

This file extends the FM_User_Manual.txt file for the files that support the FM interval arithmetic package. All of these programs use the 3 basic files discussed there:

1. fmsave.f95 Module for FM internal global variables
2. fm.f95 Subroutine library for multiple-precision operations
3. fmzm90.f95 Modules for interfaces and definitions of derived-types

These are the files included for interval arithmetic.

4. fm_interval.f95 The routines and interfaces for interval operations
5. TestFMinterval.f95 Test program for the FM interval routines
6. SampleFMinterval.f95 Small sample program using fm_interval
7. IntervalExamplesFM.f95 Code for the example interval calculations that are discussed in the paper "A Multiple-Precision Interval Arithmetic Package"

After the first 3 files have been compiled and the program TestFM.f95 has been compiled and run to verify the basic FM package has been installed successfully, as shown in FM_User_Manual.txt, files 4 through 7 can be compiled and run.

The interval arithmetic operations are made available in the user's program by putting
 use fm_interval_arithmetic
at the top of routines using interval arithmetic, and the multiple precision interval variables are declared as
 type (fm_interval)

Here are sample commands to run the 3 programs in files 5, 6, and 7. These are for the gfortran compiler on a Windows PC. Macs are very similar, as are other compilers. See FM_User_Manual.txt.

```
gfortran fm_interval.f95 -c -O3
```

```
gfortran TestFMinterval.f95 -c -O3
```

```
gfortran fmsave.o fm.o fmzm90.o fm_interval.o TestFMinterval.o -o TestFMinterval.exe  
./TestFMinterval
```

```
gfortran SampleFMinterval.f95 -c -O3
```

```
gfortran fmsave.o fm.o fmzm90.o fm_interval.o SampleFMinterval.o -o SampleFMinterval.exe  
./SampleFMinterval
```

```
gfortran IntervalExamplesFM.f95 -c -O3
```

```
gfortran fmsave.o fm.o fmzm90.o fm_interval.o IntervalExamplesFM.o -o IntervalExamplesFM.exe  
./IntervalExamplesFM
```

TestFMinterval is a program that tests all the interval operations defined in the FM interval arithmetic package. Run it first to make sure that the interval package has been successfully installed. At the end of the run, it should say:

1044 cases tested. No errors were found.

SampleFMinterval is a small program showing how to do some interval calculations. It checks a sum for stability and accuracy using 4 methods and compares the results:

1. Do the sum in double precision
2. Use FM with increasing precision
3. Use FM with different rounding modes
4. Use FM with interval arithmetic

SampleFMinterval also tests a recurrence that is horribly unstable using FM vs FM interval arithmetic. The results are saved in the file SampleFMinterval.out.

IntervalExamplesFM is a program that runs the example interval calculations that are discussed in the paper "A Multiple-Precision Interval Arithmetic Package". The results are saved in file IntervalExamplesFM.out.

The program also produces 7 other output files that contain the data on how the width of the intervals increase at each step of the calculation for different examples in the paper. These files were used to produce the graphs in the paper showing rate of increase for interval width.

The basic arithmetic operations are provided, along with assignments and logical comparisons. Here are the functions that are available for the fm_interval type variables:

abs
acos
acosh
aint
anint
asin
asinh
atan
atanh
atan2
bessel_j0
bessel_j1
bessel_jn
bessel_y0
bessel_y1
bessel_yn
beta
binomial
ceiling
cos
cosh
cos_integral
cosh_integral
dble
digits
dim

dint
dot_product
epsilon
erf
erfc
exp
exponent
exp_integral_ei
exp_integral_en
factorial
floor
fraction
fresnel_c
fresnel_s
gamma
huge
incomplete_beta
incomplete_gamma1
incomplete_gamma2
int
is_overflow
is_underflow
is_unknown
left_endpoint
log
log10
log_erfc
log_gamma
log_integral
matmul
max
maxexponent
maxval
min
minexponent
minval
mod
modulo
nearest
nint
pochhammer
polygamma
precision
product
psi
radix
range
real
right_endpoint
rrspacing
scale
setexponent
sign
sin
sinh
sin_integral
sinh_integral
spacing

sqrt
sum
tan
tanh
to_fm
to_im
to_zm
tiny