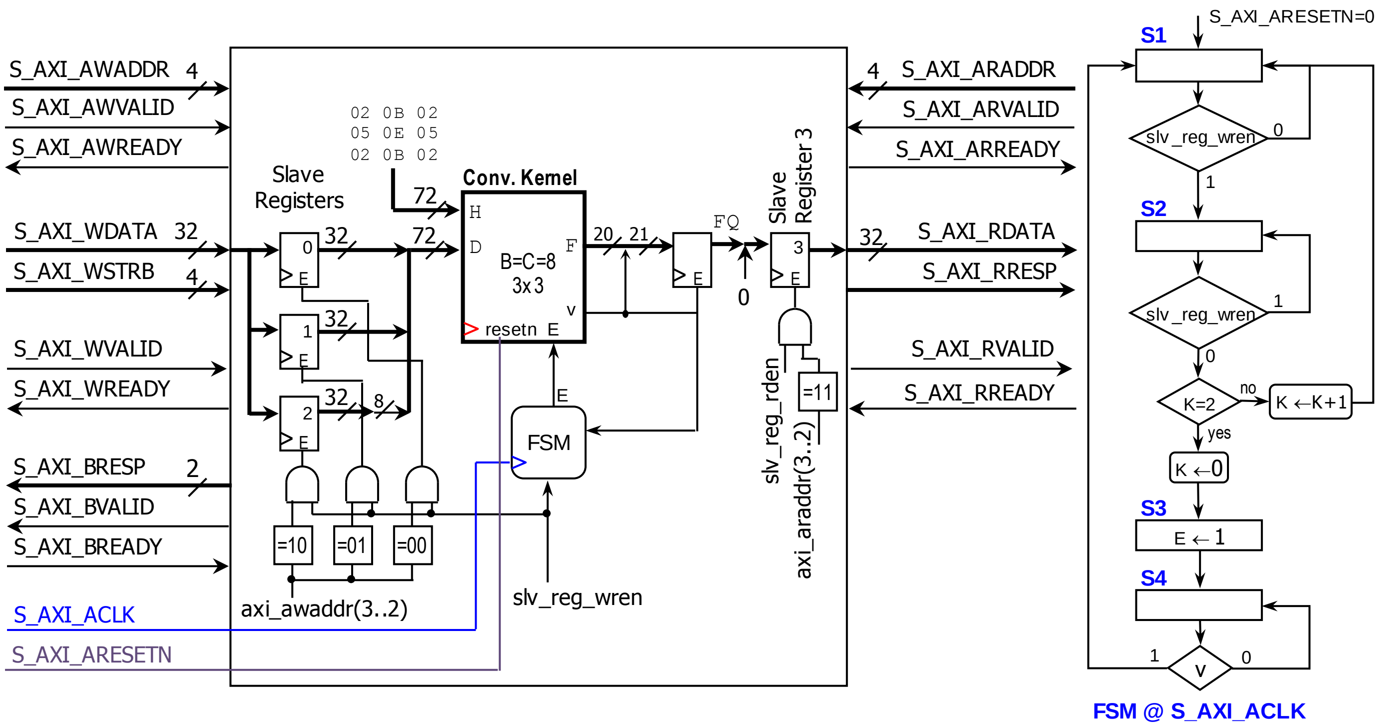
Solutions - Homework 2

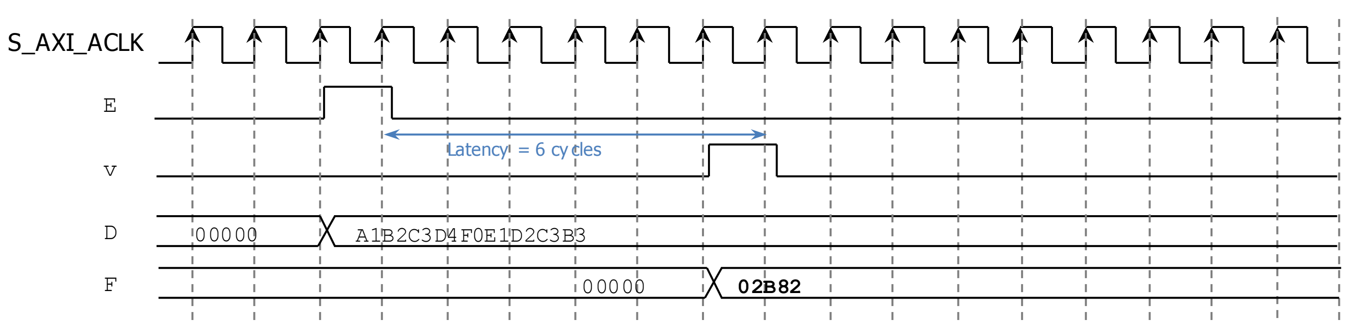
(Due date: May 25th)

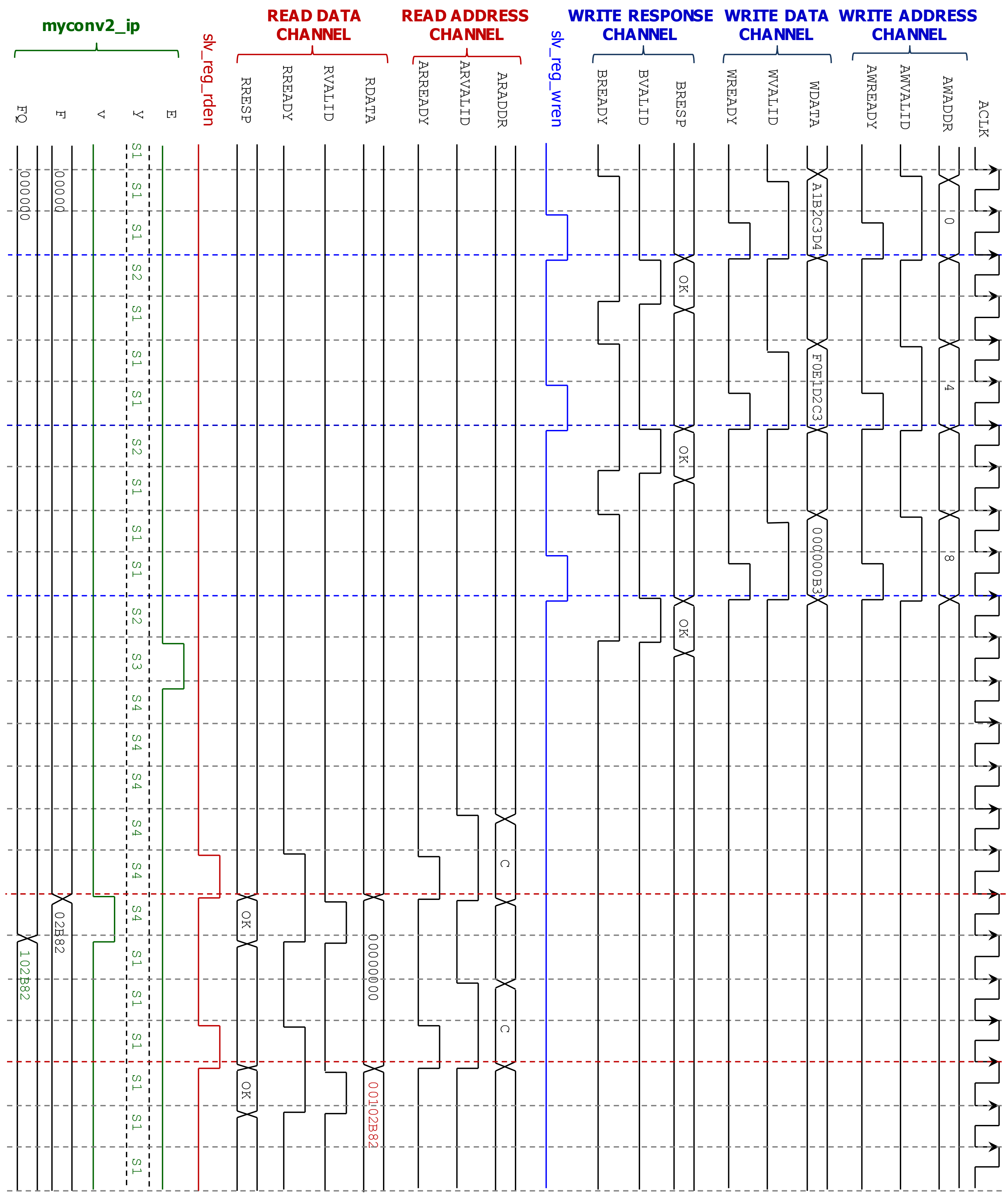
Presentation and clarity are very important! Show your procedure!

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.

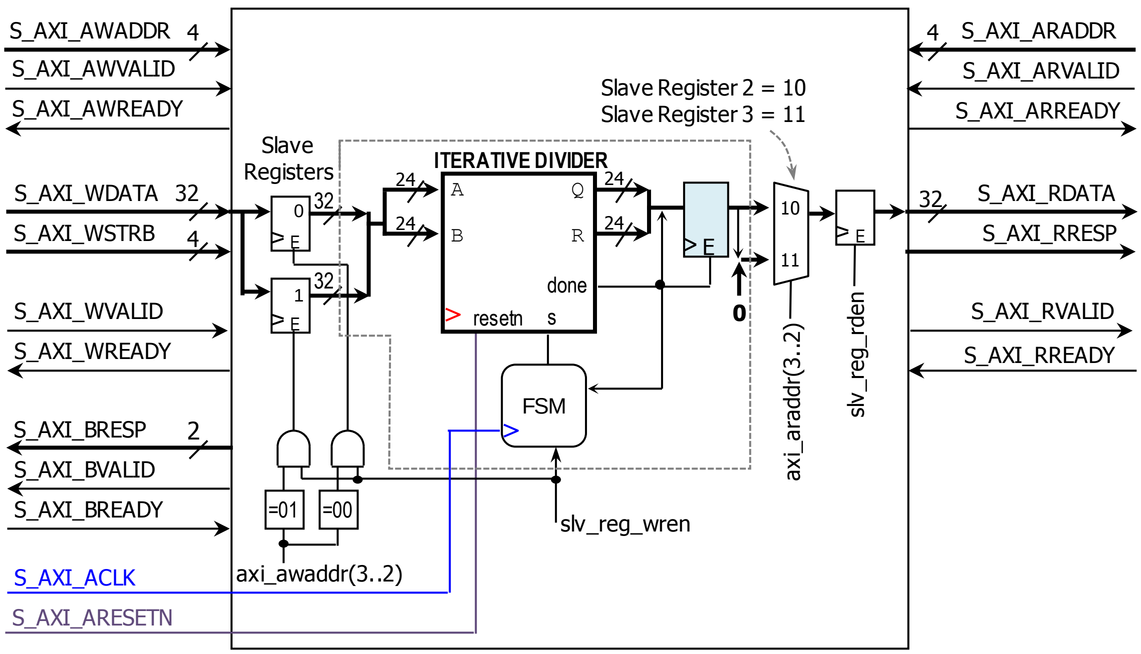


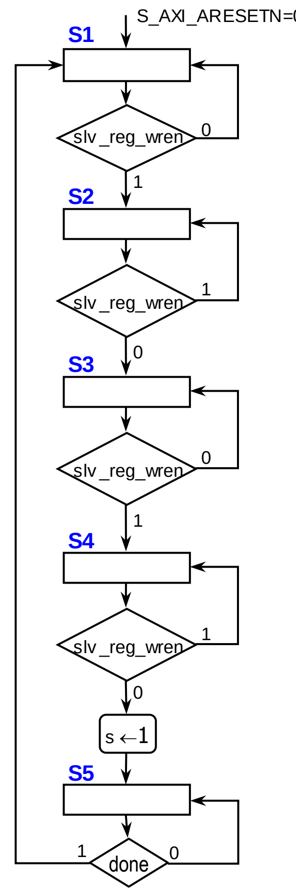



myconv2_ip
READ DATA CHANNEL
READ ADDRESS CHANNEL
WRITE RESPONSE CHANNEL
WRITE DATA CHANNEL
WRITE ADDRESS CHANNEL
FQ
F
v
y
E
slv_reg_rden
RRESP
RREADY
RVALID
RDATA
ARREADY
ARVALID
ARADDR
slv_reg_wren
BREADY
BVALID
BRESP
WREADY
WVALID
WDATA
AWREADY
AWVALID
AWADDR
ACLK
000000
00000
S1
S2
S3
S4
OK
C
0
4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

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.





FSM @ S_AXI_ACLK

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

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

```
 1 1.1 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 -
1 1 1 1.0 1 0 1 0 1
```

$c_{10}=0$ $c_9=0$ $c_8=0$ $c_7=1$ $c_6=1$ $c_5=0$ $c_4=0$ $c_3=0$ $c_2=0$ $c_1=0$ $c_0=0$

```
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
```

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

```
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: $\frac{10111\mathbf{00000}}{1010}$

Integer Division:

$\mathrm{Q} = 1001001,\ \mathrm{R} = 110$

$\rightarrow \mathrm{Qf} = 10.01001\ (x = 5)$

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