UNIT III

ANALOG-TO-DIGITAL (A-TO-D) CONVERSION

CHAPTER 7

CHIPS USED ON THE ENVIRONMENTAL SENSE KIT BOARD

OVERVIEW

The Environmental Sense Kit (ESK) is an RB5X option that adds light, temperature, and sound sensors to the robot's standard tactile, sonar, and infrared sensors. In addition, since the real world exists as analog information that RB5X's microprocessor cannot directly interpret, the ESK's analog-to-digital (A-to-D) chip serves as a translator from the real world to the digital world.

In this chapter, you learn about the chips on the ESK board, their function, identifier, and location.

The digital chips used on this board are CMOS, so remember to use caution when handling the board as the chips can be damaged by static electricity. As in previous chapters and experiments, we suggest you ground yourself by touching any unpainted surface on the robot before handling this board.

In addition to the digitial chips, the ESK board contains two linear chips. The digitial chips process microprocessor signals and the linear chips condition analog signal inputs from the sensors.

The heart of the ESK board is a chip that is both analog and digital. This chip assists in the conversion of analog input signals into digital-compatible signals.

OBJECTIVES

Upon completion of this text material, you will be able to identify all the chips used on the ESK board by their:

1. Function,
2. Identifier,
3. Part number, and
4. Location.

PREREQUISITES

1. The Environmental Sense Kit option.

REFERENCES

1. Appendix I, "Environmental Sense Kit Schematics."
2. Appendix B, "CPU Board Chip Data Sheets."

TECHNICAL INFORMATION

The following integrated circuits, or chips, are found on the ESK board. Included in the following information is the chip number, the chip designator, and the general function of the chip on the ESK board. For further details, please see Appendix I, "Environmental Sense Kit Schematics."

U1
LM10--Operational amplifier
Amplifies and rectifies the microphone input signal.

U2
9708--Six-channel, microprocessor-compatible, A-to-D converter.

U3
LM324--Quad operational amplifier
Amplifies the analog input voltage received from the photodiode inputs.

U4
CD4013--Dual D flip-flop
Aids in decoding the address bus lines and enables the output buffer (stop count signal).

U5
CD4023
Triple 3-input NAND gate
Aids in decoding the address bus lines and enables the output buffer (stop count signal).

U6
74HC04--Hex inverter
Handles signal inversion

U7
CD4002--Dual 4-input NOR gate
Aids in decoding the address bus lines and enables the output buffer (stop count signal).

U8
CD4503--Hex tri-state buffer
Handles isolation and impedance matching between the ESK and RB5X's circuitry.

Figure 17 shows the layout of the chips used on the ESK board, the chip-numbering sequence, and the part number. You can see that the chips are numbered from left to right when the ESK board is held with the component side up and the K1 relay on the right. The figure also identifies the analog input jacks, and the sensitivity-control potentiometers.

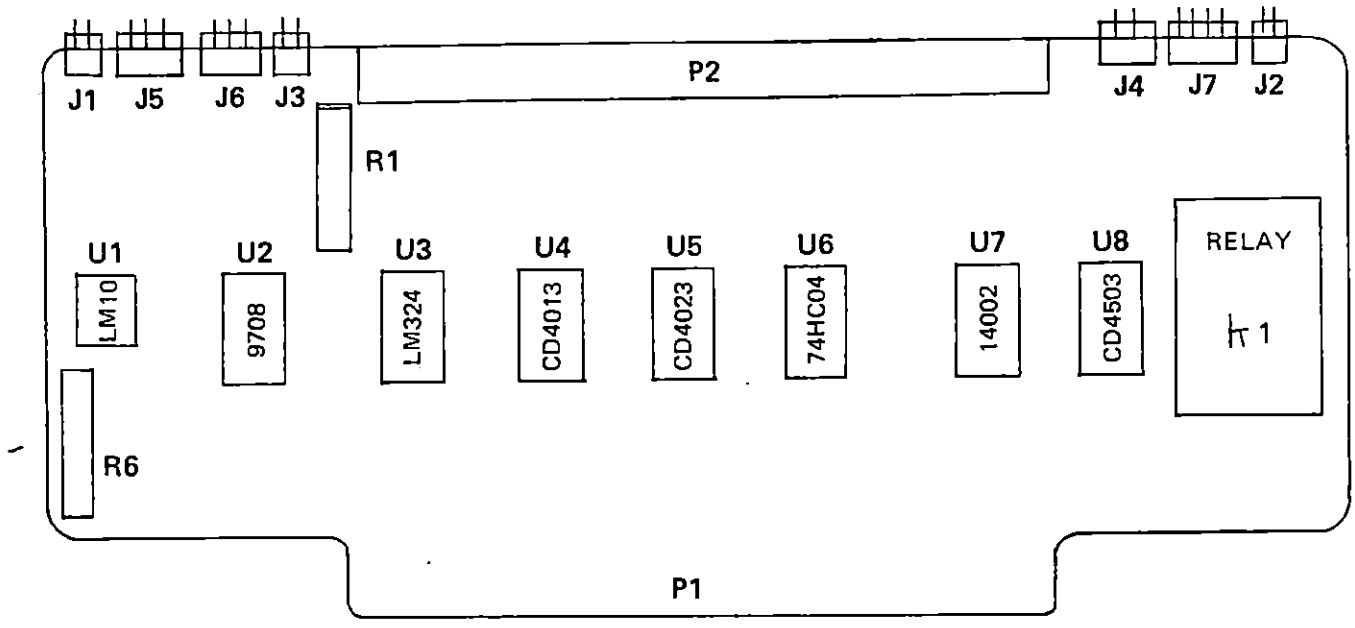


Figure 17 - Environmental Sense Kit Board

In the experiment that follows, we ask you to identify these components by part number, location, reference identifier, and function. If you carefully study the information contained in this section, your work in the experiment will be greatly simplified.

SUMMARY

You are now familiar with the chips used on the ESK board. Not only can you identify a specific chip by its part number, but also by its identifier and function. You should now understand the numbering sequence of the chips on the ESK board.

QUESTIONS

1. What is the identifier of the chip used to convert analog input signals into microprocessor-compatible signals?

_____

2. Which chip on the ESK board carries the STOP count signal to the microprocessor?

_____

3. Which pin numbers on the 9708 chip select a specific analog input signal?

_____

4. List the chips used to enable the STOP count signal to leave the ESK board.

_____

_____

5. Which chips on the ESK board are only linear in their operation?

_____

Experiment 7.1

ESK Component Identification

Overview

In Chapter 7, you studied the chips used on the ESK board, including their function and schematic identifier. In this experiment, we ask you to identify the ESK components as well as the sensors and their jacks.

Objectives

Upon completion of this experiment, you will be able to physically locate components used on the ESK board when given the following:

1. Description (function),
2. Designator (identifier), or
3. Part number.

Prerequisites

1. Chapter 7, "Chips Used on the Environmental Sense Kit Board."

2. An ESK board.

References

1. Appendix I, "Environmental Sense Kit Schematics."

2. Appendix B, "CPU Board Chip Data Sheets."

Technical Information

During this experiment, you need to refer from time to time to Figure 17, which shows the physical layout of the chips used on the ESK board. Note that the ESK board is positioned with the component side up and the K1 relay on the right. Also note that the chips are designated sequentially from left to right (U1 to U8).

Located at the top edge of the board are multipin jacks, used to connect the input sensors to the ESK board. Jacks 1, 2, 3, and 4 are used to connect the photodiodes (light sensors) to the ESK board. The photodiodes (TIL413) generate a voltage when they are exposed to light. Their greatest sensitivity is in the near-infrared end of the light spectrum. The small voltage generated by exposure to light is amplified via U3 (LM324) and applied to the A-to-D converter (9708). There are four sets of photodiodes; two sets have photodiodes connected in parallel, which increases the sensitivity of these two sets.

Jack 5 connects the microphone input to the ESK board. The signal from the microphone, traveling through J5, is amplified and rectified by U1 (LM10). The output from the LM10 is applied to the A-to-D converter (9708). You can adjust potentiometer R6, located at the lower left corner of the ESK board, to control the sensitivity of the microphone.

Jack 6 connects the temperature sensor (LM335) to the ESK board. Pin 3 of jack 6 connects directly to the A-to-D converter (9708). The LM335 operates as a two-terminal zener. The LM335 in conjunction with R1 and R19 form a voltage-divider network to determine the voltage fed to the A-to-D converter. R1 adjusts the operating point for the swing of this voltage. The internal impedence of the LM335 is temperature-dependent. This change in internal

impedence with change in temperature determines the input voltage swing at pin 3 of jack 6.

Procedure

1. Position the board in front of you with the component side up and relay K1 to the right.

2. Locate U4, and complete below its description and type:

   A. Description: _____

   B. Type: _____

3. Locate U1, and complete below its description and type:

   A. Description: _____

   B. Type: _____

4. Locate the 9708, and complete below its designator and description:

   A. Designator: _____

   B. Description: _____

5. Locate the CD4023, and complete below its designator and description:

   A. Designator: _____

   B. Description: _____

6. Locate the NOR gate, and complete below its designator and type:

   A. Designator: _____

   B. Type: _____

7. Locate the tri-state buffer, and complete below its designator and type:

   A. Designator: _____

   B. Type: _____

8. Referring to Figure 18, label all components by designator on Table 7.1 on the following page:

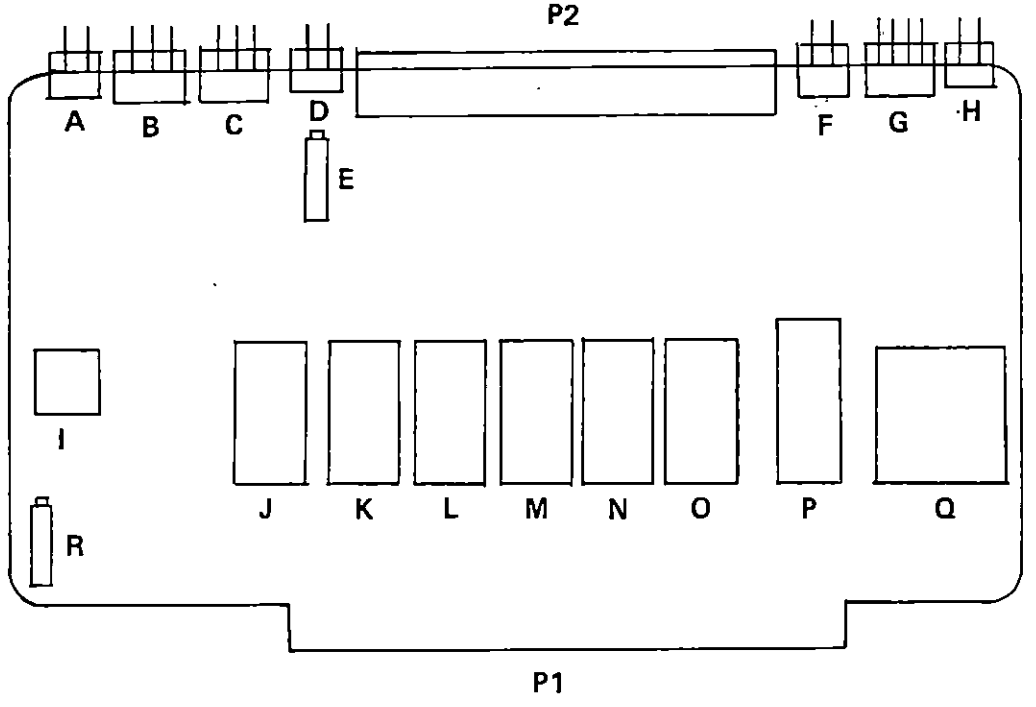


Figure 18

Component	Designator
A	
B	
C	
D	
E	
F	
G	
H	
I	
J	
K	
L	
M	
N	
O	
P	
Q	
R	

Table 7.1

9. Locate the chip marked D in Figure 18. What is this component's designator and function?

   A. Designator: _____

   B. Function: _____

10. Locate the chip marked R in Figure 18. What is this component's designator and function?

   A. Designator: _____

   B. Function: _____

Summary

In this experiment, you cross-referenced the function, identifier, part number, and physical location of the chips on the ESK board. You also learned that the chip designators are from left to right, and that the jack designators are related by function rather than by physical location (i.e., photodiodes are connected to jacks 1 through 4). You should now be able to identify the designator, the description, the type, and the location of the key components used on the ESK board.

Questions

1. What sensor is connected to jack 5?

   _____

2. Which adjustable component is used to set the operating point for the LM335?

   _____

3. Which chip is both linear and digital in its operation?

   _____

4. What is the function of the chip located beside the K1 relay?

5. Which chip or chips decode the address bus?

NOTES:

Experiment 7.2

Varying a DC Input Voltage

Overview

In this experiment, you convert a DC input voltage to a proportional value on the CRT. The A-to-D converter on the ESK board changes this voltage to a binary number. You use jack 5 on the mother board as a source for voltage, which you vary by using a potentiometer wired as a voltage divider. This variable voltage is applied to the jack 6 input connector of the ESK board (temperature-sense input). You can program either RB5X or RobotLab to respond to these decimal values. Thus, a specific DC level can trigger a specific robot response.

Tiny BASIC is too slow to effectively control the operation of the ESK board. This means you must use a machine-code subroutine to speed up any A-to-D conversion, using the LINK command in a Tiny BASIC program. This allows you to have the speed of the machine code when needed and the simplicity of Tiny BASIC when speed is not critical.

Objectives

Upon completion of this experiment, you will be able to:

1. Plot a graph of the returned decimal value versus the applied input DC voltage, and

2. Activate system-defined ports in response to specific applied DC voltages.

Prerequisites

1. Understanding of the system-defined ports and their addresses,

2. Understanding of the power-access points of jack 5 on the mother board,

3. Understanding of the bus-extender cable, and

4. Access to the following:
   A. Bus extender cable,
   B. Bread board,
   C. 1K ohm, 10-turn potentiometer,
   D. Jack 6 (ESK board) connector, and
   E. Digital voltmeter.

References

1. Mother board schematic in Appendix D, "RB5X Schematics."

2. Table 3.4 in Unit II, Chapter 3, "The RB5X System Bus."

Technical Information

The circuit you construct in this experiment supplies a variable DC input voltage, which is applied to pins 1 and 3 of jack 6 on the ESK board. Jack 6 is normally used as the temperature-sense input. Pin 1 of jack 6 connects to ground and pin 3 connects to input pin 9 of the 9708 A-to-D converter chip.

This input voltage is converted to a serial bit stream that is processed by the microprocessor, which then generates a decimal value that is proportional to the input DC voltage. The decimal value is stored as Tiny BASIC variable B. Since the input DC voltage is applied

to jack 6 of the ESK board, your Tiny BASIC program, to accept this input, must set Tiny BASIC variable A equal to 6. The following Tiny BASIC lines would display a decimal value for the DC voltage at jack 6:

```
A=6
LINK#2500
PRINT B
```

The program that activates the ESK board and places the decimal value into Tiny BASIC variable B must be in machine code and accessed using the LINK command. The machine-code subroutine used in this experiment needs to be loaded, using the POKE command, into memory starting at address #2500 and ending at address #254A.

Jack 5 of the mother board provides the +5 volts DC and ground, via the bus-extender cable and the bread board. This voltage will be applied to the ends of a 1K ohm, 10-turn potentiometer, and the wiper arm of the potentiometer will be connected to jack 6, pin 3 of the ESK board.

Procedure

1. Plug the bus-extender cable into jack 4 of the mother board.

2. Plug the ESK board into jack 2 on the mother board, with the component side toward the CPU board.

3. Construct the following circuit on your bread board.

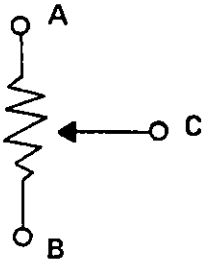


Figure 19

4. Connect circuit point A to the +5 volt wire on the bus extender.

5. Connect circuit point B to the ground wire on the bus extender.

6. Connect circuit point C to pin 3 of jack 6 on the ESK board, using a jack connector. **NOTE:** Be sure that the jack connector does not short to any other pins.

7. Connect a high-impendence voltmeter (digitial) between circuit points B and C. Be sure to observe proper polarity.

8. Set up the robot for Tiny BASIC.

9. Sweep the potentiometer to make sure that circuit point C varies from 0 volts to +5 volts. Set circuit point C to 0 volts. **NOTE:** The DC voltage at circuit point C (pin 3 of jack 6) is the voltage that the ESK board converts to a proportional decimal value.

10. Enter the following machine-code subroutine:

```
10 @#2500=#27:@#2501=#00:@#2502=#78
20 @#2503=#C4:@#2504=#A7
30 @#2505=#CB:@#2506=#0B
40 @#2507=#C4:@#2508=#09
50 @#2509=#CB:@#250A=#0B:@#250B=#C4
60 @#250C=#05:@#250D=#CB:@#250E=#08
70 @#250F=#C4:@#2510=#09:@#2511=#CB
80 @#2512=#0B:@#2513=#C2:@#2514=#00
90 @#2515=#DC:@#2516=#10:@#2517=#CB
100 @#2518=#08:@#2519=#E4:@#251A=#10
110 @#251B=#CB:@#251C=#08:@#251D=#08
120 @#251E=#84:@#251F=#00:@#2520=#05
130 @#2521=#BC:@#2522=#01:@#2523=#00
140 @#2524=#7C:@#2525=#FB:@#2526=#01
150 @#2527=#6C:@#2528=#03:@#2529=#01
160 @#252A=#74:@#252B=#F5:@#252C=#3A
170 @#252D=#DC:@#252E=#10:@#252F=#CB
180 @#2530=#08:@#2531=#84:@#2532=#00
190 @#2533=#00:@#2534=#B4:@#2535=#01
200 @#2536=#00:@#2537=#08:@#2538=#C3
210 @#2539=#09:@#253A=#D4:@#253B=#01
220 @#253C=#6C:@#253D=#09:@#253E=#C4
230 @#253F=#03:@#2540=#FC:@#2541=#01
240 @#2542=#7C:@#2543=#FC:@#2544=#3A
250 @#2545=#74:@#2546=#ED:@#2547=#3A
260 @#2548=#8A:@#2549=#02:@#254A=#5C
```

11. Check for errors and save this machine-code program on your diskette as ENVIR.MACH CODE.

12. Run the ENVIR.MACH CODE program. You have just loaded the

machine code into memory.

13. Type in NEW#1000<RET>, followed by NEW<RET>.

14. Type in the following Tiny BASIC program:

```
10 A=6:REM ACTIVATES JACK 6 OF ESK BOARD
20 LINK#2500:REM ACTIVATES THE MACHINE CODE
30 PRINT B:REM DISPLAYS DECIMAL VALUE
40 B=@#7800:IF B<>251 GOTO 10:REM PRESS BUMPER 1
TO STOP
50 STOP:REM STOP
```

15. Run the program. The CRT display should show a decimal value of approximately 2. Sweep the potentiometer through its range and note the correlation between the DC voltage and the returned decimal value.

16. Reset the potentiometer to 0 volts output and press bumper 1 on the robot to stop the program.

17. Set up a graph in the following format:

    A. Vertical axis - Decimal values in increments of 2, from 0 to 80.

    B. Horizontal axis - Voltage values in increments of .5 volts, from 0 volts to +5 volts.

18. Run the Tiny BASIC program.

19. Plot a graph of the voltage input versus the decimal value at .5 volt steps. **NOTE:** The graph between 0 and +3.5 volts should turn out to be linear.

20. Press bumper 1 on the robot to stop the program.

21. Add the following lines to the Tiny BASIC program so that an input voltage of 1 volt turns on the flashing LEDs for 1 second:

```
60 IF B=20 GOTO 70:REM CHECK FOR 1 VOLTS
70 @#7801=64:DELAY 1000:@#7801=0:REM FLASH FOR 1
SECOND
75 GOTO 40:REM BUMPER CHECK
```

22. Run and verify the program.

23. Modify this program so that 1.5 volts turns on a motor relay for one second. Record your program lines below.

_____

_____

_____

24. Run and verify your program lines.

25. Modify this program to also turn on the horn for one-half second if two volts is applied at the input. Record your lines below.

_____

_____

_____

26. Run and verify your expanded program.

Summary

In Experiment 7.2, you plotted a graph of the DC input voltage versus the returned decimal value in Tiny BASIC variable B. You observed that the minimum value is approximately 2 and that the maximum value is approximately 77. For voltages between 0 volts and 3.5 volts, the graph is linear. Any input voltage greater than approximately 4 volts returns a constant decimal value of approximately 77. Using the Tiny BASIC variable B, you are able to use a DC input voltage to activate specific output circuitry.

Questions

1. What does variable B equal when the input DC voltage is 2.75 volts?

_____

2. When variable B equals 47, what DC voltage would be applied to the input?

3. What is the lowest DC voltage that returns the maximum decimal value?

4. Write a Tiny BASIC program to turn the robot into a voltmeter with 1/2-volt resolution.

5. What two pins on mother board jack 5 have +5 volts?

NOTES:

CHAPTER 8

ENVIRONMENTAL SENSE KIT BOARD OPERATION

OVERVIEW

In Chapter 7, you learned how the ESK board with its A-to-D converter is capable of changing an input voltage into a binary value, which is converted to a decimal number and can be used with a Tiny BASIC command to control the actions of the robot.

The DC input voltage can be supplied from many sources. In the experiments at the end of this chapter, you use photodiodes, a temperature sensor, and a microphone to control the input voltage. These sources allow the robot to respond to light, temperature, and sound. This, in turn, allows you to interact with RB5X with more than just the bumper switches, the sonar, and the computer keyboard. The robot, with your software help, is better able to sense its environment and to respond to stimuli.

OBJECTIVES

Upon completion of this text material, you will understand how to:

1. Convert light intensity to decimal values;

2. Convert temperature to decimal values;

3. Convert sound intensity to decimal values; and

4. Use light, sound, and temperature to control the actions of the robot.

PREREQUISITES

1. Chapter 7, "Analog-to-Digital (A-to-D) Conversion."

2. Experiments 7.1, "ESK Component Identification," and 7.2, "Varying a DC Input Voltage."

REFERENCES

1. Appendix I, "Environmental Sense Kit Schematics."

TECHNICAL INFORMATION

The heart of the ESK board is the 9708 A-to-D converter. The 9708 has six analog inputs. A-to-D conversion is performed by a technique known as "ramping," which involves using the microprocessor to count how long it takes to charge a capacitor from a constant current source. The charge on the capacitor is compared to the analog-input voltage. When the two voltages are equal, the 9708 signals the microprocessor to stop counting. The decimal number displayed on the CRT is proportional to how high the microprocessor counted before it received the stop-count signal.

The microprocessor uses three address lines (A0 to A2) to determine which of the six analog inputs is selected (binary 001 through binary 110). The microprocessor also uses the rest of the address lines to signal the start of the sample count and to enable the tri-state buffer on the stop-output line.

The machine-code program loaded into memory beginning at #2500, along with the Tiny BASIC variable A, selects a specific analog-input signal. This machine-code program also assigns the microprocessor count to Tiny BASIC variable B. You can now either print this variable on the CRT (PRINT B) or you can have the robot respond to B (IF B<100 @#7801=128) with Tiny BASIC commands.

The photodiodes convert light to a weak, DC voltage. This weak voltage is amplified by the LM324 quad-operational amplifier chip. This

amplified DC voltage is wired to four input pins on the 9708 A-to-D converter.

The LM335 temperature sensor is a device that changes its resistance as a function of temperature. This sensor is used as a variable resistor in a voltage-divider network. The net result is that the DC output voltage changes as a function of temperature. The DC output voltage that corresponds to ambient temperature can be adjusted via resistor R1 on the ESK board. The variable DC voltage from the voltage-divider network is wired to an input pin of the 9708 chip.

The sound sensor is a dynamic microphone, the output of which is amplified and rectified with the LM10 and its associated circuit. The pulsating output of the LM10 is averaged using a resistor/capacitor (RC) network consisting of R3 and C4. This averaged DC voltage is wired to an input pin of the 9708. The sensitivity of the sound input can be controlled by adjusting resistor R6 on the ESK board. This board has output circuitry for controlling an optional solenoid and motor. (This optional circuitry is used in the following experiments, so we will not cover this area.)

The ESK board is accessed by using the ENVIR.MACH CODE machine-code program staring at address #2500 with the Tiny BASIC command LINK#2500. The Tiny BASIC variable A selects which analog input is converted; the converted output is stored in Tiny BASIC variable B.

The sensors are connected to the ESK board via jacks 1 through 6. The following table shows the relationship between the jack numbers and the sensors.

Jack	Sensor
1 through 6	Photodiodes (light)
5	Microphone (sound)
6	LM335 (temperature)

Table 8.1 - Sensor/Jack Connections

The sensor jacks can be accessed by assigning to variable A the jack number of the desired input. As an example, look at the following Tiny BASIC command:

```
A=6:LINK #2500:PRINT B
```

This command places the value of the temperature sensor into variable A and its value displays in decimal on the CRT.

You can program RB5X to respond to the value of variable B. As an example, the following program line turns on the horn when a light is shined on the photodiode plugged into jack 1:

```
A=1:LINK#2500:IF B>50 @37801=128
```

Two of the photodiodes are double diodes, which give the jacks into which they are plugged greater sensitivity to light than if a single diode were used. On RB5X, these two are generally used to monitor forward and rear light.

SUMMARY

The ESK board allows you to use light, sound, and temperature as Tiny BASIC variables, which can be used to control RB5X's actions. Tiny BASIC variable A is used to activate an input and Tiny BASIC variable B stores the ESK output. Photodiodes are used to monitor light, a microphone monitors sound, and the LM335 monitors temperature. These sensors connect to the ESK board via jacks 1 through 6. To activate an input, assign variable A to the jack number of the input sensor. The robot can PRINT variable B or it can respond to this variable.

QUESTIONS

1. What advantage is gained by using the double photodiodes instead of single photodiodes?

_____

2. The following program line activates which sensor?

```
A=6:LINK#2500:PRINT B
```

_____

3. What type of signal would you see on pin 15 of the 9708?

4. What are the consequences of moving the wiper on R6 up?

5. What type of circuit is formed by R1, R19, and the LM335?

NOTES:

Experiment 8.1

Converting Light to Computer Display

Overview

In this experiment, you convert a varying light intensity to a proportional value on the CRT. The A-to-D converter on the ESK board converts the light intensity to a binary number. You use jacks 1 through 4 on the ESK board as inputs for the light. Jacks 1 and 2 have two photodiodes in parallel, which increases their sensitivity to light. Jacks 3 and 4 are single units. The binary number from the ESK board is converted to a decimal value and displayed on the CRT. As we've already explained, Tiny BASIC is too slow to be used with the ESK. Therefore, you must use a machine-code routine to speed up the conversion and access it via the Tiny BASIC LINK command.

Objectives

Upon completion of this experiment, you will be able to:

1. Plot a graph of the displayed values versus distance from a light source,

2. Compare the photodiode sensitivity to different colored light sources, and

3. Determine the critical viewing angle of the photodiode.

Prerequisites

Have access to the following items:

1. A light source, such as a flash light;

2. A tape measurer; and

3. A protractor.

References

1. Appendix G, "Functions."

Technical Information

The photodiodes located at jacks 1 through4 on the ESK board are the same as the one on the robot's motor control board. This photodiode, along with the infrared LED on the motor control board, allows RB5X to locate reflective surfaces, such as a tape leading to the charger-nest. The photodiodes used in the ESK are most sensitive to the infrared end of the light spectrum. Fortunately, most light sources (incandescent lights, fires, etc.) emit some infrared along with the other light frequencies. This allows the photodiodes to detect the intensity of white light.

The photodiodes also have a critical viewing angle. This means that the face of the lens should be pointing directly at the light source for best reaction. As the lens moves away from a position where it views the light directly, the response decreases, especially beyond an angle of approximately 45 degrees.

The light-frequency sensitivity and the lens directivity are both demonstrated in this experiment. It should be obvious that the easiest way to vary the intensity of a light source is to move away from the source. The farther away, the lower the intensity. This experiment also demonstrates this sensitivity.

Procedure

1. Plug the ESK board into jack 2 of the mother board.

2. Connect the photodiodes to the jacks on the ESK board as follows:
   A. Double into jack 1
   B. Double into jack 2
   C. Single into jack 3
   D. Single into jack 4

3. Set up the robot for Tiny BASIC.

4. Call up and run the ENVIR.MAC CODE program that was used in Experiment 7.2.

5. Type NEW#1000<RET>, followed by NEW<RET>.

6. Type in the following Tiny BASIC program:

```
10 INPUT A:REM SELECTS INPUT DEVICE
20 LINK #2500:REM ACTIVATES MACHINE CODE
30 PRINT B:REM DISPLAYS DECIMAL VALUE
40 B=@#7800:IF B<>251 GOTO 20:REM CHECKS FOR
   BUMPER 1 PRESS
50 STOP
```

7. Run the program. The CRT shows a ?, asking you which photodiode jack you want to monitor.

8. Enter 1<RET> in response to the question mark. This accepts jack 1's photodiode signal as an input.

9. The readings displayed on the CRT are proportional to the ambient light level above the photodiode. Record the average reading here.

_____

10. Cover both of the photodiodes with your hand and record the value.

_____

(This is the lower limit of the range and should be less than 4.)

11. Move the photodiode close to a light source. Record this returned value.

_____

(This corresponds to the maximum value of the range, and should be equal to approximately 77.)

12. Plot a graph of the displayed value versus the distance of the photodiode from the light source. Use the following format.

    Horizontal axis: Distance from the photodiode to the light source in six-inch steps.
    Vertical axis: Returned decimal value from ambient value to maximum level. These values were found in Steps 9 and 11 above.

13. Press bumper 1 on the robot to stop the program. Input the value needed to read jack 3's photodiode.

14. Plot a graph of the single photodiode on the same graph paper as you did for the double photodiode in Step 12.

15. Stop the program by pressing bumper 1.

16. Enter the following POKE commands to turn on the LEDs. They test the photodiode sensitivity to different colored light sources.

```
@#7801=70
@#7802=1
```

17. Run the program and input the value necessary to activate jack 4's photodiode.

18. Hold the photodiode over each of the following activated LEDs and record the returned values.

LED Color	Returned Value
Green	_____
Yellow	_____
Amber	_____
Red	_____
Infrared	_____

19. Stop the program by pressing bumper 1.

20. Turn off the activated LEDs with the following POKE commands:

```
@#7801=0
@#7802=0
```

21. Lay out an angular displacement model using a protractor as illustrated below:

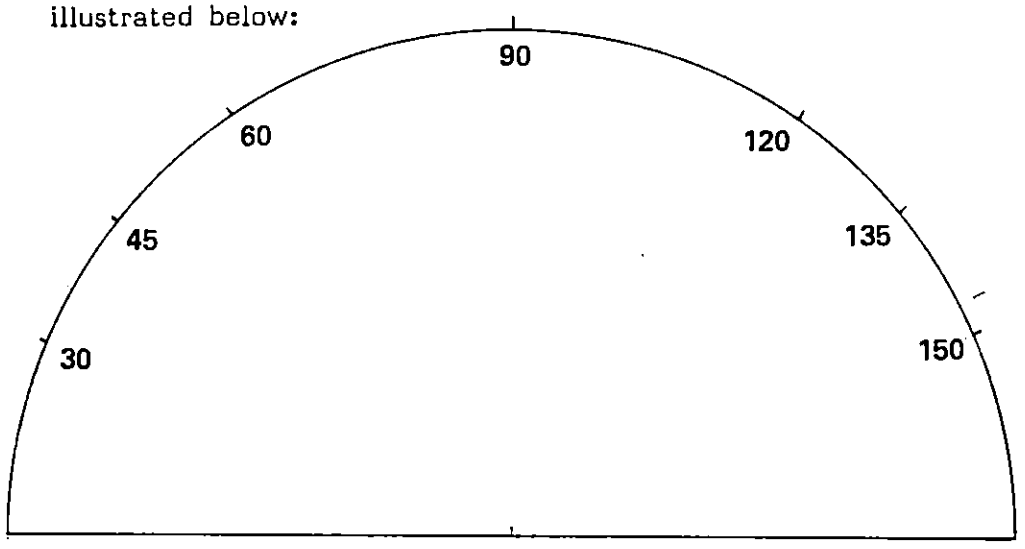


Figure 20

22. Set up the experimental area as shown below.

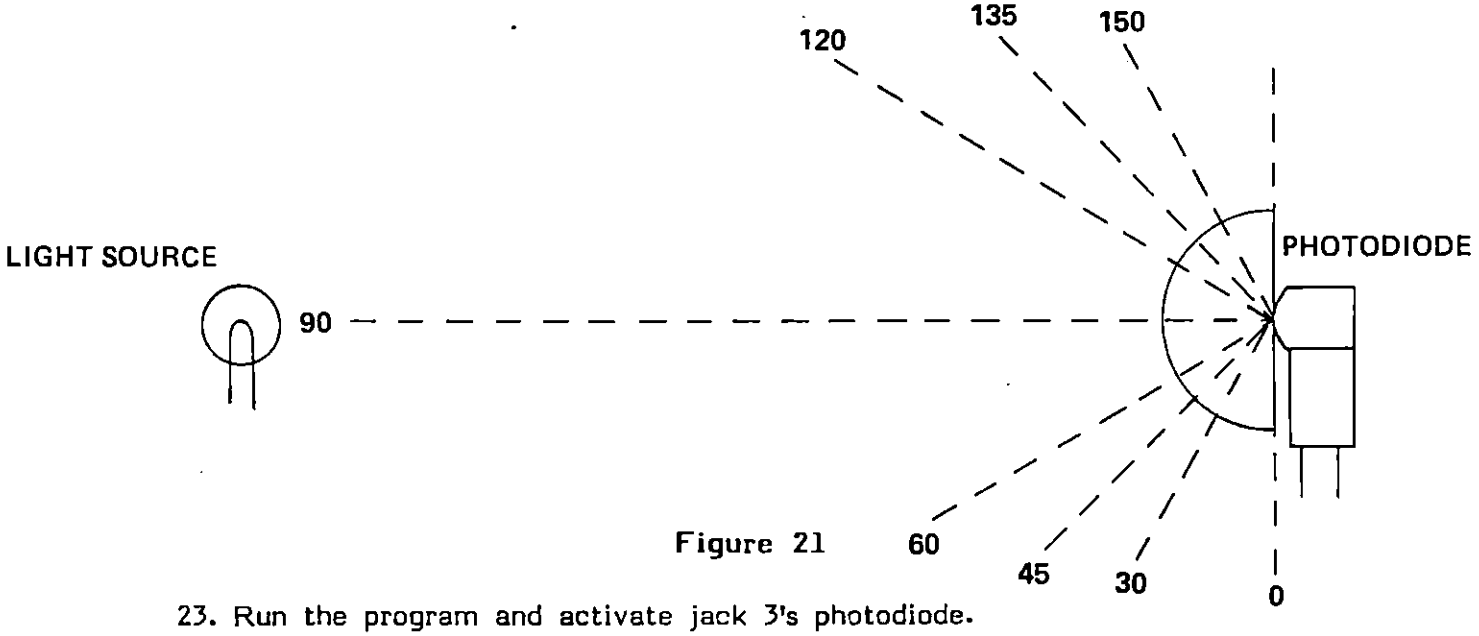


Figure 21

23. Run the program and activate jack 3's photodiode.

24. Starting with the lens of the photodiode pointing toward the zero degree angular point, complete Table 8.2.

Viewing Angle (In Degrees)	Returned Value
0	
30	
45	
60	
90	
120	
135	
150	
180	

Table 8.2

25. Plot a graph of the viewing angle versus the returned value in the following format.

    Horizontal axis: Viewing angle of 0 to 180 degrees.
    Vertical axis: Returned value from computer.

26. Stop the program.

Summary

In this experiment, you found that the returned values from the Tiny BASIC and machine-code programs are proportional to the intensity of the light reaching the photodiode. You should also have noted that the magnitude of the returned value is also dependent upon the color of the light to which the photodiode is exposed. The photodiode was most sensitive to the infrared end of the light spectrum. Another factor that effects this magnitude is the angular displacement between the light source and the detector.

Questions

1. How wide is the critical viewing angle of the photodiode?

2. At what maximum distance from the light source does the single photodiode return the maximum displayed value?

3. What is the Tiny BASIC variable that contains the returned decimal value from the machine code?

4. Record below the Tiny BASIC program line needed to activate ESK board jack 1.

5. Write a Tiny BASIC program to scan all of the photodiodes and to display their values separately.

NOTES:

Experiment 8.2

Converting Temperature to Computer Display

Overview

In this experiment, you convert temperature sensed by the LM335 into a proportional value on the CRT. The LM335 temperature sensor connects to jack 6 of the ESK board. Jack 6 has a rather limited range; specifically, between a high and a low temperature, there is only a small difference in the returned value displayed on the CRT.

Objectives

Upon completion of this experiment, you will be able to:

1. Obtain a returned value when the temperature sensor is cooled with "Freeze Spray" or some other Freon spray,

2. Obtain a returned value when the temperature sensor is heated with a soldering iron,

3. Obtain a returned value when the temperature sensor is at room temperature, and

4. Adjust the ESK board to establish the display center point for the temperature extremes.

Prerequisite

Have access to the following items:

1. "Freeze Spray" or other Freon spray.
2. Soldering iron.

References

1. Appendix I, "Environmental Sense Kit Schematic."

Technical Information

The ESK board uses the LM335 as an indicator of temperature extremes, not as a thermometer. This means that room-temperature changes of a few degrees do not cause the returned value to change. Only extremes in temperature (Freon spray, soldering iron, ice, etc.) cause significant changes in the returned values. This change probably does not show an increase or a decrease of more than 10 units from that shown at room temperature.

The temperature sensor operates in a rather narrow window, but the location of the window can be moved from approximately 77 to 52 by adjusting potentiometer R1 on the ESK board. A clockwise rotation of this potentiometer moves the readings up and a counterclockwise rotation lowers the readings.

Procedures

1. Plug the ESK board into jack 2 of the mother board.
2. Connect the LM335 temperature sensor to jack 6 on the ESK board.
3. Set up the robot for Tiny BASIC.
4. Call up and run the ENVIR.MACH CODE program that was used in Experiment 7.2.
5. Type NEW#1000<RET> followed by NEW<RET>.
6. Type in the following Tiny BASIC program:

```
10 A=6:REM SELECTS TEMPERATURE SENSOR INPUT
```

```
20 LINK #2500:REM ACTIVATES MACHINE CODE
30 PRINT B:REM DISPLAYS DECIMAL VALUE
40 B=@#7800:IF B<>251 GOTO 20:REM CHECKS FOR
   BUMPER 1 PRESS
50 STOP
```

7. Run the program. The CRT shows a decimal value that is proportional to the temperature sensed by the LM335 and the settings of potentiometer R1.

8. Adjust potentiometer R1 to the maximum clockwise setting. Record this value. _____

9. Adjust potentiometer R1 to the maximum counterclockwise setting. Record this value. _____

10. Adjust R1 for a returned value midway between the extremes of the values recorded in Steps 8 and 9 above. Record this value.

    _____

11. Cool the LM335 with Freon spray. Record this value. _____

12. Heat the LM335 with a hot soldering iron. Record this value.

    _____

13. Stop the program.

Summary

In the preceding experiment, you observed that the returned value from the Tiny BASIC and machine-code program is proportional to the temperature of the LM335 temperature sensor. The specific returned value at room temperature can be changed by adjusting potentiometer R1 on the ESK board. The maximum returned value at any setting is approximately 77.

Questions

1. What is the difference in the returned values between room temperature and body temperature?

   _____

2. With R1 set fully counterclockwise and the LM335 cooled with Freon spray, what is the difference between room temperature and the cooled value?

3. With R1 set fully clockwise and the LM335 heated with a soldering iron, what is the difference between the room temperature value and the heated value?

4. What is the returned value with the LM335 disconnected?

5. What happens to the machine-code program in RAM when you press the software reset button during program execution?

Experiment 8.3

Converting Sound to Computer Display

Overview

This experiment demonstrates the ESK's ability to convert sound intensity to a proportional CRT display value. The microphone connects to jack 5 of the ESK board. You can compare the values returned from the room's background noise, a loud shout, and the robot's horn.

Please note that, because of the sampling characteristics of the ESK, the returned values fluctuate considerably even when the sound level appears constant.

Objectives

Upon completion of this experiment, you will be able to:

1. Compare the displayed values when the sound level is:
   A. Background noise,
   B. A loud shout, or
   C. RB5X's horn.

2. Change the sensitivity of the microphone by adjusting R6 on the ESK board.

Prerequisites

None.

References

1. Appendix I, "Environmental Sense Kit Schematic."

Technical Information

The ESK uses a dynamic microphone as a sound-level sensor. The AC signal from the microphone is amplified and rectified by the LM10, which operates by a single-polarity power supply. As a result of this single-polarity operation, the LM10 provides a pulsating DC output (rectified), which is averaged by the RC network composed of R3 and C4. This averaging tends to make the pulsating DC have fewer fluctuation extremes. These fluctuations are readily noticable by observing the CRT for seemingly constant levels of sound inputs.

The range of the returned values is from 1 to 77. By adjusting R6 on the ESK board, you are able to set the sensitivity, and hence the displayed value for any sound level input. Turning the potentiometer clockwise increases the sensitivity and counterclockwise decreases the sensitivity. The robot's horn serves as a relatively constant sound-level source, and is activated by loading @#7801=128 and is deactivated by loading @#7801=0.

Procedure

1. Plug the ESK board into jack 2 of the mother board.

2. Connect the microphone to jack 5 of the ESK board.

3. Set up the robot for Tiny BASIC.

4. Call up and run the ENVIR.MACH CODE program, which was used in Experiment 7.2.

5. Type NEW#1000<RET> followed by NEW<RET>.

6. Enter the following Tiny BASIC program:

```
10 A=5:REM SELECTS MICROPHONE INPUT
20 LINK #2500:REM ACTIVATES MACHINE CODE
30 PRINT B:REM DISPLAYS DECIMAL VALUE
40 C=@#7800:REM CHECKS FOR BUMPER 1 PRESS
50 IF C=254 @#7801=128:REM BUMPER 2 SWITCHES HORN
   ON
60 IF C=247 @#7801=0:REM BUMPER 3 SWITCHES HORN
   OFF
70 IF C<>251 GOTO 10:REM BUMPER 1 TO STOP
80 STOP
```

7. Run the program. The CRT shows a decimal value, which is proportional to the background noise of the room. Record the average of the displayed values. _____

8. Adjust the sensitivity control (R6) to the full clockwise setting.

9. Press bumper 2 on the robot to activate the horn and hold the microphone directly in front of the horn. Record the average of the displayed values. _____

10. Stop the horn by pressing bumper 3.

11. Adjust the sensitivity control to the full counterclockwise setting.

12. Activate the horn and again hold the microphone directly in front of the horn. Record the average of the displayed values.

_____

13. Stop the horn by pressing bumper 3.

14. Adjust the sensitivity control five, full clockwise turns from its bottom setting. This sets its sensitivity at approximately mid-range.

15. Activate the horn and hold the microphone in front of the horn. Record the average of the displayed values.

_____

16. Deactivate the horn.

17. Talk into the microphone and note how loud you must talk to equal the levels obtained in Step 15.

18. Adjust the sensitivity control to its most sensitive setting (full clockwise) and repeat Step 17.

19. Stop the program by pressing bumper 1.

Summary

In the preceding experiment, you observed that the returned value on the CRT is proportional to the sound level and the setting of the sensitivity control. Clockwise rotation of this control increases the sensitivity and counterclockwise rotation decreases the sensitivity. You should have noted that even for seemingly constant sound levels, the returned values are not constant because of the fluctuating level of the output of the LM310 amplifier.

Questions

1. What is the maximum value that can be returned to the CRT?

2. What is the returned value with the microphone disconnected?

3. With the Tiny BASIC program of Step 6 running and the horn activated, what happens when bumper 1 is pressed?

4. Change the Tiny BASIC program used in Step 6 so that bumper 6 turns on the horn, bumper 4 stops the horn, and bumper 7 stops the program.

5. If the following program is entered and run on the robot, list the steps needed to stop program execution:

```
10 A=5
20 LINK #2500
30 PRINT "TALK INTO THE MICROPHONE"
40 IF B>23 GOTO 60
50 GOTO 10
60 PRINT"":PRINT"":PRINT"":PRINT"PRESS BUMPERS 2 AND
   4"
70 LINK #85A1
80 STOP
```

NOTES:

Experiment 8.4

RB5X's Response to ESK Board Signals

Overview

In this experiment, you use the inputs to the ESK board to control RB5X's actions. The photodiodes are used to find a light source and the robot moves toward that light. When the robot gets close to the light, it stops and sounds its horn. You signal RB5X to begin moving by speaking to it; you temporarily halt RB5X's action by holding the temperature sensor between your fingers. To get the robot moving again, speak to it. To end program execution, press bumper 5.

Be sure to capitalize on the delayed start in the program to disconnect the RS-232 cable from the robot.

Objectives

Upon completion of this experiment, you will be able to:

1. Use the photodiodes to control the actions of the robot,
2. Use the temperature sensor to control the actions of the robot, and
3. Use the microphone to control the actions of the robot.

Prerequisites

1. Completion of Experiments 8.1, "Converting Light to Computer Display;" 8.2., "Converting Temperature to Computer Display;" and 8.3, "Converting Sound to Computer Display."

References

1. Appendix G, "Functions."

2. Appendix H, "Motor Codes and Relay/Motion Assignment."

3. Appendix I, "Environmental Sense Kit Schematic."

Technical Information

To do this experiment, you should connect the ESK sensors to the ESK board as follows:

Jack Number	Sensor
1	Double photodiode
2	Double photodiode
3	Single photodiode
4	Single photodiode
5	Microphone
6	Temperature sensor

The ESK board goes in jack 1 on the mother board. For this experiment, the sensors can be easily and temporarily mounted to the LED plate using tape. Make sure they all point outward.

You will need to determine background levels for the temperature sensor and the microphone in order to establish reference levels for comparison in the Tiny BASIC program.

Procedure

1. Carefully -- but firmly -- seat the ESK board in jack 1 on the robot's mother board. Replace the LED plate, which you removed to insert the board, but leave the upper shell/dome assembly off for this experiment.

2. Temporarily affix the ESK sensors to the LED plate in the

following order:

Jack	Sensor	Location
1	Double photodiode	Front
2	Double photodiode	Rear
3	Single photodiode	Left side
4	Single photodiode	Right side
5	Microphone	Front
6	Temperature sensor	Rear

Make sure all of the sensors point outward.

3. Connect the RS-232 cable to Port 1 on RB5X's interface panel.

4. Make sure that the utility software module is in its socket.

5. Set up the robot for Tiny BASIC.

6. Run the ENVIR.MACH CODE program that was used in Experiment 7.2.

7. Type NEW#1000<RET> followed by NEW<RET>.

8. Execute the following direct command and record its value as the background level for the microphone:

```
A=5:LINK#2500:PRINT B
```

Microphone background = _____

9. Execute the following direct command and record its value as the background level for the temperature sensor:

```
A=6:LINK#2500:PRINT B
```

Temperature background = _____

10. Enter the following Tiny BASIC program and call it FLASHDANCE:

```
 5 REM FLASHDANCE PROGRAM
10 A=5:LINK#2500:REM GETS MICROPHONE VALUE
20 IF B<M GOTO 10:REM ENTER VALUE FROM STEP 8 AS
    M:REM IF SOUND =>M BEGIN
30 A=6:LINK#2500:Q=B:REM GETS TEMP. VALUE
```

```
 40 FOR I=1 TO 3:@#7801=64:DELAY 1000:REM START OF
    FLASH SEQUENCE
 50 @#7801=192:DELAY250:@#7801=0:DELAY250:NEXT I
 60 @#7801=128:DELAY250:@#7801=0:DELAY250
 70 @#7801=128:DELAY250:237801=0:REM END OF FLASH
    SEQUENCE
100 IF Q>T GOTO 10:REM ENTER VALUE FROM STEP 9
    AS T:REM HALT DUE TO TEMP INCREASE
110 C=@#7800:IF C<>251 GOTO 30:REM BUMPER 5 TO
    STOP
120 STOP
```

11. Run this program.

12. Speak to the robot to start the routine. Note the lights and sound when started.

13. Hold the temperature sensor until the routine stops. (Due to the thermo-mass of the temperature sensor, this may take several seconds.)

14. Repeat Step 12 and then press bumper 5 to stop the program.

15. Enter the following Tiny BASIC program and call it LIGHTCHASER:

```
  5 REM LIGHTCHASER PROGRAM
 10 A=5:LINK#2500:REM GET MIKE VALUE
 20 IF B<M GOTO 10:REM ENTER THE VALUE FROM STEP
    8 AS M:REM SOUND =>M BEGIN
 30 A=1:LINK#2500:W=B:REM GET FRONT PHOTODIODE
    VALUE AND ASSIGN VALUE TO W
 40 A=2:LINK#2500:X=B:REM GET REAR PHOTODIODE
    VALUE AND ASSIGN VALUE TO X
 50 A=3:LINK#2500:Y=B:REM GET LEFT PHOTODIODE
    VALUE AND ASSIGN VALUE TO Y
 60 A=4:LINK#2500:Z=B:REM GET RIGHT PHOTODIODE
    VALUE AND ASSIGN VALUE TO Z
 70 A=6:LINK#2500:Q=B:REM GET TEMP VALUE AND
    ASSIGN VALUE TO Q
 80 IF Q>T GOT 10:REM ENTER VALUE FROM STEP 9 AS
    T:REM HALT WITH TEMP INCREASE
 90 IF Y>W @#7802=10:DELAY 500:@#7802=0:REM IF LEFT
    BRIGHTER THAN FRONT, TURN CCW
100 IF Z>W @#7802=5:DELAY 500:@#7802=0:REM IF RIGHT
    BRIGHTER THAN FRONT, TURN CW
120 IF W>77 @#7801=128:DELAY250:@#7801=0:GOTO 30:REM
    IF LIGHT IN FRONT = MAX, THEN SOUND HORN
```

```
130 C=@#7800:IF C=239 STOP:REM HOLD BUMPER 5 TO
    STOP
140 STOP
```

16. Run the program.

17. Gently unplug the RS-232 cable from the robot.

18. Speak to the robot to begin the action.

19. With a light source (such as a flashlight or a lamp), play with RB5X, which chases the light around the room.

20. Hold the temperature sensor between your fingers to stop the robot; speak to restart it.

21. Press bumper 5 to stop program execution.

Summary

In this experiment, you learned ways to use light, sound, and temperature to control RB5X's actions. As you can see, these new sensors, when used in conjunction with the robot's standard sonar and bumpers, give RB5X great versatility in responding to outside stimuli.

Questions

1. Why should Q in the LIGHTCHASER program in Step 15 not be set to the ambient +2 value?

2. Why are no print statements used in the LIGHTCHASER program?

3. What program lines in the LIGHTCHASER program give you time to disconnect the RS-232 cable from the robot?

4. List the steps needed to seat the ESK board into the proper slot on RB5X's mother board.

5. Why should the sensors be connected to the ESK board prior to your seating the card in its slot on the mother board?