Steam Sound Simulator FOR MODEL TRAINS

Build this realistic steam train sound simulator for your model train layout. It features an infrared optical switch to synchronise the "chuffs" to the wheel rotation and, like our Diesel Sound Simulator, picks up its power from the track supply.

by ANDREW LEVIDO

As a follow-on from the Diesel Sound Simulator described in November, we now present a Steam Sound Simulator along similar lines. It is designed to be mounted inside a loco tender or goods van and to pick up its power supply from the track. For this reason it can only be used with pulse power type train controllers such as the *Railmaster* described in September.

As such, it has an advantage over other on-board sound systems in that it does not require a separate battery supply on the train itself.

It is possible to use the track supply to power the electronics because, in pulse power systems, the peak track voltage remains constant over the entire throttle range. Thus we can derive a constant power supply voltage using a relatively simple circuit. The track voltage is obtained from the locomotive and fed to the sound simulator circuit via a pair of fine wire leads.

We originally intended to use a "speed control" system similar to the one used in the Diesel Sound Simulator. That system measured the back-EMF generated by the motor in the locomotive, and used this to control a VCO. This approach worked very well for the Diesel Sound Simulator but a number of problems were encountered in applying it to the Steam Sound Simulator.

When a diesel locomotive comes to a stop the engine will continue to run, even if only at idle speed, so engine sounds will still be present. When a steam locomotive stops however, chuffing ceases. This effect was difficult to implement because different locomotives stopped moving at different throttle settings. It was also difficult to get a realistic chuff rate at all locomotive speeds.

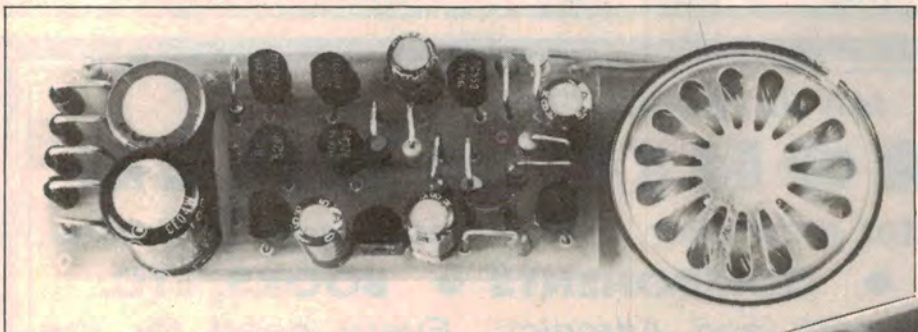
The solution was to use some kind of switch on the wheels, to provide one chuff per wheel rotation. Unlike some units, this circuit avoids the need for fancy mechanics by using an infrared LED and a matching photodiode detector. A cardboard vane attached to the axle of the carriage interrupts the beam of infrared light once every wheel rotation.

Because the steam sound does not have the low frequency content that the diesel sound has, loudspeaker requirements are not quite so critical. We used an insert from a pair of miniature dynamic headphones as the transducer. This fits easily inside the tender or van yet, at the same time, provides reasonable sound output.

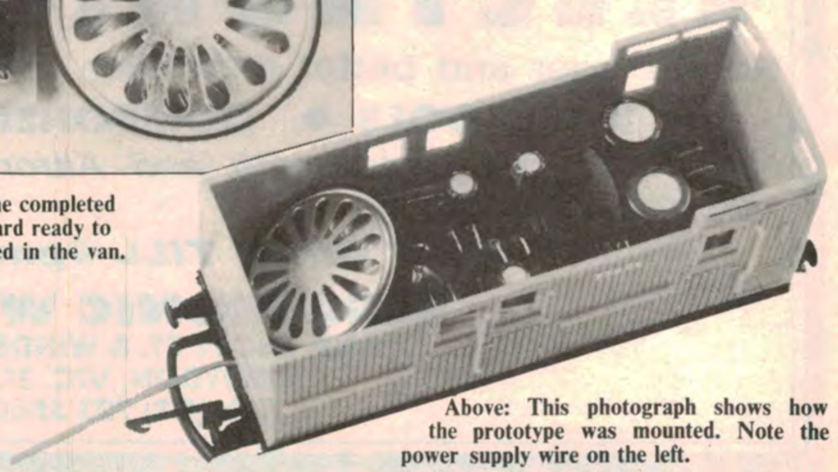
The insert used in the prototype came from a pair of headphones obtained from Dick Smith Electronics for $8.95. Don't throw away the spare transducer; you might wish to make up a second circuit later on. Note that these transducers have an impedance of 32Ω, although you can use an 8Ω speaker if you wish by making one small circuit change (see "how it works").

How it works

The output of the *Railmaster* train controller consists of a square wave with an amplitude of about 20V and a variable duty cycle. As the throttle is advanced, the duty cycle of the output waveform increases from zero to just



Above: The completed circuit board ready to be mounted in the van.

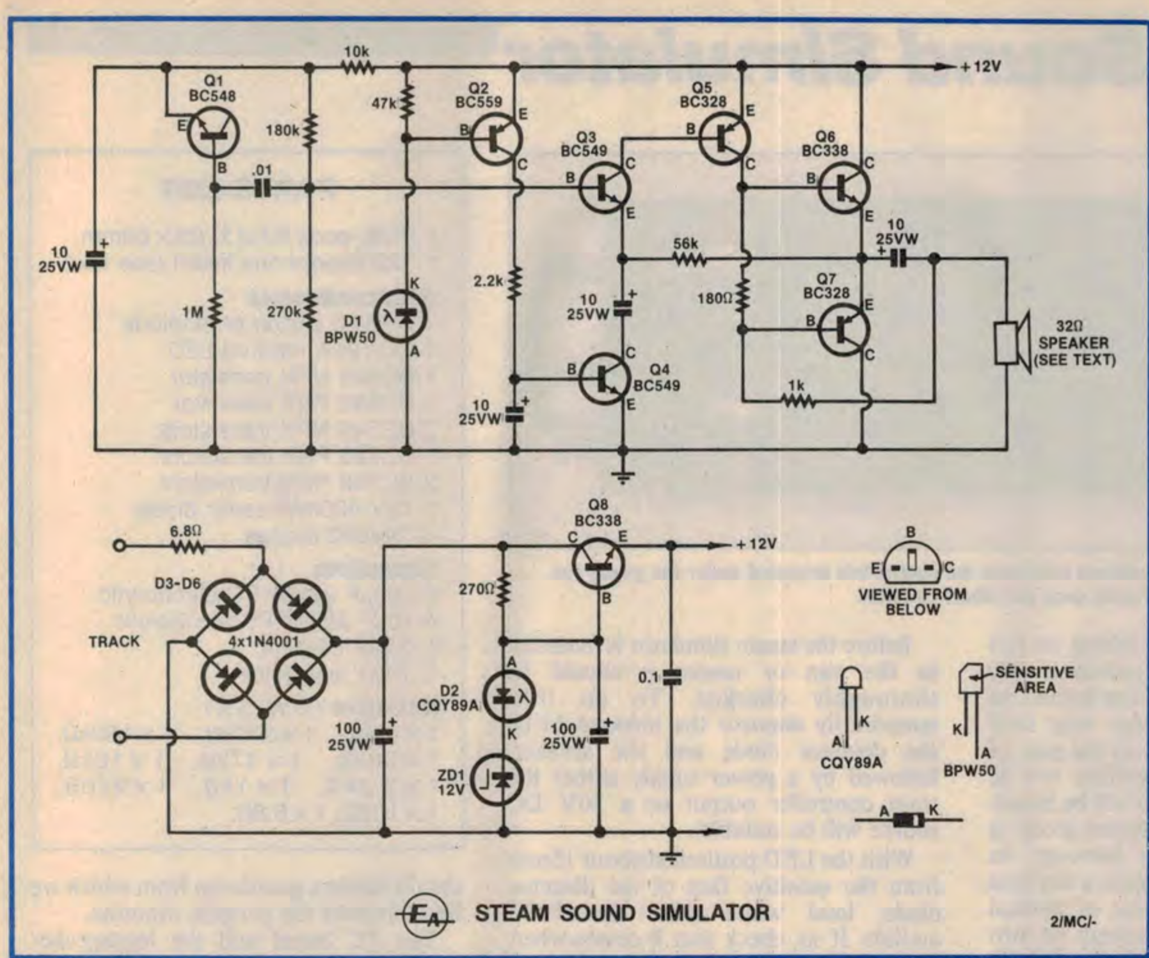


Above: This photograph shows how the prototype was mounted. Note the power supply wire on the left.

We estimate the current cost of parts for this project to be

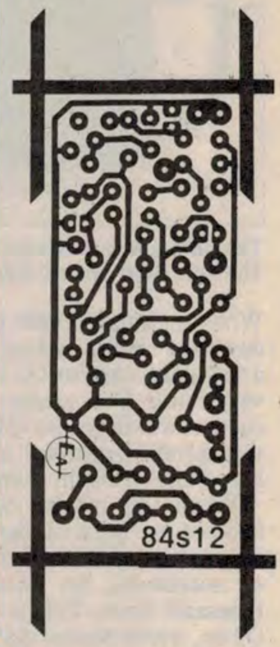
$14-18

This includes sales tax but does not include the cost of the miniature headphones.



Left: The full circuit diagram of the Steam Sound Simulator.

Below: Here is the actual size printed circuit board pattern.



over 50%. The motor responds to the average value of this voltage which thus varies from zero to 12V. The peak voltage, however, remains constant throughout the entire throttle range.

From the circuit diagram, we can see how this characteristic of the controller is exploited to produce a constant supply voltage for the electronics. The 100μF capacitor is charged to the peak track voltage through the bridge rectifier (D3-D6) and the 6.8Ω resistor. The bridge rectifier is used to ensure that the capacitor always charges with the right polarity, even when the train is reversed. The 6.8Ω resistor limits the peak charging current to an acceptable value.

Transistor Q8 and associated components form a simple voltage regulator which provides a stable +12V supply to the electronics. The voltage reference for this regulator is provided by zener diode ZD1 and the infrared LED, D2. These components ensure that a voltage of about 13V is maintained on the base of Q8.

This type of regulator was chosen over a 3-terminal regulator for a number of reasons. Firstly, it has a better start-up characteristic than the intergrated circuit regulators. This means that before the input voltage has risen to a level at which the regulator will begin to operate, it will function as a capacitance multiplier filter. This eliminates the buzzing noise which would occur at this time, if a 3-terminal regulator was used.

This type of circuit also has a lower dropout voltage than a 3-terminal regulator, so it will continue to regulate at a lower input voltage. This again is important when the train is starting or stopping. Another advantage of using this circuit is that we save some current drain by including the LED in the zener diode network, where we would otherwise have to include it in a separate branch.

The characteristic hissing sound of escaping steam is simulated by white noise source Q1. The reverse biased base-emitter junction of this transistor generates about 50mV of noise which is coupled into the base of Q3 via a .01μF capacitor. The 180kΩ and 270kΩ resistors provide bias for Q3, which is the first stage of a simple amplifier. If Q4 is ignored temporarily, it can be seen that this amplifier is similar to the 1 watt audio amplifier published in the November issue.

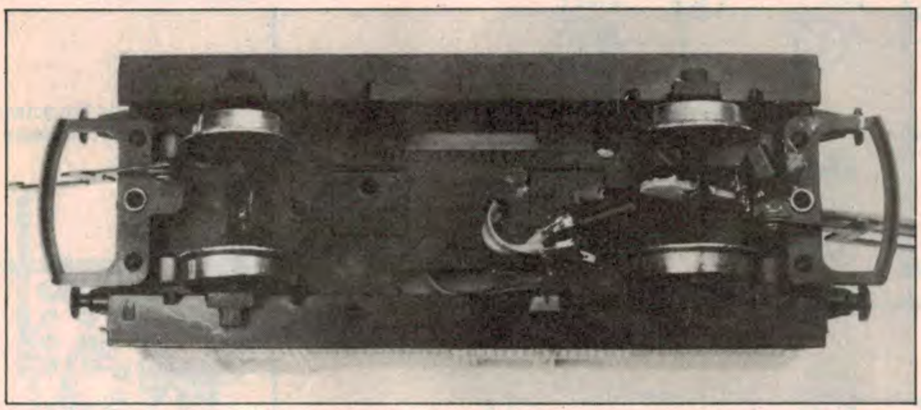
A detailed description of the operation of this amplifier was given in that issue so only a brief rundown of its operation will be given here. Q6 and Q7 form a complementary pair output stage which has the high current gain necessary to drive the low impedance load. The 1kΩ resistor provides output bootstrapping while the 180Ω resistor biases the transistors so as to eliminate crossover distortion. Q3 and Q4 provide the voltage gain of the amplifier and the 56kΩ resistor provides the overall feedback path.

In greater detail, the feedback which sets the gain of the amplifier is provided by the 56kΩ resistor and the network containing the 10μF capacitor and Q4. If Q4 is thought of as a variable resistor, it can be seen that increasing its value will result in an increase in the level of negative feedback applied to the emitter of Q3. This will result in a reduction in voltage gain. In the same way, if the resistance of Q4 decreases the gain will increase.

The actual resistance of Q4, from collector to emitter, depends on the current flowing into its base. Thus the overall gain of this amplifier is controlled by the current applied to this point. This type of circuit is known as a current controlled amplifier. In case you were wondering, the 10μF capacitor is included to prevent any DC flowing through Q4, since this would upset the bias conditions of the amplifier.

The current which flows into the base of Q4 is provided by Q2, which is controlled by the leakage current through the infrared detector diode (D1).

Steam Sound Simulator



This photograph shows the infrared LED and the photodiode mounted under the goods van. The vane interrupts the light path once per wheel rotation.

When no infrared light is falling on this device its reverse leakage current is only a few nanoamps so Q2 is not turned on very hard. This means that very little current will flow into Q4, so the gain of the current controlled amplifier will be low. Thus no steam sound will be heard.

When the infrared detector diode is exposed to infrared light however, its reverse leakage current rises to a few tens of microamps, an increase of several thousand times. This is enough to turn Q2 on, which means that the gain of the current controlled amplifier will be high. Under these conditions the white noise will be audible.

As mentioned earlier, the LED and the infrared detector diode are so arranged that the passage of light between them is interrupted by a vane attached to the axle of the chosen van or tender. In this way the white noise is modulated by the movement of the wheels. (Because the gain of the amplifier is proportional to the amount of infrared light falling on the detector, the attack and decay of each chuff can be varied by the user simply by altering the shape and size of the vane.)

If you wish to use this circuit with an 8Ω loudspeaker it is necessary to re-bias the output stage. This is easily done by replacing the 180Ω resistor between the bases of Q6 and Q7 with a 270Ω resistor.

Construction

The Steam Sound Simulator is built on a printed circuit board coded 84s12 and measuring 26 × 56mm. Before mounting any components on the board, it should be thoroughly checked. Make sure that all the holes have been drilled and that none of the tracks are touching. Follow the layout diagram closely when mounting the components. Note that all the resistors are mounted on their ends. This was done to conserve space.

Before the steam simulator is mounted in the van or tender it should be thoroughly checked. To do this, temporarily connect the infrared LED, the detector diode and the speaker, followed by a power supply (either the train controller output or a 20V DC source will be suitable).

With the LED positioned about 15mm from the sensitive face of the detector diode, loud white noise should be audible. If so, check that it ceases when the infrared beam is interrupted. If there is some problem recheck all the wiring and component positioning. Once you have it all working correctly, you are ready to mount the circuit inside the tender or, in the case of a tank loco, in the following guardsvan or a suitable goods wagon.

There must be enough room to mount the PC board and the headphone insert.

Mount the infrared LED and the detector diode in such a way that a vane attached to the axle will interrupt the light path between them. The various components can be held in place using epoxy adhesive and the leads run through small holes drilled in the floor of the tender. Make sure that the vane does not foul anything on the layout (watch the points especially).

In most cases, it will also be necessary to drill holes in the floor of the wagon to let out as much sound as possible. We solved the problem by mounting the circuit inside a guardsvan from which we had removed the perspex windows.

The PC board and the loudspeaker can be secured in position using Blue Tac adhesive. This product is made by Bostik and is available from most hardware stores. Before mounting the board, it will be necessary to make the connections from the LED and photodiode and to connect the power supply leads.

Power for the prototype was obtained directly from the locomotive via a pair of fine wires. A small socket, made from a cut down IC socket, was mounted in the locomotive, and connected to the motor terminals.The stripped and tinned ends of the wires from the sound simulator were then inserted directly into the socket.

The big advantage of this scheme is that it makes it easy to swap locomotives or to disconnect the sound effects tender and transfer it to other layouts.

Finally, if you want to run double-headed trains, just build two sound simulators. The cost is certainly quite reasonable.

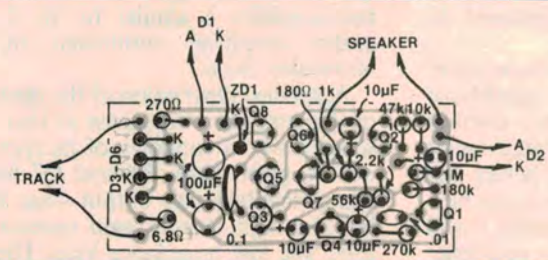
PARTS LIST

1 PCB, code 84s12, 26 × 58mm
1 32Ω headphone insert (see text)

Semiconductors
1 BPW50 silicon photodiode
1 CQY89A infrared LED
1 BC548 NPN transistor
1 BC559 PNP transistor
2 BC549 NPN transistors
2 BC328 PNP transistors
2 BC338 NPN transistors
1 12V 400mW zener diode
4 1N4002 diodes

Capacitors
2 100μF 25VW PC electrolytic
4 10μF 25VW PC electrolytic
1 0.1μF ceramic
1 .01μF polyester

Resistors (¼W, 5%)
1 × 1MΩ, 1 × 270kΩ, 1 × 180kΩ, 1 × 56kΩ, 1 × 47kΩ, 1 × 10kΩ, 1 × 2.2kΩ, 1 × 1kΩ, 1 × 270Ω, 1 × 180Ω, 1 × 6.8Ω.



Here is the circuit board overlay. Watch the orientation of the polarised components.