FORUM

Conducted by Neville Williams

MORE ABOUT AM: How diode detectors work

Last month's discussion of amplitude modulated waveforms took up so much space that we had to hold over the matter of AM detection. The following explanation of how a diode detector operates will hopefully be a little more complete and convincing than what is commonly offered in basic texts.

Just to demonstrate that we don't always pick on other people's publications, Fig. 1 is taken from our own handbook "Basic Electronics".

It is a fairly traditional diagram showing:

(a) A tuned input circuit, as for a beginner's "crystal set" and, below it an amplitude modulated radio frequency waveform.

(b) the addition of a diode detector and the way in which it passes on only one half of the modulated waveform.

(c) The further addition of a bypass capacitor C1, which substantially eliminates the half-cycles of RF carrier energy, passing on only the contour shape which is virtually the audio information required.

While this kind of explanation may be sufficient in the context of a beginner's crystal set, it certainly does not provide an adequate rectifier-based concept of diode detection – as mentioned last month.

I am reminded of my first introduction to the game of snooker, at a holiday hotel. When I protested that I knew nothing about the game, I was assured that there was nothing to it.

"You use the cue and the white ball to nudge the other balls into the pockets.

"Come on . . . have a go!"

But, as I got involved in the game, I discovered that there were a few rules and conventions that needed to be understood before one could participate intelligently.

It's a bit like that with diode detection and the sketchy nature of Fig. 1. So let's start again.

Fig. 2 shows a diode detector configuration which is fairly typical of what has been used in both valve and solid-state AM receivers – usually superhet receivers. (A particular polarity has been assumed for the diode but this does not affect the basic reasoning.)

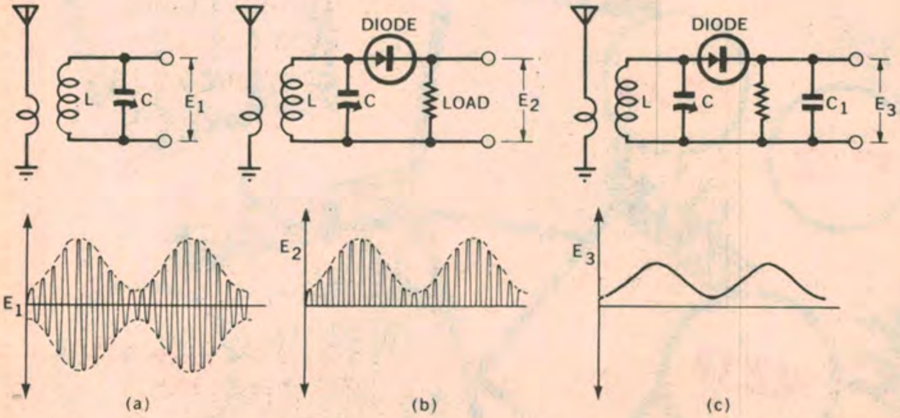

Fig. 1: This diagram, reproduced from "Basic Electronics" typifies simple diode detector explanations. It shows (a) a modulated input waveform; (b) the rectifying effect of a diode and (c) the recovered audio signal.

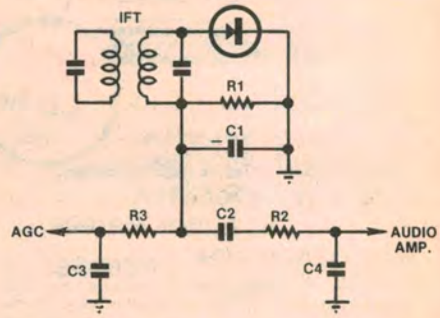

Fig. 2: Basic circuit configuration for a diode detector in a superhet receiver.

Signal is fed to the detector from the secondary of the final IF transformer, with one end connecting to the diode anode and the other to the diode cathode (and chassis earth) via the two parallel-connected components, resistor R1 and capacitor C1.

Resistor R1 must be large enough in value to present a practical load for the diode detector (or rectifier) but small enough to be a practical source resistance for the outgoing audio signal. Typical values lie within the range 47kΩ to 470kΩ.

Capacitor C1, in association with R1, must provide a long time constant in respect to the carrier frequency (or IF) but a short time constant in respect to the audio modulation. To put it another way, it must constitute an effective bypass for RF but not for AF (audio frequency). Typical values lie within the range 1000pF to 100pF.

Other components in Fig. 2 will be referred to later.

Fig. 3, included mainly for completeness, is a conventional diode conduction curve. While ever the anode is negative with respect to cathode, no current can flow through the diode. However, as the anode is made positive with respect to cathode, current begins to flow and increases, more or less linearly, with the magnitude of the applied voltage. The action is essentially the same as that of a rectifier.

Fig. 4 is a composite graph which seeks to illustrate the voltage and current

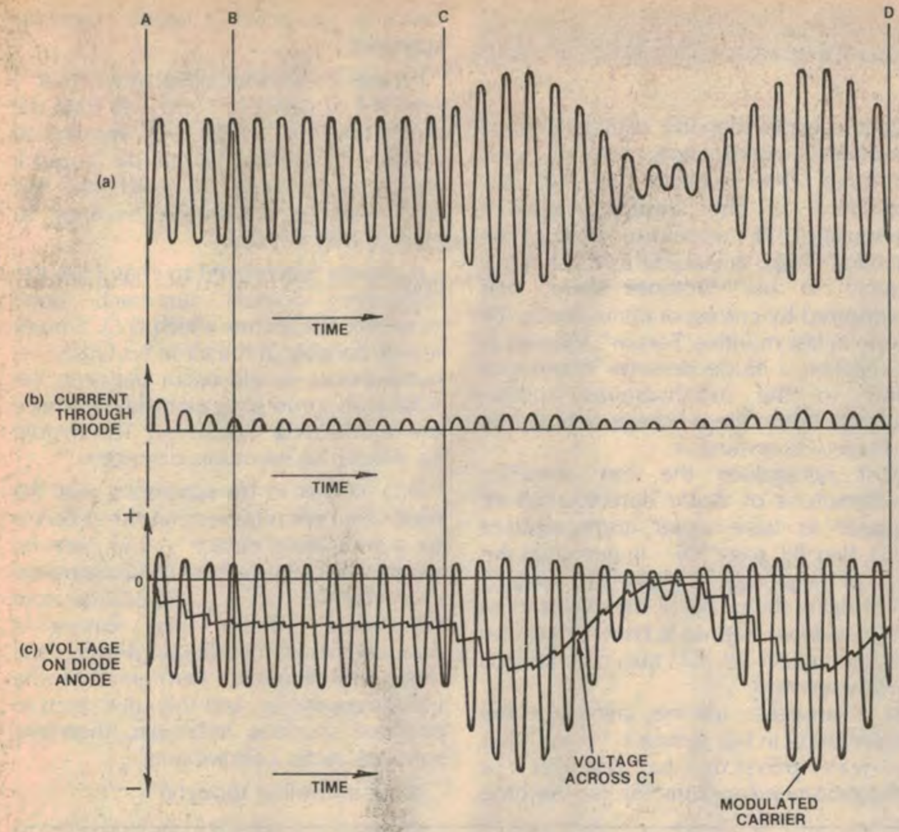

Fig. 4: Diagram (a) illustrates an input signal, unmodulated (A to C) and amplitude modulated (C to D). Diagram (b) shows the current pulses through the diode, which charge the storage capacitor (C1 in Fig. 2) thereby DC shifting the RF input waveform as in diagram (c). The voltage across C1 can be filtered to isolate the audio signal, and also the DC component for automatic gain control.

relationships in a typical diode detector circuit (eg Fig. 2) plotted against time.

Fig. 4a depicts an RF (or IF) input signal, which is unmodulated between A and C, but amplitude modulated between C and D.

If this signal was to be applied to a detector circuit (eg Fig. 2) the first few positive-going half-cycles would cause heavy uni-directional current pulses through the diode, through the secondary of the IF transformer, and through capacitor C1, building up across it a charge negative with respect to chassis-earth.

The initial charging pulses and the build-up in the voltage across C1 is illustrated respectively in Figs. 4b and 4c, in the time interval A to B.

In short, in the presence of an unmodulated signal, a diode detector circuit tends rapidly to reach a state of equilibrium such that the energy drawn from the tips of the positive-going half-cycles is just sufficient to maintain the charge across the bypass/storage capacitor (C1 in Fig. 2).

As a corollary to this, the charge or voltage across C1 assumes an average value slightly less than the peak value of the RF input to the diode.

Figs. 4a and 4b illustrate the attainment of equilibrium (time period A to B) and the equilibrium state with non-modulated input (time period B to C).

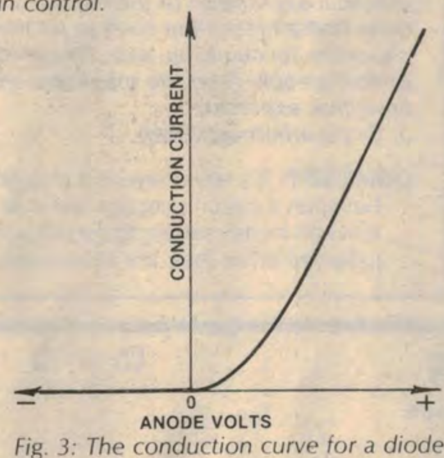

Fig. 3: The conduction curve for a diode detector is essentially similar to that of a rectifier.

When the waveform is amplitude modulated, as from point C onwards, the detector still tends to maintain the voltage across C1 at just below the peak value of the RF input waveform, even though it is now varying at an audio rate. (Obviously, for this to happen, the time constant of C1/R1 must be short enough for the charge across C1 to fluctuate in accordance with the highest modulation frequency).

So we end up with Fig. 4c, which shows:

1. The positive-going peaks of the RF input signal substantially aligned just on the conductive side of the diode characteristic.

2. An RF envelope DC shifted by reason of the diode rectifier action and alignment of the positive-going peaks.

3. A voltage across C1 which contains a DC component, the recovered audio modulation, and a residual ripple at the carrier frequency.

(Readers familiar with television technology will doubtless recognise points 1 and 2 above as being the exact parallels of what goes on in a DC Restorer stage).

Referring back to Fig. 2, the DC component can be blocked by coupling capacitor C2, while the RF component can be attenuated by series resistor R2 and RF bypass C4. If desired, the DC component can be isolated and preserved for purposes of AGC (automatic gain control) by means of a long time-constant filter, R3/C3.

How does all this stack up in respect to the discussion that has gone before?

Very well, I would say.

(1) It assumes that the passband of the tuned circuits preceding the detector will be sufficiently wide to admit the carrier and a substantial proportion of the sidebrands. To the extent that the outer sidebands are attenuated — as happens in most AM receivers — the higher frequency audio components are diminished or lost, irrespective of whether we analyse the effect in terms of their absence from a "mixer" calculation, (frequency domain), or from a summed voltage waveform (time domain).

(2) It accepts that the carrier/sideband frequency components that do pass through the selective circuits are summed at the detector into a modulated RF waveform having the general shape envisaged in the original article in our October issue, and supported by correspondents and by Dr Imrie in last month's "Forum". Viewed as a rectifier, a diode detector is sensitive only to the instantaneous applied voltage, not to the subtleties of how that voltage was arrived at.

(3) It rationalises the too simplistic explanations of diode detectors which appear to have upset correspondent D.D. (Jan '83, page 99) — in particular the role of the storage capacitor (C1 in Fig. 2) in bridging the peaks of the cycles in an RF waveform. Fig. 4c acknowledges the storage effect of C1 but puts it into proper context.

(4) It satisfies — for me, anyway — the observation in last month's "Forum" that it was possible to present "a straightforward explanation (in the time domain) of how a diode detector operates."

I made the further observation that "I regard it as easier to cope with than the mixer concept, which D.D. appears to prefer". In fairness, I did do a quick survey of textbooks to hand, old and new, without discovering anything to change that opinion.

If you do feel moved to champion the "frequency domain" approach, don't overlook the matter which D.D. himself leaves hanging in the air in his letter: . . . some mixing would occur between the sidebands, producing a product of twice the modulating frequency. This would be likened to harmonic distortion."

D.D. seems to be suggesting that the mixer concept requires that the detector be a non-linear device — and here he would be talking about a fundamental characteristic, not just departures from the ideal diode, etc. Being a (fundamentally) non-linear device, any mixer will generate harmonics of the input frequencies, and then mix them to produce spurious resultants, therefore spurious audio components.

What a horrible thought!

Readers can think up bright ideas . . .

I would like to suggest that "Electronics Australia" set aside a small space each month for readers to request electronic circuits which would give practical expression to their ideas. I'm sure that many readers can think up quite brilliant ideas but have to let them drop because they do not have the expertise to come up with an appropriate circuit. It is obvious that many brilliant people read the magazine and they are able to help because they have that expertise.
J. S. (Scarborough, Qld).

COMMENT: It's an interesting thought, although there is often a huge gap between a circuit concept and a developed working unit. Let's put it to the test and invite readers to submit some of these bright ideas so that we can judge whether they are reasonably capable of development.