2Wire Decoder Technology Irrigation Systems.

By Tony Ware B.Sc.
Chief Designer,
TWL Irrigation Ltd

About the Author.

- Tony Ware gained a B.Sc. in Electronic Engineering at the University of Manchester Institute of Science and Technology.
- His career spans 4 decades designing electronic equipment for the medical, scientific and process control industries.
- He entered the irrigation industry in 1995, designing functionally equivalent decoders to 10 different 2 and 3 wire control systems. These are currently fitted to 2/3rds of the UK and Ireland's golf courses.
- Since then, he has designed 9 different irrigation controllers.
- He invented and introduced the world's first 2Wire plug-in converter module to retrofit a multi-wire irrigation controller giving hybrid operation.
- Having invented a cable leakage location system using a transformer and clamp meter, he has trained over 100 decoder system installation teams in fault detection and location.
- His hobbies include: Breeding Warmblood Horses and German Shepherd dogs. Flying and SCUBA diving (but not on the same day!). Human anatomy and physiology.
- He divides his time between Aberdeenshire, Scotland and Budapest, Hungary, where all TWL's 2Wire products are manufactured.
- He now supports TWL Irrigation Ltd www.twl-irrigation.com which is the successor to Tonick Watering

TWL Irrigation & Underhill

Contents

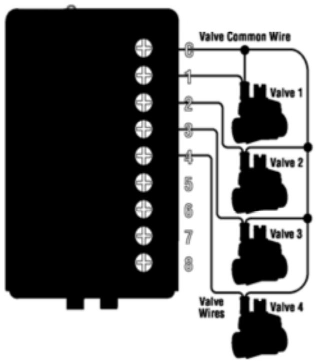
TWL Irrigation & Underhill

2Wire Advantages and Weaknesses

By Tony Ware B.Sc.
Chief Designer,
TWL Irrigation Ltd

Multi-Wire Irrigation, one wire and a common to each solenoid.

- The conventional way is to have a controller with many terminals, each with a wire to leading to an individual solenoid on an electrically activated water valve. A 'common' wire completes the circuit, daisy-chaining to the other side of each solenoid, then back to the controller. This type of controller is called **Multi-wire.**



TWL Irrigation & Underhill

To activate a valve, the controller turns on the terminal with typically 24VAC-28VAC. The current flows "down" the wire to the valve, pulling in the solenoid pin and allowing the valve to pass water. The current flows "back" to the controller through the common wire. (actually, the voltage polarity reverses 50 or 60 [in USA] times a second, hence "AC", alternating current, but the solenoid doesn't mind this!)

Multi-wire cable faults, easy to diagnose

1. Short circuit between one valve wire and the common?	1. Controller skips the station, reporting a fault.
2. Short circuit between 2 valve wires	2. Both valves come on when each is demanded.
3. Open circuit on one valve wire or open circuit solenoid.	3. The valve does not operate. Most controllers do NOT report a fault
4. Open circuit in the common wire	4. All stations beyond the open no longer work

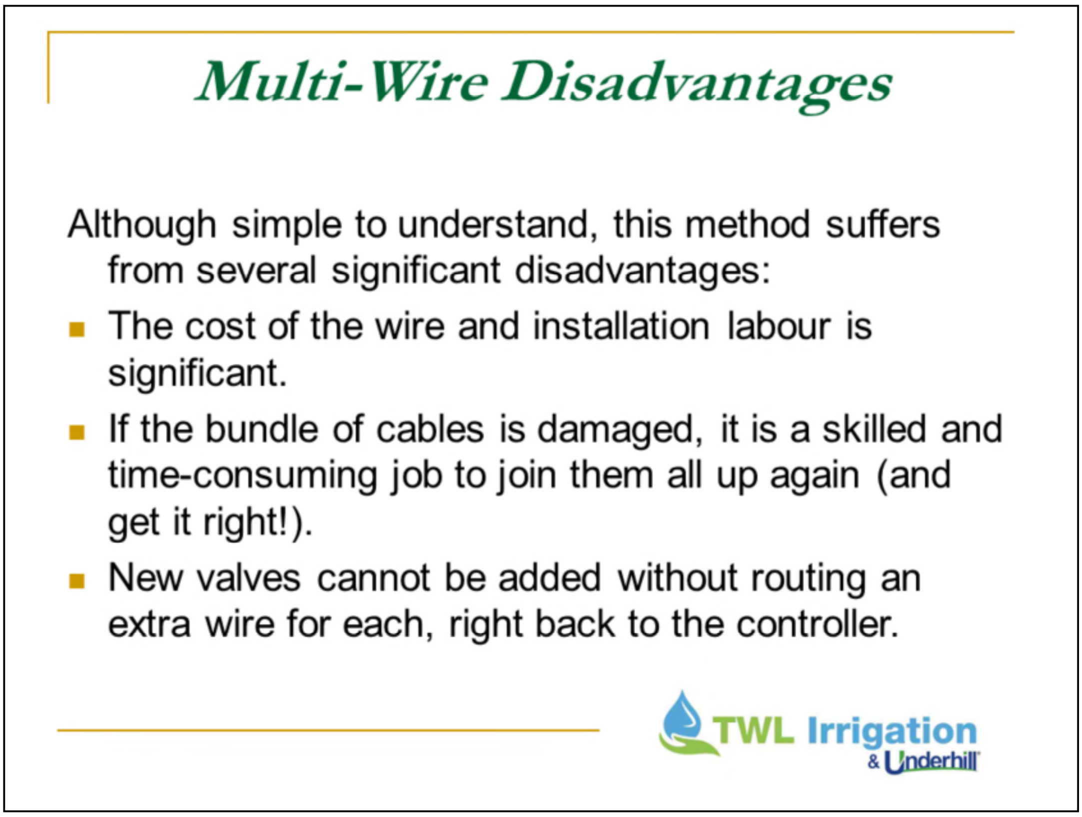
TWL Irrigation & Underhill

The main advantage of faultfinding a multi-wire system is the fault is normally confined to one, or a couple of valves. **Other valves are not affected**.

The only exception is, if the common is cut, all valves past the cut will not operate.

Faultfinding equipment needed is minimal, a $20 digital multimeter is usually adequate.

A direct path from the controller to the solenoid allows cable tracing techniques to locate lost valves (grassed over)



Installation Labour:

The USA commonly uses a PVC sheathed group of 18AWG wire, one conductor for each valve plus a common wire that goes from valve to valve.

To install, the outer sheath is carefully slit at each valve position, the common wire and the correctly coloured wire for that valve teased out. After cutting and stripping, the solenoid wires are carefully joined to the common and valve wire, taking care not to damage the other copper wires exposed in the multi-core cable. The outer sheath should then be repaired by a conscientious installer, using waterproof tape, to ensure water does not get into the cable.

It should be noted that the valve wire, once used, is no longer needed further along in the cable, but still exists and has been paid for in the cable cost per foot.

An alternative method used is individual direct burial 18AWG conductors; often with different colours for identification. Normally white is chosen for the valve common. However, after about two years underground in some soils, those coloured wires can become the same colour, a dirty black!

Damage to Cables:

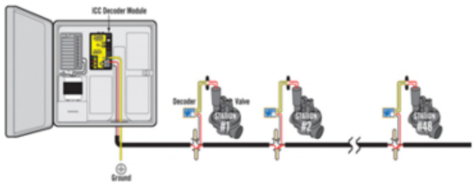
Another problem becomes painfully apparent when there is an accident with the wire.

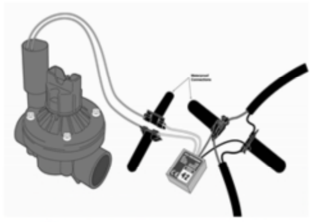
Say, for instance, that one installs an irrigation system and has a whole network – a spider web – of wire, buried in the ground. Finally, the time comes to plant the first of a group of trees. A contractor comes in with a back-hoe and the equipment makes a nice big hole, perfect for the tree. However, when the shovel rises from the hole, looking a lot like a dirty pasta fork, there hanging from it is a large clump of wires and it's obvious that half of them are broken, usually with stretching of the copper conductors!

This is one of the worst nightmares for a contractor. Before any other planting is done, someone must repair each wire. That requires figuring out which wire goes with which and reconnecting them. On bigger installations, the wires are coded with many colour combinations. However, after two years underground in some soils, those coloured wires can become the same colour, a dirty black! The nightmare grows even bigger when one realises each one must then be tested after re-joining to make sure the correct valve comes on.

Typical 2 wire decoder system

- 2Wire irrigation systems rely on uniquely pre-numbered decoders connected along a common 2 wire path, each connected to a solenoid valve. The controller feeds typically 24VAC down the path, combined with a digital signal commanding a decoder to turn the solenoid on or off. The decoder, whose number matches the signal, obeys the command. All the other decoders ignore the signal.





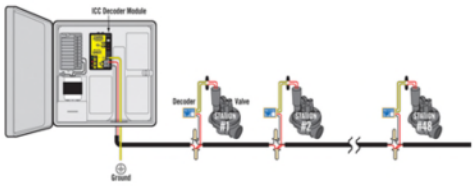
TWL Irrigation & Underhill

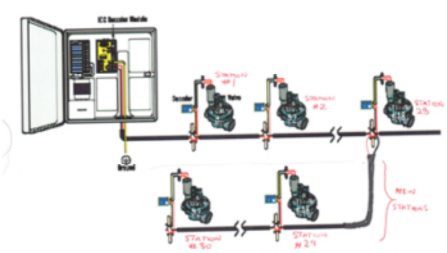
This scheme saves copper cables and with the right equipment is easy to repair, being only 2 wires rather than a huge bundle.

Installation is much quicker too. About 10 minutes per valve for 2 wire, versus 20-30minutes per valve with multi-wire sheathed cable.

2Wire. Easy expansion without trenching back to the controller

- Expansion of the network is easy, with further decoders and cable being spliced anywhere along the existing path.
- The number in each new decoder must be unique





.

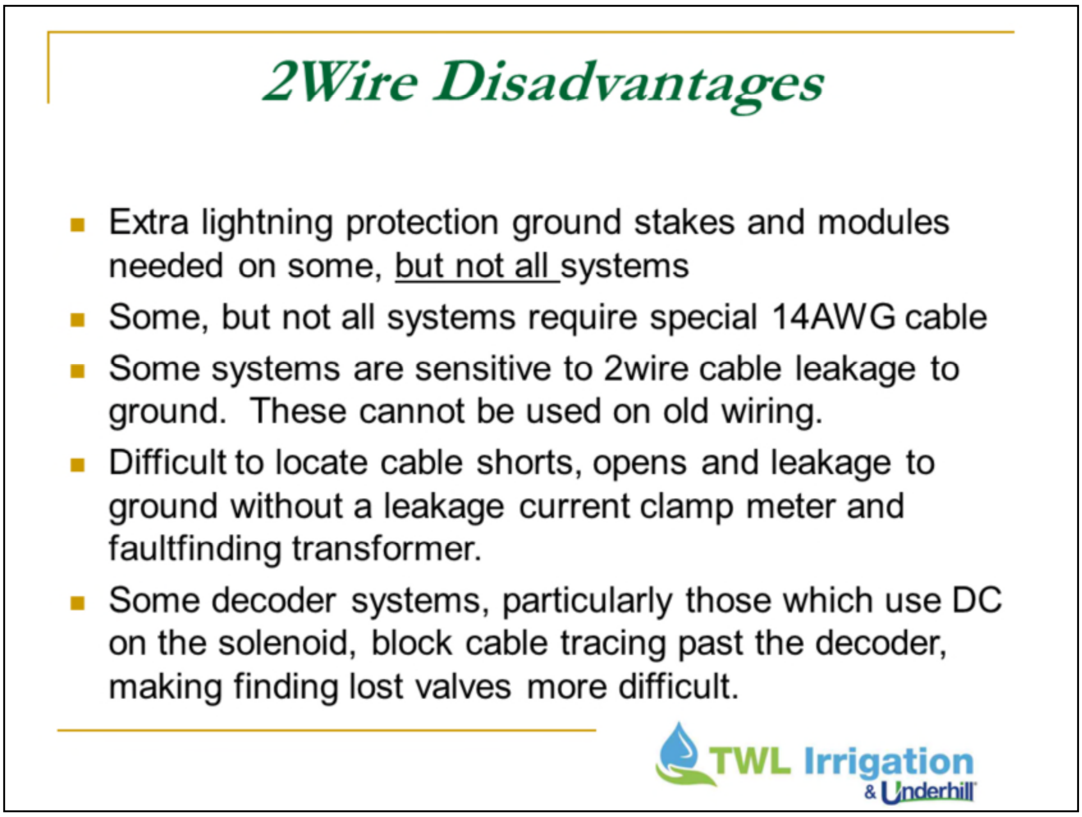
Other 2Wire Advantages

1. Much lower cabling price per foot
2. Significantly quicker installation, could be 1/3 time
3. No wasted onward conductors as with multi-wire and no spare conductors needed.

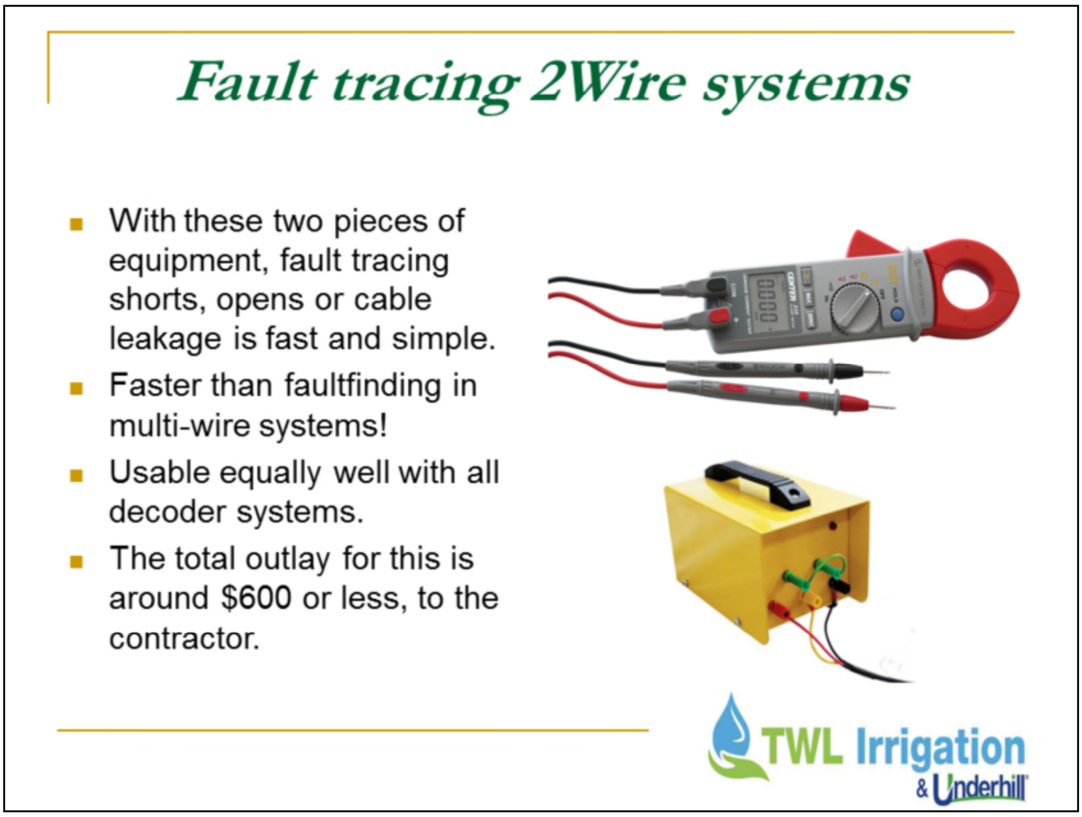
- Overall project costs may be lower, because of 1-3 above, even when factoring in the decoder costs
- Simple repair to damaged cables. Just 2 wires to re-join. Many systems are polarity independent on the 2wire path, no need to even match the colours.
- Simple checkout of entire cabling system in ½ hour.

TWL Irrigation & Underhill

Comparative project costs are covered later in the course.



On the other hand, Pure AC decoders usually pass cable tracing signals through the decoder allowing lost valves to be located like multi-wire.



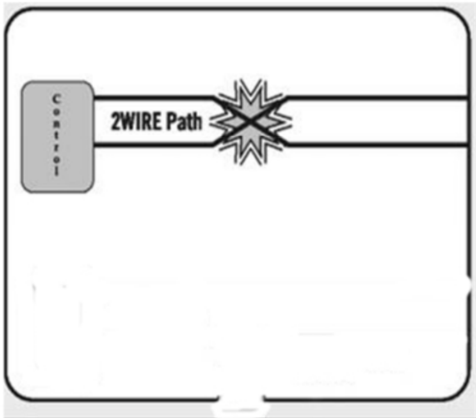
Leakage clamp meters are available from several manufacturers, but beware of ordinary clamp meters, which are not sensitive enough.

The transformer system can be home-made. 24VAC- 30VAC output, 150VA or more, with the ability to connect either the red or black to ground (earth) when finding 2wire cable leakage. Make sure it is safe to use!

Detailed instructions on how to use these pieces of equipment are covered later in the course.

2Wire cable faults
Short circuit on the 2 wire path

- High currents flow and the controller shuts down to protect itself.
- It is not obvious where the short is.

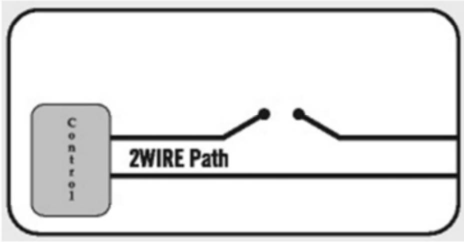


TWL Irrigation & Underhill

The problem with any shared path is that a fault somewhere along the cable can sometimes affect the whole system. However, with some low- cost measuring equipment and the following simple techniques, the fault can be more quickly located than even multi-wire.

2Wire cable faults
Open circuit in the main 2 wire path

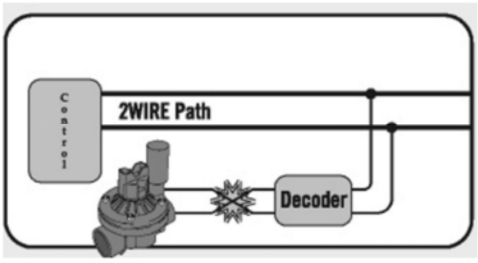
- All decoders up to the open will work, those beyond will not
- Equivalent to a break in the common line in a multi-wire system



TWL Irrigation & Underhill

2Wire cable faults
Short circuit solenoid

- **Short only shows up when a decoder is operated**
- **Sometimes stops the system working afterwards due to voltage loss down the main 2 wire path, preventing an off command from reaching the decoder.**
- **Some 2Wire systems are cleverer, will report a fault and not try to turn on the solenoid**



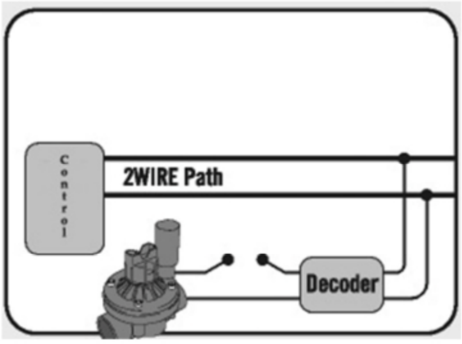
TWL Irrigation & Underhill

This depends on the type of controller used. Some will detect a faulty solenoid before operating it and signal a fault. Others will use an emergency off command which gets through anyway.

All types will indicate a fault on that station.

2Wire cable faults
Open circuit solenoid or dead decoder

- Station does not respond
- Can also be a dead decoder
- All decoder systems will report a fault
- In contrast, most Multi-wire systems will <u>not</u> report an open solenoid

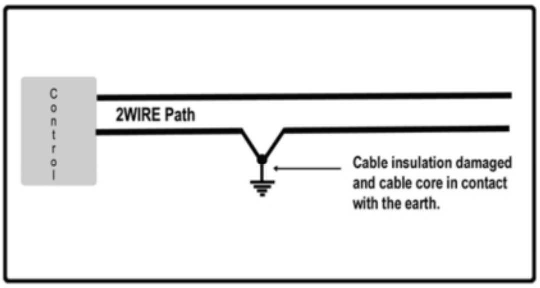


TWL Irrigation & Underhill

Controller will indicate a fault on that station.

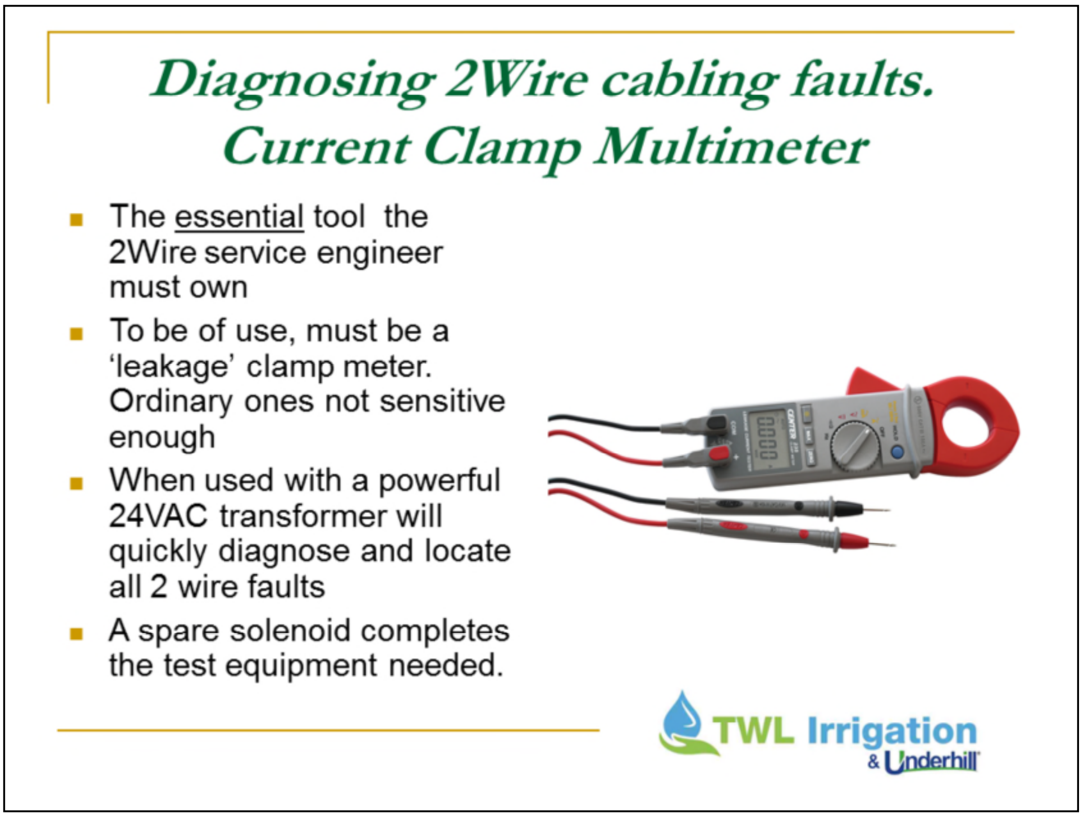
2Wire cable faults
Cable leakage to earth

- When a cable or joint is not well insulated, some electricity can leak to ground (earth). This causes problems for some makes of controllers, either refusing to control at all, or sometimes giving erratic operation, leading to the controller being suspect.
- The immunity to cable leakage varies considerably from make to make. Some controllers will stop working, others will be indifferent to quite bad leakage. The latter type will work into retrofit sites without the need to re-cable.



TWL Irrigation & Underhill

More on this subject is covered later.

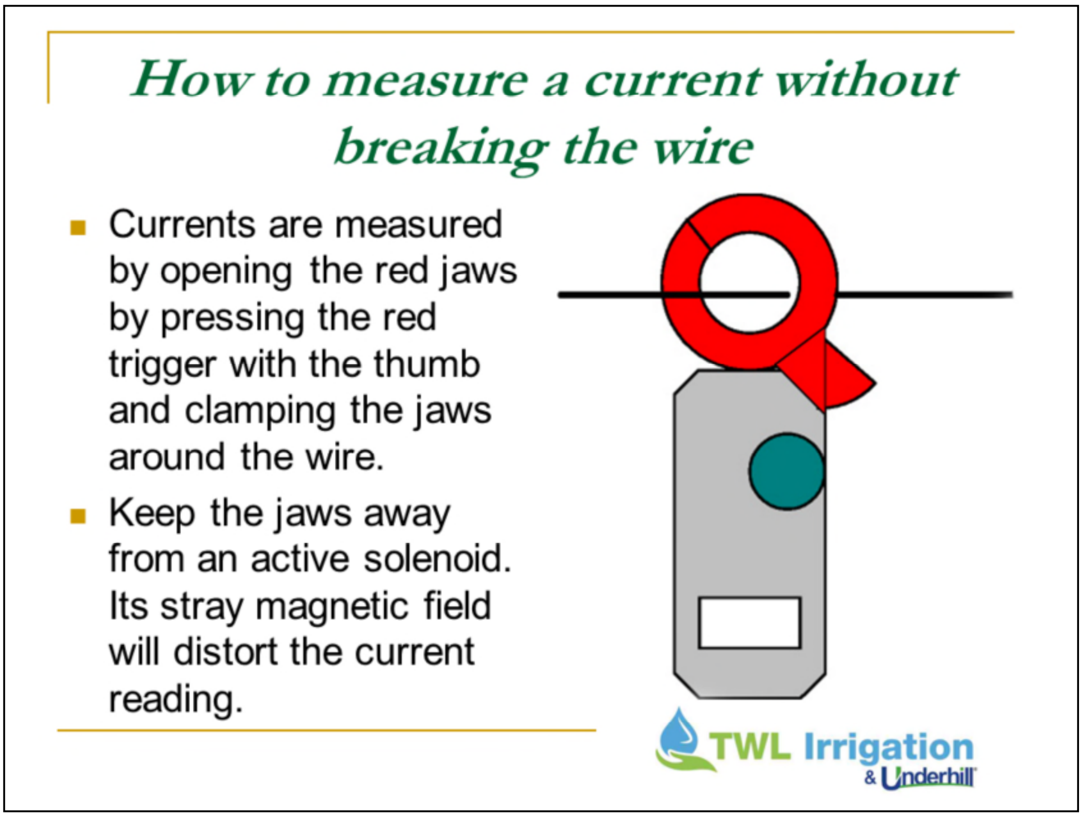


A measuring meter that reads AC volts and resistance is a valuable tool in diagnosing faults. If a sensitive current measuring capability without breaking the wire is available too, the **Leakage Clamp Meter** becomes almost indispensable.

The meter's ***AC volts (V~)*** and a spare solenoid is 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.



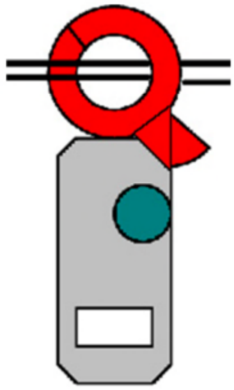
Principle of Operation.

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.

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.

Normally place the clamp around just one of the wires, not both.

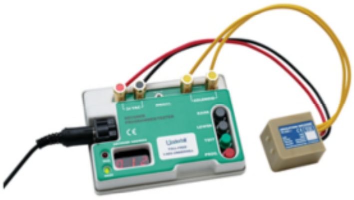
- It is important to understand that if both flow and return wires carry the same current and are placed inside the jaws, ***the multimeter will read zero***



When the test equipment system is set up for testing earth leakage, the flow and return will have different currents in them as some is leaking back through the ground, therefore the meter will read the difference in the two conductors = leakage through the earth.

2Wire. Testing a decoder

- Most decoder manufacturers offer a decoder tester
- The tester may be used to enter the decoder's station number before installation
- To be of use, the tester should be low cost or not enough will be available for each crew
- Some decoder systems use factory pre-numbered decoders. Each number must be entered into the controller for it to know what to send when commanding a station on or off.
- Other systems discover decoders, but their locations must be noted by the installer, otherwise no one knows what they will water!
- Some manufacturers offer a programmer/tester that can be used on the decoder when wired into the 2wire path. This is very convenient but adds manufacturing cost to each decoder and is itself quite costly.
- A new family of decoders is now available where an ordinary cellphone (mobile phone) with NFC and a free App can be used to program and test a decoder and its valve.



TWL Irrigation & Underhill

Examples of this are the Hunter Industries ICD-HP field programmer/tester and the 2Wire Innovations decoder, TW/NG-1 with NFC interface, so an ordinary cellphone with a free app and do the same thing. (tamper protection built-in)

2Wire. 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 (as illustrated) and a current clamp meter.

TWL Irrigation & Underhill

The transformer can be home-made. 24VAC- 30VAC output, 150VA or more, with the ability to connect either the red or black to ground (earth) when finding 2wire cable leakage. Make sure it is safe to use!

The illustration shows a 3rd yellow terminal. This is only useful with 3 wire decoder systems, uncommon in the USA.

2Wire. Using the Transformer

- A big power transformer, such as the one illustrated in the previous slide, plugs into the 115V/230V power and produces 30V AC at up to 6 Amps to power up the 2 wire path.
- 30V AC is not known to damage any decoder system
- 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 a spare solenoid, the transformer allows fault finding with the minimum of effort and confusion.

TWL Irrigation & Underhill

Detailed use of the clamp meter, transformer and spare solenoid are covered later in the faultfinding section of this course.

2Wire Decoder Types DC vs. AC

By Tony Ware B.Sc.
Chief Designer,
TWL Irrigation Ltd

TWL Irrigation & Underhill

Solenoid Power Reduction

The key to getting distance and many on together

- Remember the fridge door? A good pull is required to part the magnet in the fridge from the one in the door when they are close together. Once they are pulled apart, even a little way, the force decreases dramatically.
- If DC is applied to pull the solenoid plunger, because the force is much greater once it is fully retracted, the amount of DC can be reduced to quite small values before the spring overcomes the attraction and pulls the plunger out again.
- This is very useful if you want lots of solenoids energized on the same wire, or long distances, because if the holding power is reduced, there is more to go around for others to be turned on. Note that full power is required to start the pull, it can only be reduced once the solenoid plunger is fully pulled in.
- This system does not work with AC on the solenoid because the attractive force varies during the cycle and falls to zero twice each cycle as the AC volts go through zero on their way to the opposite polarity.
- **NOTE:** Even if the system uses DC on the solenoid, the main 2Wire path is always AC in some form.

TWL Irrigation & Underhill

DC on an AC solenoid?

Yes, all AC solenoids work well with DC. Less current is needed than with AC because its attractive force varies during the cycle and falls to zero twice each cycle as the AC volts go through zero on their way to the opposite polarity.

HANDY TIP. Finding which valve is operated with which solenoid.

Take the battery out of your electric drill. Touch the solenoid leads (disconnected from the decoder!) to the battery terminals. This will operate the solenoid and you can see where the water is coming out.

DC on the solenoid. Engineering disadvantages

- Note however that the engineering advantage gained by this clever technique can bring its own problems.
- DC on field wiring causes electrolytic destruction if exposed copper wires in contact with wet soil. Good cable and joint insulation is mandatory.
- The controller must apply the full DC power for the correct amount of time to make sure the plunger is fully in, before reducing the DC voltage. Controllers which use this technique must be 'tuned' to the make of the solenoid fitted.
- Because of potentially destructive electrolytic action caused by field cable leakage to the earth, controllers which employ this technique may refuse to irrigate if they detect leakage. It must be located and rectified before watering can continue.

TWL Irrigation & Underhill

Comparison of maximum wire length of Pure AC vs. DC on solenoid decoders

Maximum Wire length DC on Solenoid vs. Pure AC System					
Nominal wire size	Ohms per 1000' or Ohms per Km, per conductor	Rain Bird ESP-LXD, DC on solenoid	Rain Bird ESP-LXD, DC on solenoid	TWL Sapien, Pure AC system	TWL Sapien, Pure AC system
		Max 8 stations on together	Max 8 stations on together	Max 4 stations on together	Max 4 stations on together
		STAR	LOOP	STAR	LOOP
2.5mm2	7.5 Ohms/Km	3.0Km	12.0 Km	1.6Km	3.2Km
14 AWG	2.58 Ohms/1000'	1.65 miles	6.61 Miles	0.88 Miles	1.77 Miles
Note: All examples here using Rain Bird Solenoids. Pure AC systems can go further with some other solenoid types					
Pure AC distances calculated on 4 solenoids clustered together. Better distances possible when distributed along path.					

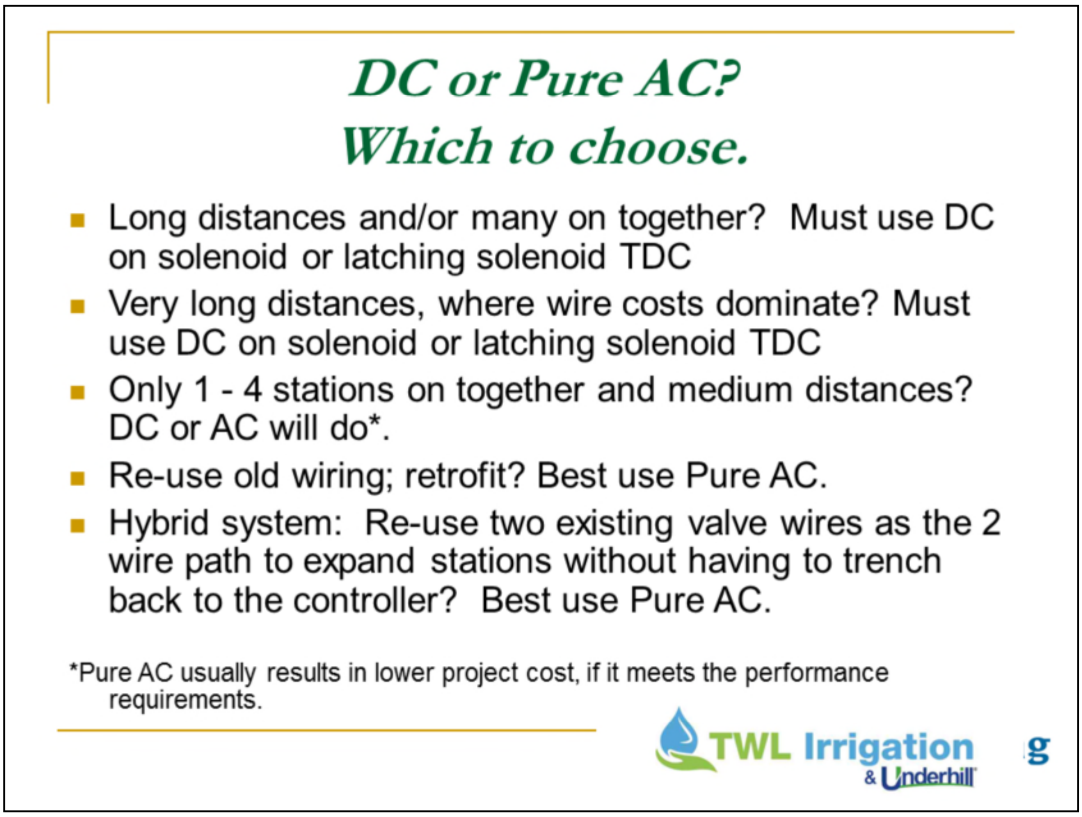
Note the significantly better distance with the ESP-LXD compared with the Sapien.

Both examples here have performance that are typical of their type.

Identifying Pure AC and DC on the solenoid

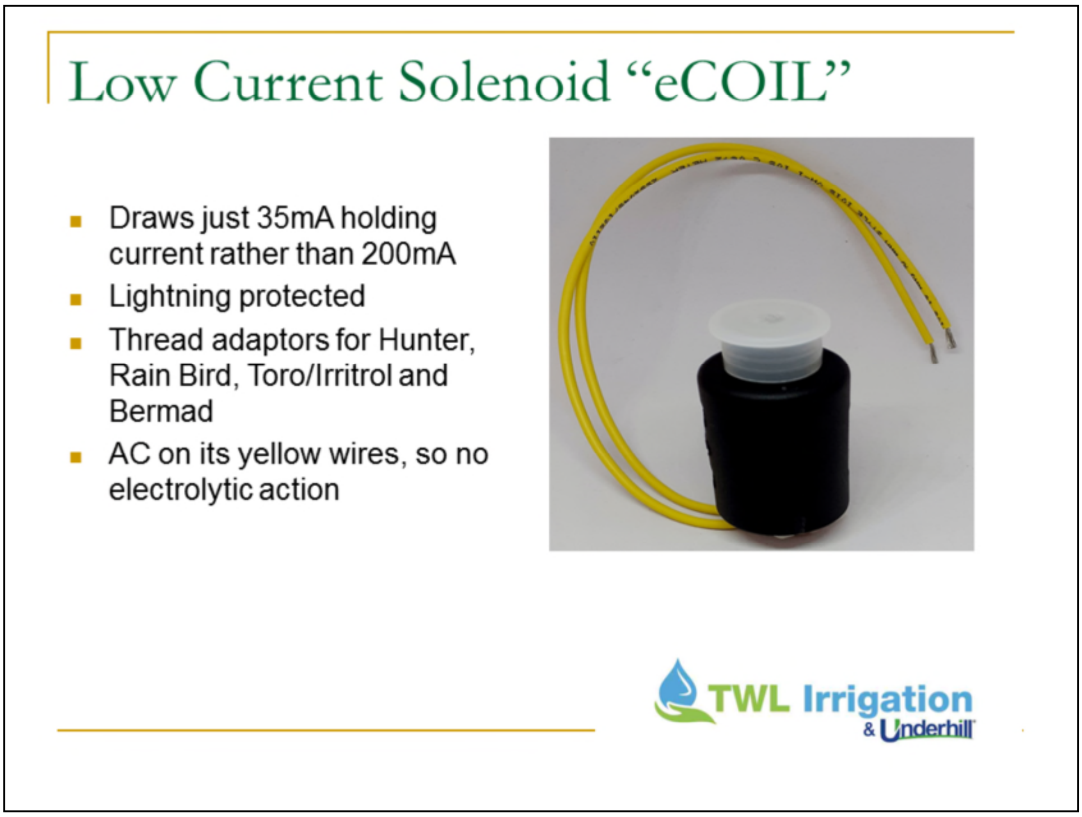
- A multi-wire system is Pure AC.
- If the decoder system manufacturer states that more than 4 solenoids can be active at a time, the system probably uses DC.
- DC on the solenoid (or latching) is a very effective technique and in no way inferior to Pure AC. It is the only way to get a significant number of solenoids on together over a large distance.
- It does however preclude retrofit in most cases and adds to the project's costs.
- Manufacturers usually do not explicitly state DC is used, instead they specify that new wire and top-quality wire joiners must be used. This ensures there will be no cable leakage to ground.

TWL Irrigation & Underhill



If you are looking at a project that with multi-wire, would require satellites, then a DC on solenoid system will be best.

If you are looking to retrofit a satellite system to 2 wire and want to use the old wiring and satellite positions, a Pure AC system will give less trouble.



When used with a pure AC decoder system, instead of a normal AC solenoid, boosts performance to that of the aforementioned DC systems.

Pure AC on all exposed wire joints, so less worry on earth leakage.

A '3 way' version, with a back water port is available for the bigger AG valves.

2Wire Lightning Protection Principles.

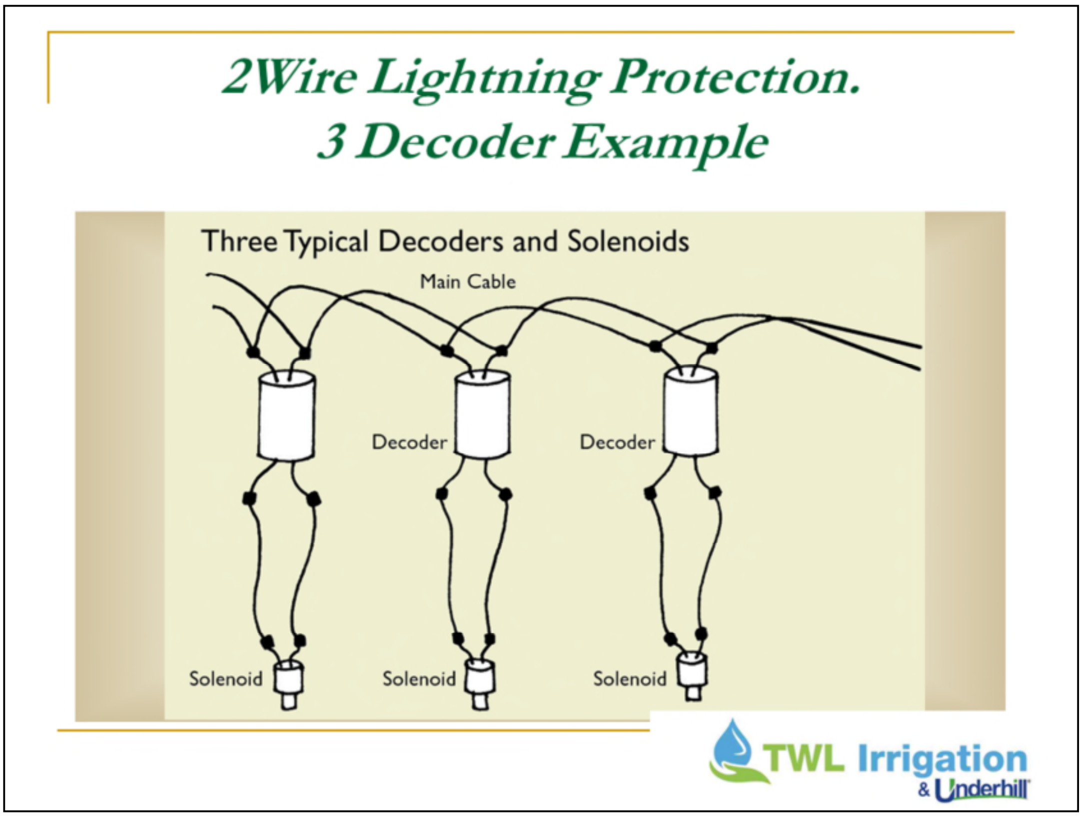
By Tony Ware B.Sc.
Chief Designer,
TWL Irrigation Ltd

TWL Irrigation & Underhill

Introduction

- This Technical Note describes the two kinds of protection against lightning damage in 2Wire irrigation control systems.
- When properly installed, lightning protection in decoder systems will generally be stronger than that found in smaller multi-wire systems. The exception is pedestal-mounted multi-wire, where extensive extra lightning protection components can be housed within the pedestal.
- In decoder-based systems, there are only two wires to protect, thus there is more space to fit tough protection components within the controller and in each decoder.

TWL Irrigation & Underhill

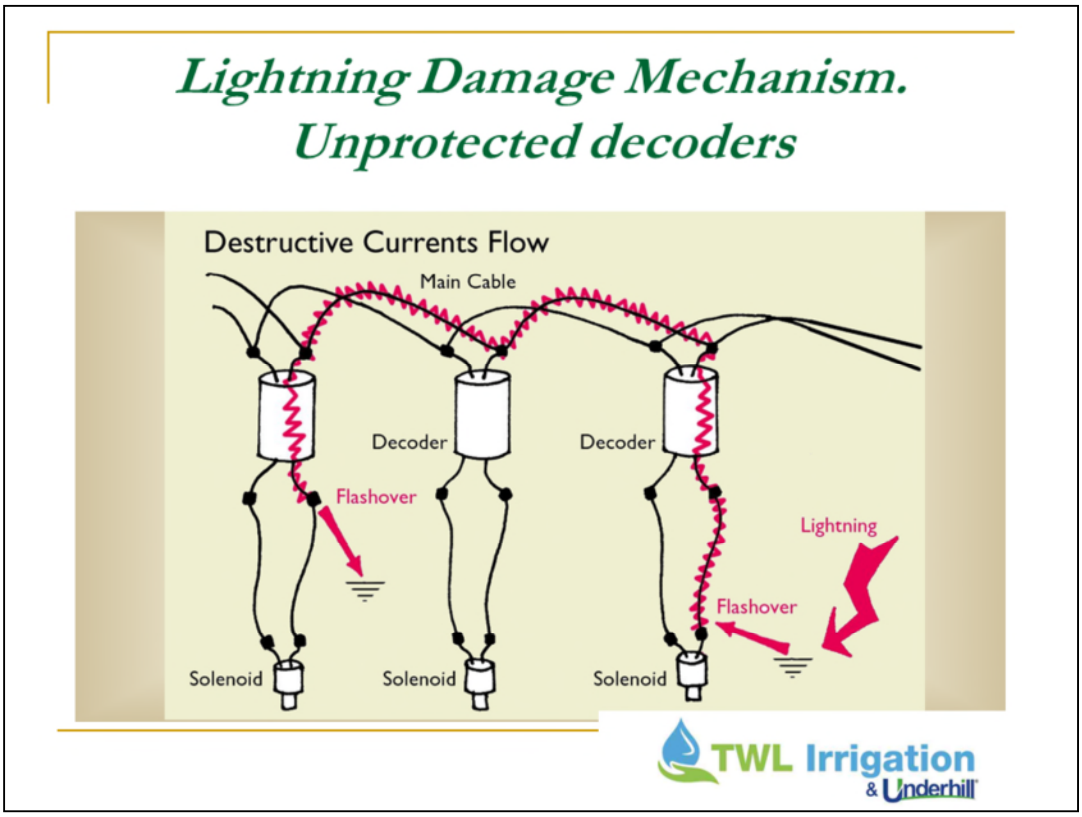


The wires on some decoders do not come out of the other end, but this diagrammatic representation helps understand the principles better.

'Main cable' is the common 2Wire path around the site to all the decoders

The black dots represent waterproof connectors, such as 3M DBY or Connector King equivalents.

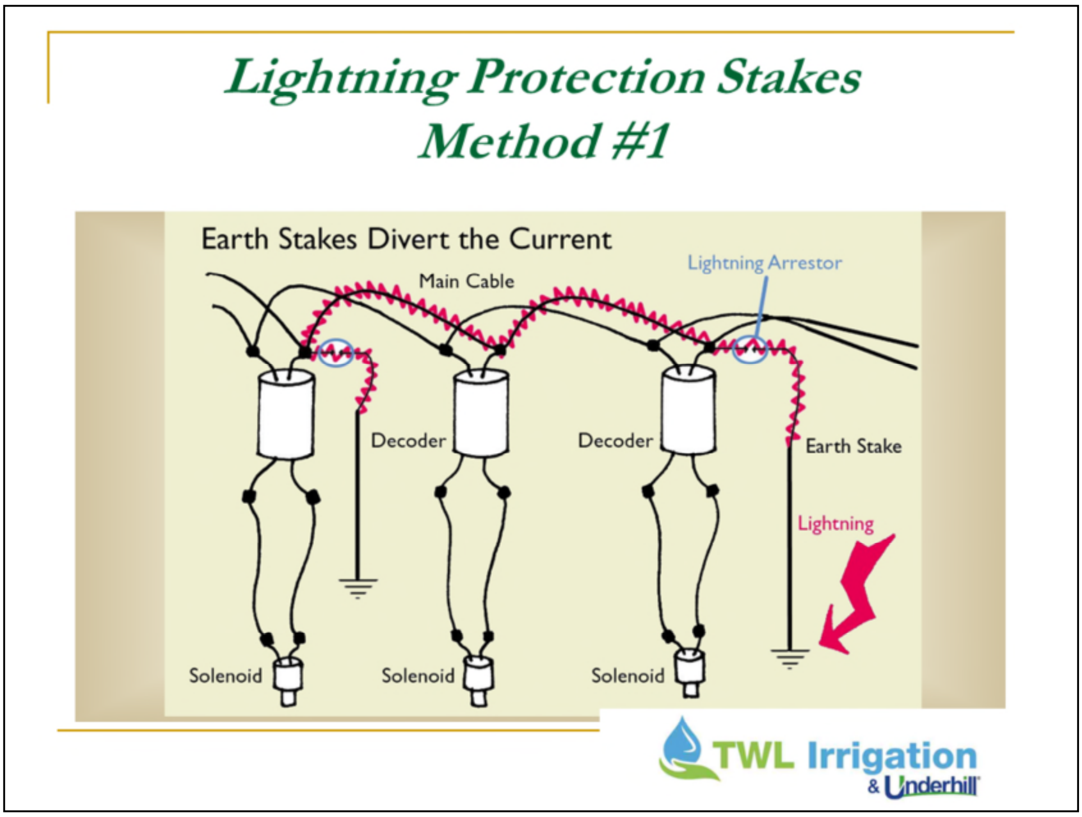
When solenoids and decoders coexist in the same valve box, just one set of solenoid joints is needed.



Where lightning strikes, the ground goes up to about 2 million volts with currents in the region of 25,000A-100,000A. Although the eye only sees one flash, there are typically 5-10 such strikes in quick succession. No affordable lightning protection scheme will withstand such a direct hit.

The more common event is a surge caused by a nearby strike. In this instance the GROUND goes up to a potential of between 6KV-10KV. Flashover from the ground onto the wiring usually occurs at a wiring joint where the insulation is at its weakest. If this is a solenoid joint, the currents, typically 10,000A-30,000A flow through the decoder, destroying it, and travel around the main cables seeking another path to go back to ground.

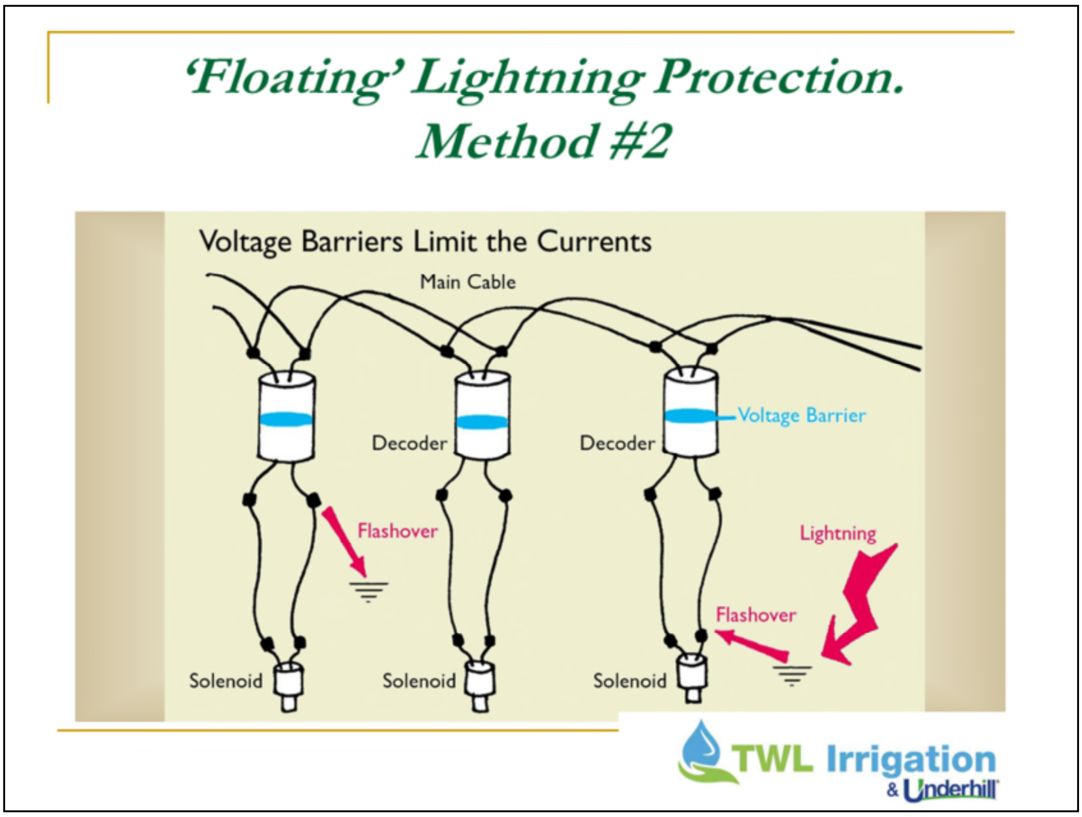
Damage may also occur when lightning discharges between two oppositely charged storm clouds that are further apart than they are above the ground. (Sheet Lightning). In this case, the cables pick up the surge indirectly through electromagnetic induction.



Many manufacturers of decoders successfully use the bypass principle, using earth stakes to shunt destructive currents around their decoders. In some form, they use Gas Discharge Tubes (GDT) which conduct at around 90V – 120V. These tubes may be incorporated inside the decoder or be external. In all cases to be effective, an earth stake must be used.

Note that the solenoid must be physically near the decoder with this method. Most manufacturers quote a few 10's of feet.

This technique makes high currents more likely in the main cable, thus putting it and its cable joints at greater risk.



The alternative 'floating' technique, relies on the construction of a voltage barrier within the decoder that can withstand 10KV and limit currents through the decoder to an amount that can be withstood by the PCB tracks without damage.

No earth stakes are needed along the cable path or next to each decoder. However, it is important to put just one earth grid/stake next to the controller. This must be electrically separate from the building earth system.

With this technique, it is not necessary to limit the distance between decoder and solenoid. In many installations this can be 1000ft with no diminution of lightning protection to either decoder or solenoid.

Peak currents in the main cable are usually smaller than with the earth stakes method, thus less likely to be damaged.

This method is harder to implement successfully in decoders that apply DC to the solenoid because they are more complicated. Method #1 is usually used instead

Separating Decoders & Solenoids

Current (A)	25,000										
			V/10ft		V/10ft		V/10ft		V/10ft		V/10ft
Distance (ft)		325		650		975		1300		1625	
Distance (m)		100		200		300		400		500	
Resistivity	3,000	113,149		56,575		37,716		28,287		22,630	
			1,741		580		290		174		116
Ohms-cm	10,000	377,165		188,582		125,722		94,291		75,433	
			5,803		1,934		967		580		387
	20,000	754,330		377,165		251,443		188,582		150,866	
			11,605		3,868		1,934		1,161		774
	50,000	1,885,825		942,912		628,608		471,456		377,165	
			29,013		9,671		4,835		2,901		1,934
	100,000	3,771,649		1,885,825		1,257,216		942,912		754,330	
			58,025		19,342		9,671		5,803		3,868
	200,000	7,543,299		3,771,649		2,514,433		1,885,825		1,508,660	
			116,051		38,684		19,342		11,605		7,737

Current (A)	25,000									
			V/10ft		V/10ft		V/10ft		V/10ft	
Distance (ft)		1950		2275		2600		2925		3250
Distance (m)		600		700		800		900		1000
Resistivity	3,000	18,858		16,164		14,144		12,572		11,315
			83		62		48		39	
Ohms-cm	10,000	62,861		53,881		47,146		41,907		37,716
			276		207		161		129	
	20,000	125,722		107,761		94,291		83,814		75,433
			553		414		322		258	
	50,000	314,304		269,404		235,728		209,536		188,582
			1,382		1,036		806		645	
	100,000	628,608		538,807		471,456		419,072		377,165
			2,763		2,072		1,612		1,289	
	200,000	1,257,216		1,077,614		942,912		838,144		754,330
			5,526		4,145		3,224		2,579	

Resistivity Ohms-cm

water %wt	Topsoil	Sandy Loam
2.5%	250,000	150,000
5%	165,000	43,000
10%	53,000	18,500
15%	19,000	10,500
20%	12,000	6,300
30%	6,400	4,200

The top table indicates the voltage the earth rises to at a distance from the ground strike of amperage given in cell B1.
The yellow figures are feet from the strike, the green is meters from the strike
The black figures are volts above normal earth potential during the strike.
The Magenta figures are the resistivity of the earth. Typical resistivity figures are given in the small table below.

The blue figures between, represent the voltage difference between two points 10 feet apart
Thus, if a decoder is earthed though its stake and its solenoid is 10ft away in the direction of the strike,
this figure will show the voltage of the earth at the solenoid with respect to its decoder.
Example:
20,000 Ohms-cm, 1300 ft from the strike of 25,000 Amps, the earth will rise to a potential of 188,582 Volts above normal.
A solenoid mounted 10ft away from its decoder will see a voltage difference in its surrounding earth of 1,161V from the decoder.

TWL Irrigation & Underhill

When an earth stake needs to be connected to the decoder for lightning protection, it is important to keep the solenoid physically near the decoder. The chart above gives figures for what happens when the solenoid is remote from the earth-staked decoder.

On the above main table, the notes explain the various entries and should be read first.

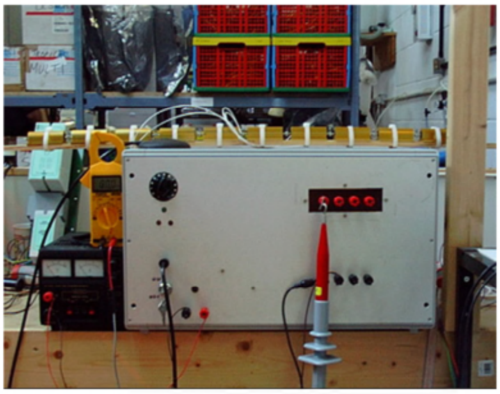
It is important to note that the above figures are simplified to assume a constant earth resistivity with depth. If the upper layer of soil is of a fairly low resistivity (topsoil) and the underlying is high (e.g., bedrock) the voltage stresses are much higher as the lightning currents are concentrated into the upper layer, producing much higher voltage gradients.

The important conclusion is that with all decoder systems that use earth stakes, the solenoid MUST remain within a few feet of the decoder for protection to be effective. Where a decoder has an earth wire, it is mandatory to earth stake it.

With the alternative floating lightning protection system (Method #2), this limitation does not apply, so the solenoid can be a great distance from the decoder with no loss of lightning protection.

An Example of a Lightning Generator

- Used for testing lightning protection
- Generates up to 8KV at 20,000A-30,000A peak
- Simulates main cable breakdown in decoder systems
- Discharges applied in turn, to each pair of wires from a decoder.



TWL Irrigation & Underhill

All new decoder and controller products should be tested using equipment like this.

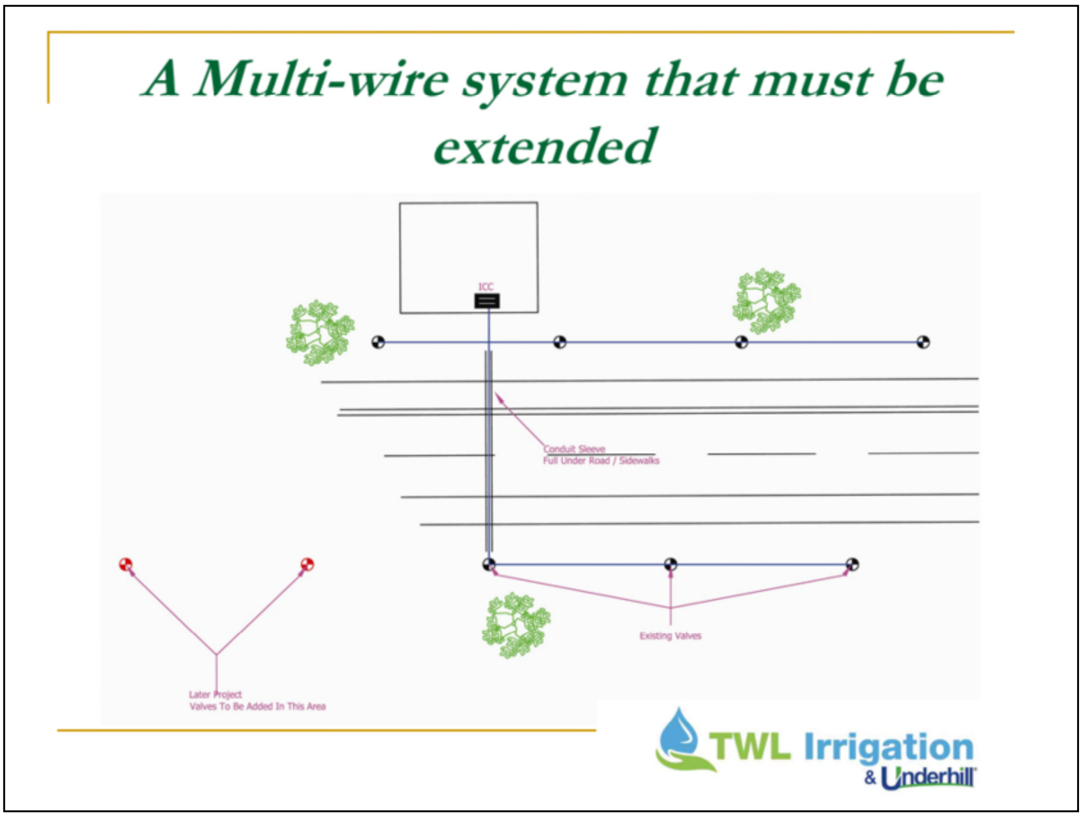
Several iterations of new controller and decoder design are usually necessary before the product can be released for sale with a known lightning immunity.

For this reason, many manufacturers warrant their 2Wire products against lightning damage.

Extending zones using a 2Wire Hybrid controller

By Tony Ware B.Sc.
Chief Designer,
TWL Irrigation Ltd

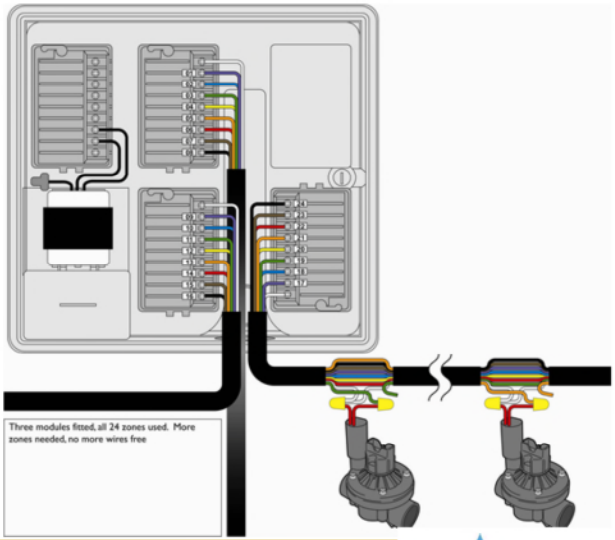
TWL Irrigation & Underhill



A common requirement is the extension of a multi-wire system, where no spare valves wires are available and trenching back to the controller is difficult.

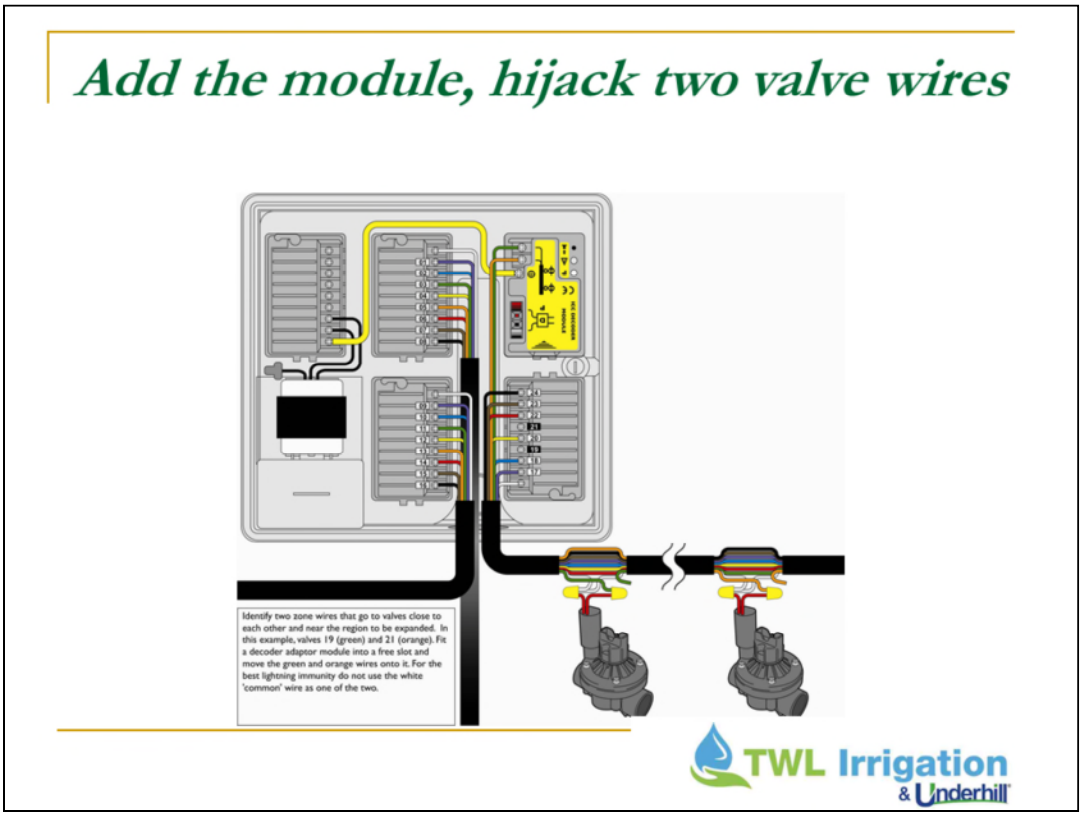
There are several multi-wire systems on the market that combine some multi-wire with 2 wire.

Controller has room for a decoder adaptor module



TWL Irrigation & Underhill

Three modules fitted; all 24 zones used. More zones needed; no more wires free.



If the existing valve wiring has leakage to earth, a pure AC hybrid decoder controller is safer to use.

Use the faultfinding transformer and the leakage clamp meter to pre-qualify the wiring.

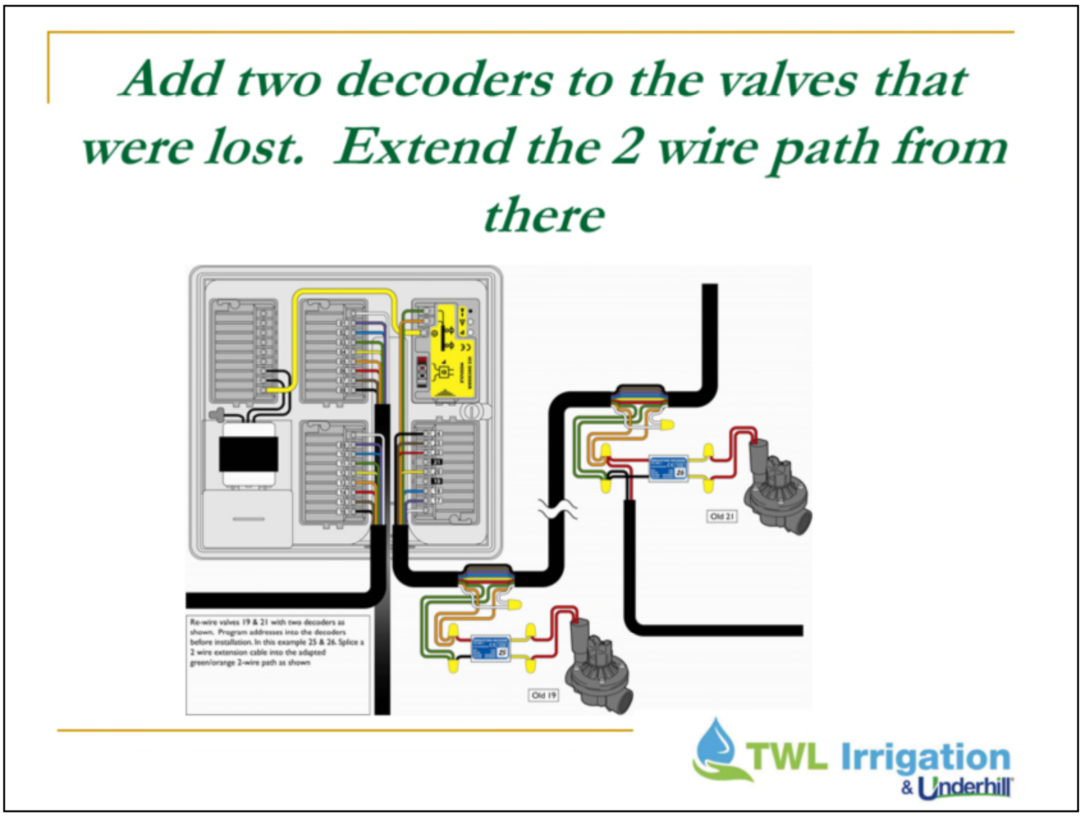
See faultfindingsection of this course to find out how.

Identify two zone wires that go to valves close to each other and near the region to be expanded.

In this example, valves 19 (green) and 21 (orange).

Fit a decoder adaptor module into a free slot and move the green and orange wires onto it.

For the best lightning immunity do not use the white 'common' wire as one of the two.

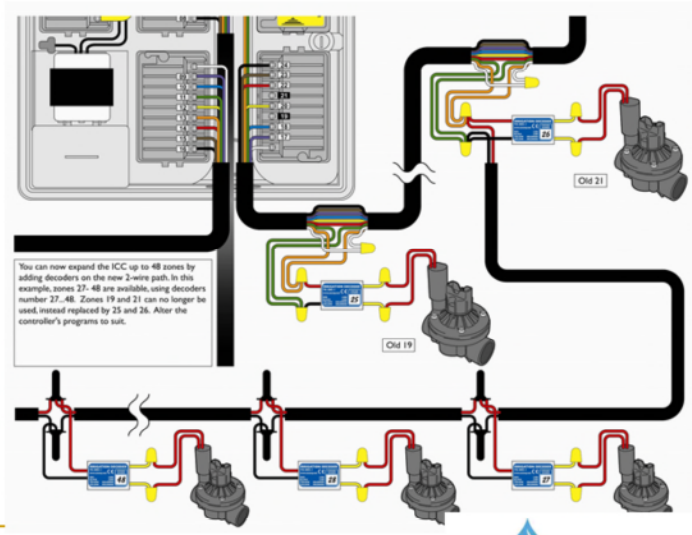


Re-wire valves 19 & 21 with two decoders as shown.

Program addresses into the decoders before installation. In this example 25 & 26.

Splice a 2wire extension cable into the adapted green/orange 2-wire path as shown

Add as many new valves as needed using the new 2 wire path



TWL Irrigation & Underhill

You can now expand the ICC up to 48 zones by adding decoders on the new 2-wire path.

In this example, zones 27- 48 are available, using decoders numbered 27...48.

Zones 19 and 21 can no longer be used, instead replaced by 25 and 26. Alter the controller's programs to suit.

Multi-Wire to 2Wire Adaptors Convert any Multi-wire to 2Wire

By Tony Ware B.Sc.
Chief Designer,
TWL Irrigation Ltd

TWL Irrigation & Underhill

Multi-wire to 2Wire Adaptors
Reasons for use

A multi-wire to 2Wire adaptor converts <u>any</u> multi-wire controller to 2Wire

Reasons for using:

1. The client may have an investment in a network of one manufacturer's controllers and is unwilling to change just because of a need for 2wire in one location.
2. A non modular controller, for which there is no specific 2 wire decoder adaptor, may have a need to add zones when there is insufficient multi-core cabling.
3. The contracting company may have standardized on one particular multi-wire controller that its crews know and can operate efficiently, but one or more installations would benefit from 2Wire.
4. Some adaptors allow the installation of 2Wire sensors, reproducing their outputs back at the adaptor. These may then be picked up by the host controller. This saves a special cable just to the sensor.

TWL Irrigation & Underhill

How the adaptor works.

- All adaptors have wires to the valve terminals and valve common on the multi-wire controller (hereafter called the host controller)
- The adaptor has a pair of 2Wire terminals to which the decoders are connected in the field
- When the host controller activates a valve, the adaptor senses this and signals the decoder to turn on.
- The host controller generally has no idea it is dealing with decoders, it just thinks it is a normal solenoid.
- The number of decoders with unique addresses cannot exceed the number of valve terminals on the host controller.
- The apparent load seen by the host controller's valve terminal when connected to the adaptor is much less than a real solenoid.
- A host controller which has an 'open circuit solenoid' detection system enabled, cannot be used with an adaptor, as its loads are much smaller.

TWL Irrigation & Underhill

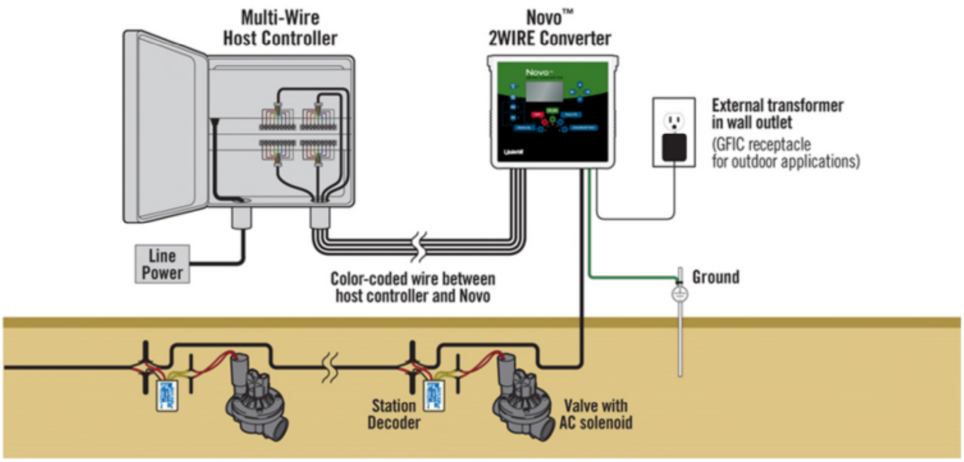
Some known manufacturers of Multi-wire to 2Wire adaptors

- HIT Products: Universal2-Plus
- TUCOR: Hybrid-3D
- TWL: Universal & Senders;
- Underhill: NOVO

TWL Irrigation & Underhill

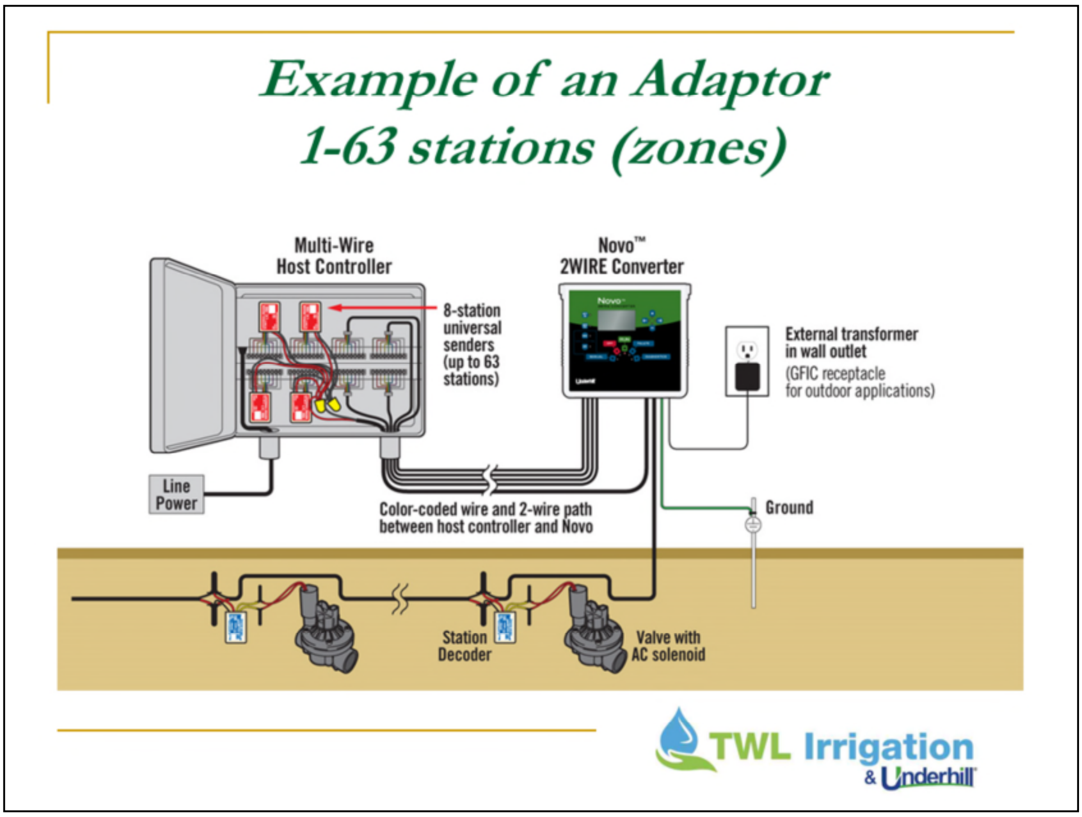
This list is not exhaustive

Example of an Adaptor 1-32 stations (zones)



TWL Irrigation & Underhill

One example using the Underhill NOVO

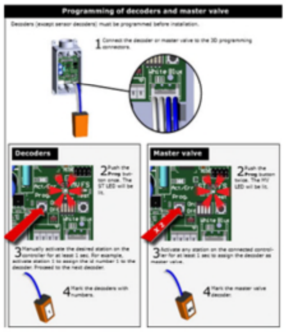


In this example, the NOVO's built-in 32 station zone terminal sensing has be extended to 63 stations by adding another 4 (red labelled) 8 way "Senders".

There cannot be more uniquely numbered decoders than there are valve terminals on any make of adaptor. In this example, the host controller has 63 valve terminals.

Programming Decoders for use with an Adaptor

- Some makes of adaptor include a built in decoder programmer used for pre-numbering the decoders before installation in the field.
- Other makes require a separate programmer/tester to be used.
- When using the TW/NG family decoders, the NFC App on a cellphone can program the decoder before or after installation.



TWL Irrigation & Underhill

The top picture is from TUCOR's Hybrid-3D, with built-in decoder programmer.

Fault Tracing Field Wiring Faults in Almost All Decoder systems

By Tony Ware B.Sc.
Chief Designer,
TWL Irrigation Ltd

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 32V 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.

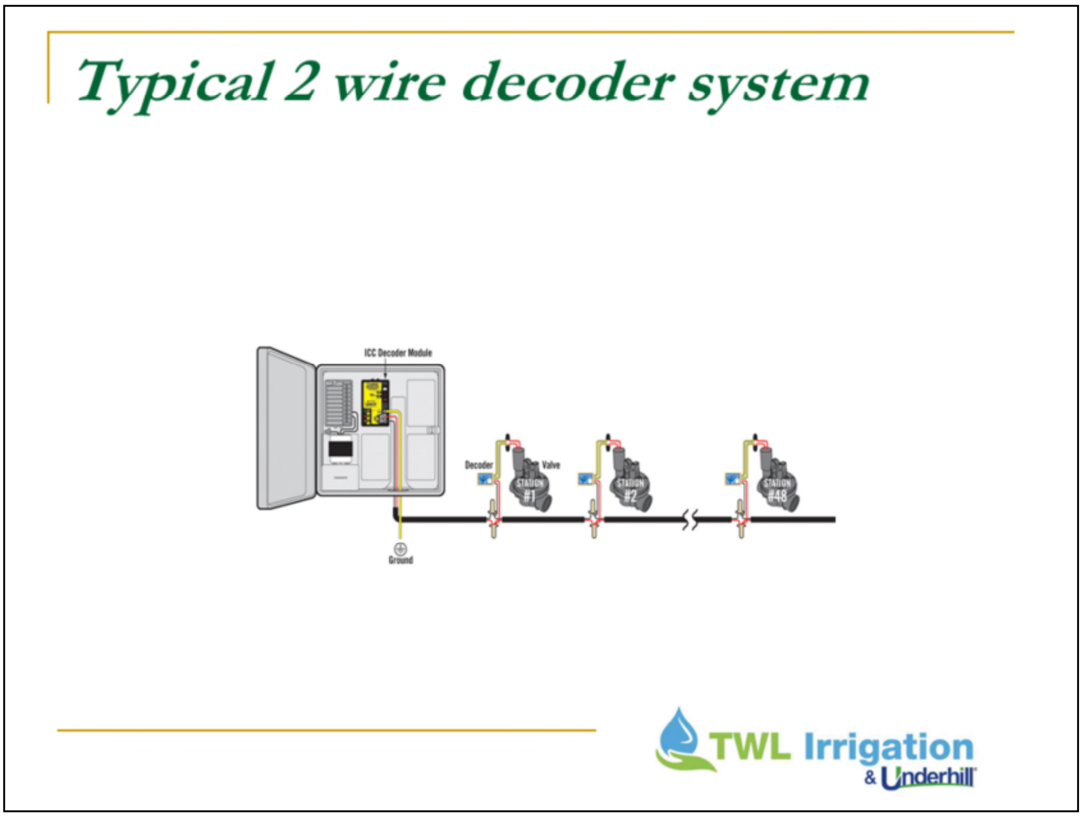
This scheme saves copper cables and with the right equipment is easy to repair, being only 2 wires rather than a huge bundle. Expansion of the network is easy, with further decoders and cable being spliced anywhere along the existing path.

The problem with any shared path is that a fault somewhere along the cable can sometimes affect the whole system. However, with some low-cost measuring equipment and the following simple techniques, the fault can be quickly located. This technique can be used with almost anyone's 2 wire controller system.

The final section of this presentation is how to do a Basic Wiring Checkout. Taking just ½ hour, this type of test equipment can tell if the wiring is in good condition or has faults.

Slide 52

TW1 Tony, 23/03/2023

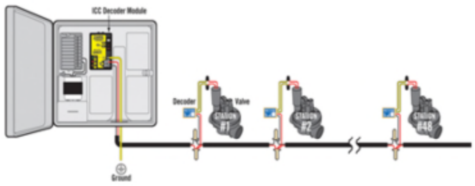


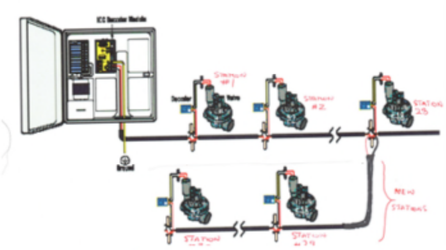
Almost all modern irrigation systems rely on many pre-numbered decoders connected along a common 2 wire path, each connected to a solenoid valve. The controller feeds typically 24V to 32V AC down the path, together with a digital signal commanding a decoder to turn on or off. The decoder, whose number 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.

2Wire. Easy expansion without trenching back to the controller

- Expansion of the network is easy, with further decoders and cable being spliced anywhere along the existing path.
- The number in each new decoder must be unique

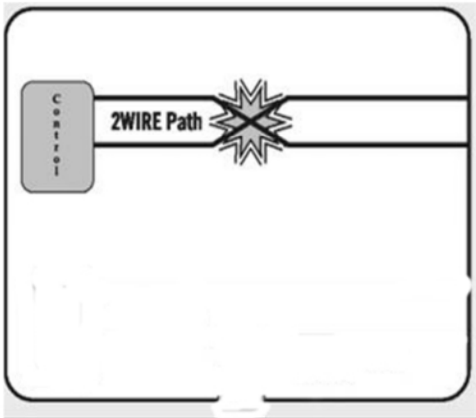




TWL Irrigation
& Underhill

2Wire cable faults
Short circuit on the 2 wire path

- High currents flow and the controller shuts down to protect itself.
- It is not obvious where the short is.

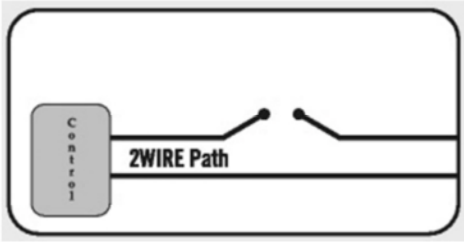


TWL Irrigation & Underhill

The problem with any shared path is that a fault somewhere along the cable can sometimes affect the whole system. However, with some low-cost measuring equipment and the following simple techniques, the fault can be more quickly located than even multi-wire.

Open circuit in the main 2 wire path

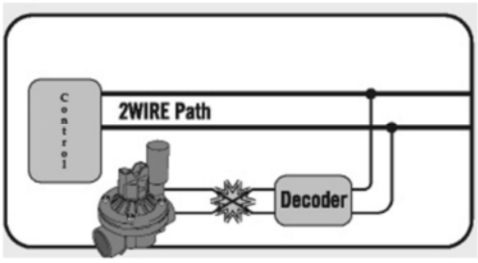
- All decoders up to the open will work, those beyond will not
- Equivalent to a break in the common line in a multi-wire system



TWL Irrigation & Underhill

2Wire cable faults
Short circuit solenoid

- Short only shows up when a decoder is operated
- Sometimes stops the system working afterwards due to voltage loss down the main 2 wire path, preventing an off command from reaching the decoder.
- Some 2Wire systems are cleverer, will report a fault and not try to turn on the solenoid



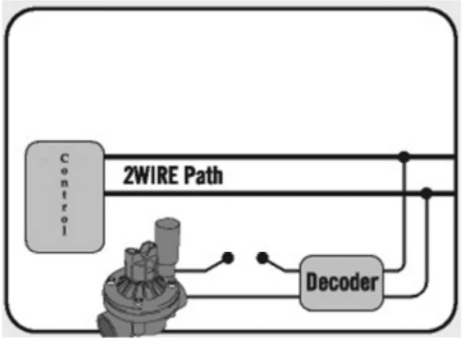
TWL Irrigation & Underhill

This depends on the type of controller used. Some will detect a faulty solenoid before operating it and signal a fault. Others will use an emergency off command which gets through anyway.

All types will indicate a fault on that station.

Open circuit solenoid or dead decoder

- Station does not respond
- Can also be a dead decoder

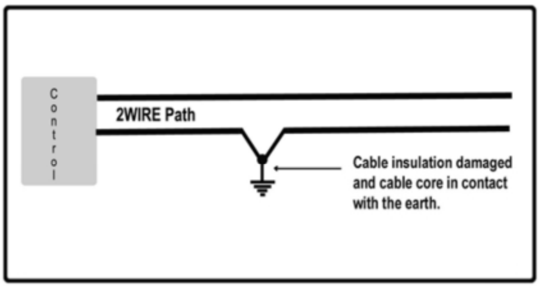


TWL Irrigation & Underhill

Controller will indicate a fault on that station.

Cable leakage to earth

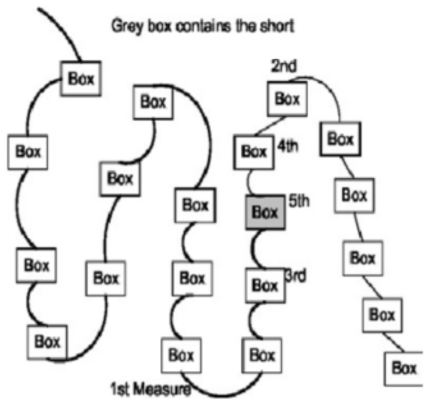
- When a cable or joint is not well insulated, some electricity can leak to earth. This causes problems for some controllers, either refusing to control at all, or sometimes giving erratic operation, leading to the controller being suspect.
- **Earth leakage must be repaired first** as it can interfere with the diagnosis of other faults.



TWL Irrigation & Underhill

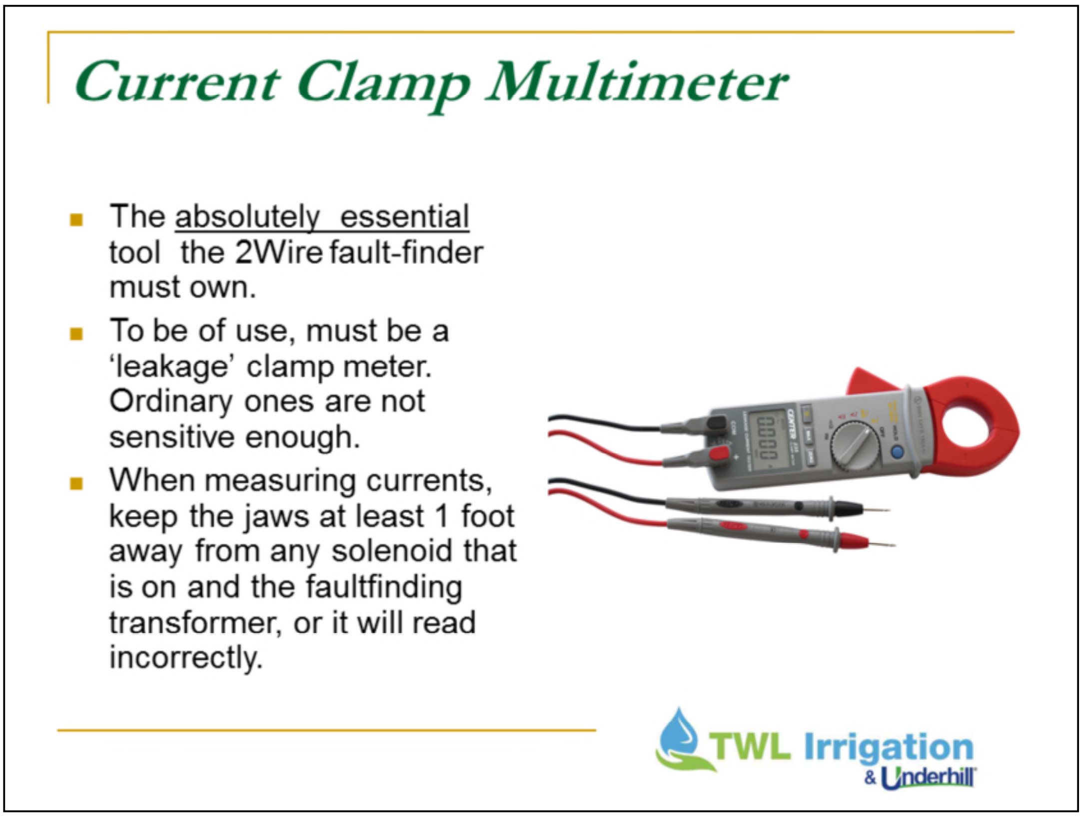
The 'Halving Procedure' minimizes the number of measurements to be made

- Usable for any type of cable fault. Shorts, opens, high resistance joints or cable leakage to ground.
- Start halfway. Make the measurement.
- Decide which half the problem is in.
- Go halfway on the problem half. Repeat
- Using this technique, 20 boxes can be covered in just 5 measurements.. See diagram.



TWL Irrigation & Underhill

Tests must be done with loops temporarily broken as the 'halving procedure' doesn't work on loops



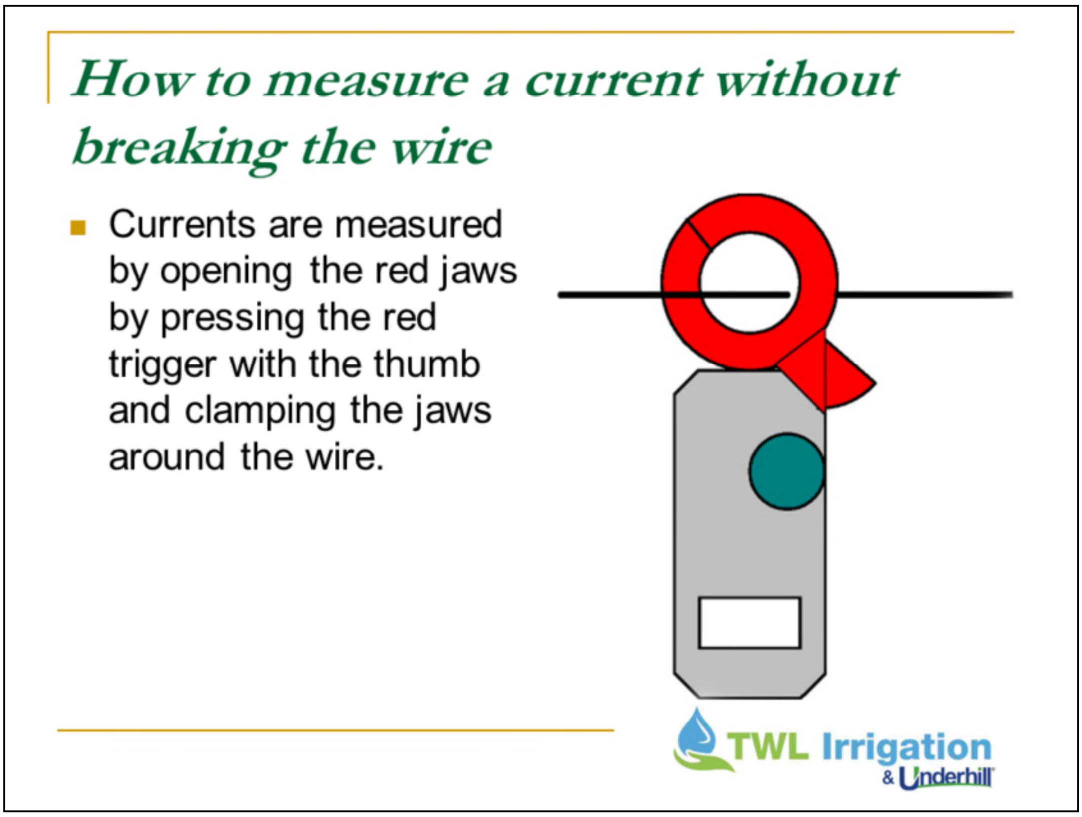
A sensitive current measuring capability without breaking the wire, called a **<u>Leakage Clamp Meter</u>** absolutely indispensable when servicing and faultfinding 2 wire systems.

The 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.

When measuring currents, keep the jaws at least 1 foot away from any solenoid that is on and the faultfinding transformer, or it will read incorrectly by picking up the stray magnetic fields.



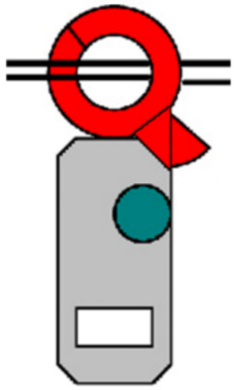
Principle of Operation.

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.

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.

Normally place the clamp around just one of the wires, not both.

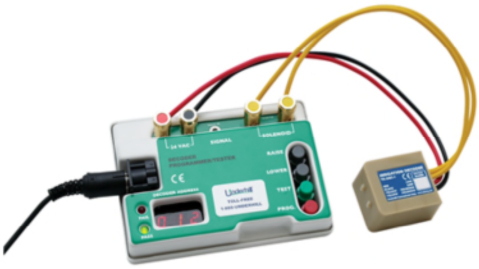
- It is important to understand that if both flow and return wires carry the same current and are placed inside the jaws, ***the multimeter will read zero***



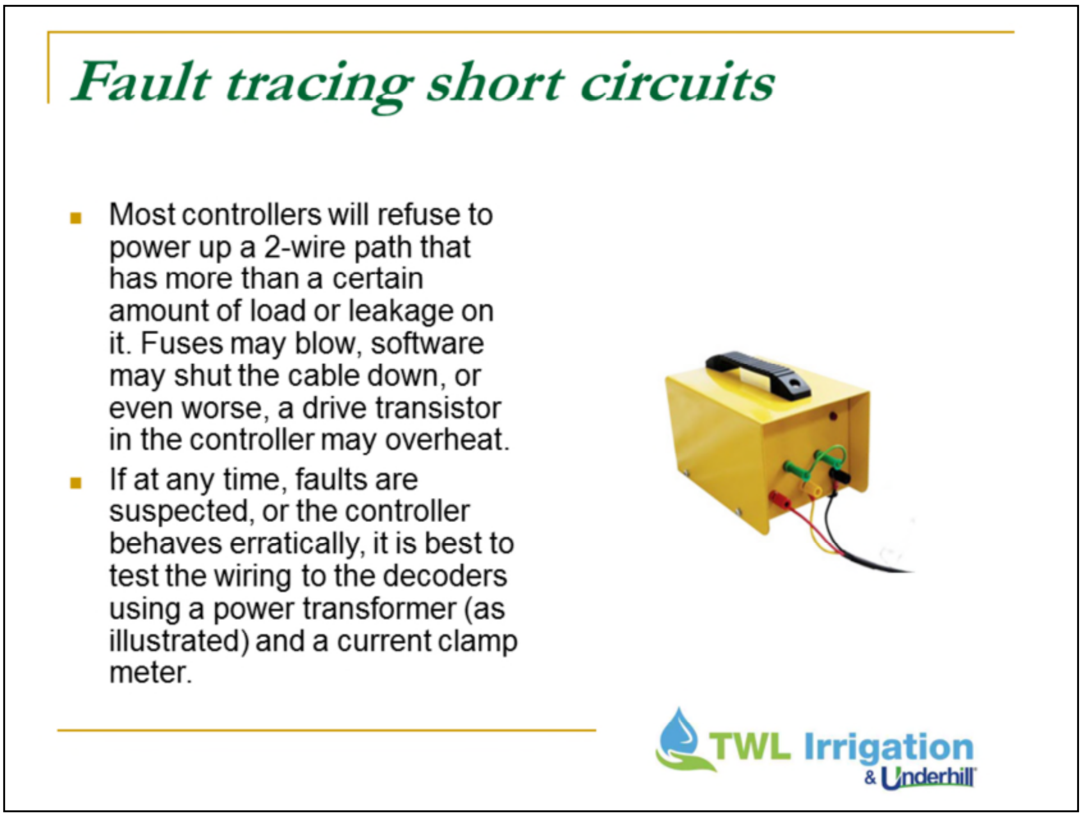
When the test equipment system is set up for testing earth leakage, the flow and return will have different currents in them as some is leaking back through the ground, therefore the meter will read the difference in the two conductors = leakage through the earth.

Testing a decoder

- All decoder manufacturers offer a decoder tester/programmer
- The tester may be used to enter the decoder's station number before installation
- To be of use, the tester must be low cost or not enough will be available for each crew
- Some decoder controllers have a built-in decoder tester/programmer.
- The new TW/NG family of decoders have a built-in NFC interface. This can be accessed using an ordinary cellphone and a free App to test the decoder and its solenoid
- Tamper protection is built-into the App



TWL Irrigation & Underhill



A big power transformer, such as the one illustrated plugs into the 115V or 230V power and produces 30V AC at up to 6 Amps to power up the 2wire 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.

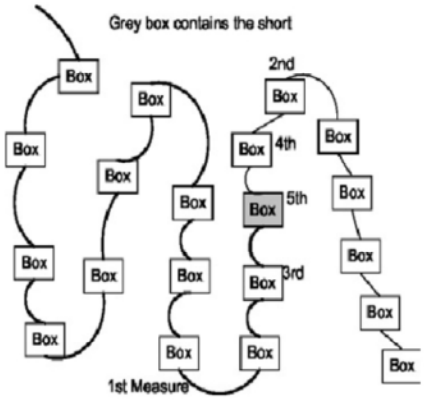
30VAC is not known to damage any 2Wire decoder type.

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 a spare solenoid, the transformer allows fault finding with the minimum of effort and confusion.

Beyond the short, the current will be much less

- 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.
- To measure the short circuit currents, place the current clamp over just one of the 2 wire path wires.



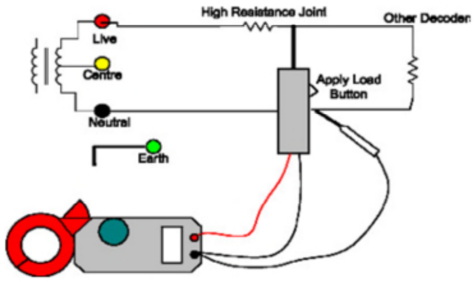
TWL Irrigation & Underhill

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 2 wire path 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

- Connect the transformer live and neutral to the 2wire path
- Go halfway down the line, expose the wiring joints
- Measure voltage across the line, with and without a solenoid load
- The picture right, shows a push-button solenoid load simulator. A spare solenoid will do just as well.
- A volt drop more than 3 or 4 volts under load indicates a high resistance joint upstream.
- Go halfway down the faulty half and repeat
- Using the halving technique, you can cover 20 boxes using 5 measurements



High resistance joints can be identified by connecting the transformer then measuring the voltage down the cable at each joint with the load probe or a spare solenoid 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.

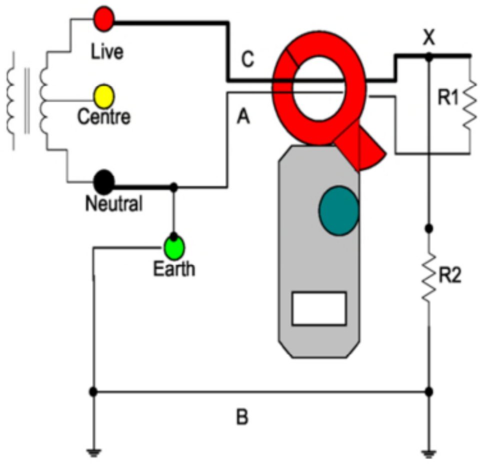
Set the meter to Volts AC (V~). When the 'apply load' button is pressed on the probe or the solenoid is attached, the voltage will drop. A voltage drop exceeding about 3 or 4 volts indicates a high resistance in one of the joints. As you travel back towards the transformer, you will eventually pass the bad joint and the voltage drops under load will go back to normal.

In a 2wire 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.

Tracing leakage to earth

- The transformer and the clamp meter can be used to easily find earth leakage. With one side of the transformer grounded (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 C. 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.

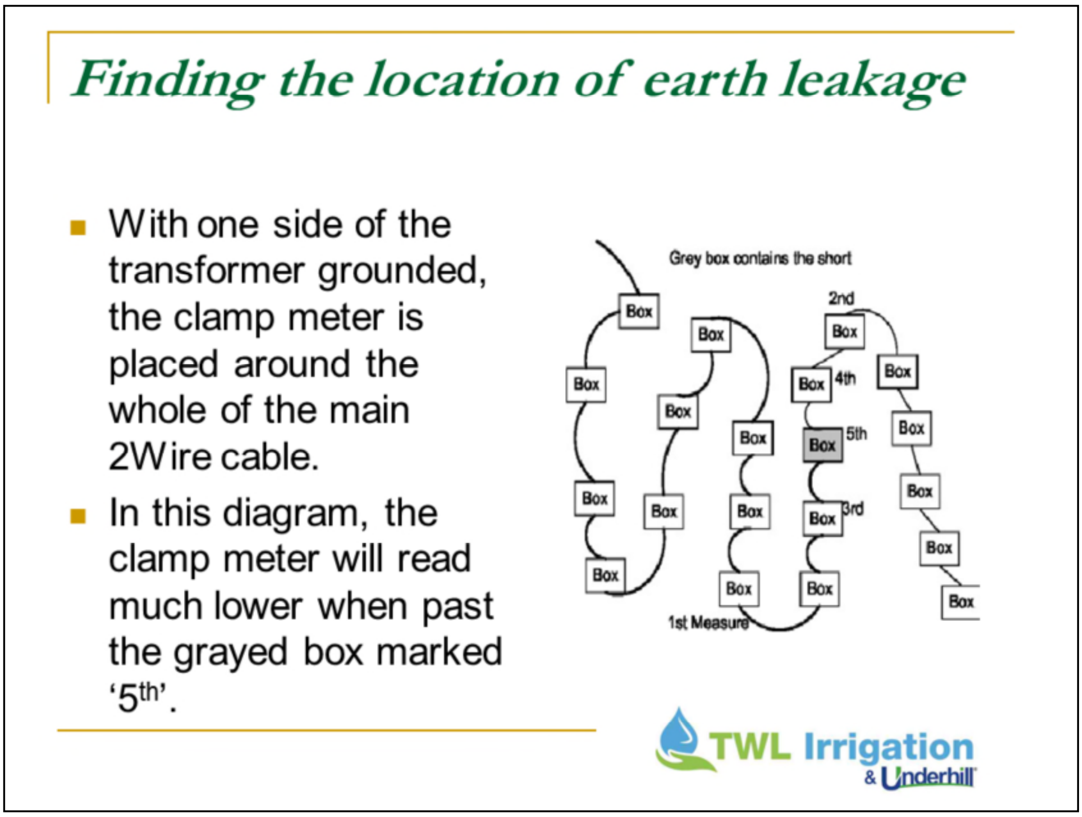


TWL Irrigation & Underhill

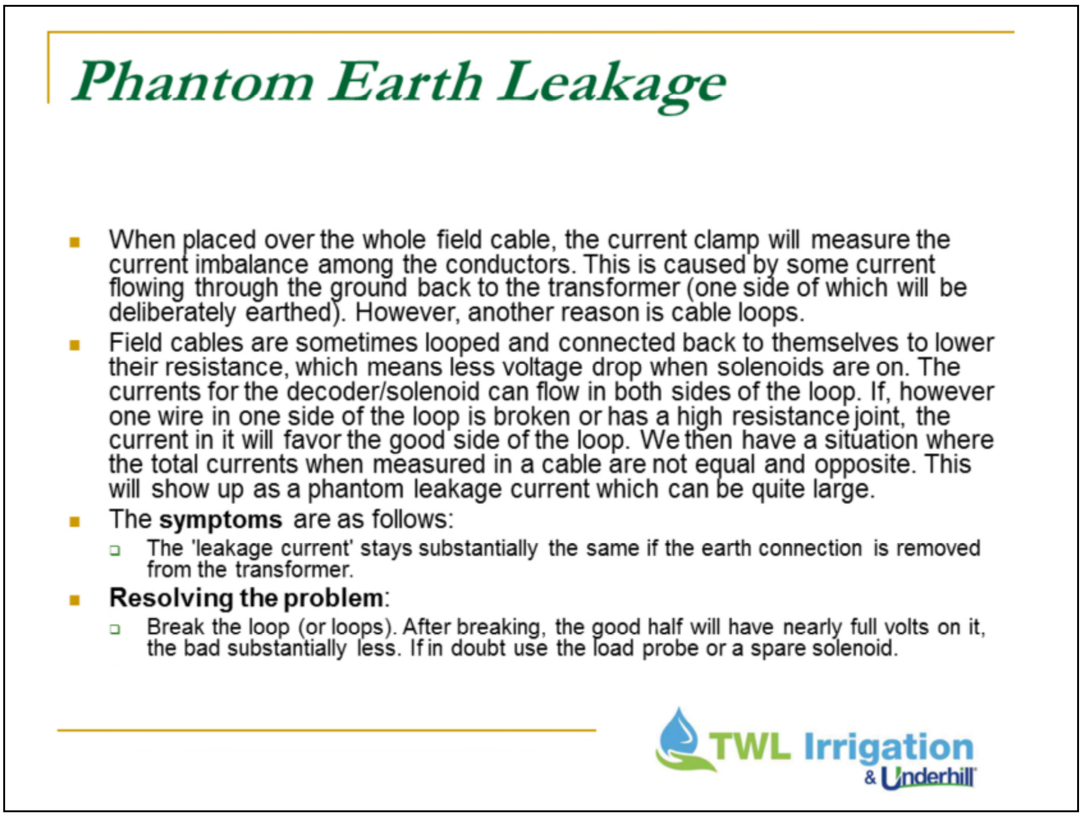
Place the clamp meter over whole main 2 wire cable. Connect the green earth link to the terminal on the transformer that produces the greatest reading on AC mA. Go out on the course placing the clamp meter round the whole main cable. When the leakage reading drops significantly you are past the leakage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

Note: When identifying which of the 2 conductors are leaking to earth. The side giving the lowest leakage when plugged into the green, is the side that is leaking.

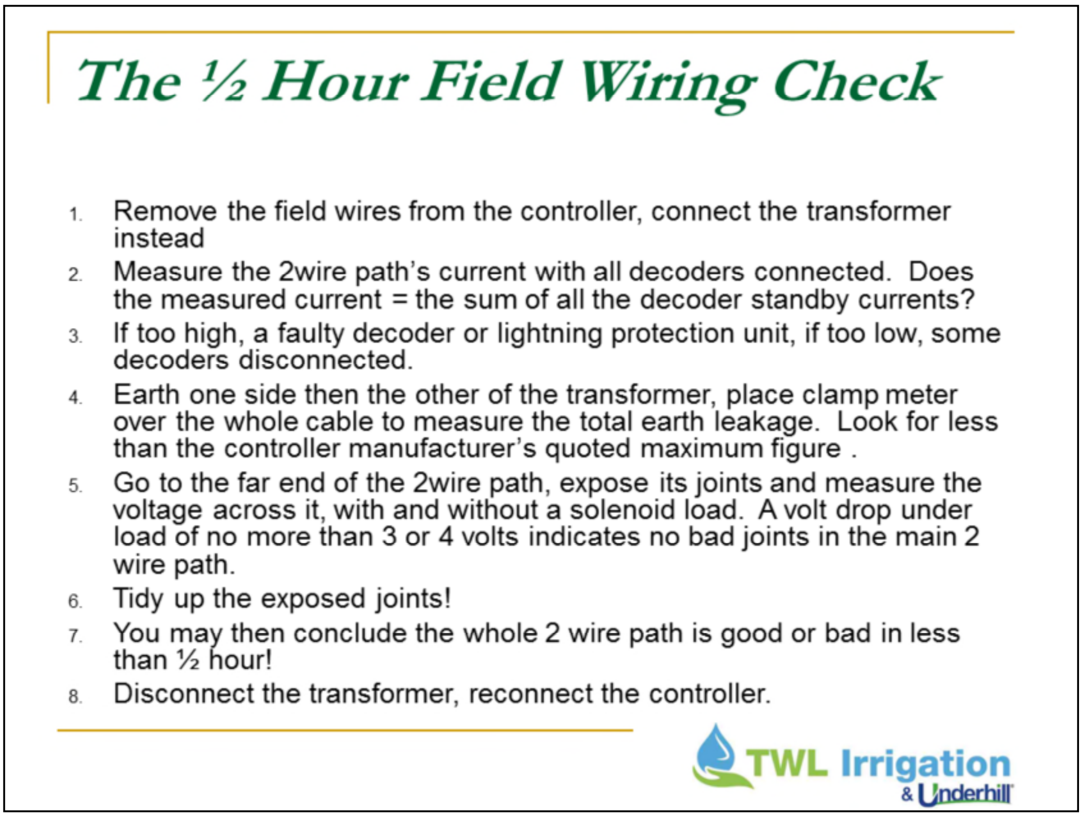
Most controllers will tolerate a few milliamperes leakage to earth, but the purse AC ones usually considerably larger, hence preffered to be used into original field wiring.



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 2 wire path cable. When the leakage reading drops significantly you are past the leakage fault, i.e. it is between you and the controller.



Any other tests are best done with loops broken as the ‘halving procedure’ doesn't work on loops. When finally rejoining the loops, check the resistance and loaded voltage with the load probe



Make sure to handout the BasicWiringCheckout.pdf, student worksheet along with the handouts for the slides.

½ Hour cable check. Conclusions

- If the wiring system passes all the above tests, it is safe to reconnect the controller and proceed with a station decoder test. Obviously for multi 2 Wire path 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.

TWL Irrigation & Underhill

Mapping 2Wire Cables

By Tony Ware B.Sc.
Chief Designer,
TWL Irrigation Ltd

TWL Irrigation & Underhill

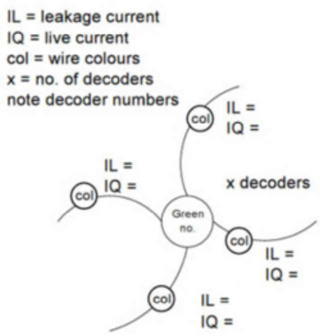
No 'As-Laid' Plans? Alas!

- The transformer and clamp meter can be used most successfully to map out the sequence that boxes are wired.
- This is most useful where the wiring information is lost or forgotten.
- Although the actual path of the wires between boxes cannot be mapped using this technique, the order in which boxes are connected can be of great assistance in general faultfinding.

TWL Irrigation & Underhill

Mapping Procedure:

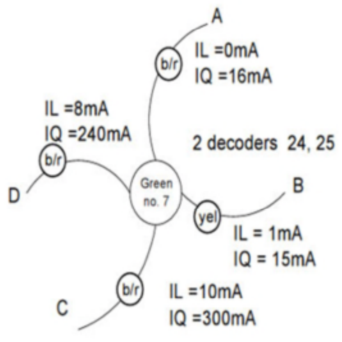
- Connect the transformer red terminal to the live field power wire, the black to the neutral. Place the transformer's green jumper lead into the yellow terminal and one of the green terminals (grounded centre tap).
- Visit each box in turn. Mark it's approximate geographical position on a sketch map. Write down the following information next to each box on the sketch.
- To note the current in each live wire. Place the clamp meter round just that wire.
- To note the leakage in each of the main cables, place the clamp meter around the whole main cable.
- After all the boxes have been visited, copy the sketch map onto one sheet of paper with each of the boxes looking something like this:



TWL Irrigation & Underhill

An example of a box's readings

- In this example 'b/r' is a black/red pair with no sheath; 'yel' has a yellow sheath
- Branch A is taking 16mA, but has no leakage current
- Branch D has 240mA and a leakage current of 8mA
- Branch C has a current of 300mA and leakage of 10mA
- Branch B has a current of 15mA and leakage of 1mA
- C is the biggest current so is the main cable incoming from the transformer
- D is the next biggest so is the main cable outgoing.
- A and B must be branches leading to other decoders.
- In this example, each decoder takes 15mA when not powering a solenoid, so….
- Branch B has 1x 15mA = 15mA. That is, it has 1 decoder on it
- Branch A has 16mA, so it almost certainly has another 1 decoder on it too.
- Branch D has 240/15=16, so probably 16 decoders further on.



TWL Irrigation & Underhill

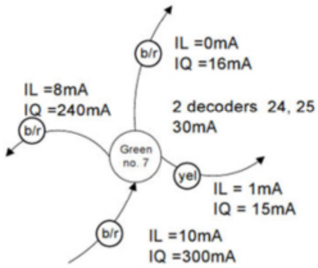
Branch or loop?

- When more than 2 cables are in a box, there may be a branch or it could be the other end of a loop coming back.
- Disconnect all cables from each other.
- With the clamp meter set to AC volts and using the probes:
- The cable with volts on it is the incoming.
- Re-attach one other cable to it.
- Check the voltage on the other unattached cable(s).
- Any unattached cable with volts on it is the returning cable from the loop.
- If no volts on it, it is a spur.
- Re-attach the remaining cables one by one, checking volts on any unattached ones as before.

TWL Irrigation & Underhill

What to do when all the readings are collected

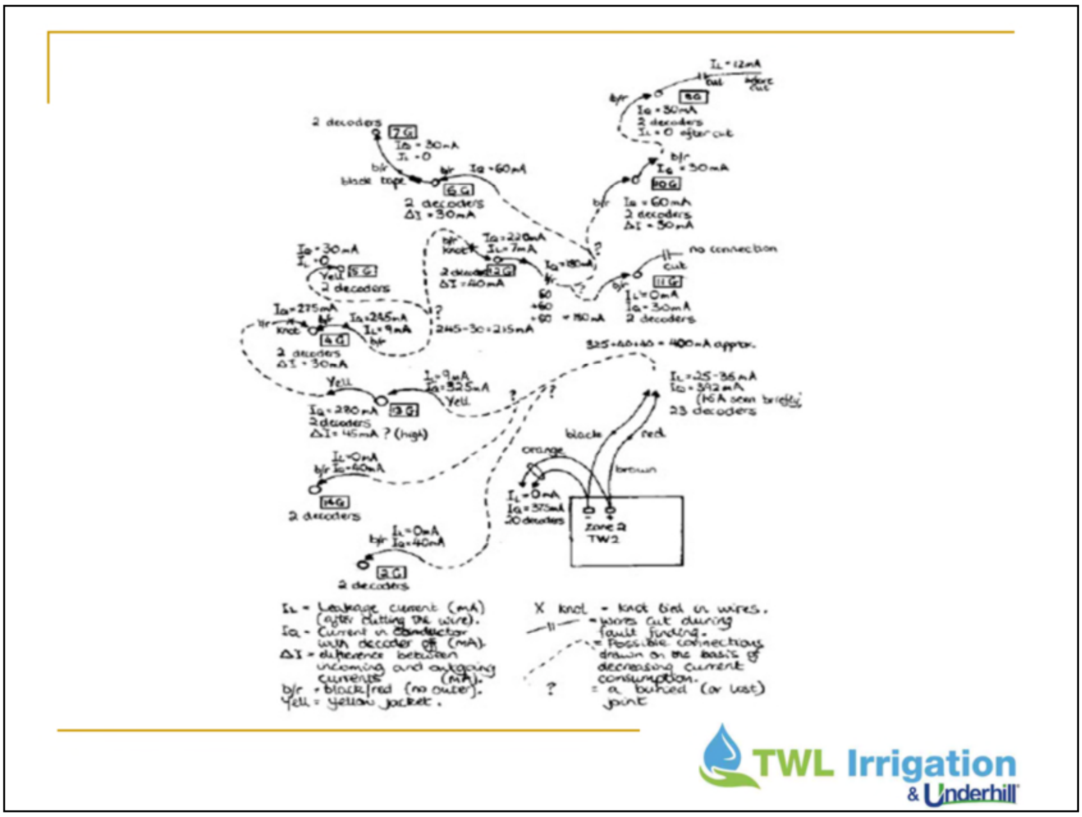
- Draw arrow heads on the wires to remind yourself which way they go
- Having filled in the detail it is now necessary to join the boxes in the diagram. In the above example you would be looking for another box not too far away that has an incoming main feed of approximately 240mA and a leakage of about 8mA. Thus, most of the boxes can be joined quite easily in an order of descending IQ.
- The only slight problem is when there are buried or lost cable joins. In this case, there will not be a box with an incoming IQ of 240mA but something less. The amount will however be a rough multiple of (in this case) 15mA. Say it was 195mA. The difference is 240 - 195 = 45mA. 45 / 15 = 3. So there is probably a buried spur between the 240mA and 195mA boxes which has around 3 decoders on it.
- Using this kind of thinking it is possible to identify the cabling order on most, if not all the boxes. Obviously keeping this kind of information safely for the next visit makes faultfinding 'a breeze' next time!



A real example from a golf course

- On the following page is a reproduction of a field map drawn on a golf course. The picture illustrates the information recorded as described in this section.
- The service engineer wrapped coloured tape on the main incoming and outgoing cables to identify them for another time
- Note that the currents do not always add up exactly and that decoder standby currents do vary.

TWL Irrigation & Underhill



This is an example taken from a real golf course