

# NAG Fortran Library Routine Document

## F07NUF (CSYCON/ZSYCON)

**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

F07NUF (CSYCON/ZSYCON) estimates the condition number of a complex symmetric matrix  $A$ , where  $A$  has been factorized by F07NRF (CSYTRF/ZSYTRF).

### 2 Specification

```

SUBROUTINE F07NUF(UPLO, N, A, LDA, IPIV, ANORM, RCOND, WORK, INFO)
ENTRY      csycon (UPLO, N, A, LDA, IPIV, ANORM, RCOND, WORK, INFO)
INTEGER    N, LDA, IPIV(*), INFO
real     ANORM, RCOND
complex  A(LDA,*), WORK(*)
CHARACTER*1 UPLO

```

The ENTRY statement enables the routine to be called by its LAPACK name.

### 3 Description

This routine estimates the condition number (in the 1-norm) of a complex symmetric matrix  $A$ :

$$\kappa_1(A) = \|A\|_1 \|A^{-1}\|_1.$$

Since  $A$  is symmetric,  $\kappa_1(A) = \kappa_\infty(A) = \|A\|_\infty \|A^{-1}\|_\infty$ .

Because  $\kappa_1(A)$  is infinite if  $A$  is singular, the routine actually returns an estimate of the **reciprocal** of  $\kappa_1(A)$ .

The routine should be preceded by a call to F06UFF to compute  $\|A\|_1$  and a call to F07NRF (CSYTRF/ZSYTRF) to compute the Bunch–Kaufman factorization of  $A$ . The routine then uses Higham's implementation of Hager's method (see Higham (1988)) to estimate  $\|A^{-1}\|_1$ .

### 4 References

Higham N J (1988) FORTRAN codes for estimating the one-norm of a real or complex matrix, with applications to condition estimation *ACM Trans. Math. Software* **14** 381–396

### 5 Parameters

1: UPLO – CHARACTER\*1 *Input*

*On entry:* indicates how  $A$  has been factorized as follows:

if UPLO = 'U',  $A = PUDU^T P^T$ , where  $U$  is upper triangular;

if UPLO = 'L',  $A = PLDL^T P^T$ , where  $L$  is lower triangular.

*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,\*) – *complex* array Input  
**Note:** the second dimension of the array A must be at least  $\max(1, N)$ .  
*On entry:* details of the factorization of A, as returned by F07NRF (CSYTRF/ZSYTRF).
- 4: LDA – INTEGER Input  
*On entry:* the first dimension of the array A as declared in the (sub)program from which F07NUF (CSYCON/ZSYCON) is called.  
*Constraint:*  $LDA \geq \max(1, N)$ .
- 5: IPIV(\*) – INTEGER array Input  
**Note:** the dimension of the array IPIV must be at least  $\max(1, N)$ .  
*On entry:* details of the interchanges and the block structure of D, as returned by F07NRF (CSYTRF/ZSYTRF).
- 6: ANORM – *real* Input  
*On entry:* the 1-norm of the **original** matrix A, which may be computed by calling F06UFF. ANORM must be computed either **before** calling F07NRF (CSYTRF/ZSYTRF) or else from a copy of the original matrix A.  
*Constraint:*  $ANORM \geq 0.0$ .
- 7: RCOND – *real* Output  
*On exit:* an estimate of the reciprocal of the condition number of A. RCOND is set to zero if exact singularity is detected or the estimate underflows. If RCOND is less than *machine precision*, A is singular to working precision.
- 8: WORK(\*) – *complex* array Workspace  
**Note:** the dimension of the array WORK must be at least  $\max(1, 2 * N)$ .
- 9: 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  $INFO = -i$ , the *i*th parameter had an illegal value. An explanatory message is output, and execution of the program is terminated.

## 7 Accuracy

The computed estimate RCOND is never less than the true value  $\rho$ , and in practice is nearly always less than  $10\rho$ , although examples can be constructed where RCOND is much larger.

## 8 Further Comments

A call to this routine involves solving a number of systems of linear equations of the form  $Ax = b$ ; the number is usually 5 and never more than 11. Each solution involves approximately  $8n^2$  real floating-point operations but takes considerably longer than a call to F07NSF (CSYTRS/ZSYTRS) with 1 right-hand side, because extra care is taken to avoid overflow when A is approximately singular.

The real analogue of this routine is F07MGF (SSYCON/DSYCON).

## 9 Example

To estimate the condition number in the 1-norm (or infinity-norm) of the matrix  $A$ , where

$$A = \begin{pmatrix} -0.39 - 0.71i & 5.14 - 0.64i & -7.86 - 2.96i & 3.80 + 0.92i \\ 5.14 - 0.64i & 8.86 + 1.81i & -3.52 + 0.58i & 5.32 - 1.59i \\ -7.86 - 2.96i & -3.52 + 0.58i & -2.83 - 0.03i & -1.54 - 2.86i \\ 3.80 + 0.92i & 5.32 - 1.59i & -1.54 - 2.86i & -0.56 + 0.12i \end{pmatrix}.$$

Here  $A$  is symmetric and must first be factorized by F07NRF (CSYTRF/ZSYTRF). The true condition number in the 1-norm is 32.92.

### 9.1 Program Text

**Note:** the listing of the example program presented below uses *bold italicised* terms to denote precision-dependent details. Please read the Users' Note for your implementation to check the interpretation of these terms. As explained in the Essential Introduction to this manual, the results produced may not be identical for all implementations.

```
*      F07NUF Example Program Text
*      Mark 15 Release. NAG Copyright 1991.
*      .. Parameters ..
      INTEGER          NIN, NOUT
      PARAMETER       (NIN=5,NOUT=6)
      INTEGER          NMAX, LDA, LWORK
      PARAMETER       (NMAX=8,LDA=NMAX,LWORK=64*NMAX)
*      .. Local Scalars ..
      real            ANORM, RCOND
      INTEGER          I, INFO, J, N
      CHARACTER       UPLO
*      .. Local Arrays ..
      complex        A(LDA,NMAX), WORK(LWORK)
      real           RWORK(NMAX)
      INTEGER          IPIV(NMAX)
*      .. External Functions ..
      real           F06UFF, X02AJF
      EXTERNAL        F06UFF, X02AJF
*      .. External Subroutines ..
      EXTERNAL        csycon, csytrf
*      .. Executable Statements ..
      WRITE (NOUT,*) 'F07NUF 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
*
*         Compute norm of A
*
      ANORM = F06UFF('1-norm',UPLO,N,A,LDA,RWORK)
*
*         Factorize A
*
      CALL csytrf(UPLO,N,A,LDA,IPIV,WORK,LWORK,INFO)
*
      WRITE (NOUT,*)
      IF (INFO.EQ.0) THEN
*
*         Estimate condition number
*
*
      CALL csycon(UPLO,N,A,LDA,IPIV,ANORM,RCOND,WORK,INFO)
*

```

```

      IF (RCOND.GE.X02AJF()) THEN
        WRITE (NOUT,99999) 'Estimate of condition number =',
+       1.0e0/RCOND
      ELSE
        WRITE (NOUT,*) 'A is singular to working precision'
      END IF
    ELSE
      WRITE (NOUT,*) 'The factor D is singular'
    END IF
  END IF
STOP
*
99999 FORMAT (1X,A,1P,e10.2)
END

```

## 9.2 Program Data

F07NUF Example Program Data

```

  4                                     :Value of N
  'L'                                   :Value of UPLO
(-0.39,-0.71)
( 5.14,-0.64) ( 8.86, 1.81)
(-7.86,-2.96) (-3.52, 0.58) (-2.83,-0.03)
( 3.80, 0.92) ( 5.32,-1.59) (-1.54,-2.86) (-0.56, 0.12) :End of matrix A

```

## 9.3 Program Results

F07NUF Example Program Results

Estimate of condition number = 1.57E+01

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