The design for this dome encoder evolved over a period of about six years. It built upon Delaney's 1979 design for a single-track incremental encoder. (A similar scheme apparently was used in 1971 for an incremental encoder on the dome of the 40 cm Photometric Telescope of the Observatoire de Haute Provence, France.[1,2]) Delaney's incremental encoder was the first of a number of encoder designs used at the 1-meter telescope prior to the current system, which was installed in May 1985. Other optical-based schemes were considered, such as using a wider coded band to make a multi-track Gray code absolute encoder. These were not pursued because of their excessive electronic and mechanical complexity and their susceptibility to skewing errors.

The current design resulted from investigations into the possibility of using inexpensive commercial bar code readers to encode absolute dome position. The idea was to place bar code symbols around the inside of the rotating part of the dome, with the absolute position at each point encoded in the corresponding bar code symbol. As the dome rotated, the bar code symbols would be drawn past a bar code reader, which would decode them and provide the absolute position of the dome.

Unfortunately, standard bar code symbols cannot be used this way. Although they can be scanned at many different speeds and from either direction, the speed and direction during any single scan must remain reasonably constant.[3] Since the dome speed or direction can change at any time, the normal motions of the dome cannot be used to reliably scan standard bar code symbols.

The hybrid encoder design solves this problem by adding a timing track adjacent to the bar code (or data) track, so that the bar code becomes self-clocking. Coincidentally, this timing track also functions as an incremental encoder of the type used in Delaney's 1979 design.

Theory of operation

The encoder read head contains three optical sensors that are used to scan the timing and data tracks. Each sensor consists of a photodiode/phototransistor pair. The photodiode emits a small infrared beam that is either reflected or absorbed by the light or dark marks on the coded band. The phototransistor measures the reflected light and generates an analog voltage proportional to the intensity of the reflected beam. The resulting analog signals are converted to digital TTL levels by a separate op-amp and schmidt trigger for each phototransitor output. These three TTL levels are fed to separate input lines on an input/output port of an 8-bit microcomputer, which then computes the dome position from these inputs.

Two of the three optical sensors scan the timing track, and the horizontal spacing between them is adjusted so that the signals they produce are in quadrature. Comparing the phase relationship between the signals from these two sensors determines the direction of dome motion, and counting the signal transitions yields the amount of motion. Most commercial incremental encoders, as well as Delaney's single-track incremental encoder, are based on this method.[4] The TTL levels generated from these two sensors are fed to a phase comparator, that outputs a direction level and clock pulse corresponding to each incremental tick of motion. These control an up/down counter, which measures the incremental position (see Figure 2). The direction level and clock pulse also control two shift registers that process the signals from the data track (see below). The up/down counter, shift registers, and other registers shown in Figure 2 are located in the microcomputer's RAM. The logic for the phase comparator and for the clocking and gating of the various registers is implemented in software.

The third optical sensor scans the data track, which consists of discrete absolute position tags separated by areas of blank space. Each tag is encoded as a serial bit stream, and framed by start bits on either side. This pattern of framing simplifies detection of the tag from either direction. Note that the tags are not a direct binary encoding of absolute position, but are instead indices used to access a look-up table of absolute positions. This scheme was used because certain bit sequences are reserved for framing, and because it reduces the number of bits needed to represent each position.

When the dome rotates, the direction level and clock pulse that the phase comparator derives from the timing track are used to shift the bits from the data track into one of two 24-bit bi-directional serial shift registers. Conceptually, these two registers can be imagined as existing side-by-side and forming a 48-bit wide window through which the microcomputer "views" the data track. After proper initialization, a minimum of 24 consecutive bits in this window will always correspond to an identical sequence of bits on the section of the encoder data track that is currently positioned in front of and immediately adjacent to the read head. The bits in this window are always aligned such that the bit in the center of the window corresponds to the data bit that has just passed under the optical sensor for the data track.