Explore the mysteries of human perception, or just impress your friends with a piece of workbench "magic."

DAVE SWEENEY

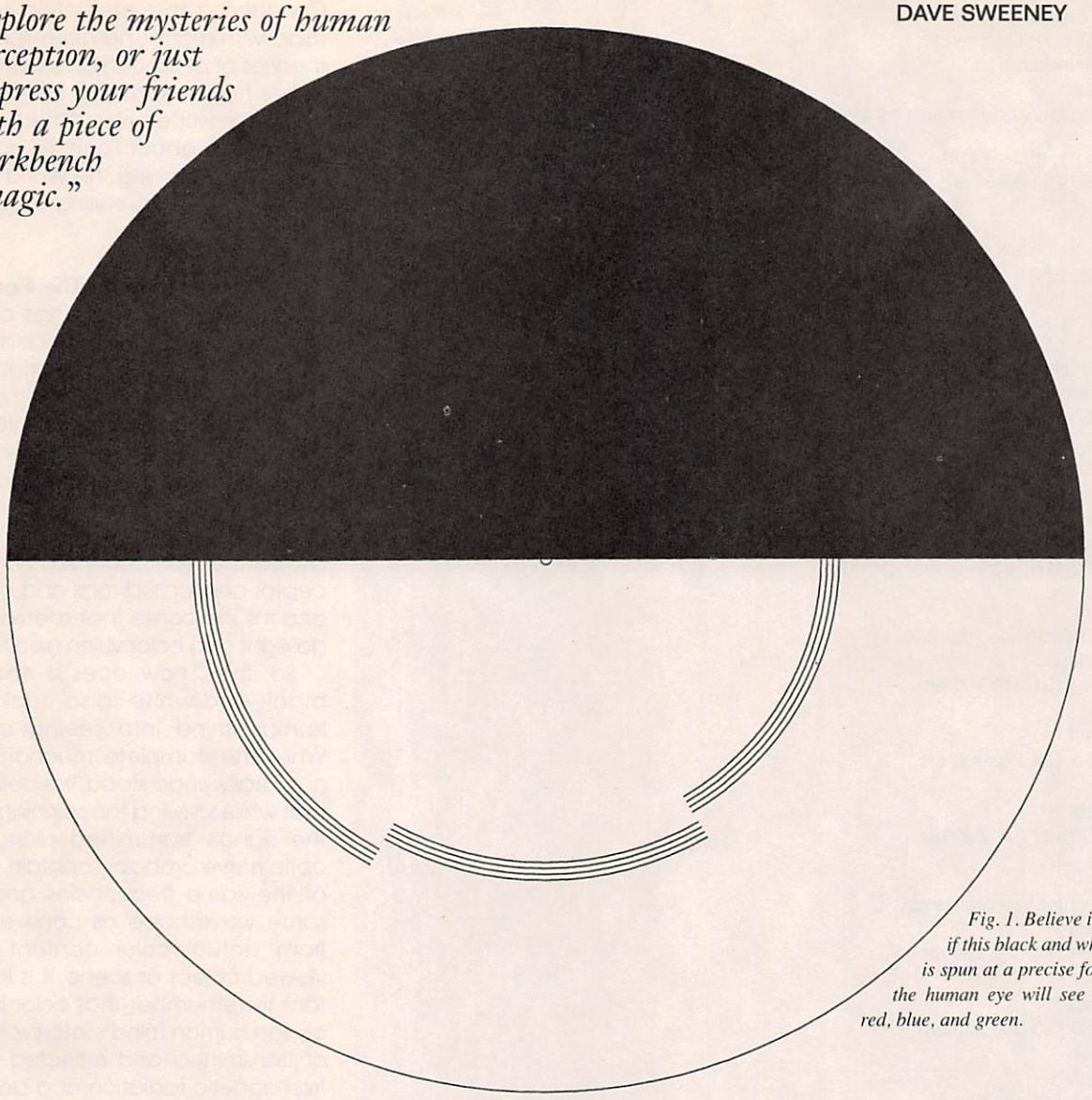

Fig. 1. Believe it or not, if this black and white disc is spun at a precise four rpm, the human eye will see lines of red, blue, and green.

EXPERIENCE THE FECHNER PHENOMENON

How would you like to enjoy some workbench entertainment, and, at the same time, explore the basics of human perception? You can do that by creating a "Fechner" Disc, which, for those unfamiliar with it, is simply a piece of paper containing a circular black and white pattern. When you spin the disc at a precise four rotations-per-second, the black lines in the pattern suddenly take on vivid colors. Spin the disc clockwise and the outer lines become red, the middle lines green, and the inner lines blue. Reverse the spin direction, and the color order reverses.

Setting up the demonstration is easily done using the disc presented in Fig. 1 and parts that are found around most electronics workbenches. First, cut out the disc pattern and mount it on a matching piece of light cardboard to give it strength. Next, attach the disc to the shaft end of an electric motor mounted in a vise. Power the motor through a speed-control circuit and get the disc spinning at just the right speed. When you see the colors, invite friends and family for a demonstration of something important. Ask them to observe the colors.

LISTING 1

```
%IPS-Adobe-1.0
%% Fechner Disc Image
.5 setlinewidth
0 setgray
%All structures define arcs as follows: center x, center y, radius, start angle, end angle

% The perimeter circle
270 350 250 0 360 arc
stroke

% The half black circle
270 350 250 0 180 arc
fill
stroke

%The inside line segments
 newpath
270 350 122 180 240  arc
stroke
newpath
270 350 125 180 240  arc
stroke
newpath
270 350 128 180 240  arc
stroke

%The middle line segments
 newpath
270 350 131 240 300 arc
stroke
newpath
270 350 134 240 300 arc
stroke
newpath
270 350 137 240 300 arc
stroke

%The outer line segments
newpath
270 350 140 300 360 arc
stroke
newpath
270 350 143 300 360 arc
stroke
newpath
270 350 147 300 360 arc
stroke

showpage

%%Trailer
%%Pages: 1
%%EOF
```

Mention the rings and point out the locations of the red, green, and blue. When they agree that they see the colors, have them focus on the disc as you cut power to the motor. The disc stops rotating and, presto, there's no more color. Your astounded subjects will stand in awe and might be heard to mutter: "Cool."

Gustav Fechner. The optical effect discussed above is called the Fechner Phenomenon and is named after Gustav Fechner (1801-1887), who studied mental perception and developed early theories of psychophysics. Born in Gross-Sächen, Prussia, Fechner received a medical degree at the University of Leipzig, then studied physics and mathematics. In 1834, he was appointed Professor of Physics at Leipzig.

Although he was essentially a physicist, he turned to the problems of philosophy and concentrated on the entire spectrum of perception. Considering the interaction of the mind with matter, he developed his theories of psychophysics. Other scientists have examined his theories and have written about them. More information about Fechner can be found by searching the World Wide Web, as well as by visiting your local library.

Color Perception and The Fechner Disc. The basic workings of the human eye are well understood: Focused by the lens with brightness limited by the pupil, light stimulates the retina and sends visual information along the optic nerve. Our brain detects that information, and based upon signals from different elements within the retina, defines a visual image. The retina contains photoreceptor cells called rods and cones, and it's the cones that specialize in daylight and color vision (see Fig. 2).

So, then, how does a spinning black-and-white disc trick the human mind into seeing color? While the complete mechanism is not totally understood, it is believed that while viewing the spinning disc, the signals transmitted along the optic nerve probably contain some of the same frequencies and the same waveshape as cone signals from actual color content in a viewed object or scene. It is important to remember that color is simply the human mind's interpretation of transmitted and reflected electromagnetic radiation of a particular frequency, that color perception can vary among individuals, and that image perception can depend greatly on the surrounding background. Interestingly, a monochrome videotape of a Fechner Disc image played back on a raster scan, monochrome television generates the same color effect as a "live" Fechner-Disc demonstration.

Speed Controller for the DC Motor. While there are many educational and philosophical aspects to the Fechner Disc demonstration, you'll probably want to do it just for the fun factor. The good news is that you'll not have to spend a lot of time or money on building the setup.

The most important component is, of course, the motor. An inexpen-

PARTS LIST FOR THE MOTOR-SPEED CONTROLLER

SEMICONDUCTORS

IC1—555 timer IC, integrated circuit
IC2—LM317T voltage regulator, integrated circuit
Q1—2N3904 NPN transistor

RESISTORS

(All resistors are ¼-watt, 5% units unless otherwise noted.)
R1—4700-ohm
R2—10,000-ohm, potentiometer
R3, R8—270-ohm
R4–R6—1000-ohm
R7—4700-ohm
R9—10-ohm, 5-watt

CAPACITORS

C1—20-µF, 15-WVDC, electrolytic
C2—0.02-µF, 15-WVDC, electrolytic
C3—10-µF, 15-WVDC, electrolytic

ADDITONAL PARTS AND MATERIALS

MOT1—Hobby motor, RadioShack 273-231 or similar
Fechner Disc (see text), perf board, wire, solder, etc.

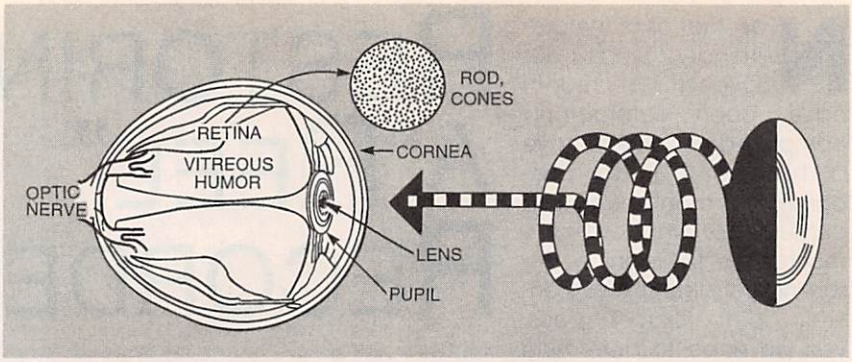

Fig. 2. Light from the spinning Fechner disc enters the eye through the pupil, stimulates the rods and cones of the retina, and is passed by the optic nerve to the brain.

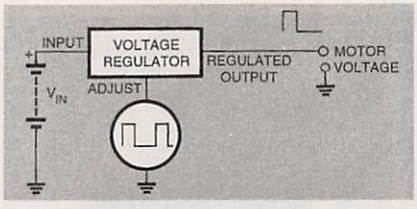

Fig. 3. In its normal configuration, the output of a motor-control circuit like this one is varied using a potentiometer connected to the regulator's ADJUST pin, but in our circuit the potentiometer will be replaced with a pulse generator.

Figure 4 provides the circuit details for our controller. The speed of motor MOT1 varies with the output frequency of IC1, a 555 timer wired as a pulse generator. Pulses applied to the base of Q1 turn it on, which in turn modulate the ADJ pin (pin 3) of the LM317T regulator, IC2. The resulting pulsed power to the hobby motor provides a voltage that is sufficient for starting the motor, yet provides a low average

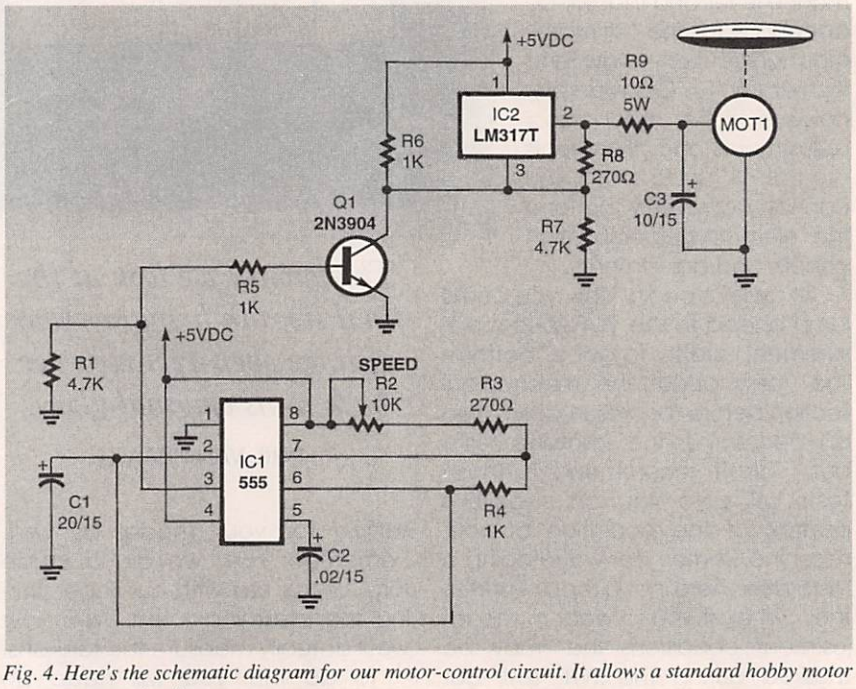

Fig. 4. Here's the schematic diagram for our motor-control circuit. It allows a standard hobby motor to turn at a precise four rpm.

sive hobby motor will work fine as long as it is reversible, but there is another important requirement: It must be capable or turning at a relatively low rate of four to five rotations-per-second. Since that rate is very slow for your typical hobby motor (most spin at thousands of rpm at their rated operating voltage), we need some way to reduce that speed. One approach is to place a potentiometer in series with the motor. Unfortunately, that won't work well with most motors. That's because most motors will simply stop once the applied voltage is significantly below the rated operating voltage. Besides, we need a way to precisely control the rate of revolution, and it is nearly impossible to achieve the needed precision using just a potentiometer.

Instead, we will use the approach shown in Fig. 3, which illustrates a concept for using a variable voltage regulator to run a small motor. In its normal configuration, pin 3 of the voltage regulator connects to a potentiometer, which controls the output voltage. However, for our motor-control circuit the potentiometer is replaced by a pulse generator, which means that the output to the motor takes the form of a train of pulses. The amplitude of the pulses is sufficient to move the rotor; however, the average power varies with pulse frequency and the motor speed varies with the average power. As a result, controlling the pulse frequency provides the motor-speed control we need.

power, and thus low speed. In the circuit shown, resistor R2 and capacitor C1 determine the pulse rate. By adjusting R2, you control the pulse frequency applied to the base of Q1, and thus the running speed of the motor.

There is one drawback to the use

(Continued on page 64)

FOR MORE INFORMATION

This article is based on the new book, *Evolution of the Audio Recorder* by the author, Phil Van Praag. It contains over 500 pages of history, evolution, restoration, photos, and a price guide. It's available at $39.95, postpaid, from EC Designs, P.O. Box 33, Genesee Depot, WI 53127.

everything from re-gluing and pinning cracked or broken cabinet joints, to buffing front panels, to restoring worn lettering, to replacing hardened rubber feet, and on and on. The list is long, but the additional work is necessary if the restoration is to be complete.

I sincerely wish you the best of luck in these pursuits. Whether your machine is a "big iron" Magnecord 1024 (Fig. 8), a professional Nagra III (Fig. 9), or a modest Acme 1500 (Fig. 10), it will be well worth the effort. If you 'stick it out' to a successful completion, I'm sure you'll derive much more satisfaction and enjoyment from the subsequent use of your "like new" tape recorder. Ω

FECHNER PHENOMENON

(continued from page 51)

of pulse-width modulation to control a DC motor: It tends to make them run hotter than they would if you simply cut off the voltage. Inexpensive motors could easily burn out if run continuously for prolonged periods of time. In short, don't run the demonstration for hours on end without some type of heatsink or another cooling arrangement, or, at the very least, shut things down and let the motor's insides cool off at regular, reasonable intervals.

PostScript for the Fechner Disc. As stated earlier, the image shown in Fig. 1 can be photocopied and attached to a motor shaft for a quick look at the Fechner Phenomenon. However, you may want to explore the way that perceived colors vary with arc segment length and with changes to the black field. To do that you could try to re-create the disc in a graphics application, but due to the pattern's need for precisely positioned, perfectly circular arcs as well as the pattern's lack of symmetry, you will benefit greatly if you write PostScript code instead. Then, by editing the PostScript text, you could create a disc of any size as well as explore the relationship between image segments and color effects.

If you read this magazine often, especially Don Lancaster's "Tech Musings" column, you are no doubt aware of PostScript, which is an object-oriented page-description language. The page-description programs are generated by software applications, transferred to a PostScript printer, and interpreted to produce a printed page. The language has an extensive array of commands and operators to facilitate the creation and placement of precise and often complex figures and graphics. Compared to PostScript's capability, our Fechner Disc is quite simple. To get you started, Listing 1 contains the PostScript code that generated the Fechner Disc in Fig. 1. Note that the image comprises a set of arc segments. An outer circle is defined as an arc segment from 0 to 360 degrees. The half black segment is defined as an arc from 0 to 180 degrees; the "fill" statement defines it as a black area.

All of the arcs have the same center coordinates, (270, 350) and various start and end angles. The remarks in the listing identify the function of each of the code statements, and show the parameter values for the image generation. To produce the image, you need to store the PostScript code as a text file and send it to a PostScript printer under an operating system command that tells the printer to process the image, not print the text. Under DOS, for example, use the COPY command with the PostScript text file as the file to copied and the PostScript printer as the destination. Ω

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