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Remote-Controlled Everything

Secure, wireless control for your next project is no longer a remote possibility.

Remote-controlled garage-door openers are becoming so common now that many people, including me, consider them as much a necessity as a toaster or lawn mower. Almost all door openers use a radio link to start the motor that raises and lowers the door.

Have you ever looked at that little transmitter clipped to the visor of your car and wondered what was inside? Maybe you opened it up (after all, you're a ham, right?) and were surprised to see only a small handful of parts. I'll bet you thought, "Gee, and they want thirty bucks for a new transmitter!"

Maybe you also started thinking of all the neat uses you could have for a small remote-control system that could reach up to 200 feet or so. How about a remote PTT switch that could key up your transmitter in the shack while you stand at the antenna with the swr meter? Or a remote TV or light control?

How about a wireless doorbell for the front gate? Or maybe a beeper in the house that alerts you when the mail arrives? The possibilities are endless. The only reason you haven't done these already is because they sounded too complicated, right? After all, you'd have to build a complete transmitter and receiver for each use.

I'm going to help you build a simple, secure radio link that can be used as the basis for a very reliable home-security system, or any other use you can think of.

Look at Fig. 1. At the left is a push-button switch that powers up the rest of the transmitter when closed. The digital-coding IC sends a serial stream of pulses to the base of a single-transistor oscillator. The oscillator turns on with a high pulse, and is off between pulses. The antenna is usually just the oscillator's inductor stretched out so that it will radiate better.

This on/off signal (just think of it as fast CW) is picked up at the receiver by a superregenerative detector. Back in earlier times, many simple receivers built by hams used superregenerative detectors. They have their limitations, which we'll talk about in a moment, but it's hard to beat a single-transistor receiver for simplicity!

The output of the detector is a demodulated audio signal that is amplified and sent to a decoder IC. If the codes selected in both the transmitter and receiver match (usually set by DIP switches), the receiver IC keys a relay that stays activated as long as the proper code is still being transmitted. The relay contacts can be used to ring a bell, fire a cannon, or whatever is desired.

Encoder/Decoder Chip

Simple, right? The system's reliability is based on the digital encoder/decoder chip's ability to make sure that only a particular code will close the relay, and not random noise or other signals coded differently. Most manufacturers of garage-door and security systems use their own proprietary coding ICs that are purposely incompatible with each other. All are based on the same principle, though.

Look at Fig. 2. This is a pinout for the National MM53200 chip. It is available from several sources, such as Jameco. Pins 1 through 12 are for setting the code you want. Twelve inputs means that you can have 2^{12}, or 4096, different codes. The connections to these pins must match in both the transmitter and the receiver. Fig. 3 shows how the connections should be made. Either a DIP switch or jumpers can be used. The IC has internal pull-ups on the code input pins, so they are either grounded for a 1 bit or left open for a 0 bit.

> ***". . . this chip set uses trinary coding with nine bits, which gives 3^9, or 19,683, different codes possible!"***

Looking at the other pins, you see a 100k resistor and a 180-pF capacitor. These two parts set the chip's internal clock frequency at about 100 kHz. Use 5% components, but do not be concerned if the clock frequencies in the transmitter and receiver do not match exactly. You would have to have at least a 15% mismatch before they wouldn't work together.

If you don't have the values specified, substitution is all right. The formula for the clock frequency is 2/RC. Other values like 47k and 470 pF are fine. You can use any other frequency, like 50 kHz, if you want, as long as the transmitter and receiver are the same. The oscillator input pin can also be driven by an external oscillator. In that case, you would delete the resistor and capacitor.

Pin 15 decides whether you have a trans-

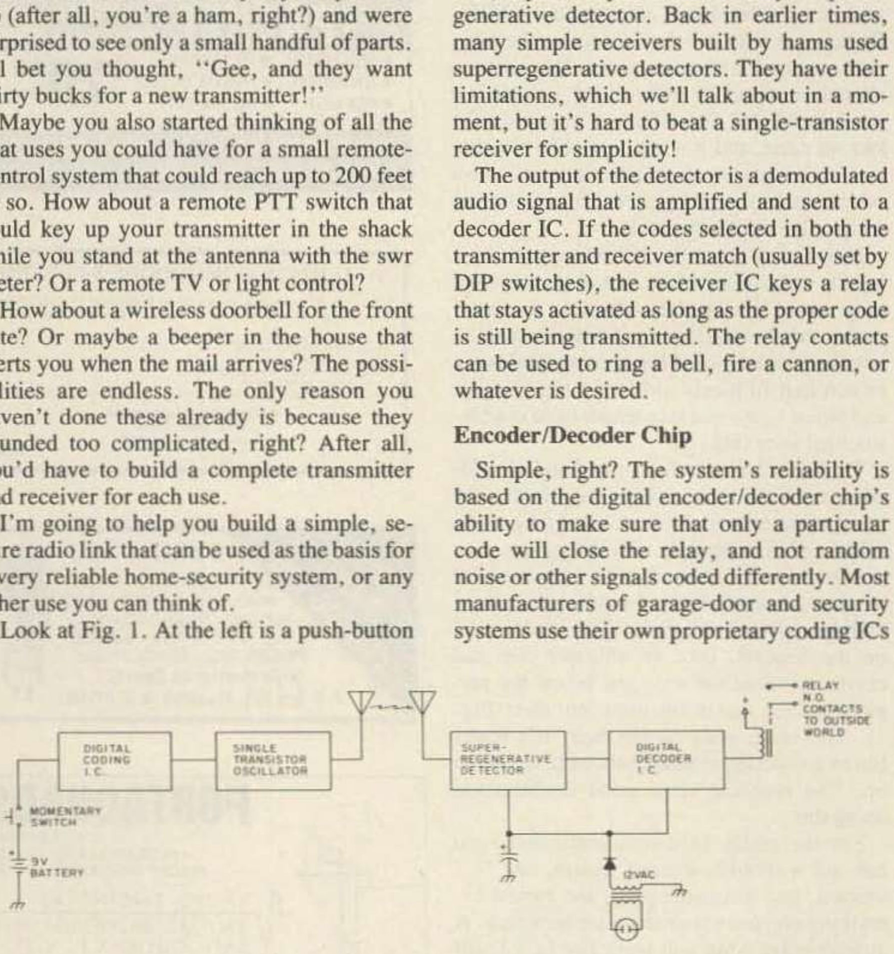

Fig. 1. Remote-control-system block diagram.

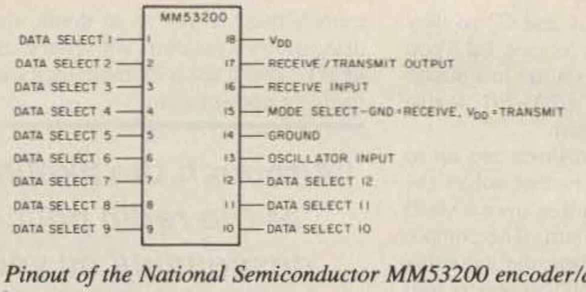

Fig. 2. Pinout of the National Semiconductor MM53200 encoder/decoder chip.

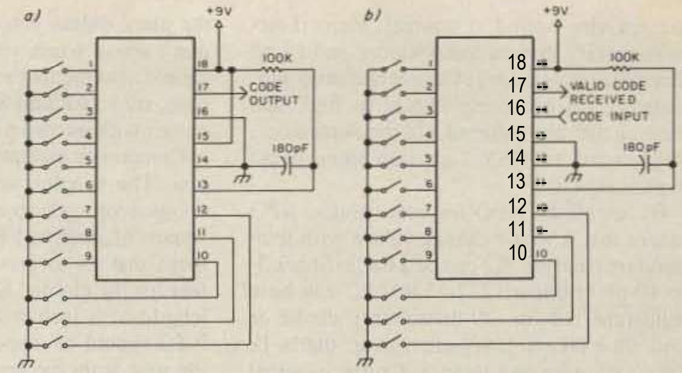

Fig. 3. Wiring the chip for: a) transmitter operation and b) receiver operation.

mitter or a receiver. Grounding it gives you a receiver. Connect it to the battery supply (pin 18) for a transmitter. Do not leave it open. If it is a receiver, send the data in on pin 16. If it's set up as a transmitter, the data comes out on pin 17, and pin 16 is grounded also. I recommend that you test the setup in Fig. 3 with a solderless breadboard, first. Just connect the code output, pin 17, from the transmitter to the code input, pin 16, on the receiver. Then watch the normally-high output from pin 17 on the receiver go low when the codes match. You can do that with a low-current LED or a voltmeter. Later on, this output will drive a transistor that will energize a relay.

Fig. 4 shows the nature of the data being sent and received in this system. Starting from the left, there is an 11.52-millisecond pause, then a start bit, then the twelve data bits, then another pause, then a start bit, etc. This data stream is continuous as long as the transmitter is powered up.

The start bit and twelve data bits make up one word. A word is the same length as the pause between words. The receiver chip has to see 4 words in a row that are valid (the transmitter code matches the code on the receiver switch inputs), and then pin 17 will go low. Do not try to drive an LED directly with this pin unless you use a low-current type. The pin will sink only a maximum of 2 milliamps.

There are other encoder/decoder ICs available, such as Motorola's MC145026, 27, 28, and 29. This is also second sourced from SGS-ATES. The 26 is the transmitter. There are three different receivers which vary mainly in how they treat the incoming data. The MC145028 receiver is like the MM53200 in that all of the bits are compared and a single output signals that they match. The 27 and 29 divide up either the first 4 or 5 bits as a valid address and the remaining bits as individual channel selects.

Another interesting thing is that this chip set uses trinary coding with nine bits, which gives 3^9, or 19,683, different codes possible! The code input pins are either high, grounded, or left open.

There is also a large number of TV remote-control chips from just about every IC manufacturer. These are made to operate with an infrared link, but most will work with rf. The major disadvantage with them is that they have no real security code to set, just bit patterns representing which switch on the keypad is pushed, but that shouldn't stop you from using them. Very few are used with rf links, and they are great if you need several channels with a single transmitter and receiver pair. An example would be for controlling the various movements and functions on a robot.

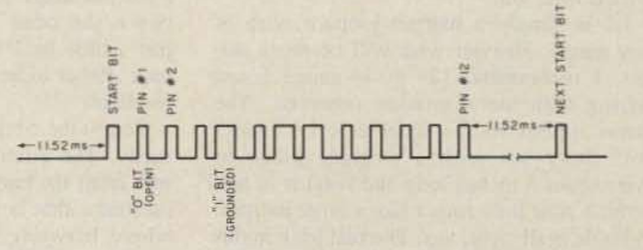

Fig. 4. Data format as sent by the transmitter chip when pins 4, 6, and 7 are grounded.

The Transmitter

Let's build a transmitter first. Fig. 5 shows how simple it can be. Don't be concerned if you don't have some of the exact part values specified. R1 and R2 can vary by 2:1 (don't go below 47k on R1), and I have listed most of the transistors that can work in this circuit, including one (MRF-901) that can be bought at Radio Shack. It is a real overkill for this circuit, though. If you have trouble getting parts for any of these circuits, they are available from me for a nominal cost as long as you don't want hundreds of them.

Returning to Fig. 5, we find a simple Pierce oscillator that has feedback from base to collector. Many hams don't have a solid understanding of what makes an oscillator oscillate. An oscillator is simply an amplifier tuned to the desired frequency that has some feedback from output to input.

Feedback means that a portion of the output signal is returned to the input, like the howl in a public address system when the volume is turned up too high. What happens then is that the microphone amplifies what it hears again and again. The howl is actually an amplifier being made to oscillate at the resonant frequency of the room, speakers, and microphone in combination. That's why you can get different frequency squeals by moving your hands around the mike. Your hands change the level and emphasis of frequencies heard by the mike, and therefore the pitch of the squeals you hear.

What we have to do in an oscillator is get a 360-degree phase shift through the entire circuit, and it *has* to oscillate if the transistor has enough gain. A 360-degree phase shift means that the amplified signal arrives at the base ("or collector or any other part of the loop") looking just like the signal just arriving, but delayed one full cycle.

If the fed-back signal were compared with the arriving signal on a dual-trace oscilloscope, the signals could be laid over the top of each other and they would match (except that

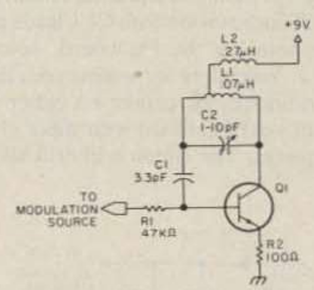

Fig. 5. The transmitter rf oscillator. Q1 can be a 2N918, 2N5179, 2N5770, 2N3563, MPSH10, MPSH11, or MRF901 (Radio Shack 276-2044).

their amplitude, or levels, wouldn't be quite the same). An old joke with rf engineers says that the sure way to build an oscillator is to design an amplifier, and vice versa! That's very true . . . feedback makes the difference.

Since we are using an NPN transistor, the base and collector are always acting oppositely, or, as the voltage rises on the base, the transistor conducts, and the voltage on the collector falls as the collector pulls more and more current. This means that the base and collector are 180 degrees out of phase, because they are acting oppositely.

Now we have half of the phase shift we need. The other half, another 180 degrees, comes from L1 and C2 in series with R1. Unless there's lots of loss through these components or the transistor doesn't have enough gain at the high frequencies we're using, the circuit should oscillate!

When you're testing this circuit, the hardest part will be finding out what frequency you're on. I'll show you how to build a simple detector to test it and make sure you're transmitting *somewhere*!

R1 and R2 are carbon film or any other type (except wire-wound, of course). Many rf circuits specify carbon composition, and I find this to be unnecessary. Decent carbon comp. resistors are becoming harder to find, and their quality has suffered. (In the September, 1985, issue of *QEX* I go into some detail explaining this.)

C1 should be NPO for best results. NPO means that it won't change values with temperature changes. C2 can be a Radio Shack 3- to 10-pF trimmer (272-1338). L2 can be a miniature .18- to .39-microhenry choke or coil. Just take a 1/4-Watt resistor that's 1k Ohms or more and wrap 5-8 turns of small wire evenly around the body. You can use 20- to 30-gauge wire of any kind. Wire-wrap wire is fine, too.

L1 is simply a hairpin loop of wire of any gauge. Heavier wire will be more stable. I recommend 12- to 14-gauge house wiring with the insulation removed. The same applies to the receiver's L1 inductor. Start out with a straight piece of wire about 3 inches long and bend it in half around your little finger like a large hairpin. A circle is all right, too. The real trick in this circuit is to get it as mechanically stable as possible.

Ideally, L1 should be a printed-circuit trace about .025 inches wide with C2's leads going through holes in the PC board, soldered across L1. You might try tacking your inductor to an unclad (no copper on either side) portion of your PC board with super glue in several places. The circuit will drift all over the place unless you get L1 and C2 so they don't move when you go to tune C2. You should also mount the transmitter in a plastic case, such as Radio Shack's 270-291. It also comes with its own perfboard.

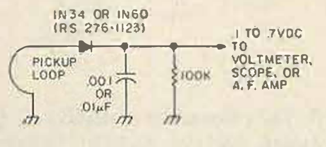

Fig. 6. The diode detector will give an indication that the transmitter is working. The pickup loop should be one turn about the same size as the transmitter loop, or larger. Use a dc voltmeter on a 2-volt scale, or a scope. An audio amplifier will work if the transmitter signal is modulated.

Component-mounting methods are up to you. The simplest is just to tack-solder the component leads to each other over a small square of unetched PC board. The components that go to ground form the mounting feet for the circuit. Keep all component lead lengths to ¼ inch or so.

L2 should be tapped on L1 about 25% of the way from the transistor base. Too close to the base, and it won't oscillate. Too far, and it gets less stable. If you've bent L1 into a hairpin shape, just put the top halfway between the bend and the base, then move just a little back towards the bend for good luck. Better to be a little unstable than not to oscillate.

To test the circuit, tie R1 to 9 volts temporarily. The circuit should draw about 5-10 mA from the battery. Now you have a CW oscillator that is probably oscillating somewhere between 180 and 500 MHz. Most garage-door-opener radios are between 290 and 400 MHz. Unless you have a spectrum analyzer (about $12,000), you won't know where you are. The circuit in Fig. 6 is a simple diode detector to show you that you're oscillating somewhere. At this point, that's all you need to know.

If you have cable TV, you can stick a short antenna into the cable converter or cable-ready TV's input, tune it to channels K or 24 (223-25 MHz) through X or 37 (301-25 MHz). Tune C1 through its full range, and at some point you should see a change in the picture or sound of the TV. Shorten or lengthen L1 if you get nothing. Please use an insulated tool. It's frustrating to watch your signal drift off as you pull your Craftsman screwdriver away. It could also cause your circuit to stop working.

The same tuning procedure applies with the diode detector. The pickup loop may have to be almost in contact with L1 before you get an indication. The most you'll see is about .2 to .7 volts. Any indication at all shows that you are transmitting. If you're in doubt about the detector, try it carefully with your 2-meter rig or HT. You'll see a lot more indication with the higher power gear.

"Although the likelihood of the radio police descending on your house is extremely small, it is your responsibility to make sure that you do not interfere with anything else."

Now that you have your transmitter working, smile smugly at your abilities and go to work on the receiver. You might also connect R1 to pin 17 of your code-transmitter chip and observe the code being sent on an oscilloscope connected to your diode detector. Or you could connect the detector to an audio amplifier and hear the musical buzz the code chip makes. It may also make some interesting viewing on your television!

A Super- What?

Superregenerative detectors are still used today in a variety of things such as radar transponders, aircraft altitude-measuring radar, police radar detectors, inexpensive radio-controlled toys and walkie-talkies, and garage-door-opener receivers. The main reason they are used is because of cost and circuit complexity; it's hard to beat a one-transistor receiver. Their main disadvantages are that they are limited mostly to AM and pulse detection. They also tend to emit quite a bit of rf. This can be controlled somewhat by isolating the detector stage from the antenna with a preamp.

Looking at Fig. 7, you might think that you're looking at an oscillator circuit. We have the Pierce-type tuned circuit connecting between the base and collector of Q1, just like the transmitter we built. The main difference here is that we connect C4 into the circuit and it, along with L2, R3, and R4, form another low-frequency oscillator at about 200 to 700 kHz. If you have the interest, you could disconnect C4 and observe that you now have a single frequency oscillator just like the transmitter.

A superregenerative detector is basically an oscillator that is rapidly turned on and off. This circuit turns *itself* on and off, so we call it a self-quenching detector. You could also turn it off and on externally with a sine- or sawtooth-wave generator connected to the transistor base through a small choke. Square waves are not desired here as they spend little time in transition (the time between fully on, or a logic high, and fully off, or ground). During the transition period, and when the transistor just begins to conduct, amplifica-

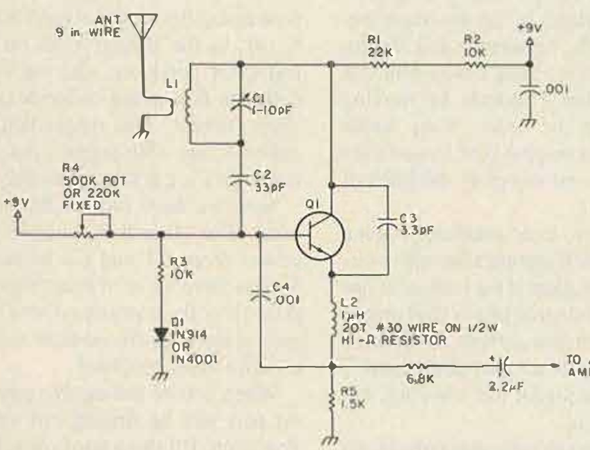

Fig. 7. The receiver. Q1 is the same transistor as is used in the transmitter. Experiment with the antenna and its coupling loop only after you have the receiver working. You should still get 100 feet or so of range just using L1 by itself.

tion of an incoming signal is achieved on the order of a *million* times, or more! That's why we can get such good sensitivity from a single amplifier stage.

The receiver in Fig. 7, although not the best, can hear signals as low as 3 to 5 microvolts. Adding a preamplifier (even a $10.00 Radio Shack TV amplifier) will help increase sensitivity and also cut down on detector radiation through the antenna. For long-term use, I recommend doing this and also putting the entire receiver in a shielded enclosure.

Why not use a superheterodyne receiver, with sensitivity down in the .2-to-.5-microvolt range? Cost, complexity, and attention to the vagaries of careful rf layout come to mind. Also, you don't need the narrow bandwidth achievable with the superhet here. The transmitter will drift as much as 2 MHz under handling and tuning, and you're going to have enough concern just finding the transmitter signal at first. You don't need razor-sharp tuning right now.

Building the Receiver

Let's look at Fig. 7 again. L1 is another loop of stiff wire, or firmly mounted smaller gauge. The antenna and its coupling loop shown in the schematic are optional. The coupling loop should be another single turn lying next to L1 on the PC board about ¼ to ½ inch away. I recommend you just worry about L1 initially, and experiment with the antenna later. The pot, R4, can be replaced with a fixed resistor after setting the quench frequency to about 300–600 kHz, as measured by a scope or frequency counter at the junction of R1 and R2. That's why we have the two resistors there instead of a single 33k resistor.

If you don't have a scope or counter, you can still make this circuit work fine. You'll need a medium- or high-impedance audio amplifier. I recommend one anyway, and I even use one myself. I have a little box with an LM-386 IC and a 9-volt battery. You could do a lot worse than the one Radio Shack sells for $11.95 (227-1008). It's the same thing, basically.

Connect the amplifier up to the audio output point shown as you tune R4 through its range. C1 should also be turned if nothing happens, or put it in the center of its range. You are listening for the characteristic rushing noise, or hiss, that tells you the detector is oscillating. If you hear nothing, touch the transistor base with your finger. If you don't hear a slight hum or squeal, then there is something wrong with the dc connections of the transistor, such as R4, R3, D1 (it's not backwards, is it?), L2, R5, or R1 and R2. Or maybe the transistor itself is connected wrong.

You may hear squeals and burps, but somewhere you'll hear the hiss. You might also try shortening or lengthening L1, which is just about the same size as L1 in the transmitter. If you turn on your unmodulated transmitter, the hiss will suddenly quiet down as it's tuned to the receiver. If you connect up your code-generating chip to the transmitter as I suggested, you'll hear the musical buzz in the receiver. At this point you have a working receiver.

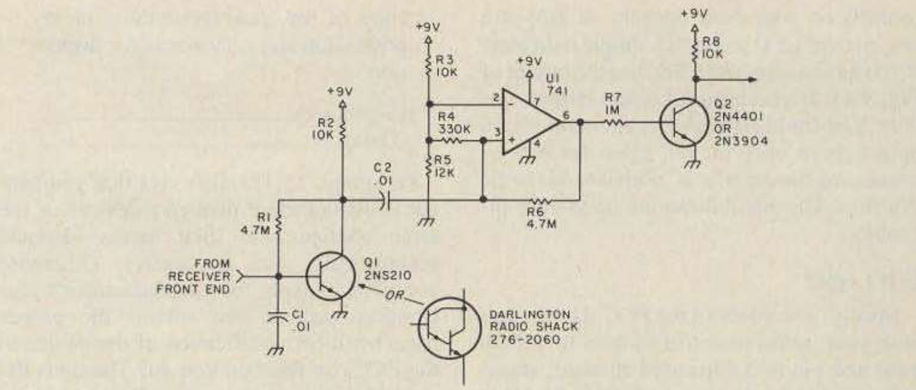

Fig. 8. The audio amp, comparator, and inverter. Use a 2N5210 if possible, or a Darlington such as Radio Shack 267-2060, an MPSA13.

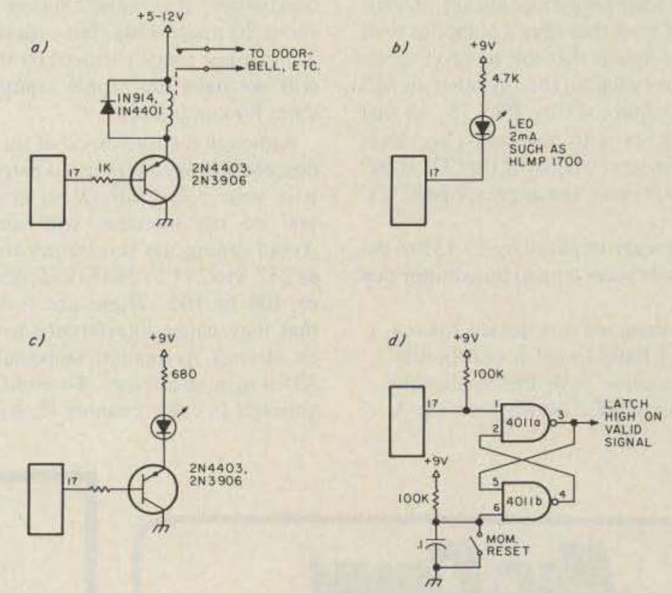

Fig. 9. Various ways to connect the decoder-chip output to the outside world. a) Driving a relay. b) Using a low-current LED. c) Using a regular LED. d) Providing a latched output. Pin 3 of the 4011 flip-flop latches high on receiving a valid radio signal.

By changing the value of L1 and C1, you can make this receiver work on just about any frequency. Now all you need is a circuit that amplifies the signal sufficiently so that the receiver chip sees nice, square 9-volt pulses.

Look at Fig. 8. The low-level audio signal is amplified by the 2N5210 transistor. This is a low-noise, high-beta (about 250–500) transistor. Use it if at all possible. You could also use two NPN units connected as a Darlington pair, or Radio Shack's 276-2060 Darlington. You should then change the base bias so that the transistor collector idles at about 4.5 volts (not critical).

Use a high-value resistor, above 500k, from Q1's base to ground to limit conduction of Q1. C1 cuts down on the amount of the high-frequency quench signal that is amplified by Q1. U1, a 741 op amp, is used as a voltage comparator and Schmitt trigger. It toggles between 9 volts and ground (almost) with a signal greater than about .3-volts input. Q2 then inverts this signal back to what it was at Q1's base.

Check and see that the Q2 collector swings less than 2 and greater than 8 volts. If it doesn't, change the value of R7 till it does. This can be verified with a scope at the collector when the receiver is receiving pulses, or by temporarily shorting pin 3 of U1 to 9 volts and ground.

Now you have a working system. Connect up the decoder chip and, with a VOM or scope, watch the normally high output pin 17 go low when it gets a valid signal. Make sure that the codes are set the same on the receiver and transmitter. If it doesn't work, look at the signal at the output of the transmitter chip. The wider pulses correspond to grounded code-selection pins 1–12. There should be very little other noise or few glitches on the received signal as the decoder chip sees it.

Output Connections

Fig. 9 shows several suggestions for connecting the outside world to the receiver. At 9(a) is the setup you'd use to replace your present garage-door receiver. Just connect the normally-open contacts of your relay across the external push-button contacts on your door opener. At 9(b) is a low-current LED to use as a simple indicator. If you have a standard LED, use the circuit of Fig. 9(c). If you need a latched output, use 9(d). You could also have an alternate-action output (push once for on, again for off) by connecting the decoder IC output to a D or JK flip-flop. The possibilities are up to your ingenuity.

Is It Legal?

Finally, a word about the FCC. Unless you tune your remote-control system to a ham band and use it as a licensed amateur, transmitter and receiver use are controlled by Part 15 of the FCC's rules and regs. Part 15 covers all low-power, unlicensed radios and computers capable of emitting radiation into the airwaves. Ever notice that sticker on your FM radio or TV set that says it complies with Part 15? That means that the receiver emits local oscillator radiation (or any other signal) that is below limits set by Part 15, so that nobody interferes with anybody else. Ever listened to 80 meters when a nearby TV is on? It interferes with you, but at prescribed FCC limits!

Anyway, you are required by 15.133 to put a sticker on your receiver and transmitter that says:

> I have constructed this device for my own use. I have tested it and certify that it complies with the applicable regulations of FCC Rules Part 15. A copy of my measurements is in my possession and is available for inspection.
>
> (Signature)____________
> (Date)____________

Paragraph 15.133 also says that you cannot construct more than five devices of the same configuration (that means identical schematically and physically). Otherwise you need to apply for a manufacturer's registration number and submit the proper paperwork for certification of the device to the FCC. So what do you do? The units described in this article can easily be made to radiate more signal, either fundamental or harmonics, than they should. The amount of radiated signal is very small, even for the transmitter. It is something on the order of about 20 microwatts, but unless you have a 3-meter test range required by the rules, you will not have the proper equipment to test them for compliance.

Although the likelihood of the radio police descending onyour house is extremely small, it is your responsibility to make sure that you do not interfere with anything else. Avoid tuning your transmitter to 242.8--243.2, 265--285, 328.6--335.4, or 404--406 MHz. These are forbidden areas that may cause interference to government or aircraft navigation (especially 328.6--335.4 MHz near an airport). To avoid all this, tune the tranmitter to cable channel K, which falls in the 220 MHz band, or channels 57 to 61 (cable TV hyper-band), which is in the 70 cm Amateur band. The possibility of interfering with any repeaters is almost nil, due to the very low power used here.

Conclusion

It is possible to make these units fit in a very small space. I used 2" x 3" board stock for the receiver and 2" x 2" for the transmitter, with room left over.

If you have problems getting your setup to work, get in touch with me. I will even fix your project in the event you can't get it going. Please include proper return postage for whatever you send. A semi-kit is also available from me for $15.00. This includes all the parts needed for one transmitter and receiver pair, less case. This kit does not include etched PC boards, but does include blank PC stock to tack solder the components to each other.

Etched boards may become available if interest is great enough. I can also supply indi-vidual parts, such as the coding ICs and the 2N5210, etc. Contact me for price. SASE, please, for all correspondence.

If you're interested, I can also direct you to a dealer in your area who can sell you units manufactured by Linear Corporation that are tuned to 310 MHz—I can get them direct for you. The cost for a single transmitter and receiver pair should be about $45.00.■