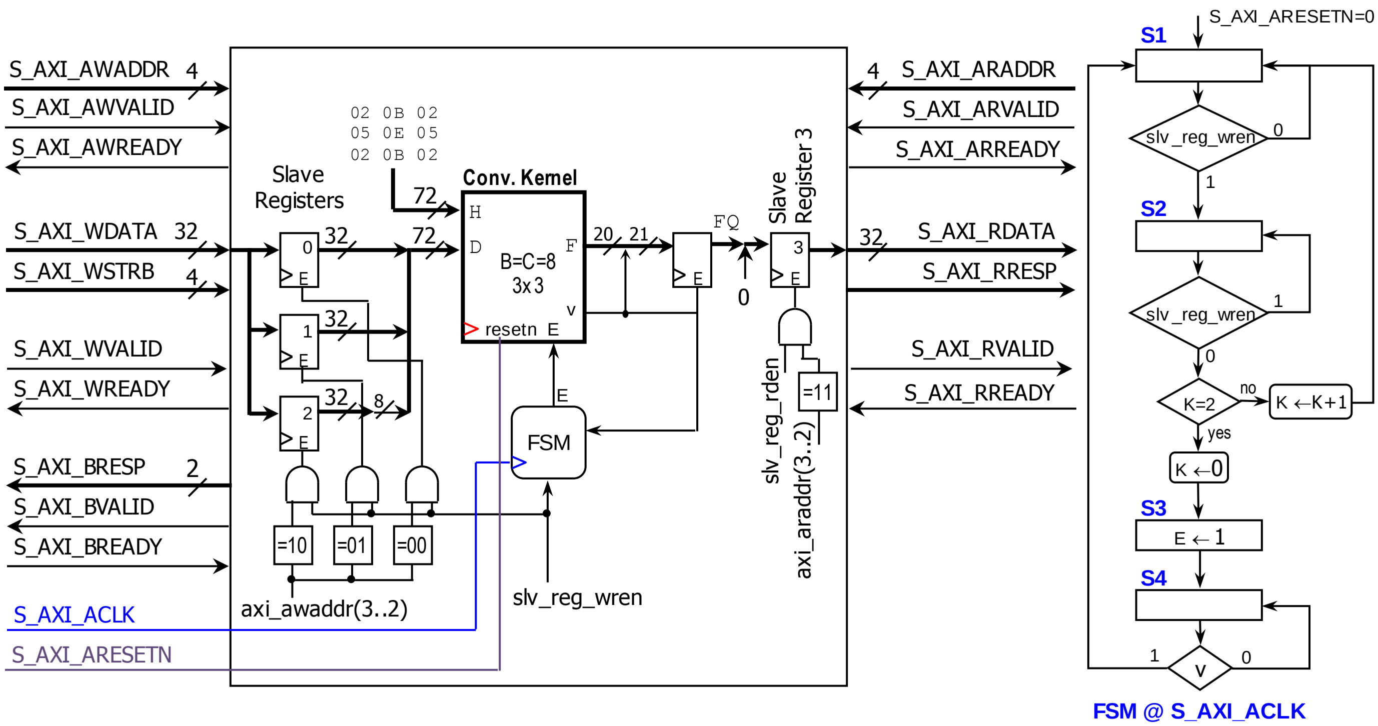
Solutions - Homework 2

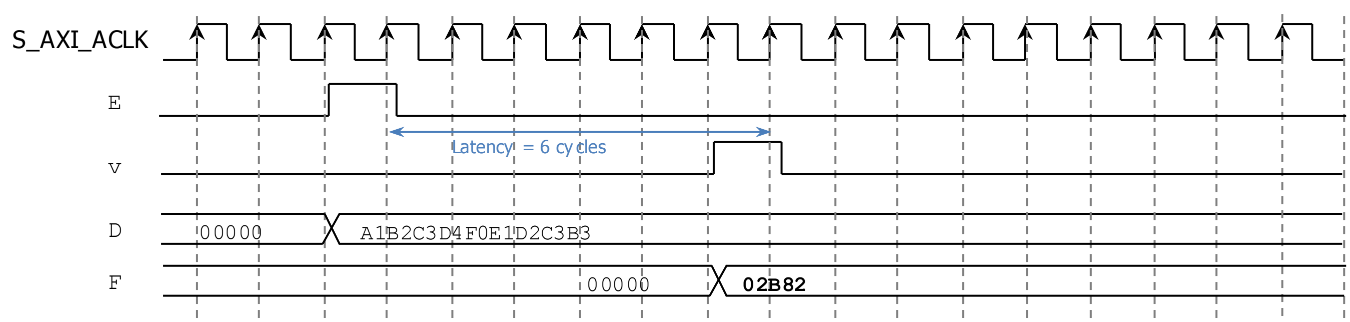
(Due date: May 26th)

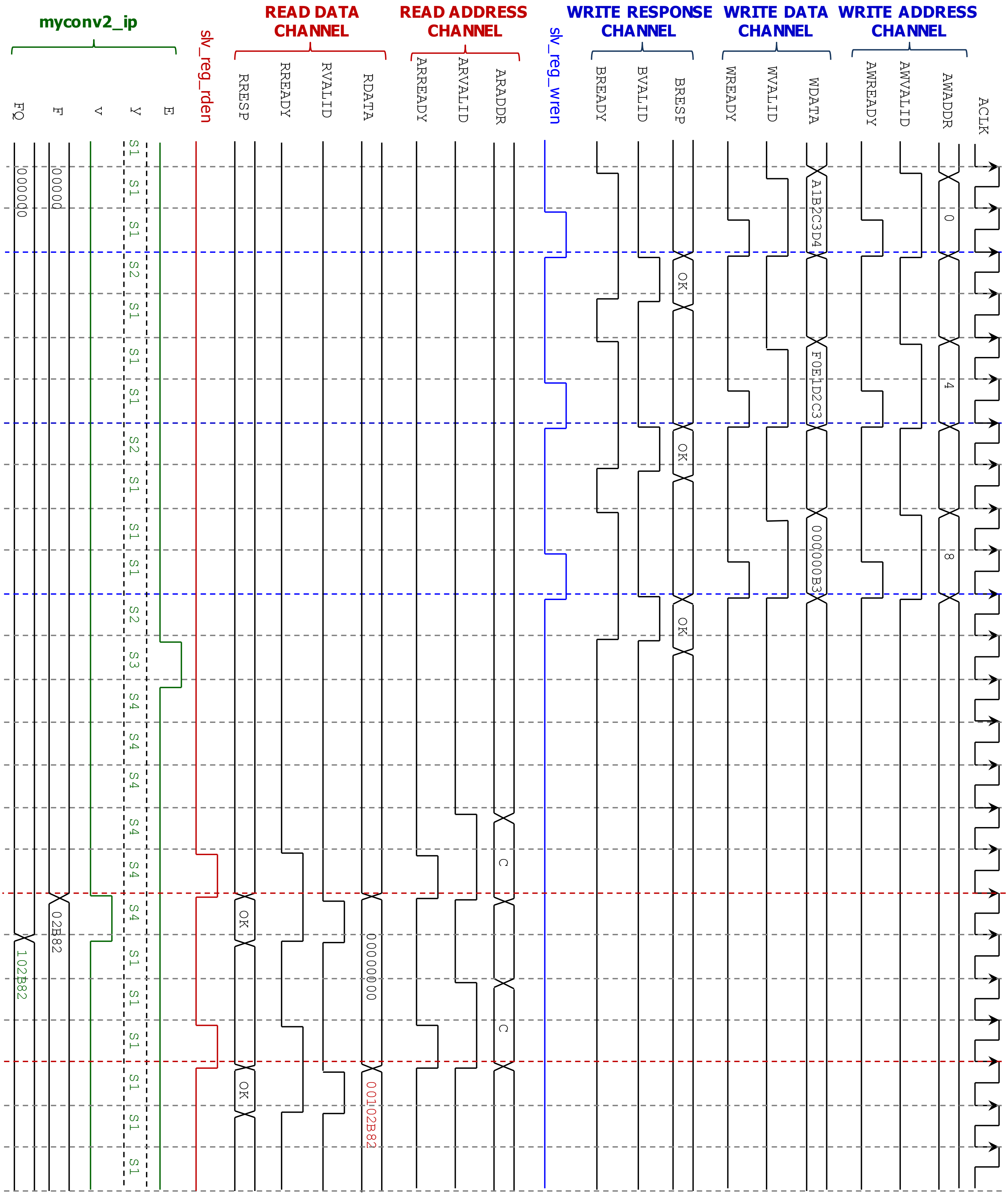
Presentation and clarity are very important! Show your procedure!

PROBLEM 1 (30 PTS)

- AXI4-Lite interface for Pipelined 2D convolution kernel (N=3, B=C=8):
  - ✓ The I/O timing diagram of the pipelined 2D convolutional kernel is shown below.
    - Input data: `0xA1B2C3D4F0E1D2C3B3`. This data is captured when `E` is asserted.
    - Output data: `0x02B82`. It appears after the processing delay (6 clock cycles) with v=1.
  - ✓ Complete the timing diagram for the AXI4-Lite Interface: Given the AXI signals for the 5 Channels, complete the signals associated with the Pipelined 2D Convolution Kernel block (`E, v, y, F, FQ` signals) on the next page.

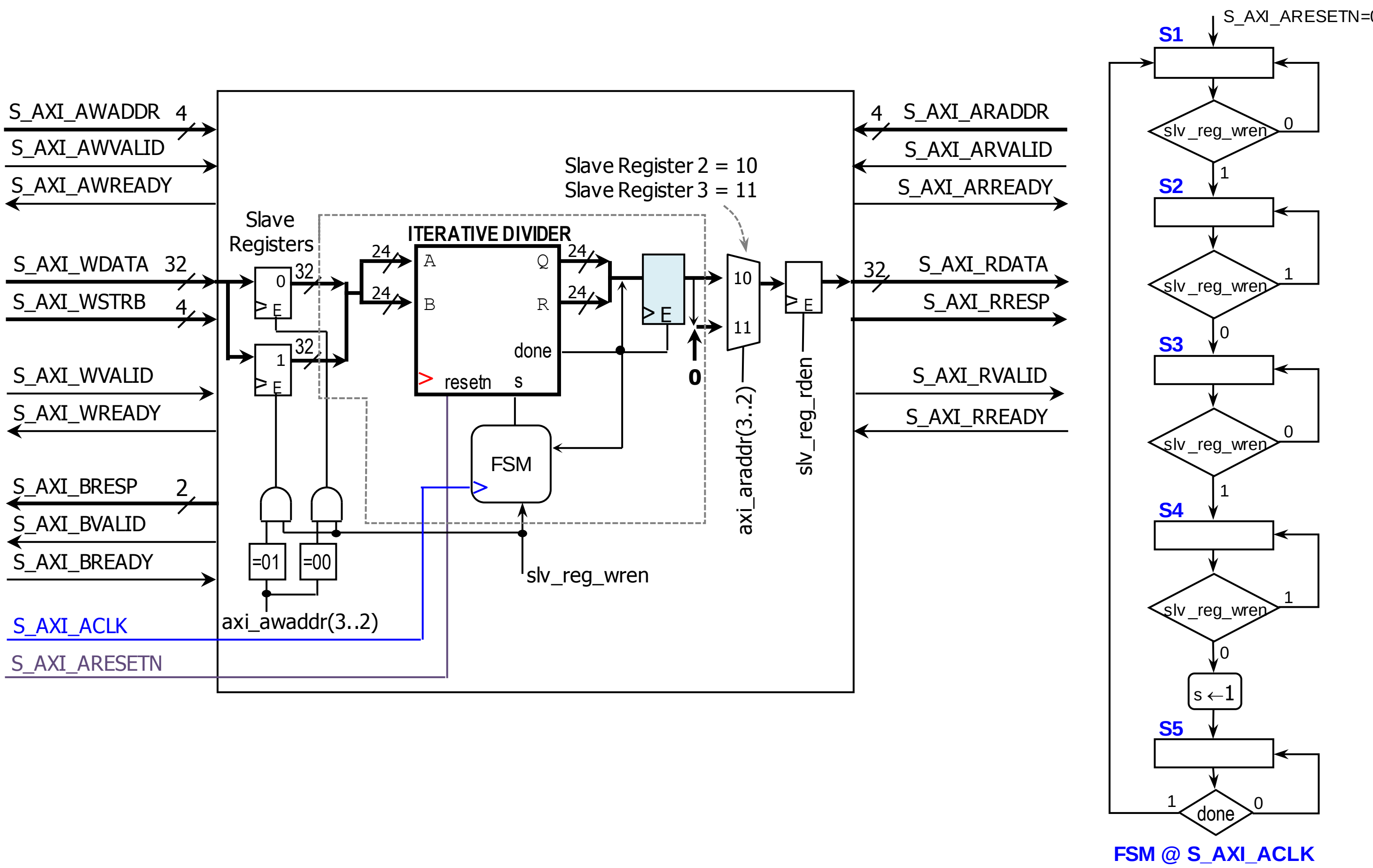





myconv2_ip
READ DATA CHANNEL
READ ADDRESS CHANNEL
WRITE RESPONSE CHANNEL
WRITE DATA CHANNEL
WRITE ADDRESS CHANNEL
FQ
F
v
y
E
slv_reg_rden
RRESP
RREADY
RVALID
RDATA
ARREADY
ARVALID
ARADDR
slv_reg_wren
BREADY
BVALID
BRESP
WREADY
WVALID
WDATA
AWREADY
AWVALID
AWADDR
ACLK
00000
00000
02B82
102B82
S1
S2
S3
S4
OK
00000000
00102B82
C
A1B2C3D4
F0E1D2C3
000000B3
0
4
8

PROBLEM 2 (35 PTS)

- AXI4-Lite interface for Iterative Divider (N=24, M=24):
  - ✓ Sketch the AXI4-Lite Interface. This includes the Slave Registers, their control signals, as well as the extra glue logic (registers, FSM, etc.) to connect the Iterative Divider to the Slave Register signals.
    - ▫ Slave Registers: Use as many as you need, indicating their number. The latched addresses depicted (axi_awaddr[3..2], axi_araddr[3..2]) support up to 4 registers. If for example, you need more registers (say up to 8), you would need axi_awaddr[4..2], axi_araddr[4..2].
    - ▫ The start signal s should not be generated via software, rather it should be issued by an FSM once the input data has been received. Sketch the FSM as well.



PROBLEM 3 (35 PTS)

- Calculate the result of the following operations. The operands are signed (2C) fixed-point numbers. The result must be a signed fixed-point number. For the division, use x=5 fractional bits.

1.101001 + 1.0001	1001.1101 - 1.010101	0.01001 + 01.11011
0.10011 × 10.101	1.011 × 1.0011	01.01110 ÷ 1.011

```
c8=1 c7=1 c6=0 c5=0 c4=0 c3=0 c2=0 c1=0 c0=0
  1 1.1 0 1 0 0 1 +
  1 1.0 0 0 1 0 0
  ---------------
  1 0.1 0 1 1 0 1
```

```
1 0 0 1.1 1 0 1 0 0 -        c10=0 c9=0 c8=0 c7=1 c6=1 c5=0 c4=0 c3=0 c2=0 c1=0 c0=0
1 1 1 1.0 1 0 1 0 1    ➡      1 0 0 1.1 1 0 1 0 0 +
                              0 0 0 0.1 0 1 0 1 1
                              -------------------
                              1 0 1 0.0 1 1 1 1 1
```

```
c8=0 c7=0 c6=1 c5=1 c4=1 c3=0 c2=1 c1=1 c0=0
  0 0 0.0 1 0 0 1 +
  0 0 1.1 1 0 1 1
  ---------------
  0 1 0.0 0 1 0 0
```

```
0.10011 x  ➡  0.10011 x  ➡      1 0 0 1 1 x
10.101        01.011              1 0 1 1
                                ---------
                                1 0 0 1 1
                              1 0 0 1 1
                            0 0 0 0 0
                          1 0 0 1 1
                        -----------------
                        0 1 1 0 1 0 0 0 1
                                ⬇
                        0.1 1 0 1 0 0 0 1
                                ⬇
                        1.0 0 1 0 1 1 1 1
```

```
1.011 x   ➡  0.101 x  ➡        1 1 0 1 x
1.0011       0.1101              1 0 1
                               ---------
                               1 1 0 1
                             0 0 0 0
                           1 1 0 1
                         ---------------
                         0 1 0 0 0 0 0 1
                               ⬇
                         0.1 0 0 0 0 0 1
```

✓ $\frac{01.0111}{1.011}$: To unsigned (denominator) and then alignment, $a = 4$: $\frac{01.0111}{0.101} = \frac{01.0111}{00.1010} = \frac{010111}{001010} \equiv \frac{10111}{1010}$

```
       0001001001
      -----------
1010 ) 1011100000
       1010
       ----
          1100
          1010
          ----
           10000
            1010
            ----
             110
```

Append $x = 5$ zeros: $\frac{1011100000}{1010}$

Integer Division:

$Q = 1001001$, $R = 110$

$\rightarrow Qf = 10.01001$ $(x = 5)$

Final result (2C): $\frac{01.01110}{1.011} = 2C(010.01001) = 101.10111$

- Represent these numbers in Fixed Point Arithmetic (signed numbers). Use the FX format [16 8]. (5 pts)

✓ `-32.1875:`
`32.1875 = 0100000.0011 → -32.1875 = 1011111.1101 = 11011111.11010000 = 0xDF.D0`

✓ `123.3125:`
`123.3125 = 01111011.0101 = 01111011.01010000 = 0x7B.50`