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AR600/RP: Laser Displacement Sensor for Road Profilometry

Introduction

The AR600 family of laser displacement sensors is produced by Acuity Research. Acuity has worked with developers of road profiling equipment to produce versions of the AR600 for use as primary sensors for inertial profilers meeting ASTM Class 1 standards. The result is an AR600 with optics, electronics, and signal processing algorithms specifically for road profiling. Optics, electronics, and signal processing algorithms have been optimized for profiling. The result is an extremely accurate, cost-effective sensor for all surface types, vehicle speeds, and vibration, sunlight, and temperature conditions encountered in profilometry applications. As of March 2003 over a dozen Acuity road profiling sensors have been in service for more than a year with no field service required.

Road Profiling Product Customers

Texas DOT	James Cox & Sons	University of Texas, Arlington
Ames Engineering	Michigan DOT	Federal Hwys Administration
Transology Assoc.	Caltrans	Dynamic Research Inc

AR600/RP Road Profiling Sensor
Key Features

Measurement spans from 1 inch to 8 inches. Typical road profiling configuration is 10 inch standoff, 6 inch span: 7 to 13 inches measurement range.

Longitudinal sampling interval of 1 inch at 70 mph, with internal averaging of smaller surface features.

Configurable sample rate to 1250 samples per second. Measurement is averaged over the distance traveled.

Configurable zero and span settings. Zero point may be set at minimum or maximum range.

Choice of 4-20 mA analog or serial digital output.

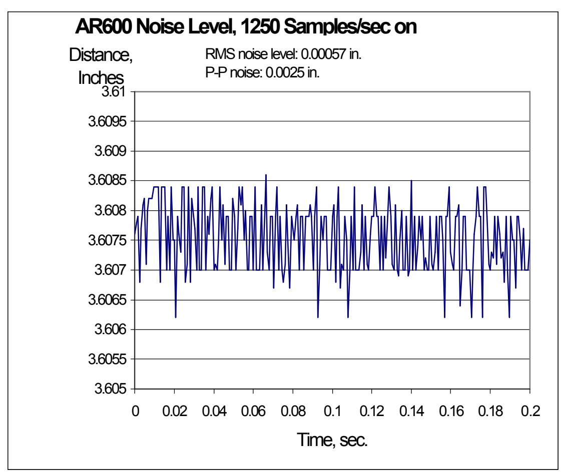
Compact size: 1.1 x 3.5 x 7.5 inches for AR600/RP-6

Cost Effective: Superior performance at prices as low as half that of other profiling laser sensors.

Measurement capability on surfaces from black (fresh tar and asphalt) to bright white coated concrete.

Loss of signal alarm line for invalid signal/beam lost indication and last valid sample hold.

Solid-state camera for lower noise, superior ambient light rejection and better edge discontinuity behavior relative to other types of optical detector.



20 mW laser provides sufficient power for operation in strong sunlight and on dark, fresh bituminous surfaces.

Full scale accuracy of 0.006" (AR600/RP-6)
Resolution: +/- 0.001" at 1250 samples per second.
RMS noise of less than .0006 inches.

AR600 for Road Profiling

Acuity's family of AR600 sensors forms the basis for the AR600 Road Profiling sensors. The standard 5 mW visible laser has been replaced with a 20 mW infrared laser and the optics modified to optimize performance on road surfaces and in full sunlight. The road profiling configuration also includes the ability to hold the last good value on its output when the beam is blocked and an alarm signal line that indicates that the present output is valid.

Measurement Ranges for Road Profiling

The standard AR600/RP is available with measurement spans of 1, 2, 4, 6, and 8 inches. The 6 inch span sensor is a new model which has been developed specifically for profiling. The shorter range models are suited for low-speed, precision measurements such as texture measurement, while the longer range systems are appropriate for high-speed or very rough surface profiling.

Model Number	Standoff (to Center of Range)	Measurement Range or Span
AR600/RP-1	3 inches	1 inch
AR600/RP-2	3.25 inches	2 inches
AR600/RP-4	5.5 inches	4 inches
AR600/RP-6	10 inches or 12 inches	6 inches
AR600/RP-8	17 inches	8 inches

Customized measurement ranges and spans are also available. Acuity can deliver a custom configuration for a cost only slightly above the price of a standard sensor.

Accuracy and Resolution

The accuracy of the AR600 sensors is 1 part in 1000, so a sensor with a 6 inch span will have an accuracy of 0.006 inches. The resolution of the sensors is 1 part in 3000, so the same sensor has a resolution of 0.002 inches. Sensors with larger spans will have larger accuracy and resolution figures, and sensors with small spans will have tighter accuracy and resolution.

Sample Rate

The sample rate of the AR600 is user configurable from 1 to 1250 samples per second. Each sample output represents the continuous average distance measured over the sample time. This provides a more realistic profile than sampling many separate points and averaging them.

Interface Features

Digital serial (RS232 or RS422) and/or 4-20 mA current loop analog outputs may be selected. The zero point of the sensor may be set anywhere in the measurement range, and the span of the current loop output may also be set to optimize the analog resolution. The zero point may be set beyond the span so that the output increases for shorter distances, which is appropriate for profiling.

Cost and Availability

The AR600/RP is priced significantly lower than alternatives which makes it practical for all types of profilers, including systems with multiple sensors on a vehicle to develop transverse as well as longitudinal profiles.

The AR600 road profiling sensors are available 2 to 3 weeks after receipt of order. For more information see the AR600 data sheet available at www.acuityresearch.com or contact Acuity Research at 650-369-6782.

Discussion: Requirements for a Road Profiling Displacement Sensor

Profiling requires accurate, low-noise displacement measurement at high sample rates in a challenging optical environment. Road surfaces vary from fresh white concrete coated with a reflective curing membrane to fresh bituminous surfaces with very low reflectance. Textured surfaces contain light and dark areas and pits and cracks that can "trap" the beam, obscuring the reflected laser light from the view of the sensor's detector.

One critical aspect of a road profiling sensor is its ability to handle the sunlight from highly reflective surfaces. Optical filters are used to block most, but not all, reflected light. The remaining light levels may still be high relative to the laser intensity, and electronic and digital signal processing filters are used to remove the effects of the remaining ambient light.

The type of optical detector used in a sensor has a significant effect on the performance and output noise level of the sensor in the presence of sunlight. The two common types of detector used in laser displacement sensors are the PSD (position sensitive detector) and the line scan camera. PSDs were used in early sensors before it was practical to put a line scan camera in a self-contained sensor. A PSD is a single long, narrow optically sensitive element which generates a signal proportional to the position of a spot of light on its surface. If other light falls on the detector or if the spot is split or distorted the PSD signal is affected by light falling anywhere on the detector. In addition, the large physical area of a PSD generates relatively high levels of noise in its output signal.

A line scan camera consists of many small detection elements or pixels. In the AR600, the pixels are processed individually to determine the location of the narrow peak of a laser spot. Since the spot is known to be small, all pixels except those which contain light from the laser spot are ignored and immunity to ambient light is improved. The small size of individual pixels also results in lower intrinsic sensor noise levels.

Sample Rate Requirements: In-Sensor Averaging vs. Multi-Sample Filtering

Selection of the optimum sample rate for profiling sensors involves several factors. Whether data from the sensor is provided as digital samples or an analog signal which is sampled externally, all samples represent the vertical distance as measured over some longitudinal distance traveled. If the measurement is taken over a very short travel distance, it may be misleading due to the microstructure of the pavement. For example, the entire measurement may be of a small pit that a tire will ride over. Many samples must therefore be taken so that the contribution of any one sample is small. The samples must then be filtered to remove the effects of small features which can significantly distort any single sample.

An advantage of line scan camera sensors over PSD based sensors lies in the inherent averaging performed by the optical detector. The pixels of a line scan camera integrate, or average, the light obtained in a single sample, or exposure. The exposure time is determined by the sample interval to which the sensor is configured. When a signal is collected over this interval, the resultant measurement is the average vertical distance observed by the sensor over the interval. In the AR600, this average is then presented as a digital or analog output. Since features smaller than the longitudinal distance travelled in the interval are averaged optically, the need for high sample rates and digital filtering to remove them is eliminated.

If the laser beam is momentarily "lost" in a pit or crack and the detector loses its view of the laser spot, no laser light is detected during that time. If the signal is lost for less than one sample period, the average distance measured by the AR600 will be based on the light that is received, and the pit or crack will not be included in the measurement. This most closely corresponds to the behavior of tires, which bridge over these features. If the signal is lost for more than one sample period, the AR600 can be configured to hold the last good sample on its output, and also generate an alarm signal indicating that no valid signal was received for that interval. For any type of sensor, the longer the sample interval the less likely it is that the signal will be lost for the entire interval.