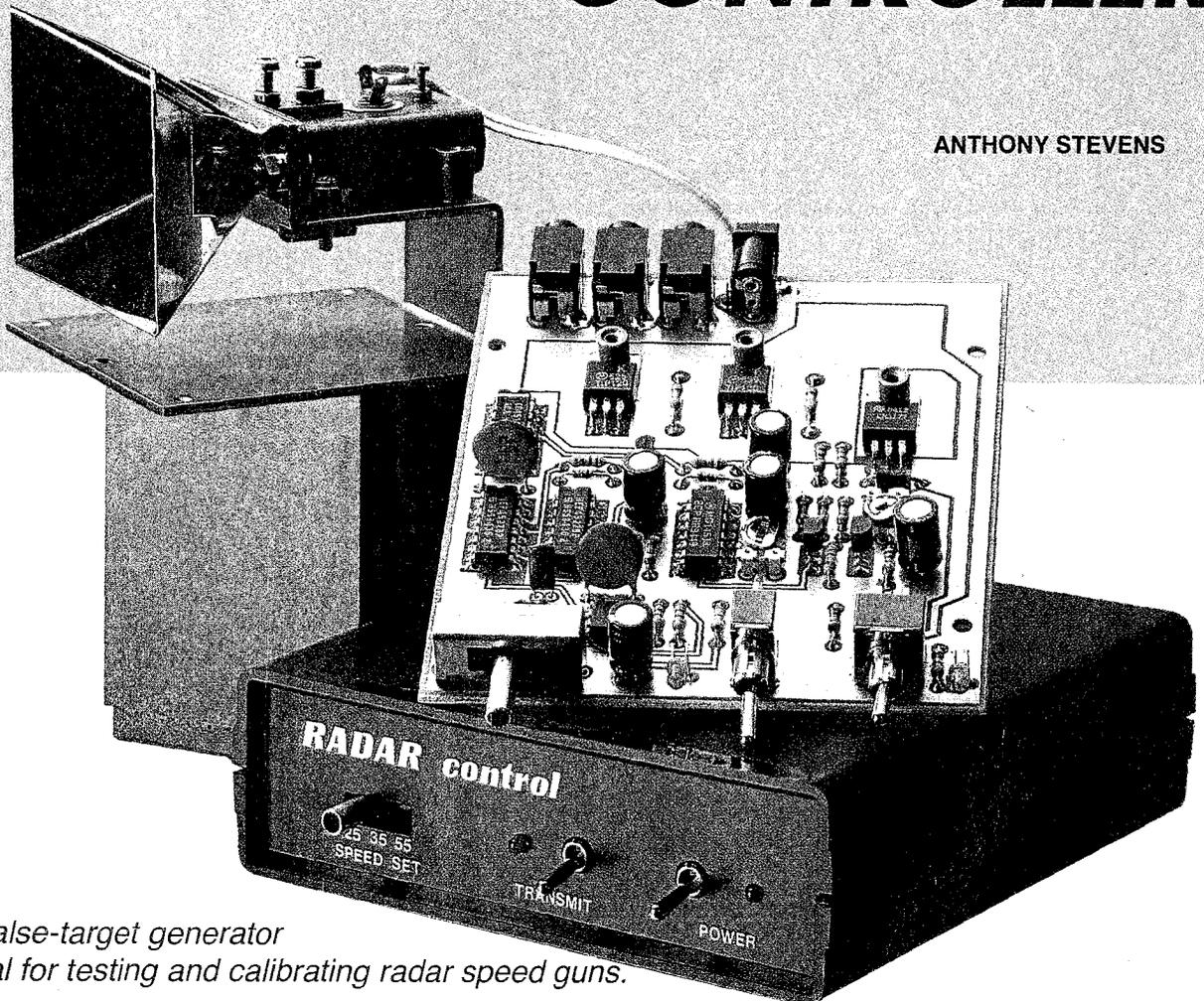


RADAR SPEED-GUN CONTROLLER

ANTHONY STEVENS



This false-target generator is ideal for testing and calibrating radar speed guns.

SINCE THE FCC HAS ALLOWED THE commercial and private use of some radar frequencies, interest in those frequencies has greatly increased. Amateur-radio operators are actively experimenting with radar for communications. On the commercial front, the burglar-alarm industry has turned to radar for intrusion-detection alarms. Boaters are using radar to guide their crafts through hazardous fog. Even professional baseball teams are getting into the act with radar guns being used to time the speed of their pitchers' deliveries. And of course everyone is familiar with radar through its use by highway police to enforce the speed limit.

As with all other electronics equipment, radar guns need to be calibrated and tested periodically for accuracy. Here is an inexpensive portable calibrator for

radar equipment. It works by generating a false target.

Radar false-target generators are used by the military as electronic camouflage on our stealth aircraft to fool the enemy's radar-tracking missiles. A similar technique is used in this radar gun calibrator. To better understand the technique, we should first understand how radar speed-guns work.

How radar works

The police have been using radar to measure vehicle speed since the late 1940's. A block diagram of a typical radar speed-gun is shown in Fig. 1.

A radar gun uses the *Doppler effect* to determine the speed of a moving object. Its output consists of a steady, unmodulated carrier. The signal travels in a tight

beam toward a target whose speed is being monitored. That target can be any object, such as a speeding baseball—or a speeding motorist. Because of the nature of microwave transmissions, the signals are reflected by the target back toward their source.

Because of the Doppler effect, the frequency of the reflected signal is slightly higher than the original transmitted signal. For each mile per hour an object is travelling toward the radar speed-gun, the reflected signal received by the gun will be shifted about 31 Hz higher. In the radar gun, the return signal is mixed with a sample of the original transmitted wave to produce a difference frequency. That difference frequency is analyzed and converted to produce a direct readout of speed.

WARNING

This radar calibrator may interfere with police radar, CB units, radio receivers, etc., up to 1000 feet away. Thus its use should be restricted to laboratory use or for educational, scientific, informational, or calibration purposes. The illegal use of a transmitter can subject the user to a \$10,000 fine, a jail term, and the seizure of transmitting equipment.

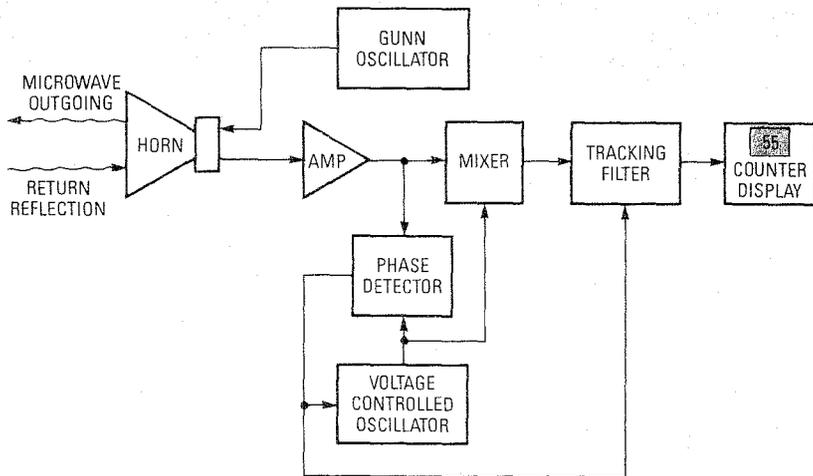


FIG. 1—SPEEDING FASTBALLS, or speeding motorists, can be timed using a radar speed-gun. A block diagram of such a unit is shown here.

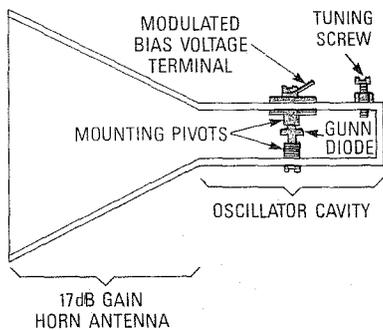


FIG. 2—THE HEART OF A RADAR SPEED-GUN used by the police, and others, or a radar false-target generator is a microwave Gunn diode. Here, the proper way to mount such a diode in a microwave horn is shown.

As shown in Fig. 2, the heart of a radar speed-gun—and our radar calibrator—is a Gunn diode oscillator. Typically these oscillators can generate an output level of about 100 mW. With that output level, and with a highly directional transmitting antenna, the range of a radar speed-gun is about $\frac{1}{2}$ of a mile.

Until recently, high-output Gunn diodes were expensive; most cost several hundred dollars or more. Now, however, a Gunn diode can be obtained for as little as \$60. That certainly makes it attractive to hobbyists for experimentation.

How the calibrator works

Our circuit generates a false target that can be used to calibrate radar speed-guns,

such as those used to time the speed of a baseball player's throw. Let's examine Fig. 3 to see how the calibrator can be made to force a speed gun to read a desired speed. As is shown in Fig. 3-a, the outgoing reference transmission and the incoming reflected transmission are both present inside the antenna cavity. Because, as described earlier, they are of slightly different frequencies, they interfere with each other in such a way that a difference signal (at a *beat frequency*) is created. That signal is detected by a mixing diode, and the low-frequency beat that results is passed on to be analyzed.

To force a speed gun to read a particular speed, all a false-target generator need do is to produce a difference signal that simulates the one that would be created by an object travelling at a certain speed. See Fig. 3-b. Assuming the output-power level is sufficient, it will "capture" the receiver, preventing it from detecting any other signal that might be present, including the Doppler-shifted reflection.

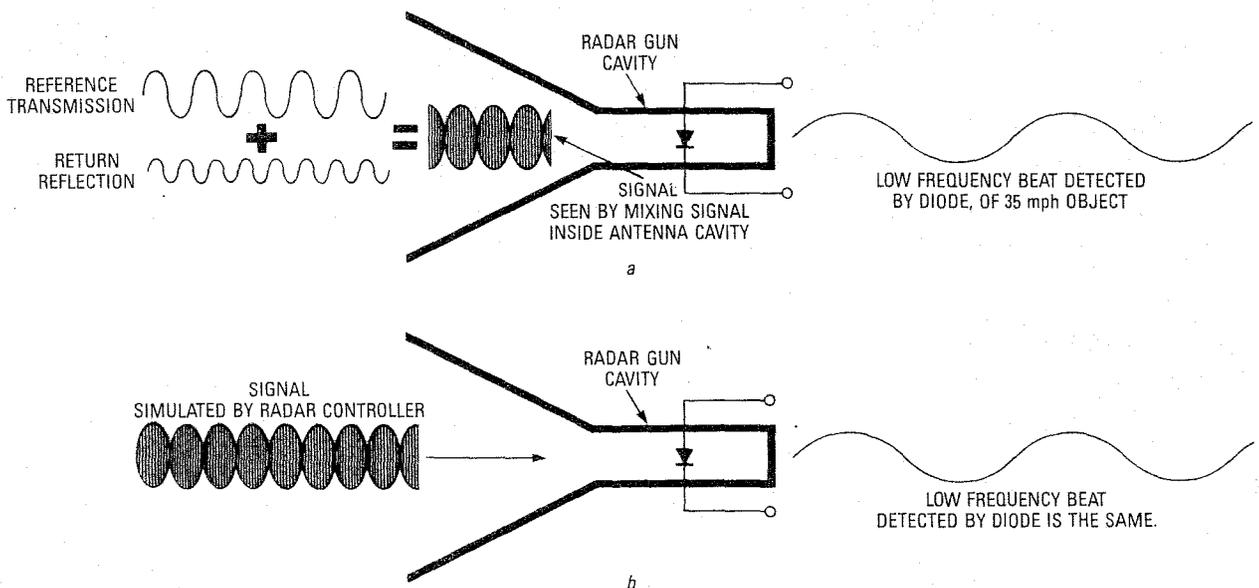


FIG. 3—WHEN THE TRANSMITTED AND REFLECTED SIGNALS are mixed in the horn's cavity, the resulting low-frequency beat can be used to determine the speed of the reflecting object, as shown in a. The calibrator works by generating a signal that simulates the one that would result if the transmitted signal were reflected by an object moving at a specified speed, as shown in b. As a result, the low frequency beat detected by the diode is the same as the one in a.

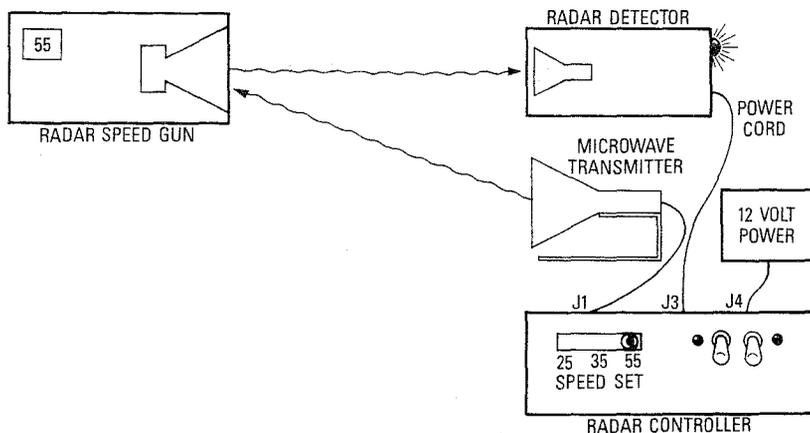


FIG. 4—USE THIS SET-UP to calibrate a radar-speed gun. The speed gun can be forced to read 25, 35, or 55 miles-per-hour by altering the setting of a switch on the calibrator.

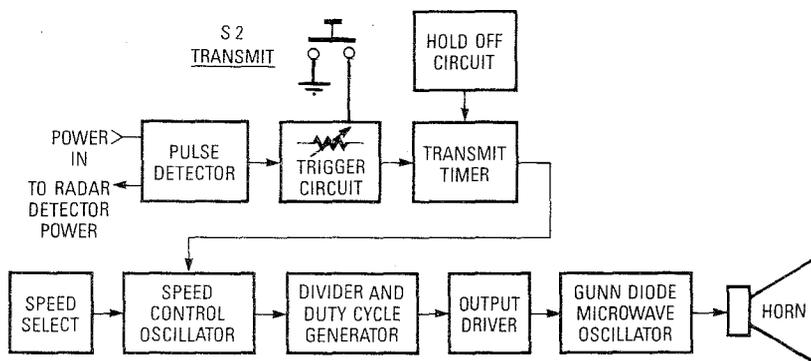


FIG. 5—THE RADAR CALIBRATOR is shown here in block diagram form.

Creating a difference signal that causes a speed gun to read a desired speed is not difficult. It's done by pulsing a carrier whose frequency is in the passband of the speed gun's receiver. Speed is simulated by varying the pulse rate. That is, the pulse rate is set at 31.4 pulses-per-second per mile-per-hour of desired reading. For a desired reading of 55 miles-per-hour the pulse rate would be $31.4 \times 55 = 1727$ pulses-per-second.

The basic set-up for calibrating a radar gun is shown in Fig. 4. A block diagram of the false-target generator is shown in Fig. 5. Note that the false-target generator is designed to work in conjunction with an automotive radar detector. The radar detector is used to make the operation of the calibrator almost automatic. When the radar detector senses a transmission from a speed gun, it sounds a buzzer or turns on a light as a warning. In doing that, the detector draws more current than normal from its 12-volt power source. The false-target generator's pulse-detector circuitry detects that surge, amplifies it, and, via the trigger circuit, triggers the transmit timer. The timer turns on the speed-control oscillator for approximately ten seconds. Using such a short transmission time is necessary to keep the Gunn diode from overheating.

A manual TRANSMIT switch (S2) is included for those not wanting to use a radar detector to trigger the Gunn oscillator. The switch is a momentary type, and it also triggers the one-shot for ten seconds.

The speed-control oscillator drives a divider network that generates the appropriate frequency and duty cycle for the output driver, which supplies voltage to the Gunn-diode oscillator. After ten seconds the transmitter timer locks itself off for a couple of seconds to give the radar detector time to settle down and reset.

About the circuit

The schematic diagram of the calibrator is shown in Fig. 6. Power is applied through J4. Power switch S1 applies power to the internal circuit through IC6, an LM317 voltage regulator; power is also applied to J3, the V_{OUT} jack, through R2, a 1-ohm sensing resistor. The voltage drop across R2 is amplified by Q1, which is slightly forward biased by R16. The TRIGGER SENSITIVITY control. Transistor Q2 amplifies the trigger signal and applies it to pin 5 (the trigger input) of one half of IC2, a 4538 dual timer. That half of the timer package is configured as a one-shot with a period of about ten seconds.

The period of the other half of IC2 is determined by C3, R19, and R11. The

PARTS LIST

All resistors 1/4-watt, 5%, carbon film unless otherwise noted

- R1—4700 ohms
- R2, R24, R25—1 ohm
- R3, R10—10,000 ohms
- R4, R21—2200 ohms
- R5—2000 ohms, 1%
- R6—6650 ohms, 1%
- R7—4420 ohms, 1%
- R8—2210 ohms, 1%
- R9, R15, R22, R23—1000 ohms
- R11—1 megohm, trimmer potentiometer
- R12, R18, R19—100,000 ohms
- R13—1 megohm
- R14, R17—47,000 ohms
- R16—5000 ohms, trimmer potentiometer
- R20—270 ohms

Capacitors

- C1—C5—10 μ F, 25 volts, electrolytic
- C6, C7—0.1 μ F, ceramic disk
- C8—470 pF, 5%, 100 volts, mylar
- C9—0.0047 μ F, 100 volts, mylar

Semiconductors

- IC1—555 timer
- IC2—4538B dual precision timer
- IC3, IC4—4522B decimal divide-by-N counter
- IC5—4518B dual synchronous divide-by-10 counter
- IC6—LM317 voltage regulator
- Q1—2N3906 PNP transistor
- Q2, Q3—2N3904 NPN transistor
- Q4, Q5—TIP120 NPN power transistor
- D1—1N4004
- D2, D3—1N4148
- D4—MA49159. Gunn diode
- LED1, LED2—Red LED

Other Components

- S1—DPDT, 3 amps, 110 volts
- S2—SPDT, momentary toggle
- S3—DP4T, slide switch
- J1, J2, J3—3.5 mm phone jack
- J4—2.1 mm phone jack

Miscellaneous: PC board, hardware (7 each—4-40 screws, 3 each—4-40 nuts), microwave horn, case, wire, solder, etc.

The following are available from Microwave Control, 1701 Broadway, Suite 236, Vancouver, WA 98663. (1-260-693-6843): Complete kit including tested Gunn diode, microwave horn, PC board, case, and all parts, \$169.50; tested Gunn diode, microwave horn, \$117.00; etched and drilled PC board, \$19.50. Please add \$4.50 for shipping and handling. Washington state residents add 7.4% for sales tax. Allow 4-6 weeks for delivery.

output of that timer, pin 9, is used to reset the first timer via pin 3. Trimmer R11 is used to adjust the hold-off time of the trigger circuit to prevent false retriggering. False retriggering can occur when the calibrator output-signal is detected by the radar detector, which in turn retrigger the calibrator. You will have to experiment with R11 to find the setting that will prevent false retriggering.

The output of the first half of the 4538, pin 6, is used to enable IC1, a 555 timer that's configured as an astable multivibrator. The oscillating frequency of IC1 is determined by R6, R7, R8, and C8. The

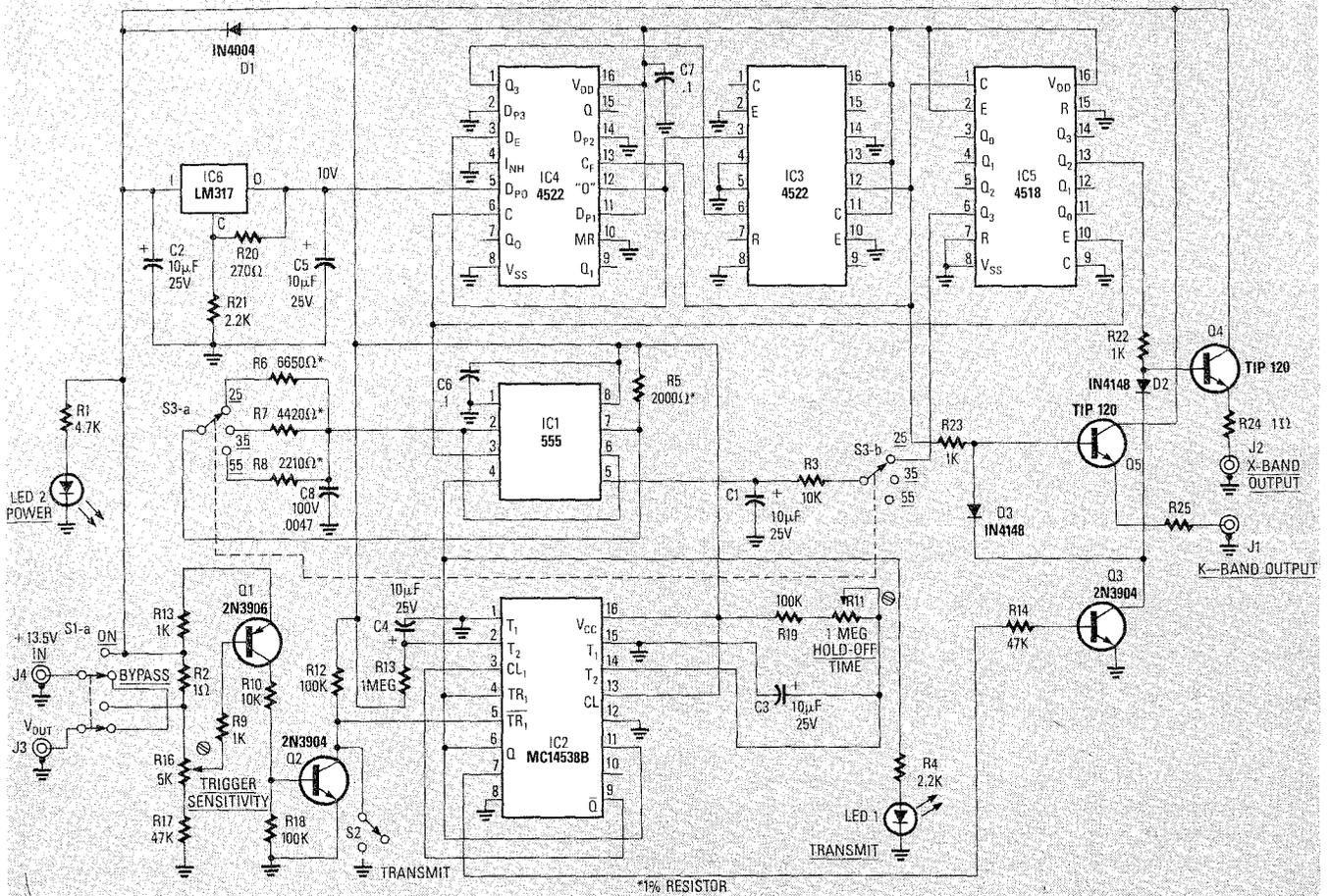


FIG. 6—ONE OUTPUT OF THE radar-calibrator circuit (J1 or J2) is fed to a Gunn diode mounted in a microwave horn. Outputs are provided for each of the two most popular speed-gun frequencies.

There are two outputs taken from the divider string. One, taken from pin 13 of IC5, is emitter coupled to J2, X-BAND OUTPUT, via driver transistor Q1. The 1-ohm resistor, R24, is included to ensure stability. The other output, taken from pin 13 of IC3, is emitter coupled to J1, K-BAND OUTPUT, via driver transistor Q2. A 1-ohm resistor, R25, is included to ensure stability. The J1 or J2 output, as appropriate, is applied to the Gunn diode. Although optional, and not shown in the illustrations, for best results a small, 0.47-pF mylar capacitor, C9, should be installed across the Gunn diode.

Diodes D2 and D3, in conjunction with transistor Q3, help ensure that the driver transistors remain off when the unit is not triggered. When switch S1 is at its slow speed settings, 25/35, the output of IC5 is divided further and fed back through R3 and C1 to modulate IC1.

Building the unit

We recommend the use of a printed-circuit board. If you wish to etch your own, an appropriate double-sided layout is provided in our PC Service section. Also, you can purchase a board from the supplier mentioned in the Parts List.

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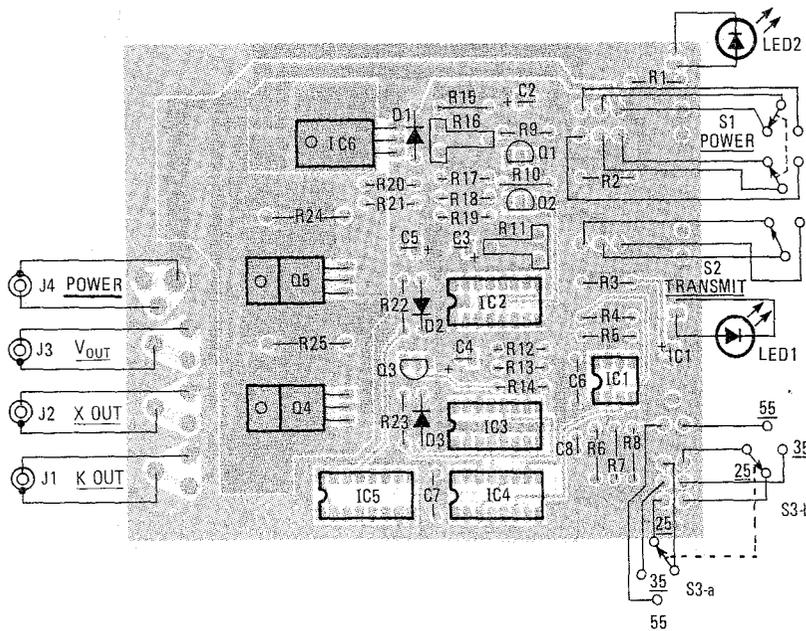


FIG. 7—THE CIRCUIT SHOULD BE MOUNTED on a double-sided PC board. The patterns can be found in the PC Service section, of this magazine.

output of the oscillator drives the divider string consisting of IC4, IC3, and IC5.

The output from each divider is a square-wave with a 40% duty cycle.

COMPACT DISCS

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merging bits per frame.

Using EFM, the 33 8-bit words become 33 14-bit words (462 bits) plus three bits each for merging bits (99 bits), plus another 27 bits for the synchronization word and its merging bits. And there, finally, is our total: $462 + 99 + 27 = 588$.

Dividing It Up

With the numbers now at hand, let's examine the percentages once again. We can do that by comparing the number of bits used for each purpose in a frame with the total number of bits—588—in that frame.

What we're most interested in is the audio information on the disc. Not surprisingly, after all we've been through, we find that all the bits used in a frame for audio—192 of them—account for only 32.7% of its information content. See Fig. 4. That's all there is; everything else is there to make sure that the music comes

service (November and December 1985, and the January through March 1986 issues). We have prepared a special reprint of the series, called *Repairing Compact Disc Players*. It's available from the **Radio-Electronics** Reprint Bookstore, 500-B Bi-County Blvd., Farmingdale, NY 11735 for \$5.00 plus \$1.00 shipping.

Postscript

There are still a few bits we haven't looked at at all yet. They're the R through W bits of the subcode, six bits that aren't used for anything at all on an audio disc. Why are they there?

When the standard used to record information on CD's was devised, some forethought was given to future needs. The R-W subcode bits were included so that the disc could be used for storing things other than audio.

Those 200 million or so bits worth of unused space can hold about 20 megabytes of data, as much as the standard hard disc drive in an IBM PC/AT. At 2000 characters per page, that's 10,000 pages of text, or about 1250 articles as long as this one—with music to read them by.

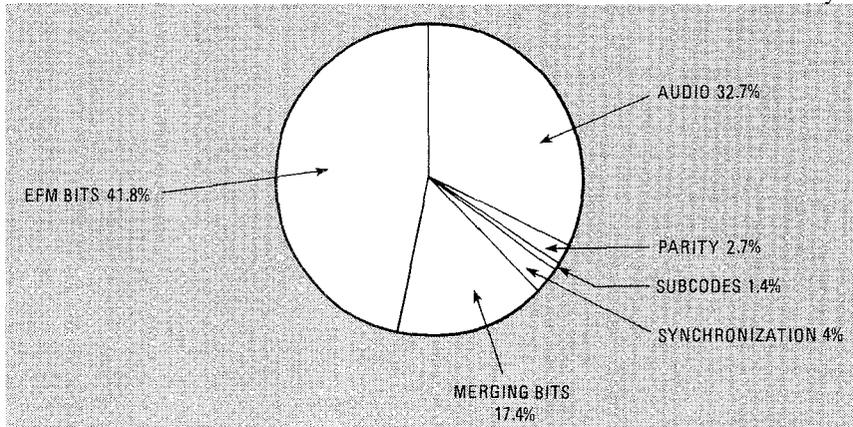


FIG. 4—THIS CHART shows the relative sizes of the subgroups that make up a frame of CD information. Note that the relationship between the "housekeeping" bits and the audio information is roughly 2:1.

through to you as easily—and sounding as good—as it can.

The 64 bits of parity information make up about 2.7% of the total, and the synchronization bits account for just over 4%. The 102 merging bits take up 17.4% of the space in a frame and, finally, the 8 subcode bits occupy a little under 1.4%.

Of course, that only adds up to 58.2%! What we are forgetting about again is EFM. Expanding the 8-bit words to 14 bits accounts for the missing 41.8%. On the surface that seems inefficient, but overall it works out for the best.

In the end, it takes a total of 588 bits of information to represent 192 bits of audio. That's more than a ratio of 2:1 for the overhead, which may at first seem wasteful. But once you've listened to a compact disc, you'll agree that it's worth it.

For the theory behind CD player operation, you may want to read the 5-part **Radio-Electronics** series about CD player

Many CD players are already equipped with a subcode output that could easily be connected to a decoder to present such things as the historical background of a piece of music, or an analysis of the score, while the music was playing.

That same subcode space on a compact disc could also be used to store some 700 digitized still video images; a new one could be displayed every five seconds. We could have still-music-video CD's, or, on a higher plane, show the actual score of the piece being played, or scenes—not graphics, but real video pictures—from operas or Broadway musicals.

And that's how all those "millions and millions" of bits on a CD are used. It may be disappointing to find out that so little of the available space actually stores audio, but it's reassuring to know that just about all the rest of what's on the disc is there to ensure that you hear music that is reproduced as faithfully as possible. **R-E**

RADAR CONTROLLER

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Once you've etched or purchased the board, mount the components on the board as shown in the parts-placement diagram, Fig. 7. Be sure that all components are oriented as shown. Bolt the regulator and power the transistor to the circuit board for heat sinking.

The Gunn diode, which is mounted in a microwave horn, draws up to 1 amp of current, so use number 18 wire for the connection between the circuit and the horn, and keep the length to 10 feet or less. *Under no circumstances* should you connect DC voltage to the Gunn diode or reverse the polarity of the connections to the diode (power is fed to the anode side; the cathode side is grounded). Doing either will almost certainly blow out that \$60.00 component.

When mounting the microwave horn, be sure that metal objects are kept away from the opening (plastic will do no harm). The power supply for the unit should be able to supply 12-volts DC at 2 amps; most automotive electrical systems are capable of meeting that requirement.

After construction and hook-up, test the unit by aiming it toward an automotive radar detector and depressing the TRANSMIT switch. That should cause LED2 to light. Also, the radar detector should react as appropriate (a buzzer should sound or an LED should flash) to the presence of a radar signal. Verify the oscillating frequency of the 555 timer by connecting a scope or frequency counter to pin 3 of that IC. With the S3 set to 55, the frequency measured should be 39,600 Hz.

Warnings

While the radar calibrator can be a useful diagnostic tool in aligning radar speed-guns, if used for illegal purposes and/or by unlicensed individuals, it can be the cause of a great deal of trouble. (Penalties of up to \$10,000 and a year in jail are some of the possible consequences of such use.) Further, because of possible interference to police radar, communications services, etc., the unit should only be used in a laboratory, and only for educational or calibration purposes.

It may be possible for certain individuals, such as licensed amateur-radio operators, to use the calibrator legally in the workshop, the laboratory, or the field, but it is left to the individual user to ascertain the requirements for such use, and to meet them.

In any event, any willful interference to another service by any individual is punishable with stiff penalties under Federal law; other local, state, or Federal penalties may also be applicable. We strongly discourage use for such applications. **R-E**