**Instruction Manual**

# KD-2300

## Noncontacting Displacement Measuring System

EC DECLARATION OF CONFORMITY

This apparatus, when installed and operated per the manufacturer's recommendations, conforms with the protection requirements of EC Council Directive 89/336/EEC on the approximation of the laws of the member states relating to Electromagnetic Compatibility, as required by the Technical Construction File Route to Conformity.

This certificate has been issued in accordance with the conditions of regulation No. 53 of U.K. Statutory Instruments 1992 No: 2372 – The Electromagnetic Compatibility Regulations.

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**DO NOT MAKE ANY MODIFICATIONS TO CABLE LENGTH, SENSOR OR CALIBRATED TARGET MATERIALS WITHOUT PRIOR CONSULTATION WITH A KAMAN APPLICATION ENGINEER**

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# Introduction

## Welcome

Welcome to the Series 2300 by Kaman — a family of precision, noncontact displacement measuring systems designed to solve a wide variety of position measurement problems.

Kaman Precision Product's MULTI-VIT (MULTI-purpose Variable Impedance Transducer) Displacement Measuring System Model KD-2300 series is a non-contacting linear proximity measuring system. This easy-to-use system makes precision static and dynamic measurements of metal targets and thickness measurements of non-conductive material backed by metal.

The simplicity and versatility of the KD-2300 solves process control, product design, inspection of metal objects, and quality control applications that require accurate and stable measurements.

This instruction manual is a valuable part of your precision measurement toolbox. It is intended to simplify your use of the KD-2300 measurement systems whether you are new to Kaman systems or a veteran user.

The information in this manual contains everything you need to know to optimize system performance. If after reviewing this manual you need additional information or assistance specific to your application, please call us at (719) 635-6979.

# Customer Service Information

Should you have any questions regarding this product, please contact an applications engineer at **Kaman Precision Products | Measuring** 719-635-6979 or fax 719-634-8093. You may also contact us through our web site at: www.kamansensors.com.

# Service Information

In the event of a malfunction, please call for return authorization:

Customer Service/Repair **Kaman Precision Products | Measuring**

**860-632-4442**

# Kaman Products Standard Limited Warranty

Products of Kaman Precision Products are warranted to be free from defects in materials and workmanship when installed and operated in accord with instructions outlined in the instruction manual.

Kaman Precision Products's obligation under this warranty shall be limited to repair or replacement (at the discretion of Kaman Precision Products) of the defective goods returned to Kaman's plant within one (1) year from date of shipment. Extreme environment sensors are limited to the maximum operating temperature as specified within the most current Kaman Measuring Systems Extreme Environment Systems data sheets.

This warranty is valid except when the products have been subject to misuse, accident, negligent damage in transit or handling, or operation outside the conditions prescribed in the data sheet or instruction manual. This will be determined by Kaman Precision Products personnel.

In no event shall Kaman be liable for incidental or consequential damages, including commercial loss, resulting from any article sold under this Agreement.

In the event Buyer fails to limit to Kaman's warranty set forth above, any express or implied warranty Buyer may make with respect to any product of which any article sold thereunder is a component, Buyer shall indemnify and hold Kaman harmless from any and all liability, costs and expenses to which Kaman may be subjected as a result of Buyer's failure to so limit its express or implied warranties.

THIS WARRANTY IS EXCLUSIVE AND IS MADE IN LIEU OF ALL OTHER WARRANTIES; AND THOSE IMPLIED WARRANTIES, INCLUDING SPECIFICALLY THE WARRANTIES OR MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE HEREBY EXPRESSLY LIMITED TO ONE (1) YEAR DURATION.

NO MODIFICATION OR ALTERATION OF THE FOREGOING WARRANTY AND LIMITATION OR REMEDIES PROVISIONS SHALL BE VALID OR ENFORCEABLE UNLESS SET FORTH IN A WRITTEN AGREEMENT SIGNED BY KAMAN AND THE BUYER.

Kaman Precision Products Warranty No. 7A

## Cautions and Safeguards

This information contains important cautions and safeguards associated with the use of your KD-2300 system. Please read the list carefully before working with the system.

- To protect against risk of electrical shock, do not place the system module in water.
- Do not operate with a damaged power cord.
- Do not let power cords or sensor cables touch hot surfaces.
- Unplug all power supplies before attempting to make any system modifications.
- Do not expose system modules to excessive heat or moisture.

## Using this Manual

Our goal is to have you taking measurements as quickly and easily as possible regardless of your familiarity with our systems. This is a do-it-yourself manual, allowing you to work and learn at your own pace, depending upon the amount of background information you need to complete each step. You can find as much or as little information as you need:

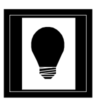
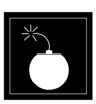
- Part I: An introduction to our technology and system configuration.
- Part II: System inventory and set-up.
- Part III: Detailed considerations and explanations of system operation and configuration.
- Part IV: Calibration.
- Appendices: Glossary, supplementary material, troubleshooting, and system modifications.

All users, despite their level of expertise, should do the following before attempting to use the KD-2300 system:

- Familiarize yourself with the icons defined below. They will appear throughout the manual.
- Inventory the system.
- Refer to ***Part III: EQUIPMENT*** on sensors and targets and ***Part IV: CALIBRATION*** for a detailed discussion of the considerations involved in making the right choices for your specific application.

## Icon Directory

A variety of symbols called icons appear throughout this instruction manual to call your attention to information requiring special consideration. The chart below details what the icons look like and how they will be used.

| | | |
|---|---|---|
|  | **CAUTION** | Describes actions that can damage either the system or endanger the person using it. |
|  | **ADVISORY** | Describes situations that could impact the measurement and utility of the product. However, an advisory does not affect the system or person. |
|  | **NOTE** | Provides additional information about the step that you are performing. |
|  | **TROUBLESHOOTING** | Tells you what to do when the system isn't functioning properly. |

## Application Information

The system speeds gaging and precision measurements by eliminating errors caused by “feel”. It uses modern electronics (eddy current operating principle) to replace LVDT’s, air gages, capacitance systems, dial indicators, and micrometers.

Applications include precision displacement (proximity) measurements of shafts, plates, foils, and other ferrous and non-ferrous metal targets. Environments that have oil, dirt, and humidity between the sensor and target will not affect the system accuracy. The system output has high noise immunity (low impedance).

As a non-conductive medium between a sensor and a metal target doesn’t affect a calibrated system, the thickness of non-conductive materials (i.e. rubber, plastic, insulation, wood) can be measured when the material is against metal. If the non-conductive material is moving, the sensor can be mounted on a rider or shoe and look through to the metal reference target.

The electrical zero can be offset up to half of the measuring range; therefore, + and - deviation from a nominal can be obtained.

Long term stability, resolution and thermal stability improve exponentially as the operating gap between the sensor and target decreases. Therefore, in extremely critical applications, the first half of the measuring range permits the best performance.

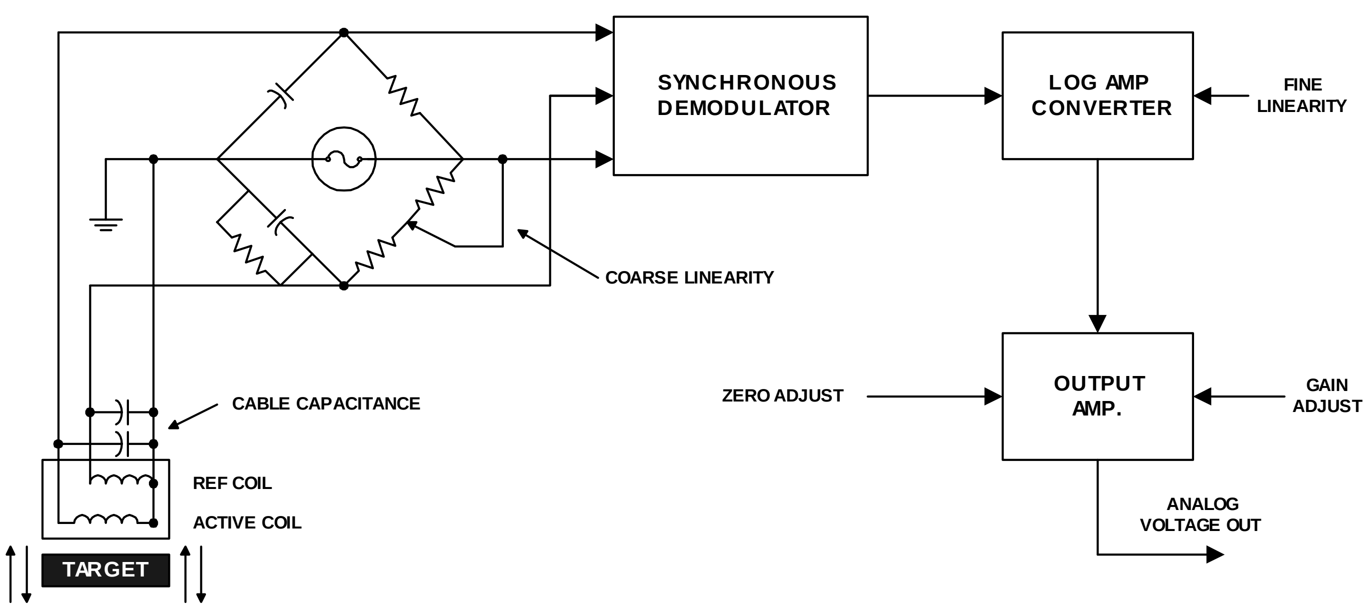
# Part I: What is the KD-2300?

## System Technology

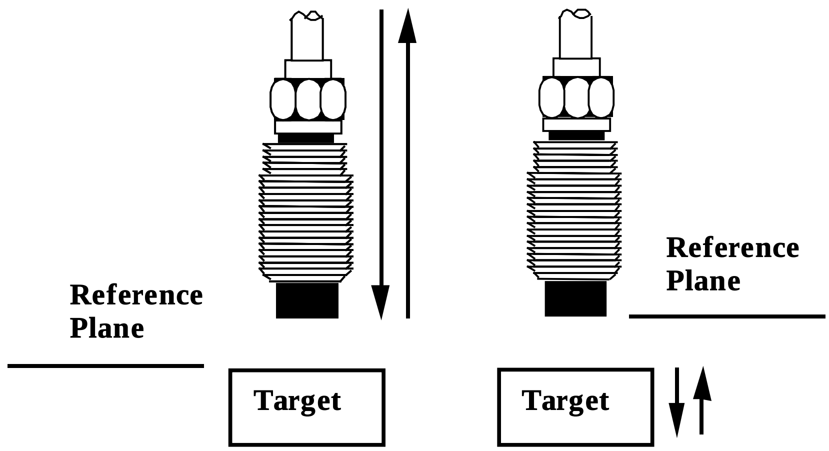
Kaman Precision Products's KD-2300 family of displacement measuring systems uses inductive technology to determine the position of a target relative to the system sensor.

An AC current flows through the sensor coil, generating an electromagnetic field that radiates out from the sensor. As the conductive target enters this field, the sensor induces a current flow; it produces a secondary opposing field, reducing the intensity of the original. This opposing electromagnetic field results in an impedance variation in the sensor coil.

The sensor coil makes up one leg of a balanced bridge network. As the target changes position within the sensor field, the bridge network senses impedance changes in the sensor coil and passes the information on to signal conditioning electronics for conversion to an analog voltage. This voltage is directly proportional to target displacement.

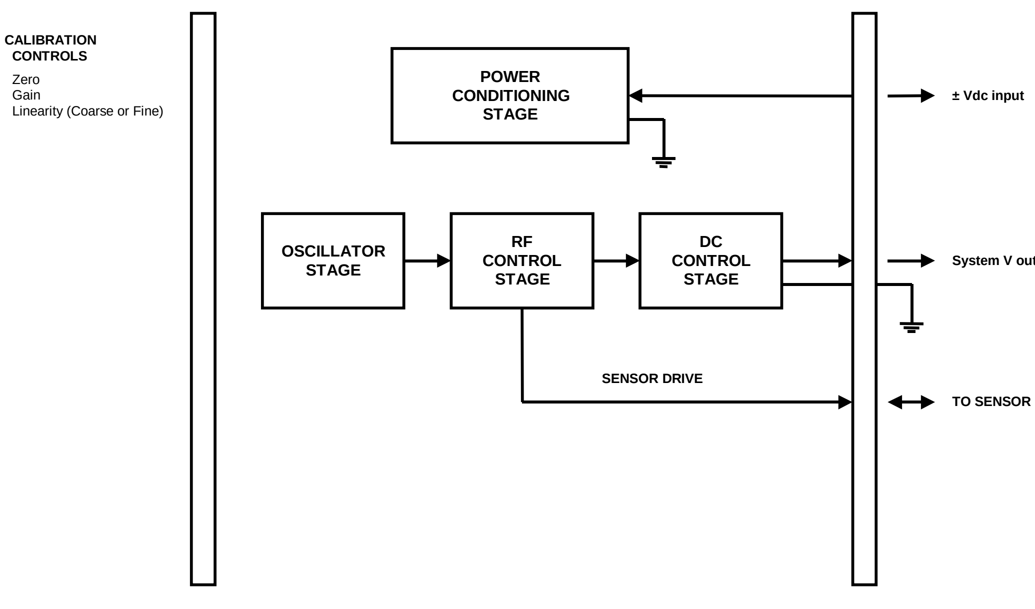


Nonconductive materials intervening between the sensor and target have little or no effect on system output. Because of this, environmental contaminants, such as oil, dirt, humidity, and magnetic fields, have virtually no effect on system performance. The function of a noncontact displacement measuring system is to monitor the position of a target relative to some reference plane. The magnitude of the analog output is dependent upon the relative position of the target within the sensor's electromagnetic field—the farther the sensor is from the target, the higher the analog output.




## System Configuration

The figure below shows a block diagram of the system configuration. Every system contains an electronics oscillator / demodulator and a sensor.



# Part II: Getting Started

## Basic System

Your KD-2300 system consists of these basic components:

- Sensor(s)
- Cable(s)
  *Depending upon the system, the standard sensor cable length may be increased in increments of 5 feet (1.55 m) up to a maximum of 30 feet (9.15 m) on special order basis.*

- Oscillator/ Demodulator
- User manual
- Accessory kit

## Module Identification

All modules have the following identification:

a. Model number
b. Serial number

Your Series 2300 system comes configured to your specifications. However, you will need to connect sensors and cables yourself.

## Connecting the Sensors

Connect sensors to oscillator/ demodulator using the connector located on the front of the electronics.

The model KD-2300 family consists of a sensor, a signal conditioning electronics, and a separate interconnection cable when not integral with the sensor. The signal conditioning electronics with each system model has been designed to provide optimum performance with its sensor, cable length, and target material (magnetic or non-magnetic); therefore,

1. Sensor cable length and type should not be altered.
2. Sensors are interchangeable only with others of the same type and cable length (with slight calibration adjustment). See CALIBRATION PROCEDURE.
3. The proper target material must be used.

## Connecting External Power Supply

The KD-2300 operates from a ± 15 Vdc power source. If your system was not configured with a power supply, you will need to provide an external power source.

The Kaman Model P-34XX power supplies are recommended, although 15 Volt regulated supplies are satisfactory. Use 24 AWG or heavier insulated wires.

**Connecting power to any other than the specified pins may cause damage to the 2300 and / or power source.** Output connections to voltmeter, recorder, or oscilloscope should be made as noted in Figure 1.

1. Mount the sensor in its application fixture in either a surface or flush mount.
2. Set the target in place for calibration.
3. Zero, Gain, and Linearity (Coarse and Fine) potentiometers are located on the control panel on the front of the module. You can adjust these using a screwdriver.
4. Determine whether your calibration will be full scale, bipolar output or high accuracy band. Proceed to the appropriate page for full instructions on the method you require.

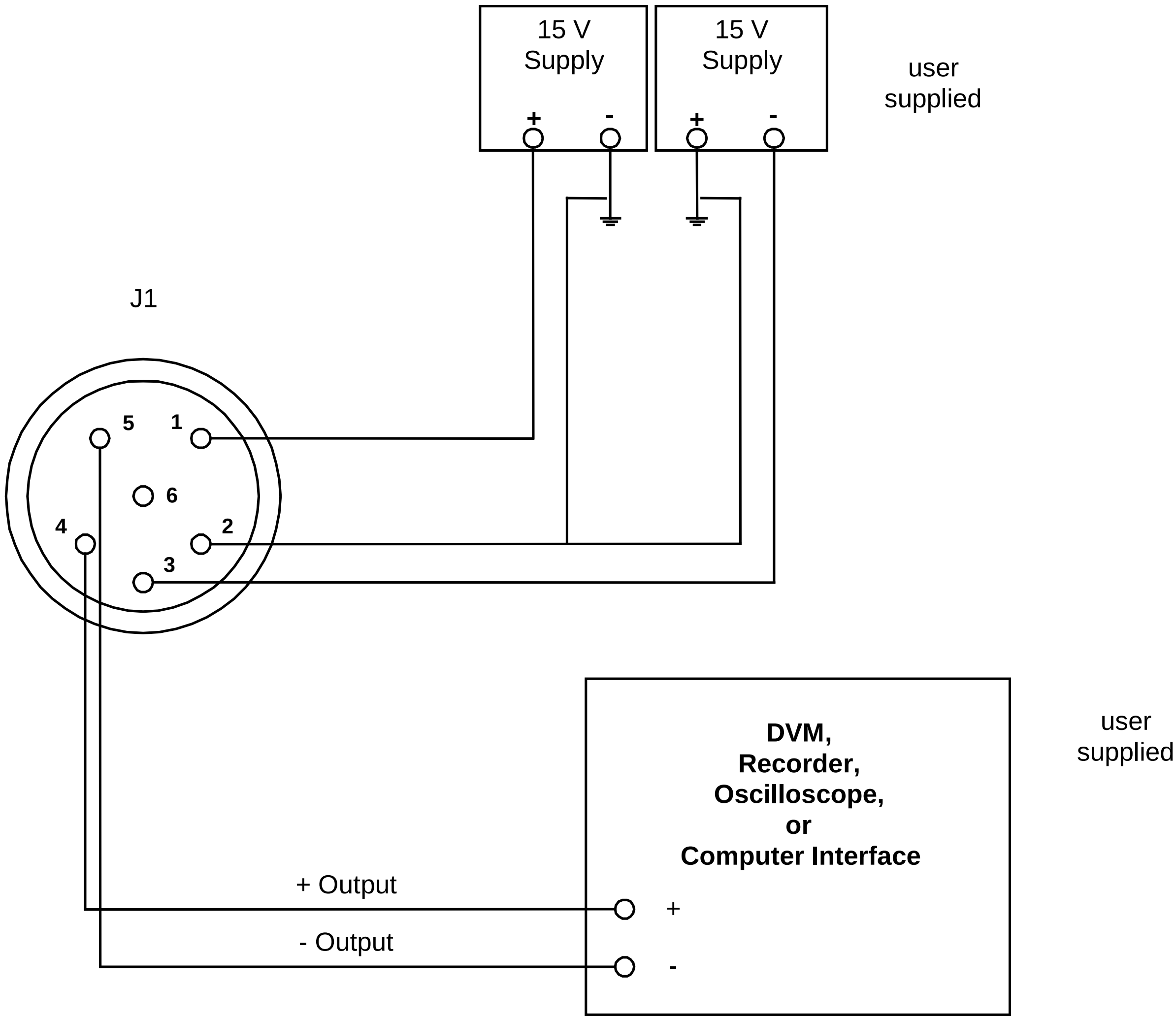
**All users, refer to *Part 3: THE EQUIPMENT.*** Fixture conductivity, conductive objects within sensor range, sensor diameter, and shielded vs. unshielded sensor types are all determining factors of how the sensor should be mounted.

Using a simulated fixture for mounting during calibration can affect the adjustments for each channel. Whenever possible, use your application fixture during calibration.

If you have more than one sensor or measuring channel in close proximity, you may require sychronization. See *Appendix B* for more information.

With a thorough knowledge of calibration controls and accurate application of the calibration procedures described in *Part 4: CALIBRATION*, you can achieve optimum results. Deviations or shortcuts can result in operator-induced errors and may complicate, rather than solve your measurement problems.

## WIRING DIAGRAM USING TWO SEPARATE 15 V LINEAR POWER SUPPLIES




| PIN | |
|---|---|
| 1 | + 15 Vdc (Positive supply input) |
| 2 | Ground (Common supply input) |
| 3 | - 15Vdc (Negative supply input) |
| 4 | + Output |
| 5 | - Output (Common with ground) |
| 6 | No connection (Sync output) |

**Figure 1**

# Part III: The Equipment

## Operating Principle*

The system uses a principle of impedance variation which is caused by eddy currents induced in a conductive metal target. The coupling between a coil in a sensor and a target is dependent upon their displacement (gap).

The electronics consists of an oscillator, linearization network, amplifiers, and a demodulator, which provides an analog voltage directly proportional to displacement.

*Patent Pending

## Specifications

TEMPERATURE

Operating Temperature Range

| | |
|---|---|
| Sensor** | -67° to 220°F (-55°C to 105°C) |
| Cable and Connector | |
| Standard -PVC | -67° to 220°F (-55°C to 105°C) |
| Electronics | 32° to 132°F (0°C to 55°C) |

POWER SUPPLY REQUIREMENTS:

| | |
|---|---|
| Voltage | ± 15 Vdc |
| Voltage Regulation | ± 0.5 Vdc |
| Current | 70mA |

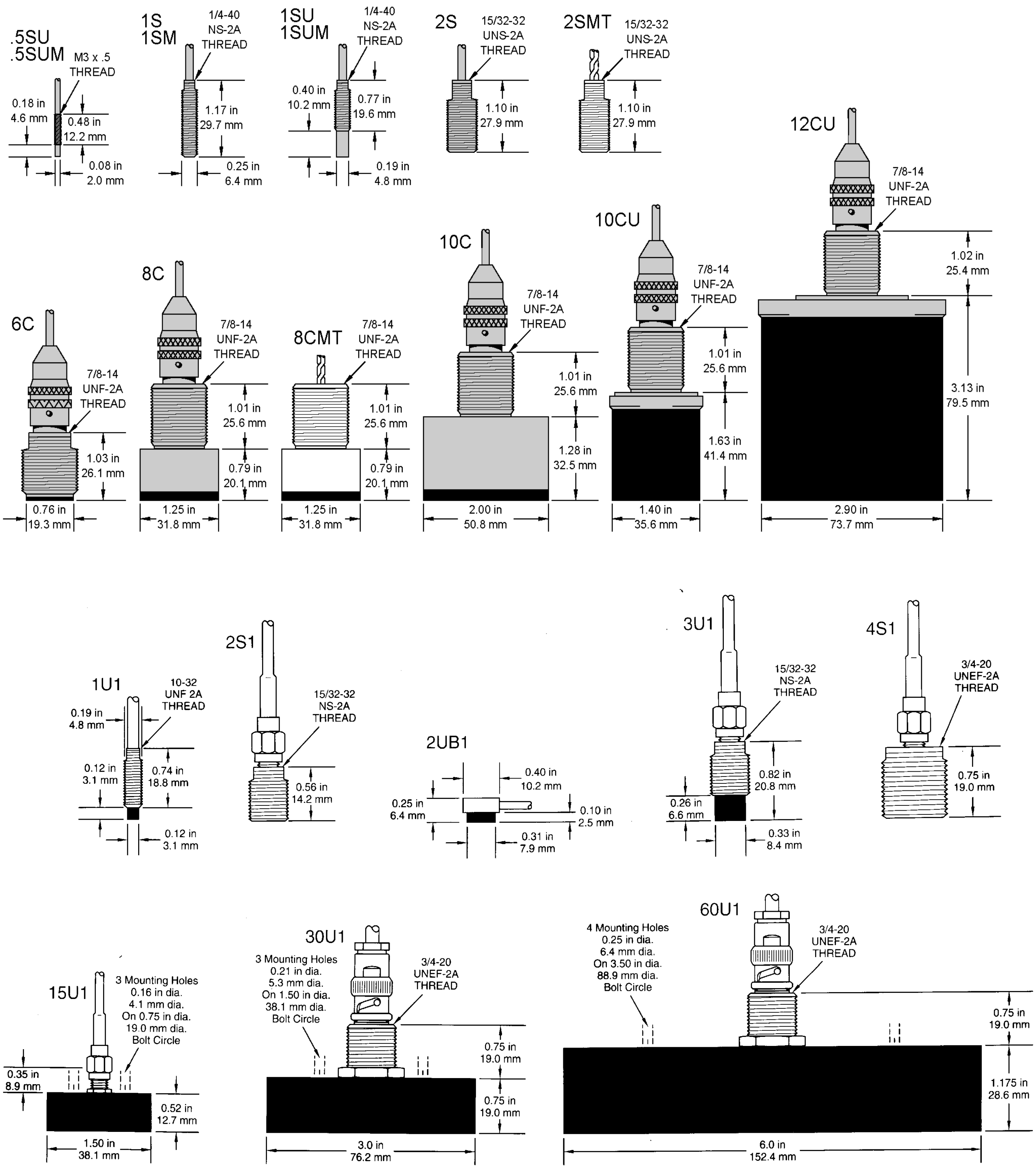
**Some sensors are available in Moderate Temperature versions. Temperature range for moderate temperature sensors is -320° to 400°F (-196°C to 204°C)

## Accessories

Recommended accessories for ease of system calibration and convenience are listed below:

- **Power Supply P-3410** provides regulated ± 15Vdc output for 1 measuring system. Input voltage is 105 - 125 VAC @ 50 - 400 Hz. PN
  Part Number: 852531-001
- **Power Supply P-3450** provides regulated ± 15 Vdc output for up to 6 measuring systems. Input voltage is 105-125 VAC @ 50-400 Hz.
  Part Number: 852531-004
- **Power Supply P-3410A** provides regulated ± 15Vdc output for 1 measuring system. Input voltage is 216 - 265 VAC @ 50 - 400 Hz. PN
  Part Number: 852531-001A
- **Power Supply P-3450A** provides regulated ± 15Vdc output for up to 6 measuring system. Input voltage is 216 - 265 VAC @ 50 - 400 Hz. PN
  Part Number: 852531-004A
- **Power and Output Cable:** 10 feet
  Part number: 853083-010
- **Micrometer Calibration Fixture** (thru -6C system)
  English part number 850854-001
  Metric part number 850854-002
  Digital part number 850854-003
- **Ceramic Calibration Spacers**, set of 7: 0.05" thru 1.0"
  Part number: 850859-001

## Sensor Options



## Sensor Specification

The table below lists the sensors available for use with the KD-2300 electronics and their standard performance specifications:

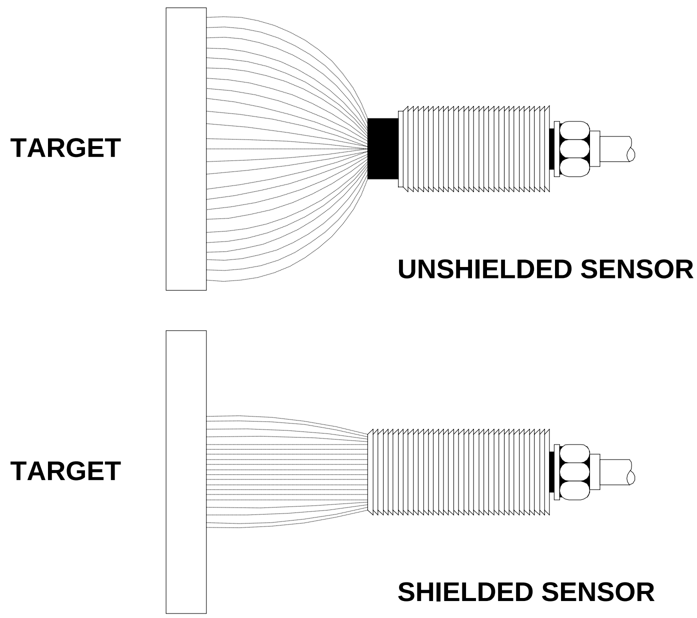
| Sensor Models | Measuring Range | Typical Offset | Linearity | Analog Voltage | Displacement Sensitivity | Thermal Sensitivity Shift * |
|---|---|---|---|---|---|---|
| **Model** | **Inch (mm)** | **Inch (mm)** | **%FS **** | **Vdc** | **mV/mil (mm)** | **%FSO/°F** |
| .5SU | 0.020(0.5) | 0.002(0.05) | 1.0% | 1.00(0.5) | 50(1000) | 0.1%FSO/°F |
| .5SUM | 0.020(0.5) | 0.002(0.05) | 1.0% | 1.00(0.5) | 50(1000) | 0.1%FSO/°F |
| 1S | 0.040(1.0) | 0.002(0.05) | 1.0% | 0.80(1.0) | 20(1000) | 0.1%FSO/°F |
| 1SM | 0.040(1.0) | 0.002(0.05) | 1.0% | 0.80(1.0) | 20(1000) | 0.1%FSO/°F |
| 1SU | 0.050(1.25) | 0.002(0.05) | 1.0% | 1.00(1.25) | 20(1000) | 0.1%FSO/°F |
| 1SUM | 0.050(1.25) | 0.002(0.05) | 1.0% | 1.00(1.25) | 20(1000) | 0.1%FSO/°F |
| 1U1 | 0.040(1.0) | 0.006(0.15) | 0.5% | 0.40(1.0) | 10(1000) | 0.1%FSO/°F |
| 2S | 0.100(2.5) | 0.010(0.25) | 1.0% | 1.00(2.5) | 10(1000) | 0.1%FSO/°F |
| 2S1 | 0.080(2.0) | 0.015(0.38) | 0.5% | 0.80(2.0) | 10(1000) | 0.1%FSO/°F |
| 2UB1 | 0.080(2.0) | 0.015(0.38) | 0.5% | 0.80(2.0) | 10(1000) | 0.1%FSO/°F |
| 3U1 | 0.120(3.0) | 0.020(0.51) | 0.5% | 1.20(3.0 | 10(1000) | 0.1%FSO/°F |
| 4S1 | 0.160(4.0) | 0.020(0.51) | 0.5% | 1.60(4.0) | 10(1000) | 0.1%FSO/°F |
| 6C | 0.250(6.4) | 0.030(0.75) | 1.0% | 1.25(0.64) | 5(100) | 0.1%FSO/°F |
| 6U1 | 0.240(6.0) | 0.035(0.89) | 0.5% | 2.40(0.6) | 10(100) | 0.1%FSO/°F |
| 8C | 0.500(12.7) | 0.050(1.25) | 1.0% | 1.00(1.27) | 2(100) | 0.1%FSO/°F |
| 10C | 0.750(19.1) | 0.100(2.5) | 1.0% | 0.75(1.91) | 1(100) | 0.1%FSO/°F |
| 10CU | 1.00(25.4) | 0.100(2.5) | 1.0% | 1.00(2.54) | 1(100) | 0.1%FSO/°F |
| 12CU | 2.00(50.8) | 0.200(5.0) | 1.0% | 1.00(5.08) | 0.5(100) | 0.1%FSO/°F |
| 15U1 | 0.600(15) | 0.150(3.81) | 0.5% | 0.60(1.5) | 1(100) | 0.1%FSO/°F |
| 30U1 | 1.20(30) | 0.300(7.5) | 0.5% | 1.20(3.0) | 1(100) | 0.1%FSO/°F |
| 60U1 | 2.40(60) | 0.600(15) | 0.5% | 2.40(0.60) | 1(10) | 0.1%FSO/°F |

* W/O Temperature Compensation

** FULL SCALE

## Measuring Range

The specified linear measuring range for an inductive system is directly proportional to the diameter of that sensor.  For any given sensor diameter, unshielded sensors have a greater measuring range than shielded sensors.  This is because the sensor's field will "couple" with the shield, in effect, limiting the amount of field available for interacting with the target.




## Sensor Mounting

Sensor mounting is critical to the operation and accuracy of the measuring system.  Fixturing must be stable through changing environmental conditions, such as temperature variation or vibration.  The impact of these changes is relative:  a 0.00001" change is negligible when only 0.001" accuracy is required.

## Conductive vs. Nonconductive

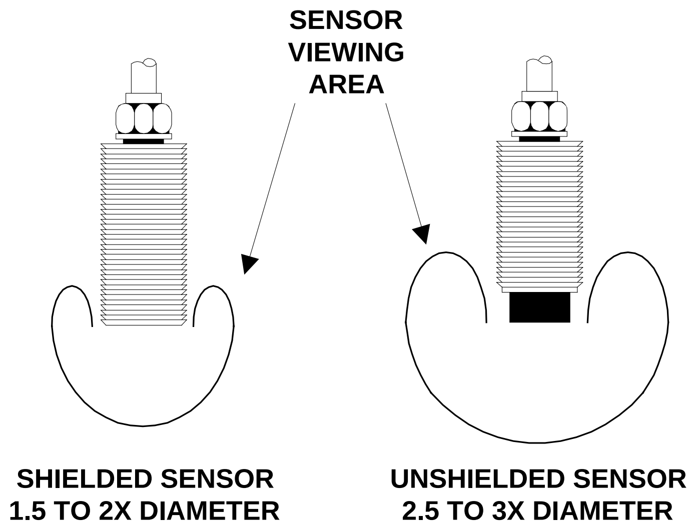
Simply keep in mind that fixturing must be capable of maintaining the accuracy required by your application.  If you do need to mount the sensor, note that the sensor's field may interact with the fixture and change your system calibration.  Shielded sensors will interact less with a conductive fixture than unshielded sensors.  When using a conductive fixture, it is important that you calibrate your sensor channels with the sensor in place in the application fixture, or in a fixture that duplicates the actual loading effects of the application fixture.  Loading is the effect of conductive material (other than the target) that is positioned within 3 times the diameter of the sensor and is a permanent part of the measuring environment.

## Simulated vs. Application Fixture

Install the sensor in the application fixture exactly as it was in the simulated one. When moving from the simulated fixture to the application fixture, deviations may occur through changes in loading or in mechanical position. To ensure maximum accuracy, calibrate the sensor in the actual application fixture whenever possible.

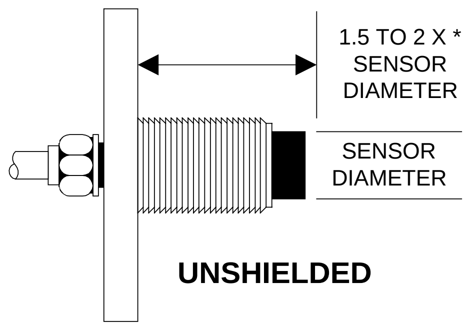
## Conductive Materials in the Measuring Area

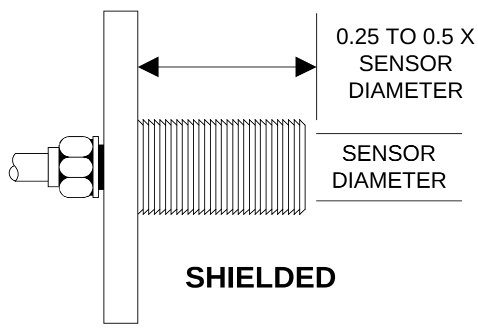
Keep in mind the following general rule: Mount unshielded sensors 2.5 to 3 times their diameter away from conductive materials; for shielded sensors use a factor of 1.5 to 2 times diameter.



## Surface Mounting

Surface mounting will not affect a sensor's calibration assuming there is nothing conductive in the sensor's "viewing range" other than the target. When surface mounting in a conductive fixture, the sensor face of an unshielded sensor should be 2.5 to 3 times its diameter away from the fixture.  The factor for shielded sensors is **0.25 to 0.5 times the diameter.**

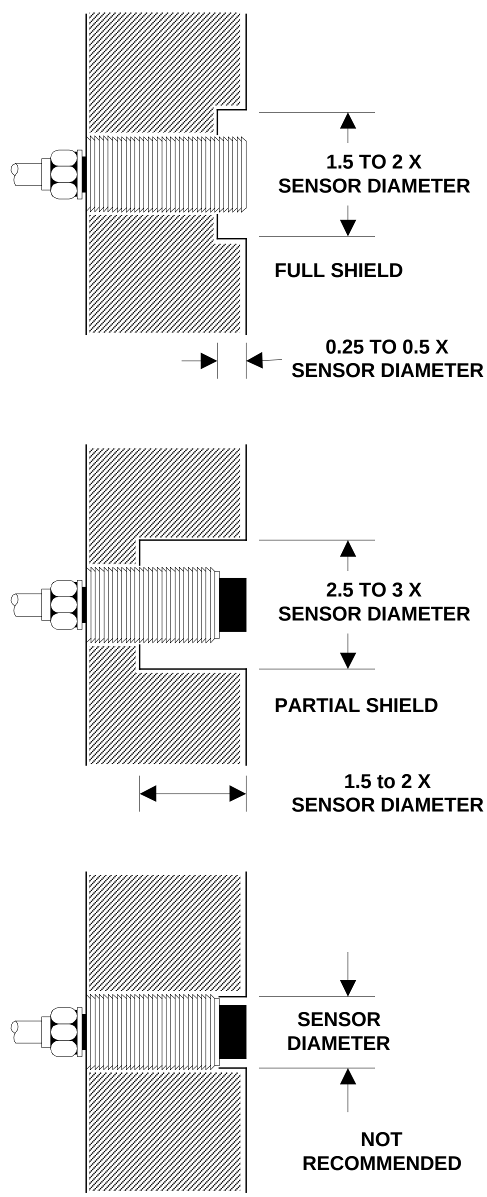



* For Sensors with peek housings, this dimension should be increased to 2.5 to 3 X.

## Flush Mounting

Flush mounting in a conductive fixture requires a cut-out area around the sensor head. The depth and width of the cutout are relative to sensor face diameter as shown in the diagram below. The cutout should never be any smaller than the dimensions arrived at by making these calculations. Smaller width and/or depth can result in loading effects so severe that you may not be able to calibrate the system. The cut-out area may serve as a collection point for refuse, metal filings, cutting oils, coolants, etc. It may also disrupt the gaseous or liquid flow patterns in the measurement area. You can effectively solve this problem by backfilling the cut-out area with a nonconductive material, such as silicon rubber or epoxy.



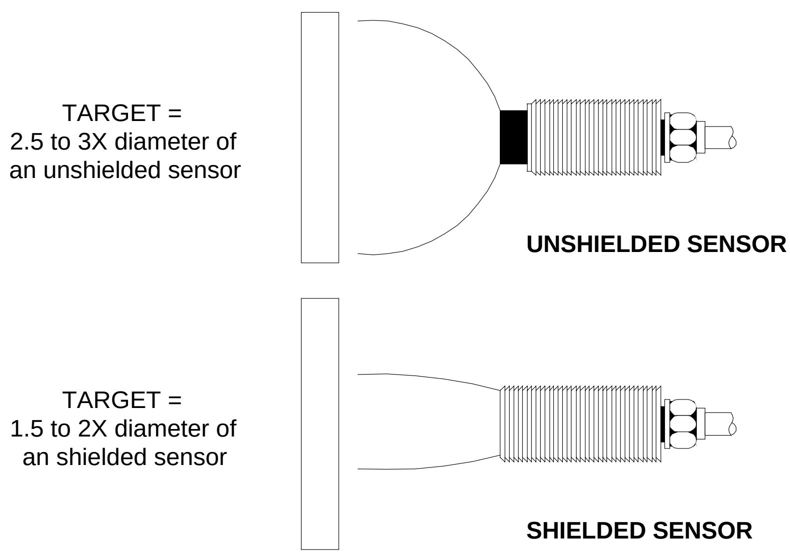
## Target Material

The essential requirement for a proper target is that it be conductive. In addition, nonmagnetic targets offer greater stability and linearity than magnetic targets (in particular, aluminum, copper and some 300 series stainless steel make ideal targets).

Kaman Precision Products can optimize any Series 2300 system to work with either a magnetic or nonmagnetic target. You will find it difficult to use a system tuned for nonmagnetic materials with a magnetic target. With some of the smaller sensors, it is impossible to use a mismatched target and system without optimization through changing the bridge module.

## Target Size

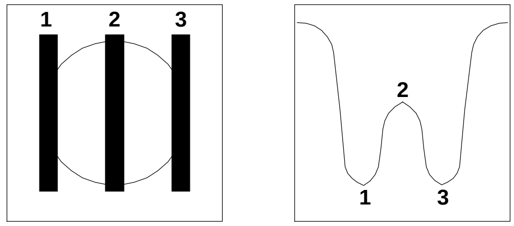
The size of your target relative to the sensor is very important. The target should be a minimum of 2.5 to 3 times larger than the diameter of an unshielded sensor and 1.5 to 2 times the diameter of a shielded sensor.




Targets larger than the recommended size will have no effect on system performance. A flat target that is 3 times the diameter of a sensor face will look the same as one that is 300 times the diameter.

Using a target smaller than the recommended size will cause some degradation in linearity and long term stability. For smaller targets, calibration over a range less than the specified range for the sensor will minimize and in some cases, eliminate the performance degradation. (Refer also to Part 4: CALIBRATION for high accuracy band calibration.)

Measurements taken using targets smaller than the recommended size are dependent on both the vertical and horizontal position of the target. A vertical view shows a rod passing left to right (three different positions) under the face of a sensor.  The diagram on the right shows the corresponding analog voltage assuming the rod remains a fixed vertical distance from the sensor.




## Target Thickness

Nonmagnetic targets with a thickness of 15-20 mils are recommended, and are typically more than adequate for the majority of applications. However, depending on the required accuracy, targets as thin as .5 mil thick have been used.  Targets that are very thin may require optimization of  the bridge module and a change in frequency.

Recommended Minimum Target Thickness:

| **Material** | **Mils** | |
|---|---|---|
| | **1 MHz** | **500 KHz** |
| Silver and Copper | 12 | 24 |
| Gold and Aluminum | 12 | 24 |
| Magnesium, Brass, Bronze, Lead | 32 | 64 |
| 300 Series Stainless | 60 | 120 |
| Alloy | 60 | 120 |

## Other Considerations

The density of the electromagnetic field produced by a sensor is greatest at the surface of the target, even though the field penetrates beyond that point.  The extent of penetration is a function of resistivity and permeability of the target, and the carrier frequency used in the measuring system.  In turn, temperature effects resistivity and permeability. Generally, highly resistive targets and lower carrier frequency allow for deepest penetration.

Field penetration only becomes a concern when the target material is too thin to capture all of the sensor's electromagnetic field.  This type of penetration, called "shine-through", reduces the strength of the interaction between target and sensor, ultimately reducing linearity, resolution and long-term stability of the measuring system.

# Part IV: Calibration

## Factory Calibration

All systems are factory calibrated; even so, we recommend that upon receipt you check the calibration and recalibrate the system using one of the procedures outlined on pages of this section. At the factory, systems are calibrated with a typical output sensitivity as shown in Part 3: THE EQUIPMENT, sensor specification table on page 14. We use flat aluminum to optimize for nonmagnetic targets and 4130 cold rolled steel to optimize for magnetic targets.

## Calibration Interval

The importance of proper calibration cannot be overemphasized because it is calibration that firmly establishes the accuracy of the measuring device. Rather than accept the measurement from the device, it is usually best to make at least a simple calibration check to be sure of the validity of the measurements. The typical calibration cycle required for this device is twelve months. However, the user's application environment and performance criteria could dictate that a more frequent calibration cycle be used to ensure system performance in a particular application. The final calibration interval is left to the discretion of the end user of the device.

## Dimensional Standards

Calibration is a means to verify that system output relates to some known physical displacement, a reference or dimensional standard with a known degree of accuracy. When choosing a dimensional standard, keep in mind that accuracy of the dimensional standard has a direct effect on accuracy of calibration, and thus on the accuracy of any measurements you take.

A micrometer fixture is available from Kaman Precision Products for use as a dimensional standard repeatable to within 100 micro inches (.0001"). The micrometer has a non-rotating spindle with an attached target. It is suitable for use with all Kaman sensors up to 2S (up to 8C with a larger target) and may be rigidly mounted.

For some applications (i.e. larger sensors) nonconductive phenolic or ceramic spacers can be used in calibration. Ceramic spacers are available from Kaman in sizes ranging from .050" (1.27mm) to 1.000" (25.4mm).

## Offset

Offset is the minimum space or gap between the sensor and target. You should position your sensor so that the target never enters this area. When offset has not been considered, linearization of the system can be difficult as the target enters the offset region. The required offset for a given sensor is typically 10 to 20% of its full-scale measuring range. See the Sensor Specifications table in Part 3: EQUIPMENT for sensor offsets.

Offset provides clearance for a moving target, preventing sensor/target contact. Contact could cause sensor damage and contact errors in measurement.

If you need to transfer the sensor from a calibration fixture to an application fixture, maintain the offset initially used in calibration. The maximum allowable tolerance on repositioning the sensor is -2% to +5% of the offset. To re-establish offset, note system output when the calibration target is at minimum displacement (plus offset)— usually 0 Vdc. Remove the sensor from the calibration fixture and move it to the application fixture. When the system output equals 0.000 Vdc (or other desired voltage) without adjusting the controls, the original offset has been re-established.

## Sensitivity

Aside from your need to know system sensitivity in order to apply any meaning to a change in system output, there are several application-specific variables that you may need to be concerned with:

- Measuring units. You may want the system output to read directly in metric units: 100 or 1000 mV/mm.
- The device you are using to monitor analog output may require a full scale voltage range other than the factory calibration.
- Improving signal to noise ratio by 10-15%, thereby improving system performance. This is especially true when operating with the first half of a sensor's measuring range. The Sensor Specification Table in *Part 3: EQUIPMENT* list the available sensors and their recommended output voltage within their full specified measuring range.

## When is the System Fully Calibrated?

Your system is fully calibrated when you complete an iteration of any of the calibration procedures and find that you did not have to adjust any of the controls at the zero, mid or full-scale reference points. During calibration, you will notice that the controls interact with each other. Because of the interaction, you will have to perform several iterations of a particular procedure before a system is calibrated. Interaction between the controls should decrease with subsequent iterations.

## Calibration Controls

You will need to calibrate each measuring channel in your system using the Zero, Gain, and Linearity (Coarse and Fine) potentiometers located on the control end of the module. The controls rotate both clockwise and counterclockwise through the use of a small screwdriver or the supplied calibration tool.

A description of each calibration control follows:

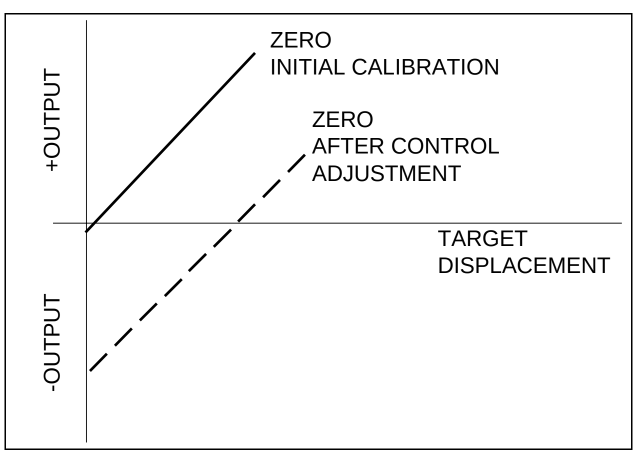
Clockwise rotation of calibration controls causes the analog output to go more positive; counterclockwise causes more negative output. If you turn a potentiometer in the same direction (clockwise / counterclockwise) until you see no change in system output, you have reached a limit of that particular control. If this occurs, your options are: 1) change the gain by changing the gain jumper (APPENDIX B); 2) check for excess loading around the sensor, or 3) make sure that your target size and material are appropriate (*Part 3: EQUIPMENT)*.

## Zero Control

The Zero control lets you set an electrical zero point. As illustrated in the diagram, the Zero control adjusts the point at which system output intercepts the x-axis.

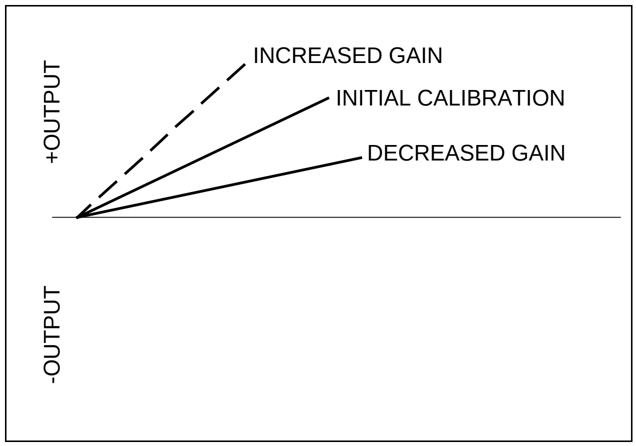
After calibration, you can use the Zero control to shift system output anywhere from 40-60% below the x-axis, depending on sensor, sensor mounting and gain. This feature is useful in applications where you need a +/- deviation from a standard, or when signal conditioning electronics require a bipolar output, such as with an A/D converter.

The Zero control is particularly useful in "zeroing out" any mechanical offset created when you move from a simulation to an application fixture. You can also use the Zero control to correct for the small amount of drift that can occur over a period of time through aging and temperature change. This slight drift is easily corrected using a master target or dimensional standard and readjusting the zero shift until the desired output reading is attained.



## Gain Control

Gain control affects the change in output of a system in volts due to a given change in displacement. In other words, gain controls the sensitivity of the system output. The diagram shows how the slope of the output curve changes as gain is increased and decreased.



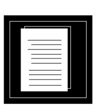

## Linearity

Coarse and Fine Linearity controls affect the shape of the system output curve. The closer the output is to a straight line, the more accurate your measurement readings will be. Adjustment of the Linearity controls interacts with the Gain and Zero controls. The linearity control is primarily used to swing the full scale endpoint. Due to the effect of the log amp, it will have some effect on the gain and less effect on the zero.

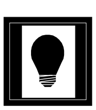
## The Three Calibration Methods

You have the option of choosing from three methods of calibration:

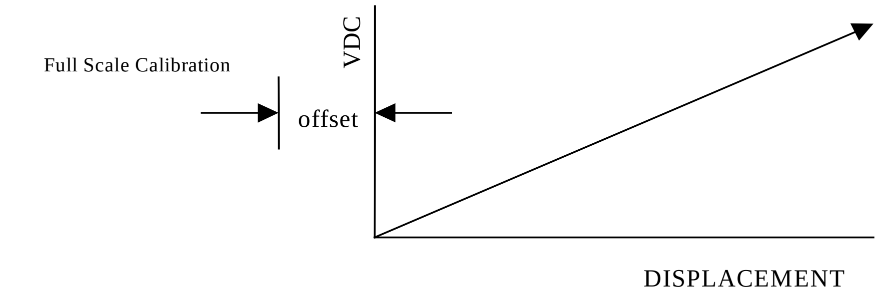
| | |
|---|---|
| **Full Scale:** | Output from 0 Vdc to some maximum value. |
| **Bipolar:** | Negative output for first half of range; positive output for second half. |
| **High Accuracy Band:** | Increased linearity by using only part of full-scale measuring range. |

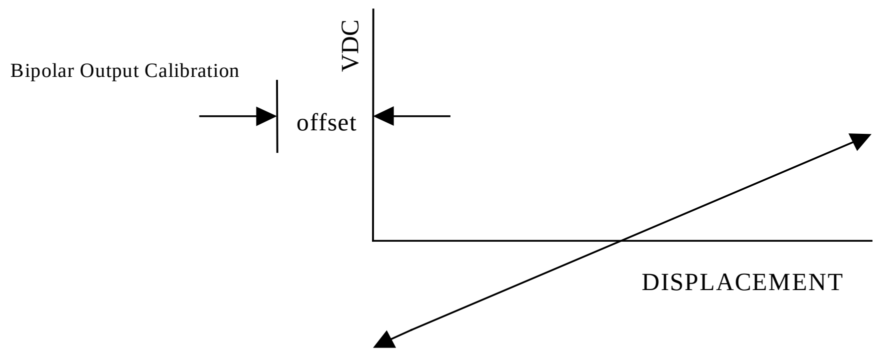


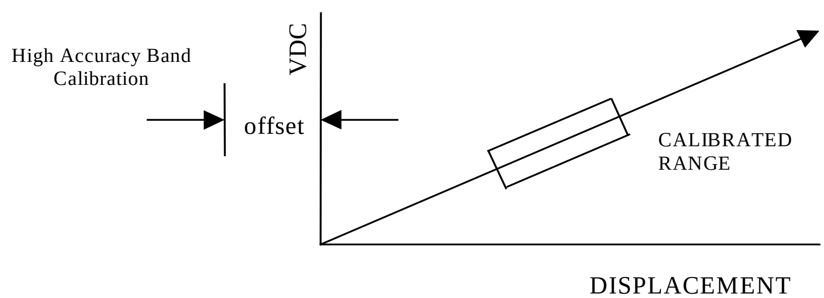
Depending on your application, you will use any one of three procedures outlined above to calibrate your system. Before calibration, we recommend that you become familiar with the following information to ensure that you have made the necessary considerations regarding your particular application.



With a thorough knowledge of calibration variables and accurate application of the calibration procedures described in the following pages, you can achieve optimum results. Deviations or shortcuts can result in operator-induced errors and may complicate rather than solve your measurement problems.

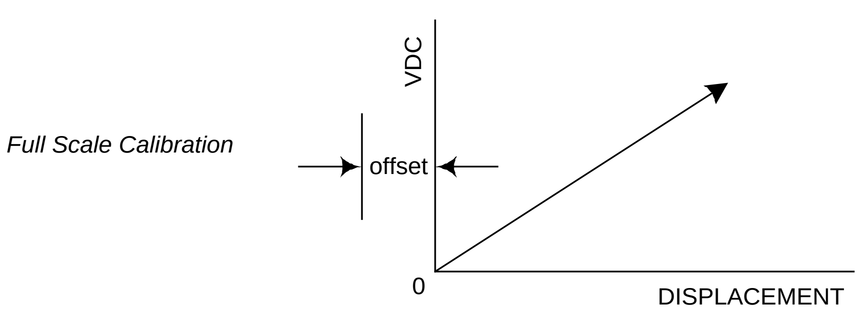



## Full Scale Calibration Procedure

Full-scale calibration produces an output voltage that varies from 0 Vdc when the target is closest to the sensor (plus offset) to some maximum positive voltage when the target is farthest from the sensor.



1. Install the sensor in the calibration or application fixture, ensuring that when the target is at its closest point to the sensor, there is a gap (offset). With curved targets, decreasing offset will improve linearity; with flat targets, increasing offset slightly will improve linearity. **In either case, never allow the target to strike the sensor face.**

2. a. Position the target using the micrometer fixture or spacers so that the total distance between the sensor and target is equal to the specified full-scale displacement for that sensor, plus offset. See the Sensor Specification Table in *Part 3: EQUIPMENT* for standard offsets.

   b. To calibrate for a specific sensitivity, follow the procedures in Step 2a, then adjust the Gain control so that system output equals your desired new full-scale output voltage.

3. Position the target to zero displacement (plus offset). Adjust the Zero control until the output voltage reads 0 Vdc.

4. Position the target at mid-scale plus offset and adjust the Gain control until the output voltage reads the desired mid-scale value. For example, assuming 10mV/mil sensitivity, and your full-scale voltage is 1 Vdc at 100 mils, then the system output at mid-scale should read 0.5 Vdc at 50 mils.

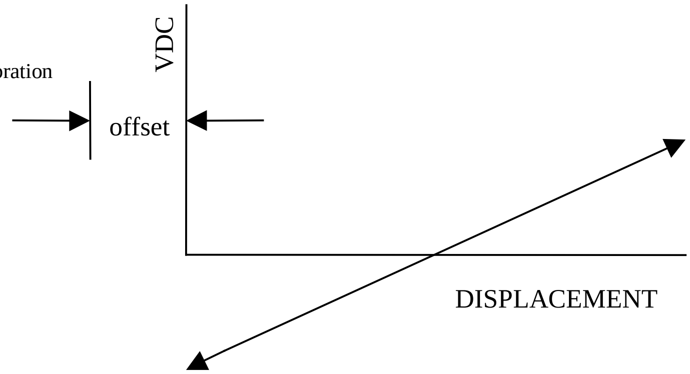
5. Reposition the target at full-scale displacement, plus offset. Read the output voltage and note the difference between the actual reading and the desired reading. Adjust the Linearity control (Coarse, then Fine) until the output reads the desired voltage level, then continue past the desired reading by an amount equal to the first difference you noted. This technique is called 100% oversetting and is used to reduce the number of iterations needed to calibrate the system. For example, if the output reads 1.350 volts and the desired reading is 1.000, adjust the Linearity control until the output reads 0.650, or 1.000- 0.350. If the output reads 0.800, adjust linearity until system output reads 1.200, or 1.00 + 0.200.

6. Repeat Steps 3 through 5 as many times as necessary until the desired output voltage at each point is reached. No further adjustment of the Zero, Gain and Linearity controls will be needed when proper calibration is obtained.

## Bipolar Output Calibration Procedure

When you use this calibration procedure, output voltage will range from a negative voltage for the first half of your measuring range to a positive output for the second half of the range.

Bipolar Output Calibration




Use this method when your application is best suited by readouts that represent a positive and negative deviation from some nominal value, in this case, 0 Vdc. Bipolar calibration also provides maximum output sensitivity. (An alternate technique is listed after Steps 1-6 that will provide bipolar output, but not maximum sensitivity).

In a bipolar calibration, clockwise rotation of the Zero control causes output to go more positive; whereas, clockwise rotation of the Gain control increases gain more negatively in the lower half of the range and more positively in the upper half. Because of this, you will adjust the Gain control when the target is closest to the sensor and adjust the Zero control at mid-scale.

1. Install the sensor in the calibration or application fixture, ensuring that when the target is at its closest point to the sensor, there is a gap (see the Sensor Specifications table in Part 3: EQUIPMENT , page 24 for offsets). With curved targets, decreasing offset will improve linearity; for flat targets, increasing offset slightly will improve linearity. In either case, never allow the target to strike the sensor face.

2. Position the target using the micrometer fixture or spacers so that the total distance between the sensor and target is equal to the specified full-scale displacement for that sensor, plus offset. Adjust the Linearity control (Coarse, then Fine) until the output is equal to the desired full-scale reading.

3. Position the target so that it is at mid-scale (plus offset) and adjust the Zero control until the output reads zero.

4. Position the target at its closest point to the sensor (plus offset) and adjust the Gain control until output reads the desired negative output voltage.

5. Move the target to its farthest point from the sensor. Read the output voltage and note the difference between the actual reading and the desired reading. Adjust the Linearity control (Coarse, then Fine) until the output reads the desired voltage level, then continue past the desired reading by an amount equal to the first difference you noted. This technique is called 100% oversetting and is used to reduce the number of iterations needed to calibrate the system. For example, if the output reads 1.350 volts and the desired reading is 1.000, adjust the Linearity control until the output reads .650 (1.000 - 0.350). If the output reads 0.800, adjust linearity until system output reads 1.200 (1.000 + 0.200).

6. Repeat Steps 3 through 5 as many times as necessary until you reach the desired output voltage at each point. No further adjustment of the Zero, Gain and Linearity controls will be needed when proper calibration is attained.

### Alternate Bipolar Output Calibration

You may not be able to achieve maximum sensitivity using this technique. This method may be preferred if the maximum voltage does not exceed the op-amp saturation voltage (5.5 V for 8 volt internal regulation.)

1. Use the Full-Scale procedure in this section to calibrate the system initially from 0 Vdc to the desired maximum.

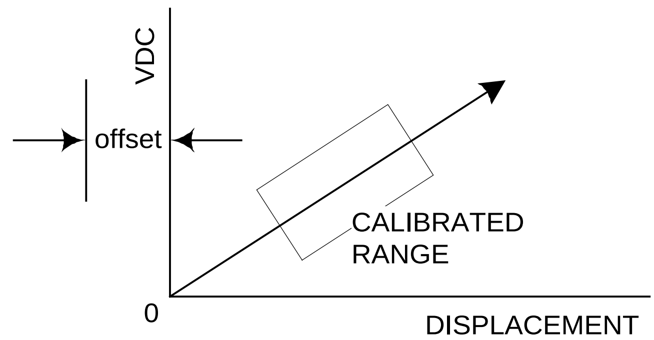
2. Position the target at mid-scale and adjust the Zero control counterclockwise until output reads 0 Vdc.

3. Check the two ends, the points closest and farthest from the sensor, to see that they equal minus and plus one half of the original full-scale output voltage. For example, if your original full-scale voltage was 0-4 Vdc, it should now be -2 to +2.

   In theory, adjusting the Zero control in this technique should not affect sensitivity or linearity. In practice, however, you may see a very slight change indicated by voltage readings other than minus and plus one-half full scale. You may then choose to use the primary bipolar technique to fine-tune the calibration.

## High Accuracy Band Calibration

*High Accuracy Band Calibration*




This procedure is used to monitor changes in position that are less than the specified linear measuring range of your sensor, or when you are interested in increased accuracy over a smaller range and not concerned about high accuracy outside of that range.

The high accuracy band procedure maximizes the linearity of output within a calibrated span. The sensor installed in your system has a specified linear measuring range that defines system performance characteristics, such as linearity, resolution and long-term stability.

Maximum linearity is centered on the mid-point of the sensor's specified maximum linearity measuring range anywhere between 25-75% of full-scale. For example, if you have a system with a 40 mil specified range, its most linear region will be between 10 and 30 mils.

While decreasing the linear measuring range of your system, it will improve system performance; conversely, increasing measuring range will degrade performance. Depending upon your measurement objectives, either can be used.

As you perform a high accuracy band calibration, keep in mind that the smaller the calibrated span the more interactive the controls will become. More interaction means more iterations before your system is fully calibrated.

When the desired span is below 20% of specified linear measuring range, the additional improvement in linearity is generally not worth the trouble caused by control interaction.

1. Install the sensor in the calibration or application fixture, ensuring that when the target is at its closest point to the sensor, there is a gap (see the Sensor Specifications table in Part 3: EQUIPMENT , page 14 for offsets). With curved targets, decreasing offset will improve linearity; for flat targets, increasing offset slightly will improve linearity. In either case, never allow the target to strike the sensor face.

2. Define the reduced measurement span you will use.

3. Position the target so that it is at the maximum displacement of your defined span, plus offset. Adjust the Linearity Control (Coarse then Fine) until the output reads the desired maximum voltage.

4. Position the target at the minimum displacement of your defined span (plus offset) and adjust the Zero control to read the desired voltage at that point. The desired voltage does not have to be zero.

5. Position the target at the mid-point between the end points of the desired span. Adjust the Gain control until the output reads the desired voltage.

6. Reposition the target so that it is at the maximum displacement of the span relative to the sensor. Note the difference between the actual reading and the desired reading. Adjust the linearity control (Coarse, then Fine) until the output reads the desired voltage level, then continue past the desired reading by an amount equal to the first difference you noted. This technique is called 100% oversetting and is used to reduce the number of iterations needed to calibrate the system. For example, if the output reads 1.350 volts and the desired reading is 1.000, adjust the Linearity control until the output reads 0.650, or, 1.000-0.350. If the output reads 0.800, adjust linearity until system output reads 1.200, or, 1.000+0.200.

7. Repeat Steps 3 through 6 as many times as necessary until you reach the desired output voltage at each point. No further adjustment of the Zero, Gain and Linearity controls will be needed when proper calibration is attained.

# Appendix A: Glossary

## Glossary

**A/D Converter** A device that converts an analog voltage to a digital representation.

**Analog Output** Output voltage of a system that is a continuous function of the target position relative to the sensor.

**Dimensional Standard** A standard of measurement or precision reference against which one correlates the output of the system, i.e. a micrometer fixture, feeler gauges, precision ceramic spacers, etc.

**Drift** Undesirable change in system output over a period of time while the sensor / target position is constant. It may be unidirectional or cyclical and caused by such things as aging of the electrical circuits or environmental changes impacting the system.

**Effective Resolution** An application dependent value determined by multiplying the equivalent input noise specification by the square root of the measurement bandwidth.

**Equivalent RMS Input Noise** A figure of merit used to quantify the noise contributed by a system component. It incorporates into a single value factor influencing a noise specification, such as signal-to-noise ratio, noise floor, and system bandwidth. Given a measurement system's sensitivity and the level of "white noise", equivalent RMS input noise can be expressed in actual measurement units.

**Full Scale Output (FSO)** The voltage output measured at full-scale displacement for which a system is calibrated. The algebraic difference between end points.

**Gain** The function of increasing and decreasing sensitivity. Changing gain will increase or decrease the slope of the output curve.

**Iteration** Repetition.

**Linearity** The closeness of a calibration curve to a specified straight line.

**Loading** The affect of conductive materials positioned within 3 times the diameter of a sensor, that are a permanent part of the measuring environment.

**Measurement Bandwidth** The difference between the upper and lower frequency response limits of a system. KD-2300 system bandwidth is 0 to 50,000 Hz.

**Noise** Any unwanted electrical disturbance or spurious signal that modifies transmitting display or recording of desired data.

**Offset** The required gap between the sensor face and the target at zero range. Usually specified in mils and is dependent upon sensor type.

**Output** The electrical quantity produced by the sensor and modified by the system as a function of target position relative to the sensor.

**Range** The spectrum of measured values that exists between the upper and lower limits of a sensor's measuring capability.

**Repeatability** The ability of a system to consistently reproduce output readings when applying the same dimensional standard repeatedly under the same conditions and in the same directions.

**Resolution** The smallest discernible change in target position relative to a reference.

**Sensitivity** The ration of change in system output voltage to a change in relative position of the target.

**Stability** The ability of the system to retain its performance throughout its specified operation and storage life.

**Variable Impedance Transducer** A device that applies a stimulus (the field produced in a coil by a single frequency AC current) to a conductive target, measures the total opposition to that field by the target, and converts it into an electrical signal proportional to the position of the target.

# Appendix B: System Modifications

## Maximum Sensitivity (Gain Control)

When increased sensitivity is needed, rotate the GAIN control clockwise until reaching the desired sensitivity. If the GAIN control reaches the full clockwise position before reaching the desired sensitivity, perform the internal gain modification described below:

Remove the cover of the unit by removing the eight cover screws. Using a hobby knife, cut the trace marked “G” (refer to the figure below). This procedure increases the maximum obtainable gain by approximately two times. System frequency response will reduce to approximately 10kHz (-3dB point) but will vary depending upon sensor and gain settings.

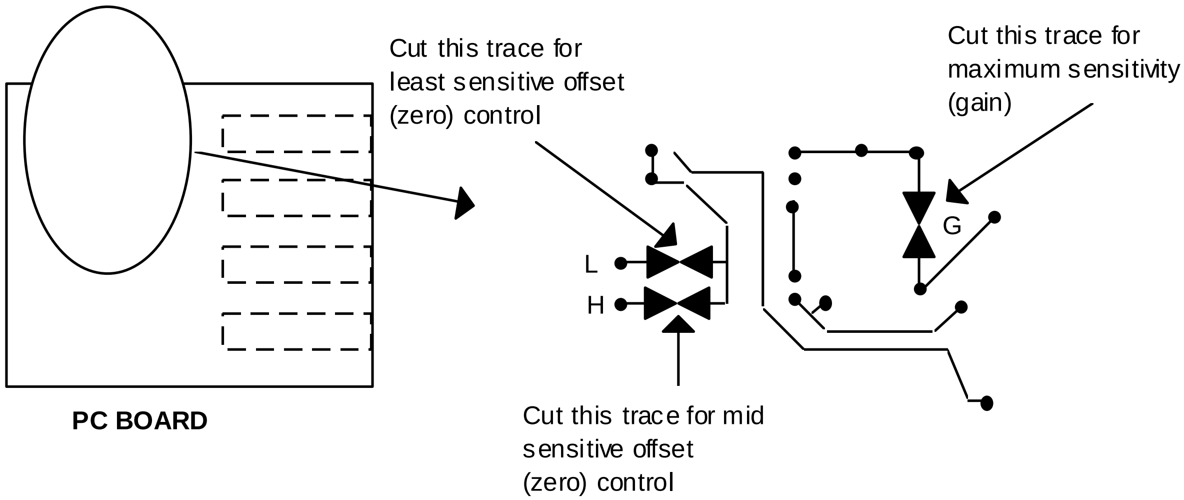
## Zero Control Sensitivity

If the OFFSET control has too little or too much adjustment capability, adjust the sensitivity as follows:

Remove the cover of the unit, by removing the eight cover screws. Locate the traces marked “H” and “L” (refer to the figure below). As shipped:

MAXIMUM SENSITIVITY -do not cut either trace.
MEDIUM SENSITIVITY -cut the trace marked “H”.
MINIMUM SENSITIVITY -cut the trace marked “L”.

This adjustment removes an offset resistor from the circuit

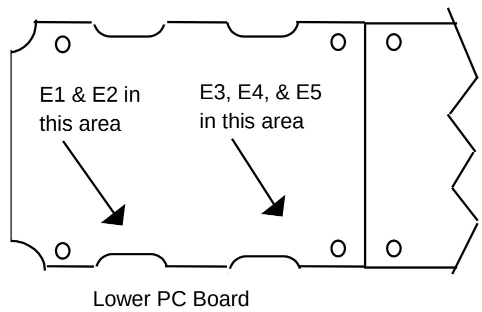



## Synchronization of Multiple Units

When two or more sensors are mounted in close proximity, their electronic fields may intermix, causing interference in the form of “beat notes”. (The frequency of the beat notes is the difference between the frequencies of the oscillator demodulator units, usually 10Hz). This problem is easily solved by synchronizing the oscillators. You will need to configure the units as master and slaves, as described below.

FOR BOTH MASTER AND SLAVE UNITS:
~ Remove oscillator-demodulator cover by removing the eight cover screws.
~ Remove the four screws securing the PC board.
~ Flip the PC board up toward the connector end of the housing, being careful not to strain the interconnection between the boards. This board may be removed temporarily by unplugging the ribbon cable from the upper PC board.

FOR MASTER UNIT
~ Locate the jumpers marked E3 and E4 near the connector end of the lower PC board. A bold arrow on the silkscreen highlights this area. Solder a jumper wire between E3 and E4.
~ Locate the jumpers marked E1 and E2. Two bold arrows on the silkscreen highlight this area. They should be connected. If they are not connected (meaning that the unit was previously used as a slave), solder a jumper wire between them.
~ Reconnect the PC board ribbon cable, re-secure the board with four screws, replace the top cover and refasten it with the eight screws.




FOR SLAVE UNITS

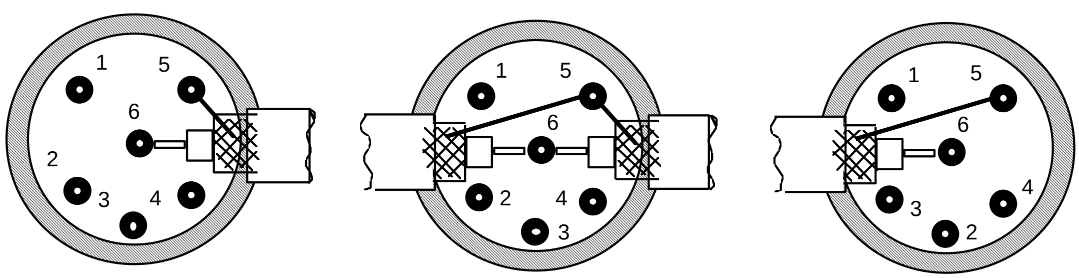
~ Locate the jumpers marked E3, E4, and E5 near the connector end of the PC board. A bold arrow on the silkscreen highlights this area. Solder a jumper wire between E4 and E5.

~ Locate the jumpers marked E1 and E2. Two bold arrows on the silkscreen highlight this area. Using a hobby knife, cut the trace between them. (This removes the crystal from the oscillator circuit).

~ Reconnect the PC board ribbon cable, re-secure the board with the four screws, replace the top cover and refasten it with the eight screws.

**POWER AND OUTPUT CABLE**

~ To interconnect the oscillators, modify the power plugs by connecting the coaxial cables between connectors of the units being synchronized as shown in the figure below.




1. Connect the outer conductor of the coaxial cable to pin 6 of the connector.

2. Connect the shield (braid) of the coaxial cable to pin 5 of the connector.

# Appendix C: Troubleshooting

## Checklist for Basic Troubleshooting

This troubleshooting section addresses the problems that commonly arise out of misapplication of the procedures in this manual, simple oversight, or changing environmental conditions. Understanding of the material outlined in this manual and a common-sense approach to system use will preclude most of the problems listed below from happening.

Approximately 98% of potential difficulties can be prevented or eliminated by going over the following checklist:

**If you have absolutely no output from your system, there is a good chance that there is no power supply voltage.**

- Check your power supply for ± 15 VDC. If you have provided your own power supply, make sure it is capable of supplying the minimum current to operate the system.
- Check loose plugs.
- Make sure the power switch is on.
- Check for a malfunctioning voltmeter.

**After ensuring that you have a correct and reliable power feed:**

- Check the security of connectors.

**Incorrect calibration procedures can cause problems:**

- Follow the calibration procedures in this manual closely.
- A calibration span that is too large or too small, incorrect offset, or gross mis-adjustments of the calibration controls can cause drift, erroneous output, or make it impossible to calibrate.
- Extremely high or low sensitivity/gain can cause drift and make the system overly sensitive to temperature variations, target size, etc.

**Problems with sensor mounting and nonrepeatable fixturing can be sources of trouble:**

- Make sure your calibration fixture is sound and repeatable.
- When you move the sensor from the calibration fixture to the application fixture, maintain the offset.
- Make every effort to provide a thermally stable environment to prevent drift. (Kaman can provide temperature compensation, but your best choice is to control the environment if possible).

**Inappropriate target materials can also lead to difficulty using the system:**

- When you calibrate, use actual target materials in the same sizes.
- Whenever possible use the actual application environment or simulate it as closely as possible.

**Do not make any arbitrary changes in sensor/cable and measurement module combinations**

## Symptoms and Causes

The following information is a Symptom/Solution cross reference. If after reviewing the previous checklist of common problems you don't remedy the problem you are having, find the symptom you are experiencing below and refer to the list of possible causes. Symptoms are marked with letters; causes/solutions are marked with numbers. For example, if you are experiencing the symptoms described in C, refer to solution 3.

SYMPTOMS

A. A saturated output of +/- 6 to 7 volts, with no change in target position and with target in range. See 2 (open only) and 3,5,6.

B. Unchanging output voltage, anywhere from +1 to -2, with change in target position. See 2 (short only) and 3, 5, 6.

C. Output drifts with no change in target position. See 3.

D. Random changes in output with no change in target position. See 1, 3, 4, 5, 7 (for multiple channel system) and 8.

E. Non-repeatability. See 3, 4, 6, 7, 8.

F. Unable to calibrate, or while calibrating you 'run out' of calibration controls. See 1, 2, 3, 5, 6, 8.

G. System does not meet linearity specification. See 3.

1.CAUSE:

Intermittent cable.

This problem is typified by large output changes (full volts vs millivolts) when the cable is moved.

SOLUTION:

1. Visually inspect the cable,
2. Test it with an ohmmeter and confirm the variable/short problem while moving the cable,
3. Replace the cable.

2.CAUSE:

Open sensor coil, shorted or open cable.

A short will yield very low to zero voltage while an open will yield saturation voltage.

SOLUTION:

1. Visually inspect,
2. Test it with an ohmmeter: zero to near zero for a short; infinite to full scale for a deflection or open. A good sensor will test 1 to 5 ohms on the average; a sensor/cable combination will be higher.
2. Replace the sensor and/or cable.

3.CAUSE:

Excess loading (static or dynamic) on the sensor caused by the fixturing.

Conductive material too close to the sensor can cause excess loading.

SOLUTION:

1. If the sensor is mounted in a conductive fixture, make sure that you have met the requirements outlined in Part 3: EQUIPMENT.
2. Remove any conductive material that you do not want to measure away from the sensor area.
3. Calibrate for a certain degree of loading. You cannot compensate for excess loading since it can only be determined empirically.

4.CAUSE:

Noisy AC feed power to the system.

SOLUTION:

1. Check for power tools, motors, soldering irons etc. on the same line; turn them off or remove them.
2. Switch lines.
3. Use an input noise filter to the module.

5.CAUSE:

A malfunctioning voltmeter.

SOLUTION:

Check the system output voltage with a different voltmeter, or inject a know voltage in the voltmeter in use to verify that it is operating properly.

6.CAUSE:

Coarse linearity misadjusted.

SOLUTION:

Recalibrate the system.

7.CAUSE:

Beat note interference when using more than one sensor.

SOLUTION:

Ensure that the sensors are at least 3 diameters apart, or Synchronize your sensor and electronics as described in APPENDIX B.

8.CAUSE:

Ground loop.

This problem is usually the result of electrical ground surges from other equipment.

SOLUTION:

1.In sensors with non-isolated coils (3U, 6U), isolate the sensors from the ground.

2.Isolate the systems(s) from potential grounds so that the ground is only through a desirable path.