CMPE 160 Laboratory Exercise 1

Combinational Logic Circuit Design Using Decoders and Multiplexers

Example Student
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Your Signature: ______________________________

Abstract

The purpose of this exercise was to use multiplexers to implement a real world scenario. The problem was converted into a boolean equation, which was implemented using a multiplexer circuit. The design was simulated to confirm correctness and then built and tested. The physical circuit performed the correct function and matched the results given by the simulation. A circuit with the same functionality was designed using a 3:8 decoder. Multiplexers and decoders are versatile means of constructing a circuit to represent a function with real meaning.

Design Methodology

A company with two parking lots wanted a method of controlling access to these two lots. Table 1 shows which parking lots an employee is allowed to use.

Table 1: *Allowed Parking Areas*

	Parking Areas Allowed	
Employee Class	$P1$	$P1$
None		
Company Officers	✓	✓
Managers	✓	✓
Engineers	✓	
Secretaries		✓
Machinists	✓	✓
Electricians	✓	
Accountants		✓

For example, company officers can park in both lots, but secretaries only have access to lot 2. However, the computer needed a way to differentiate employee types, so each person was given a card with a binary encoding of his or her employee class. Table 2 shows this representation.

Table 2: *Binary Employee Codes*

	Digital Code		
Employee Class	$S1$	$S2$	$S3$
No Input	0	0	0
Company Officer	0	0	1
Manager	0	1	0
Engineer	0	1	1
Secretaries	1	0	0
Machinists	1	0	1
Electricians	1	1	0
Accountants	1	1	1

Using Table 1 and Table 2, a multiplexer was determined to be the best choice for implementing this circuit. A mux is a circuit element that has N inputs and $\log_2 N$ select signals, along with one output. The select signals determine which input will be passed to the output. Table 3 was constructed, mapping codes to access in the form of a truth table.

Table 3: *Truth table for opening the garages*

$S1$	$S2$	$S3$	$P1$	$P2$	$P1_{mux}$	$P2_{mux}$
0	0	0	0	0	$S3$	$S3$
0	0	1	1	1		
0	1	0	1	1	1	$\overline{S3}$
0	1	1	1	0		
1	0	0	0	1	$S3$	1
1	0	1	1	1		
1	1	0	1	0	$\overline{S3}$	$S3$
1	1	1	0	1		

In Table 3, the $P1$ and $P2$ columns show a "1" when the employee is allowed in that lot and a "0" when they are not. The $P1_{mux}$ and $P2_{mux}$ represent the inputs to a 4:1 multiplexers when $S1$ and $S2$ are used as select signals.

From Table 3, a circuit was designed using $S1$, $S2$, and $S3$ as inputs and $P1$ and $P2$ as outputs. This design is shown in Figure 1.

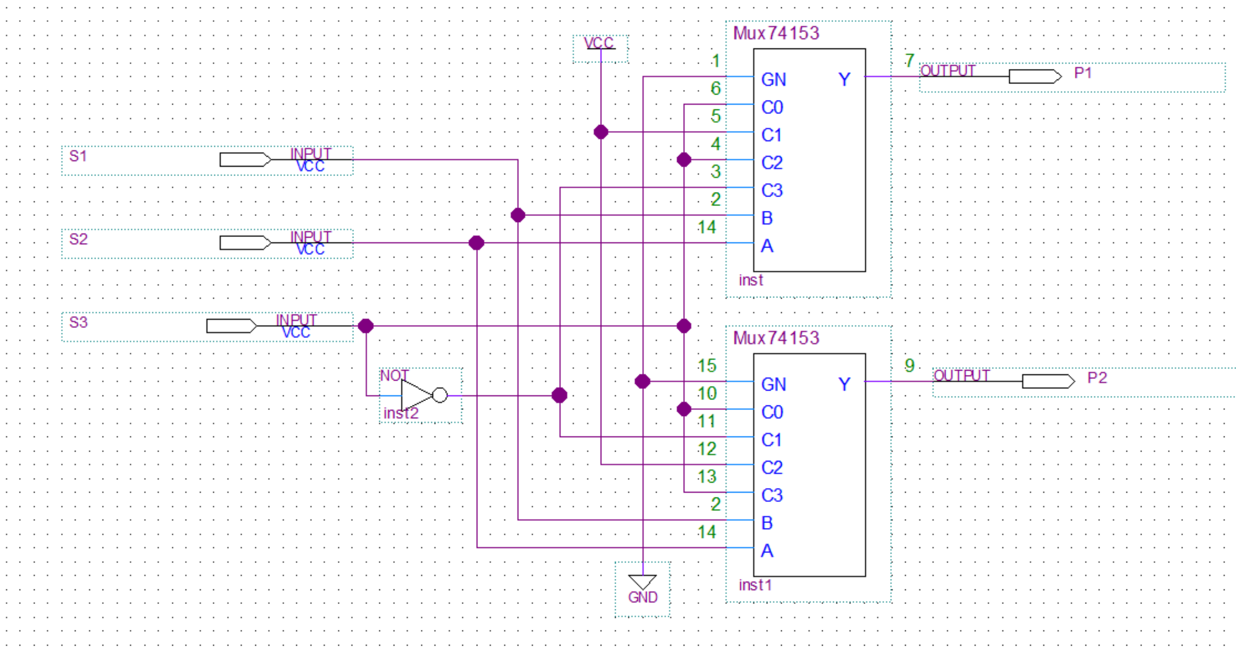

Figure 1: *Parking Lot access from two 4:1 multiplexers*

In the Mux74153 part, `GN` is an active low enable, so it is tied to ground. `C0-C3` are the inputs to the multiplexer, whose selects are `A` and `B`.

The circuit in Figure 1 was built, with $P1$ and $P2$ connecting to LEDs so that a lit LED indicated that that gate would open and a non lit LED indicated that that gate would not open. The design used two 4:1 multiplexers, one for each output. $S1$, $S2$, and $S3$ were connected to switches.

Results and Analysis

In order to verify the correctness of Figure 1, it was simulated, producing the waveform seen in Figure 2.

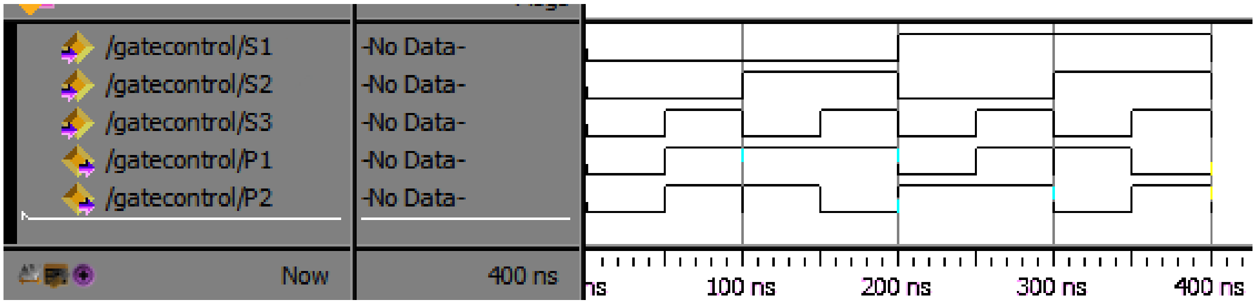

Figure 2: *Parking lot access waveform*

The waveform in Figure 2 matches the truth table in Table 3 exactly. Therefore, the circuit design was confirmed to be correct. The test results from the breadboarded circuit are shown in Table 4.

Table 4: *Test results*

$S1$	$S2$	$S3$	$P1(L1)$	$P2(L2)$
0	0	0	off	off
0	0	1	on	on
0	1	0	on	on
0	1	1	on	off
1	0	0	off	on
1	0	1	on	on
1	1	0	on	off
1	1	1	off	on

The results shown in Table 4 match the expected results in Table 3 where $L1$ and $L2$ are the LEDs the outputs were connected to. Therefore, the circuit was constructed correctly.

Questions

Redesign the parking control circuit using one 3:8 decoder rather than two 4:1 multiplexers. Provide a circuit diagram and simulation results from Quartus II/ModelSim.

If an employee group should have access to a lot, their output is tied to the appropriate OR gate, causing the OR gate to produce a one when the group's code is the input to the decoder.

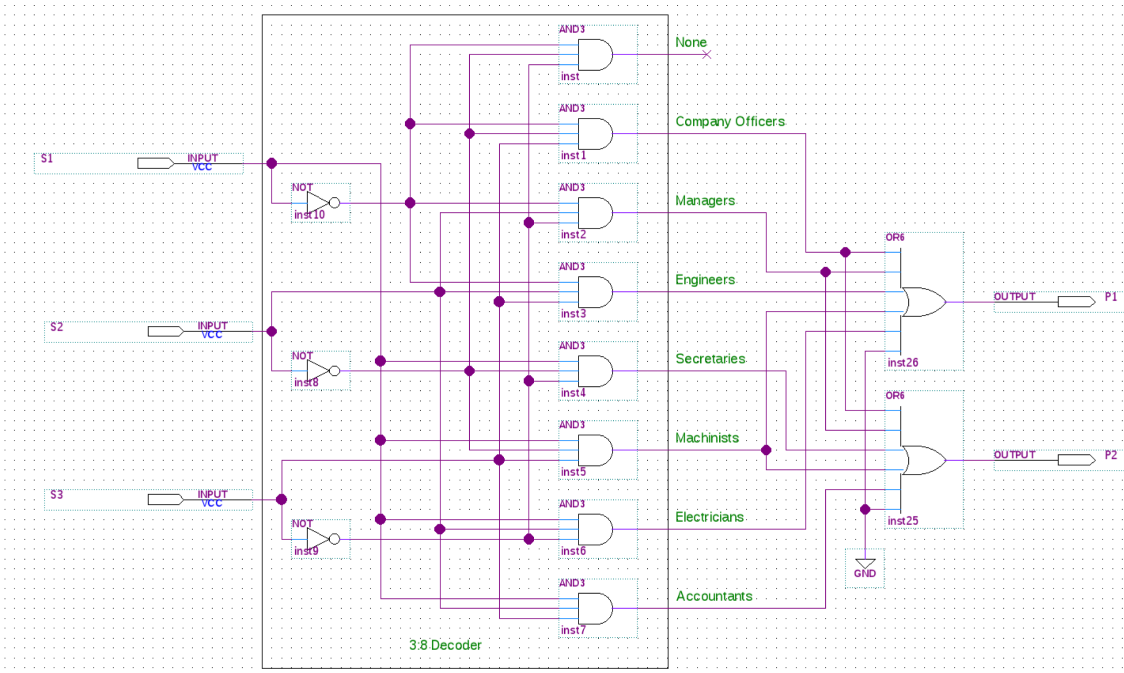

Figure 3: *Parking lot access from decoder*

The circuit was simulated and the waveform seen in Figure 4 was created.

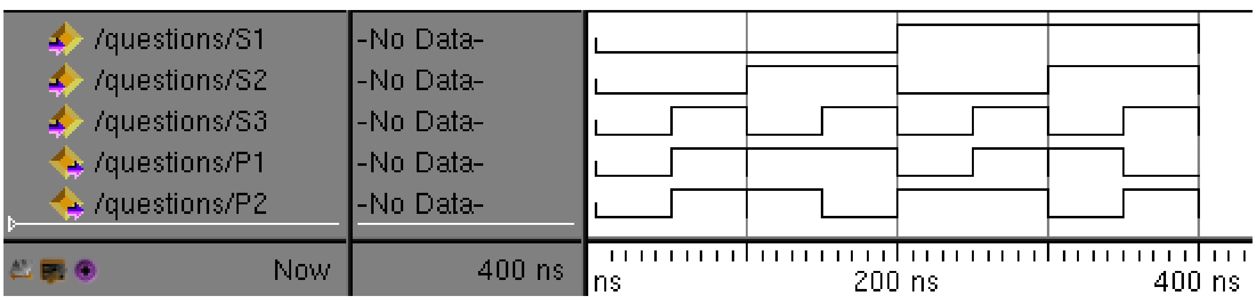

Figure 4: *Parking lot access waveform from the decoder*

This matches the waveform from Figure 2, meaning the circuit was correctly constructed.

Conclusion

Multiplexers and decoders are useful for implementing many different functions. Using basic combinational logic gates has the advantage of efficiency, but multiplexers and decoders are more generic and are easy to debug or reuse for other functions. A multiplexer is most useful as a switch between different signals, like the employee codes. A decoder is useful for an unsimplified equation taken directly from a truth table. Both of these are simpler to use and understand than a complicated circuit that, when simplified, does not appear to relate to the original function. The exercise proved successful as the circuit constructed matched the expected results, allowing for proper access to lots.