7 circuits for Tunnel Diodes

These transmitting and receiving hookups will interest the experimenter.

By **CLIVE SINCLAIR**

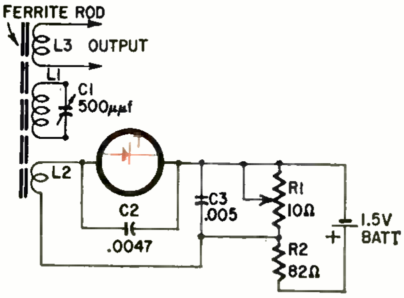
Tunnel diodes have been around a fair length of time now. We've seen several experimental circuits using them in different ways. Here, we will present circuits that show how the tunnel diode can be used as an rf amplifier and i.f. amplifier, in medium-wave and FM receivers and in an FM transceiver.

Fig. 1 shows how a tunnel diode might be used as an rf amplifier. The coils are wound on a single ferrite rod. L1 and C1 form a resonant circuit tuned to the frequency required. The tunnel diode, a 1-ma type, is biased to a negative portion of its curve by R1 and R2, which form a voltage divider across the battery.

L2, C2 and C3 form a broadly tuned circuit whose dynamic resistance must be numerically less than the negative slope resistance of the tunnel diode. Under this condition we get amplification because the negative resistance of the diode cancels some of the positive resistance of the tuned circuit, thereby raising its Q. Rf gain is thus obtained in much the same way as in a regenerative detector.

How much gain this circuit gives depends upon how close the numerical value of the tunnel-diode resistance is to the dynamic resistance of the tuned circuit—the smaller the difference, the higher the gain. If the diode's negative resistance is numerically greater than the positive resistance of the tuned circuit, the circuit will oscillate—all the resistance of the tuned circuit will have been cancelled. To get maximum gain short of oscillation, alter the diode resistance by adjusting R1. Maximum gain will be around 30 db.

Fig. 1—Tunnel-diode rf amplifier.



The same procedure works for an i.f. amplifier, with more practical results. The circuit of Fig. 1 would have to be readjusted for maximum gain each time the signal frequency was changed. In an i.f. amplifier, the frequency remains constant and retuning would not be needed.

To get gain with the circuit of Fig. 2, the diode's negative resistance must be numerically greater than the input and load impedances in parallel. Also it must be numerically less than the load impedance, which includes the shunt loss of the tuned circuit. Since it is inconvenient to vary input and output impedances to adjust the slope resistance of the diode for maximum stable gain, we have included R1 for this adjustment.

Both circuits (Figs. 1 and 2), may appear unusual, yet are conventional in the sense that they use an accepted method of amplification with a negative resistance device. Neither Fig. 1 nor Fig. 2 presents an attractive circuit because the same thing can be done better with transistors. However, at much higher frequencies, similar circuits could be used where transistors would be useless.

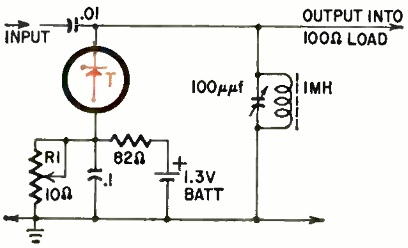


Fig. 2—Tunnel-diode 465-kc. i.f. amplifier.

Detector circuit

Unlike these circuits, Fig. 3 is both new and potentially very useful. It was developed by Standard Telephones & Cables Ltd. (S.T.C.), England, as was the circuit of Fig. 2. The circuit, then, is a detector, but one that provides full-wave rectification with only a single diode. This is done by biasing the diode to its peak current point (P in Fig. 4), so that either a negative- or positive-going signal will reduce conduction.

This might be purely academic were it not for one important advantage this detector has over a conventional one: It is sensitive to very low input voltages. An ordinary detector diode has a contact potential to overcome before efficient demodulation can occur,

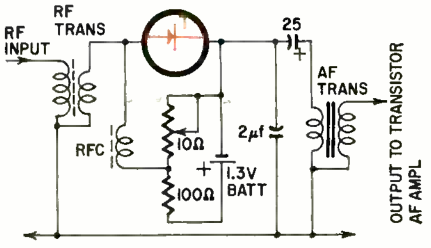
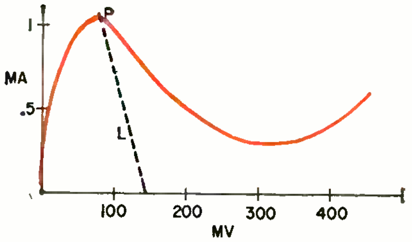


Fig. 3—Tunnel-diode detector circuit.

Fig. 4—Characteristic curve showing the point (P) to which the tunnel diode in Fig. 3 is biased. L is a load line.



the forward and reverse conductances being very much the same at very low signal levels. This means that, in a receiver, the signal has to be amplified considerably by rf or i.f. stages before being applied to the detector. Were this not so, more of the gain required in the set could be obtained by audio amplification, which is cheaper and simpler. With a detector such as in Fig. 3, such an arrangement would be possible and the cost of a set could be reduced. At ordinary AM broadcast frequencies the saving might not be very great but, in the vhf and uhf regions, rf gain becomes increasingly expensive and saving several stages becomes attractive.

As a demonstration of the potentials of this detector S.T.C. has built a medium-wave receiver in which the whole rf section consists simply of the circuit of Fig. 1 combined with that of Fig. 3. In this circuit L3 in Fig. 1 replaces the secondary of the rf transformer in Fig. 3. The audio transformer has a stepup ratio of about 3 to 1 to match the very low output impedance of the detector to that of a four-stage transistor audio amplifier. Because it needs delicate adjustment, the receiver, as it stands, is really suited only to single-station operation but it bodes well for the future of similar arrangements at very much higher frequencies.

Vhf/FM circuitry

In medium-wave receivers the transistor is so successful and well established that it is unlikely that the tunnel diode will find much application. The situation is much more promising in the FM band since transistors that can amplify and oscillate at 100 mc with a low noise level are still comparatively expensive by domestic equipment standards. They also require more complex circuits than do tunnel diodes in similar circumstances.

Tunnel diodes will probably be confined to the front end in FM receivers because transistors are more satisfactory in the i.f. sections. The same applies to receivers at all frequencies right up to the microwave region. Tunnel diodes will amplify the rf signal and reduce it to an intermediate frequency which can be comfortably handled by transistors.

The conventional transistor FM front end consists of a single-stage rf amplifier and an autodyne converter that combines the functions of mixer and oscillator. A similar arrangement with tunnel diodes needs only about half the number of auxiliary components. Compare the circuit of a typical FM front end using transistors (Fig. 5) and one with tunnel diodes (Fig. 6). The latter is not only simpler but is also likely to have a considerably lower noise level, of vital importance in this

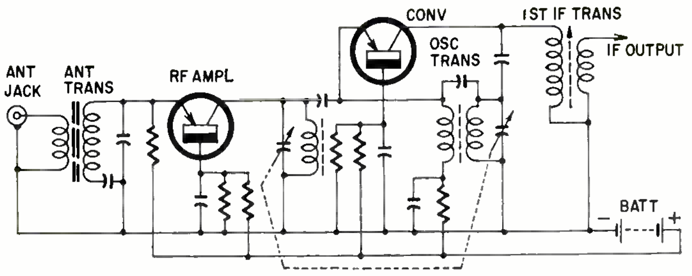


Fig. 5—Typical transistor FM front end. Compare with Fig. 6.

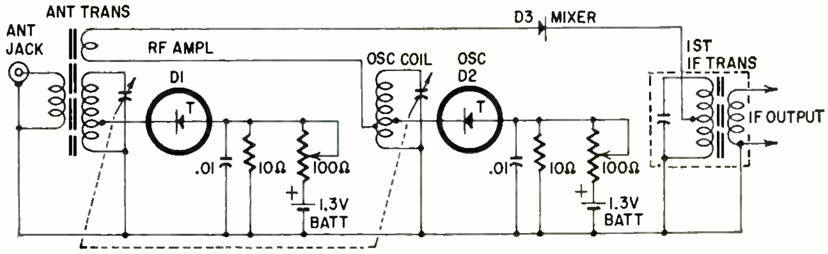


Fig. 6—FM front end using tunnel diodes. It's much simpler than circuit of Fig. 5.

type of unit. The conversion gain may be slightly lower under some circumstances but this is of no particular importance when the noise level is very low since most of the gain of an FM tuner is in the i.f. strip.

In Fig. 6, D1 is the rf amplifier. The circuit is arranged so the diode is tapped into a part of the tuned circuit with a dynamic resistance just less than the numerical value of the diode slope resistance over the negative part of the curve. Gain is controlled by adjusting the voltage across the diode and is limited either by the amount of gain that can be achieved before instability occurs or by the need to maintain an adequate bandwidth in the tuned circuit.

One advantage of the tunnel-diode amplifier over transistor types is that only a single tuned circuit is necessary and no additional input transformer is required. D2 is the oscillator and operates in much the same way, except that the dynamic resistance of the tuned circuit is higher than the negative resistance of the diode. The oscillator circuit is also very simple because no feedback coil or capacitor is required. The oscillator and rf signals are mixed in D3, a conventional diode. The circuit as shown is suitable for tunnel diodes with peak currents of around 1 ma. They can be powered by a single mercury cell instead of the two shown.

A tunnel diode may be used as a mixer in place of a conventional type—Fig. 7 is one possible circuit. It is also possible to use the same tunnel diode both as oscillator and rf amplifier and even as the mixer, but adjusting such a circuit is difficult. Trouble arises because it is impossible to make all the adjustments required simply by varying the voltage across the diode, and some means has to be included to vary the Q of the tuned circuits. Since this also changes the frequency to which the circuit is tuned, precise adjustment is a long and troublesome process.

Best results with a new component are often obtained by using unconventional circuitry. This may well be true for the tunnel diode in FM tuners. Fig. 8 is the circuit of a complete FM tuner. The principle on which it works was discovered at S.T.C. in the course of experiments designed to produce a superregenerative circuit. The tuner is basically a synchrodyne receiver. Though little used and not well known, the synchrodyne has several advantages over the superhet or the trf. It is

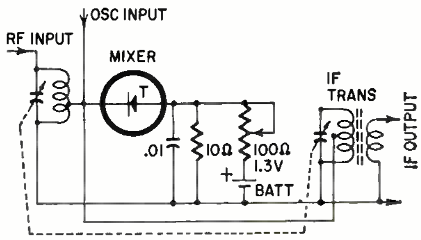


Fig. 7—Mixer circuit uses a tunnel diode.

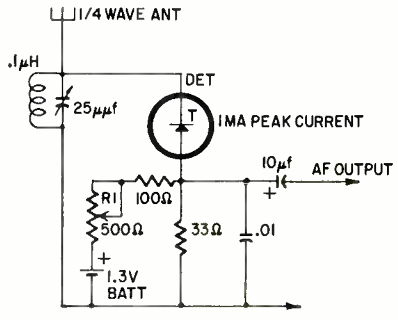


Fig. 8—Complete FM tuner needs only one tunnel diode.

most easily described as a superhet in which the intermediate frequency is zero cycles per second or dc. The local oscillator and signal frequencies are identical except that the latter is modulated. When the two are mixed, the difference output is simply the audio content of the original signal so no i.f. strip, as such, is required. The advantages of this system are low cost, simplicity and control of the bandwidth by the bandwidth of the audio amplifier.

The tuner in Fig. 8 uses a tunnel diode biased to its negative resistance region so that oscillation occurs at the resonant frequency of the tuned circuit. This circuit is tuned to the center frequency of the FM signal to be received. As the FM signal deviates from its center frequency the oscillator keeps in step with it, but the Q and hence the dynamic resistance of the tuned circuit drop rapidly as the deviation increases. The diode resistance alters in step with this so as just to cancel out the conductance of the tuned circuit and cause oscillation. As the diode resistance alters in sympathy with the modulation of the FM signal so does the voltage across it, and this forms the receiver's audio output.

The audio signal from the tuner is, of course, very small but not too small to be handled comfortably by a suitable audio amplifier. For speaker operation, feed the tuner output into a four-stage transistor amplifier. If you use a stepup transformer with a turns ratio of about 6 to 1 between the tuner and the amplifier, only three stages may be needed. If a sensitive earpiece is used one stage less will be necessary in each case.

The tunnel diode should have a 1-ma peak current (a 0.5-ma type may be used if all the resistor values are doubled) and should be a low-capacitance type such as the Philco T1925 or one of the G-E diodes. The coil may be five turns of stiff copper wire wound to a length of ½ inch on a ¼-inch diameter form.

The one disadvantage of this circuit, as it stands, is that R1 normally has to be adjusted when a new station is tuned in. This could be overcome by using several preset resistors (one for each station required), and switched tuning. It may also be possible to devise a simple control circuit that automatically adjusts the bias voltage to the correct level. The quality is excellent and from every other point of view the circuit is very satisfactory indeed. No difficulties should arise in building one of these sets.

One feature of the circuit in Fig. 8 which should not be overlooked is the ease with which it may be turned into an efficient low-power FM transmitter. Simply connect a low-impedance dynamic microphone (a miniature speaker works very well) across what are now the output terminals. To produce a deviation of ±75 kc, the microphone must provide about ±10 mv. The range of the transmitter should be about ¼ mile under good conditions, but is limited by the tiny output from the diode.

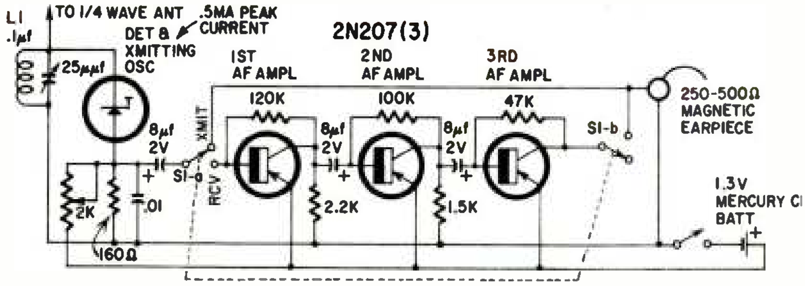


Fig. 9—FM transceiver uses tunnel diode front end and three-stage audio amplifier

Complete FM transceiver

A very simple fm/vhf transceiver may be built by using the synchrodyne principle for the receiver. The complete circuit for such a unit is shown in Fig. 9. Three subminiature transistors are used in the high-gain audio amplifier; the 2N207 was chosen because of its ability to operate well from a 1.3-volt cell. Since the total consumption of the set is less than 3 ma, a tiny Mallory RM-675 may be used as the battery and will give about 35 hours life. The earpiece also acts as the microphone and should be a very sensitive type such as those designed for use with hearing aids. S1, the TRANSMIT-RECEIVE switch, a dpdt type, is shown in the transmit position.

Coil L1 consists of five turns wound to a length of ½ inch on a ¼-inch diameter form. The diode must be a ½-ma type to make the input impedance in the transmit position as high as possible.

By using subminiature 0.1-watt resistors and tantalum capacitors throughout the unit, the transceiver could be made no larger than a matchbox and yet give remarkably good performance.

The future

One of the first applications could be a new type of remote control for TV receivers using a tunnel-diode transmitter, possibly operating in the vhf band, to avoid the need for a lengthy aerial. Such a device would be small, light and versatile—numerous controls being possible with a single unit. Tunnel diodes are likely to be used in pocket FM receivers operating in the vhf broadcast band. They may also be applied to Citizens-band transceivers.

Tiny Citizens-band transceivers small enough to fit into a buttonhole could be developed. While these would have only a limited range because of their small output power, they might be very useful for interoffice, factory and home communications.

Tunnel diodes are likely to appear in TV receivers too, particularly in the front end. Their ability to act as very low level detectors might well prove useful since it could reduce the number of i.f. stages considerably. This may lead to a small revolution in TV receiver design and could accelerate the development of small portable and pocket-size TV receivers. END