LONG-DISTANCE TRANSMISSION OF DIGITAL SCINTILLATION CAMERA SIGNALS

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A system is described for the long-distance transmission of digital positional information from a scintillation camera to a computer through a shielded multiple-twisted-pair cable. Data errors caused by noise induction along the cable are completely eliminated. The operation of the complete interface and its routine testing are described.

The cable transmission of data from a scintillation camera to a digital computer over long distances presents problems. The major one is the induction of noise along the length of the cable, thereby causing data errors (*1*). Dowsett and Roberts (*2*) have succeeded in transmitting analog signals over 1,450 ft. However, their approach is expensive: it requires high-quality amplifiers and coaxial cable and does not completely eliminate the possibility of induced noise.

More recently Grant et al (*3*) successfully transmitted digital signals over 450 ft. Their approach eliminates induced noise and the need for high-quality amplifiers, but it also is expensive because it uses shielded twin coaxial cable. Furthermore, they transmit their digital signals serially, thus increasing the transmission time.

This paper describes an inexpensive method for sending digital signals in parallel from a Dynacamera-2C (Picker Corp., Mentor, Ohio) to a PDP-11 computer 400 ft away.

MATERIALS AND METHODS

The resolution of the scintillation camera and the storage capacity of the computer dictated that the digital X–Y positional signals be described by two 7-bit words. Together these make up a 14-bit camera address. These address signals are transmitted in parallel over the same cable. The system is capable of transmitting and storing one data point every 5 μsec, which is well within the 32-μsec minimum deadtime of the camera.

The scintillation camera and computer are located four floors apart in the same building. It was necessary to run 400 ft of transmission cable along the outside of the building. The cable used has 25 pairs of polyethylene-insulated conductors and an "Alpeth" sheath composed of a 0.008-in. aluminum tape shield and a thick tough polyethylene jacket with excellent weather-resistant properties. Because such cables are used extensively by the telephone industry, they are inexpensive and of high quality.

In close proximity to the transmission cable are high-powered TV and FM transmitters and an elevator control room. The system to eliminate noise induction from such sources is shown in Fig. 1. Each of the 14 digital signals making up a positional address is sent over its own twisted pair, using commercially available (National Semiconductor Corp., Santa Clara, Calif.) line drivers (DM 8830) and line receivers (DM 8820). The line drivers take each transistor–transistor logic (TTL) signal from the analog–digital converters of the camera, step up the current drive capability, and send the signal and the inverted signal down each twisted pair. Any induced noise at the receiving end (represented in the bottom of Fig. 1) has the same polarity on both conductors of each twisted pair and is cancelled by the differential input of the line receiver. The line is ac-terminated at the receiving end by using a capacitor in series with the terminating resistor included in the receiver's integrated circuit. This greatly reduces power dissipation in the drivers. The same method of transmission is used to send additional TTL signals used in the camera–computer synchronization.

Figure 2 is a block diagram of the complete interface, which can be used in either a data transmission or a testing mode. In the data transmission mode a

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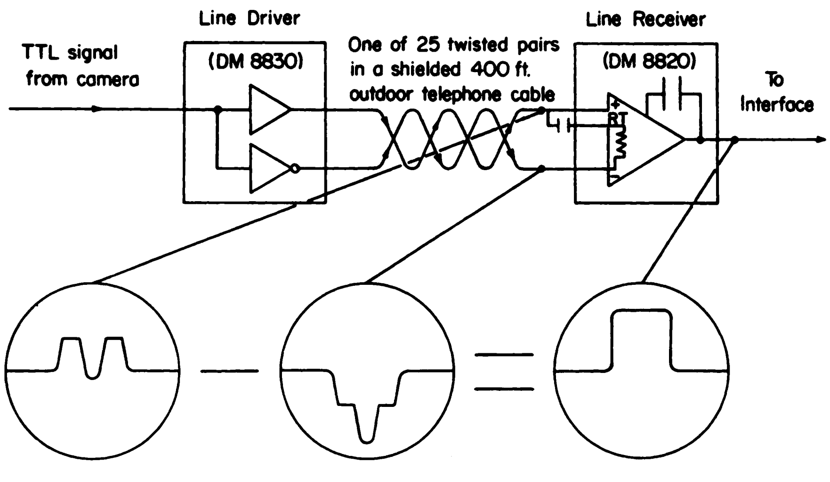

FIG. 1. Schematic representation of data transmission. Action of differential receivers is shown schematically in circular diagrams. Input is shown as square wave, and induced noise as negative-going pulse; ac-terminating capacitor is 2,000 pF.

camera-address signal representing the coordinates of a scintillation event on the camera crystal is presented in parallel to the interface. A gating control sends this address to the output latch and drivers and loads it onto the 400-ft cable. After a 200-nsec delay to allow the data to settle, a camera "done" signal is sent to the computer room, where it initiates the following interface cycle. A computer memory address is determined from the camera address and the contents of a register in the interface. This register has been previously loaded and its value is defined by the image resolution or frame size chosen, i.e., 7

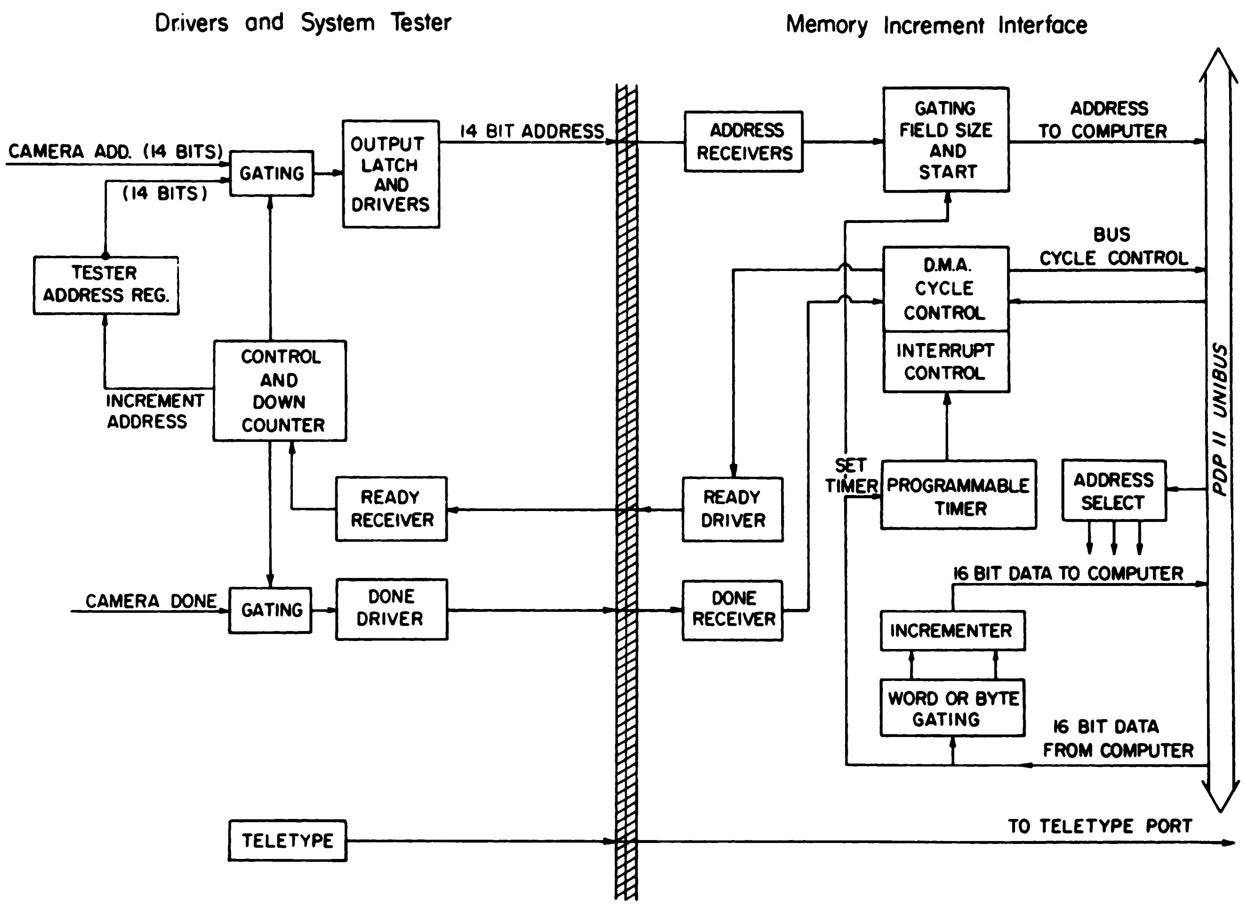

FIG. 2. Block diagram representation of camera–computer interface. Drivers and system tester are located in camera room, while memory increment interface is in computer room 400 ft away. Direct memory access (DMA), cycle control (M796), interrupt control (M782), and address selector (M105) are commercially available. Remaining circuits were constructed by authors.

bits for X and Y corresponds to a 128×128 frame, 6 bits to a 64×64 frame, or 5 bits to a 32×32 frame. In addition, word or byte storage allocation must be specified. Once this computer address has been determined, the appropriate word (or byte) is fetched by a direct memory access cycle (DMA), incremented by 1, and returned to memory. The interface has now completed processing one scintillation event from the camera. At this time a "ready" signal is sent back to the camera interface indicating that the computer can accept the next event. In this way synchronization between interface and computer is easily maintained.

Frame size, frame time, number of frames in a sequence, and word or byte storage allocation are selected using an interactive software program prior to data acquisition. A programmable timer built into the interface allows single or repetitive frames from 20 msec to 11.4 hr in duration. All operator interaction occurs through a teletype keyboard located in the camera room. We have written the software system to run under the Dos/Batch disk operating system (Digital Equipment Corp., Maynard, Mass.).

In the testing mode the camera address is replaced by the input from the tester address register, which transmits a test pattern through the interface to the computer at a rate of 10^5 cycles per second. For a given frame size the test system increments each computer address by a factor assigned to each matrix element in the frame. Therefore, a quick examination of this stored test frame establishes the integrity of the entire interface system. This test pattern can also be used for software development.

The system has been used for the past 2 years and has required no maintenance. Before each day's use the test pattern has been transmitted without error.

DISCUSSION

An inexpensive dependable memory-increment interface has been built and tested where the cable distance between the scintillation camera and the computer is 400 ft. We have found parallel digital transmission of data to be simple and reliable. The transmission distance can easily be increased since the deadtime of this system is 3 μsec plus the time for signals to travel up and down the length of the cable. For a cable 2,500 ft in length, the system deadtime would still be under 10 μsec.

The additional twisted pairs in the cable can be used to place remote computer input–output devices near the camera, to connect lines between the ends of the cable, and to replace twisted pairs that might malfunction.

No problem has been experienced with noise or data errors, even though the system is operated in a noisy environment. System operation is unaffected by grounding the cable shield at one end, both ends, or not at all.

We conclude that digitizing scintillation camera signals at the source and transmitting them over shielded multiple-twisted-pair cable is a simple, noise-free, and inexpensive method of data transmission.

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