

## PRECISION DIGITAL SOLAR ASPECT SENSOR

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Digital solar aspect sensors have been used successfully in many flight programs. These sensors give a digital output that is proportional to sun angle. Light passing through a slit forms an image of the slit on a binary-code pattern reticle that is separated from the slit plane by a fixed distance. Silicon photocells behind each column of the code pattern are illuminated by the light coming through the slit to give a digital output which is a function of sun angle. The accuracy achieved by this system is limited to about  $\frac{1}{2}$  degree, because of the angle subtended by the Sun.

Figure 1 shows a precision digital solar aspect sensor which has been developed with a resolution of  $1/256$  degree, or approximately 14 arc-seconds. The overall accuracy is 1 arc-minute. A binary coded reticle similar in principle to those used on  $\frac{1}{2}$ -degree systems is used to generate the most significant bits. If a gray code were used, as in the  $\frac{1}{2}$ -degree systems, all bit transitions would have to be made to an accuracy of better than 1 arc-minute. The precision sensor uses a natural binary code reticle, with V-brush logic to eliminate the ambiguity inherent in natural binary transitions. The reticle configuration is shown in Figure 2.

An interpolation technique is used to generate the fine angle measurements. Four columns are used, each having a 2-degree spacing but successively displaced by  $\frac{1}{2}$ -degree increments. The fine angle signal processing is shown in Figure 3. As the slit image scans across the reticle, four sine waves are generated with a period of 2 degrees but displaced 90 degrees in phase from each other. The sinusoidal waveform results from the interaction of the slit and the circular image of the Sun.

The outputs from the four columns are chopped by four quadrature square waves derived from a chain of flip-flops counting down from a fixed-frequency oscillator. These outputs are summed and passed through a bandpass filter to produce a sine wave whose phase is proportional to the sun angle. This phase angle is measured by counting the number of pulses at

the oscillator frequency that occur between the zero crossings of the phase reference and the sine wave. Upon receipt of a command signal, the number counted is transferred into a buffer storage register and held until the next command is received.

The sensor being developed has a single sensor head with a total angular field of view of 64 degrees in each of two orthogonal axes. Outputs of a number of sensor heads may be combined to extend the field-of-view capability. Complete spherical coverage with an accuracy of 1 arc-minute can be achieved in this manner. The data output consists of a Sun-presence signal from the illuminated head and a two-axis error signal from that head. Unlike analog sensors, the digital sensor is not susceptible to errors caused by other light sources such as the illuminated Earth. The detector output from these light sources is below the solar threshold level.

The electronic and mechanical design of this sensor has been completed, and two flight units are being fabricated. One of these units will be flown as an experiment aboard OAO 4. A simpler one-axis form of this sensor can be used to determine the attitude of a spinning spacecraft. A single slit command reticle is used to determine when the sensor sweeps past the Sun and to trigger a readout of the sun angle binary output in the sensitive axis.

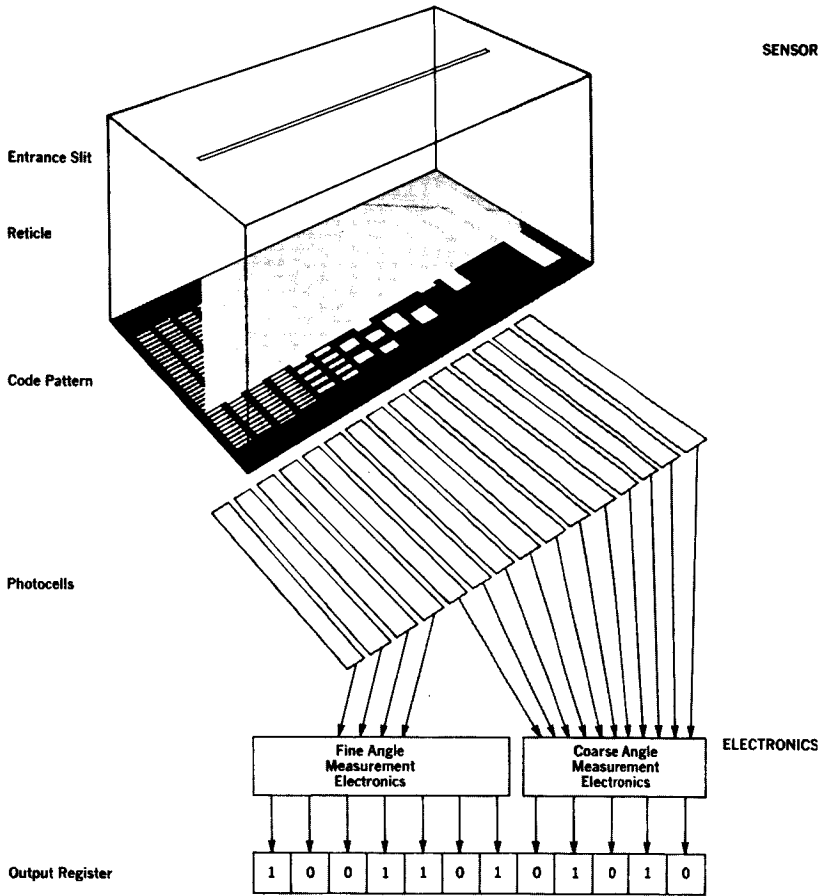


Figure 1—A precision digital solar aspect sensor.

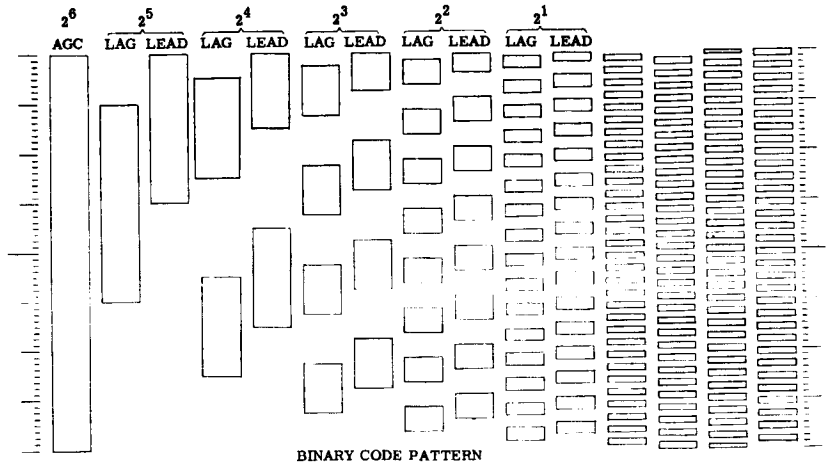


Figure 2—Reticule configuration.

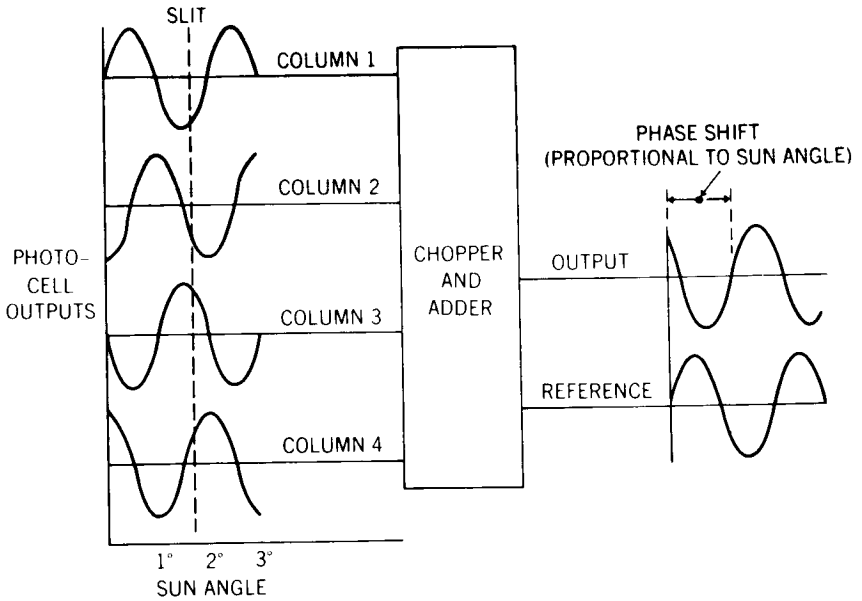


Figure 3—Precision digital solar aspect sensor interpolation technique.