

## lapack() — LAPACK linear-algebra functions

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## Syntax

```
void _flopin(numeric matrix A)
```

```
void lapack_function(...)
```

```
void _flopout(numeric matrix A)
```

where *lapack\_**function* may be

```
LA_DGBMV()
LA_DGEBAK()    LA_ZGEBAK()
LA_DGEBAL()    LA_ZGEBAL()
LA_DGEES()    LA_ZGEES()
LA_DGEEV()    LA_ZGEEV()
LA_DGEHRD()    LA_ZGEHRD()
LA_DGGBAK()    LA_ZGGBAK()
LA_DGGBAL()    LA_ZGGBAL()
LA_DGGHRD()    LA_ZGGHRD()
LA_DHGEQZ()    LA_ZHGEQZ()
LA_DHSEIN()    LA_ZHSEIN()
LA_DHSEQR()    LA_ZHSEQR()

LA_DLAMCH()
LA_DORGHR()
LA_DSYEVX()

LA_DTGSSEN()    LA_ZTGSSEN()
LA_DTGEVC()    LA_ZTGEVC()
LA_DTREVC()    LA_ZTREVC()
LA_DTRSEN()    LA_ZTRSEN()

LA_ZUNGHR()
```

## Description

LA\_DGBMV(), LA\_DGEBAK(), LA\_ZGEBAK(), LA\_DGEBAL(), LA\_ZGEBAL(), ... are LAPACK functions in original, as-is form; see [M-1] **LAPACK**. These functions form the basis for many of Mata's linear-algebra capabilities. Mata functions such as [cholesky\(\)](#), [svd\(\)](#), and [eigensystem\(\)](#) are implemented using these functions; see [M-4] **matrix**. Those functions are easier to use. The LA\_\*(\*) functions provide more capability.

\_flop<sub>in</sub>() and \_flop<sub>out</sub>() convert matrices to and from the form required by the LA\_\*(\*) functions.

## Remarks and examples

LAPACK stands for Linear Algebra PACKage and is a freely available set of Fortran 90 routines for solving systems of simultaneous equations, eigenvalue problems, and singular-value problems. The original Fortran routines have six-letter names like DGEHRD, DORGHR, and so on. The Mata functions `LA_DGEHRD()`, `LA_DORGHR()`, etc., are a subset of the LAPACK double-precision real and complex routine. All LAPACK double-precision functions will eventually be made available.

Documentation for the LAPACK routines can be found at <http://www.netlib.org/lapack/>, although we recommend obtaining *LAPACK Users' Guide* by Anderson et al. (1999).

Remarks are presented under the following headings:

*Mapping calling sequence from Fortran to Mata*  
*Flopping: Preparing matrices for LAPACK*  
*Warning on the use of rows() and cols() after \_flopin()*  
*Warning: It is your responsibility to check info*  
*Example*

## Mapping calling sequence from Fortran to Mata

LAPACK functions are named with first letter S, D, C, or Z. S means single-precision real, D means double-precision real, C means single-precision complex, and Z means double-precision complex. Mata provides the D\* and Z\* functions. The LAPACK documentation is in terms of S\* and C\*. Thus, to find the documentation for `LA_DGEHRD`, you must look up `SGEHRD` in the original documentation.

The documentation (Anderson et al. 1999, 227) reads, in part,

```
SUBROUTINE SGEHRD(N, ILO, IHI, A, LDA, TAU, WORK, LWORK, INFO)
INTEGER IHI, ILO, INFO, LDA, LWORK, N
REAL A(LDA, *), TAU(*), WORK(LWORK)
```

and the documentation states that `SGEHRD` reduces a real, general matrix, **A**, to upper Hessenberg form, **H**, by an orthogonal similarity transformation:  $\mathbf{Q}' \times \mathbf{A} \times \mathbf{Q} = \mathbf{H}$ .

The corresponding Mata function, `LA_DGEHRD()`, has the same arguments. In Mata, arguments `ihi`, `ilo`, `info`, `lda`, `lwork`, and `n` are *real scalars*. Argument `A` is a *real matrix*, and arguments `tau` and `work` are *real vectors*.

You can read the rest of the original documentation to find out what is to be placed (or returned) in each argument. It turns out that **A** is assumed to be dimensioned `LDA × something` and that the routine works on `A(1, 1)` (using Fortran notation) through `A(N, N)`. The routine also needs work space, which you are to supply in vector `WORK`. In the standard LAPACK way, LAPACK offers you a choice: you can preallocate `WORK`, in which case you have to choose a fairly large dimension for it, or you can do a query to find out how large the dimension needs to be for this particular problem. If you preallocate, the documentation reveals that the `WORK` must be of size `N`, and you set `LWORK` equal to `N`. If you wish to query, then you make `WORK` of size 1 and set `LWORK` equal to `-1`. The LAPACK routine will then return in the first element of `WORK` the optimal size. Then you call the function again with `WORK` allocated to be the optimal size and `LWORK` set to equal the optimal size.

Concerning Mata, the above works. You can follow the LAPACK documentation to the letter. Use `J()` to allocate matrices or vectors. Alternatively, you can specify all sizes as missing value (`.`), and Mata will fill in the appropriate value based on the assumption that you are using the entire matrix.

Thus, in `LA_DGHRD()`, you could specify `lda` as missing, and the function would run as if you had specified `lda` equal to `cols(A)`. You could specify `n` as missing, and the function would run as if you had specified `n` as `rows(A)`.

Work areas, however, are treated differently. You can follow the standard LAPACK convention outlined above; or you can specify the sizes of work areas (`lwork`) and specify the work areas themselves (`work`) as missing values, and Mata will allocate the work areas for you. The allocation will be as you specified.

One feature provided by some LAPACK functions is not supported by the Mata implementation. If a function allows a function pointer, you may not avail yourself of that option.

## Flopping: Preparing matrices for LAPACK

The LAPACK functions provided in Mata are the original LAPACK functions. Mata, which is C based, stores matrices rowwise. LAPACK, which is Fortran based, stores matrices columnwise. Mata and Fortran also disagree on how complex matrices are to be organized.

Functions `_flopin()` and `_flopout()` handle these issues. Coding `_flopin(A)` changes matrix `A` from the Mata convention to the LAPACK convention. Coding `_flopout(A)` changes `A` from the LAPACK convention to the Mata convention.

The `LA_*`() functions do not do this for you because LAPACK often takes two or three LAPACK functions run in sequence to achieve the desired result, and it would be a waste of computer time to switch conventions between calls.

## Warning on the use of `rows()` and `cols()` after `_flopin()`

Be careful using the `rows()` and `cols()` functions. `rows()` of a flopped matrix returns the logical number of columns and `cols()` of a flopped matrix returns the logical number of rows!

The danger of confusion is especially great when using `J()` to allocate work areas. If a LAPACK function requires a work area of  $r \times c$ , your code,

```
_LA_function(..., J(c, r, .), ...)
```

## Warning: It is your responsibility to check info

The LAPACK functions do not abort with error on failure. They instead store 0 in `info` (usually the last argument) if successful and store an error code if not successful. The error code is usually negative and indicates the argument that is a problem.

## Example

The following example uses the LAPACK function `DGHRD` to obtain the Hessenberg form of matrix `A`. We will begin with

	1	2	3	4
1	1	2	3	4
2	4	5	6	7
3	7	8	9	10
4	8	9	10	11

The first step is to use `_flopin()` to put **A** in LAPACK order:

```
: _flopin(A)
```

Next we make a work-space query to get the optimal size of the work area.

```
: LA_DGHRD(., 1, 4, A, ., tau=., work=., lwork=-1, info=0)
: lwork = work[1,1]
: lwork
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```

After putting the work-space size in `lwork`, we can call `LA_DGHRD()` again to perform the Hessenberg decomposition:

```
: LA_DGHRD(., 1, 4, A, ., tau=., work=., lwork, info=0)
```

LAPACK function `DGHRD` saves the result in the upper triangle and the first subdiagonal of **A**. We must use `_flopout()` to change that back to Mata order, and finally, we extract the result:

```
: _flopout(A)
: A = A-sublowertriangle(A, 2)
: A
```

	1	2	3	4
1	1	-5.370750529	.0345341258	.3922322703
2	-11.35781669	25.18604651	-4.40577178	-.6561483899
3	0	-1.660145888	-.1860465116	.1760901813
4	0	0	-8.32667e-16	-5.27356e-16

## Reference

Anderson, E., Z. Bai, C. Bischof, S. Blackford, J. Demmel, J. J. Dongarra, J. Du Croz, A. Greenbaum, S. Hammarling, A. McKenney, and D. Sorensen. 1999. *LAPACK Users' Guide*. 3rd ed. Philadelphia: Society for Industrial and Applied Mathematics.

## Also see

[M-1] [LAPACK](#) — The LAPACK linear-algebra routines

[R] [copyright lapack](#) — LAPACK copyright notification

[M-4] [matrix](#) — Matrix functions