*Always show all work for full credit.*

|  |  |  |
| --- | --- | --- |
| **Binary** | **Decimal** | **Hex** |
| 1110100 |  |  |
|  |  | 0x1CA |
|  | 268 |  |

* 1. Review: Fill in the missing values in the following table (all values are unsigned)
	2. Write a Boolean equation in sum-of-products canonical form for:

|  |  |  |  |
| --- | --- | --- | --- |
| A | B | C | Y |
| 0 | 0 | 0 | 1 |
| 0 | 0 | 1 | 1 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 1 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 |

* 1. Write a Boolean equation in sum-of-products canonical form for:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| A | B | C | D | Y |
| 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 0 |
| 0 | 0 | 1 | 1 | 0 |
| 0 | 1 | 0 | 0 | 1 |
| 0 | 1 | 0 | 1 | 0 |
| 0 | 1 | 1 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 |
| 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 1 |
| 1 | 1 | 0 | 1 | 1 |
| 1 | 1 | 1 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 |

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| 0 | 0 | 1 | 1 |
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| 0 | 1 | 1 | 1 |
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| 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 0 |

* 1. Implement the below with only NAND gates (it’s the same function in 5). Sketch the circuit or use JLS to create the circuit diagram:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| A | B | C | D | Y |
| 0 | 0 | 0 | 0 | 1 |
| 0 | 0 | 0 | 1 | 1 |
| 0 | 0 | 1 | 0 | 1 |
| 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 0 | 0 | 0 |
| 0 | 1 | 0 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 |
| 0 | 1 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 | 1 |
| 1 | 0 | 0 | 1 | 0 |
| 1 | 0 | 1 | 0 | 1 |
| 1 | 0 | 1 | 1 | 0 |
| 1 | 1 | 0 | 0 | 0 |
| 1 | 1 | 0 | 1 | 0 |
| 1 | 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 | 0 |

* 1. Write the Boolean equations for the circuit below (no need to minimize: give the exact equations implemented in the circuit):



**For the next four problems assume the propagation delays are:**

|  |  |
| --- | --- |
| **Gate** | $t\_{pd}$ **(ps)** |
| NOT | 15 |
| 2-input NAND | 20 |
| 3-input NAND  | 30 |
| 4-input NAND | 45 |
| 2-input NOR | 30 |
| 3-input NOR | 45 |
| 2-input AND | 30 |
| 3-input AND | 40 |
| 4-input AND | 50 |
| 2-input OR | 40 |
| 3-input OR  | 55 |
| 4-input OR | 70 |
| 2-input XOR | 60 |

* 1. Determine the propagation delay of:
	
	2. Determine the propagation delay of:
	
	3. Determine the propagation delay of:
	
	4. ERROR: No problem 11 (is/was redundant with 9; Now removed)

12.1 Consider adding 2-digit binary numbers, A and B, to produce the 2-bit result, S, and a carry-out, C:

$$\begin{matrix} &A\_{1}&A\_{0}\\+&B\_{1}&B\_{0}\\C&S\_{1}&S\_{0}\end{matrix}$$

Develop the truth table and sum-of-products equations for adding the two, 2-bit numbers and produce the 3-bits of the result.

12.2 ***Download the JLS starter file from the assignment page*** and complete the circuit. Note that it uses 2-bit inputs for A and B. You test all possible combinations of inputs to confirm your 2-bit adder works correctly.

Hints:

* Think carefully about the structure of the truth table and the terms being used for each output.
* Some product terms can be reused for different outputs.
* JLS has parts called “named wires”. Named wires can be used to organize your work and re-use common terms. Named wires have two parts: the source (“name a wire” is shown when you hover over the named wire part on the menu) and connections (“connect to a named wire”). You can use more than one of the “connect to a named wire” part to have a single wire connect multiple places without having a literal wire (line) running across the diagram. If you use named wires, try to name them with a name that describes their purpose.
* Some wires and parts have already been provided. They are intended to provide one tidy approach to laying out the circuit.
* This circuit uses multi-bit inputs and separates them into their individual bits (A0, A1, etc.) for you. Test signal values can be specified in decimal rather than binary. For example, A can be 0, 1, 2, or 3. When A is 2 its individual bits, A1 and A0, are 1 and 0 respectively. The bits of S are combined into a single, 2-bit output, which doesn’t include C.
* Carefully think about test cases. A signal generator has already been provided.
* ***DO NOT change the names of either input or output ports.*** The Autograder depends on them being named as-is.

13. JLS problem: **See assignment page and use the provided starter file!**