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ELECTRONIC SINGLE STATION IRRIGATION TIMER/CONTROLLER

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Automation of Surface Irrigation

Automation is being used increasingly to improve farm water application efficiency and to reduce labor requirements. For many years, farmers have wanted and needed time-controlled devices and structures to change their irrigation sets automatically, particularly when it is inconvenient for them to make the change, such as at night. Such equipment has not been available commercially.

Innovative irrigators and researchers have tested many different kinds of automated gates and valves and have relied almost entirely upon mechanical clocks and timers for the timing function. Alarm clocks, which have seen the most use, have only been partially successful and have a number of disadvantages. For example, they do not have a built-in linkage for releasing a gate trip and have no direct indication of the irrigation time. They are subject to damage and corrosion from dust and water and require resetting at least every 12 hours. They have only a single function and cannot be used to control both the delay interval until irrigation begins and the actual irrigation duration; two clocks are required for this. Twenty-four hour mechanical timers and electromechanical clocks have been used to a limited extent but still have some of the disadvantages of alarm clocks.

In recent years, many irrigation controllers have become available commercially for sprinkler and micro (drip) irrigation. These operate on AC electrical power which is usually available where such systems are used because of the need to operate pumps to pressurize the water. Most surface irrigation systems operate by gravity, and line electrical power is seldom available to operate timers and controllers, so electrical timers for surface irrigation need to be battery-powered.

Electronic Timers

Microprocessor-based timers have many desirable characteristics as irrigation controllers. Some timers can be powered from batteries for extended periods; this is particularly important for single-station timers that are used to control one or two gates or valves at individual field locations. This contrasts to a controller that operates many valves or gates from a central location where electrical power is more likely to be available. The high degree of precision which can be obtained from the timer's quartz crystal oscillator time base is needed where single-station timers operate independently to open and close gates or valves in sequence.

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Opening and closing must be coordinated to be certain that at least one outlet is open at all times to prevent overtopping of the supply ditch or pressure buildup in the supply pipeline. Succeeding gates or valves are usually opened before the preceding units close; cumulative errors with inaccurate timers could result in all outlets being closed. This was often a problem with mechanical timers because they could not be set to the degree of precision required.

Electronic timers can be designed to perform multiple functions. For example, they can provide the necessary time delay to sequence the opening of gates and valves to begin irrigation and also control the irrigation duration. Electronic timers can provide a digital display, either continuously or on command, of the programmed functions and can be packaged and sealed in relatively small enclosures. The basic components are relatively inexpensive and once the design and circuit boards are developed for a given unit, they can be produced in quantity economically.

Battery-powered electronic timers have been used to a very limited extent in irrigation, mostly by researchers on an experimental basis (Edling et al.1978, and Fisher et al.1978). A timer that can serve several of these functions was developed and tested because of the need for a single-station electronic timer for surface irrigation applications.

It can be used (1) as a simple on-off timer to open one gate or valve and close another simultaneously; (2) to provide programming and control for two valves used for automatic furrow cutback irrigation and (3) provide programming and control for intermittent or surge irrigation using two valves. It can provide both delay and irrigation time control for two valves or gates at one location. This paper describes this timer, its potential uses and performance tests.

CIRCUITRY AND PROGRAMMING

Hardware Design

The major design considerations for this controller were low power for battery operation, low component count for economy and generalized circuitry for use in more than one application. These criteria indicated a software-driven design making maximum use of CMOS LSI circuits.

The central element of the circuit is an 1802 CMOS microprocessor executing ROM-based software. The memory for the system is one page (256 bytes) of 5101 static CMOS RAM and eight pages (2048 bytes) of 27C16 CMOS EPROM. All input/output is handled through an 1851 CMOS Programmable Input/Output Port (PIO). CMOS SSI and MSI "glue" circuits complete the design. The contoller is powered by 4 D-size alkaline flashlight batteries.

An 18,000 microfarad capacitor charged to 24 volts supplies energy to shift solenoid armatures. A DC-to-DC converter produces 24 volts from the 5 volt logic supply. The processor turns the converter on and off, and sends signals to activate the solenoids. These signals go through a Darlington amplifier stage, then to the gates of SCR's that switch current to the solenoids. The voltage converter is off when the solenoids are activated so the capacitor will discharge below the on-state holding current of the SCR and allow the SCR to commutate to the off state.

This output structure provides a pulse of sufficient energy to operate solenoids with power ratings up to about 180 watts intermittent. The controller has six output terminals to accomodate the two dual-coil, momentarily-energized valves being used. Each group of three terminals

could, of course, be used to operate two individual solenoids. Presently, the controller will not operate dual-polarity type pilot valves, but a simple change of the final output drivers would allow this because the voltages and signals are compatible.

The operator controls programming with three SPDT, center off, toggle switches, which give six independent switch closures. Extensive software definition of these switch closures provides adequate control functions while leaving the panel uncluttered and avoiding the intimidating array of switches that some of our earlier controllers had. A four-digit LCD display shows the present time of day, program prompts, recalled parameters and system status, as selected by the operator (see Fig. 1).

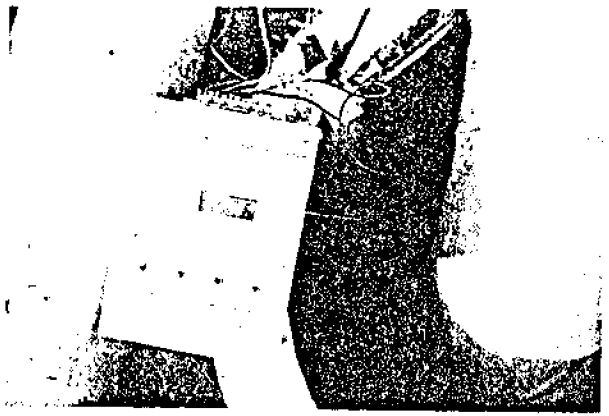

Fig. 1 Single-station timer being used with a dual coil pilot valve to control a water-operated irrigation valve.

Software Design

This controller was designed to be mid-range between a research tool in which every parameter is independently programmable, and an abuser-friendly unit that could be operated with almost no operator instruction.

The original software contained three different, rudimentary programs: simple on-off operation, automatic cutback mode, and surge irrigation control. The processor interrogates the location of a jumper on the circuit board to determine which program to run. Most program operations are contained in subroutines, called by the selected program.

It has become apparent that the on-off and cutback functions can be obtained by proper programming of the surge mode, therefore, these functions will be deleted in future models in favor of more operator-responsive input design. Only programming of the surge mode is detailed below.

The PROGRAM switch readies the controller to accept control data; if held closed more than 3 seconds, the function switches to RECALL of previously entered data. The STATUS switch calls for a display of what valves are open, and what cycle of surge is being timed presently. Held closed, the STATUS switch calls the MANUAL routine, which allows the operator to open

and close selected valves. The STEP switch steps the program quickly to the desired parameter in the PROGRAM, RECALL or STATUS modes. The RESTART switch terminates any subroutine and returns control to the main program. The HOURS and MINUTES switches increment these parameters, or the date and number of cycles. Holding either switch closed for more than three seconds advances the display at about two digits/second.

To program the controller, the operator selects PROGRAM mode, then enters parameters in the following order:

1) Present date (Julian or day of month),
2) Present time (24-hour format),
3) Date controller is to operate,
4) Time when first cycle is to start,
5) Duration of first surge cycle,
6) Surge cycle incremental time (00hr 00min to 23hr 59min),
7) Number of surge cycles (0 to 99),
8) Duration of post-irrigation.

To change any parameter, the PROGRAM mode and STEP switch bring the controller to the desired input, then changes are made as in initial programming. The controller will not act on out-of-date changes, such as altering the start time after the cycle is started, or changing to a lower number of cycles if that number has been exceeded.

To repeat a previously programmed irrigation cycle, the operator closes the RESTART switch when the STATUS readout indicates end-of-cycle. The initial irrigation date must be corrected to be in the correct relation to the present date and the controller is ready to run.

The part of the operating program containing shut-down and interrupt servicing instructions is copied to RAM storage. Using these instructions, the processor powers-down the eight pages of ROM memory and goes into an idle state. A time-base or operator-initiated interrupt brings the processor out of idle to service the interrupt. These manipulations reduce the cycle time of the processor to a few milliseconds per minute, unless valves need to be switched. The combination of an idled processor, powered down memory, low clock rate of 100 KHz, and CMOS technology reduces the total quiescent-state power drain below 15 milliwatts.

Several safeguards against improper operation are built into the software. Since all parameters are program-generated and displayed for operator selection, there is no chance of setting an out-of-range value. If all parameters have not been properly programmed, the controller will not function, preventing runaway. Upon exiting the MANUAL mode, the controller will reset the valves to their states before MANUAL operations were begun. If the controller is in a subroutine longer than about 45 seconds without an entry being made, it will time-out and return to the main program.

Future units will monitor the battery voltage and warn the operator to change batteries before they become too low. If high-frequency surge irrigation proves acceptable, the software will be modified to accept a number of surge cycles greater than 99.

The hardware-software interactions are interrupt-driven, so the controller will perform its programmed functions regardless of what routine it is running at the time. Clock update is transparent to the user's operation so time used in programming and monitoring does not interfere with the clock setting.

To prevent damage to the system during valve state changes, the controller will always open a valve as its first output cycle if there is a choice.

The processor turns on the DC-to-DC converter, charges the capacitor for a set time-delay, then turns off the converter. It sequentially activates the signal line to switch the first valve, deactivates the line, then pauses a set delay time to allow the SCR to commutate. It will then return to the main program, or repeat the cycle if the state of the second valve also needs to be changed.

TYPICAL SURFACE IRRIGATION APPLICATIONS

Open Channel Gates

Semiautomated gates are used both as check structures in a head ditch and at field turnouts from the ditch. A mechanical linkage or trip device is used to release the gate from its normally open or closed position. When the gate is controlled by an electronic timer, an electric solenoid is used to actuate the trip mechanism. Most gates are reset manually and are considered semiautomatic. Each gate usually has a single function but two are often used at one location so that the combination has a dual function; one opens while the other closes. The two momentary electrical pulses required for these can be provided from one valve control output of the single-station timer; the other output would not be used. The timer can be used to provide a single electrical pulse for a single function gate, but a single function electronic timer, when commercially available, would be more economical.

Pipeline Valves

Since automated irrigation valves are often used in pairs on a riser from a buried supply line, the single-station timer was designed to provide four momentary electrical pulses to open and close two irrigation valves.

Automatic Furrow Cutback: Irrigation runoff can often be reduced with furrow irrigation by reducing the stream size after water has advanced through the length of the field. This is accomplished with the split-set technique (Humpherys 1978) by diverting the entire irrigation water supply stream onto one-half of the field segment or set to be irrigated until all of the furrows are wet throughout their length and water runs off the field. The irrigation stream is then directed onto the other half of the field segment for the same length of time. Water is then reintroduced into the furrows of the first half so that the entire stream of water is distributed across the total set for the remainder of the irrigation. The single-station timer controls the opening and closing of the two valves in the required sequence to achieve cutback or reduced stream sizes for this technique. It then closes both valves when irrigation of that field segment is complete.

Surge Flow Irrigation: Surge flow irrigation (Stringham and Keller 1979) is a relatively new technique wherein water is applied to the field surface in a series of intermittent on-and-off surges. It is an operational practice which can improve the performance and versatility of surface irrigation systems. Since it is not feasible to manually operate a system in this manner, the system must be automated. One method of achieving surge flow is to operate two valves alternately. The valves are installed in a tee configuration at the upper end of the field in the same manner as for automatic furrow cutback so that each valve controls water flow into a length of gated distribution pipe attached to the valve (Humpherys 1983). The single-station timer can be programmed for cycle times ranging from one minute to 60 minutes such that each valve is open for the programmed time interval during each cycle. They can also be programmed for the desired number of cycles. When the valve open/close positions change, the

succeeding valve opens first after which the preceding valve closes. Thus, one of the valves is open at all times to avoid problems that could arise from a condition where all valves are closed with no place for the water to go.

For some conditions, it is desirable to increase the time for succeeding surge cycles. This provides additional time for water to advance in the furrows to the point it reached during the preceding cycle. The single-station timer can be programmed to increase each cycle time with a given time increment varying from zero to 60 minutes. After the programmed number of surge cycles had been accomplished, the timer can either close both valves to terminate irrigation or open both valves simultaneously to complete the irrigation with cutback stream sizes before closing the valves to terminate irrigation.

FIELD AND LABORATORY TESTS

The first two timers built were used with water-operated irrigation valves. Each valve controlled irrigation water in a set of gated pipe. The timers provided an electrical impulse to actuate the dual coil solenoid pilot valve (Humpherys and Pauliukonis 1983) that was used with these irrigation valves (Fig. 1). After debugging problems were solved, the timers performed reliably and satisfactorily. The first two units were each powered by a 22 1/2 volt dry cell battery. The voltage required to charge the output capacitor was provided directly from the battery. This proved inefficient since the wattage to operate the total unit was relatively large. The timers were modified and subsequently powered by four D-size batteries.

The timers were used with air-operated butterfly valves as shown in Fig. 2 for surge irrigation. One of the modified timers was used in an endurance test with these valves in the laboratory. It cycled the valves at varying time intervals over an eleven-week period. During this period of time, it operated the two valves for over 1700 cycles; this represents about 7000 valve opening-closing operations with the same set of batteries.

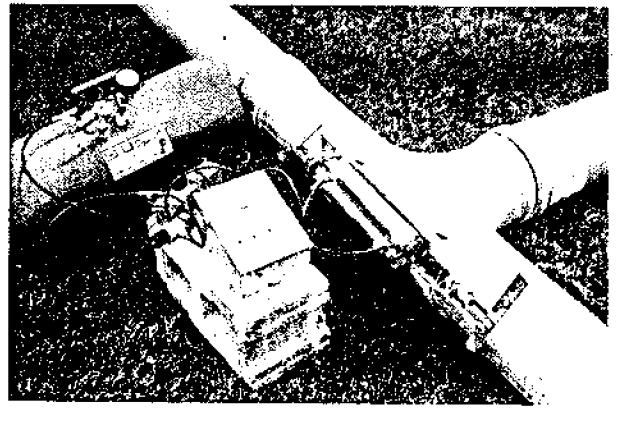

Fig. 2 Single-station timer used to control air-operated butterfly valves.

Since surge flow irrigation is still in its infancy, cycle frequency, ratio, timing and other operational parameters are not yet defined for different soil and field conditions. Cycle periods varying from as short as 8 seconds to greater than one hour have been used. For time periods less than about 4 or 5 minutes, individually controlled outlet gates on the distribution pipe may be more feasible because of the time lag in filling and emptying the gated distribution pipe each cycle. Individually controlled outlets, however, would be much more costly because of the large number of outlets involved and the communication lines required to interconnect each outlet. For cycle time periods of 4 to 5 minutes or greater, it would generally be more economical to use a single- station timer and a pipeline valve for each irrigation set. If used at only one station, one set of fresh batteries should be sufficient to power the timer for one irrigation season. If the timer were to be moved from one location to another, particularly with very short cycle periods, the batteries may have to be replaced during the season.

In addition to being used with air- and water-operated irrigation valves, the timer will be tested to operate diverter valves in a single-pipe irrigation system as shown in Fig. 3 and open channel gates and turnouts as shown in Figs. 4 and 5. For these latter applications, only one of the timer's output terminals will be used.

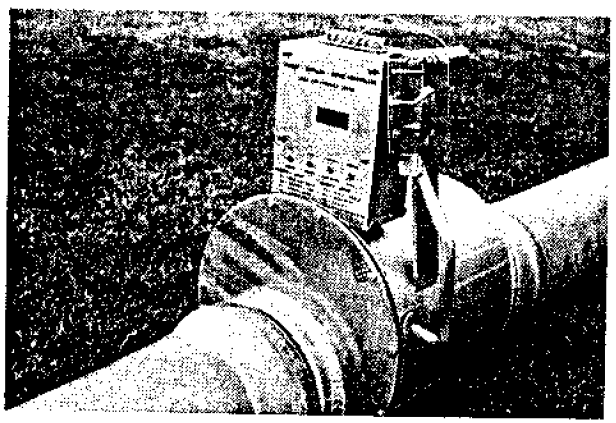

Fig. 3 Single-station timer controlling a solenoid trip on a diverter valve in a single-pipe system.

For commercial production, the timer would be installed in a covered watertight enclosure. The experimental units used to date were not assembled in this type enclosure but additional units for research purposes will be installed in gasketed plastic boxes. The LCD display will be shaded to prevent it from blacking out when exposed to the sun or high temperatures.

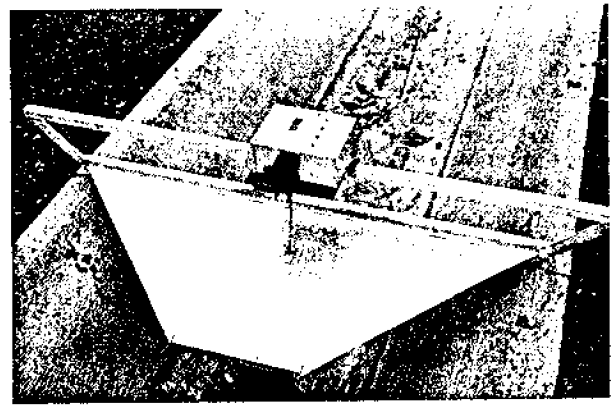

Fig. 4 Solenoid-actuated trip on a drop gate in a lined ditch controlled by the single-station timer.

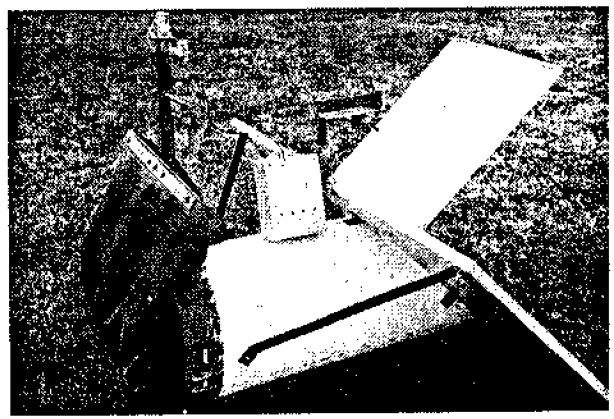

Fig. 5 Combination turnout gate with a single-station timer. The solenoid trip on the left is actuated to begin irrigation while the one on the right is actuated to terminate irrigation.

SUMMARY

A single-station microprocessor-based irrigation timer/controller was developed to (1) serve as a simple on-off timer to open one irrigation gate or valve and close another simultaneously; (2) provide programming and

control for two valves used as a pair for automatic furrow cutback irrigation and (3) provide programming and control for intermittent or surge irrigation using two valves.

The timer has a low power requirement and is powered by four D-size alkaline batteries. Its output provides an electrical pulse of sufficient energy to operate four solenoids each with power ratings up to about 180 watts intermittent. The timer is easily programmed with three SPDT, center off, toggle switches with almost no operator instruction. A 4-digit LCD display shows present time of day, program prompts, recalled parameters and system status as selected by the operator.

The timer was used in the field during the 1983 irrigation season to control water-operated irrigation valves and air-operated butterfly valves. It can also be used to control various types of gates used in open channel irrigation systems.

REFERENCES

1. Edling, R. J., H. R. Duke and M. L. Payne. 1978. Utilization of a portable solid state furrow irrigation valve controller. ASAE Paper No. 78-2546, ASAE, St. Joseph, MI 49085.

2. Fisher, H. D., A. S. Humpherys and R. V. Worstell. 1978. Electronic timers for automated surface irrigation systems. ASAE Paper No. 78-2544, ASAE, St. Joseph, MI 49085.

3. Humpherys, A. S. 1978. Improving farm irrigation systems by automation. Proc. Intl. Comm. on Irrig. and Drain., 10th Cong., Athens, Greece. Q. 35, R. 5, p. 35.90-35.98.

4. Humpherys, A. S. 1983. Automated air-powered irrigation butterfly valves. Trans of the ASAE 26(4):1135-1139.

5. Humpherys, A. S. and R. S. Pauliukonis. 1983. Momentarily-energized pilot valves for irrigation systems. Trans. of the ASAE 26(5):1471-1475.

6. Stringham, G. E. and J. Keller. 1979. Surge flow for automatic irrigation. Proc. Am. Soc. Civil Engr. Irrig. and Drain. Div., Specialty Conference, Albuquerque, New Mexico, July 17-20, pp. 132-142.