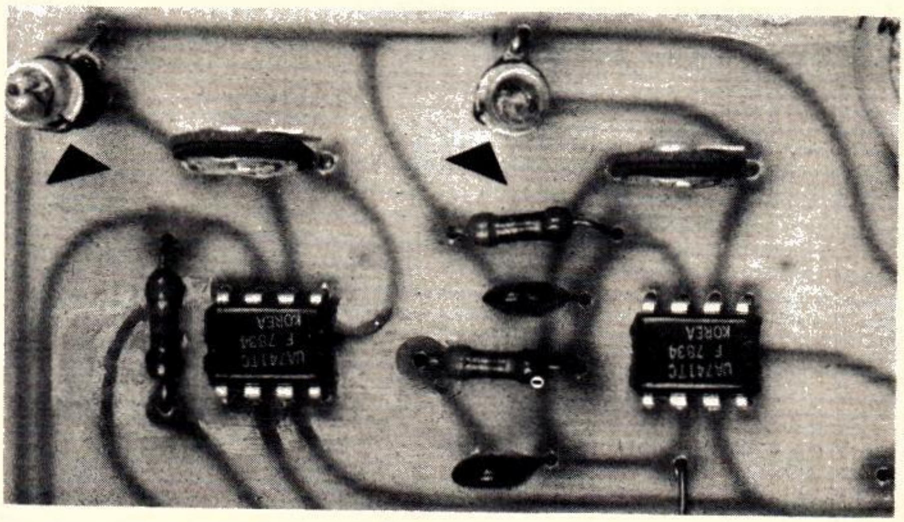
THE WEIN BRIDGE OSCILLATOR

Probably the most popular type of low frequency sine wave oscillator as it is superior in virtually all respects to phase-shift types. Unfortunately it does not seem to be all that well understood. This article sheds some light on this most useful circuit.



Twin Wein Bridge oscillator using lamps for feedback stabilisation.

MOST STUDENTS of electronics – that includes hobbyists, you learn from your hobby don't you? – would be familiar with the "Wheatstone Bridge"; that often-handy technique for measuring unknown values of resistance. The Wein Bridge is an outgrowth of the Wheatstone Bridge. The basic circuit is shown in Figure 1.

This circuit has some unique properties. The networks R1-C1 and R2-C2 form a potential divider between points A and B. Both networks have an impedance which decreases with frequency. At one frequency, and one frequency *only* (depending on the values of R1-C1 and R2-C2), the bridge will be balanced. That is, if a sinewave voltage is applied between A and B no voltage will appear across C and D. Another interesting, and useful property of this bridge is that, at the balance frequency, the phase of the voltage across C and B will be *exactly* the same as that across A and B. The same will be true for harmonics of the balance frequency, *but,* the impedances of R1-C1 and R2-C2 will not be the same as at the balance frequency and the bridge will be unbalanced.

Well, how are these properties of the Wein Bridge used in an oscillator? The basic circuit of a Wein Bridge oscillator is shown in Figure 2. The component numbering of the Rs and Cs is the same as in Figure 1. We are assuming that the amplifier has good common-mode rejection, an infinite input impedance and zero output impedance. Fortunately, an op-amp is a reasonable approximation to this and the circuit as shown will work well with a common-or-garden 741 at frequencies up to 10kHz.

The Wein Bridge components are connected such that positive and negative feedback is applied around the op-amp. This should be readily apparent from the way Figure 2 is drawn. The negative feedback is derived from the resistive potential divider R3 and R4. Positive feedback is provided by the potential divider R1-C1 and R2-C2. The amount of positive feedback through R1-C1 will *increase* with frequency as this network has a *decreasing* impedance as frequency increases. The parallel RC network formed by R2-C2 also has *decreasing* impedance with *increasing* frequency, tending to shunt the amount of applied positive feedback (via R1-C1) to ground. At the balance frequency the applied positive feedback will be a maximum, falling at frequencies above and below the balance frequency. However, if the bridge is balanced, the positive feedback and the negative feedback will be equal . . and the circuit will not oscillate. *But,* if the amount of negative feedback provided by R3-R4 is chosen to be fractionally less than the

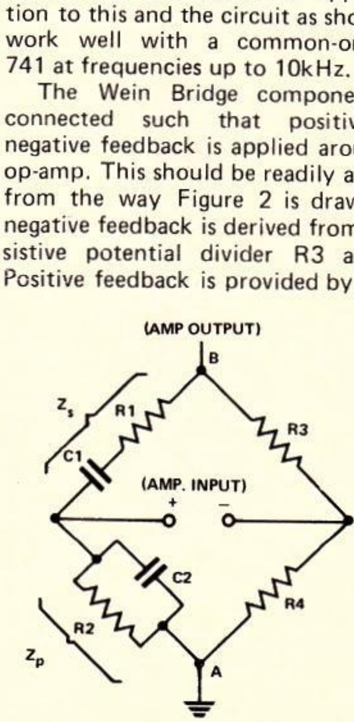


Figure 1. Basic circuit of the Wein Bridge.

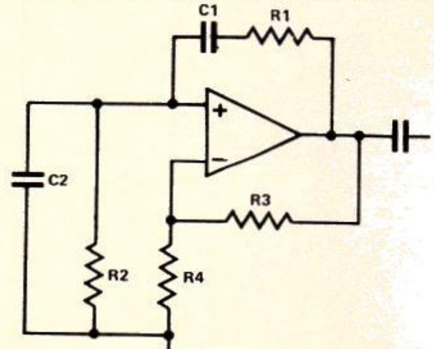


Figure 2. Basic Wein Bridge oscillator circuit.

positive feedback at the balance frequency, the circuit will oscillate. Since negative feedback predominates *at all other frequencies,* and the bridge remains unbalanced, harmonics of the balance (or resonant) frequency are suppressed and the waveform produced will be a sine wave of great purity.

In practise it is necessary to include some means of sensing the amount of negative feedback so that the amplifier gain can be held at the precise amount necessary to ensure oscillation. If the amount of negative feedback is too little, the waveform will be distorted. If too much, oscillation will not occur. Secondly, if the gain varies (for whatever reason) the feedback needs to be stabilised to prevent distortion and level variations.

The simplest way of doing this is to incorporate a thermistor or tungsten filament lamp in the negative feedback potential divider. If the latter is used for this purpose — and common lights bulbs used for bezel lamps have tungsten filaments — it would replace R4 so that gain increases of the amplifier stage cause increased current in the lamp. This, in turn, would cause the temperature of the filament to rise, increasing its resistance, thus increasing the amount of negative feedback. The use of these temperature variable devices sets a limit on the lowest frequency at which the circuit can be used. When the period of oscillation is comparable to the thermal time constant of the particular light bulb or thermistor, the change in resistance over each cycle will bring about gain variations which result in distortion of the output

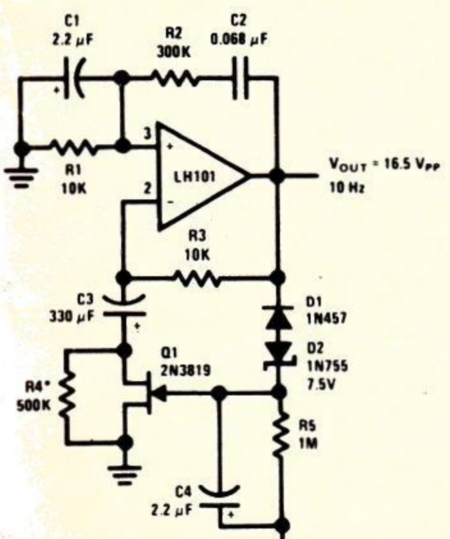


Figure 4. Example of a practical Wein Bridge oscillator with a FET in the feedback (courtesy National Semiconductors).

waveform. Also, these devices have a "settling time" that prohibits the frequency from being changed quickly in a variable oscillator using this circuit.

The solution to these problems entails using a FET as part of the feedback element. The FET becomes part of R4 — as shown in Figure 3 — driven by an RC network between the op-amp output and the gate. In this way, the 'averaging time' of the circuit can be tailored to suit the job required. An example of a practical circuit is given in Figure 4.

A lot of the advantages, and the unique properties of the circuit, become apparent from a look at the mathematics involved; it's quite straightforward really.

The impedance of C1, at a certain frequency 'f', is given by:

$$Z_{C1} = \frac{1}{j\omega C}$$

Where: Z_{C1} = impedance of C1

$$= 2\pi f$$

$$j = \sqrt{-1}$$

So the total impedance Z_s, of the series network R1-C1 is given by:

$$Z_s = R1 + \frac{1}{j\omega C}$$

Since the impedance of capacitor C2 is also given by:

$$Z_{C1} = \frac{1}{j\omega C}$$

Where: Z_{C2} = impedance of C2

$$\omega = 2\pi f$$

$$j = \sqrt{-1}$$

and C2 is in parallel with R2, the total impedance of the parallel network R2-C2 (Z_p) is given by:

$$\frac{1}{Z_p} = \frac{1}{R_2} + \frac{1}{\frac{1}{j\omega C}}$$

therefore: $$\frac{1}{Z_p} = \frac{1}{R_2} + j\omega C$$

Oscillation will occur when:

$$\frac{R3}{R4} = \frac{Z_s}{Z_p}$$

since it is this condition which will result in unity gain.

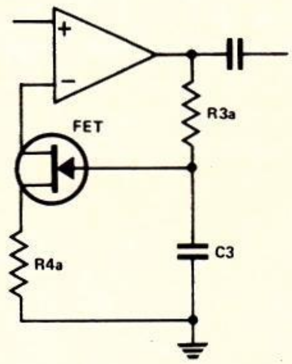


Figure 3. Feedback stabilisation using a FET.

If we let R3 = 2 X R4, and substitute this in the equations for Z_s and Z_p, this equation becomes:

$$\frac{2R4}{\frac{1}{R2} + j\omega C} = R4\left(R1 + \frac{1}{j\omega C}\right)$$

and this simplifies to: $$\omega^2 = \frac{1}{R1\,R2\,C1\,C2}$$

since $\omega = 2\pi f$,

then $$2\pi f = \frac{1}{\sqrt{R1\,R2\,C1\,C2}}$$

and $$f = \frac{1}{2\pi\sqrt{R1\,R2\,C1\,C2}}$$

The major advantage of the Wein Bridge oscillator is its inherent stability and predictable frequency output. In other low frequency oscillators employing RC networks in the feedback, the frequency of oscillation is *directly* proportional to the values of the components in the network. In the Wein Bridge, you can see from the last equation that the frequency of oscillation is proportional to the *square root* of the component values in the network. The ease with which amplitude levelling and level stability can be achieved by using simple thermal devices in the negative feedback is another advantage. Thirdly, the low distortion possible with this circuit contributes greatly to its popularity.

On the other hand, to vary the frequency, two components have to be varied simultaneously — either C1/C2 or R1/R2. The fact that the one of these is wholly above ground' complicates things — but it's not an insoluble problem as there are many Wein Bridge oscillators around! ●