

# NAG Fortran Library Routine Document

## F01LHF

**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

F01LHF factorizes a real almost block diagonal matrix.

### 2 Specification

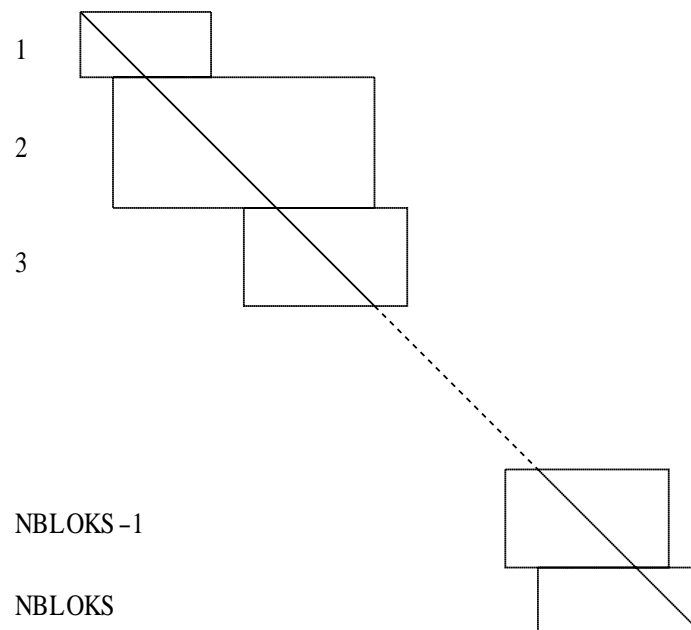
```

SUBROUTINE F01LHF(N, NBLOKS, BLKSTR, A, LENA, PIVOT, TOL, INDEX, IFAIL)
INTEGER          N, NBLOKS, BLKSTR(3,NBLOKS), LENA, PIVOT(N), INDEX,
1               IFAIL
real           A(LENA), TOL

```

### 3 Description

The routine factorizes a real almost block diagonal matrix,  $A$ , by row elimination with alternate row and column pivoting such that no 'fill-in' is produced. The code, which is derived from ARCECO described in Diaz *et al.* (1983), uses Level 1 and Level 2 BLAS. No three successive diagonal blocks may have columns in common and therefore the almost block diagonal matrix must have the form shown in the following diagram:



**Figure 1**

This routine may be followed by F04LHF, which is designed to solve sets of linear equations  $AX = B$  or  $A^T X = B$ .

### 4 References

Diaz J C, Fairweather G and Keast P (1983) Fortran packages for solving certain almost block diagonal linear systems by modified alternate row and column elimination *ACM Trans. Math. Software* **9** 358–375

## 5 Parameters

1: N – INTEGER Input

*On entry:*  $n$ , the order of the matrix  $A$ .

*Constraint:*  $N > 0$ .

2: NBLOKS – INTEGER Input

*On entry:* the total number of blocks of the matrix  $A$ .

*Constraint:*  $0 < \text{NBLOKS} \leq N$ .

3: BLKSTR(3,NBLOKS) – INTEGER array Input

*On entry:* information which describes the block structure of  $A$  as follows:

BLKSTR(1,  $k$ ) must contain the number of rows in the  $k$ th block,  $k = 1, 2, \dots, \text{NBLOKS}$ ;

BLKSTR(2,  $k$ ) must contain the number of columns in the  $k$ th block,  $k = 1, 2, \dots, \text{NBLOKS}$ ;

BLKSTR(3,  $k$ ) must contain the number of columns of overlap between the  $k$ th and ( $k + 1$ )th blocks,  $k = 1, 2, \dots, \text{NBLOKS} - 1$ . BLKSTR(3,NBLOKS) need not be set.

The following conditions delimit the structure of  $A$ :

$$\text{BLKSTR}(1, k), \text{BLKSTR}(2, k) > 0, \quad k = 1, 2, \dots, \text{NBLOKS},$$

$$\text{BLKSTR}(3, k) \geq 0, \quad k = 1, 2, \dots, \text{NBLOKS} - 1,$$

(there must be at least one column and one row in each block and a non-negative number of columns of overlap);

$$\text{BLKSTR}(3, k - 1) + \text{BLKSTR}(3, k) \leq \text{BLKSTR}(2, k), \quad k = 2, 3, \dots, \text{NBLOKS} - 1,$$

(the total number of columns in overlaps in each block must not exceed the number of columns in that block);

$$\text{BLKSTR}(2, 1) \geq \text{BLKSTR}(1, 1),$$

$$\text{BLKSTR}(2, 1) + \sum_{k=2}^j [\text{BLKSTR}(2, k) - \text{BLKSTR}(3, k - 1)] \geq \sum_{k=1}^j \text{BLKSTR}(1, k),$$

$$j = 2, 3, \dots, \text{NBLOKS} - 1,$$

$$\sum_{k=1}^j [\text{BLKSTR}(2, k) - \text{BLKSTR}(3, k)] \leq \sum_{k=1}^j \text{BLKSTR}(1, k), \quad j = 1, 2, \dots, \text{NBLOKS} - 1,$$

(the index of the first column of the overlap between the  $j$ th and ( $j + 1$ )th blocks must be  $\leq$  the index of the last row of the  $j$ th block, and the index of the last column of overlap must be  $\geq$  the index of the last row of the  $j$ th block);

$$\sum_{k=1}^{\text{NBLOKS}} \text{BLKSTR}(1, k) = n,$$

$$\text{BLKSTR}(2, 1) + \sum_{k=2}^{\text{NBLOKS}} [\text{BLKSTR}(2, k) - \text{BLKSTR}(3, k - 1)] = nk,$$

(both the number of rows and the number of columns of  $A$  must equal  $n$ ).

4: A(LENA) – *real* array Input/Output

*On entry:* the elements of the almost block diagonal matrix stored block by block, with each block stored column by column. The sizes of the blocks and the overlaps are defined by the parameter BLKSTR.

If  $a_{r,s}$  is the first element in the  $k$ th block, then an arbitrary element  $a_{ij}$  in the  $k$ th block must be stored in the array element:

$$A(p_k + (j - r)m_k + (i - s) + 1)$$

where

$$p_k = \sum_{l=1}^{k-1} \text{BLKSTR}(1, l) \times \text{BLKSTR}(2, l)$$

is the base address of the  $k$ th block, and

$$m_k = \text{BLKSTR}(1, k)$$

is the number of rows of the  $k$ th block.

See Section 8 for comments on scaling.

*On exit:* the factorized form of the matrix.

5: LENA – INTEGER *Input*

*On entry:* the dimension of the array A as declared in the (sub)program from which F01LHF is called.

$$\text{Constraint: } \text{LENA} \geq \sum_{k=1}^{\text{NBLOKS}} [\text{BLKSTR}(1, k) \times \text{BLKSTR}(2, k)].$$

6: PIVOT(N) – INTEGER array *Output*

*On exit:* details of the interchanges.

7: TOL – *real* *Input/Output*

*On entry:* a relative tolerance to be used to indicate whether or not the matrix is singular. For a discussion on how TOL is used see Section 8. If TOL is non-positive, then TOL is reset to  $10\epsilon$ , where  $\epsilon$  is the *machine precision*.

*On exit:* unchanged unless  $\text{TOL} \leq 0.0$  on entry, in which case it is set to  $10\epsilon$ .

8: INDEX – INTEGER *Output*

*On exit:* if IFAIL = 2, INDEX contains the value  $k$ , where  $k$  is the first position on the diagonal of the matrix  $A$  where too small a pivot was detected. Otherwise INDEX is set to 0.

9: IFAIL – INTEGER *Input/Output*

*On entry:* IFAIL must be set to 0, -1 or 1. Users who are unfamiliar with this parameter should refer to Chapter P01 for details.

*On exit:* IFAIL = 0 unless the routine detects an error (see Section 6).

For environments where it might be inappropriate to halt program execution when an error is detected, the value -1 or 1 is recommended. If the output of error messages is undesirable, then the value 1 is recommended. Otherwise, for users not familiar with this parameter the recommended value is 0. **When the value -1 or 1 is used it is essential to test the value of IFAIL on exit.**

## 6 Error Indicators and Warnings

If on entry IFAIL = 0 or -1, explanatory error messages are output on the current error message unit (as defined by X04AAF).

Errors or warnings detected by the routine:



## 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.

```

*      F01LHF Example Program Text
*      Mark 14 Revised.  NAG Copyright 1989.
*      .. Parameters ..
INTEGER          NIN, NOUT
PARAMETER       (NIN=5,NOUT=6)
INTEGER         NBLMAX, NMAX, IRMAX, LENA, LDB
PARAMETER       (NBLMAX=10,NMAX=20,IRMAX=5,LENA=200,LDB=NMAX)
*      .. Local Scalars ..
real           TOL
INTEGER         I, IFAIL, INDEX, IR, J, K, N, NBASEK, NBLOKS
*      .. Local Arrays ..
real           A(LENA), B(LDB,IRMAX)
INTEGER         BLKSTR(3,NBLMAX), PIVOT(NMAX)
*      .. External Subroutines ..
EXTERNAL        F01LHF, F04LHF
*      .. Executable Statements ..
WRITE (NOUT,*) 'F01LHF Example Program Results'
*      Skip heading in data file
READ (NIN,*)
READ (NIN,*) NBLOKS
WRITE (NOUT,*)
IF (NBLOKS.LE.NBLMAX) THEN
  NBASEK = 0
  N = 0
  DO 40 I = 1, NBLOKS
    READ (NIN,*) (BLKSTR(J,I),J=1,3)
    DO 20 K = 1, BLKSTR(1,I)
      IF (NBASEK+BLKSTR(2,I)*BLKSTR(1,I).GT.LENA) THEN
        WRITE (NOUT,*)
+         ' Array A is too small for this problem'
        STOP
      ELSE
+         READ (NIN,*) (A(NBASEK+(J-1)*BLKSTR(1,I)+K),J=1,
+         BLKSTR(2,I))
      END IF
20    CONTINUE
      NBASEK = NBASEK + BLKSTR(2,I)*BLKSTR(1,I)
      N = N + BLKSTR(1,I)
40    CONTINUE
    IF (N.GT.NMAX) THEN
      WRITE (NOUT,*) ' N is too large'
      STOP
    END IF
    TOL = 0.0e0
    IFAIL = -1
*
*      CALL F01LHF(N,NBLOKS,BLKSTR,A,LENA,PIVOT,TOL,INDEX,IFAIL)
*
    IF (IFAIL.EQ.0) THEN
      READ (NIN,*) IR
      IF (IR.LE.IRMAX) THEN
        READ (NIN,*) ((B(I,J),I=1,N),J=1,IR)
        IFAIL = -1
*
*      CALL F04LHF('N',N,NBLOKS,BLKSTR,A,LENA,PIVOT,B,LDB,IR,
+         IFAIL)
*
        IF (IFAIL.EQ.0) THEN
          WRITE (NOUT,*) 'Component Solution'
          WRITE (NOUT,*)
          DO 60 I = 1, N
            WRITE (NOUT,99999) I, (B(I,J),J=1,IR)
60          CONTINUE
          END IF
        ELSE

```

```

        WRITE (NOUT,*) ' Too many right hand sides specified'
      END IF
    END IF
  ELSE
    WRITE (NOUT,*) ' NBLOCKS is invalid'
  END IF
  STOP
*
99999 FORMAT (1X,I5,6X,5F6.4)
END

```

## 9.2 Program Data

F01LHF Example Program Data

```

5          : Number of blocks
2 4 3      : Number of rows, columns and column overlap, block 1
-1.00 -0.98 -0.79 -0.15
-1.00 0.25 -0.87 0.35          : End block 1
4 7 4      : Number of rows, columns and column overlap, block 2
0.78 0.31 -0.85 0.89 -0.69 -0.98 -0.76
-0.82 0.12 -0.01 0.75 0.32 -1.00 -0.53
-0.83 -0.98 -0.58 0.04 0.87 0.38 -1.00
-0.21 -0.93 -0.84 0.37 -0.94 -0.96 -1.00 : End block 2
5 8 2      : Number of rows, columns and column overlap, block 3
-0.99 -0.91 -0.28 0.90 0.78 -0.93 -0.76 0.48
-0.87 -0.14 -1.00 -0.59 -0.99 0.21 -0.73 -0.48
-0.93 -0.91 0.10 -0.89 -0.68 -0.09 -0.58 -0.21
0.85 -0.39 0.79 -0.71 0.39 -0.99 -0.12 -0.75
0.17 -1.37 1.29 -1.59 1.10 -1.63 -1.01 -0.27 : End block 3
3 6 3      : Number of rows, columns and column overlap, block 4
0.08 0.61 0.54 -0.41 0.16 -0.46
-0.67 0.56 -0.99 0.16 -0.16 0.98
-0.24 -0.41 0.40 -0.93 0.70 0.43          : End block 4
4 5 0      : Number of rows, columns and column overlap, block 5
0.71 -0.97 -0.60 -0.30 0.18
-0.47 -0.98 -0.73 0.07 0.04
-0.25 -0.92 -0.52 -0.46 -0.58
0.89 -0.94 -0.54 -1.00 -0.36          : End block 5
1          : Number of right hand sides
-2.92 -1.27 -1.30 -1.17 -2.10 -4.51 -1.71 -4.59
-4.19 -0.93 -3.31 0.52 -0.12 -0.05 -0.98 -2.07
-2.73 -1.95          : End right hand side 1

```

### 9.3 Program Results

F01LHF Example Program Results

Component Solution

1	1.0000
2	1.0000
3	1.0000
4	1.0000
5	1.0000
6	1.0000
7	1.0000
8	1.0000
9	1.0000
10	1.0000
11	1.0000
12	1.0000
13	1.0000
14	1.0000
15	1.0000
16	1.0000
17	1.0000
18	1.0000

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