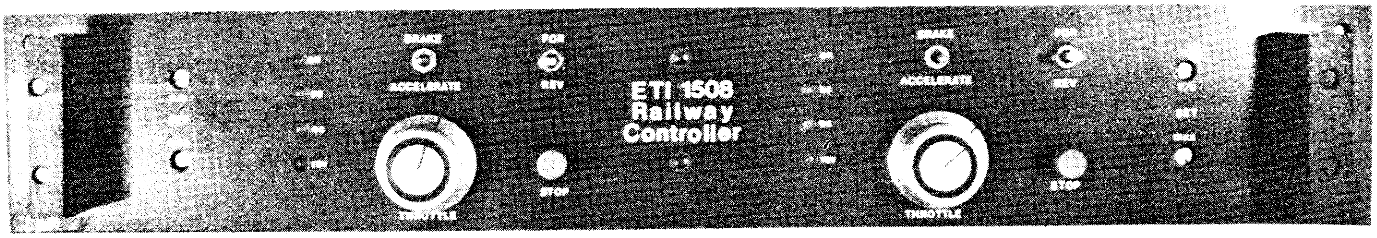
Model train controller simulates 'real' train controls

This model train, or better, railway, controller has controls that operate like 'real' train controls. In addition, it signals open circuit or short circuit conditions on the track and you can make emergency stops.

Jonathan Scott



MODEL RAILWAY controllers are one of those perennial projects which recur every year or so in some magazine or other, because they are almost ideal as a project: lots of people have model electric train sets (what other sort *is* there? Yeh, yeh — steam, but this isn't Steam Train International Today magazine! — Ed.), lots of commercial controllers are either crude or relatively expensive and there are plenty of 'angles' to explore, both electronic and philosophical.

Some controller designs are *cheap*. And that's as it should be, a hobbyist has to start somewhere. Some are designed to employ recently-released innovations. Some use microprocessors and digital tone-encoding techniques to be really comprehensive. Others are designed to make driving the train 'easy' by compensating for loads of hill-climbing or many carriages, etc. It is our belief that these are rather artificial aims, so let's see what *we* think is *really* necessary.

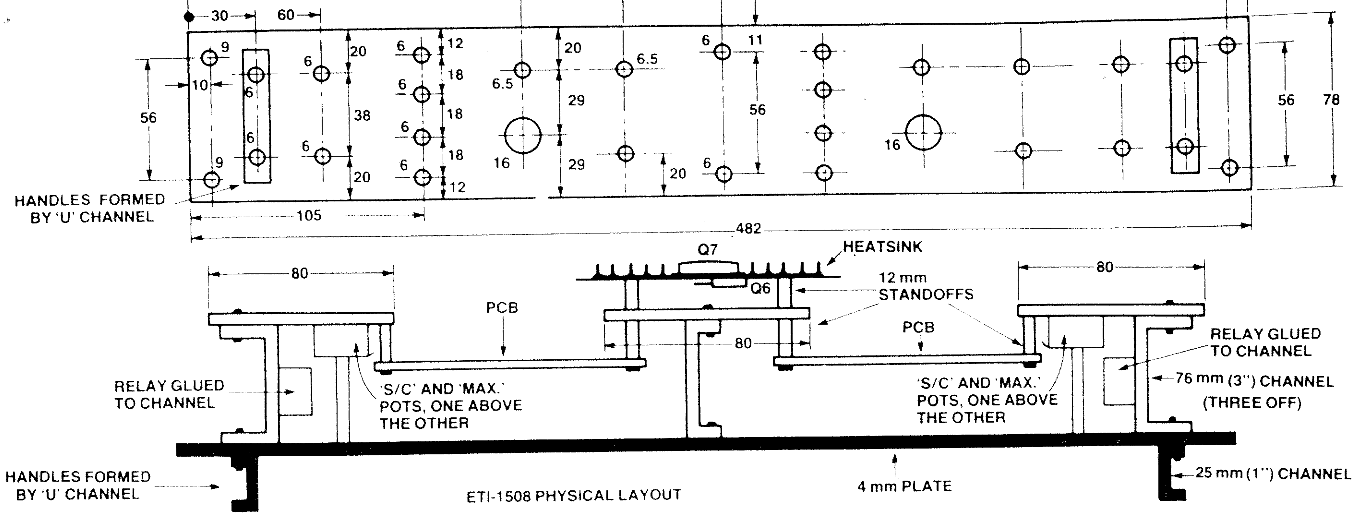
The model railway enthusiast does not just like to see it go, he likes to *drive* the train. So, a controller should pass on to the user as many of the 'inputs' as a real train would encounter, but hide from him unreal inputs which only a model exhibits. In other words, he wants to feel the effect of inertia, but not of bad contacts, feel the engine and brake work separately and to feel the effort of climbing or carrying extra load, but not feel some loss of power when junior gets his train going too, or the butler turns on the mixmaster. In addition, a controller should be able to run everything from a micro-gauge small locomotive to twin O-gauge engines. Finally, it wants to be as inexpensive to build as is possible without sacrificing anything. (After all, if you've got a butler, there's not going to be too much spare cash left to spend on luxuries like model railways!) This is precisely the philosophy adopted for this project. Our new controller has been built in rack panel form with two separate control systems running from one mains step-down transformer. Needless to say, if you want to build 1-to-21 such units in wooden consoles all run from two car batteries, then you can please yourself — our design can be used as a guide for those who want to follow that course. From our experience, hobbyists like to customise their housings.

The front panel of our controller is rather unconventional for a *model* train controller, but somewhat closer to the controls of a real train. One switch selects the thrust applied ("accelerate"), no thrust, or in the momentary (spring-loaded return) position, normal brake. This is the main control, and indeed the only one required for commuter trains such as London's Tube or Le Metro in Paris. Once the throttle knob has been set to define maximum torque, throwing the main lever to ACCELERATE causes a small jerk in the wheels, corresponding to the take-up of slack etc, followed by normal acceleration toward the top speed. Moving the main level to the centre or 'idle' position causes the train to start coasting to a final halt. Pressing it to BRAKE hastens the stop. In metropolitan trains the driver aligns the train correctly in the station by judicious pressing and releasing of the main lever, finally stopping with precision, in spite of the train's great inertia, of a few inches. This you will discover, requires *some skill*.

The throttle knob we have already mentioned. On brief runs, you never reach full speed, so the setting of this control is not critical. It sets final engine torque, and hence speed, after the acceleration is over. This is important on long runs. This control can be internally preset to match the size of model train you have; on the prototype the MAX. SET is a screwdriver preset accessible from the front, but provision has been made for it to be a preset on the pc board if you so desire.

The STOP button is the front panel control corresponding most closely to the 'communications cord' on a real train. It is the one concession to necessity over realism. When pressed it quickly shuts down the controller output, halting the train as rapidly as possible. There are two possible ways of wiring it — one which restarts the train when the button is released and another which requires the mains to be removed before it can be restored. This latter option discourages frivolous use of the STOP button (people don't *believe* it when you put a notice on it saying "Fine — $40 for unwarranted use") and provides some failsafe against accident. It is the option we recommend. This will be further discussed in the construction section.

The forward-reverse switch is the fourth and final driving control. In many normal controllers we have seen, even some with inertia, immediate reverse is possible. This is not the case in real life and not the case on our controller. The switch is 'momentary' in its action. It will only have effect when the train is stationary. This further limits the model train driver to abide by the rules of 'realism'. You cannot spoil the▶



ETI-1508 PHYSICAL LAYOUT

effect or cause physical mayhem with it.

Four indicator LEDs are provided. One is for the 'power up' condition and this illiminates when power is applied, extinguishing when the lock out condition exists, such as when the STOP button has been pressed. There are LEDs to warn of an open circuit or a short circuit. The open circuit indicator will also illuminate should the commanded current (according to the throttle setting) be impossible to achieve with the available supply voltage. The short circuit indicator warns when the load impedance drops below a value preset by the user. This value may be set from zero to five ohms. On our prototype this was again a screwdriver adjusted front panel control. There is also a LED indicating when reverse is engaged. In a normal railway system a line is 'one way' and reversing is only used (on any given power supply) for shunting. Thus the warning is given when this wrong-way condition exists.

Construction

As this project is aimed at the enthusiast with at least a basic mechanical and electrical/electronic ability we expect most constructors will tailor the physical construction to suit their own requirements. The following is an outline of the order in which to do things if you intend to more or less duplicate our prototype.

Our prototype fits conveniently behind a 78 mm high standard (19 inch — 482 mm) instrument rack panel. With the heatsink and transformer mounted separately, the whole dual controller is less than 75 mm deep and so will recess conveniently into a model baseboard. It requires a hole of about 455 mm by 75 mm for the panel.

The front panel can be made from a blank piece of aluminium sheet cut to the right size. Kit suppliers may supply predrilled and lettered panels, but if not, it's a relatively simple matter to make your own. First step is to carefully mark out the holes with a soft pencil. Centre punch the hole centres and then drill the holes according to the sizes marked on the accompanying drawings. Clear the holes of all burrs and clean the panel down with either steel wool or a weak caustic solution. You can then paint the panel and when the paint is thoroughly dry it can be carefully lettered. We used white Letraset on the black panel. A spray-on lacquer will protect the lettering. Once the panel is prepared, fit the switches and the handles. The latter were made from pieces of aluminium channel, also sprayed black. Handles aren't essential, but they can be handy.

Next, mark out and drill the three rear panel pieces. Short lengths of 75 mm (3") channel were used to secure these to the front panel. You can do a 'trial' assembly using the unassembled pc boards to mark their mounting hole positions. If you drill holes a little oversize then you have some latitude for adjustment later to allow for inaccurate marking or drilling. The mechanical assembly drawings should assist you here.

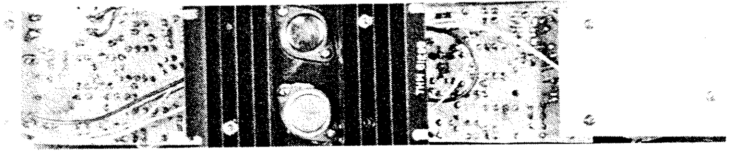
Having got the rear panel pieces sorted out, you can decide where to mount potentiometers RV2 and RV4 (the S/C and MAX. SET pots). You may elect to mount them directly on the front panel or glue them to the rear panel, as we did. We used Silastic to glue them in place. The shaft ends of the two pots were grooved with a hacksaw cut so that they could be adjusted with a screwdriver. Make sure the pot shafts line up with the panel holes. The two relays were secured to the channel pieces at either end of the panel using Silastic. You can mount all the switches and the throttle pots now. That's it for the moment with the mechanical assembly, now you can get on with the pc boards.

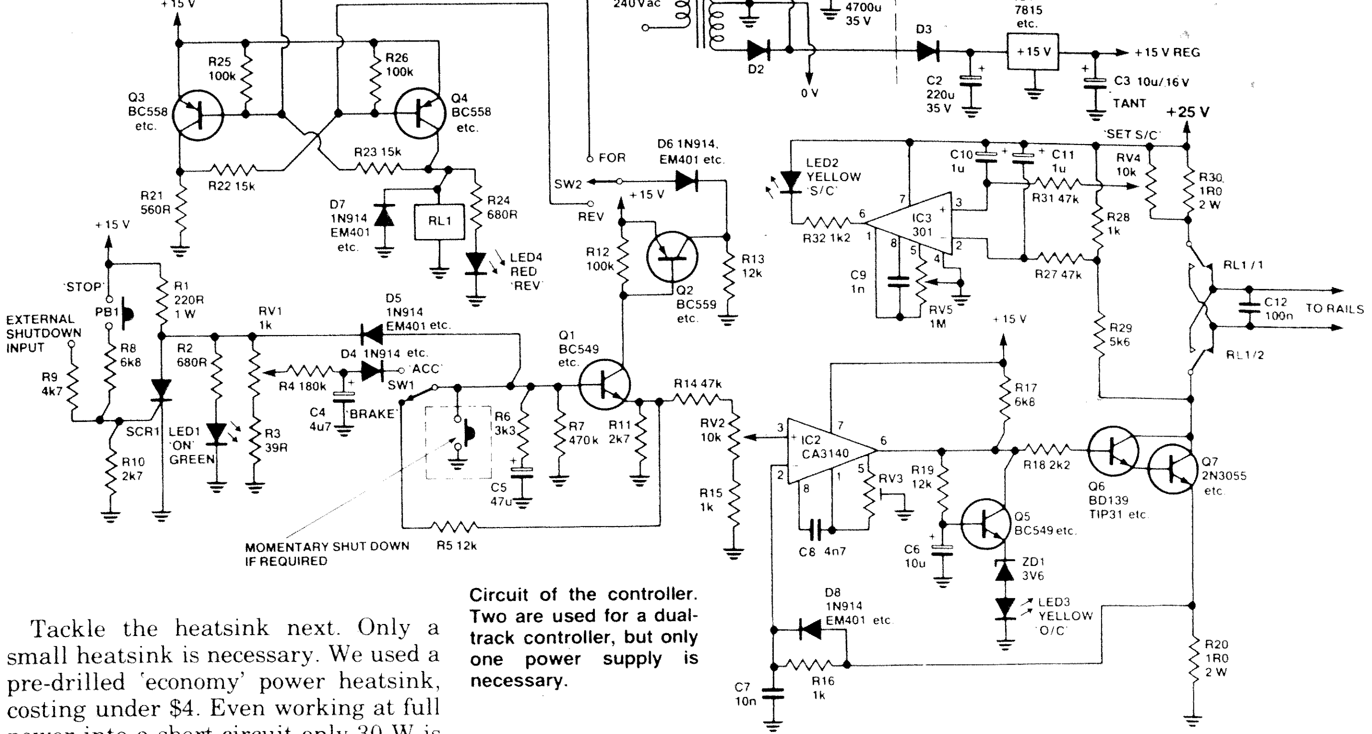
We have drawn up a component overlay and wiring diagram to assist assembling and wiring the pc board. Follow the component overlay for mounting the components to the pc board. Start by soldering the resistors and non-polarised capacitors (i.e: not the electrolytics) in place. Then follow with the polarised capacitors, making sure you get them in the right way round. A small '+' is on the overlay diagram where the positive lead is to be inserted. Identify the leads from the accompanying component pinout diagram. Solder all the semiconductors in place next, taking care you get all of them the right way round, too. You can identify which way they go from the overlay and pinout diagrams. Note that low power types for IC1 and SCR1 can be used, rather than the 'flatpack' higher power versions illustrated on the overlay. The low power versions come in transistor-type plastic packages with just three flying leads and no metal tab.

If you're using the flatpack types, we recommend that you bolt them to the pc board.

When you have fitted all the components to the pc board, make a careful check that all components are correct and those that need to be are correctly orientated. If all is well, you can now attach all the flying leads. Make sure each is of adequate length to reach from the pc board to their intended destination with some to spare.

Rear view of the controller.





Circuit of the controller. Two are used for a dual-track controller, but only one power supply is necessary.

Tackle the heatsink next. Only a small heatsink is necessary. We used a pre-drilled 'economy' power heatsink, costing under $4. Even working at full power into a short circuit only 30 W is dissipated. Mount the 2N3055s and BD139s to the heatsink taking care to insulate the 2N3055 with a mica washer. Ensure that no burrs on any of the holes can puncture the insulator. Smear the insulator both sides with thermal compound before mounting it. Check with an ohmmeter that none of the transistor leads is shorted to the heatsink. ▶

HOW IT WORKS — ETI-1508

The circuit of the train controller can be considered as five separate functional blocks: power supply, current control, current regulator, reversing control and short circuit detector.

The current control serves to interpret the driver's instructions and, taking inertia and energy into account, outputs a voltage proportional to the requisite engine torque. The current regulator forces the train to conduct this current and indicates the high resistance, or open circuit, condition, should it occur. The reversing control consists of a flip-flop driving a relay. This circuit will only toggle when the train is not being driven, preventing reversal during operation. Finally, the short circuit detector continuously searches for a low resistance condition in the load.

The power supply requirements are: a 15 V regulated rail for the electronics and an unregulated rail of between 18 and 35 volts. The circuit can tolerate severe ripple on the unregulated supply. Its only constraints are that the average voltage should lie between 18 and 30 volts with peak excursions no more than 35 volts and minimum excursions no lower than 10 volts. The supply must be able to deliver at least 1.5 amps per controller. We recommend a transformer such as the Ferguson PL36/60 VA or PL30/60 VA, which should be more than sufficient for two controllers. The +15 V rail is separately regulated for each controller, the regulator IC being mounted on the pc board (IC1). Diode D3 isolates C2 and IC1 from severe ripple on C1. IC1 may be a low power type (78L15) but provision for a 7815 was made on the pc board as these are more readily obtainable. Capacitor C3 bypasses the +15 V rail and prevents IC1 oscillating.

The current control comprises SCR1, SW1, RV1, Q1 and surrounding components (i.e: about the middle of the circuit!). If about 4 — 15 V appear on the 'EXTERNAL SHUTDOWN' input, or the 'STOP' button is pressed, SCR1 is triggered, removing drive from RV1 and discharging C5 via D5-R6. This condition is indicated by LED1 going out.

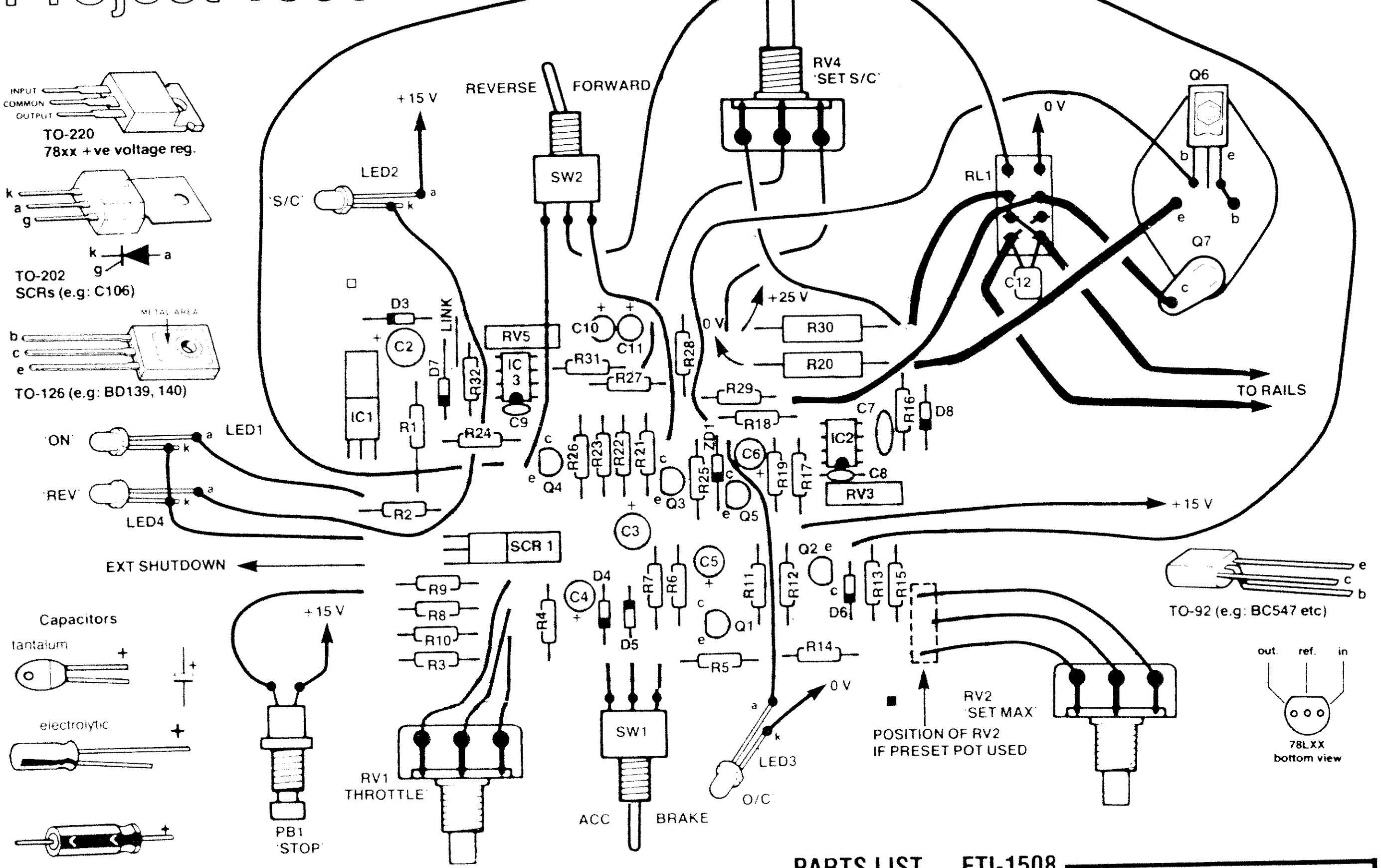
Normally, when SCR1 is not triggered, control is vested in SW1 ('ACCELERATE — BRAKE') and RV1 ('THROTTLE'). With SW1 in the mid (open) position, C5 remains discharged while C4 charges to the level set by RV1. When SW1 is moved to the ACCELERATE position, C4 discharges into C5 via R6. This causes C5 to charge to about 20% of the final voltage set by RV1. Also, a small voltage pulse appears on the base of Q1. Capacitor C5 then charges exponentially via R4 to the final level. If RV1 is reduced, D4 prevents C5 discharging through R4. Capacitor C5 discharges via R7, allowing a different rate of reduction of speed, as is the case in reality. (A train accelerates faster than it slows down if no braking is applied).

If SW1 is placed in the 'BRAKE' position, a constant current is drawn out of C5 via R6 and R5, because Q1 maintains its emitter voltage at about 0.65 V below its base. This action causes a linear reduction (rather than an exponential fall-off) of the voltage on C5. (A vehicle dissipates energy proportional to the square of speed. This linear braking effect causes the model to reflect this sharp-halt situation more realistically). Transistor Q1, acting as an emitter follower, copies this voltage on C5 out to RV2 via R14. Thus, the initial peak and the continuously varying voltage on C5 are output for the current regulator.

The current regulator consists of IC2 (a CA3140) and surrounding components. This is simply an op-amp wired to ensure that the emitter current of Q7 in amps equals the voltage on pin 3 (the non-inverting input). Trimpot RV3 is included so that a small offset voltage may be established to fix the emitter current of Q7 at a value of about 15 mA when the voltage on pin 3 of IC2 is at 0 V. This minimum current value allows the short circuit and open circuit detectors to work all the time, even when the train is stationary. This current is not sufficient to cause train movement. Resistor R16 and capacitor C7 remove hash caused by commutation and dirt on the tracks. Diode D8 is required to protect the circuit from overload when going from an open circuit condition to a short circuit condition. Transistor Q5 and surrounding components detect the open circuit condition. If the collectors of Q6-Q7 go open (i.e: no current supplied via the rails), they saturate, the voltage on R20 falls and the output of IC2 rises toward the +15 V rail. If this condition persists for more than quarter of a second or so, C6 charges up and Q5 turns on LED3 via ZD1. The delay prevents flickering due to momentary effects such as crossing isolators on the track or dirty engine pickup wheels.

Reversing is achieved by operating the relay, RL1. Transistors Q3 and Q4 form a flip-flop which drives RL1 on in one state and off in the other. When Q1 draws no current (i.e: there is no drive signals to IC2) Q2 is off, allowing SW2 to toggle the flip-flop by pulling the base of either Q3 or Q4 to ground via D6-R13. When running the train, Q2 remains turned on and SW2 has no effect because of D6. The 'REVERSE' indicator, LED4, lights when Q4 is on and the relay activated.

The short circuit detector is built around IC3. This acts as a comparator. Its output lights LED2 if the voltage across the relay contacts drops below a preset ratio of that voltage dropped across R30, the current sense resistor. Capacitors C10 and C11 prevent IC3 responding to hash. Trimpot RV5 is for nulling the op-amp offset. Capacitor C12 also helps reduce interference from getting into the high gain circuits on the pc board.



You can wire up the transistors and attach flying leads, referring to the wiring diagram, but don't connect the leads from the pc board yet.

Now you can return to the mechanical assembly. Mount the pc boards and wire up all the flying leads. Note that the +15 V and 0 V leads go to several locations each: for example, LEDs 1, 3 and 4 all have their cathodes (k) going to 0 V. Double check to see that no connections to off-board components are left unused. We used double-pole switches for SW1, SW2 and PB1. This was mainly because single-pole versions were not available at the time we constructed the prototype. The spare poles were unused.

Note that heavier gauge hookup wire should be used to connect the collector and emitter of Q7 to the rest of the circuit. Use 24 x 0.2 mm plastic insulated hookup wire at least.

Now check *everything*.

Finally, wire up the rectifier and filter capacitor as per the wiring diagram, unless you're using some other supply, and connect up the power transformer. Take care with the mains wiring. If you are using an existing transformer/rectifier, then only a filter capacitor is needed. Its value depends on the voltage: we recommend at least 3300 uF for a supply of 21 volts peak, which is the minimum unsmoothed supply recommended. Now you're ready for 'the big switch on!'.

PARTS LIST — ETI-1508

Resistors .... all ½ W, 5% unless noted

R1	220R, 1 W
R2, R24	680R
R3	39R
R4	180k
R5, 13, 19	12k
R6	3k3
R7	470k
R8, 17	6k8
R9	4k7
R10, 11	2k7
R12, 25, 26	100k
R14, 27, 31	47k
R15, 16, 28	1k
R18	2k2
R20, 30	1R, 2 W
R21	560R
R22, 23	15k
R29	5k6
R32	1k2
RV1	1k lin. pot.
RV2	10k trimpot or lin. pot
RV3	10k trimpot
RV4	10k pot.
RV5	1M trimpot

Capacitors

C1	4700u/35 V or 50 V axial electro.
C2	220u/35 V RB electro.
C3, 6	10u/16 V tant.
C4	4u7/16 V RB electro.
C5	47u/16 V RB electro.
C7	10n greencap
C8	4n7 greencap
C9	1n greencap
C10, 11	1u/16 V tant.
C12	100n greencap

Semiconductors

D1-D3	1N4001, EM401, 1N4002 etc.
D4-D8	1N914, 1N4148, 1N4001 etc.
IC1	7815, 78L15
IC2	CA3140
IC3	LM301, uA301
Q1, Q5	BC549
Q2	BC559
Q3, Q4	BC558
Q6	BD139, TIP31
Q7	2N3055
LED1	TIL220G green LED
LED2, 3	TIL220Y yellow LED
LED4	TIL220R red LED
SCR1	C106

Miscellaneous

RL1	12 V double-pole change-over relay with contacts rated at 2 A or more, coil 240 ohms or more.
SW1	SPDT toggle switch with spring return.
SW2	single-pole, three-position switch, centre-off, spring-loaded return one side.

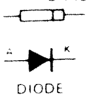
ETI-1508 pc board; PL30/60VA transformer or PL36/60VA, if needed; knobs to suit; panel metalwork, channels etc as per drawings; spacers; nuts, bolts etc; hookup wire.

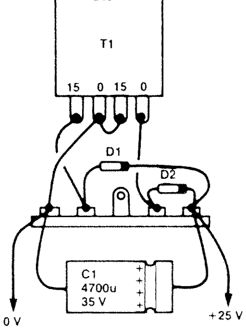
Note: For a twin-track controller, two of everything except the mechanical hardware will be necessary.

Price estimate $105 — $115 (dual track unit)

Adjustments

Once the wiring up is complete some adjustment of preset pots must be made. As well, some adjustment of component values may be desirable in order to tailor the controller action, or 'feel', to your particular requirements. You may also wish to modify the action of the 'STOP' button.





Wiring diagram of the power supply. Use a 50 V capacitor if T1 is 2 x 18 V (PL36/60 VA).

TABLE 1

Possible component variations.

FUNCTION	COMPONENT TO CHANGE	RANGE OF VALUES
Acceleration	R4	50k to 330k
Starting pulse magnitude	R6	100R to 10k
Slowing	R7	390k to 10M
Braking	R5	1k to 27k
	(Note: R4 affects this too!)	
% charge jump	C4	0 to 20 uF

*Do not forget to adjust R14 if necessary to limit maximum current to 1.5 A.

There are two preset potentiometers, the offset null pots for the two op-amps, which must be adjusted. These will probably never need readjustment once initially set. The 3140 (IC2) offset pot should be adjusted to give the required 15 mA minimum current in the output. Place a current meter across the track, and adjust this pot until 12 to 18 mA flows. Removing the meter, leaving an open circuit, should illuminate the O/C LED. Shorting the output will turn it off.

The 301 (IC3) offset pot should be adjusted with pins 2 and 3 shorted to pin 7. When you have temporarily made these connections, move the wiper to and fro, observing that one direction turns the S/C LED off, the other turns it on. Leave the wiper at the point of switching just so that the slightest movement in the appropriate direction will toggle the LED. Remove the temporary connection. Verify the correct connection and operation of the short circuit detector by following this procedure: place a locomotive on the track; adjust the 'SET S/C' pot, slowly, until the LED just goes out. If the track is now shorted, the LED should come on. This takes half a second or so. The SET pot can be adjusted to recognise any resistance from almost zero to 5 ohms at least, as the minimum acceptable value, before a short condition is indicated. This range will be adequate for all normal wiring up resistances, etc. The 'SET MAX' pot is adjusted simply to set the level which is the most current a locomotive or pair of locomotives will ever need. It can be adjusted either with a current meter if you know the value, or simply to give convenient feel to the throttle knob. If you find you are always at the beginning of the throttle range, adjust this pot down to reduce the maximum. If you always need full throttle to run a train, adjust it up.

Once you have familiarised yourself with the operation, you may wish to change certain time constants. The accompanying table shows what components affect what characteristics. Recommended values fit recent design HO scale models. If you wished to increase all the time constants because your layout is very large, you could increase C5, or vice versa. This will also affect the initial current jump, reducing it. If you need to restore this or even make it larger, increase C4 as well. If you change any of the resistors, you may need to change R14. This resistor does not directly affect the 'feel' of the controller, but limits the maximum current which may be requested, to the controller limit of 1.5 A so that prolonged short circuits at full current cannot harm the unit. It is likely that R4, C4 and C5 only will need changing, to tailor the controller for another scale, such as N-gauge, etc.

Finally, you may wish to change the STOP button action. We suggest wiring it as shown in the diagrams. It triggers the SCR when pressed. This locks out the controller until the SCR is isolated by turning off the supply. Two modifications may be implemented. Firstly, you may wish to have it stop the trian but allow it to start as soon as the button is released. This is achieved by wiring it from the top of R6 to ground. Alternately you may wire it across the SCR, anode to cathode. This has the advantage that it may be used to restore power by isolating the SCR if it is triggered by an external signal. The other option is to include a separate (possibly concealed) button across the SCR for restoring power. Whichever option you wish is open to you. We feel that the need to use the button should incur some inconvenience, so we opted for the turn-off-to-restore-power method.

The external SCR trigger input is provided for those who wish to include some logic in their layout. Position sensors, point and signal control systems, etc, may be wired to stop the train by means of applying a TTL-high (4 V or more) to this input, which has the effect of pressing the STOP button. ●

Some Notes on TRAIN DRIVING and Problems you may encounter

This controller, as we have said before, delivers constant current rather than constant voltage. Constant current produces constant motor torque. Thus, just as is the case in a car, the train will slow for hills, speed up for descents, etc. This will mean that you have to pay fairly constant attention or the train will end up derailing or throwing carriages due to speed or 'stalling' due to insufficient 'gas'. The author can barely manage to control two trains at once, so be warned that train driving is not as easy as it used to be! Braking is also not exponential, as is acceleration. This corresponds to an effect you may have noticed if you drive a car — hard braking at 25 kph causes fairly severe loss of speed, but hard braking at 125 kph causes an alarmingly mild reduction of speed; you dissipate energy proportional to speed, but the energy needed to be dissipated rises with the square of speed.

A problem which demands some discussion is that of 'starting torque'. Many model engines, particularly old ones (the author has several engines over twenty years of age) have a tendency to require an amount of current to start moving which is greatly in excess of that to keep moving. Thus they sit still until the 'starting torque' is achieved then take off at some speed. This is not due to bad contacts. To some degree this controller scheme can overcome the problem. Firstly, actual bad contact problems will be automatically resisted, and indication is given as soon as the fault becomes serious. Thus, these will be separated from other problems and can be remedied by cleaning, and so forth. Secondly, the controller gives a small 'jerk' at startup, corresponding to the takeup of coupling slack in a real train. If controls are adjusted suitably, the train will not quite stop after this jerk (which should easily exceed starting torque) and will pull away smoothly. Recall that the controller output jumps to some preset fraction of the initial throttle setting immediately after switching to the 'accelerate' position of the main control switch. Judicious adjustment of the throttle before startup can ensure a sizeable jerk and a large initial step level. If necessary, increasing the startup capacitor C4 will increase the initial step torque so that the engine does not come to rest even for a moment after startup. Reducing R6 will reduce the duration of the jerk, increased by increasing C4. Newer engines respond smoothly and may benefit purely from reduction of R6 to minimise the startup jerk. Our older engines used 15 uF for C4 successfully.

One further point arising is that the jerk may be reduced or eliminated where you wish by reducing the throttle to zero before going to accelerate mode, and bringing it up as soon as you start up, though this eliminates the initial torque step. Our prototype units delivered a typical jerk of about 30 degrees of wheel rotation on a model steam locomotive — most pleasing.

Another problem which is regretably unique to current type controllers such as this one is that they do not like the non-linear load of incandescent lamps in parallel with the engines. Two effects will be evident: when the train is stationary, the lamps are cold and look like a short circuit and so the S/C detector will respond. It will reset as soon as power is delivered however, and should be sensitive enough to be settable at the level where only a genuine short is registered. The second problem is that the cold lamps draw a lot of the current delivered in total until they heat up and begin to glow, whereupon they allow a much larger voltage across themselves while drawing the same current. This makes the train sluggish at first and likely to run away once the lamps are on. This effect is similar to and worsens the starting torque problem. In general, lamps should be avoided or at least have a few tens of ohms inserted in series to minimise the problem. Using lower voltage units and series resistances is less power economical but better. The author uses LEDs on locomotives, which are sufficient and do not affect performance.

Further thoughts on train controller design

The ETI-1508 Train Controller (December '82 issue) proved a popular design and occasioned much reader comment. Though seemingly elaborate, many readers said we han't gone far enough! After many months of experience, some improvements suggested themselves (a clever train controller!). Here they are, plus further thoughts on new design possibilities.

OUR LAST train controller project, the ETI-1508, has stirred above-average comment and enthusiasm, it seems. It was a fairly imaginative design (read oddball if you are one of the school that disapproves of radical steps). In a way, the more sceptical people had a point, for there are two drawbacks with the design, one brought on by lack of experience with different train systems on my part, and the other a purely cost-based one. This article talks about the problems, suggests short term measures to improve the situation, discusses the inherent design problems and points the way to the next generation design — work upon which continues.

The first thing to note from reader responses is that many of the heavy enthusiasts are willing to accept rather high component counts, and hence cost. When the '1508 was designed, a lot of attention was paid to keeping the circuit reasonable in size so that beyond the transformer, the cost could be low. True, the hardware was not cheap, especially if you built it entirely from scratch, but it was cheap if you used a cheap box and an existing power supply. I should have spent more time than I did wandering in model shops, because if you look at how much trains cost, controllers aren't big chips. However, remembering my days of cannibalising old equipment and buying AC127s in ones (oops, dated now) we played Scrooge. At this point, it seems fitting to mention the first inescapable design decision on train controllers.

Decisions, decisions

There are two radically separate controller designs. The '1508 epitomises one, and perhaps the Hornby 'Zero-One' the other. The Zero-One places 16 volts ac on the tracks at all times and controls engines (plural), points, signals and all accessories using only the two connections of the track. This it does by sending control signals as well as raw available power down the lines, rather like the SEC controlling off-peak systems with control tones. These are picked up by small switching units in the controlled items which do their stuff, drawing from the rails whatever power is required. This gives ease of wiring and the ability to control several trains separately without isolating track sections.

Jonathan Scott

In a way, it is quite superior to the '1508 type, which needs on train per circuit and that is all it will handle. However, it sacrifices feedback. This means no 'real train feel', no erratic response to hills, no difficulty in control and no open/short-circuit indication, etc. It is also costly as every item on the system needs an 'implant'; one is likely to pay about $200 for a starting setup, and each new item added demands another 'implant'. It is also a rather cut-and-dried design; there is little room for tinkering and improvement, because of the lack of feedback. So if you want to go that way, we can see the reason. It probably produces the best effect as far as looking is concerned, in that lights are always on and models always moving in a 'controlled' way. There are far fewer wires and fewer things to twiddle. The professional's system it is, in every way.

Jerking off

The '1508 is a sensitive analogue approach, for which we pay in complexity and 'fiddliness'. So, back to its problems. Engine takeoffs are often 'unsmooth' and sometimes need the train to be nudged. If you have the throttle up too far the train can jerk off, entirely ruining realism. If the current rises slowly, the train may never shift without a nudge, or may appear to jam for a while and then, when the power is enough to overcome static friction, it takes off at a pace.

These effects are aggravated by the fact that the unit is regulating current rather than voltage. We found that Hornby trains, which are significantly less smooth than other makes, are particularly susceptable. Airfix or Jouef ones proved quite OK in this regard. Some Hornby pickup systems are virtually the same as they were on their locomotives over twenty years ago! Tradition is nice but often painful. Even Rolls Royce have begun to change their grille design!

A voltage regulation regime gives improvement, but tends to remove the very real (steam era) effect that a locomotive engine develops more power as it speeds up, giving a positive feedback effect, demanding care and concentration from the driver. What is required is voltage regulation in the short term (seconds) and current regulation in the longer term (tens of seconds and up).

The modification shown in Figure 1 can be added quickly to the '1508 and gives this effect. Startup is smoother and far less critical. It has one drawback on the '1508: namely, that the open-circuit sensor uses the fact that there is current drive, and since the current drive is effective only after 5-10 seconds, the o/c light may take up to this long to respond.

In future designs the current sense requirement of the o/c detector can be removed so that the drawback is overcome (at a small cost of increased component count).

The suggested modification requires only three points of connection to the pc board and is thus quickly added in situ, and removed if you do not like it. Startup only requires that you use more throttle than you thought before; the margin for miss-estimation is greatly reduced. In addition, the engine appears to have more inertia when encountering a sudden hill or extra carriages, though the need for attention to the throttle in the long term is still present, which I feel is important.

You may wish to reduce the basic acceleration time constant and the idle-slowdown time constant as well, in order to restore the original feel of inertia, as the circuit here will suggest an increase

HOW IT WORKS — ETI-1508 MOD.

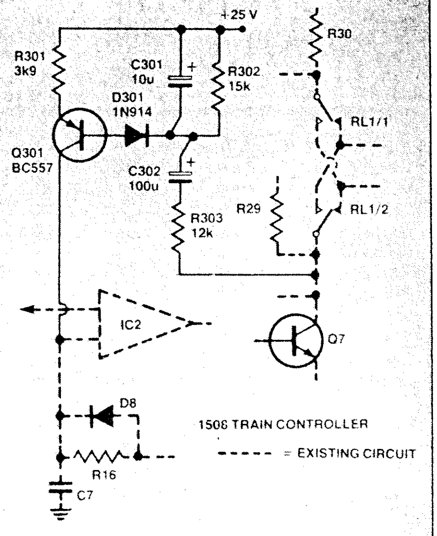
The function of the modification is to apply feedback to the main regulation amplifier in order to produce output voltage regulation effects for frequencies in the 0.1 Hz region. It achieves this by converting changes in output voltage in this frequency area into current and adding this to the signal presented to the feedback input of the control operational amplifier.

Clearly, Q301 will be turned off in the quiescent dc state by R302. Together, R302, C301, R303 and C302 form a filter which passes frequencies near 0.1 Hz to the base of Q301. When load voltage increases, the voltage at the collector of the output transistor falls with respect to the +25 V rail. This is passed on to the base of Q301 which conducts sourcing current, the amount determined by R301. Thus R301 defines the transconductance of the system at the frequency of peak gain.

Although the whole circuit may have a large ripple component because the +25 volt line has large ripple on it, this is not passed down to the op-amp because of the constant current output characteristic of the transistor.

The sourced current for a rise in load voltage in turn induces the drive to the output of the controller, effectively holding load voltage constant. Owing to the required Vbe drop of Q301 and that of D301 there is a small dead band before which the regulating action occurs, meaning that there is no effect for small signals. This, plus the bandwidth limitation of C301, assists stability and also reduces the lag before the o/c detector responds. The bandwidth limitation is such that the turn-on pulse is not significantly affected. D301 also protects the transistor b-e junction against reverse biasing when a low load impedance is suddenly added.

Sudden load reductions, as in braking or collecting extra carriages, represent rises in the output transistor collector voltage, which serves only to turn Q301 further off so that its action occurs only at or near acceleration points.



overall. (i.e: reduce R4 and R7 to around half or a little more of the previous values.)

The second half of the problem, the effect of jamming whereby the train does not take off at all without mechanical persuasion, is not solved even by the voltage regulation technique. It was hoped that the initial impulse delivered at the point of acceleration would overcome this to a large extent, which it does, but it still occurs annoyingly often.

The effect occurs because the friction of the gears and engine mechanicals requires more force to be initially applied than is necessary to sustain movement. It is worse in certain designs. The Hornby wormgear drive is again not the best way to do it. Also, engines with a higher top speed, and hence usually a lower reduction ratio, are worse. Oiling and cleaning are partially effective, but are not cures. It seems as though applying power in pulses is very helpful: this suggests that a switchmode power delivery scheme would be beneficial. I did not use a switchmode supply in the 1508 because, firstly, it did not seem justified as a power economising measure and because it tends to make engines 'sing' at the switch frequency. As the 1508 applies power, albeit a tiny amount, even when at a standstill, the engine would sing even when standing at a station. To apply the technique while avoiding obtrusive noise, excessive component count and disturbance and s/c and o/c detectors, is tricky. I have not solved this stumbling block as yet.

To summarise the needs and changes which should be implemented in a next design: (1) The o/c sense will be of an independant type, as is a s/c in the 1508, so that (2) one can use voltage regulation for frequencies above about 0.1 Hz and current regulation below this point. (This constrains the gain and configuration of the feedback loop in order to guarantee stability — for example, the drive must not permit the load impedance to affect gain of the final stage, as does the 1508 where it does not matter.**)

(3) The power delivery mechanism should be switchmode, with a frequency and duty cycle optimised for overcoming friction yet minimising noise. The circuit must apply pulses with a rate comparable to the armature time constant in order to exercise maximum force momentarily to overcome static friction, yet be fast enough to give smooth travel at low speed and hopefully be inaudible. It must also respond to input changes faster than the actual inertia of the train permits *it* to respond, and also deliver a current which it is practically possible to average out faster than the train can respond. The latter condition is necessary in order to maintain apparently slothful response in the actual model, despite real world effects like dirty contacts, which are instantaneous. ●

This may also be due to demagnetisation effects especially if you have ever made the mistake of dismantling the engine motor itself.

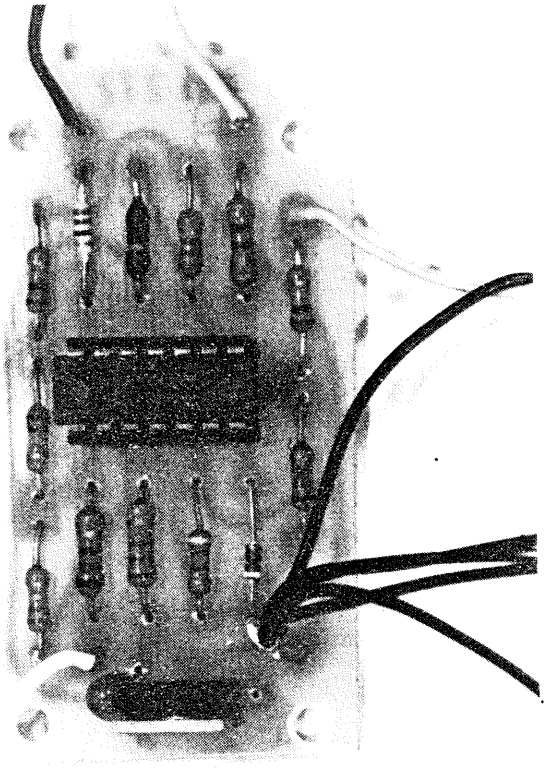
This is the limitation of effectiveness of the modification suggested earlier. Any tighter regulation of train voltage at higher frequencies than the circuit offers gives rise to oscillation when load impedance rises, disabling the o/c indicator totally. Reduction of the BC557's 3k9 emitter resistor would tighten the regulation, smoothing response further, but permitting instability for large load impedance. Curing that by reducing loop gain bandwidth elsewhere defeats the turnon impulse. That resistor may be selected (1k-10k range) to give best train response for stability.

Project 272

A three-LED power level indicator for audio amps

This simple project provides indication of when your power amp output reaches three pre-determined levels. It's more useful than a simple clipping indicator (your ear is better at that!) and is cheaper and easier to install than bargraph level displays or moving coil meters.

Jonathan Scott



IT HAS BECOME the trend to include some indication of power delivered to the speakers by a power amplifier. This is a basically sensible idea. You have some idea of when you are getting near the limitation of the amplifier or the speakers, or perhaps it tells you whether the power amp is producing signal when trying to find out where the music went. It will even indicate if you are liable to be aggravating the neighbours by shaking their ceiling, assuming you are losing touch with the actual volume delivered, as one does after a long while of high level.

Many amplifiers do not have these facilities, however, my ETI Series 5000 included. (So it doesn't have much to do with actual sound quality.) Some expensive, up-market power amps come with two calibrated panel meters, which seems to be something of a waste of $40 or so, considering how often you actually need the facility. Some include only a LED 'clipping' indicator which is even less useful if it only warns of clipping, rather than getting close to it, because the ear can report this fairly reliably'.

This project was specifically designed to go in my Series 5000 power amplifier, to allow it to have some output indication while consuming only a minute amount of panel room, of which there is precious little left due to the front panel heatsink design. It sports three LEDs which turn on at power levels of one, eight and 50 watts (into 8 ohms). Should you wish to adjust the turn-on points to suit a system other than 8 ohms or power levels higher or lower than these, the equations for figuring the correct values to substitute are given in the How It Works section.

The main features of the circuit are that it does not load or interfere with the signal as the unit has a 10k input impedance, it costs very little and takes up very little room inside the case. It is also very flexibly designed, allowing the selection of any set of levels to suit different applications.

Boards can also be cascaded to give six-level readout if desired, simply by running two in parallel and selecting the appropriate resistors to get the desired levels. While I did design it as a retro-fittable addition for my 5000 amplifier, you can install it inside almost any amplifier, even a commercial one if you wish, as it has its own on-board voltage regulator and can run on any suitable filtered dc supply, and consumes little 'backroom' space and so little panel space. It could also come in useful in applications requiring a LED meter whose scale is neither linear nor logarithmic, as these are the functions often implemented in LED meter circuits.

Construction

The construction of the circuit itself is very elementary, and can be undertaken as soon as you have worked out where you are going to mount the pc board and LEDs. You should figure out where you are going to fit the board(s) and drill the appropriate holes for them and the LEDs first. You will find it convenient to use the bare board as a template for locating the mounting bolt holes.

If you are fitting a pair to a Series 5000 amplifier, you will find that they fit neatly in the space behind the power switch, bolting to the aluminium members running from the heatsink/front panel to the rear panel. It is then convenient to use the two spare windings on the adjacent power transformer to power the meters, using the circuit given here, mounting the components on a tag strip attached to one of the mounting bolts.

The six LEDs mount easily in two columns of three above the power switch. After drilling the LED mounting holes you