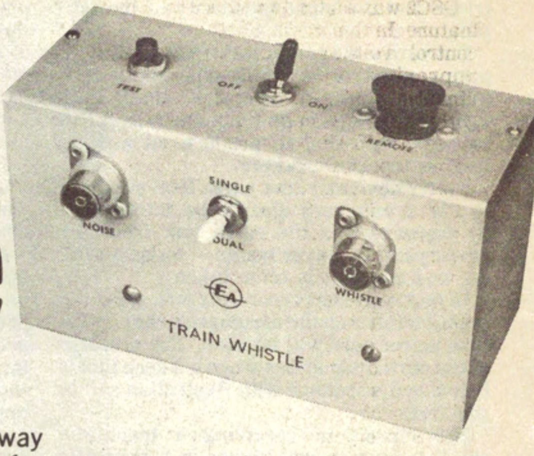
An Electronic Steam Whistle



Our "Electronic Steam Whistle" was developed with the model railway enthusiast in mind. It might also serve as a sound effects simulator for amateur theatricals. Featuring single and dual horns, with background steam, it will add realism to your model setup. A separate "Noise" outlet is also provided to simulate steam alone.

by GERRY NICHOLSON

A series of articles describing a sound effects simulator for electronic organs was published in the October, November and December 1971 issues. The steam whistle described in these articles inspired us to produce this unit. In fact, we started off with an exact copy of this circuit. Our impression of this arrangement was that, while it would no doubt be adequate as an organ sound effect, it did not provide the flexibility which a model railway enthusiast would be likely to require. However, it provided a good starting point.

We considered it essential that all the factors affecting the final sound should be capable of being varied over a wide range; preferably a wider range than appeared to be strictly necessary. This would permit the builder to vary any or all of these factors, as he thought fit, in order to achieve what he considered the best imitation of the particular whistle he had in mind.

If we consider the type of sound a steam whistle makes, we will be in a better position to decide how we can imitate it electronically. For a start, when the steam valve is opened, the sound intensity appears to rise to a constant level over a short period. In other words, it has a certain rise time. Also, during this rise time, the frequency of the whistle falls slightly.

Now consider the effect as the steam valve is closed. The steam in the whistle will take a short period to escape (as the pressure drops), thus the sound intensity fades over a short period. In other words the whistle has a certain decay time. Another feature peculiar to whistles is the background sound of the steam or air which operates them. As mentioned earlier, our device also features dual horns. This type of sound is usually produced by air horns, the two horns having a frequency ratio of about 1.5 to 1.

We must now design circuitry which will imitate the above features. To avoid confusion, we shall forget the dual horns for the present. To produce the single whistle, we require an oscillator. A simple phase shift oscillator would appear to be suitable. (TR1 and associated components). There are no inductances required, and the frequency can be varied easily by changing resistance or capacitance.

To simulate the steam, a logical choice is a white noise generator. This is merely a reverse biased diode, arranged so that avalanche takes place, producing a substantial amount of noise. We use a reverse biased BC108 (D3) emitter to base junction in this mode.

Initially, we tried mixing the output from the noise generator directly with the oscillator output, but we were not happy about the level of noise available. It may have been sufficient in some cases, but it was a marginal condition. Accordingly, we fitted the noise amplifier (TR3) which provides more than sufficient noise for any likely requirement.

The signals from the oscillator and noise generator must be mixed in the correct ratio before they are fed to the main amplifier, and they must only reach the input to this amplifier when we wish to initiate the whistle. Also a means to vary the rise and decay times of the signal must be devised. All these functions are conveniently performed in the gated amplifier stage (TR4).

The whistle and noise signals are mixed at the input to the gated amplifier. The ratio of these signals is adjusted by resistance in series with the coupling capacitors from these stages.

The gated amplifier is normally gated off by a voltage divider network consisting of the 4.7k in the emitter circuit and the 47k to the positive rail. To gate the amplifier on, in the simplest case, it would be sufficient to shunt the emitter resistor with another resistor of suitable value. However, we can provide the required attack and decay times by adding suitable time constant circuits which control the rate at which the stage is gated on or off.

The time constant circuits consist of the 1k and 2.2k resistors and the two 10uF electrolytic capacitors in the emitter circuit of TR4. The total resistance of 3.2k is that required to gate the amplifier on, but the rate at which this can happen is determined by the rate at which the capacitors can be charged or discharged through their associated resistors. The 10uF capacitor across the 4.7k emitter resistor also functions as a conventional by-pass to maintain the amplifier gain.

When the test button is pressed, the lower leg of the voltage divider to TR4 emitter becomes approximately 1.9k ohms. However, before the stage is biased on, the emitter bypass capacitor must discharge through the emitter resistor in parallel with the gating resistance, and the other electrolytic must discharge via the 1k resistor.

Thus the output of the gated amplifier rises to a constant level over a short period, as the electrolytics discharge. We have thus introduced the necessary rise time. This rise time can be increased by increasing the capacitance of either electrolytic, or the gating resistance, and vice versa for a decrease. Note: If the gating resistance is increased too much, the stage may not bias on at all, thus it is preferable to vary only the capacitance if it is desired to change the rise time.

These electrolytics also provide the decay time. When the test button is released, the emitter bypass capacitor charges via the 47k, while the other electrolytic charges through the 2.2k before the gated amplifier is biased off. Thus the output from this amplifier fades over a short period. The rise and decay time adjustments interact, thus a compromise must be accepted, but more about this later.

Earlier we mentioned that a steam whistle appears to lower pitch during the rise time. The method we used to achieve this effect is as follows. The gated amplifier output signal is fed via a 0.22uF capacitor to a rectifier (D2). The DC thus produced is proportional to the output signal amplitude and, therefore, increases during the rise time. However C2 (DC reservoir) must charge before a constant negative potential exists, thus the value of C2 controls the rate at which this potential increases.

In OSC1 a BA100 (D1) is connected in series with an 82k from TR1 base. Normally D1 is biased on, thus the 0.0047 is shunted by 82k. Under these conditions the oscillator frequency is approximately 780Hz. If the DC control voltage is now applied to the anode of D1 via a 2.2k, this diode will be biased off. The effect of the 82k as a discharge path now becomes negligible, thus the overall phase shift of the network increases, and the frequency settles at approximately 750Hz.

OSC2 was added to provide the dual horn feature. In this mode, SW2b disables the DC control voltage, thus OSC1 operates at approximately 750Hz continuously. Meantime SW2a switches the 2.2M in series with the OSC2 coupling capacitor to the gated amplifier base. Now when the test button is pressed, we hear the dual tone plus noise. The rise and decay effects still occur, but there is no frequency shift. The final frequency of our second oscillator was found to be approximately 490Hz for the most realistic dual sound.

The 10k preset pot in one leg of the OSC2 phase shift network was included to allow the frequency ratio between oscillators to be finely adjusted, but more about this when we discuss final testing.

Construction should not present any serious problems for the average reader with some previous experience. While the finished product may look a little complicated, it must be remembered that it is a collection of separate sections. To make things easier, we have described the construction on a section by section basis, with details of how to test each section before proceeding to the next one.

We constructed the two oscillators on a piece of tag board, 17 pairs of terminals long. The noise generator, noise amplifier, frequency shift network, and gated amplifier are built on a second length, 19 pairs long. We suggest the oscillator board be wired first but, if the dual horn facility is not required immediately, the OSC2 section may be omitted for the present. To allow the tag boards to fit into the small case we chose it was necessary to limit the number of tags on each board. This made it necessary to place some components on the underside of each board.

Two threaded pillars hold the tag boards apart, while another two secure the whole assembly in the case. We cut the heads off two ⅛ Whit. screws and used these as studs to sandwich the oscillator board between the pillars. Take care that no components are placed where the pillars are to be located.

If one follows the circuit and wiring diagrams, wiring OSC1 should be relatively straightforward. There are only two components under the board, the 82k and the 25uF electrolytic. Where a capacitor or resistor is soldered to tags which have at least one other tag between them, the pigtails of that component should be insulated with spaghetti, to eliminate any possible shorts. Also insulate the pigtails of those components under the board. With this section wired, check it against the OSC1 section of the circuit, and the wiring diagram.

At this stage, OSC1 can, and should, be tested. Testing will call for an amplifier or, better still, an oscilloscope. As a last resort a high impedance headphone will suffice. Connect an 18V positive battery terminal to the free end of the 1k resistor and the negative terminal to the negative rail. Connect the 820k resistor to the the amplifier, oscilloscope, or headphone, either of which should indicate a sine wave output. It must be realised, however, that much of the realism is still missing. Do not make a final judgment until the noise (steam), attack and decay, and frequency shift have been added.

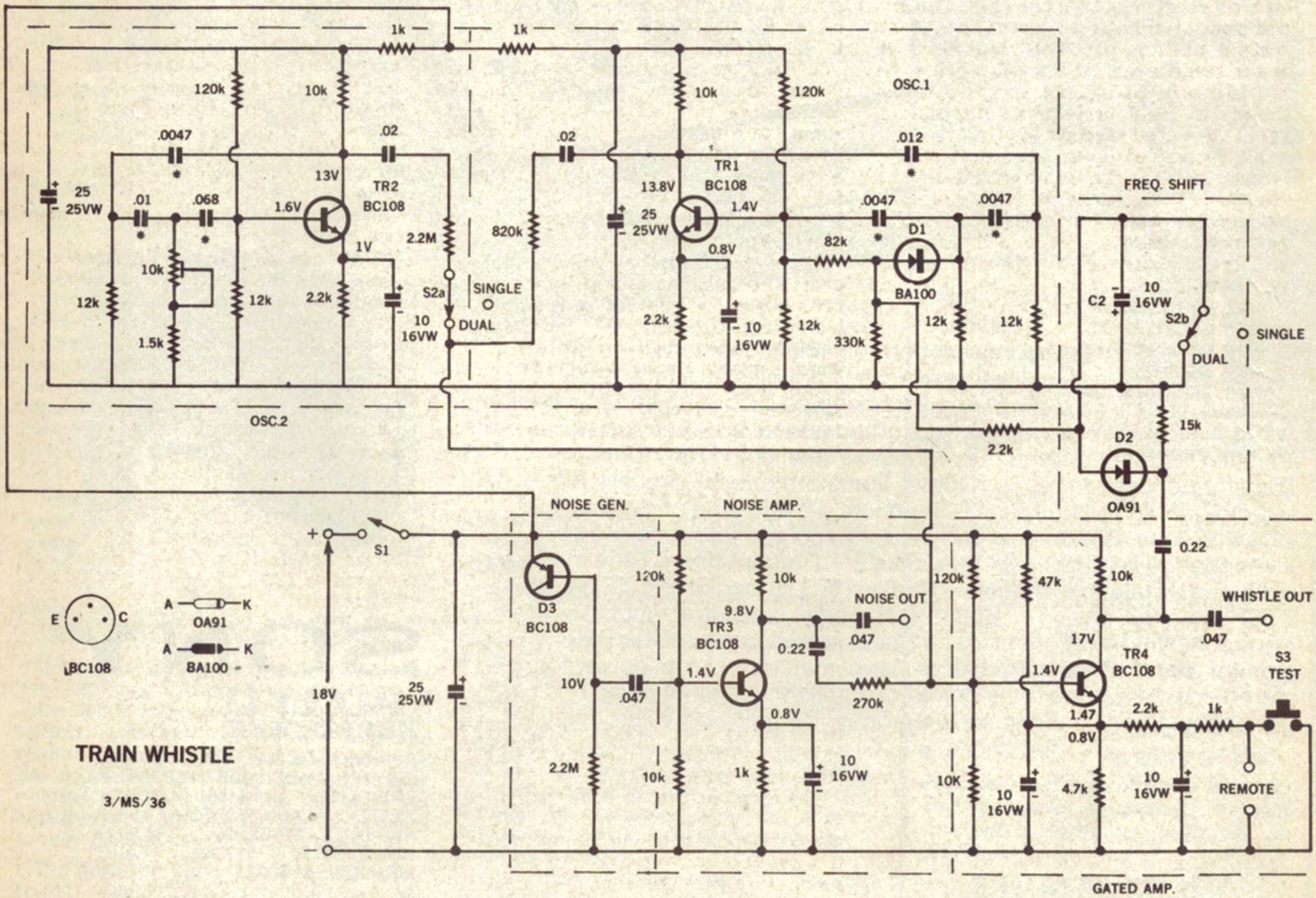
OSC2 occupies the rest of this board. The same procedure as that described for OSC1 applies to this section. The only extra component is the 10k preset pot, although the phase shift capacitor values have been changed to lower the frequency. One of these capacitors (.068uF) is situated under the board, along with the 25uF electrolytic, and a 1.5k and a 2.2k resistor.

To complete this board, interconnect the oscillator negative rails with a short length of wire as shown on the wiring diagram.

OSC2 can be tested in the same manner as OSC1, but Rv1 should be varied during the test, to ensure that the pitch of OSC2 does vary noticeably with this adjustment.

To begin the second board we can wire the noise generator. This section has only three components, so it should not take long to complete it. The collector of the BC108 is not used, so simply bend this lead up out of the way.

The noise amplifier is logically situated next to the noise generator. The 10uF emitter bypass is the only component under the board. The positive rail for this section is via a wire to the emitter of the noise generator transistor. Once again the sections should be checked against the circuit



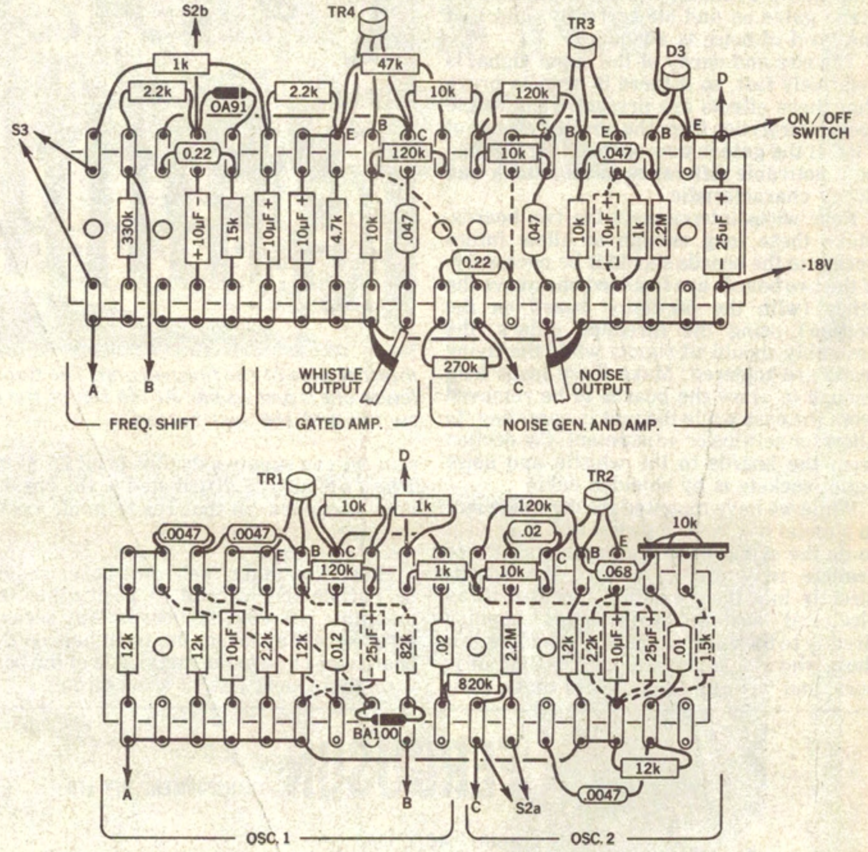
The circuit may look complex but is really only a combination of a number of relatively simple circuits. Each of these is outlined by a dashed border and its operation is explained in the text.

before testing.

To test the noise generator and amplifier, connect the positive 18V battery terminal to the emitter of the noise generator transistor (used as a diode), and the negative terminal to the negative rail. Connect the free end of the .047uF capacitor (labelled Noise Output) to the input of your amplifier or oscilloscope. If there is no output, place a fairly large value capacitor in series with the amplifier input lead and check if there is output from the noise generator at the amplifier base.

The rest of this board accommodates the gated amplifier and frequency shift network. The lk gating resistor mentioned earlier is the only component under the board. Make sure that the negative end of C1 (refer to frequency shift network) connects to the OA91 anode. A short length of wire from the gated amp collector to the 0.22uF capacitor (shown on the wiring diagram), and another length to connect the negative rail, completes this board. Check the complete section against the circuit and wiring diagram.

The gated amplifier can be tested using the amplifier or oscilloscope, as for earlier tests. Until the test button is pressed, there should be no output from the gated amplifier, although there will be signal at the base of TR4 continuously. The emitter voltage under these conditions should be approximately 1.47V. When the test button is pressed, there should be output, and the



Wiring diagrams of the two boards. The function of each section is clearly shown. The upper board is the one visible in the photograph on page 35. The lower panel is mounted below it.

Parts List

1 Metal box 5¼in (135mm) x 3⅛in (79mm) x 2⅛in (54mm)
2 Belling Lee chassis sockets, L604/S
2 Belling Lee plugs L734/P
1 2 pin speaker socket and plug to match
1 Miniature toggle switch
1 Miniature toggle switch, 2 pole 2 way
1 Miniature pushbutton switch, normally off.
1 length miniature tag board, 17 pairs of tags.
1 length miniature tag board, 19 pairs of tags.
2 9V batteries, type 216 or similar
2 clip connectors to suit above.

RESISTORS (½ watt)

2.2.2M	1 15k
1 820k	6 12k
1 330k	6 10k
1 150k	1 4.7k
1 270k	4 2.2k
4 120k	1 1.5k
1 82k	4 1k
1 47k	

1 10k preset miniature pot.

SEMICONDUCTORS.
5 BC108 transistors, or equivalant.
1 BA100 silicon diode.
1 OA91 diode.

CAPACITORS.
Electrolytics.
3 25uF 25VW, 6 10uF 16VW.
Miniature Polyesters (100VW).
2 0.22uF, 3.047uf, 2 .022uf, 1 .01uF, 3 .0047uF.
Polyesters (160VW)
1.068uF, 1 .012uF.

MISCELLANEOUS
12 ⅛in Whit. RH screws. 4 ½ in threaded pillars (⅛in Whit.).
Nuts and washers. solder lugs. foot of single core shielded cable.
hookup wire.
1 rubber grommet to suit ¼ inch hole.
20 gauge tinned copper wire.
Length of 2mm sleeving.
4 No 4 self tapping screws ¼ inch
Adhesive Lettering.
NOTE: Resistor wattage ratings and capacitor voltage ratings are those used for our prototype. Components with higher ratings may generally be used providing they are physically compatible. Components with lower ratings may also be used in some cases, providing the ratings are not exceeded.

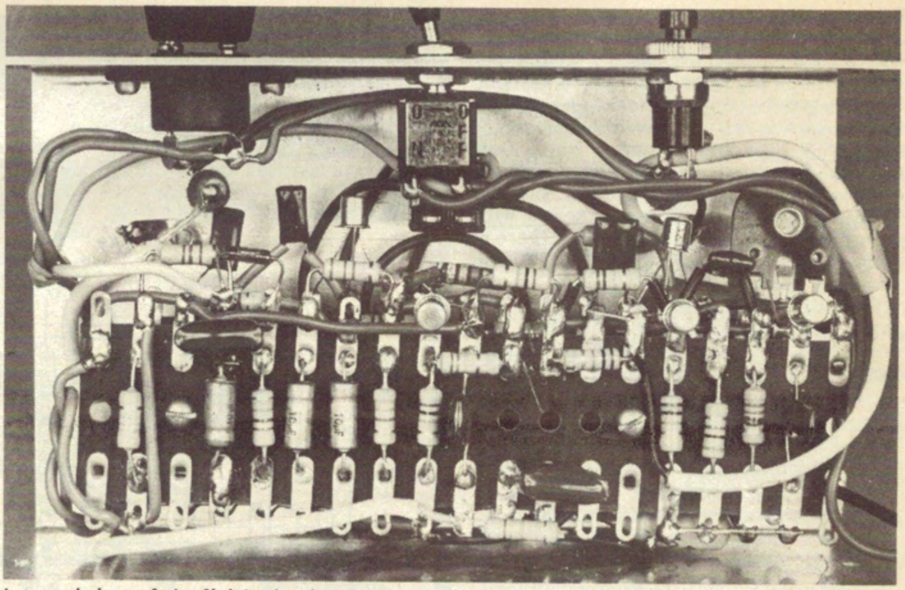
emitter voltage should be approximately 0.8V.

If the output is observed on a CRO, there should be some distortion obvious, one half cycle being more rounded than the other. This is deliberate, and adds a little to the realism of the sound. The background noise (steam) should also be obvious as "grass" superimposed on the waveform. If only an amplifier is available, simply check that the stage gates on and off correctly, and that the level of noise is adequate.

The rise and decay of the ouput signal is relatively fast, so if there is need to prove that these effects are present, remove the two electrolytics from the emitter circuit of TR4. If the gate is now opened there should be a noticable difference in the attack and decay characteristic.

Four wires interconnect the two boards. Make these long enough to allow future access to the boards should it be necessary. If the two boards are fastened one above the other (with the oscillator board on the bottom) using the threaded pillars, the assembly should sit rigidly while the flying leads are soldered. Make these leads long enough to allow the boards to be removed from the case while the unit is operating, to allow for service or adjustment. Connection from the boards to the whistle and noise outlet sockets is by shielded cable.

While we have mounted the complete unit in a metal box, and some readers may elect to do the same, this is not essential. Other readers may prefer to wire the boards directly into their existing model railway electrical system, with leads running directly to the various ancillary devices. For those who wish to use a metal box similar to ours, and have the facilities to make their own, we can supply a dyeline print for $1.00. These will also be distributed to the chassis manufacturers, so that ready made boxes should be available.



Internal view of the finished unit. The two boards are stacked one above the other and the lower one is just visible. At the top of the picture are the remote socket (left), the on / off switch and the test button.

Those who make their own boxes should be particularly careful in positioning the mounting holes for the boards. Any serious error here may locate the terminals on the boards too close to the metal side of the box, with consequent risk of short-circuits.

The train whistle should now be complete, apart from final testing and adjustment. As in the case of the initial tests, an 18V battery is required, conveniently made up from two nine volt batteries as specified in the parts list. Output from the whistle is approximately 500mV PP across 50k ohms, so the amplifier it is to drive need not be particularly sensitive. If the amplifier is very sensitive, it would be advisable to place a 50k preset pot across the whistle output, and adjust the output to a level which does not overload the input stage of the amplifier. The noise output socket should also give approximately 500mV across a 50k ohm load.

Connect the whistle output to the input of the amplifier via a suitable lead. Switch to single horn, and press the test button. The whistle pitch should fall as this button is pressed. The rise and decay effects may not be so noticeable, as they are much faster, but if they are eliminated the difference will be obvious. The whistle should be accompanied by background "steam".

If the whistle to steam ratio is not suitable, the 820k (whistle) or the 270k (noise) resistors connected to TR1 base can be changed. More resistance for less noise or whistle and vice versa. The oscillator pitch can be varied by changing any of the capacitors in the OSC1 phase shift network. These are marked with asterisks. More capacitance lowers the pitch and vice versa. If the pitch or whistle to noise ratio is altered it must be appreciated that OSC2 pitch or output must also be altered.

If C2 is increased, the rate at which OSC1 changes pitch will be decreased. If the 2.2k connecting to C2 is increased, the amount by which it changes pitch will be decreased.

As mentioned earlier, the rise and decay time settings interact to some extent. If both the electrolytic capacitors in the TR4 emitter circuit are increased in value by the same amount, the rise and decay times will increase together, and the ratio between these times will remain relatively constant. Likewise if both capacitors are lowered in value the rise time and the decay times will decrease.