Solutions - Homework 2

(Due date: September 26th)
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.

✓ 3DE38C80 + 3A80D980 ✓ 80123000 + 804E8000 ✓ 7FBEADED + FACADE90	✓ 80A18000 − 03CEC000 ✓ 09DECAF0 − 7AD90000 ✓ F0B1ABEE − 7F800000	✓ 7A09C000 × 8BEE0000 ✓ FA19D800 × CD100000 ✓ 0B094000 × 8FBEE000	✓ 7A390000 ÷ C8400000 ✓ 7F800000 ÷ CAB34C00 ✓ C9680000 ÷ 80700000

✓ $X =$ 3DE38C80 + 3A80D980:

3DE38C80: 0011 1101 1110 0011 1000 1100 1000 0000

$e + bias = 01111011 = 123 \rightarrow e = 123 - 127 = -4$ $\quad Significand = 1.1010011100011001$

3DE38C80 = $1.1100011100011001 \times 2^{-4}$

3A80D980: 0011 1010 1000 0000 1101 1001 1000 0000

$e + bias = 01110101 = 117 \rightarrow e = 117 - 127 = -10$ $\quad Significand = 1.0000000110110011$

3A80D980 = $1.000000011011 \times 2^{-10}$

$$X = 1.1100011100011001 \times 2^{-4} + 1.000000011011 \times 2^{-10}$$
$$X = 1.1100011100011001 \times 2^{-4} + \frac{1.0000000110110011}{2^6} \times 2^{-4}$$
$$X = 1.1100011100011001 \times 2^{-4} + 0.0000010000000110110011 \times 2^{-4}$$

```
 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
   1.1 1 0 0 0 1 1 1 0 0 0 1 1 0 0 1 0 0 0 0 0 0 +
   0.0 0 0 0 0 1 0 0 0 0 0 0 0 1 1 0 1 1 0 0 1 1
 ----------------------------------------------
   1.1 1 0 0 1 0 1 1 0 0 0 1 1 1 1 1 1 1 0 0 1 1
```

$X = 1.1100101100011111110011 \times 2^{-4}, e + bias = -4 + 127 = 123 = 01111011$

X = 0011 1101 1110 0101 1000 1111 1110 0110 = 3DE58FE6

✓ $X =$ 80123000 + 804E8000:

80123000: 1000 0000 0001 0010 0011 0000 0000 0000

$e + bias = 00000000 = 0 \rightarrow Denormal\ number \rightarrow e = -126$ $\quad Significand = 0.00100100011$

80123000 = $-0.00100100011 \times 2^{-126}$

804E8000: 1000 0000 0100 1110 1000 0000 0000 0000

$e + bias = 00000000 = 0 \rightarrow Denormal\ number \rightarrow e = -126$ $\quad Significand = 0.10011101$

804E8000 = $-0.10011101 \times 2^{-126}$

$X = -0.00100100011 \times 2^{-126} - 0.10011101 \times 2^{-126}$

```
 0 0 0 1 1 1 1 0 0 0 0 0 0
   0.0 0 1 0 0 1 0 0 0 1 1 +
   0.1 0 0 1 1 1 0 1 0 0 0
 -------------------------
   0.1 1 0 0 0 0 0 1 0 1 1
```

$X = -0.11000001011 \times 2^{-126}, e + bias = 0 = 00000000$

X = 1000 0000 0110 0000 1011 0000 0000 0000= 8060B000

✓ $X =$ 7FBEADED + FACADE90:

7FBEADED: 0111 1111 1011 1110 1010 1101 1110 1101

$e + bias = 11111111 = 255, f \neq 0$

7FBEADED = NaN

$X = NaN + \# = NaN$

X = 7FBEADED

✓ $X =$ 80A18000 − 03CEC000:

80A18000: 1000 0000 1010 0001 1000 0000 0000 0000

$e + bias = 00000001 = 1 \rightarrow e = 1 - 127 = -126$ $\quad Significand = 1.01000011$

80A18000 = $-1.01000011 \times 2^{-126}$

03CEC00: 0000 0011 1100 1110 1100 0000 0000 0000

$e + bias = 00000111 = 7 \rightarrow e = 7 - 127 = -120$ $Significand = 1.100111011$

03CEC000 = $1.100111011 \times 2^{-120}$

```
 0 0 0 0 1 1 1 0 1 0 0 0 0 0 0 0
   0.0 0 0 0 0 1 0 1 0 0 0 0 1 1 +
   1.1 0 0 1 1 1 0 1 1 0 0 0 0 0
   ------------------------------
   1.1 0 1 0 0 0 1 0 1 0 0 0 1 1
```

$X = -1.01000011 \times 2^{-126} - 1.100111011 \times 2^{-120}$

$X = -\dfrac{1.01000011}{2^6} \times 2^{-120} - 1.100111011 \times 2^{-120}$

$X = -0.00000101000011 \times 2^{-120} - 1.100111011 \times 2^{-120}$

$X = -1.10100010100011 \times 2^{-120}, e + bias = -120 + 127 = 7 = 00000111$

X = 1000 0011 1101 0001 0100 0110 0000 0000 = 83D14600

✓ X = 09DECAF0 − 7AD90000:

09DECAF0: 0000 1001 1101 1110 1100 1010 1111 0000

$e + bias = 00010011 = 19 \rightarrow e = 19 - 127 = -108$ $Significand = 1.10111101100101011111$

09DECAF0 = $1.10111101100101011111 \times 2^{-108}$

7AD90000: 0111 1010 1101 1001 0000 0000 0000 0000

$e + bias = 11110101 = 245 \rightarrow e = 245 - 127 = 118$ $Significand = 1.1011001$

7AD90000 = 1.1011001×2^{118}

$X = 1.10111101100101011111 \times 2^{-108} - 1.1011001 \times 2^{118}$

$X = \dfrac{1.10111101100101011111}{2^{226}} \times 2^{118} - 1.1011001 \times 2^{118}$

Representing the division by 2^{226} requires more than $p + 1 = 24$ bits. Thus, we approximate the 1st operand with 0.

$X = -1.1011001 \times 2^{118}, e + bias = 118 + 127 = 245 = 11110101$

X = 1111 1010 1101 1001 0000 0000 0000 0000 = FAD90000

✓ X = F0B1ABEE − 7F800000:

7F800000: 0111 1111 1000 0000 0000 0000 0000 0000

$e + bias = 11111111 = 255, f = 0$

7F800000 = $+\infty$

$X = \# - (+\infty) = -\infty$

X = FF800000

✓ X = 7A09C000 × 8BEE0000:

7A09C000: 0111 1010 0000 1001 1100 0000 0000 0000

$e + bias = 11110100 = 244 \rightarrow e = 244 - 127 = 117$ $Significand = 1.000100111$

7A09C000 = $1.000100111 \times 2^{117}$

8BEE0000: 1000 1011 1110 1110 0000 0000 0000 0000

$e + bias = 00010111 = 23 \rightarrow e = 23 - 127 = -104$ $Significand = 1.110111$

8BEE0000 = $-1.110111 \times 2^{-104}$

$X = 1.000100111 \times 2^{117} \times -1.110111 \times 2^{-104} = -10.000000000100001 \times 2^{13}$

$X = -1.0000000000100001 \times 2^{14},$ $e + bias = 14 + 127 = 141 = 10001101$

X = 1100 0110 1000 0000 0001 0000 1000 0000 = C6801080

✓ X = FA19D800 × CD100000:

FA19D800: 1111 1010 0001 1001 1101 1000 0000 0000

$e + bias = 11110100 = 244 \rightarrow e = 244 - 127 = 117$ $Significand = 1.001100111011$

FF19D800 = $-1.001100111011 \times 2^{117}$

CD100000: 1100 1101 0001 0000 0000 0000 0000 0000

$e + bias = 10011010 = 154 \rightarrow e = 154 - 127 = 27$ $Significand = 1.001$

CD100000 = -1.001×2^{27}

$X = -1.001100111011 \times 2^{117} \times -1.001 \times 2^{27} = 1.010110100010011 \times 2^{144},$ $e + bias = 144 + 127 = 271 > 254$

Here, there is an overflow. The value X is assigned to $+\infty$

X = 0111 1111 1000 0000 0000 0000 0000 0000 = 7F800000

✓ X = 0B094000 × 8FBEE000:

0B094000: 0000 1011 0000 1001 0100 0000 0000 0000

$e + bias = 00010110 = 22 \rightarrow e = 22 - 127 = -105$ $Significand = 1.000100101$

0B094000 = $1.000100101 \times 2^{-105}$

8FBEE000: 1000 1111 1011 1110 1110 0000 0000 0000

$e + bias = 00011111 = 31 \rightarrow e = 31 - 127 = -96$ $Significand = 1.0111110111$

8FBEE000 = $-1.0111110111 \times 2^{-96}$

$X = 1.000100101 \times 2^{-105} \times -1.0111110111 \times 2^{-96} = -1.1001100101010110011 \times 2^{-201} = -0 \times 2^{-126}$

$e + bias = -201 + 127 = -74 < 0$

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 = 7A390000 ÷ C8400000:

7A390000: 0111 1010 0011 1001 0000 0000 0000 0000

$e + bias = 11110100 = 244 \rightarrow e = 244 - 127 = 117$ $Significand = 1.0111001$

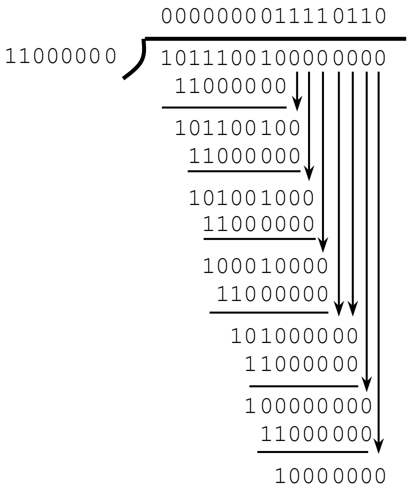
7A390000 = 1.0111001×2^{117}

C8400000: 1100 1000 0100 0000 0000 0000 0000 0000

$e + bias = 10010000 = 144 \rightarrow e = 144 - 127 = 17$ $Significand = 1.1$

C8400000 = -1.1×2^{17}

$$X = -\frac{1.0111001 \times 2^{117}}{1.1 \times 2^{17}}$$



Alignment:

$$\frac{1.0111001}{1.1000000} = \frac{10111001}{11000000}$$

Append x = 8 zeros: $\frac{10111001\mathbf{00000000}}{11000000}$

Integer division

$Q = 11110110, R = 10000000 \rightarrow Qf = 0.11110110$

Thus: $X = -\frac{1.0111001 \times 2^{117}}{1.1 \times 2^{17}} = -0.1111011 \times 2^{100} = -1.111011 \times 2^{99}$, $e + bias = 99 + 127 = 226 = 11100010$

X = 1111 0001 0111 0110 0000 0000 0000 0000 = F1760000

✓ X = 7F800000 ÷ CAB34C00:

7F800000: 0111 1111 1000 0000 0000 0000 0000 0000

$e + bias = 11111111 = 255, f = 0$

0F800000 = $+\infty$

$X = +\infty \div -|\#| = -\infty$

X = FF800000

✓ X = C9680000 ÷ 80700000:

C9680000: 1100 1001 0110 1000 0000 0000 0000 0000

$e + bias = 10010010 = 146 \rightarrow e = 146 - 127 = 19$ $Significand = 1.1101$

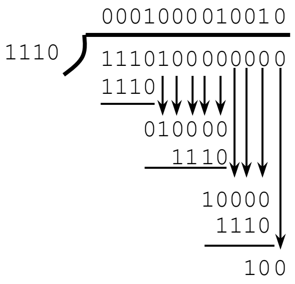
C9680000 = -1.1101×2^{19}

80700000: 1000 0000 0111 0000 0000 0000 0000 0000

$e + bias = 00000000 = 0 \rightarrow Denormal\ number \rightarrow e = -126$ $Significand = 0.111$

80700000 = -0.111×2^{-126}

$$X = \frac{1.1101 \times 2^{19}}{0.111 \times 2^{-126}}$$



Alignment:

$$\frac{1.1101}{0.111} = \frac{1.1101}{0.1110} = \frac{11101}{01110}$$

Append $x = 8$ zeros: $\frac{1110100000000}{1110}$

Integer division

$$Q = 1000010010, R = 100 \rightarrow Qf = 10.00010010$$

Thus: $X = \frac{1.1101 \times 2^{19}}{0.111 \times 2^{-126}} = 10.0001001 \times 2^{145} = 1.00001001 \times 2^{146}$
$e + bias = 146 + 127 = 273 > 254$

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

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_4_2	4	2	7	4	$[-4,3.9375]$	$[-16,-4.25]\ U$ $[4,15.75]$	48.1648
12_7_5	7	5	11	8	$[-8,7.9921875]$	$[-32,-8.03125]\ U$ $[8,31.96875]$	72.2472
16_8_3	8	3	15	64	$[-64,63.99609375]$	$[-2048,-64.125]\ U$ $[64,2047.875]$	114.3914
24_15_9	15	9	23	128	$[-128,127.99996]$	$[-8192,-128.00195]\ U$ $[128,8191.998046875]$	168.5768

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.1C	0A.B7	89.7C	9C.1F	83.FE	7E.25	B1.4B	6D.E9
DFX								

- ✓ `FA.1C`:
  `1111 1010.0001 1100` ⇒ To DFX 16_8_3 ($num0$): `0111101000011100` = `7A1C`

- ✓ `0A.B7`:
  `0000 1010.1011 0111` ⇒ To DFX 16_8_3 ($num0$): `0000101010110111` = `0AB7`

- ✓ `89.7C`:
  `1000 1001.0111 1100` ⇒ To DFX 16_8_3 ($num0$): `0000100101111100` = not a $num0$!
  ⇒ To DFX 16_8_3 ($num1$): $1\underline{1111}10001001011$ = `FC4B`

- ✓ `9C.1F`:
  `1001 1100.0001 1111` ⇒ To DFX 16_8_3 ($num0$): `0001110000011111` = not a $num0$!
  ⇒ To DFX 16_8_3 ($num1$): $1\underline{1111}10011100000$ = `FCE0`

✓ 83.FE:
1000 0011.1111 1110 ⇒ To DFX 16_8_3 ($num0$): 0000001111111110 = not a $num0$!
⇒ To DFX 16_8_3 ($num1$): $1\underline{1111}10000011111$ = FC1F

✓ 7E.25:
0111 1110.0010 0101 ⇒ To DFX 16_8_3 ($num0$): 0111111000100101 = not a $num0$!
⇒ To DFX 16_8_3 ($num1$): $1\underline{0000}01111110001$ = 83F1

✓ B1.4B:
1011 0001.0100 1011 ⇒ To DFX 16_8_3 ($num0$): 0011000101001011 = not a $num0$!
⇒ To DFX 16_8_3 ($num1$): $1\underline{1111}10110001010$ = FD8A

✓ 6D.E9:
0110 1101.1110 1001 ⇒ To DFX 16_8_3 ($num0$): 0110110111101001 = not a $num0$!
⇒ To DFX 16_8_3 ($num1$): $1\underline{0000}01101101111$ = 836F

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+0B			F9-90		
79+43			A2+EC		
C4+C3			34+FC		

DFX Format 16_8_4	Result	overflow		Result	overflow
FA2A+0A0E			C010+F2C4		
A004+B1C3			F93A-0932		
6A9A-F34C			207F-31DE		

✓ FA+0B:

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

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

optional

11111.0011 ⇒ To DFX 8_4_2 ($num0$): 0111.0011 = 73 Overflow = 0

✓ 79+43:

$c_8=1$ $c_7=1$ $c_6=0$ $c_5=0$ $c_4=0$ $c_3=0$ $c_2=1$ $c_1=1$ $c_0=0$

```
                          1 1 1 1.1 0 0 1 +
0 1 1 1 1 0 0 1 +         1 1 0 0.0 0 1 1
0 1 0 0 0 0 1 1           ---------------
                          1 0 1 1.1 1 0 0
```

1011.11 ⇒ To DFX 8_4_2 ($num0$): 00111100 = not a $num0$!
⇒ To DFX 8_4_2 ($num1$): $1\underline{1}101111$ = EF Overflow = 0

- ✓ C4+C3:

$$\begin{array}{l} \mathbf{1}\;1\;0\;0\;0\;1\;0\;0\;+ \\ \mathbf{1}\;1\;0\;0\;0\;0\;1\;1 \end{array} \;\rightarrow\; \begin{array}{l} c_8=1\;\; c_7=1\;\; c_6=0\;\; c_5=0\;\; c_4=0\;\; c_3=0\;\; c_2=0\;\; c_1=0\;\; c_0=0 \\ 1\;1\;0\;0\;0\;1.0\;0\;+ \\ 1\;1\;0\;0\;0\;0.1\;1 \\ \hline 1\;0\;0\;0\;0\;1.1\;1 \end{array}$$

100001.11 ⇒ To DFX 8_4_2 ($num0$): 00001100 = not a $num0$!
⇒ To DFX 8_4_2 ($num1$): 10000111 = not a $num1$! Overflow = 1

- ✓ F9-90:

$$\begin{array}{l} \mathbf{1}\;1\;1\;1\;1\;0\;0\;1\;- \\ \mathbf{1}\;0\;0\;1\;0\;0\;0\;0 \end{array} \;\rightarrow\; \begin{array}{l} 1\;1\;1\;1\;0.0\;1\;- \\ 0\;0\;1\;0\;0.0\;0 \end{array} \;\rightarrow\; \begin{array}{l} c_7=1\;\; c_6=1\;\; c_5=1\;\; c_4=0\;\; c_3=0\;\; c_2=0\;\; c_1=0\;\; c_0=0 \\ 1\;1\;1\;1\;0.0\;1\;+ \\ 1\;1\;1\;0\;0.0\;0 \\ \hline 1\;1\;0\;1\;0.0\;1 \end{array}$$

11010.01 ⇒ To DFX 8_4_2 ($num0$): 00100100 = not a $num0$!
⇒ To DFX 8_4_2 ($num1$): 11101001 = E9 Overflow = 0

- ✓ A2+EC:

$$\begin{array}{l} \mathbf{1}\;0\;1\;0\;0\;0\;1\;0\;+ \\ \mathbf{1}\;1\;1\;0\;1\;1\;0\;0 \end{array} \;\rightarrow\; \begin{array}{l} c_7=1\;\; c_6=1\;\; c_5=0\;\; c_4=1\;\; c_3=0\;\; c_2=0\;\; c_1=0\;\; c_0=0 \\ 0\;1\;0\;0\;0.1\;0\;+ \\ 1\;1\;0\;1\;1.0\;0 \\ \hline 0\;0\;0\;1\;1.1\;0 \end{array}$$

0001.10 ⇒ To DFX 8_4_2 ($num0$): 00011000 = 18 Overflow = 0

- ✓ 34+FC:

$$\begin{array}{l} \mathbf{0}\;0\;1\;1\;0\;1\;0\;0\;+ \\ \mathbf{1}\;1\;1\;1\;1\;1\;0\;0 \end{array} \;\rightarrow\; \begin{array}{l} c_7=1\;\; c_6=1\;\; c_5=1\;\; c_4=1\;\; c_3=1\;\; c_2=0\;\; c_1=0\;\; c_0=0 \\ 0\;0\;0\;1\;1.0\;1\;0\;0\;+ \\ 1\;1\;1\;1\;1.0\;0 \\ \hline 0\;0\;0\;1\;0.0\;1\;0\;0 \end{array}$$

00010.01 ⇒ To DFX 8_4_2 ($num0$): 00100100 = 24 Overflow = 0

- ✓ FA2A+0A0E:

$$\begin{array}{l} \mathbf{1}111101000101010\;+ \\ \mathbf{0}000101000001110 \end{array} \;\rightarrow\; \begin{array}{l} 0\;0\;0\;0\;0\;0\;1\;0\;0\;0\;0\;0\;0 \\ 1\;0\;1\;0\;0\;0\;1\;0.1\;0\;1\;0\;+ \\ 0\;0\;0\;0\;1\;0\;1\;0.0\;0\;0\;0\;1\;1\;1\;0 \\ \hline 1\;0\;1\;0\;1\;1\;0\;0.1\;0\;1\;0\;\cancel{1\;1\;1\;0} \end{array}$$

10101100.10101110 ⇒ To DFX 16_8_4 ($num0$): 0010110010101110 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): 1111101011001010 = FACA Overflow = 0

- ✓ A004+B1C3:

$$\begin{array}{l} \mathbf{1}010000000000100\;+ \\ \mathbf{1}011000111000011 \end{array} \;\rightarrow\; \begin{array}{l} 0\;0\;1\;0\;0\;0\;0\;0\;0\;0\;0\;0\;0\;0\;0\;0\;0 \\ 0\;0\;1\;0\;0\;0\;0\;0\;0\;0\;0\;0.0\;1\;0\;0\;+ \\ 0\;0\;1\;1\;0\;0\;0\;1\;1\;1\;0\;0.0\;0\;1\;1 \\ \hline 0\;1\;0\;1\;0\;0\;0\;1\;1\;1\;0\;0.0\;1\;1\;1 \end{array}$$

010100011100.0111 ⇒ To DFX 16_8_4 ($num0$): 0001110001110000 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): 1101000111000111 = not a $num1$! Overflow = 1

- ✓ 6A9A-F34C:

$$\begin{array}{l} \mathbf{0}110101010011010\;- \\ \mathbf{1}111001101001100 \end{array} \;\rightarrow\; \begin{array}{l} 11111101010.1001\cancel{1010}\;- \\ 11100110100.1100 \end{array} \;\rightarrow\; \begin{array}{l} 1\;1\;1\;1\;1\;0\;0\;1\;0\;1\;0\;0\;0\;0\;0\;0 \\ 1\;1\;1\;1\;1\;1\;0\;1\;0\;1\;0.1\;0\;0\;1\;+ \\ 0\;0\;0\;1\;1\;0\;0\;1\;0\;1\;1.0\;1\;0\;0 \\ \hline 0\;0\;0\;1\;0\;1\;1\;0\;1\;0\;1.1\;1\;0\;1 \end{array}$$

00010110101.1101 ⇒ To DFX 16_8_4 ($num0$): 0011010111010000 = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): $1\underline{00}0101101011101$ = 8B5D Overflow = 0

✓ C010+F2C4:

1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0

1100000000010000 + ➡ 1 1 0 0 0 0 0 0 0 0 0 1.0 0 0 0 +
1111001011000100 1 1 1 1 0 0 1 0 1 1 0 0.0 1 0 0

1 0 1 1 0 0 1 0 1 1 0 1.0 1 0 0

101100101101.0100 ⇒ To DFX 16_8_4 ($num0$): **0**0101101**01000000** = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): **1**011001011010100 = not a $num1$! Overflow = 1

✓ F93A-0932:

1 1 1 1 0 1 1 1 1 0 0 1 0

1111100100111010 − ➡ 11110010011.1010 − ➡ 1 0 0 1 0 0 1 1.1 0 1 0 +
0000100100110010 00000001001.00110~~010~~ 1 1 1 1 0 1 1 0.1 1 0 1

1 0 0 0 1 0 1 0.0 1 1 1

10001010.0111 ⇒ To DFX 16_8_4 ($num0$): **0**00010100**1110000** = not a $num0$!
⇒ To DFX 16_8_4 ($num1$): **1**111100010100111 = F8A7 Overflow = 0

✓ 207F-31DE:

0 0 0 0 0 0 0 0 1 1 1 1 1 1 0 0

0010000001111111 − ➡ 0100000.01111111 − ➡ 0 1 0 0 0 0 0.0 1 1 1 1 1 1 1 +
0011000111011110 0110001.11011110 1 0 0 1 1 1 0.0 0 1 0 0 0 1 0

1 1 0 1 1 1 0.1 0 1 0 0 0 0 1

1101110.10100001 ⇒ To DFX 16_8_4 ($num0$): **0**11011101**0100001** = 6EA1 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