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Title: Rewinding Relays for 12 V Operation
Author: Paul Wade, N1BWT

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Edited by ***Bob Schetgen, KU7G*** *• Senior Assistant Technical Editor*

REWINDING RELAYS FOR 12 V OPERATION

[In recent months, there have been some great changes in the League's experimenter's publication, *QEX*. Rudy Severns, N6LF, is the new Editor, and I have assumed the Managing Editor duties. We are widening the scope of the magazine considerably. While *QEX* will still carry cutting-edge material in several areas of Amateur Radio, you'll find other articles from a wide range of technical topics at various levels. If you like to build, or read about building, join up!

As an example of the good stuff in *QEX*, the following hint was a sidebar in Paul Wade's 5760 MHz transverter article in the November 1997 *QEX*. Other hints have presented seat-of-the-pants solutions to adapt various relays for 12-V operation, but this treatment casts aside experimental tactics in favor of an engineering approach.—*Ed.]*

◊ Microwave operation from high places requires portable operation for most of us. The most convenient power source is usually the 12 V battery in the vehicle that gets us there, and modern solid-state devices work fine at 12 V, or less. Most surplus coax relays, however, are designed for operation at 28 V or more and don't switch reliably at 12 V. When available, 12 V coax relays are exorbitantly priced; so it would be nice if the higher-voltage relays could be converted. Since relays are ancient technology, digging through some ancient issues of *QST* yielded an article[1] that detailed the calculations necessary to rewind relays for different voltages. I will summarize them here because the back issue is probably no longer available.

Ham folklore says it is only necessary to remove turns from the coil until it works at 12 V. I'm told this often works for 28 V relays, but let's go through the numbers and see how well.

Calculations

The relative force generated by the coil to close a relay is conveniently measured in ampere-turns, simply the current through the coil times the number of turns. If we are rewinding a relay, rather than count thousands of turns, we can simply fill the bobbin with wire and assume that the volume of wire is constant.

Using this assumption and standard US wire gauge (AWG) sizes simplifies the equations. The AWG wire diameters decrease geometrically with increasing AWG number, so that each size is approximately 1.12 times (or $10^{0.05}$) smaller than the preceding size. Using this relationship, we can calculate the number of turns per square inch, N, of bobbin cross section changes by a factor of $10^{0.1}$, or 1.26, per wire size, and the resistance, R, per cubic inch of winding changes by a factor of $10^{0.2}$, or 1.59, per wire size.

Since we are rewinding the same bobbin, area and volume are constant (k), so

$$N^2/R = k$$

Multiplying by I^2/I^2, this becomes:

$$(NI)^2 / I^2R = k$$

we can recognize NI as ampere-turns and I^2R as watts, or power.

This means that—for any wire size that fills the bobbin—the same amount of power applied provides the same number of ampere-turns. So, we need to calculate the wire size that will draw the same power at the desired voltage:

$$V_1^2 / R = V_2^2 / R$$

If V_1 is the original (higher) voltage and V_2 is 12 V, then we must increase the wire diameter by:

$$\text{number of wire sizes} = 10 \log(V_1 / V_2)$$

Remember that a larger diameter wire has a smaller AWG number. The original article had a graph, but we can easily solve this on a pocket calculator, *which they didn't have in 1956*. I've summarized the most common voltages in the following table:

Common Relay Voltages

Original	*Desired*	*# of wire sizes*
28 V	12 V	4
48 V	12 V	6
115 V	12 V	10

Procedure

The rewinding procedure is straightforward: Peel the old wire off the bobbin, measure the wire size and rewind it with larger magnet wire as calculated above. Radio Shack carries several sizes of magnet wire, which may include the one you need. Mechanical details should be much like the original relay; take notes during disassembly. The most difficult part is often prying the bobbin off the metal pole. Relays in sealed cans are a larger problem, and I welcome suggestions.

The fastest way to wind the new coil is to wrap masking tape around a dowel or pencil until the bobbin fits snugly over it. Then chuck the pencil (with the bobbin) in a variable-speed drill or lathe and run it *slowly* to wind the wire on. At *low* speeds, it's safe to guide the wire with your fingers.

Example

I found several excellent coax relays with N-connectors at a hamfest, quite cheap because they required 48 V. They were wound with #38 AWG wire. From the equation, converting from 48 to 12 V requires wire roughly six gauges larger, so I rewound one with #32 AWG wire. The original winding required 48 V at 54 mA, pulled in at 35 V and released at 15 V. After rewinding, it draws 265 mA at 12 V, pulls in at 8.5 V, and releases around 2 V. The power consumed is slightly higher now, because six wire sizes is an approximation, but I can be sure it will still operate on a low battery. My 903 MHz station now runs entirely on 12 V.

The SMA relay in my transverter was an easy one to rewind. Two screws secure the cover, and the bobbin is easily removable. The 28 V coil held pretty fine wire—I measured the diameter, guessed the enamel thickness, and estimated the wire size as #42 AWG. From the table above, the new wire should be four wire sizes larger, or #38 AWG. I rewound the coil with #38, reassembled it and tested it. The relay now switches solidly at 11 V. A better choice might be #36 AWG wire, which would give a little more voltage margin for low-battery operation, but I don't have any in the junk box. Incidentally, this relay has an unusual construction that will not operate with the coil voltage reversed, so try it both ways to find the right polarity.

Alternative

As mentioned previously, we could have just removed turns to increase the current until the relay draws the same power at the lower voltage. If we remove half the turns, the resistance drops to half. The original resistance of the 48 V relay is 48 V / 54 mA = 888 Ω. At 12 V, we need 216 mA for the same power, or a new resistance of 55 Ω, so we need one-sixteenth as many turns. We increased the current four times, so we end up with one-quarter as many ampere-turns as the original, or only one quarter as much

[1] L. B. Stein, Jr, W1BIY, "Some Hints on Relay Operation," *QST*, Jun 1956, pp 21-25.

force pulling in the relay. If we weaken the spring enough, it may work, but will it be reliable?

A few more trials convinced me that no matter how many turns of the original wire are removed from a 48 V relay, the force pulling it in at 12 V will only be 25% of that at 48 V. A 28 V relay isn't as bad—the force is only reduced by 12/28, to a bit less than half the original force. There is probably a combination of turns and spring bending that will work, but if you've done enough disassembly to remove turns, why not take the rest off and rewind it for 12 V?

International

I haven't tried modifying any relays from other countries, but it wouldn't surprise me if they use other wire-sizing systems. In the UK, they may still use SWG sizes, which differ from AWG, but the relative sizes are close enough so that increasing the diameter by the number of sizes calculated above should work. So measure the wire, convert to the nearest AWG or SWG size, and go from there. I don't know what metric standard wire is available. (The Component Data chapter of the *ARRL Handbook*[2] contains a "Copper Wire Specifications" table that lists AWG specifications with the nearest equivalent SWG.—*Ed.*)

Conclusion

Rewinding a surplus coax relay for 12 V operation requires only one simple calculation and perhaps an hour of work; why not try it rather than pay exorbitant prices or use inefficient dc-dc voltage converters? *—Paul Wade, N1BWT, 161 Center Rd, Shirley, MA 01464; e-mail* **n1bwt@qsl.net**

PAINT SPRAY HEADS AS KNOBS

◊ I needed a replacement knob for the **TONE** rotary switch on my Heathkit HW-2036A 2 meter FM transceiver. My father keeps many old things in his large garage. Among them is a one-pound coffee can full of self-propellant spray-can controls (buttons). It took about 10 minutes to find one that would friction fit over the narrow diameter shaft of the switch. Key points of this replacement knob are:

- It is very close to being the same size as the original knob.
- It is knurled.
- The knob is black with the white nozzle section, which acts as a pointer.
- The knob end (spray can control top) has an arrow indented in it that points in the same direction as the white nozzle section.
- Total out of pocket cost is nil.

I have been using this "knob" since 1989.*—ARRL Technical Specialist Lawrence W. Joy, WN8P, 2116 E Mohawk Dr, Olathe, KS 66062-2432*

A GOOD SIDETONE OSCILLATOR

◊ I've generally found that a good sidetone oscillator is difficult to find. One common approach is to build an audio multivibrator—and that does produce an acceptable sidetone. Unfortunately, it produces a square wave, and my attempts to eliminate clicks have all produced an unacceptable chirp. Other approaches I've tried also have one or more undesirable characteristics: chirp, square-wave output or no shaping of the keyed waveform. This oscillator is different. It has shaped keying, no chirp and a sine-wave output.

The basic circuit is a phase-shift oscillator with an RC network supplying the necessary 180° phase shift between the collector and base. In order for the oscillator to work, it must have enough gain to more than overcome the losses in the phase-shift network. We can, therefore, manipulate the gain to start and stop oscillation. By shifting the gain just above and below the critical point, I can shape the envelope. Since this happens without keying any of the dc paths, there are no clicks.

R2 provides emitter degeneration and makes the circuit relatively device independent. With the key down, R3 is ac bypassed, the gain of the amplifier is predominantly determined by the ratio R1 / R2, and the oscillator will run. R2 is chosen such that the oscillator will not start "full on," but rather will ramp up nicely. Smaller values of R2 produce harder keying. R2 also very helpfully provides a large base input resistance, so that the transistor does not load the feedback network.

With the key released, R1 / (R2 + R3) would determine the gain, if it were not for R4 and C1. Chose R1, R2 and R3 so that the amplifier gain is approximately 1 with the key up, and no oscillation is possible. However, R4 and C1 provide shaping of the envelope "tail." Simply adjust R4 a bit past the point where oscillation ceases with the key up, and it will be about right.

With the values shown, the circuit draws very little current, and delivers a sine-wave output with a nicely shaped envelope. With a 12 V supply, the output is about 5 V (P-P) and keying is good over the 12 to 13.5 V operating range.

There are a couple of minor bugs: The output impedance is about 10 kΩ, so the circuit requires a high-input-impedance buffer. Also, the circuit loses about three dots when you first switch it on. Since the oscillator draws so little power, I just leave it on always.*—Denton Bramwell, K7OWJ, 2853 E Country Oaks Dr, Layton, UT 84040; e-mail* **denton@cyber-west.com**

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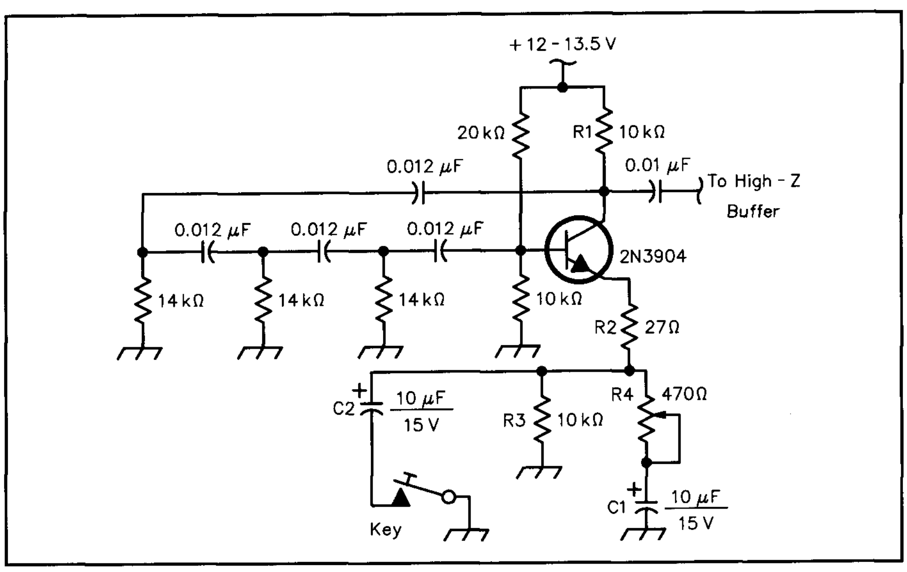

Figure 1—K7OWJ's sidetone oscillator. Use 1/4 Ω, 5% tolerance resistors, and ceramic disc capacitors except for C1 and C2, which are electrolytics. Equivalent parts may be substituted.

[2] *The 1998 ARRL Handbook* is Order No. 1743. ARRL publications are available from your local ARRL dealer or directly from ARRL. Mail orders to Pub Sales Dept, ARRL, 225 Main St, Newington, CT 06111-1494. You can call us toll-free at tel 888-277-5289; fax your order to 860-594-0303; or send e-mail to **pubsales@arrl.org**. Check out the full ARRL publications line on the World Wide Web at **http://www.arrl.org/catalog**.