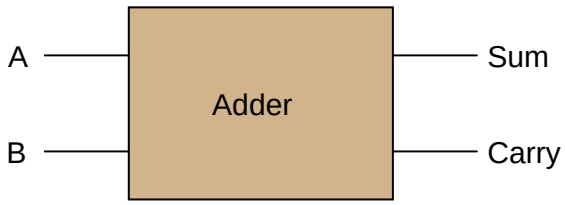

Combinatorial Logic Examples

Questions

Question 1

Design a circuit that adds two binary bits together. This circuit will have two inputs (A and B) and two outputs (Sum and Carry):

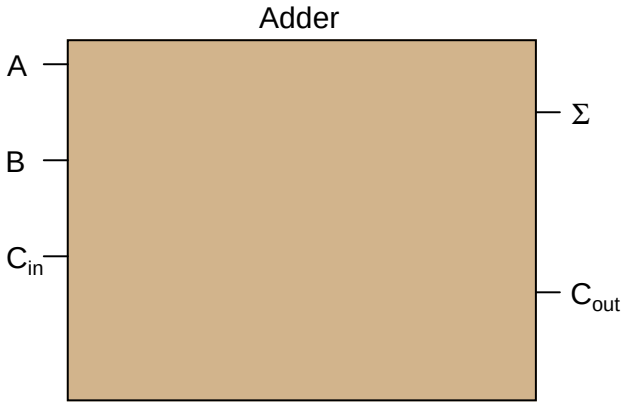


Begin the design process by drawing a truth table for the circuit, then determining the necessary gate circuitry to fulfill each output function.

Why is this circuit referred to as a *half adder*? How would a *full* adder circuit differ from this?
file 01478

Question 2

Design a circuit that adds two binary bits and a "Carry in" (C_{in}) bit together, producing a "Sum" (Σ) and a "Carry out" (C_{out}) output:



Begin the design process by drawing a truth table for the circuit, writing a boolean SOP expression for each output, then determining the necessary gate circuitry to fulfill each output function.
file 01479

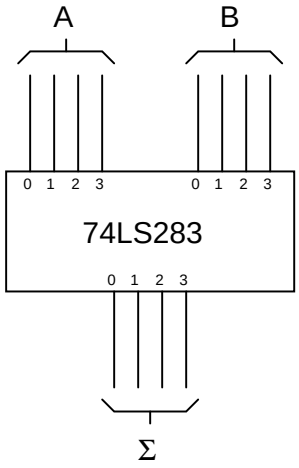
Question 3

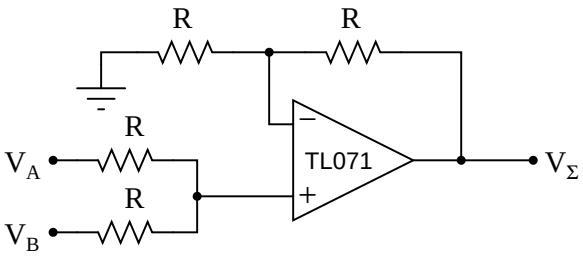
Explain the difference between a *ripple adder* and a *look-ahead* adder. What does the term "ripple" mean in this context? Why is "ripple" potentially a bad thing for a digital adder circuit?

file 02846

Question 4

Compare the following two circuits, the first one being a digital adder and the second one being an analog summer:





These two circuits perform the same mathematical function, yet the manners in which they perform this function are quite different. Compare and contrast the digital adder and the analog summer circuits shown here, citing any advantages or disadvantages of each.

file 02849

Question 5

Research the datasheet of an integrated arithmetic logic unit such as the 74AS181, and determine how its various modes of operation (addition, subtraction, comparison) are selected.

file 02845

Question 6

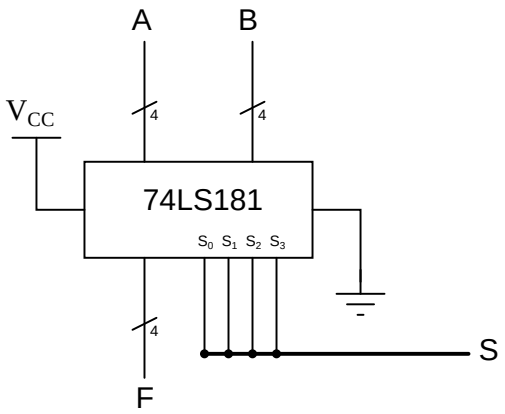
An arithmetic trick often used when working with the metric system is multiplication-by-ten and division-by-ten via shifting of the decimal point. A similar "trick" may be applied to binary numbers, with similar results.

Determine what sort of multiplication or division is accomplished when the "binary point" is shifted in a binary number. Research the datasheet of an arithmetic logic unit (ALU) circuit to see if and how this function is implemented.

file 02850

Question 7

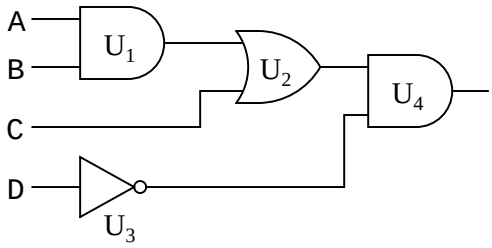
Explain the meaning of the digital lines A, B, F, and S in the following schematic diagram:



file 02848

Question 8

Predict how the operation of this logic gate circuit will be affected as a result of the following faults. Consider each fault independently (i.e. one at a time, no multiple faults):



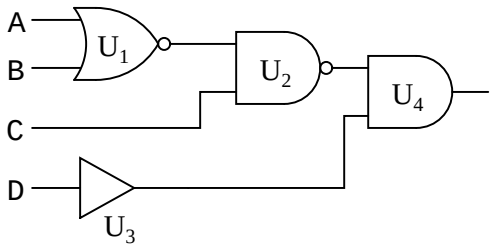
- Output of OR gate U_2 fails low:
- Output of inverter gate U_3 fails low:
- Output of AND gate U_1 fails high:

For each of these conditions, explain *why* the resulting effects will occur.

file 03831

Question 9

Predict how the operation of this logic gate circuit will be affected as a result of the following faults. Consider each fault independently (i.e. one at a time, no multiple faults):

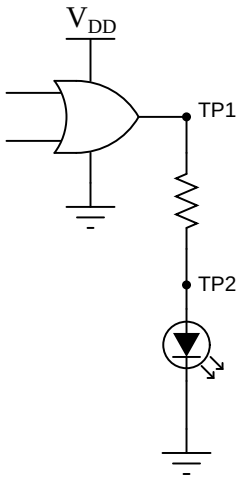


- Output of NAND gate U_2 fails low:
- Output of buffer gate U_3 fails low:
- Output of NOR gate U_1 fails high:

For each of these conditions, explain *why* the resulting effects will occur.
file 03835

Question 10

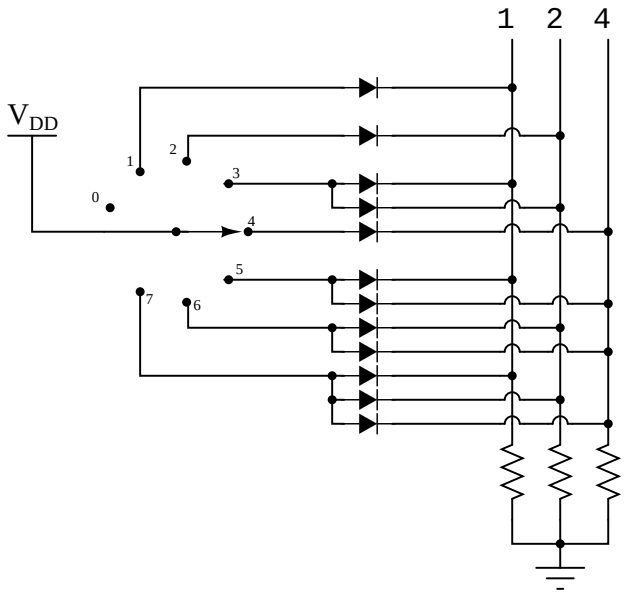
Logic probes are useful tools for troubleshooting digital logic gate circuits, but they certainly have limitations. For instance, in this simple circuit, a logic probe will give correct "high" and "low" readings at test point 1 (TP1), but it will always read "low" (even when the LED is on) at test point 2 (TP2):



Now, obviously the output of the gate is "high" when the LED is on, otherwise it would not receive enough voltage to illuminate. Why then does a logic probe fail to indicate a high logic state at TP2?
file 02866

Question 11

The simple switch-and-diode circuit shown here is an example of a digital *encoder*. Explain what this circuit does, as the switch is moved from position to position:



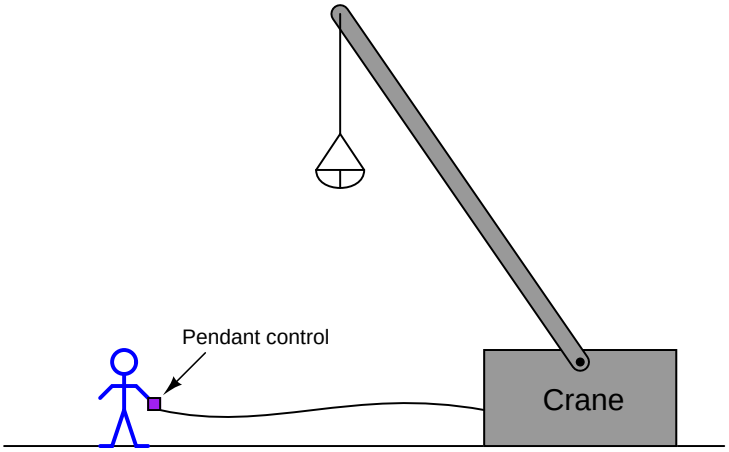
file 01408

Question 12

Suppose a crane has fifteen hydraulic solenoid valves controlling its motion:

- Tilt up (fast)
- Tilt down (fast)
- Tilt up (slow)
- Tilt down (slow)
- Turn left (fast)
- Turn right (fast)
- Turn left (slow)
- Turn right (slow)
- Cable up (fast)
- Cable down (fast)
- Cable up (slow)
- Cable down (slow)
- Bucket open (fast)
- Bucket open (slow)
- Bucket close (slow)

You are part of a team building a remote "pendant" control for this crane with fifteen buttons on it for controlling each of the fifteen solenoid valves. This control pendant connects to the main system by a multiconductor cable, but you really want to limit the number of conductors in this cable to keep it as light-weight as possible:



Draw a simple schematic diagram showing how a digital encoder and decoder circuit pair could be used to relay the same fifteen commands across fewer cable conductors, compared to if we used one conductor per pushbutton switch.

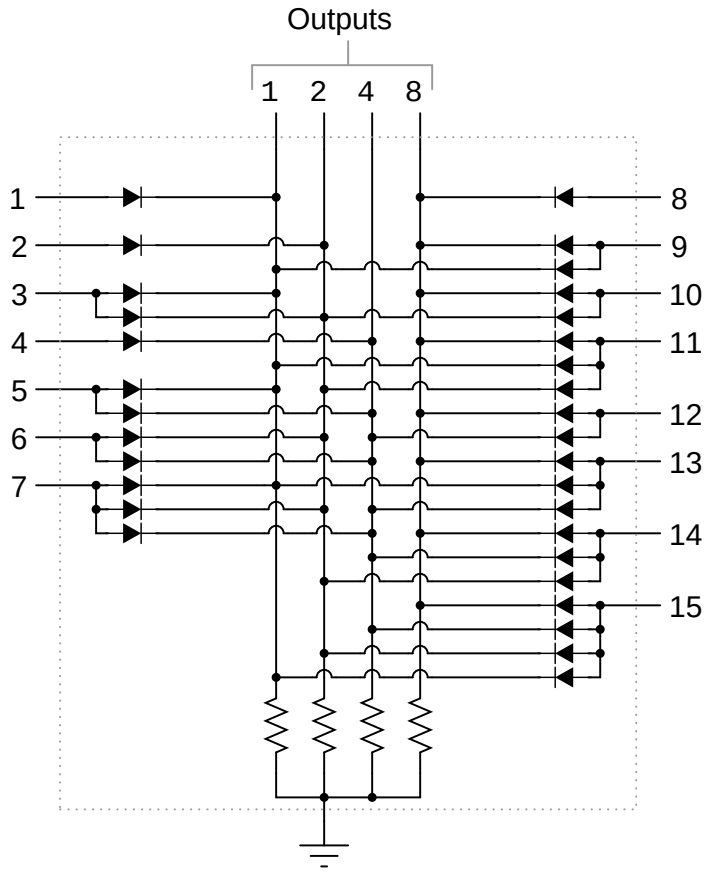
file 01415

Question 13

Having learned how to build simple encoder circuits using diode networks, you set out to form your own encoder manufacturing company: *Encoders, Inc.* After agreeing on a policy of truth in advertising, your board of directors drafts this slogan:

"Our encoder circuits are more reliable because there's less to break."

After months of hard work, you unveil your latest masterpiece, the 16-line to 4-line encoder:



However, your first customer has a complaint with your encoder circuit. He claims it often outputs false codes. After sending it back to your workshop for warranty repair, you determine there is nothing wrong with the encoder circuit itself: it always outputs the correct codes when you energize the appropriate inputs. Perhaps the problem is in how the customer is using it.

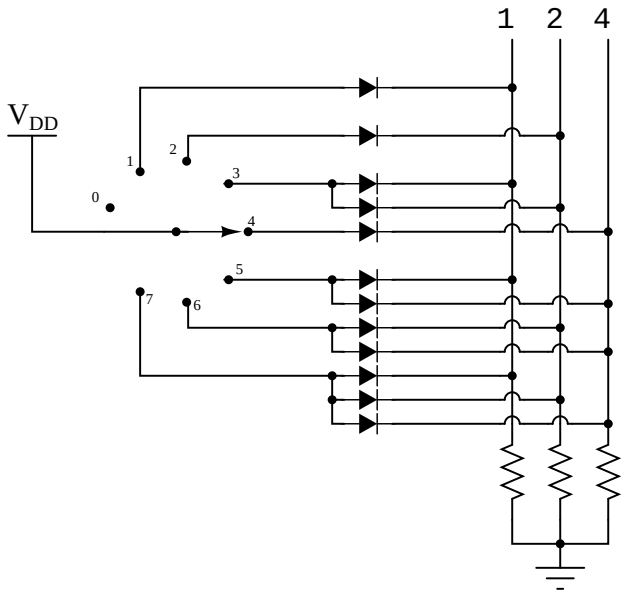
You then telephone the customer and ask him how he is using the encoder. He tells you it is used as part of a fault diagnostic circuit for an important piece of machinery. Each input of the encoder is connected to a different sensor on the machine (low oil pressure switch, high temperature switch, out-of-limit travel switches, etc.), and then the encoder outputs drive a four-LED display for maintenance technicians to view. They would have rather used a separate LED for each "trouble" sensor, but the display panel was too small to accommodate fifteen LEDs, so they decided to use four LEDs and an encoder, having their technicians interpret a binary code to determine which of the fifteen sensors is activating.

To the best of your ability, determine why your company's flagship encoder circuit sometimes produces false codes in this application. Then, recommend a solution for your customer.

file 01409

Question 14

Identify which diode is failed in this circuit, given the following truth table (showing the actual operation of the encoder circuit, not what it *should* do):



Switch position	Output code
0	000
1	111
2	010
3	111
4	100
5	111
6	110
7	111

Be sure to specify whether you think the failed diode is *open* or *shorted*.
file 03911