Digital Encoding of Co-ordinates on a German Equatorial Telescope Mounting

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Abstract: A digital system has been designed to replace mechanical setting circles for RA and declination on a German equatorial mount. The system comprises two modules: a Digital Encoding Unit (DEU) and a Display Unit (DU). Angular position and direction of movement of the slow motion controls are sensed by means of two separate shaft encoders with a resolution of 500 pulses per revolution. These signals are processed in the DEU and transmitted to the DU in serial form together with sidereal time information. The DU features a simple key-pad for operator interface, and RA and declination are displayed on a 16- digit dot-matrix liquid crystal display. Both modules were designed around 8-bit microcontrollers, and the DU features a pre-programmed catalogue in non-volatile memory (Serial EEPROM) of co-ordinates of bright reference stars.

1. Introduction

Most commercially available telescopes are supplied with an equatorial mounting, equipped with RA and declination setting circles which are used for locating objects in the sky once the circles have been calibrated. Although it is also possible to locate objects by the so-called "star hopping" method, it is often a time consuming and frustrating procedure when, for example, one is searching for a faint variable star. This is when setting circles prove their worth, provided that they are well-constructed and accurate. Unfortunately, this is not always the case, as this author experienced repeatedly when attempting to use the setting circles on the German equatorial mounting of his Meade reflector.

This problem was successfully solved by designing a digital system around optical shaft encoders to replace the conventional setting circles.

2. Brief description of shaft encoders

An optical shaft encoder is a device in which the light beams between a pair of emitters (photodiodes) and detectors (phototransistors) are alternately interrupted and allowed to pass by a series of fine slots along the edge of a disc which rotates with the shaft to which it is coupled. The slots are offset relative to the two emitter-detector pairs, with the result that, as the shaft is turned, two output pulse-trains are generated which are 90° out of phase relative

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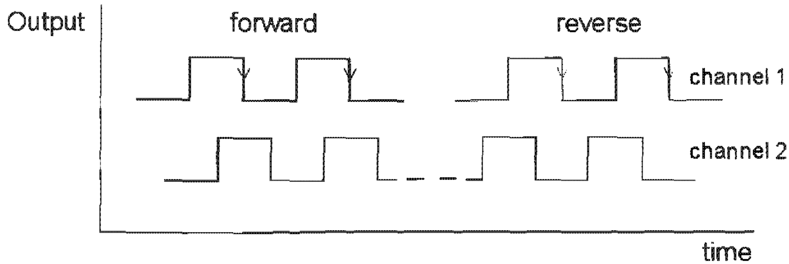

Figure 1. Shaft encoder output format

to one another, as shown in Figure 1. This arrangement makes it possible to determine in which direction the shaft is turning. For example, suppose that the falling edge of the signal from channel 1 is used as a reference, then the level (high or low) of the signal on channel 2 at that instant indicates direction. Since the shaft encoder generates a finite number of pulses in one complete revolution, it is possible to determine angular displacement of the shaft by counting the output pulses. This number is referred to as the resolution of the shaft encoder and is usually specified by the manufacturer as p.p.r. (pulses per revolution).

3. Design criteria

The first step in the design of a system such as the one being described is to determine the required resolution of the shaft encoders, of which two are required – one for right ascension (RA) and the other for declination. The resolution depends on the co-ordinate display format and on the precision of measurement required. In this design the format adopted is **xx** hours **yy.y** minutes for RA, and **xx°** **yy'** for declination. The required precision was chosen to be one half of the least significant digit in each case, which is ± 0.05 minutes for RA, and ± 0.5 arc minutes for declination. Having defined the required precision, the shaft encoder resolution could be calculated.

In the case of RA, one revolution of the polar axis is equivalent to 1440 minutes (of time). Therefore, the shaft encoder resolution required to yield a precision of 0.05 minutes, is

$$r_{RA} = \frac{1440 \text{ min/revolution}}{0.05 \text{ min}} = 28\,800 \text{ p.p.r.}$$

By similar reasoning, the required encoder resolution for the declination axis is

$$r_{dec} = \frac{21600 \text{ arcmin/rev}}{0.5 \text{ arc min}} = 43\,200 \text{ p.p.r.}$$

These numbers are far beyond the capabilities of most shaft encoders, so that some means of reduction is clearly necessary. Fortunately, in the present case the equatorial mounting was fitted with slow-motion controls on both axes in the form of worm drives with a reduction ratio of 100:1. By coupling the shaft encoders to the worm shafts instead of directly to the polar and declination axes, the above values for resolution were effectively reduced to 288 for RA and 432 for declination, respectively.

The next step was to find suitable shaft encoders. Several types were considered, and the one finally selected was a small, hollow-shaft type, manufactured by Hewlett Packard. These encoders have a resolution of 500 p.p.r. which exceeds the minimum required values as calculated above, resulting in a final precision of ±0.029 minutes/pulse for RA and ±0.432 arc minutes/pulse for declination.

In addition, the hollow shafts allowed them to be coupled directly to the worm shafts of which the diameter fortuitously matched that of the shaft encoders. It was therefore only necessary to fabricate suitable brackets for supporting the encoders on the telescope mounting.

4. System configuration

Two possible system configurations were considered: a system based on a personal computer (PC), or a dedicated, stand-alone system. Since the use of a PC at the author's open air observing site would be impractical, the stand-alone option was chosen. It was further decided to split the system into two parts, i.e., a digital encoding unit (DEU) and a display unit (DU). This would simplify interfacing to a PC, should a future need to do so arise. Block diagrams of the DEU and DU are shown in Figs. 2 (a) and (b), respectively.

4.1 The digital encoding unit

This unit is designed around the 8-bit PIC16F84 microcontroller unit (MCU) from Microchip Technology Inc. The signals from the two shaft encoders are processed by the MCU to extract information about angular displacement and direction of rotation of the two shafts. The MCU also monitors the status of two push-button switches on the unit. One switch allows the observer to change the direction of increase (decrease) in declination, such as when the declination axis is re-orientated with respect to the meridian. The other switch provides a convenient means for resetting the reference co-ordinates when necessary.

A real-time, crystal controlled sidereal clock time base is maintained in the MCU software, and this time information, as well as the status of the switches and displacement and direction of RA and declination, are compressed into a string of 16 bits which are transmitted to the display unit in serial format every 20 ms.

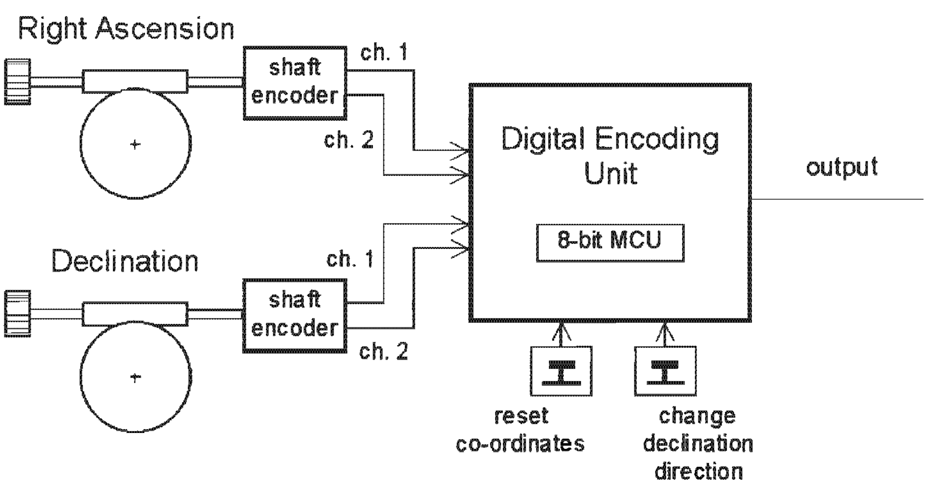

Figure 2(a). Digital encoding unit block diagram

The printed circuit board of the DEU is housed in a small enclosure which is permanently mounted on the telescope mounting and connected to the DU by means of a cable fitted with D-type connectors.

4.2 The display unit

This unit uses Microchip's PIC16C57 MCU to perform its various functions, which include decoding of the data received from the DEU, interfacing to a simple, three-key pad, controlling the display of information on the 16-digit dot-matrix liquid crystal display (LCD) and retrieving reference co-ordinates from a pre-programmed catalogue of selected bright stars stored in 48 kbytes of non-volatile memory (serial EEPROM).

The circuitry is built on a printed circuit board and housed in a calculator-type enclosure. Power for the entire system is derived from a 9V battery in the DU enclosure.

The complete system, attached to the telescope, is shown in the photograph (Fig. 3).

5. Operation

All the functions of the system are controlled by the programs in the two MCUs. This software was developed by the author over a period of several months.

After switching on the unit, the observer has a choice of three options for entering co-ordinates:

1. New co-ordinates may be entered manually via the key pad. This option is used to "calibrate" the system on a reference star which is not in the built-in catalogue.
2. The co-ordinates of any of the reference stars in memory may be retrieved. At the time of writing the catalogue contains 40 stars of magnitude 2 or brighter.
3. The last reference co-ordinates used may be recalled and used again. The active reference co-ordinates are saved in a non-volatile register so that they are retained when the system is switched off.

Once the co-ordinates of the required reference star have been entered, the telescope is aimed at the reference star and its image is centred in the eyepiece. The Enter/Execute key is then pressed, after which any movement of the axes is indicated on the LCD.

One of the menu options available via the key pad is control of the sidereal clock. The default setting is "off", but the observer can switch it on, after which the RA display is updated accordingly, unless the telescope is fitted with a motor drive, in which case no

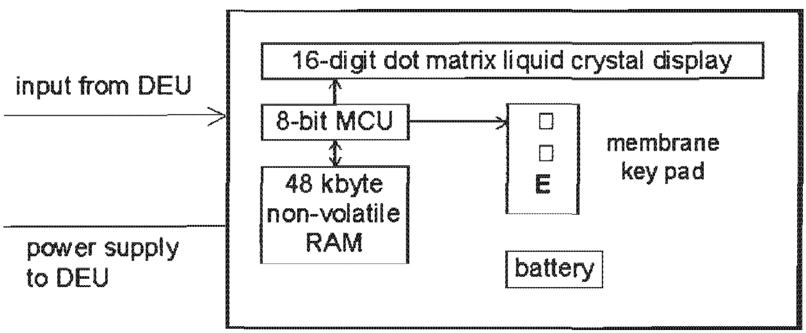

Figure 2(b). Display unit block diagram change in RA should be indicated. In the absence of a motor the sidereal clock feature is useful for manual tracking in imaging applications.

6. Test results

At the time of writing no quantitative tests have been carried out. However, several trials were performed to find variable stars which have not been observed by the author previously, so that in each case the star fields were not recognizable. After entering the co-ordinates of suitable reference stars to locate the variable stars, it was found, in each case, that the target variable star was at the centre of the field of view, thus confirming that the system was working satisfactorily. In fact, it had previously been impossible to obtain similar results with the conventional setting circles with which the telescope was fitted. In conclusion, the results emphasized the fact that an electronic system is essential if it is required to locate objects with accuracy and precision.

Figure 3. The complete encoding system installed on a German equatorial mount.

Anyone interested in obtaining more information about this system may contact the author at telephone number (027) 219 1868 or by e-mail at astronomer@skywatch.co.za.