

# NAG Fortran 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
  real            X(N), F(N), D(N), A, B, PINT
```

### 3 Description

This routine 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) – <b>real</b> array	<i>Input</i>
3:	F(N) – <b>real</b> array	<i>Input</i>
4:	D(N) – <b>real</b> array	<i>Input</i>

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

5:	A – <b>real</b>	<i>Input</i>
6:	B – <b>real</b>	<i>Input</i>

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

7:	PINT – <b>real</b>	<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. 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:

$IFAIL = 1$

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 the routine is approximately proportional to the number of data points included within the interval  $[a, b]$ .

## 9 Example

This example program 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

**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.

```
*      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 ..
      real             A, B, PINT
      INTEGER          IFAIL, N, R
*      .. Local Arrays ..
      real             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,*) '
      WRITE (NOUT,*) '
      Read A, B pairs until end of file and compute
      definite integrals
40    READ (NIN,*,END=60) A, B
      IFAIL = 0

      CALL E01BHF(N,X,F,D,A,B,PINT,IFAIL)

      WRITE (NOUT,99999) A, B, PINT
      GO TO 40
    END IF
60  STOP

*
99999 FORMAT (1X,3F13.4)
      END

```

## 9.2 Program Data

## E01BHF Example Program Data

9	X(R), F(R), D(R)		N, the number of data points
7.990	0.00000E+0	0.00000E+0	
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