RECORDING WATER USE BY MEANS OF DIGITAL EQUIPMENT

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ABSTRACT

A device made of digital components is described that automatically (i) senses a discrete loss of water in individual hydroponic cultures; (ii) stores this information as identifying numbers in an 8 2-digit word memory; and (iii) displays this information on an electric typewriter at 1-minute intervals.

As many as 16 readings a day can be obtained in a greenhouse, if the ratio of leaf area to water surface area is high enough. This equipment, then, gives a sensitive measurement of water use related to climatic, genetic, or physiologic treatments.

Additional index words: Plant water, Hydroponics, Data collection.

RECORDING equipment can be a valuable tool for measuring water use by plants. Climatic, edaphic, and genetic factors can be evaluated for their influence on water needs from water use data. Water use measurements can be made routinely, but they may not be made as frequently as desirable, or they may require working at inopportune times unless an automated system is available.

Therefore, a device was built to sense the loss of water in hydroponic containers and to replace this loss automatically. The device included a recorder as well as a controller for automatic replenishment. A schematic diagram of the device is shown in Fig. 1. With a few modifications the device could sense changes in soil water suction and provide an accounting of water use by soil-grown plants.

Transpiration causes the water level in the hydroponic container to drop to a level sufficient to open a circuit. The break in this circuit causes a number identifying the particular container to be stored in a memory. Every 10 seconds a signal is passed to a valve-opening circuit, which in turn causes a fixed amount of water to be added to the container if the sensing circuit is open. Every minute the contents of the memory are printed on an electric typewriter.

The recorder is constructed with the SN7400 series of digital integrated circuits. A 64-bit buffer memory composed of eight 8-bit shift registers (SN7491A) accepts and stores directly encoded switch openings of two-place Binary Coded Decimal numbers (BCD) (2=0010, 3=0011, 8=1000). An entire BCD number is formed by using four bits for each place of the decimal number. Thus, the 64-bit memory consists of eight parallel 8-bit words with 4 bits representing each
place of the two-place decimal numbers. This part of the system will accept up to the decimal number 99.

Using 60-cycle line frequency as a standard, the clock unit provides other clock frequencies, derived by using decade (SN7490) and divide-by-12 (SN7492) counters. Periods of 167 milliseconds, 10 seconds, 1 min, and 5 min are used to control typewriter printing, valve opening, readout, and carriage return function timings, respectively.

The controller uses the 167-msec and 1-min clock pulses to generate other pulses to shift data through the shift registers and gate the information to the BCD to Decimal Converter (SN74145). Memory input and output gating allows a given switch to have its decimal number equivalent encoded into BCD and stored into the memory. The storage operation is implemented through a temporary storage register of eight flip-flops. Output is similarly treated by another set of flip-flops and two levels of NOR gates, which allow the four bits of each place to be serially applied to the BCD to decimal converter.

Contact bounce noise is removed from the switch opening by the use of an amplifierdamped by a large capacitor. The valve clock register consists of a D-type flip-flop (SN7474), triggered on and off by the 10-second clock pulse when the valve switch is open. When the valve switch is closed, the flip-flop remains off. When the flip-flops are on, i.e., open, transistor switches are also on, and in turn drive the valve solenoids that replace the hydroponic solutions.

The BCD to decimal conversion is accomplished by a medium-scale-integrated circuit (SN74145). This activates transistor switches that apply the necessary current at 80 volts to drive the typewriter key solenoids. An electric typewriter already having a receptacle to accept external signals to the key solenoids was available.

Cost for the electronic components was less than $400. Detailed plans can be provided upon request. A dual trace oscilloscope is helpful in checking voltages during assembly. Ground loops between components must be avoided. Some difficulty was encountered until it was realized that the input gating should be shielded from memory, clock, and controller. Although a physical separation was made, shown by the dashed line between the coil drivers and the remaining equipment, the drivers could have gone into the same box with enough shielding and grounding. If paper punch or magnetic tape recording equipment is available, the BCD converter could be changed to a proper interface to permit the use of these recording devices. For additional background information, readers might be interested in: Malmstadt, H. V., and C. G. Enke. 1969. Digital electronics for scientists. W. A. Benjamin Co., New York.