Encoding and Decoding of Digital Signals

Laboratory assignment two
ECE 203
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Lab report due during your lab check slot on 16 April

Please keep track of how long you spend doing this laboratory assignment. Specifically, how much time is needed to do the problems after studying enough to understand the concepts?

Please carefully review lecture four before starting this assignment. If you make catastrophic wiring mistakes, this could result in be exploding integrated circuits sending chunks of plastic into your forehead.

In this laboratory assignment, you will be implementing two circuits. The first will encode signals for transmission through fewer communication wires. The second will decode the signal.

Please show your work in your lab report. For example, if you do algebraic simplification, show your steps.

Don't unwire this lab when you're done. You'll need to use it as a starting point for your next assignment! Please make your design compact. It will make the next assignment easier.

1 Background

You have been hired by a space flight company to design an orbital rocket control system. An *actuator* is a device which performs a mechanical action in response to an input signal. Most of actuator signals for the rocket generated by error-tolerant primary control computers located very near the actuators. However, a few signals must come from the pilot control panel. The pilot should be able to push buttons to generate any of the following signals: "open hatch," "decompress cabin," "release safety harness," and "eject pilot".

2 Design change

Initially, it seemed wise to use a heavily shielded cable with separate wire for each of the lines, for a total of four wires. However, after the rocket was built, the design team decided to add a "self-destruct" button for use by the pilot in case the rocket was on course toward a populated area during takeoff or landing. There is a time delay associated with the self-destruct signal, giving enough time to press the "eject pilot" button before it takes effect.

3 Backward compatability

Unfortunately, the addition of a new signal complicates transmission from the pilot control panel to the actuators. A number of other devices have been built around the control signal cable – replacing it with a cable composed of five wires would take a huge amount of time. Instead, your team suggests encoding the button information so that it requires fewer bits.

4 Redesign: Encoder

Given that only one button will be pressed at a time, the following six conditions must be representable:

1. no action
2. open hatch (H)
3. decompress cabin (C)
4. eject pilot (P)
5. release safety harness (S)
6. self-destruct (D)

Determine a way to encode these five conditions using only three bits of information, i.e., assign a three-bit binary number to each of the five conditions. By using three bits, you will require only three of the four wires in the existing cable.

For each of the three encoded signal wires (J, K, and L), find a function of the inputs (H, C, P, S, and D). Implement these functions using whichever gates are most convenient.

For example, if one had only two input buttons, A and B, and three codes carried on two signal wires (J and K), the following encodings could be used:

Input	Code (JK)
none	00
A	01
B	11

In this case,

$$J = B$$

and

$$K = A + B.$$

In other words, you can build your circuit with Or gates. Recall that you can build three-input Or gates from two-input Or gates, i.e.,

$$A + B + C = (A + B) + C.$$

This implementation is your input circuit. It will consist of five input switches, some logic gates to implement the encoding, and three output signals connected to LEDs. You can leave off the display LEDs on the inputs, but not on the J, K, and L, or the outputs. Don't omit the 510 Ω pull-down resistors on the inputs.

5 Redesign: Decoder

Near the actuators, it is necessary to decode the signals to get individual H, C, P, S, and D outputs. You'll need to use at least one logic gate for each output. In general, an easy approach is using inverters to get access to $\overline{J}$, $\overline{K}$, and $\overline{L}$ and then use a number of AND gates. Recall that

$$A \cdot 1 = A,$$

i.e., you can build a three-input AND gate from a four-input AND gate.

Some combinations of J, K, and L can never be generated. When building your decoder, you may use a Karnaugh map and enter don't-cares for impossible combinations of J, K, and L. This may simplify your implementation.

Keep in mind that only three signal wires may connect the encoder to the decoder.

Each output requires a LED.

6 Resources

This is one possible resource list. You may find another way to build a pair of circuits that solve the problem just as well.

Input network

- Five input switches
- Five 510 Ω resistors

Encoder

- Four two-input OR gates (two of which are used to build a three-input OR gate)

Internal display

- Three 330 Ω resistors
- Three LEDs

Decoder

- Three inverters
- Four two-input ANDs
- One three-input AND

Output display

- Five 330 Ω resistors
- Five LEDs

7 Special notes

This lab requires a fair amount of wiring. If you try to stay organized you will be less susceptible to errors and it will be easier to debug any bugs that show up. You can use the logic probe to help make sure that you are making the right connections. If your circuit works correctly, the output LEDs on the decoder will be the same as the switch states.

8 Sneak preview of next lab

We hope this lab is fun. It should also prepare you for the next lab on Error Detection in Digital Communication Lines.

> *Unfortunately, the control panel to actuator signal cable is routed near other electrical devices, e.g., motors, that can interfere with the transmission of digital signals. Despite the signal cable's shielding, there was a problem when the first designer was testing it in orbit. Although nobody is certain exactly what happened, it appears that a spurious "decompress cabin" signal appeared at the actuators while the orbital rocket was in a vacuum and the designer was not wearing a pressurized suit. Your job is to make the communication of control signals error-resistant.*

9 Requirements

Prepare a laboratory report. This report should contain the following information.

- A problem statement or objective for the laboratory assignment
- Anything you used in achieving this objective, e.g., truth tables or algebraic simplification, etc.
- A list of the parts required for the circuits you implemented
- Schematic diagrams of the circuits you implemented.
- A brief discussion of how you verified that the implementation meets the requirements
- Comments and observations
- A circuit floorplan (optional)

The lab will be graded as follows:

Component	Weight
Circuit quality	5
Report clarity	2
Derivation and schematic	1
Layout style and neatness	1
Correct LED and switch use (resistors, etc.)	1