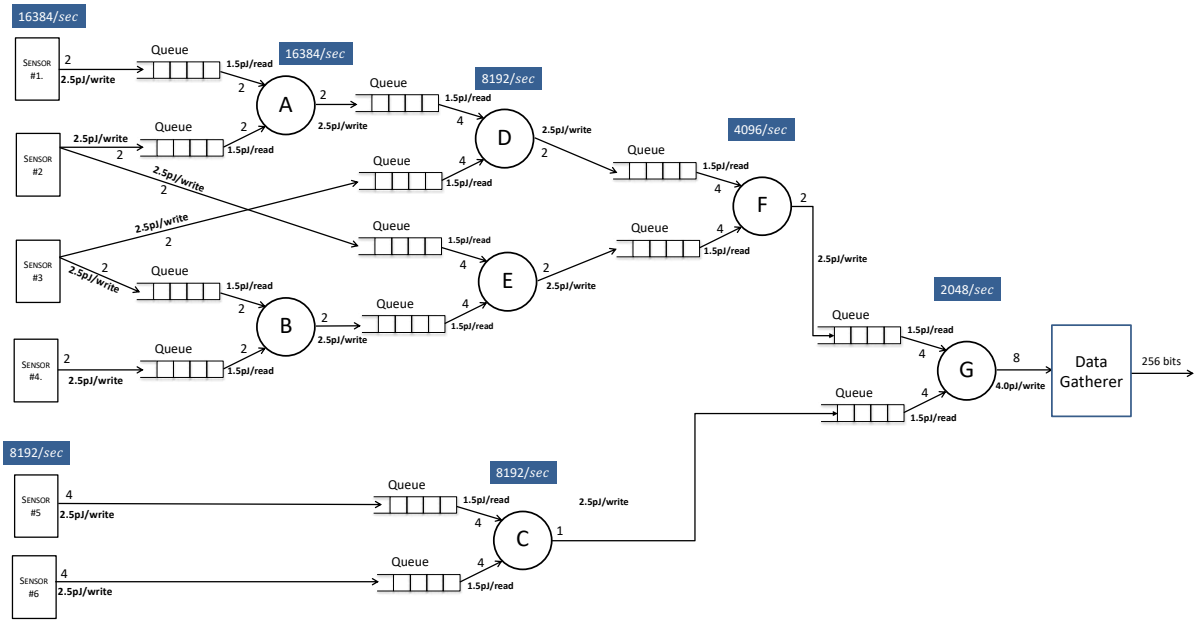
Problem 1. SDF Power Analysis

The following circuit executes a spectral imaging sensor fusing algorithm. The display image is 128 x 128 16-bit pixels. The display rate is 32 frames/second. There are six sensors and seven SDF processing elements. Each token is two-bytes wide. Node-G produce 8 tokens each operation.

Energy consumption:

A single write operation to a queue consumes: 2.50 pJ/write
A single read operation from a queue consumes: 1.50pJ/read
Sensor evaluation: 45.0 pJ/Token
Nodes A, B, C each consume: 2.0 pJ/clock and require 1000 clocks to complete the "Firing"
Nodes D, E each consume: 3.0 pJ/clock and require 2000 clocks to complete the "Firing"
Nodes F each consume 3.5 pJ/clock and require 3000 clocks to complete the "Firing"
Node G consumes 4.0 pJ/clock and require 4000 clocks to complete the "Firing"
A single token-write to the Data Gathering Unit consumes 4.0 pJ/Op
A single 256-bit write from the Data Gathering Unit to the Dual-Port memory 2.56nJ



QUESTIONS:

(15 pts) What is the periodic schedule for the SDF network (exclude the data gatherer) ?

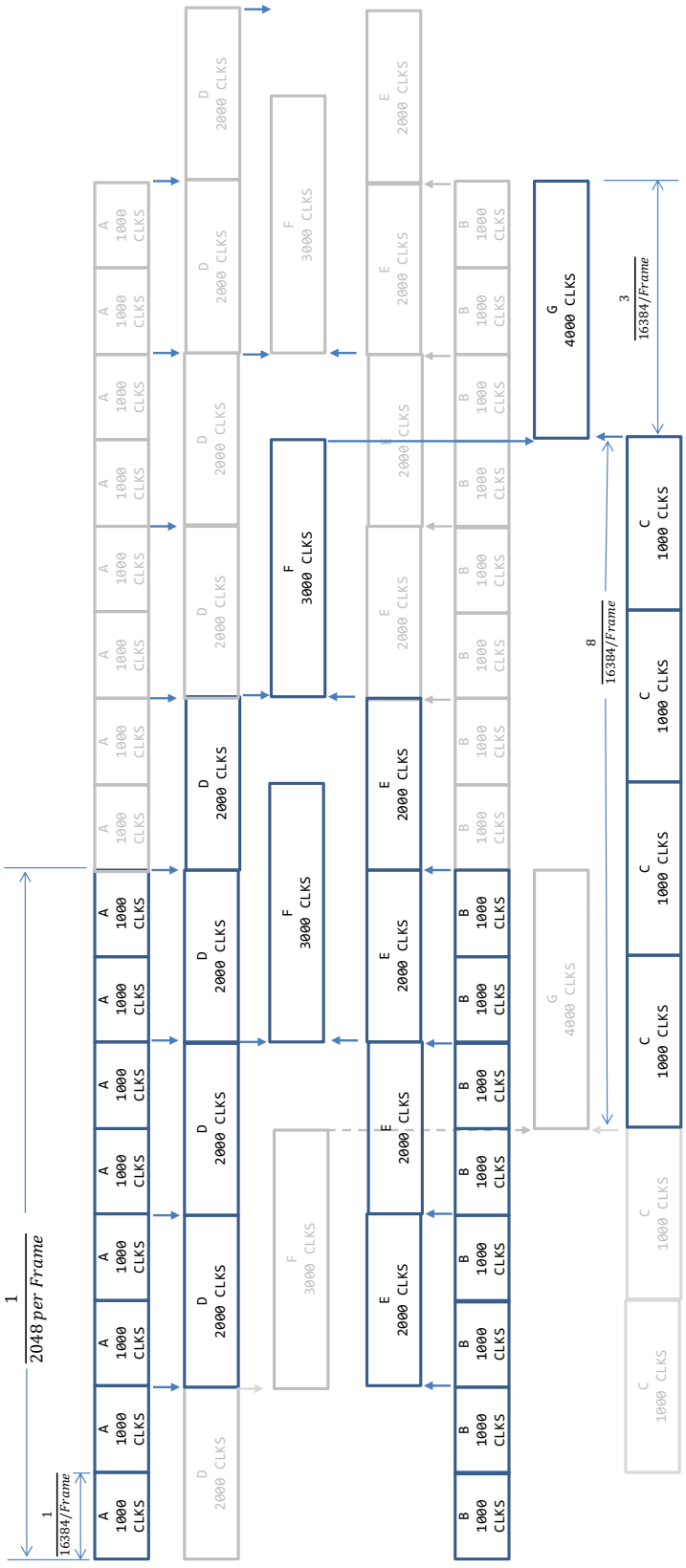
AADAADFAADAADF
BBEBBEFBBEBBEF → G
CCCC

(4((2A)D))(4((2B)E))(2F)(4C)G
8(AB)4(DE)(2F)(4C)G or (4C)(8(AB)4(DE)(2F))G

(5 pts) How many bytes of data are generated each second by Node-G?

Frame = 128 X 128 * 2 bytes * 32 = 1,048,576 bytes/sec
Each firing of G produces 16 bytes therefore it requires 2048 firings per frame

(15 pts) Draw the timing schedule of operations for the slowest frequency that the processors in the SDF can run at.



(5 pts) Wh ıcy of each proc ıing schedule in

A =	524.2 MHz	B =	524.2 MHz	C=	262.1 MHz
D =	524.2 MHz	E =	524.2 MHz	F =	393.2 MHz
G =	262.1 MHz				

(15 pts) Calculate the amount of energy consumed per frame?

A single write operation to a queue consumes: 2.50 pJ/write
A single read operation from a queue consumes: 1.50pJ/read
Sensor evaluation: 45.0 pJ/Token
Nodes A, B, C each consume: 2.0 pJ/clock and require 1000 clocks to complete the "Firing"
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Node G consumes 4.0 pJ/clock and require 4000 clocks to complete the "Firing"
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A single 256-bit write from the Data Gathering Unit to the Dual-Port memory 2.56nJ

Sensors 1 & 4			
OP	2	45	90.00
Writes	2	2.5	5.00
		SUM	95.00
16,384 Firings			

Sensors 2 & 3			
OP	4	45	180.00
Writes	4	2.5	10.00
		SUM	190.00
16,384 Firings			

Sensors 5 & 6			
OP	2	45	90.00
Writes	4	2.5	10.00
		SUM	100.00
8,192 Firings			

One NODE A Firing			
OP	1	2000	2000.00
Reads	4	1.5	6.00
Write	2	2.5	5.00
			2011.00

One NODE B Firing			
OP	1	2000	2000.00
Reads	4	1.5	6.00
Write	2	2.5	5.00
			2011.00

One NODE C Firing			
OP	1	2000	2000.00
Reads	8	1.5	12.00
Write	1	2.5	2.50
			2014.50

One NODE D Firing			
OP	1	6000	6000.00
Reads	8	1.5	12.00
Write	2	2.5	5.00
			6017.00

One NODE E Firing			
OP	1	6000	6000.00
Reads	8	1.5	12.00
Write	2	2.5	5.00
			6017.00

One NODE F Firing			
OP	1	10500	10500.00
Reads	8	1.5	12.00
Write	2	2.5	5.00
			10517.00

One NODE G Firing			
OP	1	16000	16000.00
Reads	8	1.5	12.00
Write	8	4	32.00
			16044.00

Data Gatherer			
Write	1	2560	2560.00
			2560.00

Energy per Frame			
	Number of Firings	Energy per	Total Energy (pJ)
Sensor 1	16384	95.00	1,556,480
Sensor 2	16384	190.00	3,112,960
Sensor 3	16384	190.00	3,112,960
Sensor 4	16384	95.00	1,556,480
Sensor 5	8192	100.00	819,200
Sensor 6	8192	100.00	819,200
Node A	16384	2011.00	32,948,224
Node B	16384	2011.00	32,948,224
Node C	8192	2014.50	16,502,784
Node D	8192	6017.00	49,291,264
Node E	8192	6017.00	49,291,264
Node F	4096	10517.00	43,077,632
Node G	2048	16044.00	32,858,112
Data Gatherer	1024	2560.00	2,621,440
			270,516,224

	# CLKS	pJ/CLK	Total Energy
Node A	1000	2	2000
Node B	1000	2	2000
Node D	2000	3	6000
Node E	2000	3	6000
Node C	1000	2	2000
Node F	3000	3.5	10500
Node G	4000	4	16000

(10 pts) You are given a NiMH battery (1.2V) with 2550 mA-hour capacity which translates to 127.5 ma for 20 hours. NOTE: 3600 Joule = 1 WATT-HOURS. How long will the battery provide energy for this system?

The SDF system consumes 270.5µJ

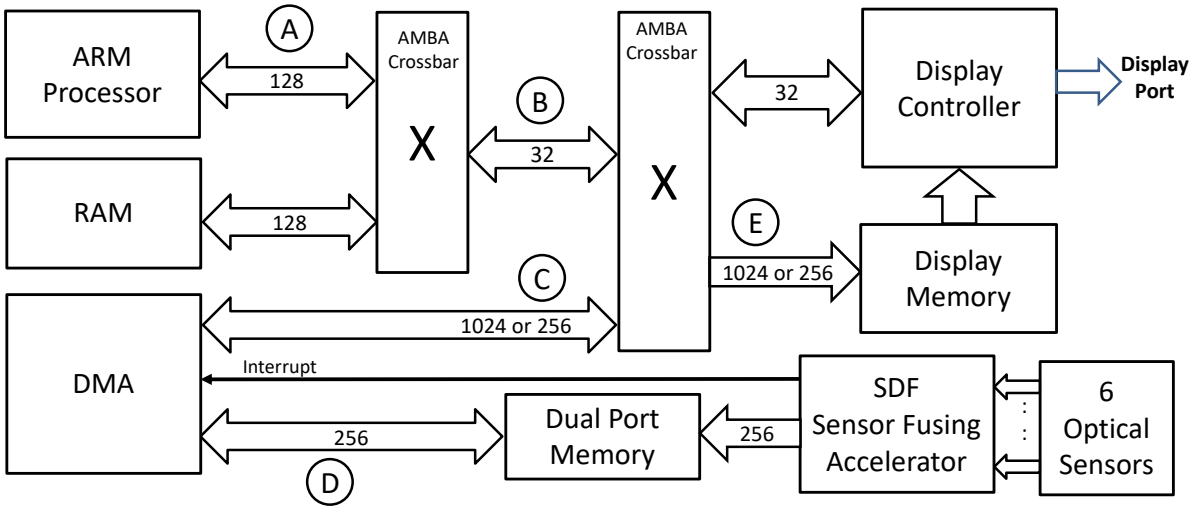
The NiMH battery can provide 1.2V x 2.55A-Hour x 3600 = 11,016 Joules

Total number of frames that can be displayed are: 11,016J / 270.5e-6J = 40.72 million frames

At 32 frames per second, we get 40.72e+6/32 = 1.27 million seconds which is ~353.5 hours or 14.72 days

Problem 2. System Performance Optimization (20 Points)

In this problem you will determine the optimal width of the data busses indicated by A, B, C, D, and E in the system block diagram below. The data busses that have a number indicate the fixed width of the that data bus, e.g., the RAM is 128 bits wide. The max width of any non-fixed-width data bus is 1024 bits.



The SDF Sensor Fusing Accelerator (from question #1) produces frame data for the Display Controller by fusing data from 6 optical sensors. The frame data is buffered in a dual-port memory. When the fusing is complete for each frame, an interrupt is sent to the DMA Unit. The DMA transfers the frame data to the Display Memory at a frame rate that is determined by the SDF Sensor Fusing Accelerator. The processor executes code from the RAM. The RAM is initially loaded with code from the SD Memory and the Display Controller is initialized by the ARM processor before the display operations begin.

What is the optimal width each bus? Explain why.

Bus A: Match the width of the RAM bus

Bus B: Only need 32 bits wide for control registers in the Display controller. The CPU does not write to the Display Memory

Bus C: Optimize for 256-bit wide streaming (if possible), otherwise go for performance

Bus D: Match the DP Memory

Bus E: Optimize for 256-bit wide streaming (if possible), otherwise go for performance

Problem 3. True or False (15pts)

Statement:	**T/F**
Linux drivers are event-driven and registered with the kernel for call-backs.	T
The first stage boot loader (FSBL) loads the DTC into memory during boot up. The DTC tells the operating system where all hardware components in the system are located.	F
Kernel modules are limited to user-space only	F
The AXI bus supports AXI4, AXI4-Streaming, AXI-Lite, APB and AHB protocols	F
A signal is an asynchronous notification sent to a process or to a specific thread within the same process to notify it of an event that occurred.	T
The primary cause of Flash Memory (SD-Card) wear out are cosmic rays and/or alpha particles.	F
A blocking interface is the preferred mechanism for a software client to interface with a driver in terms of program flow control	F
The OCM is located in the FPD and is used by the FSBL during bootup	F
Precision and resolution are critical for repeatability	F
The PROC file system is created right at the end of bootup by the 'systemd' process (PID = 1)	F
A signaling race condition in the kernel can fixed by synchronizing the offending signal.	T
In the last 15 years, improvements in battery technology is now approaching the same growth rate as Moore's Law predicted for Integrated Circuits.	F
RAMDISKS provide a mechanism for Linux to emulate a hard disk using non-volatile memory	F
The ARM processor family supports little-endian and big-endian data along with the ability to write to IO ports with special instructions to improve performance	F
Linux categorizes drivers by classes, which become Linux devices when implemented	T