NAG Library Function Document

nag_ztpmqrt (f08bqc)

1 Purpose

nag_ztpmqrt (f08bqc) multiplies an arbitrary complex matrix C by the complex unitary matrix Q from a QR factorization computed by nag_ztpqrt (f08bpc).

2 Specification

```
#include <nag.h>
#include <nagf08.h>
```

```
void nag_ztpmqrt (Nag_OrderType order, Nag_SideType side,
     Nag_TransType trans, Integer m, Integer n, Integer k, Integer l,
     Integer nb, const Complex v[], Integer pdv, const Complex t[],
     Integer pdt, Complex c1[], Integer pdc1, Complex c2[], Integer pdc2,
     NagError *fail)
```

3 Description

nag_ztpmqrt (f08bqc) is intended to be used after a call to nag_ztpqrt (f08bpc) which performs a QR factorization of a triangular-pentagonal matrix containing an upper triangular matrix A over a pentagonal matrix B. The unitary matrix Q is represented as a product of elementary reflectors.

This function may be used to form the matrix products

$$QC, Q^{\mathrm{H}}C, CQ \text{ or } CQ^{\mathrm{H}},$$

where the complex rectangular m_c by n_c matrix C is split into component matrices C_1 and C_2.

If Q is being applied from the left (QC or $Q^{\mathrm{H}}C$) then

$$C = \begin{pmatrix} C_1 \\ C_2 \end{pmatrix}$$

where C_1 is k by n_c, C_2 is m_v by n_c, $m_c = k + m_v$ is fixed and m_v is the number of rows of the matrix V containing the elementary reflectors (i.e., **m** as passed to nag_ztpqrt (f08bpc)); the number of columns of V is n_v (i.e., **n** as passed to nag_ztpqrt (f08bpc)).

If Q is being applied from the right (CQ or CQ^{H}) then

$$C = \begin{pmatrix} C_1 & C_2 \end{pmatrix}$$

where C_1 is m_c by k, and C_2 is m_c by m_v and $n_c = k + m_v$ is fixed.

The matrices C_1 and C_2 are overwriten by the result of the matrix product.

A common application of this routine is in updating the solution of a linear least squares problem as illustrated in Section 10 in nag_ztpqrt (f08bpc).

4 References

Golub G H and Van Loan C F (2012) *Matrix Computations* (4th Edition) Johns Hopkins University Press, Baltimore

5 Arguments

1: **order** – Nag_OrderType *Input*

On entry: the **order** argument specifies the two-dimensional storage scheme being used, i.e., row-major ordering or column-major ordering. C language defined storage is specified by **order** = Nag_RowMajor. See Section 2.3.1.3 in How to Use the NAG Library and its Documentation for a more detailed explanation of the use of this argument.

Constraint: **order** = Nag_RowMajor or Nag_ColMajor.

2: **side** – Nag_SideType *Input*

On entry: indicates how Q or Q^{H} is to be applied to C.

side = Nag_LeftSide
Q or Q^{H} is applied to C from the left.

side = Nag_RightSide
Q or Q^{H} is applied to C from the right.

Constraint: **side** = Nag_LeftSide or Nag_RightSide.

3: **trans** – Nag_TransType *Input*

On entry: indicates whether Q or Q^{H} is to be applied to C.

trans = Nag_NoTrans
Q is applied to C.

trans = Nag_ConjTrans
Q^{H} is applied to C.

Constraint: **trans** = Nag_NoTrans or Nag_ConjTrans.

4: **m** – Integer *Input*

On entry: the number of rows of the matrix C_2, that is,

if **side** = Nag_LeftSide
then m_v, the number of rows of the matrix V;

if **side** = Nag_RightSide
then m_c, the number of rows of the matrix C.

Constraint: $\mathbf{m} \geq 0$.

5: **n** – Integer *Input*

On entry: the number of columns of the matrix C_2, that is,

if **side** = Nag_LeftSide
then n_c, the number of columns of the matrix C;

if **side** = Nag_RightSide
then n_v, the number of columns of the matrix V.

Constraint: $\mathbf{n} \geq 0$.

6: **k** – Integer *Input*

On entry: k, the number of elementary reflectors whose product defines the matrix Q.

Constraint: $\mathbf{k} \geq 0$.

7: **l** – Integer *Input*

On entry: l, the number of rows of the upper trapezoidal part of the pentagonal composite matrix V, passed (as **b**) in a previous call to nag_ztpqrt (f08bpc). This must be the same value used in the previous call to nag_ztpqrt (f08bpc) (see **l** in nag_ztpqrt (f08bpc)).

Constraint: $0 \leq \mathbf{l} \leq \mathbf{k}$.

8: **nb** – Integer *Input*

On entry: nb, the blocking factor used in a previous call to nag_ztpqrt (f08bpc) to compute the QR factorization of a triangular-pentagonal matrix containing composite matrices A and B.

Constraints:

$\mathbf{nb} \geq 1$;
if $\mathbf{k} > 0$, $\mathbf{nb} \leq \mathbf{k}$.

9: **v**[*dim*] – const Complex *Input*

Note: the dimension, *dim*, of the array **v** must be at least

$\max(1, \mathbf{pdv} \times \mathbf{k})$ when **order** = Nag_ColMajor;
$\max(1, \mathbf{m} \times \mathbf{pdv})$ when **order** = Nag_RowMajor and **side** = Nag_LeftSide;
$\max(1, \mathbf{n} \times \mathbf{pdv})$ when **order** = Nag_RowMajor and **side** = Nag_RightSide.

The (i, j)th element of the matrix V is stored in

$\mathbf{v}[(j-1) \times \mathbf{pdv} + i - 1]$ when **order** = Nag_ColMajor;
$\mathbf{v}[(i-1) \times \mathbf{pdv} + j - 1]$ when **order** = Nag_RowMajor.

On entry: the m_v by n_v matrix V; this should remain unchanged from the array **b** returned by a previous call to nag_ztpqrt (f08bpc).

10: **pdv** – Integer *Input*

On entry: the stride separating row or column elements (depending on the value of **order**) in the array **v**.

Constraints:

if **order** = Nag_ColMajor,

if **side** = Nag_LeftSide, $\mathbf{pdv} \geq \max(1, \mathbf{m})$;
if **side** = Nag_RightSide, $\mathbf{pdv} \geq \max(1, \mathbf{n})$.;

if **order** = Nag_RowMajor, $\mathbf{pdv} \geq \max(1, \mathbf{k})$.

11: **t**[*dim*] – const Complex *Input*

Note: the dimension, *dim*, of the array **t** must be at least

$\max(1, \mathbf{pdt} \times \mathbf{k})$ when **order** = Nag_ColMajor;
$\max(1, \mathbf{nb} \times \mathbf{pdt})$ when **order** = Nag_RowMajor.

The (i, j)th element of the matrix T is stored in

$\mathbf{t}[(j-1) \times \mathbf{pdt} + i - 1]$ when **order** = Nag_ColMajor;
$\mathbf{t}[(i-1) \times \mathbf{pdt} + j - 1]$ when **order** = Nag_RowMajor.

On entry: this must remain unchanged from a previous call to nag_ztpqrt (f08bpc) (see **t** in nag_ztpqrt (f08bpc)).

12: **pdt** – Integer *Input*

On entry: the stride separating row or column elements (depending on the value of **order**) in the array **t**.

Constraints:

if **order** $=$ Nag_ColMajor, **pdt** $\geq$ **nb**;
if **order** $=$ Nag_RowMajor, **pdt** $\geq \max(1, \mathbf{k})$.

13: **c1**[*dim*] – Complex *Input/Output*

Note: the dimension, *dim*, of the array **c1** must be at least

$\max(1, \mathbf{pdc1} \times \mathbf{n})$ when **side** $=$ Nag_LeftSide and **order** $=$ Nag_ColMajor;
$\max(1, \mathbf{k} \times \mathbf{pdc1})$ when **side** $=$ Nag_LeftSide and **order** $=$ Nag_RowMajor;
$\max(1, \mathbf{pdc1} \times \mathbf{k})$ when **side** $=$ Nag_RightSide and **order** $=$ Nag_ColMajor;
$\max(1, \mathbf{m} \times \mathbf{pdc1})$ when **side** $=$ Nag_RightSide and **order** $=$ Nag_RowMajor.

On entry: C_1, the first part of the composite matrix C:

if **side** $=$ Nag_LeftSide
then **c1** contains the first k rows of C;

if **side** $=$ Nag_RightSide
then **c1** contains the first k columns of C.

On exit: **c1** is overwritten by the corresponding block of QC or $Q^{\mathrm{H}}C$ or CQ or CQ^{H}.

14: **pdc1** – Integer *Input*

On entry: the stride separating row or column elements (depending on the value of **order**) in the array **c1**.

Constraints:

if **order** $=$ Nag_ColMajor,

if **side** $=$ Nag_LeftSide, **pdc1** $\geq \max(1, \mathbf{k})$;
if **side** $=$ Nag_RightSide, **pdc1** $\geq \max(1, \mathbf{m})$.;

if **order** $=$ Nag_RowMajor,

if **side** $=$ Nag_LeftSide, **pdc1** $\geq \max(1, \mathbf{n})$;
if **side** $=$ Nag_RightSide, **pdc1** $\geq \max(1, \mathbf{k})$..

15: **c2**[*dim*] – Complex *Input/Output*

Note: the dimension, *dim*, of the array **c2** must be at least

$\max(1, \mathbf{pdc2} \times \mathbf{n})$ when **order** $=$ Nag_ColMajor;
$\max(1, \mathbf{m} \times \mathbf{pdc2})$ when **order** $=$ Nag_RowMajor.

On entry: C_2, the second part of the composite matrix C.

if **side** $=$ Nag_LeftSide
then **c2** contains the remaining m_v rows of C;

if **side** $=$ Nag_RightSide
then **c2** contains the remaining m_v columns of C;

On exit: **c2** is overwritten by the corresponding block of QC or $Q^{\mathrm{H}}C$ or CQ or CQ^{H}.

16: **pdc2** – Integer *Input*

On entry: the stride separating row or column elements (depending on the value of **order**) in the array **c2**.

Constraints:

if **order** $=$ Nag_ColMajor, **pdc2** $\geq \max(1, \mathbf{m})$;
if **order** $=$ Nag_RowMajor, **pdc2** $\geq \max(1, \mathbf{n})$.

17: **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_ENUM_INT_3

On entry, **side** $= \langle value \rangle$, **k** $= \langle value \rangle$, **m** $= \langle value \rangle$ and **pdc1** $= \langle value \rangle$.
Constraint: if **side** = Nag_LeftSide, **pdc1** $\geq \max(1, \mathbf{k})$;
if **side** = Nag_RightSide, **pdc1** $\geq \max(1, \mathbf{m})$.

On entry, **side** $= \langle value \rangle$, **m** $= \langle value \rangle$, **n** $= \langle value \rangle$ and **pdv** $= \langle value \rangle$.
Constraint: if **side** = Nag_LeftSide, **pdv** $\geq \max(1, \mathbf{m})$;
if **side** = Nag_RightSide, **pdv** $\geq \max(1, \mathbf{n})$.

On entry, **side** $= \langle value \rangle$, **pdc1** $= \langle value \rangle$, **n** $= \langle value \rangle$ and **k** $= \langle value \rangle$.
Constraint: if **side** = Nag_LeftSide, **pdc1** $\geq \max(1, \mathbf{n})$;
if **side** = Nag_RightSide, **pdc1** $\geq \max(1, \mathbf{k})$.

NE_INT

On entry, **k** $= \langle value \rangle$.
Constraint: **k** ≥ 0.

On entry, **m** $= \langle value \rangle$.
Constraint: **m** ≥ 0.

On entry, **n** $= \langle value \rangle$.
Constraint: **n** ≥ 0.

NE_INT_2

On entry, **l** $= \langle value \rangle$ and **k** $= \langle value \rangle$.
Constraint: $0 \leq \mathbf{l} \leq \mathbf{k}$.

On entry, **m** $= \langle value \rangle$ and **pdc2** $= \langle value \rangle$.
Constraint: **pdc2** $\geq \max(1, \mathbf{m})$.

On entry, **nb** $= \langle value \rangle$ and **k** $= \langle value \rangle$.
Constraint: **nb** ≥ 1 and
if $\mathbf{k} > 0$, $\mathbf{nb} \leq \mathbf{k}$.

On entry, **pdc2** $= \langle value \rangle$ and **n** $= \langle value \rangle$.
Constraint: **pdc2** $\geq \max(1, \mathbf{n})$.

On entry, **pdt** $= \langle value \rangle$ and **k** $= \langle value \rangle$.
Constraint: **pdt** $\geq \max(1, \mathbf{k})$.

On entry, **pdt** $= \langle value \rangle$ and **nb** $= \langle value \rangle$.
Constraint: **pdt** $\geq$ **nb**.

On entry, **pdv** $= \langle value \rangle$ and **k** $= \langle value \rangle$.
Constraint: **pdv** $\geq \max(1, \mathbf{k})$.

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_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

The computed result differs from the exact result by a matrix E such that

$$\|E\|_2 = O(\epsilon)\|C\|_2,$$

where ϵ is the ***machine precision***.

8 Parallelism and Performance

nag_ztpmqrt (f08bqc) makes calls to BLAS and/or LAPACK routines, which may be threaded within the vendor library used by this implementation. Consult the documentation for the vendor library for further information.

Please consult the x06 Chapter Introduction for information on how to control and interrogate the OpenMP environment used within this function. Please also consult the Users' Notefor your implementation for any additional implementation-specific information.

9 Further Comments

The total number of floating-point operations is approximately $2nk(2m - k)$ if **side** = Nag_LeftSide and $2mk(2n - k)$ if **side** = Nag_RightSide.

The real analogue of this function is nag_dtpmqrt (f08bcc).

10 Example

See Section 10 in nag_ztpqrt (f08bpc).