

About our DCC columnist

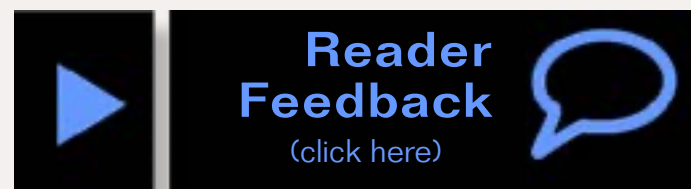


Bruce Petrarca is a well-known expert on all things DCC.

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DCC Impulses: How Do I Get the Sound Out?

Your Guide to Efficient Sound Installations



Getting your money's worth out of your loco ...

When I began doing DCC sound installations over a decade ago, I drew on what I learned in school, in physics class and in the process of designing speakers for my stereo. I didn't have the money to buy a set of speakers, so I designed my own when I was in high school.

The best enclosure for a speaker is an infinitely large board with the speaker

in the middle. There is no "box" to color the sound or reduce the efficiency of the speaker.

If you can't make the board infinite, the next best thing is to make it large enough so that the sound traveling around the edge is out of phase and won't cancel the sound coming off the other side. See the sidebar on page 28.

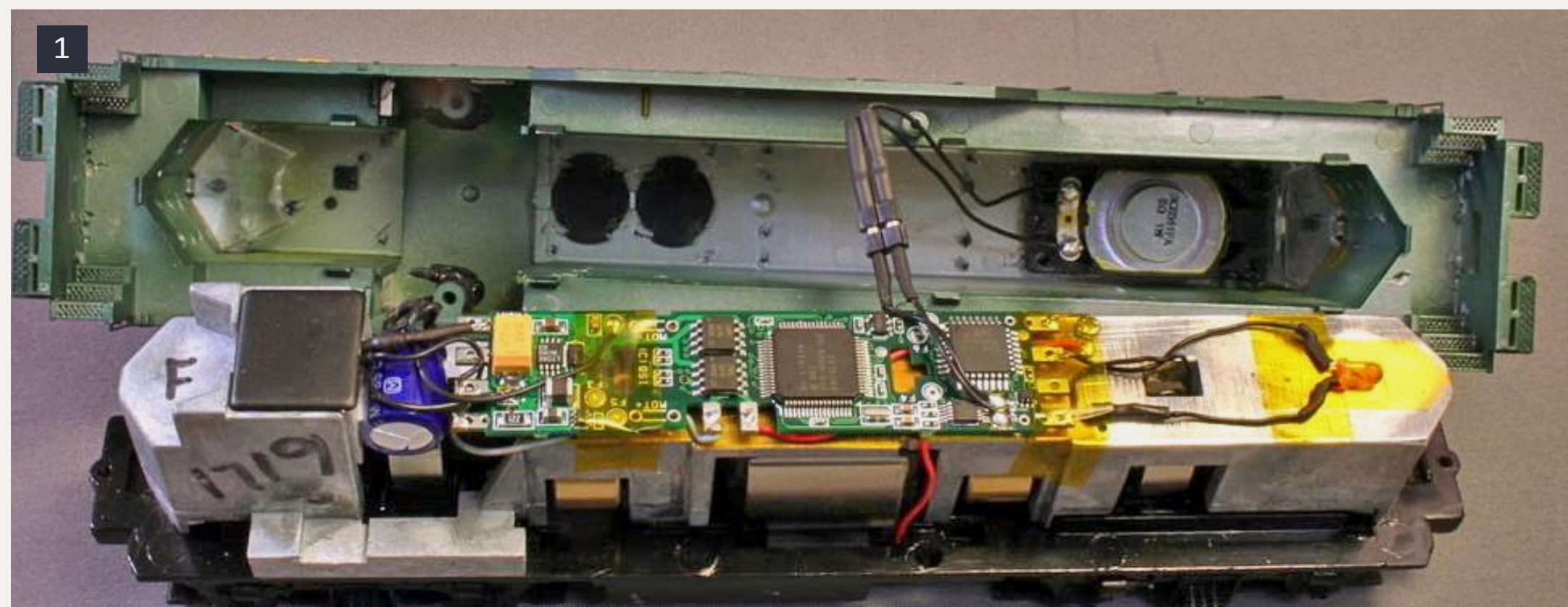
The speakers that will fit in HO locos only require about 8 inches of total path length to keep the sound from canceling.

Knowing this, and not having a large variety of boxes (enclosures) on the market back then, I began installing

speakers in the hoods of diesels as shown in 1.

This loco got the full treatment, including LED lighting. The loco was disassembled and the weight was machined flat down to the top of the motor to provide room for the decoder and the speaker.

In this installation, the sound from the cone of the speaker goes up through the fan grilles. Life-Like very nicely covered the fan grilles near the cab (round black plastic pieces in the roof of the shell), so the sound from the magnet side of the speaker cannot wrap around using that short path.



1: Life-Like Proto 2000 GP9 with the speaker firing out through the fan grille.

The close clearance between the weight and the shell for the back ¾ of the loco forces the sound from the magnet side of the speaker to travel all the way to the front truck opening to get out. By the time it travels back to where the speaker is located, it has traveled at least 12 inches, so it won't cancel the sound coming out through the grills.

I didn't consider this "thinking outside the box" was unique until I started getting requests for installations from all over the world, as far away as India.

I asked a fella from South Carolina, when he booked the installation, why he was sending his locos to me in Arizona. He said that he had a friend who had a loco that I had put sound in. That loco sounded so much better than the rest of his fleet that the friend's wife, sitting downstairs in the

living room, could tell when he was running "my" loco upstairs on the layout.

This led me to realize that I was doing something that few other installers were doing: working outside the box!

I started demonstrating this technique at clinics around Arizona and all the way to several NMRA national conventions. I found folks were amazed.

I did have an attendee at one of the national conventions come up to me and say, "I did sound for years for Bob Seeger. I know that the physical concepts you discuss are correct. I just never thought of applying them to my models before. Thanks."

That's why I am writing this column and why I developed the accompanying video. You might want to stop now and watch the video before you read on (see video below).



This month's SMP, on page 29, will deal with how to connect more than one speaker to a sound decoder.

Some terminology

A cross section of a speaker with the parts labeled is shown in 2. While this details many internals of a speaker, for this column the major items of concern are the magnet, the cone and the frame.

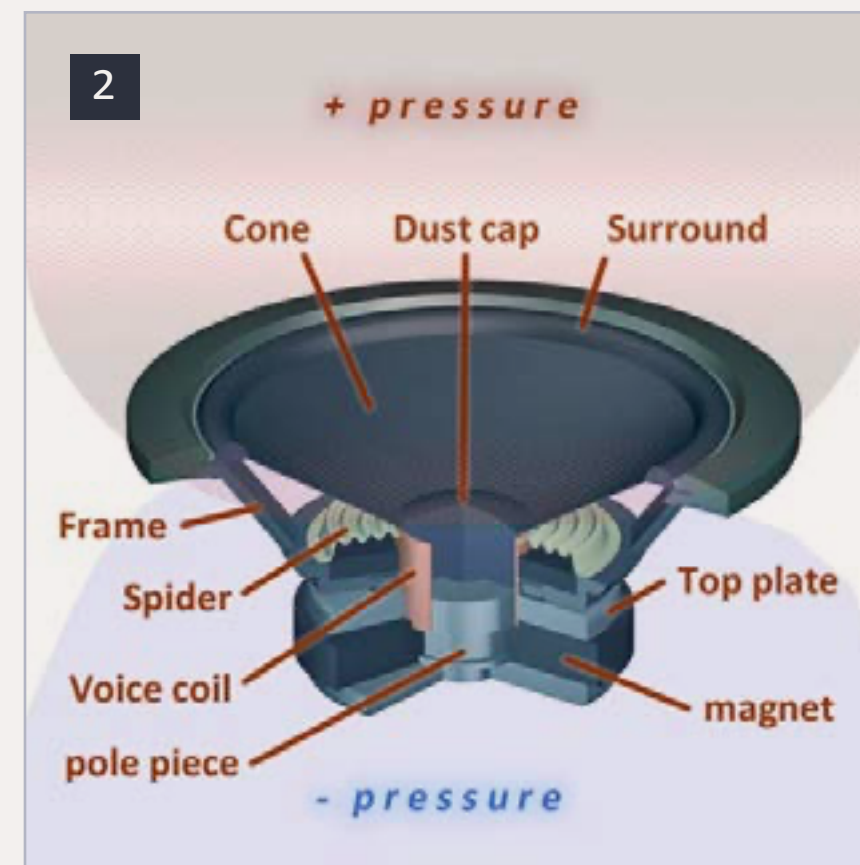
Seeing this cross sectional diagram should help you understand how, when the speaker moves back and forth, it compresses air on the side that the cone is moving toward. For more technical details, see the sidebar on page 28.

In this column, I'm going to refer to a sound wave generated on the cone side of the speaker as positive pressure and that from the magnet side as negative pressure.

Yes, sound comes off both sides of the speaker and, no, it doesn't matter which side of the speaker faces the listener.

Side note on bass

The name for low frequency sound is pronounced like a piece of sports equipment (base) and spelled like a fish (bass). Don't ask me why, I'm just the messenger.



2: Speaker Cross-section with parts labeled – adapted from Wikipedia.

An efficient speaker system

The more efficient you make the acoustic design (the speaker system) the better the final sound will be. The amplifier won't be as taxed and the subtle nuances of the sound will be more evident with an efficient system.

The examples I'll use will be for HO scale, as that is a very popular scale and the smallest scale where truly good sound can be consistently reproduced, in my opinion.

However, these principles will apply in all scales. Acoustic design principles are universal.

Physics are in control

“Nothing beats cubic inches” was the motto of drag racers in the 1960s. That is true in speakers, too. We can tweak a bit, but, in general, the bigger the speaker, the better the sound.

You will get proportionally weaker sound with less bass when you don't have the room for larger speakers.

Reproducing bass, like diesel rumble, requires moving a lot of air, which means a large speaker with a lot of cone movement.

The best laid plans ...

The first step is planning. This can range from fairly trivial to extremely complex. If you fail to plan, then you plan to fail.

How I plan for sound

1) I select a decoder with adequate motor and light power and the correct sound set for my loco. My budget for money and available space are part of the selection criteria.

2) Next, I look for the largest speaker(s) that I can fit into the loco with a minimum of modification to the loco. Here is where I make the decision “box or no box?”

3) Finally, I look at the lighting. Can I use the original lights? Should I replace them with LEDs? Do I want to add lights (like a strobe) or split functions (marker lights or ditch lights on separate functions from the head-light)? Does the decoder I selected in #1 have enough function outputs for the lights I've planned?



3: SoundTraxx Tsunami aftermarket installation in an Atlas SD-35 designed for sound.



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Frequently #2 changes the space budget and may change the decisions in #1 and #3. Yes, this can be a long and repetitive process, not unlike designing a track plan for your layout. Both projects are full of compromises and accommodations.

If you know of a similar loco that has sound that fits your desires, find out how that installation was done. Don't reinvent the wheel!

The speaker alone

The sound coming from a speaker just sitting in the air without an enclosure or baffle will not be very satisfying, as you can hear on the video.

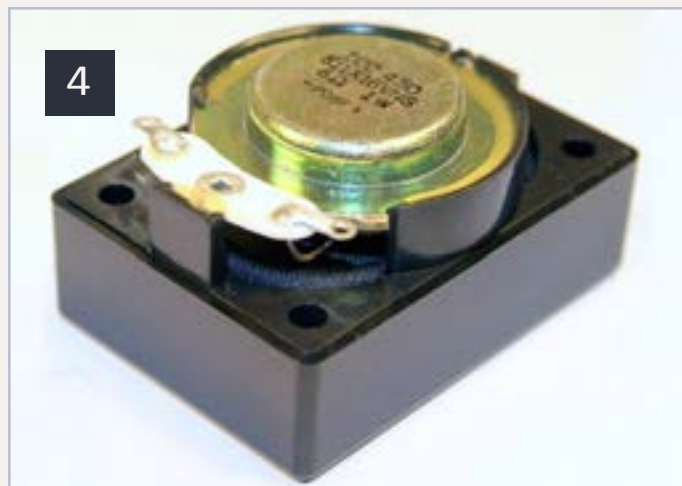
Acoustic path

The sound must get from the speaker to the listeners' ears. Sound travels in waves, like ripples on a pond. There must be a clear path from the speaker to the ear.

Since most of us are above our locos as they are running on the layout, an acoustic path from the speaker out the top of the loco to our ears is functionally the best.

I saw a loco where the owner cut a hole in the top of an oil tender and used 2-56 machine screws to bolt the speaker outside the top of the tender with the magnet inside the tender and the cone facing out. The result wasn't pretty but it had a great path to the listeners' ears.

The opposite case came several years ago from a customer who complained



4: 28 x 40 mm speaker in a machined enclosure – The Box.

about the sound level after he installed a decoder in his Bachmann Consolidation, "just like the example on your web site." I suggested that he send the loco to me for programming. When it arrived, I discovered that it needed more than just having a few CVs adjusted. He hadn't done the installation at all like my web site example. I found the speaker floating freely inside the tender box (no baffle or enclosure) with no provision (holes) for the sound to come out of the tender. Yup, you had to put your ear against the tender shell to hear the loco sounds. I reworked it similarly to the Bachmann Consolidation example on page 24.

The box

Let's start out with some examples of installations that use an enclosure or box.

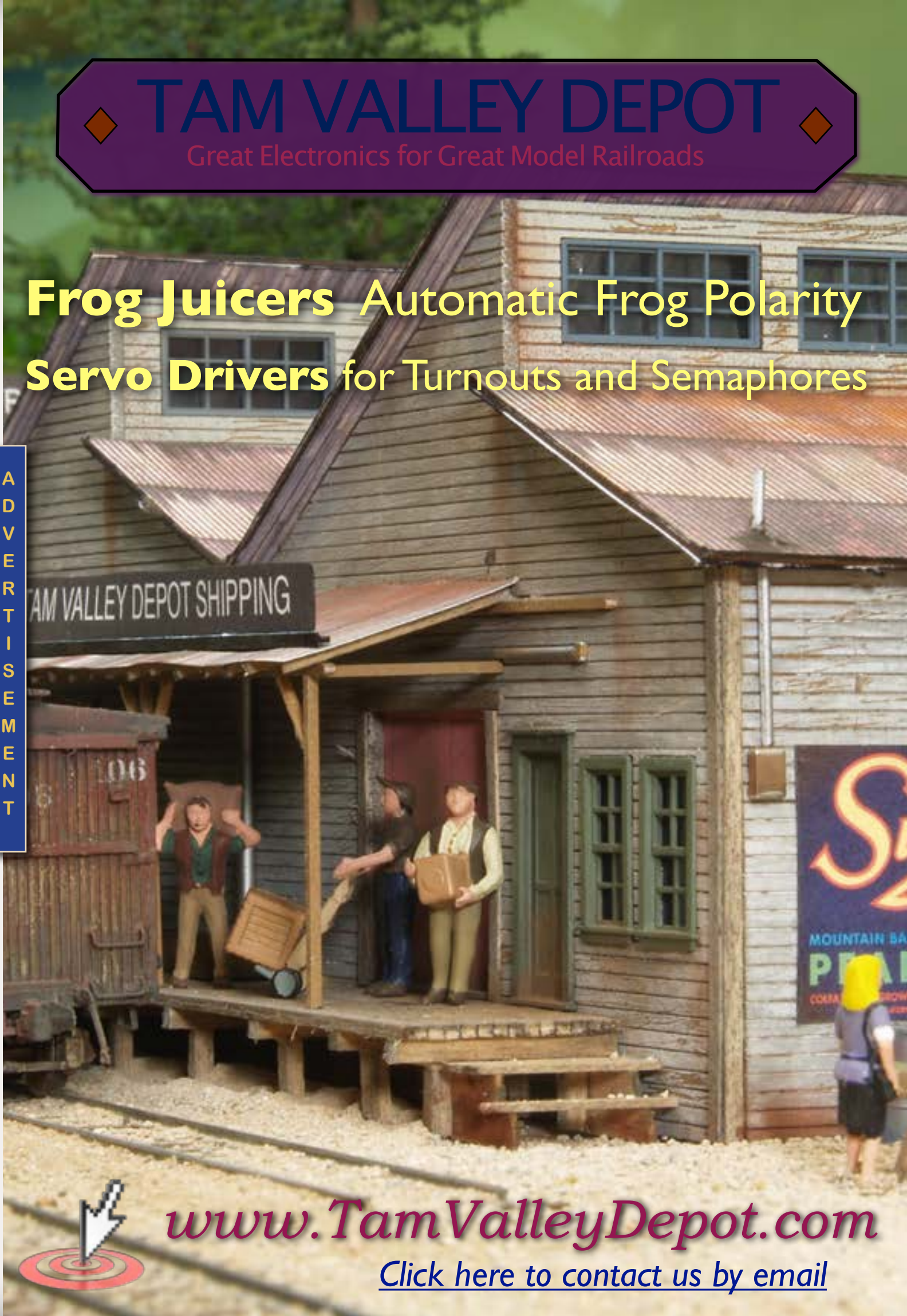
One way to eliminate the cancellation is to use a machined or molded enclosure that snaps over a speaker, as shown in 4. To my ear, the box

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reduces and colors the sound when compared with the speaker in a baffle. Check out the comparison on the video and see if you don't agree.

Most steam loco installations fit this style, as they use the tender shell as a big box. The larger the box, the less it colors the sound. I like to install the speaker under the coal or wood load. That way, the sound can be channeled upward toward the listeners' ears.

Let's look at a typical example:

Bachmann Consolidation

Here is how I did it in a Bachmann Consolidation. Follow along with my discussion with figures 5, 6 and 7.

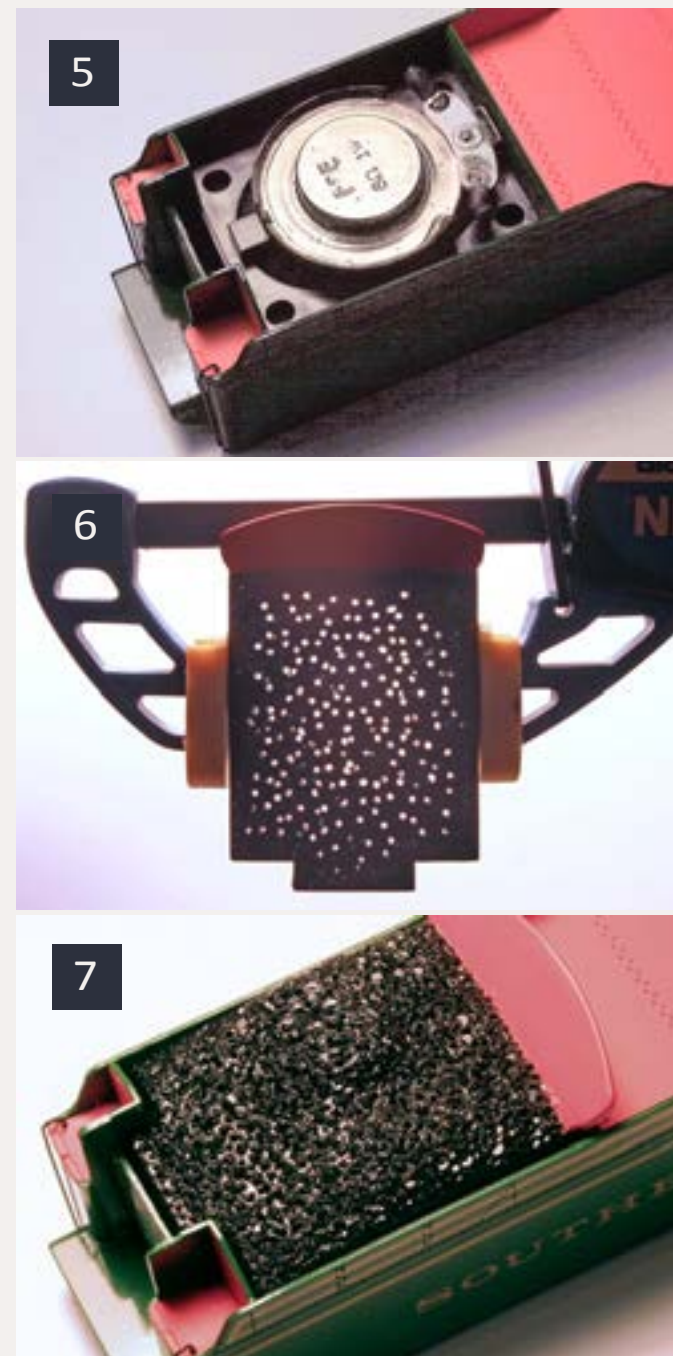
Firstly, I mounted the speaker (a 28 x 40 mm unit) in the area below the coal load. This is shown in 5. A few bits of styrene were necessary to complete the "sound board" acoustically separating the magnet side from the cone side. I mounted the speaker magnet side up to take advantage of the shape of Bachmann's plastic coal load.

The area on the cone side of the speaker is open into the main tender shell. You can't see this detail in 5, as it is below the speaker on the cone side.

Next, I drilled about a hundred holes in the coal load. I used a #70 drill in my motor tool and randomly drilled from the inside out. That is the trick! If you drill from the outside in, the drill will always be in the bottom of the molded coal features and be very

predictable. By drilling inside out, the resulting changes to the molded coal are more random. The coal load (after the drilling) is shown backlit in 6 to reveal the many holes that give the sound a path to the listeners' ears.

The final installation of the coal load into the tender is shown in 7. I used a bit of caulk to hold it in place – easily



5-7: Details of a sound installation in an HO Bachmann Consolidation.

removed if necessary. The holes are almost invisible.

Brass diesels

One of the best ways to get the sound out of brass diesel locos that have lots of open fan grilles is to use a box. I have installed enclosed speakers inside many of these locos, allowing the sound to make its way out the many openings in the brass shell.

This is one place where I find that spending the extra money and purchasing a manufactured enclosure (as shown in 4) or an enclosed speaker is the best use of time and resources.

Thinking outside the box

Okay, but let's get to the basis of this column, thinking outside of the box: building a speaker baffle, not an enclosure.

There are a few things that will allow the sound out without having the positive and negative pressure waves cancel.

Route positive pressure one direction and negative pressure another. For example, positive pressure goes up through the fan grilles and the negative pressure goes down through the loco and out the front truck, as shown in 1.

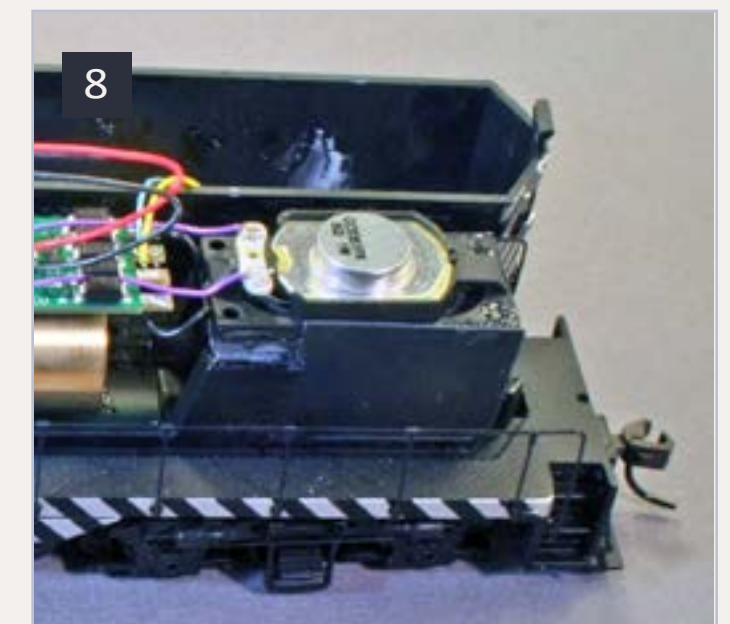
An alternative method is shown in 8. The speaker was cantilevered off the rear of the weight of this Atlas GP-7. Then I cut some plastic pieces to bridge between the speaker and the loco frame on both sides and the rear

of the speaker. This routes the positive pressure out the rear truck and leaves the negative pressure to find its way through the loco to the front truck area before it exits.

To avoid cancellation, the shortest trip that the sound can make between the cone side and the magnet side of the speaker should be at least 8 inches (8).

Direct high frequencies up by routing the sound from one side of the speaker out the top of the loco or tender, if possible.

Seal around the speaker. What does this mean? I use caulk to adhere speakers to the shell or plastic parts that make up the baffle. I use styrene cement to assemble plastic parts into baffles or sound boards to route the pressure waves where I want them. This is a bit like a megaphone in some cases.



8: Atlas GP7 with the speaker over the rear truck.

Where speakers are cantilevered, as seen in 8 and 9, I mount them as close as possible to the shell. I use caulk to adhere them to the frame. I know some folks who have used foam weather strip to enhance the seal between the speaker and the shell. Personally, I find this makes the loco too difficult to open and close. I will, however use plastic to extend the edges of the speaker down to the frame, as shown in 8.

Warning, don't get caulk or any adhesive on the cone or the surround of the speaker. It will reduce or eliminate the sound from the speaker.

Atlas' sound design

The Atlas factory sound design, as shown in 3, on page 22, utilizes the "out of the box" concept. The positive pressure from the speakers is forced

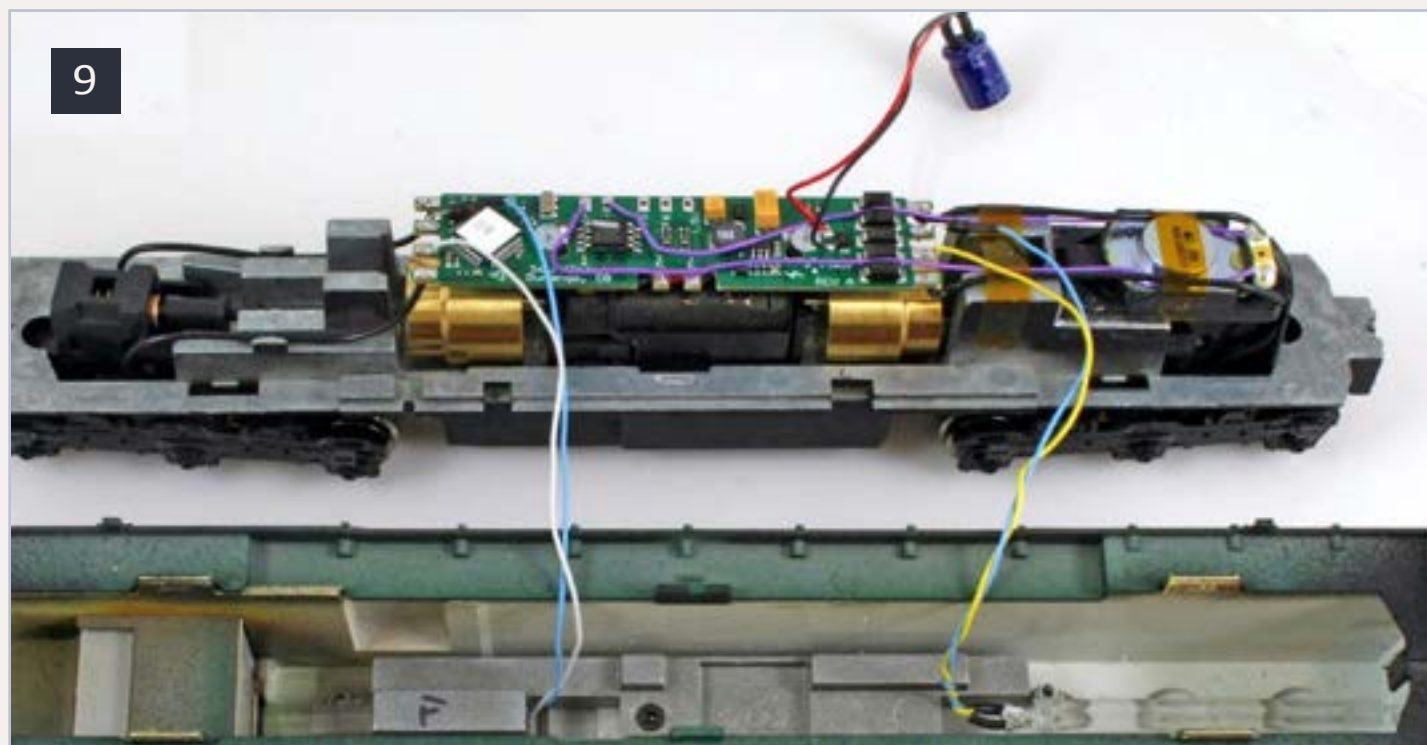
out near the front truck. The negative pressure makes the long trip to the rear truck and out.

Kato SD45

Another example of a way to get the sound out when there are no open fan grills in a diesel shell, still thinking outside the box, is shown in 9.

In this case, I cantilevered a 16 x 35 mm speaker over the rear truck. I positioned it as far back as possible in the shell. The speaker is held down with caulk.

Photo 9 was taken before styrene pieces, as shown in 8, were added to enhance the sound. This enhancement is especially noticeable before the shell is in place.



9: Kato SD-45 with the speaker cantilevered over the rear truck.



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Bose Wave Radio

Just a side point here, the acoustic design of the Bose Wave Radio is arguably one of the most efficient and best bass reproducing systems in the world for its size.

How do they do it? Basically the same way I'm suggesting. They just have the advantage of knowing their speakers very well and being able to design the path to the outside world consistently so that they can actually phase the bass frequencies to add, not just "not cancel".

Speaker selection

Okay, what should you look for in a speaker? I spent years at Litchfield Station searching for the best

speakers I could find in a given size. Every speaker type I sold was tested for performance and consistency. If you have a dealer that is that committed to helping your sound installation projects, then they deserve your financial support.

I have seen folks buy inexpensive noisemakers, masquerading as speakers and then not know why their installation doesn't sound good. \$100 for a decoder, but only \$1.49 for a "speaker" doesn't make sense to me.

Buy quality product from a reputable dealer. Good speakers cost about \$10 or less. Don't scrimp.

Here are important specifications to look for when selecting speakers.

10

DECODER	IMPEDANCE
Digitrax	8 - 32 ohms
LokSound Select	4 - 8 ohms
LokSound V3.5	100 ohms
LokSound V4.0	4 - 8 ohms
SoundTraxx Older	8 ohms
SoundTraxx Tsunami	4 - 16 ohms

10: Impedance table.

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11



11: A 27 mm high-bass speaker.

Size – The speaker(s) must fit your plan. Buy from dealers who tell you all the dimensions before you buy.

Ohms – Your decoder will be looking for a specific load impedance. This

table shows the target load impedances for several different decoders. See the SMP on page 29 for details on how to wire multiple speakers (10).

Watts – The wattage rating for a speaker is the maximum that the speaker is designed to withstand. Yes, folks frequently use speakers with lower wattage ratings than the decoder driving them. Why? Because they want a specific size and can only get that size in the lower rating. They are asking for trouble. Most HO and smaller decoders put out one watt. A few are rated up to two watts. I look for speakers that are rated 1-watt at a minimum.

High-Bass – This is a name applied to a style of speaker that is gaining

popularity amongst model railroaders. They use a very soft surround and a metal cone to get enough cone movement to reproduce an extra octave of bass over similarly sized conventional speakers. An example is shown in 11. For those of you who aren't musicians, an octave is twice as much; say extending the cutoff from 400 Hz to 200 Hz. No, this extra sound is not free; they are physically much deeper than their conventional counterparts. If you have the depth available, they will generally give you the best sound possible.

Frequently, the larger cone excursion necessary to achieve the better bass response also allows the speaker to handle more power (higher wattage

rating). The cone of some high-bass speakers actually comes forward beyond the mounting ring by up to 0.02 inches on peaks. Take care when mounting such speakers to provide for this throw.

My web site has an entire page devoted to speaker selection and wiring: mrdccu.com/curriculum/speakers.htm.

Polarity

Some speakers and decoders have polarity markings (a + sign or color dot). These raise a question with modelers as to what they do with them. With a single speaker installation, don't even think about them.

They don't matter to you. If you are doing a multiple speaker installation, they matter. I cover that in this month's SMP, on page 29.

Design the Install

Just to recap, here are the items to consider, when thinking "out of the box":

Go large in speaker size and use a high-bass style speaker if you can fit it.

Match the speaker impedance to what the decoder wants.

Use the speaker, the locomotive internals and plastic to separate the positive and negative pressure waves and route them out so that the total path from one side of the speaker to the other is 8 or more inches.

Consider the sound path from the speaker to your listeners' ears. Make it as direct as possible with a minimum of obstructions.

Seal the speaker to the mounting with caulk. Why caulk? It is easy to remove if the speaker fails or you decide to change the design later.

Why do I talk mm?

Most of the speakers available for our hobby come from the notebook and tablet computer industry. They are almost exclusively made in China, where technical references are metric. The most accurate way of referring to a speaker size is in

millimeters. Get a set of calipers that measure in millimeters and you've got it covered.

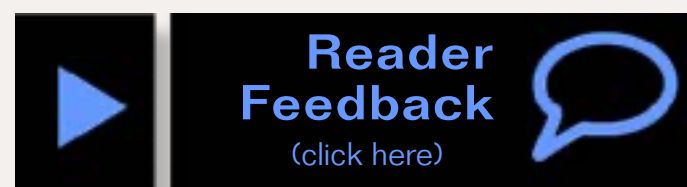
More examples

My web site has lots of examples of various installations, some "out of the box" and some using enclosures in different scales. Go to mrdccu.com/install and navigate from there.

Until next month

Have fun experimenting with these concepts. Watch the video again, perhaps.

Use the Reader Feedback link to vote for this column and to discuss what you find in it. I hope you rate it "awesome"...



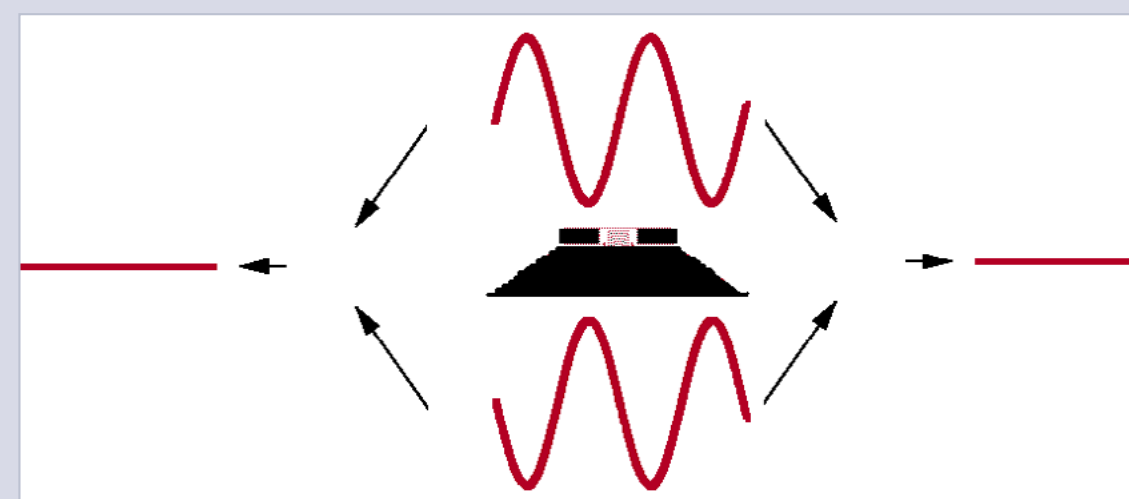
Sound Waves and Phase

Let's look at phase and cancellation in a simplistic way. You don't need to know this to apply the principles of this column, but inquiring minds want to know.

Sound is pressure waves, as noted in the column. They travel with a speed that varies depending upon what medium they are in: air, water, etc.

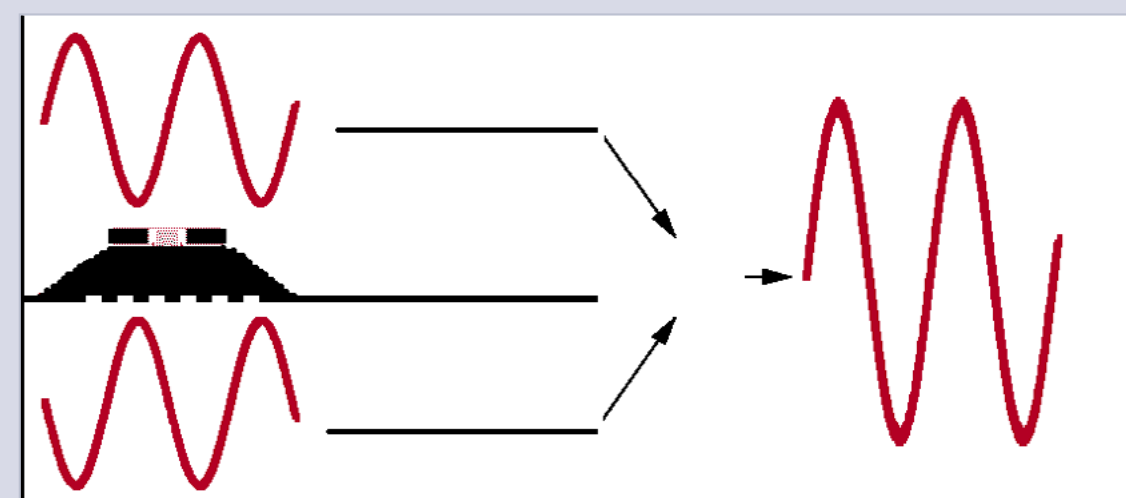
The sound waves coming off opposite sides of a speaker are out of phase with each other (180°). When the cone is moving away from the magnet, it is generating positive pressure in front of it and negative pressure behind it.

If these waves are allowed to interact with each other immediately, they cancel out. This is a speaker in free air with no baffle or enclosure.



However, if either wave is delayed before they are allowed to mix, they won't cancel. This delay occurs when they are forced to travel a distance related to the wavelength of the lowest frequency to be reproduced.

In the Bose Wave Radio discussed in this column, the path length is selected so that very low bass arrives at the front of the radio at the same time. This way, the waves actually add to each other. ■



SMP* from Mr. DCC – How do I connect multiple speakers to my decoder safely?

Once you know the impedance your decoder wants to see, you can design a multiple speaker installation to provide that value. The table on page 26, shows the impedance range for many decoders. Our challenge is to connect multiple speakers and be within that range.

12



12: A series-parallel wiring of four speakers.

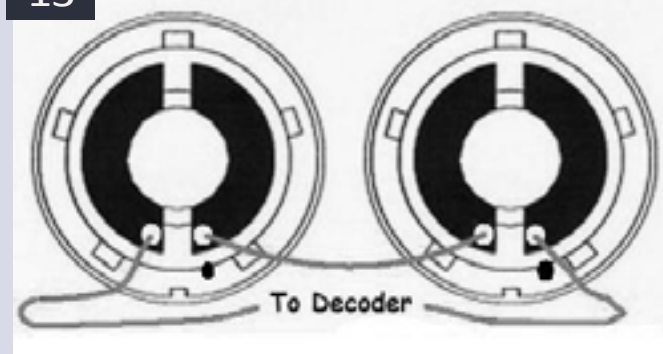
Since it is the most popular range, I'll show you how to create an 8 to 16 ohm load for the decoder when wiring multiple speakers!

Two speakers

To connect two speakers, select identical 4- or 8-ohm speakers. Mount them side by side or across from each other in an "A" frame, if your loco has one. Wire them in series aiding. That means that you connect the positive lead of one speaker to the negative lead of the other and then connect the remaining two terminals to the decoder, through a coupling capacitor, if required for your decoder (usually older decoders). The capacitor can be connected instead of the wire between the two speakers, if that is more convenient.

If your speakers are not marked with a polarity mark, you can physically

13



13: Two identical speakers wired in series aiding – the effective impedance is twice that of each speaker individually.

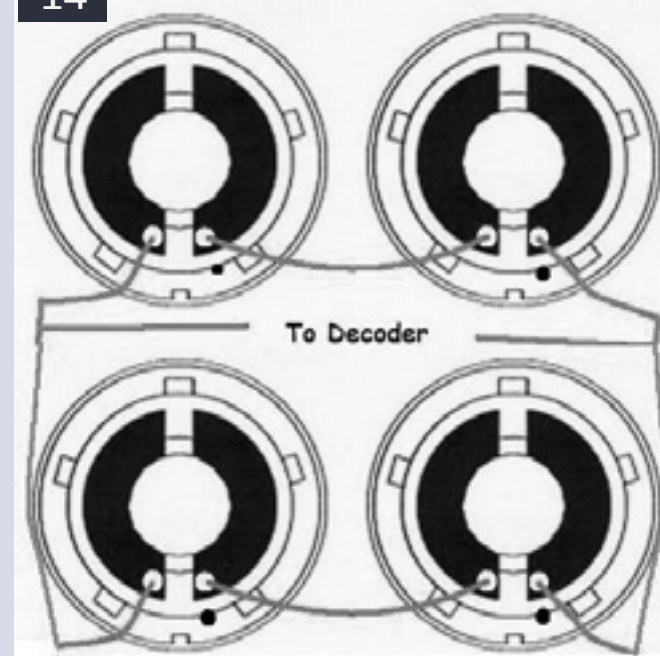
line them up together and mark the terminal on the same side of each of them, as shown in 12.

Two 4-ohm speakers wired in series will give an 8-ohm load when wired this way. Two 8-ohm speakers will provide a 16-ohm load.

Four speakers

Four speakers are easy, too. If you have the room this is a fantastic installation. Mount four identical

14



14: Four identical speakers wired in series-parallel – the effective impedance is exactly that of each speaker individually.

speakers in a line (as in 12) or a 2 x 2 array (as in 13). Wire two sets of 8-ohm speakers in series aiding, as discussed previously. Then you connect the two series sets in parallel. See 14. This provides the desired 8-ohm load.

A four-speaker inline arrangement is shown in 12. It uses 27 mm (1.1 inch) high-bass speakers. They are mounted on a styrene soundboard ready for use in an O-scale F3A under the fan grills.

Three speakers

Three speakers are only practical when you have 4-ohm speakers available. Wire the three 4-ohm speakers in series, just as shown for two speakers above. The resulting impedance is 12 ohms.

Now that you have used the polarity marks to connect the speakers together so that they won't cancel each other, you needn't worry about which wire goes to the terminal marked "speaker +" on the decoder. It doesn't matter.

* SMP comes from the Amtrak world and is short for Standard Maintenance Procedure. ■

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