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Power Supplies and Control Circuits

Contents

An RF and DC Switching Notebook

By Dave Mascaro, WA3JUF

Here is a collection of circuits I've used to switch and key transverters, preamps, power amps and IF rigs.

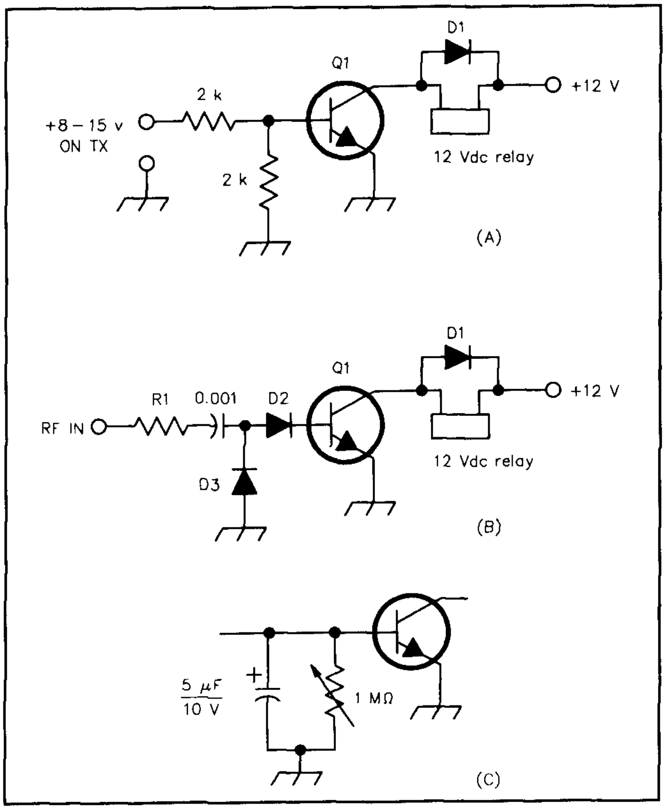

Fig 1—Relay drivers for relays with 12-V dc coils. In A, the relay is keyed from a low-current 8-15 V dc supply. In B, the relay is keyed by rectified RF. The value of R1 may range from 1000 to 10 kΩ, and must be determined. For SSB operation, the circuit in C keeps the relay from dropping out between syllables. Resistors are ¼-watt film or composition.

D1—1N4001 or equiv. (50 PIV, 1 amp).

D2, D3—Silicon switching diodes, 1N914, 1N4148 or equiv.

Q1—MPS-A13, 2N2222A or equiv.

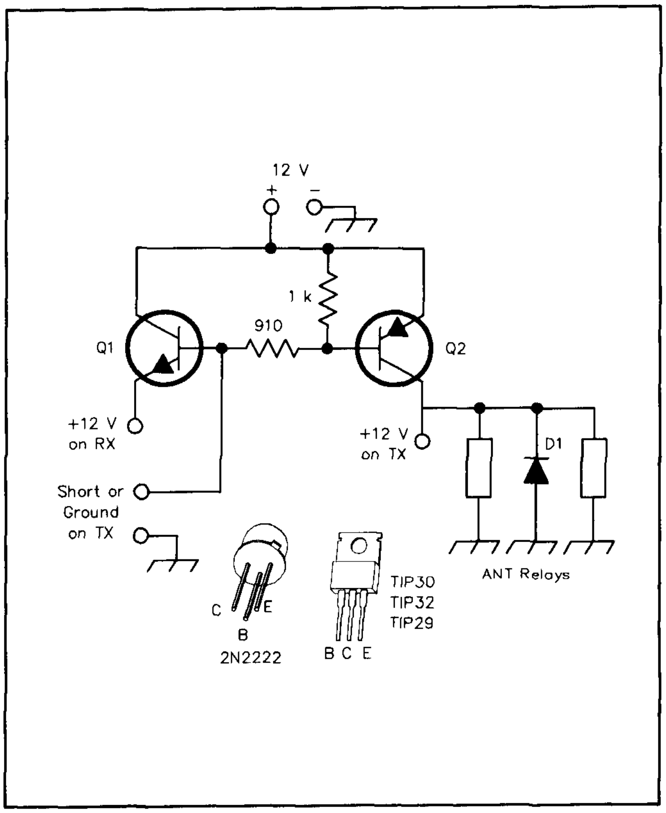

Fig 2—Transverter keying from the normally open (N.O.) contacts of the IF rig. Resistors are ¼-watt film or composition.

D1—1N4001 or equiv.

Q1—2N2222A, TIP29 or equiv.

Q2—TIP30, TIP32 or equiv.

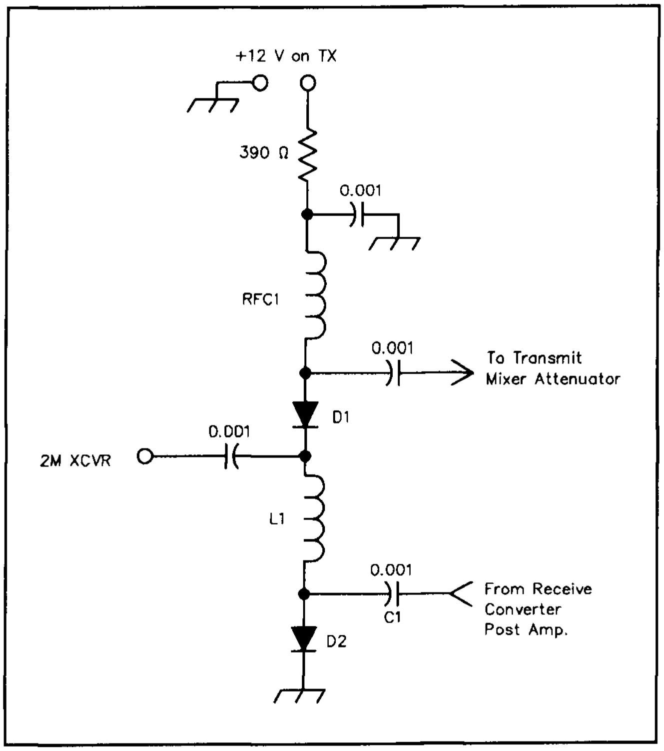

Fig 3—Transverter-RF switching of the IF. If the receive post amplifier has a dc-blocking capacitor, C1 is unnecessary.

D1, D2—PIN diodes, Phillips BA182, Motorola MPN3401 or equiv.

L1—For 2 meters: 12 turns #26 AWG, 0.1-in. dia., or λ/4 length of miniature coax at frequency being switched.

RFC1—For 2 meters: 12 turns #24 AWG, 1/16-in. dia.

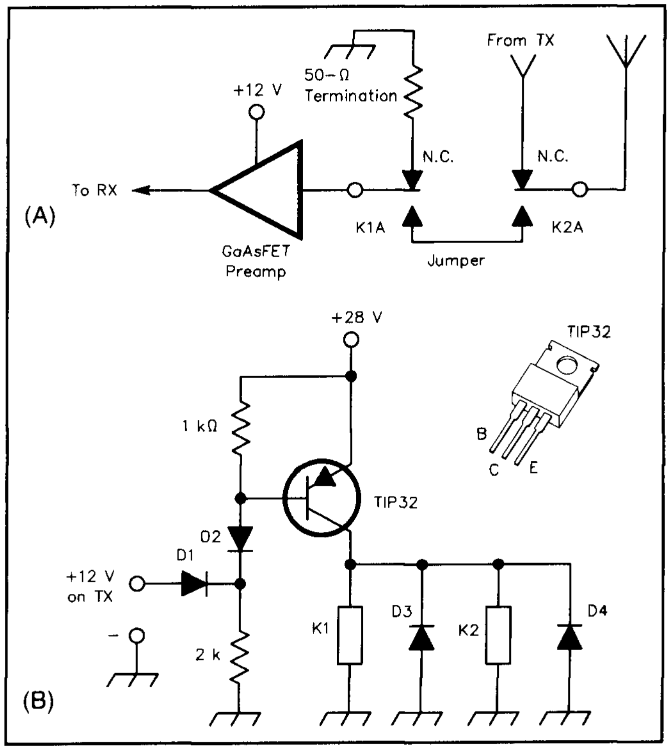

Fig 5—Switching a mast-mounted preamp. RF connections are shown at A. Use a double-male type-N adaptor for the common connection between the relays. B shows the control wiring. When control or relay power is off, the relays are in the TRANSMIT position, and the preamp input sees the 50-Ω termination. This scheme protects the preamp when the station is off the air. The preamp should be powered by a dedicated supply or NiCd batteries.

D1-D4—1N4001 or equiv.

K1, K2: Transco-type dual-coil relays.

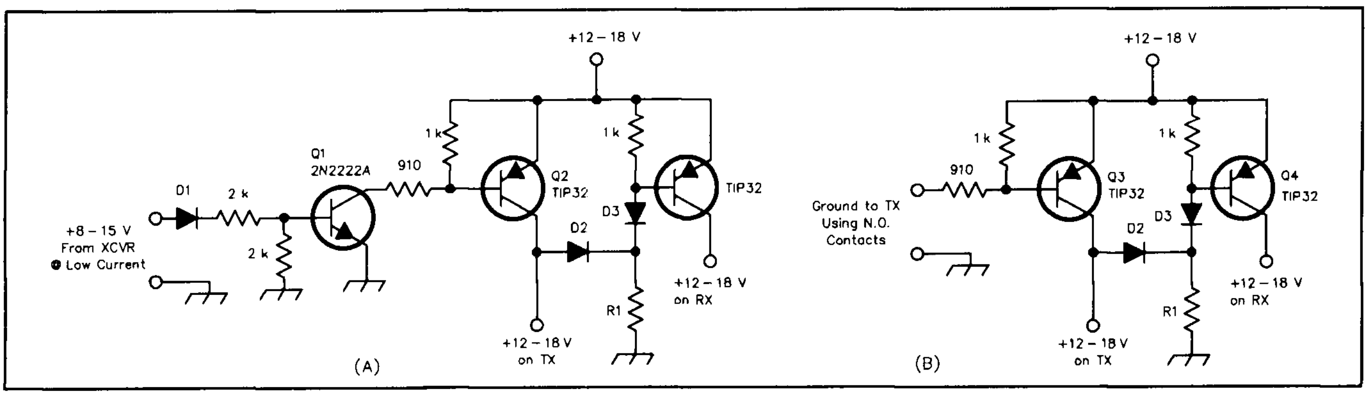

Fig 4—Transverter keying/switching. As drawn, these circuits will switch the supply between the receive and transmit sides of the transverter. At A, the circuit is switched by a +12 V signal from the IF transceiver. At B, the circuit is switched by a N.O. relay contact in the transceiver. Either circuit may be used to energize 2-coil Transco-type relays by changing R1 to 2 kΩ. Also, increase the supply from 12-18 V to 28-30 V. Resistors are 1/4-watt film or composition.

D1—Silicon diode, 1N914 or 1N4001.

D2, D3—1N4001 or equiv.

Q1—2N2222A or equiv.

Q2-Q4—TIP32 or equiv.

R1—For 12-V switching, 560 Ω; for 28-V switching, 2 kΩ.

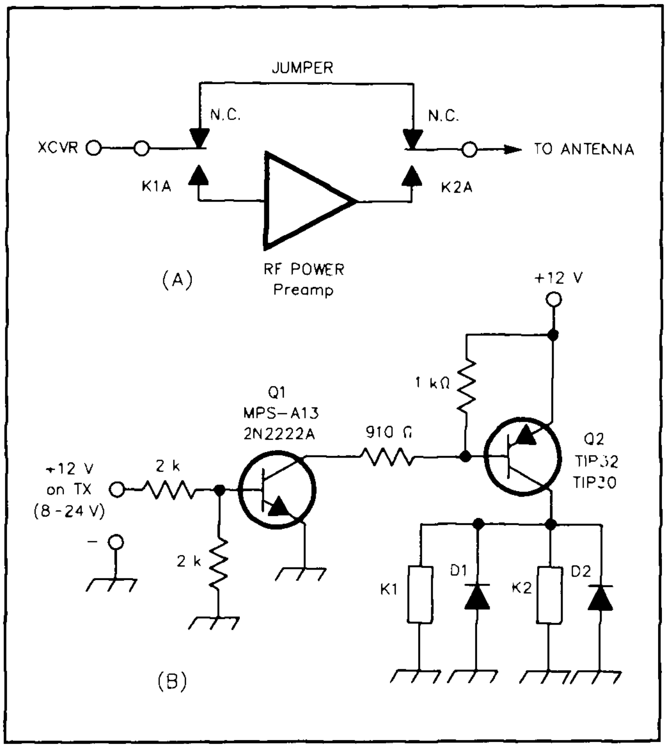

Fig 6—Switching external power amplifiers. These circuits are useful for switching "brick" amplifiers connected to transceivers. While "hard" keying with dc (A) is preferred, the RF-sensing circuit at B may be used. Resistors are ¼-watt film or composition.

D1, D2—1N4001 or equiv.
K1, K2—12 V dc miniature coaxial relays.
Q1—MPS-A13, 2N2222A or equiv.
Q2—TIP30, TIP32 or equiv.

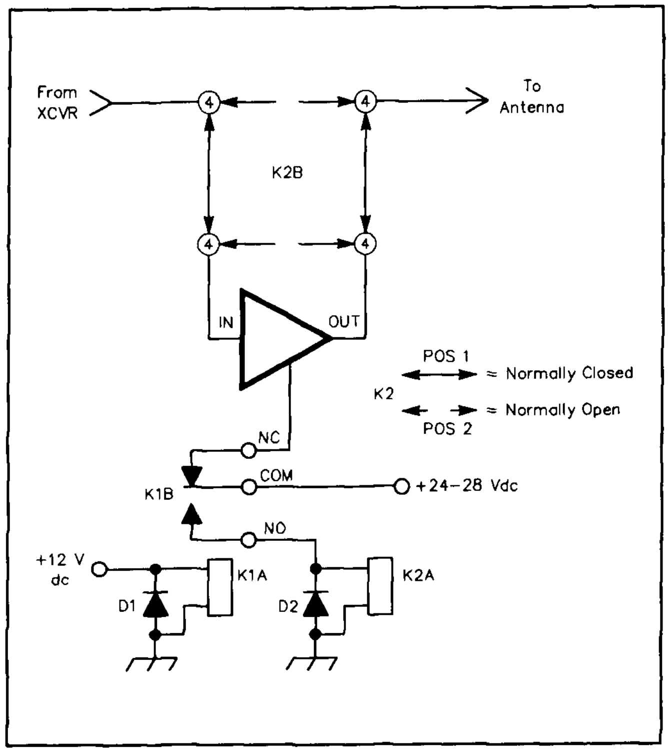

Fig 7—Using a single Transco transfer relay to select/bypass an amplifier. In this example, the amplifier is also powered from 28 V dc. K1 also removes amplifier supply voltage when the amplifier is bypassed, because the amplifier input is connected to its output by K2. An amplifier that operates from another supply voltage can be switched by substituting a DPDT relay for K1. One set of contacts is used to switch the amplifier, the other to switch K2.

D1, D2—1N4001 or equiv.
K1—Control relay, SPDT, 12-V dc coil.
K2—Transco 310C00200 transfer relay.

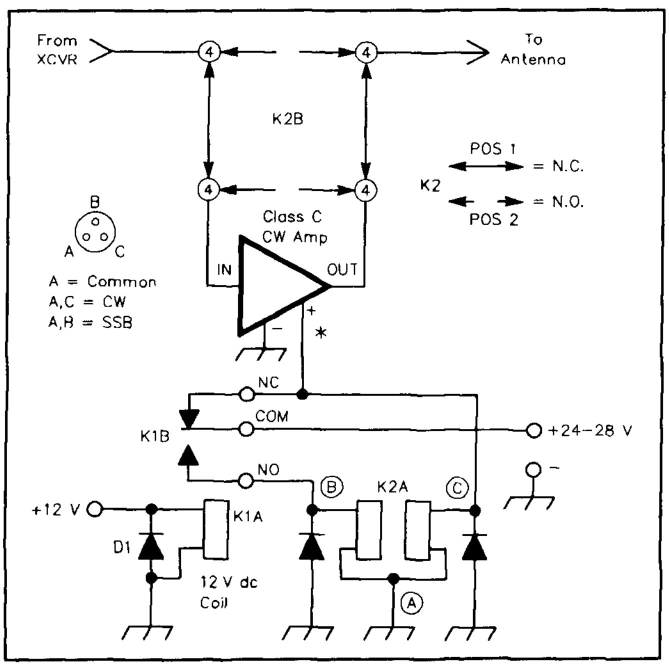

Fig 8—Using a single General Communications transfer relay to select/bypass an amplifier. K2 has two coils, unlike the Transco relay depicted in Fig 7, which has only one. See the caption of Fig 7 for information on using amplifiers operating from a supply voltage other than 28 V dc.

D1-D3—1N4001 or equiv.
K1—Control relay, SPDT, 12-V dc coil.
K2—General Communications 2NRP1 transfer relay.

How To Use PIN Diodes In A 2-Meter IF Switch

By Greg Raven, KF5N

It is rare to see PIN diode RF switches in homebrew amateur equipment. Most experimenters have probably tried building a PIN diode switch, with limited success. Excellent switches can be built that are comparable to mechanical switches in both insertion loss and isolation. A PIN diode switch is physically small and lightweight, so they are great for portable equipment. Most of the RF relays that hams have obtained via surplus channels require 28 volts, which is incompatible with the 12-volt systems commonly used. Any voltage can be used with a PIN diode switch with proper design of the bias network. This article describes the design details of a PIN diode switch that is useful for IF switching in microwave transceivers.

To RF, the PIN diode looks like a small resistor when forward biased, and like a small capacitor with zero or reverse bias. A simple narrow-band switch that has good performance is shown in Fig 1. In transmit mode, a positive bias voltage is applied to the resistor. Both diodes are forward biased.

Note that L1 and C1 form a parallel resonant circuit at the frequency of operation. The reactance of L1 is chosen to be 50 ohms. This means that this resonance is very low Q, due to the external loading, making the circuit relatively broadband. The shunt PIN diode is across the path to the receive terminal, providing very good isolation. In practice, the parasitic inductance of the diode package limits the isolation. Isolation can be improved by adding a second inductor (L2) in parallel with D2, the series diode. L2 is chosen to resonate with the *off* capacitance of the diode. This value is given on the manufacturer's data sheet. C6 blocks dc from the inductor.

In the receive mode, 0 volts bias is applied to the diodes. C1, L1 and C2, plus the capacitance of the shunt PIN form a quarter-wavelength section of lumped transmission line. The pi-section equivalent of a $\frac{1}{4}$-λ transmission line simply requires the reactance,of the shunt capacitors and the series inductor equal 50 Ω. The capacitance of the shunt PIN diode is "parasitically absorbed" into C2.

In some set-ups that use a class-A final amplifier that remains active during receive, excess thermal noise will be present at the transmit port. This noise will be conducted into the receiver via the capacitance of the series diode D2. If this is a problem, the transmit to receive port isolation can be improved by using L2/C6 to resonate with the off-capacitance of D2.

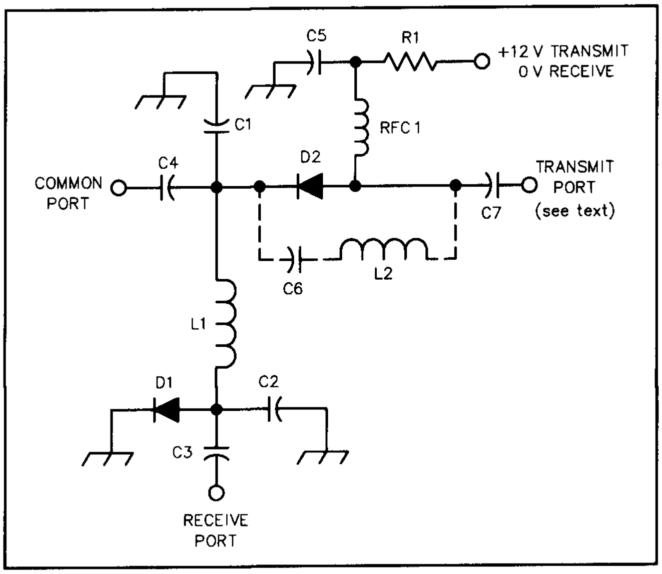

Fig 1—Schematic of a PIN-diode T/R switch. See the text for information on calculating C1 and L1. C6 and L2 may be necessary in some cases; see text for details.

C1-C7—Ceramic chip capacitors. C3-C7 are series-resonant type.
D1, D2—PIN diodes. See text.
L1, L2—See text.
R1—Calculated; see text.
RFC1—Reactance should exceed 500 Ω at operating frequency.

Resonating the series diode becomes more important with higher-frequency designs or higher-power diodes, which tend to have more *off* capacitance. The impedance of the transmitter in the *off* state can actually increase the insertion loss of the switch in the receive mode, if the isolation is not high enough. (The transmitter tends to load the switch.)

If the transmitter-to-receiver isolation in transmit mode is not good enough, another shunt PIN diode can be added. It should be incorporated into another ¼-λ transmission-line section. This extra diode typically improves isolation from about 30 dB to more than 50 dB. The disadvantage is the additional loss that the diode and other components add to the receive path. This loss should not be a problem in most applications.

Design Example

Choose a PIN diode app pF ˙ate to the power level and frequency of your application. I just happened to have a few surplus Unitrode UM9401 diodes. This diode is perfect for this kind of antenna switch. The capacitance is a relatively low 1.5 pF, while the forward ε istance is about an ohm.

Choose C1 and L1, using a design frequency of 144 MHz.

$$C1 = \frac{1}{50(2\pi)144 \times 10^6} = 22.1 \text{ pF}$$ (use a 22-pF chip cap)

$$L1 = \frac{50}{(2\pi)144 \times 10^6} = 55.3 \text{ nH}$$ (use an airwound coil, 20 gauge close spaced, 0.25 inch inside diameter, 4 turns.)

C2 = 22 pF (the shunt capacitance of D2 is small enough to ignore. No parasitic absorption of its capacitance is needed.)

$$R1 = \frac{12 - 1.5}{0.05} = 210\ \Omega$$ (Switch designed for 12 V. Assume a voltage drop of 0.75 V for each diode. Use a diode bias current of 50 mA.)

That is all there is to it. The coupling capacitors C3, C4 and C5 are series resonant. I typically use 470 pF chip caps at 2 meters.

The circuit was breadboarded "deadbug" style, using a piece of PC board. SMA connectors were used for the antenna, receive, and transmitter ports. The entire circuit is only 1.5 inches square. The circuit took about 15 minutes to build. It was measured on a network analyzer with the following results:

Transmit port to antenna port insertion loss	: 0.15 dB
Receive port to antenna port insertion loss	: 0.17 dB
Transmit to receive isolation (switch on)	: 29.2 dB
Current drain in transmit mode	: 50.0 mA
Current drain in receive mode	: 0.0 mA

This switch should be able to handle up to 50 watts in the transmit mode. The intermodulation performance of this switch in the receive mode is excellent. The circuit is useful to at least 900 MHz. For 1296 MHz and above, transmission lines are substituted for the lumped elements. I have built PIN switches for the 900-MHz band, and I am sure they will work at 1296 MHz and higher. With the right devices, low-loss switches can be made to switch kilowatt power levels.

Three Useful Circuits

By Rick Fogle, WA5TNY

LATCHING RELAY DRIVER CIRCUIT

The circuit of Fig 1 drives a latching relay that has only one coil. When the logic level at point A changes state, a pulse is applied to the coil of K1. The polarity of the pulse depends on whether the logic level is going from positive to negative, or negative to positive. The pulse duration depends on the coil resistance and the value of C1. Pulse duration should be long enough to drive the relay to its opposite state.

VOLTAGE DOUBLER

The circuit in Fig 2 operates a small Transco-type relay (SMA connectors) with a 28-V coil from a 12-V dc supply. U1 generates square waves. Together with D1, D2, C1 and C3, it forms a half-wave, voltage-doubling power supply.

VOLTAGE INVERTER

Fig 3 shows a circuit that uses a square-wave generator to provide a negative supply for FET or step-recovery diode (SRD) bias from a positive 12-V source. The output voltage is approximately equal to the input voltage, but opposite in polarity.

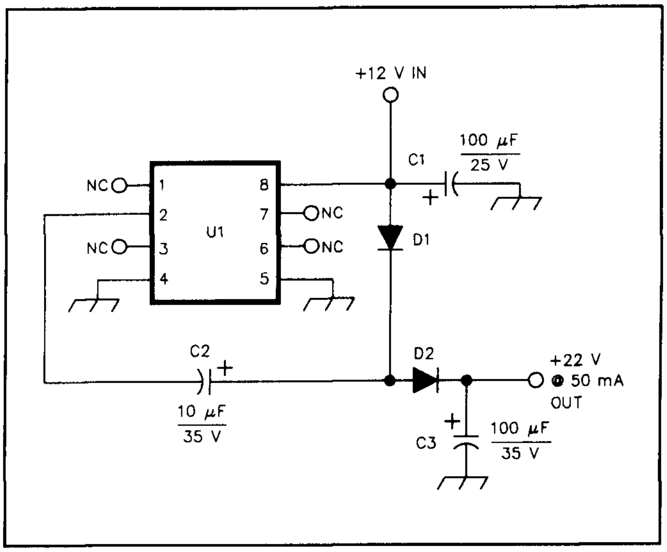

Fig 2—Voltage doubler to operate 28-V relay coils from 12-V supply.

D1, D2—1N4001 or equiv.

U1—Siliconix Si7661CJ square-wave generator.

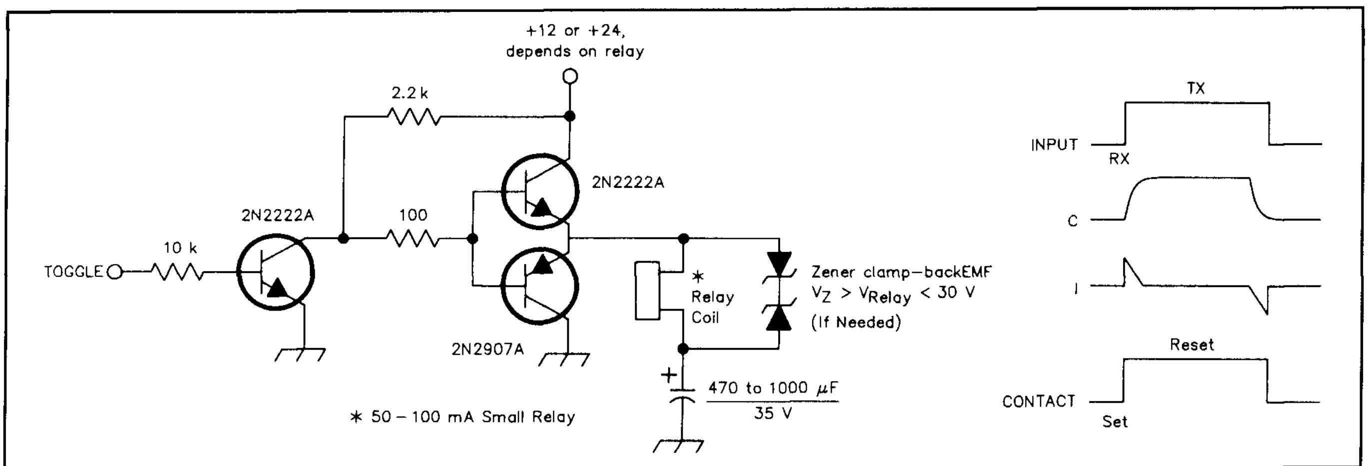

Fig 1—Latching relay driver circuit. Vcc is either 12 or 24 V dc, depending on the coil voltage of K1. The circuit shown will handle coil currents of 50-100 mA. Resistors are ¼-watt film or composition.

C1—Electrolytic capacitor, 470-1000 µF, 35 V.

D1, D2—Zener diodes; breakdown voltage should be greater than the coil voltage of K1 but less than 30 V.

K1—12- or 24-V latching relay.

Q1, Q2—NPN switching transistor, 2N2222A or equiv.

Q3—PNP switching transistor, 2N2907A or equiv.

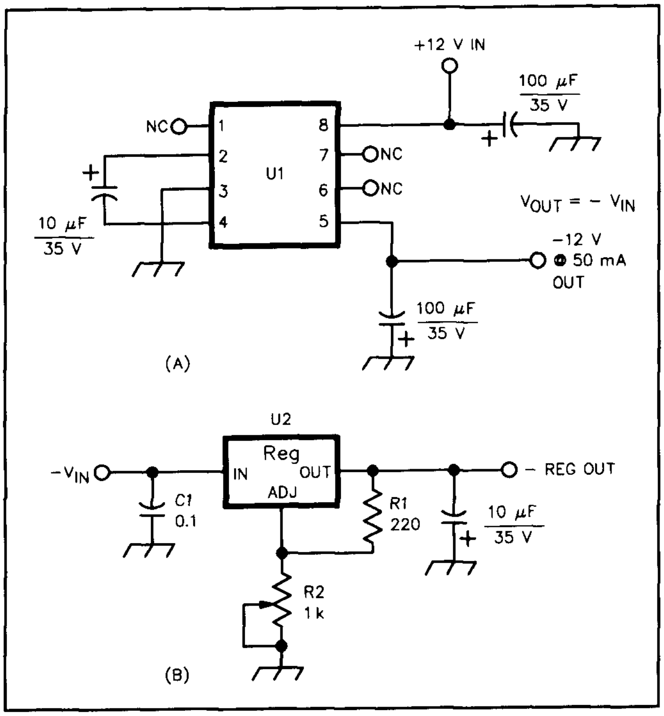

Fig 3—At A, the voltage inverter. Its output is not regulated. If regulation is needed, use the circuit shown at B. Resistors are ¼-watt film or composition.

C1—Ceramic disk, mounted close to U2.
U1—Siliconix Si7661CJ square-wave generator.
U2—National LM337L negative-voltage regulator, or equiv.

Power Supply for GaAsFET Amplifier

By Zack Lau, KH6CP

(From *QEX*, March 1991)

I have used this circuit to supply numerous GaAsFET low-level amplifiers with good results. It's an active supply to compensate for device and temperature variations. It fits in well with the no-tune concept of microwave circuitry. After all the work of coming up with RF circuitry that doesn't need tuning, why should you need a set of trimmers to adjust dc bias parameters?

Circuit Description

This circuit isn't original—a similar circuit appeared in an article by Al Ward, WB5LUA.[1] Unfortunately, the author didn't supply a printed circuit-board pattern, which is the need this article fulfills. In addition to Al's article, you may want to refer to Avantek application note AN-S003.

The negative bias generator is a simple 555 oscillator circuit feeding a diode rectifier. The use of high-speed rectifier diodes permits a higher oscillator frequency, allowing smaller filter capacitors. A high-frequency supply comes up to operating voltage faster, reducing the stress on the GaAsFETs. Common switching diodes (1N914/1N4148) will work if you don't exceed their limited current capabilities. Three-terminal regulators provide stiff voltages for the active bias circuitry that don't exceed the FET limits.

The active circuit uses R3 to set the desired GaAsFET drain current. R1 and R2 act as a voltage divider that sets the drain voltage. Don't forget that in addition to the emitter base voltage drop, there is often a drain resistor that adds yet another voltage drop.

The Hand-Waving Explanation of Circuit Operation

The circuit is based on a PNP transistor which tries to maintain 0.7 V across the base-emitter junction. If this voltage

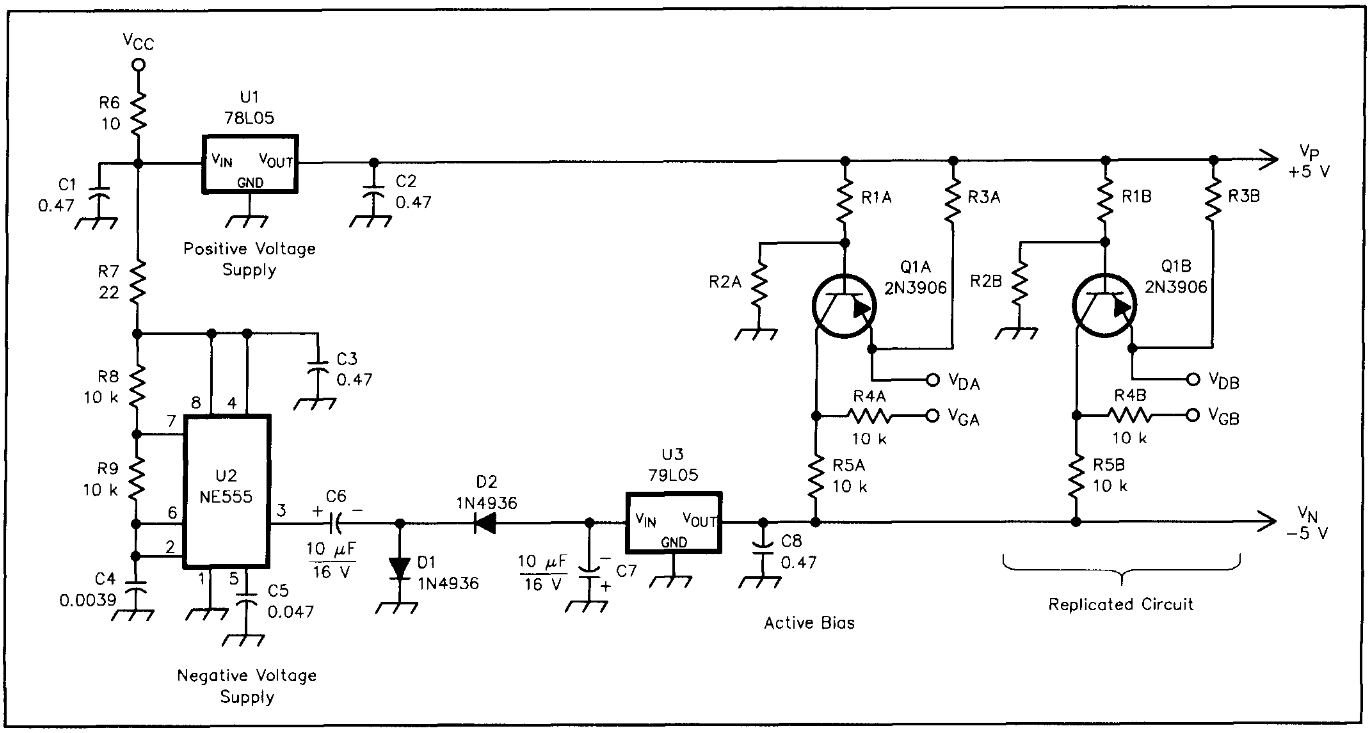

Fig 1—Schematic of the GaAsFET amplifier power supply.

is too low, the current across the base is reduced, making the FET gate voltage more negative. The more negative gate-source voltage reduces the drain current, which increases the emitter voltage. Since the base voltage is approximately fixed, the base-emitter voltage is therefore increased until it's approximately the voltage drop for a saturated transistor. Similarly, too low a drain current increases V_{be}, increasing the current across the base, making the FET gate voltage more positive, which increases the drain current.

Choosing Values for R1, R2, R3

$$R3 = (V_p - V_d) / I_d \qquad \text{(Eq 1)}$$

$$R1 = R2\,(V_{be}+V_p - V_{dd})/(V_{dd} - V_{be}) \text{ approx.} \qquad \text{(Eq 2)}$$

V_p = The positive supply bus

V_{dd}= The drain voltage supplied to the GaAsFET amplifier (don't forget any voltage drops from series resistors)

I_d = The drain current

V_{be} = The base-emitter drop (0.7 V, but temperature sensitive)

I have had pretty good luck using Eq 2 with R1 and R2 values in the low to mid-kilohm range. These equations seem to be close enough for picking standard resistor values.

Experimental Results

The resistance values are assumed to be those marked on 5% ¼-W resistors. The voltages were measured with a Fluke 77 multimeter.

R1	*R2*	*R3*	V_{dd}	V_p
2 k	3.9 k	15	3.92	5.03
2.2 k	4.3 k	51	3.99	5.04

Construction

The printed circuit board is designed to allow a variable number of devices to be powered. If you only need to power a few devices, you might wish to cut the board short. With a bit more work, more than 6 devices can be accommodated by replicating the active bias pattern and extending the board. It may be necessary to heat sink or replace the 78L05 with a bigger device if you supply too many FETs. The pads are purposely made big enough for swaged terminals, which are ideal for this application if you have access to the expensive swaging tool ($300+ new).

Reliability

Since the negative supply comes on shortly after the positive supply, questions about damaging the FETs invariably arise. So far, out of over 20 devices operating from 2304 to 10368 MHz, only one failure has been noted. I suspect this reused 72084 failed as a result of excessive heat or static dis-

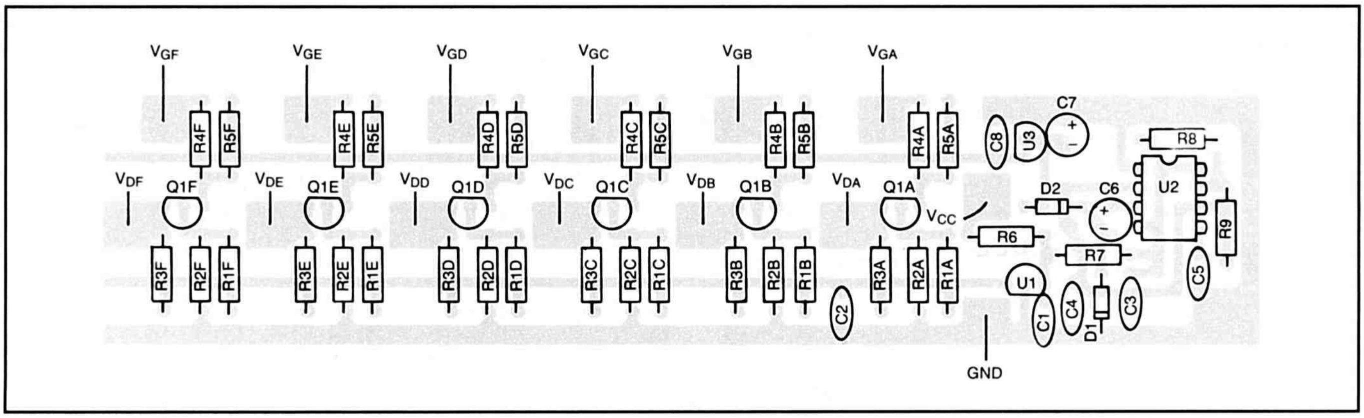

Fig 2—Component layout of the power supply.

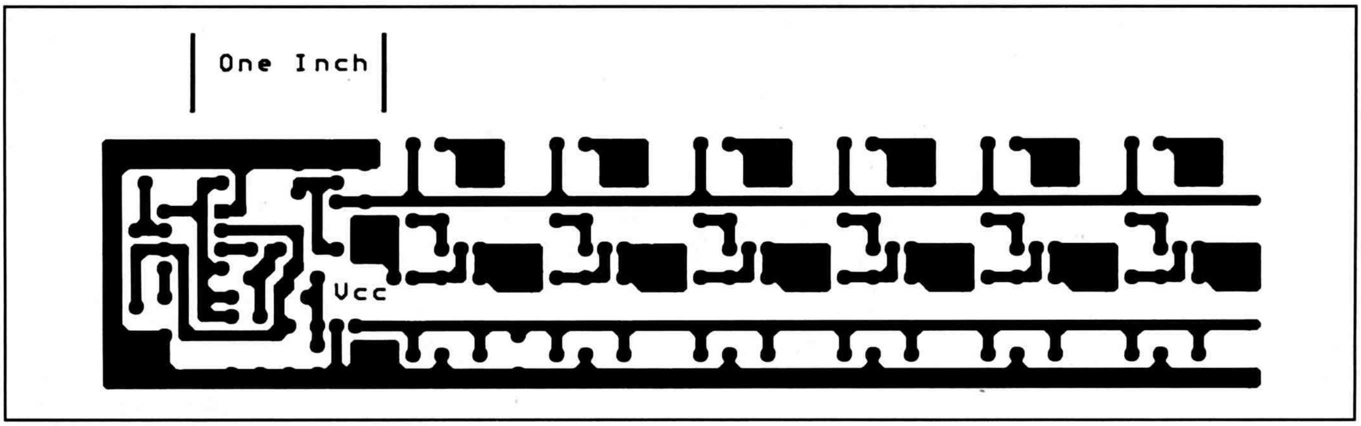

Fig 3—Etching pattern for the power supply.

charge, as it's not always easy to remove devices from circuits that didn't work as well as hoped. Actually, my biggest problem with microwave devices are the leads breaking off while attempting to reuse them!

There is a trade-off between current limiting and voltage limiting. By raising the open-circuit voltage, you can increase the drain series resistance, improving the current limiting abilities of your supply. However, if the voltage is too high, you can exceed the V_{DS} rating of the device. There are situations where a more sophisticated supply is needed to avoid exceeding device ratings. An example might be a 5-volt maximum V_{DS} FET that needs a drain bias of 40 mA at 4 V, as well as 51 Ω of series resistance for RF stability!

[1] A. Ward, "Simple Low-Noise Microwave Preamplifiers," *QST*, May 1989, pp 31-36, 75.

[2] Avantek AN-A, as well as other Avantek applications notes, are available from your local Avantek distributor. If you do not know the location of your local distributor, contact Avantek, 3175 Bowers Ave, Santa Clara, CA 95054-3292, tel 408-727-0700.