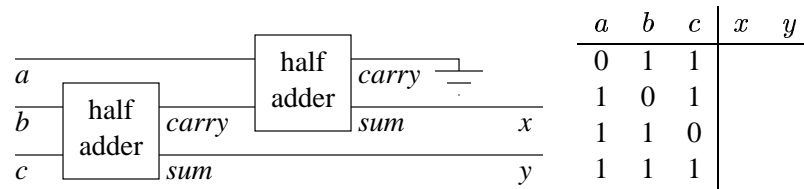


Question 4.1–1: (Solution, p 4) Draw two truth tables illustrating the outputs of a half-adder, one table for the *sum* output and the other for the *carry* output.

Question 4.1–2: (Solution, p 4) Fill in the truth table at right for the following circuit. Ignore rows not included in the table.

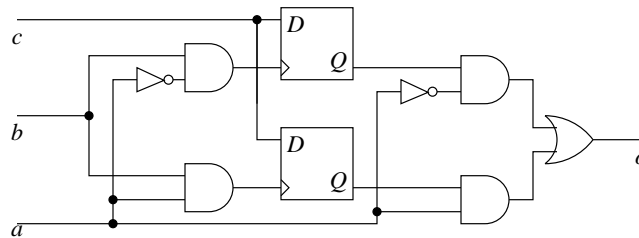


Question 4.1–3: (Solution, p 4) What distinguishes the meanings of a half adder’s inputs and outputs from a full-adder’s?

Question 4.1–4: (Solution, p 4) Using only four-bit adders, construct an eight-bit adder. Each four-bit adder has two four-bit inputs and one five-bit output. Your eight-bit adder should have two eight-bit inputs and a one eight-bit output (don’t worry about the ninth output bit).

Question 4.2–1: (Solution, p 4) How is a D flip-flop’s behavior different from a D latch’s behavior?

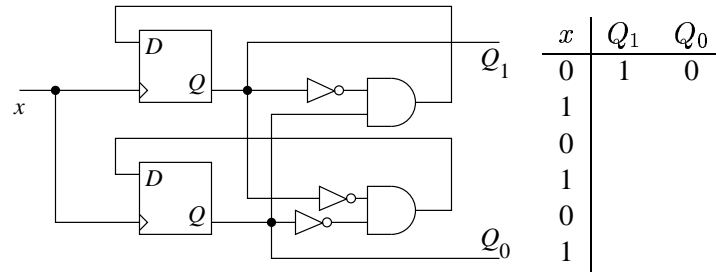
Question 4.2–2: (Solution, p 4) The below circuit at left includes two D flip-flops. Recall that a D flip-flop’s stored state remains unchanged as long as *set* = 0. At the instant that *set* switches to 1, its stored bit switches to *value*, and it retains this value until *set* changes to 1 again.



Say a user enters the sequence of inputs given in the table at right, one after the other. Label what the output of the circuit will settle into after each of the user’s inputs.

<i>a</i>	<i>b</i>	<i>c</i>	<i>o</i>
1	1	1	?
0	1	1	?
0	0	1	?
0	0	0	?
0	1	0	?
0	0	0	?
1	0	0	?

Question 4.2–3: (Solution, p 4) Suppose the upper D flip-flop in the below circuit were holding 1 and the lower D flip-flop held 0, while the *x* input were 0. Then somebody toggles the *x* input five times (to 1, then 0, then 1, then 0, then 1). Complete the table to show how the output values would change.



Question 5.1–1: (Solution, p 5) Define the fetch-execute cycle as it relates to a computer processing a program. Your definition should describe the primary purpose of each phase.

Question 5.1–2: (Solution, p 5) Explain in detail what HYMN does during the fetch phase of the fetch-execute cycle.

Question 5.1–3: (Solution, p 5) Translate each of the following HYMN instructions into machine code. Express your answers in binary.

- a. HALT
- b. ADD 14₍₁₆₎
- c. LOAD 12₍₁₆₎
- d. JUMP 03₍₁₆₎

Question 5.1–4: (Solution, p 5) Suppose our computer starts with the following in memory.

addr	data	translation
00000	100 00100	LOAD 00100
00001	110 00101	ADD 00101
00010	111 00100	SUB 00100
00011	101 00111	STORE 00111
00100	000 00101	HALT
00101	000 00110	HALT

a. Show the hexadecimal values taken on by the registers as this program executes. (Stop once the computer executes a HALT instruction.)

IR
PC
AC

b. What memory locations, if any, change? What values are stored in these locations?

Question 5.2–1: (Solution, p 5) Suppose we were to start the computer with the following in memory.

addr	data	translation
00000	100 11110	LOAD 11110
00001	101 11111	STORE 11111
00010	110 11110	ADD 11110
00011	101 11111	STORE 11111
00100	110 11110	ADD 11110
00101	101 11111	STORE 11111
00111	000 00000	HALT

If the user typed multiples of 25 starting at 25 (25, then 50, then 75,...) when prompted, what would the computer display?

Question 5.2–2: (Solution, p 5) Suppose we were to start the computer with the following in memory.

addr	data	translation
00000	100 11110	LOAD 11110
00001	110 11110	ADD 11110
00010	010 00001	JPOS 00001
00011	000 00000	HALT

If we repeatedly type the number $32_{(10)}$ when prompted, how many times would we type it before the computer halts?

Question 5.2–3: (Solution, p 5) What should we place into the computer's memory so that, when started, the computer displays the powers of two from $1_{(10)}$ to $64_{(10)}$ before halting?

Solution 4.1–1: (Question, p 1)

x	y	sum
0	0	0
0	1	1
1	0	1
1	1	0

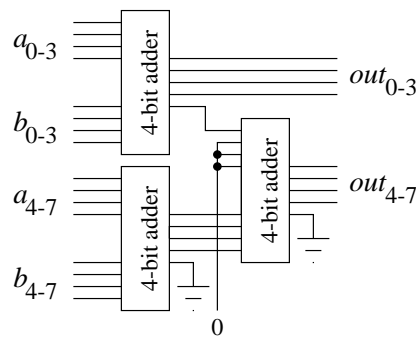
x	y	$carry$
0	0	0
0	1	0
1	0	0
1	1	1

Solution 4.1–2: (Question, p 1)

a	b	c	x	y
0	1	1	1	0
1	0	1	1	1
1	1	0	1	1
1	1	1	0	0

Solution 4.1–3: (Question, p 1) A half adder has two inputs and outputs the sum of these two bits, while a full adder has three inputs and outputs the sum of these three bits.

Solution 4.1–4: (Question, p 1) The design of this circuit is similar in structure to the design of a full adder using half adders.



Solution 4.2–1: (Question, p 1) In a D flip-flop, the memory value changes only at that instant that the *clock* input becomes 1. In a latch, however, the memory value continues adopting any values given as long as its *set* input is 1. (In a D flip-flop, if the *D* input changes while *clock* remains 1, the remembered value doesn't change. In a latch, however, the *D* input changing while *set* is 1 results in a change to the remembered value.)

Solution 4.2–2: (Question, p 1)

a	b	c	o
1	1	1	1
0	1	1	1
0	0	1	1
0	0	0	1
0	1	0	0
0	0	0	0
1	0	0	1

Solution 4.2–3: (Question, p 1)

x	Q_1	Q_0
0	1	0
1	0	0
0	0	0
1	0	1
0	0	1
1	1	0

Solution 5.1–1: (Question, p 2) The fetch-execute cycle is the process by which a classical computer executes instructions. In the fetch phase, the computer determines the next instruction to be completed by fetching the instruction from memory. In the execute phase, the computer executes this instruction.

Solution 5.1–2: (Question, p 2) It loads from memory from the address contained in the PC, storing the data found there into the IR.

Solution 5.1–3: (Question, p 2)

- a. 000 00000
- b. 110 10100
- c. 100 10010
- d. 001 00011

Solution 5.1–4: (Question, p 2)

- a. IR 84 C5 E4 A5 00
PC 00 01 02 03 04
AC 05 0B 06
- b. Memory location $00111_{(2)}$ changes to hold $06_{(16)}$.

Solution 5.2–1: (Question, p 2)

- ? 25
- 25
- ? 50
- 75
- ? 75
- 106

(This last output is somewhat tricky: In the last ADD instruction, the CPU computes $75 + 75 = 150$, but this exceeds the maximum eight-bit two's-complement number. So the computer wraps around and ends up at $150 - 256 = -106$.)

Solution 5.2–2: (Question, p 3) It would read from the user four times before halting (with the AC progressing from 32 to 64 to 96 to -128).

Solution 5.2–3: (Question, p 3) Here is one possible solution. (Of course there are others.)

addr	data	translation
00000	100 00110	LOAD 00110
00001	101 11111	STOR 11111
00010	101 00111	STOR 00111
00011	110 00111	ADD 00111
00100	010 00001	JPOS 00001
00101	000 00000	HALT
00110	000 00001	1