Signalling -

A system design for Safety, Flexibility, Simplicity

Updated April 2024

A team of Taunton Model Engineers have been looking into signalling for our railways at West Buckland. How are we doing?

The Overall Scheme

Starting with a clean sheet, the first thing written was a mini ‘Mission Statement’:
“The purpose of West Buckland Railway Signalling is to promote safe running of the railways.”

Cardinal Objective number One - “Safety”.

Then we asked “What are we building railways for, and what do members expect?” It seems some members enjoy passenger hauling, or just driving around. A few like to shunt wagons, others are determined to re-enact all the worst railway disasters of the 19th century. Seeking consensus on how signalling should work? Best advice, light blue touch-paper, and run!

Evidently building a safe signalling system accommodating all our many and varied railway fetishes was never going to be easy. A large project like signalling cannot be rolled-out overnight. It will evolve; howls of indignation will be heard along the way. Embracing “Flexibility” as our second Cardinal Objective should offer reassurance that not many reasonable requests get ‘ruled-out’ forever.

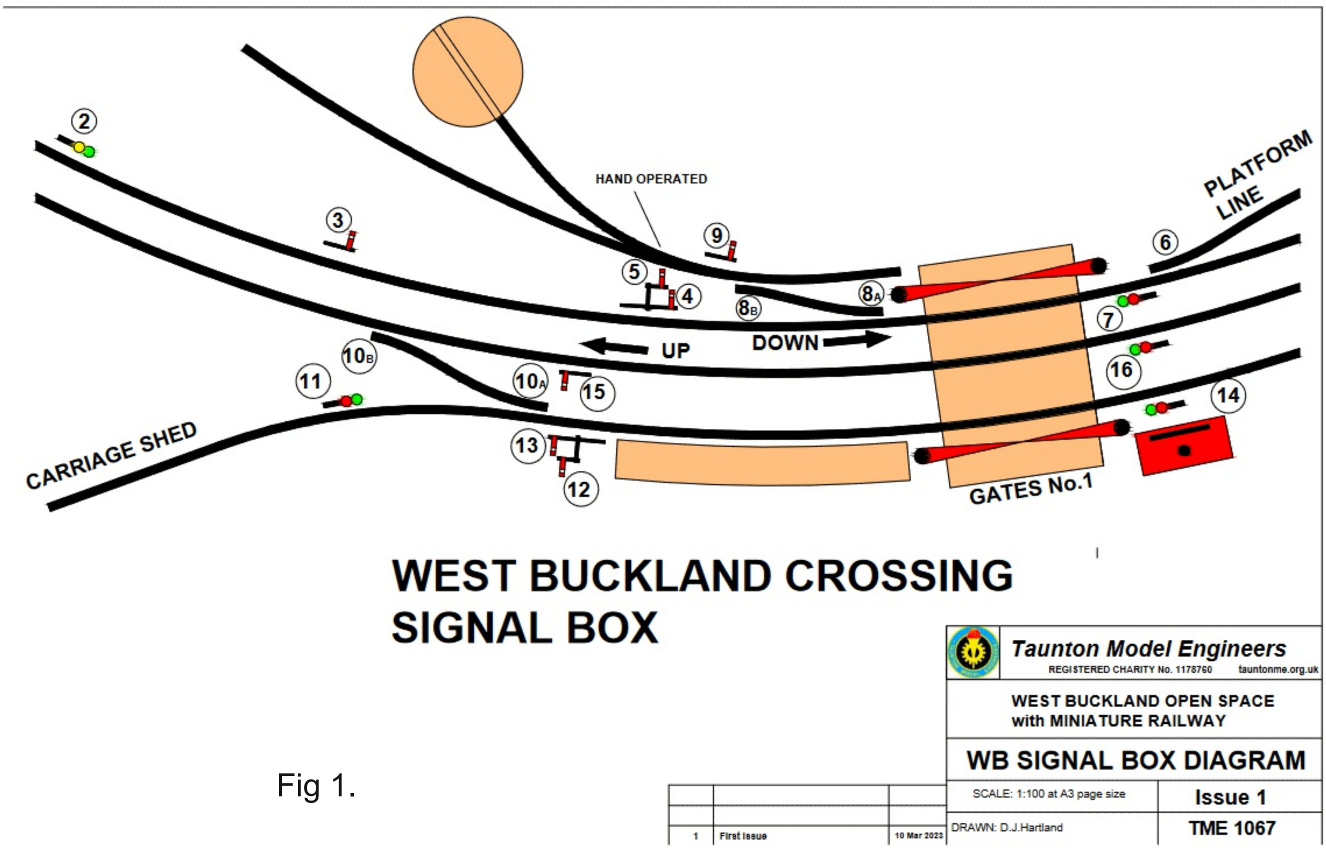

Fig 1.

Projects of this scale generate what would have been, in former times, 'paperwork'. Lots of it. When this all ends up lost, in a box in someone's loft, the project collapses. To avoid this, and in the spirit of co-operation with any kindred spirits, we decided to 'Open Source' all our design work by publishing it to the internet, and have set-up a web-site, our own online library, for the purpose - https://tauntonme.github.io/ (See here for all the latest, and more detail than we have space for here!). Signalling team members are encouraged to spend an hour or two learning the essentials of how to use "GitHub.com", the site 'hosting' our library and web site. Newcomers may feel some slight culture-shock at first, but there are numerous tutorial videos on Youtube to ease the pain. Using GitHub provides the means of working collaboratively with disciplined 'version control' maintaining project history and 'traceability' for design decisions. Once up and running, team members are invited to join as new 'collaborator's so that we can all work with the drawings, code and other types of files we'll create and save there. Over one hundred million companies and individuals worldwide now use GitHub, apparently. This is how projects are managed these days. No filing cabinets, no plan chests, no box in the loft. Local members keeping backups ensure that if any one thing fails, nothing is lost.

The Signals

With safety paramount, a common sense assumption was that lineside railway signals would use coloured LED lights as these are low-cost, simple, versatile and reliable. The alternative, using semaphore signals, involves a great deal more work, but in keeping with 'not excluding reasonable requests', it was agreed to use a common interface so that even if colour lights were used to start with, semaphore signals could be substituted in the future.

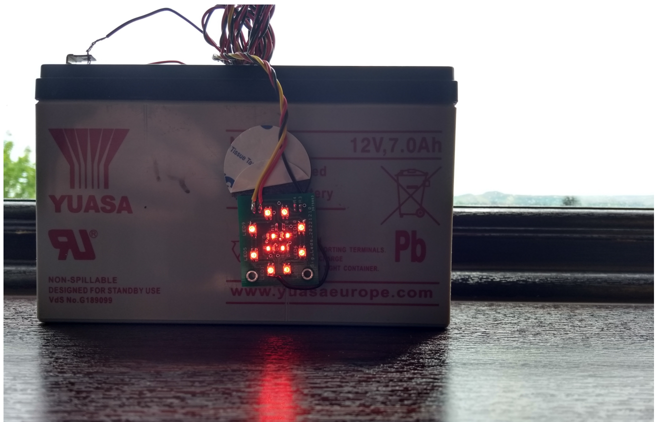

Fig 2. These LEDs not bright enough !

For the colour light signals, there are varied experiences of these. Subjectively, the colour of a piercing LED point source is harder to discern at a distance than for a similar light energy spread over an area. A one inch diameter printed circuit board disc was designed and soldered up using 12 LEDs – Fig 2. This was demonstrated on site where some deemed it "not bright enough". A new board has been designed using 'high brightness' LEDs. These surface-mount devices are not 'human-solderable', but excellent Bridgwater company 'Circuitbase Ltd' built them for us. With a dedicated control board with proven 'CAN Bus' interface we have a clear, bright signal complete. For full details see tauntonme.github.io/ under 'LED Signals'.

The Layout

Out in the field, two separate signalling systems are planned – one for the ground level, and one for the raised track. The raised track will be interesting, runnable in either direction, design ideas have coalesced. Work on this can proceed once the traverser and steaming bays are in place and the track is ready to operate. Cable ducts have already been laid in the concrete.

For the ground level, Fig 1 is the plan of the eventual track layout showing the area of greatest site activity, and illustrates the obvious that not much else is worth doing until the level crossing is finished, complete with all necessary and desirable controls and interlocks. Work is progressing in this direction, control gear will be housed in the signal box, next to the crossing.

Position Switches

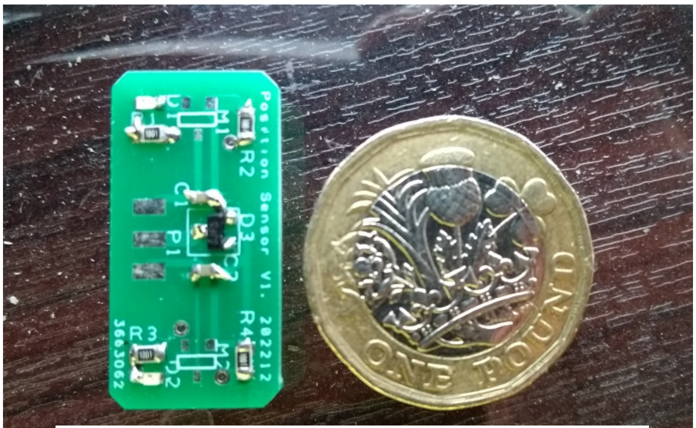

Fig 3. Dual Hall Position Sensor

The signalling system needs to know at all times, the position of moving parts. Fig 1 gives a feel for the range involved: signals, crossing gates, signal-box levers and turnouts (‘points’ in old money) – all of these from the control point of view, look very similar, so similar that we devised an all encompassing “Moving Part Rule” (see web site for full info). This specifies pairs of switches or sensors operated by each moving part sending electrical information to the signals controller so it can determine whether parts are in either of two ‘safe’ positions ‘A’ or ‘B’, or any unsafe position ‘X’ (or ‘Wrong’). This is all standard and familiar signalling hardware practice. A dual Hall effect magnetic switch was designed with turnouts in mind – Fig 3. This has two magnetic sensors at 19mm centres, the idea being a small 3mm diameter 4mm long magnet is moved from being directly above one to the other as the moving part moves. This switch needs now to be developed into a weatherproof box with linkage to connect to the relevant moving part.

Detecting the Trains

Railway signals may offer clues to train positions as reported by any train or movement detectors. ‘Track circuiting’ has been a popular method of monitoring train position, still used in places on the Big Railway, although giving way to modern methods such as ‘axle counting’. Track circuiting has an advantage in providing continuous evidence of a train in section. Further consideration, however, can be dismissed as in our design brief, track circuiting had already been ruled out. On the big railways, with trains passing many times daily, the rails are kept clean enough for the necessary electrical connections to be reliably made through rails wheels and axles. This would not be so on our railways where a few day’s worth of leaves and rust on our steel rails would defeat the whole system.

Instead, we must choose among a number of proximity detector technologies all of which, unlike track circuits, provide pulsed, or discontinuous, indication of a train passing. It is then up to the signalling system to assemble and maintain some record of train passage over detectors, into and out of sections. Work on methods of train detection began long ago. On the design bench we have a promising prototype detector which uses inductive coupling methods similar to those used by Frauscher Sensortechnik GmbH in their range of axle counters (see 'Rosenberger'). This work ‘ran into the buffers’ a while ago and will be picked up again hopefully soon, that’s just how it is. It’s easy enough getting sensors to deliver analogue electrical proxies for the clickety-clack of metal wheels trundling by. Interpreting these into a certainty of where a train might be, and where it may be heading, or if it has stopped where we’d rather it hadn’t, or started rolling back, is more of a challenge.

Compared to the Big Railway, we also have to contend with a wider range of wheel types, materials and geometries. If big thick wheels are always detected but dainty pony truck wheels might not be, what happens when a ‘marginal’ wheel is detected by some, but not all, train detectors? A good solution will be found, design of the rest of the signalling system proceeds in acknowledgment. Baked into the specification for train detectors will be ‘a simple interface’, with complexity of train-detection managed entirely within the train detectors.

The Control System

At first sight signalling control systems might appear complicated and difficult. They can be, but only if we let anyone make them that way!

Complexity tends to creep into areas of unresolved debate. Turnouts could be pneumatic, motorised, lockable, or spring loaded, or 'trailable' or not - the railway will be up and running before contentious issues such as these are put to rest. Designing around unanswerables underlines the need for flexibility, but we need to be on guard against profligate complexity.

A third cardinal objective begs for adoption, "Simplicity".

Argument supporting Choice of Technology

How do we choose a controller technology? Looking down from above, our site and signal systems might seem complicated, but as we look closer, we can see individual lineside signals and what might affect what they show. It can be seen that each signal shows the logical result of testing the condition of only a small and constant selection from the whole. There may, for example, be a signal to show 'Clear' only when safe for trains to cross the crossing. A logical test of gate and gate lock positions is sufficient. Similar argument applies to all signals. Therefore we do not have one large system. We have maybe a few dozen small systems, all of trivial complexity, with few if any interdependencies. This could be considered a 'broad' system topology, implementing a moderately sized family of small, independent functions. Site-wide the total number of switches and sensors feeding inputs to the controller easily tops one hundred, with each small function using only a few.

A controller forever re-evaluating a few dozen simple Boolean logic expressions, with no need of analogue processing, mathematics, or anything remotely difficult, this describes a 'shallow' system topology. 'Deep Thought' computing not required!

Broad topologies lend themselves to 'bottom up' design approaches. We could hard-wire functions one at a time using a handful of logic gates, or even relays as used on some other miniature and model railways, but hard-wired logic is inflexible by design. Every change involves time-consuming and error-prone wire cutting and soldering, argument sufficient to rule out such obsolete methods. A safer, more flexible, and simpler, 21st century solution is sought.

Programmable Logic Controllers (PLCs) could be a natural choice. Many reputable PLC manufacturers offer kit more than capable of meeting our control needs. The problem with PLCs becomes apparent when we consider our 'broad' topology, the large number of I/O (inputs / outputs) - inputs from sensors and switches, and outputs to devices all around the site. This gets expensive and unwieldy using multiple I/O expansion modules, or expensive and untidy using multiple PLCs.

Looking for inspiration from other miniature railways using modern signalling systems, there's not much useful to be found, but the East Herts Miniature Railway has a sophisticated, professional standard computerised system. Their published design data (https://ehmrs.github.io/) shows what looks to be a first class system, meeting our objectives of safety and flexibility, but our members would show no appetite for this degree of computerisation. A simpler solution for West Buckland is needed to keep members engaged. We don't want to end up with a 'one-man project'. Nevertheless, the East Herts data includes many useful hints and tips!

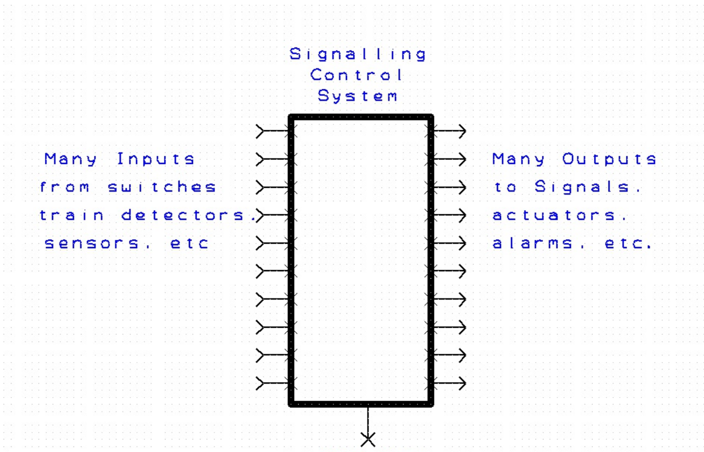

Fig 4

For the simpler West Buckland controllers, we could imagine a very simple system-diagram with a box in the centre, the input connections joining from the left, and output connections leaving to the right (Figure 4). How it works is like this. Constantly up to date information about the state of the railway arrives from the left on the input wires. Whatever is in the box works with this in some way, and sets all the outputs according to whatever rules we've given it, job's a good 'un!

Given that in terms of raw computing power our signalling needs barely tickle 'trivial', a low-cost industrial control module (ST Nucleo-L432KC) costing about £10 will be more than 'powerful' enough as the computing core system component. It doesn't have enough I/O (input and output) pins, but this can be expanded out to any number using daisy-chained shift register chips at a few pence each. Connections to these delicate low voltage logic chips need some protective buffering circuits to make them robust and abusable enough for connection to the Big Bad World, costing a pound or two per pin. That describes our controller hardware needs. The occasional dabbler in hobby-electronics could follow this.

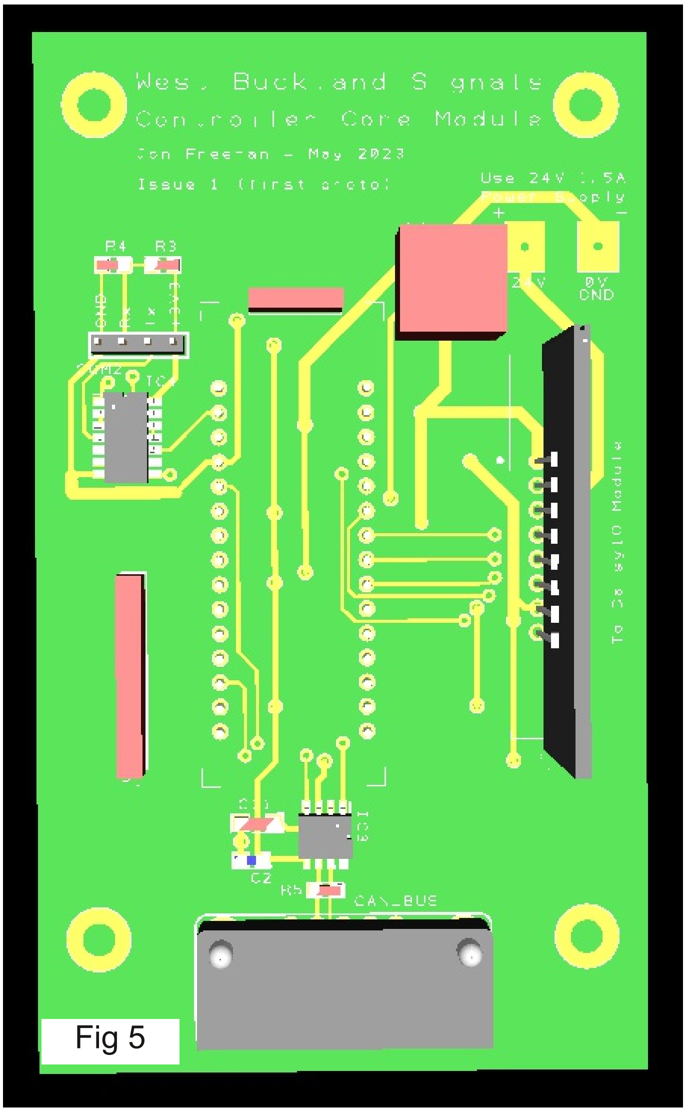

Fig 5

Figure 5 shows a simulated view of a controller printed circuit during design. This was completed in May 2023, a working kit of controller and expansion boards have been extensively 'bench tested' since, and an informative three minute demo video explaining this and much more has been published on the TME Members Group Facebook page (https://www.facebook.com/670956094/videos/1026308101878957/) . It's worth a look!

To make all this work requires a 'programme' which is where some readers may get nervous, but key to this is use of good 'Plain English'. Every location of interest on the site - every signal, every track section, each of the three ports of every turnout etc - should be given a sensible Plain English name. The interesting part of the programme then becomes, almost, 'Plain English!', easy for humans to read, understand, and change. The programme repeatedly runs round a 'forever loop', reading all the inputs, deciding what if anything to do, and changing any outputs as per coded instruction.

That’s how difficult the controller needs to get. Really. The hardest parts of the signalling project are the physical site work, and getting members to agree what they want!

For readers who may still think signalling systems need electro-mechanical relays, think of the £10 industrial controller as a rack of many thousand ‘virtual’ relays, costing a fraction of a penny each. A fair if imperfect analogy. All “relays” fit in one tiny chip and don’t need a massive cabinet on a concrete base. They are reliable, consume immeasurably close to zero power, and operate millions of times faster than electro-mechanicals while eliminating race-hazard! Out of the box no “relays” are wired up, that’s what the programme does! Anyone interested in programming is encouraged to look at the code on the tauntonme.github.io web site, any comment or constructive criticism welcome, and if you’d like to get involved ...

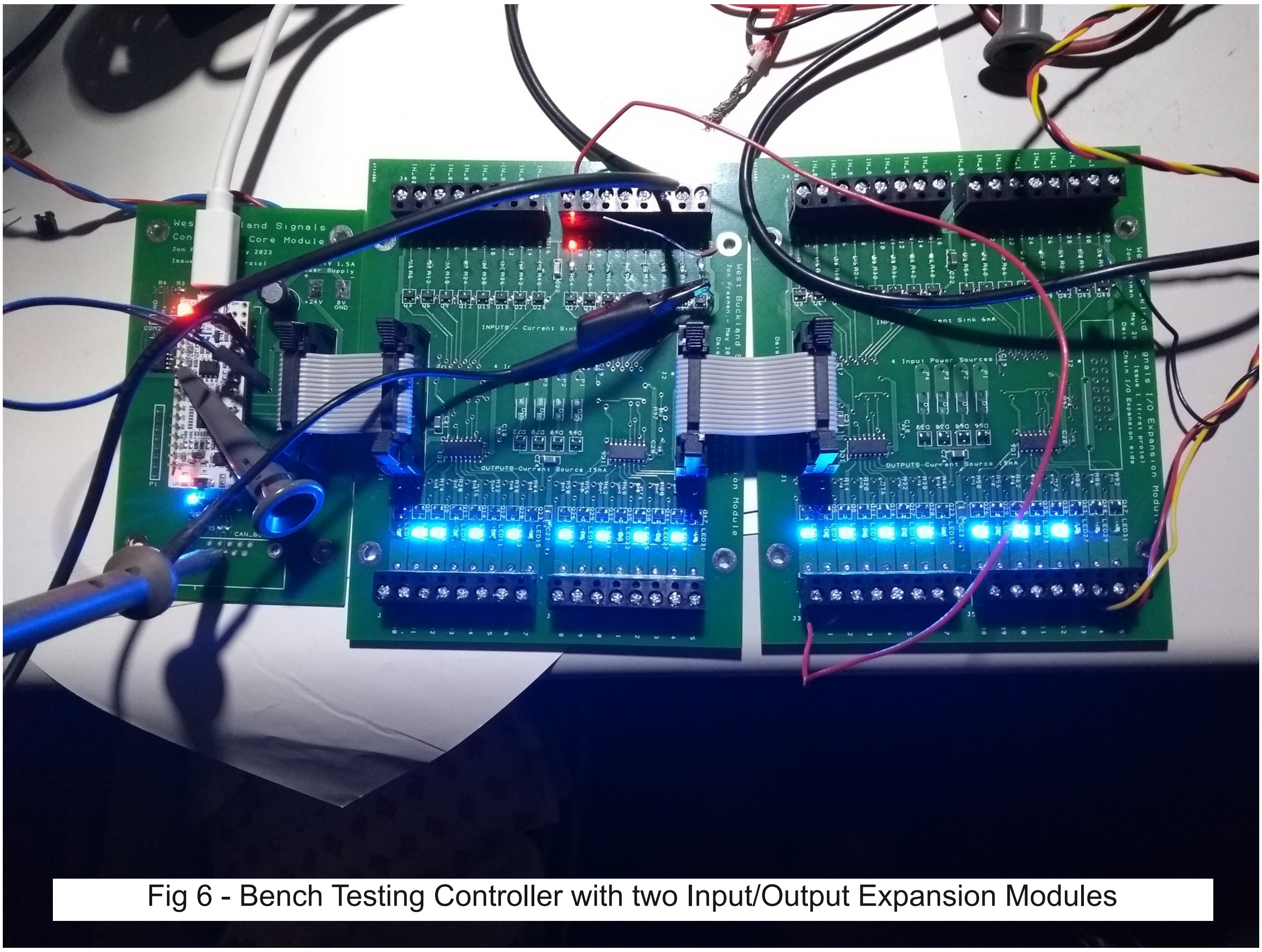

Fig 6 - Bench Testing Controller with two Input/Output Expansion Modules

Level Crossing and Signal Box

The signal box was donated to the Club last year and is being rebuilt within a timber frame, see Fig 7. The level crossing gates are complete and actuated by pneumatic cylinders worked by compressed air. They swing beautifully! Position sensor switches will be fitted to each gate in accordance with the ‘Moving Part Rule’. Controller printed circuit boards have been designed, built and tested. This will in the first instance be connected up to test the automation of level crossing workings, and to give some experience of control systems and programming. Later it is planned to extend this to include signals, turnouts and the rest. This may use the same circuit board or another similar. It makes little difference whether all controller functions live on the same circuit board in the same box or not. It might make sense to keep a dedicated level crossing controller, in communication with others looking after everything else.

In Conclusion

Hopefully this has given a fair over-view of how the signalling system will work. Bolt-on goodies such as display panels, data loggers and whatever else may be wanted, can be designed to be compatible if anyone is up to the challenge.

Our web-site based data repository (https://tauntonme.github.io/) has lots more interesting stuff there already, including any updates, and much more on the electronics.

If you're not with us yet but think you might like to get involved then please let us know, all are welcome. There is work to be done on the lever frame, making signals, developing position detectors, building the signal box, painting…. And of course, we have to raise some money to pay for all this work!

Fig 7 - Signal Box - Under Construction

Author - Jon Freeman B. Eng. Hons.

Original work May 2023. Updated Jan 2024 incorporating input from Taunton Model Engineers