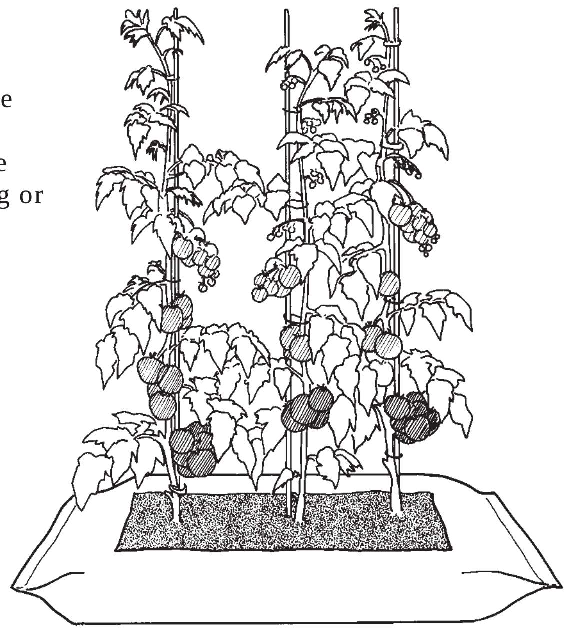
AN ENVIRONMENTAL CONTROL SYSTEM: AUTOMATIC WATERING

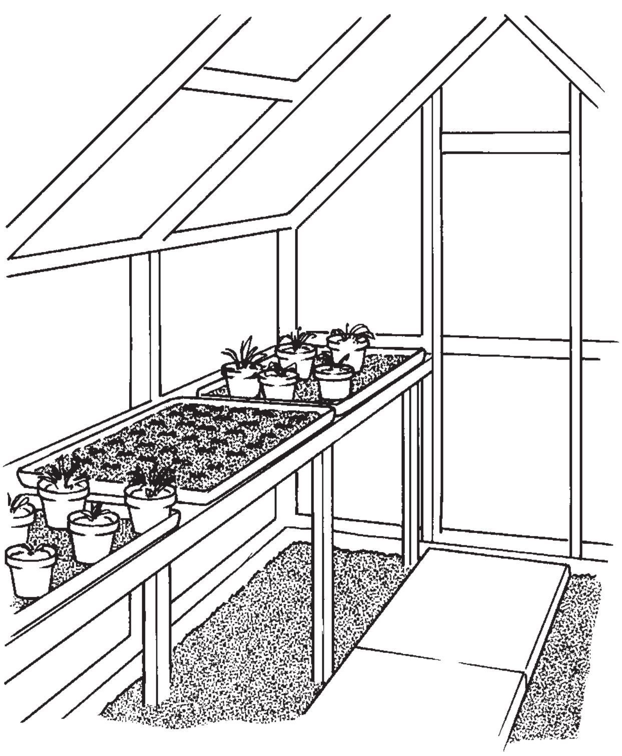
Systems for the automatic control of one or more aspects of special environments have become increasingly common with the advent of microelectronic devices capable of being programmed to respond 'intelligently' to data. It is not uncommon, for example, in even a small museum to find continuous monitoring and control of temperature, humidity and light levels to conserve artefacts.

Homes, garden centres and farms are places where there are different needs to preserve plants by controlling - among other things - soil moisture. Traditionally, this is done through observation and manual watering - although in some instances sprinkler systems are timed to come on automatically over a cycle.

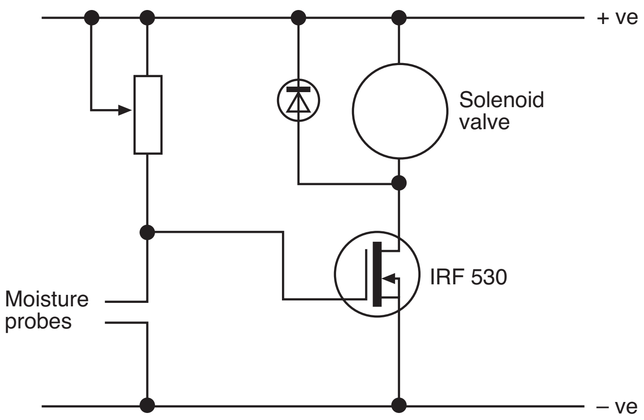


DESIGN OPPORTUNITIES

With the increasing interest in growing plants, there are many opportunities outside industrial or commercial contexts for watering control systems - especially where the occupant(s) of a house are likely to be away for long or short periods.



Designing and making a system to automatically water a plant is not a difficult task. A simple sensor controlling a transistor, that turns on a pump, or opens a solenoid valve, when the soil is dry can achieve the task. A circuit such as this is shown here.



The moisture probes are inserted into the soil. When the soil becomes dry its electrical resistance will rise. This causes the voltage at the junction of the probes and the variable resistor to rise. When this voltage rises to a sufficient level the transistor switches on and the solenoid valve opens.

The open valve allows water to flow onto the soil. As the soil becomes wetter its electrical resistance falls. This causes the voltage at the junction of the moisture probes and the variable resistor to fall. When this voltage falls sufficiently the transistor will switch off and the solenoid valve will close.

Although this simple system achieves the task it does have one major disadvantage. This is that electric current is always flowing through the moisture probes. Firstly, this is wasteful of energy. A battery powered system would have a very short lifespan as the batteries would need to be changed at quite short intervals. A system such as this should have very long intervals between servicing to make it worthwhile. Secondly, when an electric current flows through the probes, and the damp soil, a process known as **electrolysis** will occur. This will have the effect of corroding the probes quite quickly. The electrical resistance between two corroded probes will be substantially higher than two clean ones. This means that the circuit would need regular adjustment to keep it operating correctly.

Both of these problems can be overcome by a more sophisticated control system. What is needed is a check on the moisture content of the soil periodically instead of continuously. Such a system would need to be able to **'sleep'** for long periods of time, e.g. 1 to 2 hours, when it would not be checking the moisture content of the soil and would consume very low levels of current.

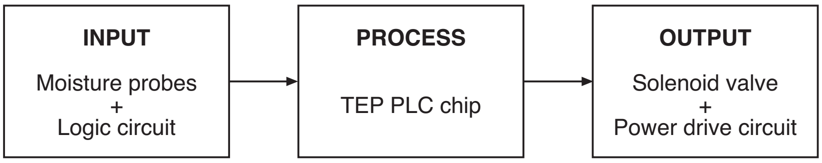
DESIGN SPECIFICATION

When a design brief has been agreed on, it is necessary to draw up a design specification. This is a detailed description of what a product or system would be like, what it will do and who will use it. The following description is an example of what an ideal watering system would do and how, in principle, the basic problem could be solved.

When the 'sleep' period is over the system would need to activate. It would check the moisture level in the soil. If the plants require water the system will open the solenoid valve until the soil was sufficiently moist. When this has been achieved the system should 'sleep' again until the next time it checks the soil.

Such a system would overcome the problems of excessive power consumption and the electrolysing of the moisture probes. To design and make such a system, using individual components, would be a very complex task. This problem can be overcome by using a programmable microprocessor such as the TEP PLC Chip. Using this device would enable a simple set of components to complete this complex task.

A block diagram of the basic system is shown here.



THE PROCESS BLOCK

Using TEP's PLC Chip
These notes explain the way the PLC chip works and how it can be programmed to respond to a wide variety of watering - or other environmental monitoring - situations. (These notes should be read with reference to Study File 3.)

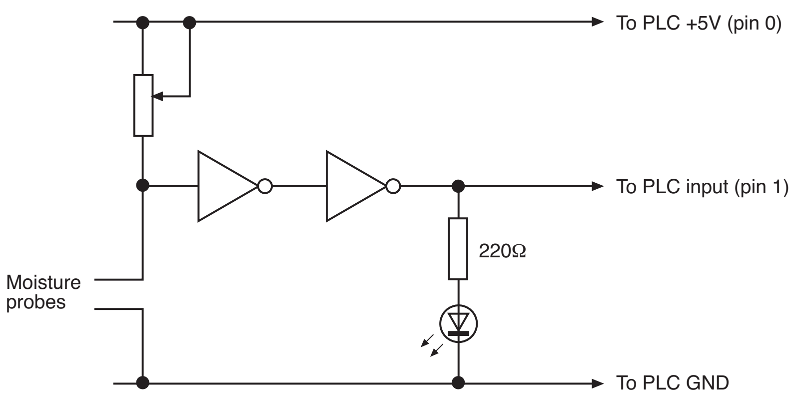
The TEP PLC Chip forms the process stage of the system. It reads information from the sensor and controls the solenoid valve depending upon the state of the information from the sensor. It also provides the sleep function for the system.

THE INPUT BLOCK

The input block contains the moisture probes. These must be connected into a circuit that converts the change in electrical resistance of the soil into a logic level that the TEP PLC Chip can read. This should be:

logic 1 for dry soil
logic 0 for wet soil.

A good circuit for this purpose is shown here.



The moisture probes and the variable resistor form a potential divider. The voltage at the junction of these two components is fed to the first NOT gate. When the soil is wet this voltage will be low. As the soil gets dryer this voltage will rise. The NOT gate will 'read' this voltage as a logic 0 when it is below 1.5 volts and as a logic 1 when it is above 3.5 volts.

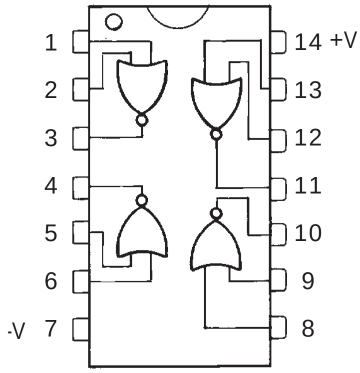
When the soil is wet the voltage will be below 1.5 volts as the electrical resistance between the probes is low. The first NOT gate will read this as a logic 0. Its output will, therefore, be a logic 1. This logic 1 is fed to the input of the second NOT gate. The output from the second NOT gate will, therefore, be a logic 0. This logic 0 is fed to the PLC Chip and also to an LED. The LED will not be lit when the soil is wet.

As the soil gets drier its electrical resistance will rise. This will cause the voltage at the junction of the moisture probes and the variable resistor to rise. When it rises to a level that is greater than 3.5 volts the first NOT gate will read it as a logic 1. This will cause the output of the first NOT gate to switch to a logic 0 and the output from the second NOT gate to switch to a logic 1. This logic 1 is fed to the PLC Chip and also to the LED. The LED will light when the soil is dry.

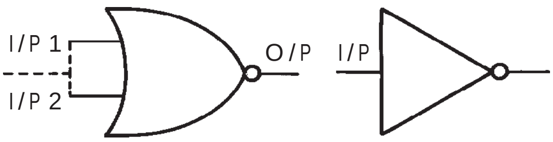
The circuit converts the change in electrical resistance of the soil to either a logic 1 or logic 0 that the PLC Chip can read.

Notice that the power supply to the sensor circuit is supplied by the PLC Chip. The PLC will only switch power on to the circuit when it needs it to sense the moisture content of the soil. This overcomes the problem of excessive power consumption and the electrolysing of the moisture probes.

A very effective way to make this circuit is to use a 4001 I.C. This I.C. is both cheap and readily available. It contains four NOR gates. The internal connections to the individual gates are shown here.

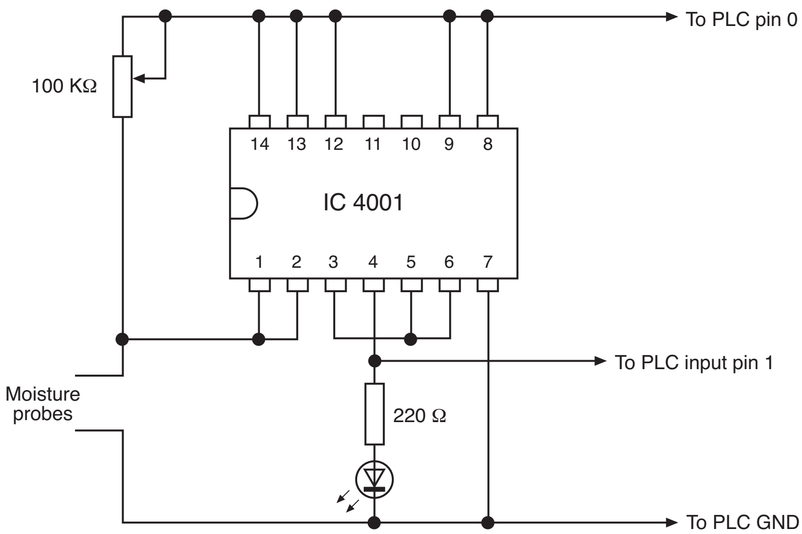


A NOR gate can be converted into a NOT gate by connecting both input together like this.

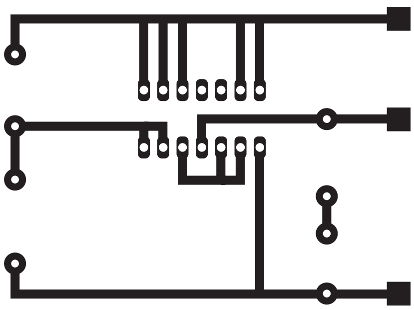


NOR Gate = NOT Gate
with both inputs connected together

This is the circuit diagram showing all of the component values that you will need to use.



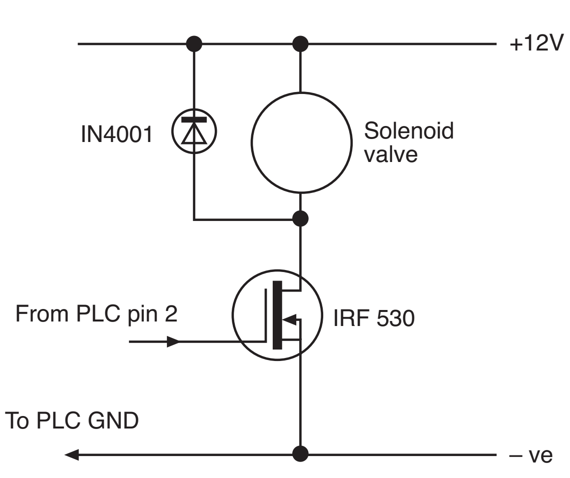
You could construct this circuit on strip-board or you could make a purpose built PCB for it. This is the PCB layout.

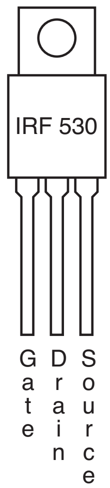


THE OUTPUT BLOCK

The output block contains the solenoid valve. This opens when current flows through it. The PLC Chip cannot supply enough current to open the solenoid valve so a transistor must be used to drive it.

This circuit example uses a Field Effect Transistor (FET). This is a good type of transistor to choose because of the way that FETs operate. Unlike conventional bipolar transistors they do not need a current flowing in to them to make them switch on. Instead they sense the voltage that is on the gate connection. If this voltage is greater than +2v they switch on and if it is less than +2v they switch off.





Interesting Fact: The type of FET shown can switch on a load of up to 17 amps with only 20 nA (0.00000002 A) flowing into the gate!

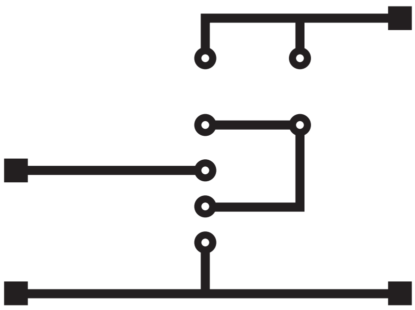
Note that -

1. The circuit has a 12 volt power supply. This is because the solenoid valve needs this voltage to operate.

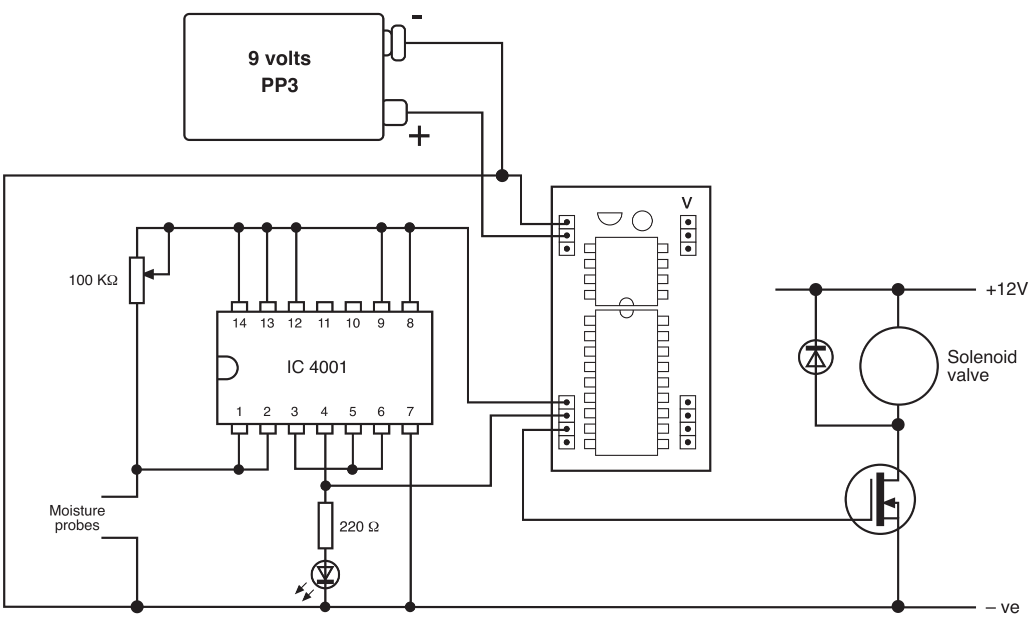
2. The negative rail is connected to the PLC ground connection. This allows the PLC to turn on the FET.

3. A diode is connected across the solenoid valve. This is to suppress the **back e.m.f.** that is produced when the solenoid valve is switched off.

You could construct this circuit on strip-board or you could make a purpose built PCB for it. This is the PCB layout.



Once you have made the input and output circuits you can connect the three stages of the system together.



PROGRAMMING THE PLC CHIP

Refer to Technology Study Files 2 and 3)

Connect the PLC chip to the computer via the special lead and set the screen for programming. Type in the program:

```
aws:    input 1
        high 0
        if pin1 = 0 then aws
        if pin1 = 1 then water

water:  high 2
        pause 10000
        low 2
        if pin1 = 0 then aws
        goto water
```

This is not the complete program as it does not contain the code that sets the system to sleep. This is because you will need to test the system. This is not convenient if you have to wait for an hour for it to start up!

Download the program to the PLC by pressing Alt-R.

The system should respond in this way: If you put the probes into wet soil then the LED on the sensor should not be lit (You can adjust the variable resistor in the sensor circuit if necessary). The solenoid valve should be closed.

If you put the probes into dry soil then the LED on the sensor should be lit. The solenoid valve should open for 10 seconds. If the soil is still too dry then the solenoid valve will open again for another 10 seconds. The solenoid valve will continue to open and close with 10 second intervals until the soil is wet and the LED on the sensor goes out.

This is how the basic program works:

aws:

input 1 -- *Sets pin 1 ready to read an input*

high 0 -- *Switches on the power to the sensor*

if pin1 = 0 then aws -- *If the soil is wet then pin1 will read a 0. This line sends the program back to the start so no watering takes place.*

if pin1 = 1 then water -- *If the soil is dry then pin1 will read a 1. This line sends the program to the start of the procedure that is labelled* ***water***

water:

high 2 -- *Switches on the FET which opens the solenoid valve.*

pause 10000 -- *Keeps the solenoid valve open for 10 seconds.*

low 2 -- *Switches off the FET which closes the solenoid valve.*

if pin1 = 0 then aws -- *Checks the input to pin1. If the soil is wet enough it will send the program back to the start again. If the soil is too dry then this procedure continues to the next line.*

goto water -- *Sends the program back to the start of the water procedure to open the solenoid valve for a further 10 seconds.*

Once you have got the system working on this basic level you will need to incorporate the code that sends the system to sleep. You will need to add these lines to the program.

```
aws:    low 0
        sleep 3600000
        input 1
        high 0
        if pin1 = 0 then aws
        if pin1 = 1 then water

water:  high 2
        pause 10000
        low 2
        if pin1 = 0 then aws
        goto water
```

low 0 -- *This switches off the power to the sensor.*

Sleep 3600000 -- *This sends the PLC to sleep for 3600 seconds (1 hour). The current drain is very low (approx. 20µA) when it is sleeping.*

When you download this program the system will now sleep for 1 hour before checking the soil. If the soil is dry then the solenoid valve will open until the soil becomes wet enough. When the soil is wet enough the system will turn off the power to the sensor and go to sleep again for another hour. You may find that it is possible to extend the sleep period to conserve even more power.

This basic system uses three of the eight available PLC i/o lines. By using three more you could expand the system to monitor two sensors and control two valves. The effectiveness of this control system lies with the PLC's ability to sleep for long periods of time.