SENSORS AND SIGNAL PROCESSING
AN OPTICAL EDGE SENSOR FOR TRANSPARENT FILM APPLICATIONS

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ABSTRACT

Sensing the edge of transparent film webs has always been somewhat difficult. Optical sensors typically see through the low opacity webs while pneumatic, ultrasonic and other sensors have their own sets of unique problems.

In transparent film applications, the typical usable optical sensor output can be as low as 10% of that obtained from a normal opaque web. Any error or thermal drift will be amplified through the system electronics along with the desired small control change. If a web were 10% opaque, a 5% thermal drift would become 50% of the usable output signal. Light emitters and sensing elements both have quite dramatic temperature characteristics.

By using modulated infrared "IR" techniques along with careful circuit design and stabilization, a sensor and companion amplifier have been developed that is usable with most transparent film web applications. Being low intensity IR in nature, it is useful in some photosensitive film applications. Its temperature drift of less than 1% across the 0 to 50 C range is the key to transparent film applications.

This precision sensor is made possible by utilizing modern design techniques, some of which were borrowed from the aerospace industry. Constructed using Surface Mount Technology (SMT), the carefully selected circuits were fine tuned for stable and predictable operation.

The temperature-compensated mini sensor is small in size, low in power consumption, has excellent power supply stability, and temperature stability. The new sensor exhibits good plane change tolerance, ambient light immunity, electrostatic discharge immunity, and an excellent linear proportional control range.

The companion X10 amplifier provides the operator with a manual adjustment or control knob to compensate for web opacity. When properly adjusted, this control position relates to the opacity of the web material being used. The primary purpose of the amplifiers is to provide the controller with full-scale or typical sensor

levels regardless of web (10% to 100%) opacity. The operator adjustment procedure is quite simple and easily mastered.

INTRODUCTION

Since heat is amid the IR (infrared) portion of the light spectrum, the IR sensor and IR emitter must be very carefully corrected to achieve stable operation with variations in room temperature. Utilizing the modulation component, the temperature-compensated mini sensor is virtually made immune to other changes in ambient or room lighting. Using synchronous detection makes it immune to rapidly changing reflections or any other frequencies of modulated light. Stable regulators and temperature compensation make changes in its output small and within strict limits. (Fig. 1)

ERROR MODEL

The linearity plot (Fig. 2) was data taken from a production unit. It clearly illustrates the linear operation of the sensor with an opaque (100%) web. It is shown here only to dramatize the effect of a transparent web.

The advantages of the linear proportional band using opaque webs are subtle, but evident. To the systems analyst, the system gain is partly a function of the sensor slope. If the slope changes across the proportional band due to nonlinearity, so does the gain setting to achieve optimum performance. To the operator, it simply saves some of the adjustment on the system gain or sensitivity control when the guide point is changed.

Consider for a moment, the transparent wrapping on a package of cigarettes. Although it appears totally transparent to the naked eye, it has approximately 10% opacity to IR light. Simply, this means the output from the sensor will be from 0 to 10% of nominal sensor output. This is clearly below the published and guaranteed linear range of the sensor. If we were to amplify the 10% signal by a factor of ten, we could clearly see the nonlinear effect. However, we would also see that it is still quite suitable for practical operation.

It is important to notice that any thermal drift would be amplified by ten also. If a sensor had only 5% drift in its output across the temperature range of 0 to 50 degrees C, this would now become 50% of the usable output. If it were left alone, literally, a few degrees of temperature change within the room or of the equipment would cause the web to shift position.

The temperature plot (Fig. 3) was also data taken from an early production unit. Although the output of the typical unit is specified to be within 5% across the temperature range, each temperature-compensated mini sensor unit is tested to be within the 1% across that 0 to 50 degrees C window.

SYSTEM DEFINITION

In its conceptual stage, the temperature-compensated mini sensor was carefully documented in the form of a design plan which included a long list of product specifications. This collective effort produced a product that put in production in March, 1990 and has an excellent track record since. It boasts many new and unique features. There are two versions available at this time. The less expensive standard mini sensor has only 5% temperature stability which is quite acceptable for opaque web applications. The temperature-compensated mini sensor is the one recommended for use with the in-line X10 amplifier for transparent web installations. (Fig. 4)

SYSTEM INTEGRATION

The temperature-compensated mini sensor was designed for compatibility with the wide variety of web guiding controllers. Deviating from previous products, it has no output with no web and maximum output with full web. These controllers have a polarity switch which can be used for selecting the appropriate control direction or phase. Being a very sensitive device, this unit requires careful factory adjustment and these internal adjustments should never be altered in the field. Changing them may void factory warranties.

Operating from a single power supply of +10 to +15 VDC (at less than 30 mA), its power requirements and power stability are excellent.

PHOTOSENSITIVE CONSIDERATIONS

Some transparent webs are especially treated for photosensitive applications. I have reports of several installations using other IR sensors in such cases. This is, of course, determined by the sensitivity of the web emulsion. The plot (Fig. 5) illustrates the optical spectrum of the IR emitter which centers approximately 950 nm in wavelength and outside the normal visible portion of the light spectrum.

If the other IR sensors were useful for that reason, the mini sensor will be even more useful. It has a smaller optical footprint of 0.2 inch where the other IR sensors are 0.6 inch.

Due to its improved optics, the light spreading is dramatically lowered and provides a more even column of IR light which is typically 7 mm in diameter. Only half of this is typically on the web as the web is centered on the field of view. The overall light magnitude is lowered to only about 3% of that emitted by the other IR sensors. And as mentioned before, the linearity is considerably improved.

The photo film optics engineer should also consider the exposure time of the moving web to determine its value in a particular installation.

SUMMARY/CONCLUSIONS

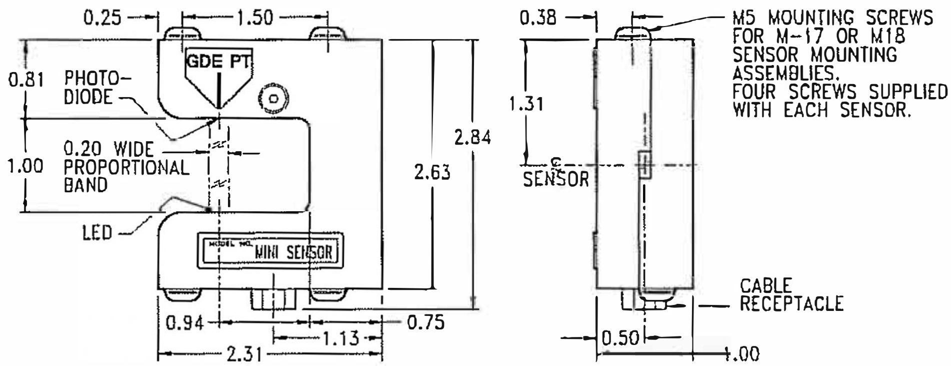
This temperature-compensated mini sensor is the most stable sensor of its kind that we know of in the industry today. It is this superb stability that makes it suitable for the transparent film portion of the web sensing and controlling industry.

Even though several manufacturers have ultrasonic sensors, the temperature-compensated mini sensor with X10 amplifier combination has certain advantages. Still in production are some pneumatic sensors that are sometimes still requested by customers for certain applications.

There is also one sensor that automatically senses and corrects for opacity. This automatic opacity sensing unit was designed in Germany and has been in production for over two years. Its patented process automatically senses the web opacity and adjusts the sensor output accordingly. It is quite useful in transparent film extrusion applications where periodic dramatic opacity variations (like printing or labels) are not encountered. Needless to say, it has increased complexity and cost than the manual system discussed here.

REFERENCES

Figure Sheets 1-562 and 1-568, Fife Corporation, Post Office Box 26508, Oklahoma City, Oklahoma 73126; U.S.A., Phone: (405) 755-1600, Fax: (405) 755-8425



NOTES:

1. All dimensions are in inches. For millimeters multiply by 25.4.
2. The SE-11 Sensor is available in four models:
   - SE-11-EC - Voltage Out at less than 5% Temperature Coefficient.
   - SE-11-IC - Current Out at less than 5% Temperature Coefficient.
   - SE-11-ET - Voltage Out at less than 1% Temperature Coefficient.
   - *SE-11-IT - Current Out at less than 1% Temperature Coefficient.
3. Output is proportional to web position.

SPECIFICATIONS:

SE-11 Sensor Weight:	5 oz (140 gr)
Operating Temperature Range:	32-121 F (0-50 C) See Note 2. for output variation with temperature coefficient.
Power Required:	10 to 15 VDC at less than 30 milliamps.

Fig. 1

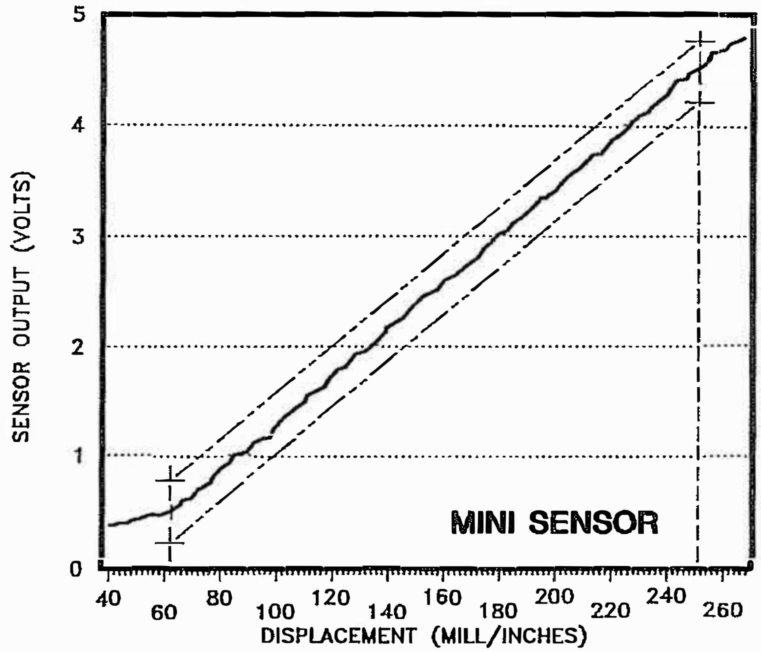


Fig. 2 Linearity Plot

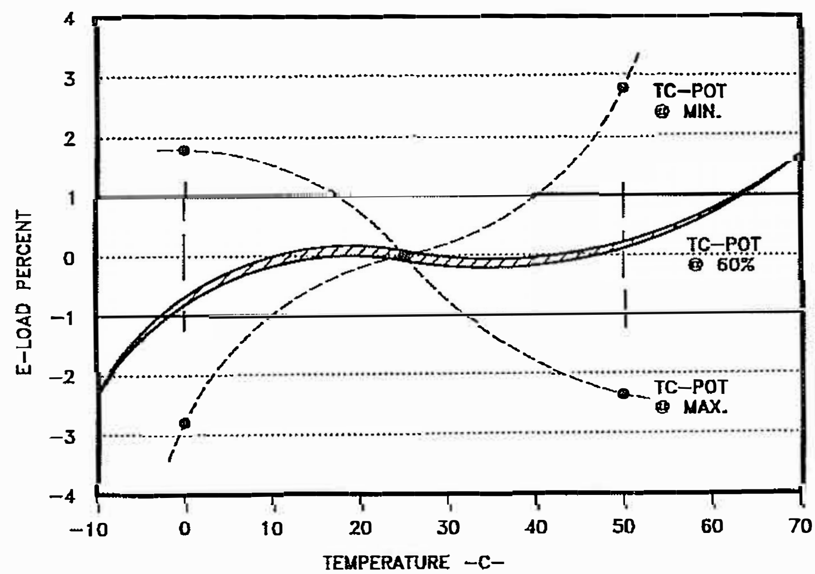


Fig. 3 Temperature Plot

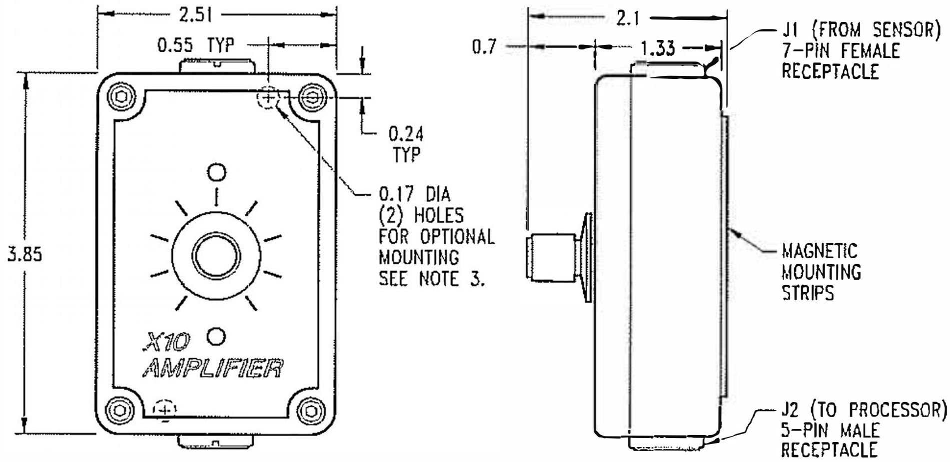

2.51
0.55 TYP
0.24
TYP
0.17 DIA
(2) HOLES
FOR OPTIONAL
MOUNTING
SEE NOTE 3.
3.85
X10
AMPLIFIER
2.1
0.7
1.33
J1 (FROM SENSOR)
7-PIN FEMALE
RECEPTACLE
MAGNETIC
MOUNTING
STRIPS
J2 (TO PROCESSOR)
5-PIN MALE
RECEPTACLE

Fig. 4

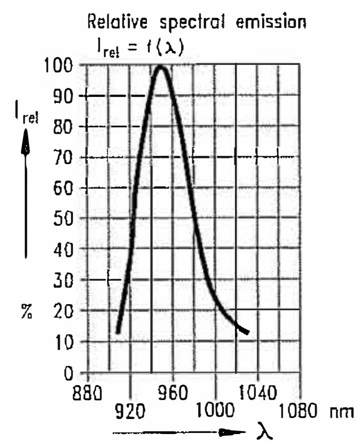

Relative spectral emission
I_rel = f(λ)
I_rel
%
100
90
80
70
60
50
40
30
20
10
0
880
920
960
1000
1040
1080 nm
λ

Fig. 5

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A pair of edge sensors could be used to measure relative changes in web width for wide webs, such as 100 to 300 inch wide opaque paper webs: What types of sensors would be suitable for 0.005 inch resolution? How should the signals from the two sensors be processed to get web width, since the edges may be rough and may wander?
Dirk Swinehart, Mead

I believe that's a little bit beyond the scope of this particular sensor because we're just talking about 0.2 inch control range. If your web goes beyond that and you're center guiding, you can lose control. He's talking about a pretty wide web there and the only way I know of to attack that problem is to use the overhead scanning laser type of setup. We have a camera sensor, and have had a camera sensor on the market for a long time, but I didn't really think of it for this particular application. The one he is discussing is a new one that I haven't been introduced to yet.

Since the original presentation, these mini sensors have been used in web width measurement systems with considerable success. The camera system discussed also has a good record for web width in certain applications. Mainly in the metals industry.

Is there any advantage of optical sensors compared to ultrasonic?
Mark Kleiman, Polaroid Corp.

Oh yes, well it depends again on the application. I think that ultrasonics has certain advantages and certain disadvantages. One of the advantages is sometimes they can go to higher temperatures. One of the biggest disadvantages is, they often have a plane change problem. One of the things that I didn't point out on the minisensor, the linearity plot you saw, that is valid for the sensor across the entire plane change of 10 percent to 90 percent of the gap with no hiccups. That is an advantage of the optics that I don't think most ultrasonic sensors have. Most ultrasonic sensors use the 40 kilohertz standard products transducer elements. They have inherent problems that can't easily be overcome.

They are high Que. They are ring up or ring down slowly making them difficult to use in close proximity. The web itself does not always absorb well enough. In a lot of cases you are working with very thin films and that has some effect on the plane change problem. There are a lot of little subtle things about the ultrasonic sensors. Some of them are even sensitive to shaking your keys, some of the older ones especially. The newer ones are getting away from those kinds of problems. Some webs may be optically opaque and yet be nearly transparent to sound.