

# NAG Library Function Document

## nag\_rand\_leap\_frog (g05khc)

### 1 Purpose

nag\_rand\_leap\_frog (g05khc) allows for the generation of multiple, independent, sequences of pseudorandom numbers using the leap-frog method.

### 2 Specification

```
#include <nag.h>
#include <nagg05.h>

void nag_rand_leap_frog (Integer n, Integer k, Integer state[],
                        NagError *fail)
```

### 3 Description

nag\_rand\_leap\_frog (g05khc) adjusts a base generator to allow multiple, independent, sequences of pseudorandom numbers to be generated via the leap-frog method (see the g05 Chapter Introduction for details).

If, prior to calling nag\_rand\_leap\_frog (g05khc) the base generator defined by **state** would produce random numbers  $x_1, x_2, x_3, \dots$ , then after calling nag\_rand\_leap\_frog (g05khc) the generator will produce random numbers  $x_k, x_{k+n}, x_{k+2n}, x_{k+3n}, \dots$

One of the initialization functions nag\_rand\_init\_repeatable (g05kfc) (for a repeatable sequence if computed sequentially) or nag\_rand\_init\_nonrepeatable (g05kge) (for a non-repeatable sequence) must be called prior to the first call to nag\_rand\_leap\_frog (g05khc).

The leap-frog algorithm can be used in conjunction with the NAG basic generator, both the Wichmann–Hill I and Wichmann–Hill II generators, the Mersenne Twister and L'Ecuyer.

### 4 References

Knuth D E (1981) *The Art of Computer Programming (Volume 2)* (2nd Edition) Addison–Wesley

### 5 Arguments

- 1: **n** – Integer *Input*  
*On entry:*  $n$ , the total number of sequences required.  
*Constraint:*  $n > 0$ .
- 2: **k** – Integer *Input*  
*On entry:*  $k$ , the number of the current sequence.  
*Constraint:*  $0 < k \leq n$ .
- 3: **state**[*dim*] – Integer *Communication Array*  
**Note:** the dimension, *dim*, of this array is dictated by the requirements of associated functions that must have been previously called. This array **MUST** be the same array passed as argument **state** in the previous call to nag\_rand\_init\_repeatable (g05kfc) or nag\_rand\_init\_nonrepeatable (g05kge).  
*On entry:* contains information on the selected base generator and its current state.

*On exit:* contains updated information on the state of the generator.

- 4: **fail** – NagError \* *Input/Output*  
 The NAG error argument (see Section 2.7 in How to Use the NAG Library and its Documentation).

## 6 Error Indicators and Warnings

### NE\_ALLOC\_FAIL

Dynamic memory allocation failed.  
 See Section 3.2.1.2 in How to Use the NAG Library and its Documentation for further information.

### NE\_BAD\_PARAM

On entry, argument  $\langle value \rangle$  had an illegal value.

### NE\_INT

On entry,  $n = \langle value \rangle$ .  
 Constraint:  $n \geq 1$ .

### NE\_INT\_2

On entry,  $k = \langle value \rangle$  and  $n = \langle value \rangle$ .  
 Constraint:  $0 < k \leq n$ .

### NE\_INT\_ARRAY

On entry, cannot use leap-frog with the base generator defined by **state**.

### NE\_INTERNAL\_ERROR

An internal error has occurred in this function. Check the function call and any array sizes. If the call is correct then please contact NAG for assistance.

An unexpected error has been triggered by this function. Please contact NAG.  
 See Section 3.6.6 in How to Use the NAG Library and its Documentation for further information.

### NE\_INVALID\_STATE

On entry, **state** vector has been corrupted or not initialized.

### NE\_NO\_LICENCE

Your licence key may have expired or may not have been installed correctly.  
 See Section 3.6.5 in How to Use the NAG Library and its Documentation for further information.

## 7 Accuracy

Not applicable.

## 8 Parallelism and Performance

nag\_rand\_leap\_frog (g05khc) is not threaded in any implementation.

## 9 Further Comments

The leap-frog method tends to be less efficient than other methods of producing multiple, independent sequences. See the g05 Chapter Introduction for alternative choices.

## 10 Example

This example creates three independent sequences using `nag_rand_leap_frog` (g05khc), after initialization by `nag_rand_init_repeatable` (g05kfc). Five variates from a uniform distribution are then generated from each sequence using `nag_rand_basic` (g05sac).

### 10.1 Program Text

```

/* nag_rand_leap_frog (g05khc) Example Program.
 *
 * NAGPRODCODE Version.
 *
 * Copyright 2016 Numerical Algorithms Group.
 *
 * Mark 26, 2016.
 */
/* Pre-processor includes */
#include <stdio.h>
#include <math.h>
#include <nag.h>
#include <nag_stdlib.h>
#include <nagg05.h>

#define STATE(I, J) state[(J - 1)*lstate + I - 1]

int main(void)
{
    /* Integer scalar and array declarations */
    Integer exit_status = 0;
    Integer i, j, lstate;
    Integer *state = 0;
    /* NAG structures */
    NagError fail;
    /* Double scalar and array declarations */
    double *x = 0;
    /* Set the sample size */
    Integer nv = 5;
    /* Set the number of streams */
    Integer n = 3;
    /* Choose the base generator */
    Nag_BaseRNG genid = Nag_Basic;
    Integer subid = 0;
    /* Set the seed */
    Integer seed[] = { 1762543 };
    Integer lseed = 1;

    /* Initialize the error structure */
    INIT_FAIL(fail);

    printf("nag_rand_leap_frog (g05khc) Example Program Results\n\n");

    /* Get the length of the state array */
    lstate = -1;
    nag_rand_init_repeatable(genid, subid, seed, lseed, state, &lstate, &fail);
    if (fail.code != NE_NOERROR) {
        printf("Error from nag_rand_init_repeatable (g05kfc).\n%s\n",
            fail.message);
        exit_status = 1;
        goto END;
    }

    /* Allocate arrays */
    if (!(x = NAG_ALLOC(nv, double)) ||
        !(state = NAG_ALLOC(lstate * n, Integer)))
    {
        printf("Allocation failure\n");
        exit_status = -1;
        goto END;
    }
}

```

```

/* Prepare n streams */
for (i = 1; i <= n; i++) {
  /* Initialize the I'th stream to a repeatable sequence, using the same
  seed for each stream */
  nag_rand_init_repeatable(genid, subid, seed, lseed, &STATE(1, i),
    &lstate, &fail);
  if (fail.code != NE_NOERROR) {
    printf("Error from nag_rand_init_repeatable (g05kfc).\n%s\n",
      fail.message);
    exit_status = 1;
    goto END;
  }

  /* Prepare the I'th out of N streams */
  nag_rand_leap_frog(n, i, &STATE(1, i), &fail);
  if (fail.code != NE_NOERROR) {
    printf("Error from nag_rand_leap_frog (g05khc).\n%s\n", fail.message);
    exit_status = 1;
    goto END;
  }
}

/* Loop over each of the n streams */
for (i = 1; i <= n; i++) {
  /* Generate nv variates from a univariate distribution */
  printf(" Stream %12" NAG_IFMT "\n", i);
  nag_rand_basic(nv, &STATE(1, i), x, &fail);
  if (fail.code != NE_NOERROR) {
    printf("Error from nag_rand_basic (g05sac).\n%s\n", fail.message);
    exit_status = 1;
    goto END;
  }

  /* Display the variates */
  for (j = 0; j < nv; j++)
    printf("%11.4f\n", x[j]);
  printf(" \n");
}

END:
  NAG_FREE(x);
  NAG_FREE(state);

  return exit_status;
}

```

## 10.2 Program Data

None.

## 10.3 Program Results

nag\_rand\_leap\_frog (g05khc) Example Program Results

```

Stream          1
  0.7460
  0.4925
  0.4982
  0.2580
  0.5938

Stream          2
  0.7983
  0.3843
  0.6717
  0.6238
  0.2785

Stream          3

```

0.1046  
0.7871  
0.0505  
0.0535  
0.2375

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