POSITION
Measurement & Control

Summer 1998 | Practical Information on SpaceAge Control, Inc. Position Transducers

Are you choosing a position sensor or transducer but aren't sure how to weigh your options? Check Tom's parameter list. Prioritizing movement, environment, and contact requirements enables you to make the best decision.

New Position Transducer Literature Now Available

Also Downloadable on the Web

Our new *Position Transducer* literature with data sheets and technical information on our complete line of position transducer products is now available.

If you would like a copy of this guide mailed to you, please complete and return the reply card on page 5, call us at 805-273-3000, make a request via our Web site (http://www.spaceagecontrol.com), or e-mail us (email@spaceagecontrol.com).

You may also download the literature from our Web site in Adobe Acrobat (pdf) format. Simply go to http://www.spaceagecontrol.com/litroom.html. ❑

Selecting Position Transducers

By Tom Anderson

Editor's Note: Thank you to Circuit Cellar INK magazine for allowing us to print an abridged version of an article from their May 1998 issue. For more information on Circuit Cellar INK magazine, please visit their Web site (www.circuitcellar.com) or e-mail them at subscribe@circellar.com.

As an application development manager for a position transducer supplier, I get numerous queries on how to solve a broad range of position measurement challenges.

These inquiries run the gamut from the common (aircraft flight control surface movement) to the exotic (Formula One racecar suspension travel) to the seemingly impossible (three-dimensional tracking of a golf ball in flight from a fixed position).

These position-measurement challenges usually share one common element. They can be solved using a variety of solutions, but it's not always easy to determine the best one.

There are possibly more options for measuring position than any other type of sensed variable. While there may be more suppliers for pressure transducers, the variety of position-transducer types and technologies is unmatched.

The 1997 Thomas Register lists 264 suppliers of pressure transducers and 229 suppliers of displacement and position transducers. However, there are 13 categories related to displacement and position measurement, compared to just four categories for pressure measurement.

In this article, I introduce you to various position transducer selection parameters. You'll also find information on position-measurement techniques, technologies, and choices.

BASIC TERMINOLOGY

But first, a brief note on semantics: for ease of communication, this guide refers to transducers and sensors as being the same. While not strictly true, it's not generally relevant whether you are using a position sensor or transducer. The goal of both is the same - to find out where something is!

Transducers that are the focus of this article provide position, displacement, and proximity measurements, which are defined as [1]:

- position - location of the object's coordinates with respect to a selected reference
- displacement - movement from one position to another for a specific distance or angle
- proximity - a critical distance signaled by an on/off output

In this article, I focus primarily on transducers for position and displacement measurement. And unless otherwise noted, I use the term "position transducer" to refer to displacement and proximity transducers as well.

THE PARAMETERS

On what basis should you select a position transducer? As a starting point, let's look at the laundry list of parameters shown in Figure 1. While this list is not all-inclusive, it helps you begin to decide what parameters are relevant to your application.

Perhaps the first parameter to address in any application is whether the transducer can physically touch the object being monitored. If your application is sensitive to outside influences, a noncontact transducer may be the most appropriate. Otherwise, a contact sensor might offer advantages not found in a noncontact sensor.

At first thought, noncontact transducers may seem like the superior solution for all applications. However, the decision isn't that clear cut.

(continued on page 2)

SpaceAge Control, Inc.

PLEASE ROUTE TO: ❑______ ❑______ ❑______ ❑______

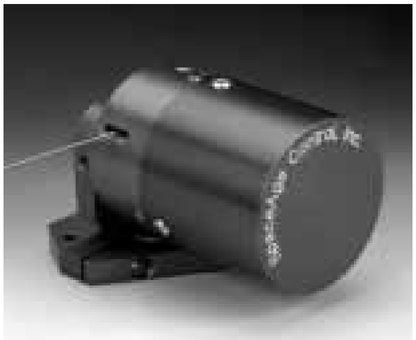


Photo 1 *— Cable position transducers provide extended ranges in small sizes. Flexible cable allows for easy installation.*

(continued from page 1)

Noncontact products can emit potentially harmful laser- or ultrasonic-based signals. These products also rely on having a clear visual environment to operate in. Frequency response isn't always as high as with a contact sensor, but costs are often higher. Finally, operating-temperature ranges are typically not as broad.

Another parameter to consider early on is whether you need to measure linear or rotary movement. Note that using cable position transducers (like the one shown in Photo 1), cams, pulleys, levers, electronics, software, and other methods can enable a rotary transducer to measure linear motion, and vice versa. Lack of space, cost, and ease of mounting are a few reasons for doing this.

Once you decide if you require a contact or noncontact solution and are measuring rotary or linear movement, selecting a transducer technology becomes much easier.

Next, determine if you're monitoring one-dimensional or multidimensional motion. If the motion is multidimensional, see if you need to measure in multiple dimensions or if the object is moving in multiple dimensions and you only have to measure one of them. Often, multidimensional motion is measured with multiple one-dimensional transducers.

Also, think about the type of signal you need to obtain. If you need a signal that specifies a unique position, be sure to specify a transducer with absolute output.

However, if all you need is relative position from a prior position or a simple on/off indicator, then incremental or threshold technology is more appropriate.

An important difference between incremental and absolute transducers is that incremental transducers typically need to be reinitialized after powerdown by moving the monitored object to a home position at powerup. This limitation is unacceptable in some applications.

Threshold measurements are on/off in nature and usually involve limit switches or similar devices. As you might guess, absolute devices are usually more expensive than incremental or threshold devices.

Travel, also known as range, varies from microns to hundreds of feet (or more, depending on your definition of "transducer"). The range of many precision transducers is limited to 10 inches or less.

If your application needs to operate on the Space Station or some other size- and weight-sensitive platform, you need to specify the maximum values for the transducer's dimensions and weight.

The application's operating environment can have a large impact on your technology choice as well. You need to determine what operating and storage temperatures the device will be in and whether you need to meet commercial, industrial, or military environmental requirements.

Also consider whether excessive humidity, moisture, shock, vibration, or EMF will be encountered. See if your environment has other unique aspects, such as high or low pressure or the presence of hazardous or corrosive chemicals.

An often-overlooked parameter is the method and time required for transducer installation and mounting. For testing applications, this parameter may not be so important. However, OEM and large-volume applications often require simple installation and removal to reduce labor costs and enable easy maintenance.

See if the transducer can only be mounted with manufacturer-provided special mounting bases or if a variety of mounting techniques can be used. Besides the common threaded-fastener approach, some other nonpermanent mounting techniques include suction cups, magnets, industrial adhesives, grooved fittings, and clamping.

In going through the previous parameters, you might have asked yourself, "Hey, what about accuracy?" While accuracy is certainly important and sometimes critical, it's often the last degree of freedom in the selection of a transducer.

As you may know from experience, accuracy is not a well-agreed-on term. Typically, various components of accuracy - linearity, repeatability, resolution, and hysteresis - are quoted for vendor convenience or per user requirements.

With the availability of software calibration tools today, linearity isn't as important as it once was. For many applications, in fact, repeatability is the most important component.

Accuracy is typically specified in absolute units like mils or microns or in relative units such as percent of full-scale measurement. If you are comparing the accuracy of one device against another, make sure you are comparing apples to apples.

(continued on page 3)

Parameter	Relevant?	Ranking	Choices		
Contact	❑ Yes ❑ No		❑Contact	❑ Noncontact	
Motion Type	❑ Yes ❑ No		❑ Linear	❑ Rotary	
Dimensions	❑ Yes ❑ No		❑ One Dimensional	❑Multidimensional	
Measurement Type	❑ Yes ❑ No		❑ Absolute	❑ Incremental	❑Threshold(Proximity)
Range	❑ Yes ❑ No		❑ Less than 1"	❑ 1–30"	❑ Greater than 30"
Physical Size/Weight	❑ Yes ❑ No		❑ Size Restriction_____	❑ Weight Restriction_____	
Environmental	❑ Yes ❑ No		❑ Humidity ❑ Vibration ❑ Moisture	❑ Corrosion ❑ Temperature	❑ Other______
Installation/Mounting	❑ Yes ❑ No		❑ Removable	❑ Installation	❑ Time Limit _____
Accuracy	❑ Yes ❑ No		❑ Linearity ❑Hysteresis	❑ Resolution	❑ Repeatability
Lifetime	❑Yes ❑ No		❑ Cycles_____	❑ Hours of Continuous Operation_____	
Cost	❑ Yes ❑ No		❑ Less than $50	❑ $50–$500	❑ Greater than $500
Delivery	❑ Yes ❑ No		❑ Less than 1 Week	❑ 1–4 Weeks	❑ Greater than 4 Weeks
Output	❑ Yes ❑ No		❑ Analog Voltage ❑ Sensor Bus_____	❑ Analog Current ❑ Visual	❑ Digital ❑ Other______
Frequency Response	❑ Yes ❑ No		❑ Less than 5 Hz	❑ 5–50 Hz	❑ Greater than 50 Hz

Figure 1 *— What are your requirements? This table helps you rank your most important parameters and value specifications. Select the relevant parameters, prioritize them, and then choose the appropriate value for the parameters.*

(continued from page 2)

For example, see if the accuracies being quoted are at a single temperature or over a temperature range. If you need it, find out if temperature compensation is available.

If you expect to see significant numbers of cycles or if the transducer will be in service for an extended period of time, specify the lifetime and reliability requirements as well. When choosing the transducer, find out what warranties are offered as well as how maintenance and repairs are handled.

A transducer that can be repaired in-house can reduce costs significantly. You should also consider what type of periodic recalibration is recommended and whether calibration procedures are provided.

It's a good idea to ask vendors what type of use their transducers see most often. Common uses include OEM, retrofit, industrial control, commercial, and test and measurement. Hopefully, the transducer has seen previous use in your type of application.

In the early stages of transducer specification, product cost sometimes doesn't even make the list. More often than not, this parameter gains importance as the project moves forward.

When you're determining costs, make sure to look at the initial acquisition cost as well as the cost over the product's life. For example, are special signal-conditioning electronics, power supplies, electrical connectors, housings, installation tools, or mounting fixtures required?

Ask the vendor for typical repair, maintenance, and replacement costs. And, inquire about the cost of the transducer in volume and single-unit quantities. The cost savings (e.g., a cost of $100 in volume but $600 in single quantities) may be an important factor if small-quantity replacement units will be needed in the future.

Another parameter that's occasionally overlooked is the time it takes the product to be delivered to you after you order it. The custom nature of some transducers combined with production processes and manufacturing economics requires lead times of eight weeks or more.

This delivery schedule might be acceptable now, but what about in six months when you need extra quantities or a spare part? Evaluate whether or not you can afford to be without a part for an extended period of time.

Obviously, the transducer is going to be a part of a system. So, determine your preferred electrical input and output requirements. Common output choices include analog AC and DC voltage, resistive, current (4-20 mA), digital, and visual (meter).

Increasingly, outputs using sensor bus protocols are being offered. Most position transducers require 50 V or less, and some are self-powered.

Finally, for fast-moving applications, determine the maximum velocity or acceleration that needs to be monitored. Ensure that your data-acquisition or control system has an adequate sampling rate to record the resulting datastream.

CHECK YOUR REQUIREMENTS

Now that you're aware of the key parameters, you need to determine which ones are relevant to your application and of these relevant parameters, which are most critical.

If you don't prioritize your requirements, it's going to be difficult to make a selection decision. You may come to the conclusion that there is no transducer that can meet your needs. This may be true, but it's more likely that your requirements are too stringent and that you need to make a tradeoff to arrive at the optimum selection.

For example, an engineer recently approached our company looking for a transducer with ±0.0001-inch resolution over 30 inches, and he wanted to keep the cost under $500. He was adamant that all three specifications be met. Our products didn't meet all his specifications and we were at a loss as to where we would refer him.

After some more discussion, we found out that the resolution requirement was only necessary over a limited portion of the total range and that the cost goal, while important, did have some flexibility. Hence, in this situation, range was most important, followed by resolution, and then cost.

The moral of this story: focus on your top requirements. Make the best decision you can, given the specifications you need. And keep in mind, you can't have everything - unfortunately.

NEXT STEPS

In this article, I've given you some parameters for selecting position transducers. But in case you hadn't noticed, I didn't provide any information on what type of technology you should select for your position transducer.

The constant change in transducer technology and the difficulty in generalizing about a particular technology's capabilities and limitations mean there's no way I can cover this area in detail here.

Additionally, choosing the technology should come after determining and prioritizing your requirements. Once your requirements are well-known, the choice of technology tends to be self-selecting.

For example, just knowing whether you require a contact or noncontact technology can cut your choices almost in half. If you need the latter, a laser position sensor may be a good choice.

To get a feel for the capabilities of some of the more prevalent linear position-measurement technologies, Figure 2 maps out

***Figure 2** — It's true: you can't have it all. As with many specification decisions, tradeoffs must be made when you're selecting a position transducer. This graph shows the typical performance of some linear position transducers as compared by maximum range, best accuracy, and cost.*

(continued on page 4)

(continued from page 3)

how these technologies compare against each other based on cost, accuracy, and maximum range. Note that not all technologies are shown.

Now, it may be difficult to clearly define the parameter values you require as well as which parameters are most important in your application. However, it can be even more difficult to obtain these parameters from vendors and then compare one vendor's statements against another's.

To get information on products beyond what you see in the vendor's product literature, review transducer-related publications such as *Measurements & Control* and *Sensors* for articles on position-measurement products and technologies.

Also, be sure to ask your colleagues about their experiences and recommendations. They may have a position transducer on hand that you may be able to test for your application.

Of course, in this day and age, make an effort to search Web engines and Internet newsgroups. Numerous engineering, instrumentation, and measurement-oriented newsgroups can be reached via search engines. Extensive sources of position-transducer manufacturers can be found in the *Thomas Register* and the *Sensors Buyer's Guide*.

Contact vendors and request references of similar applications. Ask these references why they selected the product they did and whether they're happy with their decision. Also, find out what other options they considered.

Finally, see if the vendor has product samples or evaluation units you can use for testing before purchase. If the vendor is hesitant to do this, offer to provide them with a test report summarizing your evaluation. This information may be valuable to them, and they may be more willing to assist you.

REFERENCES

[1] J. Fraden, *AIP Handbook of Modern Sensors*, American Institute of Physics, New York, NY, p. 264, 1993, 1996.

RESOURCES

Texts

Schaevitz Engineering, *Handbook of Measurement and Control,* Pennsauken, NJ, 1976.

I. Busch-Vishniac, *Electromechanical Sensors and Actuators,* Springer-Verlag, New York, NY, 1998.

INTERNET

Thomas Register Directory of *American Manufacturers,* Thomas Publishing Co., New York, NY, 1997.

Sensor's Buyer's Guide, www.sensorsmag.com

Thomas Register www.thomasregister.com

SOURCES

Dynamic Control Systems
7088 Venture St., Ste. 205
Delta, BC
Canada V4G 1H5
604-940-0141
Fax: 604-940-0793
www.dynavision.com

MicroStrain, Inc.
294 N. Winooski Ave.
Burlington, VT 05401
802-862-6629
Fax: 802-863-4093
www.microstrain.com

Midori America
2555 E. Chapman Ave., Ste. 400
Fullerton, CA 92831
714-449-0997
Fax: 714-449-0139
www.thomasregister.com/midori

OakGrigsby, Inc.
84 N. Dugan Rd.
Sugar Grove, IL 60554
630-556-4200
Fax: 630-556-4216
www.oakgrigsby.com

Senix Corp.
52 Maple St.
Bristol, VT 05443
802-453-5522
Fax: 802-453-2549
www.senix.com

SpaceAge Control, Inc.
38850 20th St. E
Palmdale, CA 93550
805-273-3000
Fax: 805-273-4240
www.spaceagecontrol.com

Quick Takes

Missed An Issue?

Back issues of *Position Measurement & Control* can be viewed on our Web site at http://www.spaceagecontrol.com.

E-Mail Still Available

Just a reminder that e-mail can be a fast and cost-effective way to communicate with us. If you would like to reach us by e-mail, our company e-mail address is email@spaceagecontrol.com. Of course, always feel free to reach us by phone (805-273-3000) or fax (805-273-4240).

American Express Now Accepted

We now accept American Express in addition to MasterCard and Visa credit card payment methods. ❑

Position Measurement & Control

Summer 1998

S025A(NC)

Position Measurement & Control is published for the customers of SpaceAge Control, Inc. and the engineering and instrumentation community. Subscriptions are free.

SpaceAge Control, Inc.

SpaceAge Control, Inc.
38850 20th Street East
Palmdale, CA 93550 USA
805-273-3000 ● Fax: 805-273-4240
email@spaceagecontrol.com
http://www.spaceagecontrol.com

✂ Cut here. ✂

Measuring Flutter

Scaled Composites Tests Aircraft Performance

Editor's Note: Many thanks to George Atherton of Microstar Laboratories for providing the basis for this article.

With a legacy of firsts in the aerospace industry, Scaled Composites, Inc. has a history of using innovative designs, technologies, and methods. The people at Scaled Composites get called in when someone has a concept to prove. Scaled Composites designs and builds proof-of-concept (POC) prototypes that run anywhere from 18% (radio-controlled) to full size.

A current example of their work is the VisionAire Vantage proof-of-concept demonstrator. This full-scale prototype, developed, built, and test flown by Scaled Composites, Inc. under contract to VisionAire Corporation, proved a design for an entirely new class of aircraft: the single-engine business jet.

The prototype Vantage fuselage has an airframe structure formed entirely of carbon fiber as a grid-stiffened stressed skin, made and cured in one piece. The wings have a composite sandwich structure of carbon fiber skins and spars, with a sealed-foam PVC core surrounding the fuel tanks. The production Vantage will be conventional pre-preg composite.

The Vantage's test instrumentation is based on a Microstar Laboratories DAP acquisition board located in a mid-height tower PC bolted to the floor on the copilot side of the cockpit. The DAP communicates with the co-pilot through related DASYLab software, running on the PC, with virtual instruments displayed on an LCD monitor. The co-pilot uses a trackball built into the seat armrest to interact with the displays.

The instrumentation incorporates over 70 inputs, analyzed in real time. Inputs included conventional instrument readings of air temperature, airspeed, altitude, angle of attack, sideslip, fuel levels as well as not-so-conventional readings of control surface positions, and vibration that pilots call flutter.

Control surfaces can vibrate to the point of structural failure. When the instrumentation system reports unacceptably low damping of vibrations, the pilot stops pushing the envelope. In some test flights, the pilot "raps the stick," pilot talk for abusing the flight controls to deliberately excite vibration. This data is recorded along with all resulting vibration in the aircraft so that engineers can assess how quickly this damps out.

Key to the measurement of flutter is the measurement of control surface movements. For the Vantage program, Scaled Composites mounted SpaceAge Control Series 160 and 161 position transducers on the ailerons, flaps, rudder, and elevator.

The position transducers were mounted to the composite aircraft frame using standard bases and Click Bond adhesive. First, the position transducers were screwed to a composite pad. Then the pad was affixed to the aircraft frame using the adhesive.

Other sensors used include three-axis accelerometers, three-axis rate gyros, two-axis vertical gyros, thermocouples, and pressure transducers.

(continued on page 6)

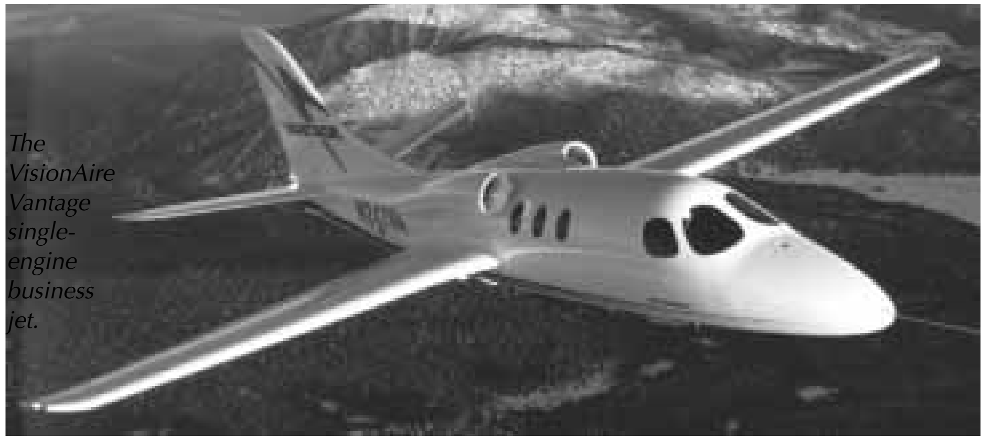
✂ Cut here. ✂

(continued from page 5)

Today's powerful data acquisition systems dramatically reduce turnaround time between test flights. Rick Lee, an engineer at Scaled Composites, stated that what is performed in real time today would have taken data technicians a week and a half of postprocessing before the next flight in years past.

To take out noise, Scaled Composites oversamples on many inputs after signal conditioning through a 50 Hz lowpass analog filter. Then data reduction is performed in real time, reducing the data stored on the PC.

The VisionAire Vantage has drawn a crowd wherever it goes including a large audience at Oshkosh in 1997. If you want to buy a Vantage, you now have to wait in line for the next available delivery: June 30, 2001. With operating costs 40% below comparable twin-engine jets and at a price of only $1.8 million, these 6-place single-engine business jets fly right off the shelves.



The VisionAire Vantage single-engine business jet.

For more information on the companies mentioned in this article, please contact:

Microstar Laboratories, Inc.
2265 116th Avenue NE
Bellevue, WA 98004 USA
425-453-2345
425-453-3199 (fax)
http://www.mstarlabs.com
info@mstarlabs.com

Scaled Composites, Inc.
1624 Flight Line
Mojave, CA 93501-1663 USA
805-824-4541
805-824-4174 (fax)
http://www.scaled.com
info@scaled.com

VisionAire Corporation
P.O. Box 4189
Chesterfield, MO 63006-4189 USA
314-530-1007
314-530-0005 (fax)
http://www.visionaire.com
info@visionaire.com

Click Bond
2151 Lockheed Way
Carson City, NV 89706 USA
702-885-8000
702-883-0191 (fax)
http://www.clickbond.com
sales@clickbond.com

Help us save a tree! Check this box ☐ and fax this side of the newsletter to 805-273-4240 if you no longer wish to receive *Position Measurement & Control.*

RETURN SERVICE CORRECTION

SpaceAge Control, Inc.
Miniature and Subminiature Position Transducers
38850 20th Street East ● Palmdale, CA 93550 USA
805-273-3000 ● Fax: 805-273-4240
email@spaceagecontrol.com
http://www.spaceagecontrol.com

Presorted
First Class Mail
U.S. Postage Paid
Mojave, CA
Permit No. 99