# BLAS笔记

**BLAS**是Basic Linear Algebra Subprograms的缩写，即基本线性代数子程序，简介可以参考：[Wiki BLAS](https://en.wikipedia.org/wiki/Basic_Linear_Algebra_Subprograms)。它的函数分成3个levels，即

* **Level1** (vector - vector)，计算y的线性代数表达式为：  
  $$y \leftarrow \alpha x + y$$
* **Level2** (matrix - vector)，计算y的线性代数表达式为：  
  $$y \leftarrow \alpha A x + \beta y$$  
  或者求解x向量  
  $$T x = y$$
* **Level3** (matrix - matrix)，线性代数表达式为：  
  $$C \leftarrow \alpha AB + \beta C$$

BLAS有很多实现方案，常见的如下所示

* CPU
  + Intel MKL (Only Intel CPU)
  + Netlib BLAS (Fortran77语言实现)
  + Netlib CBLAS (C语言实现)
  + GSL (GNU Scientific Libaray, 实现CBLAS接口)
  + OpenBLAS
  + LAPACK (Fortran77语言实现)
  + uBLAS (boost库的一部分)
  + Eigen BLAS (Fortran77与C语言的实现)
* GPU
  + cuBLAS (Only NVIDIA GPU)
  + rocBLAS (Only AMD GPU)
  + clBLAS (OpenCL BLAS实现，AMD主导)
  + clBLAST (tuned OpenCL BLAS实现)

对于CPU的BLAS方案，最常使用的是Intel MKL与OpenBLAS；GPU的BLAS方案，最常用的是cuBLAS（NVIDIA GPU）与clBLAST。clBLAS已经基本上停止维护，性能不佳，一般考虑使用clBLAST方案。

BLAS APIs的定义可以参考[netlib官网](http://www.netlib.org/blas/)，对于BLAS函数的前缀，比如S/D/C/Z，与后缀U/C等进行了说明，详见：https://www.gnu.org/software/gsl/doc/html/blas.html

|  |  |
| --- | --- |
| 前缀 | 说明 |
| S | 单精度 |
| D | 双精度 |
| C | 单精度复数 |
| Z | 双精度复数 |
| DS | 输入单精度，输出双精度 |

|  |  |
| --- | --- |
| 后缀 | 说明 |
| C | 复数计算，做向量共轭（conjugated） |
| U | 复数计算，不做向量共轭（unconjugated） |

例子

sdot：实数单精度dot计算

ddot：实数双精度dot计算

dsdot：输入单精度实数，输出双精度实数的dot计算

cdotc：单精度复数计算，并对第一个输入当精度向量进行共轭计算

cdotu：单精度复数计算，无向量共轭计算

zdotc：双精度复数计算，并对第一个输入双精度向量进行共轭计算

zdotu：双精度复数计算，无向量共轭计算

|  |  |
| --- | --- |
| 常见操作 | 说明 |
| **DOT** | scalar product, $x^T y$ |
| **AXPY** | vector sum, $ax + y$ |
| **MV** | matrix-vector product,$Ax$ |
| **SV** | matrix-vector solve, $A^{-1}x$ |
| **MM** | matrix-matrix product, $AB$ |
| **SM** | matrix-matrix solve, $A^{-1}B$ |

|  |  |
| --- | --- |
| 常见缩写 | 说明 |
| **GE** | general |
| **GB** | general band |
| **SY** | symmetric |
| **SB** | symmetric band (对称带状) |
| **SP** | symmetric packed(对称包装) |
| **HE** | hermitian(赫米特) |
| **HB** | hermitian band |
| **HP** | hermitian packed |
| **TR** | triangular |
| **TB** | triangular band |
| **TP** | triangular packed |

对于包装的内存存储格式主要是为了节省内存，比如说

|  |  |  |
| --- | --- | --- |
| UPLO | Triangular matrix ***A\*** | Packed storage in array AP |
| `U' |  |  |
| `L' |  |  |

## BLAS APIs

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Level | 函数名 | CLBlast | OpenBLAS | cuBLAS | clBLAS | GSL BLAS |
| Level1 | srotg | × | √ | √ | √ | √ |
| Level1 | drotg | × | √ | √ | √ | √ |
| Level1 | crotg | × | √ | √ | √ | × |
| Level1 | zrotg | × | √ | √ | √ | × |
| Level1 | srotmg | × | √ | √ | √ | √ |
| Level1 | drotmg | × | √ | √ | √ | √ |
| Level1 | srot | × | √ | √ | √ | √ |
| Level1 | drot | × | √ | √ | √ | √ |
| Level1 | crot | × | × | √ | × | × |
| Level1 | zrot | × | × | √ | × | × |
| Level1 | csrot | × | √ | √ | √ | × |
| Level1 | zdrot | × | √ | √ | √ | × |
| Level1 | srotm | × | √ | √ | √ | √ |
| Level1 | drotm | × | √ | √ | √ | √ |
| Level1 | sswap | √ | √ | √ | √ | √ |
| Level1 | dswap | √ | √ | √ | √ | √ |
| Level1 | cswap | √ | √ | √ | √ | √ |
| Level1 | zswap | √ | √ | √ | √ | √ |
| Level1 | hswap | √ | × | × | × | × |
| Level1 | sscal | √ | √ | √ | √ | √ |
| Level1 | dscal | √ | √ | √ | √ | √ |
| Level1 | cscal | √ | √ | √ | √ | √ |
| Level1 | zscal | √ | √ | √ | √ | √ |
| Level1 | hscal | √ | × | × | × | × |
| Level1 | csscal | × | √ | √ | √ | √ |
| Level1 | zdscal | × | √ | √ | √ | √ |
| Level1 | scopy | √ | √ | √ | √ | √ |
| Level1 | dcopy | √ | √ | √ | √ | √ |
| Level1 | ccopy | √ | √ | √ | √ | √ |
| Level1 | zcopy | √ | √ | √ | √ | √ |
| Level1 | hcopy | √ | × | × | × | × |
| Level1 | saxpy | √ | √ | √ | √ | √ |
| Level1 | daxpy | √ | √ | √ | √ | √ |
| Level1 | caxpy | √ | √ | √ | √ | √ |
| Level1 | zaxpy | √ | √ | √ | √ | √ |
| Level1 | haxpy | √ | × | × | × | × |
| Level1 | dsdot | × | √ | × | × | √ |
| Level1 | sdsdot | × | √ | × | × | √ |
| Level1 | sdot | √ | √ | √ | √ | √ |
| Level1 | ddot | √ | √ | √ | √ | √ |
| Level1 | hdot | √ | × | × | × | × |
| Level1 | cdotu | √ | √ | √ | √ | × |
| Level1 | zdotu | √ | √ | √ | √ | × |
| Level1 | cdotc | √ | √ | √ | √ | × |
| Level1 | zdotc | √ | √ | √ | √ | × |
| Level1 | cdotu\_sub | × | √ | × | × | √ |
| Level1 | cdotc\_sub | × | √ | × | × | √ |
| Level1 | zdotu\_sub | × | √ | × | × | √ |
| Level1 | zdotc\_sub | × | √ | × | × | √ |
| Level1 | snrm2 | √ | √ | √ | √ | √ |
| Level1 | dnrm2 | √ | √ | √ | √ | √ |
| Level1 | scnrm2 | √ | √ | √ | √ | √ |
| Level1 | dznrm2 | √ | √ | √ | √ | √ |
| Level1 | hnrm2 | √ | × | × | × | × |
| Level1 | sasum | √ | √ | √ | √ | √ |
| Level1 | dasum | √ | √ | √ | √ | √ |
| Level1 | scasum | √ | √ | √ | √ | √ |
| Level1 | dzasum | √ | √ | √ | √ | √ |
| Level1 | hasum | √ | × | × | × | × |
| Level1 | ssum | √ | √ | × | × | × |
| Level1 | dsum | √ | √ | × | × | × |
| Level1 | scsum | √ | √ | × | × | × |
| Level1 | dzsum | √ | √ | × | × | × |
| Level1 | hsum | √ | × | × | × | × |
| Level1 | samax | × | × | × | √ | × |
| Level1 | damax | × | × | × | √ | × |
| Level1 | scamax | × | × | × | √ | × |
| Level1 | dzamax | × | × | × | √ | × |
| Level1 | isamax | √ | √ | √ | √ | √ |
| Level1 | idamax | √ | √ | √ | √ | √ |
| Level1 | icamax | √ | √ | √ | √ | √ |
| Level1 | izamax | √ | √ | √ | √ | √ |
| Level1 | ihamax | √ | × | × | × | × |
| Level1 | samin | × | × | × | × | × |
| Level1 | damin | × | × | × | × | × |
| Level1 | camin | × | × | × | × | × |
| Level1 | zamin | × | × | × | × | × |
| Level1 | isamin | √ | √ | √ | × | × |
| Level1 | idamin | √ | √ | √ | × | × |
| Level1 | icamin | √ | √ | √ | × | × |
| Level1 | izamin | √ | √ | √ | × | × |
| Level1 | ihamin | √ | × | × | × | × |
| Level1 | smax | × | × | × | × | × |
| Level1 | dmax | × | × | × | × | × |
| Level1 | cmax | × | × | × | × | × |
| Level1 | zmax | × | × | × | × | × |
| Level1 | ismax | √ | √ | × | × | × |
| Level1 | idmax | √ | √ | × | × | × |
| Level1 | icmax | √ | √ | × | × | × |
| Level1 | izmax | √ | √ | × | × | × |
| Level1 | ihmax | √ | × | × | × | × |
| Level1 | smin | × | × | × | × | × |
| Level1 | dmin | × | × | × | × | × |
| Level1 | cmin | × | × | × | × | × |
| Level1 | zmin | × | × | × | × | × |
| Level1 | ismin | √ | √ | × | × | × |
| Level1 | idmin | √ | √ | × | × | × |
| Level1 | icmin | √ | √ | × | × | × |
| Level1 | izmin | √ | √ | × | × | × |
| Level1 | ihmin | √ | × | × | × | × |
| Level2 | sgemv | √ | √ | √ | √ | √ |
| Level2 | dgemv | √ | √ | √ | √ | √ |
| Level2 | cgemv | √ | √ | √ | √ | √ |
| Level2 | zgemv | √ | √ | √ | √ | √ |
| Level2 | hgemv | √ | × | × | × | × |
| Level2 | sgbmv | √ | √ | √ | √ | √ |
| Level2 | dgbmv | √ | √ | √ | √ | √ |
| Level2 | cgbmv | √ | √ | √ | √ | √ |
| Level2 | zgbmv | √ | √ | √ | √ | √ |
| Level2 | hgbmv | √ | × | × | × | × |
| Level2 | chemv | √ | √ | √ | √ | √ |
| Level2 | zhemv | √ | √ | √ | √ | √ |
| Level2 | chbmv | √ | √ | √ | √ | √ |
| Level2 | zhbmv | √ | √ | √ | √ | √ |
| Level2 | chpmv | √ | √ | √ | √ | √ |
| Level2 | zhpmv | √ | √ | √ | √ | √ |
| Level2 | ssymv | √ | √ | √ | √ | √ |
| Level2 | dsymv | √ | √ | √ | √ | √ |
| Level2 | csymv | × | × | √ | √ | × |
| Level2 | zsymv | × | × | √ | √ | × |
| Level2 | hsymv | √ | × | × | × | × |
| Level2 | ssbmv | √ | √ | √ | √ | √ |
| Level2 | dsbmv | √ | √ | √ | √ | √ |
| Level2 | hsbmv | √ | × | × | × | × |
| Level2 | sspmv | √ | √ | √ | √ | √ |
| Level2 | dspmv | √ | √ | √ | √ | √ |
| Level2 | hspmv | √ | × | × | × | × |
| Level2 | strmv | √ | √ | √ | √ | √ |
| Level2 | dtrmv | √ | √ | √ | √ | √ |
| Level2 | ctrmv | √ | √ | √ | √ | √ |
| Level2 | ztrmv | √ | √ | √ | √ | √ |
| Level2 | htrmv | √ | × | √ | × | × |
| Level2 | stbmv | √ | √ | √ | √ | √ |
| Level2 | dtbmv | √ | √ | √ | √ | √ |
| Level2 | ctbmv | √ | √ | √ | √ | √ |
| Level2 | ztbmv | √ | √ | √ | √ | √ |
| Level2 | htbmv | √ | × | × | × | × |
| Level2 | stpmv | √ | √ | √ | √ | √ |
| Level2 | dtpmv | √ | √ | √ | √ | √ |
| Level2 | ctpmv | √ | √ | √ | √ | √ |
| Level2 | ztpmv | √ | √ | √ | √ | √ |
| Level2 | htpmv | √ | × | × | × | × |
| Level2 | strsv | √ | √ | √ | √ | √ |
| Level2 | dtrsv | √ | √ | √ | √ | √ |
| Level2 | ctrsv | √ | √ | √ | √ | √ |
| Level2 | ztrsv | √ | √ | √ | √ | √ |
| Level2 | stbsv | √ | √ | × | √ | √ |
| Level2 | dtbsv | √ | √ | × | √ | √ |
| Level2 | ctbsv | √ | √ | × | √ | √ |
| Level2 | ztbsv | √ | √ | × | √ | √ |
| Level2 | stpsv | √ | √ | √ | √ | √ |
| Level2 | dtpsv | √ | √ | √ | √ | √ |
| Level2 | ctpsv | √ | √ | √ | √ | √ |
| Level2 | ztpsv | √ | √ | √ | √ | √ |
| Level2 | sger | √ | √ | √ | √ | √ |
| Level2 | dger | √ | √ | √ | √ | √ |
| Level2 | hger | √ | × | × | × | × |
| Level2 | cgeru | √ | √ | √ | √ | √ |
| Level2 | zgeru | √ | √ | √ | √ | √ |
| Level2 | cgerc | √ | √ | √ | √ | √ |
| Level2 | zgerc | √ | √ | √ | √ | √ |
| Level2 | cher | √ | √ | √ | √ | √ |
| Level2 | zher | √ | √ | √ | √ | √ |
| Level2 | chpr | √ | √ | √ | √ | √ |
| Level2 | zhpr | √ | √ | √ | √ | √ |
| Level2 | cher2 | √ | √ | √ | √ | √ |
| Level2 | zher2 | √ | √ | √ | √ | √ |
| Level2 | chpr2 | √ | √ | √ | √ | √ |
| Level2 | zhpr2 | √ | √ | √ | √ | √ |
| Level2 | ssyr | √ | √ | √ | √ | √ |
| Level2 | dsyr | √ | √ | √ | √ | √ |
| Level2 | csyr | × | × | √ | × | × |
| Level2 | zsyr | × | × | √ | × | × |
| Level2 | hsyr | √ | × | × | × | × |
| Level2 | sspr | √ | √ | √ | √ | √ |
| Level2 | dspr | √ | √ | √ | √ | √ |
| Level2 | hspr | √ | × | × | × | × |
| Level2 | ssyr2 | √ | √ | √ | √ | √ |
| Level2 | dsyr2 | √ | √ | √ | √ | √ |
| Level2 | csyr2 | × | × | √ | √ | × |
| Level2 | zsyr2 | × | × | √ | √ | × |
| Level2 | hsyr2 | √ | × | × | × | × |
| Level2 | sspr2 | √ | √ | √ | √ | √ |
| Level2 | dspr2 | √ | √ | √ | √ | √ |
| Level2 | hspr2 | √ | × | × | × | × |
| Level2 | sgemvbatched | × | × | √ | × | × |
| Level2 | dgemvbatched | × | × | √ | × | × |
| Level2 | cgemvbatched | × | × | √ | × | × |
| Level2 | zgemvbatched | × | × | √ | × | × |
| Level2 | hshgemvbatched | × | × | √ | × | × |
| Level2 | hssgemvbatched | × | × | √ | × | × |
| Level2 | tstgemvbatched | × | × | √ | × | × |
| Level2 | tssgemvbatched | × | × | √ | × | × |
| Level2 | sgemvstridebatched | × | × | √ | × | × |
| Level2 | dgemvstridebatched | × | × | √ | × | × |
| Level2 | cgemvstridebatched | × | × | √ | × | × |
| Level2 | zgemvstridebatched | × | × | √ | × | × |
| Level2 | hshgemvstridebatched | × | × | √ | × | × |
| Level2 | hssgemvstridebatched | × | × | √ | × | × |
| Level2 | tstgemvstridebatched | × | × | √ | × | × |
| Level2 | tssgemvstridebatched | × | × | √ | × | × |
| Level3 | sgemm | √ | √ | √ | √ | √ |
| Level3 | dgemm | √ | √ | √ | √ | √ |
| Level3 | cgemm | √ | √ | √ | √ | √ |
| Level3 | zgemm | √ | √ | √ | √ | √ |
| Level3 | hgemm | √ | × | √ | × | × |
| Level3 | cgemm3m | × | √ | √ | × | × |
| Level3 | zgemm3m | × | √ | √ | × | × |
| Level3 | ssymm | √ | √ | √ | √ | √ |
| Level3 | dsymm | √ | √ | √ | √ | √ |
| Level3 | csymm | √ | √ | √ | √ | √ |
| Level3 | zsymm | √ | √ | √ | √ | √ |
| Level3 | hsymm | √ | × | × | × | × |
| Level3 | chemm | √ | √ | √ | √ | √ |
| Level3 | zhemm | √ | √ | √ | √ | √ |
| Level3 | ssyrk | √ | √ | √ | √ | √ |
| Level3 | dsyrk | √ | √ | √ | √ | √ |
| Level3 | csyrk | √ | √ | √ | √ | √ |
| Level3 | zsyrk | √ | √ | √ | √ | √ |
| Level3 | hsyrk | √ | × | × | × | × |
| Level3 | ssyrkx | × | × | √ | × | × |
| Level3 | dsyrkx | × | × | √ | × | × |
| Level3 | csyrkx | × | × | √ | × | × |
| Level3 | zsyrkx | × | × | √ | × | × |
| Level3 | cherk | √ | √ | √ | √ | √ |
| Level3 | zherk | √ | √ | √ | √ | √ |
| Level3 | cherkx | × | × | √ | × | × |
| Level3 | zherkx | × | × | √ | × | × |
| Level3 | ssyr2k | √ | √ | √ | √ | √ |
| Level3 | dsyr2k | √ | √ | √ | √ | √ |
| Level3 | csyr2k | √ | √ | √ | √ | √ |
| Level3 | zsyr2k | √ | √ | √ | √ | √ |
| Level3 | hsyr2k | √ | × | × | × | × |
| Level3 | cher2k | √ | √ | √ | √ | √ |
| Level3 | zher2k | √ | √ | √ | √ | √ |
| Level3 | strmm | √ | √ | √ | √ | √ |
| Level3 | dtrmm | √ | √ | √ | √ | √ |
| Level3 | ctrmm | √ | √ | √ | √ | √ |
| Level3 | ztrmm | √ | √ | √ | √ | √ |
| Level3 | htrmm | √ | × | × | × | × |
| Level3 | strsm | √ | √ | √ | √ | √ |
| Level3 | dtrsm | √ | √ | √ | √ | √ |
| Level3 | ctrsm | √ | √ | √ | √ | √ |
| Level3 | ztrsm | √ | √ | √ | √ | √ |
| Level3 | strsmbatched | × | × | √ | × | × |
| Level3 | dtrsmbatched | × | × | √ | × | × |
| Level3 | ctrsmbatched | × | × | √ | × | × |
| Level3 | ztrsmbatched | × | × | √ | × | × |
| Level3 | xerbla | × | √ | × | × | √ |
| Levelx | saxpby | × | √ | × | × | × |
| Levelx | daxpby | × | √ | × | × | × |
| Levelx | caxpby | × | √ | × | × | × |
| Levelx | zaxpby | × | √ | × | × | × |
| Levelx | shad | √ | × | × | × | × |
| Levelx | dhad | √ | × | × | × | × |
| Levelx | chad | √ | × | × | × | × |
| Levelx | zhad | √ | × | × | × | × |
| Levelx | somatcopy | √ | √ | × | × | × |
| Levelx | domatcopy | √ | √ | × | × | × |
| Levelx | comatcopy | √ | √ | × | × | × |
| Levelx | zomatcopy | √ | √ | × | × | × |
| Levelx | homatcopy | √ | × | × | × | × |
| Levelx | simatcopy | × | √ | × | × | × |
| Levelx | dimatcopy | × | √ | × | × | × |
| Levelx | cimatcopy | × | √ | × | × | × |
| Levelx | zimatcopy | × | √ | × | × | × |
| Levelx | himatcopy | × | × | × | × | × |
| Levelx | sgeadd | × | √ | × | × | × |
| Levelx | dgeadd | × | √ | × | × | × |
| Levelx | cgeadd | × | √ | × | × | × |
| Levelx | zgeadd | × | √ | × | × | × |
| Levelx | sbstobf16 | × | √ | × | × | × |
| Levelx | sbdtobf16 | × | √ | × | × | × |
| Levelx | sbf16tos | × | √ | × | × | × |
| Levelx | dbf16tod | × | √ | × | × | × |
| Levelx | sbdot | × | √ | × | × | × |
| Levelx | sbgemv | × | √ | × | × | × |
| Levelx | sbgemm | × | √ | × | × | × |
| Levelx | sim2col | √ | × | × | × | × |
| Levelx | dim2col | √ | × | × | × | × |
| Levelx | cim2col | √ | × | × | × | × |
| Levelx | zim2col | √ | × | × | × | × |
| Levelx | him2col | √ | × | × | × | × |
| Levelx | scol2im | √ | × | × | × | × |
| Levelx | dcol2im | √ | × | × | × | × |
| Levelx | ccol2im | √ | × | × | × | × |
| Levelx | zcol2im | √ | × | × | × | × |
| Levelx | hcol2im | √ | × | × | × | × |
| Levelx | sconvgem | √ | × | × | × | × |
| Levelx | dconvgemm | √ | × | × | × | × |
| Levelx | hconvgemm | √ | × | × | × | × |
| Levelx | saxpybatched | √ | × | × | × | × |
| Levelx | daxpybatched | √ | × | × | × | × |
| Levelx | caxpybatched | √ | × | × | × | × |
| Levelx | zaxpybatched | √ | × | × | × | × |
| Levelx | haxpybatched | √ | × | × | × | × |
| Levelx | sgemmbatched | √ | × | √ | × | × |
| Levelx | dgemmbatched | √ | × | √ | × | × |
| Levelx | cgemmbatched | √ | × | √ | × | × |
| Levelx | zgemmbatched | √ | × | √ | × | × |
| Levelx | hgemmbatched | √ | × | √ | × | × |
| Levelx | sgemmstridedbatched | √ | × | √ | × | × |
| Levelx | dgemmstridedbatched | √ | × | √ | × | × |
| Levelx | cgemmstridedbatched | √ | × | √ | × | × |
| Levelx | zgemmstridedbatched | √ | × | √ | × | × |
| Levelx | hgemmstridedbatched | √ | × | √ | × | × |
| Levelx | cgemm3mstridedbatched | × | × | √ | × | × |
| Levelx | sgemmwithtempbuffer | √ | × | × | × | × |
| Levelx | dgemmwithtempbuffer | √ | × | × | × | × |
| Levelx | cgemmwithtempbuffer | √ | × | × | × | × |
| Levelx | zgemmwithtempbuffer | √ | × | × | × | × |
| Levelx | hgemmwithtempbuffer | √ | × | × | × | × |
| Levelx | sgemmtempbuffersize | √ | × | × | × | × |
| Levelx | dgemmtempbuffersize | √ | × | × | × | × |
| Levelx | cgemmtempbuffersize | √ | × | × | × | × |
| Levelx | zgemmtempbuffersize | √ | × | × | × | × |
| Levelx | hgemmtempbuffersize | √ | × | × | × | × |
| Levelx | clearcached | √ | × | × | × | × |
| Levelx | fillcache | √ | × | × | × | × |
| Levelx | overrideparameters | √ | × | × | × | × |
| Levelx | sgeam | × | × | √ | × | × |
| Levelx | dgeam | × | × | √ | × | × |
| Levelx | cgeam | × | × | √ | × | × |
| Levelx | zgeam | × | × | √ | × | × |
| Levelx | sdgmm | × | × | √ | × | × |
| Levelx | ddgmm | × | × | √ | × | × |
| Levelx | cdgmm | × | × | √ | × | × |
| Levelx | zdgmm | × | × | √ | × | × |
| Levelx | sgetrfbatched | × | × | √ | × | × |
| Levelx | dgetrfbatched | × | × | √ | × | × |
| Levelx | cgetrfbatched | × | × | √ | × | × |
| Levelx | zgetrfbatched | × | × | √ | × | × |
| Levelx | sgetrsbatched | × | × | √ | × | × |
| Levelx | dgetrsbatched | × | × | √ | × | × |
| Levelx | cgetrsbatched | × | × | √ | × | × |
| Levelx | zgetrsbatched | × | × | √ | × | × |
| Levelx | sgetribatched | × | × | √ | × | × |
| Levelx | dgetribatched | × | × | √ | × | × |
| Levelx | cgetribatched | × | × | √ | × | × |
| Levelx | zgetribatched | × | × | √ | × | × |
| Levelx | smatinvbatched | × | × | √ | × | × |
| Levelx | dmatinvbatched | × | × | √ | × | × |
| Levelx | cmatinvbatched | × | × | √ | × | × |
| Levelx | zmatinvbatched | × | × | √ | × | × |
| Levelx | sgeqrfbatched | × | × | √ | × | × |
| Levelx | dgeqrfbatched | × | × | √ | × | × |
| Levelx | cgeqrfbatched | × | × | √ | × | × |
| Levelx | zgeqrfbatched | × | × | √ | × | × |
| Levelx | sgelsbatched | × | × | √ | × | × |
| Levelx | dgelsbatched | × | × | √ | × | × |
| Levelx | cgelsbatched | × | × | √ | × | × |
| Levelx | zgelsbatched | × | × | √ | × | × |
| Levelx | stpttr | × | × | √ | × | × |
| Levelx | dtpttr | × | × | √ | × | × |
| Levelx | ctpttr | × | × | √ | × | × |
| Levelx | ztpttr | × | × | √ | × | × |
| Levelx | strttp | × | × | √ | × | × |
| Levelx | dtrttp | × | × | √ | × | × |
| Levelx | ctrttp | × | × | √ | × | × |
| Levelx | ztrttp | × | × | √ | × | × |
| Levelx | sgemmex | × | × | √ | × | × |
| Levelx | cgemmex | × | × | √ | × | × |
| Levelx | gemmex | × | × | √ | × | × |
| Levelx | gemmbatchedex | × | × | √ | × | × |
| Levelx | gemmstridedbatchedex | × | × | √ | × | × |
| Levelx | csyrkex | × | × | √ | × | × |
| Levelx | csyrk3mex | × | × | √ | × | × |
| Levelx | cherkex | × | × | √ | × | × |
| Levelx | cherk3mex | × | × | √ | × | × |
| Levelx | nrm2ex | × | × | √ | × | × |
| Levelx | axpyex | × | × | √ | × | × |
| Levelx | dotex | × | × | √ | × | × |
| Levelx | dotcex | × | × | √ | × | × |
| Levelx | rotex | × | × | √ | × | × |
| Levelx | scalex | × | × | √ | × | × |

**注释**：

* ×表示未实现
* √表示已实现
* Levelx表示自定义扩展，一般考虑性能提高，比如说支持batched功能等
* OpenBLAS支持bfloat16

### rot

当x，y为实数的时候

当x，y为复数的时候

其中，

## 参考

* [Norm (mathematics)](https://en.wikipedia.org/wiki/Norm_(mathematics))
* [Hermitian matrix](https://en.wikipedia.org/wiki/Hermitian_matrix)
* [Packed Storage](https://www.netlib.org/lapack/lug/node123.html#:~:text=For%20complex%20Hermitian%20matrices%2C%20packing,the%20upper%20triangle%20by%20rows.)
* [MKL BLAS](https://oneapi-src.github.io/oneMKL/domains/blas/blas.html)
* [Wolfram BLAS](https://reference.wolfram.com/language/LowLevelLinearAlgebra/guide/BLASGuide.html)
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* [GSL BLAS](https://www.gnu.org/software/gsl/doc/html/blas.html)
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