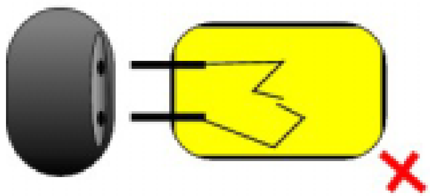
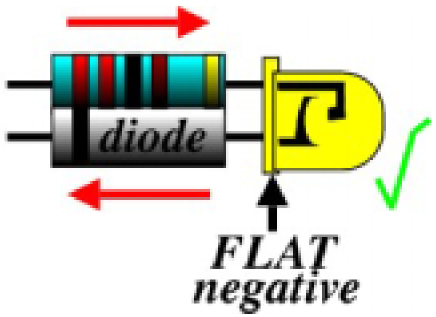
Preparing the Ground - Measurement (Mixed with a Bit of Historical Context)

A Prelude to 'Bringing Light to the Little People'   or   'Light out of Darkness'

by Phil Spiegelhalter - Solent Area Group





Introduction

One of the delights of G-Scale Garden Railways is the frequent provision of LIGHT inside carriages, wagons, and locomotives, allowing Night-time running on warm summer evenings. Of course this is not restricted to G-Scale, and the latest British N-Gauge coaches are now designed for plug-in LED light strips.

Particularly noticeable when you progress to Digital Control (MTS/NMRA dcc/Mfx) is the added benefit of Constant-Brightness or Always-On Lighting. The downside is that bulbs therefore fail more frequently ....because you are actually using them!

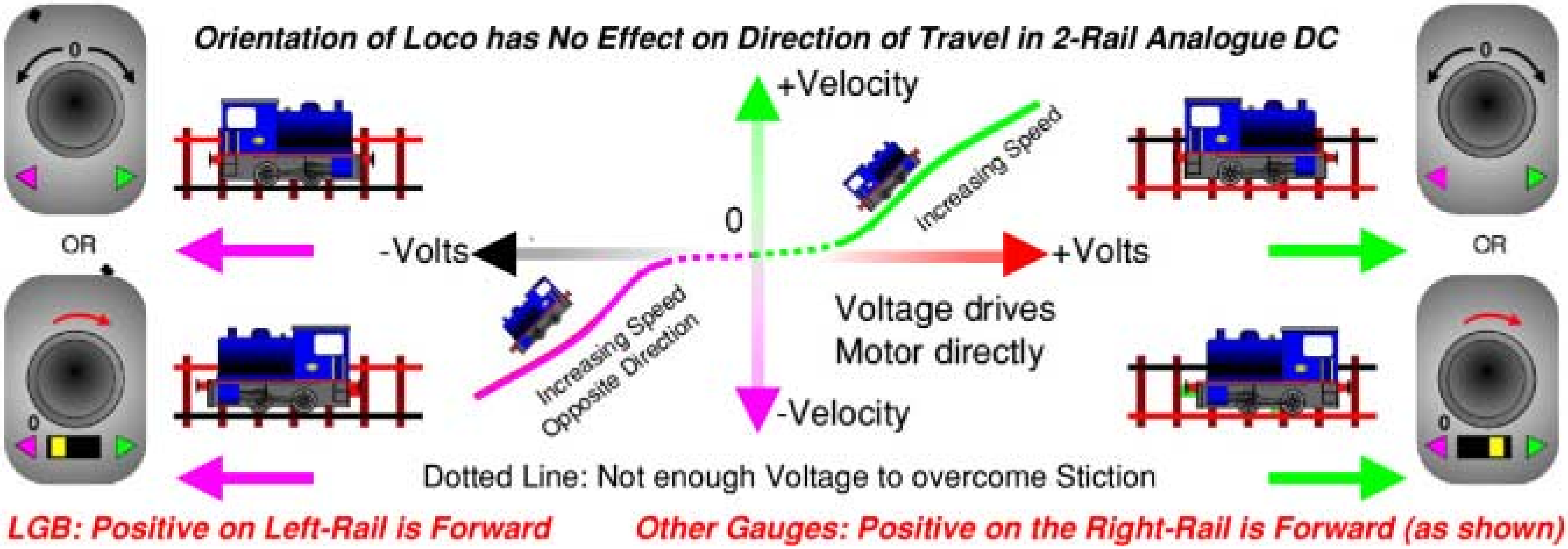
For those considering a Digital Future; it is no longer recommended to place bulbs or other resistive loads across the track without a diode/rectifier involved, as this may hinder 'RailCom'® Bi -directional Communication. Therefore, I have been progressively replacing bulbs or adding light, with LEDs (Light Emitting Diodes) which can last almost indefinitely when installed appropriately.

TRACK POWER and Voltage Measurements

Before adding LED lighting, it is useful to remember the different ways in which the trains can be powered...... and the way the voltages involved can be described.

This is important to know because the wrong voltage will destroy components!!

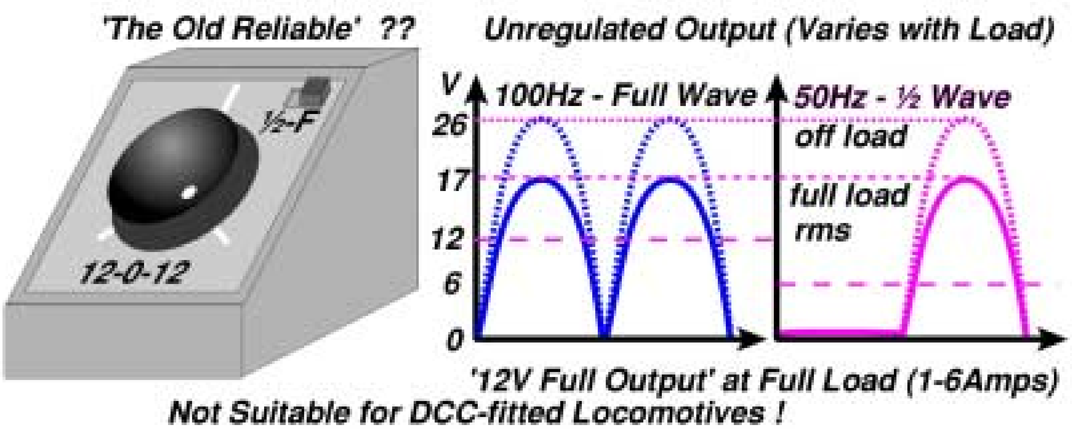
DC (Analogue) - Track Polarity Controls Direction



In the 'Traditional'/ Historical Method of DC Analogue Control shown above, a variable d.c. voltage is applied to the track.

The greater the Control Movement; the greater the voltage, the faster the train will move, and by reversing the polarity, it goes the other way. An initial voltage is usually required to overcome 'static friction'.

'Pre-electronic Era' 'old-style' controllers do not produce a smooth '12V' output; it is dc...(one direction current flow) but with a large 100Hz 'ripple' component included (or 50Hz with a ½-wave switch for more buzz and lower speed).



..So much for 'Standards'...

So that different Locomotives behave similarly despite being from differing manufacturers, common 'standards' ensure that all locomotives will travel in the same direction, albeit at differing speeds depending on gearing and motor consumption.
[The LGB difference in 'Forward' track polarity will re-appear when progressing from LGB's MTS to NMRAdcc]

There is no 'ruling body' of standards in the UK, but partial use of standards created by the NEM and NMRA.
LGB defined the original G-Scale values, and competitors generally complied, although some use '12V' motors in place of '24V', whilst others require much larger currents than the Bühler motors used by LGB.

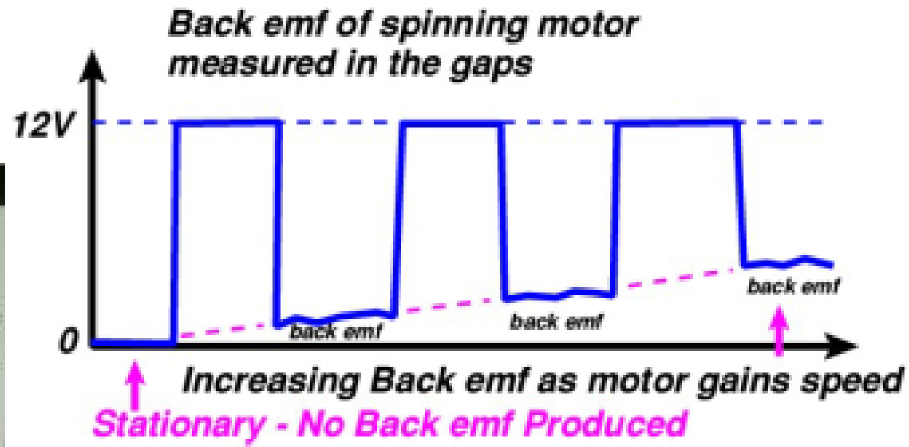
Hot Topic

Modern 'Electronic Era' controllers provide a 'regulated but variable dc output - you control the voltage, without 'restricting' the current as with earlier Rheostat-based controllers. Transistors are used to amplify the user's control signal and output it to the track.

If a transistor is used in a variable, or 'linear' manner, to control (resist) current flow, as in the 'traditional concept' controller (acting like a rheostat), the unwanted voltage is 'dropped' across the transistor, and the POWER [Power = Current × Voltage] is dissipated inside the transistor causing it to heat up; and this must dissipated to its surroundings, or it will fail! Large Components -High Price.

Efficient but some Potentially Incompatible ?

By SWITCHING the transistor(s) on and off fully, they operate much more efficiently; allowing smaller, better and cheaper devices. [From P=IV: when used as a switch, the Current(I) is either zero, so *no* power is dissipated, or the Voltage(V) across the transistor is *minimal*, therefore minimising the heating (power-loss) inside the transistor. To do this, the user-control varies the proportion of the cycle the transistor is switched-on for.

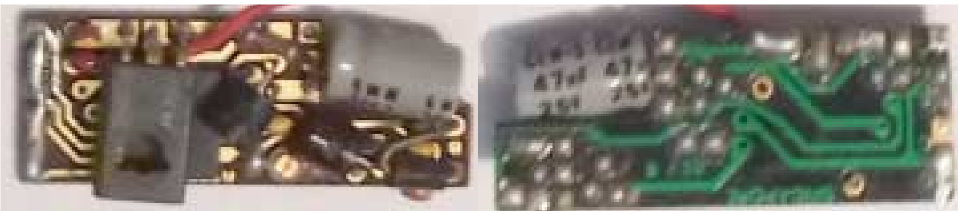


Following on from the ½-wave mode of *pre-electronic-era* controllers, early units used the same mains-based 50/60-100/120Hz low frequency for their pulse rate. These are NOT suitable for use with decoder-fitted locos, or 'Coreless Motors' because of the heavy jogging and Buzz effect of the low pulses. A decoder would have to shutdown and then reset on each 100Hz cycle of the waveform.

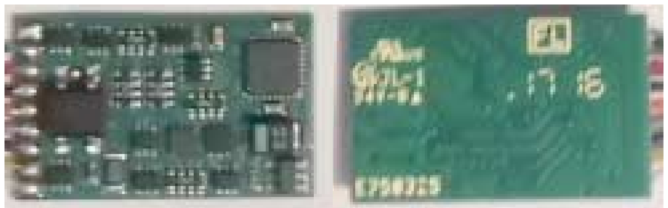
[Check when buying a new analogue-controller if it is suited for use with decoder-fitted locos]

Shrink to Fit

Integrated Circuits made smaller and faster switching available: Switched-Mode Power Supplies replaced 50-60Hz transformers, by being more energy efficient and by having regulated outputs more suited to electronic components.
The onboard Loco Decoder provides customised opportunities to control speed, lighting, sound and other functions such as uncoupling, and can now be less than 1cm^2 for smaller gauges. Production Progress in Consumer Electronics is shown below..



1980	**2016**
Zero-1	**Lenz**
Loco	**Std dcc**
Module	**Decoder**



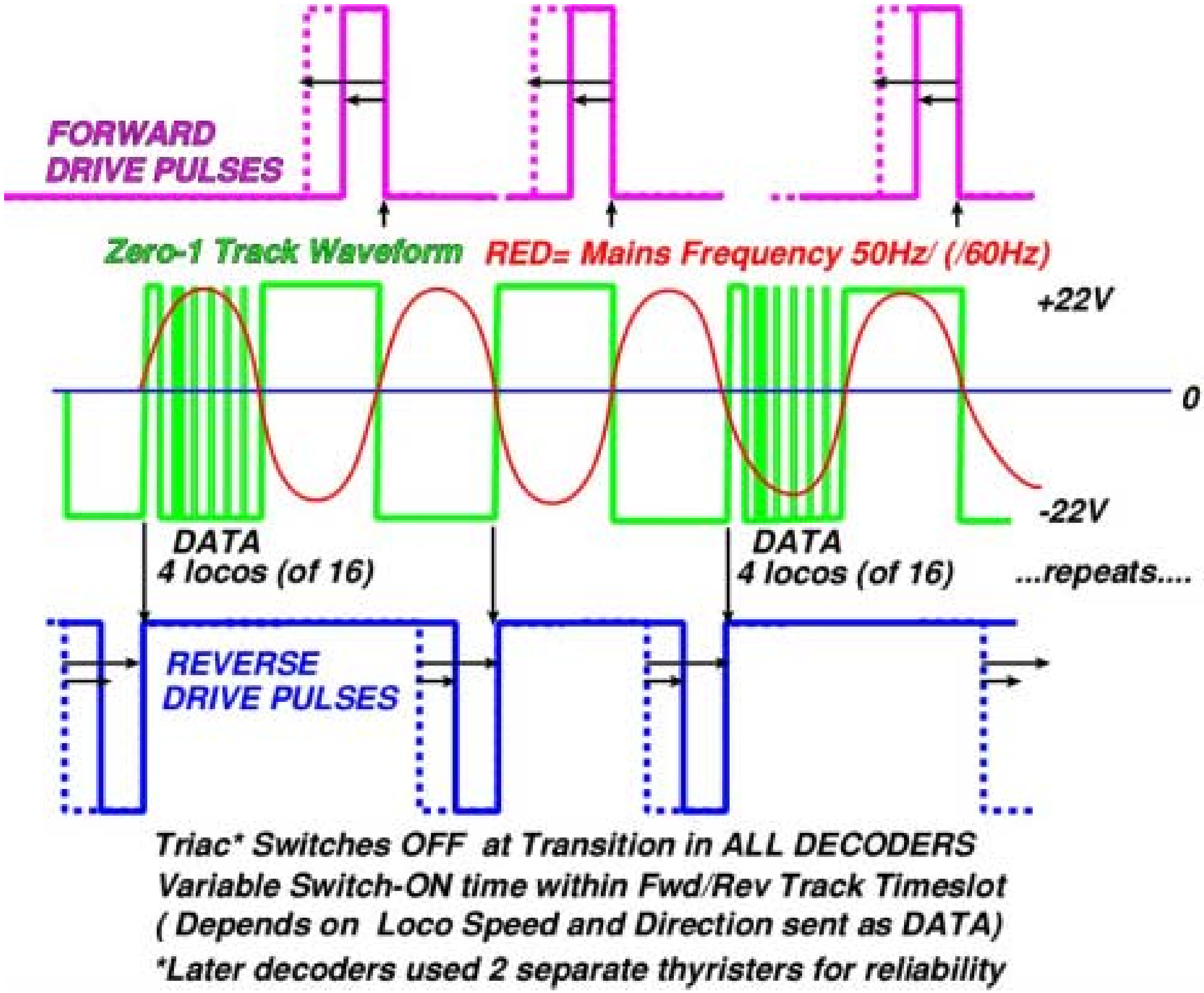
4 Coding Pins - Triac (First Generation Zero-1 Module) - TMS1000 beneath ***Both Decoders 1Amp*** **Motor and 4 functions - HF pulse drive**

Hornby Zero-1
Zero-1 was an early digital system based around 50Hz in Europe and 60Hz in the Americas - thus also producing an international incompatibility.

It used the pioneering TMS1000 SingleChip 4-bit Microprocessor, offering 16 locos, 99 accessories and 14 speed steps. A '3-wire' decoder design kept a common motor connection to the chassis, but meant that the motor-drive could only be *turned-on* during the *desired direction* power pulses.

Higher speeds were obtained by turning on earlier in the Power Pulses. All locos moving in the same direction are taking their power at the same time.

No locos took *motive-power* during the *data* timeslots, which could also be used for Accessory (Point and Signal) control.

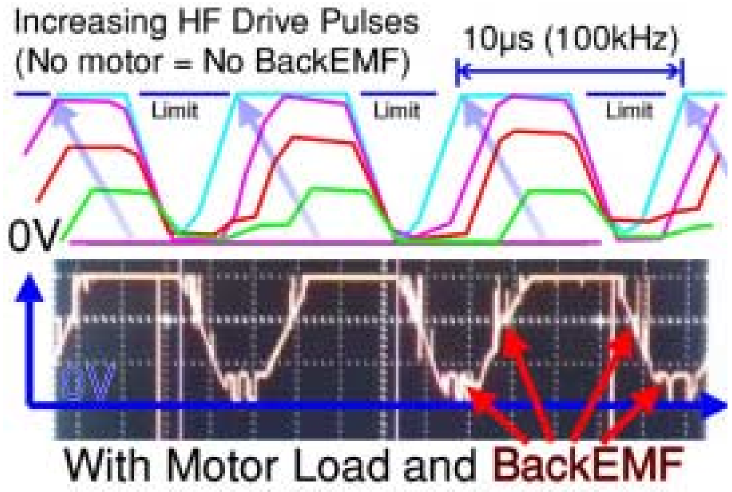


This was followed in Europe by the Motorola M80, and others, which are still supported today: including Lenz's ideas which were adopted by Arnold, Roco, LGB as MTS and then became the NMRAdcc standard, initially with 127 locos, and 14 speed steps.

High Frequency* Pulse Rate Drive

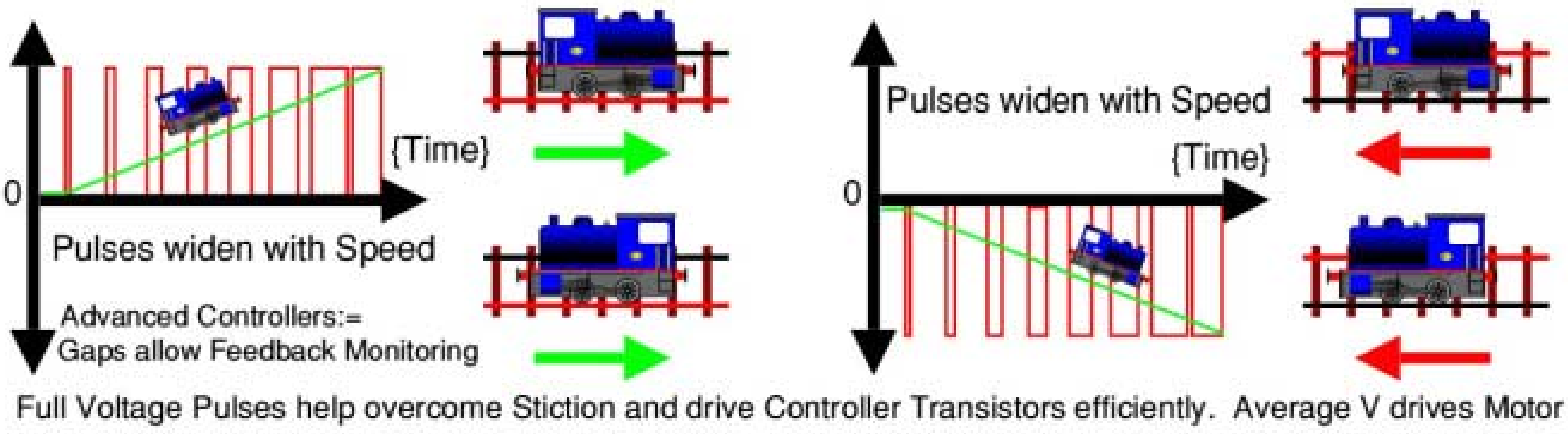
***NOT to be confused with High Frequency Track Cleaners*

Separate analogue controllers have also benefitted from the same technological advances; giving users a choice between continuous smoothed variable dc with large transistors and heat-sinks, or pulsed-outputs. Some models are switchable between both modes. The 4 channel 'series Q' controller shown here runs at 100kHz !!



It is still a good idea to confirm whether a new controller is suitable for driving decoder-fitted locos - before buying!

2-Rail: **DC (Pulse Width Modulation) PWM) - Track Polarity Controls Direction**



Feedback - BackEMF

At the highest speed; the pulses could merge together - creating a smooth full-track-voltage as before.
However, some Advanced Controllers may use the gap - *during which time the motor continues to spin, and acting as a generator, creates a varying voltage* which can be measured back at the controller as feedback! [**Back *E*lectro-*M*otive-*F*orce** (volts)]

This **back** (*opposing*) **- emf** can be measured; automatically adjusting the controller output in order to maintain a train's speed. The back-emf, *or lack of*, might also be used to warn of a stalled or overloaded motor. The photograph shows how noisy the back-emf signal is when received back at the controller via the track. If the back-emf is *measured within* the locomotive - by the onboard decoder, it is likely to be a *less noisy*, and *more reliable*, signal. The decoder can identify the motor rotation speed from the changes which occur as the motor commutates between coils, and this can also be used to synchronise on-board sound generation.

Sound

Whilst it can be irritating in some situations, the addition of appropriate sound to a railway layout can add to the sense of realism. We particularly noticed this when we started in G-Scale - visiting gardens with sound-fitted locos running in and out of sight behind 'obstructions' in the garden, and adding to the spacial effect. G, and other large-scale locos have an inbuilt advantage for adding sound, as they potentially have more internal space for the decoder, amplifier and large speaker. Mobile phones have probably helped develop miniature speakers - of small 'sugar-cube' size and similar. Sound decoders are now available from less than £40.
A separate issue, largely affecting the UK sound market, is the cost of creating appropriate sound files for British locos, as most decoder makers are based overseas. External software can also be used to 'stereo-pan' sound around a layout 'following' a train.

Alighting in the Dark ? - the original trigger for writing this !

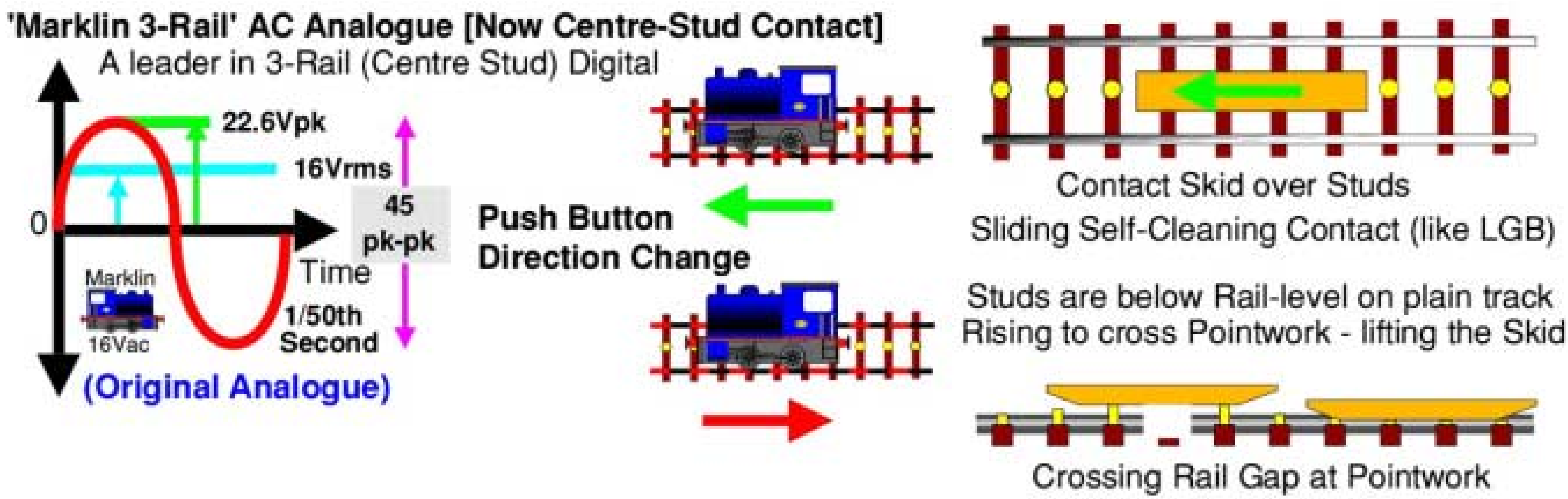
Most unrealistically, with traditional analogue, whenever the train stops for passengers to alight, it all goes dark! Super-Capacitors *can* be used to maintain the lighting or effect for a time. One of the most visible advantages of Digital Control Systems is the simple provision of constant-brightness track-powered lighting. Battery Power can be used with plastic wheels - in which case, using LEDs will make the batteries last longer. Train-Tech now produce motion-triggered LED lighting and sound modules aimed at 00/H0 and N gauges, with an integral Lithium coin cell; the lights remaining on for 4 minutes after movement has stopped.

NMRAdcc and Mfx® both allow for control of on-board lighting, sound, uncouplers, doors, operating features such as cranes etc.

Märklin H0 - 3-Rail / Stud Contact Analogue a.c. Control

Originally introduced around 1935, Märklin H0 used 3-Rail Track with a.c. motors. The outside running-rails are commoned, and this makes layout design including Reverse-Loops extremely easy: [Post-War, Hornby-Dublo 3-rail was d.c., as was Trix-Twin]
Listen to a conversation in a Continental Model Railway Shop with a 'newcomer', and the dealer may be explaining how a Reverse Loop presents no polarity problems in 3-Rail unlike 2-Rail tracks!

Märklin 3-Rail in its current form of 'Centre-Stud Contact' is still prominent on the Continent, and other manufacturers all produce a.c. versions of their locomotives. With 'C-Track', the continuous and highly visible centre rail was replaced by a small stud projecting through a sleeper in the track, and the 'locomotive pickup shoe' was replaced with a longer 'skid' contact.



An Mfx$^{+®}$-fitted Locomotive placed on the Digital Track is Automatically identified by the Central Controller, and the Controller Display then shows a picture of the Locomotive, gives it a name, and offers the correct function buttons to the user.
[RailComPlus initially from Lenz/ESU/Zimo is NMRAdcc's implementation of 2-way communication with locos and accessories.]
Although Märklin H0 is '3-rail'/centre-stud contact 'a.c.', their other gauges from Z to 1 and now LGB are all 2-rail 'd.c.' systems.
As with several other European controllers, the Märklin Central Station can operate multiple protocols: Mfx and NMRAdcc....

Modern Märklin Digital - Mfx®   Mfx^{+}®

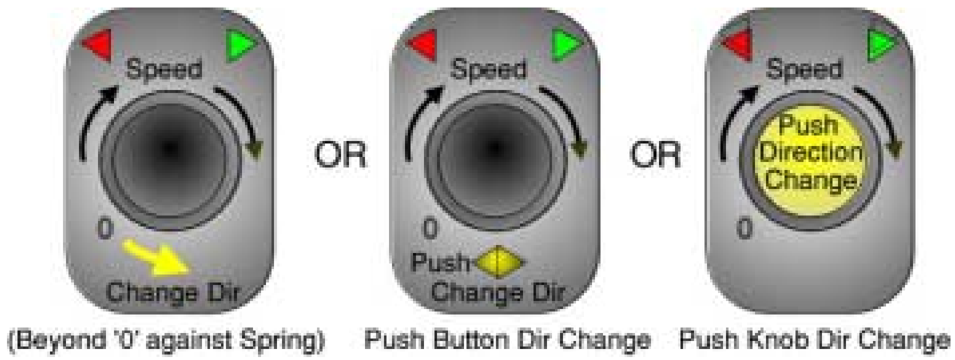
This is currently the most advanced Digital Control System, having evolved from their original 'Motorola 80' system and now addressing 65,000 devices with two-way communication: The present version of the Märklin Central Controllers 3 and 3+ offer....

Highlights

- Digital multi-protocol controller (Mfx, Mfx^{+}, DCC, Motorola).
- High resolution, modern colour touch screen.
- Built-in, central track diagram control board.
- Housing with a central stop button and 2 rotary knobs,
  - all three of industrial quality.
- Up to 32 controllable locomotive functions.
- Route control (including shuttle train control).
- 2 USB hosts such as for mouse, keyboard, USB stick, etc., and 1 USB loading socket.
- Connections for network, external speakers, Märklin Bus.
- Central Station 3 plus is multiple device capable.
- Built-in speaker.
- Built-in SD card slot.
- Built-in, powerful Booster.
- 5.0 amps max. output when using the 60101/L51095 SMPS (recommended for 1 Gauge and LGB).
- Up to 320 Motorola and 2,048 DCC solenoid can be controlled.
- 2 built-in locomotive card readers.
- Built-in s88 connection.
- Direct connect for 2 Mobile Stations and Bus expansion device.
- Expansions can be connected by means of the Märklin Bus.

Changing Direction

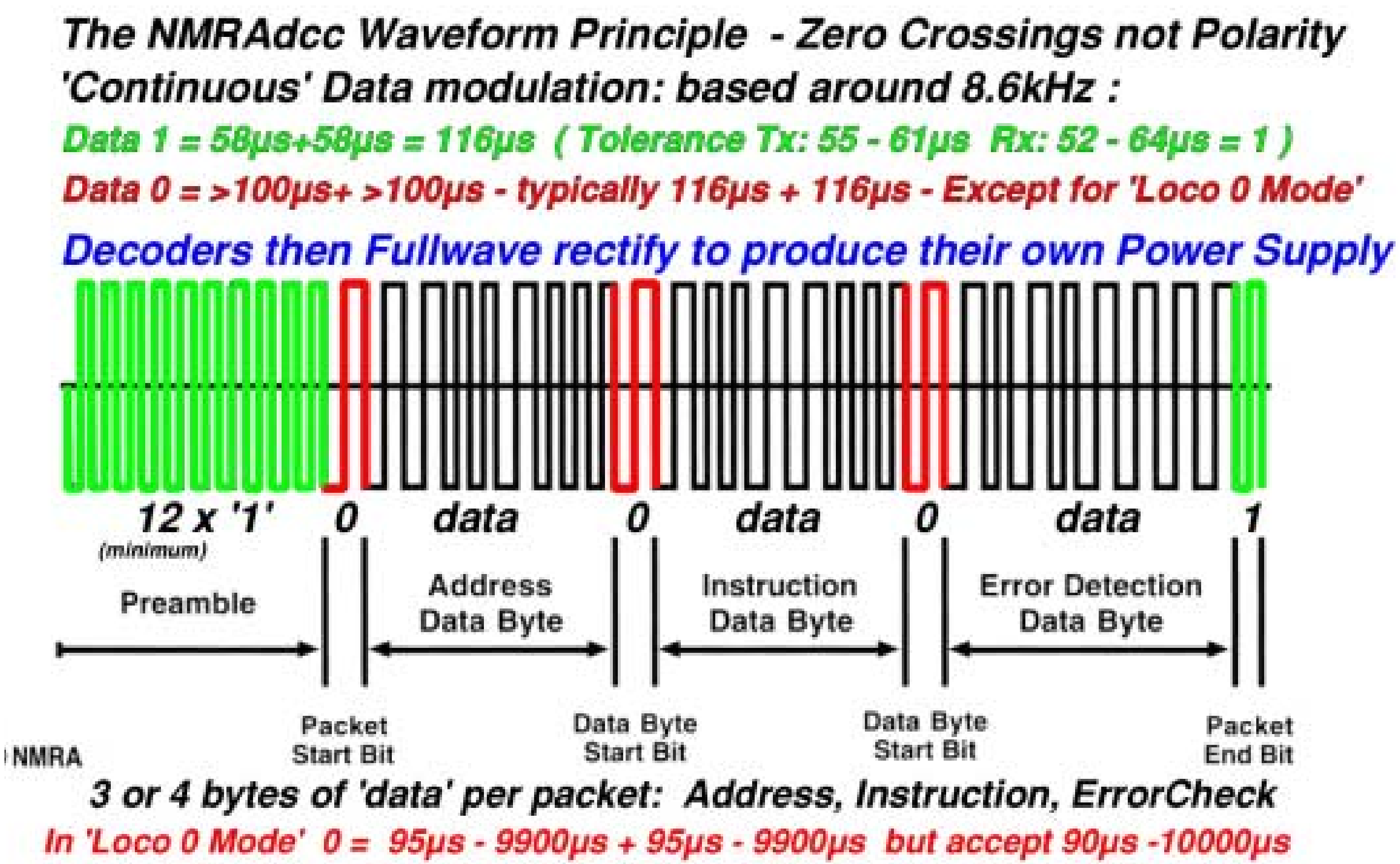
Trains on track may move *Forwards* or *Backwards*. Clockwork, Battery, 3-Rail/stud electric, Live-Steam and Radio Control locos all work on the principle that the direction that the *individual* locomotive is **facing** is the '**forward**' direction. This is continued by both NMRAdcc and Märklin Mfx Digital.



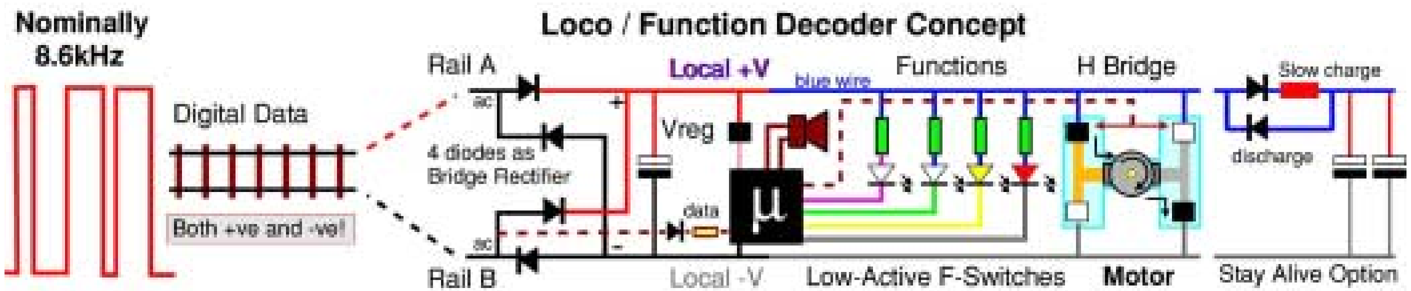
Only 2-Rail Analogue differs from this by dictating that all trains on a section of track will move 'Clockwise' or 'Anticlockwise' ***regardless*** of the way they are facing. [And LGB is the opposite direction to other Gauges]

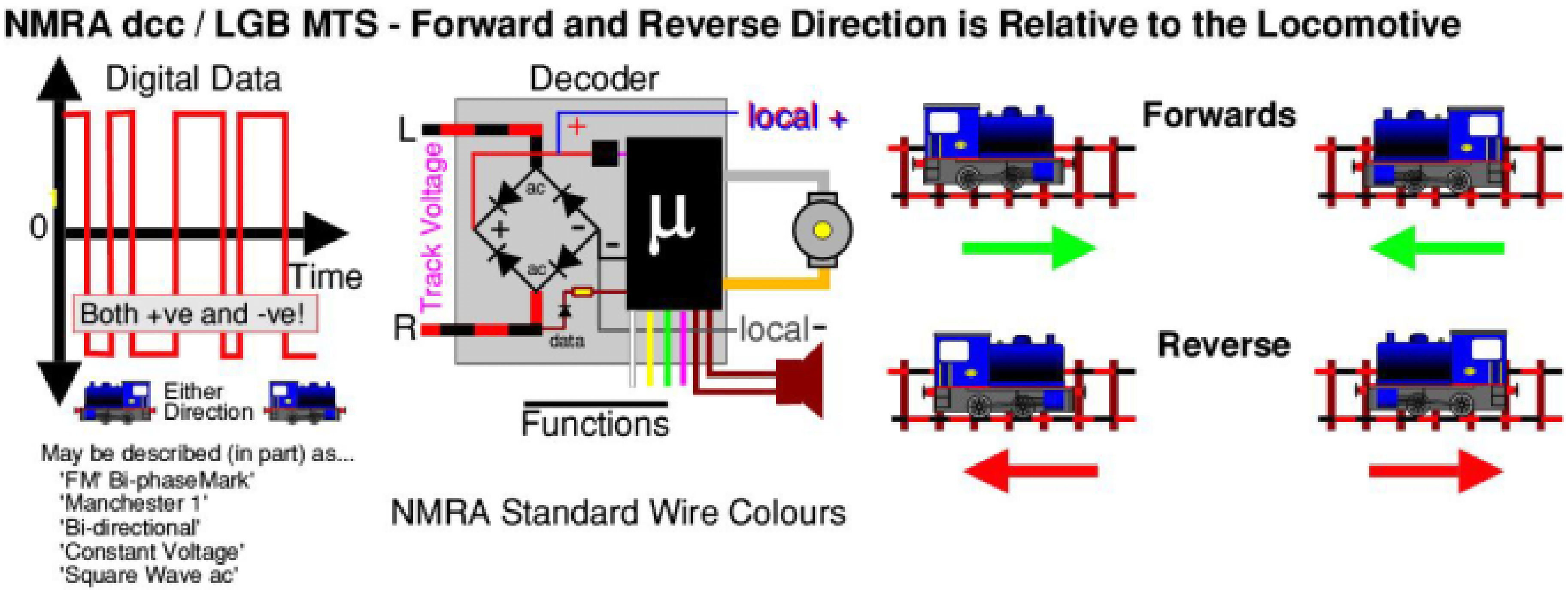
NMRAdcc Progress

Bernd Lenz's solution overcame the limitations of Zero-1 by using the Data waveform as the source of power for the Decoder. Each 'mobile' decoder full-wave rectifies the track signal to locally power itself, with its own *internal* positive and negative. The onboard software then controls the motor pulses - with both sides of the motor totally isolated from track or chassis, an H-bridge allows drive in either direction. The motor pulses from all the decoders are spread across the waveform - unlike the Zero-1 method in which all in one direction fired together!



'Loco 0' is a mode for 'analogue compatibility' with an unfitted loco driven on the track; but not recommended or available on all. The duration of the '0' is *stretched* on one polarity or the other to alter the ***average*** voltage on the track, and the (directly connected) motor responds by buzzing and getting hot at Speed 0, or moving. Not usable with Auto-Reversers.





2-Rail Digital uses a 'constant amplitude' alternated onto the track at ~8.6kHz, by data transmitted from the Central Controller'. Hence it is an a.c. waveform albeit not a 'sinewave'! Half the signal would be blocked by a diode!

It is a common misconception that because Mains Electricity is a Sinewave, that all 'a.c.' signals must be!

Audio is a very common example of an a.c. signal, in its electrical state, that you will have heard of! *No part of 'dcc' stands for 'd.c.', however, the assumption is that the motors fitted to locomotives are 'd.c. types' - but this may change in future, as Märklin / Trix already have 3 phase drive motors offering precise speed control - and existing European decoders may be compatible.*

Independent Control of Multiple Locomotives - How Many, and How Much Current?

Different Central Controllers are aimed at different markets, and are provided with differing Power Supplies and Expansion Paths.

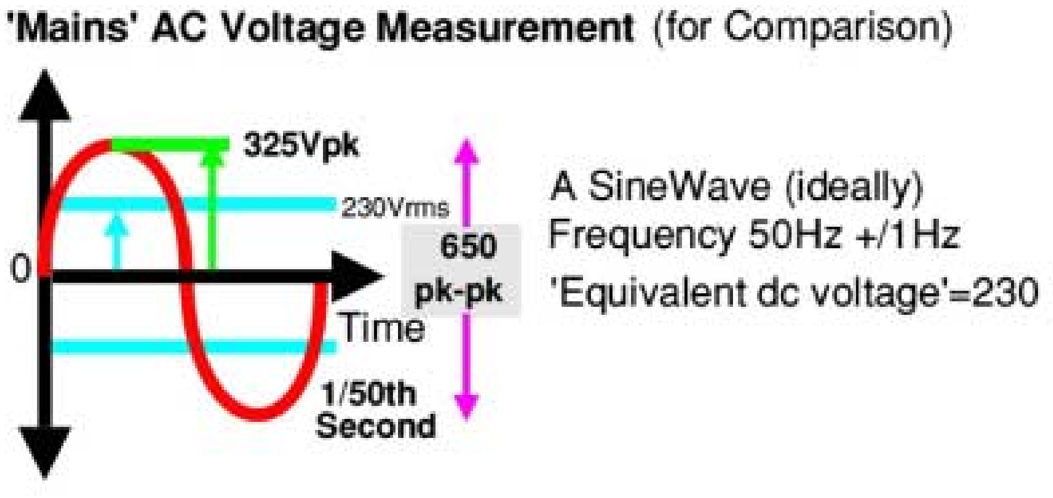
Obvious items are Boosters for extra (or replacement) Power Districts, additional handsets, consoles, and Graphic Track Displays.

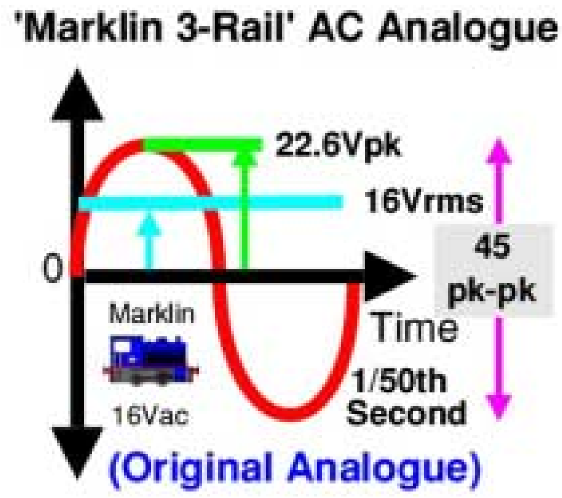
Less obvious is the number of locos which the SYSTEM repeatedly transmits data for - the 'Active' Locos - whether left moving or stationary (with Sound and Lights to be controlled). A single handset does not limit the system to running only a single train.

The more locos included, the longer the cycle time - which may then show as a slower response. The Dimax System Menu gives the user control, but most are fixed: 8 (MTS3) 16 (Roco Multimaus) 32 (MultiCentralePro). How many locos do you have **on track?**

Track Voltages: Don't get confused by the different ways the Voltage can be described....

Whereas with d.c. there is a single measurement of the notional 'maximum' track voltage which can be used to usefully describe the system {12V d.c.), there are 3 equally valid measurements used for a.c. voltage:



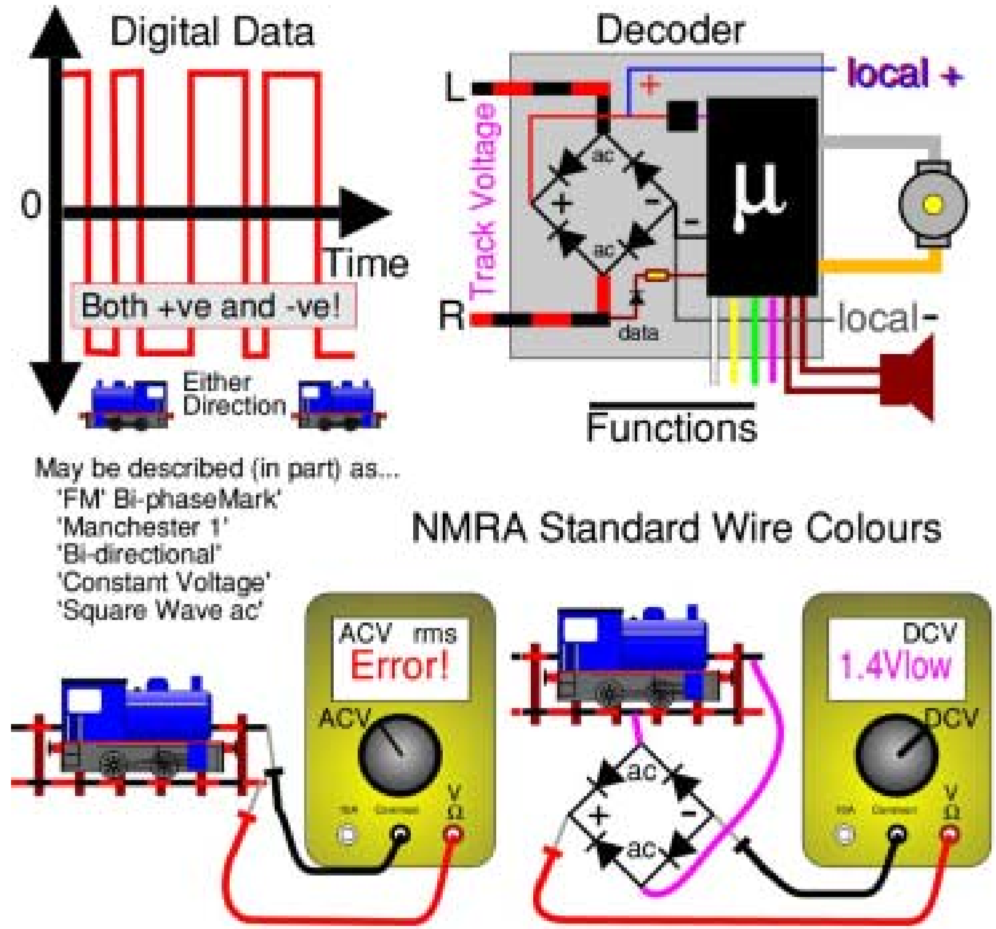


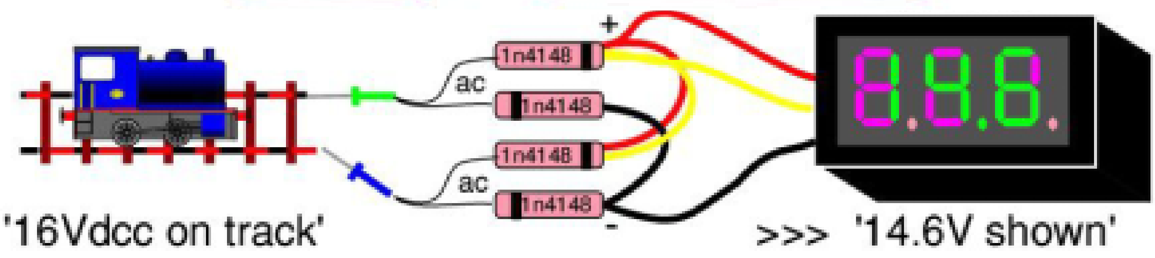
Looking at the familiar 'Mains' example, we have the Peak Voltage of 325V 0-peak telling us the highest instantaneous voltage across the circuit at any time, or 650V peak-to-peak variation (from -325 to +325V, 50 times per second) which is most easily measured on an oscilloscope, or the more familiar 'rms' root-mean-square value which is the *equivalent* d.c. voltage or current giving the same heating (or 'power') effect. - 230Vrms (previously 240V a.c.) [Energy = Power × Time. *For bills:* kW x hours]

For model use, we have the safer lower voltage of 16V a.c. rms which is still often provided for 'accessory outputs', alongside notional 12-16V dc and 16Vac systems, as manufacturers offer 2-rail AND 3-rail (stud contact) versions of each model.

Lighting bulbs are now standardised as 16V for both a.c. and d.c. in H0 [but rectifiers / LEDs are now recommended].
If 'Pre-Digital' models equipped with bulb-based directional lighting are not appropriately adapted for near-continuous use at full-track voltages, there is a risk of adjacent plastic mouldings being melted. Changing to LEDs is stongly recommended a.s.a.p.!

DCC Voltages Described ... and Measured





Common dcc 'on track' voltages are 14-16Vac for (00/H0) and 18-22V for G when measured from 0 to Peak (0-pk).

As an almost-square-shaped waveform, the Zero-to-Peak (or $^{\text{Peak-Peak}}/_{2}$) closely describes the effective voltage. [Roco use 16V for N, H0e, and H0]

On an oscilloscope, it is easier to measure the Pk-Pk, which would then be 28V (00/H0) to 44V (G) and divide by 2.

A Digital Multimeter will NOT usually indicate this value correctly on its 'a.c.' range, as this uses 'sampling' and is calibrated for the rms (Root Mean Square) of SineWaves (often 50-60Hz), which is the heating or power equivalent DC voltage [/ current }.

Using either an Analogue or Digital Multimeter on a DC Volt Range with a Bridge Rectifier, will show the 'local V' or Full-Speed Motor Voltage, and the track voltage by adding 1.4V, to the displayed value, to compensate for the 'Diode Drops' in the Rectifier.

An 'Automotive' Digital Voltmeter [<£5] Module with 4 x 1N4148 diodes makes an effective cheap voltmeter for dcc/dc/ac between 4V* and 30V. (Just add +1.4V to displayed value in all cases).
*minimum varies with the display colour !!

You should now feel equipped to consider adding LED lighting, or converting to Digital