There are various ways to measure or *detect* the amplitude (as opposed to the power) of a waveform. Here we'll consider one of the simplest, used by most portable radios, etc, the *Envelope Detector*.

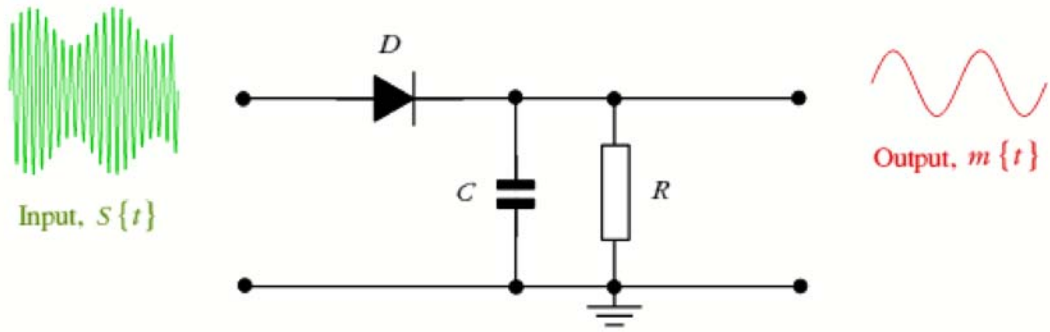

Figure 9.2 Envelope Detector (AM Demodulator/Detector).

This is essentially just a halfwave rectifier which charges a capacitor to a voltage ≈ to the peak voltage of the incoming AM waveform, $s\{t\}$. When the input wave's amplitude increases, the capacitor voltage is increased via the rectifying diode. When the input's amplitude falls, the capacitor voltage is reduced by being discharged by a ‘bleed’ resistor, *R*. The main advantage of this form of AM *Demodulator* is that it is very simple and cheap! Just one diode, one capacitor, and one resistor. That's why it is used so often. However, it does suffer from some practical problems.

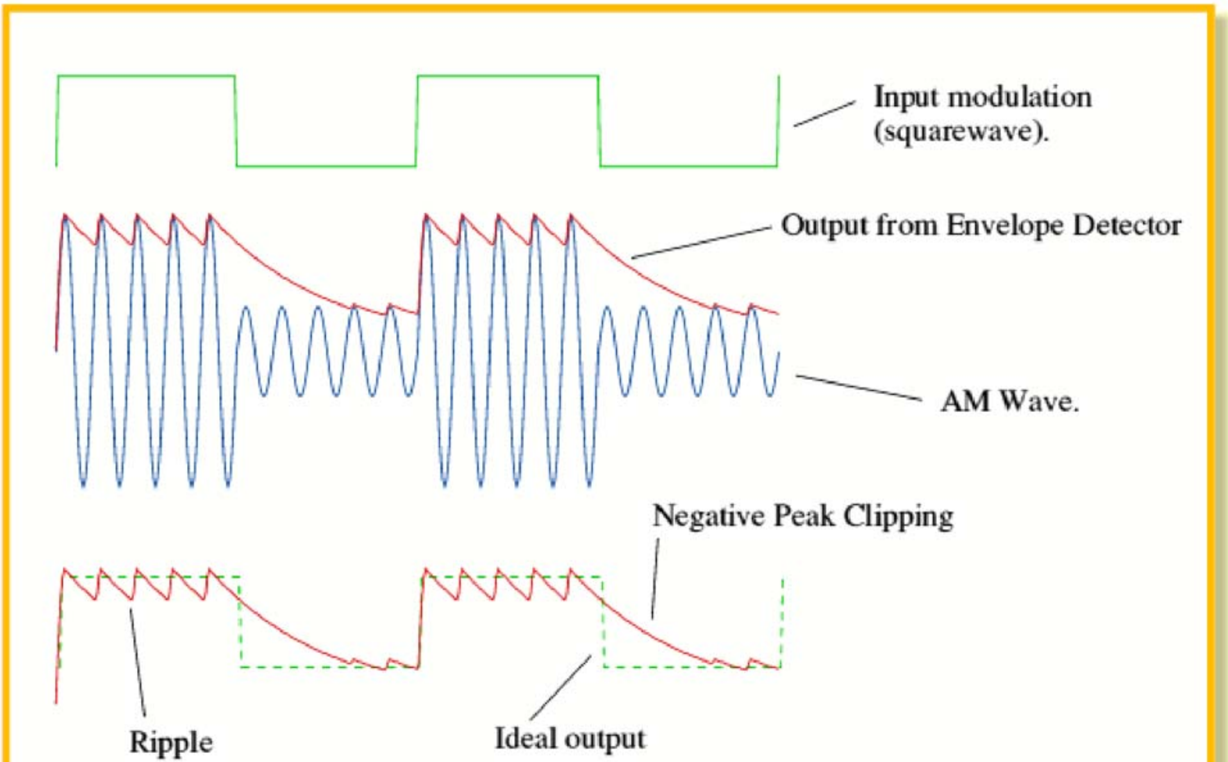

Figure 9.3 Ripple & Peak Clipping effects.

The circuit relies upon the behaviour of the diode — allowing current through when the input is +ve with respect to the capacitor voltage, hence 'topping up' the capacitor voltage to the peak level, but blocking any current from flowing back out through the diode when the input voltage is below the capacitor voltage. Unfortunately, all real diodes are non-linear. The current they pass varies with the applied voltage. As a result, the demodulated output is slightly distorted in a way which depends upon the diode's *I/V characteristic*. For example, most AM transistor radios produce output signals (music, Radio 4, etc) with about 5-10% distortion. OK for casual listening, but hardly Hi-Fi! As a result, this simple type of AM demodulator isn't any good if we want the recovered waveform to be an accurate representation of the original modulating waveform. The circuit also suffers from the problems known as *Ripple* and *Negative Peak Clipping*. These effects are illustrated in figure 9.3. The ripple effect happens because the capacitor will be discharged a small amount in between successive peaks of the input AM wave.

The illustration shows what happens in the worst possible situation where the modulating signal is a squarewave whose frequency isn't much lower than the carrier frequency. Similar, but less severe, problems can arise with other modulating signals.

Consider what happens when we have a carrier frequency, f_c, and use an envelope detector whose *time constant*, $\tau = RC$. The time between successive peaks of the carrier will be

$$T = \frac{1}{f_c} \qquad \text{... (9.12)}$$

Each peak will charge the capacitor to some voltage, V_{peak}, which is proportional to the modulated amplitude of the AM wave. Between each peak and the next the capacitor voltage will therefore be discharged to

$$V'_{peak} = V_{peak} \operatorname{Exp}\{-T/\tau\} \qquad \text{... (9.13)}$$

which, provided that $T \ll \tau$, is approximately the same as

$$V_{peak}' \approx V_{peak}[1 - T/\tau] \qquad \text{... (9.14)}$$

The peak-to-peak size of the ripple, ΔV, will therefore be

$$\Delta V \approx \frac{V_{peak}T}{\tau} = \frac{V_{peak}}{f_c \tau} \qquad \text{... (9.15)}$$

A sudden, large reduction in the amplitude of the input AM wave means that capacitor charge isn't being 'topped up' by each cycle peak. The capacitor voltage therefore falls exponentially until it reaches the new, smaller, peak value. To assess this effect, consider what happens when the AM wave's amplitude suddenly reduces from V_{peak} to a much smaller value. The capacitor voltage then declines according to

$$V_{drop} = V_{peak} \operatorname{Exp}\{-t/\tau\} \qquad \text{... (9.16)}$$

This produces the negative peak clipping effect where any swift reductions in the AM wave's amplitude are 'rounded off' and the output is distorted. Here we've chosen the worst possible case of squarewave modulation. In practice the modulating signal is normally restricted to a specific frequency range. This limits the maximum rate of fall of the AM wave's amplitude. We can therefore hope to avoid negative peak clipping by arranging that the detector's time constant $\tau \ll t_m$ where

$$t_m = 1/f_m \qquad \text{... (9.20)}$$

and f_m is the highest modulation frequency used in a given situation.

The above implies that we can avoid negative peak clipping by choosing a small value of τ. However, to minimise ripple we want to make τ as large as possible. In practice we should therefore choose a value

$$1/f_m \gg \tau \gg 1/f_c \qquad \text{... (9.21)}$$

to minimise the signal distortions caused by these effects. This is clearly only possible if the modulation frequency $f_m \ll f_c$. Envelope detectors only work satisfactorily when we ensure this inequality is true.

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