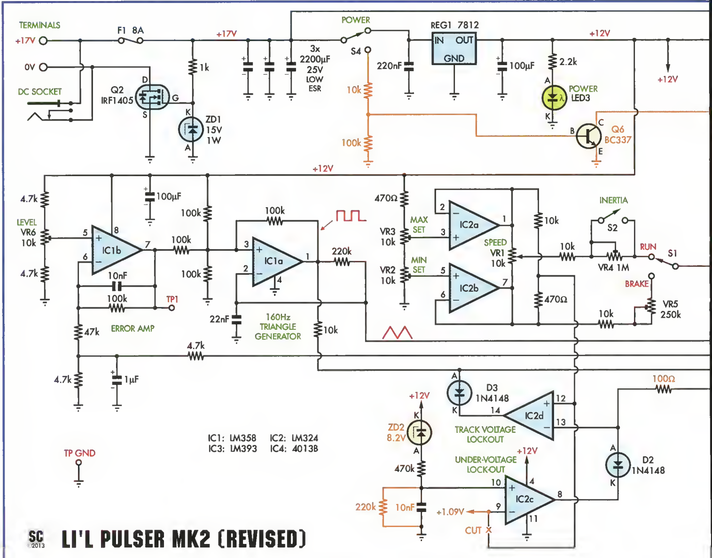


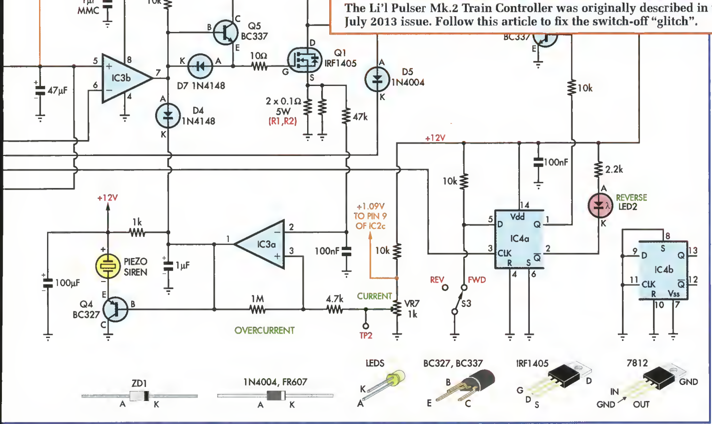
Fig.1: this circuit diagram shows the required changes to the original Li'l Pulser Mk.2 circuit in orange. Note that Q6 and its associated base divider resistors are only added as a 'belts and braces' measure if you are building the revised PCB (see text & Fig.3).

Li'l Pulser Mk2: fixing the switch-off lurch

By NICHOLAS VINEN

Our new Li'l Pulser Model Train Controller, described in the July 2013 issue, has been very popular but a design flaw has become apparent. At switch-off, any locomotive(s) on the track can suddenly lurch forward, even if they are stationary at the time. This is regardless of the position of the speed control knob and the brake switch. Here's the cure.

The Li'l Pulser Mk.2 Train Controller was originally described in the July 2013 issue. Follow this article to fix the switch-off "glitch".



IF YOU'VE BUILT the Li'l Pulser Mk.2, then you'll want to fix the switch-off flaw. The magnitude of the effect varies, depending on how the unit is switched off (via its front panel controls or the mains power supply), what type of supply is being used, the types of locos involved and so on. It can range from a minor issue to one serious enough to cause derailment.

While this can be solved by taking the locos off the track or disconnecting the controller from the track before switching it off, that's inconvenient. So we set about figuring out why this was happening and how to fix it.

The cause

Take a look now at the circuit of Fig.1. This shows the relevant sections of the original circuit published in the July 2013 issue but with a number of changes shown in orange.

Ignore the changes for the moment while we discuss the problem and how it occurs. Comparator IC3b generates the PWM waveform to drive Mosfet Q1, which switches the supply voltage to the tracks, controlling how much power the locos receive. This works by comparing a 160Hz triangle waveform to a control voltage, with the control voltage indicating the desired loco speed; the higher the control voltage, the higher the output PWM duty cycle and thus the higher the motor speed.

The control voltage is low-pass filtered by an RC network, to prevent it from changing too rapidly and also to simulate train inertia. The amount of filtering applied depends on whether or not the inertia switch is on and the position of inertia control pot VR4 but regardless, there is always some filtering of this signal.

When the unit is switched off and its power supply capacitors discharge, the power supply to the op amp generating the triangle signal collapses and so the triangle signal's voltage drops rapidly. But this filtering of the control signal causes the control voltage to drop much more slowly. In other words, the 47µF capacitor at pin 5 of comparator IC3b remains charged for some time after power is removed.

This means that at switch-off, the

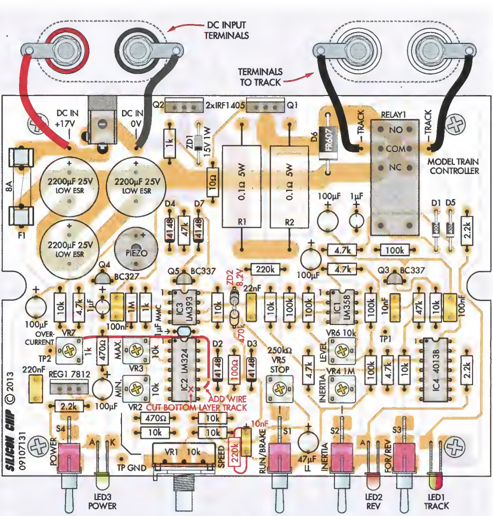


Fig.2: here's how to make the changes to the original PCB to eliminate the switch-off lurch. The changes are all indicated in red and are easy to do (see text).

control voltage rises relative to the triangle waveform (by dint of the triangle voltage dropping) and so the PWM duty cycle increases until it reaches 100%. It stays at 100% until the power supply has collapsed to the point where there is no longer sufficient voltage to turn the Mosfet on, at around 3-4V. This can take a significant fraction of a second.

During that time, the full input supply voltage, typically around 17V, is applied across the tracks. Hence the sudden jerk from the locomotive(s).

This can happen regardless as to whether the Li'l Pulser's power switch (S4) is thrown or its power supply is turned off at the mains outlet but it tends to be worse when switched off via S4. That's because if the supply is switched off at the wall, the Li'l Pulser's input capacitors remain in parallel with its output capacitors and so the supply voltage drops more slowly. Depending on that amount of capacitance, the supply voltage may drop slowly enough that the control voltage drops as fast or faster, preventing any output pulses.

The solution

We have taken a two-pronged approach to solving this. The first set of modifications pretty much eliminates the jerking and can be easily applied to existing PCBs. We have also produced a revised PCB which incorporates these changes and will supply this to new constructors. The revised board also incorporates a few extra components which provide further protection against a switch-off pulse when power is switched via S4, which as described above, tends to be the worst case.

These circuit changes are shown in orange on Fig.1, as noted above. First, we have taken the power-up reset circuit, based around op amp IC2c and converted it into an under-voltage lock-out, which still also performs the original reset function although by a different means.

Originally, an RC filter from the 12V rail, connected to pin 10 of IC2c, provided a time delay. This was compared against a reference voltage at pin 9, which was derived from the outputs of the min/max speed buffer op amps IC2a & IC2b. This is the same reference voltage used by op amp IC2d (at pin 12) to time the switch-over of the reversing relay.

In operation, some time after power-on, reset is asserted and Mosfet Q1 is held off until the capacitor at pin 10 charges to a higher voltage than the reference. The reset is then released and normal operation begins.

For the new circuit, we drastically reduced that capacitor value from 10µF to 10nF, effectively eliminating the time delay. Instead, 8.2V zener diode ZD2 plus the voltage divider formed by the 470kΩ resistor and an additional 220kΩ resistor prevent the reset from being released until the power supply voltage has risen past about 11V. This takes some time (for the supply capacitors to charge, etc) so despite the much smaller capacitor value, there is still a reset delay at start-up.

This 11V threshold must be reasonably accurate; it has to be below the minimum supply voltage, or else reset will not be released at power-up. At the same time, it can't be too far below the supply voltage as we want reset to occur shortly after switch-off, before any unwanted output pulses can be delivered to the tracks.

To this end, we have changed the reset reference voltage from one which varies depending on the positions of VR2 and VR3 to a fixed 1.09V (nominal) derived from an existing divider across the 12V rail (10kΩ/1kΩ). Pin 10 must rise above this voltage in order for the reset to be released and since the 470kΩ and 220kΩ resistors form a roughly 2:1 divider, that sets the threshold at 8.2V + 1.09V x (470kΩ + 220kΩ) ÷ 220kΩ = 11.6V.

In practice, at the low current it is being operated, ZD2 will be at the lower end of its breakdown voltage range, so the actual threshold will tend to be closer to 11V. The minimum output of REG1 is 11.4V but also consider that the 1.09V reference is derived from the supply voltage and so the threshold

Extra Parts For PCB Modifications

1 8.2V zener diode (ZD2)
1 10nF MKT capacitor
1 470kΩ 0.25W resistor
1 220kΩ 0.25W resistor
1 100Ω 0.25W resistor
1 short length light duty hook-up wire

Parts List Changes For Revised PCB

Additional parts
1 BC337 NPN transistor (Q6)
1 8.2V zener diode (ZD2)
1 10nF MKT capacitor
1 220kΩ 0.25W resistor
1 100kΩ 0.25W resistor
1 10kΩ 0.25W resistor
1 100Ω 0.25W resistor

Deleted part
1 10µF electrolytic capacitor

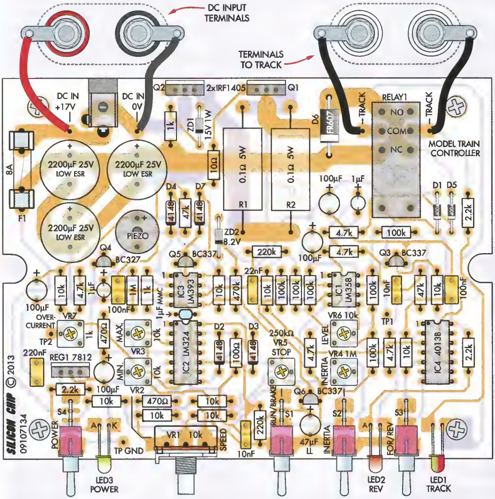


Fig.3: follow this parts layout diagram if you're building a new unit using the revised PCB (09107134). This version also adds transistor Q6 and two associated resistors.

drops somewhat if the supply is on the low side.

Now since the 10nF capacitor only provides a very short delay (with a time constant of 10ms) and with a threshold of about 11V, once the unit is switched off, the 12V supply doesn't have to drop by much before it enters the reset state which forces Q1 to stay off while the supply voltage decays to zero.

Making the changes

We made these changes to our prototype and it no longer causes any noticeable motor pulse at switch-off. Fig.2 shows what is required. Start by removing the 470kΩ resistor to the right of IC3, the 10kΩ resistor directly below it and the 10µF electrolytic capacitor to the left of S1.

Since it's a double-sided board, it has plated through-holes so the easiest way to remove the resistors is to clip their leads off close to the body, then pull the stubs out with pliers while heating the solder joints. The holes can then be cleared with a solder sucker. The electro can be rocked out while heating the pads and gently pushing on the body and its mounting holes cleared of solder too.

Next, cut the track to pin 9 of IC2, on the underside of the board (shown in Fig.2 with a red 'x'). Fit a fresh 470kΩ resistor and ZD2 to the pads originally used for the 470kΩ resistor, with the cathode of ZD2 to the top of the board and 'air wire' them together. The 100Ω resistor and 10nF capacitor can be fitted as usual, with the added 220kΩ resistor wired across the new capacitor under the board.

Finally, run a short length of insulated wire (eg, Bell wire or Kynar) under the board, from the now-isolated pin 9 of IC2 to the top-most pad of VR7.

When you reassemble and test the unit, you should find that it now operates as before but without the switch-off pulse from the motor(s). If the unit fails to operate, check the voltages at pins 9 & 10 of IC2. Pin 10 should have a slightly higher voltage when power is applied; it's unlikely that it won't but if not, you may need to change ZD2 to the next lowest voltage (eg, 7.5V).

New PCB & further changes

To make it easier for new constructors, we can now supply a revised PCB for the Li'l Pulser, incorporating all the modifications. This new PCB is coded 09107134 and is available via the SILICON CHIP Online Shop.

Fig.3 shows the overlay diagram for the revised PCB. You will need to refer to the original assembly notes in the July 2013 issue when building it.

In addition to the above changes, we have also added NPN transistor Q6 and two more resistors so that as soon as S4 is switched to the off position, Q6 turns on and rapidly discharges the 47µF control voltage filter capacitor, so there is no possibility of an output pulse regardless of how quickly the under-voltage lock-out circuit kicks in.

This is a bit of a 'belts and braces' approach, ie, it isn't totally necessary but it provides some extra cheap insurance against any sort of output pulse being delivered to the tracks.

With these changes the unit will now behave itself at switch-off but otherwise operate identically. **SC**