# Low distortion oscillator

## 2 — Constructional design

by J. L. Linsley Hood

The basic oscillator design was described in the first part of the article, with the modifications to the normal Wien bridge circuit. Because this design is very suitable for the construction of a battery operated instrument, constructional details of a portable unit are given. A few modifications have been made to the basic circuit, for reasons of practical convenience, and these are noted where appropriate.

### Output attenuator

It was mentioned previously that the desired output impedance for an instrument of this type was 600Ω, and this is provided on all ranges, except the 0 to 1V, by a resistive transmission line attenuator. However, the impedance from the 0 to 1V output will vary from zero, at the minimum output setting of the potentiometer, to 800Ω. If a twin gang potentiometer is used, with the second gang connected as a variable resistance, shunted by a fixed resistor in the line to the 1V output point, a reduced range of output impedance values can be arranged. For example, with a 2.2kΩ second gang, shunted by a 680Ω fixed resistor, the output impedance would range from 519Ω at zero output, to about 1250Ω at the maximum impedance point, and down to 680Ω at the maximum setting. This arrangement is shown in the circuit diagram.

### Squarer circuit

It is very convenient in audio work if a good square-wave output is also available from the oscillator. This waveform can be derived from a sinewave by using successive stages of amplification in a c.m.o.s. 74C04 hex inverter or similar i.c.

To obtain automatic balancing of the mark-to-space ratio, the first stage is made self-biasing as a d.c. unity-gain amplifier, by a 1MΩ resistor connected between the input and output. Because the a.c. gain of each inverter stage is at least 100, the overall gain of the four stages in series is about $10^8$. The two output gates are connected in parallel to obtain a lower output impedance. The output stages are driven from one state to the other by very small excursions from the mid-point value of the 3V pk-to-pk input signal. A typical rise and fall time from such a configuration is 200ns, which is adequate for audio work. If very fast transition times are required for logic applications, the output signal can be used via a suitable interface device to drive a conventional t.t.l. element. Care is needed in the layout and termination of high speed circuitry if the potential rise and fall times are not to be degraded.

### H.f. loop correction

Any amplifier system having several stages within the feedback loop is prone to unwanted parasitic oscillations unless gain/phase correction is operative in those regions where the phase shift approaches 180°. In direct coupled systems the l.f. phase shifts can be ignored, but the h.f. phase shifts may be troublesome, and can cause the problem of "squegging". In this circuit a small capacitor of between 33 to 100pF is connected across the source and drain of the bootstrap f.e.t. Because the capacitor required will depend on the stray capacitance, it is difficult to predict the value necessary. To preserve the circuit gain, and lowest t.h.d. for the highest practical frequency, this capacitor should be the smallest value which avoids "squegging"; therefore, some experimentation is worthwhile.

In the original circuit the gate of the bootstrap f.e.t. was connected to the emitter of the input transistor. This configuration gives the highest loop gain and the lowest distortion in the 100Hz to 2kHz region. However, the value of capacitor between the source and drain of the f.e.t., which is necessary to give the required h.f. loop compensation, is greater in this case than if the gate of the f.e.t. and the base of $Tr_1$ are connected in parallel as shown in the circuit. The author's prototype used the last mentioned configuration to produce a less rapid increase in t.h.d. towards the high-frequency end of the operating range.

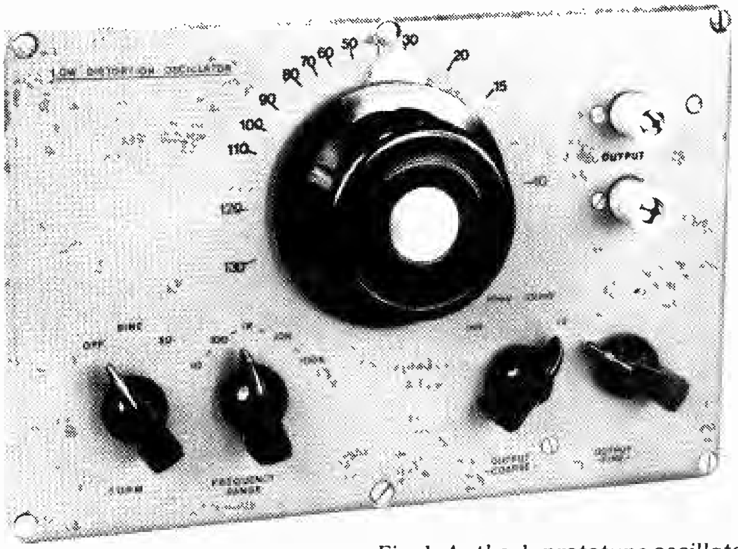

*Fig. 1. Author's prototype oscillator. The complete instrument is powered by two 9V batteries which fit inside the case.*

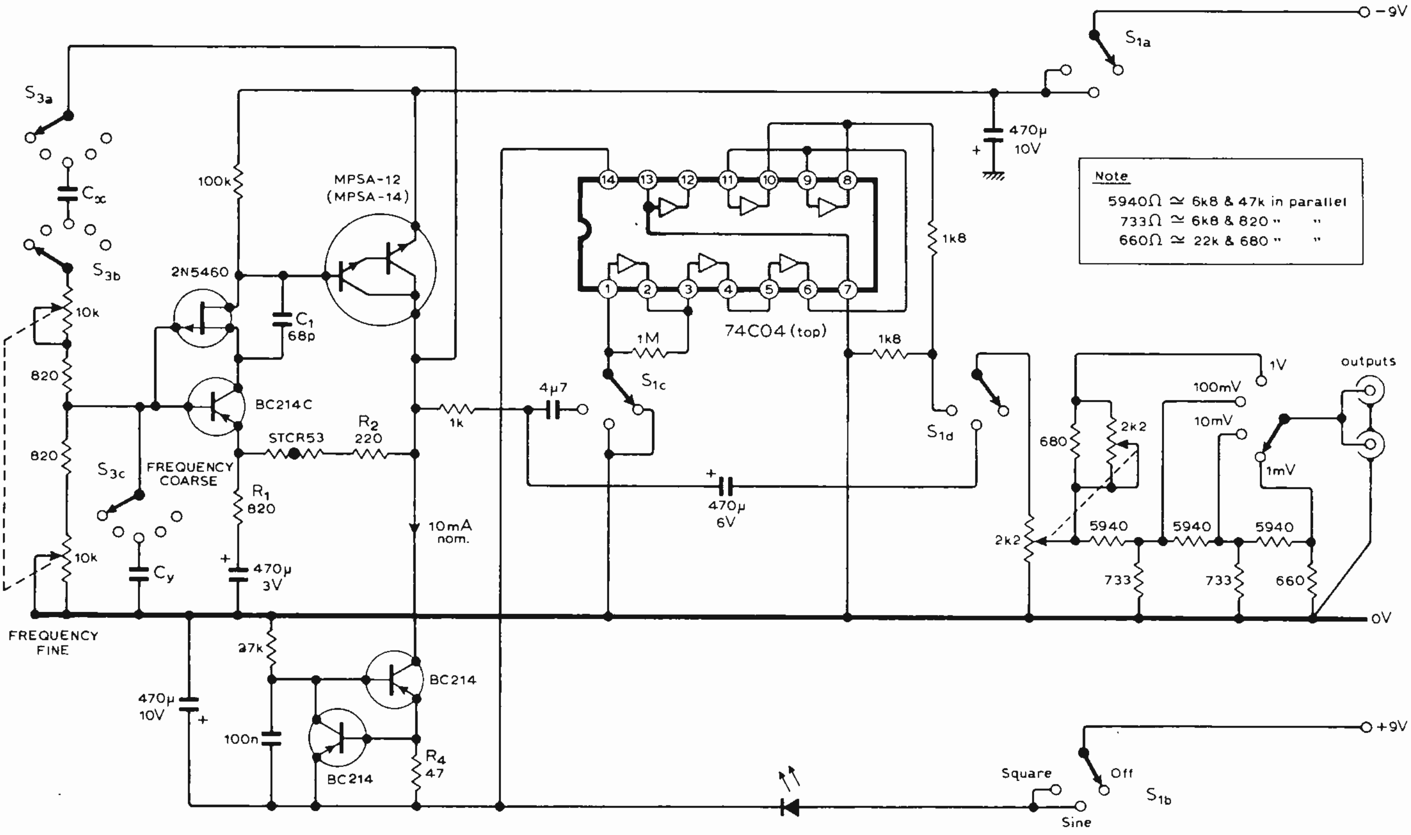

*Fig. 2. Full circuit as used in the author's final prototype.*

## Amplitude stabilization

The problem of amplitude stabilization with low-distortion oscillators generally arises because any low distortion system approximates to a high Q tuned circuit. As a result the oscillator can only respond slowly to a step-function change in amplitude. A voltage sensitive device such as a thermistor, which provides a convenient method of amplitude stabilization when used in a feedback network, must also have a long time-constant. Therefore, negative feedback applied to a low distortion oscillator through a long time-constant voltage dependent device, results in a second order feedback system, whose response when switched on is a characteristic overswing, followed by a damped train of excursions about the final value.

It is undesirable to resolve this dilemma by increasing the t.h.d. of the oscillator, so various artifices are used in practical designs to overcome the difficulty. In this circuit the cold resistance of the thermistor is reduced to a value approaching its normal operating condition by passing the $10\mu A$ emitter current of $Tr_1$ through the device which pre-heats it. In addition, a small fixed resistor is connected in series with the thermistor to limit the lower, hot, circuit resistance value.

## Construction

For reasons of practical simplicity the oscillator was built in a standard die-cast aluminium alloy box measuring 22×14.5×6cm. The unit is powered by two PP7 9V batteries which fit conveniently in the box. Frequency control is by a twin-gang $10k\Omega$ potentiometer. If a logarithmic law is used and connected so that the minimum resistance value occurs when the control is turned anti-clockwise, the final frequency scale will be more linear than if a linear potentiometer is used. Also, if the limit resistors $R_2$ and $R_3$ in Fig. 4 of the first article are reduced to $820\Omega$, the 1 to 10 range required from this control can be accommodated in a 180° swing which avoids any overlap of the scales.

The frequency range capacitors can be mounted between the tags of the three-pole four-way wafer switch to minimise stray capacitance. Although the suggested values for the capacitors are in the 1.47 series, made up by paralleling $1\mu F$ and $0.47\mu F$ etc, an adequate alternative is the $1.5\mu F$ component range.

Two output sockets wired in parallel are used to allow the connection of an oscilloscope. In the case of stereophonic equipment, the two signals can be applied to both channels simultaneously. Note that this is only suitable when the two inputs have a high impedance, and do not have any significant voltage or current feedback.

As current consumption of the circuit is approximately 10mA on sinewave, and about 15mA on square wave, battery life should be adequate for normal use.

## Calibration

In the absence of a frequency counter, the oscillator may be calibrated on the 100Hz to 1kHz range by Lissajous figures on an oscilloscope, with an input to one axis derived from the 50Hz mains supply. If the components are of reasonable quality, the other ranges should have a similar scale pattern. Alternatively, the mean resistance value of the two halves of the potentiometer can be measured and the frequency of the oscillator calculated, assuming accurate values for the capacitor and for $R_2$ and $R_3$, using the formula $F = 1/2\pi RC$. The overall frequency stability of the instrument is very good, which makes it suitable for low distortion measurements using a sharply tuned notch circuit.

## Printed circuit board

A p.c.b. which accommodates the Wien bridge oscillator, frequency range capacitors, square wave generator and output attenuator will be available for £3.00 inclusive from M. R. Sagin at 23 Keyes Road, London, NW2. The board follows the author's complete circuit as shown.

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## Correction

In the article 'Amateur radio equipment — 1' on p.64 of the August issue, the stability figure for the Eddystone 1001 receiver was shown as "one part in 10 per dec. C". This should have read "one part in $10^4$ per deg. C."