INSTRUCTION MANUAL

Model 400A, 402A, 403A, 404A, 405A, 406A, 407A

Force Transducer Systems

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Aurora Scientific Inc.
360 Industrial Parkway S., Unit 4
Aurora, Ontario, Canada L4G 3V7
Tel: 1-905-727-5161
Toll Free: 1-877-878-4784
Fax: 1-905-713-6882
Email: info@AuroraSci.com
Web Site: www.AuroraScientific.com

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1.0 Introduction

1.1 Transducer

The Model 400A series of force transducers were designed to fill the need for research instruments that possess excellent frequency response and resolution, and are also extremely thermally stable. The design is based on a variable displacement capacitor whose plates are formed by vacuum metalization on the surface of cantilevered fused silica beams.

The active, force measurement, capacitor is compared electrically to a matched reference device of identical size and construction mounted beside it. An output signal current is generated by the electronic drive system that is proportional to the value of both the reference capacitor and the force measurement capacitor. When the two values of capacitance are equal, no force applied to the output tube, the two currents are equal and subtracting them yields a zero result. When a force is applied the beam bends and the value of the force capacitor, $C_{(Force)}$, changes. The electronic subtraction then yields a non-zero result. The difference will be proportional to the change in capacitance and therefore the force applied.

Note that thermal effects and mechanical vibration, as well as pick up of external noise sources such as power line interference, will affect both the reference and force measurement capacitors equally. The subtraction process cancels any disturbance that occurs to both devices simultaneously. This is a physical analog of the circuit technique known as common mode rejection and at least 20 dB improvement in signal to noise ratio is gained from it.

The capacitance gap is formed by acid etching the thick substrate plate to the required depth. The capacitors are formed by vapour depositing gold onto the glass. The output tube is made of boro-silicate glass and the housing is aluminum, which makes it an excellent electrostatic shield. Very thick cross-sections have been used in the housing to insure extreme rigidity when mounting the unit. The external aluminum surfaces have been anodized. The transducer head is water resistant below the joint between the cover and the housing. This joint can be made water resistant by removing the top cover and applying a small quantity of vacuum grease to the mating surfaces between the housing and the cover. Please note that there is a hole in the top cover where the output tube enters the housing and liquids should be prevented from entering the transducer at this location. Please ensure that you review chapter 3 before using your new transducer.

1.2 Electronics

A block diagram of the electronics is shown in Figure 1. A 1.1 MHz sinusoidal oscillator is used to drive both the force measurement, $C_{(Force)}$, and the reference, $C_{(Reference)}$, capacitors. Detector circuitry within the transducer head converts the high frequency AC to a DC current signal proportional to the value of each capacitor. The signal is then sent back to the electronics where a differential transimpedance amplifier converts the current signals to proportional voltages. A differential amplifier generates the difference between these two signals and the resultant signal is passed through a buffering amplifier that is also used to provide controls for offset and amplitude scale factor.

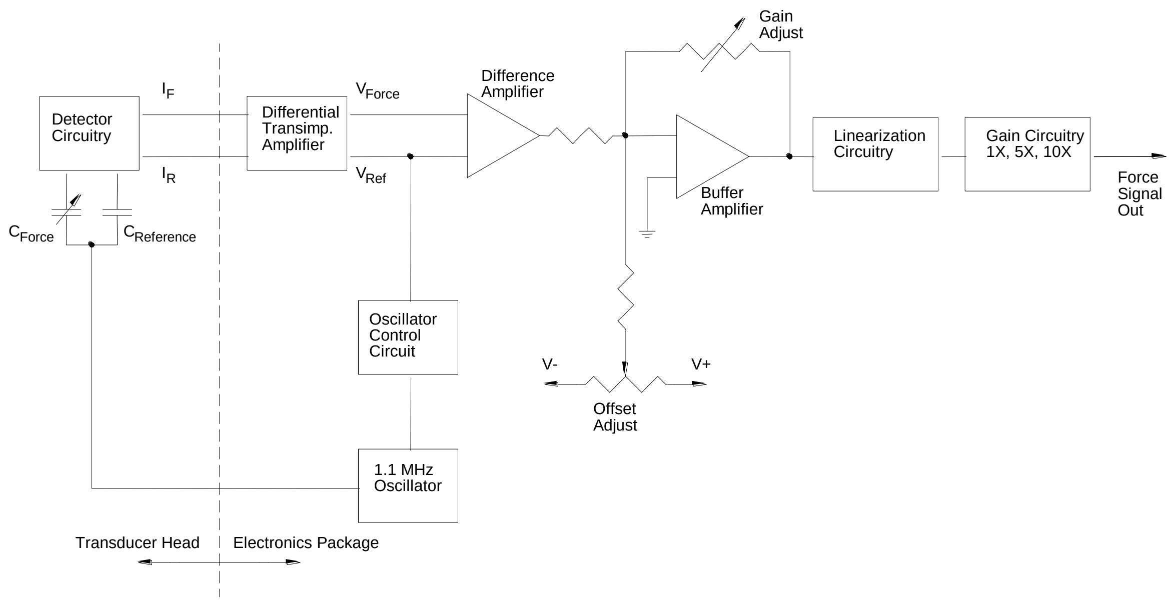

Figure 1 Block Diagram of Electronics

Note that before being passed to the differential amplifier the signal from the reference capacitor is also used to drive the oscillator control circuitry. If, for example, a temperature change at the transducer made the current through the reference capacitor increase, this would be reflected in the signal driving the oscillator control circuitry. This circuitry would then lower the amplitude of the oscillator enough to account for the thermal variation. The frequency response of the oscillator control circuit is high enough to also accommodate changes due to mechanical vibrations, power line disturbances, etc., and is responsible for a further improvement of at least 40 dB in signal-to-noise ratio.

After the signal has passed through the entire demodulation and control network, it still must be linearized. This is due to the fact that the capacitance change as a function of gap is non-linear. In fact, a different correction function must be applied for positive and negative forces since the capacitance varies as a 1/d function. A piece-wise linear approximation is used.

This is done with a 4 diode break-point network which improves the typical 10% full-scale non-linearity to better than 1%. Of course, for less than full-scale response, the correction is even better; at 50% of full scale, the typical linearity is 0.2%.

The signal passes through a gain stage before being output to the front-panel BNC connector. A switch allows the operator to choose a gain of 1X, 5X or 10X. The output signal is also sent to a front-panel mounted digital voltmeter that displays the current output of the instrument.

2.0 Specifications

Series 400A – Specifications

Specifications	Model #						
	400A	402A	403A	404A	405A	406A	407A
Full Scale [+/- mN]	50	500	5	100	10	0.5	1000
Sensitivity [mN/volt]	5	50	0.5	10	1	0.05	100
Resolution [µN]	1	10	0.1	2	0.2	0.01	20
Step Response Time [millisec]	0.3	0.1	1.0	0.3	1.0	5.0	0.1
Resonant Frequency [Hz]	2000	4000	600	2000	600	100	4000
Compliance [micron/mN]	0.1	0.01	1.0	0.1	1.0	10.0	0.01
Zero Drift [µN/deg C]	5	50	0.5	10	1	0.05	100
Gain Drift [%/deg C]	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Hysteresis [%]	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Maximum Overload Force [mN]	250	2500	100	250	100	20	2500
Output Tube Length (L) [mm]	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Output Tube Diameter (D) [mm]	1.0	1.0	1.0	1.0	1.0	1.0	1.0

General Specifications

Operating Temperature:		0 to 40°C.
Linearity of Output:		±1% of full scale over full scale. ±0.2% of full scale over 50% of full scale.
Power Requirements:		120 ±10% VAC, 50/60 Hz, 20 Watts, maximum. 100 VAC, 220 VAC and 240 VAC optional.
Cable length supplied:		6 feet (1.8 m).
Dimensions of electronics:		3.5 in. (8.9 cm) high x 8.4 in. (21.3 cm) wide x 10 in. (25.4 cm) deep (1/2-rack mountable, adapter kits available).
Weight:	Electronics:	5 lbs. (2.25kg).
	Head:	105 grams.

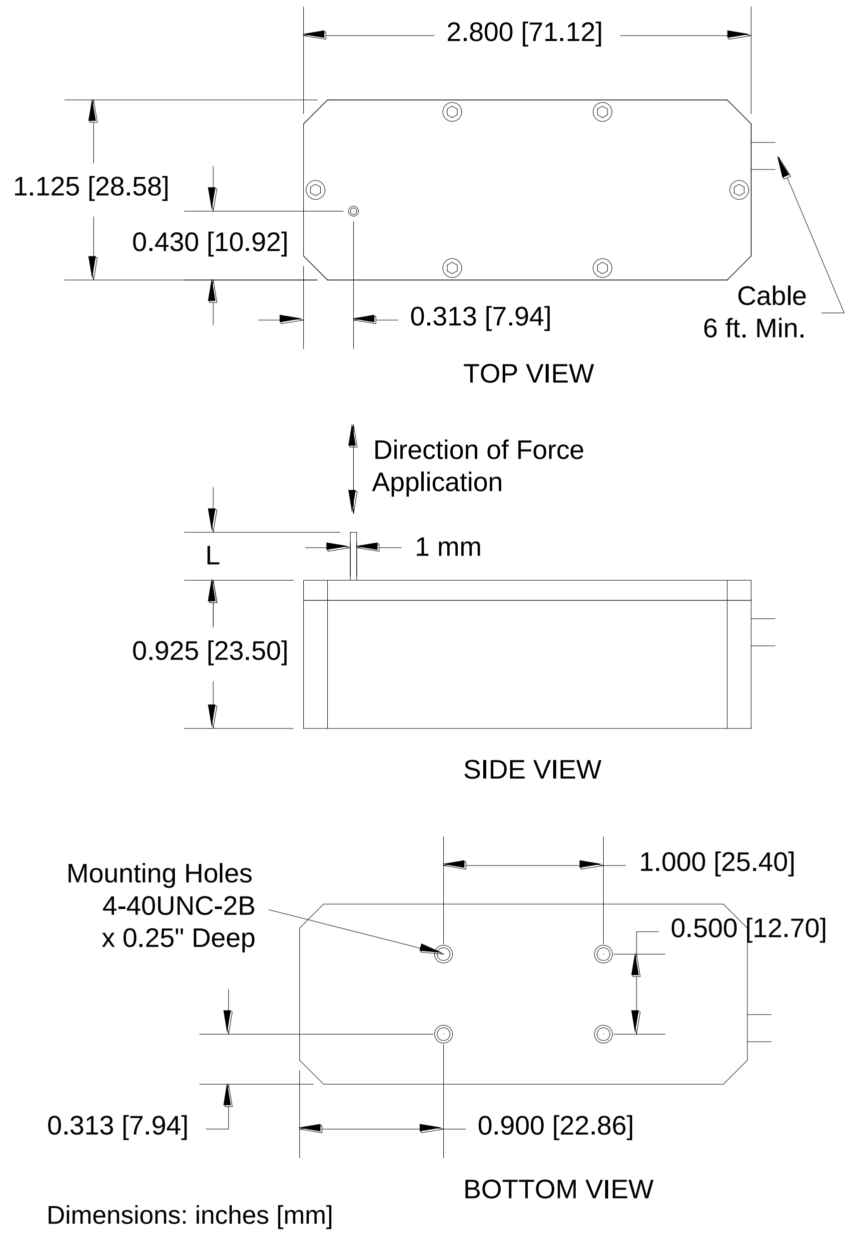

Figure 2 Series 400A Dimensions

3.0 Operating Procedures

3.1 Initial Operation

Remove the transducer head from its plastic case by removing the #4-40 screws at the base. **CAUTION: Avoid touching the output tube.** Although the unit can withstand sever overload and is very rugged, it is possible to overlook how easy it is to develop relatively high forces manually. When not using the transducer store it in the plastic case supplied. The case will greatly reduce the chance of damage to the transducer. Rest the head on a workbench with the output tube pointing upwards. Keep the head off to one side so that you don't inadvertently bump into it.

1. Remove the electronics from its shipping material. Make sure the power switch is in the OFF position.

2. Connect the transducer to the electronics by means of the 5-pin connector on the front of the case.

3. Attach an oscilloscope, computer-based data acquisition system, strip-chart recorder or other signal measuring device to the front panel BNC connector and plug the AC line cord in.

4. Switch the unit on and observe the force output signal (the front-panel digital voltmeter can be used for this observation). If the output can be brought to zero volts using the front panel offset control then the system is probably operating correctly.

5. Use a small strip of paper (3 mm wide x 2 cm long) to lightly push on the end of the output tube, applying force in the direction of the transducer body in the axial direction of the output tube. By applying force through a strip of paper you will be less likely to break the transducer. It is very easy to overload and break the transducer by directly pressing on the output tube with your finger. While pressing on the output tube note that the output on the oscilloscope follows the application of the force. **BE VERY CAREFUL NOT TO OVERLOAD THE TRANSDUCER.** Be mindful of the scale factors given in the table in Section 2.

6. This completes the procedure to verify operation. Replace the head in its case if it is not to be used immediately.

3.2 Mounting the Transducer Head

Use the four #4-40 tapped screw holes in the bottom of the housing to mount the transducer. (Note that the 4 holes are only 1/4 inch deep.) The head can be mounted in any orientation. Try to mount it to a plate that is relatively more resilient than the housing in order to avoid bending the housing and causing an offset in the output signal. Mounting to a plastic plate is probably desirable. You should allow about one hour for the system to stabilize at room temperature before using.

The body of the transducer is waterproof below the line of the top cover. Care should be taken to prevent liquids from entering the transducer head through the output tube hole. The cable and cable entry end should be kept out of water. Prolonged periods of immersion in saline may cause the cable jacketing to swell, leak, or become brittle when dried out. If immersion is necessary then carefully remove the top cover. Apply a thin coating of petroleum jelly around the top edge of the housing and re-attach the cover. Also apply the jelly around the output tube entry hole. It is recommended, however, that the unit be removed from the bath upon conclusion of the day's work. If at all possible, make mechanical arrangements for mounting the transducer that do not require immersion.

3.3 Attaching Loads

The transducer is designed to measure loads applied along the axial direction of the output tube. See arrow A-A in Figure 3.

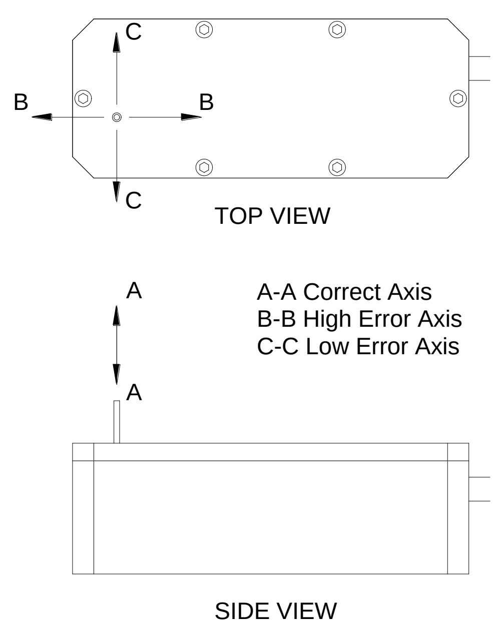

Figure 3 Series 400A Loading

Note, however, that outputs are also obtained for forces applied in the directions of arrows B-B and C-C. The error in the C-C direction is relatively low, but the error in the B-B direction is substantial. Care must be taken to ensure that the force to be measured is collinear with the axis of the output tube or it may be impossible to determine the meaning of the measurement.

The output tube is formed of borosilicate glass and can be immersed in most solutions without cause for concern. The most common method for attaching tissue specimens to the tube is to form a small hook from a section of fine wire and to bond it into the end of the tube.

A good temporary bond may be made by means of low melting point paraffin. Dip the end of the tube in melted paraffin forming a small head at the end. Because the other end is sealed, the paraffin probably will not be drawn very far into the tube by capillary action. Heat the wire and then gently push it into the paraffin while re-melting the wax using heat from a match or alcohol flame. Before the paraffin cools ensure that the orientation of the wire hook on the free end is correct. Such bonds using 57-degree Centigrade melting point paraffin have measured breaking strengths ranging from 33 to 63 grams for the 1-mm diameter tube. Dental impression compound may also be used to form a temporary bond.

Alternately a small quantity of epoxy may be used. Note that epoxy will make a permanent bond and once the hook is attached it might be very difficult to remove it without damaging the transducer.

Note that the weight of any coupling added to the tube can change the resonant frequency of the transducer. This is especially true with a high frequency unit such as Model 400A. The resonant frequency follows the proportion:

$$f_R \approx \sqrt{\frac{K}{M}}$$

where K is the equivalent spring constant and M is the equivalent mass. For the Model 400A, the equivalent mass is 120 mg. Thus a hook that has a mass of 10 mg will lower the resonant frequency from 2.0 kHz to 1.92 kHz, 20 mg lowers it to 1.85 kHz, and 30 mg. to about 1.78 kHz.

3.4 Calibration

Each unit is carefully calibrated at the factory, but in some applications a more precise scale factor over a limited range may be required, or verification of calibration may be desired.

If the transducer is to be used in tension (the normal mode of operation for muscle physiology) then mount the transducer head in such a way that the output tube points downward and is perfectly vertical. A small hook must be attached to the output tube to be used to suspend weights (refer to section 3.3 for instructions on attaching the hook). If the transducer is being used in compression then mount the head so that the output tube points vertically upward. In this case calibration weights can be placed directly on the top of the output tube therefore no hook is required.

CAUTION: THERE ARE HAZARDOUS VOLTAGES PRESENT WITHIN THE CABINET OF THE ELECTRONICS WHEN THE UNIT IS PLUGGED IN.

1. Unplug the power cord from the electronics box. Remove the top cover from the electronics box. This will allow access to the circuit board. A single Philips head screw is located on the back edge of the lid. Remove this screw and slide the top cover backwards to remove it.
2. Locate the zero and gain adjustment potentiometers. The zero pot (labelled R15) is located just left of the centreline of the electronics board (when viewed from the front of the instrument). The gain pot (labelled R9) is located right of the zero pot.
3. Center the front panel offset knob (set it to 5 turns from either end so that the dial reads 5.0).
4. Plug the transducer head into the electronics box. Plug the electronics box into the correct power source. **CAUTION: DO NOT TOUCH ANY CONNECTIONS NEAR THE BACK OF THE INSTRUMENT CASE. ENSURE THAT ANY TOOLS ARE KEPT WELL CLEAR OF THE BACK OF THE CASE. THERE ARE HAZARDOUS VOLTAGES PRESENT WITHIN THE CABINET OF THE ELECTRONICS WHEN THE UNIT IS PLUGGED IN.**
5. Turn the instrument on and allow it to warm up for 15 minutes.
6. Turn the zero pot on the circuit board until the output voltage reads 0.000 volts.
7. Place the appropriate weight shown in Table 1 on the output tube and adjust the gain pot on the circuit board to read the voltage shown in Table 1.
8. Remove the weight and re-adjust the zero pot as stated in step (6).
9. Repeat steps (6) through (8) until the output with and without the weight are correct. Since the gain affects the zero and vice-versa it usually takes several adjustments of both pots until the transducer is calibrated correctly.
10. After the gain and zero pots are set, check the calibration. Apply a series of known weights to the output tube and record the voltage output. The output can be used to check linearity and to calculate the output scale factor.

Table 1 Calibration Weight, Output and Scale Factor for Series 400A Force Transducers

Model #	Calibration Weight [mg]	Output [volts] Gain = 1X	Scale Factor [mg/volt]
400A	200	0.400	500.0
403A	50	1.000	50.0
402A	2000	0.400	5000.0
404A	500	0.500	1000.0
405A	100	1.000	100.0
406A	20	4.000	5.0
407A	5000	0.500	10000.0

4.0 Warranty

The Model 400A series transducer is warranted to be free of defects in materials and workmanship for a period of three years from the date of purchase. Aurora Scientific Inc. will repair or replace, at our option, any parts which upon inspection by Aurora Scientific Inc. are found to be defective due to materials or workmanship. This warranty does not cover breakage of the output tube or fused silica beams caused by careless handling nor to damage due to immersion in any fluid. A repair charge will always be made for failures of these types. Obligations under this warranty are limited to repair or replacement of the instrument. Aurora Scientific Inc. shall not be liable for any other damages of any kind, including consequential damages, personal injury, or the like. Damage to the system through misuse will void this warranty. Aurora Scientific Inc. pursues a policy of continual product development and improvement therefore we reserve the right to change published specifications without prior notice.

5. 0 Terms and Conditions for Returning Equipment

1. Aurora Scientific Inc. **will not** accept any equipment returned without prior authorization in the form of a return material authorization number.

1. **Please call Customer Service at (905) 727-5161 or toll free at 1-877-878-4784 to obtain an RMA#. Please specify the product line.**

2. Please package equipment properly. Goods that are damaged in shipment are the responsibility of the shipper.

3. **Aurora Scientific, Inc. withholds the right to assess charges for the repair or replacement of such damaged goods, regardless of warranty status.**

4. Warranty repairs will be shipped back to the customer via FedEx. If you require or request another form of shipment, the cost of such service is your full responsibility.

5. Aurora Scientific, Inc. **will not** be responsible for any return or replacement **shipping charges** incurred due to an incorrect order placed by the customer.

Drawings

This section consists of the following drawing:

1.) Series 400A Assembly Drawing S400-0001, Rev. 1