

APPLICATION NOTE

The Sizing of Cables for Decoder Systems.

This application note seeks to help define the required copper core size of cables to be used with decoder systems.

There is a technical limitation on the number of solenoids that can be concurrently active on one control cable. This is analogous with the sizing of a hydraulic pipe to carry a desired water flow to remote sprinklers.

In electricity, voltage, volts is analogous with pressure, current Amps (A) or (mA) with flow and resistance (Ohms) with pipe friction losses. The relationship is $V=I.R$ where V is volts, I is amps and R is Ohms. This is called Ohms Law

Each solenoid, like a sprinkler, consumes current (flow), usually around 0.25 Amps, or in milliamps 250mA (1000mA = 1 Amp) at 24V applied. It is usual to provide a minimum of 18V for successful operation of a solenoid.

For example, one solenoid would drop a voltage through 10 Ohms of cable resistance given by $V=I.R$ $V = 0.25 \times 10$ $V = 2.5V$.

If in this example, if the controller produces 30V, then the voltage at the solenoid will be $30 - 2.5 = 27.5V$ ignoring any losses through the decoder.

In addition to solenoids, each decoder takes a small but significant current when it is powered up and listening for 'On' signals. This is called a quiescent or standby current. Although small, a large number of decoders will reduce the available currents for solenoids.

The Metric cable standards are 2.5mm², 4mm² and 6mm² cores of copper cross sectional area. These have two-way (out + return) resistances of approximately 16 Ohms/1000m, 10 Ohms/1000m and 6.6 Ohms/1000m.

The nearest corresponding American Wire Gauge (AWG) is 14, 12 and 10 respectively. These have two-way (out + return) resistances of approximately 5 Ohms/1000ft, 3.3 Ohms/1000 ft and 2 Ohms/1000ft.

The prospective voltage drop calculations, if done exactly, would require a complex spreadsheet and accurate models of solenoid and decoder current/voltage relationships and their positions on the cable, which would be most onerous. Alternatively, the following approximate technique can be used, then de-rated.

Page 2 has a USA units example, whilst page 3 a Metric units example.

APPLICATION NOTE

USA Units Example:

Assume the decoders are uniformly distributed along the cable. The average voltage drop due to their quiescent currents can be approximated by placing the lumped total current half way along the cable.

A typical cable would contain up to 60 stations.

If they were all single output decoders, the total quiescent current would be $60 \times 7\text{mA}^* = 420\text{mA}$, say 400mA.

So, 400mA total on, say, a 5000' cable of 14 AWG.

Put 400mA load at $\frac{1}{2}$ of 5000' = 2500ft.

Cable resistance at 2500' is $2500/1000 \times 5 \text{ Ohms} = 12.5 \text{ Ohms}$.

Using Ohms Law

$V = I.R$ so average drop is $400/1000 \times 12.5 = 5\text{V}$ due to decoders alone.

The Translator sources 30V approx at full load. The decoder/solenoid needs 19V minimum. Therefore, max. voltage drop allowed is $30-19 = 11\text{V}$.

In this example there is a drop of 5V through decoder quiescent currents, this leaves $11-5 = 6\text{V}$ for drops due to solenoids.

For decoders at the far end of the cable, the max. allowable current draw can be calculated:-

At 5000ft, the cable resistance is $5000/1000 \times 5 = 25 \text{ Ohms}$

Using Ohms Law

$I_{\text{max}} = V/R$ $I_{\text{max}} = 6/25 = 0.24\text{A}$ maximum.

This illustrates that it is only possible to turn on one solenoid (0.25A/250mA rating) at the end of 5000 ft using 14 AWG wire.

With 10 AWG, the results are much better.

Average resistance = $\frac{1}{2} \times 5000' = 2500/1000 \times 2 \text{ Ohms} = 5 \text{ Ohms}$ at 2500'

Decoder currents: $400/1000 \times 5 = 2 \text{ volts}$ average drop due to decoders alone.

Max drop allowed, $11\text{V} - 2\text{V} = 9\text{V}$ for solenoids.

At 5000' with 10AWG, cable resistance = $5000/1000 \times 2 = 10 \text{ Ohms}$

Using Ohms Law, as before,

$I_{\text{max}} = V/R$ $I_{\text{max}} = 9\text{V}/10 \text{ Ohms} = 900\text{mA}$ maximum current draw from solenoids when using 10AWG at 5000ft.

* (This 7mA applies to Tonick TW/WM. Other decoders take different currents. Multiple output decoders have the same quiescent current as a single.)

APPLICATION NOTE

Metric Units Example:

Assume the decoders are uniformly distributed along the cable. The average voltage drop due to their quiescent currents can be approximated by placing the lumped total current half way along the cable.

A typical cable would contain up to 60 decoders. If they were all single output, the total quiescent current would be $60 \times 7^* = 420\text{mA}$, say 400mA.

So, 400mA total on, say, a 1500m cable of 2.5mm^2 .

Put 400mA load at 750m.

Cable resistance at 750m is $750/1000 \times 16 \text{ Ohms} = 12 \text{ Ohms}$.

Using Ohms Law

$V = I.R$ so average drop is $400/1000 \times 12 = 4.8\text{V}$ due to decoders alone.

The Translator sources 30V approx at full load. The decoder/solenoid needs 19V minimum. Therefore, max. voltage drop allowed is $30-19 = 11\text{V}$.

In the example there is a drop of 5V through decoder quiescent currents, this leaves $11-5 = 6\text{V}$ for drops due to solenoids.

For decoders at the far end of the cable, the max. allowable current draw can be calculated:-

At 1500m of 2.5mm^2 , the cable resistance is $1500/1000 \times 16 = 24 \text{ Ohms}$

Using Ohms Law

$I_{\text{max}} = V/R$ $I_{\text{max}} = 6/24 = 0.25\text{A}$ maximum.

This illustrates that it is only possible to turn on one solenoid (0.25A/250mA rating) at the end of 1500m using 2.5mm^2 wire.

With 6mm^2 wire, the results are much better.

Average resistance = $\frac{1}{2} \times 1500/1000 \times 6.6 \text{ Ohms} = 5 \text{ Ohms}$ at 750m

Decoder currents: $400/1000 \times 5 = 2 \text{ volts}$ average drop due to decoders alone.

Max drop allowed, $11\text{V} - 2\text{V} = 9\text{V}$ due to solenoids.

At 1500m with 6mm^2 , cable resistance = $1500/1000 \times 6.6 = 10 \text{ Ohms}$

Using Ohms Law, as before,

$I_{\text{max}} = V/R$ $I_{\text{max}} = 9\text{V}/10 \text{ Ohms} = 900\text{mA}$ maximum current draw from solenoids

* (This 7mA applies to Tonick TW/WM. Other decoders take different currents. Multiple output decoders have the same quiescent current as a single.)

APPLICATION NOTE

If voltage drop or cable resistance is predicted to be excessive, there are some well-tried ways of circumventing the problem. All the following ways can be combined if necessary.

- 1) Loop the field cable back to the Translator. This halves the resistance.
- 2) Position Translators like satellites around the course. Their communications can run several thousand feet if armoured cable is used with the armouring earth-staked every 1500ft/750m or so. Of course, mains power is needed at each Translator, as is an environment suitable for electronics.
- 3) Use more Translators on separate cables. Do not double-solenoid a decoder, put one solenoid each on a dual output decoder. Run the stations separately.
- 4) Use Translators with 40V output. However, this may not be allowed in USA, as unlike most of the world, 40V may be considered hazardous there. Most other countries allow up to 48V RMS before requiring the field cable to be placed in a duct.
- 5) Analogous to pipes of reducing diameter, combine a 6mm² (8 or 10AWG) 'main' or 'ring main' with 2.5mm² (14AWG) 'spurs'. The approximate relative cost of 4mm² to 2.5mm² is 1.44:1 and of 6mm² to 2.5mm² is 2:1

When insufficient volts are present under load, the following symptoms may be apparent.

With no solenoids on, a distant decoder could have enough voltage to respond to an 'On' command. The electrical load then increases by the solenoid current and the water turns on. The voltage then drops below the threshold where the decoder functions, so it turns off. The water turns off as fast as the valve can mechanically shut off. The voltage then recovers to its former value.

On some types of decoders, the line voltage may drop under load (or become unbalanced with respect to the third signal wire), preventing successful reception of an 'Off' command. The Translator, unlike some older controllers, will then briefly remove power to the cable, re-apply it and turn back on any decoders still required. Older controllers may just leave the decoder running.

The Translator uses a change of measured cable current to determine whether a solenoid has been turned on or off. If the voltage is very low, the change in current may be near or below the threshold set in the Translator. (See 'sensitivity' in the Translator menu). The Translator may well report 'Fail to Turn On' or 'Fail to Turn Off', until the threshold has been reduced.

If excessive cable resistance is present:

With the TW/WM or Aquarius, Two Wire series, a second decoder may not respond to an 'On' command, which it would do if it were on alone. This is due to disturbances on the signalling waveform from the inductive load of the first solenoid. This is not a problem with Tonick three wire decoders, which use a separate signal wire.