Electronics for Model Railways

Chapter 3

Layout wiring options

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In memory of Margaret

Contents

Layout wiring options

Some layouts are planned and some layouts just 'develop' with time.
While a lot of thought often goes into designing the tracks, the wiring of the layout is often looked at afterwards. This can easily lead to ad-hoc wiring schemes involving duplication of work, greater fault liability and even ripping out some parts to start again.
This is all avoidable if the layout wiring is considered along with the rest of planning of the layout. Don't lay the track then think about the wiring; plan your wiring requirements before laying the track.

This, in turn, means that you should give some thought about what type of layout you are aiming to produce - from an electrical standpoint.
As we will see later, there are a variety of ways to operate and control a layout, with each requiring different wiring systems (e.g. DC, DCC, CBUS, etc.). You may even decide to buy particular brands of track and points that best match your final layout configuration (e.g. do you need insulfrog or electrofrog points).

Layout Wiring Goals

The wiring of a model railway should have as its main aims:
Reliability (not prone to breakdowns, overheating, fire or shock risks)
Maintainability (easily looked after and corrected when things go wrong)
Alterability (the existing layout can be easily altered or added to)
These goals can be established by implementing some 'standards' with respect to the wiring.

Reliability complications include

- Long wiring runs (voltage drop, induction, interference)
- Multiple baseboards / connections
- Multiple operators
- Mixing DC and DCC
- Signalling
- Feedback / automation

Maintainability / alterability complications include

- No / incorrect documentation
- No wiring scheme
- No diagrams
- No fault history
- Inaccessible mountings

Safety

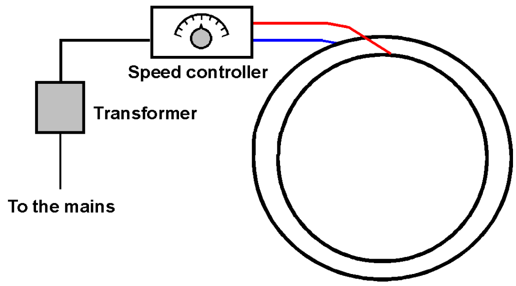
A short, but important, word before we begin.

- All the wiring that runs above and below your baseboard should be at low voltage.
- Mains voltages should never be allowed on the baseboard.

There are a number of circuit diagrams available on the Internet for constructing home made loco controllers. Most use mains transformers to feed the rest of the circuit. Please don't attempt this unless you really know what you are doing. An alternative is to use 'wall warts' or 'power bricks' – power supplies that are sold for use with consumer goods or computers. These are double insulated and safe to use.

Different operating approaches

Model railways are a hobby. That means that there is no 'correct' way to design a layout. It's about what you want to achieve. Some may aim to run an exact timetable for a particular railway line in a particular era. Others may prefer a more eccentric and chaotic narrow-gauge layout based on imagination. Yet others may enjoy the challenge of constructing a fully-automated, computer-controlled layout. Last, and not least, some may be content with a simple *'Thomas the Tank'* layout running round a loop.
All these, and others, are legitimate layouts. They only differ in the complexity of the layout wiring.



A simple loop of track, with a point or two, is easily wired by even the newest beginner, only requiring two wires from the controller to the track.
Moving beyond a simple loop, to the medium and large sized layouts, there are different attitudes to how a layout should be run. These differences lead to different wiring requirements.

Firstly, there is the ongoing discussion as to whether the train is controlled by the driver or by the signalman. In most layouts, the trains are controlled by the operator (driver) with the signals being purely ornamental (doing nothing) , or an optional extra (manually operated) or simply tied to the trackside detectors. The other view is that to emulate the real world, train movements are controlled by the setting of the signals and therefore the hobbyist should have the primary role of signalman. The train movements are then dictated to by the signals, either manually or automatically. That leads to different wiring approaches.

Purely manual

Everything is left to the operator.
There is no interlocking.
Trains can run into the back of each other.
Its up to you to control everything.
Everything is wired back to the control panel.

Manual with train detectors for signals

Train detectors are used – but only to operate the signals.
They have no effect on the trains.
Trains are still controlled by the operator.
It is still up to the operator to ensure trains don't run into each other.

Manual with some interlocking

Train detectors are used to operate the signals.
They also operate relays that ensure power is switched off in the preceding section.
The operator runs the trains but is prevented from running trains into each other.

Manual with computer assistance

The operator still runs the trains by hand.
The train detector information is fed back to the computer.
The computer controls the power to the sections.
The signals can be operated directly by the train detectors or by the computer.
Useful for 'glass panel' operators - those using mouse controls on a monitor screen.

Fully automatic.

The train detector information is fed back to the computer.
The computer controls train movements based on this information.

Layout options

The 'train set' of our youth was simple. A pair of wires from the controller was attached to the track of the oval and the train ran in circles. One operator, one controller and one loco on the track at a time – layout control at its simplest.
When a more complicated layout is planned, that involves having several locos on the track, or several operators, a number of different wiring methods are available.

There are two main approaches to layout wiring:

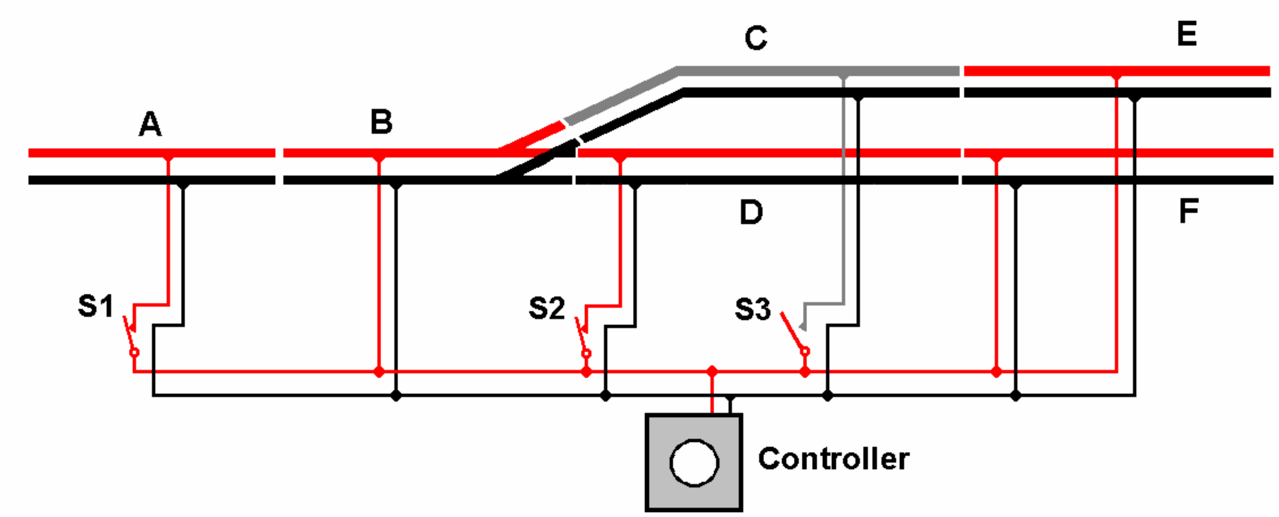
- Block or cab control
- Bus-based layouts

Block control

Real-world railways divided up mainline track into long blocks, with entry to each block controlled by signals. This prevented trains from running into the back of each other.
This concept can be adopted for model railways in various options. We can carry out all operations manually, through electronic modules, or through computer control.

For us, block control is a common means of controlling multiple DC locos on a layout. If you divide your layout into sections of track that are electrically isolated from each other, you can place multiple DC locos on the layout, each in a separate track section.
If you are installing track, you can use plastic rail joiners to isolate adjoining rails. If the track is already laid, the rails can be cut with a fine-toothed saw or with a cutoff disc in a Dremel drill (don't forget to wear protective glasses).
Since each loco sits on an isolated section of track, it can be operated in that section, independently from any other locos on other sections.
You would create a block for each section of track on which you are likely to run, or park, trains.   Some sections will be long (e.g. a stretch of main line) and others short (e.g. a siding or a passing loop). The more blocks you create, the more flexible the layout becomes – but the complexity of the wiring and switching also increases.
Since each block requires to be powered independently, they need their own separate power wiring back to the loco controller.

This illustration shows a basic block system (sometime referred to as a *'Star'* or *'Point to Point'* system).



All the track sections shown are isolated from each other but are all connected to a central point (the controller), usually via switches or relays.
The operator decides which locos to run by powering up that particular section by throwing its power switch.
In the example, sections B, E and F are permanently wired to the controller so these track sections are always powered.
Because switches S1 and S2 are thrown, sections A and D are also powered but section C is unpowered as switch S3 has not been thrown.

So, throwing these two switches allows the operator to drive the train from block A, through block B, to block D. If switch S2 is now turned off, block D has no power and the train sits stationary in the block.
Now, if switch S3 is thrown, a train in block C is powered and could be driven from block C, though block B to block A.

Pros:

- Each section is independent, so a failure in one section need not prevent the rest of the layout from working.
- Each section only draws a proportion of the total layout current.
- You can concentrate the entire layout's device controls (circuit breakers, block detectors, light switches, point control modules, etc.) in one accessible location.

Cons:

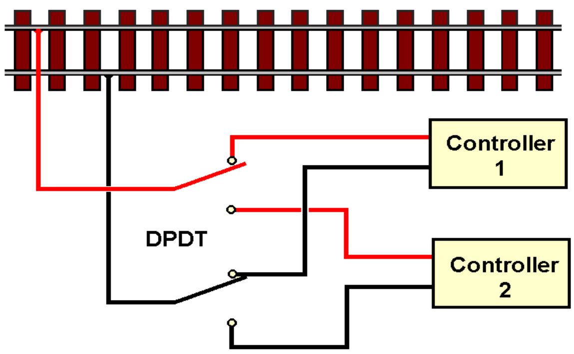
- The huge amount of wiring that is involved produces cable management problems, unless meticulous records are kept.
- The long runs to the remotest parts of the layout may cause voltage drops in the cable and connectors, reducing the efficiency of the devices at the far end (e.g. locos running more slowly, LEDs dimmer, CDU's being less punchy).

Multiple operators

The simple illustration above shows three tracks sections that can be switched between being powered and unpowered. It is designed for one operator, running one train at a time, using a single controller. That is enough for many home layouts, with the switches to power the blocks mounted in a central control panel.

For larger home layouts and club layouts, there is a need to have multiple operators, each running their own locos – while still maintaining electrical and physical separation.
For every loco running on the layout, there is an operator with a separate controller and two controllers should not be connected to the same block at the same time.

In some cases, the operation is simple: one operator can be handling the main station while another handles the mainline, another the marshalling yard, and so on. To maintain movement, there would have to be a common handover point for each operator's domain. So, for example, the operator of the main station and the operator of the main line would require control over a common block (e.g. entry to the station throat).



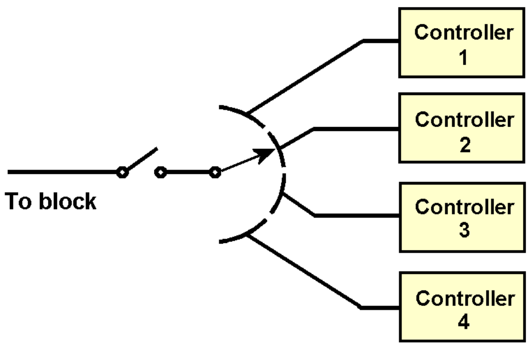
The illustration shows a DPDT (double-pole double-throw) switch. When set one way, it connects controller 1 to the block; when set in the other direction, controller 2 is connected to that block. You might prefer to have a 'centre-off' version of this switch so that, in mid-position, the block is left unpowered.
This approach suits layouts where operators have defined layout districts to control and eventually have to hand over the loco to another operator. It is less suitable if you want to control a train as it goes all round a layout.

Cab Control

The most flexible approach is to allow all operators and all controllers access to all blocks. This is known as *'cab control'*. It gives any one operator the ability to control his/her train anywhere on the layout. Naturally, this raises problems of *'interlocking'* – making sure that no two controller access the same block at the same time. This can be achieved through lots of switches, or through more complex arrangements using electronics and relays.

We could have a separate switch for each controller to every block, but this quickly creates problems. Imagine a control panel that allowed 6 controllers access to 80 blocks – a total of 480 switches! However, there is an even bigger problem. To ensure that one controller had sole access to a block, we would have to ensure that the other five controller's switches were switched off – accidents waiting to happen! Luckily, there is an improved switching system that drastically cuts down the needs to a single switch for each block.

Let's consider a single block for the moment. If there were four operators, for example, we could have an switch arrangement like that shown in the illustration. It uses a 1-pole, 4-way rotary switch. If controller 2 wants access to the block, the knob is turned to position 2. This prevents the other three controllers from connecting. The on/off switch can be left in the 'off' position when the block is not being used, preventing unintended train movements.



This works well for a single block and can be replicated again and again for other blocks, with a rotary switch and on/off switch for each extra block added.

Switch panels

With a small layout, cab control is usually achieved by fitting all the switches to a central control panel.
It is still possible to have a central switching panel in a larger layout, as long as the operators are happy to have a main co-ordinator in charge of all layout block switching.
The main co-ordinator decides which operator can take over a block and provides access to the block to the chosen controller. The co-ordinator informs the chosen operator that he/she is ready to go – verbally, through lights, or through switching track signals. This method may be thought useful for running timetables, with the co-ordinator as the signalman, dispatcher, or 'Fat Controller'. It still allows some degree of flexibility. So, if block 12 should never be available to controller 3, then controller 3 will not be wired to block 12's rotary switch.

Central control might be considered too restrictive and a common alternative is to wire smaller local control panels throughout a large layout. The blocks of a goods yard may be given their own control panel, as may a station or a fiddle yard.
This system is usually accompanied by portable handheld throttles that plug into the layout close to the control panel. This way, any operator can walk up to a control panel, plug in a handheld throttle, dial his controller number on a block switch, and start running the train in that block. If required, a number of block switches can be similarly set, allowing the operator to run the train across multiple blocks.
Moving from control panel to control panel, an operator can run a train anywhere on the layout.
Another advantage of using local panels, is the shorter wire runs between the track and the panels.

Electronic switching

While switches are the simplest way to ensure cab control, power to blocks can be controlled electronically. When a relay switches one controller's power to a block, it prevents other relays from switching until the block is released by that operator.
Many home-brew designs have appeared to meet the needs of particular layouts.

Ready-made modules are available for automatic block control.
Heathcote Electronics have a range of modules that implement interlocking and also include acceleration and deceleration of the loco.

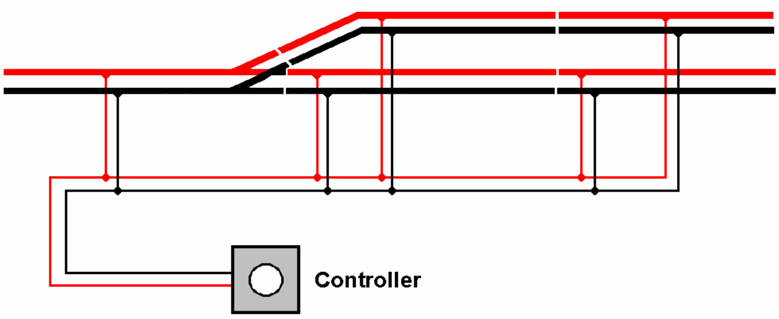
MERG's SuperBloc system produces electronic kits that ensure there is never more than one train in each section at any one time. Trains can be controlled manually by setting signals in each area, or run automatically via interconnected block controllers. It is designed for DC motors.

Finally, control of blocks could be achieved by linking electronic boards to a personal computer.

CTI Electronics market a range of boards, under the 'Train Brain' range for controlling DC locos, via a PC and MERG produce a range of kits for DCC in its CBUS range for standalone or PC working.

Bus control

This approach dispenses with lots of block switches
This illustration shows that a single pair of wires is taken from the controller and routed round the layout.



Wires are then run from each piece of track to connect to this 'bus'.

So, all sections of the track have power at all times. Control of individual locos have to be controlled by other means – this is the basis of DCC-based layouts.
In some cases, a bus could be wired as a loop, although not for DCC.

Pros:

- The huge potential reduction in layout wiring.
- Fewer wires means the wiring is cheaper/quicker to install.
- Fewer wires means reduced maintenance problems (fewer wires to break, fewer connections to corrode, fewer wires to have to trace/colour code/document.
- Fewer wires means less interference between longs runs of parallel wires (noise, crosstalk, induction).
- Easy to extend. Adding an extra baseboard, or adding a terminus, does not require lots of extra wires to be run back to the central point. The devices are simply tapped on to the existing bus which is extended to the new work area.

Cons:

- Vulnerability to breakdowns. Since the entire layout relies on a single pair of wires, any breakdown in the bus could stop the entire layout from working. A system of cutouts to various sections is necessary to restrict the breakdown to the section that is causing the problem.
- Without using additional boosters (see below), the bus has to handle the entire current demands of all attached devices.

DCC (Digital Command Control)

DCC is becoming ever more popular due to its many extra facilities, including track wiring simplification. At the level used by most small layouts, a single controller is wired to all sections of track. The entire track system is powered at all times and special decoders are fitted to each loco. That allows the controller to send messages to specific locos on the layout, instructing them to move, change speed, change direction, switch on loco lights, make sounds, etc.
Locos are free to move around the entire track system without the need for track breaks, isolated sections, section switches or relays. Movement between stretches of track is seamless.

Pros:

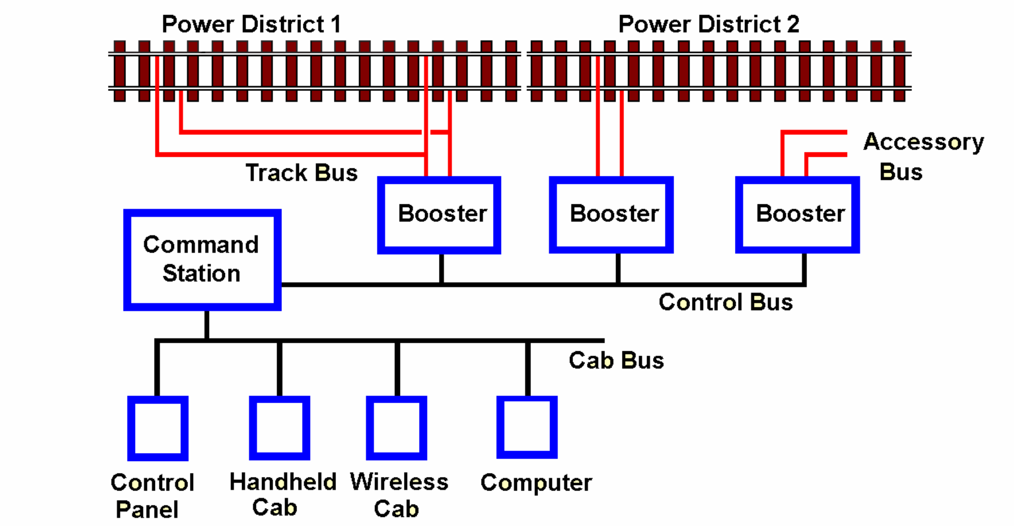
- No block/section switches or relays.
- Less wiring / fewer connection problems.
- Can run multiple locos – even on same stretch of track.
- Automation software, commercial and public domain, is easily integrated.
- Stay-alive capacitors can be fitted to locos. This minimises problems with insulated frogs and dirty track (particularly welcome for smaller gauges with short wheelbases).
- Points and accessories can be controlled via trackside decoders. These attach to the DCC bus and get their power and instructions via this single bus. No need for a separate accessories bus.

Cons:

- Expensive. Savings on wiring costs are wiped out by high cost of decoders.
- Requires initial tweaking of decoders (setting the CV, motor tuning).

Large scale DCC

Large DCC-based layouts create additional problems that need extra wiring.
If many locos, or locos that consume heavy current, are used then the total current demand may be greater than that available from a DCC controller. Up to a point, that can be satisfied by adding a booster to the controller. Beyond that, the layout would have to be divided into separate isolated sections with each section having its own power booster.
Also. large club layouts usually have multiple operators, each controlling their own work area on the layout. The wiring system has to take that into account.
These problems are overcome at the expense of more complex wiring.
This illustration shows a large DCC-based layout that has locos with high current demands and multiple operators.



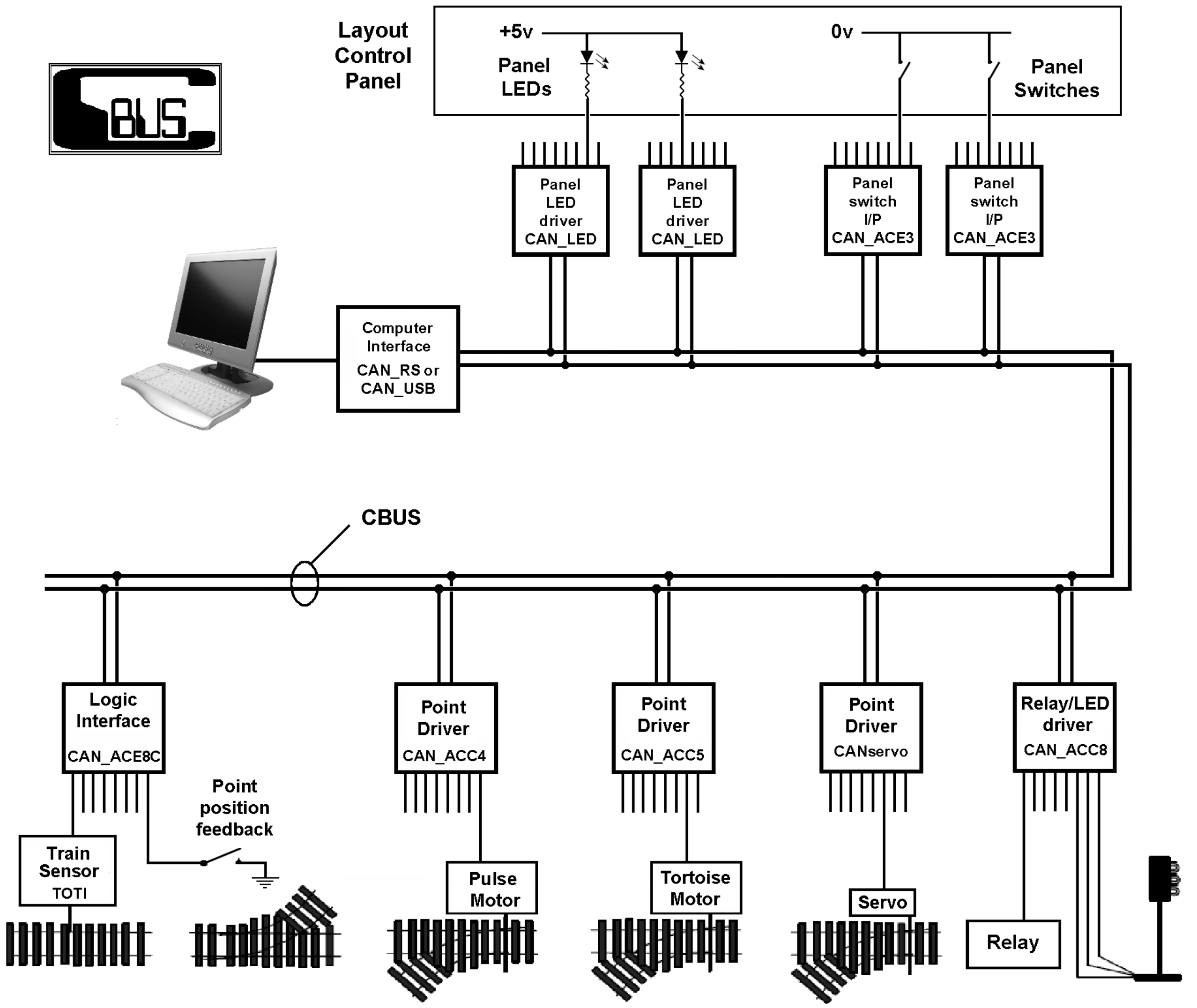
A single DCC command station still controls the entire layout and locos can move freely throughout the layout without any block switches. The layout is separated into a number of isolated sections that connect to the command station through separate boosters. The boosters have their own power supply and that means that the command station and its wiring does not have to carry the total current of the entire layout. Each booster powers its own district. The commands to control locos and DCC accessories come from the command station and are sent to each booster via its own bus – the Control Bus.
Another requirement for multiple operators is a connection between their hand-held controllers and the command station. This wiring connection is known as a 'Cab Bus' and may be specific to a particular commercial DCC system, as there is no NMRA standard for CAB buses. The Cab Bus (or Throttle Bus), as shown, also allows computers and/or control panels to communicate with the command station.

Other buses

Star and Bus wiring is not restricted to loco traction. It is also applicable to point control, signalling, lighting, etc. For example, if a factory used 20 LEDs for internal illumination, it would be very messy to have 40 wires routed back to the power supply. A single 'accessory bus' could take the power to the building, where is would fan out to individual LEDs. In other words, a bus to the building and a star formation inside the building.
Where heavy current peaks are expected, it is best to have a separate loco traction bus and an accessories bus. That way, if a loco suddenly pulls away, the lights don't dim in the station; or if a group of solenoids are operated for setting a route, the loco does not suddenly jerk down to a slower speed. For larger layouts, it is advantageous to have a separate power supply for the accessories.

CBUS

MERG promotes a 2-wire layout control system that has huge implications for layout wiring. This is covered extensively in another chapter.
It is based on the distributed bus method and is extensively covered in MERG's Technical Bulletins (there are many different TBs in the G32 list).
There are also many articles in back copies of the MERG Journal.



This diagram shows the versatility of the system. Apart from power, all the devices that are shown interface with each other over a single pair of wires – the CBUS.

The devices include switches, LEDs, various point motor controllers, track occupancy indicators, relays, etc.

This 2-wire bus can replace much of the traditional layout wiring.
For those beginning to plan a new layout, the CBUS system should be given consideration. Even for existing layouts, CBUS can be used to implement new additions such as signal and point operations, or track occupancy feedback to a mimic/control panel. This can be achieved without altering the existing track power arrangements.

CBUS offers two additional features:

Traction

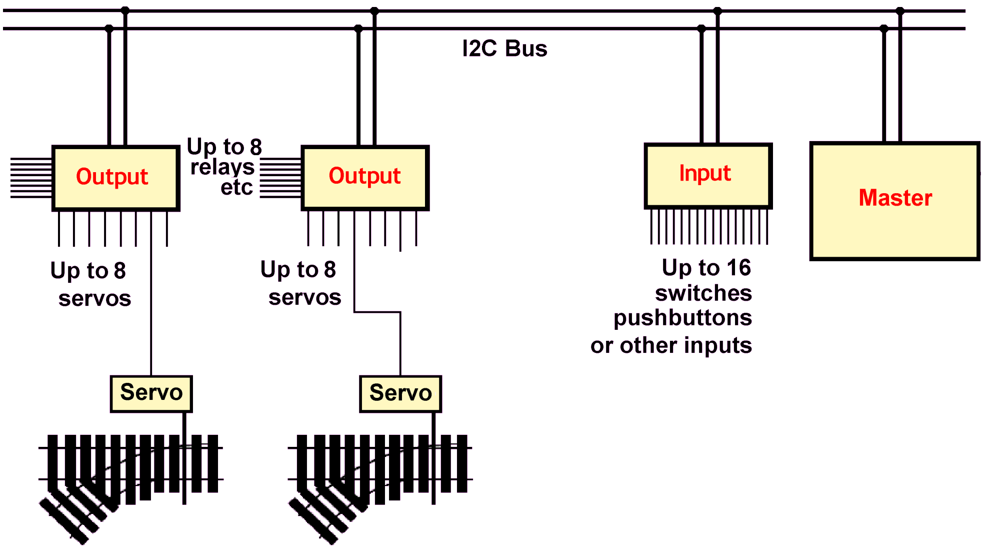
MERG sell a CANCMD, which is a DCC command station that be controlled by MERG hand controllers (the CANCAB) . This allows walk-around operation, following trains around your layout.

Automation

MERG sell a CANUSB4 unit, which allows your CBUS modules to connect to your computer via its USB interface. Automations software, such as RocRail or JMRI, can then be used to set up automated working of your layout.
or by computer.

EzyBus

This is also a 2-wire system and is based on only three different types of module.
The illustration shows a simple control panel controlling 16 points.



The Input Module

Each module can handle up to 16 inputs. Up to 8 separate input modules can be added to a system, offering a total of 128 different inputs.
The inputs can be switches, push buttons, micro switches, reed switches, relay contacts, or train detectors, (any device that takes a pin down to 0V).

The Output Module

Each module has a row of pins for connecting up to 8 servos.
The servos can be used for points, gates, signals, animations, etc.
It also has another 8 digital connection pads whose outputs can either be made high or low. The digital outputs can be used for other non-servo point controllers, frog switching or for control of lights, sounds, relays, motors, etc.

The Master Controller

The system knowledge is stored in the master module.
The pins of output modules are programmed from the menu of the master controller, which has an LCD screen and a number of push buttons.
Once set up, the master controller remains connected to handle all activities. You only need to return to the master controller if you want to add or change something.

EzyBus is covered in a separate chapter.

Summary of buses

This chart looks at the wiring demands of the most popular layout control systems.
The simplest DC system only needs track power – a single bus.

If you need to control points or accessories from a control panel, you need to run wires directly from the panel to each device. This includes the signal to operate the device and the power for that device.
Similarly, if you want to have panel lights indicating track occupancy, you have to run signal wires back from every detector to the panel (plus the power for the detectors).

Bus systems simplifies and reduced the layout wiring and this chart shows some comparisons.

Read the chapters on DCC, CBUS and EzyBus for fuller explanations.

	DC	**Simple DCC**	**CBUS**	**EzyBus**
Traction	Direct from controller to track (maybe via switches or relays)	Directly from controller to track or via a booster	Use existing controller or use CBUS (with CANCMD and CANCAB)	Use with existing DC or DCC controllers
Accessory Bus commands	Direct from switches etc. to devices	Carried by the DCC track bus	Uses CBUS with CANACC8, etc.	Direct from Input Modules to Output Modules
Occupancy and other feedback	Direct from detectors back to control panel	Direct from detectors back to control panel	Uses CBUS with CANACE8C	Direct from Input Modules to Output Modules
Accessory power	Needs 12V feed	Via track bus	Needs 12V feed	Needs 12V feed