

CE1901 LABORATORY PROJECT

SUMMARY

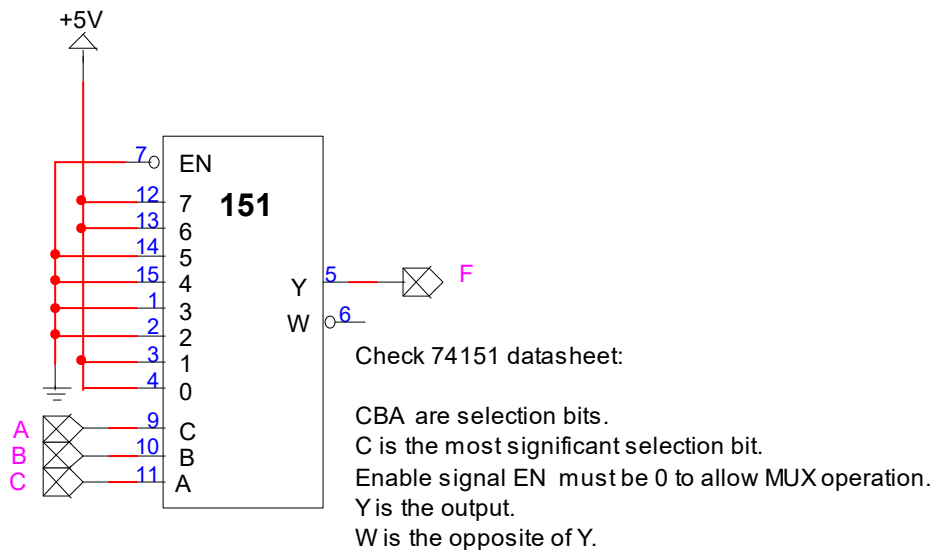
Multiplexers are functional level components that use a selection binary number to choose one of many input data signals to pass to the output. The 74LS00-series integrated circuit family includes many multiplexers. Three that remain available for purchase from electronics distributors are the 74LS151, the 74LS153, and the 74LS157.

CHIP	FUNCTION	UNIT PRICE	DISTRIBUTOR
74LS151	Single 8:1 MUX	\$0.90	Digi-Key Electronics (http://www.digikey.com)
74LS153	Dual 4:1 MUX	\$0.90	Digi-Key Electronics
74LS157	Quad 2:1 MUX	\$0.79	Digi-Key Electronics

Engineers can use multiplexers to implement standard-form (canonical) equations like

$$F(ABC) = \sum_m (0,1,6,7)$$

by wiring the function input variables to the selection control signals and wiring each data input to its logic-0 or logic-1 based on its corresponding value in the truth table.



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These laboratory exercises focus on the design and implementation of canonical logic equations to control a mobile robot. The equations become the computer brain of the robot and allow the robot to complete tasks. The robot consists of a plexiglass body, two bidirectional motors, three line sensors, a collision sensor, and a prototype breadboard used to interconnect integrated circuit chips (ICs) to implement logic equations. The line sensors reside under the body and point down toward the ground. The collision sensor resides on the front of the body and points ahead of the robot. The equations are implemented using 74LS151 multiplexers.

PRELIMINARY READING

Figure 1 shows a top view of the laboratory robot. Note the DC motors and wheels mounted on the rear of the robot and the collision sensor on the front of the robot. The toggle switch applies battery power to the robot components. Engineers use the central white plugboard (also called a breadboard) to interconnect integrated circuit chips to each other and to the robot sensor and motor signals. The sensor, motor, and power supply signals terminate at metal wire connection ports along each side of the robot's plexiglass body. Although they are difficult to see in this photograph, the wire connection ports have names etched into the plexiglass.

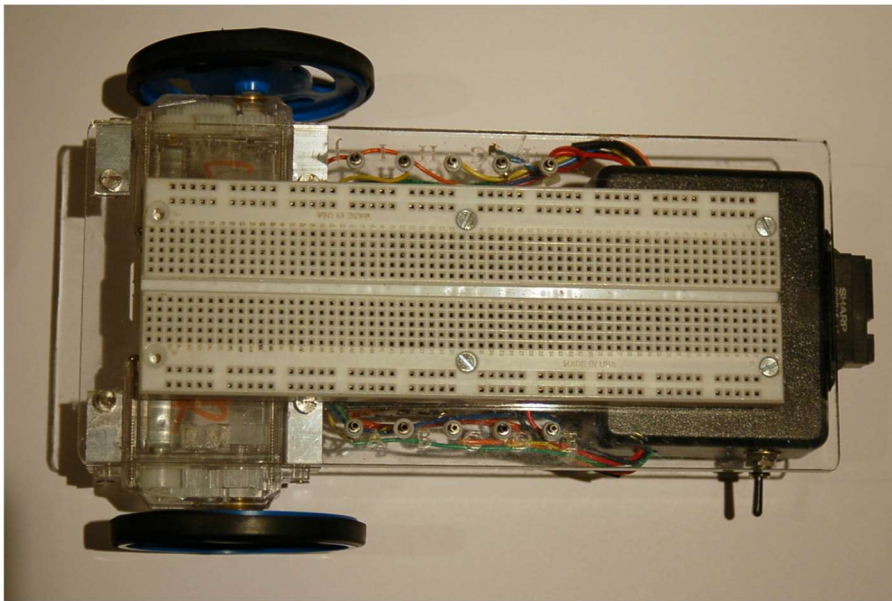


Figure 1: Top View of the Laboratory Robot

Figure 2 shows a bottom view of the laboratory robot. The robot sensors and motors operate from logic voltages 0V and 5V. Thus, four (4) AA batteries generate a 6V power supply. Each AA

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battery produces 1.5V and a series connection sums the battery voltages ($1.5+1.5+1.5+1.5 = 6V$). A **voltage regulator** component inside the robot reduces the power from 6V to 5V for use by the robot components. Note the motors, the battery compartment, and the line tracker component with three infrared line sensors just to the right of the battery compartment. Each infrared sensor is actually an infrared transmitter and receiver pair. Each infrared transmitter sends infrared energy down toward the ground. Surfaces reflect infrared energy similarly to the reflection of visible light energy. Thus, each infrared sensor will see a reflection of the energy it transmitted if that sensor is over a light colored surface. The sensor will not see a reflection if it is over a dark surface.

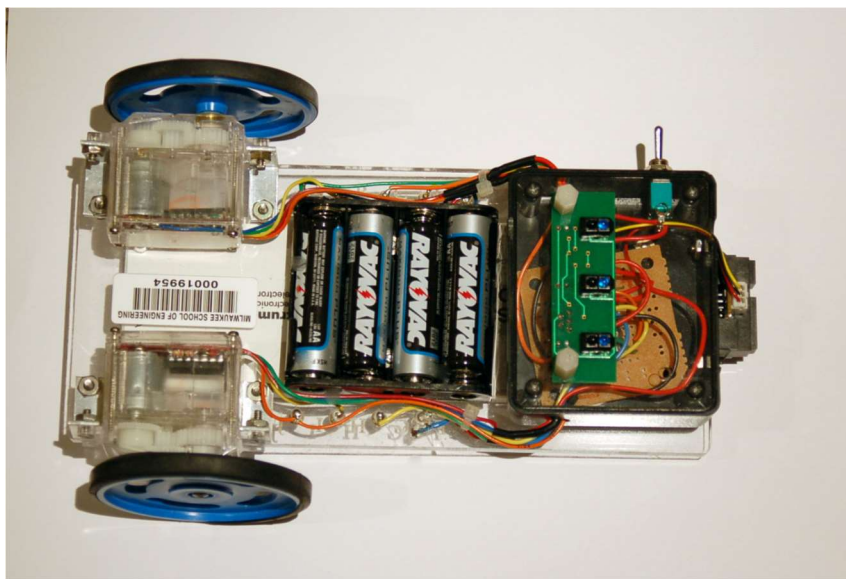


Figure 2: Bottom View of the Laboratory Robot

Table 1 summarizes the robot input and output signals. Note that the battery power terminals are called VCC (+5V) and GND (0V). In circuit theory, ground (GND) represents the return path for current returning from the circuit to the power supply – hence the negative terminal of the battery.

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Table 1: Robot Electrical Signals

NAME	TYPE	MEANING	IF 0	IF 1
A	Control	Right motor direction	reverse	forward
B	Control	Right motor on/off	off	on
C	Sensor	Right line sensor	over black	over white
D	Sensor	Collision sensor	no collision	collision
E	Power: GND	Battery negative (0V)		
F	Power: VCC	Battery positive (+5V)		
G	Sensor	Center line sensor	over black	over white
H	Sensor	Left line sensor	over black	over white
I	Control	Left motor on/off	off	on
J	Control	Left motor direction	reverse	forward

Engineers can use these signals to create a robot brain. Each robot sensor (C, D, G, and H) is an **input** to a logic circuit that implements canonical logic equations designed to control the robot behavior. A canonical logic equation would be needed for each **output** control signal A, B, I, and J. Figure 4 illustrates this equation mapping in block diagram form.

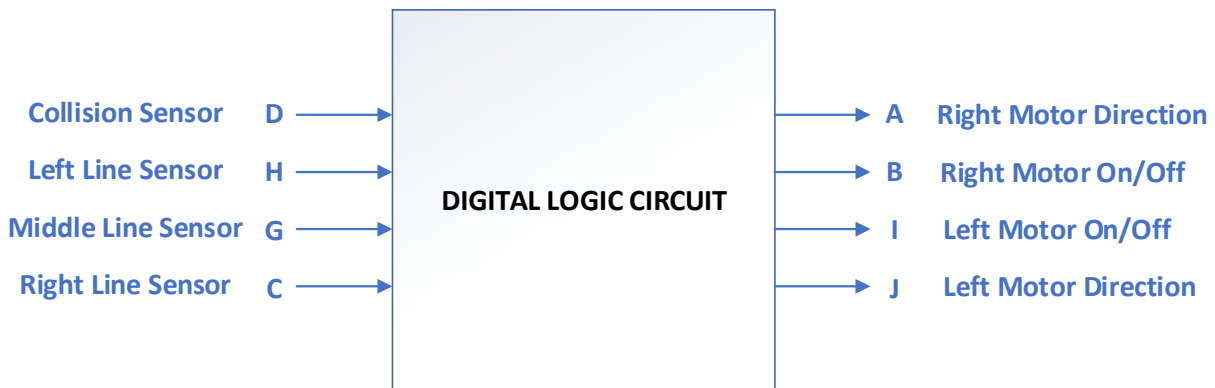


Figure 4: Block Diagram of Design Problem

Each sensor input signal becomes one column of a binary number in a sixteen-row truth table used to design the output equations. Note that not every robot behavior demands that an engineer use every signal as input. Similarly, an engineer may not need every output signal for basic behavioral control. For example, an engineer could decide to turn on the motors when

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the robot is on and control only the forward or reverse motor direction. In this case, the engineer would wire robot signals B and I to the battery power supply (logic 1 = VCC = +5V) and only implement canonical equations for direction control signals A and J. Similarly, some robot tasks might not require the center line sensor and thus an engineer could ignore sensor signal G. In this case, the number of truth table rows decreases from sixteen to eight – reducing the complexity of the canonical equations. Figure 5 shows the block diagram under these simplifications.

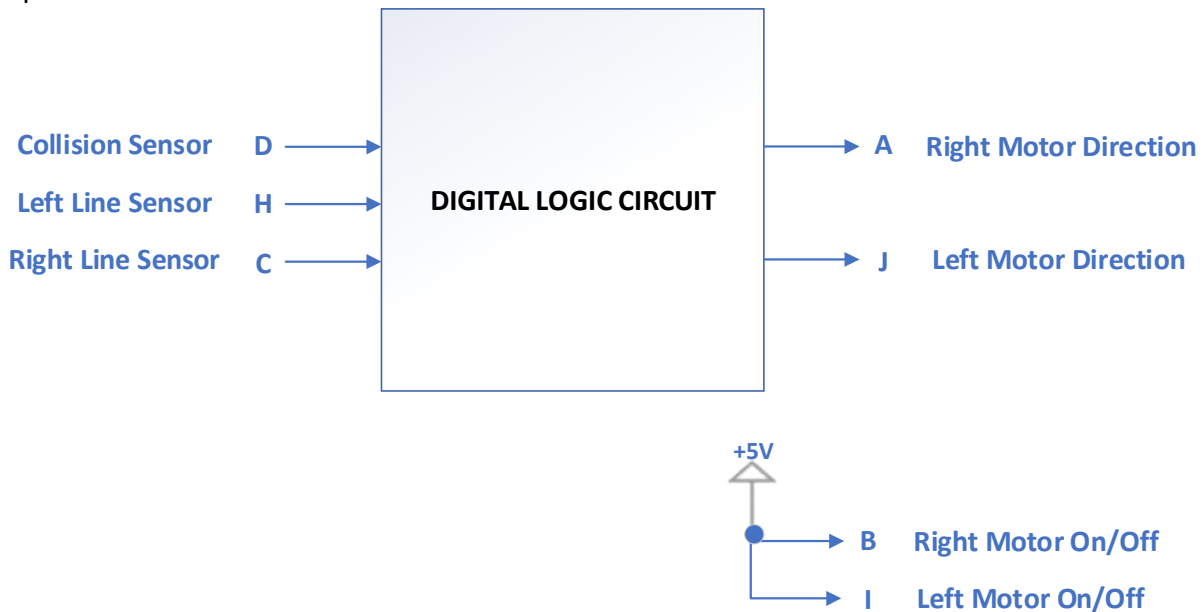


Figure 5: A Block Diagram with Reduced Signal Set

KEY POINTS

Remember these key points about the robot signals:

- motor forward = logic 1 = +5V
 - motor reverse = logic 0 = 0V
 - motor on = logic 1 = +5V
 - motor off = logic 0 = 0V
 - collision = logic 1 = +5V
 - no collision = logic 0 = 0V
 - line sensor over white = logic 1 = +5V
 - line sensor over black = logic 0 = 0V
- Not very input and output is needed to solve problems.

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PRE-LABORATORY WORK

1. **Complete** a truth table for each output in Figure 5. The task is to keep the robot centered over a black line of electrical tape placed on a white surface in a random path. You will place the robot onto the track with the center sensor aligned over the black line. Horizontal tape forms road blocks on the track at periodic intervals. The first step in design is to determine appropriate behaviors for each input pattern. **Use** Figure 6 to help think about how the logic outputs for the left and right line sensors change as the robot rolls along the track.

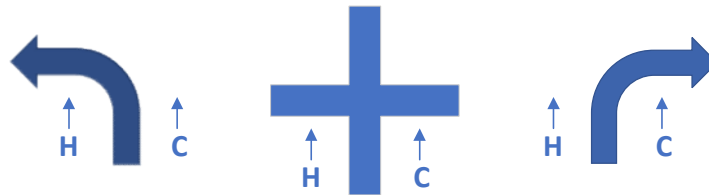


Figure 6: Robot Motion and Sensor Position Along the Track

INPUTS			DESIRED BEHAVIOR	OUTPUTS	
D	H	C		Left Motor Dir	Right Motor Dir
D	H	C		J	A
0	0	0	Road Block! Reverse!		
0	0	1	Turn Left		
0	1	0	Turn Right		
0	1	1	Forward		
1	0	0	Collision! Reverse!		
1	0	1	Collision! Reverse!		
1	1	0	Collision! Reverse!		
1	1	1	Collision! Reverse!		



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2. **Review** the 74151 data sheet. Pay close attention to the IEEE Std. 91-1984 schematic symbol as well as the truth table. Note that the 74151 names its selection bits C, B, and A rather than S2, S1, and S0. Note that bit C is the most significant bit in the data sheet truth table. Finally note that the 74151 also has an enable control bit called G. You must enable the 74151 for it to become active.
3. **Implement** your solution as a Quartus schematic blueprint using two 74151 multiplexers; one for each direction signal. **Don't forget to enable each MUX!**
 - a. **Complete** both schematic and waveform simulation.
 - b. **Type** 74151 into the part selection box. Place two 74151s onto the blueprint.
 - c. **Type** "GND" and "VCC" into the part selection box. Place on the blueprint.
 - d. **Wire** multiplexer data inputs to VCC and GND.
 - e. **Wire D, H, and C** to multiplexer selection inputs C, B, and A respectively.
 - f. **Simulate** your work and verify it matches your truth table.
 - g. **Remember** that if you get an "inst names already exists" error when compiling, ensure that every component in the schematic has a unique "inst" name. You may have to double click a component and change its inst numbers to inst99 or inst98 for example to ensure they all have unique inst names.

DELIVERABLES DUE DURING THE LABORATORY PERIOD

Each student must complete these deliverables. This is not a team exercise.

1. **Demonstrate** the pre-lab work to your instructor.
2. **Check out** a Digi-bot, batteries, and a blue wire kit from EECS Tech Support.
3. **Use** the 74LS151 ICs from your laboratory kit.
4. **Build** and **demonstrate** a working Digi-Bot.
5. **Complete** a laboratory submission packet.
6. **Submit** your laboratory packet using the method required by your instructor.