Tonick Watering

Two Wire Technology

DIAGNOSING FIELD WIRING FAULTS

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Diagnosing Field Wiring Faults.

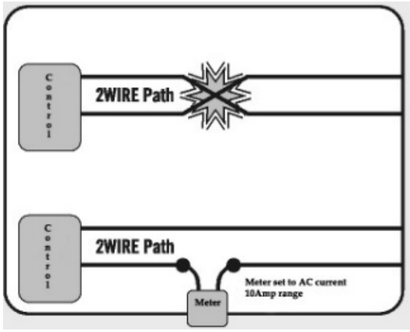
Introduction

Almost all modern irrigation systems rely on many pre-numbered decoders connected along a common 2 wire path, each connected to a solenoid valve. The controller feeds typically 24V to 40V AC down the path, together with a digital signal commanding a decoder to turn on or off. The decoder, whose number matches the signal, obeys the command, all the others ignore it.
This scheme saves copper cables and with the right equipment is easy to repair, being only 2 wires rather than a huge bundle. Expansion of the network is easy, with further decoders and cable being spliced anywhere along the existing path.

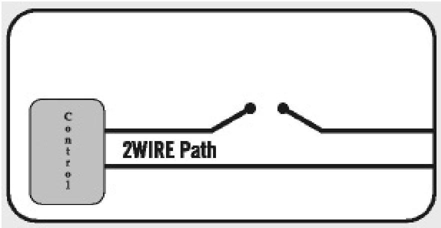
The problem with any shared path is that a fault somewhere along the cable can sometimes bring down the whole system. However with some low cost measuring equipment and the following simple techniques, the fault can be quickly located.

Types of Faults:

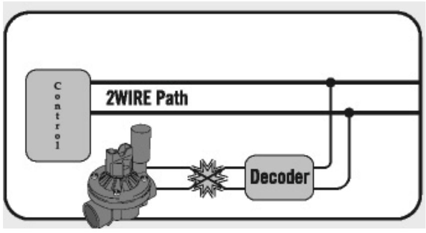
Short circuit in the main 2 wire path.



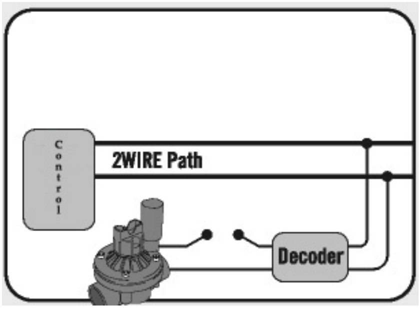
Open circuit in the main 2 wire path.



Short circuit in the solenoid.



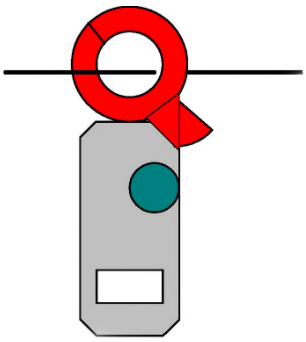
Open circuit in the solenoid.



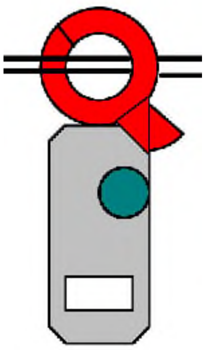
Fault-finding Equipment.

A measuring meter that reads AC volts and resistance is a valuable too in diagnosing faults. If a sensitive current measuring capability without breaking the wire is available too, the **Leakage Clamp Meter** becomes almost indispensable.
meter's *AC volts (V˜)* are used to detect the location of high resistance joints and open circuits. Its *Resistance* (Ω) allows testing of solenoid coils. It can also be used for the measurement of end-to-end resistance of the cable.
Its *Clamp Current Measuring* (Ã*)* is used with great effect to detect the point of short circuits, abnormal currents in decoders and the whereabouts of earth leakage from the cable.

Principle of Operation.
When a current flows, it produces a magnetic field. This is how the solenoid can lift its plunger. If a ring of magnetic material is placed around a wire carrying a current, it can be used to detect and measure that current. If the ring can open like the jaws of a crab's claw, be placed around the wire, then closed, there is no need to break the wire to measure the current. Such a device is called a Current Clamp Meter. However, most clamp meters have been designed to measure hundreds of amps and are not sensitive enough to measure the current taken by an individual decoder. However a **Leakage Clamp Meter** can easily measure to less than zero point one of a milliamp (0.1mA) and can be used to check a decoder's standby current, which is often a reliable indication of its goodness. Also knowing the standby currents of decoders allows an estimate of the number on a branch of the cable! Most modern decoders take between 0.5mA to 5mA when not operating a solenoid.



Both Voltage and Resistance are measured using the red and black test leads.
When measuring resistance (Ohms, Ω), there must be no voltage on the circuit being measured.
Currents are measured by opening the red jaws by pressing the red trigger with the thumb and clamping the jaws around the wire. Make sure the jaws shut fully. Keep the open ends of the jaws clean and free from grit and water. A build up of rust or deposits will cause false readings.

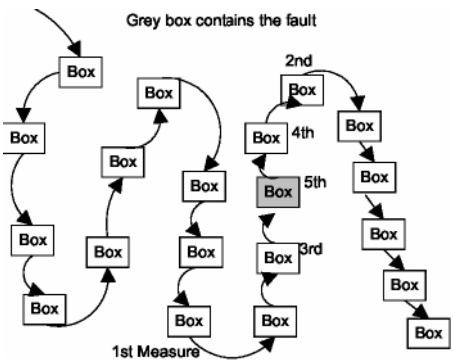


It is important to understand that if both flow and return wires carry the same current and are placed inside the jaws, ***the multimeter will read zero***

General notes:

Having a clamp meter means it is hardly ever necessary to cut wires to pinpoint faults.
Making a general sketch of the wiring on a clipboard then writing down decoder numbers found and any line currents/voltages measured will sometimes help diagnosis later over a cup of coffee! The sketch, if filed, can help in subsequent visits.

The Halving Procedure can minimize the number of measurements to pinpoint the fault. The procedure is:-
Go to roughly the halfway point. Make a measurement. Decide which half of the run the fault is in. Walk to the point roughly halfway between the beginning/end of the faulty half. Make another measurement. Decide whether the half is between you and the end, or you and the place were you were last. Repeat the procedure. For example in a run with 20 boxes, the box containing the fault can be located in a maximum of 5.



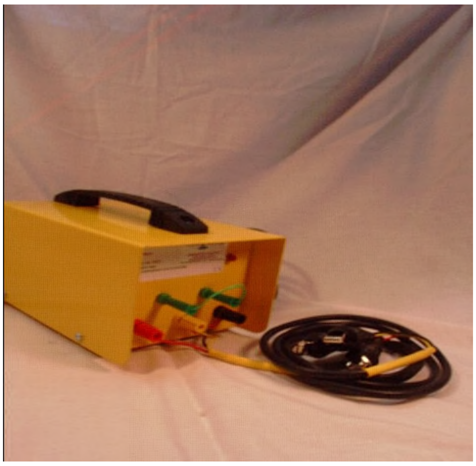
This and any other tests must be done with loop(s) broken as the ‘halving procedure’ doesn't work on loops.

Measuring the standby currents down a run allows comparison between the number of decoders expected 'downstream' and the actual current. Most solenoids when energized take 150mA - 250mA.

Earth leakage faults should be cleared first. (See later in this article) The presence of this type of fault will impede the diagnosis of other faults. Also it may happen that a 'short circuit' and earth leakage are both from the same severed cable end

Fault Tracing Short Circuits.

Most controllers will refuse to power up a 2-wire path that has more than a certain amount of load or leakage on it. Fuses may blow, software may shut the cable down, or even worse, a drive transistor in the controller may



overheat. If at any time, faults are suspected, or the controller behaves erratically, it is best to test the wiring to the decoders using a power transformer and a current clamp meter.

A big power transformer, such as the one illustrated left plugs into the mains and produces 30V AC at up to 6 Amps to power up the 2 wire path. The field wiring is removed from the controller and the transformer's output is connected to it instead. Because of its size, the transformer can still produce a powerful voltage in the presence of quite serious field wiring faults. Because it lacks signaling circuitry, the transformer itself cannot turn decoders on or off. However, this is not a disadvantage for the sort of faults that would shut down or damage a controller.

When used with a current clamp meter, digital voltmeter and the good old Mk. 1 hand, the transformer allows fault finding with the minimum of effort and confusion.
Be careful not to exceed the transformer's maximum current for more than a minute or so. Check the initial current with a clamp meter as soon as the transformer is connected to the wire path.

The transformer illustrated will produce around 30V AC at currents of at least 6A. This is enough to locate all but a dead short circuit on the wiring. The 30V is produced between the red terminal (live) and the black terminal (neutral). The 30V AC is divided in half at the yellow terminal (centre tap). That is, 15V AC from yellow to black and likewise 15V AC from yellow to red. This yellow terminal is useful in 3 wire paths as used with some older decoder systems. The two green sockets are connected to the earth pin on the 13A mains plug.

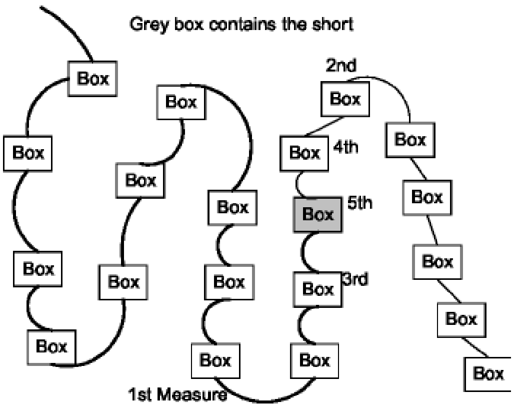
The output of the transformer is isolated from earth unless the green wire is plugged into either the black, yellow, or red terminal. Do not under any circumstances connect more than one of these terminals at a time to the green earth.

Ascertain the whereabouts of major branches of the cable run. Go to the junctions and determine which branch the short is in.

Having identified the branch, do a 'halving procedure' along the run to pinpoint the short. Be aware that all decoders do take standby currents, so a rough knowledge of the number 'downstream' will prevent chasing a phantom current drain.

Do remember to make a rough sketch of the cables and decoder locations. Write down the current readings on it as you go.

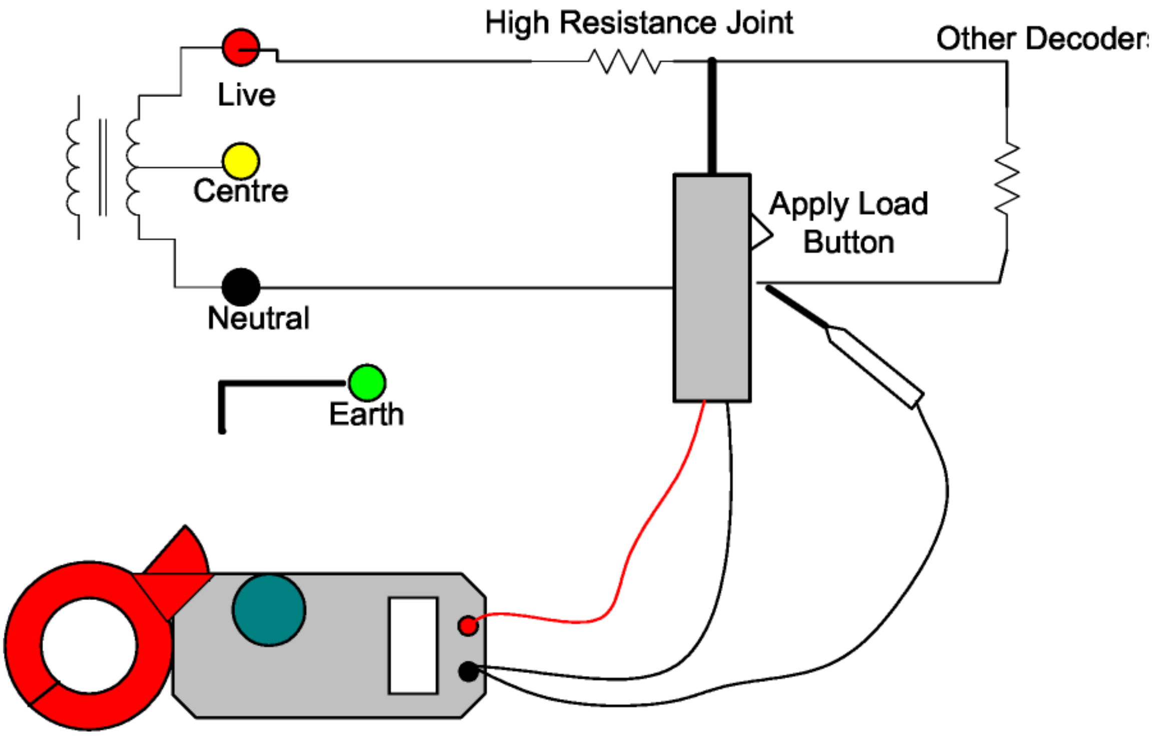
In the figure below, the thick connecting lines indicate higher than normal currents measured. Once you are past the short, the currents will either fall to near zero (if the voltage is cut off downstream) or go back to near normal.
Short is somewhere in this branch



To measure the short circuit currents, place the current clamp over just one of the power wires.
If the joints are made so that the individual wires in the main cable are not accessible individually, the main cable will have to be split open to reveal the individual conductors.
Remember it is the currents in the main cable you are trying to measure, not those in the decoders attached.
Once the area of the short is found, the exact cause can be identified. Check for warm decoders or joints, especially if the short is several amps. Place the current clamp over individual wires to see which ones are carrying the current. Do not forget that a current flowing 'out' from the transformer must 'return' down the other conductor.

Fault Tracing High Resistance Joints.

High resistance joints can be identified by connecting the transformer then measuring the voltage down the cable at each joint with the load probe and multimeter. If you do not have a load probe, get a helper to touch the wires of a spare solenoid to the multimeter probes while measuring the volts. Set the meter to Volts AC (V˜). When the 'apply load' button is pressed on the probe or the solenoid is attached, the voltage will drop. A voltage drop exceeding about 3 or 4 volts indicates a high resistance in one of the joints. As you travel back towards the transformer, you will eventually pass the bad joint and the voltage drops under load will go back to normal.
In a 2 wire system, just measure between the two joints in the box. An excessive voltage drop will tell you that one or other side is high resistance, but not which side.
As before, the 'halving procedure' search technique can be used to reduce the number of measurements made. See the general notes section in Fault Tracing Procedures



Fault Tracing Open Circuits.

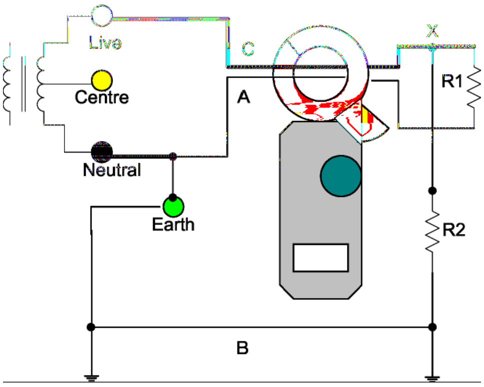
Open circuits are just an extreme case of high resistance joints! The techniques in the previous section apply. As before, the 'halving procedure' technique can be used to reduce the number of measurements made.

Fault Tracing Leakage to Earth.

When a cable or joint is not well insulated, some electricity can leak to earth. This causes problems for some controllers, either refusing to control at all, or sometimes giving erratic operation, leading to the controller being suspect.

Earth leakage must be repaired first as it can interfere with the diagnosis of other faults.

The transformer and the clamp meter can be used to easily find earth leakage. With one side of the transformer earthed, leakage currents can flow back through the ground causing unequal currents in the main 2 wire path.



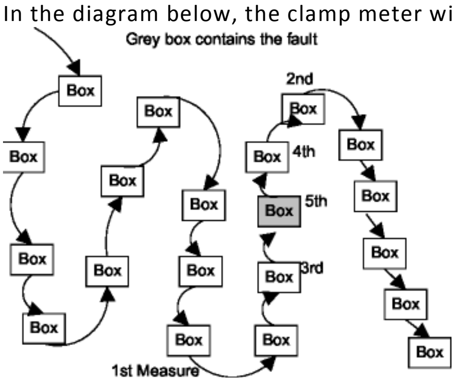
In the diagram, point X represents a leakage point to earth through some value of resistance R2. R1 is representative of a quantity of decoders. Current flows 'out' of the transformer through C and splits at X to flow 'back' through A and B. The resistors R1 and R2 are effectively in parallel and see almost all the transformers voltage. The clamp meter will read the difference between the currents in A and C which is equal to that flowing in B.

To locate the leakage point(s).

Place the clamp meter over whole main 2 wire cable. Connect the green earth link to the terminal on the transformer that produces the greatest reading on AC mA. Go out on the course placing the clamp meter round the whole main cable. When the leakage reading drops significantly you are past the leakage fault, i.e. it is between you and the controller.

The 'halving procedure' can be used to minimize the number of measurements made to pinpoint the fault.

In the diagram below, the clamp meter will read much lower when past the greyed box.



PHANTOM EARTH LEAKAGE (broken loops).

When placed over the whole field cable, the current clamp will measure the current imbalance among the conductors. This is caused by some current flowing through the ground back to the transformer (one side of which will be deliberately earthed). However, another reason is cable loops.
Field cables are sometimes looped and connected back to themselves to lower their resistance, which means less voltage drop when solenoids are on. The currents for the decoder/solenoid can flow in both sides of the loop. If however one wire in one side of the loop is broken or has a high resistance joint, the current in it will favor the good side of the loop. We then have a situation where the total currents when measured in a cable are not equal and opposite. This will show up as a phantom leakage current which can be quite large.
The **symptoms** are as follows:
The 'leakage current' stays substantially the same if the earth connection is removed from the transformer.
Resolving the problem:
Break the loop (or loops). After breaking, the good half will have nearly full volts on it, the bad substantially less. If in doubt use the load probe.
Any other tests are best done with loop(s) broken as the ‘halving procedure’ doesn't work on loops. When finally rejoining the loop(s), check the resistance and loaded voltage with the load probe.

Fault Tracing Decoders.

Failed decoders that are taking a higher than normal standby (quiescent) current can be isolated using the current clamp multimeter, or detecting warmth with the fingers or lips. The leakage clamp meter can easily measure to zero point one of a milliamp (0.1mA) and can be used to check a decoder's standby current which is often a reliable indication of its goodness.
Other than a high standby current, the best way to detect station failure is with the controller or a decoder programmer/tester. The suspect decoder can then be cut out and tested as shown below. This illustrates one such decoder Programmer/Tester made by the author's company.

If one like this is not available, the controller itself can be used with the decoder wired directly into the 2 wire path terminals and a solenoid temporarily attached to give the decoder a load. Use Manual-single Station, set the required decoder number and then command the controller to Run.
With the decoder disconnected, the resistance of the solenoid coil can be checked using the multimeter on Resistance (Ohms, Ω). Most solenoids have a resistance of between 25Ω and 55Ω, depending on the make.

Fault Tracing Solenoids.

A failed solenoid is usually indistinguishable from a failed decoder as far as the controller is concerned.
With the controller set to energize the solenoid, (Manual - Single Station), it is sometimes possible to probe the voltage output connections of the decoder with a voltmeter. If the 24-30V AC is measured, it is most likely an open circuit coil.
A short circuit coil, although rare, will cause an excessive current to flow *only when the decoder is activated.* The best way to isolate this problem is to place the current clamp meter over one of the field wiring power conductors at the controller and observe the current as each decoder is turned on.

Conclusions.

With these low cost test equipments and simple procedures it is usually possible to clear a fault in less than half a day, sometimes just half an hour.

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Basic Wiring Checkout

Step 1: Earth potentials
Note connections then remove field wiring from controller. Plug faultfinding transformer into 230VAC line power, 3 pin socket. Check potential of transformer's green socket against controller's lightning ground lug/terminal. Investigate voltages in excess of 1V AC

Step 2: Multimeter zero reading
Connect power wires of field wiring zone to red and black terminals of transformer. Use the transformer extension cable with the crocodile clips (wire colours same as transformer terminal colours). Leave signal wire (if present) open circuit. Place multimeter current clamp set to Amp AC over whole transformer cable. Check it reads zero. Switch to mA range, check meter still reads zero, or at least less than 2 mA. Keep current clamp at least 1ft from the transformer, or it will pick up stray magnetic fields.

Step 3: 2Wire Cable path standby current
Place clamp over just the red wire. Use the table of decoder currents below to verify that the current being taken is roughly in line with the numbers of decoders fitted on the zone. Beware that a multi output decoder takes roughly the same current as a single. Thus counting the station numbers will not necessarily indicate the number of decoders fitted.

TABLE OF DECODER STANDBY CURRENTS AT 50Hz

# decoders on wire path	1	20	40	54	72	90 90
	Current in mA					
Underhill TK-DEC-1	3	60	120	162	-	-
Tonick TW/2W	3	60	120	162	216	270
Aquamonix TWiN	3	60	120	162	216	270
Aquamonix TWinCOIL	4.5	90	180	243	324	405
Aquamonix POT	2.5	50	100	135	180	225
Toro SC3000/Trident	3.5	70	140	189	252	315
Tonick TW/TOR	2.5	50	100	135	180	225

If the manufacturer cannot or will not tell you what his decoder will draw at 60Hz, apply the transformer in step 3 and measure 2 or 3 decoders in the field. Add this data to the above table
Decoder currents vary slightly depending on the voltage applied. Near the controller they will take more, at the end of a long run, less. After a bit of practice you can judge the sort of voltage levels on a decoder from its standby current. This may save breaking into the joint to gain access with the voltmeter.

Step 4: only for 3 wire decoder systems. Ignore.

Step 5: Earth leakage
Connect the green earth link in turn to red, then black to allow a path back to the transformer for any earth leakage in the field. Place the current clamp over the whole transformer cable (at least 30cm away from the transformer). If there is any earth leakage it will show on the meter as an excess over that read in step 2. Note both readings Check with your decoder manufacturer what is the maximum earth leakage reading its system can tolerate.

Step 6: Overall Cable voltage Drop
Remove any green wire connected to transformer red or black
Go to the point on the path wiring furthest from the controller.
Set the multimeter to AC Volts (V˜)
Expose the wiring joints and touch the multimeter red and black probes to the power wires. You should read the transformer's voltage less a couple of volts.
With the probes in place, touch the wires of a spare solenoid to the probe tips. There will be a further volt drop, but this should not be more than about 5V. Any more than this indicates one or more bad cable joints between you and the controller.

Conclusions:
If the wiring system passes all the above tests, it is safe to reconnect the controller and proceed with a wire path decoder test. Obviously for multi wire path decoder controllers, the electrical tests must be repeated for each path. If any test fails, carry out the appropriate faultfinding procedures in the previous sections.
With these low cost test equipments and simple procedures it is usually possible to clear a fault in less than half a day, sometimes just half an hour.

TEST SHEET TO RECORD BASIC WIRING CHECKOUT RESULTS

Controller Model	**Path 1**	**Path 2**	**Path 3**	**Path 4**	**Notes:**
Number of Decoders					
Step1: Ground Potential (V)					Just 1 reading, covers all paths
Step2: Zero OK?					Keep clamp away from transformer
Step 3: Standby Currents (mA)					
Step 4: Signal Lead Currents (mA)					Only if a 3 wire system
Step 5: Earth Leakage green-red (mA)					
Green black (mA)					
Step 6: Transformer output voltage (V)					Measure at the transformer
voltage (no solenoid), power to power (V)					At furthest point from controller
voltage with solenoid, power to power (V)					At same point
voltage with solenoid, power1 to signal (V)					Only if 3 wire system
voltage with solenoid, power2 to signal (V)					Only if 3 wire system

Date ....
Contact Name ....
Position ....
Phone no...
Company...
Golf Course ....

For advice on the significance of these results, please:
Email tony@tonick.co.uk

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