CONTENTS: Concept Document Layout

Part 1: Systems 0 – 50V (AC/DC)

> "Start by reading this – covers 95% of scenarios, so put the simple thing first"
> For locomotive construction that utilises power of voltages no greater than 50V (AC or DC).

Part 2: Systems 50V+

> "Don't read this if you don't have to". For locomotive construction that has higher voltages than 60V – essentially the bulk of the existing document. This takes the design to another level.
>
> 1. A: ELV definition and requirements
> 2. B: LV definition and requirements
> 3. C: Legal aspects (licensed persons to conduct electrical design/testing/approval)
> 4. D: Failure Analysis, Risk Management etc
>
> Basically, if you want to go above 50V, you need to do the work. Otherwise, stick to safety.

Part 3: Radio Control Systems

- Digital Control only; Analog radio links illegal
- Two methods of remote traction control isolation
- Loss of signal/broken link failsafe design

PART 1: Systems 0 – 50V

This needs to be as simple as possible. It covers 95% of the hobby at least.

MANDATORY

All failures of any traction system designed (be it from resistive control through to full digital adaptive control) can be rendered safe and failsafe by the inclusion of three components, wired between the power supply (batteries, alternators etc) and the traction control system (resistors, electronics, wiring to traction motors etc):

1. A manual traction power isolation switch. This disconnects power directly at the source (at the battery, alternator etc). The result is comprehensively rendering the locomotive 'dead' in the event of any electrical failure in any system.
2. A correctly rated fuse or circuit breaker. This limits the maximum failure power between the power supply feed and the traction control system.
3. A normally-open relay, that must be switched from the driver's controls ("ignition"). This ensures power can be removed to the traction control system regardless of any fault with the traction control system (e.g. 'stuck open' throttle).
    a. The type of switch on the drivers controls is up for debate, but could equally be a key switch or 'missile-trigger' protected toggle switch – any type that prevents accidental switching.
    b. If a Key switch is used, it is suggested a Toggle or latching emergency stop switch is wired in series, ensuring that in an emergency, the keyswitch is not required to be operated for speedy isolation.

See *SHEET 1* for layout. All components are wired in series in this order.

RECOMMENDED

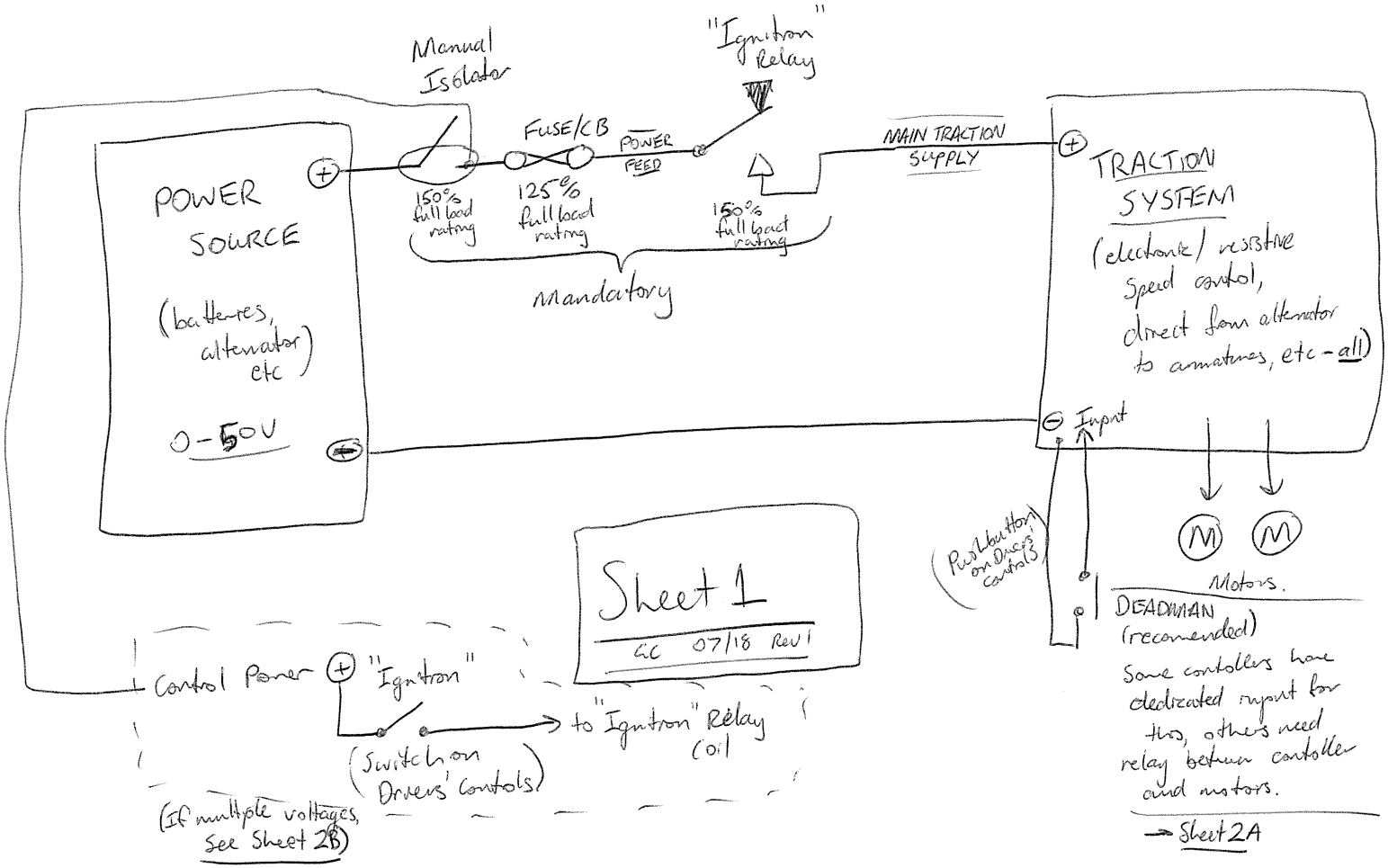
The addition of a closed-loop Deadman control is recommended, but not required, if the mandatory conditions are met. The argument has been put forward that no steam locomotive has this feature; but all steam locomotives have a regulator that is identified in a couple of seconds, while most diesel-outlines do not have commonly identified controls identifiable 'at a glance'. A deadman button removes this difference, and requires the driver to constantly acknowledge their presence at the controls.

The deadman can take any form, as long as it is triggered when the driver is no longer in control (i.e. is failsafe) – could be (certainly not limited to) a pushbutton, a tether latch (similar to a speedway bike), a seat contact (driver falls off, engine stops), a vigilance control with a 10sec timer, or even a guard's button to pull the train up if in an emergency. The presence of this functionality is what is important.

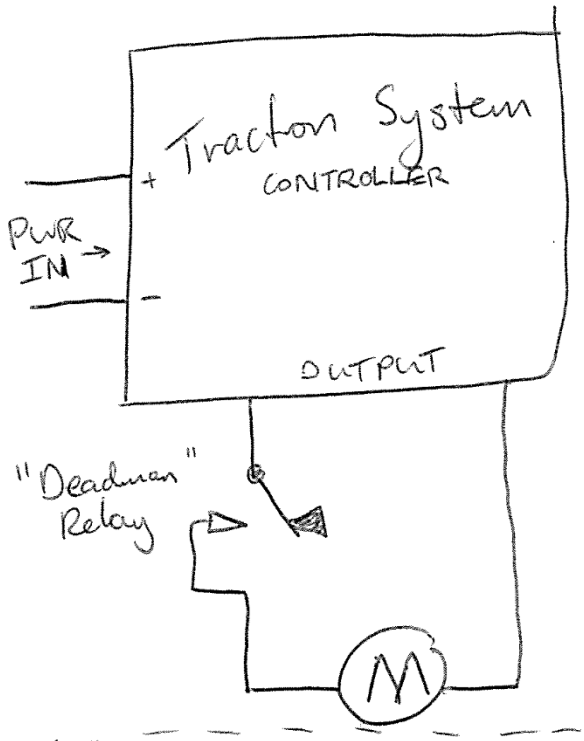
See *SHEET 1* for layout.

Most electronic controllers come with an 'enable' line for exactly this purpose, that must be connected before the controller can operate (i.e. failsafe by nature). It is easily wired in. If the controller does not have this facility, an interposing normally-open relay between the traction control system and the motors themselves can be used, with an identical outcome.

See *SHEET 2A* for interposing relay layout.


Manual Isolator
"Ignitron" Relay
Fuse/CB
POWER FEED
MAIN TRACTION SUPPLY
POWER SOURCE
(batteries, alternator etc)
0-50V
150% full load rating
125% full load rating
150% full load rating
Mandatory
TRACTION SYSTEM
(electronic/resistive speed control, direct from alternator to armatures, etc - all)
Input
Push button on Drivers' controls
M
M
Motors.
DEADMAN (recomended)
Some controllers have dedicated input for this, others need relay between controller and motors.
→ Sheet 2A
Sheet 1
GC 07/18 Rev1
Control Power
"Ignitron"
(Switch on Drivers' Controls)
to "Ignitron" Relay Coil
(If multiple voltages, see Sheet 2B)

Sheet 2A
aC 07/18 Rev 1



→ Control Power (+) → Deadman Relay Coil,
(Pushbutton on Drivers' controls)

If No "enable" input on speed controller

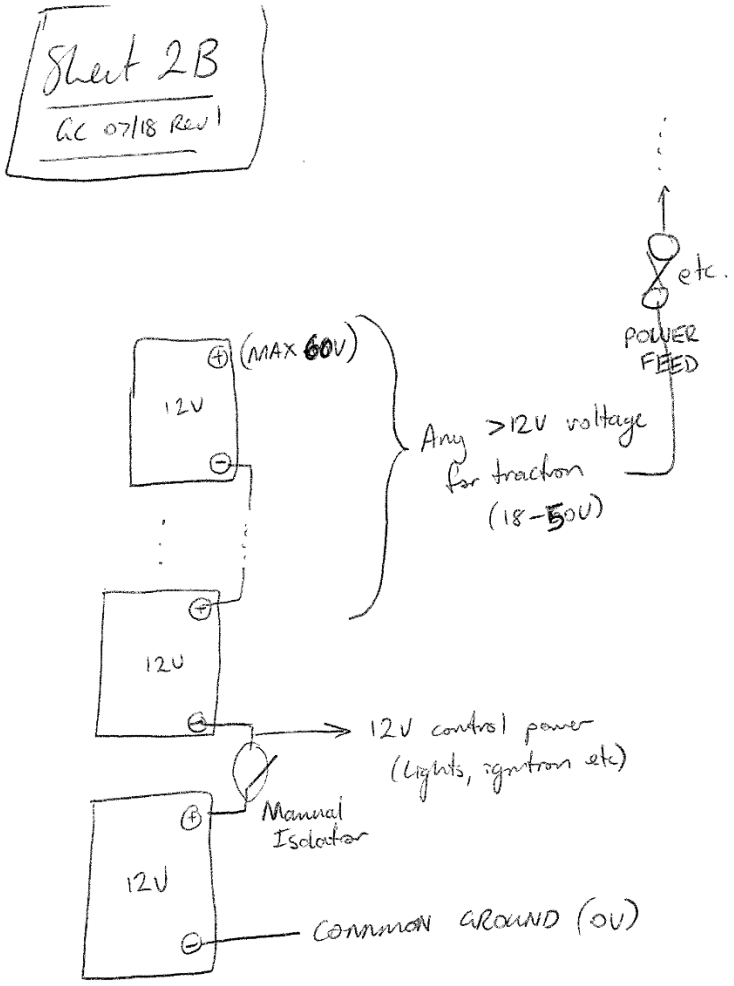
MULTIPLE-VOLTAGE SYSTEMS

Many miniature locomotives utilise multiple different voltages for their systems. For example, most locomotives' traction systems are a higher voltage (24V or 48V) than the auxiliary control system (usually 12V, to run lights, horns, air brakes, relays etc).

In order to ensure multiple voltages in use on a locomotive are adequately able to be isolated, the manual isolator must be located at a point in the system that, when operated, removes power from both the Traction and Control/Auxiliary systems together. This comprehensively renders the locomotive 'dead' in the event of any electrical failure in any onboard system.

When using batteries in series, the isolator must be wired directly after the first battery in the chain, before any power connections are made. This has the net effect of isolating both the traction and control/auxiliary power.

See *SHEET 2B* for manual isolator position within battery arrangement.



PART 2: Systems > 50V

Existing document covers standards, procedures, failure analysis etc.

A note can be added to simply say PART 1 covers up to 120V ripple-free DC also. Don't change the title of Part 1 – keep it simple for most people. If you're reading this part, you actually want to know.

Basically, if you're going down this path, you have to be prepared to wear the pain of jumping through the big-boy-pants hoops to get there.

PART 3: Radio Control Systems (R/C)

With the rapid development of radio control gear during the last two or three decades, radio control has become far more predictable in failure, moving in the direction of failsafe control. Drones and model aircraft have pushed this technology to be better at mitigating any failure scenario, which has reduced the risk of crashing expensive equipment – or in this case, preventing the loss of control of a locomotive.

As such:

MANDATORY

1. All radio control systems for use on miniature locomotives must be of digital control. No analogue radio system is to be used, as these systems by their nature go into an unknown state when the signal is lost in most cases, and are susceptible to crosstalk or interference from similar-frequency controllers.

2. All digital radio control systems must include/be configured to 'return to the off position' in the event of either loss of signal or corruption/interference of signal.

   In practical terms, this means any locomotive under digital remote control must come to an immediate stop if the locomotive:
   - Runs out of range
   - The transmitter fails (battery flat etc)
   - Another transmitter is used in the vicinity that affects the control.

   Luckily, modern digital frequency-hopping systems are fully capable of doing these things with no intervention, provided these protections are turned on.

   This can be comprehensively and simply tested by driving the locomotive under radio control (at a safe speed on an empty, looped track) and turning the transmitter off (or disconnecting the batteries in the transmitter).

RECOMMENDED

1. Locomotives should be fitted with a physical activation system that interrupts the traction circuit in the same way either the "ignition" switch or deadman control renders the traction system failsafe. This can take any form, but be accessible to a person standing adjacent to the track, should a locomotive under radio control pass by.

   Possible implementations may consist of (but are not limited to):
   - A normally-closed latching pushbutton
   - A lever or bar somewhere on the locomotive, operating a latching electrical interrupt
   - A toggle switch

   All of which are wired in series with the "ignition" or deadman circuit, so upon activation, the locomotive traction power is removed. It is recommended to have this activation also apply brakes.

2. Provide a second method of failsafe control.
   a. Utilise a multiple-channel transceiver system, with one channel dedicated to maintaining a 'healthy' relay state on the "ignition" or deadman circuits. This

separates the radio control operation from the speed control, so if one channel (or the speed control) fails, the other channel can be used to stop the locomotive, removing power from the traction system.

OR

b. Use a separate remote control system as a redundant link. This could either be a physically separate system utilising an entirely different transmitter/receiver pair, or a separate receiver that 'listens' to the single transmitter, opening the "ignition" or deadman relays if the transmitter is no longer detected as being healthy. This is a technologically-advanced option, but is in widespread use in industry.