

NAG Library Function Document

nag_ztbsv (f16skc)

1 Purpose

nag_ztbsv (f16skc) solves a system of equations given as a complex triangular band matrix.

2 Specification

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

void nag_ztbsv (Nag_OrderType order, Nag_UploType uplo, Nag_TransType trans,
               Nag_DiagType diag, Integer n, Integer k, Complex alpha,
               const Complex ab[], Integer pdab, Complex x[], Integer incx,
               NagError *fail)
```

3 Description

nag_ztbsv (f16skc) performs one of the matrix-vector operations

$$x \leftarrow \alpha A^{-1}x, \quad x \leftarrow \alpha A^{-T}x \quad \text{or} \quad x \leftarrow \alpha A^{-H}x,$$

where A is an n by n complex triangular band matrix with k subdiagonals or superdiagonals, x is an n -element complex vector and α is a complex scalar. A^{-T} denotes A^{-T} or equivalently A^{-T} ; A^{-H} denotes $(A^H)^{-1}$ or equivalently $(A^{-1})^H$.

No test for singularity or near-singularity of A is included in this function. Such tests must be performed before calling this function.

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 A is upper or lower triangular.

uplo = Nag_Upper
 A is upper triangular.

uplo = Nag_Lower
 A is lower triangular.

Constraint: **uplo** = Nag_Upper or Nag_Lower.

- 3: **trans** – Nag_TransType Input
On entry: specifies the operation to be performed.
trans = Nag_NoTrans
 $x \leftarrow \alpha A^{-1}x.$
trans = Nag_Trans
 $x \leftarrow \alpha A^{-T}x.$
trans = Nag_ConjTrans
 $x \leftarrow \alpha A^{-H}x.$
Constraint: **trans** = Nag_NoTrans, Nag_Trans or Nag_ConjTrans.
- 4: **diag** – Nag_DiagType Input
On entry: specifies whether A has nonunit or unit diagonal elements.
diag = Nag_NonUnitDiag
The diagonal elements are stored explicitly.
diag = Nag_UnitDiag
The diagonal elements are assumed to be 1 and are not referenced.
Constraint: **diag** = Nag_NonUnitDiag or Nag_UnitDiag.
- 5: **n** – Integer Input
On entry: n , the order of the matrix A .
Constraint: $n \geq 0$.
- 6: **k** – Integer Input
On entry: k , the number of subdiagonals or superdiagonals of the matrix A .
Constraint: $k \geq 0$.
- 7: **alpha** – Complex Input
On entry: the scalar α .
- 8: **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 triangular 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
 $j = \max(1, i - k), \dots, i$.

If **diag** = Nag_UnitDiag, the diagonal elements of AB are assumed to be 1, and are not referenced.

- 9: **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: **pdab** \geq **k** + 1.
- 10: **x**[*dim*] – Complex *Input/Output*
Note: the dimension, *dim*, of the array **x** must be at least $\max(1, 1 + (\mathbf{n} - 1)|\mathbf{incx}|)$.
On entry: the vector *x*.
On exit: the solution vector *x*.
- 11: **incx** – Integer *Input*
On entry: the increment in the subscripts of **x** between successive elements of *x*.
Constraint: **incx** \neq 0.
- 12: **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 *<value>* had an illegal value.

NE_INT

On entry, **incx** = *<value>*.

Constraint: **incx** \neq 0.

On entry, **k** = *<value>*.

Constraint: **k** \geq 0.

On entry, **n** = *<value>*.

Constraint: **n** \geq 0.

NE_INT_2

On entry, **pdab** = *<value>*, **k** = *<value>*.

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_ztbsv (f16skc) is not threaded in any implementation.

9 Further Comments

None.

10 Example

Solves complex triangular banded system of linear equations, $Ax = y$, where A is a complex triangular 4 by 4 matrix, with 2 subdiagonals, given by

$$A = \begin{pmatrix} -1.94 + 4.43i & & & \\ -3.39 + 3.44i & 4.12 - 4.27i & & \\ 1.62 + 3.68i & -1.84 + 5.53i & 0.43 - 2.66i & \\ -2.77 - 1.93i & 1.74 - 0.04i & 0.44 + 0.10i & \end{pmatrix}$$

and

$$y = \begin{pmatrix} -8.86 - 3.88i \\ -15.57 - 23.41i \\ -7.63 + 22.78i \\ -14.74 - 2.40i \end{pmatrix}.$$

10.1 Program Text

```

/* nag_ztbsv (f16skc) 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;
    Integer exit_status, i, incx, j, kd, n, pdab, xlen;

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

    /* Nag Types */
    NagError fail;
    Nag_OrderType order;
    Nag_TransType trans;
    Nag_UploType uplo;
    Nag_DiagType diag;

#ifdef NAG_COLUMN_MAJOR

```

```

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

    exit_status = 0;
    INIT_FAIL(fail);

    printf("nag_ztbsv (f16skc) 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, &kd);
#else
    scanf("%" NAG_IFMT "%" NAG_IFMT "%*[\n] ", &n, &kd);
#endif

    /* Read the uplo storage 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 the unit-diagonal 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. */
    diag = (Nag_DiagType) 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
    /* Read increment parameter */
#ifdef _WIN32
    scanf_s("%" NAG_IFMT "%*[\n] ", &incx);
#else
    scanf("%" NAG_IFMT "%*[\n] ", &incx);
#endif

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

```

```

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

/* Input matrix AB and vector x */

if (uplo == Nag_Upper) {
    for (i = 1; i <= n; ++i) {
        if (diag == Nag_NonUnitDiag)
#ifdef _WIN32
            scanf_s(" ( %lf , %lf )", &AB_UPPER(i, i).re, &AB_UPPER(i, i).im);
#else
            scanf(" ( %lf , %lf )", &AB_UPPER(i, i).re, &AB_UPPER(i, i).im);
#endif
        for (j = i + 1; 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
            if (diag == Nag_NonUnitDiag)
#ifdef _WIN32
                scanf_s(" ( %lf , %lf )", &AB_LOWER(i, i).re, &AB_LOWER(i, i).im);
#else
                scanf(" ( %lf , %lf )", &AB_LOWER(i, i).re, &AB_LOWER(i, i).im);
#endif
            }
#ifdef _WIN32
            scanf_s("%*[\n] ");
#else
            scanf("%*[\n] ");
#endif
        }
        for (i = 0; i < xlen; ++i)
#ifdef _WIN32
            scanf_s(" ( %lf , %lf )%*[\n] ", &x[i].re, &x[i].im);
#else
            scanf(" ( %lf , %lf )%*[\n] ", &x[i].re, &x[i].im);
#endif
    }

    /* nag_ztbsv (f16skc).
     * Solution of complex triangular band system of linear equations.
     *
     */
}

```

```

nag_ztbsv(order, uplo, trans, diag, n, kd, alpha, ab, pdab, x, incx, &fail);
if (fail.code != NE_NOERROR) {
    printf("Error from nag_ztbsv (f16skc).\n%s\n", fail.message);
    exit_status = 1;
    goto END;
}

/* Print output vector x */
printf("%s\n", " Solution x:");
for (i = 0; i < xlen; ++i) {
    printf("( %11f , %11f )\n", x[i].re, x[i].im);
}

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

    return exit_status;
}

```

10.2 Program Data

```

nag_ztbsv (f16skc) Example Program Data
  4 2                               :Value of n and kd
  Nag_Lower                          :Storage of A
  Nag_NoTrans                        :Transpose A?
  Nag_NonUnitDiag                   :Unit diagonal elements?
  ( 1.0, 0.0)                        :Value of alpha
  1                                  :Value of incx
(-1.94, 4.43)
(-3.39, 3.44) ( 4.12,-4.27)
( 1.62, 3.68) (-1.84, 5.53) ( 0.43,-2.66)
                (-2.77,-1.93) ( 1.74,-0.04) ( 0.44, 0.10) :End of matrix A
( -8.86, -3.88)
(-15.57,-23.41)
( -7.63, 22.78)
(-14.74, -2.40)                               :End of vector x

```

10.3 Program Results

nag_ztbsv (f16skc) Example Program Results

```

Solution x:
( 0.000000 , 2.000000 )
( 1.000000 , -3.000000 )
( -4.000000 , -5.000000 )
( 2.000000 , -1.000000 )

```
