

# NAG Library Function Document

## nag\_ztpsv (f16slc)

### 1 Purpose

nag\_ztpsv (f16slc) solves a system of equations given as a complex triangular matrix stored in packed form.

### 2 Specification

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

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

### 3 Description

nag\_ztpsv (f16slc) 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 matrix, stored in packed form,  $x$  is an  $n$ -element complex vector and  $\alpha$  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: **alpha** – Complex *Input*  
*On entry:* the scalar  $\alpha$ .
- 7: **ap**[*dim*] – const Complex *Input*  
**Note:** the dimension, *dim*, of the array **ap** must be at least  $\max(1, n \times (n + 1)/2)$ .  
*On entry:* the  $n$  by  $n$  triangular matrix  $A$ , packed by rows or columns.  
The storage of elements  $A_{ij}$  depends on the **order** and **uplo** arguments as follows:  
if **order** = Nag\_ColMajor and **uplo** = Nag\_Upper,  
 $A_{ij}$  is stored in **ap**[( $j - 1$ )  $\times$   $j/2 + i - 1$ ], for  $i \leq j$ ;  
if **order** = Nag\_ColMajor and **uplo** = Nag\_Lower,  
 $A_{ij}$  is stored in **ap**[( $2n - j$ )  $\times$  ( $j - 1$ )/2 +  $i - 1$ ], for  $i \geq j$ ;  
if **order** = Nag\_RowMajor and **uplo** = Nag\_Upper,  
 $A_{ij}$  is stored in **ap**[( $2n - i$ )  $\times$  ( $i - 1$ )/2 +  $j - 1$ ], for  $i \leq j$ ;  
if **order** = Nag\_RowMajor and **uplo** = Nag\_Lower,  
 $A_{ij}$  is stored in **ap**[( $i - 1$ )  $\times$   $i/2 + j - 1$ ], for  $i \geq j$ .  
If **diag** = Nag\_UnitDiag, the diagonal elements of AP are assumed to be 1, and are not referenced; the same storage scheme is used whether **diag** = Nag\_NonUnitDiag or **diag** = Nag\_UnitDiag.
- 8: **x**[*dim*] – Complex *Input/Output*  
**Note:** the dimension, *dim*, of the array **x** must be at least  $\max(1, 1 + (n - 1)|\mathbf{incx}|)$ .  
*On entry:* the vector  $x$ .  
*On exit:* the solution vector  $x$ .

- 9: **incx** – Integer *Input*  
*On entry:* the increment in the subscripts of **x** between successive elements of *x*.  
*Constraint:* **incx**  $\neq$  0.
- 10: **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\_INT

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

### NE\_INTERNAL\_ERROR

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\_ztpsv (f16slc) is not threaded in any implementation.

## 9 Further Comments

None.

## 10 Example

Solves complex triangular system of linear equations,  $Ax = y$ , where  $A$  is a complex triangular 4 by 4 matrix, stored in packed storage format, given by

$$A = \begin{pmatrix} 4.78 + 4.56i & & & \\ 2.00 - 0.30i & -4.11 + 1.25i & & \\ 2.89 - 1.34i & 2.36 - 4.25i & 4.15 + 0.80i & \\ -1.89 + 1.15i & 0.04 - 3.69i & -0.02 + 0.46i & 0.33 - 0.26i \end{pmatrix},$$

and

$$y = \begin{pmatrix} -14.78 - 32.36i \\ 2.98 - 2.14i \\ -20.96 + 17.06i \\ 9.54 + 9.91i \end{pmatrix}.$$

### 10.1 Program Text

```

/* nag_ztpsv (f16slc) 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 ap_len, exit_status, i, incx, j, n, xlen;

    /* Arrays */
    Complex *ap = 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 A_UPPER(I, J) ap[J*(J-1)/2 + I - 1]
#define A_LOWER(I, J) ap[(2*n-J)*(J-1)/2 + I - 1]
    order = Nag_ColMajor;
#else
#define A_LOWER(I, J) ap[I*(I-1)/2 + J - 1]
#define A_UPPER(I, J) ap[(2*n-I)*(I-1)/2 + J - 1]
    order = Nag_RowMajor;
#endif

    exit_status = 0;
    INIT_FAIL(fail);

    printf("nag_ztpsv (f16slc) 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 "%*[\n] ", &n);
#else
    scanf("%" NAG_IFMT "%*[\n] ", &n);
#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

    ap_len = n * (n + 1) / 2;
    xlen = MAX(1, 1 + (n - 1) * ABS(incx));

    if (n > 0) {
        /* Allocate memory */
        if (!(ap = NAG_ALLOC(ap_len, 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 A and vector x */

```

```

    if (uplo == Nag_Upper) {
        for (i = 1; i <= n; ++i) {
            if (diag == Nag_NonUnitDiag)
#ifdef _WIN32
                scanf_s(" ( %lf , %lf )", &A_UPPER(i, i).re, &A_UPPER(i, i).im);
#else
                scanf(" ( %lf , %lf )", &A_UPPER(i, i).re, &A_UPPER(i, i).im);
#endif
            for (j = i + 1; j <= n; ++j)
#ifdef _WIN32
                scanf_s(" ( %lf , %lf )", &A_UPPER(i, j).re, &A_UPPER(i, j).im);
#else
                scanf(" ( %lf , %lf )", &A_UPPER(i, j).re, &A_UPPER(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 )", &A_LOWER(i, j).re, &A_LOWER(i, j).im);
#else
                scanf(" ( %lf , %lf )", &A_LOWER(i, j).re, &A_LOWER(i, j).im);
#endif
            if (diag == Nag_NonUnitDiag)
#ifdef _WIN32
                scanf_s(" ( %lf , %lf )", &A_LOWER(i, i).re, &A_LOWER(i, i).im);
#else
                scanf(" ( %lf , %lf )", &A_LOWER(i, i).re, &A_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_ztpsv (f16slc).
     * Solution of complex triangular system of linear equations,
     * using packed storage.
     */
    nag_ztpsv(order, uplo, trans, diag, n, alpha, ap, x, incx, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_ztpsv.\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(ap);
NAG_FREE(x);

return exit_status;
}

```

## 10.2 Program Data

```

nag_ztpsv (f16slc) Example Program Data
  4                               :Value of n
  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
( 4.78, 4.56)
( 2.00,-0.30) (-4.11, 1.25)
( 2.89,-1.34) ( 2.36,-4.25) ( 4.15, 0.80)
(-1.89, 1.15) ( 0.04,-3.69) (-0.02, 0.46) ( 0.33,-0.26) :End of matrix A
(-14.78,-32.36)
( 2.98, -2.14)
(-20.96, 17.06)
( 9.54, 9.91)                               :End of vector x

```

## 10.3 Program Results

```

nag_ztpsv (f16slc) Example Program Results

```

```

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

```

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