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DOUG'S DESK

CONSTRUCTION PROJECTS, TECHNIQUES, AND THEORY

Using Transistors As Diodes—Some Tricks

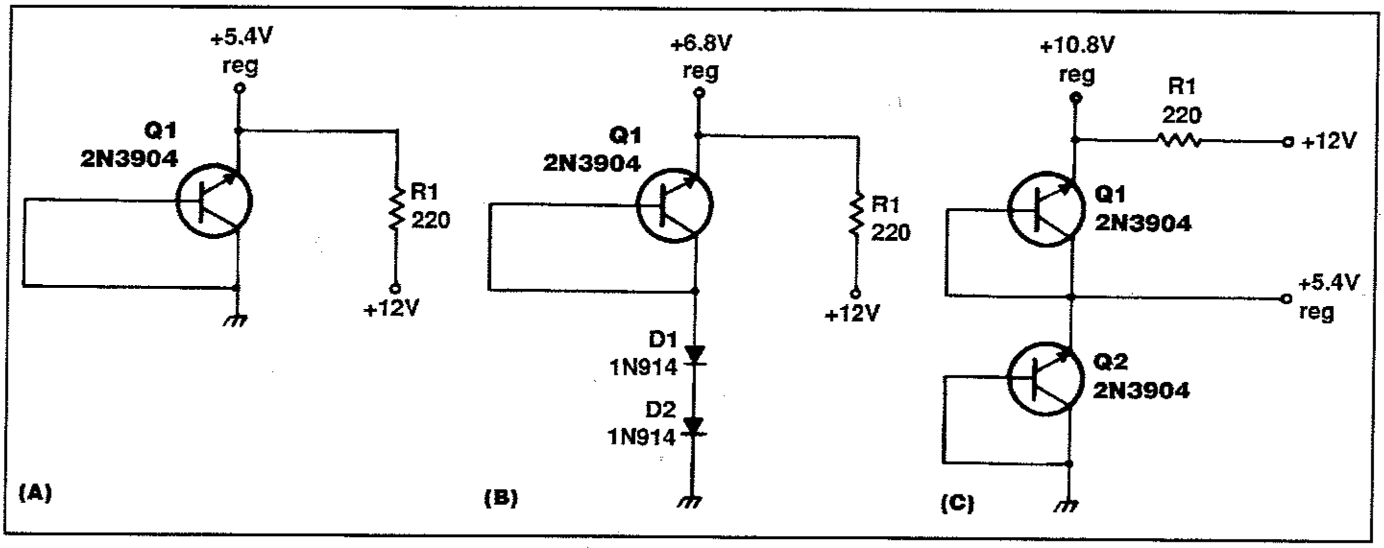

Fig. 1– Examples of NPN transistors used as diodes. Circuit (A) shows a +5.4 Vdc regulator. The regulated voltage may be increased by adding diodes, as shown at (B). Circuit (C) illustrates transistors in series to provide +10.8 V, regulated. Regulated +5.4 V is also available.

How many times have you needed a VVC (voltage variable capacitor) diode (a.k.a. Varactor) or a Zener diode, only to discover that your goodie trove was without those parts? It can happen at the most critical of times — when those parts are the only ones needed to complete a project. I know this from experience! Most of us, however, have a host of assorted small-signal NPN transistors on hand, and they can be used as voltage regulators or tuning diodes. This is not a new trick. Engineers and radio amateurs have been doing this for many years. I became aware of this approach many years ago when writing *Solid State Design for the Radio Amateur* (ARRL publication) with renown QRPer W7ZOI. Some of his circuits used bipolar transistors for the foregoing purposes. I am aware, though, that a large number of experimenters have not discovered this simple alternative to a trip to the parts store or the long wait for a catalog order to arrive. Therefore, I want to share this helpful information with the readers of *CQ*.

How It's Done

An NPN transistor—such as a 2N3904, 2N2222 ,or 2N4400—can be used in the examples given in fig. 1. Circuit (A) shows how to connect a 2N3904 for use as a low-current voltage regulator. Not all small-signal transistors regulate at 5.4 volts, as shown. Each transistor has its own characteristics. The maximum "zener" voltage I obtained was +8. You will observe at (A) in fig. 1 that positive voltage is applied through a limiting resistor, R1, to the emitter of Q1. The same method is used when working with standard Zener diodes. A 2N3904, for example, is on par with a 400 mW Zener diode in terms of the maximum power dissipation. The base and the collector terminals are grounded.

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The regulated voltage may be increased by adding silicon diodes in the Q1 ground return, as illustrated at (B) of fig. 1. Each diode you add will elevate the regulated voltage by approximately 0.7 volt. In this example the regulated voltage has risen from 5.4 (at [A]) to 6.8 volts by virtue of D1 and D2.

Two NPN transistors may be used in series to elevate the regulated voltage from that of a single transistor. This can be seen at (C) in fig. 1. Two 2N3904 transistors yield a regulated voltage of 10.8. Furthermore, a 5.4 volt tap point is available between Q1 and Q2. This can be an advantage in the event regulation is needed at a lower voltage elsewhere in the circuit. A typical example would be a VFO power source.

Power transistors in TO-220 and TO-3 packages are suitable for use as huskier regulators when used with power resistors of the appropriate wattage rating.

I would be derelict in my reporting if I failed to say that silicon junction diodes are also suitable as voltage regulators. It is a common practice to use a single silicon power diode as a bias regulator for the base circuit of a transistor RF power amplifier when it is configured for class A or AB linear service. The regulated voltage is 0.7, which is the threshold voltage for silicon diodes. Two or more diodes may be used in series to increase the value of the regulated voltage. In essence, we are using the diode junctions of the transistors when utilizing the fig. 1 circuits. When diodes are used as regulators, it is necessary to apply the positive unregulated voltage to the anode of the diode.

Transistors as Tuning Diodes

Fig. 2 shows two transistors used as diodes. Q3 acts as a varicap diode and Q2 operates as a 5.4 volt Zener diode. This circuit provides an example of a VFO that operates in the 40 meter band. The isolating buffer and amplifier stages have not been included in order to simplify the illustration.

Q3 causes frequency changes via the change in its junction capacitance as reverse voltage is applied to the emitter through R3. In other words, R3 and Q3 replace expensive, generally hard-to-find, double-bearing air-variable capacitors.

As is the situation with the voltage regulators in fig. 1, a point will be reached when the transistor current levels off and there will be no further change in junction capacitance. RFC1 isolates the VFO RF circuitry from RF ground. C3 is adjusted to provide the tuning range desired, by means of Q3 and R3.

This circuit was tested with a homemade, parallel-tuned Colpitts VFO that operates from 2.3 to 2.5 MHz. Q3 caused a frequency shift of 45 kHz. Greater changes in frequency will occur with VFOs that operate at higher frequencies, such as 5 or 7 MHz.

It is important to recognize that VVC-tuned VFOs, such as the one in fig. 2, have greater short-term drift than those which are tuned with well-designed air variable capacitors. As the Q3 (fig. 2) junction current and temperature increases upon advancement of R3, the internal capacitance of the transistor changes accordingly. Normally, short-term drift stabilizes within the first five minutes of VFO operation. Hence, the thermal problems with real VVC tuning diodes, and transistors used as varactors, can be tolerated for noncritical amateur radio applications.

The tuning range of a VFO can be extended by using two or three NPN transistors in parallel at Q3. Bear in mind that if you add transistors, the minimum capacitance of the VVC circuit will increase in proportion to the number of transistors used, up to a practical limit (usually three).

The fig. 2 VFO Circuit

Series tuning is used in the VFO of fig. 2. Q3 provides a much greater tuning range in a series-tuned circuit than if it were used in a parallel-tuned VFO. Otherwise, the fig. 2 circuit is the same as most Colpitts VFOs. Series tuning requires more inductance at L1 than when using parallel tuning. If a toroid core is selected for use at L1, it should be a temperature-stable type. Amidon (and others) no. 6 (yellow) core material is recommended if you cannot obtain a no. 7 core (white). The latter type is available from Amidon Associates, Inc.[1] The no. 7 cores are more stable than the no. 6 types. They have a permeability that is slightly greater than the no. 6 cores, but are not designed for operation above 30 MHz. No. 6 material is rated for use up to 50 MHz. The completed toroidal inductor should be doped with two coatings of low-loss sealant, such as General Cement polystyrene Q Dope. This will lock the turns in place to prevent frequency changes caused by movement of the turns during vibration or changes in ambient temperature. I discovered that Elmer's Glue, or a similar white woodworker's glue, is satisfactory as a low-loss coil cement. Tests indicated that there was no degradation of coil Q after the glue had dried, nor was there a discernible inductance change.

Fig. 2– Schematic diagram of a practical 7 MHz VFO that uses an NPN transistor (Q3) in place of an air variable tuning capacitor. Q2 is a +5.4 V regulator which is used as a Zener diode substitute. D2 and D3 serve as a DC switch for VFO frequency offset during receive. See text for information about C1 through C8. L1 has 53 turns of no. 28 enam. wire on an Amidon T68-7 (white) toroid core, or 56 turns of no. 28 enam. wire on a T68-6 (yellow) toroid core. R1 is a 10K ohm linear-taper carbon control (see text). RFC1 and RFC2 are miniature Mouser 1 mH RF chokes (note 3). ⟶

Q2 functions as a 5.4 volt DC regulator (see fig. 1[A]). D2 and D3 act as a DC switch to offset the VFO frequency during RECEIVE. This is an important feature if the VFO is used at the transmitter operating frequency. Without the offset circuit the VFO will be heard in the receiver. C7 is chosen to provide the desired frequency offset. A 10 or 22 pF NP0 capacitor should be okay for 7 MHz operation. The operating voltage for D2 and D3 is supplied through the TR relay or manual TR switch.

VFO frequency stability will be enhanced if you use polystyrene capacitors at C5 and C6. Silver-mica capacitors are less temperature-stable than the former type. C2, C4, C7, and C8 should be zero temperature (NP0) disc ceramic capacitors for best stability. C4 should be the lowest value that will ensure reliable oscillation (oscillator starting). This will greatly aid the VFO stability. Trimmers C1 and C3 need to be NP0 ceramic for best frequency stability. Small air variable trimmers are suitable as substitute components.

Typical buffer and amplifier stages that should follow a VFO are described in *Solid State Design for the Radio Amateur, W1FB's Design Notebook,* and *W1FB's QRP Notebook.* These books are available from The ARRL.[2]

A quality potentiometer is required for R3 in order to ensure smooth, reliable operation. I suggest that you use a 2 watt carbon-composition control, such as the Allen-Bradley brand. Tuning of the VFO will be less critical if you employ a 10-turn potentiometer and dial mechanism. Alternatively, a 180-degree imported vernier drive may be used with R3 to slow down the tuning rate (available from Mouser Electronics[3]).

Summary

If you are a builder of amateur equipment, you should find the tips in this article helpful. Do not be afraid to experiment with various transistors for regulator and VVC applications. You may wish to develop a file that indicates which transistors work best for these applications. You will find that most small-signal transistors cost substantially less than VVC or Zener diodes. It pays to be thrifty!

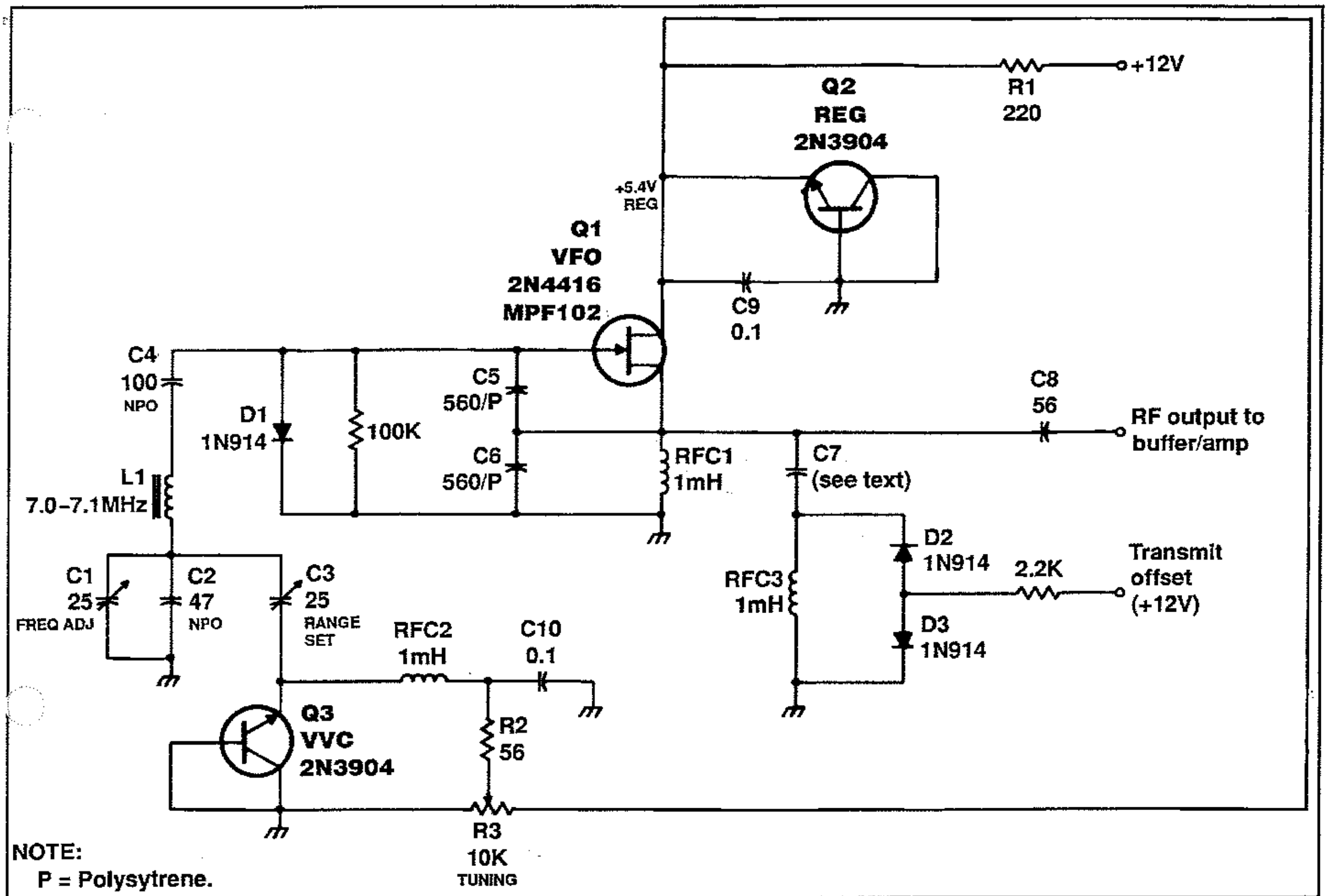
Notes

1. Amidon Assoc., Inc., 3122 Alpine Ave., Santa Ana, CA 92704. Phone 714-850-4660 for parts or a catalog.

2. The ARRL, Inc., 225 Main St., Newington, CT 06111, or ARRL book distributors.

3. Part no. 45KN012 (1.5 in. dia.) or 556-S50 (2 in. dia.). Phone 800-346-6873 for catalog or to order.

73, Doug, W1FB



NOTE:
P = Polysytrene.