TPL – The theory

My aim was to see if I could create an automated layout with lots going on that didn’t just run around in circles. Having looked at JMRI (briefly I must say) and DCC++ I began to wonder whether I could actually make a simpler automation system and run it entirely on the Arduino used for DCC++.

Some of the automation techniques I read about using python scripts in JRMI made my blood run cold… there’s a lot I could say here but won’t without a pint or two.

It seemed to me that basing an automation on “signals controlling trains” leaves a lot of complex technical problems to be solved… and wanting to be cheap, I didn’t want to invest in a range of block occupation detectors or ABC braking modules which are all very well on circular layouts but not good at complex crossings or single line operations with passing places. Also I didn’t want the automation to be an obvious cycle of movements… some random timings and decisions need to be introduced so that two trains don’t always arrive at the same place in the same order, nor go on the same journey in a predictable cycle.

By reversing the usual assumptions, and slaughtering a few sacred cows, I think I have a workable, extendable and cheap solution. DCC-EX, which grew out of the early TPL system, provides a clean and efficient API for the TPL automation to call.

A small amount of code (already in CommandStation-EX v4) , sits between the layout owner and DCC so that the layout owner can write automation scripts in a form that is much more user friendly. In fact the automation is written in the Arduino IDE (or PlatformIO) as per a normal Arduino script but all the C++ boilerplate code is stripped away where you don’t need to see or understand it. This means that you already have all the tools you will need and there is nothing else to download or install.

[NOTE: For memory/performance worriers… The TPL code is surprisingly small and requires very little PROGMEM or RAM to execute. It is only included in the compilation of the CommandStation code if the compiler detects a “myRoutes.h” and “myLayout.h” file. During execution, a TPL automation is much more (perhaps 2 orders of magnitude) time efficient than the code required to process incoming requests from an external automation processor. ]

When TPL is enabled, there are a few differences in comparison to a basic CommandStation build.

* The automation takes place entirely within the Command Station. Thus TPL can only make sense of routes if the turnouts, sensors, signals pins etc are already defined. The user must create a myLayout.h file (for details see later) which is used to provide a definitive list of these items, effectively describing your layout and how the command station can manipulate it electronically. The JMRI idea of defining turnouts externally and loading some of them to EEPROM and handling others through DCC accessory calls or Output pins is unsuitable. Thus the DCC++ commands for defining or deleting turnouts, outputs and sensors will be trapped and ignored.  
  Having these items defined in one, easily editable, file and being able to upload them to the Command station in a single click with existing tools makes this a simple and elegant solution.

- It is assumed that JMRI, if used at all, will only be used for programming or manual throttle operations. Turnouts already known to TPL may still be manipulated by the <T id 0/1> command.

* Sensors defined in TPL are not polled continuously as for JMRI. They will therefore not be sent to JMRI if they change.

* Throttle operations through JMRI, Withrottle (Engine Driver etc) will be limited to locos that are not taking part in, or have been released from, an automation (such as manual shunting) or when TPL automation is paused (for placement of locos before being sent on an automated journey)
* Other commands that would interfere with the automation may be rejected.
* Additional TPL diagnostic and control commands may be added. (TBA)
* TPL refers to turnout state as LEFT or RIGHT to avoid confusion. Turnout definition can choose whether “activated” means LEFT or RIGHT on an individual basis.

Sensors

* T{PL allows for sensors that are LOW-on or HIGH-on, this is particularly important for IR sensors that have been converted to detect by broken beam, rather than reflection.
* Magnetic/Hall sensors are not particularly useful as they cant be used to detect the non-loco end of a train approaching a buffer or clearing a crossing, but are still supported.
* Handling sensors in the automation is made easy because TPL throws away the concept of interrupts (“oh… sensor 5 has been detected… which loco was that and what the hell do I do now?”) and instead has the route scripts work on the basis of “do nothing, maintain speed until sensor 5 triggers and then carry on in the script”

- TPL supports the <1 JOIN> feature of CommandStation-EX. This allows a script to automatically detect the address of a loco on the programming track, then drive it onto the main track to join in the fun.

# Introduction to the Automation process

The first thing to understand is the concept of a route… this is the steps required to get from A to B (but can also be the steps to handle an animation such as a level crossing, sludge farm or fairground)

These steps may be something like:

* Wait between 10 and 20 seconds for the guard to stop chatting up the girl in the ticket office.
* Move forward at speed 30
* When I get to sensor B stop.

Similarly, the route from B to A could be something like this

* Wait 15 seconds for the tea trolley to be restocked
* Move backwards at speed 20
* When I get to A stop.

Notice that the sensors at A and B are near the ends of the track (allowing for braking distance but don’t care about train length or whether the engine is at the front or back.)

So this automation script could look like this:

BEGINROUTES

SETLOCO(3)

ROUTE(1)

DELAYRANDOM(100,200) // random wait between 10 and 20 seconds

FWD(30)

AT(2) // sensor 2 is at the far end of platform B

STOP

DELAY(150)

REV(20)

AT(1)

STOP

FOLLOW(1) // follows Route 1 again… forever

ENDROUTES

The process starts at BEGINROUTES and in this casesets the loco address to 3 and drops through to Route(1) . If there are going to be multiple locos, it’s a bit different as we will see.

Notice that the route instructions are followed in sequence by loco 3, the AT command just leaves the loco running until that sensor is detected. Although the above is trivial, the routes are designed to be independent of the loco address so that we can have several locos following the same route at the same time (not in the end to end example above!) perhaps passing each other or crossing over with trains on other routes.

The example above assumes that loco 3 is sitting at A and pointing in the right direction. A bit later I will show how to script an automatic process to take whatever loco is placed on the programming track and send it on it’s way to join in the fun.

Now your Arduino script looks like this in the Arduino IDE: in file **myRoutes.h  
The presence of this file is what makes this compilation TPL and not just CommandStation.**

BEGINROUTES

SETLOCO(3)

ROUTE(1)

DELAYRANDOM(100,200) // random wait between 10 and 20 seconds

FWD(30)

AT(2) // sensor 2 is at the far end of platform B

STOP

DELAY(150)

REV(20)

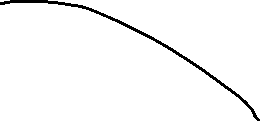
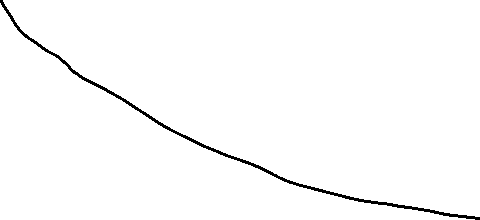
AT(1)

STOP

FOLLOW(1) // follows Route 1 again… forever

ENDROUTES

OK, that was too easy, what about routes that cross (passing places etc) … lets add a passing place between A and B. S= sensors, T=Turnout number. So now our route looks like this:



Station A

S1

S2

Station B

T1

T2

BEGINROUTES

SETLOCO(3)

ROUTE(1)

DELAYRANDOM(100,200) // random wait between 10 and 20 seconds

TR(1)

TL(2)

FWD(30)

AT(2) // sensor 2 is at the far end of platform B

STOP

DELAY(150)

TR(2)

TL(1)

REV(20)

AT(1)

STOP

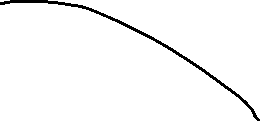
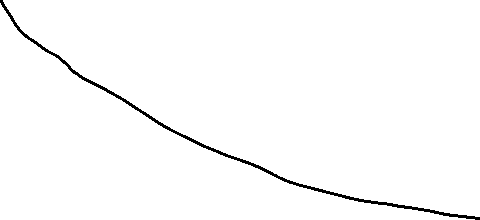
FOLLOW(1) // follows Route 1 again… forever

ENDROUTES

All well and good for 1 loco, but with 2 (or even 3) on this track we need some rules. The principle behind this is

* To enter a section of track that may be shared, you must RESERVE it. If you cant reserve it because another loco already has, then you will be stopped and the script will wait until such time as you can reserve it. When you leave a shared section you must free it.
* Each “section” is merely a logical concept, there are no electronic section breaks in the track.

So we will need some extra sensors (hardware required) and some logical blocks (all in the mind!):



Station A

S1

S2

S11

S12

S14

S13

Station B

T1

T2

Block 1

Block 2

Block 3

Block 4

We can use this map to plan routes, when we do so, it will be easier to imagine 4 separate routes, each passing from one block to the next. Then we can chain them together but also start from any block.

So… lets take a look at the routes now. For convenience I have used route numbers that help remind us what the route is for… any number up to 255 is Ok. Anyone want more than that and I will fix it.

BEGINROUTES  
 … see later for startup

ROUTE(12) // From block 1 to block 2

DELAYRANDOM(100,200) // random wait between 10 and 20 seconds

RESERVE(2) // we wish to enter block 2… so wait for it

TR(1) // Now we “own” the block, set the turnout

FWD(30) // and proceed forward

AFTER(11) // Once we have reached AND passed sensor 11

FREE(1) // we no longer occupy block 1

AT(12) // When we get to sensor 12

FOLLOW(23) // follow route from block 2 to block 3

ROUTE(23) // Travel from block 2 to block 3

RESERVE(3) // will STOP if block 3 occupied

TL(2) // Now we have the block, we can set turnouts

FWD(20) // we may or may not have stopped at the RESERVE

AT(2) // sensor 2 is at the far end of platform B

STOP

FREE(2)

DELAY(150)

FOLLOW(34)

ROUTE(34) // you get the idea

RERSERVE(4)

TR(2)

REV(20)

AFTER(13)

FREE(3)

AT(14)

FOLLOW(41)

ROUTE(41)

RESERVE(1)

TL(1)

REV(20)

AT(1)

STOP

FREE(4)

FOLLOW(12) // follows Route 1 again… forever

ENDROUTES

Does that look long? Worried about memory on your Arduino…. Well the script above takes just 70 BYTES of program memory and no dynamic.

If you follow this carefully, it allows for up to 3 trains at a time because one of them will always have somewhere to go. Notice that there is common theme to this…

* RESERVE where you want to go, if you are moving and the reserve fails, your loco will STOP and the reserve waits for the block to become available. (these waits and the manual WAITS do not block the Arduino process… DCC and the other locos continue to follow their routes)
* Set the points to enter the reserved area.. do this ASAP as you may be still moving towards them. (TPL knows if this is a panic and switches the points at full speed, if you are not moving then the switch is a more realistic sweep motion)
* Set any signals (see later)
* Move into the reserved area
* Reset your signal (see later)
* Free off your previous reserve as soon as you have fully left the block

# Starting the system

Starting the system is tricky because we need to place the trains in a suitable position and set them off. We need to have a starting position for each loco and reserve the block(s) it needs to keep other trains from crashing into it.

For a known set of locos, the easy way is to define the startup process at the beginning of ROUTES , e.g. for two engines, one at each station

// ensure all blocks are reserved as if the locos had arrived there

RESERVE(1) // start with a loco in block 1

RESERVE(3) // and another in block 3

SENDLOCO(3,12) // send Loco DCC addr 3 on to route 12

SENDLOCO(17,34) // send loco DCC addr 17 to route 34

ENDPROG // don’t drop through to the first route

CAUTION: this isn’t ready to handle locos randomly placed on the layout after a power down.

Some interesting points about the startup… You don’t need to set turnouts because each route is setting them as required. Signals default to RED on powerup and get turned green when a route decides.

Startup can also SCHEDULE a “route” that is merely a decorative automation such as flashing lights or moving doors but has no loco attached to it. For example, using a signal connection to flash a red light on the pin for signal 7, green will turn it off!

ROUTE(66)

RED(7)

DELAY(15)

GREEN(7)

DELAY(15)

FOLLOW(66)

ENDROUTES

Fancy Startup

TPL can switch a track section between programming and mainline automatically.

Here for example is a startup route that has no predefined locos but allows locos to be added at station 1 while the system is in motion. Let’s assume that the track section at Station1 is isolated and connected to the programming track power supply. Also that we have a “launch” button connected where sensor 17 would be and an optional signal (ie 2 leds) on the control panel connected where signal 17 would be (see Signals below).

BEGINROUTES  
 PROG\_TRACK(0) // start as program track connected to mainline

ROUTE(99)

AFTER(17) // user presses and releases launch button   
RESERVE(1) // Wait until block free and keep others out

PROG\_TRACK(1) // power on the programming track

GREEN(17) // Show a green light to user

// user places loco on track and presses “launch” again

AFTER(17)

READ\_LOCO // identify the loco

RED(17) // show red light to user

PROG\_TRACK(0) // connect prog track to main

SCHEDULE(12) // send loco off along route 12

FOLLOW(99) // keep doing this for another launch

The READ\_LOCO reads the loco address and the current route takes on that loco. By altering the script slightly and adding another sensor, it’s possible to detect which way the loco sets off and switch the code logic to send it in the correct direction. (easily done with diesels!)

Signals

Signals are now simply a decoration to be switched by the route process… they don’t control anything.

GREEN(5) would turn signal 5 green and RED(5) would turn it red.

Sounds

You can use FON(n) and FOFF(n) to switch loco functions… eg sound horn

Numbers:

The code currently supports 64 Turnouts 64 sensors and signals according to the pins available. Its OK to use sensor numbers higher than the actual number of sensors connected. These can only be set, tested and reset in the scripts. If a sensor is set on by the script, it can only be set off by the script… so AT(5) SET(5) for example effectively latches the sensor 5 on when detected once.

You can give names to routes turnouts signals and sensors etc using #define statements.

Future plans

* Some of the constructs above are not yet in the code, or need cleaning up a bit. Its early days but world situation suggests I will have plenty of time on my hands.
* I want to add some more commands for controlling animations, such as SERVO, STEPPER and LED