Solutions - Homework 2

(Due date: October 4th)

Presentation and clarity are very important! Show your procedure!

PROBLEM 1 (36 PTS)

- Calculate the result (provide the 32-bit result) of the following operations with 32-bit floating point numbers. Truncate the results when required. When doing fixed-point division, use 8 fractional bits. Show your procedure.

✓ 40C00000 + C2EA9000	✓ 5A09D378 – 4C490FD8	✓ 7A09D300 × 4D080000	✓ 800C0000 ÷ 494C0000
✓ 10DAD000 + 10FAD000	✓ 801BEEDA – 7F800000	✓ 90DECADE × FF800000	✓ 7F800000 ÷ 800ABBAA
✓ 801A8000 + 92CE8000	✓ BA09D380 – 39DEC0DE	✓ 0B09A000 × 8FACC000	✓ C9746000 ÷ 40490000

✓ X = 40C00000 + C2EA9000:

40C00000: 0100 0000 1100 0000 0000 0000 0000 0000

$e + bias = 10000001 = 129 \rightarrow e = 129 - 127 = 2$ $Mantissa = 1.1$

40C00000 = 1.1×2^2

C2EA9000: 1100 0010 1110 1010 1001 0000 0000 0000

$e + bias = 10000101 = 133 \rightarrow e = 133 - 127 = 6$ $Mantissa = 1.11010101001$

C2EA9000 = $-1.11010101001 \times 2^6$

$X = 1.1 \times 2^2 - 1.11010101001 \times 2^6 = \frac{1.1}{2^4} \times 2^6 - 1.11010101001 \times 2^6$

$X = 0.00011 \times 2^6 - 1.11010101001 \times 2^6$

To subtract these numbers, we first convert to 2C:

$R = 0.00011 - 01.11010101001 = 0.00011 + 10.00101010111$ (2C addition)

The result (in 2C) is: $R = 10.01000010111$, $-R = 01.10111101001$

```
  0 0 0 0 1 1 1 0 0 0 0 0 0 0
  0 0.0 0 0 1 1 0 0 0 0 0 0 +
  1 0.0 0 1 0 1 0 1 0 1 1 1
  -------------------------
  1 0.0 1 0 0 0 0 1 0 1 1 1
```

For floating point, we need to convert to sign-and-magnitude:

$\Rightarrow R(SM) = -1.10111101001$

$X = -1.10000101 \times 2^6, e + bias = 6 + 127 = 133 = 10000101$

X = 1100 0010 1101 1110 1001 0000 0000 0000 = C2DE9000

✓ X = 10DAD000 + 10FAD000:

10DAD000: 0001 0000 1101 1010 1101 0000 0000 0000

$e + bias = 00100001 = 33 \rightarrow e = 33 - 127 = -94$ $Mantissa = 1.10110101101$

10DAD000 = $1.10110101101 \times 2^{-94}$

10FAD000: 0001 0000 1111 1010 1101 0000 0000 0000

$e + bias = 00100001 = 33 \rightarrow e = 33 - 127 = -94$ $Mantissa = 1.11110101101$

60A10000 = $1.11110101101 \times 2^{-94}$

$X = 1.10110101101 \times 2^{-94} + 1.11110101101 \times 2^{-94}$ (unsigned addition)

$X = 11.1010101101 \times 2^{-94} = 1.11010101101 \times 2^{-93}$

```
  1 1 1 1 1 0 1 0 1 1 0 1 0
    1.1 0 1 1 0 1 0 1 1 0 1 +
    1.1 1 1 1 0 1 0 1 1 0 1
    -----------------------
  1 1.1 0 1 0 1 0 1 1 0 1 0
```

$X = 1.11010101101 \times 2^{-93}, e + bias = -93 + 127 = 34 = 00100010$

X = 0001 0001 0110 1010 1101 0000 0000 0000 = 116AD000

✓ X = 801A8000 + 92CE8000:

801A8000: 1000 0000 0001 1010 1000 0000 0000 0000

$e + bias = 00000000 = 0 \rightarrow Denormal\ number \rightarrow e = -126$ $Mantissa = 0.000110101$

801A8000 = $-0.000110101 \times 2^{-126}$

92CE8000: 1001 0010 1100 1110 1000 0000 0000 0000

$e + bias = 00100101 = 37 \rightarrow e = 37 - 127 = -100$ $Mantissa = 1.10011101$

92CE8000 = $-1.10011101 \times 2^{-100}$

$X = -0.000110101 \times 2^{-126} - 1.10011101 \times 2^{-100} = -\frac{0.000110101}{2^{26}} \times 2^{-100} - 1.10011101 \times 2^{-100}$

Representing the division by 2^{26} requires more than $p+1=24$ bits. Thus, we round down the 1st operand to 0.
$X=-1.10011101\times 2^{-100}$
X = 1001 0010 1100 1110 1000 0000 0000 0000= 92CE8000

✓ X = 50A9D378 – 4C490FD8:
50A9D378: 0101 0000 1010 1001 1101 0011 0111 1000
$e+bias=10100001=161\rightarrow e=161-127=34$ $\quad$ $Mantissa=1.01010011101001101111$
50A9D378 = $1.01010011101001101111\times 2^{34}$

4C490FD8: 0100 1100 0100 1001 0000 1111 1101 1000
$e+bias=10011000=152\rightarrow e=152-127=25$ $\quad$ $Mantissa=1.10010010000111111011$
4C490FD8 = $1.10010010000111111011\times 2^{25}$

$X=1.01010011101001101111\times 2^{34}-1.10010010000111111011\times 2^{25}$
$X=1.01010011101001101111\times 2^{34}-\dfrac{1.10010010000111111011}{2^{9}}\times 2^{34}$
$X=1.01010011101001101111\times 2^{34}-0.00000000110010010000111111011\times 2^{34}$ (unsigned subtraction)

```
0 0 0 0 0 0 0 0 0 1 1 0 1 1 0 0 1 0 0 0 0 1 1 1 1|1 1 1 1 1 0 0 0
  1.1 0 1 1 0 0 1 1 1 0 1 0 0 1 1 0 1 1 1 1 0 0 0|0 0 0 0 0 0 0 0 -
  0.0 0 0 0 0 0 0 0 1 1 0 0 1 0 0 1 0 0 0 0 0 1 1|1 1 1 0 1 1 0 0
-----------------------------------------------------------------
  1.0 1 0 1 0 0 1 0 1 1 0 1 1 1 0 1 1 1 1 0 0 0 0|0 0 0 1 0 1 0 0
```

$X=1.0101001011011101111 0000\times 2^{34}, e+bias=34+127=161=10100001$
X = 0101 0000 1010 1001 0110 1110 1111 0000 = 50A96EF0

✓ X = 801BEEDA – 7F800000:
FF800000: 1111 1111 1000 0000 0000 0000 0000 0000
$e+bias=11111111=255, f=0$
FF800000 = $+\infty$
$X=\#-(+\infty)=-\infty$
X = FF800000

✓ X = BA09D380 – 39DEC0DE:
BA09D380: 1011 1010 0000 1001 1101 0011 1000 0000
$e+bias=01110100=116\rightarrow e=116-127=-11$ $\quad$ $Mantissa=1.0001001110100111$
50A9D378 = $-1.0001001110100111\times 2^{-11}$

39DEC0DE: 0011 1001 1101 1110 1100 0000 1101 1110
$e+bias=01110011=115\rightarrow e=115-127=-12$ $\quad$ $Mantissa=1.10111101100000001101111$
4C490FD8 = $1.10111101100000001101111\times 2^{-12}$

$X=-1.0001001110100111\times 2^{-11}-1.10111101100000001101111\times 2^{-12}$
$X=-1.0001001110100111\times 2^{-11}-\dfrac{1.10111101100000001101111}{2^{1}}\times 2^{-12}$
$X=-1.0001001110100111\times 2^{-11}-0.110111101100000001101111\times 2^{-11}$ (unsigned addition)

```
0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  1.0 0 0 1 0 0 1 1 1 0 1 0 0 1 1 1 0 0 0 0 0 0 0 +
  0.1 1 0 1 1 1 1 0 1 1 0 0 0 0 0 0 1 1 0 1 1 1 1
---------------------------------------------------
  1.1 1 1 1 0 0 1 0 0 1 1 0 0 1 1 1 1 1 0 1 1 1 1
```

$X=-1.11110010011001111101111\times 2^{-11}, e+bias=-11+127=116=01110100$
X = 1011 1010 0111 1001 0011 0011 1110 1111 = BA7933EF

✓ X = 7A09D300 × 4D080000:
7A09D300: 0111 1010 0000 1001 1101 0011 0000 0000
$e+bias=11110100=244\rightarrow e=244-127=117$ $\quad$ $Mantissa=1.000100111010011$
7A09D300 = $1.000100111010011\times 2^{117}$

4D080000: 0100 1101 0000 1000 0000 0000 0000 0000
$e+bias=10011010=154\rightarrow e=154-127=27$ $\quad$ $Mantissa=1.0001$
4D080000 = 1.0001×2^{27}

$X = 1.0001001110100 11 \times 2^{117} \times 1.0001 \times 2^{27} = 1.00100100111000000 11 \times 2^{144}$
$e + bias = 144 + 127 = 271 > 254$

Here, there is an overflow. The value X is assigned to $+\infty$.
X = 0111 1111 1000 1000 0000 0000 0000 0000 = 7F800000

✓ X = 90DECADE × FF800000:
FF800000: 1111 1111 1000 0000 0000 0000 0000 0000
$e + bias = 11111111 = 255, f = 0$
FF800000 = $-\infty$
$X = (-|\#|) \times -\infty = \infty$
X = 0111 1111 1000 0000 0000 0000 0000 0000 = 7F800000

✓ X = 0B092000 × 8FACC000:
0B092000: 0000 1011 0000 1001 0010 0000 0000 0000
$e + bias = 00010110 = 22 \rightarrow e = 22 - 127 = -105$ $\quad Mantissa = 1.0001001001$
0B092000 = $1.0001001001 \times 2^{-105}$

8FACC000: 1000 1111 1010 1100 1100 0000 0000 0000
$e + bias = 00011111 = 31 \rightarrow e = 31 - 127 = -96$ $\quad Mantissa = 1.010110011$
0FACE000 = $1.010110011 \times 2^{-96}$

$X = 1.0001001001 \times 2^{-105} \times -1.010110011 \times 2^{-96} = -1.0111001000100001011 \times 2^{-201} = -0 \times 2^{-126}$
$e + bias = -201 + 127 = -74 < 0$

Here, there is underflow (not even denormalized numbers different than zero can represent it). Then $X \leftarrow -0$.
X = 1000 0000 0000 0000 0000 0000 0000 0000 = 80000000

✓ X = 800C0000 ÷ 494C0000:
800C0000: 1000 0000 0000 1100 0000 0000 0000 0000
$e + bias = 00000000 = 0 \rightarrow Denormal\ number \rightarrow e = -126$ $\quad Mantissa = 0.00011$
800C0000 = -0.00011×2^{-126}

494C0000: 0100 1001 0100 1100 0000 0000 0000 0000
$e + bias = 10010010 = 146 \rightarrow e = 146 - 127 = 19$ $\quad Mantissa = 1.10011$
494C0000 = 1.10011×2^{19}

$$X = -\frac{0.00011 \times 2^{-126}}{1.10011 \times 2^{19}}$$

```
         0000001111
110011 ) 1100000000
         110011
         -------
         1011010
          110011
          -------
          1001110
           110011
           -------
            110110
            110011
            ------
                11
```

Alignment:
$$\frac{0.00011}{1.10011} = \frac{000011}{110011}$$

Append x = 8 zeros: $\frac{1100000000}{110011}$

Integer division
$Q = 1111, R = 11 \rightarrow Qf = 0.00001111$

Thus: $X = -\frac{0.00011 \times 2^{-126}}{1.10011 \times 2^{19}} = -0.00001111 \times 2^{-145} = -(0.00001111 \times 2^{-19}) \times 2^{-126}$
$X = -0.000\ 0000\ 0000\ 0000\ 0000\ 0000\ 1111 \times 2^{-126}$. $Denormal \rightarrow e + bias = 00000000$
X = 1000 0000 0000 0000 0000 0000 0000 0000 = 80000000

✓ X = 7F800000 ÷ 800ABBAA:
7F800000: 0111 1111 1000 0000 0000 0000 0000 0000
$e + bias = 11111111 = 255, f = 0$
0F800000 = $+\infty$
$X = +\infty \div -|\#| = -\infty$
X = FF800000

✓ X = C9746000 ÷ 40490000:

C9742000: 1100 1001 0111 0100 0110 0000 0000 0000

$e + bias = 10010010 = 146 \rightarrow e = 146 - 127 = 19$ $\quad$ $Mantissa = 1.1110100011$

C97420000 = $-1.1110100001 \times 2^{19}$

40490000: 0100 0000 0100 1001 0000 0000 0000 0000

$e + bias = 10000000 = 128 \rightarrow e = 128 - 127 = 1$ $\quad$ $Mantissa = 1.1001001$

0BEEF000 = 1.1001001×2^{1}

$$X = -\frac{1.1110100011 \times 2^{19}}{1.1001001 \times 2^{1}}$$

```
                  000000000000100110111
11001001000 ) 1111010001100000000
              11001001000
              -----------
                101011011000
                 11001001000
                ------------
                 100100100000
                  11001001000
                 ------------
                   101101100000
                    11001001000
                   ------------
                    101000110000
                     11001001000
                    ------------
                      11111010000
                      11001001000
                      -----------
                        110001000
```

Alignment:

$$\frac{1.1110100011}{1.1001001} = \frac{1.1110100011}{1.1001001000} = \frac{11110100011}{11001001000}$$

Append x = 8 zeros: $\frac{1111010001100000000}{11001001000}$

Integer division

$Q = 100110111, R = 110001000 \rightarrow Qf = 1.00110111$

Thus: $X = -\frac{1.1110100011 \times 2^{19}}{1.1001001 \times 2^{1}} = -1.00110111 \times 2^{18}$

$e + bias = 18 + 127 = 145 = 10010001$

X = 1100 1000 1001 1011 1000 0000 0000 0000 = C89B8000

PROBLEM 2 (8 PTS)

- Complete the table for the following DFX formats:

$B = 2^{n-p_0-2}$

$num0 \in [-2^{n-p_0-2}, 2^{n-p_0-2} - 2^{-p_0}]$

$num1 \in [-2^{n-p_1-2}, -2^{n-p_0-2} - 2^{-p_1}] \cup [2^{n-p_0-2}, 2^{n-p_1-2} - 2^{-p_1}]$

$Dynamic\ Range = 20\log_{10}(2^{n-2-p_1+p_0})$

DFX format	p_0	p_1	Number of bits of significand	Boundary value	$num0$ range	$num1$ range	Dynamic Range (dB)
8_3_2	3	2	7	8	$[-8, 7.875]$	$[-16, -8.25]\ U$ $[8, 15.75]$	42.1441
16_12_4	12	4	15	4	$[-4, 3.999755859]$	$[-1024, -4.0625]\ U$ $[4, 1023.9375]$	132.4532
24_16_8	16	8	23	64	$[-64, 63.99998474]$	$[-16384, -64.00390625]\ U$ $[64, 16383.99609375]$	180.618
32_24_16	24	16	31	64	$[-64, 63.99999994]$	$[-16384, -64.00001525]\ U$ $[64, 16383.99998474]$	228.7828

PROBLEM 3 (16 PTS)

- Convert the following signed fixed point numbers in format [16 8] to the dual fixed point format 16_8_3. If more bits are required, you are allowed to use the format 17_8_3.

FX	FA.CE	04.2F	8D.EE	AF.27	81.BE	80.E4	8A.BB	AB.CE
DFX								

- ✓ `FA.CE`:
  `1111 1010.1100 1110` ⇒ To DFX 16_8_3 ($num0$): `0111101011001110` = `7ACE`

- ✓ `04.2F`:
  `0000 0100.0010 1111` ⇒ To DFX 16_8_3 ($num0$): `0000010000101111` = `042F`

- ✓ `8D.EE`:
  `1000 1101.1110 1110` ⇒ To DFX 16_8_3 ($num0$): `0000110111101110` = not a $num0$!
  ⇒ To DFX 16_8_3 ($num1$): `1111110001101111` = `FC6F`

- ✓ `AF.27`:
  `1010 1111.0010 0111` ⇒ To DFX 16_8_3 ($num0$): `0010111100100111` = not a $num0$!
  ⇒ To DFX 16_8_3 ($num1$): `1111110101111001` = `FD79`

- ✓ `81.BE`:
  `1000 0001.1011 1110` ⇒ To DFX 16_8_3 ($num0$): `0000000110111110` = not a $num0$!
  ⇒ To DFX 16_8_3 ($num1$): `1111110000001101` = `FC0D`

- ✓ `80.E4`:
  `1000 0000.1110 0100` ⇒ To DFX 16_8_3 ($num0$): `0000000011100100` = not a $num0$!
  ⇒ To DFX 16_8_3 ($num1$): `1111110000000111` = `FC07`

- ✓ `8A.BB`:
  `1000 1010.1011 1011` ⇒ To DFX 16_8_3 ($num0$): `0000101010111011` = not a $num0$!
  ⇒ To DFX 16_8_3 ($num1$): `1111110001010101` = `FC55`

- ✓ `AB.CE`:
  `1010 1011.1100 1110` ⇒ To DFX 16_8_3 ($num0$): `0010101111001110` = not a $num0$!
  ⇒ To DFX 16_8_3 ($num1$): `1111110101011110` = `FD5E`

PROBLEM 4 (30 PTS)

- Calculate the result of the following operations where the numbers are represented in dual fixed-point arithmetic. Note that the results must be in the same format. Include an overflow bit when necessary.

DFX Format: 8_4_2	Result	overflow		Result	overflow
FA+09			EB+AF		
E2+BB			C0-C2		
FB-7A			F8+3A		

DFX Format 16_8_4	Result	overflow		Result	overflow
FA2A+0A09			F939-0932		
C000+F1C3			F343-6AA9		
F990-0A32			D001+F170		

- ✓ `FA+09`:

$c_7=0$ $c_6=0$ $c_5=0$ $c_4=0$ $c_3=0$ $c_2=1$ $c_1=0$ $c_0=0$

```
1 1 1 1 1 0 1 0 +        1 1 1 1 0.1 0 +
0 0 0 0 1 0 0 1     ➡    0 0 0 0 0.1 0 0 1
                         ------------------   optional
                         1 1 1 1 1.0 0 0 1
```

`11111.0001` ⇒ To DFX 8_4_2 ($num0$): `0111.0001` = `71` Overflow = 0

✓ E2+BB:

1 1 1 0 0 0 1 0 +
1 0 1 1 1 0 1 1

$c_7=1$ $c_6=1$ $c_5=0$ $c_4=0$ $c_3=0$ $c_2=1$ $c_1=0$ $c_0=0$

1 1 0 0 0.1 0 +
0 1 1 1 0.1 1
0 0 1 1 1.0 1

00111.01 ⇒ To DFX 8_4_2 ($num0$): **0**1110100 = not a $num0$!
⇒ To DFX 8_4_2 ($num1$): **1**0011101 = 9D Overflow = 0

✓ FB-7A:

1 1 1 1 1 0 1 1 −
0 1 1 1 1 0 1 0

1 1 1 1 0.1 1 −
1 1 1.1 0 1 0

$c_7=0$ $c_6=0$ $c_5=0$ $c_4=0$ $c_3=0$ $c_2=1$ $c_1=1$ $c_0=0$

1 1 1 1 0.1 1 +
0 0 0 0 0.0 1 1 0
1 1 1 1 1.0 0 1 0

optional

11111.0010 ⇒ To DFX 8_4_2 ($num0$): **0**1110010 = 72 Overflow = 0

✓ EB+AF:

1 1 1 0 1 0 1 1 +
1 0 1 0 1 1 1 1

$c_7=1$ $c_6=1$ $c_5=0$ $c_4=1$ $c_3=1$ $c_2=1$ $c_1=1$ $c_0=0$

1 1 0 1 0.1 1 +
0 1 0 1 1.1 1
0 0 1 1 0.1 0

00110.10 ⇒ To DFX 8_4_2 ($num0$): **0**1101000 = not a $num0$!
⇒ To DFX 8_4_2 ($num1$): **1**0011010 = 9A Overflow = 0

✓ C0-C2:

1 1 0 0 0 0 0 0 −
1 1 0 0 0 0 1 0

1 0 0 0 0.0 0 −
1 0 0 0 0.1 0

$c_7=0$ $c_6=0$ $c_5=0$ $c_4=0$ $c_3=0$ $c_2=0$ $c_1=0$ $c_0=0$

1 0 0 0 0.0 0 +
0 1 1 1 1.1 0
1 1 1 1 1.1 0

11111.10 ⇒ To DFX 8_4_2 ($num0$): **0**1111000 = 78 Overflow = 0

✓ F8+3A:

1 1 1 1 1 0 0 0 +
0 0 1 1 1 0 1 0

$c_7=1$ $c_6=1$ $c_5=1$ $c_4=1$ $c_3=0$ $c_2=0$ $c_1=0$ $c_0=0$

1 1 1 1 0.0 0 +
0 0 0 1 1.1 0 1 0
0 0 0 0 1.1 0 1 0

optional

00001.1010 ⇒ To DFX 8_4_2 ($num0$): **0**0011010 = 1A Overflow = 0

✓ FA2A+0A09:

1111101000101010 +
0000101000001001

0 0 0 0 0 0 1 0 0 0 0 0 0
1 0 1 0 0 0 1 0.1 0 1 0 +
0 0 0 0 1 0 1 0.0 0 0 0 1 0 0 1
1 0 1 0 1 1 0 0.1 0 1 0 ~~1 0 0 1~~

10101100.10101001 ⇒ To DFX 16_8_4 ($num0$): **0**010110010101001 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): **1**111101011001010 = FACA Overflow = 0

✓ C000+F1C3:

1100000000000000 +
1111000111000011

1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 0 0 0 0 0 0 0 0 0 0.0 0 0 0 +
1 1 1 1 0 0 0 1 1 1 0 0.0 0 1 1
1 0 1 1 0 0 0 1 1 1 0 0.0 0 1 1

101100011100.0011 ⇒ To DFX 16_8_4 ($num0$): **0**001110000110000 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): **1**011000111000011 = not a $num1$! Overflow = 1

✓ F990-0A32:

```
                                                     1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0
1111100110010000 -        11110011001.0000 -          1 1 1 1 0 0 1 1 0 0 1.0 0 0 0 +
0000101000110011          00000001010.0011~~0011~~    1 1 1 1 1 1 1 0 1 0 1.1 1 0 1
                                                     ---------------------------------
                                                      1 1 1 1 0 0 0 1 1 1 0.1 1 0 1
```

11110001110.1101 ⇒ To DFX 16_8_4 ($num0$): 0000111011010000 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): 1111100011101101 = F8ED Overflow = 0

✓ F939-0932:

```
                                                     1 1 1 1 0 1 1 1 1 0 0 1 0
1111100100111001 -        11110010011.1001 -          1 0 0 1 0 0 1 1.1 0 0 1 +
0000100100110010          00000001001.0011~~0010~~    1 1 1 1 0 1 1 0.1 1 0 1
                                                     -------------------------
                                                      1 0 0 0 1 0 1 0.0 1 1 0
```

10001010.0110 ⇒ To DFX 16_8_4 ($num0$): 0000101001100000 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): 1111100010100110 = F8A6 Overflow = 0

✓ F343-6AA9:

```
                                                     0 0 0 1 1 0 1 0 0 0 1 1 0 0
1111001101000011 -        11100110100.0011 -          1 0 0 1 1 0 1 0 0.0 0 1 1 +
0110101010101001          11111101010.1010~~1001~~    0 0 0 0 1 0 1 0 1.0 1 1 0
                                                     --------------------------
                                                      1 0 1 0 0 1 0 0 1.1 0 0 1
```

101001001.1001 ⇒ To DFX 16_8_4 ($num0$): 0100100110010000 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): 1111010010011001 = F499 Overflow = 0

✓ D001+F170:

```
                           1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0
1101000000000001 +          1 0 1 0 0 0 0 0 0 0 0.0 0 0 1 +
1111000101110000            1 1 1 0 0 0 1 0 1 1 1.0 0 0 0
                           -------------------------------
                            1 0 0 0 0 0 1 0 1 1 1.0 0 0 1
```

10000010111.0001 ⇒ To DFX 16_8_4 ($num0$): 0010111100010000 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): 1100000101110001 = C171 Overflow = 0

PROBLEM 5 (10 PTS)

- Complete the timing diagram of the following iterative unsigned multiplier ($N = 4, M = 4$).
  Register: $sclr$: synchronous clear. Here, if $sclr = E = 1$, the register contents are initialized to 0.
  Parallel access shift register: If $E = 1$: $s\_l = 1 \rightarrow$ Load, $s\_l = 0 \rightarrow$ Shift