A.M. RECEIVERS
DEVICES & CIRCUITS
PART 1

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The construction of an amplitude modulation (a.m.) receiver can be considerably simplified by the use of one of the semiconductor devices which have been especially developed for this particular application. This and future articles will review the various types of device available and include a selection of typical circuits which the reader can construct and with which he can experiment.

Practical constructional details will not be included, since a variety of circuits are covered and constructional details for specific receivers are regularly included in our pages. Audio amplifier sections will not be included since the audio output from any of the receiver circuits can be fed into a standard audio amplifier. Integrated circuits will be used throughout, since this reduces the number of components used compared with discrete (separate) transistor designs.

Amplitude Modulation

The amplitude of an a.m. signal varies at the frequency of the audio signal concerned. For example, one may consider a 1MHz radio frequency carrier wave (which is far above the level of human hearing) and which varies in amplitude at an audio frequency of 1kHz. When a receiver is tuned to this signal, the 1kHz frequency will be heard from the loudspeaker.

Amplitude modulation is used on long, medium and short wave transmissions. Frequency modulation can be used at much higher frequencies (e.g. f.m. sound at about 90MHz) for high quality reception, but cannot be used with advantage at relatively low frequencies.

A.M. receivers are usually simpler than f.m. receivers and it is therefore sensible for a beginner to commence with a.m. circuits. Signals at the high f.m. frequencies cannot be received from distant transmitters, so if you wish to receive a signal from a station more than about 50 to 100 miles away, it will be an a.m. signal you will select. However, the fact that distant a.m. signals can reach your aerial inevitably means that one is much more likely to experience interference from unwanted signals than with f.m. reception.

T.R.F. or Superhet?

There are two main types of a.m. receiver, the so-called "t.r.f." (tuned radio frequency) and the superheterodyne or "superhet". The t.r.f. type is far simpler than the superhet, so the beginner who wishes to experiment is strongly advised to commence with a t.r.f. circuit.

In a t.r.f. receiver the incoming signal is amplified, detected or demodulated in a stage which converts the radio frequency wave into an audio signal and the audio signal is then amplified so that it can feed a loudspeaker or an earphone.

In a superhet the incoming signal is changed in frequency to another radio frequency signal known as the intermediate frequency. It is convenient to obtain most of the selectivity (or ability to reject interference from adjacent signals) at this intermediate frequency before the signal is demodulated and fed to an audio amplifier and hence to a loudspeaker.

A t.r.f. receiver can give good audio quality provided there are no interfering signals, thus if you require a simple bed-side or kitchen receiver for local programmes, a t.r.f. circuit will be satisfactory.

If, however, you wish to receive stations from Europe on medium waves or even from other continents on short waves, one will normally obtain much better results using a superheterodyne receiver.

T.R.F. Circuits

The remainder of this article will be devoted to t.r.f. circuits mainly for the purpose of helping the beginner. Numerous t.r.f. circuits have been published using discrete transistors, but a unique integrated circuit was released some years ago which has been designed especially for use in t.r.f. receivers.

This device is the Ferranti ZN414 which is ideal for use by the home constructor and is readily available. It requires only a low voltage power supply and provides a very high gain when used in a simple circuit.

The ZN414 is encapsulated in a simple transistor metal envelope, and the pin connections are shown in Fig. 1. There are only three leads, these being input, earth, and a common lead for output and the positive voltage supply.

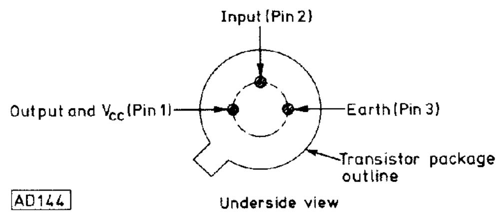

Fig. 1: Pin connections of the ZN414

ZN414 basic circuit

A basic t.r.f. receiver circuit using the ZN414 device is shown in Fig. 2. The inductance L1 is a winding on a ferrite rod or slab aerial which will be described in detail later. This inductance must

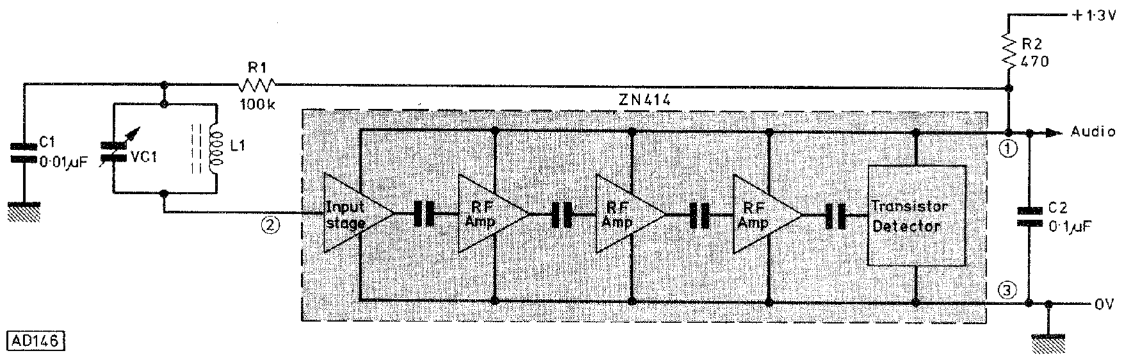

Fig. 2: A basic t.r.f. receiver circuit using the ZN414

resonate with the variable capacitor VC1 at the frequency of the desired station; in other words, VC1 is the receiver tuning capacitor.

The upper end of resistor R2 is fed from a positive supply of about 1·3V, normally a single cell or a potential divider circuit. A small bias current passes through R1 and the winding of L1 to the input (pin 2) of the ZN414. This input stage has a very high input impedance so that a negligible load is imposed on the tuned circuit; the selectivity of this tuned circuit is therefore almost unaffected by the connection of the ZN414.

The input stage is capacitively coupled to three internal cascaded r.f. amplifiers which in turn feed a transistor detector stage. The output capacitor in conjunction with the load resistor R2 filters radio frequencies from the output, but leaves the audio signal almost unaffected. There are ten transistors fabricated on the ZN414 chip.

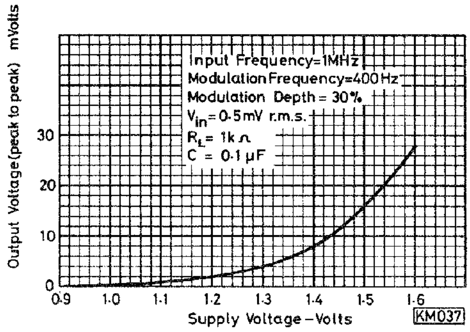

Fig. 3: Gain characteristics of the ZN414

As shown in Fig. 3, the gain of the ZN414 is dependent on the voltage applied to the upper end of R2 in Fig. 2. It is therefore necessary to stabilise this voltage if one does not wish the gain to vary with the state of discharge of the battery used.

The current taken by the ZN414 circuit itself is only about 0·3mA, but when a strong signal is being received this can rise to about 0·5mA. The additional current taken in the presence of a strong signal results in a greater voltage drop across R2 of Fig. 2 so that the ZN414 operates at a slightly lower voltage; thus the gain is reduced in the presence of a strong signal and one has automatic gain control built into the circuit.

The audio output from the Fig. 2 circuit is relatively small. It can be used to operate a sensitive earpiece, but generally it is better to feed it into an audio amplifier circuit. It is important that the output capacitor C2 should be soldered as close as possible to pins 1 and 3 of the ZN414 and that the device leads should be kept fairly short, or the high gain of the device may result in instability. This is of the order of 4,000 times voltage gain or some 72dB.

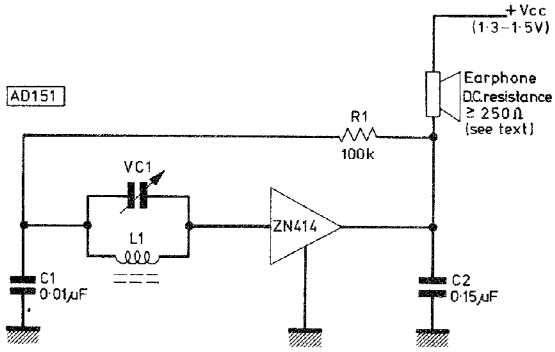

Fig. 4: A simple radio receiver circuit using a ferrite rod aerial

Earpiece Radio Receivers

The circuit of Fig. 4 shows one of the simplest possible radio receiver circuits for use with a ferrite rod aerial, L1. The load resistor R2 of Fig. 2 has been replaced with a sensitive earpiece which should have an impedance of not less than 250Ω.

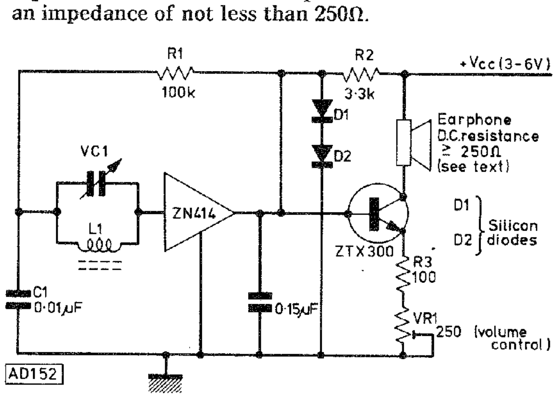

Fig. 5: Adding a single transistor amplifier stage

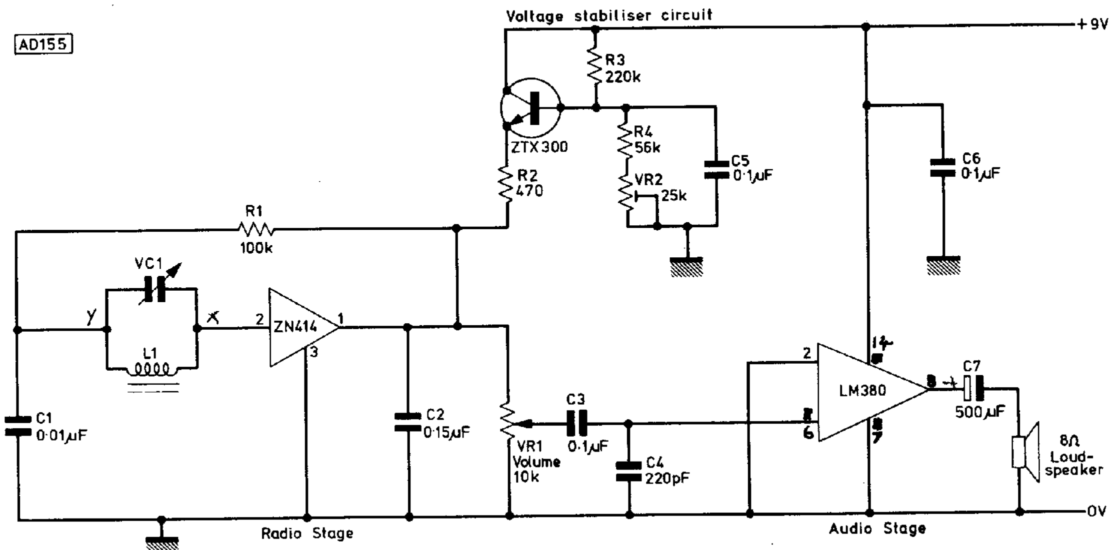

Fig. 6: A small loudspeaker radio receiver circuit, using a single transistor voltage stabiliser circuit

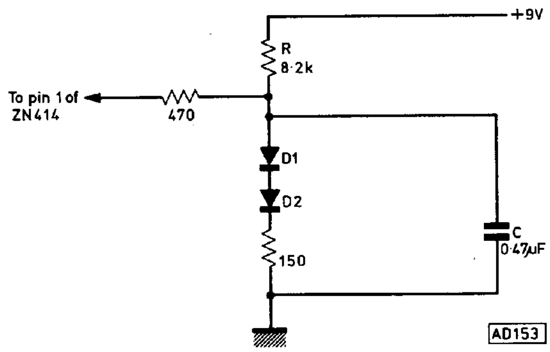

Fig. 6(a): An alternative voltage stabiliser using two silicon diodes

It is normally preferable to employ at least a single transistor amplifier stage (such as that shown in Fig. 5) so that the requirements of the earpiece are far less critical and a cheaper earpiece is satisfactory. A volume control is also incorporated in the Fig. 5 circuit, whilst the two forward biased diodes limit the voltage across the ZN414; the Ferranti BAW 37A double diode may be used here.

Loudspeaker circuits

The audio output from a ZN414 circuit can be fed to almost any audio amplifier which can drive a loudspeaker. Audio amplifiers using discrete transistors have been published for use with the ZN414, but simpler circuits can be made using an integrated circuit audio amplifier.

A small loudspeaker radio receiver circuit is shown in Fig. 6. In this circuit the ZN414 device is fed from a simple single transistor voltage stabiliser circuit so that the gain is almost independent of the power supply voltage used. If no stabiliser circuit is used, the gain will fall considerably as the battery ages. The supply voltage to the ZN414, and therefore the gain, can be set by means of VR2. The audio signal passes through the d.c. blocking capacitor C3 to the input of an integrated circuit audio amplifier. C4 helps to remove any radio frequencies from the audio signal and prevents spurious noise.

The LM380 was selected for this circuit partly because an extremely simple circuit can be employed, but also because it contains protection circuits. If the output of this device is shorted to ground accidentally, the output current will be limited to a safe value so that the device is not destroyed. In addition, if the device becomes so hot that it is in danger of failing, the output current is automatically reduced until it cools to a safer temperature.

Diode stabilisers

An alternative to the transistor voltage stabiliser of Fig. 6 involves the use of two series connected forward biased silicon diodes in the circuit of Fig. 6(a). The larger the value of R, the greater the gain of the ZN414. The voltage drop across this resistor is added to the voltage drop of about 1·3V across the two forward biased diodes.

It is also possible to employ a small light emitting diode instead of the two silicon diodes of Fig. 6(a), but the current required to enable the light emitting diode to provide a reasonable light output will be greater than that required by the Fig. 6(a) circuit. In other words, the value of R must be reduced.

Frequencies

The variation of the ZN414 gain with frequency is typically similar to that shown in Fig. 7. The peak gain is at about 1MHz, but the device can be used with a reasonable gain from about 100kHz up to about 3MHz. However, one should remember that the gain is much reduced near these limiting frequencies. The lowest frequency for reasonable gain is set by the values of the internal coupling capacitors shown in Fig. 2, whilst the maximum practicable frequency is determined by the properties of the internal transistors in the device.

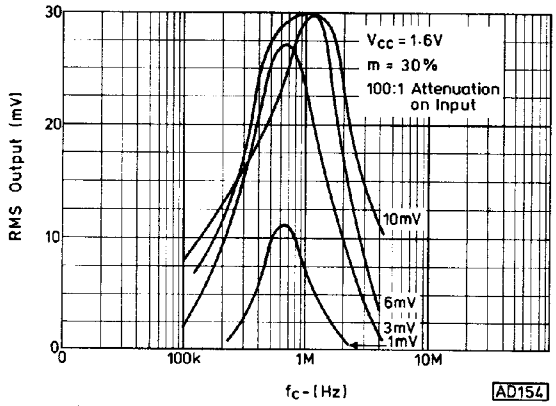

Fig. 7: Frequency response of the ZN414

It can be seen from Fig. 7 that there is a considerable difference in the output voltage as the input rises from 1mV up to 3mV, but any further increase in the input voltage produces a relatively small change in the audio output level owing to the a.g.c. action.

Aerial

The aerial may consist of a ferrite rod about 12cm in length with 55 to 65 turns of 28 gauge wire wound as a single layer for medium wave. The long wave coil may consist of some 250 turns of 38 gauge single silk covered wire wound in a random way with turns on top of one another, as indicated in Fig. 8. The exact number of turns will depend on the value of the tuning capacitor placed in parallel with the coil (typically 200pF).

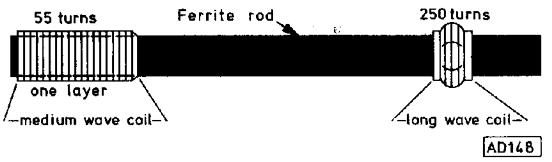

Fig. 8: The ferrite rod aerial with l.w. and m.w. coils

Only one aerial coil has been shown in the circuits of Figs. 2, 4, 5 and 6. If both medium and long wave coils are required, the switched circuit of Fig. 9 may be used with any of these circuits. It is important that the aerial coil should have a high Q (magnification) so that reasonable selectivity is obtained.

If one requires an extremely small receiver (possibly using the circuit of Fig. 4), there will not be enough space for a reasonably long ferrite rod aerial in the case. One can employ a ferrite slab with only a medium wave coil wound on it in such receivers; the slab should not be less than about 3cm in length unless one intends to use the receiver only fairly close to a transmitter. A longer ferrite slab will produce a greater signal voltage.

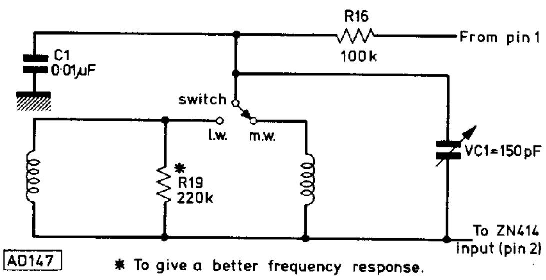

Fig. 9: Switching circuit for l.w. and m.w. coils

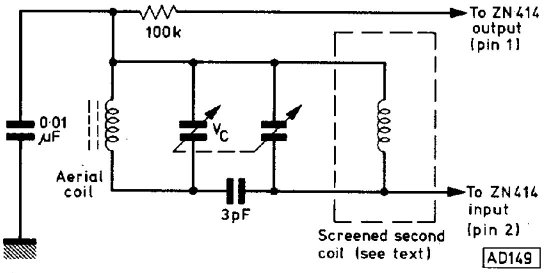

Fig. 10: A double tuned circuit for greater selectivity

If greater selectivity is required, a double tuned circuit can be used before the ZN414 as shown in Fig. 10, but this requires careful alignment for optimum performance. The Q factors of the two tuned circuits should be similar. If the two tuned circuits are not correctly matched, each station may be received at two points in the band. This type of double tuned circuit is especially useful when one has a larger external aerial coupled to the ferrite rod. The lead from the external aerial should be connected to a few turns of wire around the ferrite rod, the other end of the winding preferably being connected to earth.

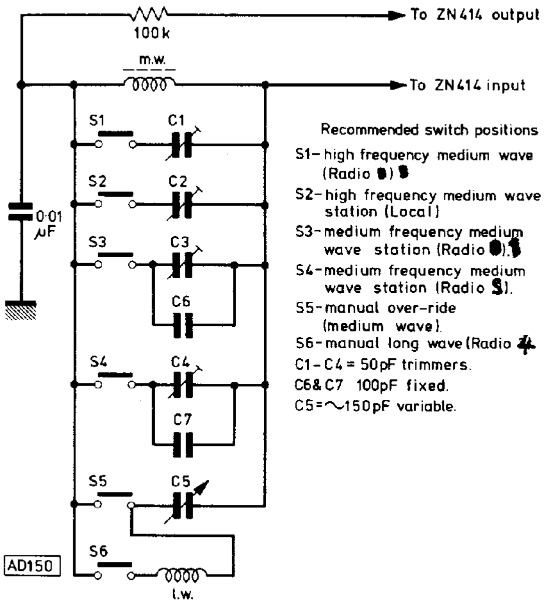

Fig. 11: A six position switching circuit

The circuit of Fig. 11 shows how four pre-selected stations may be selected by the push buttons S1 to S4. The buttons S5 and S6 enable the normal medium and long wave bands respectively to be tuned by means of the variable capacitor C5.

Next month we will consider superheterodyne receivers for a.m. reception.