I. Why Study?

1. Industrial processes often require monitoring inputs that are not mechanical on/off contacts—examples:
   
   A. The voltage coming out of a power supply or generator
   B. The temperature of a water bath or other liquid
   C. Whether a light beam shining across a conveyor belt is broken or not
   D. Need to know how to interface these inputs to the PLC
   
   E. Can buy specialized input sensors that convert these inputs to contact closures, but they are expensive
   F. This lesson will teach you how to interface these inputs to the PLC directly, without converting to relay contact closures

2. Sometimes inputs come not from sensors or relay contacts, but from digital electronic devices like computers, and this lesson will teach you how to get those inputs into the PLC

II. Background—input circuitry of the PLC

1. Thus far, we have been treating the inputs to the PLC (0000 through 0009) as 24-V relay coils
   
   A. To energize an input, we applied +24 V to it, and ground (0 V) to the common terminal C1
   
   B. We normally used the built-in 24-VDC supply of the PLC

2. But this PLC can also handle lower voltage signals from computers and digital electronic devices.
   
   A. These signals are usually 5 Volts/ground
      
      i) ON = approximately +5 V
      ii) OFF = approximately 0 V (ground)
B. To tell the PLC to do this, you simply change the “INPUT VOLT.” switch on the side of the PLC from “24V” to “5V” (SHOW)

i) This makes inputs 000 through 007 into 5-V inputs—i.e., it makes them more sensitive so they need only 5 V to activate, instead of 24 V

ii) Note that inputs 008 and 009 remain as 24-V inputs

iii) So you have 8 5-V inputs, and 2 24-V inputs when the switch is set to the “5V” position

C. Input circuitry:

![Diagram of input circuitry]

**Fig. 1**
D. To activate inputs 0000 through 0007, apply +5 V to the input screw, and ground (0 V) to C1

i) Each of these inputs will draw approximately 1 mA from the 5-V source

ii) Input voltage can be somewhat less than 5 V to trigger (SHOW using variable DC power supply and observing input LED for input 0000)

E. Can still use inputs 0008 and 0009

i) Apply +24 V to the input screw and the ground of the 24-VDC supply to C1

ii) If both input voltages are used, you tie the grounds of the two power supplies (5-V and 24-V) together

III. Background Information—the voltage comparator IC (SHOW example LM324)

1. function: tells which of two input voltages is the greater (connect up with pots and 2 DMMs on the inputs, oscilloscope on the output, and SHOW operation)
A. if \( V_1 > V_2 \), the comparator’s output will be a little less than whatever power supply you connect it to, in this case +5 V (high)

B. if \( V_1 \leq V_2 \), then you get 0 V out (low)—the output is connected to the ground pin through an internal transistor that turns on

C. note that the + and – signs on the inputs do not indicate polarity

   i) both voltages are positive

   ii) the signs are algebraic

   iii) + indicates “non-inverting” input

   iv) – indicates “inverting” input

D. the power supply voltage can be anything from +3 to +30 VDC, but must be at least 1.5 V higher than the highest input voltages (\( V_1 \) and \( V_2 \)) that you are comparing

2. Pin-out (Fig. 2A)
3. **Uses**

A. To tell the PLC when an analog voltage is above a certain level

   i) The analog voltage is applied to one of the inputs, say V1

   ii) A constant reference voltage is applied to the other input voltage

   iii) If the input analog voltage is less than the reference, the comparator's output is 0 V
iv) But if the input voltage exceeds the reference, the comparator output goes high and tells the PLC

B. To tell the PLC when some physical quantity (converted to an analog voltage by a transducer) is above a reference level

C. To tell if a voltage or physical quantity is between a lower and an upper limit, i.e., if it is within a given range

IV. Example interface circuits using the voltage comparator

1. Over voltage warning alarm

   A. purpose—to flash a lamp if a voltage being monitored exceeds a certain safe level, say 2.5 V

   B. circuit (Fig. 3, SHOW)

   ![Diagram](L.119.7.3)

   i) apply monitored voltage to V1 input

   ii) apply 2.5-V constant reference to V2 input

   (a) can make from a pot (Fig. 3A)
b) connected to a regulated DC power supply that's higher than 4 V

iii) Send output pin directly to PLC input 0000, with the input voltage switch set to “5V”

iv) Connect the +5-V ground pin to C1 of the PLC

v) When will input 0000 be activated?

(a) When the output goes high (when $V1 > V2$)—i.e., when the monitored voltage exceeds 2.5 V

(b) When $V1 \leq V2$ the comparator output is 0 V, so the PLC input is not activated

C. PLC program—left as exercise to the student

2. Over temperature warning alarm

A. purpose—to flash a lamp if a temperature being monitored exceeds a certain safe level, say 30º C

B. circuit (SHOW)

i) same basic comparator circuit

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Fig. 3A—Connecting a potentiometer (pot) to create a variable voltage
ii) but we need to convert the monitored temperature to a voltage

(a) done with a thermistor (SHOW)

(b) symbol

\[ \text{Fig. 4--thermistor symbol} \]

(c) operation—changes resistance with temperature (SHOW)

- supposed to be 1,000 \( \Omega \) at 25° C
- how does it vary with temperature?
- So we write: \( T \uparrow R \downarrow \)
- Called an “NTC” (negative temperature coefficient) thermistor

(d) To produce a change in \textit{voltage} from this change in \textit{resistance}, we put the thermistor into a \textit{voltage divider} (begin Fig. 5)
• Important basic electronic circuit

• Two resistors connected in series across a power supply

• The output voltage is taken from the middle where the two resistors connect to one another

• The top resistor is called a “pull up” because it tries to raise the output voltage as it gets smaller in resistance (imagine if it had 0 Ω of resistance…)

• The bottom resistor is called a “pull down” because it tries to lower the output voltage as it gets smaller in resistance (what would happen if it had no resistance and were like a wire?)

• So the two resistors in a voltage divider fight over what should be the output voltage—which one wins? What if their resistances are equal?

• The pot we are using to set the reference voltage is another example of a voltage divider—the sliding contact or wiper of the pot divides the fixed resistance into two parts, one a pull up and the other a pull down
(e) If we keep our previous circuit, with the reference voltage connected to V1, then we will need to put the voltage from the thermistor voltage divider into V2

iii) Can put the thermistor on the top of the voltage divider, or on the bottom

(a) If on the top, what will the voltage coming out of the divider do as the temperature increases?

(b) If on the bottom, what will it do?

(c) Let’s put it on the top—so as the temperature increases, the divider output voltage will increase and try to turn off the comparator output

iv) Now we need to set a reference voltage and select the bottom resistor of the voltage divider

(a) For the reference voltage, we are free to choose just about any value, so long as it’s not too close to the power supply voltage of the comparator, or ground

(b) So we usually pick a round number in the middle, say 2.5 V

(c) Then we can set the pot exactly in the center to make our 2.5-V reference voltage

(d) Next we measure the resistance of the thermistor at the target temperature of 30º C (SHOW)

(e) Remember that the comparator will trigger when the output of the voltage divider just exceeds the 2.5-V reference level

(f) When will the voltage divider put out 2.5 V (i.e., half of the power supply voltage?)

3. Broken light beam warning indicator

A. purpose—to trigger the PLC if a light beam is broken

i) may be a security system
ii) or counting boxes on a conveyor belt, etc.

B. Circuit (SHOW)

i) same basic comparator circuit

ii) but we substitute a light sensor for the thermistor

(a) we can use a photoresistor (SHOW)

(b) symbol

![Photoresistor Symbol]

(c) operation (SHOW)

- resistance changes with light
- in what way?
- So we can write: light $↑$ R $↓$

iii) Do we place the photoresistor in the top or the bottom of the voltage divider to activate the PLC input when the beam breaks?

iv) What function does the other resistor in the voltage divider now perform?

4. Out-of-range voltage indicator

A. Purpose—to activate the PLC whenever an input goes outside a certain range
i) Say within the 2-V to 3-V range—so that either less than 2 V or greater than 3 V will activate the PLC

ii) Could be a voltage from a power supply under test during production

iii) Or could be a voltage representing some physical quantity like temperature or pressure that’s being monitored

iv) Provides more information than the simple comparators discussed above

(a) Tells not just if the input is too high

(b) But also if it’s too low

(c) If it’s outside the allowable range, then the PLC is triggered

B. Circuit

i) Similar to the simple comparator, but now we must make two comparisons, one against the upper limit and one against the lower

ii) And activate the PLC if the input voltage is above the upper limit or below the lower limit

iii) So we use two comparators and have the PLC process their outputs

(a) One comparator that activates (puts out a high) if the voltage is too high

(b) The other comparator activates if the voltage is too low

(c) Run each comparator’s output to a separate PLC input

(d) Have the PLC trigger activate the warning device (when?) if either comparator output is high

iv) Called a “window comparator” because it tells us if the input voltage goes outside an allowable window
v) Still requires only one LM324 chip because this chip has 4 comparators on it

vi) Only a single power and ground hookup for the entire chip

V. Introduction to the laboratory exercises

1. go over examples from the lab exercises

2. student should look over the assignments in advance and prepare schematic diagrams, including pin numbers on the IC

VI. MATERIALS

1. PLC

2. 2 DMMs

3. LM324 comparator IC, socket, and wires

4. variable DC power supply
5. 2 10-kΩ pots
6. 1-kΩ sealed thermistor
7. photoresistor
8. flashlight
9. resistor decade box
10. heat gun