Judd Communications Depth Sensor

SPECIFICATIONS

Power: +12 to 18 VDC, 50 mA
(maximum sample time 2.6 seconds)

Output: 0 to 2.5 or 0 to 5 VDC

Range: .5 to 10 meters (1.6 to 32.8 feet)

Beam width: 22 degrees

Accuracy: ± 1 cm or .4 % distance to target

Resolution: 3 mm (.12 inches)

Temp. range: -40° to + 70°C (-40° to 158°F)

Size: 8 x 8 x 13 cm (3 x 3 x 5 inches)

Weight: .6 kg (1.3 lbs.)

Mounting: 1/2 inch threaded pipe

Cable length: 7.6 meters (25 feet)

Max. cable length: 304 meters (1000 feet)

Temperature Sensor Accuracy: ± .5°C, -40 to +85°C

Temperature Sensor Resolution: .5°C

INTRODUCTION

The Judd Communications Depth Sensor is an inexpensive solution for remotely measuring snow depth or water levels. The sensor measures the distance from the sensor to a target. The sensor works by measuring the time required for an ultrasonic pulse to travel to and from a target surface. An integrated temperature probe with solar radiation shield, provides an air temperature measurement for properly compensating the distance measured. An embedded microcontroller calculates a temperature compensated distance and performs error checking.

Both distance and air temperature can be output as an analog signal between 0 to 2.5 Volts or 0 to 5 Volts. The depth sensor is user configurable by means of internal dip switches. Several configurations are possible and allow the depth sensor to work with as many different type of systems as possible.

Accurate measurement of snow depth poses many difficult problems. The Judd Communications Depth Sensor has proven very effective in measuring snow depth, which makes it well suited for other various applications.

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OPERATION

Ultrasonic simply means sound waves that are above the range of human hearing in frequency. The depth sensor's ultrasonic ranging system operates at a frequency of 50 kilohertz (50,000 cycles). The key component of the ultrasonic system is the transducer. The transducer is first used as a speaker to transmit an ultrasonic pulse, then it is used as a microphone to listen for the pulse after being reflected off a surface. By measuring the amount of time that it takes the ultrasonic pulse to travel from the transducer to a surface and back again, a distance can be calculated.

The Judd Communications Depth Sensor outputs an analog signals that are proportional to the distance and air temperature being measured. Both measurements are output sequentially through a single output. The output signal has two ranges: 0 to 2.5 Volts or 0 to 5 Volts. The range is selected by a jumper on the main circuit board. The output signals can be can be scaled using the following multipliers:

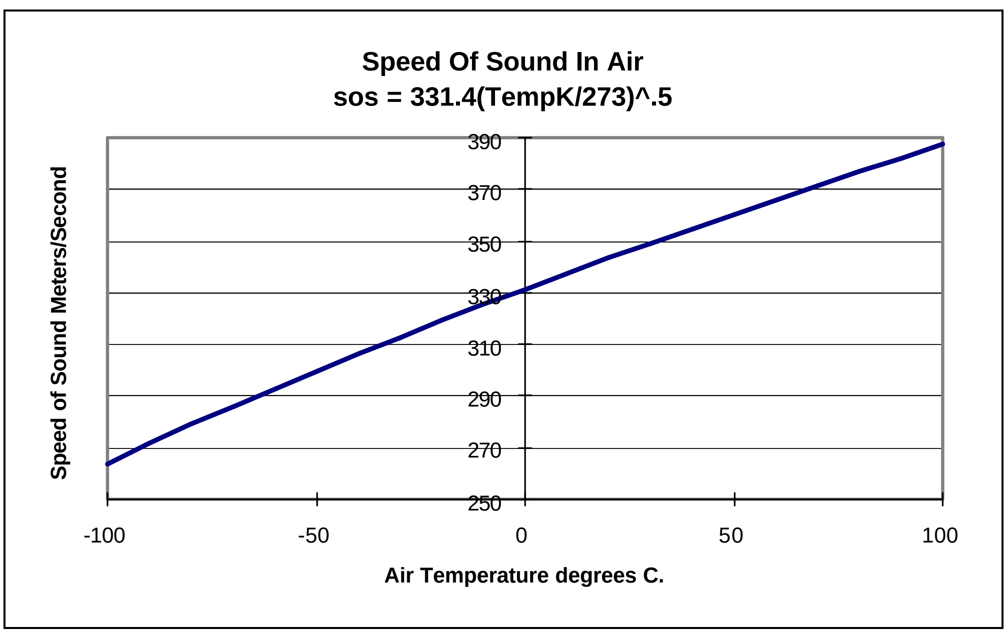
Distance:

Scale	**0-2.5 Volt Range**	**0-5 Volt Range**
Inches	196.85 inches/Volt	98.43 inches/Volt
Centimeters	500 cm./Volt	250 cm./Volt

Air Temperature:

Scale	**0-2.5 Volt Range**	**0-5 Volt Range**
Degrees Kelvin	200 degrees/Volt	100 degrees/Volt

The JC Depth Sensor performs multiple echo processing. Multiple echo processing dramatically improves the reliability of measurements. For each measurement cycle, two initial measurements are made. If the difference between the two distances is <u>less than</u> 1 centimeter, then the second sample is saved, and output. If the difference between the two samples is <u>greater than</u> 1 centimeter, then the oldest sample is discarded and another measurement is made and another comparison is made. This retry algorithm will continue up to a maximum of ten times. When a valid measurement can not made, or no echo is returned, a value of zero is output. When a zero is output to the digital to analog converter, the output voltage is typically in the range of 3-5 millivolts.



Graph 1

The speed of sound in air varies with temperature. Graph 1 shows the relation. An accurate air temperature measurement is required for calculating the speed of sound in air. From this, a correction factor can be calculated for properly compensating the measured distance. With the air temperature measurement taken from its built in probe, the JC Depth Sensor outputs a temperature compensated distance.

Judd Communications Depth Sensor, Analog Version

The JC Depth Sensor has a beam width of 22 degrees. The closest object to the sensor will be detected if it is within its beam width. The diameter of the cone is equal to .38 multiplied by the height of the sensor above the target.

When installed correctly and operated within its limitations, the JC Depth Sensor can provide accurate and reliable distance measurements. The following are the most likely causes of erroneous measurements:

- The sensor is not perpendicular to the target surface
- The target is small and reflects little sound
- The target surface is rough and uneven
- The target surface is a poor reflector of sound, such as low density snow (< 5%)
- The transducer is obstructed by ice or debris
- Strong winds are blowing the echo out from under the sensor

SENSOR WIRING

Color	Function	Datalogger Connection
Red	+12V	+12V
Black	Ground	Ground
Clear	Shield	Ground
Green	Sensor Enable	2.5 to 12 V Control Port
White	Output High	Single or Differential input High*
Brown	Output Low	Differential input Low*

*When single ended inputs are used, the Brown lead is not used.

SENSOR PROGRAMMING

The following steps show how to make temperature and depth measurements with the JC Depth Sensor.

1. Turn on the sensor by applying a +5 to +12 Volt control signal to the green lead.
2. Wait for 800 milliseconds for the depth sensor to warm up and output a temperature measurement.
3. Sample the Air Temp. output by making a differential voltage measurement between the white (+) and the brown lead (-).
4. Wait for 1800 milliseconds for the depth sensor to output a distance measurement.
5. Sample the Distance output by making a differential voltage measurement between the white (+) and the brown lead (-).
6. Reset and turn off the sensor by removing the control signal from the green lead.

PROGRAMMING EXAMPLE

The following programming example shows how a Campbell Scientific CR10 datalogger is programmed for use with the Judd Communications depth sensor. It assumes that you have a depth sensor connected as follows:

Datalogger Connection	
Red	+12V
Black	Ground
Clear	Ground
Green	Control port 1 (C1)
White	Differential input channel 3 high (3H)
Brown	Differential input channel 3 low (3L)
Blue	Not connected

Judd Communications Depth Sensor, Analog Version

```
*     1       Table 1 Programs
        01: 5       Sec. Execution Interval

01:  P10      Battery Voltage
        01: 1       Loc [:Battery  ]
```

The depth sensor sampling routine works best as a subroutine. The following command will call subroutine #1 once an hour.

```
      02:  P92      If time is
        01: 0       minutes into a
        02: 60      minute interval
        03: 1       Call Subroutine 1
```

The following command will allow the user to activate the depth sensor by pressing the "F1" key while monitoring the input locations using the TERM or Graph TERM program.

```
      03:  P91      If Flag/Port
        01: 11      Do if flag 1 is high
        02: 1       Call Subroutine 1
```

If somebody left the depth sensor on, turn it off

```
      04:  P92      If time is
        01: 0       minutes into a
        02: 60      minute interval
        03: 30      Then Do


      05:  P91      If Flag/Port
        01: 11      Do if flag 1 is high
        02: 21      Set low Flag 1
```

End statement terminating IF time then DO command

```
      06:  P95      End
--------------------------------------------------
Final Storage, or Output Processing
--------------------------------------------------
```

One hour output

```
      07:  P92      If time is
        01: 0       minutes into a
        02: 60      minute interval
        03: 10      Set high Flag 0 (output)
```

Send hourly data to final storage
Array ID, Julian day, Time, Air Temp, Depth

Assign an output array ID of 101

```
      09:  P80      Set Active Storage Area
        01: 1       Final Storage Area 1
        02: 101     Array ID or location


      10:  P77      Real Time
        01: 120     Day,Hour-Minute

      11:  P71      Average
        01: 1       Rep
        02: 3       Loc Air TempF

      12:  P70      Sample
        01: 1       Reps
        02: 4       Loc Depth


      13:  P        End Table 1

--------------------------------------------------
Table 2 not used
--------------------------------------------------
      *     2       Table 2 Programs
        01: 0.0000  Sec. Execution Interval

      01:  P        End Table 2

-------------------------------------------------
Subroutines
-------------------------------------------------
      *     3       Table 3 Subroutines
```

Assign the depth sensor subroutine a number, note that this number and the calling number need to be the same.

```
      01:  P85      Beginning of Subroutine
        01: 1       Subroutine Number
```

Turn ON the depth sensor

```
      02:  P86      Do
        01: 41      Set high Port 1
```

Wait 0.8 seconds for the sensor to output the Air Temp.

```
      03:  P22      Excitation with Delay
        01: 1       EX Chan
        02: 80      Delay w/EX (units=.01sec)
        03: 0       Delay after EX (units=.01sec)
        04: 0       mV Excitation
```

Air Temp is output in milliVolts, scaled to Kelvin, and then convert to Celsius.

```
      04:  P2       Volt (DIFF)
        01: 1       Rep
        02: 5       2500 mV slow Range
        03: 3       IN Chan
        04: 2       Loc [:Air TempC]
        05: .2      Mult
        06: -273    Offset
```

Air Temp is also converted and saved in Fahrenheit

```
      05:  P37      Z=X*F
        01: 2       X Loc Air TempC
        02: 1.8     F
        03: 3       Z Loc [:Air TempF]

      06:  P34      Z=X+F
        01: 3       X Loc Air TempF
        02: 32      F
        03: 3       Z Loc [:Air TempF]
```

The depth sensor needs another 1.8 seconds to make up to 10 measurements and perform error checking and temperature compensation.

```
      07:  P22      Excitation with Delay
        01: 1       EX Chan
        02: 180     Delay w/EX (units=.01sec)
        03: 0       Delay after EX (units=.01sec)
        04: 0       mV Excitation
```

Distance is output in milliVolts, scaled to inches, and then converted to depth by subtracting the distance measured from the reference distance. Use a multiplier of -.19685 for output in inches and -.5 for ouput in centimeters.

```
      08:  P2       Volt (DIFF)
        01: 1       Rep
        02: 5       2500 mV slow Range
        03: 3       IN Chan
        04: 4       Loc [:Depth    ]
        05: -.19685 Mult    Convert to inches
        06: 46      Offset  Sensor mounted at 46"
```

Turn OFF depth sensor.

```
      09:  P86      Do
        01: 51      Set low Port 1
```

The end of subroutine 1, return to main program

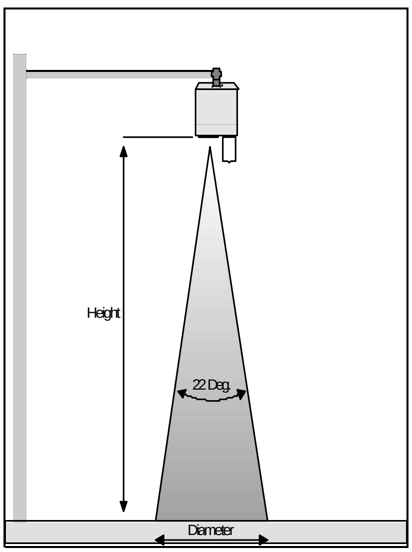
```
      10:  P95      End

      11:  P        End Table 3
```

INSTALLATION

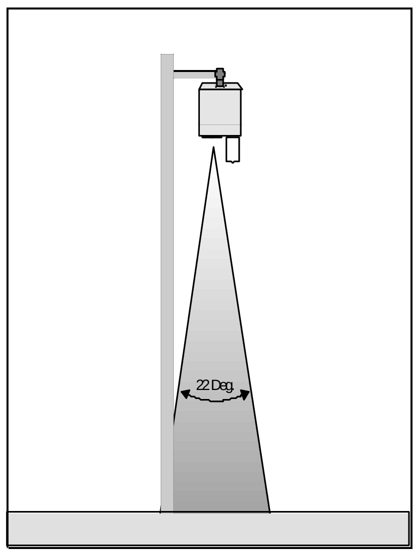
When mounting the sensor pay careful attention to the cone of the ultrasonic beam. The beam width is 22 degrees which means that the diameter of the beam will be 39% of the distance to the target, as shown in Figure 1. This means that after traveling 10 meters the beam diameter will be 3.9 meters. In this example the sensor would need to be mounted at least half the distance of the beam diameter, or 1.95 meters, away from the mast. Be careful to avoid obstructed beam paths.

To determine the minimum distance the sensor must be mounted away from the mast use this formula:
Crossarm length = .194 x Height

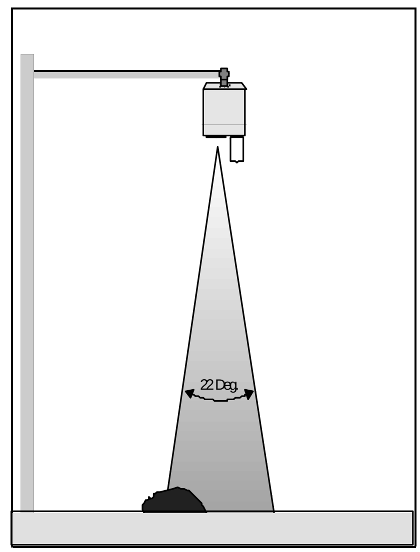
<u>Depth Sensor Beam Width Examples</u>



Correct, unobstructed path



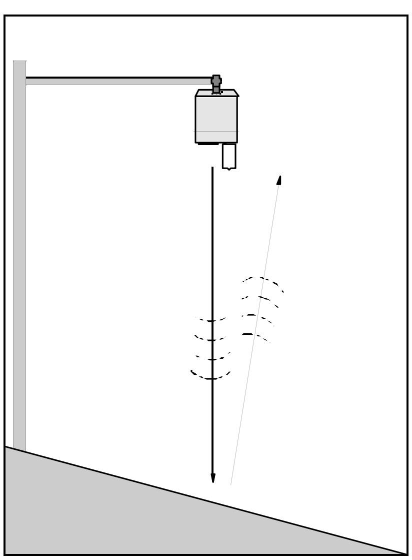
Incorrect, mast in beam



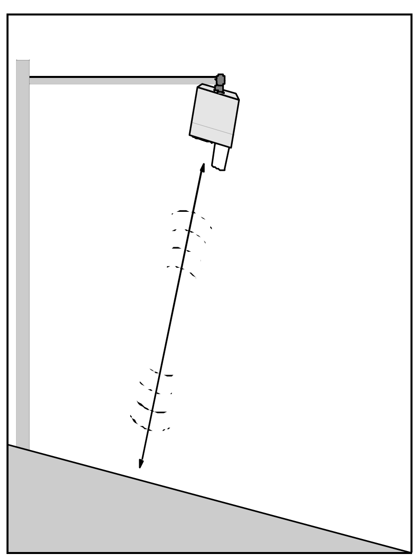
Incorrect, obstruction in beam

<u>Perpendicular to Surface</u>

The JC Depth Sensor must be mounted perpendicular to the target surface. Mounting the sensor at an angle will result in erratic and unreliable measurements.



Wrong!

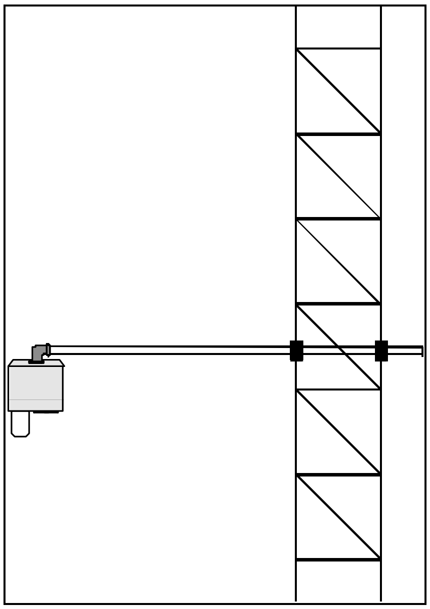


Right

To improve the accuracy of the sensor measurements, mount the sensor as close to the target as possible. This will minimize errors that are a percentage of the distance measured. However, the sensor can not measure closer than .5 meters to the target, and should be mounted at least 1 meter away from the target.

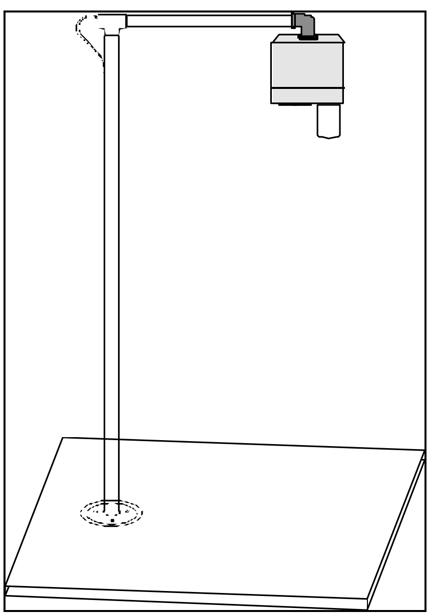
MOUNTING

Decide how the sensor will be mounted. Will it be attached to an existing structure or will it be mounted on a separate stand?


Sensor mounted on a tower

If mounting to an existing structure such as a tower, attach the depth sensor to a 6 to 8 feet section of 1/2 inch galvanized threaded water pipe (the same kind available at your local hardware or plumbing store). For more rigidity, use ¾ inch pipe with a reducer. The cable should pass through the center of the pipe unless you have ordered the sensor with the connector option. Screw the pipe into the sensor being careful not to twist up the cable. Do not over tighten the sensor to the pipe. When the sensor is threaded to the pipe you will notice a small gap of bare threads. This should be covered with electrical tape to prevent rust. If you ordered the connector option, be sure to cover both halves of the connector to keep out moisture. The sensor should be mounted 4-6 feet away from any vertical supporting structure. A good rule of thumb is 2 feet out, for every 10 feet the sensor is mounted above the surface. The mounting should be adjusted so that the transducer is held parallel to the snow surface. Secure the pipe to the supporting tower by using U bolts or tower clamps.

Measure the distance from the transducer to the target. Write this value down, it will be used later when programming the datalogger.


Sensor mounted on an interval stake

If interval measurements are desired build a stand for the sensor using the following parts:

base	3/4 inch plywood 2 X 2.5 feet
threaded pipe base	secure to plywood with wood screws, centered along one side, 6 inches in from the edge
48 inch 1/2 inch pipe	thread into pipe base
1/2 inch "T"	attach to top of pipe
8 inch 1/2 inch pipe	attach to T

Thread the cable through the pipe and have it exit the unused hole on the T section, unless you have ordered the sensor with the connector option. Screw the sensor onto the pipe being careful not to twist up the cable. Do not over tighten the sensor to the pipe. Once the stand is assembled you will notice four small areas of bare threads where the pipe and couplers join. These should be painted or covered with electrical tape to prevent rust. If you ordered the connector option, be sure cover both halves of the connector to keep out moisture. Secure the cable to the mast using electrical tape or wire ties. The sensor should be adjusted so that the transducer is held parallel to the surface of the plywood. The Plywood should be painted with white exterior paint to prevent weathering.

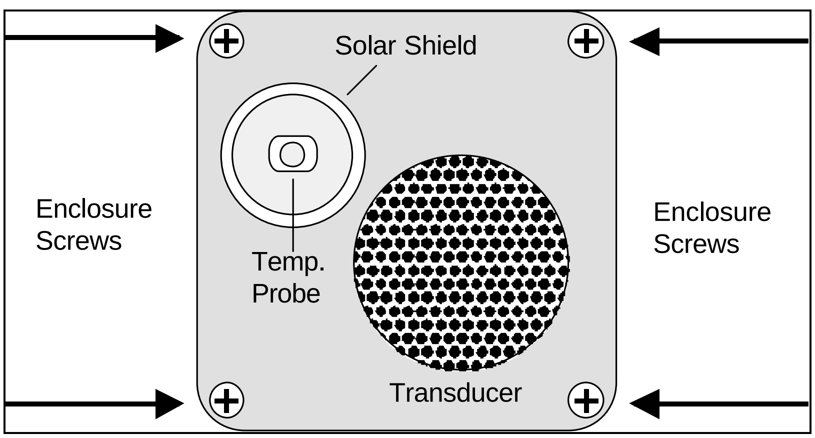
Note the distance from the transducer to the ground or the plywood. Write this value down, it will be used later when programming the datalogger.

MAINTENANCE

When properly installed, the JC Depth Sensor should require minimal maintenance. To prevent condensation, a desiccant pack is located inside the sensor and should be inspected whenever the sensor is opened. Try to avoid opening the sensor, especially in a humid environment. Feel the desiccant pack to determine its condition. If the clay granules feel hard and grainy, the desiccant is still dry. If the clay granules feel soft, they have soaked up moisture and the packet should be replaced. Used desiccant packs can be reactivated by warming them to 250° F for 16 hours. Replacements can be ordered from Judd Communications. See the following section for instructions on how to open the sensor housing.

The Solar Radiation Shield on the bottom of the sensor is made of white PVC plastic, and will yellow after several years of exposure to ultraviolet light. The shield is easily removed by gently twisting it counter-clockwise to unscrew it. Replacement fittings can be obtained from any plumbing supply store, or ordered from Judd Communications. Check the shield periodically for discoloration and to make sure that nest building insects have not taken up residence.

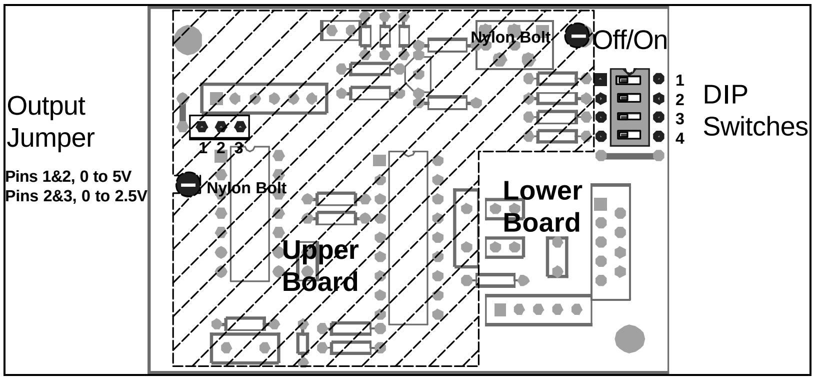
CONFIGURATION



Sensor bottom view

To open the sensor to change configuration options or replace the desiccant pack, loosen the four Phillips screws on the bottom of the sensor. The screws are captive and can be loosened, but not removed. Once the screws are loosened, the sensor bottom can be carefully moved aside revealing the inside of the sensor. At this point note how the desiccant pack and internal cabling are positioned.

When reassembling the sensor, be careful get cables and desiccant pack back into their original locations. When placing the sensor bottom back into place make sure that none of the cables will pinched before tightening the lid screws. The lid will not close if the desiccant pack is not positioned properly. DO NOT FORCE THE COVER! DOING SO WILL DAMAGE THE CIRCUIT BOARDS!



JC Depth Sensor circuit board assembly

The sensor output has two ranges 0 to 5 volts and 0 to 2.5 volts. The desired range is selected by a jumper connecting the pin combinations shown in the circuit board illustration. To access the output range selection jumpers, remove the nylon bolts that hold the upper circuit board in place. Carefully lift the upper circuit board out of the way, exposing the lower circuit board.

The four DIP switches can be used to configure the sensor to operate in different modes**.** *The default setting is OFF for all four switches.*

Dip Switch	Function (switch ON)
1	Free run mode
2	Fast free run mode
3	Temperature compensation disable
4	Hold air temp. output 1 sec. longer

DIP Switch 1

Normally the depth sensor makes one measurement upon power up and then holds the output until it is powered down. In Free Run Mode, the sensor will make continuous repeated measurements with a pause of one second between. Only the distance measurement is output In Free Run Mode. Normally, when using Free Run Mode, the Green Sensor Enable wire would be connected to with the Red wire to +12 Volts so the sensor is enabled continuously. The measurements are made using the error check retry algorithm so the output is updated every 1.5 to 3.5 seconds.

Free Run Mode is used with systems that need continuous operation. It is also useful when the sensor is used with a datalogger or control system that can not control the delay between sensor enable and sensor output measurement.

DIP Switch 2

Fast Free Run Mode works the same as Free Run Mode only the error check retry algorithm is not used. This allows the sensor to make continuous measurements at a rate of 2 per second. If Temperature Compensation is turned off (DIP Switch 3), then measurements are made at the rate of 4 per second.

Fast Free Run Mode is used with systems that need quick updates such as robotics and industrial control operations. This mode can also be used by those who are implementing their own signal processing algorithms.

DIP Switch 3

Temperature compensation can be disabled by turning ON this switch. With temperature compensation disabled, the sensor will output a raw distance measurement.

This mode is enabled when a user wants to use an external temperature measurement, for compensation. To compensate with an external temperature measurement follow these steps:

1. Obtain the raw distance measurement from the sensor. (make sure DIP Switch 3 is ON)
2. Get the external temperature measurement.
3. Calculate the Correction Factor. CF = ((Temp C. + 273)/273)^.5
4. Multiply the raw distance by the CF.

DIP Switch 4
600 milliseconds after power up the air temperature measurement will be output, and stay on the output for at least 200 milliseconds before the output changes over to the distance measurement. Some dataloggers and control systems do not have the ability to make millisecond resolution delays. When DIP Switch 4 is turned on, the air temperature measurement is held on the output for an addition second for a total of 1.2 seconds.
This enables dataloggers and control systems with at least one second delay resolution to obtain the air temperature measurement.

Normal sensor timing sequence with DIP switch 4 OFF:

0 to 400 ms	sensor warm up
400 to 800 ms	air temp. output
600 to 2600 ms	error checking
2600 ms -	distance output

Sensor timing sequence with DIP switch 4 ON:

0 to 600 ms	sensor warm up
600 to 1800 ms	air temp. output
1800 to 3600 ms	error checking
3600 ms -	distance output

MISC.

Some control systems and dataloggers want to know minimum and maximum range values instead of scale multipliers. These values do not denote the actual maximum range of the sensors.

Distance:

Scale	**Minimum**	**Maximum**
Inches	0	492.15
Centimeters	0	1250

Air Temperature:

Scale	**Minimum**	**Maximum**
Degrees Kelvin	0	500

WARRANTY

The Judd Communications Depth Sensor is warranted by Judd Communications to be free of defects in material and workmanship under normal use and service for a period of one year from the date of shipment. Judd Communications obligation under this warranty is limited to repairing or replacing defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to Judd Communications. This warranty shall not apply to any Judd Communications products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. Judd Communications is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Return Materials Authorization, contact Judd Communications. Phone (801)424-2889

Non-warranty products returned for repair should be accompanied by a purchase order to cover the repair.