CS 4341 Computer Architecture

Homework 5

1. Show how the time-iterative multiply algorithm calculates 23×25 in an k=6-bit system, giving a 12-bit result. Here 23 is the multiplier and 25 is the multiplicand. Show your working.

   Answer:
   When the M'Cand is negative, we shift in 1's to the LH end of the U register on each shift operation. When the M'Cand is positive, we shift in zeros. So, in general we shift in the sign of the M'Cand.

   The exception is the final shift following a subtraction in the k'th cycle, where the M'pr is negative (qns 5 and 6). Then we shift in a zero.

   You can derive these facts from the table in the printed notes.

```
C     U      V    M'Cand = 011001 = 25
0  000000 010111  add and shift
 + 011001
  -------
0  011001 010111  shift in the sign of the M'Cand
   \\\\\\ \\\\\\
0  001100 101011  add and shift
 + 011001
  -------
0  100101 101011  shift in the sign of the M'Cand
   \\\\\\ \\\\\\
0  010010 110101  add and shift
 + 011001
  -------
0  101011 110101  shift in the sign of the M'Cand
   \\\\\\ \\\\\\
0  010101 111010  shift
   \\\\\\ \\\\\\
0  001010 111101  add and shift
 + 011001
 -------
0  100011 111101
   \\\\\\ \\\\\\
0  010001 111110    shift in the sign of the M'Cand
   \\\\\\ \\\\\\
0  001000 111111   = 575
```

2. Repeat question 1 with a multiplier of 25 and a multiplicand of 23. Show your working as above.

   Answer:

```
C     U      V   M'Cand = 010111 = 23
0  000000 011001  add and shift
  +010111
  -------
0  010111 011001

0  001011 101100  shift
0  000101 110110  shift
0  000010 111011  add and shift
  +010111
  -------
0  011001 111011

0  001100 111101  add and shift
  +010111
  -------
0  100011 111011

0  010001 111110  shift
0  001000 111111  == 575
```

3. Repeat question 1 with a multiplier of 23 and a multiplicand of -25. Remember to propagate the sign of the UV register on all shifts. Show your working as above.

Answer:
It's important to remember that we are simulating an extended M'Cand of 12 bits.

```
C     U      V     M'Cand = 100111
0  000000 010111  add and shift
  +100111
  -------
1  100111 010111

1  110011 101011 add and shift
  +100111
  -------
1  011010 101011

1  101101 010101 add and shift
  +100111
  -------
1  010100 010101

1  101010 001010 shift
1  110101 000101 add and shift
  +100111
  -------
1  011100 000101

1  101110 000010  shift
1  110111 000001  == -575
```

4. Repeat question 3 with a multiplier of -25 and a multiplicand of 23. After all 6 iterations have completed apply a correction step by subtracting the multiplicand from the U register. Show your working as above.

   Answer:

```
C     U      V   M'Cand = 010111
0  000000 100111  add and shift
  +010111
  -------
0  010111 100111  shift in the sign of the M'Cand

0  001011 110011  add and shift
  +010111
  -------
0  100010 110011  shift in the sign of the M'Cand
   010001 011001  add and shift
  +010111
  -------
0  101000 011001  shift in the sign of the M'Cand

0  010100 001100  shift
0  001010 000110  shift

0  000101 000011  add and shift
  +010111
  -------
0  011100 000001

0  001110 000001  Subtract to correct
  -010111
  -------
1  110111 000001
```

5. Repeat question 4 with a multiplier of -25 and a multiplicand of 23, but this time, instead of applying the correction step after all 6 iterations, subtract the multiplicand in the last iteration when the multiplier is negative.

Answer:

```
C     U      V   M'Cand = 010111
0  000000 100111  add and shift
  +010111
  -------
0  010111 100111  shift in the sign bit of the M'Cand

0  001011 110011  add and shift
  +010111
  -------
0  100010 110011  shift in the sign bit of the M'Cand
0  010001 011001  add and shift
  +010111
  -------
0  101000 011001  shift in the sign bit of the M'Cand

0  010100 001100  shift
0  001010 000110  shift

0  000101 000011  subtract and shift
  -010111
  -------
0  101110 000011  shift in complement of sign of M'Cand

0  110111 000001  = -575
```

6. Repeat question 5 with a multiplier of -25 and a multiplicand of -23. Again, subtract the multiplicand in the last iteration.

Answer:

```
C     U      V    M'Cand = 101001
0  000000 100111  add and shift
 + 101001
  -------
1  101001 100111  shift in the sign bit if the M'Cand

1  110100 110011  add and shift
 + 101001
  -------
1  011101 110011  shift in the sign bit if the M'Cand


1  101110 111001  add and shift
 + 101001
  -------
1  010111 111001  shift in the sign bit if the M'Cand

1  101011 111100  shift
1  110101 111110  shift

1  111010 111110  subtract and shift
 - 101001
  -------
0  010001 111111  shift in complement of sign of M'Cand

0  001000 111111    = 575
```