

# NAG Library Routine Document

## F08FEF (DSYTRD)

**Note:** before using this routine, please read the Users' Note for your implementation to check the interpretation of ***bold italicised*** terms and other implementation-dependent details.

### 1 Purpose

F08FEF (DSYTRD) reduces a real symmetric matrix to tridiagonal form.

### 2 Specification

```
SUBROUTINE F08FEF(UPLO, N, A, LDA, D, E, TAU, WORK, LWORK, INFO)
INTEGER          N, LDA, LWORK, INFO
double precision A(LDA,*), D(*), E(*), TAU(*), WORK(max(1,LWORK))
CHARACTER*1      UPLO
```

The routine may be called by its LAPACK name *dsytrd*.

### 3 Description

F08FEF (DSYTRD) reduces a real symmetric matrix  $A$  to symmetric tridiagonal form  $T$  by an orthogonal similarity transformation:  $A = QTQ^T$ .

The matrix  $Q$  is not formed explicitly but is represented as a product of  $n - 1$  elementary reflectors (see the F08 Chapter Introduction for details). Routines are provided to work with  $Q$  in this representation (see Section 8).

### 4 References

Golub G H and Van Loan C F (1996) *Matrix Computations* (3rd Edition) Johns Hopkins University Press, Baltimore

### 5 Parameters

- 1: UPLO – CHARACTER\*1 *Input*  
*On entry:* indicates whether the upper or lower triangular part of  $A$  is stored.  
UPLO = 'U'  
The upper triangular part of  $A$  is stored.  
UPLO = 'L'  
The lower triangular part of  $A$  is stored.  
*Constraint:* UPLO = 'U' or 'L'.
- 2: N – INTEGER *Input*  
*On entry:*  $n$ , the order of the matrix  $A$ .  
*Constraint:*  $N \geq 0$ .
- 3: A(LDA,\*) – **double precision** array *Input/Output*  
**Note:** the second dimension of the array  $A$  must be at least  $\max(1, N)$ .  
*On entry:* the  $n$  by  $n$  symmetric matrix  $A$ .

If UPLO = 'U', the upper triangular part of A must be stored and the elements of the array below the diagonal are not referenced.

If UPLO = 'L', the lower triangular part of A must be stored and the elements of the array above the diagonal are not referenced.

*On exit:* A is overwritten by the tridiagonal matrix  $T$  and details of the orthogonal matrix  $Q$  as specified by UPLO.

- 4: LDA – INTEGER *Input*  
*On entry:* the first dimension of the array A as declared in the (sub)program from which F08FEF (DSYTRD) is called.  
*Constraint:*  $LDA \geq \max(1, N)$ .
- 5: D(\*) – **double precision** array *Output*  
**Note:** the dimension of the array D must be at least  $\max(1, N)$ .  
*On exit:* the diagonal elements of the tridiagonal matrix  $T$ .
- 6: E(\*) – **double precision** array *Output*  
**Note:** the dimension of the array E must be at least  $\max(1, N - 1)$ .  
*On exit:* the off-diagonal elements of the tridiagonal matrix  $T$ .
- 7: TAU(\*) – **double precision** array *Output*  
**Note:** the dimension of the array TAU must be at least  $\max(1, N - 1)$ .  
*On exit:* further details of the orthogonal matrix  $Q$ .
- 8: WORK( $\max(1, LWORK)$ ) – **double precision** array *Workspace*  
*On exit:* if INFO = 0, WORK(1) contains the minimum value of LWORK required for optimal performance.
- 9: LWORK – INTEGER *Input*  
*On entry:* the dimension of the array WORK as declared in the (sub)program from which F08FEF (DSYTRD) is called.  
 If LWORK = -1, a workspace query is assumed; the routine only calculates the optimal size of the WORK array, returns this value as the first entry of the WORK array, and no error message related to LWORK is issued.  
*Suggested value:* for optimal performance,  $LWORK \geq N \times nb$ , where  $nb$  is the optimal **block size**.  
*Constraint:*  $LWORK \geq 1$  or  $LWORK = -1$ .
- 10: INFO – INTEGER *Output*  
*On exit:* INFO = 0 unless the routine detects an error (see Section 6).

## 6 Error Indicators and Warnings

Errors or warnings detected by the routine:

INFO < 0

If INFO = - $i$ , argument  $i$  had an illegal value. An explanatory message is output, and execution of the program is terminated.

## 7 Accuracy

The computed tridiagonal matrix  $T$  is exactly similar to a nearby matrix  $(A + E)$ , where

$$\|E\|_2 \leq c(n)\epsilon\|A\|_2,$$

$c(n)$  is a modestly increasing function of  $n$ , and  $\epsilon$  is the *machine precision*.

The elements of  $T$  themselves may be sensitive to small perturbations in  $A$  or to rounding errors in the computation, but this does not affect the stability of the eigenvalues and eigenvectors.

## 8 Further Comments

The total number of floating-point operations is approximately  $\frac{4}{3}n^3$ .

To form the orthogonal matrix  $Q$  F08FEF (DSYTRD) may be followed by a call to F08FFF (DORGTR):

```
CALL DORGTR(UPLO,N,A,LDA,TAU,WORK,LWORK,INFO)
```

To apply  $Q$  to an  $n$  by  $p$  real matrix  $C$  F08FEF (DSYTRD) may be followed by a call to F08FGF (DORMTR). For example,

```
CALL DORMTR('Left',UPLO,'No Transpose',N,P,A,LDA,TAU,C,LDC,
+          WORK,LWORK,INFO)
```

forms the matrix product  $QC$ .

The complex analogue of this routine is F08FSF (ZHETRD).

## 9 Example

This example reduces the matrix  $A$  to tridiagonal form, where

$$A = \begin{pmatrix} 2.07 & 3.87 & 4.20 & -1.15 \\ 3.87 & -0.21 & 1.87 & 0.63 \\ 4.20 & 1.87 & 1.15 & 2.06 \\ -1.15 & 0.63 & 2.06 & -1.81 \end{pmatrix}.$$

### 9.1 Program Text

```
*      F08FEF Example Program Text
*      Mark 16 Release. NAG Copyright 1992.
*      .. Parameters ..
      INTEGER          NIN, NOUT
      PARAMETER        (NIN=5,NOUT=6)
      INTEGER          NMAX, LDA, LWORK
      PARAMETER        (NMAX=8,LDA=NMAX,LWORK=64*NMAX)
*      .. Local Scalars ..
      INTEGER          I, INFO, J, N
      CHARACTER        UPLO
*      .. Local Arrays ..
      DOUBLE PRECISION A(LDA,NMAX), D(NMAX), E(NMAX-1), TAU(NMAX-1),
+      WORK(LWORK)
*      .. External Subroutines ..
      EXTERNAL         DSYTRD
*      .. Executable Statements ..
      WRITE (NOUT,*) 'F08FEF Example Program Results'
*      Skip heading in data file
      READ (NIN,*)
      READ (NIN,*) N
      IF (N.LE.NMAX) THEN
*
*          Read A from data file
*
      READ (NIN,*) UPLO
      IF (UPLO.EQ.'U') THEN
          READ (NIN,*) ((A(I,J),J=I,N),I=1,N)
      ELSE IF (UPLO.EQ.'L') THEN
          READ (NIN,*) ((A(I,J),J=1,I),I=1,N)
```

```

      END IF
*
*      Reduce A to tridiagonal form
*
      CALL DSYTRD(UPLO,N,A,LDA,D,E,TAU,WORK,LWORK,INFO)
*
*      Print tridiagonal form
*
      WRITE (NOUT,*)
      WRITE (NOUT,*) 'Diagonal'
      WRITE (NOUT,99999) (D(I),I=1,N)
      WRITE (NOUT,*) 'Off-diagonal'
      WRITE (NOUT,99999) (E(I),I=1,N-1)
    END IF
*
99999 FORMAT (1X,8F9.4)
      END

```

## 9.2 Program Data

F08FEF Example Program Data

```

4                               :Value of N
'L'                             :Value of UPLO
2.07
3.87  -0.21
4.20  1.87  1.15
-1.15  0.63  2.06  -1.81      :End of matrix A

```

## 9.3 Program Results

F08FEF Example Program Results

```

Diagonal
  2.0700  1.4741  -0.6492  -1.6949
Off-diagonal
 -5.8258  2.6240  0.9163

```

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