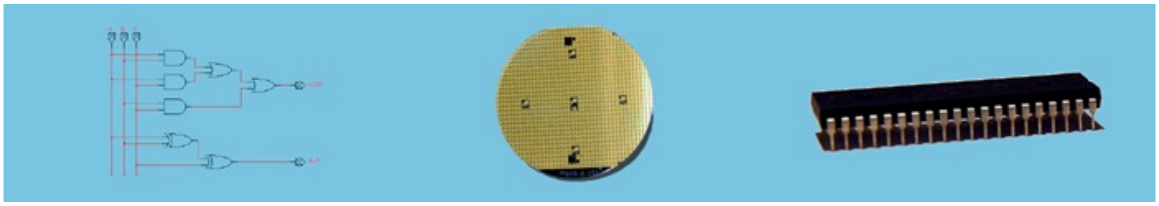
CE1900 WEEK 3 LABORATORY EXERCISES



LABORATORY SUMMARY

These laboratory exercises focus on the design and implementation of **K-map minimized** 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 are mounted under the body and point down toward the ground. The collision sensor is mounted on the front of the body and points ahead of the robot.

Students will complete two design tasks:

- **Design** canonical and minimized equations for a line-following robot.
- **Implement** the minimized equations using standard logic chips.

The laboratory exercises reinforce these CE1900 learning objectives:

- **Design** canonical equations from a truth table.
- **Design** minimized equations using the K-map technique.
- **Implement** minimized equations using standard 7400 family logic chips.
- **Use** datasheets to aid in circuit construction and timing analysis.

Print this document and **bring** it to lab with the preliminary activities completed in the spaces provided. **Hint:** save your color print cartridge by selecting “black-and-white” printing from your print options.

REMEMBER

Complete all preliminary lab exercises ***before you come to lab***.
Review the in-class laboratory exercises to preview the work you will do in the lab.

PRACTICE PROBLEMS

Test your progress in meeting your course learning objectives by completing these practice problems. Practice problems are for your personal study and may be collected and checked as part of your overall lab grade. **Ask** your instructor for help if needed.

1. **Derive** the K-map minimized logic equation for a four-bit greater-than-10 detector. **Mathematically,** G(ABCD) = 1 if and only if ABCD > 10. **Use** the Quartus software to **draw** and **simulate** your blueprint.
2. **Calculate** the gate reduction ratio for function F(ABCD) = ∑m(8,9,10,11,12,13,15).
3. **Derive** the K-map minimized logic equation for the function F(ABCD) = AB < CD. **Mathematically,** F(ABCD) = 1 if and only if the two-bit value AB is less than the two bit value CD. **Use** the Quartus software to **draw** and **simulate** your blueprint.
4. **Derive** the K-map minimized logic equation for function F(ABC) = ∑m(1,3,5,6,7).
5. **Reverse-engineer** the K-map that was used to derive the minimized logic equation F(ABCD) = D' + BC'. **Note** that the D' notation means "D bar" or "not D".
6. **Calculate** the gate reduction ratio for the function given in practice problem 5.
7. **Minimize** the function F(ABC) = ∑m(4,5,7) using the combining theorem from Boolean algebra. **Repeat** using a K-map and **compare** your answers.
8. Logic signals P1, P2, and P3 represent power-on signals from the computers of an industrial welding robot in a Harley Davidson motorcycle plant. Signal EMERG represents an emergency stop button placed near the robot so that a human factory worker can shut the system down in there is an emergency. **Signal** G is the on-off signal for the motors pulling the assembly line chain. This chain moves motorcycle parts past the welding robot. The motors are on when G is on. **Derive** the K-map minimized logic function for G if G(P1,P2,P3,EMERG) = 1 if and only if at least two of the power signals are on and the emergency stop signal is off.

PRELIMINARY LAB READING: THE ROBOT ELECTRICAL SIGNALS

The robot used this week is the same digi-bot used in the last laboratory. **Review** that document if needed to refresh you memory about the robot. The robot input and output signals are summarized again in Table 1.

Table 1: Robot Electrical Signals

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

KEY POINTS

Remember these key points about the robot signals:

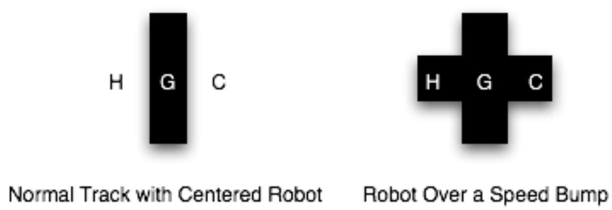
- motor forward = logic 1 = +5V
- motor reverse = logic 0 = 0V
- motor on = logic 1 = +5V
- motor off = logic 0 = 0V
- collision! = logic 1 = +5V
- no collision = logic 0 = 0V
- line sensor over white = logic 1 = +5V
- line sensor over black = logic 0 = 0V

PRELIMINARY LAB EXERCISES

Each student must complete these exercises before coming to the laboratory period.

1. **Complete** the design of both canonical and K-map minimized equations for a robot that follows the black line using only the left and right sensors, drives over speed bumps, ***and*** avoids collisions by ***turning left*** when a collision is sensed. Assume that the motors are always moving forward when the power is applied and thus the circuit should control motor on and off.

    a. **Start** by finishing the truth table.



INPUT SIGNALS			**OUTPUT SIGNALS**		
COLLISION SENSOR	**LEFT LINE SENSOR**	**RIGHT LINE SENSOR**	**LEFT MOTOR ON/OFF**	**RIGHT MOTOR ON/OFF**	**BEHAVIOR**
D	**H**	**C**	**I**	**B**	
0	0	0			speed bump
0	0	1			
0	1	0			
0	1	1			
1	0	0			collision!
1	0	1			collision!
1	1	0			
1	1	1			

2. **Record** the canonical sum-of-products equation for I = F(D,H,C):

   I = ____

3. **Record** the canonical sum-of-products equation for B = F(D,H,C):

   B = ____

4. **Record** the K-map minimized sum-of-products equation for I = F(D,H,C):

   I = ____

D \ HC	00	01	11	10
0				
1				

5. **Record** the K-map minimized sum-of-products equation for B = F(D,H,C):

   B = ____

D \ HC	00	01	11	10
0				
1				

6. **Use** the Quartus software to draw a gate blueprint for the reduced equations from prelab exercise 4 and 5.

    a. **Note** that you can build both output circuits on the **same diagram!**
    b. **Verify** correct operation by completing simulation waveforms and checking the output voltages for each input voltage pattern.
    c. **Print** your Quartus blueprint and Quartus simulation diagrams. **Add** hand-written comments to the printout that **demonstrate** you understand how to read the diagram. For example, "Here we see the robot ignoring the speed-bump because J=1 and A=1 when H=0 and C=0." You don't have to add comments for all possible input conditions. **Add** comments for two or three.
    d. **Use** the 7400 family datasheets on the CE1900 website to help you identify the required chips. **Write** the chip number below each gate on your blueprint diagram. Only NOT, AND2 and OR2 components are allowed. AND3 and OR3 can be formed by chaining AND2 and OR2 components together.
    e. **Use** the 7400 family datasheets on the CE1900 website to help you add pin numbers to each gate connection on your blueprint diagram.

7. **Complete** this summary table about the circuits for equations J and A. **Calculate** the gate reduction ratios for each circuit.

CIRCUIT	NUMBER OF GATES	NUMBER OF WIRES
canonical I		
minimized I		
canonical B		
minimized B		

Gate reduction ratio (canonical gates / minimized gates) for equation I: ________

Gate reduction ratio (canonical gates / minimized gates) for equation B: ________

The remainder of this document consists of laboratory exercises that must be completed during the laboratory period. **Read** through these exercises now to get a sense of the laboratory requirements. **Complete** the exercises during your assigned lab period.

LABORATORY EXERCISES

Each student must complete the weekly quiz. A two-person team must construct and demonstrate the robot during the two-hour laboratory period in academic week 3.

1. **Take** the weekly CE1900 quiz given by your instructor at the start of lab.
2. **Check** out the following items from the EECS Technical Support Center (S-348). **Complete** the quantity for the 7404, 7408, and 7432 chips based on your circuit designs.

ITEM	**QUANTITY**
Digi-bot	1
Digital wire kit (blue box)	1
AA batteries	4
Logic probe	1
7404 NOT gate IC	
7408 quad 2-input AND-gate IC	
7432 quad 2-input OR-gate IC	

3. **Build** the minimized logic equations you designed in the pre-lab exercise using the Digi-bot protoboard, the 7400 family chips, and the wires from the wire kit.

   a. **Remember** that each chip ***must*** be connected to the battery VCC and GND because the internal circuit must have energy to work.
   b. **Remember** that the design choices made in this document always had the motors moving forward when the robot was powered. **Don't forget** to wire robot signals A and J – the motor direction signals – to VCC.
   c. **Remember** that the design ignored the center line sensor. **Do not** wire this robot signal to any chip because it isn't used!

4. **Test** your robot on the track provided in the laboratory room. **Debug** your wiring by carefully checking every connection if the robot fails to meet the requirements.
5. **Demonstrate** your robot to the instructor. The instructor will complete the signature block at the end of this document. The signature block serves as proof that you have completed the laboratory assignments. **Keep** this document in your binder for CE1900 in case you need to refer to it in future work or in case the instructor asks to see the signature block again at a later date.

6. **Estimate** the total amount of time you spent working on the pre-lab and lab exercises. **Record** that time in minutes: ______________________________.

FOR INSTRUCTOR USE ONLY: DO NOT WRITE IN THIS TABLE

ITEM	COMMENTS	SCORE
Prelab exercises		
Quartus schematic		
Robot demonstration		

Instructor Signature: ____