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Learning to Work With Diodes

There is probably no simpler semiconductor device than the junction diode. Diodes are inexpensive and easy to use. Despite their widespread availability, and the many applications for diodes, many experimenters are unaware of how to use them in simple circuits. This month we will explore the interesting field of diodes and show how to make them perform routine tasks in your favorite circuits.

Types of Diodes

Diodes are available in many sizes and shapes, but they function in essentially the same manner when ac or dc voltage is applied to them. The two general diode classes are high speed, low power switches (suitable for RF use into the microwave spectrum) and high current rectifier diodes for use in power supplies. There is also the LED (light emitting diode) that is used for visual indication of circuit functions, such as in combination with an ON-OFF switch. LEDs may also be used as 1.5-V reference diodes, because they conduct at 1.5 V. Silicon diodes, on the other hand, conduct at approximately 0.7 V, and germanium diodes (like the 1N34A or 1N60) conduct at roughly 0.4 V.

Voltage-variable capacitor diodes (VVC) are designed for use as RF tuning devices. They are often used instead of mechanical tuning capacitors. The voltage applied to them is varied by means of a potentiometer. The resulting change in potential causes the diode junction capacitance to vary in a reasonably linear fashion. Tuning diodes are sometimes called "varactors" (variable reactance diodes). Special varactors are available for frequency multiplication (like 144 MHz to 432 MHz). They must be used with appropriate high-Q tuned circuits. Frequency multiplication occurs when a few watts of RF power are applied to the input circuit. Varactors require no operating voltage and produce a fair amount of RF power at the chosen output frequency. Efficiencies as great as 70% have been obtained with varactor multipliers.

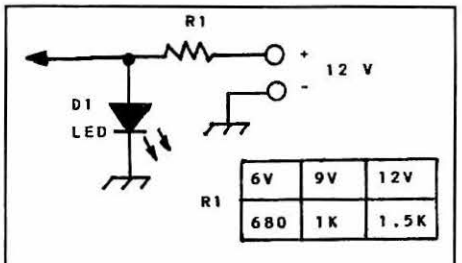


FIGURE 1: LEDs are used as visual indicators by dropping the supply voltage to a safe value. R1 is chosen to limit the LED current to 6-8 mA dc. R1 values for three common supply voltages are provided.

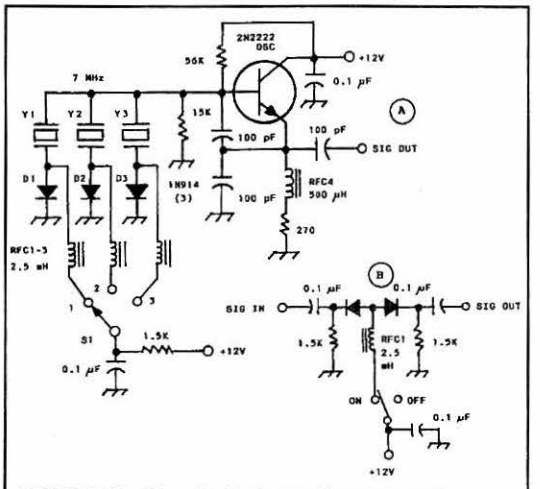


FIGURE 2: Circuit A shows how to use diodes for switching three oscillator crystals. S1 routes the diode turn-on voltage to the crystal of choice. The circuit at B illustrates how diodes can be used as series switches in a signal line.

How to Use LEDs

As I stated earlier, LEDs conduct at 1.5 V dc. A typical LED draws 8-10 mA of current when illuminated. The higher the current the brighter the glow, but the shorter the LED life span. It is a good idea to limit the current (choice of series resistor value) to 6-8 mA for all-round reliable performance. Figure 1 lists R1 values for three common operating voltages.

You may tap into the junction of R1 and D1 to obtain a low current regulated voltage of 1.5. The current drawn by the external circuit must be taken into account when choosing the value for R1. This resistor will need to be lower in value as the total circuit current is increased. The steady-state current taken by the external circuit should not exceed 5 mA.

Diodes as RF Switches

Small-signal, high-speed diodes of the 1N914 class may be used as dc switches for selecting crystals or L and C tuned circuits. An example of crystal switching is provided in Figure 2A. When a positive voltage is applied to the anode of the diode it conducts and creates a short circuit to ground. A mechanical switch is used to activate the diodes when selecting the crystals. An RF choke is used to isolate the RF energy from circuit ground.

Figure 2A shows the shunt method for diode switching. The circuit at B may be used for series switching in signal lines. Sufficient current must be allowed to flow through the diode junction in order to minimize the dc resistance of the junction. Allow approximately 20 mA of current to flow for complete 1N914 diode turn-on. Small rectifier diodes can also be used as RF switches in most circuits that operate below 10 MHz.

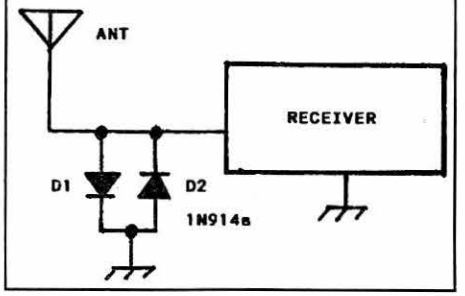
Receiver Input Protection

Small-signal diodes of the 1N914 class are useful for protecting the front-end circuits of receivers when the diodes are used back-to-back, in parallel, as shown in Figure 3. Two diodes connected in this manner will conduct on positive and negative RF sine-wave peaks of 0.7 V or greater. This creates a short circuit across the receiver antenna jack. The diodes do not conduct at RF signal levels below 0.7 V. This makes them "invisible" to the receiver under normal conditions.

This form of protection is especially worthwhile when receivers are used near transmitters or when the receiving antenna is close to a transmitting antenna. If strong nearby commercial radio stations cause the diodes to conduct partially, you may hear spurious signals in your receiver because of rectification effects. If this happens, use two 1N914 diodes in series for each leg of the protective circuit. This will increase the effective diode threshold voltage to 1.4. The diodes will still protect your receiver front end.

Diodes Used With Voltage Regulators

FIGURE 3: Back-to-back diodes can be used, as shown, to prevent damage to receiver input circuits when high level RF energy is picked up by the receiving antenna.



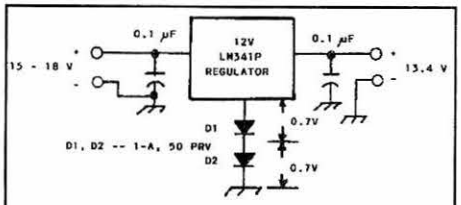


FIGURE 4: The dc output from a voltage regulator IC can be increased by inserting one or more diodes in series with the ground lead of the IC. Each silicon diode will elevate the regulator output by 0.7 volt.

Figure 4 illustrates how you can add one or more diodes to a three-terminal voltage regulator to increase the regulated dc output voltage. For example, one diode in the ground lead of a 5-volt regulator will increase the output voltage to 5.7. Two silicon rectifier diodes in series would increase the output voltage to 6.4. Each diode used will add 0.7 volt to the dc output. The best diodes to use for this application are 1-A, 50-or 100-PRV units.

Polarity-Guarding Diodes

It is not uncommon for an experimenter or ham operator to mistakenly reverse the positive and negative leads of a power supply or battery when attaching the power source to a piece of equipment. Severe damage can occur to the equipment semiconductor devices and electrolytic capacitors if this error is allowed to occur. I once ruined the power-amplifier transistors in a Yaesu FT-301D when I cross-connected a 12-volt battery to the system. It taught me an expensive lesson!

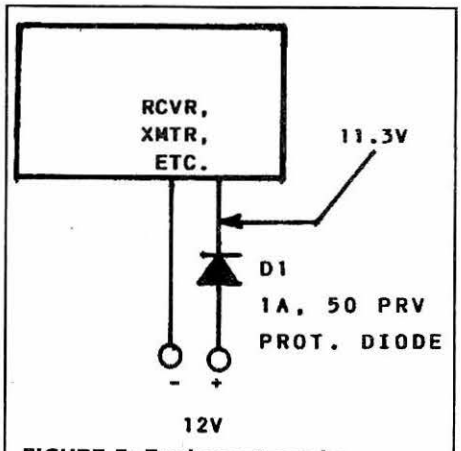


FIGURE 5: Equipment can be protected from cross-polarization of the supply voltage if you install a series diode in the supply line.

You can add a polarity-guarding diode in series with the dc supply voltage to your equipment, as shown in Figure 5. Connected in this manner, positive dc current can flow into the equipment, but negative dc current will be blocked. When this method is used there will be a voltage drop of 0.7 across the diode.

Most home-made and commercial apparatus will work okay at, for example, 11.3 volts rather than 12.0 volts. The diode chosen for this application must have a current rating in excess of the current taken by the equipment. Thus, if a transceiver draws a maximum current of 10 amperes, the diode would be rated at 15 or more amperes to allow a reasonable safety factor.

You should consider mounting large diodes of this type on a heat sink. This will prevent diode junction overheating. Heat sinks are not needed for lower current drains, such as 3 amperes for a 6- or 10-ampere diode.

Diodes as Speech Clippers

The positive and negative voice peaks in a transmitter can be clipped off by means of two small-signal diodes, such as 1N914s. This increases the average talk power, which makes the transmitted signal appear louder. Diodes generate harmonic currents when used as shown in Figure 6. Therefore, some type of filtering is required after the diode clipper in order to help restore the audio to a sine wave. This can be done with resistors and capacitors, or by means of capacitors and inductors. This type of circuit has been used for many years in 2-meter FM transceivers.

Diode Detectors and Mixers

One of the earliest radio receivers developed was called a "crystal set." A piece of galena was used in combination with a "cat's whisker" wire to form a diode junction that would rectify (demodulate) broadcast band AM signals and convert them to pulsating dc which produced voices and music in a pair of ear phones. A simple crystal radio circuit is shown in Figure 7. An earth ground and a random-length wire antenna are all that you need to hear strong BC

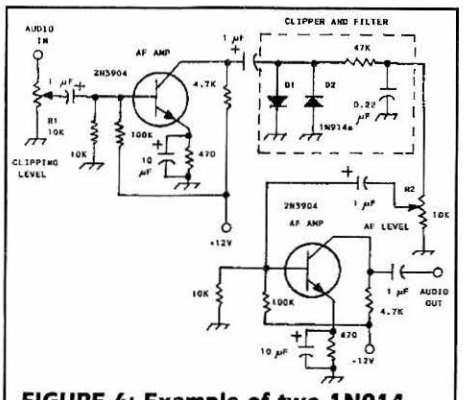


FIGURE 6: Example of two 1N914 diodes in a speech clipper circuit. R1 sets the clipping level and R2 determines the magnitude of the clipped and filtered audio.

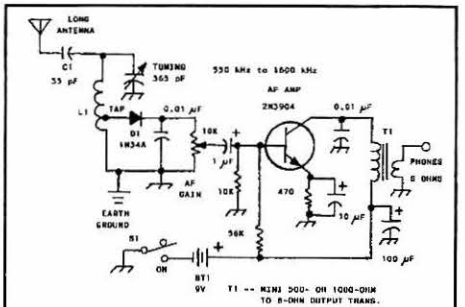


FIGURE 7: Diagram of a simple crystal radio that uses a 1N34A germanium diode. L1 (220 µH) for best station separation (high Q), consists of 85 close-wound turns of no. 22 enamel wire on a 3-inch length of 2-3/8 OD PVC pipe, or equivalent insulating form. C1 may be smaller in value to obtain greater Q, if some signal loss is acceptable. Tap L1 at 15 turns above the grounded end (do not allow adjacent turns at tap point to short circuit).

band stations. A 1N34A or other small signal germanium diode may be used as a detector for maximum sensitivity. A 1N914 can also be used, but it may not respond to weak signals because of its higher barrier voltage.

Diodes are used also in receiver and transmitter mixers, and in receiver product detectors. The preferred diodes for mixers (usually four in combination) are known as "hot carrier" diodes. Rather than containing a silicon sandwich type of junction, these diodes have a sort of cat's whisker that contacts a small piece of semiconductor material. The internal capacitance and resistance of hot-carrier diodes is much lower than that of small signal junction diodes. This makes it easier to select matched pairs of diodes for circuits that require excellent electrical balance (such as mixers and balanced modulators).

Summary Comments

Use care when selecting a diode for a particular task. The PRV (peak reverse voltage) or PIV (peak inverse voltage) rating should exceed the normal circuit voltage in order to prevent diode damage. The diode current rating is important also. Make certain that it is greater than the current that will flow through it. Also, avoid using power-supply diodes for most RF applications. These diodes will, however, be suitable for use in audio circuits. The cathode ends of many diodes are marked with a band. Other diodes have the diode electrical symbol printed on them to make identification of the anode and cathode ends an easy matter.