MODERN FM RECEIVING TECHNIQUES PART THREE

In this third article on FM receiver circuitry, Brian Dance continues this discussion of the NE563, a PLL IF amp. Then he will consider how the signal from the demodulator circuit is processed so that separate 'left' and 'right' signals are obtained which can be amplified and fed to the loudspeakers. Only modern high performance circuits will be discussed.

The limiter circuit feeds the stage which provides AGC at pin 4. The variation of the pin 4 voltage with the input signal level is shown in Fig. 17. The limiter also provides muting current to pin 8 where the output impedance is about 20k. When the potential at this pin falls below about 1.1V, the circuit is muted. The muting level is set by VR1. The writer has found the action of this muting circuit to be extremely good. Any signal of reasonable strength will raise the potential of pin 8 above 1.1V when VR1 is suitably adjusted, but inter-station noise is eliminated. If muting is not required, pin 8 may be left unconnected.

A signal strength meter, M1, may be used if desired, but it must have a reasonably high impedance. The readings of this meter vary with the setting of VR1. A meter with a full scale deflection of about 5V is suitable. The meter deflection is a logarithmic function of the input voltage over a very wide range (from 10uV to at least 0.5V).

The NE563 device requires a power supply voltage in the range +10 to +15V, the current required being typically 38mA (maximum 42mA). The power dissipated in this complex device renders it warm to the touch and results in some drift of the centre frequency for the first minute or so after power is first applied; however, this has no effect except when one wishes to receive very weak signals. The internal circuit of the NE563 provides a typical hum rejection of about 33**dB**.

PERFORMANCE

The total harmonic distortion at the NE563 output is quoted as 0.4%. This value having been measured at a modulating frequency of 1kHz when the deviation was the normal maximum of ±75kHz. The

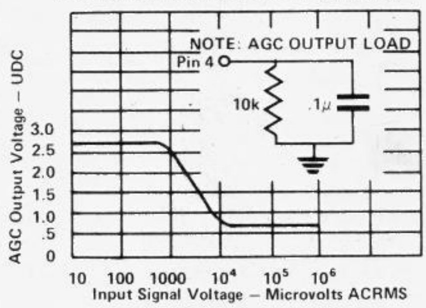

Fig. 17. Typical NE563 AGC characteristic.

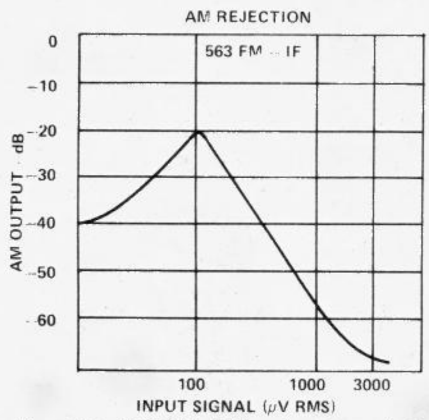

Fig. 18. NE563 AM rejection plotted against input voltage.

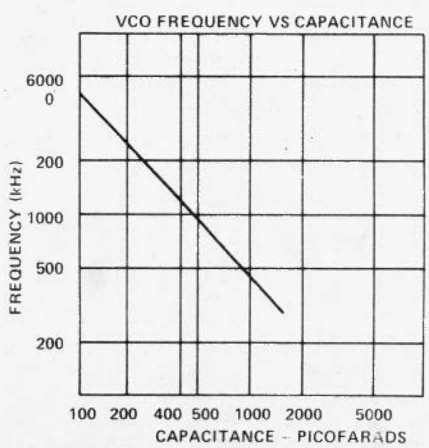

Fig. 19. VCO free running frequency plotted against the capacitance connected between pins 11 and 12.

audio output voltage is about 0.4V RMS. The AM rejection is shown in Fig. 18 for various input signal levels. This rejection is excellent for input levels exceeding a few mV and is probably better than that offered by other well known circuits at such levels.

The input sensitivity is about 9μV for a 30dB signal to noise ratio at 10.7MHz (allowing for a 6dB loss in the ceramic filter), whilst the corresponding level at the mixer input is about 1mV. The capture and lock ranges are about 250kHz and 290kHz respectively for the circuit of Fig. 16 at input levels exceeding 1mV. They fall with decreasing input levels, reaching about 80kHz and 140kHz at an input of 10μV.

The NE563 device can, of course, be used at other frequencies than those suggested in the circuit of Fig. 16. The phase locked loop section can be operated at frequencies of less than 1kHz up to several MHz. The VCO capacitor required for various phase locked loop operating frequencies can be obtained from Fig. 19.

The writer has used a 9.8MHz crystal manufactured by Aero Electronics Ltd., Horley, Sussex, RH6 9SU in the circuit of Fig. 16. Another crystal of the same frequency manufactured by Cathodeon Crystals Ltd., Linton, Cambridge, CB1 6JU to code A04851 gave equally satisfactory results.

An economical Taiyo ceramic resonator type CR-9.8 has also been used instead of a 9.8MHz crystal, but a few circuit modifications are required. The capacitor C8 can be omitted and the resonator connected in parallel with a 2.2k ohm resistor and a 5pF capacitor between pins 1 and 16. The NE563 will oscillate if one merely connects a capacitor between pins 1 and 16, but the frequency will drift considerably. A 22pF capacitor will produce oscillation at about 9.8MHz.

A crystal oscillator is less likely to produce spurious oscillations than the ceramic resonator. Although one has the additional cost of the crystal, the circuit is very simple and ideal for the amateur constructor. Problems may occur with this type of circuit if the input contains spurious frequencies.

The demodulated signal is a multiplex one containing a number of separate parts as shown in Fig. 20. They are:

(1) The normal audio signal which has a waverform representing the sum of the signals in the left and right hand channels. If monaural reception is being employed, this sum signal is used as the audio output. As shown in Fig. 20, the maximum frequency of this signal is 5kHz.

(2) A low level19kHz 'pilot tone' which is synchronised with a 38kHz sub-carrier. This pilot tone is required for the operation of the stereo decoder circuit.

(3) A 'left minus right' signal which is modulated onto a 38kHz sub-carrier. This signal is proportional to the sound amplitude in the left channel minus that in the right channel, the maximum frequency in each channel being 15kHz. Thus the modulated left minus right signal occupies a frequency band of 38 + 15kHz, that is from 23kHz to 53kHz as shown in Fig. 20. There is a small gap in this signal at 38kHz, since no audio frequencies below about 30Hz are transmitted.

(4; The 38kHz sub-carrier itself is suppressed at the transmitter to a level of not more than one per cent of the total signal.

It can be seen from Fig. 20 that a stereo signal requires a much greater bandwidth than a simple monaural signal. This inevitably means that at a given input level from the aerial the signal to noise ratio will be worse for stereo reception than for monaural reception — actually about 20dB worse.

The pilot tone is normally switched off at the transmitter when a monaural signal of more than a few minutes duration is being transmitted. This automatically ensures that the stereo decoder in the receiver is switched to the monaural state for the optimum signal to noise ratio.

A number of types of stereo decoder circuit have been published. For example, in the switching type the 19kHz pilot tone is obtained from the multiplex signal by means of a tuned circuit and is doubled in frequency to re-generate the 38kHz suppressed sub-carrier; the latter is used to switch the multiplexed input signal. Apart from the necessity of setting up the tuned circuit, such systems have the disadvantage that they do not provide the best channel separation.

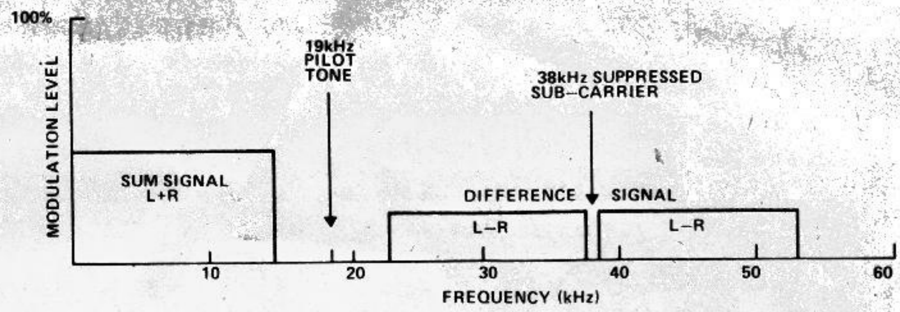

Fig. 20. The frequency spectrum of a stereo multiplex signal.

In this article only modern phase locked loop decoding circuits will be discussed, since they provide optimum performance with circuit simplicity and ease of adjustment. The frequency of the loop automatically locks onto a harmonic of the pilot tone and any normal changes of the component values with time or temperature will not affect the performance. Circuits of this type provide excellent channel separation (typically better than 40dB) and employ an integrated circuit designed especially for the application.

The CA3090AQ

The CA3090 is a unique stereo decoder integrated circuit first introduced by RCA in mid-1971 as the CA 3090Q. An improved version was made available in 1973 under the coding CA309AQ. Both devices are encapsulate in 16pin quad-in-line packages which require a supply of about 22mA at 12V.

Unlike other phase locked loop decoders, these devices have voltage controlled oscillators which are tuned by a 2mH inductance. The use of an inductance tuned oscillator is said to result in better stability at extremes of temperature (which may be useful in car radio receivers) and better stability as the circuit ages.

The CA3090AQ has the following advantages over the CA3090Q:

(i) It can drive directly a stereo indicator lamp which requires a current of up to 100mA. (The indicator lamp is illuminated when th 19kHz pilot tone causes the loop to lock, showing the circuit is switched to the 'stereo' mode).

(ii) The steady voltage level at the stereo defeat/enable contact (pin 4) controls the operating mode, this voltage level being independent of the pilot tone level provided that the latter is above a certain minimum level.

(iii) The CA3090AQ is capable of providing rather lower distortion than the CA3090Q.

Circuit

The fairly complex internal circuit of the CA3090AQ is shown in block form in Fig. 21 together with a typical external circuit. The demodulated multiplex signal from the receiver detector is applied to pin 1 of the CA3090AQ where the input impedance is about 50k. The low distortion pre-amplifier stage feeds the signal to both the 19kHz and the 38kHz synchronous detectors.

The voltage controlled oscillator generates a 76kHz signal which is divided in frequency to produce a 38kHz signal and two 19kHz signals in phase quadrature. The 19kHz pilot tone from the demodulator circuit is compared with the locally generated 19kHz signal. An error signal is generated which is used to control the voltage controlled oscillator frequency so that it remains locked with a harmonic of the pilot tone.

A second synchronous detector compares the locally generated 19kHz signal with the 19kHz pilot tone. If the amplitude of the latter exceeds a certain value set by an externally adjustable threshold voltage, a Schmitt trigger circuit is energised. The signal from the Schmitt trigger operates thelamp driver circuit which switches the stereo indicator lamp on or off. It also switches the circuit from monaural to stereo operation.

The output signal from the 38kHz detector and the multiplex signal from the pre-amplifier are applied to a matrix circuit which produces the left and right hand audio signals; the latter are applied to their respective internal amplifiers. The external capacitors C7 and C8 provide the normal 50μs de-emphasis.

A light emitting diode D1 in series with the resistor R4 is shown in Fig. 21. LEDs consume much less current than tungsten filament lamps and are more reliable. However, D1 and R4 may be

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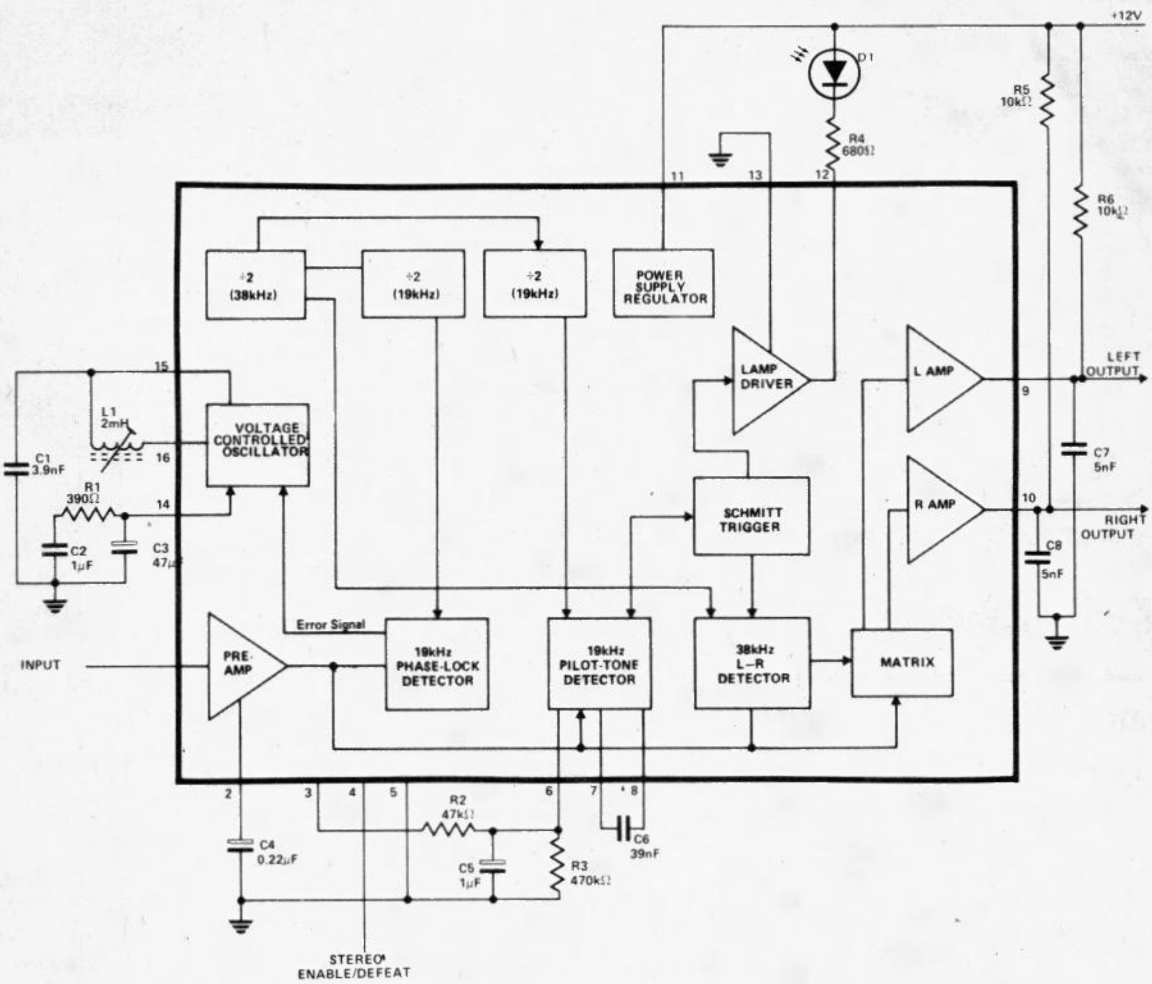

Fig. 21. The circuit used with the CA3090AQ with the internal circuit shown in block form.

replaced by a small lamp consuming not more than 100mA if desired.

The core of the inductance L1 should be set half way between the points at which the indicator lamp just switches as the core adjustment is changed. The centre frequency of the voltage controlled oscillator is then very close to 76kHz. The capture range of the loop is typically ±10% of the centre frequency.

A 2mH coil especially designed for use with the CA3090 device is the Toko type YXNS 30450NK which has its adjuster colour coded blue. It employs 270 turns on a ferrite core which provides a Q factor of about 118. The connections are made to the two pins on the opposite side to the row of three pins on the base of this coil.

If the voltage applied to pin 4 of the CA3090AQ exceeds about 1.2V, the device is switched to the stereo mode. At lower voltages it is switched to the monaural mode. The tolerance range of the pin 4 voltage is 0.9V and 1.6V. The CA3090AQ may be used without the stereo defeat and enable function if a suitable control voltage is not readily available; in this case pin 14 should be directly grounded.

The CA3090AQ provides a typical 2nd harmonic distortion level at the outputs of 0.2%, whilst the 3rd, 4th and 5th harmonic distortion is typically less than 0.1%. The channel separation is typically 40dB (minimum 25dB).

To be continued next month....