Wien Bridge Oscillators using E^2POTs

by Applications Staff, October 1994

Wien Bridge Oscillators

In 1939, William R. Hewlett (later of Hewlett-Packard fame) first combined the network described by Wien in 1891 with a gain stabilizing element in a bridge configuration, to produce an oscillator based on a 6J7 vacuum tube. Few circuit designs can match the low distortion, good amplitude stability, ease of tuning, and circuit simplicity offered by the Wien bridge oscillator.

The Wien bridge oscillator is based upon an amplifier with two feedback paths, making up the two arms of the bridge. One arm of the bridge is the Wien network, which provides the frequency tuning elements, and another arm which establishes amplitude equilibrium. Figure 1 shows the configuration using an Operational Amplifier. Positive feedback is provided by the Wien network comprised of equal-valued C1, R1, C2, and R2 elements. Negative feedback is provided by R3 and R4.

To understand how the Wien bridge oscillator works, assume that at power-up, the negative feedback is made less than the positive feedback. Oscillation will start to occur at the frequency where the phase shift and amplitude attenuation in the Wien arm is a minimum. Figure 2 shows the response functions for magnitude and phase from the amplifier output to the noninverting (+) input with C=0.01µF and R=10KΩ. Notice that when the phase equals zero degrees, the magnitude of the positive feedback is a maximum and equal to 1/3. The oscillator amplitude will continue to increase until the amplifier saturates (and produces horrible square waves) or until amplitude equilibrium is maintained below saturation by adjusting the ratio of R3 and R4. Hewlett did this by taking advantage of the positive temperature coefficient of an incandescent lamp. It is interesting to note that when equilibrium is reached, the negative feedback factor will also be 1/3 (in a practical circuit, due to non-ideal components, the negative feedback will be slightly less).

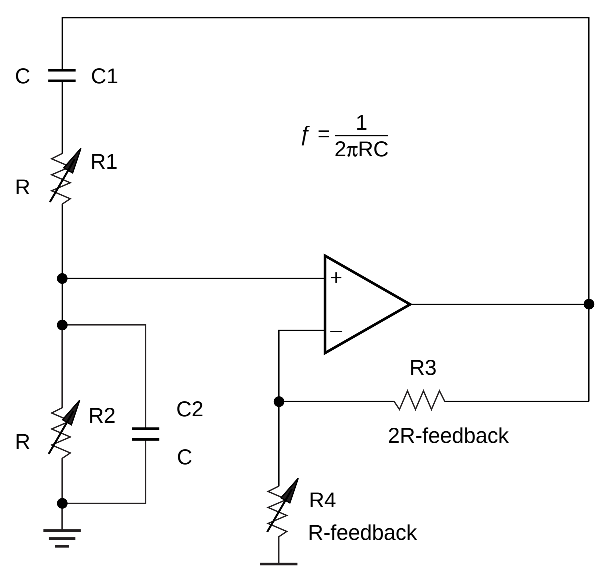


Figure 1. Wien Bridge Oscillator

A Wien bridge Oscillator with E^2POTs

Notice that to change frequency, it is necessary to either change both Rs or both Cs of the network and that the Rs or Cs have to change by the same amount or "track" each other. Hewlett accomplished this by using a pair of ganged air-variable capacitors mechanically linked to a tuning knob. You could get similar results by using a pair of ganged potentiometers instead.

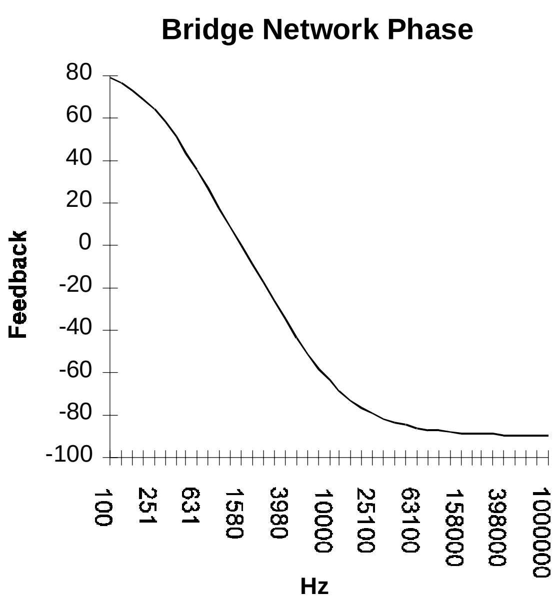
However, ganged variable capacitors and resistors are rather bulky and expensive mechanical items that require manual adjustment to change frequency. Since a pair of Xicor E^2POTs can be electronically ganged together, they can provide a solid state solution and eliminate the need for any mechanical mounting considerations involved with the air-variable capacitors or the ganged mechanical pots. The benefit of using these digital pots is that the control circuitry can be located remotely from the actual oscillator since the pots are controlled digitally, you don't have to worry about the frequency being inadvertently bumped out of adjustment.

Circuit description

Figure 3 shows the Xicor X9C103 E^2POT in a Wien bridge circuit along with remote pushbutton control circuitry. The frequency is determined by the combination of C1, C2, R1+U1, and R2+U2. Assuming that C1=C2 and R1+U1=R2+U2, the frequency is:

$$f = \frac{1}{(2\pi C1(R1+U1))}$$

The negative feedback is set by the combination of R3, R4A, R4B, and Q1. Q1 in parallel with R4B, plus R4A, forms the shunt elements in the negative feedback path. The channel resistance of Q1 is controlled by the amplitude detector circuit comprised of CR3, U3B, R11, and C7. U3B compares the positive peaks of the oscillator output detected by CR3, to the voltage reference established by R11 and R12. The amplitude detector scheme automatically sets the negative feedback so that the peak output just equals the reference voltage. This limits the oscillator voltage swing so that U3A does not saturate and maintains the amplitude equilibrium, which is important when generating sine waves. To ensure that cycle by cycle limiting is not occurring, the time constant of R11 and C7 is much longer than the lowest frequency which the oscillator can be tuned.



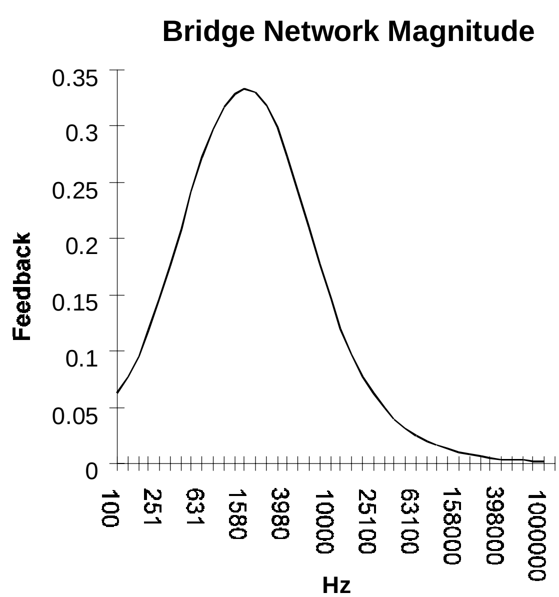


Figure 2. Bridge Network Phase and Magnitude

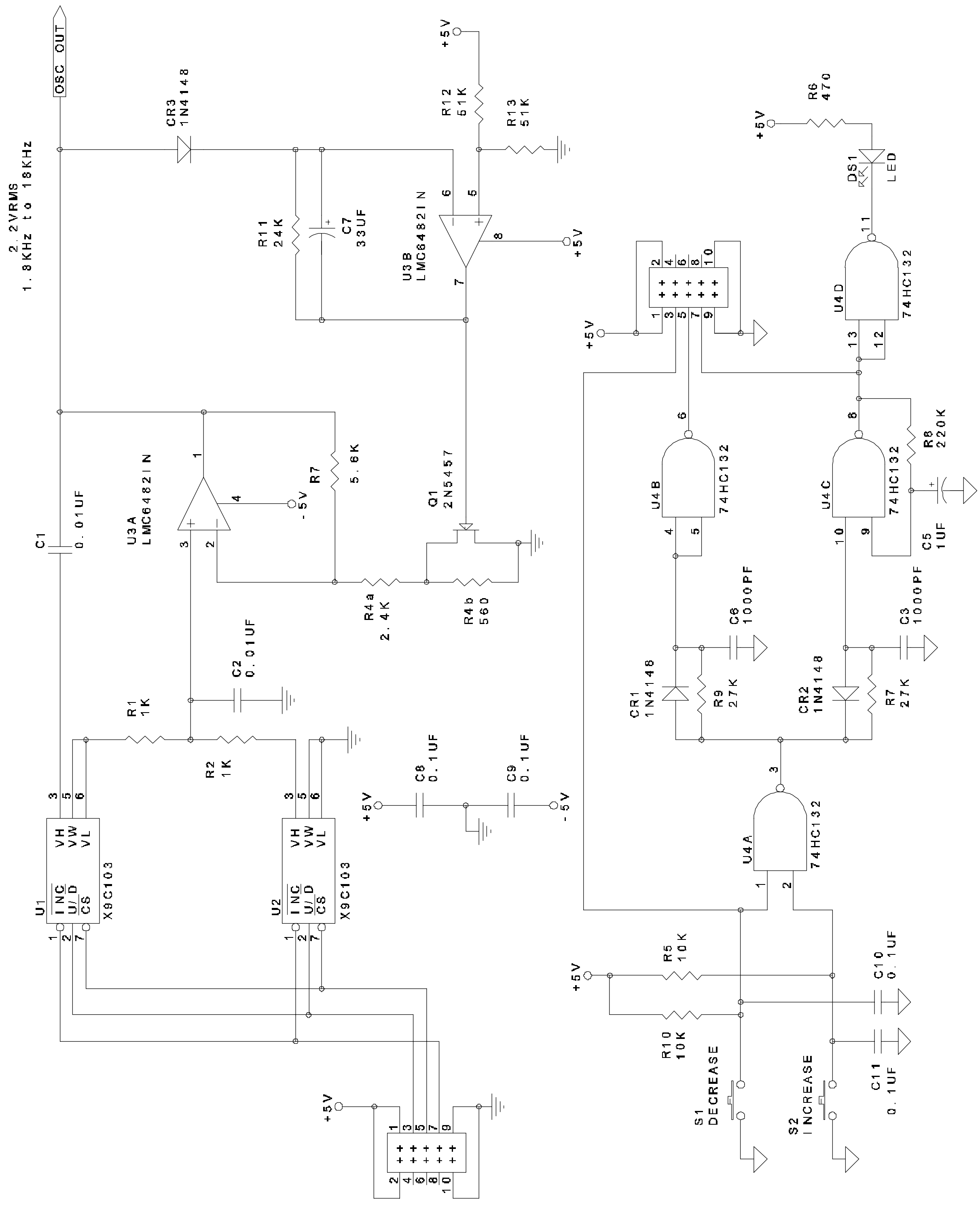


Figure 3. Xicor X9C103 Wien Bridge

Beyond the fact that equal valued Rs and Cs must be used in the Wien arm of the oscillator, there is nothing critical about the components used. Any Op Amp can be used as long as the input or output common mode voltage ranges are not exceeded. The FET can be most any N-channel device as long as R11 and C7 are optimized to keep the gain control loop stable.

This circuit design can be modified to suit just about any application. For example, you may wish to add an additional Xicor E^2POT in place of R13 in order to control the output amplitude. You could also implement digital range selection by using a MOSFET switch to select alternate values of C1 and C2 in decade increments. This should allow selection of decade ranges of 20Hz to 200Hz, 200Hz to 2KHz, 2KHz to 20KHz, and 20KHz to 200KHz.

Performance

Naturally, for the oscillator to work properly, the two digital pots have to be initially ganged together. This is accomplished simply by holding either of the controller pushbuttons down for at least 100 steps. After this procedure is performed, the pots will always "track" and the frequency can be set as desired. Figure 4 shows the output frequency verses step number. With the values used in the schematic the frequency range should be approximately 2KHz to 20KHz in 100 steps. The output amplitude is $2.2V_{RMS}$.

The total distortion and noise of this circuit was measured to be approximately 0.5% and most of the distortion products are second harmonics. This second harmonic is caused by the channel resistance of the gain control FET, Q1, being modulated by the oscillator frequency. You can further reduce the distortion by adding a small amount of Q1 drain signal onto the gate with an appropriate resistor divider network.

The amplitude stability of this oscillator is excellent with no change in output being perceptible over the full range. No doubt, this is why these oscillators proved to be so useful in test application.

Remember, one of the advantages of the E^2POTs is their nonvolatility, so the frequency will always be maintained, even if the oscillator and controller is powered-down. In fact, after the frequency is set, the controller can be removed. This circuit could prove useful in embedded built-in test equipment (BTE) applications where it is desirable to have a programmable oscillator with low distortion and good amplitude stability.

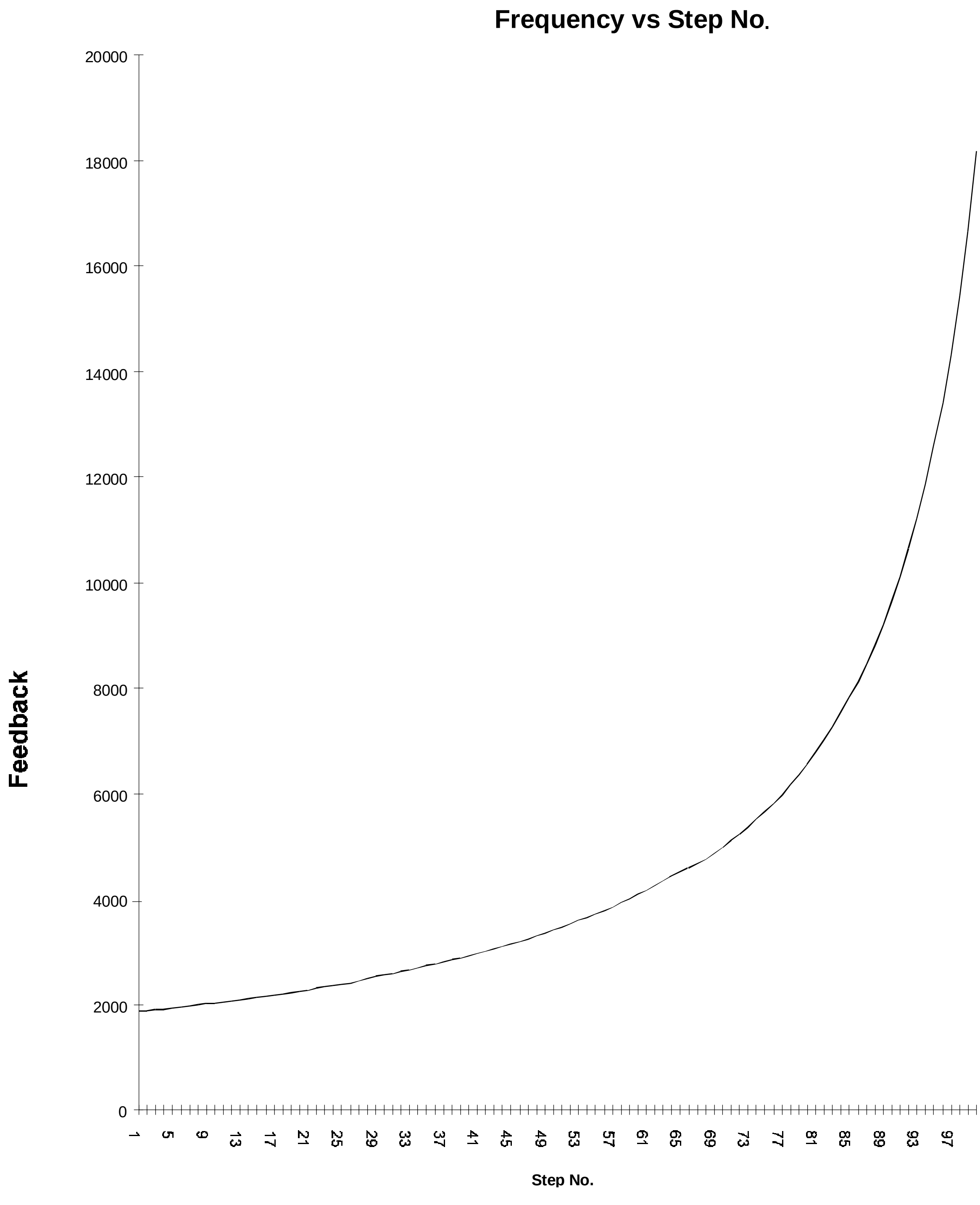


Figure 4. Oscillator Tuning