Fitting an S-CAB Battery Powered Radio Control Into A Connoisseur O Gauge Tank Locomotive: Or Zen and the Art of Training

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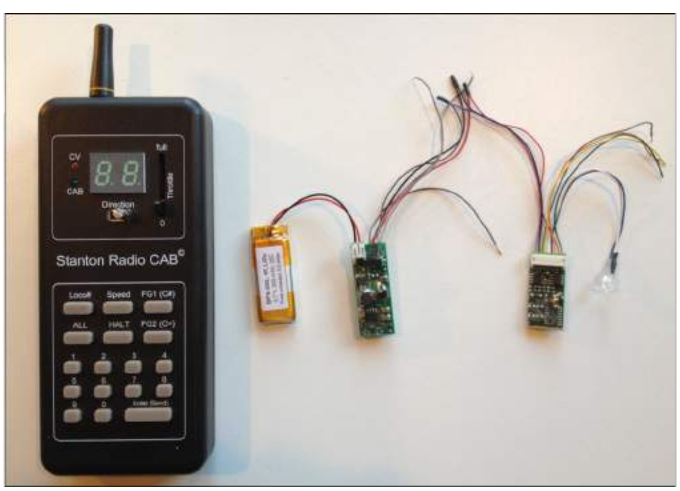
To **Mike Walton**, **Neil Stanton** and **Jim McGeown,** I give many thanks for the improvement of this article through your valuable suggestions.

CONTENTS:

1. Introduction:

This article is about putting an S-CAB battery powered control system with NCE radio decoder shown below:

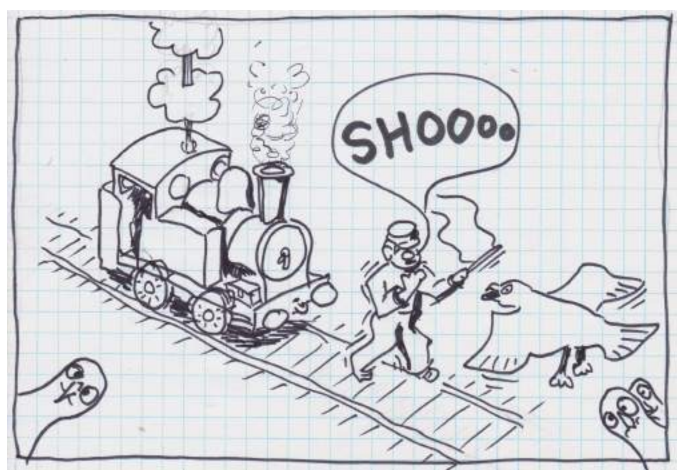


[1] *S-CAB controller and parts for locomotive: LiPo Battery, Battery Power Supply controller and Radio Receiver Decoder*.

… installed into a Jim McGeown, Connoisseur O Gauge locomotive:

[2] *Connoisseur O Gauge 0-4-0T.*
Above illustration used with permission from Jim McGeown and Connoisseur Models.

Every model railway, which powers its locomotives through the rail to wheel, has to contend with poor contact. A multitude of insidious dust particles, one thousandth of an inch high, flock like seagulls to the railhead, fouling the pristine and only recently cleaned surface.



[3] *A bird brain cartoon*.

Wiping the track with oil cleaner only causes more grief, attracting more dust, lifting driver wheels clear of the low voltage rail and losing all electrical contact. This monstrous and dreaded condition is known as:

Dead Rail Syndrome: DRS

Then, just when you think that using a graphite stick rubbed on the railhead is the cure to all your conductivity problems, along comes that wiring problem which taxes every resource and scrap of experience that you can draw on. There is a solution:

Battery Power.

DRS and complicated wiring can be cured or eliminated by cutting all dependence on powered track and relegating that powered track to the subservient role of secondary power. Battery power is the cure and puts an uninterruptable source between track and wheel.

It is not unusual for large institutions to use batteries as their prime power source. The largest of aviation facilities, the Instrument Flight Rules Centre (IFR Centre), which guides massive aircraft safely and timely, relies on batteries to provide secure dependable power to its electronic equipment. Twice daily two diesel engines start up and turn the generators that recharge the batteries while during the rest of the time recharging takes place by the local electrical utility. Every year a third of the lead acid batteries are swapped out for new ones in a three-year cycle.

Once upon a time it was considered fanciful to presume on board power would be feasible in a model locomotive. Now it is available from several manufacturers and is affordable, reliable and tiny.

S-CAB, owned by Neil Stanton, produces a battery powered, radio DCC decoder locomotive control system. S-CAB does almost the same thing as the IFR Centre power supply but for model locomotives and on a much smaller scale. And unlike lead acid batteries, S-CAB batteries are LiPos with a good life span before replacement.

Locomotives which are battery powered are usually described as dead rail. No power whatever is received from the rail. Recharge usually takes place by a plug–in or battery exchange. S-CAB is capable of being recharged by all three methods, from the rail, a plug-in or battery exchange.

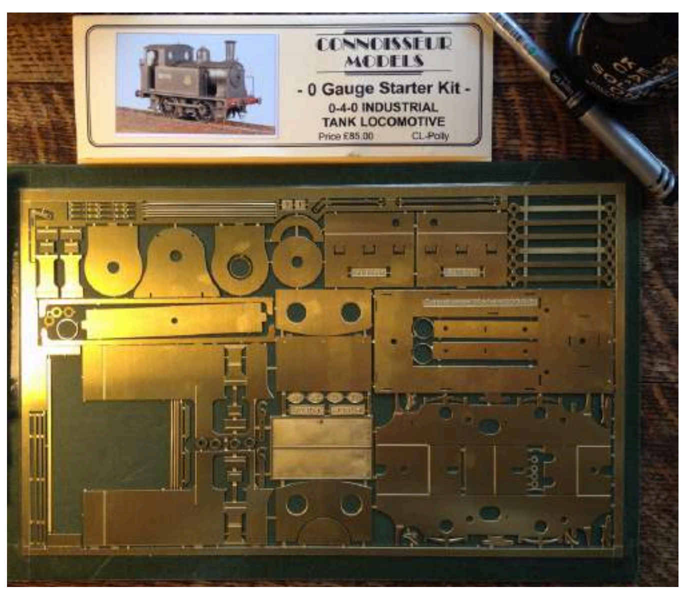
The NCE Radio Receiver DCC Decoder (RADEC), Battery Power Supply and Battery were selected and installed under Neil's personal guidance, although, done once, it is a simple exercise to do again. The only difficult part in a tank locomotive installation is when trying to find space for all those wires. Thankfully, the wires are low current and low voltage and the skinniest of wire can be used.

The locomotive selected for this adventure was a Connoisseur Models O Gauge locomotive. Connoisseur Models, owned by Jim McGeown, produces an O Scale brass locomotive kit 0-4-0T.

[4] *Locomotive in builder's grey as tested with bronze toolbox. By this time she had suffered considerable abuse from testing. Still running strong and now painted in glorious Southern colours*.

Jim's 0-4-0T is a simplified version of an S14 and is an entry-level project for those who are unsure of what it is that they are getting into. Building the kit, though, is straightforward and Jim leads you through the construction with excellent instructions.

Connoisseur's kit etchings are a work of art and truly have much of that magic essence called quality (See the Post-Postscript at the end of this article). As I cut the little parts out I felt that I had taken a glue brush and was daubing on the work of a master:



[5] *Brass etched fret for O Gauge Starter Kit 0-4-0T. The boiler has been removed by Jim McGeown and pre-rolled.*

An S14 is a small tank engine, to say the least, and presented a number of minor challenges during the planning stage but once every wire and board and battery was in place, in retrospect, it looked easy. There was far too much unnecessary fretting and dithering on my part beforehand but then, this is a blue-sky project.

The journey started, though, and I decided to marry the two, the S14 and S-CAB.

URLs for websites are given at the end of this article.

2. Planning the Parts Layout:

The essential running parts of S-CAB are shown in Fig 1. and are, from left to right at the top:

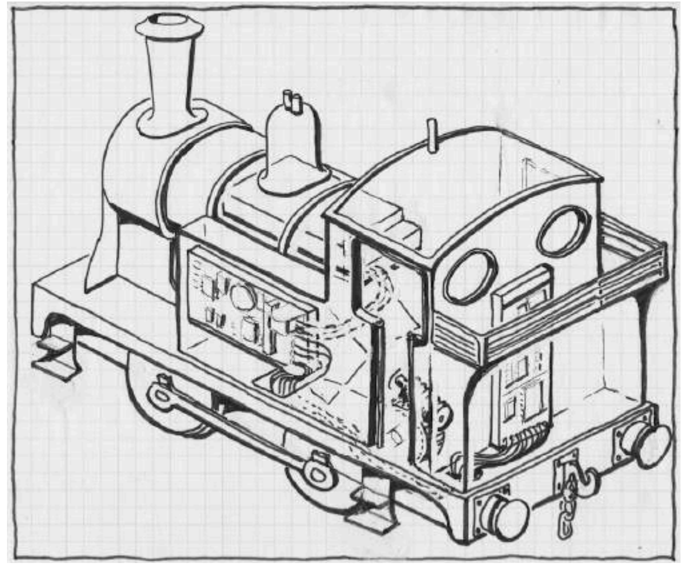
1. Transmitter, CAB
2. Battery, LiPo
3. Battery Power Supply, BPS
4. Radio Receiver DCC Decoder, RADEC

[6] *A selection of the bits available from S-CAB and to be discussed in this article.*

Also eventually needed are:

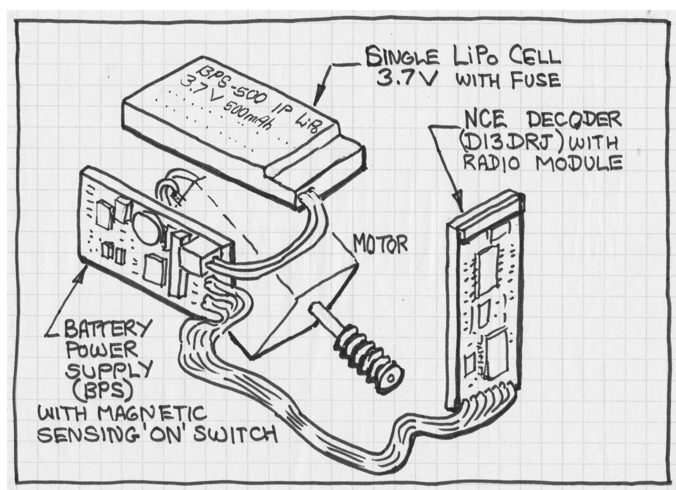
5. Loco Battery recharge by track or locomotive plug
6. Transmitter USB cable to recharge the transmitter

The locomotive with installed battery, battery power supply (BPS), radio receiver-decoder (RADEC) and motor looks like this as in this phantom view:



[7] *Phantom view of Connoisseur O Gauge tank engine with relative positions of Decoder, Battery, BPS and Motor.*

There is not one single space within the loco to put everything, all of it, all together. Also, the BPS should be properly ventilated and the Decoder needs to have its antenna at least partially visible. After much deliberation I came up with the layout as in the phantom view. Stripping away the brass locomotive and leaving the essential S-CAB parts, we have a pretty picture:



[8] *Relative positions of S-Cab components with locomotive removed.*

This arrangement makes room for a speaker in the opposite side tank, should that be a favoured option.

A close second choice had two parallel wired batteries, one in each tank and the BPS in the boiler top. This would have given much greater battery capacity. Perhaps this will be done in the next installation, a Connoisseur Southern G6.

Every component is joined to the others by wires. Do not be daunted by the number of wires. A patient unhurried approach and a recognition that it will take more than one evening to put each wire and every bit of shrink-tubing in its proper place will bring forth Zen and the Art of Training. Neil has done some of the wiring and all that is left are the motor connections, wheel wiper connections and the lights.

It is a little cramped in the loco body but nothing like a modern cell phone. We will not be trying for that complexity in this article.

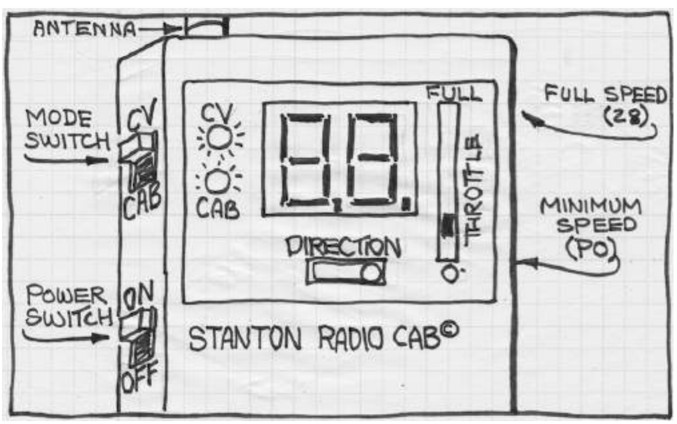
3. The Transmitter Throttle:

The throttle has three levels or Tiers of functions:

Tier 1: Speed and direction:

Speed is set by a vertical slider in 28 steps
Direction is set by a horizontal slider.
Speed is displayed on the LED screen.

When the throttle is ready to control a locomotive the green LED labeled CAB is ON and the yellow CV LED is OFF.



[9] *Upper face of S-CAB Throttle showing Tier 1 controls*.

Tier 2: Locomotive selection and Decoder addressing

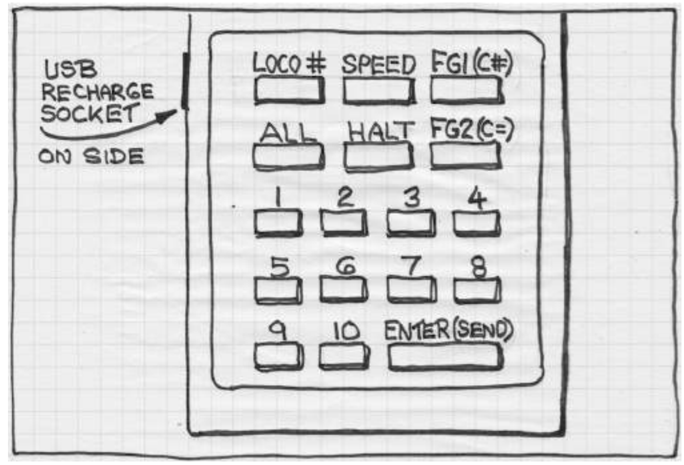
Up to one of 15 locos can be selected by keypad although the Throttle always powers up with Loco 03.

Example: Selecting a Loco:

To select locomotive number 25 do the following:

Slide Power Switch *ON*;	LED displays [L3]
Slide Mode Switch to *CAB*	LED displays [L3]
Cab Green LED goes *ON*	LED displays [L3]
Push key [LOCO#];	LED displays [L3]
Push number keys; [2], [5]	LED displays [L3]
Push key [ENTER/SEND];	LED displays [25]

The throttle now controls locomotive 25, one of a maximum of 15 at any one time.



[10] *Lower face of S-CAB Throttle showing Tier 2 and Tier 3 controls*.

Tier 3: CVs (Configuration Variables)

Configuration variables are items stored in a decoder's memory, which control the status of the decoder's output.

The first CV that is usually changed is the decoder's address, which is of course the locomotive's address. All new decoders from the manufacturer come as loco address 03 or, as displayed on the LED screen, L3.

Example: How to change the decoder (loco) address to **48**:

Turn ***OFF*** all S-CAB locos in range
Turn ***ON*** loco(s) which is(are) to have S-CAB decoder address changed to 48.
Slide Throttle to ***0***

Slide Power Switch ***ON***;	LED displays **[L3]**
Slide Mode switch to ***CV***;	LED displays **[C]**
CV **Yellow** LED goes ***ON***	LED displays **[C]**
Push key **[FG1(C#)]**	LED displays **[C1]**
Push key **[FG2(C=)]**	LED displays **[U3]**
Push keys new address **[4], [8]**	LED displays **[48]**
Push key **[ENTER(SEND)]**	LED displays **[48]**
Slide Mode Switch to ***CAB***	LED displays **[48]**
CV **Yellow** LED goes ***OFF***	LED displays **[48]**
CAB **Green** LED goes ***ON***	LED displays **[48]**

Slide Throttle up; motor speed should increase and display LED should show power range from **P0** up to **28**.

Note that any S-CAB locos which are ***ON*** and within S-CAB Throttle range will have their addresses changed to **48** and all will respond simultaneously to the CAB commands.

For details on additional CV changes refer to S-Cab's tutorial on CVs. There you will find details on how to modify other CV's:

http://www.s-cab.com/uploads/2/0/3/9/20398179/s-cab_throttle_ug.pdf

The website also describes a radio adapter which will change manufacturer specific CVs.

A new throttle is always a surprise both in its weight and scale. I have an average sized hand with the usual aging arthritic pains but the throttle fits comfortably for two hours. Here are a few specifications on the S-CAB Throttle:

Weight: 194g (7oz)
Dimensions: 16cm Long x 7cm Wide x 2.7cm Thick
(6-1/2 x 2-3/4 x 1 inches)
Transmit duration: 35ms

Transmitter charging requires a USB connector. A cord is included in the KIT package and plugs into any standard USB socket.

4. Connecting the Wires:

It is right and proper to read S-CAB's wiring instructions. In fact, always read the instructions.

The next step is to define firstly, the frame and secondly, the footplate:

1. Frame (also known as the frames, the running frame, the running plate, the running board): the metal plate or steel bars which run from front buffer to the rear buffer and to which all the other parts of the locomotive are secured.

2. Footplate: the metal plate that rests on the frame, usually covered in wood, and on which the fireman and engineer stand and work. The footplate defines the Cab area but may also include the coalbunker. The footplate is usually raised up from the frame.

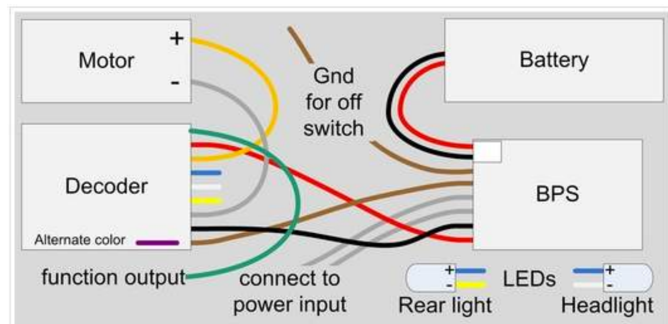
The Connoisseur S-14 does not have a raised footplate in the locomotive cab. Therefore the wires between the decoder-receiver, the BPS and the motor cannot be hidden in a space between the frame and the footplate. The wires from the decoder can either be run along the floor and tucked discretely to the side near the door or passed through a hole in the frame. In this installation, a hole was drilled in the coalbunker floor to pass the wires from the decoder to the bottom of the frame. The frame was then notched to pass the wires back to the BPS. In other S-CAB installations, the wires were passed between the frame and the footplate. The Connoisseur O2 is such an example (Southern preferences clearly evident here). If possible, it is far simpler to pass the wires between the footplate and the frame.

The decoder and BPS come from S-CAB with several wires already connected:

1. The Decoder power leads, red and black, are connected to the BPS.

2. The BPS will have a brown wire connected to the decoder violet wire. This permits the operator to issue a keyboard command to shut down the S-CAB system:

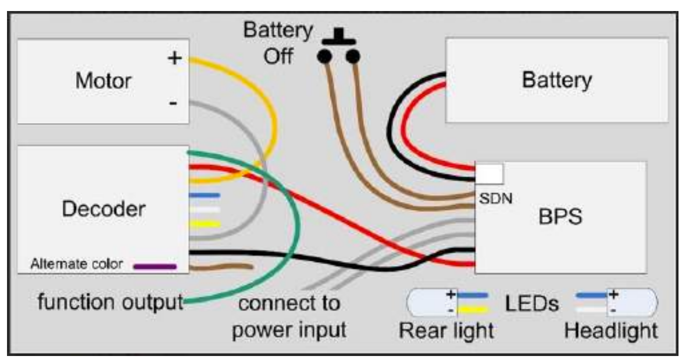
http://www.s-cab.com/uploads/2/0/3/9/20398179/installation.pdf



Wiring diagram for a non-sound decoder Also applies for sound decoder with addition of a speaker.

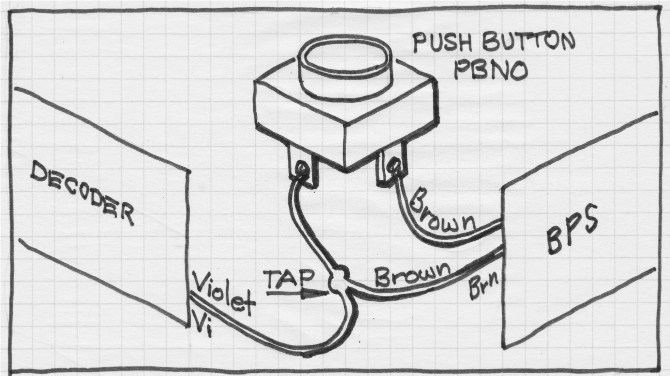
[11] *Wiring enabling a CAB command to tell decoder to switch Battery OFF.*
Above illustration used with permission from S-CAB.

Alternatively, a Push Button Normally Open (PBNO) switch can be wired to the two brown wires of the BPS. Pushing the PBNO switch, briefly, turns off S-CAB.



[12] *Wiring for PBNO to manually push Battery OFF*
Above illustration used with permission from S-CAB.

Both systems to turn off the loco can be used if wired up in parallel. To do this tap into the Brown/Violet (Brn/Vi) wire at the shrink tube junction, fabricated by Neil, with another wire and lead it and the flying brown wire to a PBNO.

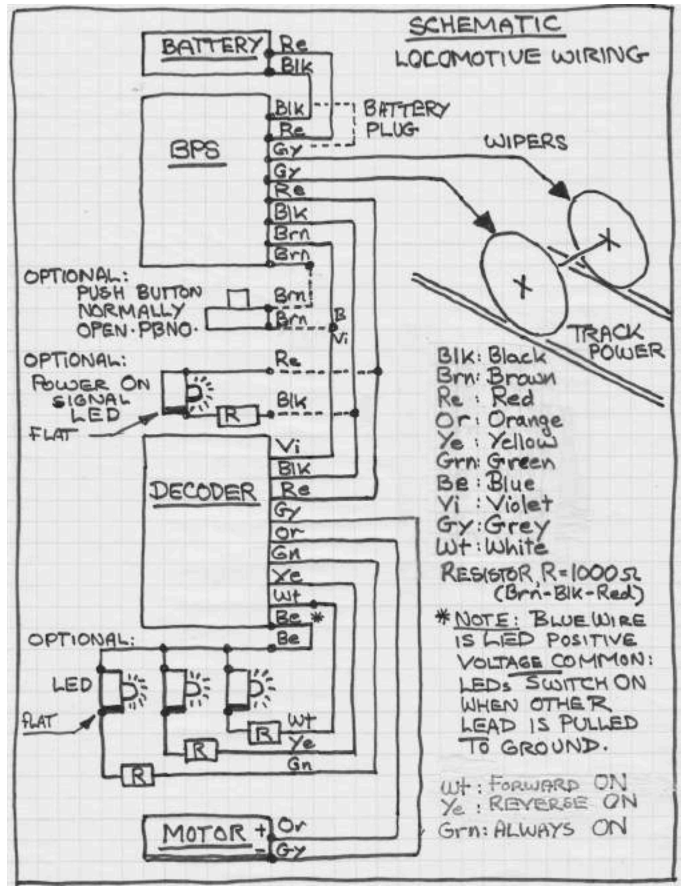


[13] *Illustration for PBNO wiring to push Battery OFF but still enabling S-CAB transmitter OFF*.

The PBNO on the S14 loco is glued onto the frame immediately behind the rear right steps. Sometimes it is easier to just push the button or touch a magnet to the off reed switch than find the Transmitter and switch it ON and select the loco and push function+5+5+5 and then switch the transmitter OFF.

[14] *PBNO hiding on bottom of frame*.

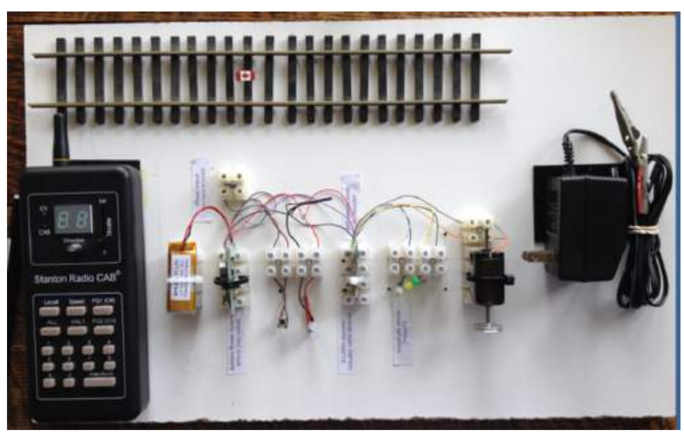
The pretty pictures above can be represented by a complete schematic showing parts and wires and connections:



[15] *Complete tank loco S-CAB wiring diagram*.

On the complete schematic none of the wires are in the same order as found on the boards. This was done to avoid having lines cross.

It may be necessary to disconnect the wires to pass them you an opening so use the above illustration to guide yourself in their reconnection.



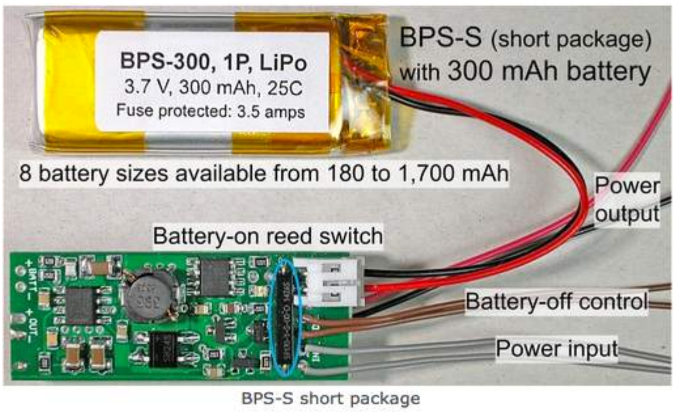
[16] *Test set-up to evaluate the parts working together before wiring into the loco.*

To test the system all the components including motor, charger and LEDs were brought together on a breadboard. This is a good method for testing a new system with which one is not familiar. The connections are accessible, measurements are easily taken and modifications can be readily made.

5. Installing the BPS:

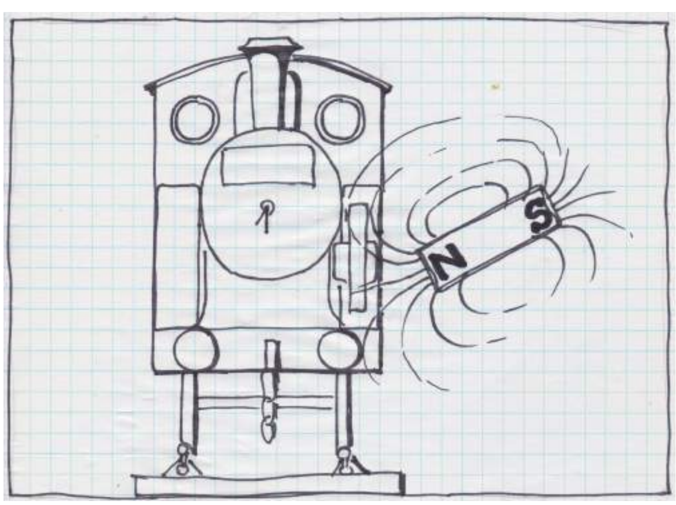
The BPS has two functions. Firstly, it is a power supply for the decoder, taking in the 3.7V from the LiPo battery and boosting it to a nominal 11V for the decoder. Secondly, it monitors the battery voltage and charges the battery as necessary from either the track or a dedicated plug installed somewhere on the loco. The BPS can be turned OFF by the throttle or by a Push Button switch.

The actual BPS output voltage can be set to any value between 8.5 and 12V but will only be fixed after discussions with Neil and before placing an order.



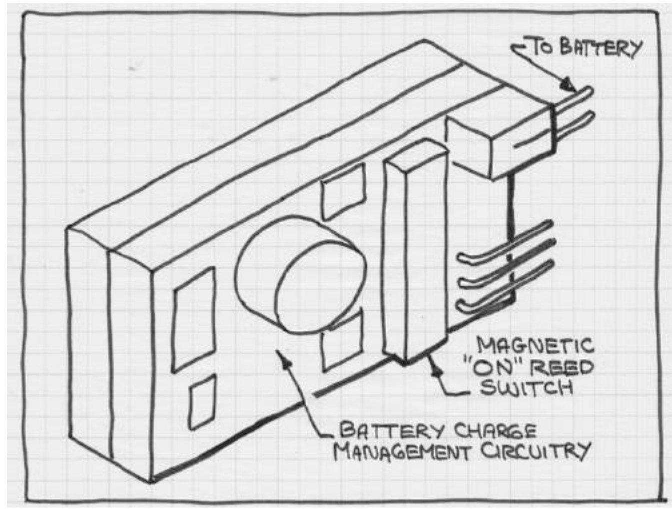
[17] *BPS and Battery wiring, functions and colours. Above illustration used with permission from S-CAB*.

The BPS and Decoder are turned ON by the influence of a magnet which trips a magnetic sensing reed switch. Even though a magnet be separated from the reed switch, brass is “transparent“ to the slowly moving magnetic field.



[18] *Bringing a magnet close to the “ON” reed switch on the BPS turns the BPS and the decoder ON. Correspondingly, bringing a magnet close to the “OFF” reed switch turns everything OFF.*

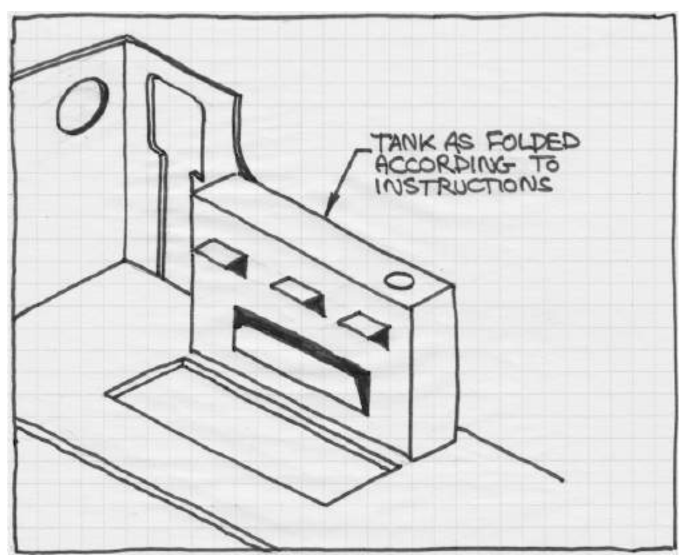
The smallest of modern powerful magnets will suffice as a tool to turn the switch ON. Lee Valley, a supplier of these magnets in Canada sells a quarter inch diameter magnet, which can be inserted into the eraser end of a pencil. The one problem with this idea is the ease with which the pencil seems to disappear for other purposes such as writing.



[19] *Magnetic reed “ON” switch location on BPS. This has to be close to the loco’s surface.*

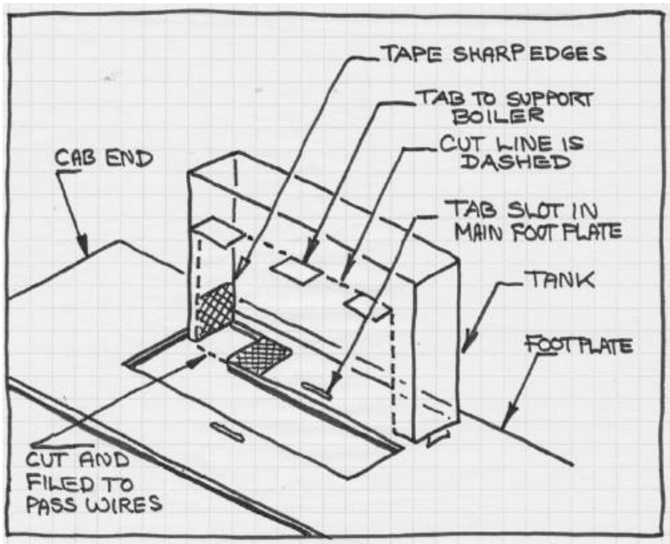
It is advisable that the BPS be oriented such that the reed ON switch is close to the locomotive body shell. Having decided that the BPS would go in the side tank, there was presented the awkward fact that the side tank was already assembled and the BPS would not go through the little hole.

Some problems would have been better solved if they had been met prior to soldering brass parts together … in hindsight.



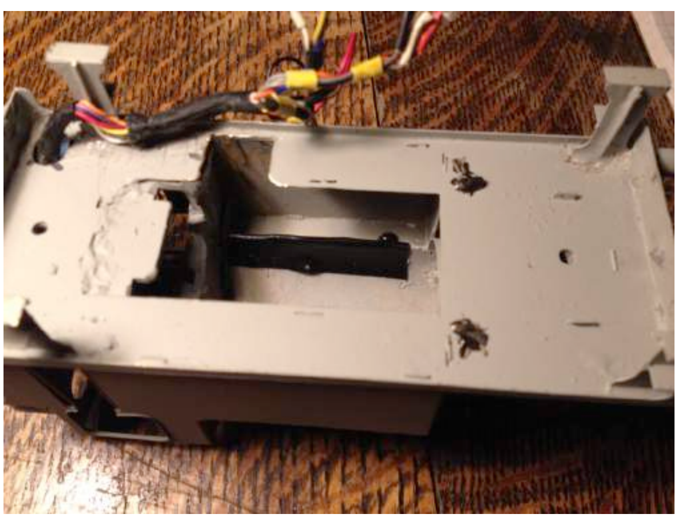
[20] *Loco side tank before mutilation showing the rectangular hole on the inside of the water tank, which had to be made larger.*

However, it was only when the loco was together that it was possible to see the best locations to squirrel the various boards and components away. As a result, serious nibbling, carving and filing of sheet metal took place after assembly, especially to fit the S-CAB BPS. John Wayne did not say, “Courage Pilgrim, courage”.



[21] *Side tank showing metal to be cut out along the dashed line.*

An attack on the boiler side was made. First the brass was cut (hacked?) away and a notch for the wire feed nibbled into the frame. All sharp edges were lined with a durable super sticky tape. Gorilla© tape was used here but sailcloth tape would probably work equally well. Needless to say, all of this would have been easier before assembly.



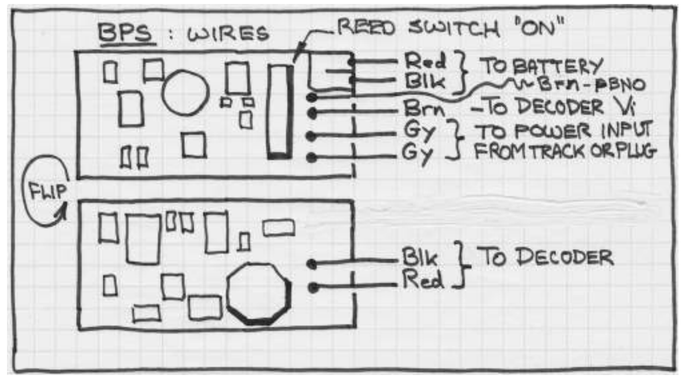
[22] *Notched frame and side tank metal removed and viewed through the frame.*

The BPS is a snug fit lengthwise in the tank but is otherwise a comfortable fit.

PBS dimensions: 0.57”H x 1.74”W x 0.37”D

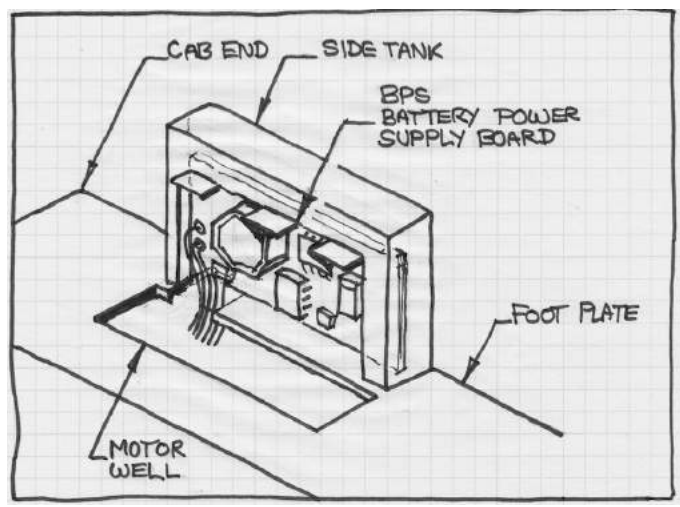
Water Tank Size: 1.06”H x 1.80”W x 0.36”D

Although the required Depth dimension is a little shy of the available space due to one of the components projecting slightly, there is no interference with the motor.



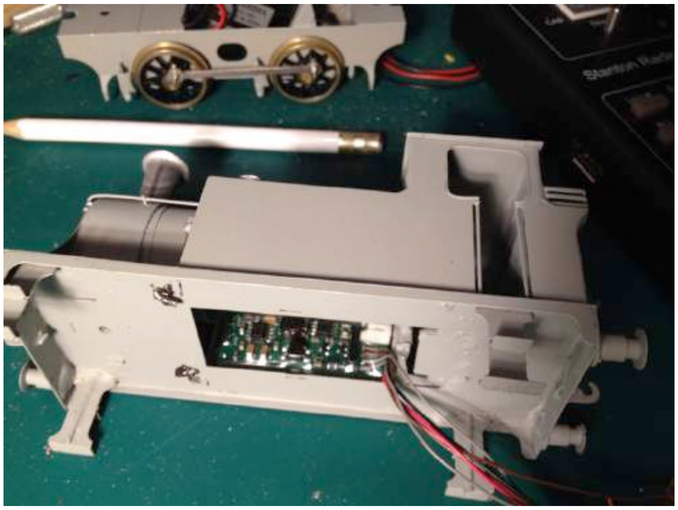
[23] *Both sides of BPS with wire colours and functions.*

Fitting the various components and boards can require a lot of putting in and lifting out. It is preferable to keep this to a minimum. Installing and removing parts will cause metal fatigue and eventually the wire connectors will fail. This is true of all electronics. Once the BPS is installed resist the temptation to fuss with it.



[24] *BPS location in side tank with wire feed through taped notch.*

There are a number of wires that run from the BPS to the decoder, battery and recharging track (or plug). All of these must be cut to a minimum length and carefully positioned to avoid rubbing against the wheels and motor. A small amount of 5 minute epoxy is sufficient to hold the wires in place to the underside of the frame.



[25] *BPS in side tank viewed through loco frame motor well*.

As previously mentioned, other S-CAB installations had the wires passed from coalbunker to side water tank through the space between frame and cab floor.

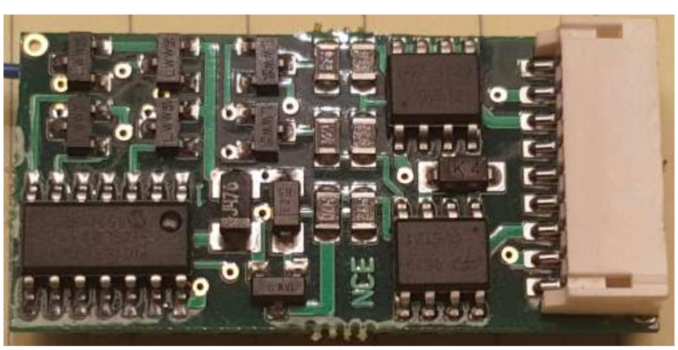
6. Installing the radio Receiver-Decoder (RADEK):

The radio receiver-decoder is a sandwich of NCE's D13DRJ and an NCE radio module.

The double-sided board has both the Length and Width of a standard board and is barely a quarter inch thick.

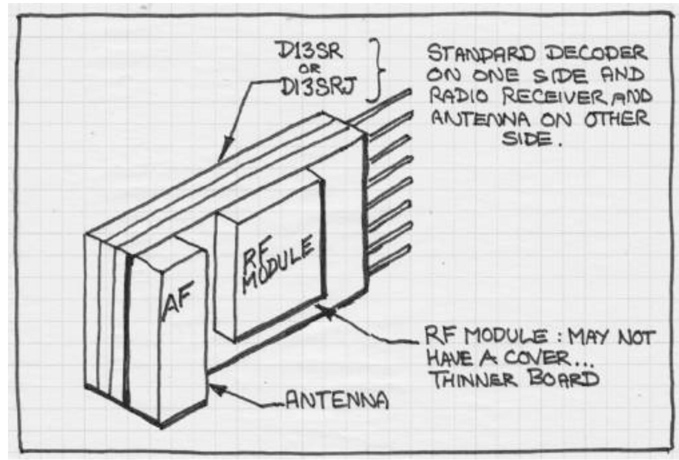
Decoder dimensions: 0.63"H x 1.40"W x 0.25"D

[26] *Double sided radio Decoder from NCE. Radio receiver side above and decoder side below.*



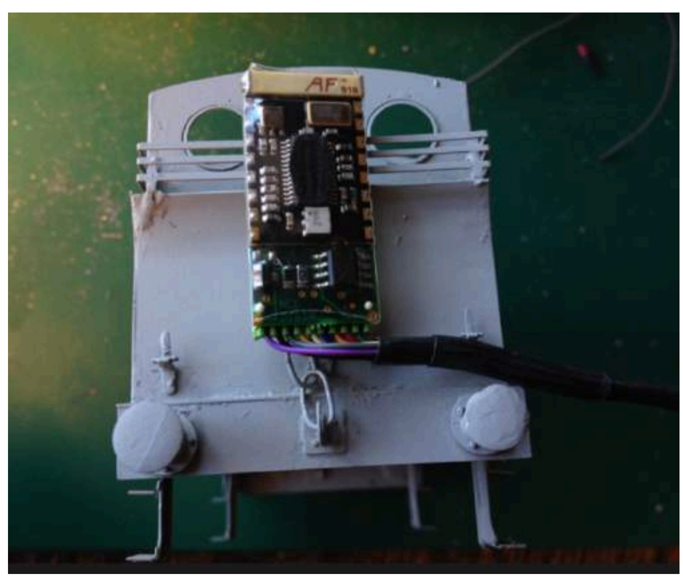
[27] *Above illustrations used with permission from NCE*.

The NCE D13DRJ decoder must only be connected to battery power through the BPS and never to the track DCC or any other source.



[28] *Antenna (AF) location on the NCE radio Decoder. This works best with a clear line of sight but works reasonably well with obstruction.*

Obviously, putting the radio-decoder on the outside of the loco would spoil the effect of the model. Inside it must go but then reception of radio signals from the outside through metal (brass) becomes a problem. Normally one would expect signals to be highly attenuated and the antenna would have a hard time picking up enough signal for the receiver (Faraday Cage effect). This forced certain decisions onto the placement design. Fortunately, an 0-4-0T has a strategically placed and sized coal bunker and this became a wonderful bin in which to position the decoder with its radio antenna. On the opposite end of the decoder, the nine decoder wires spread out on the bottom of the bunker and make their way to a quarter inch hole where tucked against the loco valence they snake over to the BPS board.

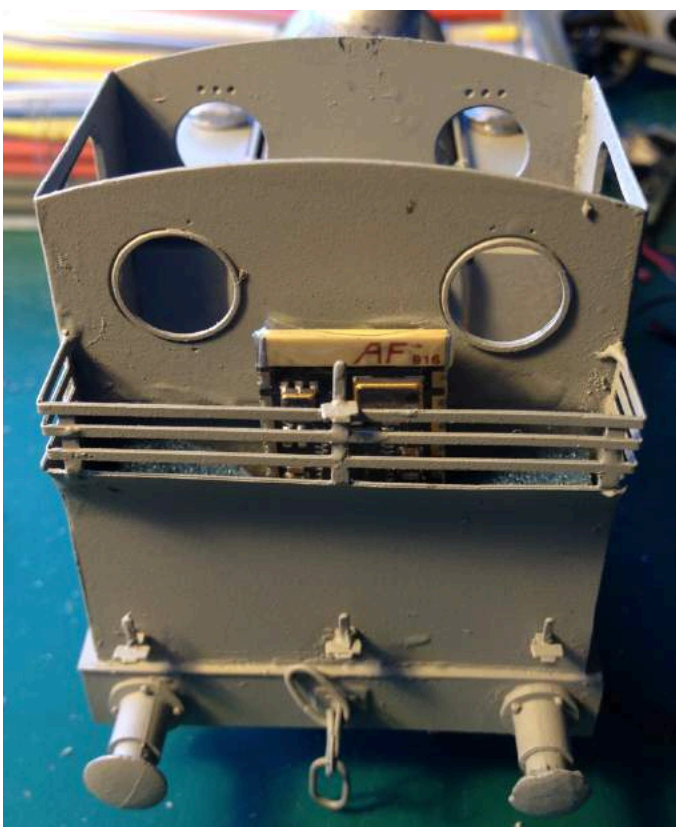


[29] *Possible location and orientation of Decoder*.

Whether the receiver has its antenna poking out the top of the bunker or plays coy, just poking out the top makes a difference.

[30] *Trying out the location and orientation of the radio decoder. Lots of room in the bunker but questions needed to be answered as to whether it would be shielded in this position.*

I tried both orientations. Antenna sticking out, the reception distance is over 30 feet. Coyly hidden, about 20 feet. In the railway room, I'm never less than 10 feet away so the difference is moot. Furthermore, the shell is not a perfect Faraday cage and radio signals from the transmitter are not entirely blocked by the brass metal shell. Here the antenna is the white thingy marked AF along the top of the decoder:



[31] *The Decoder standing tall in the bunker. A bit too obvious.*

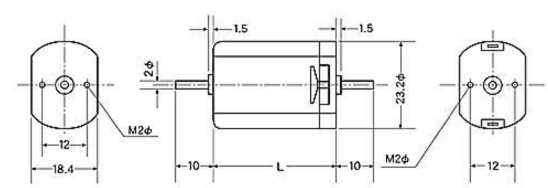
The final decision was to lay the decoder sideways in the bunker.

[32] *The Decoder, hiding, lying down, in the bunker but still obeying radio instructions.*

7. Installing the Motor:

Jim McGeown recommends a Mashima MH1833D motor for the tank engine. Mashima's MH1833D is a powerful dc motor in a OO size package and when connected to a worm and gear for a reduction of 40:1 the 0-4-0T pulled over 30 wagons on the level and 8 weighted wagons up a 4% incline.

●MH-1824,1830,1833

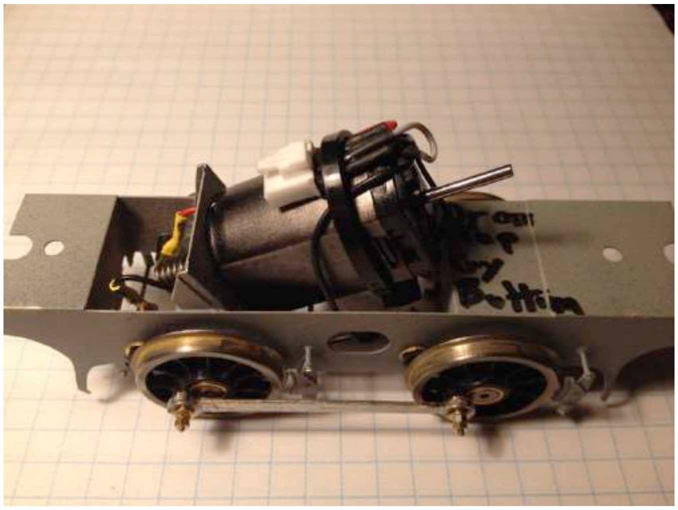


MODEL No.	LENGTH(L) (mm)	RATED VOLTAGE D.C.(V)	RATED SPEED (r.p.m)	RATED CURRENT (mA)	NUMBER OF POLE	REMARKS
MH-1824	24	12	9,200	80	5	SKEWED ARMATURES
MH-1830	30	12	9,200	80	5	SKEWED ARMATURES
MH-1833	33	12	8,500	90	5	SKEWED ARMATURES

[33] *Series 18xx Mashima motor. The last two digits in place of the xx are the length in mm.*
Above Illustration Courtesy of Mashima.

Unfortunately, Mashima intends or already has, ceased production of small hobby motors. There appears, though, to be quite a stockpile of these motors in both the UK and USA.

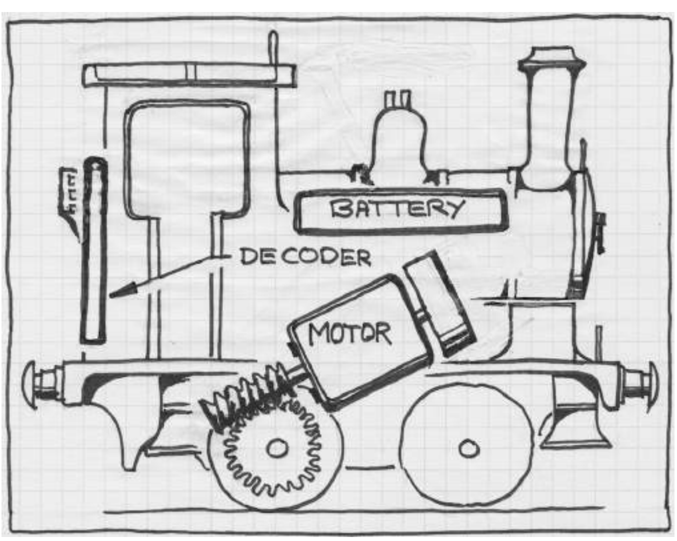
It is awkward to have the motor connected to the upper body when painting or doing maintenance. This inconvenience and possibility of fatigue damage to the wiring can be mitigated by the insertion of a miniature four-pin plug/socket. Simply disconnect the plug/socket and the motor and the upper works can be dealt with separately. The plug/socket combo is a common item in radio control model shops.



[34] *Motor orientation with motor leading worm gear has wiring implications. A flywheel will be fitted after clearance is checked from the battery*.

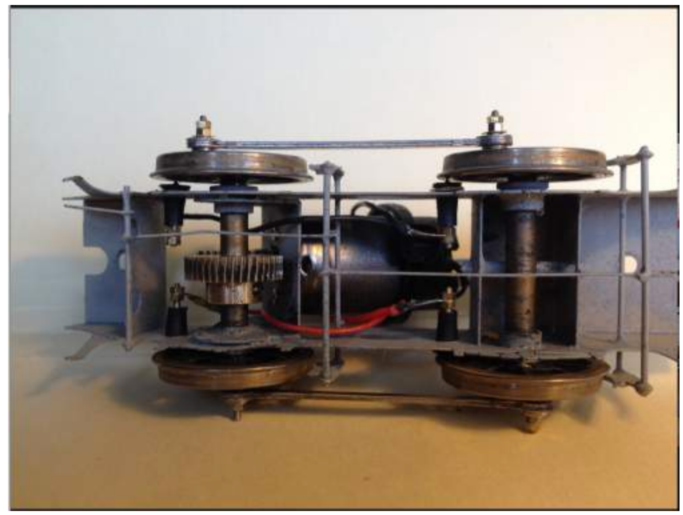
One thing to be mindful of is the relative placement of the motor and battery. Considerable latitude is allowed the builder in his orientation of the motor and it is quite possible for the motor to both press on, and to sever, the wires and also for the motor shaft and flywheel to damage the battery casing. LiPo cells have only a thin plastic casing and are easily damaged.

On a Connoisseur S14, 0-4-0T, the motor and gear box are installed with the motor leading the worm gear. That is, the motor is towards the front of the loco and the worm towards the rear. On other locos the worm leads the motor. These two situations require opposite wiring connections.



[35] *Phantom side view of Loco showing Motor, Battery and Decoder*.

Note that the motor plastic end housing has two connectors and two embossed marks, a (+) (Positive) and a (-) (Negative). For the S14 the Orange lead from the Decoder should go to the motor connector marked (+) (Positive) and the Grey wire to the other one marked (-) (Negative). However, if the motor is reversed and the worm leads the motor then the Grey wire should go to the positive connector and the Orange wire to the negative connector. This will give you a fighting chance that the engine goes forward when the throttle slide switch is put forward.



[36] *Underneath of loco showing Slater's Plunger Pickups at wheel rims*.

8. Installing the Battery:

The battery selected was a single 550mAhr LiPo cell. The charge rating, 550mAhr means that it will supply 550mA for one hour or 55 mA for 10 hrs or the product of any combination of time and current equaling 550. In practice, a heavy current draw will pull less useful charge from the battery and waste more energy directly as heat than a light current draw over a long time.

LiPo is short for Lithium Polymer, not that the Polymer part has much to do with the chemistry or construction. S-CAB has a description of battery feeding and care at:

http://www.s-cab.com/battery-care.html

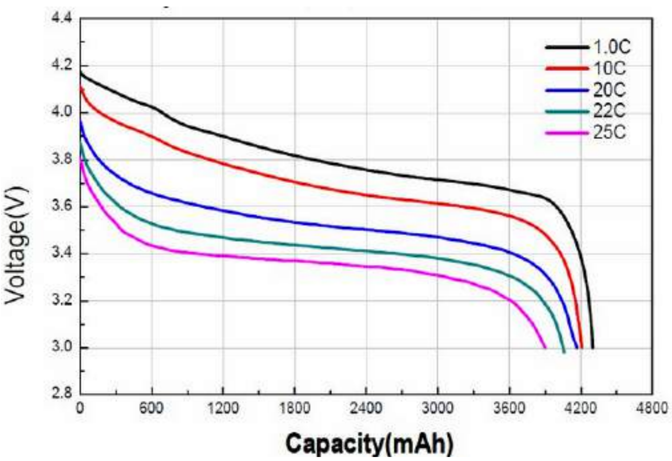
A long involved description can be found at:

https://en.wikipedia.org/wiki/Lithium_polymer_battery

There are many other sites on the Internet offering considerable battery technical information:

http://www.powerstream.com/tech.html
http://www.manoonpong.com/Other/main_page=page_2.pdf

A LiPo battery cell is a nominal 3.7V. This means that the cell is about 3.7V but will be more when fresh and less when stale. Common 1.5V alkaline cells typically start off at about 1.65V and rundown to about 1.3V at which point they have too much internal resistance to be useful. A LiPo 3.7V battery should not go above 4.2V when recharging and not below 2.7V when discharging. Most battery discharge curves look like this:

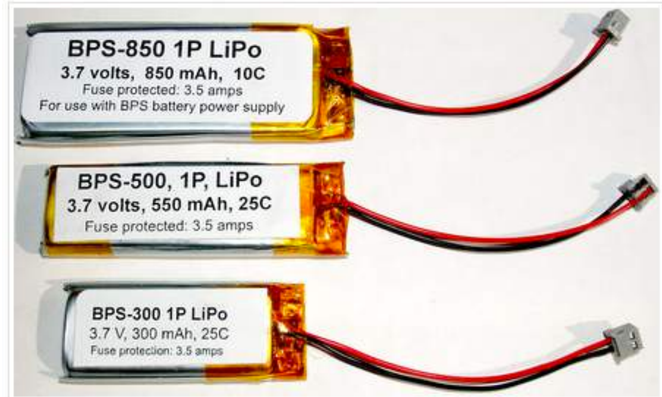


[37] *Lipo batteries change voltage as they discharge over time. The voltage also drops as the current increases.*
Graph courtesy of Alibaba OEM performance data.

For LiPo battery cells, voltage variation within the 4.2V to 2.7V range is of no concern to the S-Cab BPS as it automatically boosts the LiPo voltage to a well regulated nominal 11V.

The advantage of using a single cell and not putting three cells in series, which would give a nominal 11.1V, is the simplicity of charging. LiPos cannot be simply series charged like NiCads. Each cell must be separately charged and monitored which is a difficult and complex procedure while in motion on the track. Other makers of battery-powered locomotives require that the loco be stopped and plugged in to recharge.

S-CAB offers many different battery cell options based on four main sizes, of which the smallest is simply a stay alive option. The three larger cells shown below are the main power sources.



[38] *Three main battery sizes from S-CAB*
Above illustration used with permission from S-CAB.

The four batteries have the following nominal dimensions:

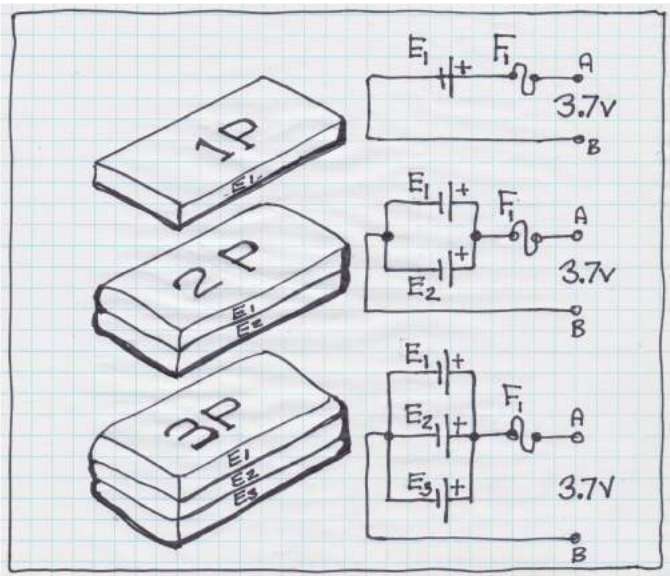
1. BPS-180 0.97"L x 0.68"W x 0.30"D
2. BPS-350 1.82"L x 0.71"W x 0.25"D
3. BPS-500 2.25"L x 0.70"W x 0.25"D
4. BPS-850 2.50"L x 1.00"W x 0.25"D

LiPo cells are soft wrapped such that the final dimensions are not exactly as above and may vary due to manufacturing conditions.

In order to increase the total capacity available it is possible to construct parallel combinations of the above cells. This does not increase the voltage which stays at 3.7V but it does increase the endurance. It is possible to put three of these in parallel, not only stacked but also wired and split to allow fitting into tight places. Illustrated below is a one cell battery and then, two and three cell units, wired in parallel. The output voltage of all three units is a nominal 3.7V and is boosted by the BPS to a nominal 11V.

[39] *Batteries wired in parallel to increase capacity. The voltage is the same at 3.7v for all three examples.*

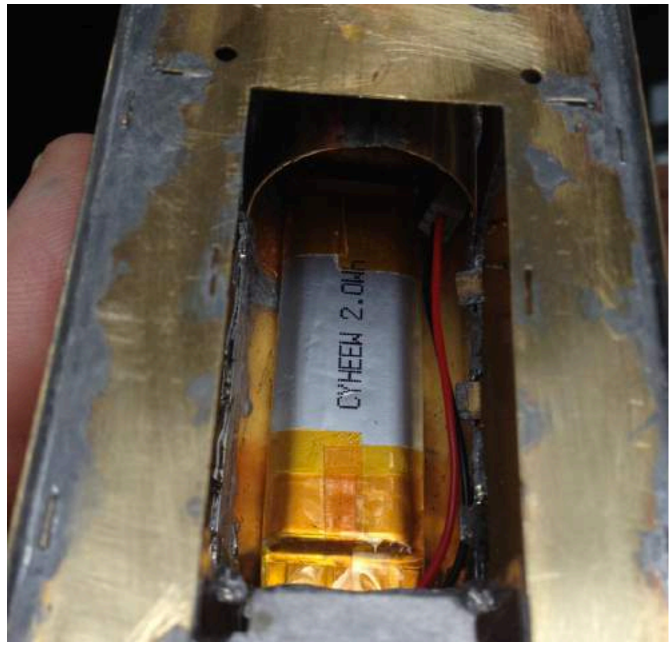
The schematic below further illustrates the wiring. The cells are connected in parallel, not in series. Not illustrated, for fear of confusing the point, would be a set of series cells in which the total battery voltage is the addition of each cell's voltage. Thus three 3.7 V cells in series would give 11.7V. Instead, these cells are connected in parallel and any number of them would always make a battery with a 3.7V terminal voltage between A and B.



[40] *Schematic showing battery with identical cells in parallel. Adding more cells does not increase the terminal voltage between A and B.*

In assembling a battery with parallel cells a manufacturer uses cells with common characteristics. It is not a good idea to willy-nilly DIY parallel units. Cells should be closely matched for internal resistance and similar charge/discharge rates and this is only something that an electronics shop or an OEM is properly equipped to do.

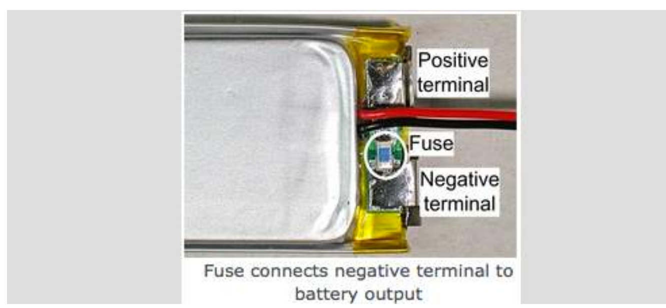
In any event, a battery that has worked well for Jim's 0-4-0T is a single cell 550mAh and a good location for it is tucked into the roof of the boiler.



[41] *Battery taped to boiler roof and viewed through motor well.*

The battery should be securely attached to the chassis or body. A short piece of Gorilla© tape will do the job of fixing the battery to the loco chassis. Do not bury the motor in tape, as this would prevent its proper ventilation and cooling. Lead the wires through the notch in the floor plate cut earlier and plug them into the BPS.

If things go sadly wrong, there is a fuse:



[42] *Fuse location on battery … wrapping removed. Above illustration used with permission from S-CAB.*

The fuse is in a surface mount package and is wired onto the contacts and secured inside the battery wrapping. If the fuse blows the voltage will read 0.0V (open circuit) at the battery terminals and not the usual 2.7V for a discharged battery.

Recharging Methods:

Batteries can be recharged by four methods:

1. from the track
2. by a plug installed on the locomotive
3. by exchanging batteries
4. by inductive coupling

Plug charging, battery exchange and inductive coupling are true dead rail techniques. The first three methods can be practiced on this installation but note that battery exchange is hard on the locomotive and can also lead to premature failure of the battery plug.

1. Track Charging:
Track power requires two items, a relatively clean track and power pick-up from the track to the locomotive.

2. Plug-in Charging:
A plug is such a simple device yet entire careers and factories have been built around their design and manufacture. Ideally a plug should be invisible, robust and perfect. Most model RC plugs fail to satisfy these requirements.

3. Battery Exchange:
The fragile tiny plug on most LiPo batteries is not built to withstand constant insertions. Locomotive details are not constructed to withstand constant handling. Of all three methods this has to be the absolutely worst idea. I don't recommend it at all.

4. Inductive Coupling and other exotic methods:
Inductive coupling is common for powered toothbrushes. Unlike methods 2 and 3 it is the least invasive but potentially inefficient. It can require close or resonant coupling of a transformer core with a coil or metamaterial built into the locomotive. This is a good idea and shows great promise but is difficult to achieve in practice as it requires clever electrical engineering design and adds another layer of complexity. The model railway, Grand Maket in St Petersburg, Russia is run entirely by inductive coupling. Links to this site are at the end of this article.

The following notes on track battery charging are abstracted from an email from S-CAB with some additions from the author.

Track power is the most convenient source for battery charging and S-CAB BPS design assumes three possibilities: DC, DCC, or AC.

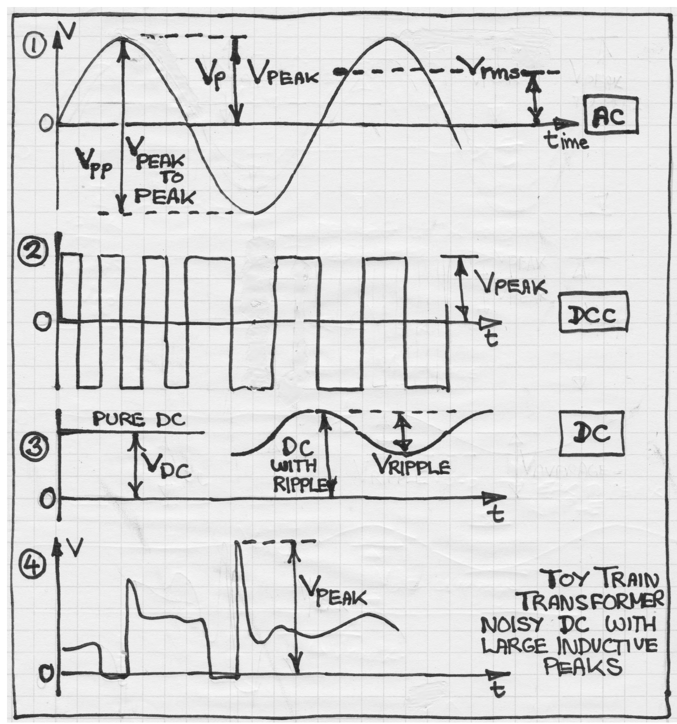
Types of Track Power:

1. AC:
Alternating current has a sinusoidal waveform and there are precise mathematical relationships between different methods of measuring AC voltage. A voltmeter set to AC, will measure what is called "RMS voltage", which is what everyone assumes when they say AC voltage. However, the true maximum voltage of AC is roughly 1.5 times (1.44, to be precise) times the RMS value. This means the voltage limits for AC (specified in RMS) must be between 4 and 10 volts and ideally between 8 (12/1.5 = 8) and 9 volts (RMS).

2. DCC:
Digital Command Control powers the track with positive and negative pulses forming what is called a "square wave". Both positive and negative voltages must lie within the same range as DC. The magnitude of the positive pulse must be less than 15 volts and the negative pulse must not be less than minus 15 volts.

3. DC:
This is a fixed voltage and ideally should be in the range of 12 to 13 volts. It can be a as low as 6 volts but must not exceed 15 volts. DC here refers to Pure DC with negligible ripple.

DC is the best, and often the most economical, power source for battery charging. Layouts already wired with DCC or using AC should comply with recommended voltages. Some O gauge layouts use higher than 12 volts (RMS) transformer supplies and if this is not well regulated it must be monitored to ensure a peak of less than 15V.

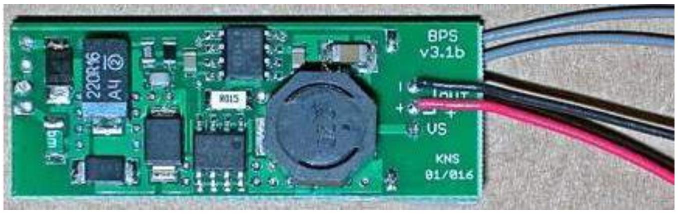


[43] *Comparative drawing of the various power supply waveforms. Note the wild behaviour of a toy train set transformer*.

4. **WARNING**: Avoid use of Toy train set DC controllers/throttles.

Toy DC controllers/throttles as usually found in cheap train sets are not recommended for BPS-v3.1b battery charging and may cause BPS failure.

If you purchased an S-CAB BPS battery power supply this year or late December of last year, it most likely is version 3.1b and the foregoing warning applies.



[44] *Photo of V3.1 BPS as supplied by S-CAB cid:image002.jpg@01D1E13F.D93EB610*

When powered by an appropriate power source, BPS charges a 3.7 volt LiPo battery. Energy stored in the battery is electronically converted to 11 volts output for powering model locomotive decoders and motors.

These controllers, which are designed for operating DC powered locos, are pervasive throughout model railroading. Most do not provide DC. In fact, they output a voltage of high peaks and valleys, which produces unrealistic measurements and requires an oscilloscope to determine peak voltage. Tests of a popular DC controller determined peak voltage output was 22 volts when a voltmeter measured 8 volts. In a test where the voltmeter indicated 12 volts, the peak voltage was 25 volts and the BPS was toast.

I plan to investigate ways to convert DC controller/throttle output to something acceptable for use for battery charging, but anyone building or modifying a layout is well-advised to use regulated DC power.

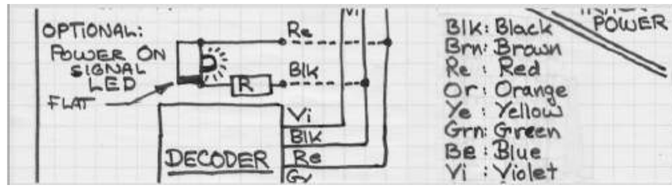
End of Neil's email.

9. Attaching Lights (LEDs):

A headlight is usually a handy power-on indicator. Most North American locos have a substantial light fixture on their smoke box nose. Not so our petite tank engine, a somewhat older design. At the most it wore a diminutive oil lamp mounted on one of several petards, front and rear.

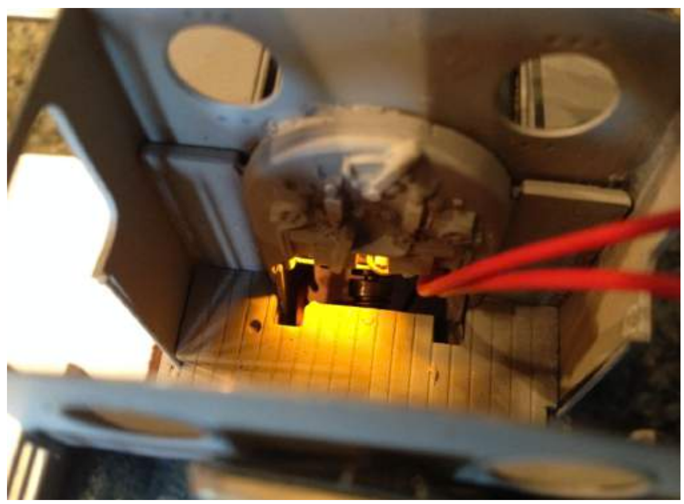
A flickering LED candle is a common cheap item available from the local hardware store and readily represents an oil lamp. The candle unit is easy to disassemble and yields an LED and a 3.7V coin battery. I spent a pleasant spring afternoon on the front veranda trying to file a 5mm LED into the shape of an oil lamp. By the time I had finished it didn't quite resemble an oil lamp and has, for the time being, been put aside.

Since the oil lamp idea did not work out very well, it was decided to connect two candle flicker LED's in parallel to mimic the light coming from a locomotive's firebox. Each LED was connected with its own 1000-Ohm resistor in series and then connected across the power leads, Red and Black, from the BPS to the Decoder. This was quite successful and now signals clearly that the BPS is switched on. The two LEDs draw less than 20mA and put a very light load on the battery.



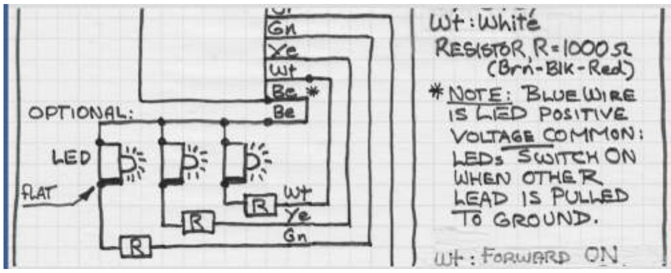
[45] *Section of wiring diagram showing power-ON LED. It is connected to the wires running from The Battery to the BPS.*

It is an eerie scene to have several fire boxes flickering away in a darkened room. I highly recommend them. As an aside, I have been told that the control chip buried inside the LED is actually one of those sound chips, which plays Happy Birthday or We Wish You A Merry Christmas.



[46] *Boiler fire as represented by two flickering candle LEDs and intended as a power-ON indicator. The two red wires are connected to the battery for performance tests.*

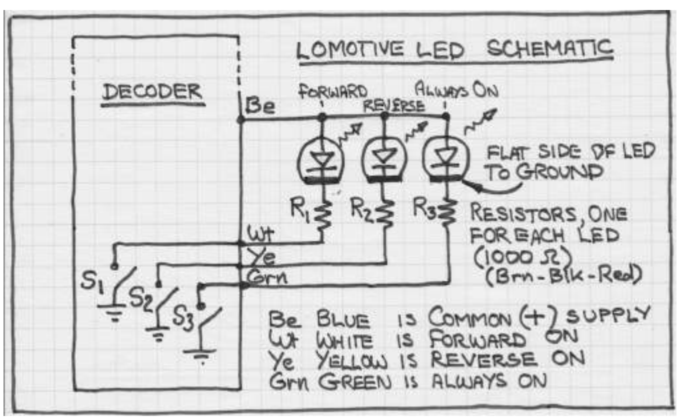
An LED connected between Red and Black from BPS to decoder, is only one of two options available for a Power ON signal. There are three other LED options readily available at the decoder when the decoder is ON. These three LED options are Forward ON, Reverse On and Always ON and are connected in the following manner.



[47] *Section of the complete locomotive schematic showing Decoder LEDs and wire colours*.

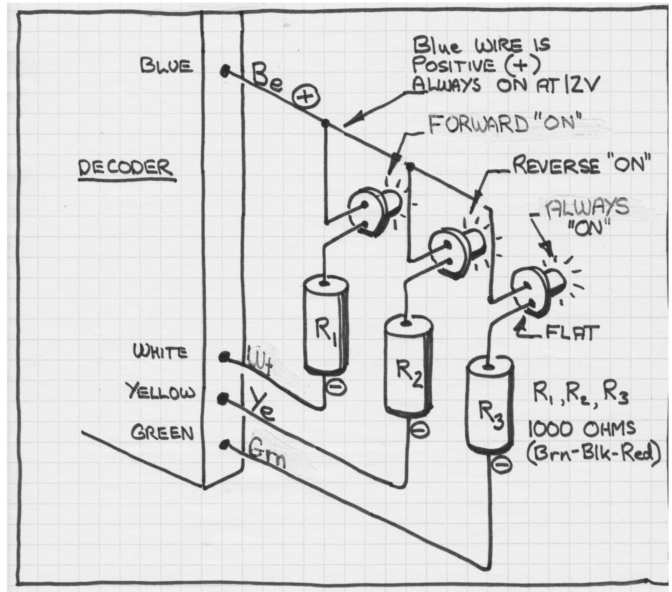
All the LEDs share a Blue common wire. There is also a second wire to each LED and which identifies each LED. These second wires are White, Yellow and Green. The White wire is ON when the locomotive is going forward. The Yellow wire is ON when the loco is in reverse. The Green wire is always ON.

As described earlier in the schematic, each LED requires its own resistor. 12V is present at the decoder Blue wire at all times. An LED and a one thousand Ohm resistor are then connected in series to either the White or the Yellow or the Green wire. These wires connect to transistors inside the decoder and represented by S1, S2 and S3. These are either OFF or ON. If the transistor is OFF then the incoming wire is disconnected from ground and the LED is OFF.



[48] *Each decoder LED is tied to a transistor which acts as a switch to turn ON/OFF the corresponding LED*.

The foregoing schematic can be represented by a pretty picture. Note the flat side of each LED is to the bottom of the picture.



[49] *Pretty picture of the previous locomotive LED schematic*.

When wiring the LEDs be sure that shrink tubing covers all bare wire and that components are well secured to the chassis. Shrink tubing of the right diameter can be slipped over both wire and resistor. This effects both electrical insulation and mechanical strength.

Changing their CV values can alter the characteristics of the LEDs. See the S-CAB Throttle User Guide for guidance on editing CV values:

http://www.s-cab.com/uploads/2/0/3/9/20398179/s-cab_throttle_ug.pdf

10. Evaluating the Performance:

Test Set 1.

This exercise involved chasing the locomotive down the track with an Ammeter connected to leads trailing out of the cab and different loads pulled behind. She and her train grounded more than once onto the basement floor. What pains we engineers take to please Martha.

The current draw was measured by cutting the red positive lead coming from the battery and going to the BPS and connecting these two leads to the ammeter. This dicey proposition was rewarded with somewhat variable data and the reported values are gross averages.

[50] *Set up to test current draw at differing wagon loads and grades*.

Bearings and gears were lubricated with light machine oil. The battery was previously fully charged and ran on unpowered track for the tests. The temperature was 28C and winds were 0 … tests were done in the kitchen and basement. The loco weighed 410g but slipped when fully loaded on the 4% slope thus requiring an additional 240g for adhesion. This weight came from 3 sockets slipped over the steam dome and funnel and all tests were done at this weight:

Weight: 410g + 240g = 650g (23oz)
Motor: Mashima MH1833D
Gear box: Single start worm and 40T gear
Gear reduction: 40:1
Battery: S-CAB 550mAh LiPo
Meter: Fluke 75
Quiescent current draw: 130mA

On the 2% and 4% incline tests, Forward is going uphill and Reverse, down.

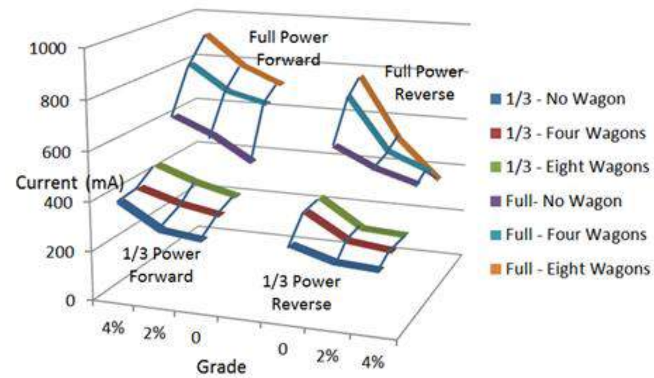
Each wagon weighed about 160g. (5-1/2oz)

The tests:

Load	Grade %	Battery Current, I (mA)			
		1/3 Power		Full Power	
		Forward	Reverse	Forward	Reverse
Loco Only	0	270	290	450	550
	2	290	240	550	470
	4	390	230	620	420
Four Wagon	0	320	370	660	720
	2	350	270	700	500
	4	400	250	810	430
Eight Wagon	0	350	380	710	770
	2	390	270	780	510
	4	450	260	910	350

[51] *Table 1. Note: On the grades, Reverse is downhill*.

The above numbers are fine and dandy but it took a visual presentation through Excel by Mike Walton to breath life into them:

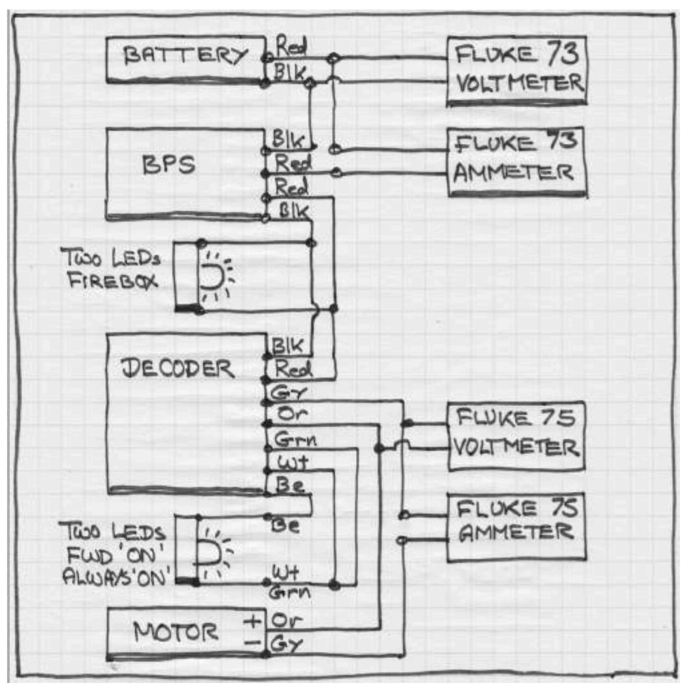


[52] *Carpet plot illustrating the three dimensional relationship amongst Current, Grade and Wagon load. Graph courtesy of Mike Walton*.

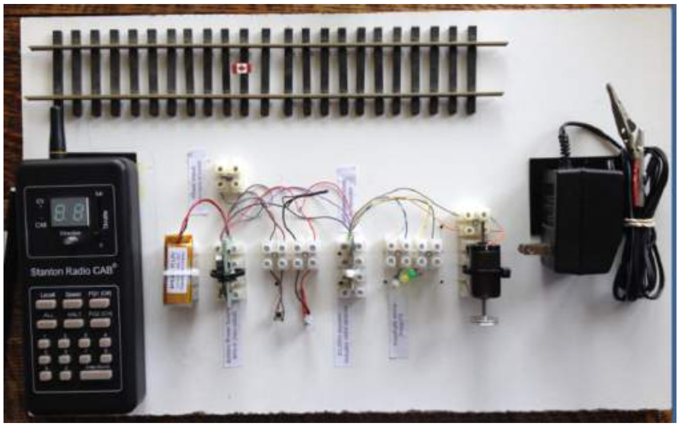
More information on Carpet plots can be found on Wikipedia. They are a common technical writing tool used in the aviation and material science fields.

<u>Test Set 2.</u>

The next set of tests used the following circuit and the breadboard as in Fig. 9.1, to calculate the power over time and under different loads and measure the useful battery duration.



[53] *Wiring diagram of Motor-Loading and current draw test set up*.



[54] *Parts for above test*.

These tests started with a fully charged battery at no load and continued with discrete changes in the motor/generator load.

Full test results are available from the author at:

rplanglois@gmail.com

Please place “S-CAB tests” in the email subject line.

More tests are ongoing. Standby.

11. Conclusions:

The train motored for hours when running around on a continuous track and recharging at less than 50% duty cycle.

Would I have done anything differently? It is possible to squeeze a double 300mAh battery into each side tank for a total of four batteries and 1200mAh. Then the BPS could have gone into the boiler top where the battery is. However, I do not think it is necessary to have such a large battery capacity if strategic sections of track are powered and the loco spends a reasonable time on those sections. Even on an out of doors layout with dirty track, it would have enough occasional contact time to recharge.

Only one of the side tanks is occupied in the scheme chosen. The other could hold a speaker or extra weight, and S-CAB/NCE do offer a sound equipped decoder. I do not find sound pleasing or deeply realistic and have not tried those decoders so equipped.

My own layout, “The Southern: Gosport, Lee and Portsmouth” is operations focused and runs either Canadian or British outline. It is an around the room 10ft by 25ft with 70 feet of mainline, several sidings and a fiddle yard. The mainline is powered by Digitrax DCC to run the CPR D10s and RDCs but otherwise all the British outline steamers are S-CAB and use the DCC track to recharge. Up to this point we have not had too much trouble operating the Digitrax wireless throttles and the S-CAB throttles at the same time. The S-CAB throttles transmit four times over a period of 35mS and even with a number of operators there has not been any noticeable stepping-on or transmission conflict.

I have also installed S-Cab in two other Connoisseur locomotives, a Southern G6 and a Southern 02. When time permits I will review these installations for the Journal. The big difference, in short: I laid the wires in the cab, sandwiched between frame and cab floor and also used double batteries.

Comments from interested parties:

Mike suggested that the table of test values would be much more informative if presented as a graph. When the data arrived as a graph in my email I was struck by the clarity of the story. Thank you Mike for the suggestion and doing the graphing.

- Gordon wanted to know why tests took place on a 4% slope when no modeler would use such steep grades. My answer is “Thoroughness, Gordon, Thoroughness.“ I probably should have done grades of 0, 1, 2, and 4 percent as this would have shown more clearly the trends and yet, still covered any outliers.

- Neil’s comments on the above tests:

“Your load tests are very informative. Once BPS load exceeds 500 mA, it begins the limit current by reducing voltage. The resettable fuse will trip at 800 mA. I would have expected the loco to stall in some of your tests.

With 12 volts on the track, the loco uses power from the rails instead of the battery, which recharges as necessary and may never discharge completely.

To compute battery run time, it’s best to use power because of the step-up voltage ratio. Battery voltage 3.7 stepped to 11 volts is 3 to 1 ratio. Therefore, output current of 500mA converts to 1.5 amps at battery. Run time = 500mAh/1500mA = 20 minutes.“

12. Resources:

Connoisseur Models:

http://www.jimmcgeown.com/

S-CAB and NCE:

http://www.s-cab.com/

https://ncedcc.zendesk.com/hc/en-us/articles/201713349-D13DRJ-Dead-Rail-Decoder

http://www.s-cab.com/uploads/2/0/3/9/20398179/s-cab_throttle_ug.pdf

http://www.s-cab.com/uploads/2/0/3/9/20398179/installation.pdf

<u>Dead Rail Groups and Articles</u>:

https://groups.yahoo.com/neo/groups/S-CAB/info

http://www.deadrailsociety.com/

http://www.pmrr.org/Articles/index39.htm

<u>Battery Technology</u>:

http://www.s-cab.com/battery-care.html

https://en.wikipedia.org/wiki/Lithium_polymer_battery

http://www.powerstream.com/tech.html

http://www.manoonpong.com/Other/main_page=page_2.pdf

https://en.wikipedia.org/wiki/Carpet_plot

<u>Inductive Charging:</u>

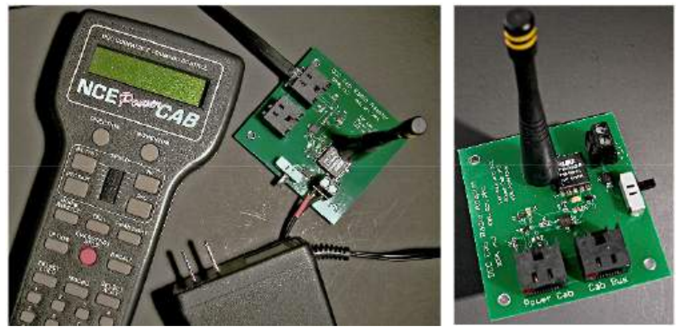
https://en.wikipedia.org/wiki/Inductive_charging
https://grandmaket.ru/en/

<u>Battery Powered EMU</u>

https://en.wikipedia.org/wiki/Battery_electric_multiple_unit

13. Postscript: Changing Manufacturer Specific CV's:

The NMRA defines a block of CV values. In addition, each manufacturer has their own set of CVs particular to their own decoders. Only the NMRA defined CVs can be changed by the S-CAB Throttle. To change manufacturer specific CVs requires an extra piece of kit from S-CAB known as a Radio Programming Adapter (RAPA).



55. *The S-CAB Radio Programming Adapter (RAPA) with an NCE controller and power supply for changing manufacturer specific CV's.*

Contact S-CAB for more details.

Post–Postscript: Zen and the Art of Motorcycle Maintenance by Robert Pirsig

In his book, Robert discusses the meaning of quality. He asks what is quality and makes the point that unlike mass or colour, quality cannot be measured. It cannot be put on a scale, pointed to and compared to another object of lesser quality. Yet most of us form an opinion when looking at two objects that one of them has a greater quality than the other, unless, in a politically correct age, all things have the same quality. So what is quality?