

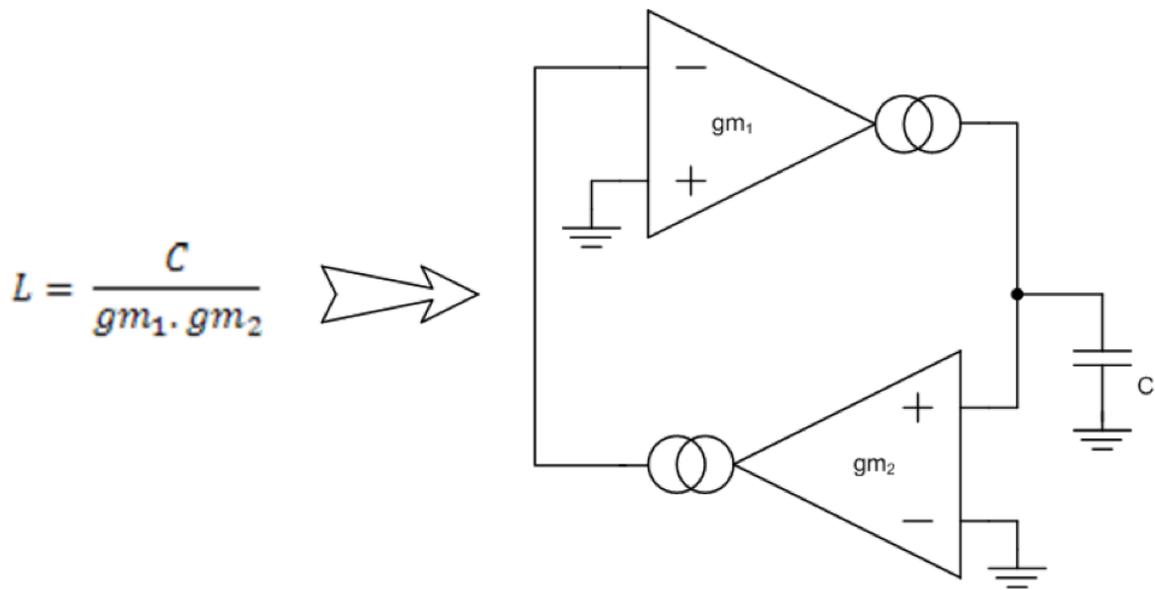
Quadrature Oscillator (Part 1)

A quadrature oscillator produces two sinewaves with 90° phase difference between them. These are useful to pan signals (particularly in a quadraphonic environment), or to make a frequency-shifter when combined with a pair of ring-modulators.

At resonance, the voltage across a parallel L-C network and the current circulating within it are 90 degrees out of phase. Replacing the inductor with a gyrator circuit means that the circulating current is represented by a voltage across a capacitor, meaning that this circuit contains two quadrature voltages, which is what we want in a quadrature oscillator. So how do we get from an L-C tank to an oscillator?

An active inductor

A gyrator is a circuit that 'inverts' the AC characteristics of whatever is placed across its' output, when observed from its' input. This means that a capacitor can 'look like' an inductor, and the value realized is a function of both the capacitor value and the gyrator action. Fortunately it is quite easy to realise a gyrator, and even make it electronically adjustable.



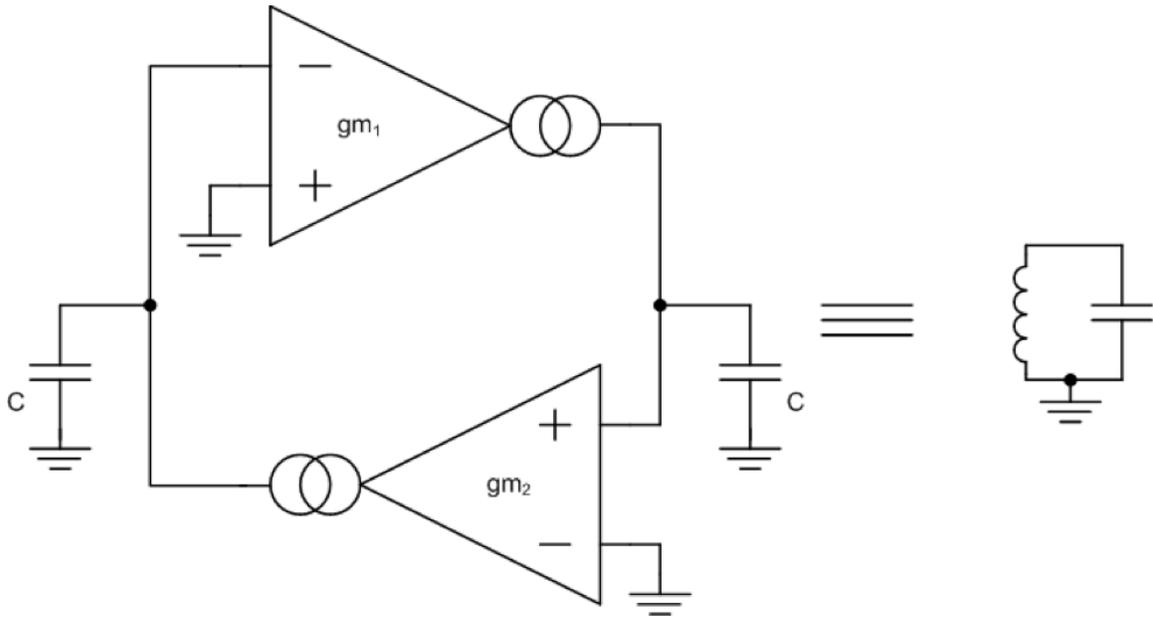
Two back-to-back voltage-controlled current sources let us realize the gyrator, and placing a capacitor on the output gives us a tunable inductor. We can even calculate the value of the inductance in terms of gm (the VCVS gain) and capacitance -

$$L = \frac{C}{gm_1 \cdot gm_2}$$

Given the resonance of a tuned circuit ($\omega = \sqrt{L \cdot C}$), if we use the same value capacitor to complete the tank, and use two identical VCVS the resonant frequency becomes

$$\omega = \frac{C}{gm}$$

And our 'tank' looks like this -



Making it oscillate

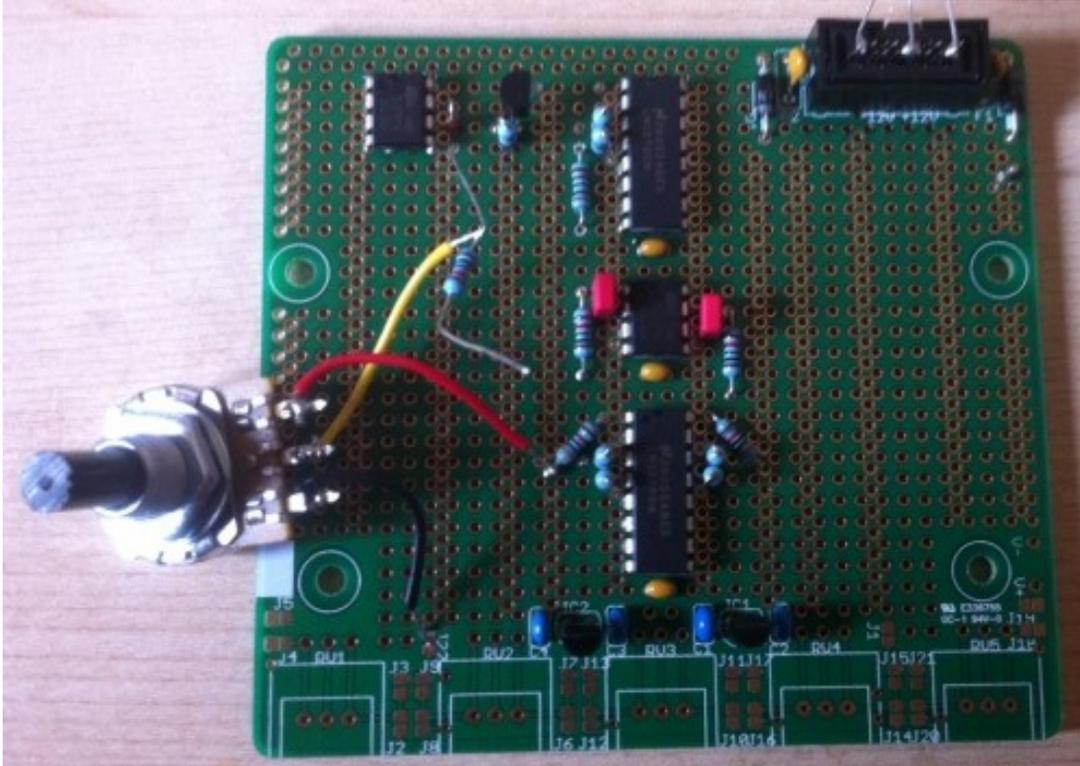
Oscillations in a tank circuit decay as a result of losses, which are usually modeled as a resistor across the tank. Putting a negative resistance in parallel with this cancels the losses, and this can be implemented with another VCVS to complete the oscillator. Circuit noise is sufficient to start the oscillations, but a limiting circuit may be required to stop the signal level clipping against the supply rails.

Quadrature Oscillator (Part 2)

The Circuit

I used one of my Euro Prototyping PCB's to build a VCO based on the concept proposed in the last entry, to see if the idea worked in reality. LM13700 Operational Transconductance Amplifiers were used for both the gyrators and negative resistance, with minimal circuits to make the circuit work. With two OTA's in one package, and dual op-amps as integrators the core of the oscillator is very compact, however I needed another LM13700 for the negative resistor.

For simplicity I fixed the current in the gyrators by connecting the Iabc pin of each OTA to ground via a 22k resistor, but controlled the negative resistance (feedback) with a voltage-current converter connected to a potentiometer. The schematic for the circuit is at the end of this document, and the circuit components can easily be matched with the elements in the diagrams in the last post.

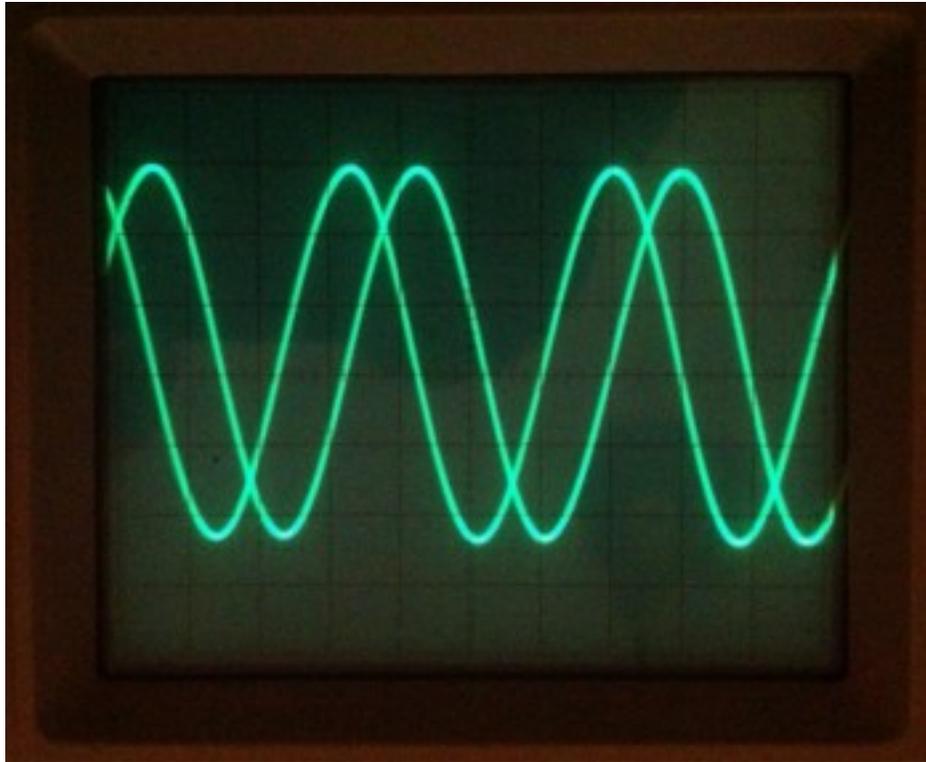


The test circuit for the oscillator - the potentiometer controls the feedback

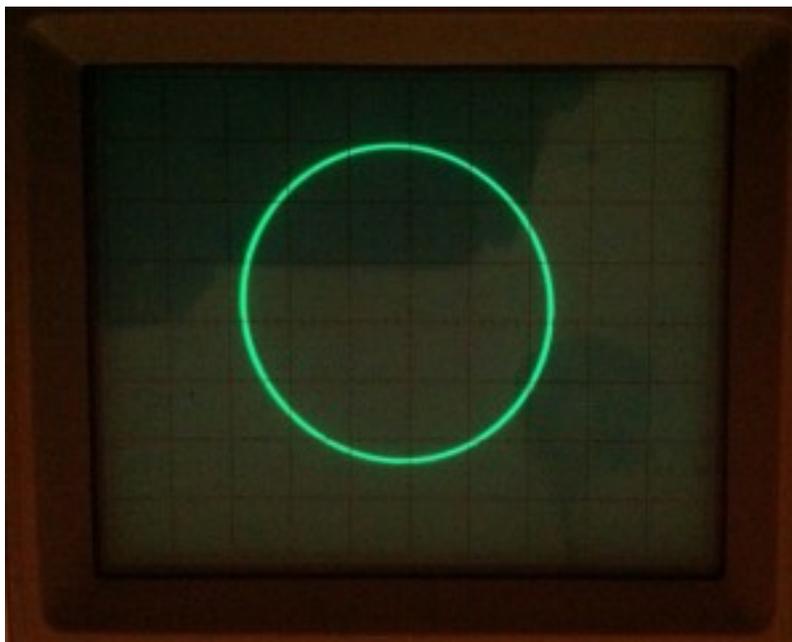
The Results

Adjusting the potentiometer slowly, the circuit oscillated, with the amplitude increasing gently, until the oscillator clipped against the supply rails. Lowering the feedback, the amplitude slowly reduced, until it reached zero. Further adjustment revealed a small range of potentiometer settings where the amplitude was static, with a nice sinewave output from each integrator. Success!

Here are some 'scope pictures to show the sine outputs, and a Lissajous plot to check the phase and amplitude relationship of the two signals.



Quadrature outputs from the oscillator - nice sinewave too.



X-Y (Lissajous) plot of the two waveforms. A circle confirms phase quadrature and low harmonic content.

Conclusion

The 'active L-C' oscillator clearly works, but even at a fixed frequency the feedback that sustains oscillation will need better control than I used here. How much better will need further investigation, but in the interim I can add an expo-converter and make the oscillator tunable to test the sustaining amplifier further.

