Sound Modelling

by Robert A Smith

As I arrived on the platform of Bewdley station several give-away sounds told me that the steam train was about to depart for Bridgnorth. Apart from the carriage doors being slammed and the guard blowing his whistle, the locomotive's safety valve suddenly lifted and created an additional loud hiss of steam. After a minute or so the noise died down and I heard the block bell from the signal box giving the signalman permission to pull off the platform starter and allow the train to enter the block section. Sure enough, the signal dropped (and no doubt bounced a few times – I don't recall). By this time I was standing next to the locomotive – a Great Western 'Hall' – and, with a brief whistle, the driver eased the regulator open and the first powerful blast came from the engine. After a few more blasts of increasing frequency I heard the sudden frantic sound of rapid piston strokes as the wheels slipped. Regaining its grip, the 'Hall' then proceeded to pull the train out with an ever-increasing frequency of blasts from its chimney. The sounds gradually became quieter and more muffled due to the increasing distance of the loco from my vantagepoint on the platform, plus the fact that it no longer needed to work as hard.

Struck by the tremendous 'atmosphere' of the experience, I found myself wondering how much of that scene I could reproduce on my model railway - probably just the visual image of the train pulling out of the station and maybe the signal dropping if I managed to get my signals working. That is my first recollection of realising the limitations of conventional 'visual' model railways. So much of the real-life (prototype) atmosphere is created by 'sounds' of the railway that are not accompanied by anything visual for the modeller to reproduce. Although I did not realise it at the time, this episode had sown a seed that would eventually turn into a prolonged search for a realistic sound 'dimension' to my model railway.

I wonder whether the following words of the late Carl Legg that were published in MRJ Portfolio (MRJ 142, p. 116) struck a similar chord for any other readers?

> "A distant shrill, the rails started to sing, and the gathering thunder of wheels on rails suddenly obliterated the tranquillity of the lineside. It may have been the 'Cornish Riviera Express' or the 'Red Dragon' but a rush of excitement entered my life for a moment as it sped by and disappeared, accompanied by the clatter of the outer home swinging back to danger."

Carl was actually describing "the spectacle of a 'Castle' at the head of fourteen coaches" but I noticed that four out of the five adjectives he used ('shrill', 'sing', 'thunder', 'tranquillity' and 'clatter'), related to the *audible* not the *visual* spectacle. What does this tell us about our search for realism and that elusive 'atmosphere'?

Background

The above account of my experience at Bewdley relates to the late 1970s when, as a teenager, I was fortunate enough to have a family holiday near the Severn Valley Railway. Until then my enthusiasm for model railways had been fed by the apparent realism of photographs in the model press - photographs of models such as those by Rev Peter Denny and Allan Downes. Suddenly I

was aware of a major shortcoming in my search for realism – photographs could capture only the *visual* aspects of a scene and the sounds are equally important in creating 'atmosphere'.

In 1981 I was fortunate enough to have a chance to operate Peter Denny's 'Buckingham' and I then observed another shortcoming in my model railway. The realistic operation of Buckingham - using correct block signalling practice and following a near-prototypical timetable - added a further dimension of which I had been insufficiently aware up to that time. This also explained why I had not been interested in operating my railway and had preferred to build the models that added to the visual realism. I then knew that, for me, an important part of enjoyable layout operation was going to be the accurate re-enactment of prototype operating procedures.

In Search of Realism

When my son was born in 1987 I took the opportunity to start building an 'O' gauge model railway in the garage and garden. (The conversion from 00 gauge was assisted by marrying the daughter of an 'O' gauge enthusiast in 1984!) By designing the layout around a branch-junction station, with two fiddle yards and a garden terminus, I was able to devise a fairly complex timetable requiring four operators. I began running this timetable before any scenery was attempted and it provided a rigorous test of the layout's wiring and operation. After another five years or so I had almost completed the scenic part of the junction station and was enjoying the operating sessions during which quite a number of interested friends were being trained to operate the various stations and fiddle yards.

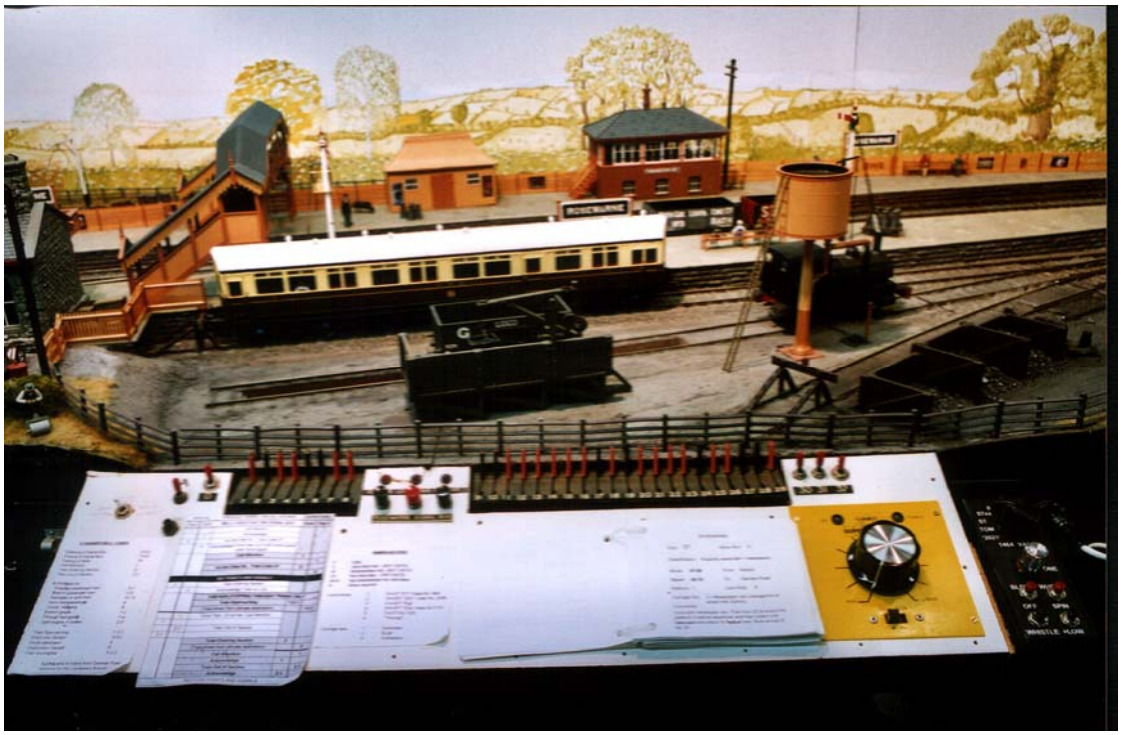

Figure 1. The full signalman's control panel at the junction station with lever frame, three push buttons for block bells, instructions for block signalling and the timetable sheets.

At that stage the bells used to communicate between signal boxes were my only attempt at adding realistic sounds. However, whilst attending a local model railway exhibition I was attracted to an 'O' gauge layout that seemed to have some kind of sound effects. It did not take long to realise that the sound effects were actually synchronised to the movements of the locomotives – I was impressed! This was well beyond what I thought was available commercially and I had been a reader of model railway literature since about 1970. I spent a lot of time at that exhibition layout and discovered that the sound system was a simple 'synthesizer' manufactured by a company called Q-kits and it belonged to Richard Gardner who lived just 4 miles from me! Richard had written two articles about the sound systems from Q-kits [1,2]. It seems that the Q-kits system had been available for many years, and that several systems were available in the United States but were not really suitable for British layouts. Shortly after that I met Michael Walshaw operating an *audible* steam crane at Guildex when he was assisting on Nigel Macmillan's 'Campbeltown & Machrihanish Light Railway' 7mm scale layout. These three gentlemen led the way for me and I am extremely grateful to them for taking the time to attend these exhibitions.

Michael Walshaw also used a Q-kits system on his own 00-gauge layout 'Westport Station' and, as the Q-kits units were still commercially available at that time, I acquired one for my railway. Because I only ran steam locomotives I did not purchase the diesel options and I opted for five speakers positioned under the baseboards, rather than on-board sound. I think I was doubtful about the quality of the sound from small on-board speakers, and convinced that if the sounds were going to add realism then they had to be of high acoustic quality. The voltage from the track is used by the Q-kits system to provide an input related to speed of the locomotive for controlling 'chuff' rate. All other controls were available as knobs and push-buttons on the box of electronics.

It was not long before I had assessed the suitability of the Q-kits system for meeting my requirements. There were some good features – the ability to vary the chuff start-voltage, rate and cut-off (duration of chuff), plus a 'blow-off' (safety valve lifting) button. But there were also several shortcomings:

1. poor whistle quality,
2. lack of any reverberation – the sound was 'dead' as if the listener was in a small carpeted and curtain-lined room.
3. the need for different settings of chuff start-voltage, rate and cut-off for each locomotive,
4. constant chuff volume regardless of the effort being required from the locomotive (it was very unrealistic to *hear* a locomotive working hard when it *looked* as though it was coasting or braking).
5. the continuous background 'hiss' (albeit with a separate volume control).
6. the need to localise the sound source to the vicinity of the locomotive (on a 20-foot long 'O' gauge layout I was obviously going to need a system for 'throwing' the sound to the speakers nearest the locomotive being driven. Q-kits marketed a train detection system for doing this, but I had not chosen this option due to the expense).

I will briefly explore some of the wider sound-modelling issues in the next section. Then, in order to bring the reader up to date with current sound system technology, the following section will summarise the options available commercially before I go on to explain how I overcame the above shortcomings of my sound system.

Modelling sound

There are many different types of sounds on a railway that build up the 'atmosphere' described at the start of this article. Not all of these are best produced by a synthesizer and many can be simple recordings played back at appropriate times. Michael Walshaw has written a very interesting article about his Westport layout [] where he combines many different sound sources including a loop tape playing seagull sounds. As my layout is based near to the Cornish coast I was fortunate to receive from Michael a copy of his seagull sounds tape. I play this through a speaker in the roof of my railway room and it creates a totally different illusion in the minds of the operators – confirmation that the sound 'dimension' is crucial to creating 'atmosphere'.

The block bells obviously make an important audible contribution to the realism of the layout. Other sounds, such as steam locomotive whistles and station sounds (slamming doors, coupling up, shunting etc) are recorded onto simple record-playback modules and triggered by magnet-fitted locomotives passing over reed switches on my layout, or by other push-buttons. It is the combination of all these sound effects that create the realism for which I have been searching.

Current sound system technology

Many different qualities of record-playback modules are available commercially. I was keeping a record of these commercial offerings but they are now too numerous for me to review them all. Generally you get what you pay for in terms of sound quality, length of recording, reliability and consistency. Some of the cheap ones (£5 to £10) designed for *noisy* greetings cards are poor quality, only record about 10 seconds of sound (just enough for a whistle) and their batteries have a limited life – somewhere between 100 and 500 playback cycles. These are available from Greenweld, 1st Class Trains, Express Models, Quasar Electronics etc.

[Image]

Figure 2. A 10-second record/playback module of the type used in greetings cards. Microphone, loudspeaker, batteries, record and playback switches are all included

I have now moved over to a better quality 30-second voice recorder from Quasar Electronics (http://quasarelectronics.com/3131.htm - self-assembly kit at £13 or £20 ready-built). This makes a digital recording and includes a microphone, play and record switches, pads for remote switches for play and record, and built-in amplification for a 4 to 8 ohm speaker. A 12 V dc power supply and a loudspeaker are required.

[Image]

Figure 3. The 30-second record/playback module from Quasar Electronics.

The ultimate sound capability in the future will probably be part of a Digital Command Control (DCC) operation system where the flexibility, automation, use of digital recordings, and synchronisation to actual train movement will out-perform any analogue synthesizer. DCC units are already available with sound capability and various reviews have been published by people using them as designed (in the locomotive) or as a stand-alone under-baseboard unit. I was certainly impressed with the ZTC system demonstrated at Guildex, especially the synchronisation and the ability to program different sounds into each locomotive to accurately reflect the sounds made by that locomotive's class. I gather that other DCC manufacturers have similar sound capabilities but would recommend a survey of the market to find good sound quality. There is also a considerable difference in quality if only on-board speakers are used. Small speakers in locomotives produce a 'tinny' sound due to the absence of low frequencies. I hope that DCC manufacturers are looking at speaker design to try to improve on this. Use of a horn [] or a reflex-chamber (as in most PC-based multimedia speakers) can enhance the low frequencies.

However, many people like me are reluctant at this stage to move to DCC, for various reasons, and an analogue synthesizer is then a way of providing the enhanced realism offered by synchronised sound. The Q-kits system is no longer available but there are other commercial offerings. At this stage I would again suggest listening to the systems at exhibitions as the sound quality and synchronisation aspects are sometimes ineffective. Some manufacturers have sound clips on their web-sites and these are useful but no substitute for an actual demonstration.

With the experience gained by Michael Walshaw and myself we are producing our own sound system for steam and diesel locomotives offering on-board and under-baseboard sound. In the future we hope to make a kit available for people to build their own system based on the design that we have adopted.

Sound System Improvements

In order to address the shortcomings described above, various additions were made to the Q-kits system and other parts were completely modified. In fact very little of the original system remains! The schematic diagram of a typical synthesizing sound system should help to explain the modifications.

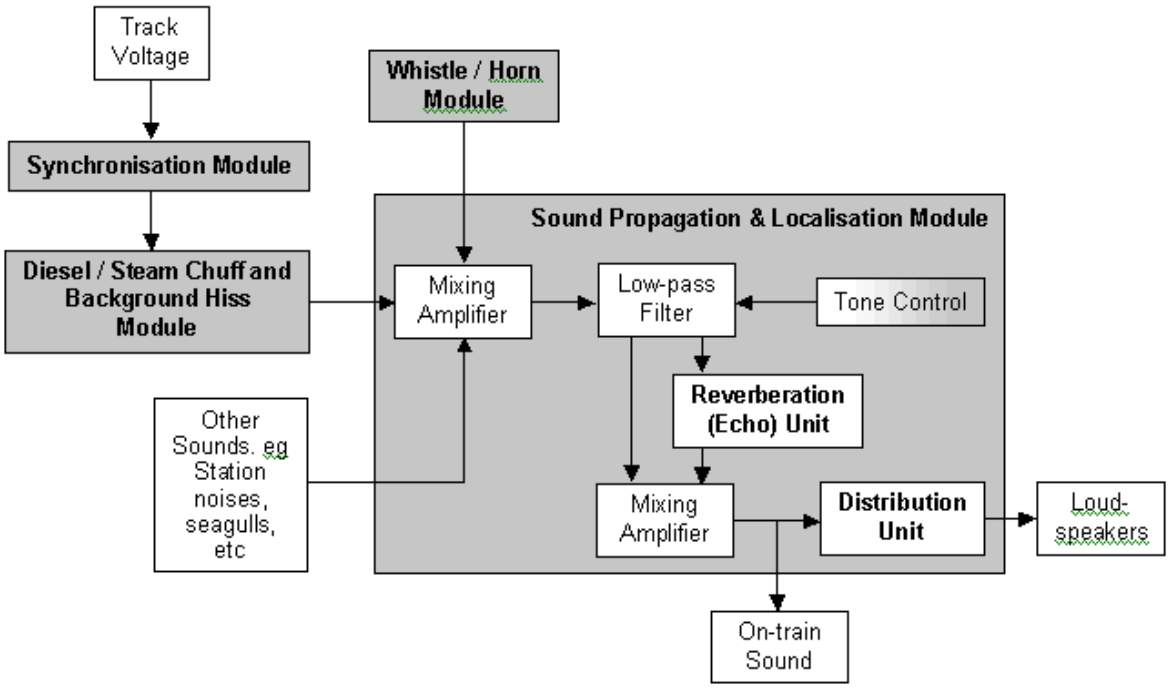

Figure 4. Schematic of the modules required in a sound system showing how they might be linked.

1. *Whistle quality.*

The Q-kits whistle was a single tone and I spent a long time determining the correct pitch of GWR whistles from recordings (885 Hz and 925 Hz, with all other harmonics more than 20 dB quieter) and modifying the circuit of my whistle/horn module (see) to give these two pitches depending on the buttons pressed. (It turned out that Mike Cole of Q-kits had got it quite close!) I then checked that these were in tune with my recording of 'Clun Castle'.

2. *Reverberation – the sound was 'dead' as if the listener was in a small carpeted and curtain-lined room.*

For a sound to be realistic it needs to simulate the effects of travelling the scale distance to the observer and having encountered reflecting obstructions like those in the model. There do not seem to be many options available for simulating these echoes. The music industry uses items called 'echo' units and 'reverberation' units. I assume that an 'echo' unit provides a single echo after a certain delay, whilst a 'reverberation' unit produces a series of gradually-decaying echoes. Hence a 'reverberation' unit is most suitable (see). Such units are now available as electronic packages from music shops, but they seem to still be rather expensive. Fortunately the early 'spring line' reverberation units were still available and my spring line cost me about £20 in 1994 from a music shop that sold electric guitars etc. I believe they are more difficult to find now. [*Optional section:* It is literally a spring suspended in a metal 'tank' so that it is free to vibrate. An acoustic vibration is introduced at one end and travels to the other end where some of it is detected and the rest is reflected back. This process repeats at each end until all of the sound energy has transferred out of the spring.]

Figure 5. A typical spring-line reverberation tank containing two or three springs [*Optional*].

By feeding some of the signal from my sound system into the spring line input, and mixing the output with the original sound, a very convincing effect is produced that sounds to me like I have suddenly put the sound source into a realistic open space.

3. *Different settings of chuff start-voltage, rate and cut-off for each locomotive.*
I grappled with producing an electronic method to solve this problem and eventually resorted to using different pre-set resistors for the 'start', 'cut-off' and 'rate' chuff characteristics of each loco, selected using a single rotary switch (see) in the Synchronisation Module (see). The 'start' setting has a tendency to vary with the load of the train but as my layout is restricted to relatively short trains I have not found this to be a problem and a single setting for each locomotive suffices. The 'rate' control adjusts the chuff rate in relation to the controlling voltage, while the 'cut-off' control changes the length of the chuff - these both change from loco to loco and are pre-set for each of my locos.

Figure 6. Rotary switch that selects the pre-set resistor values for chuff start-voltage, rate and cut-off.

Another solution is the mechanical clutch mechanism developed by Michael Walshaw []. He has decoupled the speed voltage input to the sound system from the actual track voltage and this

allows him to manually start increasing the voltage to the sound system as soon as he sees the loco move. Single-handed operation of the controller is still possible through ingenious mechanical design.

4. *Chuff volume related to the effort being required from the locomotive.*
This issue, that of modifying the volume of the 'chuffs' to reflect the effort of the loco, was the most obvious shortcoming of the Q-kits system and required the most extensive modifications. If nothing is done about this then the loco sounds as if it is still working hard even when it slows down to a stop. It is possible to make these adjustments manually using the volume control but this requires a dedicated sound-system operator and I have found this is not a popular job amongst my operators!

As an automated alternative, I have developed an electronic solution. This determines the rate of acceleration of the locomotive based on the rate of increase of the track voltage. The volume of the chuffs is modified to reflect the rate of acceleration, on the basis that this should be directly related to the work the locomotive is doing. If the track voltage remains constant because the loco is coasting, the volume gradually decays and so I call this the Auto-Coast feature. This is the most significant improvement I have made to my Q-Kits sound system and means it can be used quite realistically without needing anyone to supervise it.

In addition, I added an extra feature that I call 'wheel-slip' where the operator presses a button that applies a sudden extra voltage to the loco-speed input. This extra voltage gradually decays through a capacitor and fortunately the volume seems to decrease as well, as if the driver has backed off the regulator. This of course is not synchronised to the wheels of the loco! Michael Walshaw can achieve the same effect with his mechanically-clutched system, by manipulating the chuff-rate pot with a spare finger or thumb [].

5. *Background 'hiss'.*
I believe this background 'hiss' is supposed to represent the 'blower' of a steam locomotive, which comes on when the locomotive stops working hard to maintain the draught up the chimney, keeping the fire from going out and stopping it from blowing back into the cab. I found the solution by linking it into the auto-coast feature mentioned above. I arranged for the background hiss volume to be suppressed as the chuff volume increases – that is when the acceleration increases. The effect is that as the controller is turned up and the locomotive starts to move, the first chuff is preceeded by a quietening of the blower. The hiss only returns when the locomotive has been coasting or braking for some distance.

6. *Localisation of the sound source to the vicinity of the locomotive.*
Michael Walshaw solved this problem [] by combining under-baseboard speakers with on-board speakers in the locomotives (see). The higher frequencies from the on-board speakers tend to give the required localisation of the sound whilst the larger speakers under the layout fill in the low frequencies to provide greater accuracy of tone.

I have yet to experiment with on-board sound, preferring to find a way of outputting the signal from the nearest under-baseboard speakers to the locomotive using a Distribution Unit (see). Track circuits could be used to throw the sound in this way, but I have not yet developed a

suitable circuit for building them into my system. I believe Q-kits offered these as ‘track circuit modules’, as well as a simpler ‘speaker-activating module’ that just had a series of manually operated switches to fade in the correct speaker. Although I did not invest in the track circuit modules (but wish I had) I thought I could improve the manually operated switch version by winding my own large linear rheostat (wound on a strip of wood with resistance wire). The input sound signal is fed in via the wiper, and various tappings feed the different speakers on my layout (see). By increasing the density of turns at the ends the volume diminishes as the loco enters the tunnel or goes under a bridge.

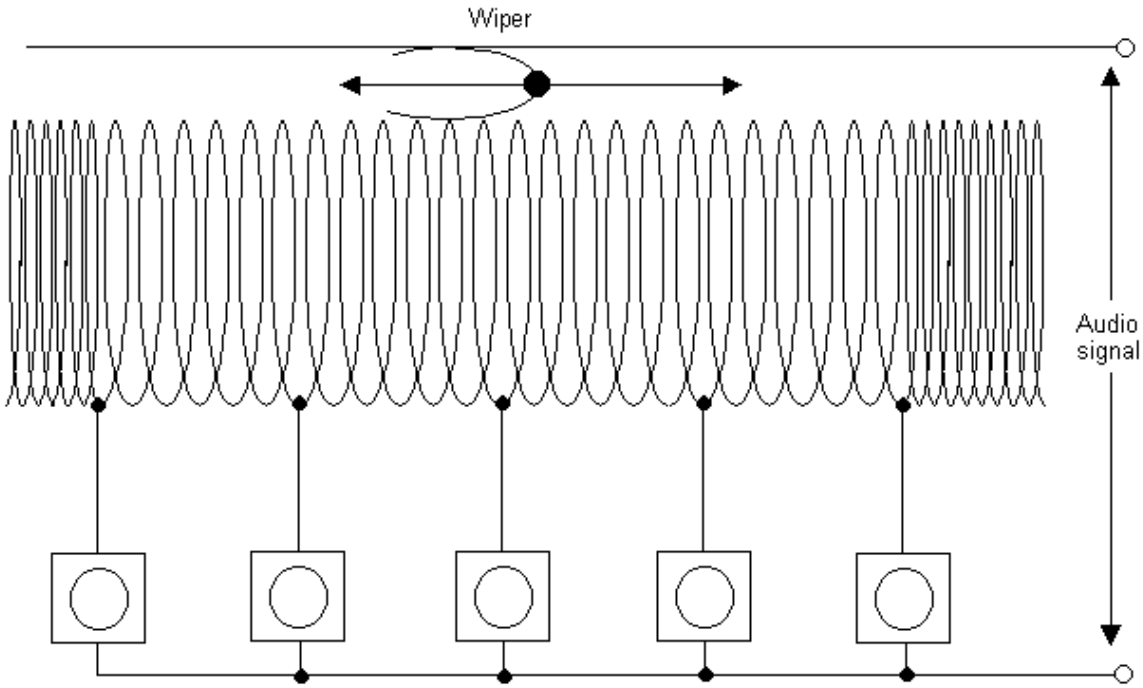

Figure 7. Photograph of the sound distribution system using a linear rheostat, and electrical connections for the linear rheostat that localises the sound based on the position of the wiper.

Michael Walshaw [2] describes an early version of this type of rheostat method, when he had a dedicated Sound Effects Operator to operate a control like this to move the sound source across the layout in synchronisation with the moving loco. Unfortunately his exhibition team hated it, so he devised his on-board speaker system, described in [3], to localise the sound.

The train operator can 'throw' the sound by sliding the wiper along the rheostat to follow the train's movement. An advantage of this method is that all of the speakers are operating but at different relative volumes, and the sound moves gradually along with the train. If you shut your eyes and listen to an express train passing on my sound system the effect is very realistic. The practical problems have not all been solved with this rheostat method and I am struggled to provide a clean movement of the wiper. The solution was to replace the wire-wound rheostat with copper-clad strip-board (Veroboard) with discrete resistors soldered between tracks. This needed quite a lot of small-value (2.7 ohm) resistors - three between each speaker tapping - in order to prevent sudden jumps of the sound along the layout (amazingly noticeable!).

Diesel sound synthesis.
It was not until Michael Walshaw made known to me his requirement for diesel-electric sounds as well as steam that I even started thinking about how to simulate them. Fortunately there were some circuits on the internet that I could use as a starting point. Although the one I chose turned out to use obsolete components I was able to adapt it to modern ones and get it working. To start with it sounded like a demented wasp but when I added the special facility for dividing down the square-wave output it suddenly came to life. By adding in small amounts of sound at fractions of the main frequency a very authentic 'throbbing' sound is produced that can be tuned to sound like engines with different numbers cylinders.

The next challenge is to get the frequency and volum synchronised to the speed and acceleration of the locomotive. My current thinking is that both frequency and volume should increase with power output of the locomotive and reduce to an idle speed and volume when coasting or braking.

The diesel horn circuit from the same internet source has so far failed to work and I suspect I will have to start from scratch.

Conclusions
I can thoroughly recommend the benefits of sound in creating a realistic atmosphere on a model railway, particularly in the larger scales where you feel closer to the locomotives. Whilst DCC is likely to provide the most effective way of producing realistic synchronised sound in the future, there are still options for those of us using analogue control.

As a by-product of developing my own sound simulators for steam and diesel-electric locomotives, I have learned a lot about the important factors and hope I have shared some of

these with you in this article. If the response to this article is favourable then it would be interesting to explore the sound dimension further in future articles.

References

1. Early article by Richard Gardner. *Scale Trains*, Vol 1, March 1982.
2. "Train Sounds in Stereo", by Richard Gardner. *Scale Model Trains*, pp 194-195.
3. "Sounds of Westport", by Michael Walshaw. *Modelling Railways Illustrated*, Vol 3, No 3, pp 134-138, Nov 1995.
4. "Model Sound Effects", by Michael Walshaw. *Your Model Railway*, Vol 2, No 11, pp 803-805, Nov 1985.