Design a Logic Probe

Experiment 20
Design Specifications

Design a logic probe as shown in the block diagram of Figure 1 of Experiment 20 with a signal input lead, a ground lead, and a power input lead.

The logic probe should have three output LEDs. Only one LED at a time should light when the input is a steady DC level between zero and +5 V.

- LED 1 should light when the input voltage is below 0.8 V.
- LED 2 should light (a) when the input is open (floating) or (b) when the input voltage is between 0.8 and 2.2 V.
- LED 3 should light when the input voltage is above 2.2 V.
  - All voltage levels have a tolerance of approximately ±12%.

Your design should use only one LM324 chip. You may use all four of the LM324's op amps. No extra credit will be awarded.

You may use either the +5 or +9V ANDY board supply or a DC voltage supplied by the Velleman function generator.
+9V supply may be replaced with a +5V supply from the ANDY board or a DC voltage from the Velleman function generator.

Figure 1: Block diagram of a logic probe
Light Emitting Diode (LED)

• A nonlinear component that ‘looks’ like a battery when it is on and an open when it is off.

\[ I > 0 \]

\[ \text{If } V_D \text{ is much less than 0V, the diode can be damaged.} \]

BE CAREFUL: The 10 segment LED array is more sensitive than the discrete LEDs.
Discrete LEDs

anode → cathode
Anode vs. Cathode

• Switch your DMM to the diode symbol.
• Place the red probe into the V-Ω plug and the black probe into the COM plug.
• Place your probes across the diode.
  – If the result is a very small number, then your red probe is contacting the anode and the black probe is contacting the cathode of the diode.
  – If the result is an overload (overflow) condition, then the red probe is contacting the cathode and the black probe is contacting the anode of the diode.
Simulating a LED in PSpice

No LED part in the student PSpice so we use a series combination of parts.

- **D1N4002**
  - Allows current to flow when the voltage on the anode is 0.39V higher than the voltage on the cathode.

- **Vdc**
  - Set to the difference in the voltage needed on the anode to turn the LED on
    - Our red and green LEDs need ~ 2.2V.
Voltage Comparator

• Op Amp circuit without a feedback component.
  – Output voltage changes to force the negative input voltage to equal the positive input voltage.
    • Maximum value of the output voltage, $V_o$, is $V+$ if the negative input voltage, $v_1$, is less than the positive input voltage, $v_2$.
    • Minimum value of the output voltage, $V_o$, is $V-$ if the negative input voltage, $v_1$, is greater than the positive input voltage, $v_2$. 
Example: DC Sweep of V2

Output voltage of the LM324 (voltage marker) will change from V- to V+ when V2 equals the voltage at the - input pin (4.5V).

LED

The light emitting diode (discrete as well as any one of the LEDs in the 10 segment LED display) is modeled as a battery in series with Dbreak.

A resistor is needed in series to limit the current to under 10mA.
DC Sweep

- Sweep Variable: Voltage Source
- Name: V2
- Sweep Type: Linear
- Start Value: -9
- End Value: 9
- Increment: 0.1
Nonideal Op Amps

• The output voltage of an ideal Op Amp is either V+ (VPOS) or V- (VNEG).

• The output voltage of a real Op Amp, such as the LM 324, is not quite 9V (supposed to be 1.5V less than V+).
  – To measure exactly what the maximum voltage is, disconnect the all components on the output of the LM 324, place a 1-10 kΩ resistor on the output pin, and apply a volt on the + input terminal that is greater than the voltage on the – input terminal and measure the voltage between the output pin and ground.
  • Use this voltage when you determine the resistor to use in series with the LED to limit the LED current to 10mA.
Alternative Implementation
Output voltage switched from roughly 0V to -9V when $V_{in} > V_{ref}$.
LM 324 Quad Op Amp

The recessed “U” on the DIP (dual inline package) package should be matched with the image when looking down at the package after it has been inserted into the breadboard.
Varying Input Voltage

- You also must construct a voltage divider so that you can vary the input voltage to the logic probe during validation.

![Diagram of a voltage divider](image)

Figure 3: Input test circuit for logic probe validation
Final Report

• Your report should explain the design principles you used and must include additional schematic diagrams for each of the following steps showing the locations of any PSpice voltage and/or current probes with the following PSpice screen snapshots:
  – Schematic diagram showing the bias voltages (Procedure Part B, step 6).
  – PSpice graph of logic probe input voltage versus the output voltages from the op amps (Procedure Part B, step 7). The graph should cover the entire range of voltages that illustrate all three logic levels.
  – PSpice graph of logic probe input voltage versus the voltage across the series combination of an LED and its current limiting resistor using at least one PSpice differential voltage probe (Procedure Part B, step 8).
  – PSpice graph of reduced logic probe input voltage (using the circuit in Figure 2) versus the current through each of the three LEDs (Procedure Part B, step 9).

• In addition to the PSpice graphs described above, you should also include tabulated, numerical data from the graphs described in steps 7–9 in the procedure above.

• Finally, your report should contain a table of the turn-on and turn-off voltages for each LED and a discussion of the hysteresis of these voltages.
  – If there is significant hysteresis, how might you modify your design to eliminate these effects?