# PROCESS CONTROL SYSTEMS

11

LEARNING ACTIVITY PACKET

# ULTRASONIC LEVEL MEASUREMENT AND CONTROL

33255-XD

# ULTRASONIC LEVEL MEASUREMENT AND CONTROL

## INTRODUCTION

Ultrasonic waves are sound waves with frequencies above the human ear's audible range. Ultrasonic sensors transmit and reflect ultrasonic waves to measure the distance between the sensor and an object or the height of material in a container. This LAP covers the construction, operation, and calibration of ultrasonic level sensors.

## ITEMS NEEDED

Amatrol Supplied

1 T5552 Process Control Learning System
1 T5552-L1 Ultrasonic Liquid Level Sensor Module

School Supplied

1 Water Supply (10 Gallons)
1 Compressed Air Supply
1 Digital Multimeter
1 Small Precision Screwdriver

FIRST EDITION, LAP 11, REV. A



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# SEGMENT 1

## ULTRASONIC LEVEL MEASUREMENT

### OBJECTIVE 1 DESCRIBE THE FUNCTION OF AN ULTRASONIC LEVEL SENSOR AND GIVE AN APPLICATION

An ultrasonic level sensor is a radiation-based level-measuring device that uses the transmission and reflection of ultrasonic waves to determine the level of material in a container.

Figure 1. Ultrasonic Level Sensor

Ultrasonic level sensors are generally used in applications that require the sensor to not touch the material because of possible contamination. For example, chemicals used to make pharmaceutical drugs can react with contaminants on the sensor or the actual sensor material and make defective products.

Ultrasonic sensors are also used for applications where another type of sensor (e.g. a pressure type level sensor) would present a safety hazard. For example, figure 2 shows an ultrasonic level sensor measuring the level of petroleum in a container. In applications that use flammable fluids, it is safer to use sensors that do not have to directly contact the fluid because it decreases the possibility of an explosion from an electrical surge or spark.

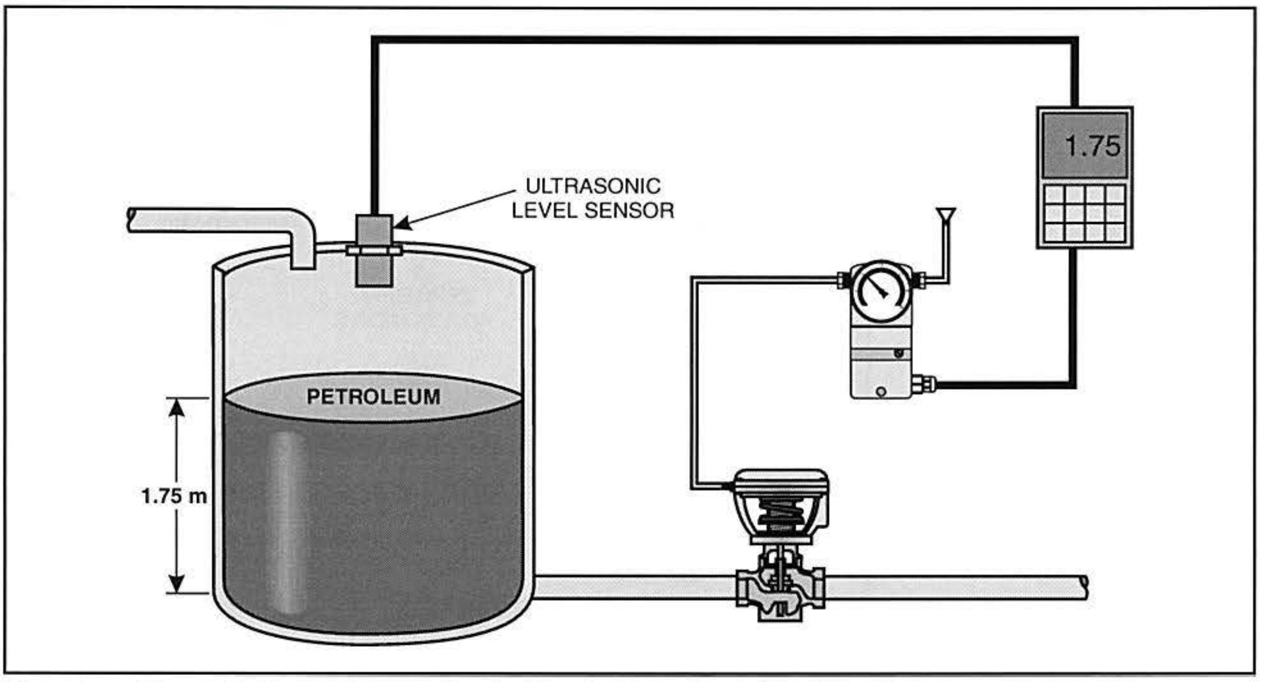


Figure 2. Ultrasonic Sensor Measuring the Level of Petroleum in a Container

## OBJECTIVE 2 DESCRIBE THE OPERATION OF AN ULTRASONIC LEVEL SENSOR


Ultrasonic level sensors often have a tubular body that is constructed from durable plastic or stainless steel. Ultrasonic waves are transmitted and received from one end of the sensor; signal wires are attached to the other end. Zero and span adjustments are usually located on the same end as the signal wires, as figure 3 shows.

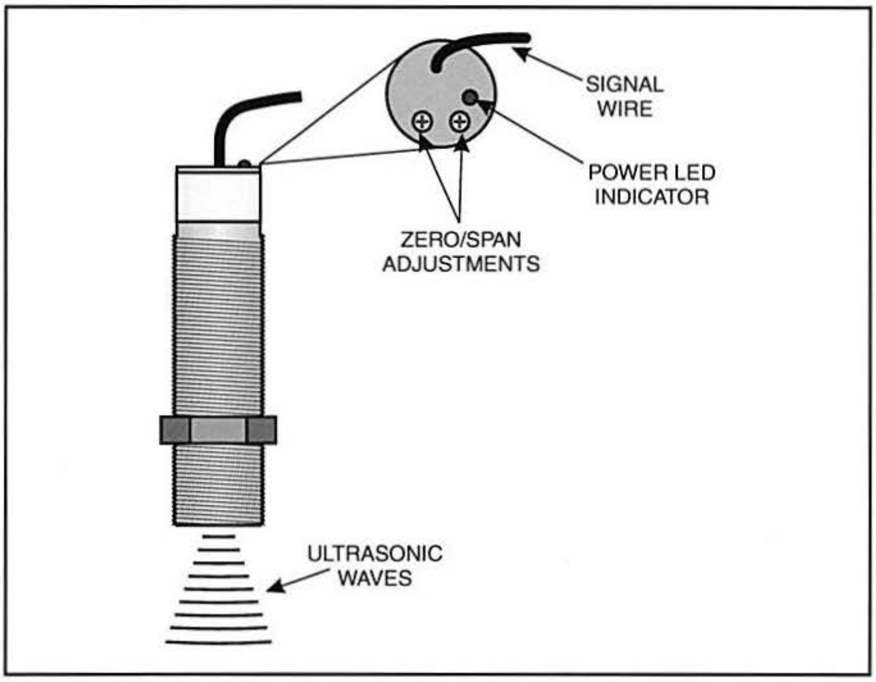


Figure 3. External Construction of an Ultrasonic Level Sensor

The internal components of an ultrasonic level sensor include a transmitter and a transducer, as figure 4 shows. The transmitter consists of electronic circuitry that performs two operations. First, it sends an electrical signal to the transducer to create ultrasonic waves. Secondly, it transmits an electrical analog output based on the time it takes for the reflected ultrasonic waves to be received.

The transducer consists of piezoelectric crystals, backing material, and electrodes. The piezoelectric crystals have a dual function. When an electrical signal is applied to the crystals, they vibrate and create ultrasonic waves. When the crystals sense the reflected ultrasonic waves, they create an electrical signal. The backing material dampens the crystal vibrations to prevent infinite pulses of ultrasonic waves. The electrodes receive electrical signals from the transmitter and send electrical signals from the crystals to the transmitter.

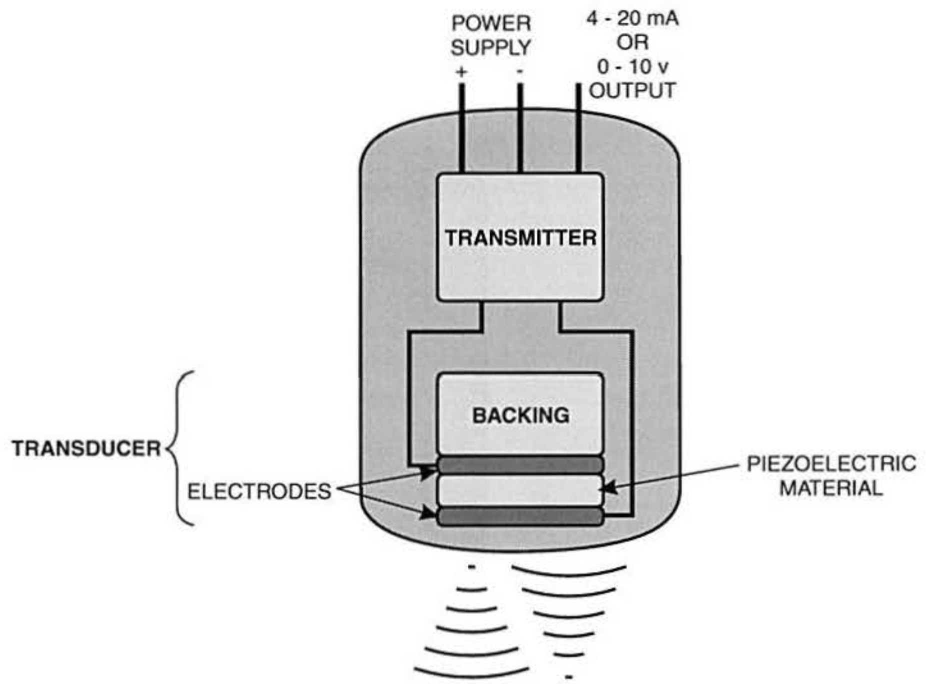


Figure 4. Internal Construction of an Ultrasonic Level Sensor

An external power source supplies a voltage (often 20-30 VDC) to the ultrasonic level sensor transmitter. The transmitter sends bursts of voltage through the electrodes to the crystals, causing them to vibrate (an effect known as converse piezoelectricity). The vibration of piezoelectric crystals at their natural frequency creates ultrasonic waves in pulses.

Between pulses (i.e. ultrasonic wave transmissions), the sensor cycles off and waits for the waves to reflect off the material being measured and return to the sensor. The returning waves cause mechanical stress on the piezoelectric crystals, resulting in the generation of voltage (an effect known as direct piezoelectricity). The transmitter receives the voltage signal and generates an analog output (typically 4-20 mA or 0-10 V) that is proportional to how long it took for the wave to arrive, which depends on the level in the container. If the level in the container is low, it takes longer for the reflected wave to return to the sensor than when the level is high.

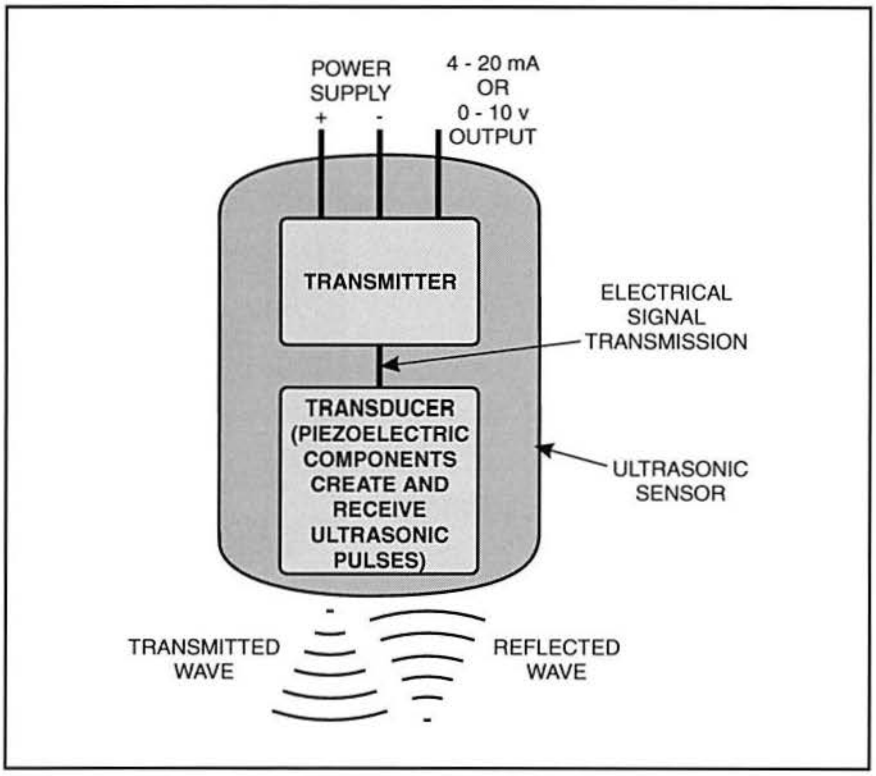


Figure 5. Operation of an Ultrasonic Level Sensor

In most cases, a single sensor transmits and receives the ultrasonic waves. However, some systems use a separate transmitter and receiver. Figure 6 shows the use of one sensor on the left and the use of a separate transmitter and receiver on the right.

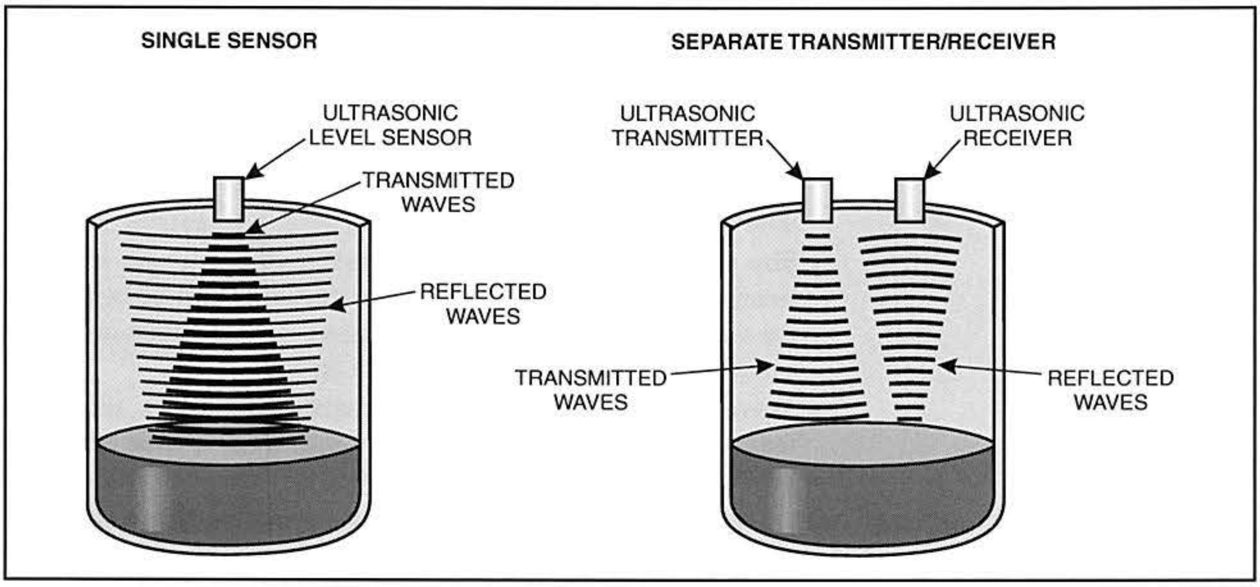

Figure 6. Examples of Ultrasonic Level Sensors

Ultrasonic level sensors typically operate in the 20-45 kHz frequency range. Using higher frequencies (e.g. MHz, GHz) causes the waves to penetrate the surface of the material being measured, resulting in false readings.

Ultrasonic sensors that have a larger diameter are generally able to operate over a longer distance because they send out waves at a lower frequency (though still within the 20-45 kHz range). Waves at a lower frequency tend to travel farther than waves at a higher frequency in level measurement because there is less opportunity for the waves to get absorbed by foreign materials.

Four important factors to consider when installing and operating an ultrasonic level sensor are:

- **Temperature -** The speed of sound changes as the temperature of the medium through which it is traveling changes. Generally, as the temperature increases, the speed of sound increases.
- **Type of material -** Different materials absorb, reflect, and transmit sound waves differently depending on the frequency of the waves. High frequency waves (e.g. on the order of MHz and higher) tend to penetrate and transmit through many materials rather than reflect off of them. However, these same materials reflect ultrasonic waves at lower frequencies.
- **Size of the container -** Ultrasonic waves often leave the sensor in beams that have a certain width. The container must be larger than the width of the beam so that the waves do not reflect off of the container sides and give measurement errors.
- **Wave obstructions -** Foreign materials and debris should be removed from the container before using an ultrasonic sensor so the waves do not reflect off of them and give measurement errors.

The manufacturer's specifications list the operating temperatures for the sensor as well as the ultrasonic beam width to prevent errors resulting from these factors. Typically, containers should be at least 1 ft wider than the beam width.

## OBJECTIVE 3 DESCRIBE HOW TO WIRE AN ULTRASONIC LEVEL SENSOR FOR NON-INVERTED MEASUREMENT

Read This

Some ultrasonic level sensors have two wiring configurations, non-inverted and inverted. In non-inverted measurement, the sensor's analog output gets larger as the ultrasonic waves travel farther away from the sensor. For example, figure 7 shows a level sensor transmitting ultrasonic waves. When the liquid level is at its highest point, the wave reflects back to the sensor quickly, resulting in a 4 mA sensor output. When the liquid level is at the lowest point, it takes longer for the wave to reflect back to the sensor, resulting in a 20 mA output.

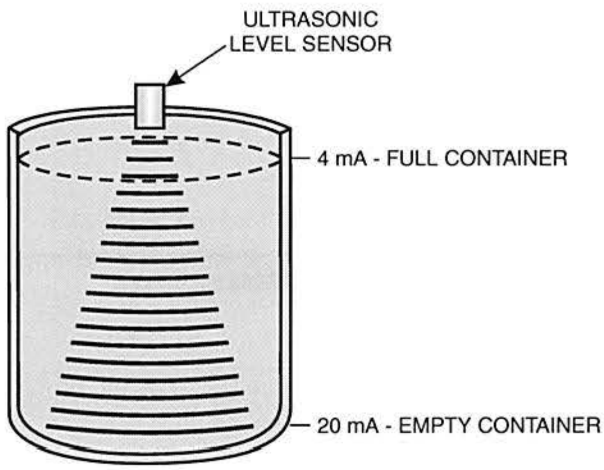


Figure 7. Non-Inverted Measurement

Non-inverted measurements are generally used to indicate the distance between the sensor and an object, as shown in figure 8. For non-inverted measurements, calculating the distance between the sensor and the top of the liquid is simpler than calculating the actual level because there is a direct relationship between the output and the distance. The output increases as the distance increases, and the output decreases as the distance decreases.

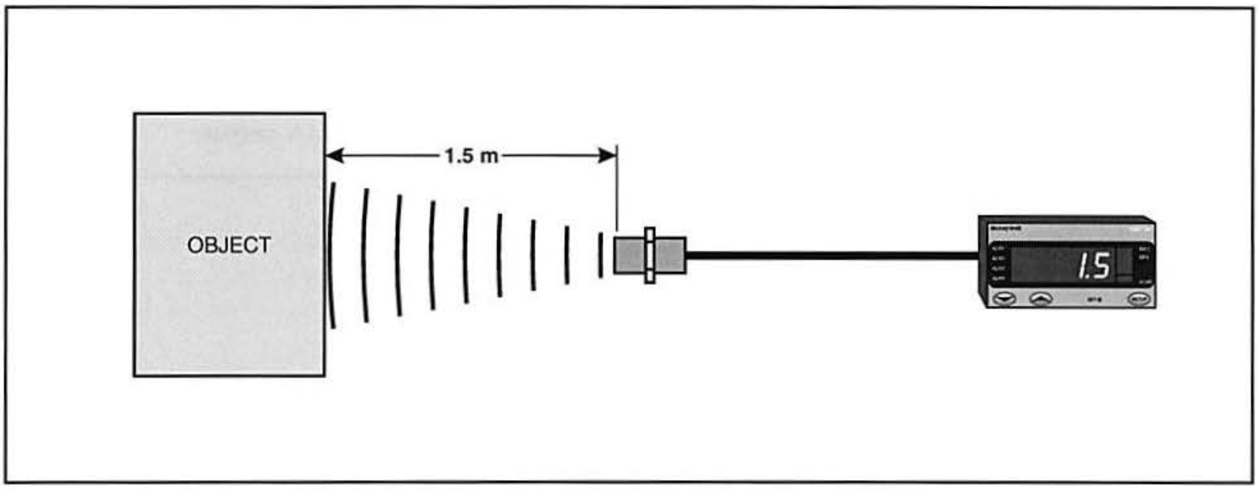


Figure 8. Application of Non-Inverted Measurement

## Wiring for Non-Inverted Measurement

Figure 9 shows an ultrasonic level sensor wired to a process meter or controller for non-inverted measurement. The positive and negative wires are connected to the positive and negative wires on the external power supply. The third wire, the analog current output in this case, is wired to the positive input terminal on the process meter and the negative input terminal is wired back to the negative terminal on the power supply to complete the circuit. The fourth wire is not used in non-inverted measurement.

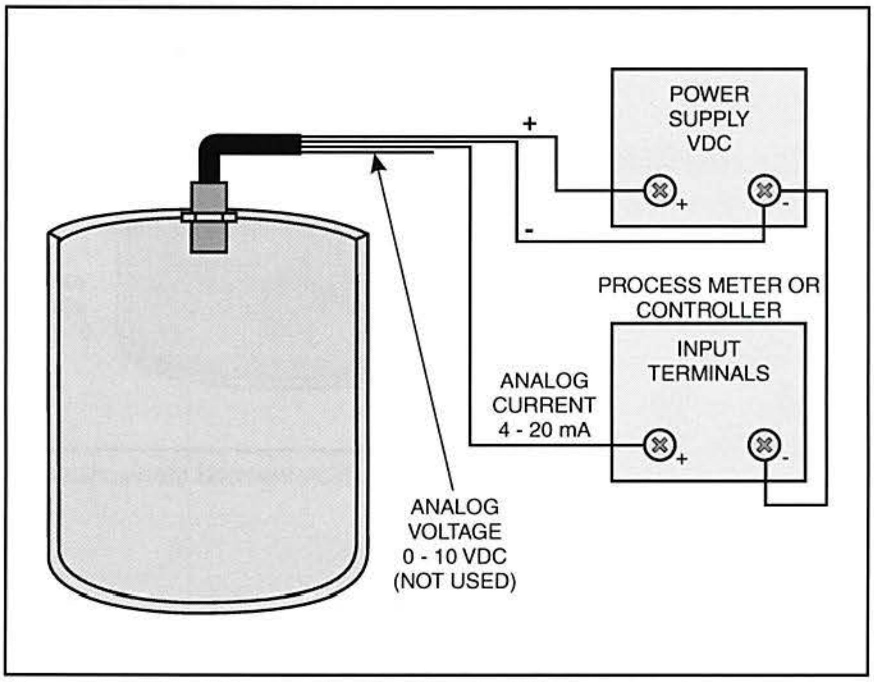


Figure 9. Wiring Diagram for Non-Inverted Measurement

If the circuit requires a voltage output from the sensor, the voltage output wire replaces the current wire, as shown in figure 10. In this case, the current wire is not used.

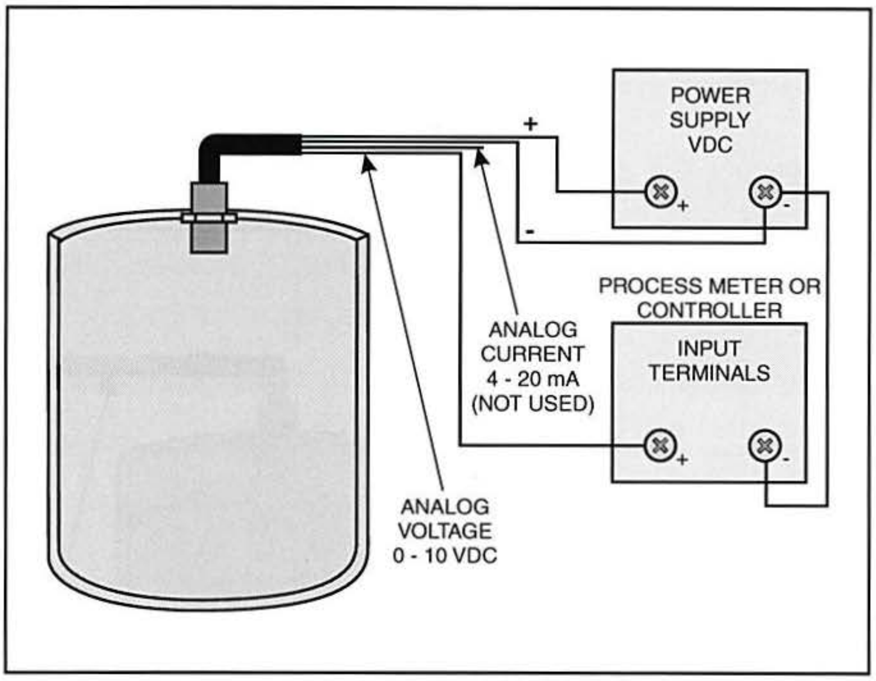


Figure 10. Non-Inverted Measurement with Voltage Output

## OBJECTIVE 4 DESCRIBE HOW TO WIRE AN ULTRASONIC LEVEL SENSOR FOR INVERTED MEASUREMENT

Inverted measurement causes the sensor's analog output to decrease as the ultrasonic waves travel farther away from the sensor (level gets lower). For example, figure 11 shows an example of a level sensor transmitting ultrasonic waves. When the liquid level is at the highest point, the sensor output is 20 mA. When the liquid level is at the lowest point (i.e. the ultrasonic wave travels farthest from the sensor), the sensor output is 4 mA.

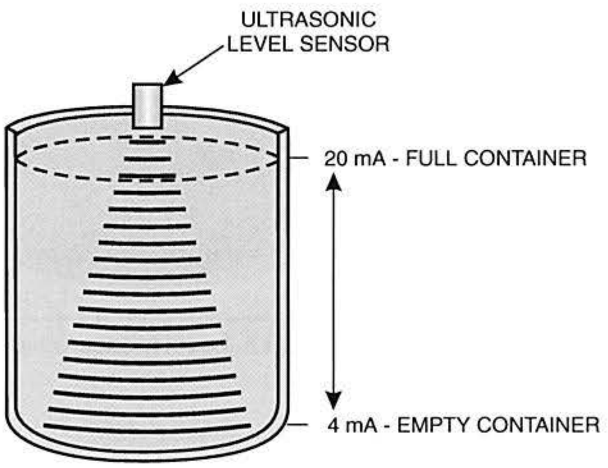


Figure 11. Inverted Measurement

Level measurement is a common application of the inverted configuration, as figure 12 shows.

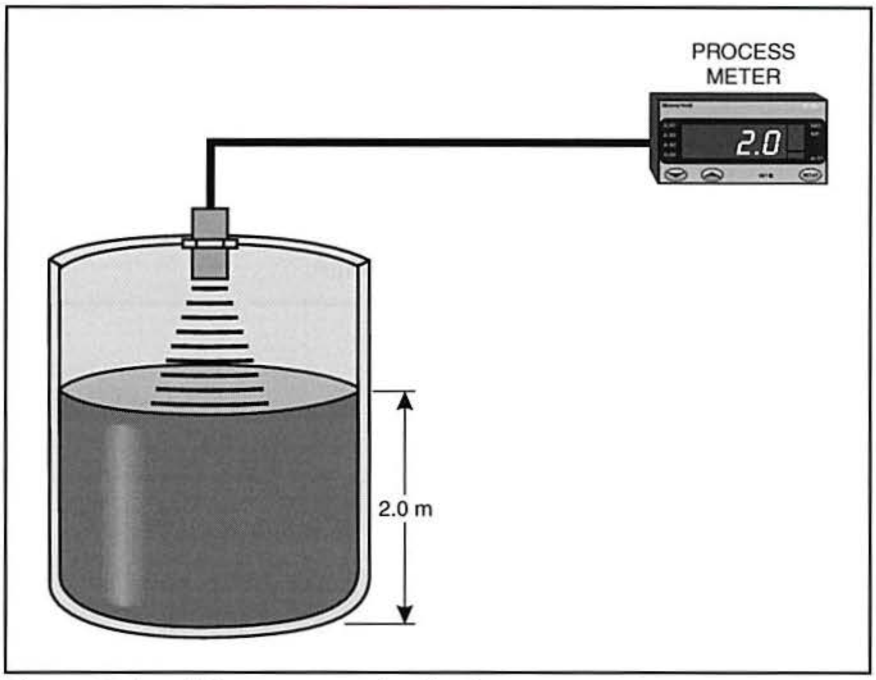


Figure 12. Level Measurement Application

## Wiring for Inverted Measurement

Wiring an ultrasonic sensor for inverted measurement is similar to wiring the sensor for non-inverted measurement. However, the fourth wire is connected to the positive power supply wire instead of being left out of the circuit. Shorting the fourth wire to the power supply connection inverts the output from 4-20 mA (0-10 V) to 20-4 mA (10-0 V).

For example, figure 13 shows an ultrasonic level sensor wired to a process meter or controller and an external power supply. The positive and negative wires are connected to the positive and negative wires on the external power supply. The signal wire that carries the desired analog output, current in this case, is wired to the positive input terminal on the process meter. The negative input terminal of the process meter input is wired to the negative terminal on the power supply to complete the circuit. The fourth wire (i.e. the voltage output wire) is connected to the positive power supply in a short circuit that inverts the output.

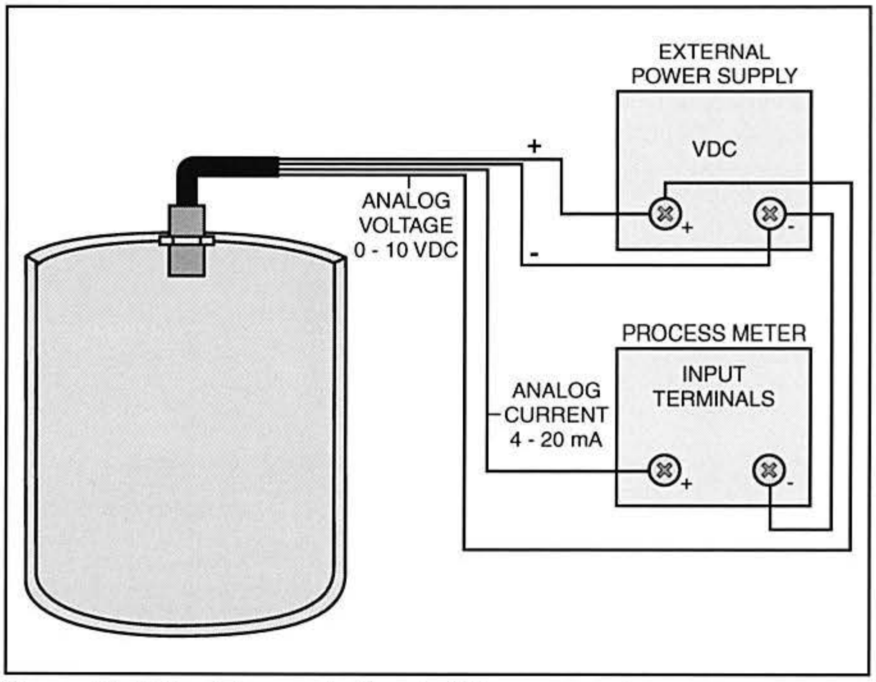


Figure 13. Wiring Diagram for Inverted Measurement

For a voltage output, the current wire is shorted to the power supply and the voltage wire is connected to the process meter, as shown in figure 14.

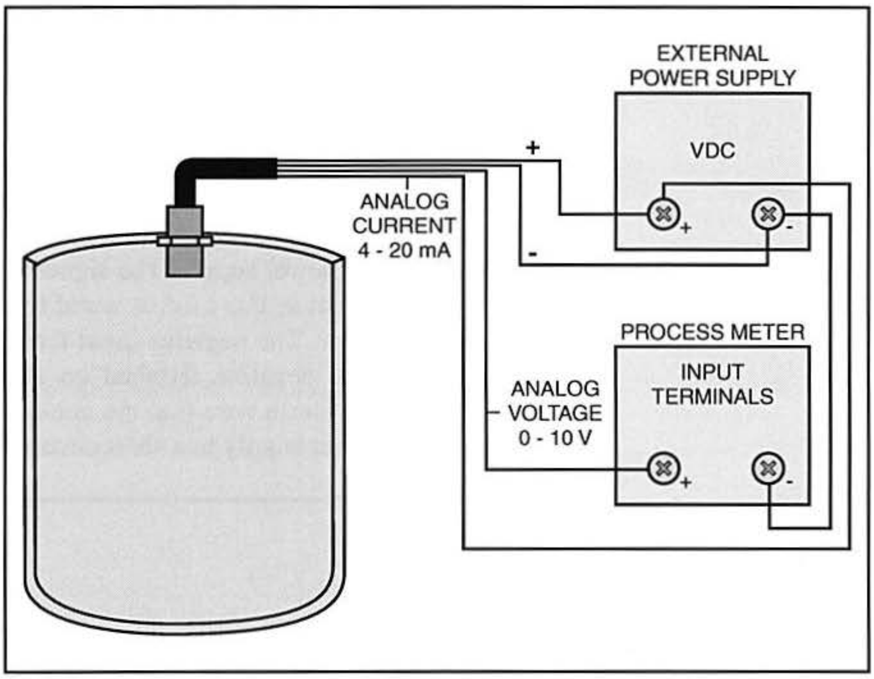


Figure 14. Inverted Measurement with Voltage Output

## SKILL 1 CONNECT AND OPERATE AN ULTRASONIC LEVEL SENSOR

**Procedure Overview**

In this procedure, you will connect an ultrasonic level sensor to a power supply and process meter. You will then operate the sensor in a level measuring circuit and observe the changes in the value on the process meter as you manually manipulate the level. The readings on the process meter may not be accurate because the sensor is not yet calibrated.

Do This

❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to set up the T5552, as shown in figure 15.

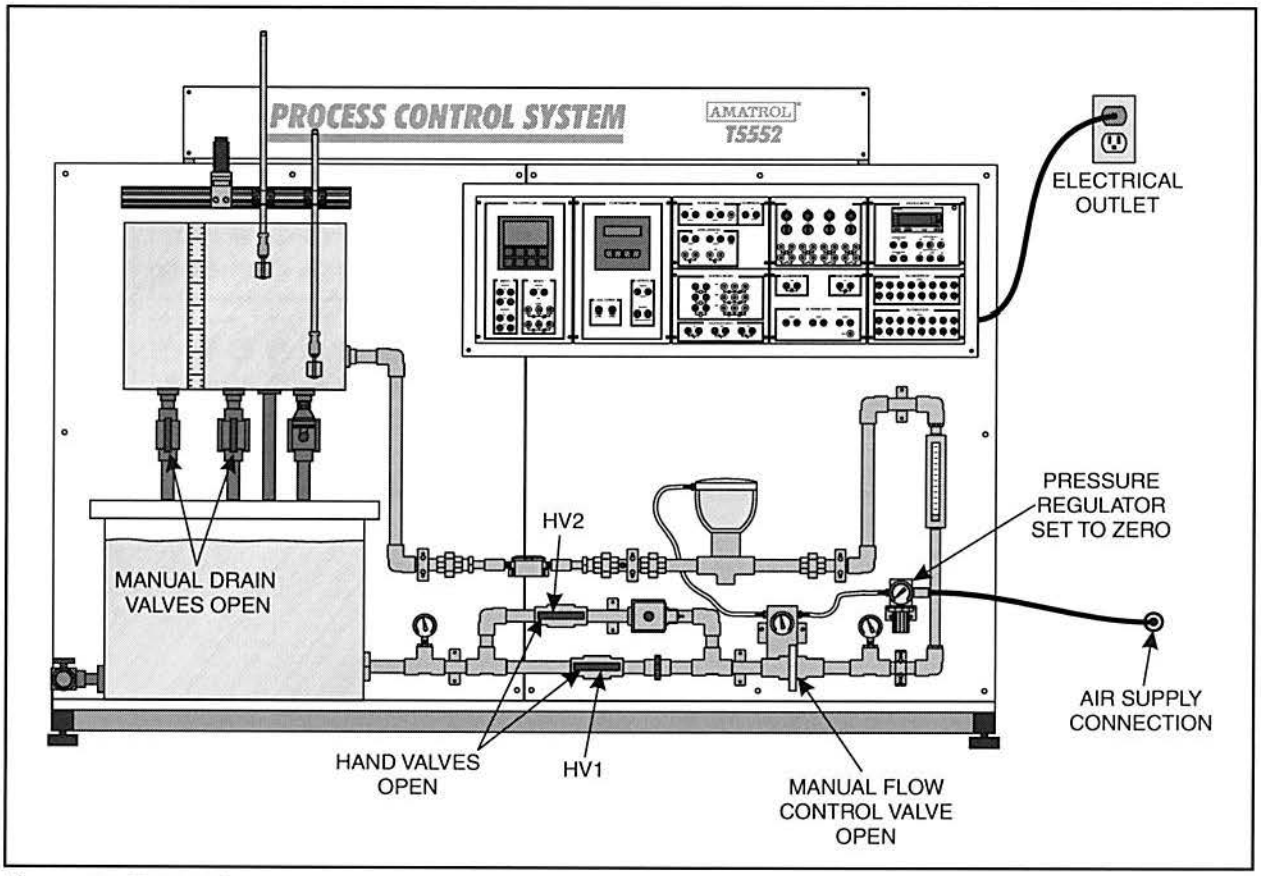


Figure 15. T5552 Setup

A. Fill the reservoir tank with water.

B. Connect the air supply line to the T5552.

C. Set the pressure regulator to 0 psi.

D. Open the process tank manual drain valves.

❑ 3. Connect the circuit shown in figure 16.

This circuit allows you to measure the level in the process tank using the ultrasonic level sensor. It also allows you to measure the output from the ultrasonic sensor using a multimeter or loop calibrator. The ultrasonic level sensor is wired in the inverted configuration.

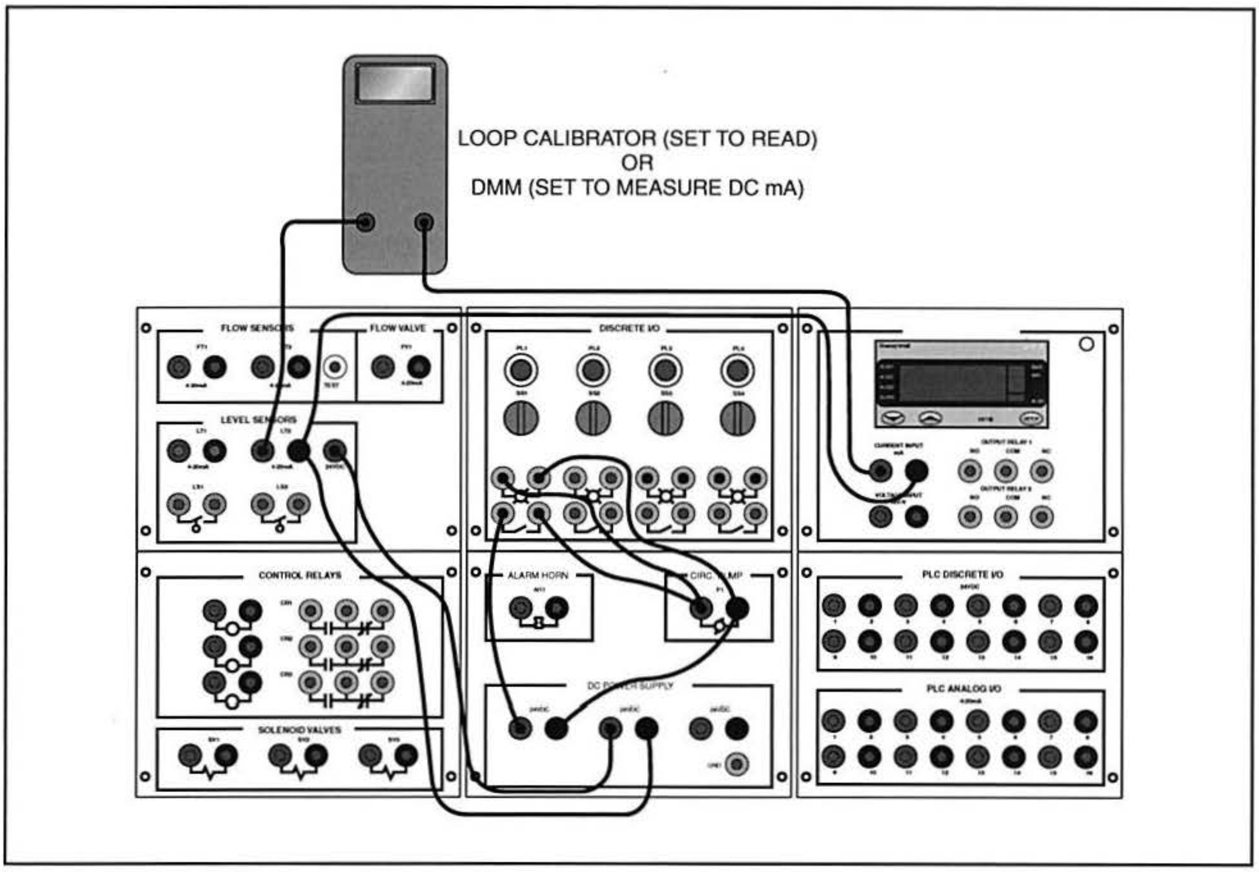


Figure 16. Level Measuring Circuit

Figure 17 shows the P&ID for the T5552. The active components and wiring are highlighted.

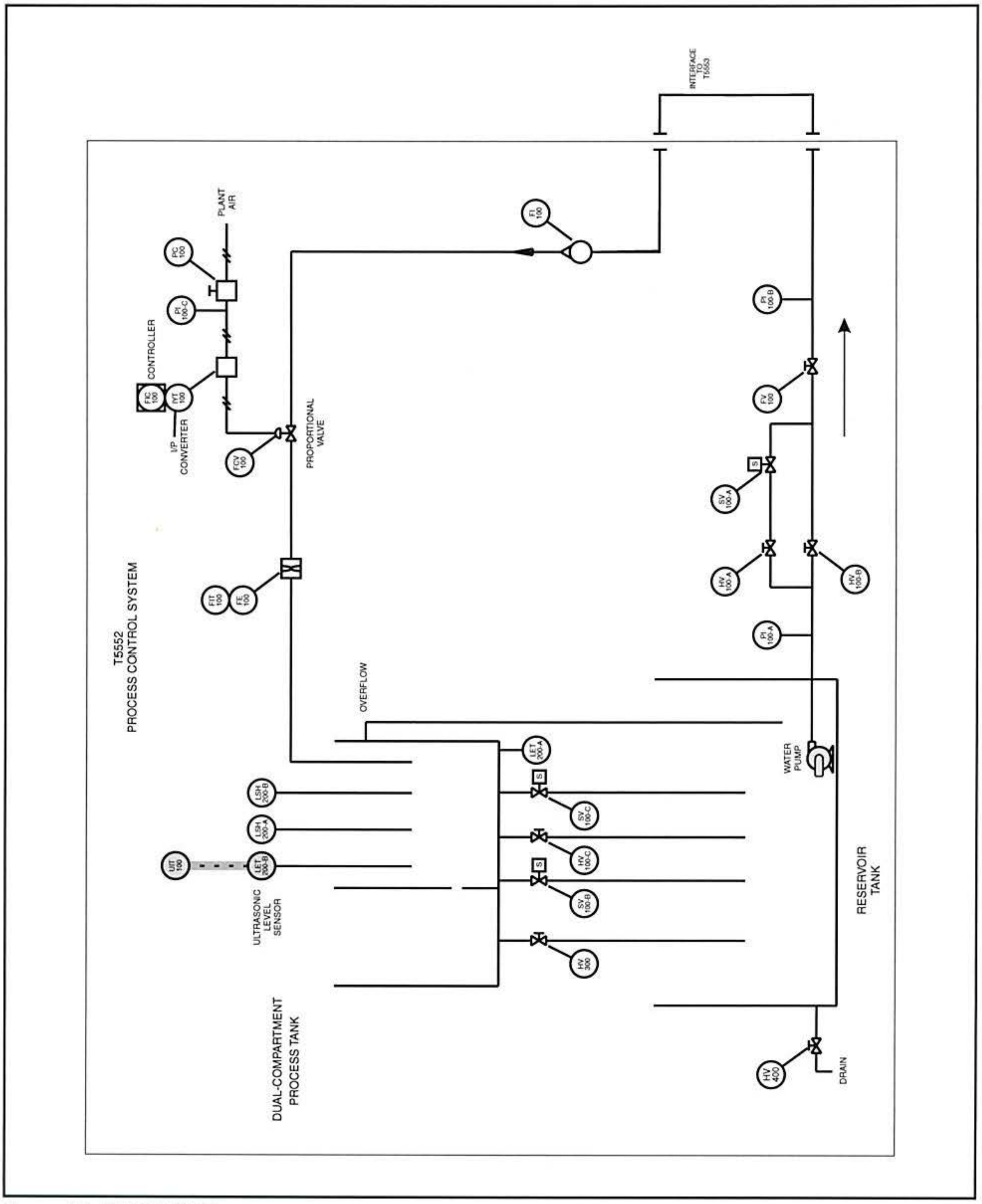


Figure 17. T5552 P&ID

Figure 18 shows the wiring schematic for the level measuring circuit.

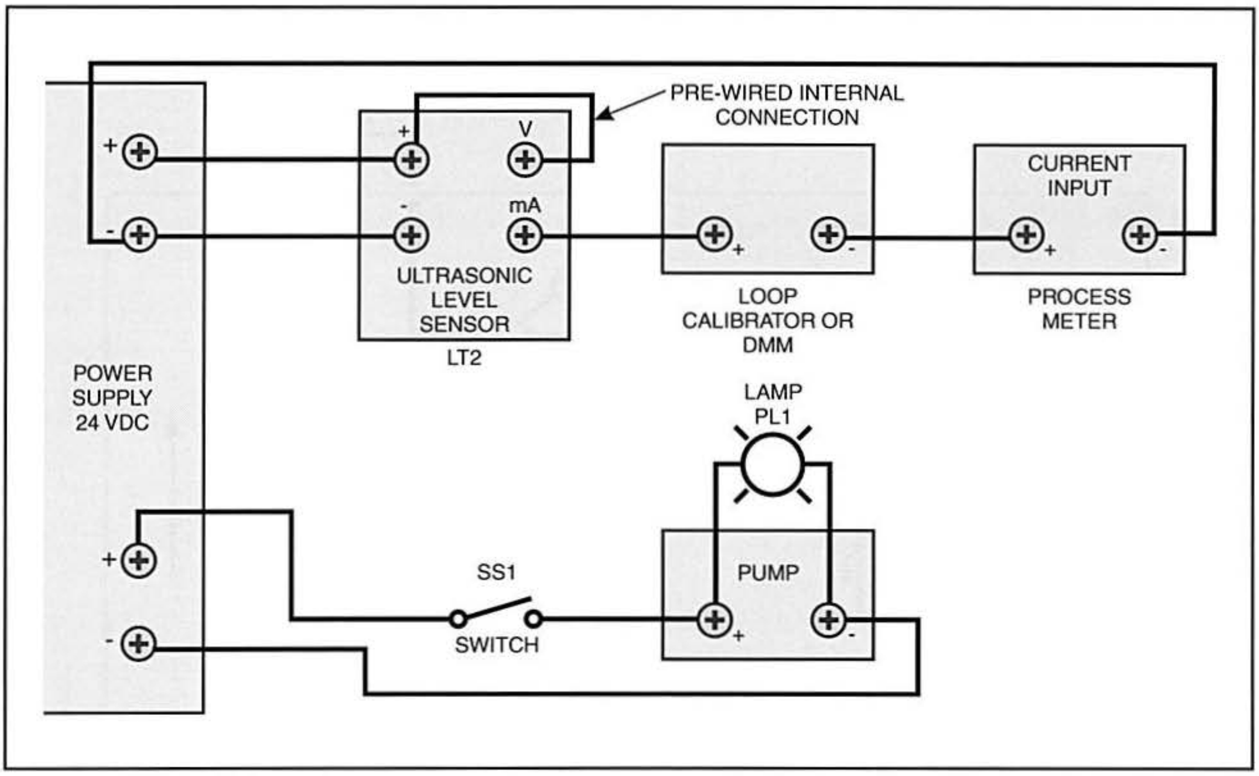


Figure 18. Wiring Schematic

❑ 4. Program the Honeywell UDI 1700 process meter according to the values listed in the table in figure 19.

| MENU | PARAMETER | VALUE |
|---|---|---|
| ConF | InPt | 4_20 |
| | ruL | 10.0 |
| | rLL | 0.0 |

Figure 19. Simpson Hawk 3 Process Meter Settings

These settings indicate the type of input signal being received and scale the display in terms of the PV units (inches).

❑ 5. Perform the following substeps to operate the ultrasonic level sensor.

   A. Record the value of the sensor output from the multimeter or loop calibrator with the tank empty. Also, record the displayed value from the Simpson process meter.

   Sensor Output Value ______________________________ (mA)

   Meter Display Value ____________________________ (inches)

   This is the minimum output value of the sensor. You may notice that the value does not equal 4 mA because the sensor is not calibrated. The displayed value on the process meter should also be at a minimum. However, it may not be 0 because the sensor is not calibrated.

   B. Turn on selector switch **SS1** to start the pump.

   C. Close the process tank manual drain valves so the liquid level will increase.

   D. When the level reaches approximately 2 inches on the process tank sight scale, turn off selector switch **SS1** to stop the pump. Record the output of the sensor from the multimeter or loop calibrator and the displayed value from the process meter.

   Sensor Output _____________________________________ (mA)

   Meter Display Value ____________________________ (inches)

   You should notice that the output and the displayed values are larger than the values you recorded in substep A.

   E. Turn on selector switch **SS1** to start the circulation pump so the liquid level will increase.

   F. When the level reaches 10 inches on the tank sight scale, turn off selector switch **SS1** to stop the pump. Record the output of the sensor from the multimeter or loop calibrator and the displayed value from the process meter.

   Sensor Output _____________________________________ (mA)

   Meter Display Value ____________________________ (inches)

   This is the maximum output of the sensor without calibration. The displayed value is also at a maximum.

❑ 6. Perform the following substeps to shut down the T5552.

   A. Open the process tank manual drain valves to empty the tank. When the tank is empty, close the valves.

   B. Turn off the main circuit breaker.

   C. Disconnect the circuit.

SEGMENT 1

# SELF REVIEW

1. An ultrasonic level sensor is a _________-based level measuring device.
2. Ultrasonic level sensors operate using the transmission and _____________ of ultrasonic waves.
3. Ultrasonic level sensors use the vibration of _________ crystals to create ultrasonic waves.
4. Ultrasonic level sensors typically operate in the _________ kHz frequency range.
5. Four important factors to consider when operating an ultrasonic level sensor are the type of material, the size of the container, wave obstructions, and ________________.
6. _______ measurements are generally used to indicate the distance between the sensor and an object.
7. _______ measurement causes the ultrasonic level sensor's analog output to decrease as the ultrasonic waves travel farther away.

# SEGMENT 2

## ULTRASONIC LEVEL SENSOR CALIBRATION

**OBJECTIVE 5** **DESCRIBE HOW TO CALIBRATE AN ULTRASONIC SENSOR FOR NON-INVERTED MEASUREMENT**

Read This

Calibrating an ultrasonic sensor for non-inverted measurement requires three basic steps:

### Step 1: Position the Sensor at the Top of the Tank

The ultrasonic level sensor should be positioned so that the transmitted waves do not reflect off of any surface other than the material in the tank. To accomplish this, the sensor should be positioned far enough from the tank walls to prevent reflection off of them and the tank should not contain foreign debris or other objects that may obstruct the waves. Figure 20 shows proper and improper positioning. The manufacturer's specifications list the diameter of the ultrasonic beam to help ensure proper positioning.

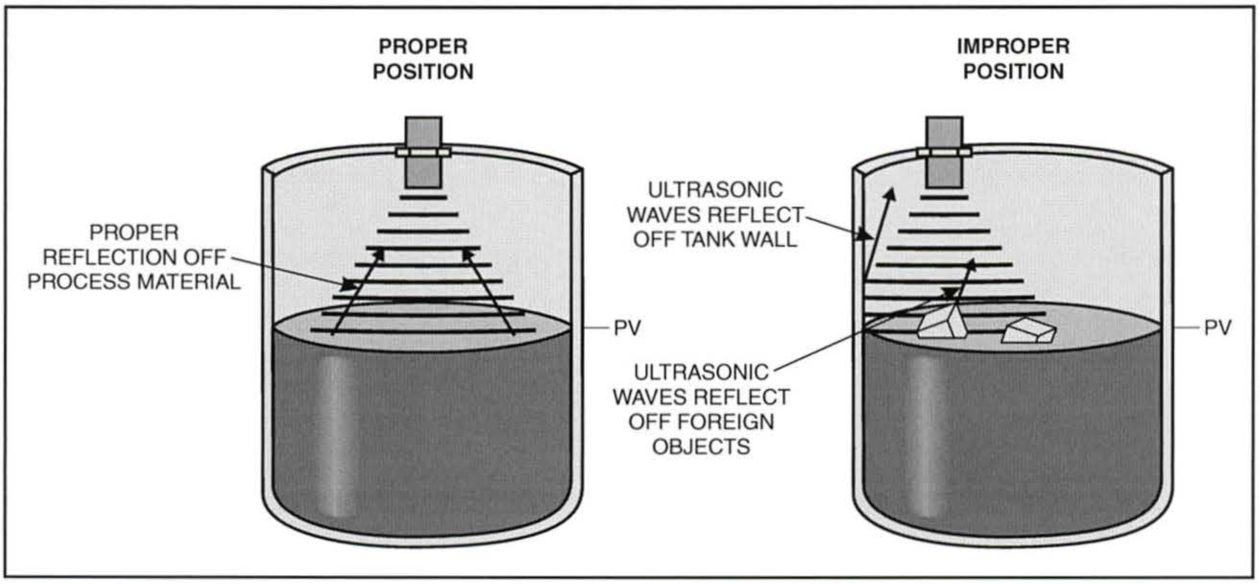


Figure 20. Proper vs. Improper Sensor Positioning

## Step 2: Adjust the Sensor Zero

Many ultrasonic level sensors have potentiometers that adjust the zero and span of the output. Setting the adjustments involves placing a loop calibrator or digital multimeter (DMM) in series with the output of the sensor if the current output is used. Figure 21 shows an ultrasonic sensor's current output wired to a loop calibrator.

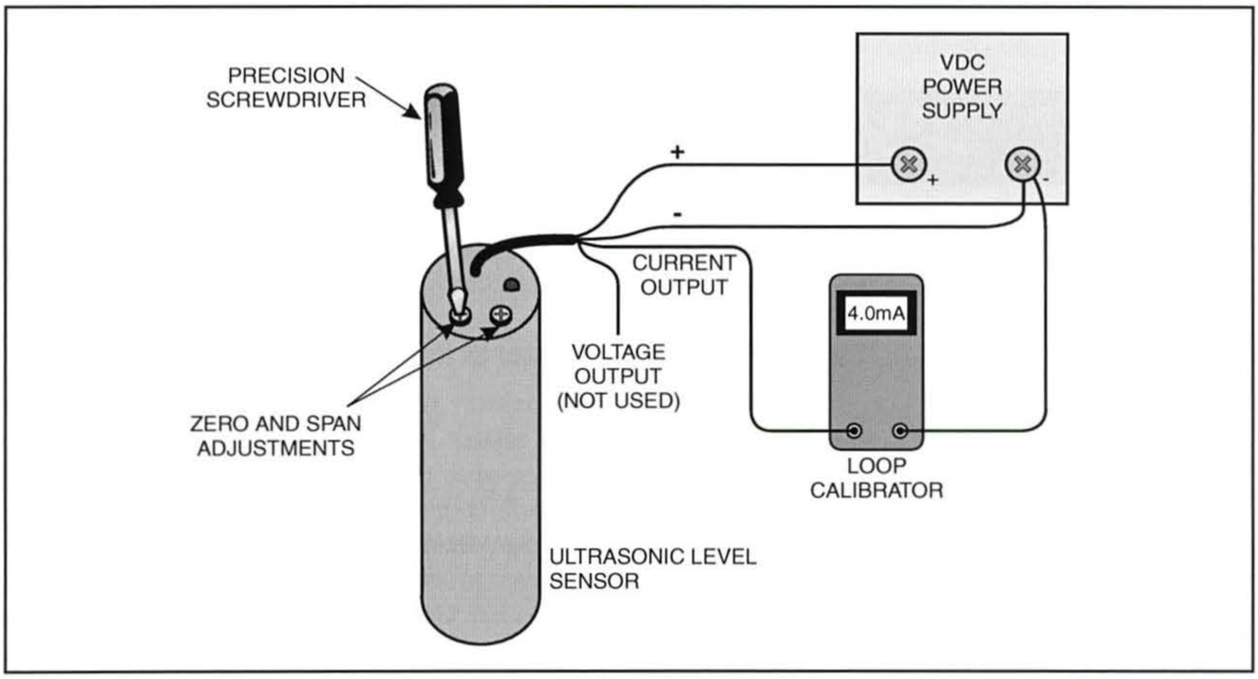


Figure 21. Calibrating an Ultrasonic Level Sensor with Current Output

When the system requires a voltage output, the voltage signal wire is used instead of the current signal wire and a DMM is placed in parallel with the signal and ground, as shown in figure 22.

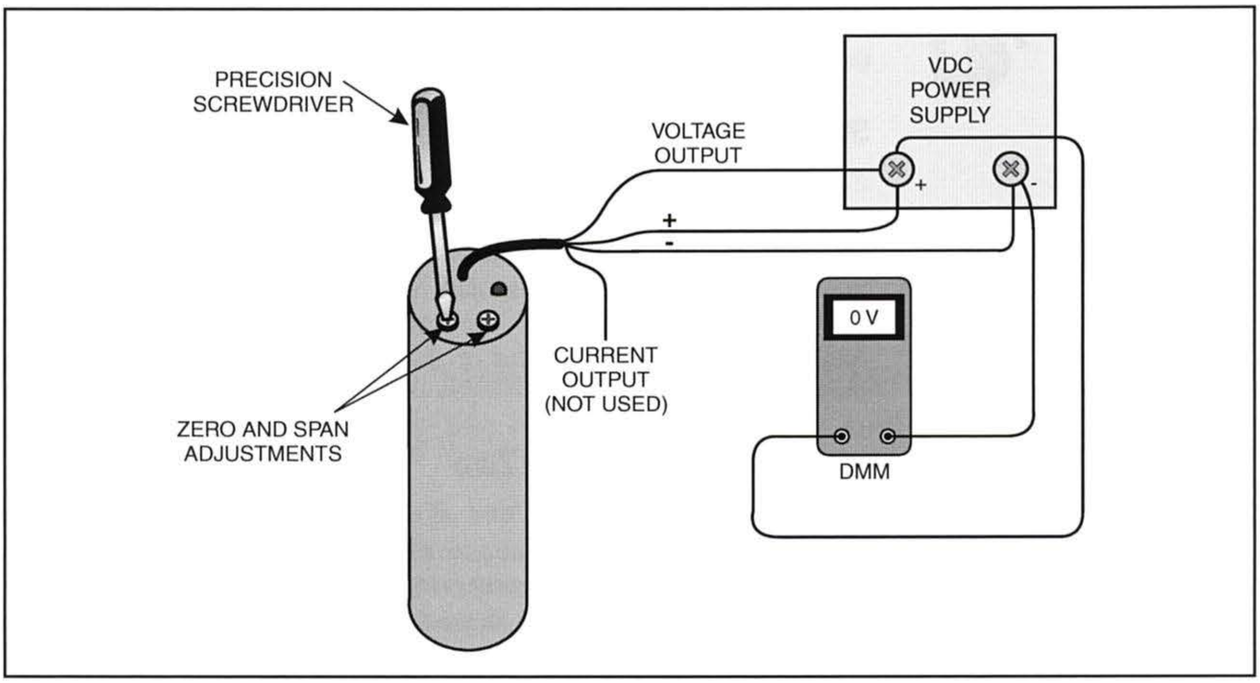


Figure 22. Calibrating an Ultrasonic Level Sensor with Voltage Output

Set the zero adjustment by filling the tank to its highest level and turning the zero adjust potentiometer (usually using a precision screwdriver) until the display on the measurement device reads 4 mA or 0V.

## Step 3: Adjust the Sensor Span

Set the span adjustment by emptying the container to the minimum point and turning the span adjust potentiometer with a precision screw driver until the display on the measurement device reads 20 mA or 10V.

## OBJECTIVE 6 DESCRIBE HOW TO CALIBRATE AN ULTRASONIC SENSOR FOR INVERTED MEASUREMENT

Read This

Calibrating an ultrasonic sensor for inverted measurement requires the same three basic steps that are used for non-inverted measurement:

### Step 1: Position the Sensor at the Top of the Tank

The same precautions taken to prevent measurement errors in non-inverted measurement are also taken to prevent them in inverted measurement. Therefore, the sensor should not be positioned too close to the tank walls and the tank should not contain foreign debris or other objects that may obstruct the waves. Recall that manufacturer specifications list the diameter of the ultrasonic beams to help ensure proper positioning.

### Step 2: Adjust the Sensor Zero

The same potentiometers that adjust the zero and span output on the ultrasonic level sensor for non-inverted measurement also adjust the output for inverted measurement. However, it is important to read the manufacturer's specifications to ensure that the proper potentiometer is adjusted, as the functions may switch depending on the type of measurement (i.e. inverted or non-inverted). For example, the potentiometer that adjusts the 4 mA output for non-inverted measurement may adjust the 20 mA output for inverted measurement, as shown in figure 23.

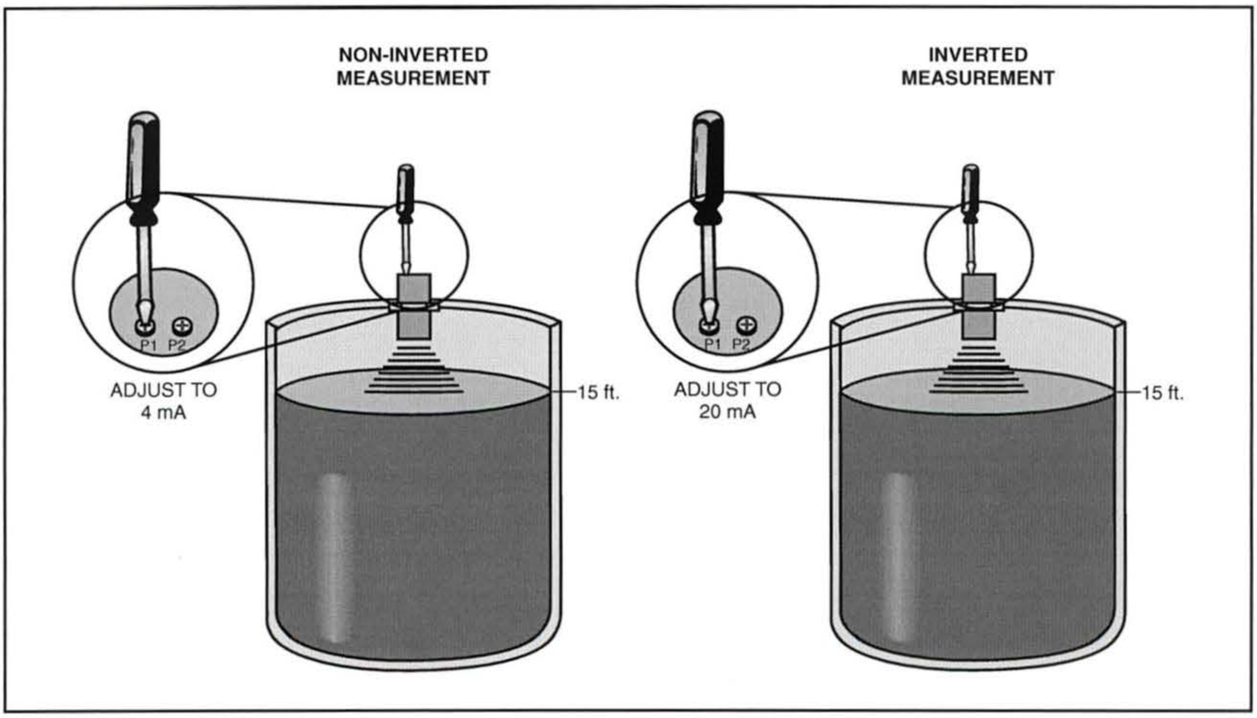


Figure 23. Adjust the Sensor Zero

Set the zero adjustment by emptying the tank to its minimum level and turning the zero adjust potentiometer (usually using a precision screwdriver) until the display on the loop calibrator or DMM reads 4 mA or 0 V.

### Step 3: Adjust the Sensor Span

Set the span adjustment by filling the container to its maximum level and turning the span adjust potentiometer until the display on the loop calibrator or DMM reads 20 mA or 10 V.

## SKILL 2 CALIBRATE AN ULTRASONIC LEVEL SENSOR

**Procedure Overview**

In this procedure, you will connect an ultrasonic level sensor and then calibrate the sensor for inverted measurement so that it accurately measures the level of liquid in the process tank.


❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to set up the T5552, as shown in figure 24.

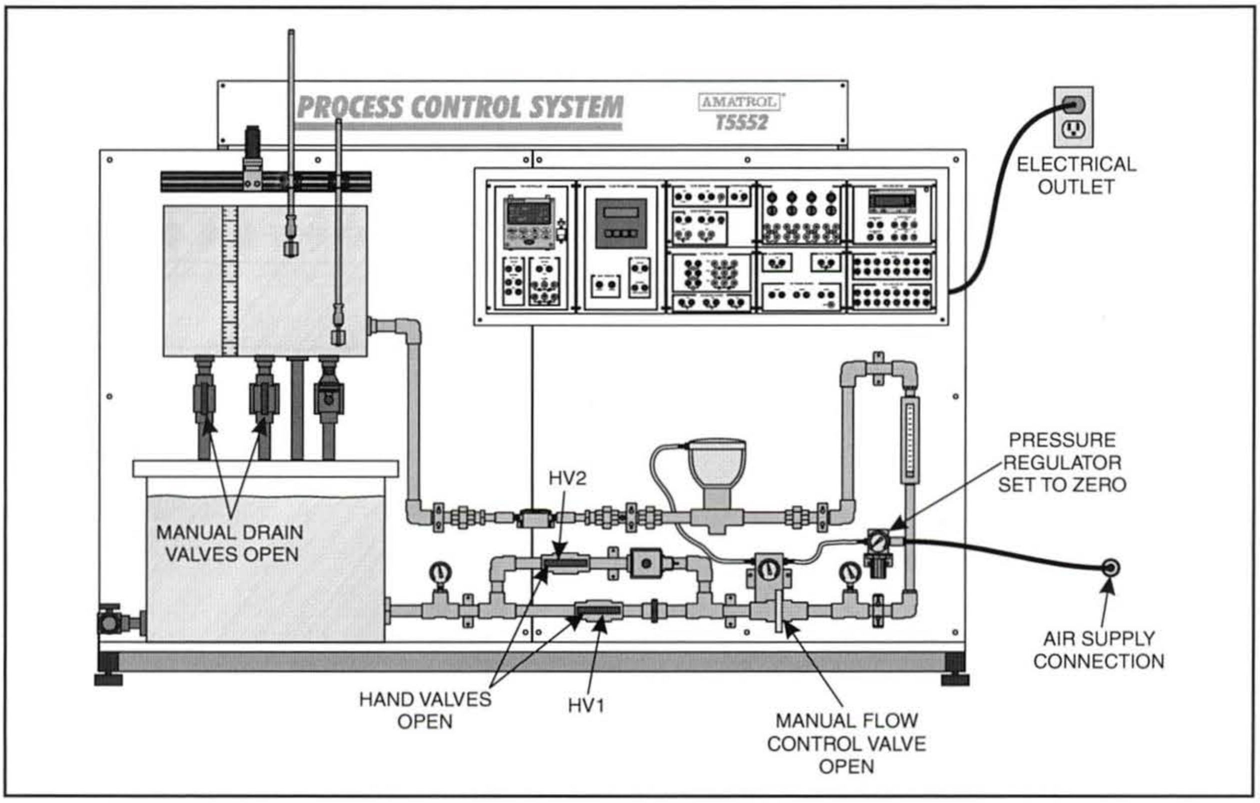


Figure 24. T5552 Setup

A. Fill the reservoir tank with water.

B. Connect the air supply line to the T5552.

C. Set the pressure regulator to 0 psi.

D. Open the process tank manual drain valves.

❑ 3. Connect the circuit shown in figure 25.

This circuit allows you to calibrate the ultrasonic level sensor and measure the level in the process tank. It also allows you to measure the output from the ultrasonic sensor using a multimeter or loop calibrator.

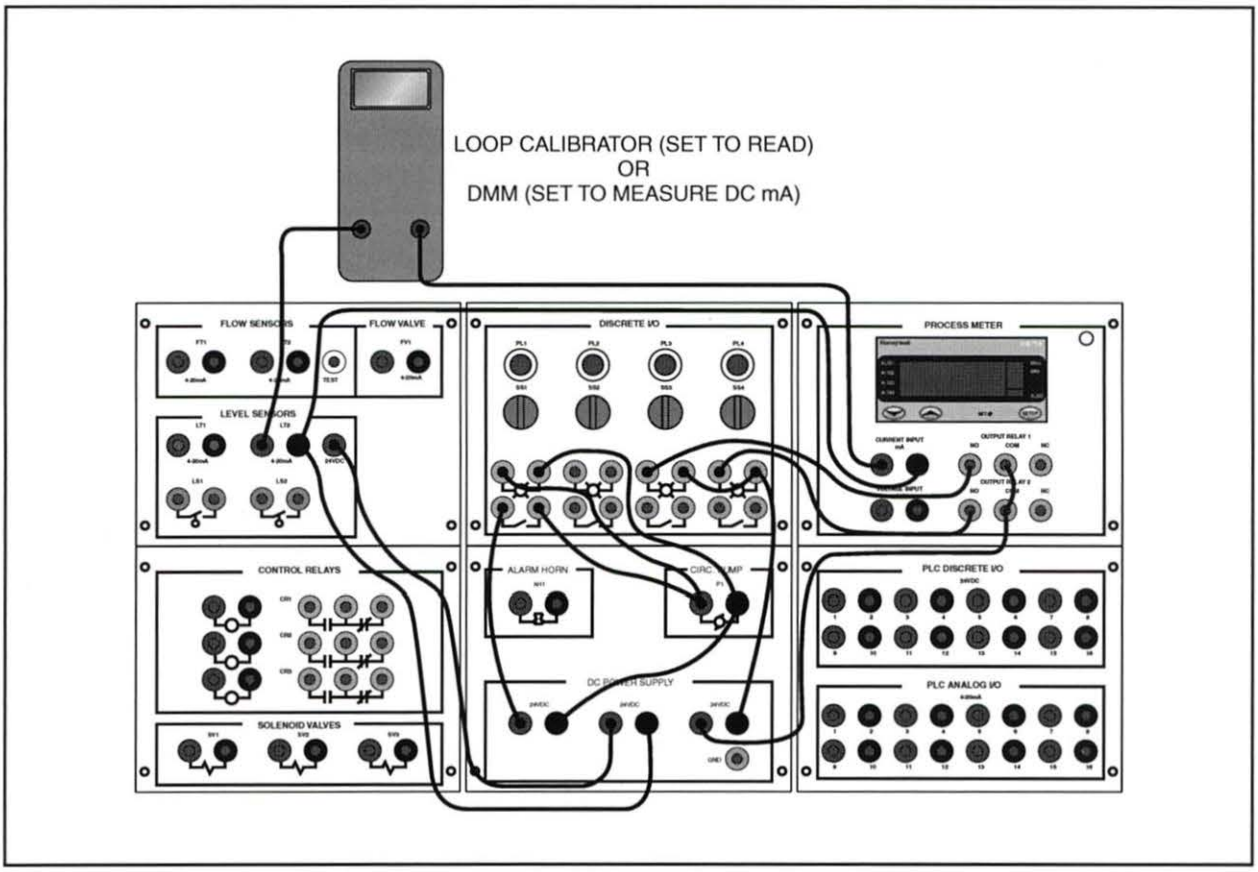


Figure 25. Calibration and Measurement Circuit

Figure 26 shows the P&ID for the T5552. The active components and wiring are highlighted.

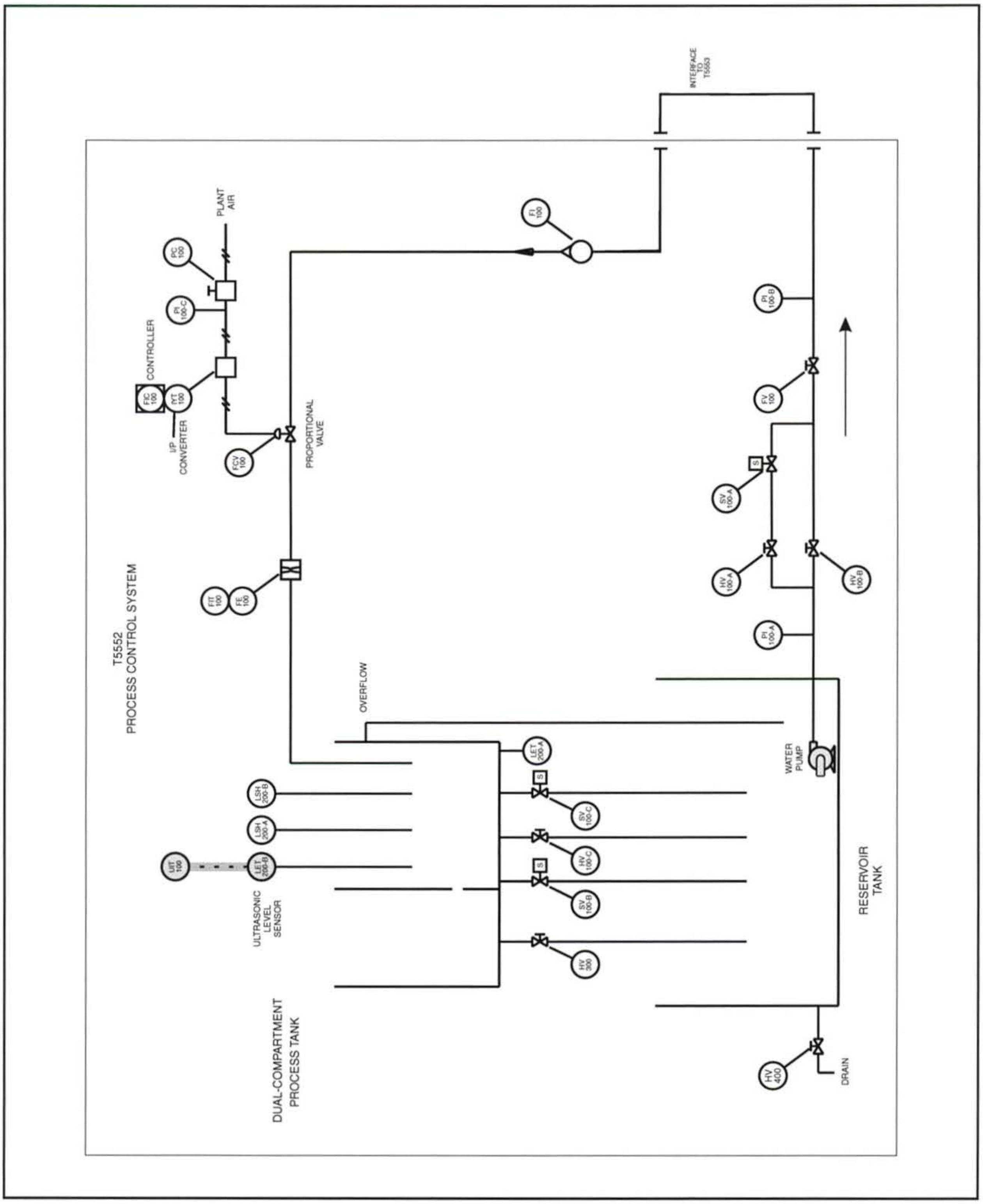


Figure 26. T5552 P&ID

Figure 27 shows the wiring diagram for the circuit.

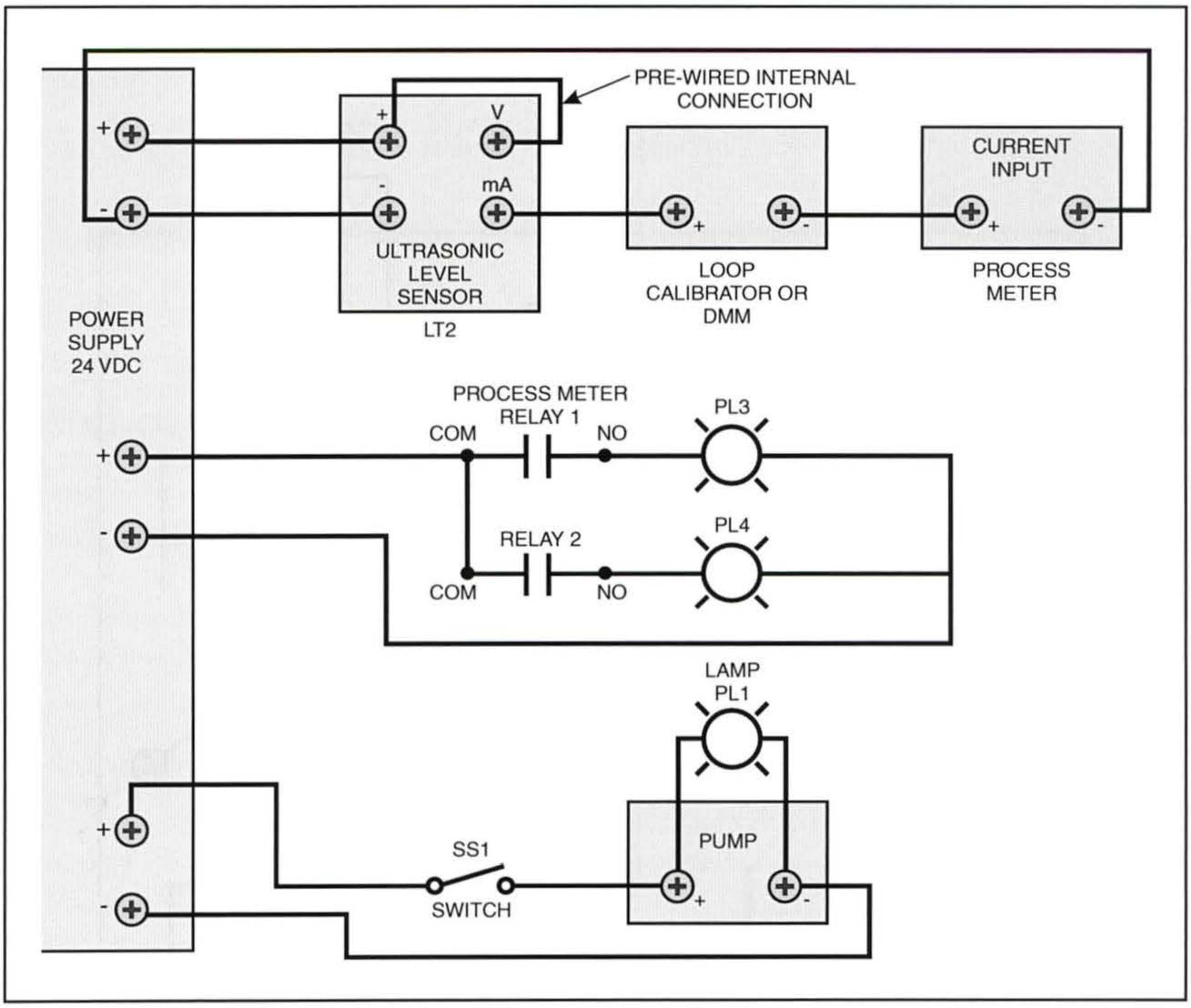


Figure 27. Wiring Diagram for Calibration and Measurement Circuit

❑ 4. Remove the lockout/tagout.

❑ 5. Perform the following substeps to set the zero for the ultrasonic sensor.

A. Turn on the main circuit breaker.

B. Make sure the water in the process tank is at the zero-inch mark.

**NOTE**

You may notice that a small amount of water cannot be drained from the tank using the manual drain valves. The bulkhead fittings in the bottom of the tank prevent complete drainage. For this reason, the 0-inch mark on the tank scale is located at the height of the fittings.

C. Use a precision screwdriver to adjust the P2 potentiometer on the top of the sensor, as shown in figure 28, until the display on the multimeter or loop calibrator indicates 4 mA.

Figure 28. Adjustment of Potentiometer P2

The ultrasonic sensor is shipped in the inverted measurement configuration. Therefore, a full tank gives a maximum output (20 mA) and an empty tank gives a minimum output (4 mA). In the non-inverted configuration, P2 is still adjusted for the point farthest away from the sensor. However, it is adjusted to 20 mA instead of 4 mA.

❑ 6. Perform the following substeps to set the span for the ultrasonic sensor.

A. Close the process tank manual drain valves.

B. Turn on selector switch **SS1** to start the circulation pump.

C. Fill the tank to the **10-inch** mark.

When the level reaches the 10-inch mark, turn off selector switch **SS1** to stop the pump.

D. Using a precision screwdriver, adjust potentiometer P1 on the ultrasonic level sensor, as shown in figure 29, until the display on the multimeter or loop calibrator indicates 20 mA.

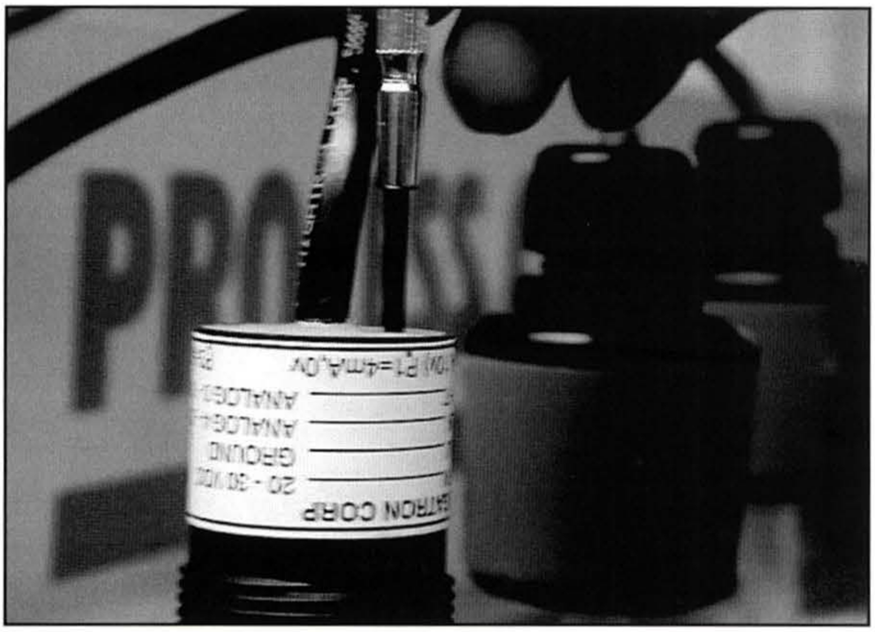

Figure 29. Adjustment of Potentiometer P1

❑ 7. Program the Honeywell UDI 1700 process meter according to the values listed in the table in figure 30. These settings allow the process meter to display the level height, which the ultrasonic sensor measures. They also indicate low-level (2 inches) and high-level (8 inches) alarm conditions to the process meter.

| MENU | PARAMETER | VALUE |
|---|---|---|
| ConF | inPt | 4_20 |
| | ruL | 10.0 |
| | rLL | 0.0 |
| | ALA 1 | P_Lo |
| | PLA 1 | 2.0 |
| | AHY 1 | 0.1 |
| | ALA 2 | P_Hi |
| | PhA 2 | 8.0 |
| | AHY 2 | 0.1 |
| | USE 1 | A1nd |
| | USE 2 | A2nd |

27.7

Figure 30. Honeywell UDI 1700 Process Meter Settings

❑ 8. Perform the following substeps to measure the output of the ultrasonic level sensor.

A. Open tank manual drain valves HV3 and HV4 to drain the process tank.

B. Close the manual drain valves (HV3 and HV4) when the process tank empties.

Indicator light PL3 should turn on, indicating a low level alarm.

C. Turn on selector switch **SS1** to start the pump.

The process meter should display the water level in inches.

D. When the level exceeds 2 inches on the tank scales, turn off selector switch **SS1** to stop the pump.

When the level exceeds 2 inches, indicator light PL3 should go out indicating a sufficient level in the tank. There should be no alarms between 2 and 8 inches. These are the low and high-level parameters you set on the process meter (PLA1 = 2.0, PhA2 = 8.0). Past 8 inches, indicator light PL4 should turn on, indicating a high level alarm.

E. In the following table, record the reading on the process meter and the sensor output for each reading listed.

| LEVEL MEASUREMENTS | | |
|---|---|---|
| TANK SCALE READING (in) | PROCESS METER READING (in) | SENSOR OUTPUT (mA) |
| 2 | | |
| 4 | | |
| 6 | | |
| 8 | | |

Figure 31. Level Measurement Table

F. Determine if the tank scale readings and the process meter readings are close.

Are tank scale and process meter the readings within 0.3 inch of each other? ________________________________(Yes/No)

You should find that the readings are close. If the readings are off by more than 0.3 inch, you should recalibrate the ultrasonic sensor.

❑ 9. Perform the following substeps to shut down the T5552.

A. Open the process tank manual drain valves to drain the tank.

B. Close the process tank manual drain valves after the tank empties.

C. Turn off the main circuit breaker.

D. Disconnect the circuit.

E. Plot the output versus the level using the values you recorded in the table in step 8.

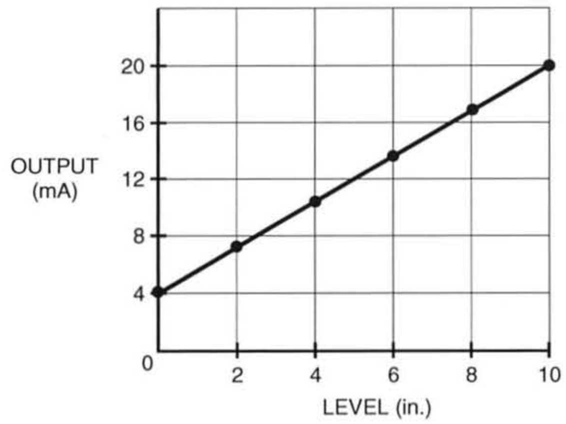


Figure 32. Output vs. Level

Your plot should look similar to the one in figure 32.

**SEGMENT 2**

# SELF REVIEW

1. Manufacturer's specifications list the ____________ of ultrasonic beams to help ensure proper positioning.

2. Proper sensor positioning helps to ensure that the ultrasonic waves do not __________ off of any surface other than the material being measured.

3. The first step in calibrating an ultrasonic level sensor is to __________ the sensor.

4. The final two steps in calibrating an ultrasonic level sensor include adjusting the sensor zero and adjusting the sensor ____________.

5. The same potentiometers that adjust the zero and span output for non-inverted measurement also adjust the output for _______ measurement.

6. The potentiometer that adjusts the 4 mA output for non-inverted measurement may adjust the _______ output for inverted measurement.

# SEGMENT 3

## LEVEL CONTROL

### OBJECTIVE 7 DESCRIBE THE OPERATION OF A CLOSED LOOP LEVEL CONTROL SYSTEM THAT USES AN ULTRASONIC SENSOR


Although ultrasonic sensors use a different method of sensing level than other sensors (e.g. pressure-type level sensors), they operate in a closed loop system in the same manner as other sensors; they provide an electrical output signal that is proportional to the level. However, the controller parameters must be set to match the configuration used, either inverted or non-inverted.

Figure 33 shows an ultrasonic level sensor wired in a closed loop system for non-inverted measurement. In this system, the high level point (full tank) is 25 ft and the low level point (empty tank) is 0 ft. The Hi and Lo input parameters on the controller correspond to the displayed value when the signal input is at a maximum and minimum, respectively. For non-inverted measurement, the maximum sensor output (maximum controller input) occurs when the container is empty and the minimum sensor output (minimum controller input) occurs when the container is full. Therefore, 0 is the Hi input parameter and 25 is the Lo input parameter.

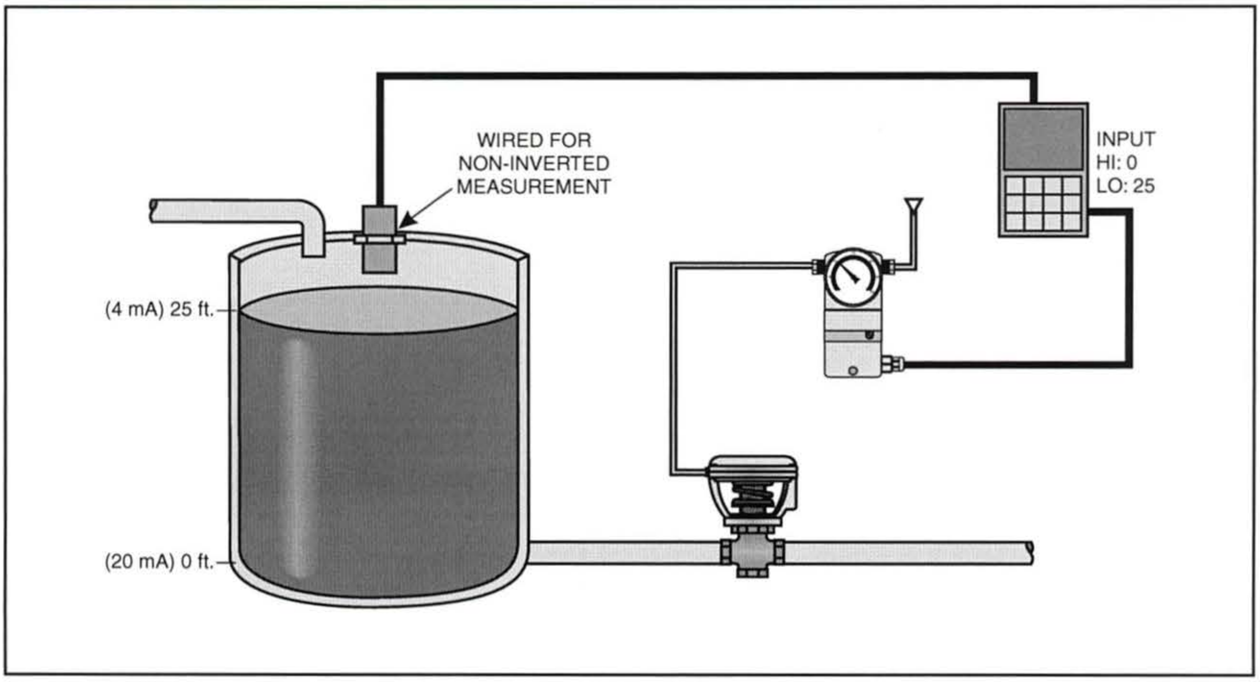


Figure 33. Non-Inverted Measurement in a Closed Loop System

Some controllers display or flash a configuration error for this type of setup because the low limit is greater than the high limit. However, the error usually serves as a warning to ensure that the setup is intentional and does not prevent the controller from functioning.

If the sensor is wired for inverted measurement, as shown in figure 34, the maximum sensor output occurs when the level is at a maximum and the minimum sensor output occurs when the level is at a minimum. Therefore, the Hi input parameter is 25 and the Lo input parameter is 0.

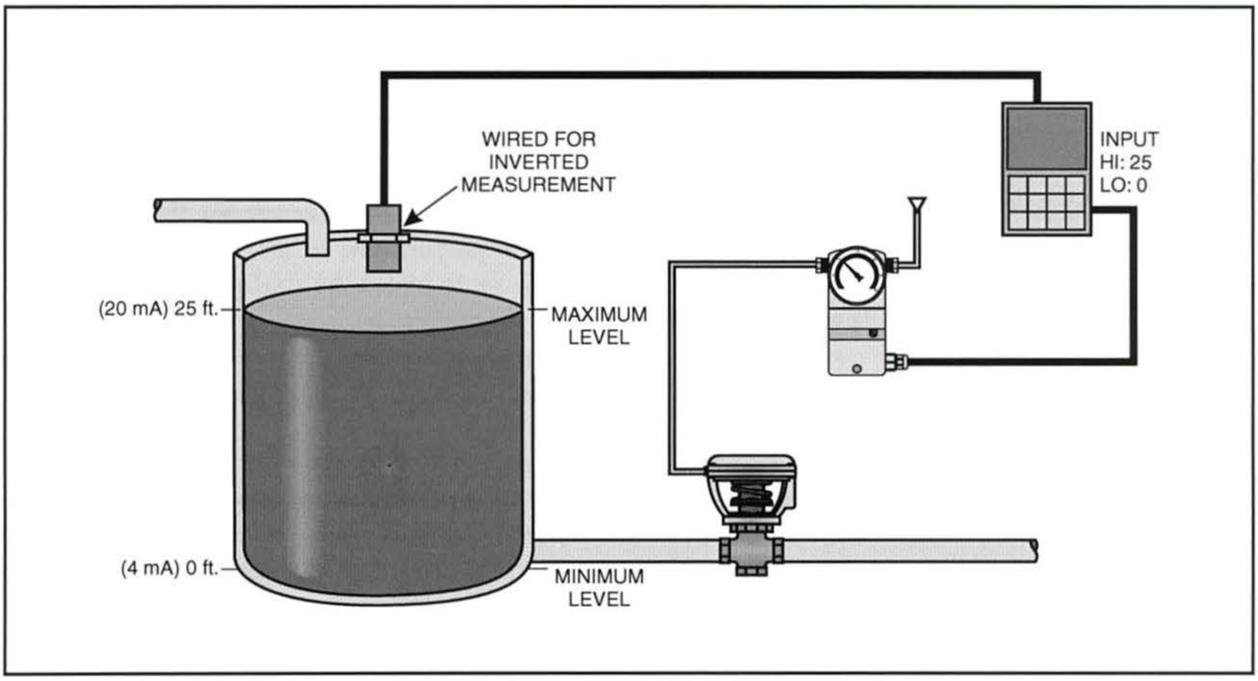


Figure 34. Inverted Measurement in a Closed Loop System

Also, because the controller receives the value of the PV from the sensor, it may be necessary to set the controller as reverse acting, depending on the type of valve used in the system. For example, if the sensor is wired for non-inverted measurement and an air-to-close valve is used, the controller should be set as reverse acting, as shown in figure 35. For non-inverted measurement and an air-to-open valve, the controller should be set as direct acting. The controller settings are opposite for inverted measurement: direct acting for an air-to-close valve and reverse acting for an air-to-open valve.

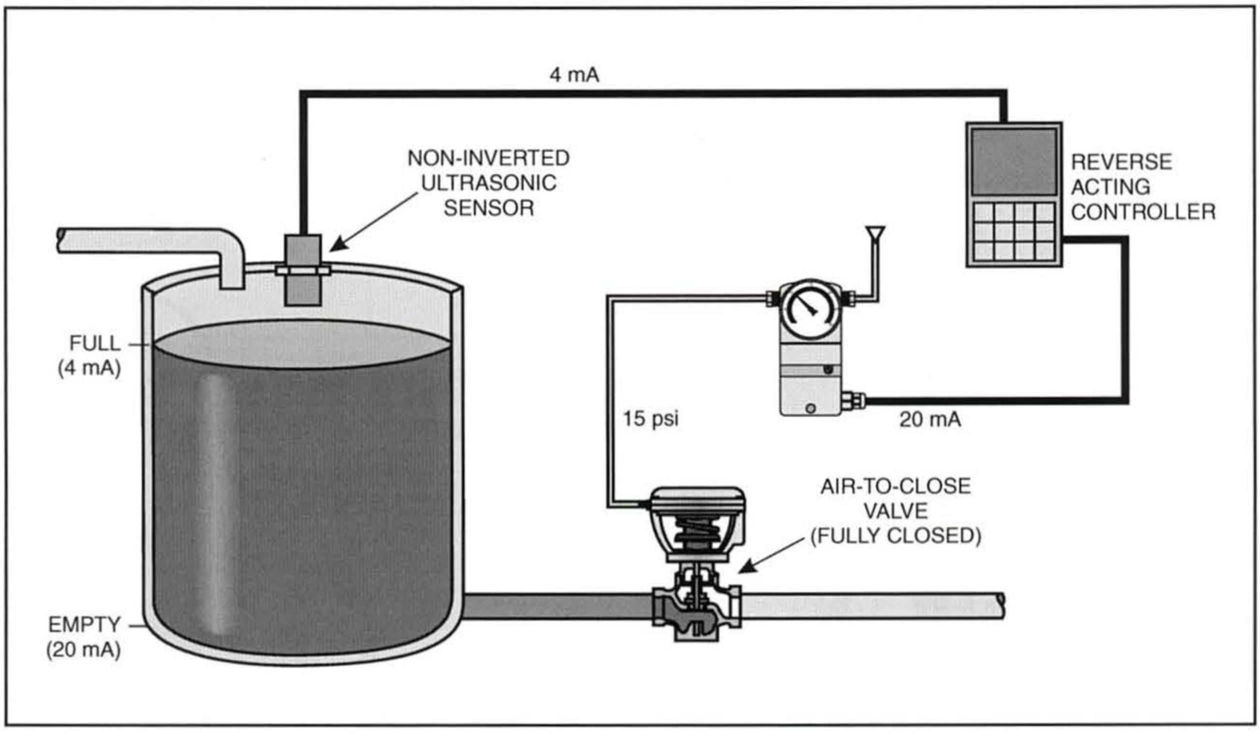


Figure 35. Non-Inverted Sensor Wired to a Reverse Acting Controller

As you should recall, PI control is often used in controlling level systems because it provides an immediate response and eliminates offset. Derivative control can also be added to the control system to speed up the response of the system if large errors occur. The settings for the control method when using an ultrasonic level sensor are the same as those for other types of level sensors because the settings are based on system response. The difference in response times between an ultrasonic level sensor and a pressure-type level sensor, for example, is negligible.

## SKILL 3 OPERATE A CLOSED LOOP SYSTEM THAT USES AN ULTRASONIC LEVEL SENSOR

**Procedure Overview**

In this procedure, you will connect an ultrasonic sensor to a Honeywell controller to control the level in the process tank.


❑ 1. Perform a lockout/tagout.

❑ 2. Perform the following substeps to set up the T5552, as shown in figure 36.

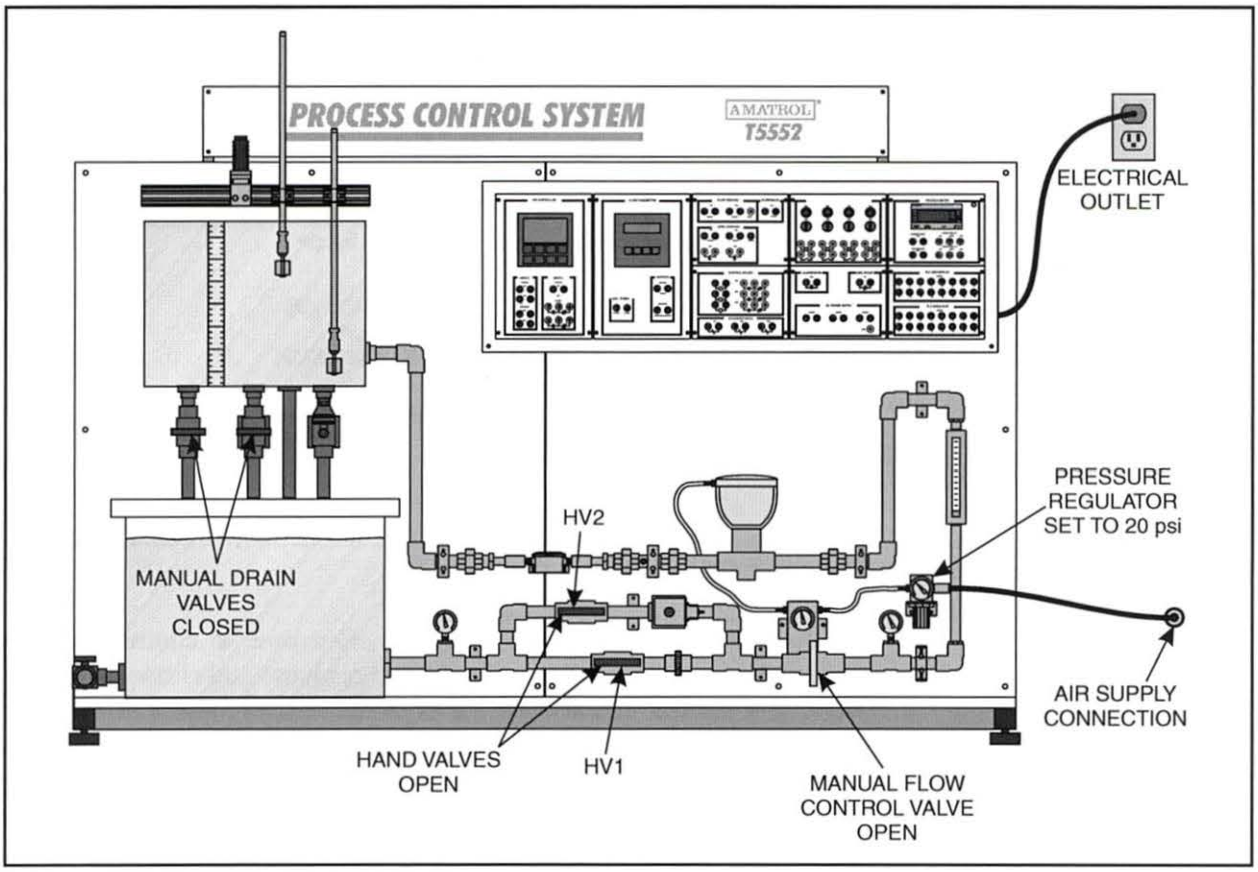


Figure 36. T5552 Setup

A. Fill the reservoir tank with water.

B. Connect the air supply line to the T5552.

C. Set the pressure regulator to 20 psi.

D. Close the process tank manual drain valves.

❑ 3. Connect the circuit shown in figure 37.

This is the same circuit as in figure 16, and it allow you to recheck the calibration of the sensor.

If the process meter is not properly configured, configure it before proceeding (see Skill 1 step 4 for settings).

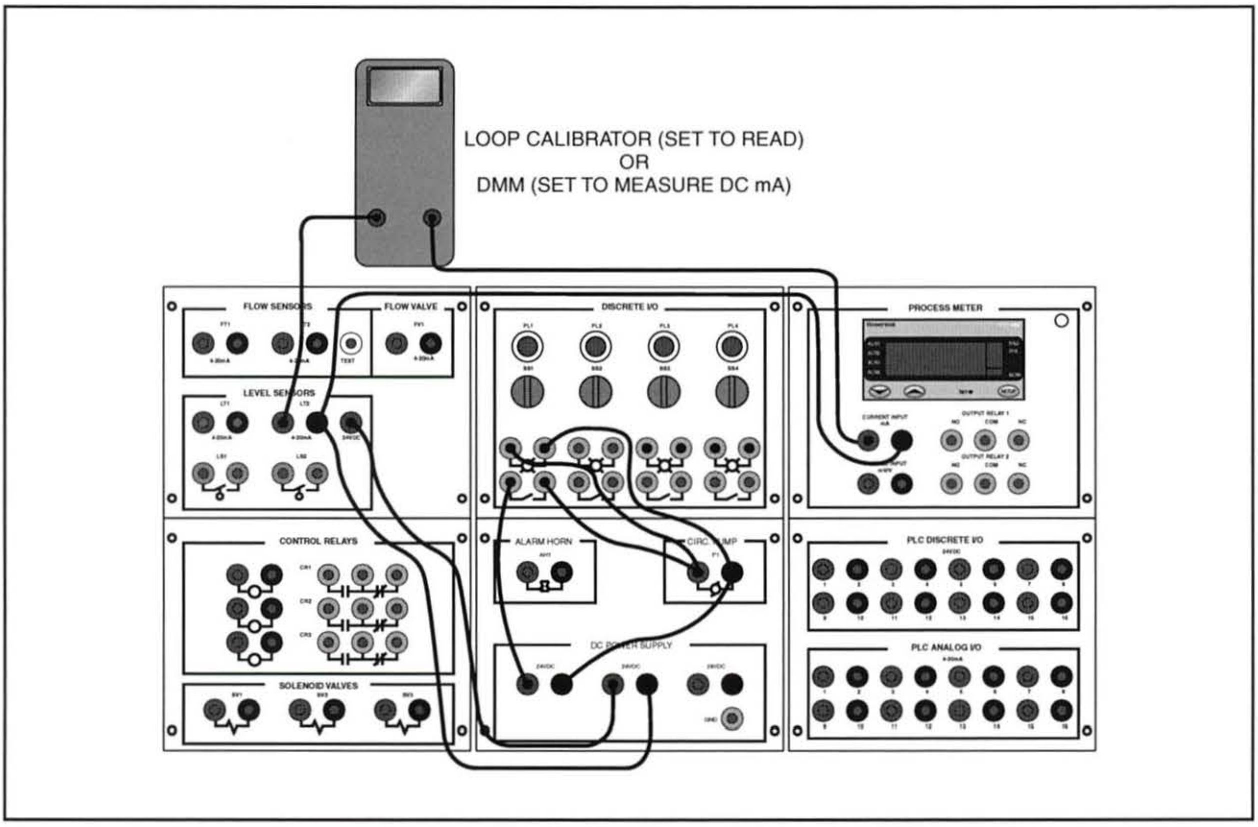


Figure 37. Calibration Circuit

Figure 38 shows the wiring diagram for the circuit.

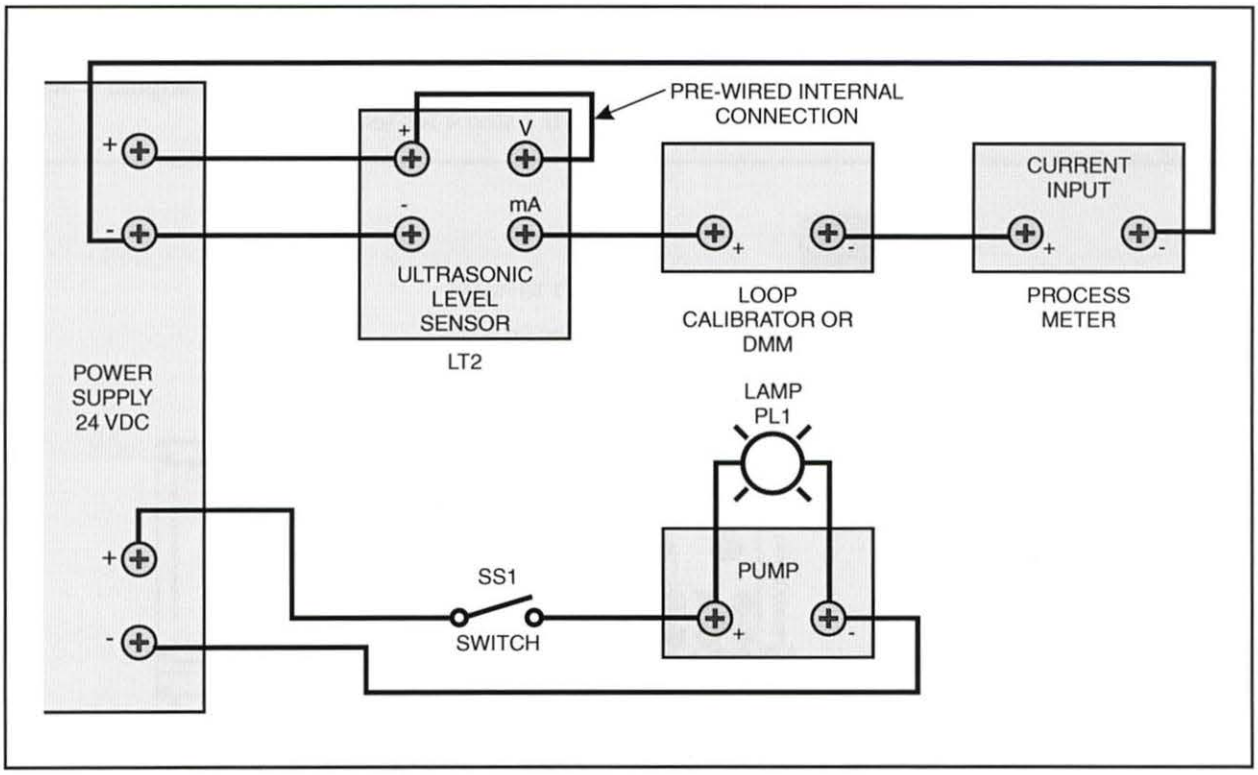


Figure 38. Wiring Diagram for Calibration Circuit

❑ 4. Perform the following substeps to check the calibration of the ultrasonic level sensor.

A. Remove the lockout/tagout.

B. Check the output of the sensor when the water level in the tank is at the zero-inch mark using the multimeter or loop calibrator.

If the output is not 4 mA, adjust potentiometer **P2** until the output reads 4 mA.

C. Check the output of the sensor when the tank is full (10 inches) using the multimeter or loop calibrator.

If the output is not 20 mA, adjust potentiometer **P1** until the output reads 20 mA.

D. Turn off the main circuit breaker and disconnect the circuit.

❑ 5. Connect the circuit shown in figure 39.

This circuit allows you to control the level in the process tank using the Honeywell controller. The ultrasonic level sensor sends a feedback signal to the controller and the controller sends a corrective signal to the proportional valve through the I/P converter.

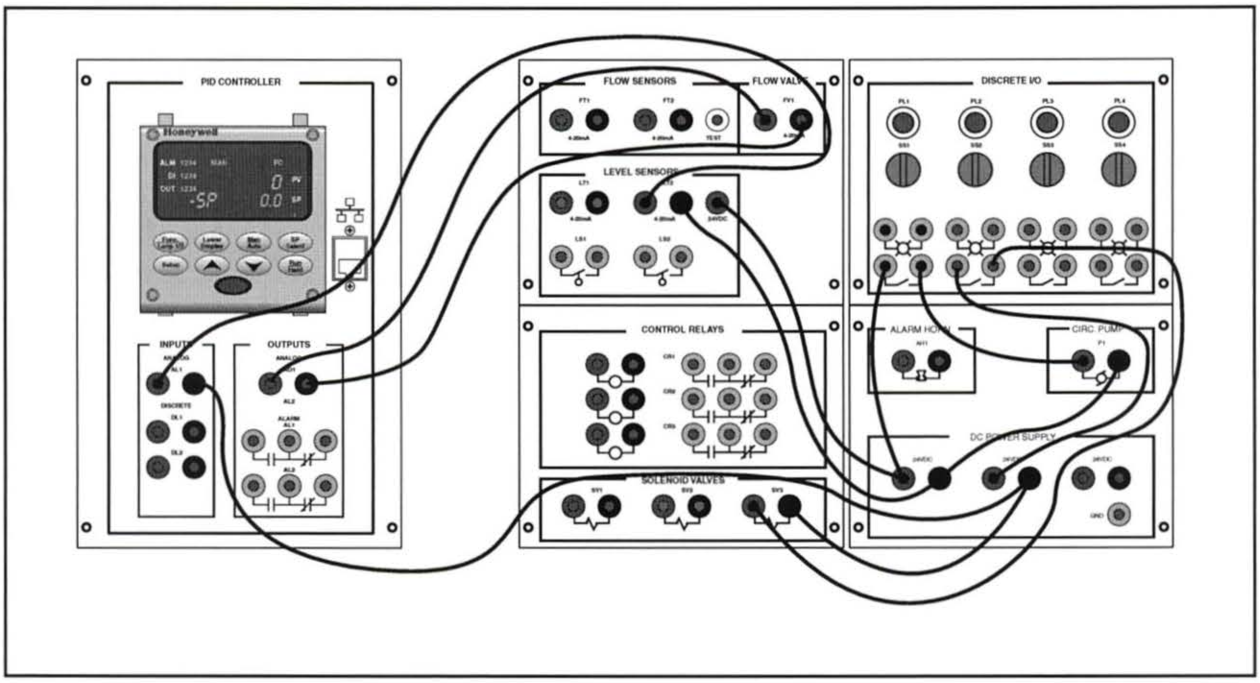


Figure 39. Level Control Circuit

Figure 40 shows the P&ID for the T5552. The active components and wiring are highlighted.

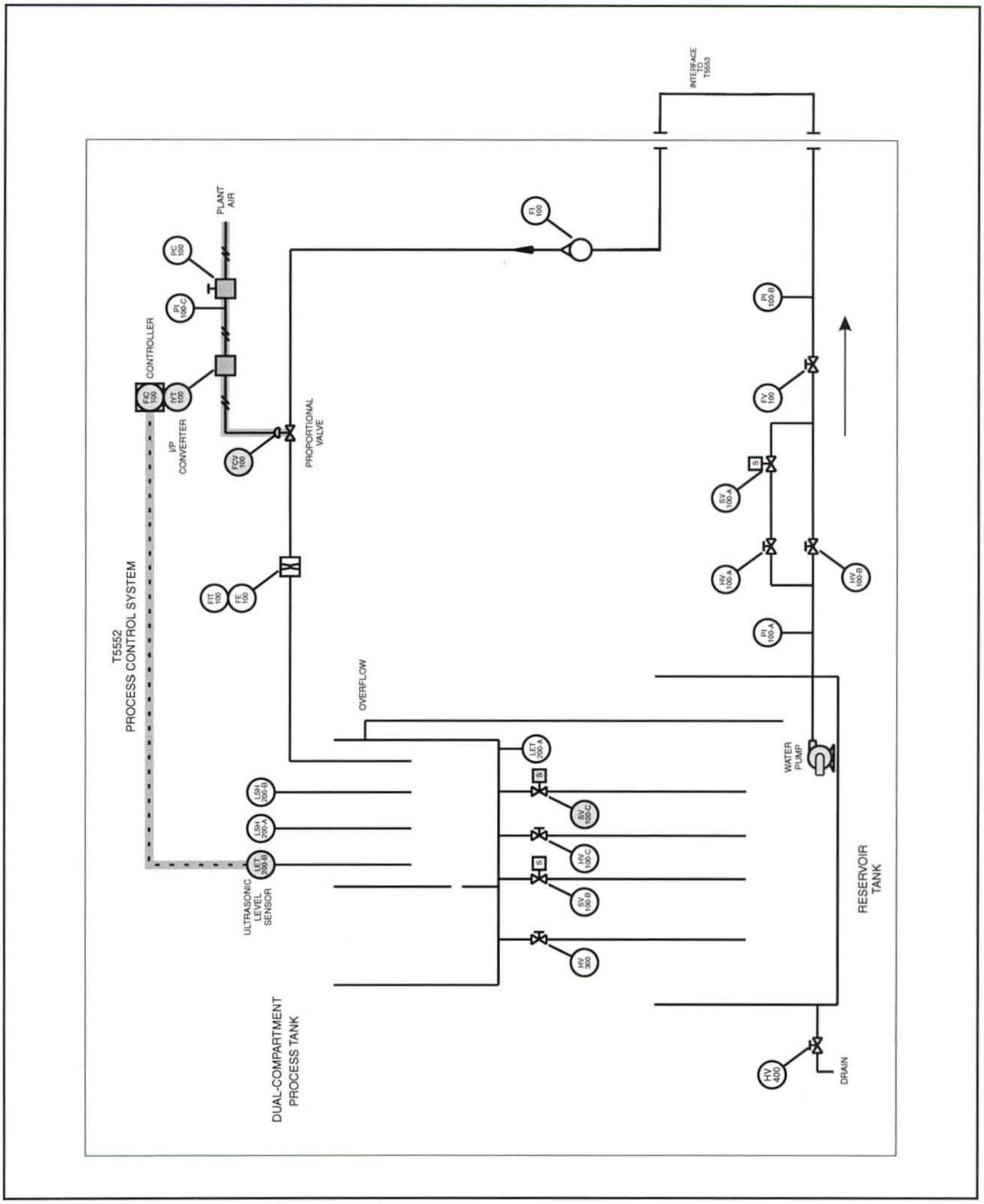


Figure 40. T5552 P&ID

Figure 41 shows the wiring diagram for the circuit.

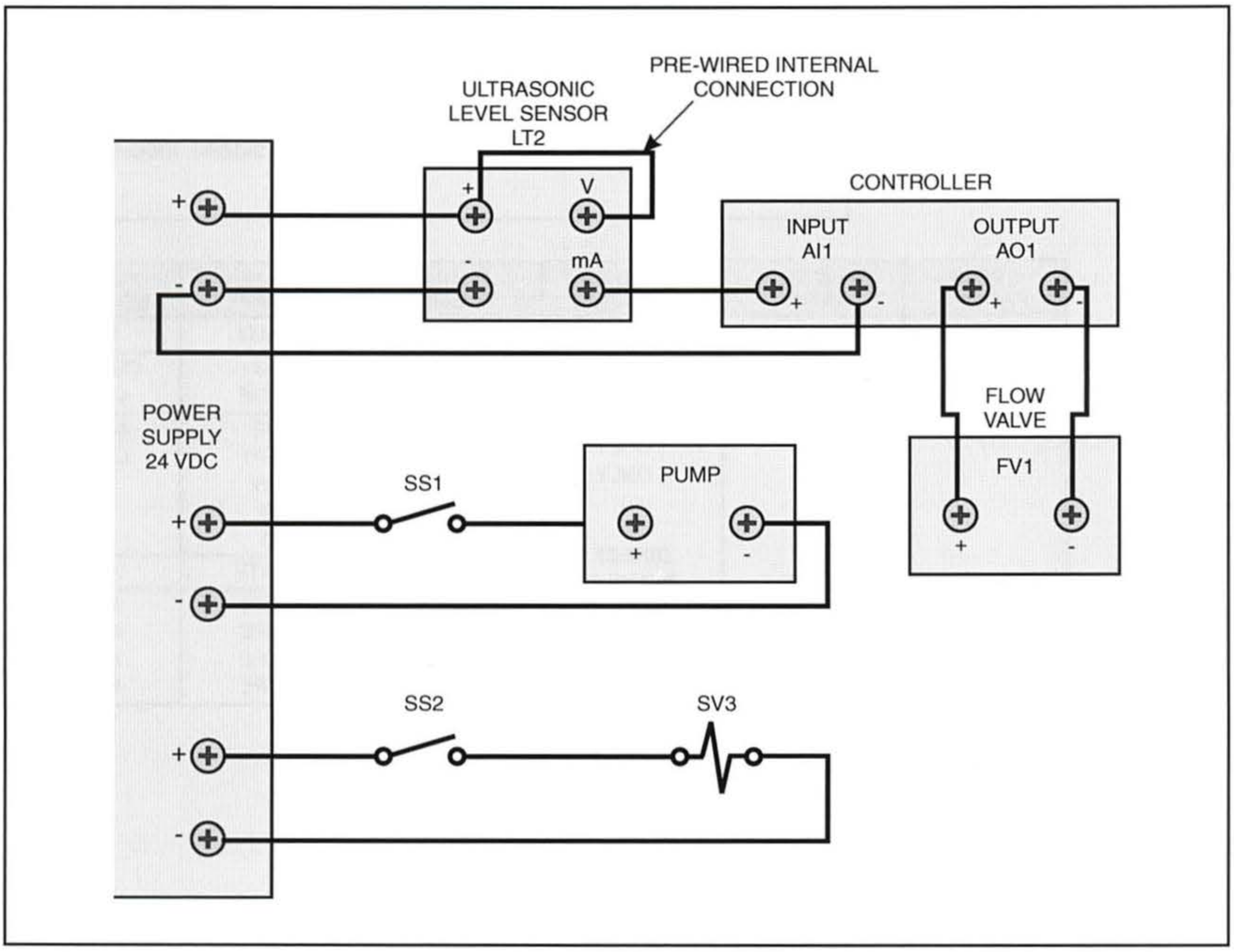


Figure 41. Wiring Diagram for Level Control Circuit

❑ 6. Remove the lockout/tagout and turn on the main circuit breaker.

❑ 7. Set the Honeywell controller to the settings in figure 42.

> **NOTE**
>
> If the system does not respond correctly, it may be necessary to tune it using the Ziegler-Nichols open or closed loop-tuning method.

| GROUP PROMPT | FUNCTION PROMPT | VALUE OR SELECTION |
|---|---|---|
| **TUNING** | GAIN | 20 |
| | RATE MIN | 0 |
| | RSET MIN | 0.25 |
| **CONTROL** | PV SOURC | INP 1 |
| | PID SETS | 1 ONLY |
| | LSP'S | 1 ONLY |
| | SP HiLIM | 10 |
| | SP LoLIM | 0 |
| | ACTION | DIRECT |
| | OUT RATE | DISABLE |
| | PCT/M UP | 0 |
| | PCT/M DN | 0 |
| | OUTHiLIM | 100 |
| | OUTLoLIM | 0 |
| | I Hi LIM | 100 |
| | I Lo LIM | 0 |
| | PborGAIN | GAIN |
| | MINorRPM | MIN |

| GROUP PROMPT | FUNCTION PROMPT | VALUE OR SELECTION |
|---|---|---|
| **ALGROTHM** | CONT ALG | PID A |
| **OUT ALG** | OUT ALG | CURRENT |
| | C1 RANGE | 4-20 mA |
| **INPUT 1** | IN1 TYPE | 4-20 mA |
| | XMITTER1 | LINEAR |
| | IN1 HIGH | 10.0 |
| | IN1 LOW | 0 |
| | BIAS IN1 | 0 |
| **COM** | ComSTATE | DISABL |
| **ALARMS** | A1S1TYPE | NONE |
| | A1S2TYPE | NONE |
| | A2S1TYPE | NONE |
| | A2S2TYPE | NONE |

Figure 42. Settings for the Honeywell Controller

❑ 8. Perform the following substeps to operate the level control circuit.

A. Adjust the controller setpoint to **5.0**.

B. Place the controller in automatic mode.

C. Turn on selector switch **SS1** to start the circulation pump.

As the tank begins to fill you should notice that the level on the controller closely matches (within 0.2 inch) the scale on the tank.

D. Turn on selector switch **SS2** to energize solenoid drain valve SV3 and allow water to drain from the process tank.

E. Record the process variable value at which the process reaches a steady state.

Steady State Value ______________________________(inches)

You should find that the process reaches a steady state at 5.0 inches. The use of integral control eliminates offset.

F. After the system settles at the setpoint, adjust the SP to **8.0**. Then observe the reaction of the system to this new setpoint.

You should notice that the system responds by opening the control valve, allowing the level to rise to the new SP.

❑ 9. Perform the following substeps to observe the system's response to a disturbance.

A. After the PV settles at the new SP (8.0), close the manual flow control valve approximately halfway to decrease flow into the tank.

You should notice that the level begins to decrease. However, the controller responds by decreasing its output to allow more flow into the tank.

> **NOTE**
>
> If the tank does not begin to refill to the SP, the manual flow control valve is closed too far for the system to recover. If this is the case, slightly open the flow control valve until the level begins to rise.

B. When the level recovers to the SP of 8.0, fully open the manual flow control valve.

You should notice that the level in the tank begins to rise. However, the controller should respond by increasing its output to allow less flow into the tank. This enables the PV to decrease back to the SP.

C. When the level recovers to the SP of 8.0, adjust the controller SP to **3.0**.

You should notice that the controller responds by decreasing its output. The system should reach a steady state at the new SP (3.0 inches).

D. Adjust the manual flow control valve as in substeps 9A and 9B to observe the response of the system to a disturbance at this new setpoint.

You should find that the system returns to the SP after each disturbance.

❑ 10. Perform the following substeps to shut down the T5552.

A. Open the process tank drain valves to empty the tank. When the tank is empty, close the valves.

B. Turn off the main circuit breaker.

C. Disconnect the circuit.

SEGMENT 3

# SELF REVIEW

1. Ultrasonic level sensors provide an electrical output signal that is ____________ to the level.

2. When using an ultrasonic level sensor in a closed-loop system, the controller _______ must match the configuration used, either inverted or non-inverted.

3. _______ (P/PI/PD/PID) control is used in level control systems because it provides an immediate response and eliminates offset.

4. _________ control can be added to a control method to speed up the response of the system.

5. If the ultrasonic sensor is wired for inverted measurement, the _______ sensor output occurs when the level is at a maximum.

6. If the ultrasonic sensor is wired for non-inverted measurement and an air-to-close valve is used, the controller should be set as _______ acting.