

# ELECTRONIC INSTRUMENTATION AND SYSTEMS LABORATORY

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

MICHIGAN STATE UNIVERSITY

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- I. **TITLE:** Lab IX - Light Activated Exhaust Fan
- II. **PURPOSE:** One use of bipolar junction transistors (BJTs) is to switch circuits on and off. Switching various loads on or off can cause problems especially when the load is inductive. Sometimes the load contains a large amount of energy and isolating this from the control circuitry is very important especially in the case of a component failure. Sensors play a role in many electronic circuits. In this lab we will use a light sensitive resistor to sense a smoke filled room and turn on an exhaust fan. When the room is again clear of smoke it will turn off the fan. This type of photo-resistor is also used in auto-focus cameras, street lamp switches and contrast controls for TVs.

The concepts covered are:

1. the bipolar logic inverter;
2. switching resistive and inductive loads;
3. using a damping diode to discharge a coil;
4. using a relay for load isolation;
5. using a photo-resistor as a sensor;
6. using a magnet to activate a circuit.

The laboratory techniques covered are:

1. Using a x10 probe to measure a BJT's breakdown voltage;

III. **BACKGROUND MATERIAL:**

See Lab Lecture Notes.

IV. **EQUIPMENT REQUIRED:**

- 1 HP Infinium Oscilloscope
- 1 Fluke 8840A Digital Multimeter
- 1 HP33120A Function Generator / Arbitrary Waveform Generator
- 1 HP6216C DC Power Supply
- 1 BK 1680 Precision DC Power Supply (13.8 V)
- 2 HP2260A 10:1 Miniature Passive Probes

## V. PARTS REQUIRED:

- 1 PB-104 Proto-Board
- 1 BNC-to-Banana adapter
- 1 Exhaust fan
- 1 Reed relay
- 1 Magnet
- 1 CdS (Cadmium Sulfide) photocell mounted on a gray block
- 1 Green LED
- 1 Red LED
- 1  $470\ \Omega \pm 5\%$  (Yellow-Violet-Brown-Gold) resistor
- 2  $1\ \text{k}\Omega \pm 5\%$  (Brown-Black-Red-Gold) resistor
- 2  $10\ \text{k}\Omega \pm 5\%$  (Brown-Black-Orange-Gold) resistor
- 1  $10\ \text{k}\Omega$  potentiometer
- 1  $.1\ \mu\text{F} \pm 10\%$  polyester (glossy green stamped 104K) capacitor
- 1 1N4002 diode
- 2 2N3904 NPN transistors

## VI. LABORATORY PROCEDURE

### A) Inverter

1. Set one of your power HP power supplies to a 50 mA limit and a voltage value of 10 V. ***Please make sure that the negative terminal of the power supply is shorted to the ground terminal.*** Measure the voltage with the DMM and re-adjust the voltage as close to 10 V as possible. Turn **OFF** the supply.

***If you built the circuit last week on the Proto-Board, you must allow your partner to do it this week no matter how long it takes.*** Indicate who will be building the circuits this week in your Lab Report. Your lab instructor is keeping a record of this. If you fail to alternate building the circuits with your partner as indicated in the lab, your lab report will not be accepted and you will receive a grade of 0 for that lab.

2. This week we are going to have you and your partner layout the test circuits.
3. Using the 2N3904 pinout of Fig. 1, construct the logic inverter also shown in Fig. 1 in about the center of the Proto-Board so that we can leave room for the next sections' circuits.

Follow the general layout procedure where the +Power Supply is connected to a bus strip of the Proto-Board and likewise for the ground.

Put a  $0.1\ \mu\text{F}$  bypass capacitor from the +10 V bus strip to ground on the Proto-Board to prevent oscillations due to long wires.

4. Have your lab partner check the wiring on the Proto-Board.
5. If you are unsure about any connections, ask your lab instructor to also inspect this for you because errors in wiring can permanently damage the Proto-Board.

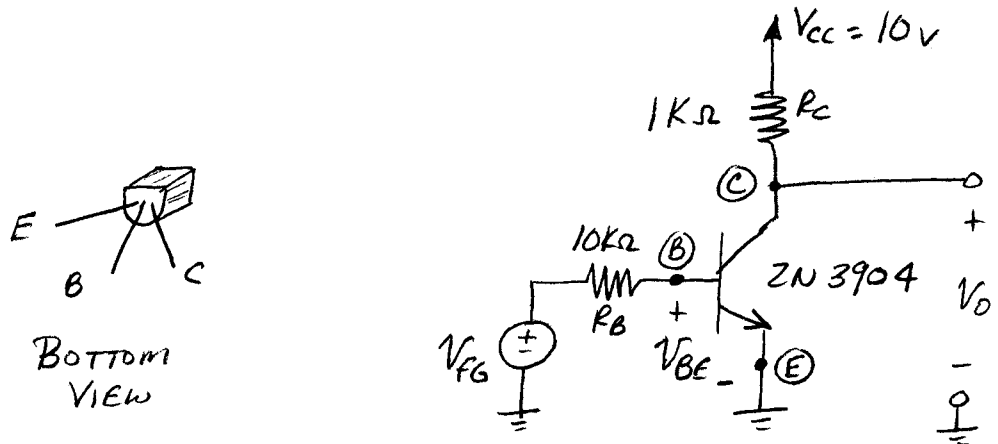


Figure 1. 2N3904 pinout and logic inverter.

6. Turn on the oscilloscope. Press the **Default Setup** button to clear the settings of the last user. If not already present, connect two 10:1 probes to your scope. One for channel ① and one for channel ②.
7. We are about to apply power to our circuit. ALWAYS WATCH THE VOLTAGE WHEN FIRST TURNING ON THE POWER SUPPLY. If it dips from its prescribed setting of 10 V, quickly turn off the power supply. Something is seriously wrong.

Turn on the power supply. If the voltage dips quickly turn off the supply and ask your instructor for help. If this is not the case continue on.

8. Turn on the function generator. Again watch for any dips in voltage of the power supply. Set the termination to **HIGH Z**.

[Recall from Lab II:

Press the Blue **Shift** button, followed by pressing the **Enter** button just above the Shift button. **A: MOD MENU** should appear on the display. Pressing the > button once should cause **B: SWP MENU** to appear. Pressing the > button again should cause **C: EDIT MENU** to appear. Pressing the > button again should cause **D: SYS MENU** to appear. We can go down into this menu by pressing the ∨ button which will cause **1: OUT TERM** to appear. Pressing the ∨ again will cause **50 OHM** to appear.

Pressing > will finally cause **HIGH Z** to appear. To pick this option all we need to do is to press the **Enter** button again. This resetting of the high resistance termination option will remain in effect until we turn off the function generator. So please do not turn off the function generator until instructed to do so. ]

9. Set the function generator to a 10 Vp-p **squarewave** at a frequency to 1.00 kHz. Next press the **Offset** button and set the value to 5 V. Again watch for any dips in the the power supply.
10. Display  $V_{FG}$  and  $V_{OI}$  on the scope. Press the **Auto-Scale** button on the scope and then press the **Trigger Coupling** button until **HF Reject** is lit. Enable averaging if not already done so. This is under the title bar **Setup, Acquisition, Averaging, Enabled, # of Averages - 16** (or 64 if needed). Readjust the scope settings if necessary so that  $V_{OI}$  is displayed in the lower half of the screen with its ground reference one division from the bottom of the screen and so that  $V_{FG}$  is displayed in the upper half of the screen with its ground reference one division from the center of the screen. Set the time base to 200  $\mu\text{s}/\text{div}$  if necessary. Measure  $V_{OI(MAX)}$  and  $V_{OI(MIN)}$  and record. Measure  $V_{FG(MAX)}$  and record.

Print a copy of these waveforms for each member of the lab group. Label the section number on top, label which waveform is which and attach as indicated the Lab Report.

11. Repeat VI-A-10 for  $V_{BE}$  and  $V_{OI}$
  12. Turn off the power supply and disconnect the wires from the function generator.
- B) Switching an Inductive Load
1. Make sure that the power supply is off and function generator is disconnected.

**CAUTION:** You are about to use the BK Precision DC Power Supply (Model 1680). This black box has a fixed voltage of 13.8 V and can supply a current up to 3 Amps. The supply is turned ON by pressing the red dot on the rocker switch. The green LED will then light. Follow the directions below carefully.

With the BK Precision DC Power Supply (Model 1680) **OFF**, use a banana wires to connect this supply to the proto-board. Please check that the ground of the proto-board is connected to the black terminal of the BK Precision power supply. Double check that all power supplies are **OFF** and build the circuit as shown in Fig. 3 using the remaining parts still assembled from your inverter. The pinout for the reed relay and

LEDs is shown in Fig. 2.

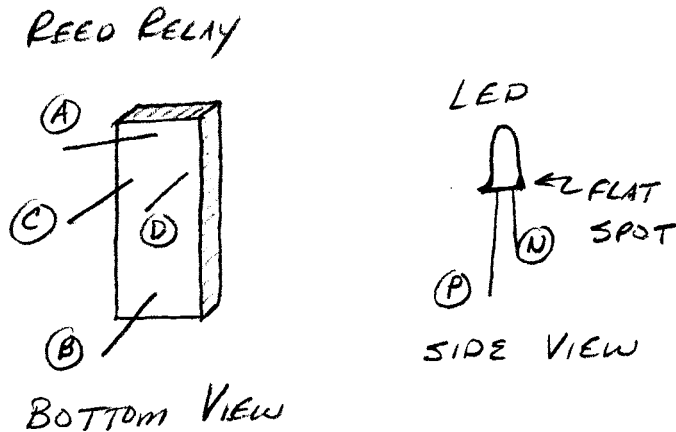


Figure 2. Pinout of the reed relay and the LEDs

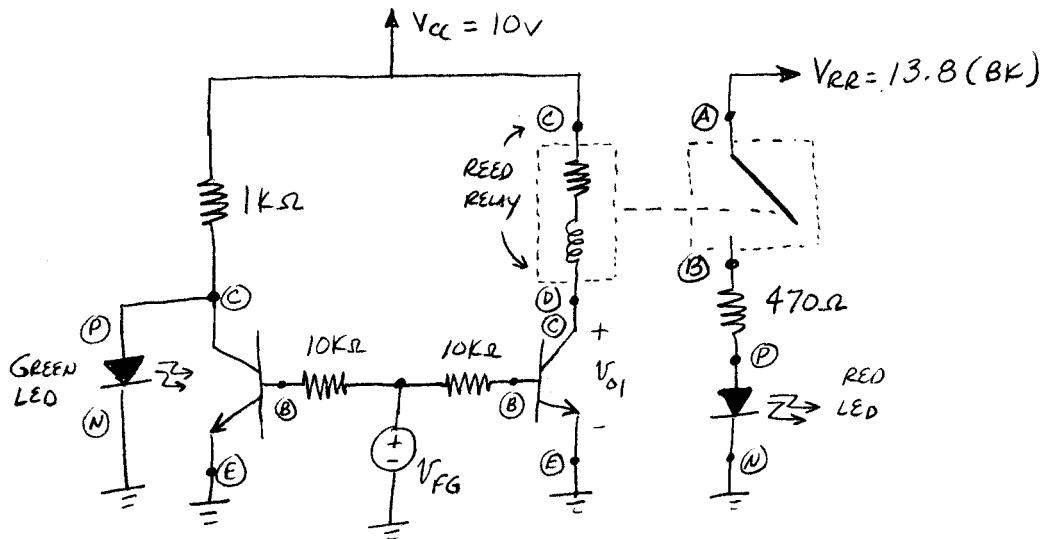


Figure 3. Two inverters and relay circuit

2. Turn ON both power supplies and reconnect the function generator. Watch for dips in the HP power supply meter. (If the BK Precision supply's green light does not come on, there is something seriously wrong. Turn OFF the supply and ask your instructor for help.)

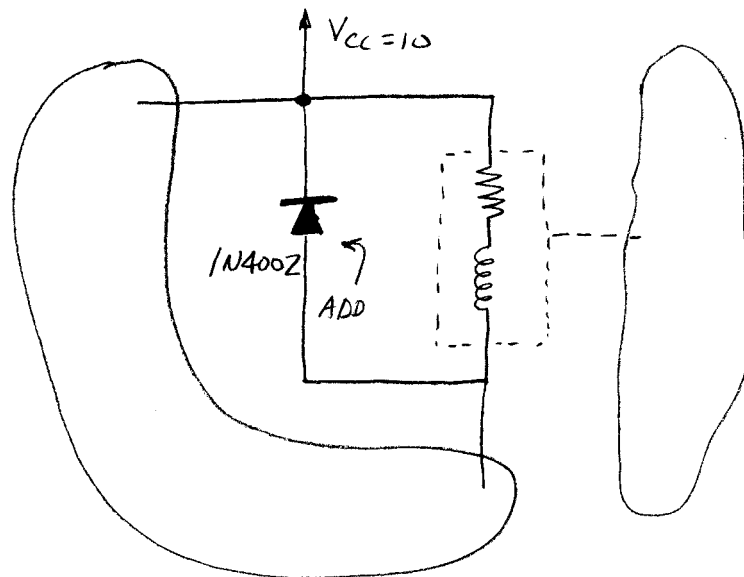
You should hear a "whining" from the relay since you are opening and closing it 1000 times per second.

Display  $V_{FG}$  and  $V_{OI}$  on the scope using your scope probes. Press the **Auto-Scale** button on the scope and then press the **Trigger Coupling** button until **HF Reject** is lit. Readjust the scope settings if necessary so that  $V_{OI}$  is displayed in the lower half of the screen with its ground reference one division from the bottom of the screen and so that  $V_{FG}$  is displayed in the upper half of the screen with its ground reference one division from the center of the screen. Set the time base to 200  $\mu\text{s}/\text{div}$  if necessary.

Disable the averaging function (You can do this with a right mouse click and select averaging in the dialog box). Using the tool bar, measure  $V_{OI(MAX)}$ . You may see the maximum jumping all over the screen. The tool bar measurement will record the range of values it captures. Record the maximum value measured in all of the sampling. This is the breakdown voltage of your BJT and is referred to as  $BV_{CEO}$  in transistor data sheets.

Try to play with the **Stop** feature to display the largest spike at  $V_{OI}$  that you can capture. Print a copy of these waveforms for each member of the lab group. Label the section number on top, label which waveform is which and attach as indicated in your Lab Report.

3. Disconnect the function generator to stop the switching of the relay coil. Add a 1N4002 diode across the relay coil as shown in Fig. 4. Your lab instructor should verify that this is done correctly and sign off in Section VI-B-3 before you proceed. If you fail to do this, you will receive a grade of 0 for this lab and be asked to leave.



**Figure 4.** Adding a damping diode

4. Reconnect the function generator again to start the switching of the relay coil. Again watch for any voltage dips. Display  $V_{FG}$  in the upper half of the screen and  $V_{OI}$  in the lower half of the screen. Readjust the scope settings if necessary to 5 V/div for both channels as well as 200  $\mu$ s/div for the time base. Measure and record  $V_{OI(MAX)}$ .

Print a copy of these waveforms for each member of the lab group. Label the section number on top, label which waveform is which and attach as indicated in your report.

5. Explain what has happened.
6. Lower the frequency of the function generator to 1 Hz. Explain what is happening with the LEDs.

### C) Adding a Light Sensor Activation

1. Obtain a CdS (Cadmium Sulfide) photocell mounted on a gray block. Using the DMM, measure and record the resistance with the device pointing at the room lights and with your hand blocking the light.
2. Turn **OFF** both the power supply and disconnect the function generator. Replace the function generator shown in Fig. 3 with a voltage divider formed with a resistor / pot and the CdS photocell as shown in Fig. 5.

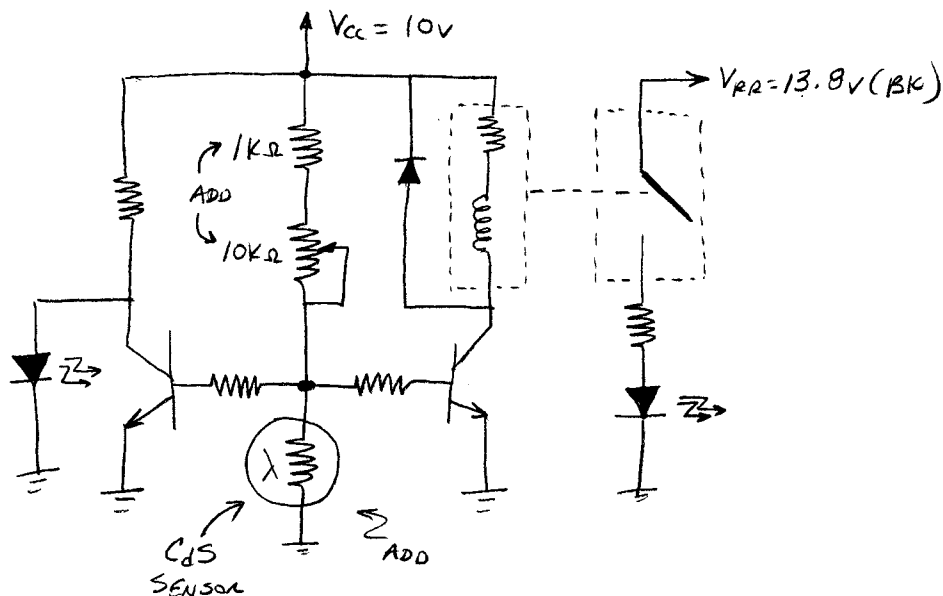


Figure 5. CdS photocell sensor

3. Turn **ON** the power supply. Again watch for any dips in voltage. Adjust the pot so that only the Green LED is on when you expose the CdS photocell to room light and only the Red LED is on when you cover (but do not touch) the CdS photocell with your hand. Measure and record the value of the voltage across the CdS photocell under these two conditions using the Fluke digital voltmeter
4. Explain in your own words what is happening.

D) Adding an Exhaust Fan

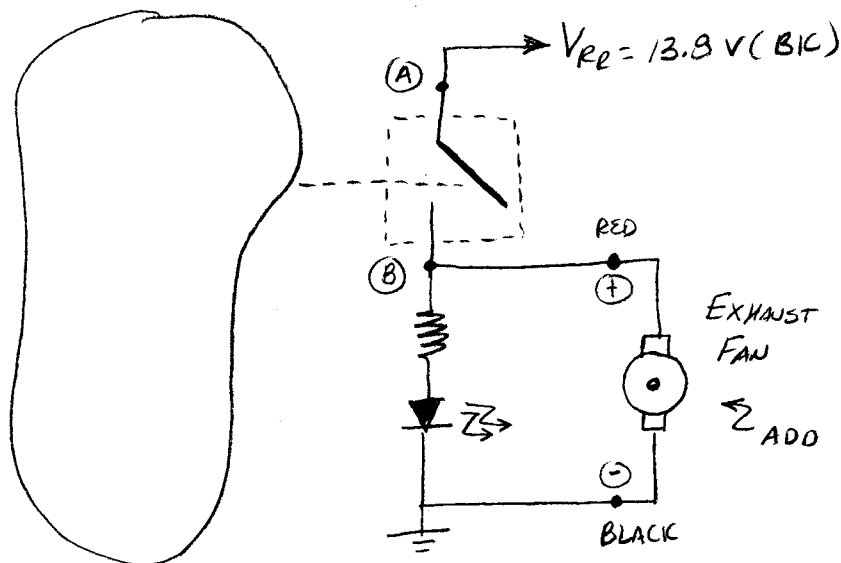
1. Turn **OFF** the power supply

- 2.

**CAUTION:** You are about to connect a very powerful fan. Keep your fingers out of the blades at all times. Follow the directions below carefully.

Locate the exhaust fan on your lab bench. Double check that your power supply is **OFF**. Connect the terminals of the fan as shown in Fig. 6.

***DO NOT TURN ON YOUR POWER SUPPLY UNTIL YOUR LAB INSTRUCTOR HAS VERIFIED THE CONNECTIONS AND SIGNED OFF IN YOUR LAB REPORTS.***



**Figure 6.** Adding an exhaust fan

3. With your instructor still present, turn **ON** the power supplies. The fan should be not be running. (If anything goes wrong turn off the supply.) Cover the CdS photocell with your hand simulating a smoke filled room. What has happened to the exhaust fan?

Remove your hand and allow light to reach the CdS photocell.

4. Ask your lab instructor for a magnet, if one is not on your lab bench. Pass the magnet near but do not touch the relay. Your fan should at some point come on. Can you explain what has happened?
5. Turn **OFF** the power supply and disconnect the wires / connectors to your Proto-Board. Leave the probes attached to the scope and return all cables (but not your probes) to the appropriate racks and submit your Lab Report. Disassemble your circuit. Put your remaining parts back into the parts box. Return wires to the other clear box. Brush the surface of your lab bench clean. Turn **OFF** the DMM and scope.

# Lab Report

## Lab IX - Light Activated Exhaust Fan

Name: .....

Partner: .....

Date: .....

Lab Section Number .....

### Code of Ethics Declaration

All of the attached work was performed by our lab group as listed above. We did not obtain any information or data from any other group in this lab or any other lab section.

Signature .....

VI-A-1

\_\_\_\_\_ is constructing this week's circuits.

VI-A-10

$$V_{OI(MAX)} = \text{_____} = V_{CC}$$

$$V_{OI(MIN)} = \text{_____} = V_{CE(SAT)}$$

$$V_{FG(MAX)} = \text{_____}$$

Mark VI-A-10 on the top right side of your plot and attach as the next page.

VI-A-11

$$V_{BE(MAX)} = \text{_____} = V_{BE(ON)}$$

Mark VI-A-11 on the top right side of your plot and attach behind VI-A-10.

VI-B-2

$$V_{OI(MAX)} = \text{_____} = BV_{CEO}$$

Mark VI-B-2 on the top right side of your plot and attach behind VI-A-11.

VI-B-3

I \_\_\_\_\_ (Lab instructor's initials) verify that Fig. 5 is wired correctly.

VI-B-4

$$V_{OI(MAX)} = \text{_____}$$

Mark VI-B-4 on the top right side of your plot and attach behind VI-B-2.

VI-B-5

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VI-B-6

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VI-C-1

$$R_{\text{CdS (LIGHT)}} = \underline{\hspace{2cm}}$$

$$R_{\text{CdS (DARK)}} = \underline{\hspace{2cm}}$$

VI-C-3

$$V_{\text{CdS (LIGHT)}} = \underline{\hspace{2cm}}$$

$$V_{\text{CdS (DARK)}} = \underline{\hspace{2cm}}$$

VI-C-4

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VI-D-2

I, \_\_\_\_\_ (lab instructor's signature), verify that  
the exhaust fan is correctly connected.

VI-D-3

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VI-D-4

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