Lab 7

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Exercise

- Write a program in ARM assembly language in order to multiply two matrices.
- The first matrix is made by *N* rows and *M* columns.
- The second matrix is made by *M* rows and *P* columns.
- The resulting matrix is made by *N* rows and *P* columns.
- All martrices are made by signed numbers expressed on a word.
- *N*, *M*, *P* are constants, to be defined with `EQU`.

Declaration of matrices

- The first two matrices are defined as constant in a READONLY memory area.

- The third matrix has to be allocated in a DATA READWRITE area.

Matrix multiplication

- Let a_{ik} be the element at row *i* and column *k* of matrix *A*
- Let b_{kj} be the element at row *k* and column *j* of matrix *B*
- *The product of matrices A* and *B* generates a matrix *C* which elements are:

$$c_{ij} = \sum_{k=1}^{n} a_{ik} b_{kj}$$

Example 1

N = 3, M = 4, P = 2

$$A = \begin{pmatrix} 4 & -3 & 5 & 1 \\ 3 & -5 & 0 & 11 \\ -5 & 12 & 4 & -5 \end{pmatrix} \qquad B = \begin{pmatrix} -2 & 3 \\ 5 & -1 \\ 4 & 3 \\ 9 & -7 \end{pmatrix}$$

$$C = \begin{pmatrix} 6 & 23 \\ 68 & -63 \\ 41 & 20 \end{pmatrix}$$

Overflow handling

- Intermediate sums have to be calculated on two words.
- At the end of a row*column multiplication, check the most significant word of the partial sum.
- In case of overflow, it is required to store as result the maximum number (positive or negative, depending on the overflow) expressable on a single word.

Overflow conditions

- If one of the following conditions is true, the result is not representable on a word.
  - The most significant word is different from 0 or from 0xFFFFFFFF
  - The most significant word is equal to 0 or 0xFFFFFFFF, but the most significant bit of the least significant word is different from the bits of the most significant word.

Example 2: matrix A

- N = 4, M = 7, P = 5
- All numbers are in hexadecimal

$$A = \begin{pmatrix} 00000BB8 & 000036B0 & FFFFC568 & 00002328 & 00006590 & FFFF30F8 & 00001388 \\ 00015BA8 & 000013498 & 00000BB8 & 000059D8 & 00014820 & FFFFE890 & FFFF8AD0 \\ 0000A7F8 & FFFFF448 & 00014438 & 00006978 & FFFFDCD8 & 0000C350 & 00006D60 \\ FFFEA840 & 0000A028 & 00017AE8 & FFFE6DA8 & 00010D88 & 00009858 & FFFFDCD8 \end{pmatrix}$$

Example 2: matrix B

$$B = \begin{pmatrix} 00009088 & FFFE7578 & 0 & 0000E290 & FFFFB1E0 \\ 00002328 & 00012110 & 00016F30 & FFFFF060 & 0000E678 \\ FFFFA628 & 00015F90 & FFFECF50 & 00003E80 & FFFFF060 \\ 0 & FFFF0DD0 & 00014FF0 & 00004E20 & 00015BA8 \\ 00002328 & 00014FF0 & 00006D60 & 0 & FFFF7B30 \\ 00014050 & 00001388 & 000084D0 & FFFFADF8 & 000003E8 \\ 00011170 & FFFEFA48 & 00002328 & 00014050 & 000036B0 \end{pmatrix}$$

Example 2: matrix C

$$C = \begin{pmatrix} 80000000 & 1B7A4D40 & 7FFFFFFF & 5E3C2540 & 2D4CAE00 \\ 7D1C32C0 & 7FFFFFFF & 7FFFFFFF & 7FFFFFFF & 6164DC80 \\ 7FFFFFFF & BA5279C0 & 80000000 & 7FFFFFFF & 6A372980 \\ 8D05CBC0 & 7FFFFFFF & 80000000 & 80000000 & 80000000 \end{pmatrix}$$

Example 2: calculation of $c_{1,3}$

1. 00000BB8 * 00000000 =000000000 00000000
   Partial result: 000000000 00000000
2. 000036B0 * 00016F30 = 00000000 4E709100
   Partial result: 00000000 4E709100
3. FFFFC568 * FFFECF50=00000000 45BCC880
   Partial result: 00000000 942D5980
4. 00002328 * 00014FF0 = 00000000 2E224D80
   Partial result: 00000000 C24FA700

Example 2: calculation of $c_{1,3}$

5. 00006590 * 00006D60 = 00000000 2B646600
   Partial result : 00000000 EDB40D00
6. FFFF30F8 * 000084D0=FFFFFFFF 9497A980
   Partial result : 00000000 824BB680
7. 00001388 * 00002328 = 00000000 02AEA540
   Partial result : 00000000 84FA5BC0

- The result is not representable on a single word because the first bit of the least significant word is different from the bits of the most significant word.
- $c_{1,3}$ = 7FFFFFFF

Example 2: calculation of $c_{2,1}$

1. 00015BA8 * 00009088 = 000000000 C4473140
   Partial result: 000000000 C4473140
2. 000013498 * 00002328 = 00000000 2A60FFC0
   Partial result : 00000000 EEA83100
3. 00000BB8 * FFFFA628=FFFFFFFF FBE324C0
   Partial result : 00000000 EA8B55C0
4. 000059D8 * 00000000 = 00000000 00000000
   Partial result : 00000000 EA8B55C0

Example 2: calculation of $c_{2,1}$

5. 00014820 * 00002328 = 00000000 2D0FA500
   Partial result : 00000001 179AFAC0
6. FFFFE890 * 00014050=FFFFFFFF E2ACAD00
   Partial result : 00000000 FA47A7C0
7. FFFF8AD0 * 00011170 =FFFFFFFF 82D48B00
   Partial result : 00000000 7D1C32C0

- Despite the fact that at step 5 the partial result is on 2 words, the final result is represantable on a single one.

Example 2: calculation of $c_{1,1}$

1. 00015BA8 * FFFE7578=FFFFFFFD E836BEC0
   Partial result : FFFFFFFD E836BEC0
2. 000013498 * 00012110 = 00000001 5C72E180
   Partial result : FFFFFFFF 44A9A040
3. 00000BB8 * 00015F90= 00000000 1017DF80
   Partial result : FFFFFFFF 54C17FC0
4. 000059D8 * FFFF0DD0=FFFFFFFF AB00F780
   Partial result : FFFFFFFE FFC27740

Example 2: calculation of $c_{1,1}$

5. 00014820 * 00014FF0 = 00000001 AE957E00
   Partial result : 00000000 AE57F540
6. FFFFE890 * 00001388=FFFFFFFF FE363C80
   Partial result : 00000000 AC8E31C0
7. FFFF8AD0 * FFFEFA48=00000000 77CE2A80
   Partial result : 00000001 245C5C40

- The result is not representable on a single word, because the most significant word is different from 0 and from FFFFFFFF.
- $c_{1,1}$ = 7FFFFFFF