Number 26 on your Feedback card

Intro to Superhets

Part 3: Accessories and conclusion.

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The addition of accessory circuits allows the superhet receiver to be used in many applications that might otherwise be avoided. An accessory circuit in any receiver is any circuit, other than the power supply, that makes the receiver more useful to the user and does not take part in receiving the signal. Circuits falling into that category are AVC, AGC, AFC, noise limiter, S-meter, tuning meter, squelch, and BFO. Each circuit contributes to the comfort and convenience of the user.

AVC-AGC

AVC and AGC circuits are essentially the same and are used for the same purpose, that is, to reduce the gain of controlled stages based upon the level of an incoming signal. AVC stands for Automatic Volume Control; it was used to control receiver gain in AM radios as shown in **Fig. 1**. The objective was to provide a means for adjusting the signal level at the detector in order to provide a fairly constant audio level recovery as various stations were tuned and when the signal amplitude of a selected station varied due to propagation changes. The AVC voltage was developed at the AM detector as the rectified output from the received signal which made the voltage proportional to the amplitude of the received signal.

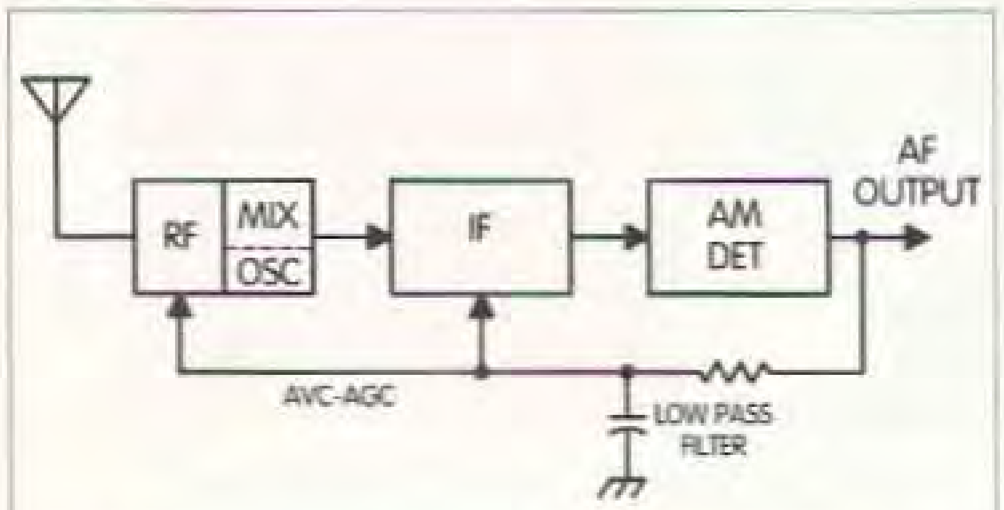

Fig. 1. AVC-AGC voltage derived from the detector and used to control the gain of the RF and IF stages.

When television came into being, a concern for controlling the picture contrast developed. AVC was then used in TV sets for controlling the contrast, but now audio "volume" was not of concern so the name was changed to AGC for Automatic Gain Control. The AGC function is now used in many applications beyond those required in receivers.

Because the AVC-AGC voltage is developed at the detector, it contains all of the modulation products as well as represents the received signal amplitude. All of the modulation products must be removed before the voltage can be used for gain control, and an RC filter having a long time constant is utilized.

AFC

AFC is Automatic Frequency Control, used to counteract the oscillator drift in tunable receivers. One of many available AFC circuits is shown in **Fig. 2**. AFC in an FM receiver is essentially in the same form as the steering voltage function used in a PLL circuit. When an AFC circuit is connected to a tunable oscillator, the frequency of the oscillator can be varied by changing the tuning voltage applied to it. The receiver's oscillator can be kept tuned to a given station or signal by applying a DC voltage to the AFC circuit that was derived from the FM detector. The polarity of the derived voltage determines in which direction the oscillator is to be moved, and the amplitude determines how far.

S-meter

An S-meter used in older receivers was an analog function utilizing a milliammeter which was connected into

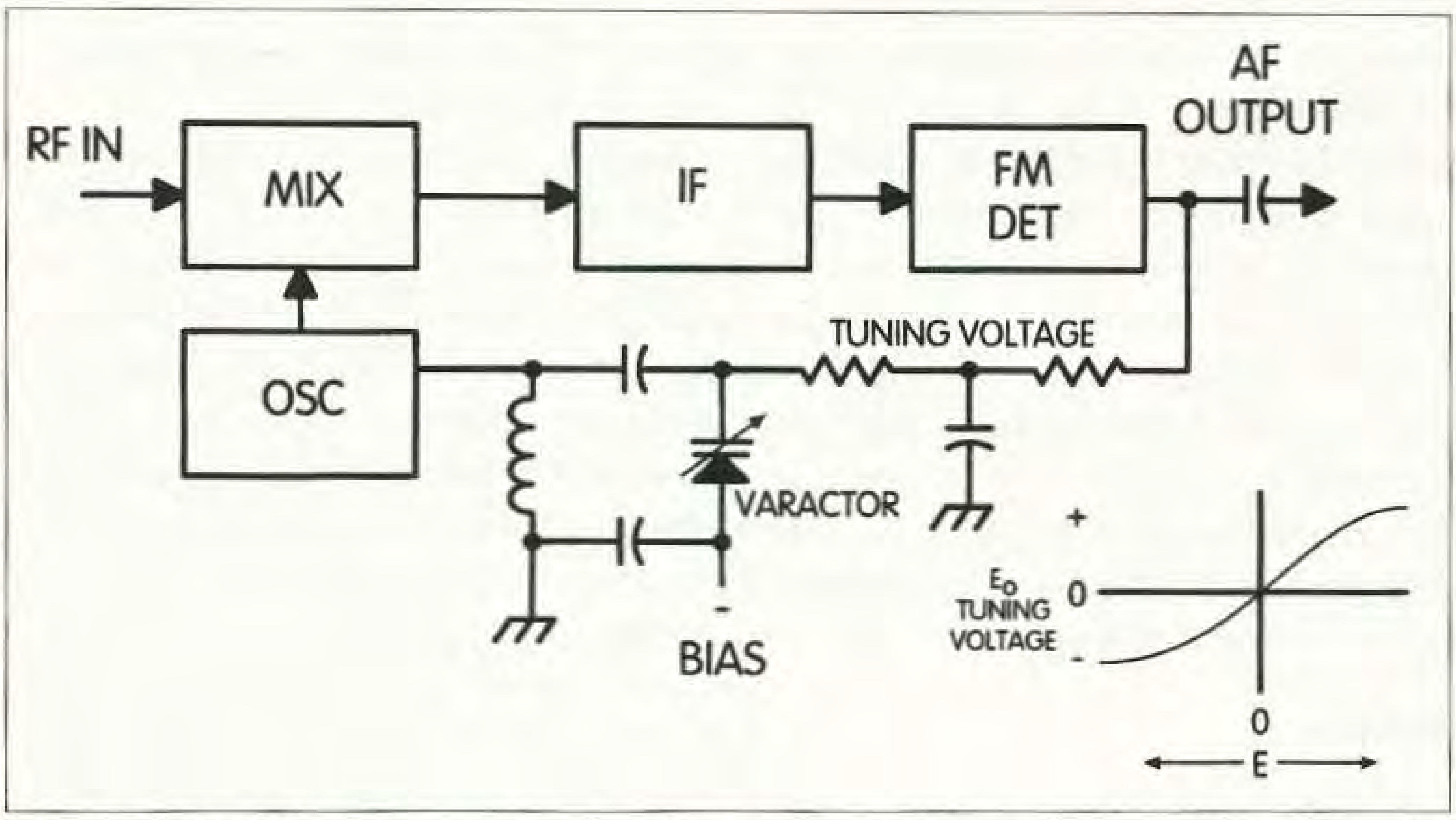

Fig. 2. An AFC circuit implemented with a varactor. Tuning voltage is derived from the FM detector.

the receiver's circuit to measure the relative signal strength of an incoming signal. The meter provided a visual indication of signal strength. Modern receivers use an LCD/LED bar for the same purpose. At one time, electron-ray tubes, sometimes called cat's-eye tubes, were used. They provided a soft green glow in a somewhat round configuration where a dark pie-shaped wedge existed on one side. The wedge would get narrower as the signal strength increased, and provided the user with an indication of tuning. The wedge provided little in the way of a relative signal strength between stations unless the strength differences were significant.

Signal strength indications are relative and not absolute because of the many involved variables that affect the meter indication. In the past, S-meters had a scale calibrated in S-units from 0 to 9 and decibel graduations above 9. Each S-unit was equal to 6 dB of signal voltage change at the antenna terminals, providing a signal strength indication (0 to 9) from 0–54 dB. Signal strength above S9 was indicated directly in decibels.

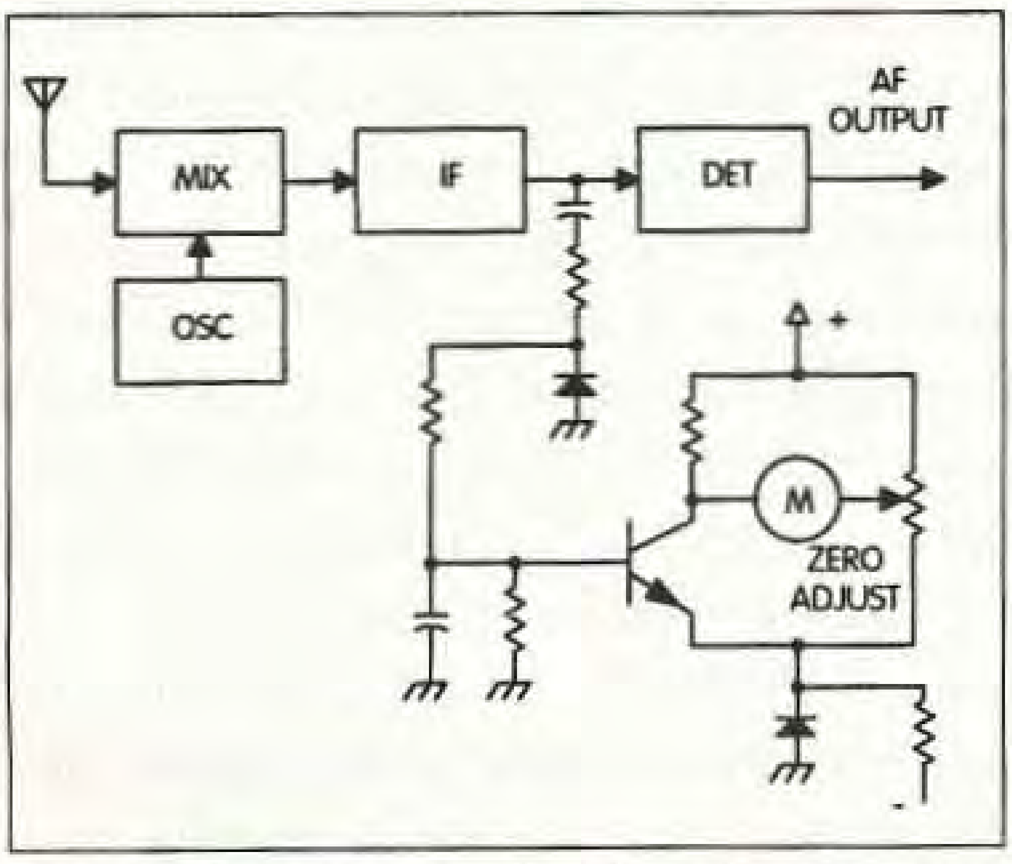

Fig. 3. S-meter circuit. The signal output from the IF is sampled, rectified and filtered. The rectified voltage amplitude is essentially proportional to signal amplitude.

The circuit for an S-meter is similar to that of a basic voltmeter having an amplifier driver, and receives its signal voltage level from any circuit in the receiver that provides a relatively proportional response to the amplitude of an incoming signal. **Fig. 3** shows one of the many techniques for implementing an S-meter, in which the incoming signal is sampled and rectified, with the resulting DC voltage applied to a meter within a bridge circuit. The transistor is biased to obtain a "zero" indication on the meter in the absence of an incoming signal. The rectified voltage, which is essentially proportional to the strength of the incoming signal, will drive the meter up scale, providing the user with an indication of relative signal strength.

Tuning meter

A tuning meter follows the same circuit design concept as the S-meter, except that the meter is a center-zero device. For the tuning meter to function, the detector must be capable of producing a DC output voltage relative to the incoming signal's position within the receiver's passband. A circuit

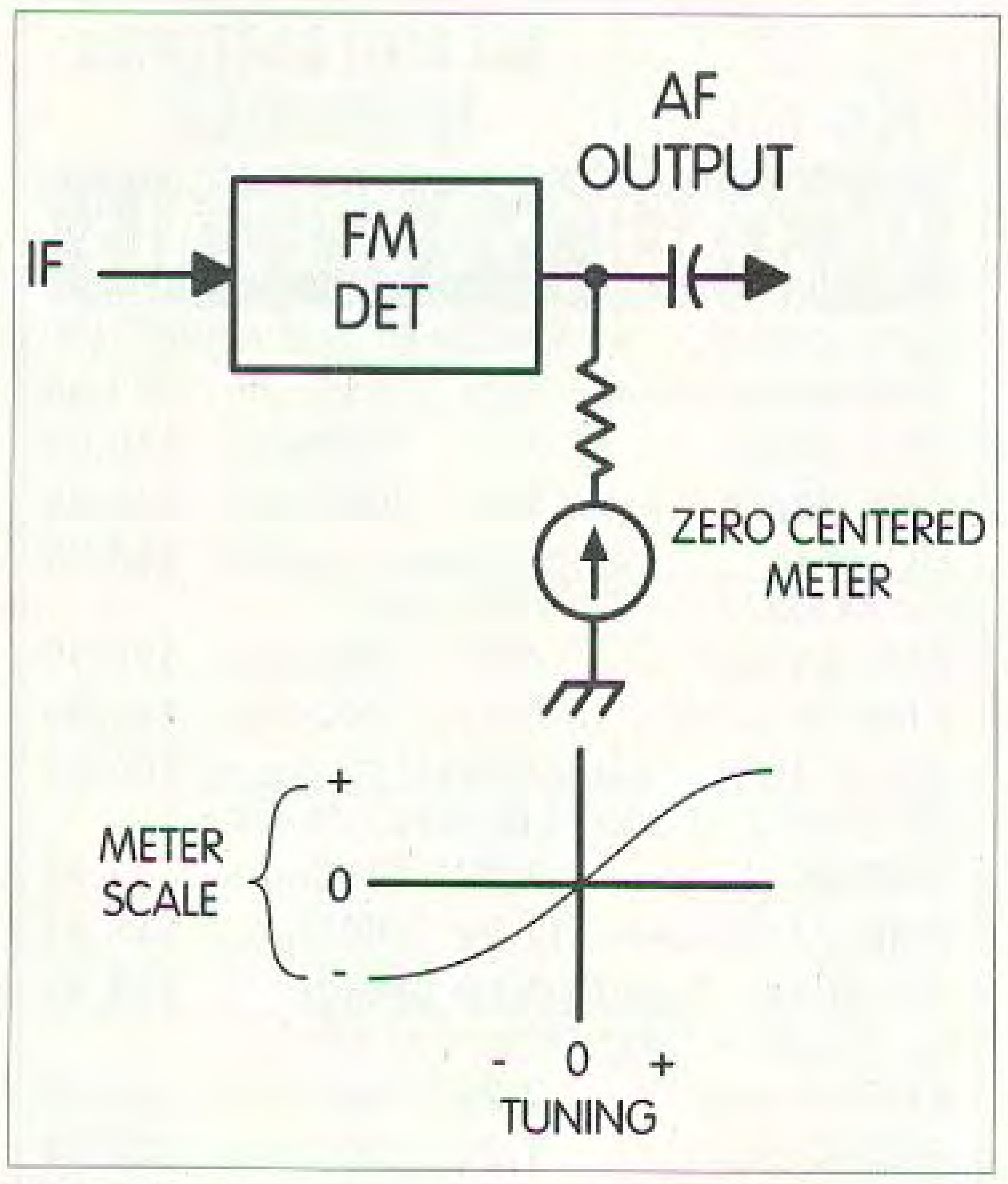

Fig. 4. A tuning meter used with an FM detector capable of producing a DC voltage that is relative in amplitude to the position of a received signal within a receiver's passband.

configuration for a tuning meter is shown in **Fig. 4**. The meter obtains its control voltage from an FM detector, where the voltage amplitude and polarity follow the position of the received signal relative to the center of the receiver's passband. As long as the received signal is in the center of the passband, the meter will indicate zero, but as the signal moves to either side, the meter will indicate the change by moving to one side or the other as well.

Having an FM signal centered in the receiver's passband is important from the standpoint that the quality of the recovered audio will degrade when the signal approaches the edges of the passband. A tuning meter provides an indication of when the receiver is properly tuned. Because of oscillator drift in some FM receivers, AFC has been used to keep the receiver tuned to the selected station. In this case, the tuning meter would just verify that the receiver remains tuned.

Squelch

Constant noise from a receiver becomes bothersome for people having to listen for many hours per day. This noise is the random noise that the receiver detects during the time stations are off the air. A squelch circuit will quiet the receiver's audio circuit during a no-signal period by applying a control voltage to a gated audio amplifier.

Many methods have been devised to squelch a receiver. They have ranged from mechanical to electronic, with an electronic version shown in **Fig. 5**. Early squelch circuits used a relay to short out the audio amplifier input terminals when a signal was not present. Relays had a slow response, in addition to a reaction differential (hysteresis) which caused them to remain closed should the received signal amplitude be marginally low, or open if not set tight enough.

Various electronic circuits have been developed that get around the problem. In essence, there are two forms of squelch control circuitry. The first follows the pattern of the relay which operates as a function of received signal strength (signal strength operated); the other is a noise-operated system. FM receivers amplify and rectify the noise output from the detector (at approximately 20 kHz) which occurs in the absence of an incoming signal. The noise level decreases as the strength of the received signal rises. Using the noise detection approach makes the squelch action faster and more reliable. Once detected, the noise-derived voltage is used to control the passage of audio from the detector to the audio amplifier through a gated audio path. In **Fig. 5**, an FET is used to clamp the audio channel, significantly reducing the audio voltage level presented to the audio amplifier.

Squelch circuits in modern receivers are implemented within the IF/detector IC in most cases. However, it's possible to implement a squelch function using discrete parts should it become desirable to add the function to an "already designed" receiver.

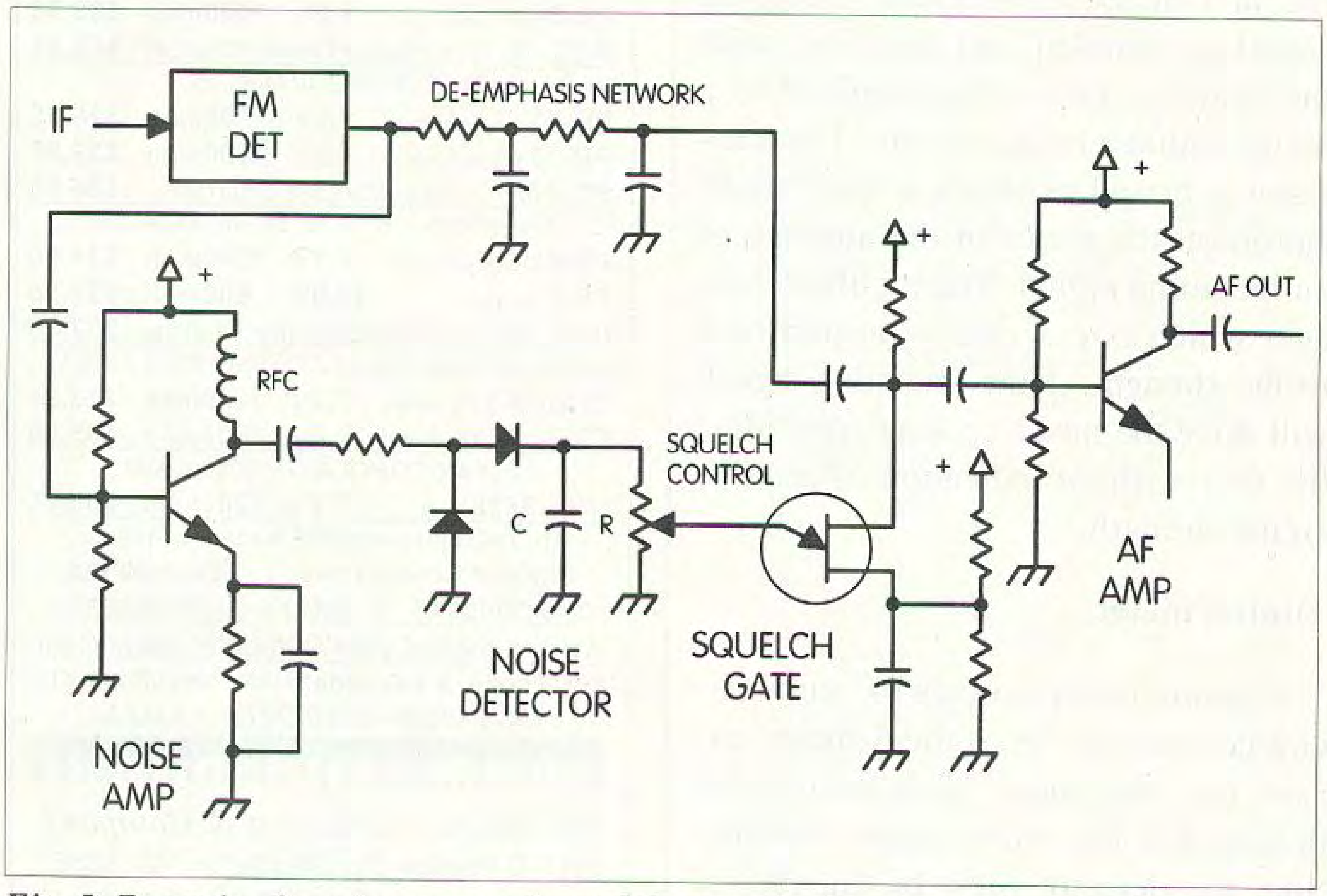

Fig. 5. Example of a noise-operated squelch gate. The function is based on the presence of white noise in the signal channel during the absence of an incoming signal. Values of C and R establish a time constant for opening and closing the squelch gate.

Noise limiters

Noise in receivers is always a problem. Since noise is characteristically an amplitude voltage function, it affects AM receivers the most. The purpose of the noise limiter is to discriminate between sounds made by noise sources and those received from a transmitter. This is a difficult task for a noise limiter because noise is typically generated as pulse noise or continuous noise.

Pulse noise comes in spurts like the pulses made by an automobile ignition system. Continuous noise is like that made by electric motors, shavers, alternators, and so forth. Because of the structure of continuous noise, it is extremely difficult to eliminate once it gets into the receiver. Pulse noise, on the other hand, is easier to remove because pulses are widely spaced, allowing a limiter circuit time to react and reduce the effects of the noise pulse.

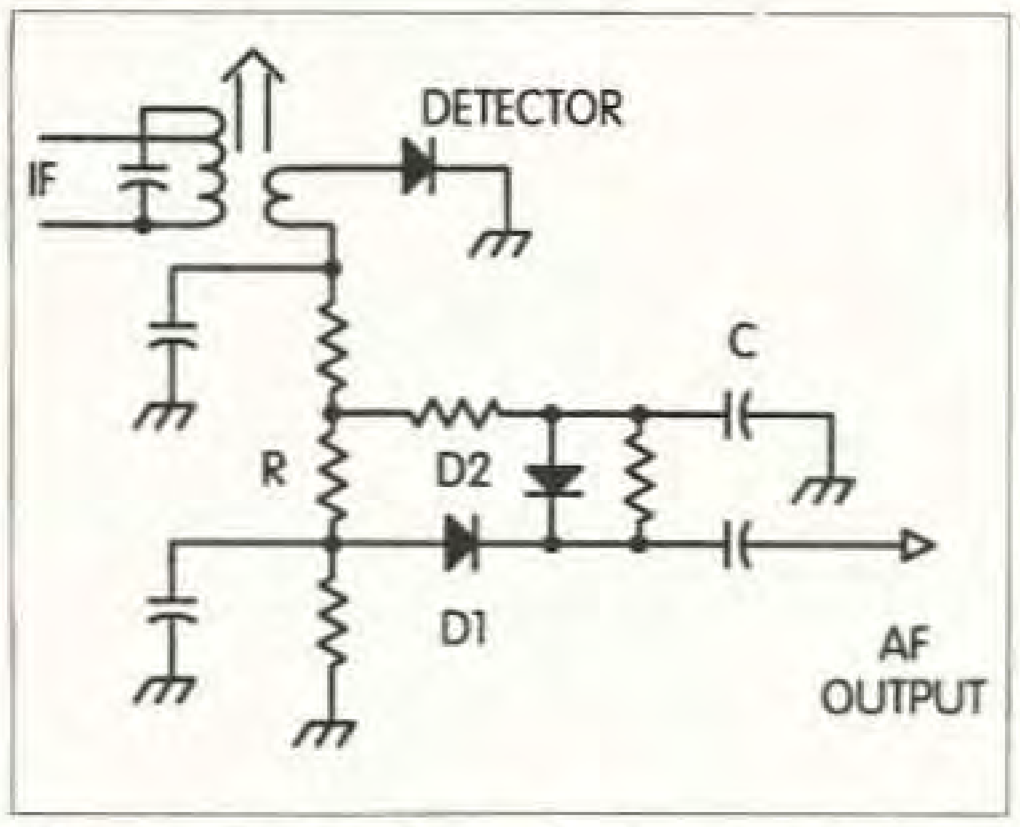

Fig. 6. Series-shunt diode noise limiter used with an AM detector. Capacitor C establishes a long time constant to hold the switch threshold during a noise pulse.

Perhaps the simplest and most effective noise limiter is a series-shunt limiter as shown in **Fig. 6**. Signal and noise voltages are developed across the resistor network and would normally be transferred to the audio stage. However, very little of the noise pulse is allowed to pass through the circuit onto the audio stage as the noise pulse itself is used as the trigger to close the noise gate.

The voltage across resistor R will increase during a noise pulse, causing diodes D1 and D2 to react. The noise pulse has a steep wavefront and a high amplitude that drives the shunt diode D2 into conduction during the duration of the pulse. During conduction, D2 shorts the audio path to ground through the low reactance of capacitor C.

Simultaneously, diode D1 will be reverse biased, essentially disconnecting the audio path between the detector and the audio amplifier. Some of the noise pulse will pass through because the diodes are not perfect switches, but the offending high amplitude portion of the pulse is removed. The circuit is self-adjusting in terms of signal amplitude, such that an incoming signal at any fairly constant amplitude will charge capacitor C to a threshold voltage value and the signal amplitude at that level will not be treated as noise, unless it also exhibits a steep wavefront. Noise limiters are quite effective for the communication of voice with minimal distortion, but the rapid level changes contained in music will cause a noise limiter to clip and distort the audio

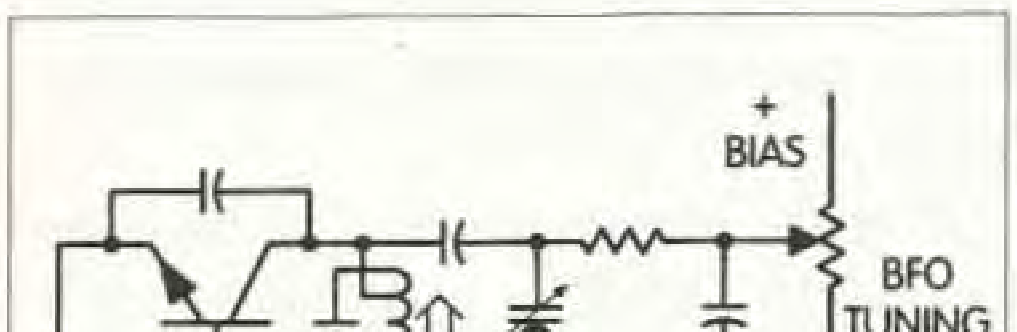

Fig. 7. A variable frequency BFO implemented with a Colpitts oscillator. A varactor is utilized for frequency control.

BFO

When a continuous wave (CW) signal or a single sideband (SSB) signal is to be received, it is necessary for the receiver to beat (mix) a local signal against the incoming signal. The beat note created when listening to a CW signal must be audible; otherwise, the operator hears only noise popping in the receiver. The typical beat note produced is usually between 400 and 1200 Hz and is selected for ease of copying. A BFO can be implemented by using either a fixed or variable frequency oscillator. A variable one is shown in **Fig. 7**.

For SSB operation, the BFO is used for carrier reinsertion where the oscillator is heterodyned against the incoming signal to become the carrier that was removed at the transmitter. To provide proper recovery of audio, the BFO's frequency must be in the same relationship position to the sideband as was the original carrier. If the BFO was operating at any other frequency, the audio would tend to sound unnatural.

Final notes

The superheterodyne receiver concept was developed in 1932 and has existed with little change over these many years. The development of integrated circuits has made the assembly and design of a receiver much simpler, with results far exceeding those of the original design. With the evolution of receivers, the number of conversion steps and the narrowing of the signal passband have brought forth some very interesting designs.

Perhaps one of the simpler design versions is the direct conversion superheterodyne, which converts directly from RF to audio. It embodies the principles of the superheterodyne without the complications of the IF amplifier. In other words, the detector is preceded by a mixer-oscillator providing a direct frequency conversion from a selected radio frequency to an audio signal. Because of the close frequency proximity between the RF and oscillator, the trick is to prevent the local oscillator from masking the incoming signal. 73