steam train

Many owners of model railways want their 'world of trains' to be as realistic as possible. A means of imitating the sound of a real steam train is, therefore, more than welcome. This article describes a simple method of building an electronic circuit of few components that will produce the required sound. To add even more authenticity, the rhythm of the steam train sound is regulated automatically and is practically proportional to the speed of the train.

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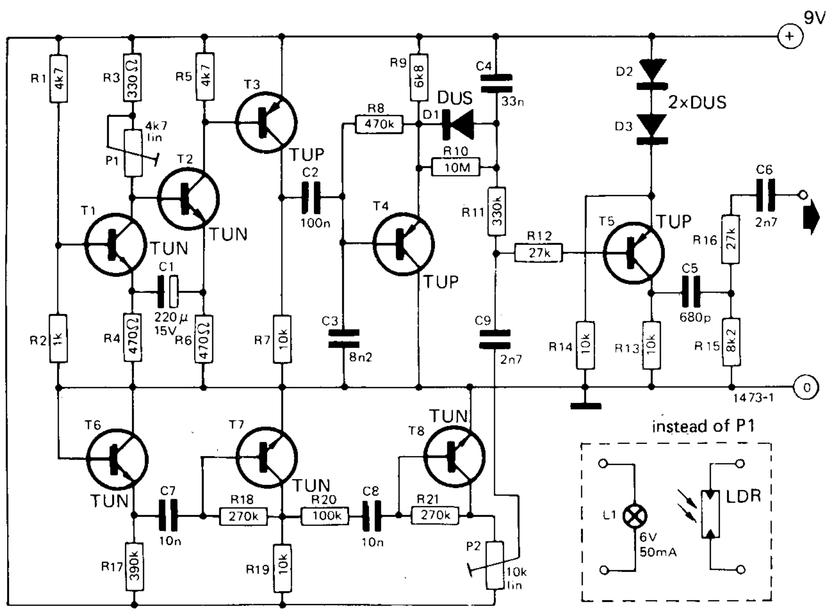

Parts list

Resistors:
R_1 = 4k7
R_2 = 1 k
R_3 = 330 Ω
R_4 = 470 Ω
R_5 = 4k7
R_6 = 470 Ω
R_7 = 10 k
R_8 = 470 k
R_9 = 6k8
R_{10} = 10 M
R_{11} = 330 k
R_{12} = 27 k
R_{13} = 10 k
R_{14} = 10 k
R_{15} = 8k2
R_{16} = 27 k
R_{17} = 390 k
R_{18} = 270 k
R_{19} = 10 k
R_{20} = 100 k
R_{21} = 270 k
P_1 = 4k7 lin.
P_2 = 10 k, trimmer

Capacitors:
C_1 = 220 µ, 15 V
C_2 = 100 n
C_3 = 8n2
C_4 = 33 n
C_5 = 680 p
C_6 = 2n7
C_7 = 10 n
C_8 = 10 n
C_9 = 2n7

Semiconductors:
T_1, T_2, T_6, T_7, T_8 = TUN
T_3, T_4, T_5 = TUP
D1,D2,D3 = DUS

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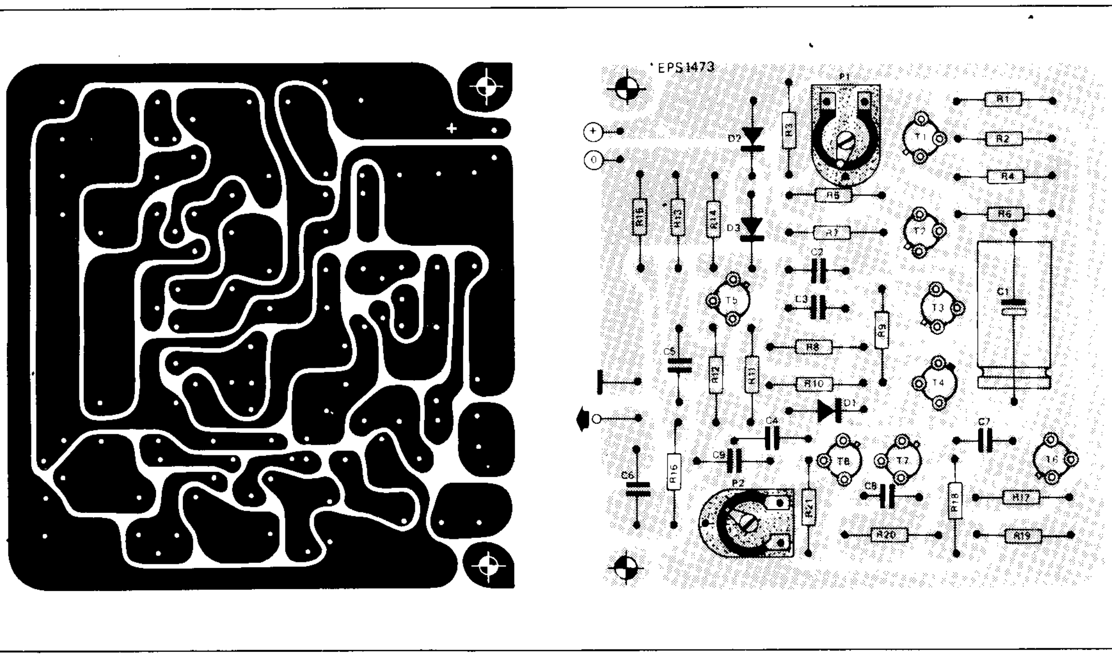
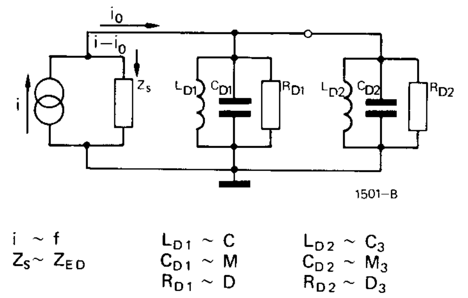


Figure 1. The electroni steam train circuit.

Figure 2. Circuit dia gram for power supply

B



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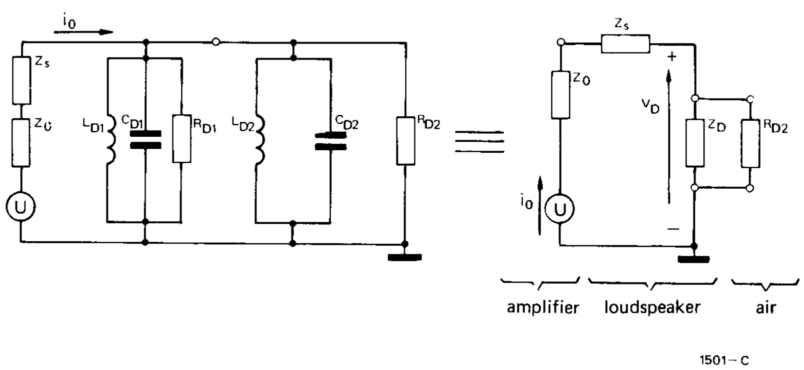
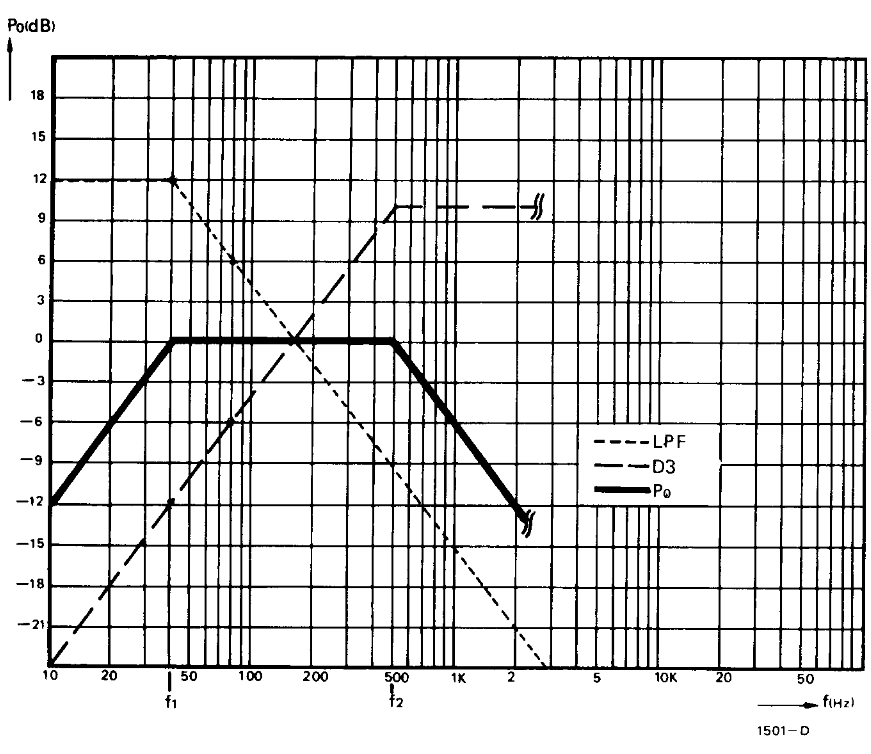


D



is independent of frequency. This dissipation is affected in two ways:

1) The voltage

$$v_D = \frac{Z_D}{Z_D + Z_s + Z_0} \times v$$

is frequency-dependent due to the impedances Z_D, Z_s and Z_0.

2) Furthermore, the radiation resistance (D_3) is not constant: it rises proportionally to the square of the frequency up to a certain frequency (usually between 300 Hz and 1 kHz). Above that frequency it remains constant.

The first problem can be countered by arranging for the power amplifier to have a negative output impedance, such that $Z_0 = -Z_s$. In this case

$$v_D = \frac{Z_D}{Z_D + Z_s - Z_s} \times v = v!$$

The variation in radiation resistance can also be compensated in a simple way: an increase in power proportional to the square of the frequency is equivalent to a rise of 6 dB/oct. This can be compensated by a simple 6 dB/oct low-pass filter in front of the amplifier.

When both techniques are used, the resulting frequency response rises at 6 dB/oct up to the cut-off frequency of the low-pass filter, and from there on remains 'flat' up to the frequency where D_3 becomes constant (somewhere above 300 Hz) (see figure D).

This means an almost ideal bass response, independent of the volume of the cabinet! The volume only influences the efficiency of the system, not the frequency response.

The demands placed on the loudspeaker are that the magnetic system must be 'good' (the flux must remain constant during all movements of the voice-coil); that the cone and its surround must be sufficiently stiff (to operate as a piston); and that it must be able to handle sufficient power.

The cabinet is only of secondary importance, provided it is stiff and airtight – and provided the loudspeaker fits inside!

The circuit

Figure 1 shows the complete circuit diagram. The sound of a real engine is produced by the regular escape of waste steam. This hissing sound is produced electronically by a noise generator. The rapid increase and slow fading of the noise as well as its rhythm, is controlled by an astable multivibrator and a pulse shaper. The output of the noise generator T_6 is amplified by transistors T_7 and T_8. The amount of noise, or noise level, can be adjusted by means of potentiometer P_2. The transistors T_1 and T_2 form the astable multivibrator which produces a square wave.

The rhythm of the steam sound can be varied by means of P_1. By coupling the spindle of this potentiometer to the speed control on the supply transformer for the locomotive, the rhythm of the steam sound is automatically controlled by the speed of the train. Should this arrangement be too difficult, the potentiometer can be replaced by a light-dependant resistor (LDR); practically any type of LDR will do. A suitable lamp is then connected in parallel with the power supply for the train and placed with the LDR in an opaque envelope to ensure that other light sources, such as room lighting, have no effect.

The light intensity now depends on the speed of the train; this controls the value of the LDR and this adjusts the rhythm of the sound to match the speed. To ensure satisfactory control, it may be necessary to try several lamps of different wattage. The capacitors C_2, C_3 and C_4 convert the square wave produced by the astable multivibrator into a certain pulse shape. This pulse drives transistor T_5 quickly into conduction, but cuts it off again at a much slower rate. For a short time, transistor T_5 then feeds the amplified noise signal to the output while amplifying it even more, after which the amplification is reduced slowly. The output signal can be further amplified by means of an external amplifier or radio set.

The supply

The circuit can be fed from a 9 V battery. Figure 2 shows the circuit for a mains supply.

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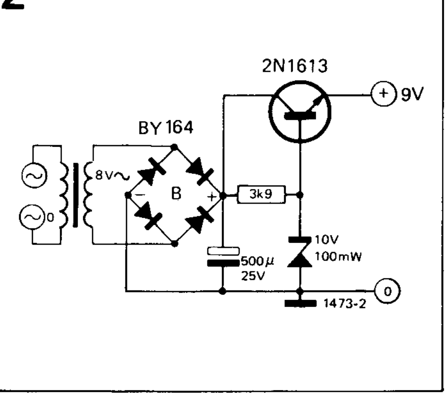

steam whistle

Many model railways still run on 'steam'. For greater realism the steam locomotives are nowadays often fitted with an artificial smoke device. They become even more realistic when an imitation steam whistle is also provided.

In general, electronic imitation of sounds is not so easily done. Analysis of a specific sound by looking at an oscilloscope display, or, better still, with the aid of a spectrum analyser, will make clear just how complicated that sound can be. The spectrum analyser is the clearer, because it displays the various frequency components with their relative amplitudes. But even given sufficient information about the composition of a sound, its electronic imitation is still no pushover. An accurate imitation usually requires a 'truckload' of circuitry.

An acceptable imitation, however, can be achieved with less complication. The problem in this case is nonetheless the same, how to dream up a suitable circuit. Any attempt to seriously calculate component values is futile, particularly when the sound produced is only an approximation to the original. Then there is always the consideration that a spectrum analyser is not normally readily available, never mind a genuine working steam whistle! One is forced to the conclusion that trial and error is the only available approach.

The circuit

We already know two aspects of the circuit. A steam whistle produces a tone, so that the heart of the circuit must be an oscillator. Secondly, a steam whistle is blown – which means hiss. The circuit must therefore also contain a noise generator. This noise generator must modulate the oscillator. Experiment will determine which method of modulation is to be used.

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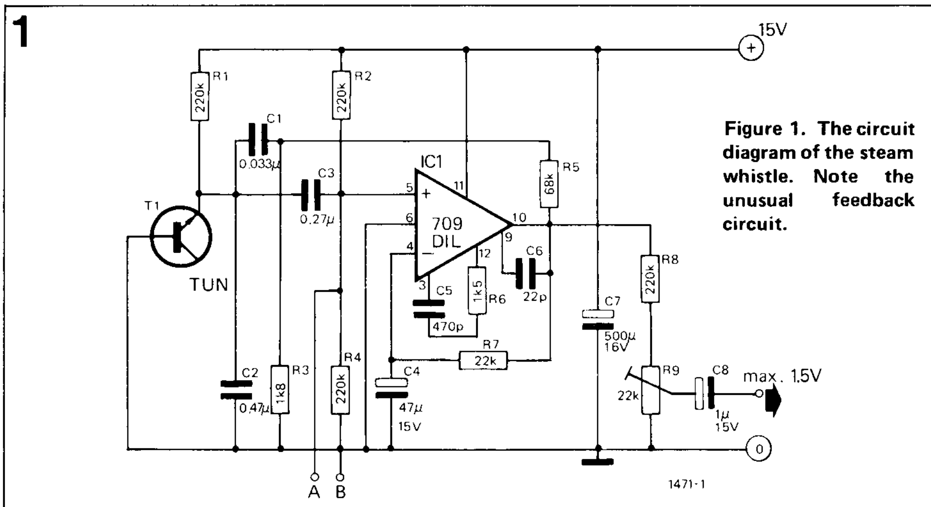


Figure 1. The circuit diagram of the steam whistle. Note the unusual feedback circuit.

Assuming that the brute-force excitation of the original steam whistle gives rise to strong overtones, the oscillator will have to be some kind of multivibrator producing a fairly sharp-edged waveform. The selected square-wave oscillator is a 709 in a positive feedback arrangement (and including the usual compensation).

The noise-generator is a reverse-biassed base-emitter junction of an NPN transistor.

At the supply voltage of 15 V this junction operates in the breakdown region (Zener), producing plenty of noise. Resistor R_1 limits the current to protect T_1. Since the noise is directly injected into the oscillator feedback path, it causes an irregular frequency-modulation of the square-wave. This irregular jittering of the waveform causes the output to sound piercingly shrill – very like a real steam whistle.

The pitch of the note can be varied by

changing the values of the capacitors. The influence of the noise generator is largely determined by R_3. Varying R_3 adjusts the shrillness of the note, but one must bear in mind that it will also affect the pitch to some extent.

Keying possibilities

Due to the fact that almost any disturbance of the circuit has an influence on the pitch, it is not possible to key the whistle by electronically switching the feedback. The best approach turned out to be short-circuiting the points A and B. This disturbs the biassing of the 709, causing the oscillation to stop immediately.

This keying can be done, of course, with a push-button (break contact) – but it is much more interesting to let the locomotive switch the whistle on and off. This can be achieved with a Light Dependant Resistor in two operating modes. The whistle sounds either when light falls upon the LDR or when the LDR is shielded. Figure 2 gives the circuits for both modes. When the whistle is to be started by illumination of the LDR, the circuit with T_2 is sufficient. If the triggering is to be done by shadowing the LDR, T_3 and R_{13} have to be added. The board layout in figure 3 enables either arrangement to be used. In the first case, a jumper lead is required between the base and collector connections for T_3.

The positioning of the LDR is very important. When a shadow is to trigger the whistle, the illumination under 'silent' conditions has to be very strong.

A real train usually gives a warning signal just before entering and leaving a tunnel. An LDR positioned under the track will arrange for the model train to automatically do the same. The same applies to a level-crossing. Here once again an LDR mounted under the track, between the sleepers, will greatly add to the realism of a model railway.

Sometimes a quite weak shadow is enough to start the circuit. Some adjustment of the sensitivity is possible with R_{12}.

When the ambient light level in the 'playroom' is on the low side, it will be necessary to shine extra light on the LDR. The same applies to the circuit that whistles upon illumination. To start the circuit it is neccessary to distinctly illuminate the LDR. ■

2

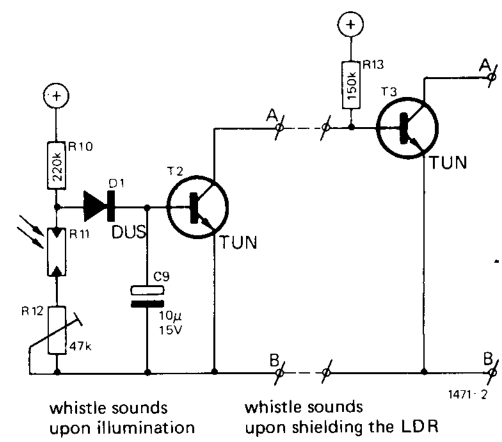
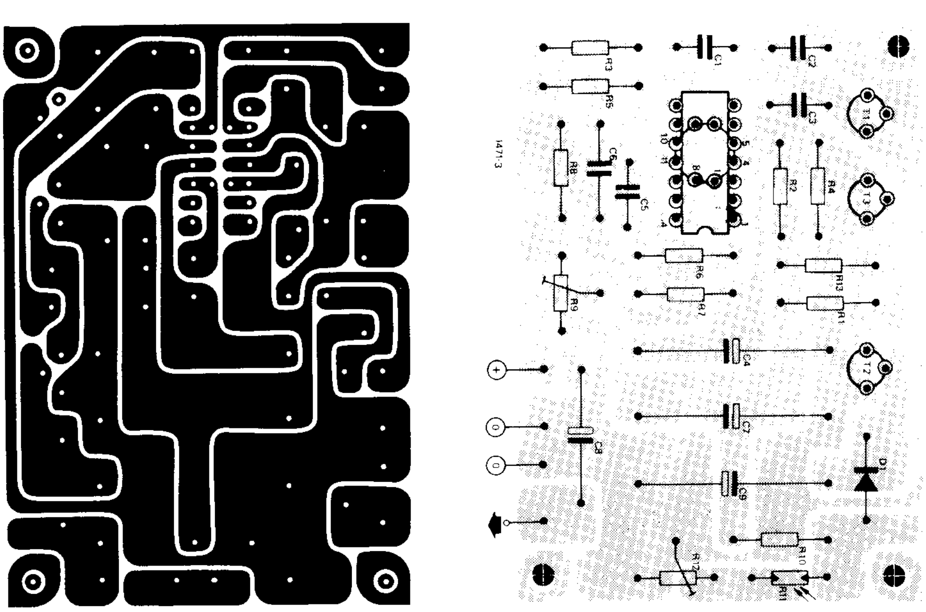


Figure 2. The optical keying switch for the steam whistle, which will respond to either illumination or shading of the LDR.

Figure 3. Printed circuit board and layout for the steam whistle with optical switch.

3



Parts list

Resistors:
R_1, R_2, R_4, R_8, R_{10} = 220 k
R_3 = 1k8
R_5 = 68 k
R_6 = 1k5
R_7 = 22 k
R_9 = 22 k, trimmer
R_{11} = LDR 03
R_{12} = 47 k, trimmer
R_{13} = 150 k

Capacitors:
C_1 = 0.033 µ
C_2 = 0.47 µ
C_3 = 0.27 µ
C_4 = 47 µ/15 V
C_5 = 470 p
C_6 = 22 p
C_7 = 500 µ, 16 V
C_8 = 1 µ, 15 V
C_9 = 10 µ, 15 V

Semiconductors:
T_1 t/m T_3 = TUN
D_1 = DUS
IC_1 = 709