

# NAG Library Function Document

## nag\_zhbmV (f16sdc)

### 1 Purpose

nag\_zhbmV (f16sdc) performs matrix-vector multiplication for a complex Hermitian band matrix.

### 2 Specification

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

void nag_zhbmV (Nag_OrderType order, Nag_UploType uplo, Integer n, Integer k,
               Complex alpha, const Complex ab[], Integer pdab, const Complex x[],
               Integer incx, Complex beta, Complex y[], Integer incy, NagError *fail)
```

### 3 Description

nag\_zhbmV (f16sdc) performs the matrix-vector operation

$$y \leftarrow \alpha Ax + \beta y,$$

where  $A$  is an  $n$  by  $n$  complex Hermitian band matrix with  $k$  subdiagonals and  $k$  superdiagonals,  $x$  and  $y$  are  $n$ -element complex vectors, and  $\alpha$  and  $\beta$  are complex scalars.

### 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  $A$  is stored.  
**uplo** = Nag\_Upper  
 The upper triangular part of  $A$  is stored.  
**uplo** = Nag\_Lower  
 The lower triangular part of  $A$  is stored.  
*Constraint:* **uplo** = Nag\_Upper or Nag\_Lower.
- 3: **n** – Integer *Input*  
*On entry:*  $n$ , the order of the matrix  $A$ .  
*Constraint:*  $n \geq 0$ .

- 4: **k** – Integer *Input*  
*On entry:*  $k$ , the number of subdiagonals or superdiagonals of the matrix  $A$ .  
*Constraint:*  $k \geq 0$ .
- 5: **alpha** – Complex *Input*  
*On entry:* the scalar  $\alpha$ .
- 6: **ab**[*dim*] – const Complex *Input*  
**Note:** the dimension, *dim*, of the array **ab** must be at least  $\max(1, \mathbf{pdab} \times \mathbf{n})$ .  
*On entry:* the  $n$  by  $n$  Hermitian band matrix  $A$ .  
This is stored as a notional two-dimensional array with row elements or column elements stored contiguously. The storage of elements of  $A_{ij}$ , depends on the **order** and **uplo** arguments as follows:  
if **order** = Nag\_ColMajor and **uplo** = Nag\_Upper,  
 $A_{ij}$  is stored in **ab**[ $k + i - j + (j - 1) \times \mathbf{pdab}$ ], for  $j = 1, \dots, n$  and  $i = \max(1, j - k), \dots, j$ ;  
if **order** = Nag\_ColMajor and **uplo** = Nag\_Lower,  
 $A_{ij}$  is stored in **ab**[ $i - j + (j - 1) \times \mathbf{pdab}$ ], for  $j = 1, \dots, n$  and  $i = j, \dots, \min(n, j + k)$ ;  
if **order** = Nag\_RowMajor and **uplo** = Nag\_Upper,  
 $A_{ij}$  is stored in **ab**[ $j - i + (i - 1) \times \mathbf{pdab}$ ], for  $i = 1, \dots, n$  and  $j = i, \dots, \min(n, i + k)$ ;  
if **order** = Nag\_RowMajor and **uplo** = Nag\_Lower,  
 $A_{ij}$  is stored in **ab**[ $k + j - i + (i - 1) \times \mathbf{pdab}$ ], for  $i = 1, \dots, n$  and  $j = \max(1, i - k), \dots, i$ .
- 7: **pdab** – Integer *Input*  
*On entry:* the stride separating row or column elements (depending on the value of **order**) of the matrix  $A$  in the array **ab**.  
*Constraint:*  $\mathbf{pdab} \geq \mathbf{k} + 1$ .
- 8: **x**[*dim*] – const Complex *Input*  
**Note:** the dimension, *dim*, of the array **x** must be at least  $\max(1, 1 + (\mathbf{n} - 1)|\mathbf{incx}|)$ .  
*On entry:* the  $n$ -element vector  $x$ .  
If  $\mathbf{incx} > 0$ ,  $x_i$  must be stored in **x**[( $i - 1$ )  $\times$   $\mathbf{incx}$ ], for  $i = 1, 2, \dots, \mathbf{n}$ .  
If  $\mathbf{incx} < 0$ ,  $x_i$  must be stored in **x**[( $\mathbf{n} - i$ )  $\times$   $|\mathbf{incx}|$ ], for  $i = 1, 2, \dots, \mathbf{n}$ .  
Intermediate elements of **x** are not referenced. If  $\mathbf{n} = 0$ , **x** is not referenced and may be **NULL**.
- 9: **incx** – Integer *Input*  
*On entry:* the increment in the subscripts of **x** between successive elements of  $x$ .  
*Constraint:*  $\mathbf{incx} \neq 0$ .
- 10: **beta** – Complex *Input*  
*On entry:* the scalar  $\beta$ .
- 11: **y**[*dim*] – Complex *Input/Output*  
**Note:** the dimension, *dim*, of the array **y** must be at least  $\max(1, 1 + (\mathbf{n} - 1)|\mathbf{incy}|)$ .  
*On entry:* the vector  $y$ . See **x** for details of storage.

If **beta** = 0, **y** need not be set.

*On exit:* the updated vector *y*.

12: **incy** – Integer *Input*

*On entry:* the increment in the subscripts of **y** between successive elements of *y*.

*Constraint:* **incy**  $\neq$  0.

13: **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 3.2.1.2 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\_INT

On entry, **incx** =  $\langle value \rangle$ .

*Constraint:* **incx**  $\neq$  0.

On entry, **incy** =  $\langle value \rangle$ .

*Constraint:* **incy**  $\neq$  0.

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, **pdab** =  $\langle value \rangle$ , **k** =  $\langle value \rangle$ .

*Constraint:* **pdab**  $\geq$  **k** + 1.

### NE\_INTERNAL\_ERROR

An unexpected error has been triggered by this function. Please contact NAG.

See Section 3.6.6 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 3.6.5 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\_zhbmV (f16sdc) is not threaded in any implementation.

## 9 Further Comments

None.

## 10 Example

This example computes the matrix-vector product

$$y = \alpha Ax + \beta y$$

where

$$A = \begin{pmatrix} 1.0 + 0.0i & 2.0 - 1.0i & 3.0 - 1.0i & 0.0 + 0.0i & 0.0 + 0.0i \\ 2.0 + 1.0i & 2.0 + 0.0i & 3.0 - 2.0i & 4.0 - 2.0i & 0.0 + 0.0i \\ 3.0 + 1.0i & 3.0 + 2.0i & 3.0 + 0.0i & 4.0 - 3.0i & 5.0 - 3.0i \\ 0.0 + 0.0i & 4.0 + 2.0i & 4.0 + 3.0i & 4.0 + 0.0i & 5.0 - 4.0i \\ 0.0 + 0.0i & 0.0 + 0.0i & 5.0 + 3.0i & 5.0 + 4.0i & 5.0 + 0.0i \end{pmatrix},$$

$$x = \begin{pmatrix} -1.0 + 1.0i \\ 2.0 + 2.0i \\ -3.0 - 1.0i \\ 2.0 + 3.0i \\ -1.0 + 1.0i \end{pmatrix},$$

$$y = \begin{pmatrix} 3.0 - 0.5i \\ -0.5 - 6.0i \\ 0.5 - 8.5i \\ 2.5 - 6.0i \\ 14.0 - 2.0i \end{pmatrix},$$

$$\alpha = 1.0 + 0.0i \quad \text{and} \quad \beta = 2.0 + 0.0i.$$

### 10.1 Program Text

```

/* nag_zhbmvm (f16sdc) 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>

int main(void)
{
    /* Scalars */
    Complex alpha, beta;
    Integer exit_status, i, incx, incy, j, k, kd, n, pdab, xlen, ylen;

    /* Arrays */
    Complex *ab = 0, *x = 0, *y = 0;
    char nag_enum_arg[40];

    /* Nag Types */
    NagError fail;
    Nag_OrderType order;
    Nag_UploType uplo;

#ifdef NAG_COLUMN_MAJOR
#define AB_UPPER(I, J) ab[(J-1)*pdab + k + I - J - 1]
#define AB_LOWER(I, J) ab[(J-1)*pdab + I - J]

```

```

    order = Nag_ColMajor;
#else
#define AB_UPPER(I, J) ab[(I-1)*pdab + J - I]
#define AB_LOWER(I, J) ab[(I-1)*pdab + k + J - I - 1]
    order = Nag_RowMajor;
#endif

    exit_status = 0;
    INIT_FAIL(fail);

    printf("nag_zhbmvm (f16sdc) Example Program Results\n\n");

    /* Skip heading in data file */
#ifdef _WIN32
    scanf_s("%*[\n] ");
#else
    scanf("%*[\n] ");
#endif
    /* Read the problem dimension */
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &n, &kd);
#else
    scanf("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &n, &kd);
#endif
    /* Read uplo */
#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 scalar parameters */
#ifdef _WIN32
    scanf_s(" ( %lf , %lf ) ( %lf , %lf )%*[\n] ",
            &alpha.re, &alpha.im, &beta.re, &beta.im);
#else
    scanf(" ( %lf , %lf ) ( %lf , %lf )%*[\n] ",
            &alpha.re, &alpha.im, &beta.re, &beta.im);
#endif
    /* Read increment parameters */
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &incx, &incy);
#else
    scanf("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &incx, &incy);
#endif

    pdab = kd + 1;
    xlen = MAX(1, 1 + (n - 1) * ABS(incx));
    ylen = MAX(1, 1 + (n - 1) * ABS(incy));

    if (n > 0) {
        /* Allocate memory */
        if (!(ab = NAG_ALLOC(pdab * n, Complex)) ||
            !(x = NAG_ALLOC(xlen, Complex)) || !(y = NAG_ALLOC(ylen, Complex)))
        {
            printf("Allocation failure\n");
            exit_status = -1;
            goto END;
        }
    }
    else {
        printf("Invalid n\n");
        exit_status = 1;
        return exit_status;
    }

    /* Read A from data file */
    k = kd + 1;

```

```

    if (uplo == Nag_Upper) {
        for (i = 1; i <= n; ++i) {
            for (j = i; j <= MIN(i + kd, n); ++j)
#ifdef _WIN32
                scanf_s(" ( %lf , %lf )", &AB_UPPER(i, j).re, &AB_UPPER(i, j).im);
#else
                scanf(" ( %lf , %lf )", &AB_UPPER(i, j).re, &AB_UPPER(i, j).im);
#endif
        }
#ifdef _WIN32
        scanf_s("%*[\n] ");
#else
        scanf("%*[\n] ");
#endif
    }
    else {
        for (i = 1; i <= n; ++i) {
            for (j = MAX(1, i - kd); j <= i; ++j)
#ifdef _WIN32
                scanf_s(" ( %lf , %lf )", &AB_LOWER(i, j).re, &AB_LOWER(i, j).im);
#else
                scanf(" ( %lf , %lf )", &AB_LOWER(i, j).re, &AB_LOWER(i, j).im);
#endif
        }
#ifdef _WIN32
        scanf_s("%*[\n] ");
#else
        scanf("%*[\n] ");
#endif
    }

    /* Input vectors x and y */

    for (i = 1; i <= xlen; ++i)
#ifdef _WIN32
        scanf_s(" ( %lf , %lf )%*[\n] ", &x[i - 1].re, &x[i - 1].im);
#else
        scanf(" ( %lf , %lf )%*[\n] ", &x[i - 1].re, &x[i - 1].im);
#endif
    for (i = 1; i <= ylen; ++i)
#ifdef _WIN32
        scanf_s(" ( %lf , %lf )%*[\n] ", &y[i - 1].re, &y[i - 1].im);
#else
        scanf(" ( %lf , %lf )%*[\n] ", &y[i - 1].re, &y[i - 1].im);
#endif

    /* nag_zhbmvm (f16sdc).
     * Hermitian banded matrix-vector multiply.
     */
    nag_zhbmvm(order, uplo, n, kd, alpha, ab, pdab, x, incx,
               beta, y, incy, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_zhbmvm.\n%s\n", fail.message);
        exit_status = 1;
        goto END;
    }

    /* Print output vector y */
    printf("%s\n", " y");
    for (i = 1; i <= ylen; ++i) {
        printf("(%11f,%11f)\n", y[i - 1].re, y[i - 1].im);
    }

END:
    NAG_FREE(ab);
    NAG_FREE(x);
    NAG_FREE(y);

    return exit_status;
}

```

## 10.2 Program Data

```
nag_zhbmV (f16sdc) Example Program Data
  5  2                               :Values of n and kd
  Nag_Lower                          :Value of uplo
  ( 1.0, 0.0) ( 2.0, 0.0)             : alpha, beta
  1  1                               : incx, incy
  (1.0, 0.0)
  (2.0, 1.0) (2.0, 0.0)
  (3.0, 1.0) (3.0, 2.0) (3.0, 0.0)
                               (4.0, 2.0) (4.0, 3.0) (4.0, 0.0)
                               (5.0, 3.0) (5.0, 4.0) (5.0, 0.0) :End of matrix A
  (-1.0, 1.0)
  ( 2.0, 2.0)
  (-3.0,-1.0)
  ( 2.0, 3.0)
  (-1.0, 1.0)                       : the end of vector x
  ( 3.0,-0.5)
  (-0.5,-6.0)
  ( 0.5,-8.5)
  ( 2.5,-6.0)
  (14.0,-2.0)                       : the end of vector y
```

## 10.3 Program Results

nag\_zhbmV (f16sdc) Example Program Results

```
  y
  ( 1.000000,  2.000000)
  ( 3.000000,  4.000000)
  ( 5.000000,  6.000000)
  ( 7.000000,  8.000000)
  ( 9.000000, 10.000000)
```

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