 + 1.4i & 0.6 - 2.9i \\ -0.2 - 2.9i & -1.5 + 0.1i \\ 3.5 + 0.8i & 2.2 + 3.7i \end{pmatrix}.$$

### 10.1 Program Text

```

/* nag_zher2k (f16zrc) Example Program.
*
* NAGPRODCODE Version.
*
* Copyright 2016 Numerical Algorithms Group.
*
* Mark 26, 2016.
*/

#include <stdio.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagf16.h>
#include <nagx04.h>

int main(void)
{
    /* Scalars */
    Complex alpha;
    double beta;
    Integer adim1, adim2, exit_status, i, j, k, n, pda, pdb, pdc;

    /* Arrays */
    Complex *a = 0, *b = 0, *c = 0;
    char nag_enum_arg[40];

    /* Nag Types */
    NagError fail;

```

```

Nag_OrderType order;
Nag_UploType uplo;
Nag_TransType trans;
Nag_MatrixType matrix;

#ifdef NAG_COLUMN_MAJOR
#define A(I, J) a[(J-1)*pda + I - 1]
#define B(I, J) b[(J-1)*pdb + I - 1]
#define C(I, J) c[(J-1)*pdc + I - 1]
    order = Nag_ColMajor;
#else
#define A(I, J) a[(I-1)*pda + J - 1]
#define B(I, J) b[(I-1)*pdb + J - 1]
#define C(I, J) c[(I-1)*pdc + J - 1]
    order = Nag_RowMajor;
#endif

    exit_status = 0;
    INIT_FAIL(fail);

    printf("nag_zher2k (f16zrc) Example Program Results\n\n");

    /* Skip heading in data file */
#ifdef _WIN32
    scanf_s("%*[\n] ");
#else
    scanf("%*[\n] ");
#endif

    /* Read the problem dimensions */
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &n, &k);
#else
    scanf("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &n, &k);
#endif

    /* Read the uplo parameter */
#ifdef _WIN32
    scanf_s("%39s%*[\n] ", nag_enum_arg, (unsigned)_countof(nag_enum_arg));
#else
    scanf("%39s%*[\n] ", nag_enum_arg);
#endif
    /* nag_enum_name_to_value (x04nac).
     * Converts NAG enum member name to value
     */
    uplo = (Nag_UploType) nag_enum_name_to_value(nag_enum_arg);
    /* Read the transpose parameter */
#ifdef _WIN32
    scanf_s("%39s%*[\n] ", nag_enum_arg, (unsigned)_countof(nag_enum_arg));
#else
    scanf("%39s%*[\n] ", nag_enum_arg);
#endif
    /* nag_enum_name_to_value (x04nac), see above. */
    trans = (Nag_TransType) nag_enum_name_to_value(nag_enum_arg);
    /* Read scalar parameters */
#ifdef _WIN32
    scanf_s(" ( %lf , %lf )%*[\n] ", &alpha.re, &alpha.im);
#else
    scanf(" ( %lf , %lf )%*[\n] ", &alpha.re, &alpha.im);
#endif
#ifdef _WIN32
    scanf_s("%lf%*[\n] ", &beta);
#else
    scanf("%lf%*[\n] ", &beta);
#endif

    if (trans == Nag_NoTrans) {
        adim1 = n;
        adim2 = k;
    }
    else {

```

```

    adim1 = k;
    adim2 = n;
}

#ifdef NAG_COLUMN_MAJOR
    pda = adim1;
#else
    pda = adim2;
#endif
    pdb = pda;
    pdc = n;
    if (k > 0 && n > 0) {
        /* Allocate memory */
        if (!(a = NAG_ALLOC(k * n, Complex)) ||
            !(b = NAG_ALLOC(k * n, Complex)) || !(c = NAG_ALLOC(n * n, Complex)))
        {
            printf("Allocation failure\n");
            exit_status = -1;
            goto END;
        }
    }
    else {
        printf("Invalid k or n\n");
        exit_status = 1;
        return exit_status;
    }

    /* Input matrix A. */
    for (i = 1; i <= adim1; ++i) {
        for (j = 1; j <= adim2; ++j)
#ifdef _WIN32
            scanf_s(" ( %lf , %lf )", &A(i, j).re, &A(i, j).im);
#else
            scanf(" ( %lf , %lf )", &A(i, j).re, &A(i, j).im);
#endif
#ifdef _WIN32
            scanf_s("%*[\n] ");
#else
            scanf("%*[\n] ");
#endif
    }
    /* Input matrix A. */
    for (i = 1; i <= adim1; ++i) {
        for (j = 1; j <= adim2; ++j)
#ifdef _WIN32
            scanf_s(" ( %lf , %lf )", &B(i, j).re, &B(i, j).im);
#else
            scanf(" ( %lf , %lf )", &B(i, j).re, &B(i, j).im);
#endif
#ifdef _WIN32
            scanf_s("%*[\n] ");
#else
            scanf("%*[\n] ");
#endif
    }
    /* Input matrix C. */
    if (uplo == Nag_Upper) {
        for (i = 1; i <= n; ++i) {
            for (j = i; j <= n; ++j)
#ifdef _WIN32
                scanf_s(" ( %lf , %lf )", &C(i, j).re, &C(i, j).im);
#else
                scanf(" ( %lf , %lf )", &C(i, j).re, &C(i, j).im);
#endif
        }
#ifdef _WIN32
        scanf_s("%*[\n] ");
#else
        scanf("%*[\n] ");
#endif
    }
}

```

```

    else {
        for (i = 1; i <= n; ++i) {
            for (j = 1; j <= i; ++j)
#ifdef _WIN32
                scanf_s(" ( %lf , %lf )", &C(i, j).re, &C(i, j).im);
#else
                scanf(" ( %lf , %lf )", &C(i, j).re, &C(i, j).im);
#endif
        }
#ifdef _WIN32
        scanf_s("%*[\n] ");
#else
        scanf("%*[\n] ");
#endif
    }

    /* nag_zher2k (f16zrc).
     * Rank 2k update of complex Hermitian matrix.
     */
    nag_zher2k(order, uplo, trans, n, k, alpha, a, pda, b, pdb, beta,
              c, pdc, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_zher2k.\n%s\n", fail.message);
        exit_status = 1;
        goto END;
    }
    if (uplo == Nag_Upper) {
        matrix = Nag_UpperMatrix;
    }
    else {
        matrix = Nag_LowerMatrix;
    }
    /* Print updated matrix C */
    /* nag_gen_complx_mat_print_comp (x04dbc).
     * Print complex general matrix (comprehensive)
     */
    fflush(stdout);
    nag_gen_complx_mat_print_comp(order, matrix, Nag_NonUnitDiag, n, n, c,
                                  pdc, Nag_BracketForm, "%7.3f",
                                  "Updated Matrix C", Nag_IntegerLabels,
                                  0, Nag_IntegerLabels, 0, 80, 0, 0, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_gen_complx_mat_print_comp (x04dbc).\n%s"
              "\n", fail.message);
        exit_status = 1;
        goto END;
    }
}
END:
    NAG_FREE(a);
    NAG_FREE(b);
    NAG_FREE(c);

    return exit_status;
}

```

## 10.2 Program Data

```

nag_zher2k (f16zrc) Example Program Data
 4 2 :Values of n and k
 Nag_Lower :Value of uplo
 Nag_NoTrans :Value of trans
 (-0.5, 0.5) :Value of alpha
 -1.0 :Value of beta
 ( 1.7, -2.3) ( -1.8, 2.4)
 ( 2.9, -2.1) ( 1.2, 1.4)
 (-2.9, 1.0) ( 0.6, 0.8)
 ( 1.5, 0.9) ( -1.4, -1.7) :End of matrix A
 (-0.3, -1.9) ( 2.1, -1.1)
 (-2.4, 1.4) ( 0.6, -2.9)

```

```

( -0.2, -2.9) ( -1.5,  0.1)
(  3.5,  0.8) (  2.2,  3.7)           :End of matrix B
(  4.78, 0.00)
(  2.00,-0.30) (-4.11,  0.00)
(  2.89,-1.34) (  2.36,-4.25) (  4.15,  0.00)
(-1.89,  1.15) (  0.04,-3.69) (-0.02,  0.46) (  0.33,  0.00) :End of matrix C

```

### 10.3 Program Results

nag\_zher2k (f16zrc) Example Program Results

Updated Matrix C

	1	2	3	4
1	( -9.200,  0.000)			
2	( -1.260,  4.500)	( 12.050,  0.000)		
3	( -6.450, -0.900)	(-12.730,  6.890)	(  8.860,  0.000)	
4	( -1.010, -4.750)	(  1.125, -4.425)	( -3.065,  0.835)	( -0.320,  0.000)

---