CHAPTER 9

Paper Speakers

JESS ROWLAND

You will need:

- Papers of various weights and character.
- Conductive metal foils (aluminum or copper).
- Some neodymium magnets.
- Amplifier with speaker terminals.
- Lightweight hookup wire.
- Optional: a craft cutter.

One logical extension of experimenting with transducers is building your own speakers. As the familiar black cone has shown, humble paper turns out to be an excellent mechanism for transferring mechanical motion into sound waves. You can build paper speakers at home with supplies from your local hardware store. Grab yourself a roll of aluminum foil, some construction paper, tape, scissors, a magnet, and a few other odds and ends, and you can be designing your own flexible speakers in no time. The process can be refined as desired, with techniques ranging from home craft to high tech depending on what you want and the availability of materials.

Paper speakers employ the same basic physics behind any electromagnetic audio speaker. As seen in Chapter 3, in an ordinary speaker, coils of wire are formed into a hollow coil that can move freely in and out of a hole in a magnet. The coil is affixed to a cone, usually of paper or plastic. The audio signal passes through an amplifier to the coil; the current of the alternating voltage creates a fluctuating magnetic field in the coil that interacts with the fixed field of the central magnet to push and pull the cone out and in, sending sound vibrations through the air to your ears. In this chapter we'll apply these 3D principles to 2D surfaces. This kind of speaker is not as efficient as a "normal" speaker, so if you're looking for *loud*, try something else. But if you want to disperse sound in different way, paper speakers might work for you. And they present inherently visual artistic possibilities that conventional speakers do not.

MATERIALS: FOIL, MAGNET, AND PAPER

Instead of ordinary wire, we need conductive material that is flat, flexible and thin and can be applied to the surface of paper. Metal foils made of aluminum or copper are

Copyright © 2020. Taylor & Francis Group. All rights reserved.

Collins, N. (2020). Handmade electronic music : The art of hardware hacking. ProQuest Ebook Central http://ebookcentral.proquest.com
Created from princeton on 2021-03-05 18:03:46.

great for this purpose because they can carry an audio signal well with little resistance and can be arranged in a wide variety of patterns and designs.

Commercial-grade aluminum foil is about as thin as common foils get, roughly 0.6 mils (1 mil is 0.001 inches or 0.0254 millimeters). "Heavy-duty" aluminum foil is a bit thicker at 1.3 mil. I would not recommend using any foil greater than 2 mil—for the sake of both your cutting tools and your hands (those edges are sharp, careful!). With copper, I suggest 1 mil foil, the thinnest available.

For maximum sound output, use the strongest magnets you can find. Neodymium rare-earth magnets are much stronger than ceramic or clay magnets and can be found at any well-stocked hardware store (thanks to widespread use in computer drives, neodymium magnets have become remarkably inexpensive).

The choice of material used for the vibrating surface is important, too—some materials work better than others. In a paper speaker, the surface corresponds to the cone of a traditional speaker. Firm, taut membranes are good for propagating vibrations to the air and pushing sound across a room; thick and floppy ones are not so good. You can test a material's suitability by flicking it with your finger and listening for the sound it makes. You'll notice that floppy material won't make much sound while sized papers, vellum, and plastic film will "ping" slightly, like a quiet drum. Poor acoustic materials include tissue paper, fabrics, and wood (unless it's thin veneer).

PREPARING THE MATERIALS

You can build a simple flat flexible inductive circuit with copper or aluminum foil tape available at hardware stores (this tape is commonly applied to windows for intrusion alarms and apparently used as a ground border to keep snails out of gardens). Apply the tape to the paper so that it makes flush contact with a good strong magnet or set of magnets (Figure 9.1). Circular patterns around a circular magnet work well or straight lines around a rectangular one. Direct contact between the path of the tape and the magnet creates the physical vibration that produces sound. Make sure you have an "in" and "out" end of the tape to hook up to your amplifier.

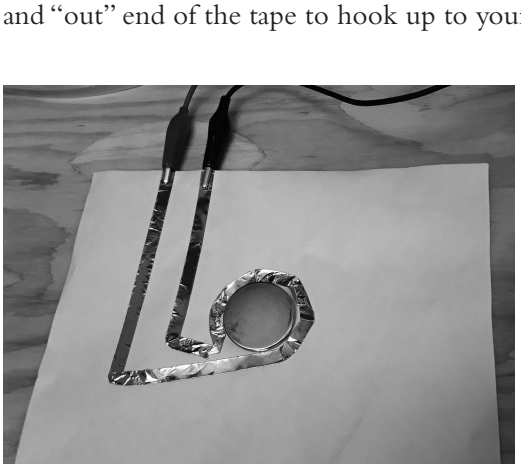

Figure 9.1
Paper speaker using copper foil tape and neodymium magnet on paper.

Copyright © 2020. Taylor & Francis Group. All rights reserved.

Collins, N. (2020). Handmade electronic music : The art of hardware hacking. ProQuest Ebook Central http://ebookcentral.proquest.com
Created from princeton on 2021-03-05 18:03:46.

An alternative method, which takes a little more work but offers a wider range of possibilities, is to apply foil onto a low-tack adhesive backing such as frisket film (which can be found in any art store). Roll the foil over the backing, applying an even, moderate pressure. This ensures that the foil adheres to the surface evenly, without too many wrinkles (it can take a bit of work to perfect your technique). Once you've got your foil on an adhesive backing, you have a conductive foil sheet out of which to create any flat flexible circuitry you could desire. You can cut out your design from this surface with scissors and apply the design to paper directly or cut the design with a craft cutter.

USING A CRAFT CUTTER

Cutting a labyrinth by hand can seem to take forever, and foil tape has limited design possibilities. A more effective way of cutting out patterns uses a craft cutter. The craft cutter works just like a printer, except instead of a printhead, it has a blade that will cut into flat material. Like a printer, you feed it a digital file of a graphic image. You can design and create your own circuit pattern using either the software that comes with the cutter or a graphic design program such as Adobe Illustrator. The cutter cuts out the appropriate pattern from whatever you feed into the machine. They are designed for cutting paper and vinyl, but with a few tweaks you can use them for cutting your speaker foil.

Craft cutters come with instructions for use, and you'll need to make some slight adjustments in order to cut foil. Usually, the cut-depth and strength settings need to be near the very low end of the range so the blade will cut through the foil without cutting through the backing. Make sure you have a fresh, sharp blade in the cutter.

Take your foil sheet adhered to backing and tape it down to the cutting mat (cutting mats come with most cutters, but you can also just use thick paper). Feed your foil face-side up into the cutter so that the cutter can cut your pattern onto the foil (Figure 9.2).

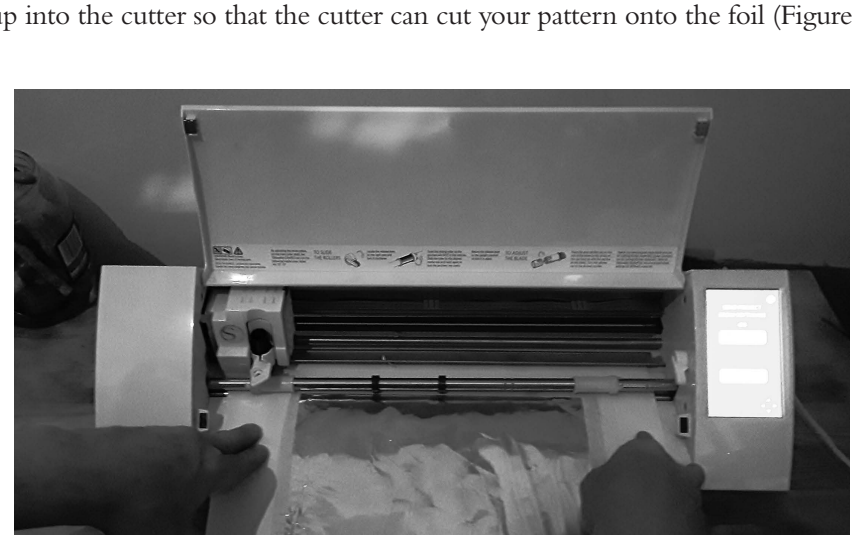

Figure 9.2 Feeding a foil sheet with adhesive backing, placed on a white cutter mat, into the craft cutter.

Copyright © 2020. Taylor & Francis Group. All rights reserved.

Collins, N. (2020). Handmade electronic music : The art of hardware hacking. ProQuest Ebook Central http://ebookcentral.proquest.com
Created from princeton on 2021-03-05 18:03:46.

COMBINING IT ALL TOGETHER

The craft cutter will cut out your design, but you still need to remove the unwanted bits of foil from the adhesive backing—a process known as "weeding." A dull X-Acto blade works well for this. Just be careful not to cut accidentally into bits of the design you want to keep.

Once the weeding is done, you can affix your design to the paper surface. Spray a bit of standard spray adhesive on the paper. Carefully place your pattern, foil-side down, onto the paper. Then peel off the low-tack temporary adhesive backing, and you're left with a permanently adhered circuit. Now you can see why a low-tack backing is essential: it needs to be *less* adhesive than the permanent surface, otherwise peeling it off will be difficult.

Next you need to adhere magnets to your paper sheet. In an ordinary speaker, the magnet and coil are separate, but for paper speakers, everything lies on the same paper surface. Instead of vibrating a cone coupled to the coil, here the electromagnetic field shimmies the paper that holds both the magnet and the circuit foil. The strength of this vibration depends on the strength of the coil's field and the fixed magnets—multiple magnets often make the speaker louder.

The taping technique can yield interesting speaker geometries. Figure 9.3 is an example of a speaker made with a craft cutter: just a single circuit of copper foil weaving around in a circular pattern, with the magnets on the back held in place with a sheet of adhesive film. They fit into the "circles" of the circuit design to maximize edge-to-edge connection with the copper foil.

THE ELECTRICALS

Now it's time to send some audio into your speaker. It's almost impossible to solder to aluminum, so if you are using aluminum tape for the patterns, use clips leads to make the connection from speaker cable to the tape; copper tape can be soldered, but do so

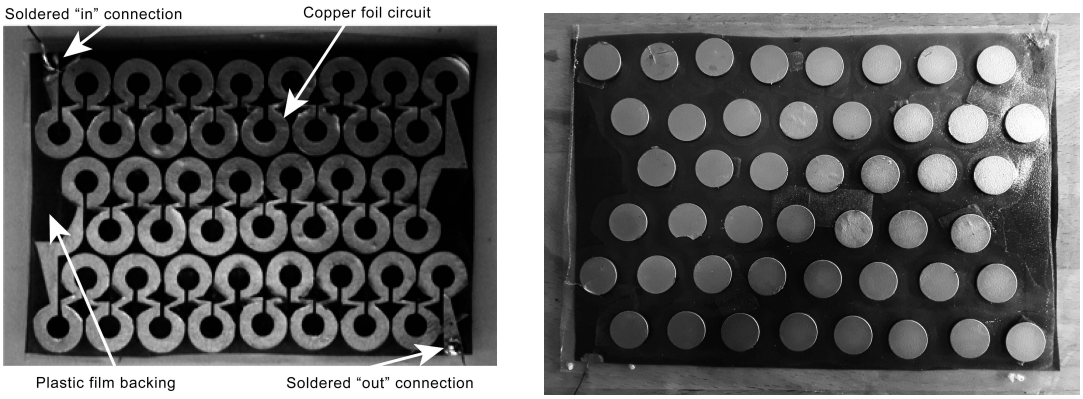

Figure 9.3 Both sides of a copper foil circuit on plastic film, showing magnets in place.

Copyright © 2020. Taylor & Francis Group. All rights reserved.

Collins, N. (2020). Handmade electronic music : The art of hardware hacking. ProQuest Ebook Central http://ebookcentral.proquest.com
Created from princeton on 2021-03-05 18:03:46.

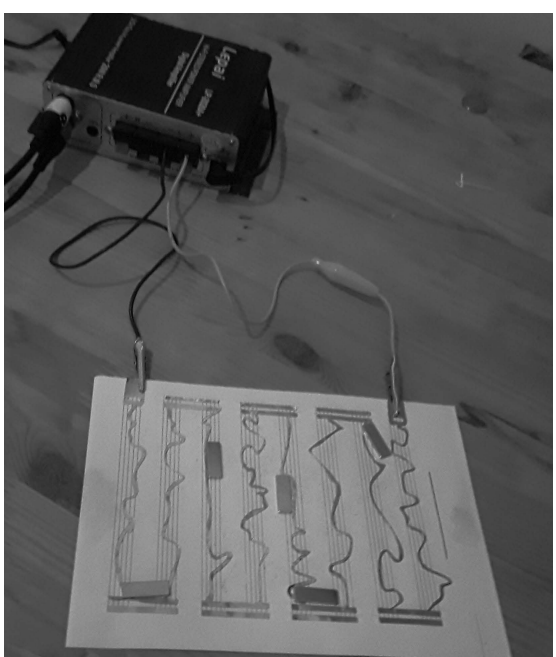

Figure 9.4
Hookup for a paper speaker with rectangular magnet accents.

quickly: you don't want to set the paper on fire. We can use the same amplifier (with speaker terminals) from our transducer experiments in the previous chapter. You hook up your paper speaker just like you would a "normal" speaker in a component stereo system. Connect the in (+) and out (−) of your amplifier to the two ends of your foil pathway (Figure 9.4). Keep in mind that the resistance along the circuit might not match the rating for the amplifier you use. A small circuit of foil can have extremely low resistance (around 1 Ohm or less) while most amplifiers are rated for 4–8 Ohms. Effectively, such a low resistance acts like a "short circuit." With this in mind, try placing a very small resistor (4–8 Ohms) in series with your foil circuit, and you will be able to turn up the amplifier and get a stronger signal without fear of damaging the amp. (The resistor should be rated at 5 watts or greater to prevent it from overheating.)

MAKE IT INTERACTIVE

Instead of gluing a magnet to the paper, you can hold the magnet and move it over the speaker surface to vary the sound. A band around your hand with a magnet adhered makes performance easier. Place it very close—or on—the surface of your paper speaker circuit, turn up the volume, and roam the surface to change the sound.

You'll notice that the vibration is louder in some locations than others. The strongest part of a magnetic field—for both the permanent magnet and the foil—is at its edges: placing the edge of your magnet against the edge of the circuit will yield the strongest response. The strength of the interaction weakens with the distance between the magnet and the tape traces on the paper. Exploring the surface with a magnet can

Copyright © 2020. Taylor & Francis Group. All rights reserved.

Collins, N. (2020). Handmade electronic music : The art of hardware hacking. ProQuest Ebook Central http://ebookcentral.proquest.com
Created from princeton on 2021-03-05 18:03:46.

yield unexpected results from the wily electromagnetic pathways you have created in your circuit.

FOUND MATERIALS FOR YOUR PAPER SPEAKER

Found materials (the soul of hacking) can be great. Other conductive materials can add flair and style to your paper speaker. Chocolate bars are usually wrapped in aluminum foil. Hershey's don't work well for this purpose, since the foil wrapper is extremely thin, but high-end chocolates often come in tinted aluminum already applied to a paper surface (and, as a further bonus, contain tasty ingredients).

There are also colorful conductive aluminum papers and foil origami sheets available at craft or art stores. Shopping can be tricky, though, since only some foil papers are conducive, while most use metallic plastic, which looks promising but will not conduct at all. Bring a multimeter when you go shopping and test the foil with the resistance setting—conductive material should read less than 1 Ohm between any two points on the surface. Caveat emptor, but you might get lucky.

WEARABLE AND WIRELESS

Besides paper, other flat, flexible materials can make for good speakers as well. As mentioned at the start of this chapter, you need a surface that propagates sound well. Most fabrics are, sadly, poor at this. But sew-on patches (not too thick), ties, and scarves can sometimes work. Figure 9.5 shows a speaker tie. If you tried to make a Windsor knot with this, it would mangle the copper foil circuit—walk that line between classy and tacky by wearing a clip-on tie. Of course, for most wearables, you still need to worry about the amplifier and sound input, but it's easy enough to hack a Bluetooth speaker for parts. Figure 9.6 shows a scavenged circuit from a Bluetooth speaker used for the

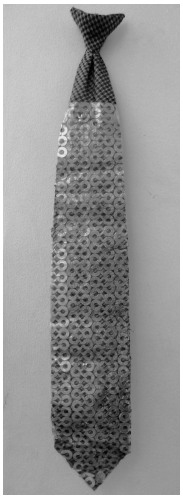

Figure 9.5 Clip-on tie speaker

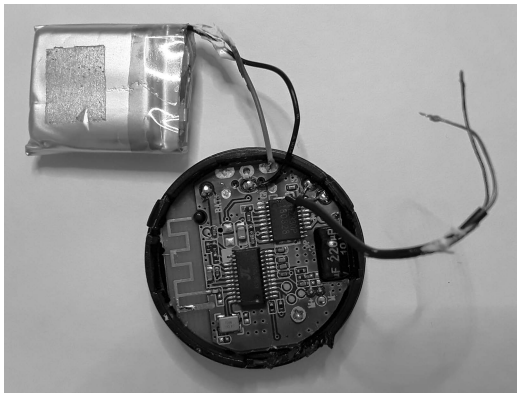

Figure 9.6 A scavenged Bluetooth speaker circuit with battery (top left) and connections to speaker (wires on the right).

Copyright © 2020. Taylor & Francis Group. All rights reserved.

Collins, N. (2020). Handmade electronic music : The art of hardware hacking. ProQuest Ebook Central http://ebookcentral.proquest.com
Created from princeton on 2021-03-05 18:03:46.

back of the tie: break open a Bluetooth speaker (carefully) to extract the goodies from inside. The guts usually include a Bluetooth receiver, an amplifier, a rechargeable battery, and wires to connect to your speaker.

ONWARD!

The best way to discover is to explore and test. It can be difficult to know which circuits, which magnets, and which materials will work the way you want them to, and the only way to find out for sure is to try them out. But messing with paper speakers opens up all kinds of new avenues for discovery, not just for speaker building, but for ways of spatializing sound and integrating audio electronics into visual design. Remember David Tudor's sage advice: a loudspeaker isn't just a hole for sound to come through, it's a musical instrument. Or an art object.

Copyright © 2020. Taylor & Francis Group. All rights reserved.

Collins, N. (2020). Handmade electronic music : The art of hardware hacking. ProQuest Ebook Central http://ebookcentral.proquest.com
Created from princeton on 2021-03-05 18:03:46.