

# NAG Library Routine Document

## E01BHF

**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

E01BHF evaluates the definite integral of a piecewise cubic Hermite interpolant over the interval  $[a, b]$ .

### 2 Specification

```
SUBROUTINE E01BHF(N, X, F, D, A, B, PINT, IFAIL)
  INTEGER          N, IFAIL
  double precision X(N), F(N), D(N), A, B, PINT
```

### 3 Description

E01BHF evaluates the definite integral of a piecewise cubic Hermite interpolant, as computed by E01BEF, over the interval  $[a, b]$ .

If either  $a$  or  $b$  lies outside the interval from  $X(1)$  to  $X(N)$  computation of the integral involves extrapolation and a warning is returned.

The routine is derived from routine PCHIA in Fritsch (1982).

### 4 References

Fritsch F N (1982) PCHIP final specifications *Report UCID-30194* Lawrence Livermore National Laboratory

### 5 Parameters

1:	N – INTEGER	<i>Input</i>
2:	X(N) – <i>double precision</i> array	<i>Input</i>
3:	F(N) – <i>double precision</i> array	<i>Input</i>
4:	D(N) – <i>double precision</i> array	<i>Input</i>

*On entry:* N, X, F and D must be unchanged from the previous call of E01BEF.

5:	A – <i>double precision</i>	<i>Input</i>
6:	B – <i>double precision</i>	<i>Input</i>

*On entry:* the interval  $[a, b]$  over which integration is to be performed.

7:	PINT – <i>double precision</i>	<i>Output</i>
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*On exit:* the value of the definite integral of the interpolant over the interval  $[a, b]$ .

8:	IFAIL – INTEGER	<i>Input/Output</i>
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*On entry:* IFAIL must be set to 0,  $-1$  or  $1$ . If you are unfamiliar with this parameter you should refer to Section 3.3 in the Essential Introduction 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, if you are 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:

IFAIL = 1

On entry,  $N < 2$ .

IFAIL = 2

The values of  $X(r)$ , for  $r = 1, 2, \dots, N$ , are not in strictly increasing order.

IFAIL = 3

On entry, at least one of A or B lies outside the interval  $[X(1), X(N)]$ , and extrapolation was performed to compute the integral. The value returned is therefore unreliable.

## 7 Accuracy

The computational error in the value returned for PINT should be negligible in most practical situations.

## 8 Further Comments

The time taken by E01BHF is approximately proportional to the number of data points included within the interval  $[a, b]$ .

## 9 Example

This example reads in values of N, X, F and D. It then reads in pairs of values for A and B, and evaluates the definite integral of the interpolant over the interval  $[A, B]$  until end-of-file is reached.

### 9.1 Program Text

```
*      E01BHF Example Program Text
*      Mark 14 Revised. NAG Copyright 1989.
*      .. Parameters ..
      INTEGER          NIN, NOUT
      PARAMETER        (NIN=5,NOUT=6)
      INTEGER          NMAX
      PARAMETER        (NMAX=50)
*      .. Local Scalars ..
      DOUBLE PRECISION A, B, PINT
      INTEGER          IFAIL, N, R
*      .. Local Arrays ..
      DOUBLE PRECISION D(NMAX), F(NMAX), X(NMAX)
*      .. External Subroutines ..
      EXTERNAL        E01BHF
*      .. Executable Statements ..
      WRITE (NOUT,*) 'E01BHF Example Program Results'
*      Skip heading in data file
      READ (NIN,*)
      READ (NIN,*) N
      IF (N.GT.0 .AND. N.LE.NMAX) THEN
        DO 20 R = 1, N
          READ (NIN,*) X(R), F(R), D(R)
20      CONTINUE
      WRITE (NOUT,*)
      WRITE (NOUT,*) 'Integral'
```

```

      WRITE (NOUT,*) '          A          B          over (A,B)'
*      Read A, B pairs until end of file and compute
*      definite integrals
40     READ (NIN,*,END=60) A, B
      IFAIL = 1
*
      CALL E01BHF(N,X,F,D,A,B,PINT,IFAIL)
*
      IF (IFAIL.EQ.0) THEN
        WRITE (NOUT,99999) A, B, PINT
        GO TO 40
      ELSE
        WRITE (NOUT,*)
        WRITE (NOUT,99998) IFAIL
      END IF
    END IF
60    CONTINUE
*
99999 FORMAT (1X,3F13.4)
99998 FORMAT (1X,' ** E01BHF returned with IFAIL = ',I5)
      END

```

## 9.2 Program Data

E01BHF Example Program Data

9			N, the number of data points
7.990	0.00000E+0	0.00000E+0	X(R), F(R), D(R)
8.090	0.27643E-4	5.52510E-4	
8.190	0.43749E-1	0.33587E+0	
8.700	0.16918E+0	0.34944E+0	
9.200	0.46943E+0	0.59696E+0	
10.00	0.94374E+0	6.03260E-2	
12.00	0.99864E+0	8.98335E-4	
15.00	0.99992E+0	2.93954E-5	
20.00	0.99999E+0	0.00000E+0	
7.99	20.0		A, B pairs until end of file
10.0	12.0		
12.0	10.0		
15.0	15.0		

## 9.3 Program Results

E01BHF Example Program Results

A	B	Integral over (A,B)
7.9900	20.0000	10.7648
10.0000	12.0000	1.9622
12.0000	10.0000	-1.9622
15.0000	15.0000	0.0000

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