the wetting near the humidifier.

Ventilated high humidity propagation is a new method of propagation that is proving to be both reliable and versatile. It offers a good alternative method of propagating that will develop cuttings into vigorous and healthy plants.

COMPUTER CONTROL OF IRRIGATION SYSTEMS

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Irrigation is for the purpose of maintaining an adequate water supply within the active root zone. In order to maintain the soil water system within acceptable bounds it is first necessary to estimate the present state of the soil-water system. The estimation may be made indirectly by maintaining a budget of available water or directly by measuring soil-water content distribution or a closely related variable (4). Changes in the state of the system are made by manipulating the irrigation system so that water is applied at the proper time and in the proper quantity as established by some irrigation management policy.

The objective of this work was to develop a digital computer control system (DCCS) as an aid for irrigation system management such that: 1) its cost is of the order of magnitude of a low-cost microcomputer; 2) all system components are readily available from local outlets, or they are low cost so that they can be kept in stock; and 3) the system operates in manual, timer, and direct digital-control modes. The system should be simple to operate and flexible in order to meet the demands of a controlled production system.

DIGITAL COMPUTER CONTROL SYSTEM

Hardware components. A block diagram of the components of a DCCS system are shown in Figure 1. At one end is the soil system and at the other is the computer system. The computer system acquires information about the soil system through an analog front end, here exemplified by a single sensor. Acquired data is processed by the computer system, and any necessary actions are carried out through an output subsystem, here exemplified by a single-controlled solenoid valve.

A DCCS was developed based on a low-cost home computer using readily-available components for both the analog front end and the output subsystem (7). The characteristics of each component are the following:

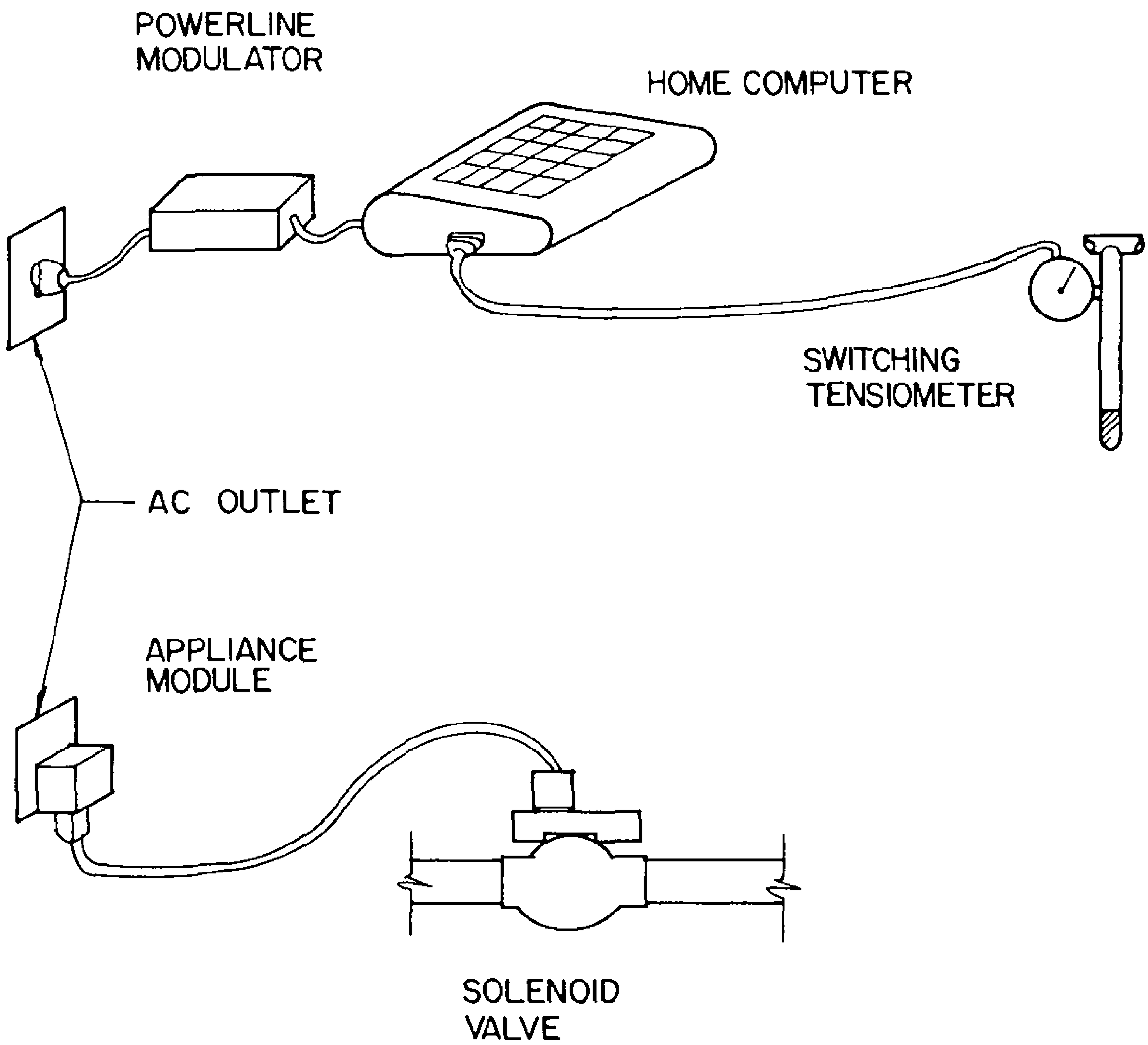

Figure 1. Elements of the digital computer control system.

1) **Microcomputer.** Low-end home computer with joystick and paddle ports. This type of computer was used to take advantage of its low price, availability and widespread available support.

2) **Output subsystem.** Because of the characteristics of irrigation systems, the output subsystem needs only to control discrete devices such as solenoid valves or pumps that control the flow of water and fertilizer. The control device used here was a power-line modulator circuit (PLMC) with a receiver module for each device to be controlled.

This type of system uses the AC wiring line to encode a high-frequency signal that is received by the modules which, in turn, react to commands encoded in the signal. Since the AC wiring is used to transmit the signals, this system has the added advantage that no additional wiring is required for control signals. The use of a power-line modulator imposes two restrictions on the system. First, the maximum number of devices that can be controlled is 256 and second, the time required to transmit and execute a signal to change the state of a device is about 2.5 seconds.

3) **Analog front end.** Each joystick port of the microcomputer

provides five discrete inputs, and each paddle port provides an analog-digital (A/D) port, typically with eight-bit resolution. Although it has been shown that control of irrigation systems can be attained using a small number of sensors (3), systems or management procedures requiring a large number of sensors can be accommodated at a relatively low cost by using multiplexers. An example is the system developed by Stone *et al.* (6).

A list of the components used is given in Table 1. All components are available from department stores, consumer electronics outlets, or mail order. Also, no single device, including the computer, costs more than $100.

Table 1. Components used in the field implementation of the DCCS[1].

Microcomputer system	C-64, disk drive and monitor.
Power line encoder	X10 Powerline modulator.
Receiver modules	Radio Shack appliance module.
Discrete sensors	Switching tensiometer.

[1]Mention of trade names does not imply endorsement by the authors.

Software component. The software allows the user of the computer system, in this case the irrigation-system manager, to use the computer in three different control modes: manual, timer and automatic.

1) **Manual control mode.** In manual operation the user controls the irrigation system from the DCCS terminal. This mode is necessary to provide the user with a manual override of the other modes as well as the necessary utility to test newly-installed equipment.

2) **Timer control mode.** In this mode the DCCS acts as a timer and executes commands from a user-created schedule. A variation of this mode that consists of specifying cycled applications was included. This accommodates systems in which high-frequency applications are necessary, such as mister systems in greenhouse propagation houses. The timer mode is used mainly when watering frequency and amounts are decided externally from the computer. This is the case when irrigation is based on visible plant stress, estimations of water use from pan evaporation, or the operator's opinion. In this mode the control loop is open since no data are acquired at any time about the state of the system.

3) **Automatic control mode.** In this mode data about the state of the system are acquired through the analog front end of the DCCS and are used as inputs to a control algorithm. Control algorithms based on real time data have been presented in the literature (3, 5). The DCCS developed here uses a moisture threshold sensor consisting of a tensiometer and an optoisolator as described by Zazueta (7). The tensiometer and optoisolator can be replaced by any other device that produces a TTL signal. Moreover, if the distance to the sensor is small, the sensors can be directly connected to the joystick

ports of the computer. Alternatively, when a switching tensiometer is used, the magnetic switch may be used to interrupt power to the solenoid valve unless irrigation is required.

Software is available from the IFAS Computer Support Office, Building 120, University of Florida, Gainesville, Florida 32611.

FIELD EXPERIENCE

Computer-controlled systems using the hardware and software described here have been installed at many location in Florida, including extension demonstrations, greenhouses, mist houses, field nurseries, citrus and blueberries. The DCCS can be installed by any individual familiar with electrical installation procedures and with minimal computer skills.

Labor savings related to irrigation activities have been significant in field installation. A benchmark system was used to compare irrigation controlled manually and by computer. With the computer-controlled system the time required in irrigation-related activities was reduced to 12 percent of the original time used and water use was cut to 34 percent of the water use before the system was installed. Also, irrigation is now scheduled in such a way that there is minimum interference with other activities in the greenhouses or in the field (2).

It has been demonstrated that it is practical and economical to use low-cost home computers as irrigation-system controllers. The availability of these computers and supporting hardware, as well as their low cost, make them very practical for agriculture production systems. Furthermore, these small computer systems provide flexibility and low-cost expansion capability, which cannot be achieved with other types of control systems such as timers, dedicated microprocessors, or higher-level computers.

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UNIFORMITY ANALYSIS OF VARIOUS TYPES OF MIST PROPAGATION NOZZLES

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Abstract: Fourteen different types of nozzles were evaluated for mist propagation. Spacing recommendations are presented for 85 percent or better coefficient of uniformity under the nozzle. Growers can take this information to construct their own mist propagation beds.

REVIEW OF LITERATURE

Today several different types of mist nozzles are available for propagation. Stoltz *et al.* (2) evaluated 10 different types of nozzles used in propagation at that time. They expressed the common problem of wear, which results in larger particle size and increased flow rate. Since then a new line of durable hard-plastic nozzles has been introduced. The hard-plastic nozzles are less expensive and will not wear as fast as metal ones. Sumner and Gibson (3) evaluated seven nozzles used in mist propagation. Four were of durable plastic. Their findings indicate that these durable-plastic nozzles are fairly uniform for spacings tested.

MATERIALS AND METHODS

Fourteen different types of nozzles were tested. Table 1 lists nozzle types and their description. The information in parenthesis denotes nozzle orifice size (large to small). Nozzles were evaluated for uniformity by collecting water in one fluid-ounce containers in a straight line spaced at 6 in. intervals with the first located 6 in. from the nozzle. The nozzles were all mounted on 18 in. risers along with a pressure gauge to determine the pressure at the nozzle. Water collected in each container was then measured. Data was collected at pressure settings of 20, 40, and 60 psi. Droplet particle size was estimated by using water-sensitive paper. Droplets were measured with a hand lens using a known scale.