WORKING NOTE AC54

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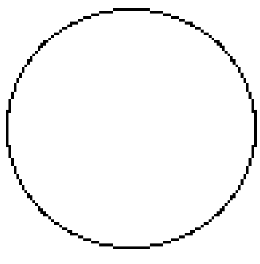
SOME NOTES ON THE POTENTIAL OF A MODEL RAILWAY SYSTEM AS AN AID TO TEACHING COMPUTING FOR REAL-TIME CONTROL.

The aim of our proposed (or, more precisely, deeply desired) model railway layout is to instruct students in the principles of real-time control systems. A model railway is an excellent medium for this purpose for several reasons :

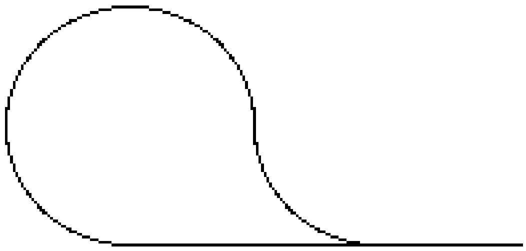
- It is clear at all times what's happening : there are no hidden components to obscure the workings of the system.
- If something goes wrong, it doesn't matter too much : the worst we can do is to burn out a few integrated circuits. The engines and controllers are designed to be rugged, and to survive robust use.
- Trains are, compared with much other computer-driven machinery of similar complexity, cheap.
- The same system can be used to demonstrate several important ideas : hardware needed for motor control; acquisition and use of sensory information; safe and unsafe system states; timing and sequencing operations; and so on.
- The systems are adaptable, and readily reconfigured to meet new requirements.
- (Not least !) They are enjoyable to use, and gain the students' attention in ways which a more conventional, but less exciting, device could not match.

It is perhaps worth adding that the idea is not original : the Mechanical Engineering Department of the University of Newcastle (in England) has used a model railway for the same purpose (1), and found it most satisfactory.

To get full value from such a system, it should be sufficiently complex to provide for various sorts of interaction between its parts. This layout will suffice to illustrate motor control :

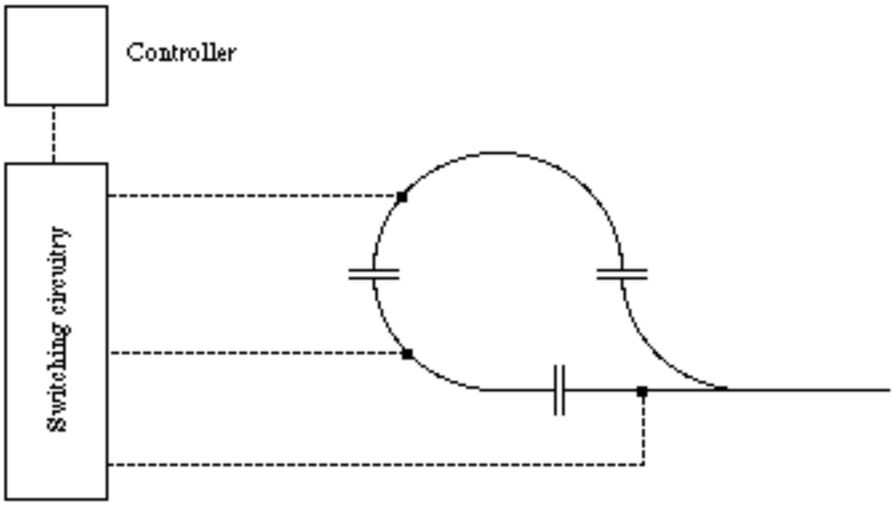


(A circle is better than a straight line, because the engine can't fall off the end.) At this level, though, there's little point in using a train, because the same point can be made just as well with an isolated motor. Perhaps the simplest example of a layout which really introduces novel control features is this, which provides an interesting problem in track control :



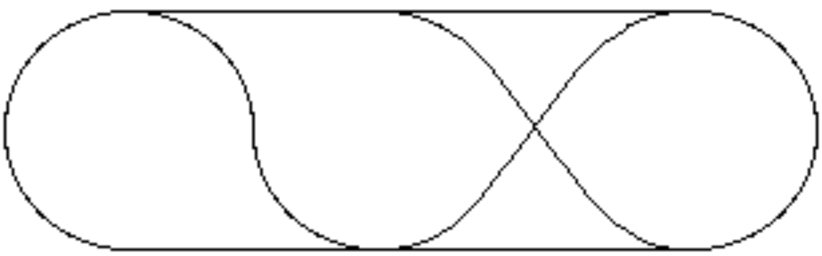
For a twin-rail system, the polarity of the power supply applied to different sections of the track must be reversed from time to time, as the engine turns round as it traverses the loop. (The loop is, topologically speaking, equivalent to a Möbius strip.) Even with a three-rail system, the control which must be exercised to drive the engine round the track, stop it at the right time taking account of the state of the points, and reverse it is far from trivial. This is a useful illustration, because it shows the importance of the interactions between the different factors concerned : the position of the engine, its direction of motion, the setting of the points, and the topology of the track.

To control a train on any but the simplest layout, the track must be broken up into sections. At least two sections are needed to handle the layout shown above, but using three sections gives added flexibility. The diagram below shows how the sections might be defined and connected. The control system must also keep information on the position of the train (inferred by observing which track section draws current – one can distinguish engines from short circuits), and it must include further circuitry not shown on the diagram to administer the points.



Additional problems of interacting systems can be illustrated with several engines operating at the same time; the aim is to keep several engines in motion as far as possible, avoiding possible deadlocks in which each engine is blocking the further progress of another. This is an obvious extension of the ideas shown in the diagram above, as the idea of track sections makes it easy to separate the control for the different engines. A simple approach is to use a separate controller for each engine, when the "switching circuitry" in the diagram becomes a crossbar switch; alternatively, one may control each track section independently, and adjust each control voltage to suit the engine currently occupying the section.

Putting all these ideas together, I would like to aim at a collection of parts sufficient to set up a layout like this :



Points should be capable of electrical control. Three engines, with associated controllers and power supplies, would be sufficient to illustrate all essential principles, though four would be better.

REFERENCE

(1) *A good training ground for designers,* New Scientist **77**, p856 (30 March 1978)