STEAM WHISTLE

for model railroads

Back in the days of steam, Australian locos were renowned for their impressively sonorous whistles. Now you can imitate these impressive sounds with our electronic steam whistle. Use it as part of a model train layout or as sound effects for amateur theatricals. Or build one for the kids for their tricycle.

by GERALD COHN

With a certain amount of modification, the circuit could also be made to imitate the deeper, more resonant sound of a ship's foghorn or even the mournful sound of a factory siren. Why not give it a blast?

Steam whistles work in a particular way which we should discuss before looking at the circuit.

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 tends to fall slightly.

Now consider the effect as the steam valve is closed. The steam in the whistle will take a short time to escape (as the pressure drops). Thus the sound intensity fades over a short period or, in other words, the whistle has a short decay time.

Finally, we have to consider the background hiss of the steam which is used to operate the whistle and be able to simulate the complex tonal structure of the whistle itself.

THE CIRCUIT

The circuit presented here effectively imitates all of the sound features described above, with the exception of the slight drop in frequency during the rise time. It uses two phase-shift oscillators (Q1 and Q2), a white noise source Q3, a gated amplifier Q4, and a power amplifier stage (LM380). Let's find out how it all works.

Each phase-shift oscillator is implemented using a single transistor, together with a few resistors and capacitors in a feedback network. The transistor is used as a common emitter amplifier, and thus produces a 180° phase-shift between its input and output. For oscillation to occur at a particular frequency, however, a further 180° phase-shift must occur, and this is produced by the RC feedback networks connected to Q1 and Q2.

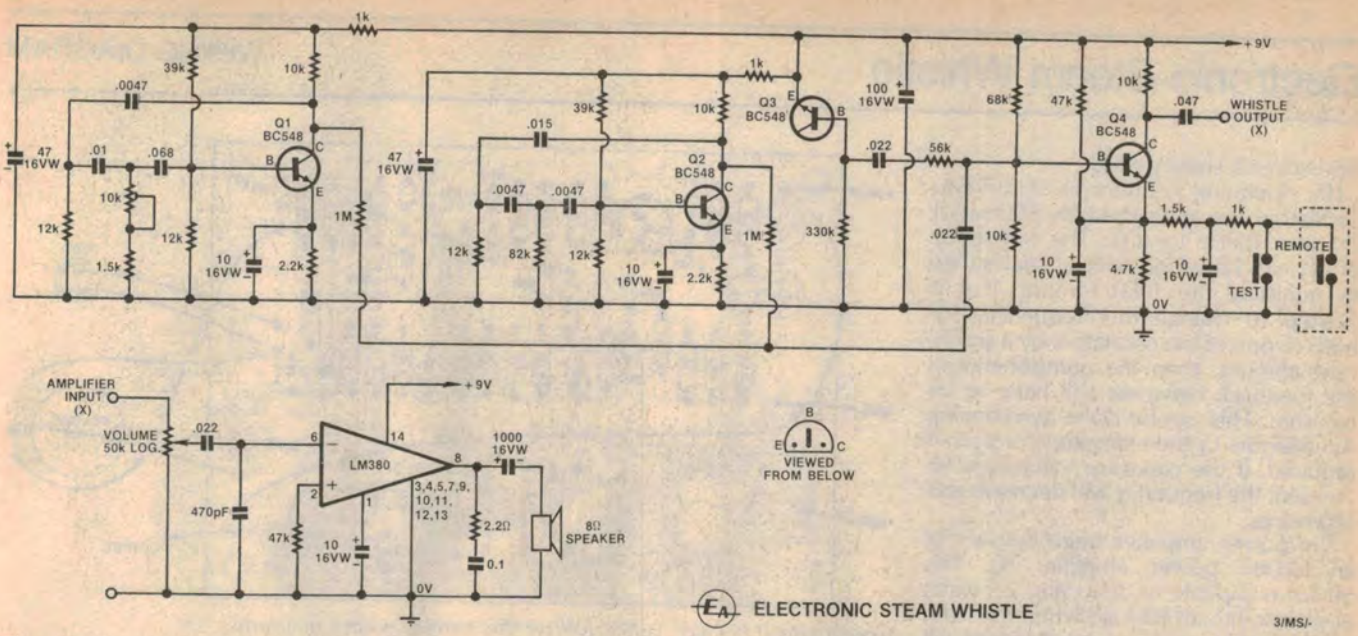
A reactance such as a capacitor can have a phase-shift of between 0 and 90°, but never more than this. It is for this reason that we have used three RC stages in each feedback loop, each stage contributing to the overall 180° phase-shift.

The configurations shown in our circuit are what are known as a phase lead networks. The opposite, a phase-lag network, has the capacitors and the resistors transposed. Usually the values of the resistors are all equal, as are the capacitor values. In our circuit we have not met this general criteria, but instead have used resistors and capacitors with different values.

The effect of varying the component values is to vary the degree of phase-shift from one stage to another. In other words, the phase-shift is not equal for each of the three sections. Using this approach we can obtain frequencies which are normally awkward to obtain using standard component values.

The supplies to each of the two oscillators in the circuit are independently decoupled from the main supply line using 1kΩ resistors and 47μF electrolytic capacitors. This has been done to assure a stable frequency of oscillation despite supply line variations.

The outputs of the two oscillators are



The circuit uses two phase-shift oscillators, a white noise source, a gated amplifier, and an LM380 power amplifier.

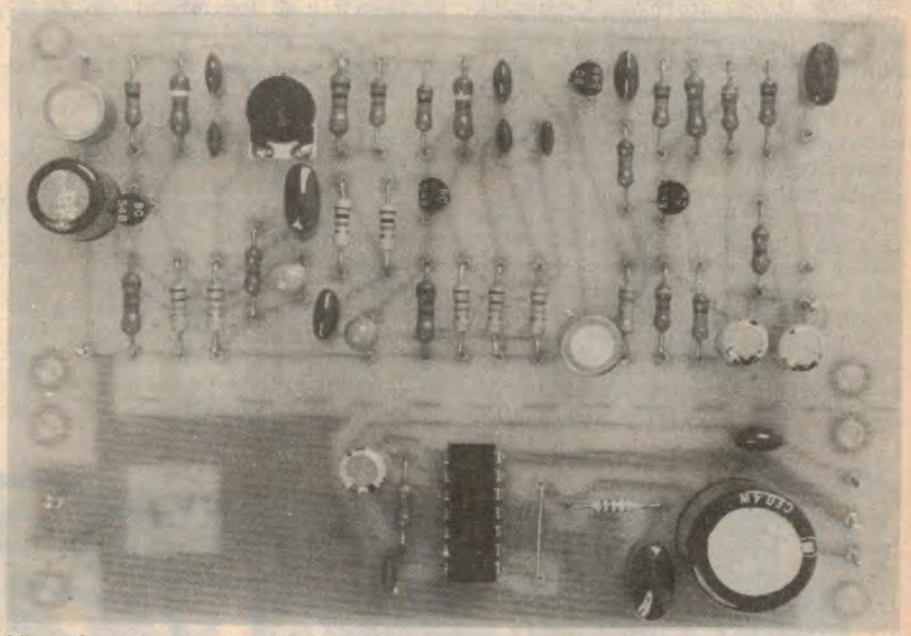
taken from the collectors of their respective transistors and mixed resistively using two 1MΩ resistors. The value of 1MΩ has been used to minimise loading on the oscillators.

The steam sound is implemented using white noise generator Q3. This consists simply of a reverse biased BC548 emitter-base junction, arranged so that avalanche breakdown takes place to produce a substantial amount of noise. We used the transistor here because its emitter-base junction has a lower breakdown voltage than most PN junction diodes.

The output from the noise generator is now mixed with the mixed output of the two oscillators, but this time the mixing is capacitive rather than resistive. This gives us a signal consisting of the outputs of the two oscillators combined with the signal from the noise source. The signal is then fed to the input of gated amplifier Q4 which amplifies the signal, but only does so when enabled. The operation is as follows:

Q4 is normally gated off by a voltage divider network consisting of the 4.7kΩ resistor in the emitter circuit and the 47kΩ resistor to the positive rail. To gate the amplifier on it would be sufficient to shunt the emitter resistor with another of suitable value. However, we can provide the required attack and decay times by adding suitable time constants to control the rate at which the amplifier is gated on or off.

The time constant circuit consists of the 1.5kΩ and 1kΩ resistors and the two 10μF electrolytic capacitors in the emitter circuit of Q4. The total resistance of 2.5kΩ 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 10μF capacitor across the 4.7kΩ emitter resistor also functions as a bypass to maintain a higher level of amplifier gain.



View showing the assembled PCB. The bottom section of the board containing the power amplifier stage can be cut off and used separately.

With the test button pressed, the lower leg of the voltage divider to the emitter of Q4 becomes approximately 1.6kΩ. However, before the stage is biased on, the emitter bypass capacitor must discharge through the emitter resistor and the parallel gating resistors, while the other capacitor must discharge via the 1kΩ resistor.

Thus the output of the gated amplifier rises to a constant level over a short period, as the capacitors discharge. We have now introduced the required rise time for the whistle simulation. The rise time can be made longer by increasing the values of the capacitors or the resistors. The converse is true if the rise time is to be made shorter.

It should be noted, however, that increasing the resistors in the gating network can lead to the stage not being biased on. It is therefore preferable to vary the values of the two capacitors instead of the resistors.

The same capacitors used to provide the rise time are used to give us the decay time. When the test button is released, the emitter bypass capacitor charges via the 47kΩ resistor, while the other capacitor charges via the 1.5kΩ resistor before the amplifier is biased off. Thus the output from this amplifier stage

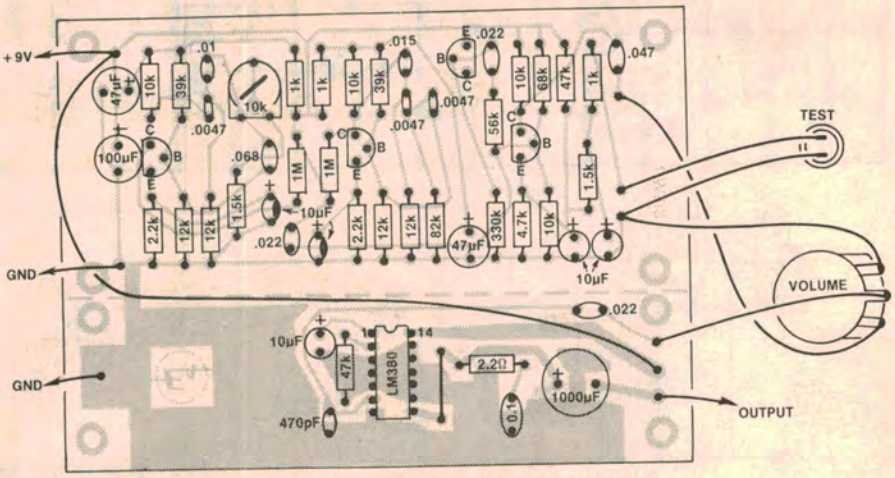
fades over a short period.

The operating frequencies of the two oscillators are approximately 600Hz for Q1 and 400Hz for Q2. The frequency of Q1 can be varied over a small range by adjusting the 10kΩ trimpot. If it is desired to change the frequencies of both or one of the oscillators by a significant amount, then the components in the feedback networks will have to be adjusted. This can be done by changing the resistors or the capacitors, or both if required. If the capacitor values are increased, the frequency will decrease and vice-versa.

The power amplifier stage consists of an LM380 power amplifier IC. This device is capable of delivering 2.5 watts of power into an 8Ω load when run from a 22V supply rail. The output power will be somewhat lower in this particular application because we are using only a 9V rail.

The signal from the gated amplifier is fed to the input of the LM380 via a 50kΩ potentiometer which functions as a volume control. The input is AC-coupled to the signal source via a .022μF capacitor. The 470pF capacitor connected between the input and ground is to ensure amplifier stability.

Current drain of the circuit in the quiescent state is about 7.5mA and rises to 30mA when the amplifier is gated on (this assumes an unclipped output). The maximum drain occurs when the volume control pot is set for full volume (output signal is clipping) and is 77mA. Considering these sort of currents it would be advisable to use a 9V plug pack adaptor where possible. If a 216 type 9V battery is used, then expect a reasonably short life from it. It all depends on how much the whistle is used.



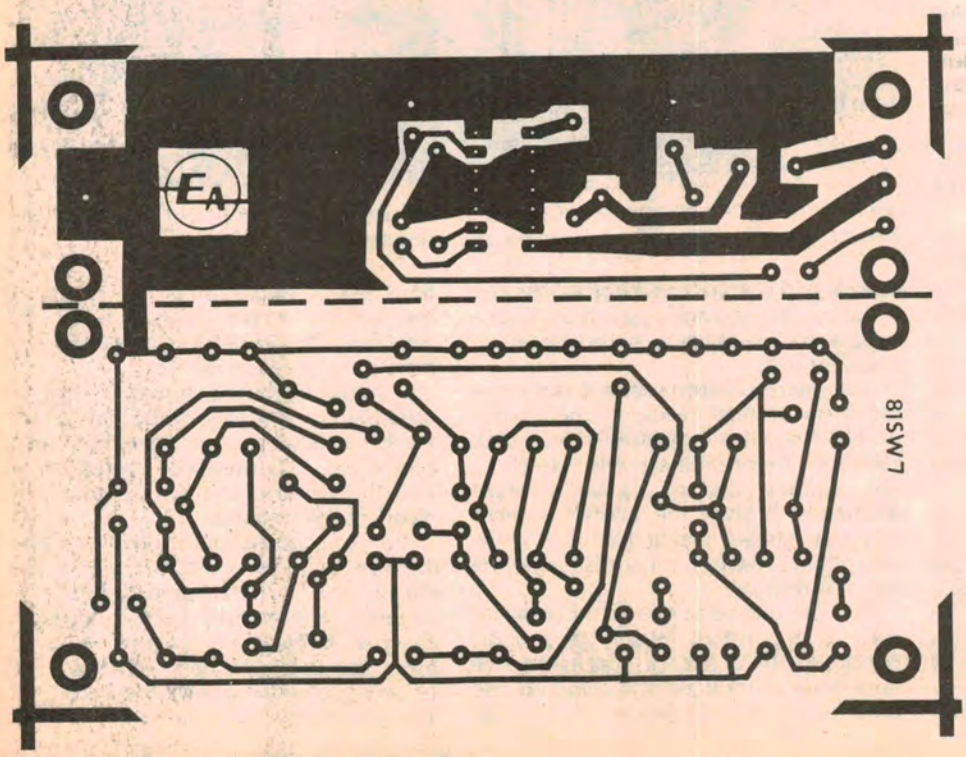
Construction is easy! – just follow this simple wiring diagram.

CONSTRUCTION

We have designed a printed circuit board (PCB) onto which all of the components, with the exception of the volume potentiometer and pushbutton switch, are mounted. The usual precautions should be taken when assembling the board, in particular with regard to polarised components. Care should also be taken when soldering the transistors to the board as excessive heat can destroy them. The same thing applies to the LM380 power amplifier IC. The "remote" pushbutton switch is optional.

The PCB has been designed in such a way that the power amplifier stage can be cut away from the rest of the board and used separately if desired. If this is done, then the power amplifier can also be used for other projects at a later stage. All that need be done to separate the two is to cut along the dotted line on the PCB.

We suggest that PC stakes be used for all external connections to the board. These connections include those to the loudspeaker, the potentiometer, test switch and the battery or power supply. If this approach is adopted, then the pads on the PCB will survive repeated lead connection and removal, should this be necessary.



We estimate that the current cost of parts for this project is approximately

$18.00

This includes sales tax, but not the power supply.

At left is an actual size reproduction of the PC pattern. Ready-made boards are available from the usual retail outlets.

"That siren was a test. We wanted to determine whether you were awake and watching our program." (From "Radio-Electronics".)

PARTS LIST

1 printed circuit board, code 81sw7, 121 × 85mm
1 8Ω loudspeaker
1 50kΩ potentiometer
1 momentary contact pushbutton switch

SEMICONDUCTORS
4 BC548 transistors
1 LM380 power amplifier IC

CAPACITORS
1 1000μF 16VW electrolytic
1 100μF 16VW electrolytic
2 47μF 16VW electrolytic
5 10μF 16VW electrolytic
1 0.1μF metallised polyester (greencap)
1 .068μF greencap
1 .047μF greencap
3 .022μF greencap
1 .015μF greencap
1 .01μF greencap
3 .0047μF greencap
1 470pF ceramic

RESISTORS (all ¼W, 5%)
2 x 1MΩ, 1 x 330kΩ, 1 x 82kΩ, 1 x 68kΩ, 1 x 56kΩ, 2 x 47kΩ, 2 x 39kΩ, 4 x 12kΩ, 4 x 10kΩ, 1 x 4.7kΩ, 2 x 2.2kΩ, 2 x 1.5kΩ, 3 x 1kΩ, 1 x 2.2Ω, 1 x 10kΩ trimpot.

When you have completed the assembly of the board, go back over the construction making sure that all the components have been placed in their proper locations and that all polarity sensitive components (transistors, IC and electrolytic capacitors) are correctly oriented. Check also for dry solder joints and solder bridges between tracks. If everything appears to be OK, you are ready to test the unit.

Apply power to the board (assuming that the potentiometer, loudspeaker and test button have been connected) and then press the test button. You should hear two tones in the loudspeaker, together with a hissing sound. The hissing sound is that produced by the noise generator, while the two tones are produced by the two phase-shift oscillators. The frequency of the first oscillator can be shifted by varying the preset potentiometer on the PCB. You will find that the most pleasing sound occurs when the two oscillators are running at harmonically-related frequencies.

Well, there you have it, a stream whistle that can be used with your model railway layout. It will add just that much more realism to the whole thing. Happy whistling!