A simple decoder for linking photocell arrays to a microcomputer

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Inputs from photocell arrays (such as those incorporated in mazes) to a microcomputer must be decoded. For up to 31 channels, this can be conveniently done by using cascaded 8-to-3 line priority encoders (74LS148) and five lines on a parallel data bus. The arrangement is expandable. It is currently used in an automatized Y-maze for vibrissio-tactile discrimination learning in mice.

Automatic monitoring of animal behavior in a labyrinth is a typical application that requires connecting an array of photocells to a microcomputer. Most microcomputers provide an opportunity to read the input/output (I/O) register of an eight-line TTL-compatible interface (e.g., for printers, disk drives, etc.) or have special interface cards for customer-built parallel I/O devices. Yet, connecting even a modest number of photocells via a parallel interface requires decoding of the input, particularly when using interpreted high-level languages such as BASIC. Decoding becomes especially important if two or more photocells can be activated by the animal at once, a situation that can arise fairly often in certain types of mazes. For the automatization of a tubular Y-maze used for visual and vibrissio-tactile discrimination learning in mice (Fluehmann, Lipp, & Schwegler, 1981; Lipp, Eslami, Soares, Schwegler, & Fluehmann, 1981; Lipp, Schwegler, & Pestalozzi, 1980), we needed a device that would monitor an advancing mouse and its choices. Since the maze controller had to be a Hewlett-Packard 85 desk computer (HP 85) with a built-in BASIC interpreter, the decoding of simultaneously activated photocells could be achieved only with a peripheral device; software solutions were too slow.

Here we describe a simple hardware interface that decodes up to 31 photocell inputs on five lines of an eight-line data channel, leaving three lines for expansion, such as for interrupt signal lines. Four 8-to-3 line priority encoders (74LS148) decode an array of photocell inputs in such a way that the bit patterns on the five data lines cor-

respond to decimal numbers 0 to 31. In case of simultaneously broken photobeams, only the number of the channel with the highest decimal number is placed on the data lines. The TTL circuitry with pin assignments is shown in Figure 1. Further details about the 74LS148 are given elsewhere (Lancaster, 1976; Texas Instruments, 1976).

Photoelements used are manufactured by ASEA-HAFO (a Swedish company). Infrared light emitter (GaAs, 1A48C, 940-nm wavelength) and silicon phototransistor (2B50C) are of identical size (5 mm long, 4.7-mm circular diameter = standard size TO-18). In our application (3-10-cm length of infrared beam), the light-emitting diodes are connected to a constant-current (nonpulsed) source of 100 mA per diode (1.25 V). The maximal emitter-collector voltage of the 2B50 phototransistor is 30 V; the maximal collector current is 100 mA. Resistance under ambient light conditions in the laboratory is approximately 30 M Ω . Switching times (ON/OFF, 5 V, 1 mA) are approximately 9 μ sec. Capacitance (collector-emitter) is 10 pF (5 V, 1 mA).

The inactive input to the decoder is a voltage of 5 V, which is connected, via the phototransistors, to the input pins of the 74LS148, each one grounded through a 2K2 resistor. Under infrared radiation of the transistor, this results in a voltage of 4.6 V at the input pins. Breaking an infrared beam pulls the decoder input low (its active state). This simple arrangement does not require additional circuitry typical for photocell input, such as Schmitt triggers or latched logic gates. Since it worked flawlessly after the first installation, we do not know whether the problem-free inputting must be ascribed to the particular type of phototransistor or to the distally connected decoder circuitry.

The four priority encoders are cascaded via their enable input and enable output pins (EI/EO). Their three-line outputs share a common data bus (driven by two 74LS240

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bus drivers, and linked to a final 7407 line driver), which corresponds to the three least significant bits on the data lines. Activating a given input of a priority encoder disables the distal encoders, enables the corresponding line drivers, and results in a binary representation of the input number (0 to 7) on the common data bus (000 to 111, positive logic). When two inputs of the same encoder are activated at once, only the higher decimal number is transmitted. The next two most significant bits of the data channel (3 and 4) are toggled by means of AND gates (74LS08), depending on which priority encoder is active. The inactive status of the data bus to the computer interface is all lines high; that is, any number read by the microcomputer that is equal to or larger than 31 (11111)

must indicate inactive photocells. If an animal breaks any light beam between 0 to 7, bits 3 and 4 of the data bus are pulled low, and the remaining bits show the activated photocell with the highest number (00000 to 00111). If beams 8 to 15 are broken, bit 4 remains low and bit 3 is switched to high, thus transmitting numbers between 8 and 15 (01000 to 01111). Interrupting any photobeam between 16 and 23 reverses the status of bits 3 and 4 and transmits numbers between 16 and 23 (10000 to 10111), and interrupting beams 24 to 30 transmits the binary patterns of 11000 to 11110. The last channel of this priority decoder (pin 4) must be disabled in this arrangement, since its binary pattern (11111) cannot be distinguished from the inactive state of the data bus. If the computer

Figure 1. Diagram of TTL circuitry used to decode an array of 31 photocell inputs (0-30). The data bus must connect to a TTL-compatible parallel interface. A simpler configuration decoding only 15 channels (and using four data lines) can be obtained by linking pin 14 (NODE X) directly to pin 3 of the line driver 7407. In this case, photocells labeled 16 to 30 would be transmitted as 0 to 15. For further explanations, see text.

interface requires negative logic, the same circuitry can be used, but the numbering of the inputs will be reversed; that is, input 30 will appear as 0, and input 0 as 30.

If only 15 photocell inputs need to be decoded, the AND gate can be bypassed and the GS output of the second priority decoder (marked by an X on Figure 1) can be linked directly to pin 3 of the 7407 line driver. The circuit can easily be expanded to decode up to 62 channels. One way to achieve this is to place lines 3 and 4 on a line driver. A replicate arrangement (4 74LS148 and 2 74LS240, 1/2 74LS08, and 1 7407) can then be linked to the same data bus, but with the enable output pin (Nr 15) of the last decoder linked to line 7 of the data bus. Upon activation of this second decoder device, a flag signal on line 7 permits the computer to distinguish the active device and to perform an arithmetic operation with the inputted number. Should the microcomputer have more than one eight-line I/O port (as, for instance, the Hewlett-Packard HP 85), a similar decoder may be connected to another port to perform an alternating reading routine.

Reading the data input with the microcomputer is straightforward. The byte on the data line is read using an ENTER or equivalent command. Preferably, the three higher bits of the byte (which may vary) are masked by means of a binary AND operation. For example, a decoder input of 7 with the most significant bit on the data line set may appear as "10000111" (the 5 lower bits being used by the decoder for data transmission). The number perceived by the computer (135) is then "AND"ed with "00011111" (31). The result, "00000111" (7), contains the inputted number with the three topmost bits masked. A typical entering subroutine in interpreted BASIC may take about 50 msec. With a decision routine incorporated, a 10-Hz checking loop can be maintained. This is usually sufficient for monitoring animal locomotion.

This photocell arrangement and its decoder circuitry are fairly insensitive to noise. All phototransistor lines (up to 150 cm long) and the decoder box itself operate in close

proximity (5-10 cm) to 16 magnetic valves activated by switching currents of 1 VA and more.

Other solutions for connecting photocell inputs to microcomputers have been described (Dillon, Millman, Tombaugh, Ferguson, & Bezanson, 1979; Emmett-Oglesby, Spencer, & Arnoult, 1982; Osaka, 1980; Thompson, 1979). The one presented here, however, is relatively simple, and is easily constructed. Its chief advantage is the convenience of a numerically clean input that can be easily incorporated in I/O programming.

We have used this circuit without failure over many months in a maze system in which a microcomputer interactively controls vibrissal-tactile and visual discrimination learning of mice.

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