Chapter 19 - The Oscillator

The Electronics Curse

“Your amplifiers will oscillate, your oscillators won't!”

Question, What is an Oscillator?

A Pendulum is an Oscillator...

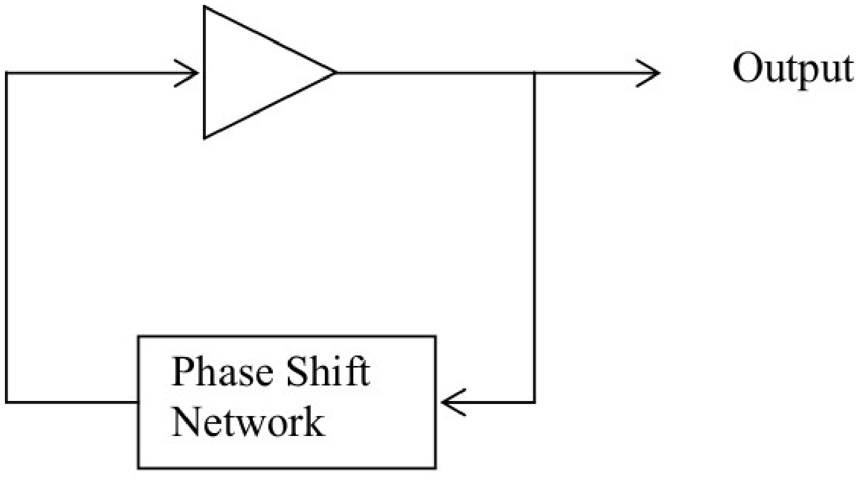
“Oscillators are circuits that are used to generate A.C. signals. Although mechanical methods, like alternators, can be used to generate low frequency A.C. signals, such as the 50 Hz mains, electronic circuits are the most practical way of generating signals at radio frequencies.”

Comment: Hmm, wasn't always. In the time of Marconi, generators were used to generate a frequency to transmit. We are talking about kiloWatts of power! e.g. Grimeton L.F. Transmitter.

Oscillators are widely used in both transmitters and receivers. In transmitters they are used to generate the radio frequency signal that will ultimately be applied to the antenna, causing it to transmit. In receivers, oscillators are widely used in conjunction with mixers (a circuit that will be covered in a later module) to change the frequency of the received radio signal.

Principal of Operation

The diagram below is a '**block diagram**' showing a typical oscillator. Block diagrams differ from the circuit diagrams that we have used so far in that they do not show every component in the circuit individually. Instead they show complete functional blocks – for example, **amplifiers** and **filters** – as just one **symbol** in the diagram. They are useful because they allow us to get a high level overview of how a circuit or system functions without having to show every individual component.



Block Diagram of an Oscillator

The Barkhausen Criterion

[That's NOT ‘dog box’ in German!]

Comment: In electronics, the **Barkhausen stability criterion** is a mathematical condition to determine when a linear electronic circuit will oscillate. It was put forth in 1921 by German physicist Heinrich Georg Barkhausen (1881–1956). It is widely used in the design of electronic oscillators, and also in the design of general negative feedback circuits such as op amps, to prevent them from oscillating.

The ‘loop gain’ of an oscillator is the total gain that the signal experiences starting from any point in the circuit and going around the loop until it gets back to the starting point. For example, suppose the amplifier has a gain of 10 dB, that half the power is “bled off” to the output (resulting in a loss of 3 dB), and that the phase shift network also has a loss of 3 dB.

Converting the losses into negative gains, we get the following figures:

Amplifier	10dB
Loss of output signal	-3dB
Phase shift network	-3dB
Total loop gain	4 dB [10 - 6 dB]

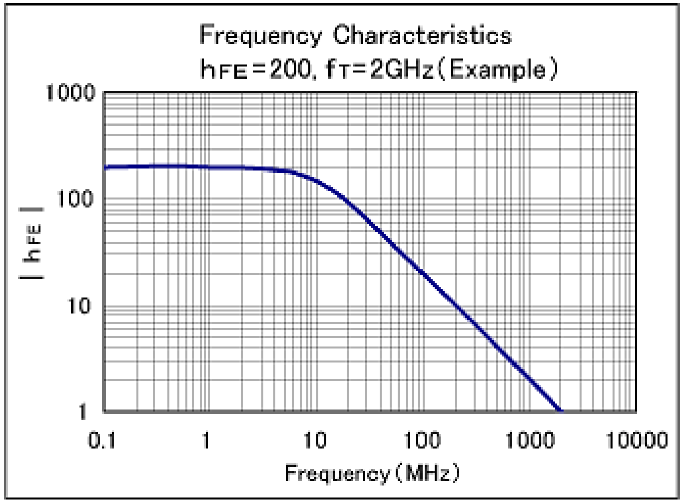
Amplifier = Gain = ‘make bigger’

As the signal grows bigger, ultimately the gain of the amplifier will be reduced (for example, it may be limited by the power supply voltage to the amplifier) until we reach the point that the amplified signal that is passed through the phase shift network and back to the input of the amplifier is only just as strong as the input to the amplifier that caused it. At this point, the signal is no longer growing, but remains constant and we have reached a stable oscillating state. If the oscillator has been designed correctly, then the output will be a constant amplitude signal at the desired frequency.

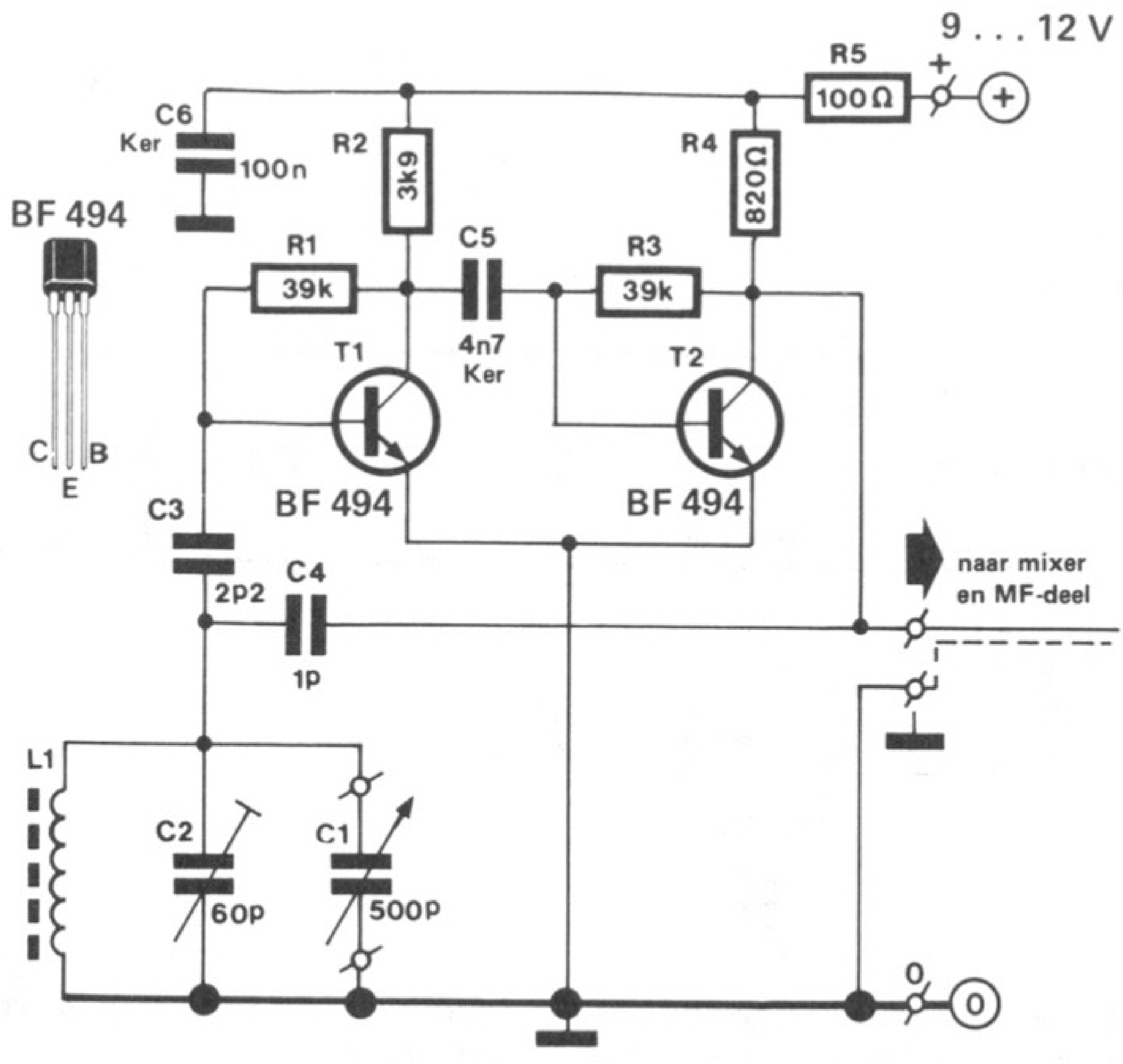
Feeding back some of the output of the amplifier back to the input in such a way that it reinforces the original input signal is called **positive feedback**. This is the same effect that you get when the audio output of a PA system is fed back to the microphone creating “howl-round” or “feedback”.

A Quick recap...

- Transistors (bipolar) have 'current gain'
- Transistors have a frequency dependence. i.e. they have lower gain as the frequency increases...
- The frequency where the gain (hfe = 1) is the 'fT' or 'transition frequency'.
- Transistors will need to have more gain to account for the circuit loss.



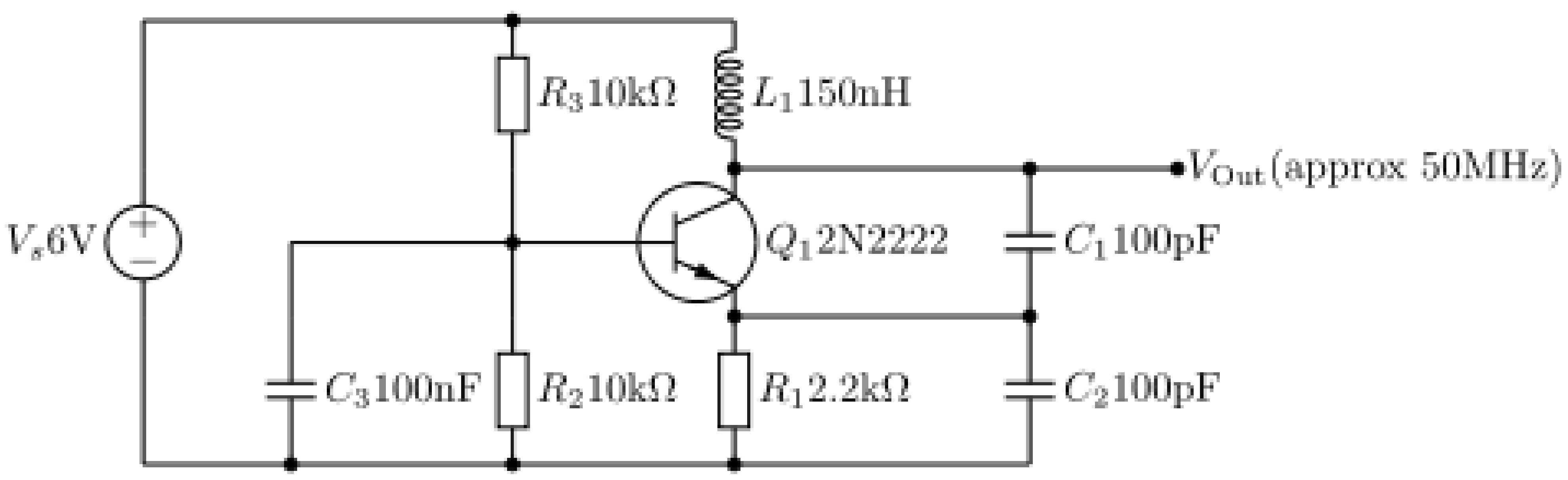
The Franklin Oscillator



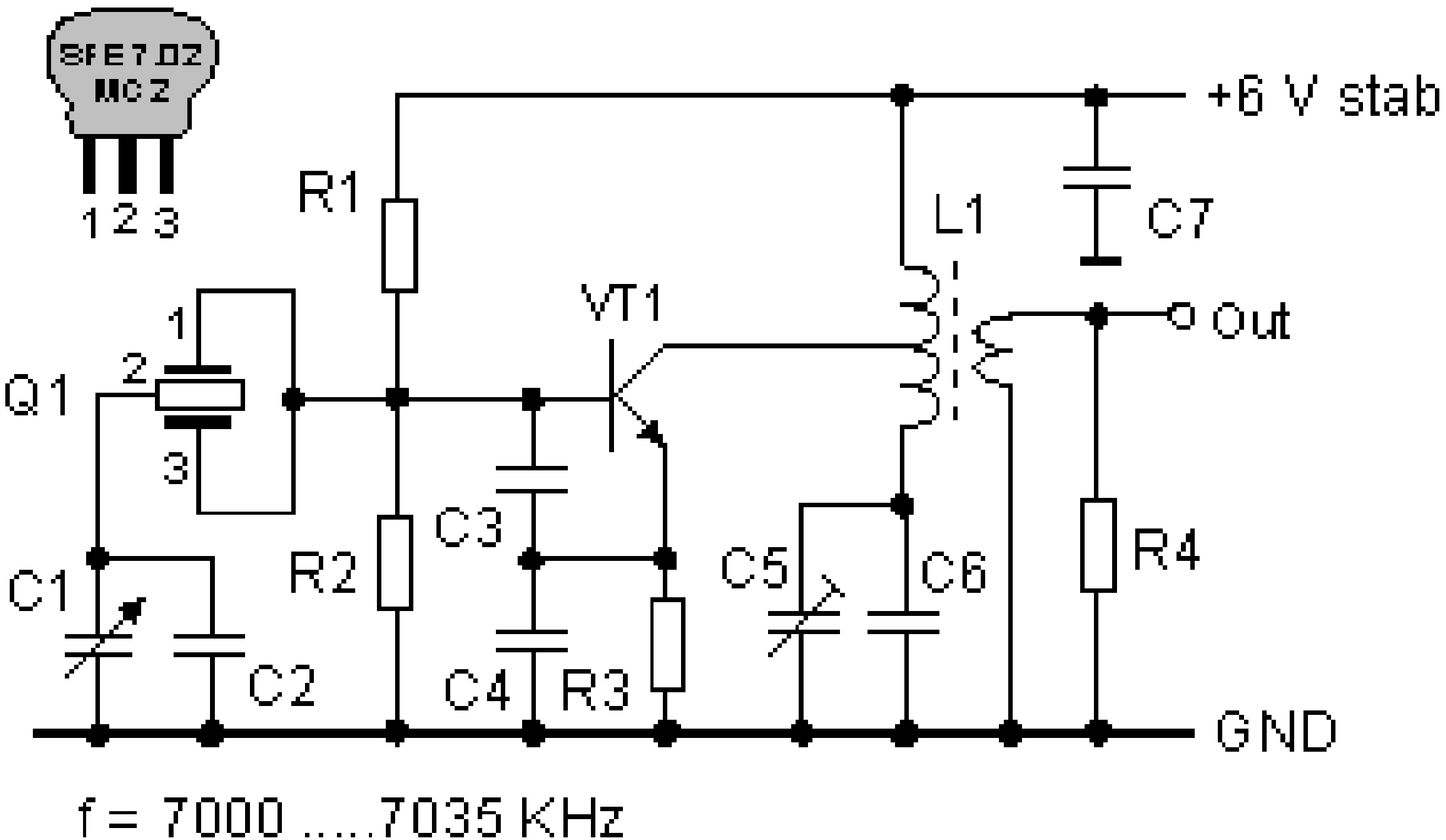
The Colpitts Oscillator

Note: A **Colpitts oscillator**, invented in 1918 by American engineer Edwin H. Colpitts

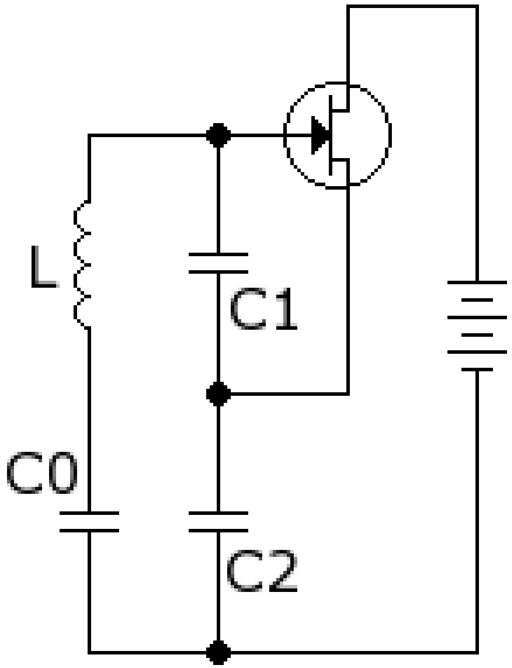
The Colpitts oscillator is typical of how these concepts can be implemented in a practical circuit.



The Colpitts Oscillator [2]



The Clapp Oscillator



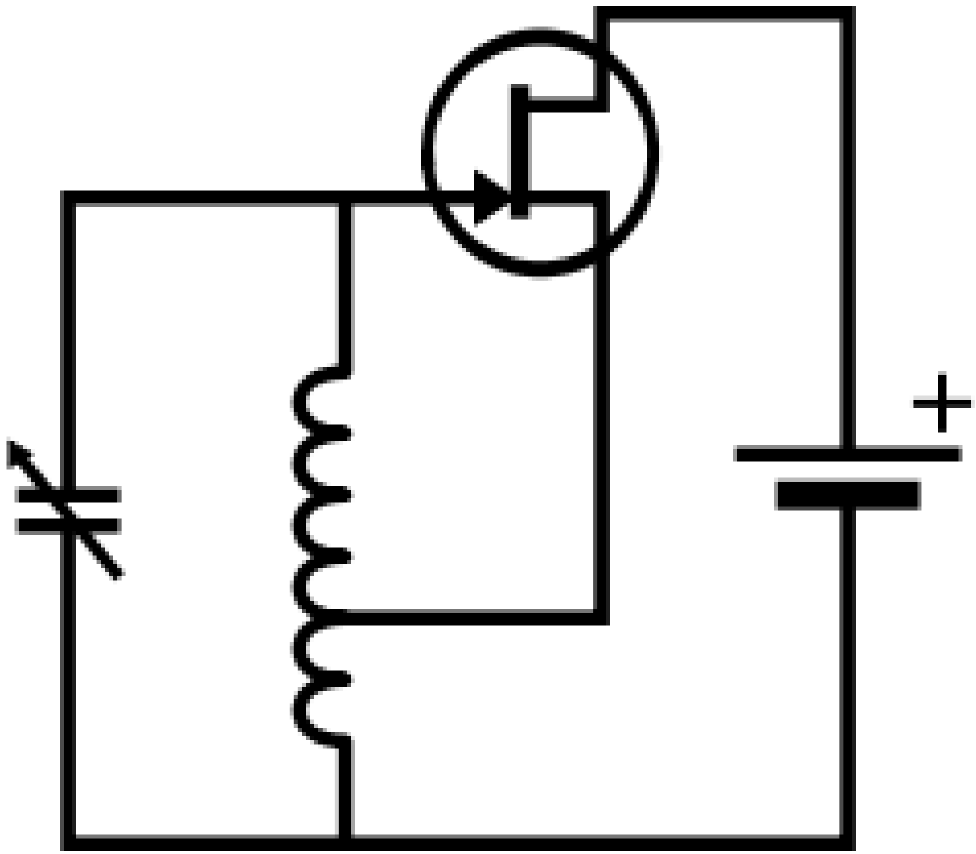
A Clapp circuit is often preferred over a Colpitts circuit for constructing a variable frequency oscillator (VFO). In a Colpitts VFO, the voltage divider contains the variable capacitor (either C1 or C2). This causes the feedback voltage to be variable as well, sometimes making the Colpitts circuit less likely to achieve oscillation over a portion of the desired frequency range. This problem is avoided in the Clapp circuit by using fixed capacitors in the voltage divider and a **variable capacitor (C0)** in series with the inductor.

It was published by James Kilton Clapp in 1948.[1] According to Vačkář,[2] oscillators of this kind were independently developed by several inventors, and one developed by Gouriet had been in operation at the BBC since 1938.

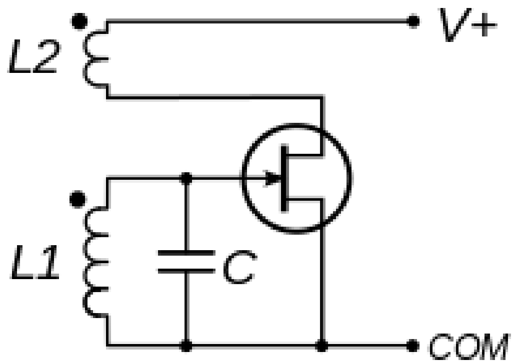
The Hartley Oscillator

Note: The circuit was invented in 1915 by American engineer Ralph Hartley.

Another way of feeding the output of the amplifier into a parallel tuned circuit, and the output of the tuned circuit back to the input of the amplifier, is to use a **centre-tapped inductor** in the tank (tuned) circuit. This is the principal of the **Hartley oscillator**.



The Armstrong Oscillator

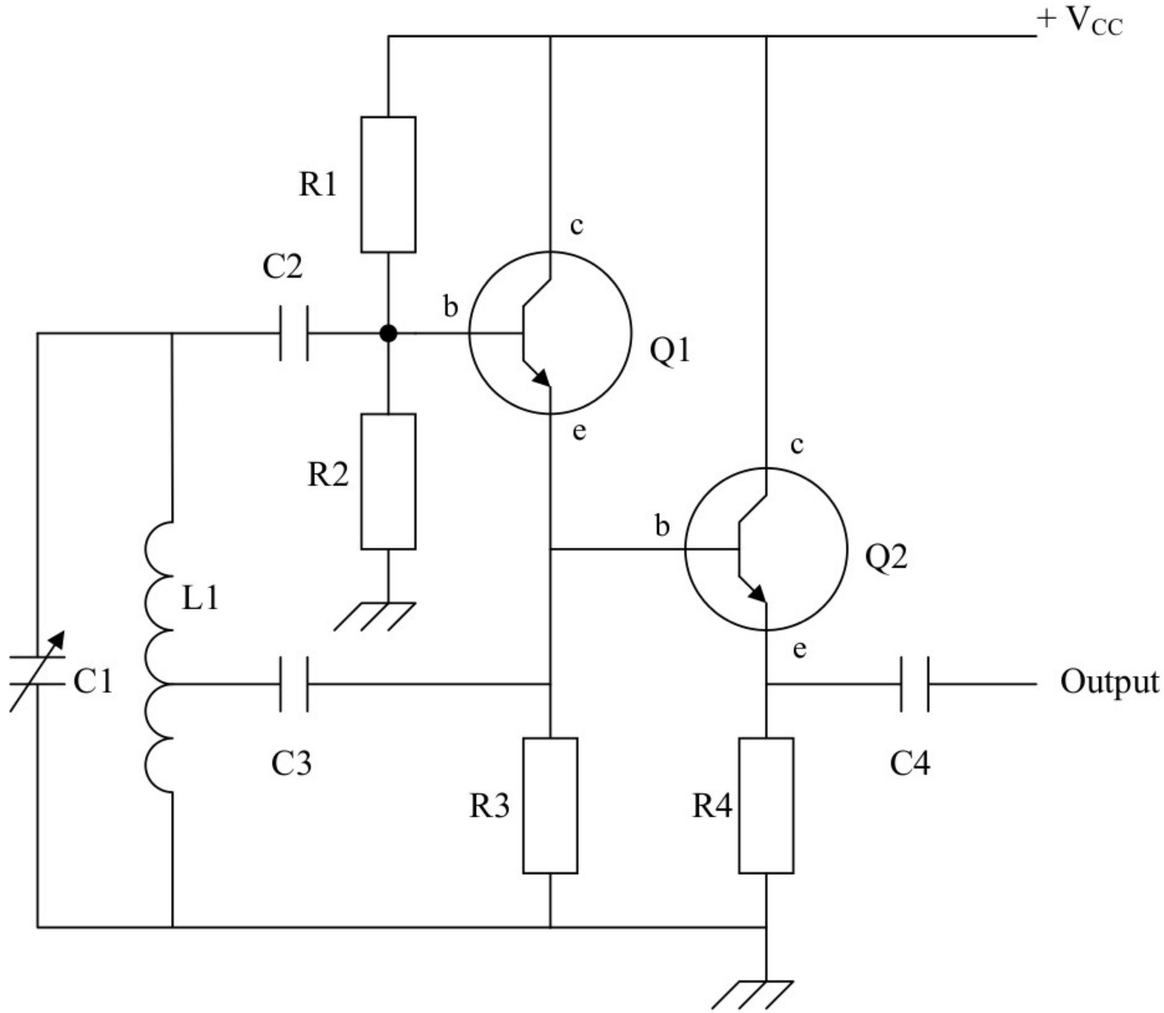


Armstrong Oscillator

The Armstrong oscillator[1] (also known as the Meissner oscillator[2]) is an electronic oscillator circuit which uses an inductor and capacitor to determine the oscillation frequency; an LC oscillator. It is the earliest oscillator circuit, invented by US engineer Edwin Armstrong in 1912 and independently by Austrian engineer Alexander Meissner in 1913, and was used in the first vacuum tube radio transmitters. It is sometimes called a *tickler oscillator* because its distinguishing feature is that the feedback signal needed to produce oscillations is magnetically coupled into the tank inductor in the input circuit by a "tickler coil" *(L2, right)* in the output circuit. Assuming the coupling is weak, but sufficient to sustain oscillation, the oscillation frequency *f* is determined primarily by the tank circuit *(L1 and C, right)* and is approximately given by:-

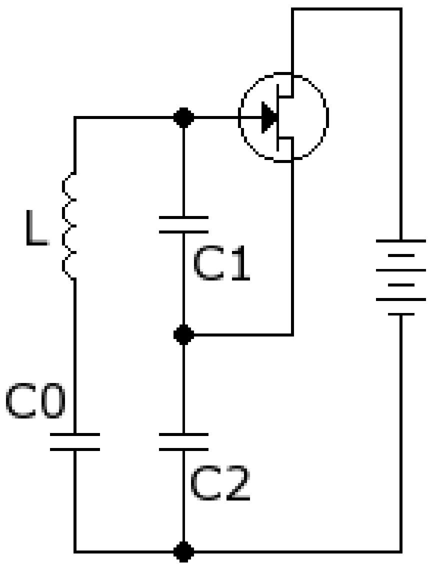
$$f = \frac{1}{2\pi\sqrt{LC}}$$

An Oscillator with Buffer [stage]



This 'emitter-follower' stage is used to 'isolate' the output load from the tuned circuit. [Not shown are the decoupling capacitors needed]

The ‘Clapp’ Oscillator



The Clapp oscillator is one of several types of LC electronic oscillator constructed from a transistor (or vacuum tube) and a positive feedback network, using the combination of an inductance with a capacitor for frequency determination.

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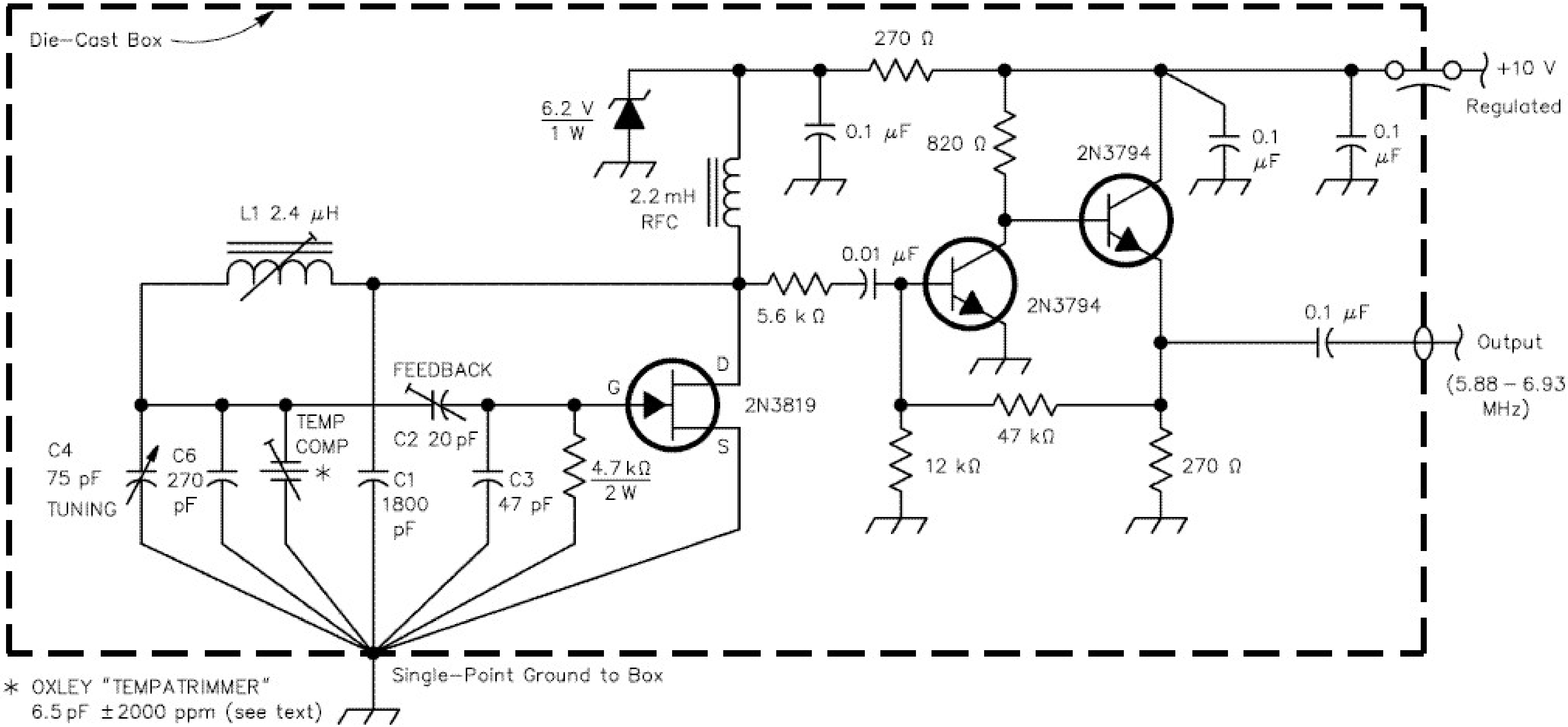
Other Types of Oscillator



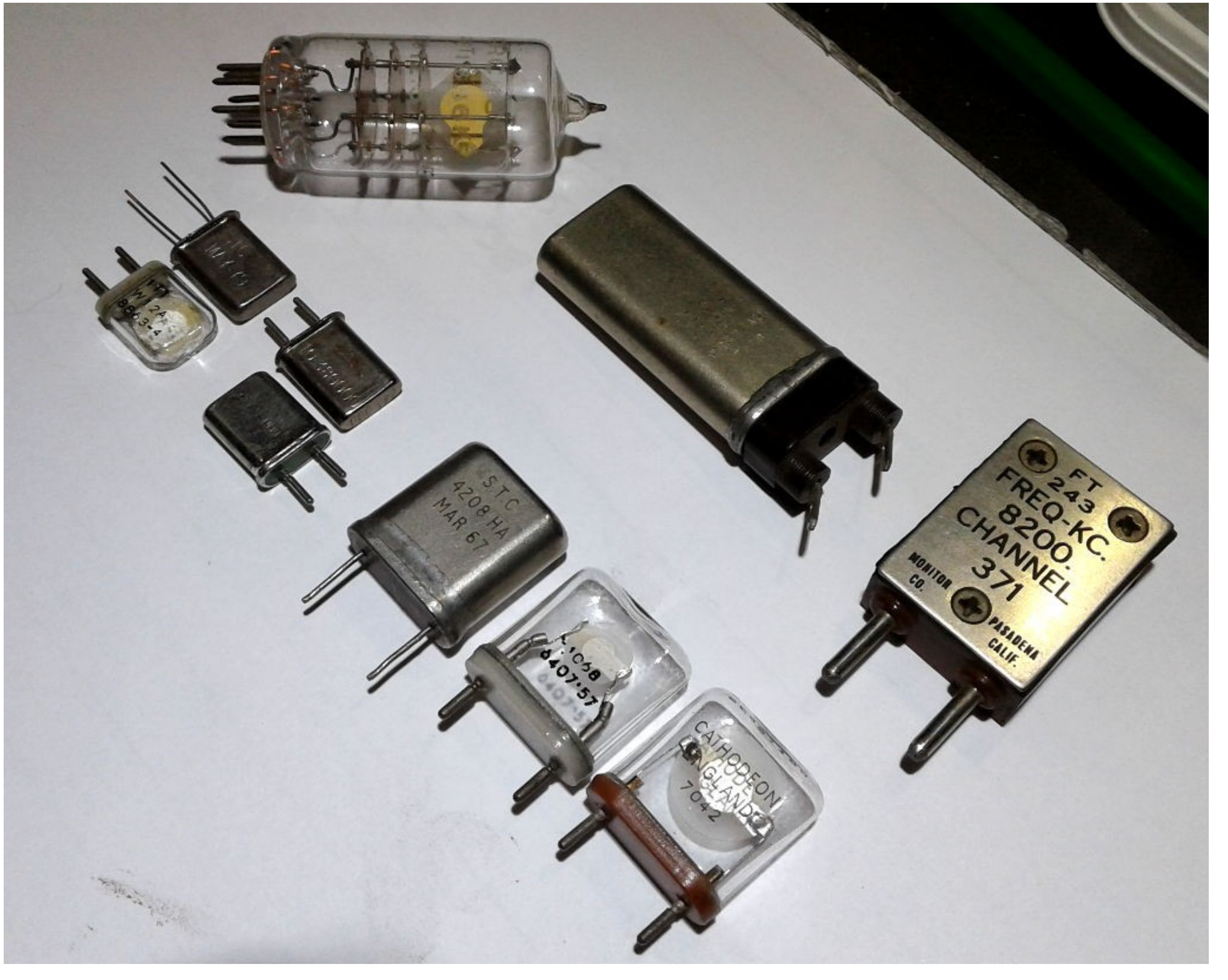
The genuine ‘Vackar’ oscillator circuit by G3PDM.

Temperature Stability

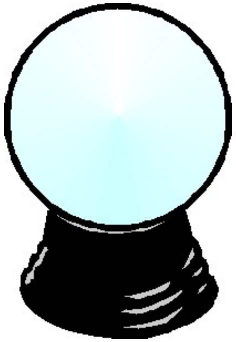
- Frequency drift can cause ‘major issues’.
  - Loss of signal [QSO]
  - Transmitting outside of band [NOT ALLOWED!]
- Regulations require the amateur to be able to measure the operating frequency OR
- The VFO should be frequency stabilised by a crystal reference. [Synthesizer mode or ‘locked’ mode]

Crystals as Resonators

- A ‘typical’ Crystal at H.F. has a ‘Q’ in the thousands.



Crystals NOT:-



Quartz crystals exhibit the piezoelectric effect and act like series tuned circuits. They can be used to control the frequency of an oscillator. Crystal-controlled oscillators exhibit excellent frequency stability, with very little drift. However they are essentially fixed-frequency oscillators; although the frequency can be "pulled" slightly using a variable capacitor, the tuning range is not nearly as wide as for oscillators using ordinary tuned circuits. Crystal oscillators that allow the frequency to be varied are called "variable crystal oscillators", abbreviated "VXO".

Crystals can be 'cut' for specific high temperature operation. So that they can be used as a very stable frequency source. Usually inside a temperature controlled oven.

Crystals in general these days are used as "Frequency Reference" for a "Phase Locked Loop" or a "Direct Digital Synthesiser" [DDS].

Alternative Oscillators

Comment: The author forgot the simplest form a **multi-vibrator**. Described as "an electronic see-saw". He also 'forgot' the **Pierce Oscillator**, the simplest form of crystal oscillator...

But there are many other 'types' of oscillator.

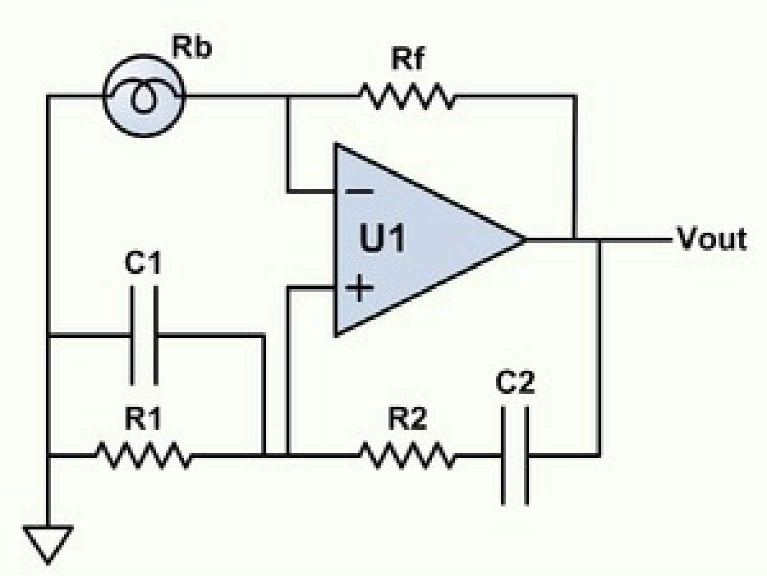
RC Oscillators - including "Wien" bridge, "Twin-T", etc.

SAW Resonators - Surface Acoustic Wave Resonators are used at UHF for Car and Gate Remotes.

An oscillator that uses a tuned circuit as its phase shift network will oscillate at (or very close to) the resonant frequency of the tuned circuit.

Comment: It also depends on the 'QUALITY' or 'Q' of the tuned circuit.

Perhaps the most famous...



In the 1930's, messrs Hewlett and Packard built and manufactured a simple oscillator. It's output level was stabilised by a bulb! [Globe in SA]

They made a lot of them...

When they retired the company HP had become a global conglomerate.

Oscillators Summary

Oscillators are circuits that generate AC signals. Oscillators consist of an amplifier with **positive feedback** through a phase-shift network. The phase shift network usually also serves as a band-pass filter. An oscillator will oscillate at any frequency and amplitude where the **Barkhausen criteria** for oscillation are met:

The loop gain is unity.
The sum of the phase shifts around the feedback loop is zero or an integer multiple of 360˚.
The output of an oscillator should be **buffered** to prevent the frequency of the oscillator from changing as the load on the oscillator varies.

There are several different oscillator circuits, including the **Colpitts, Hartley and Clapp** oscillators, which differ in the precise arrangement of the tank circuit. An oscillator that allows the frequency to be varied is called a **Variable Frequency Oscillator (VFO)**. If the frequency is varied by applying a control voltage, then it is a **Voltage Controlled Oscillator (VCO)**.

Quartz crystals exhibit the piezoelectric effect and act like series tuned circuits. They can be used to control the frequency of an oscillator. Crystal-controlled oscillators exhibit excellent **frequency stability**, with very little drift. However they are essentially fixed-frequency oscillators; although the frequency can be "pulled" slightly using a variable capacitor, the tuning range is not nearly as wide as for oscillators using ordinary tuned circuits. Crystal oscillators that allow the frequency to be varied are called "**variable crystal oscillators**", abbreviated "**VXO**".