OSCILLATORS

An **electronic oscillator** is an electronic circuit that produces a repetitive electronic signal, often a sine wave or a square wave.

A low-frequency oscillator (LFO) is an electronic oscillator that generates an AC waveform between 0.1 Hz and 10 Hz. This term is typically used in the field of audio synthesizers, to distinguish it from an audio frequency oscillator.

Types of electronic oscillator

There are two main types of electronic oscillator: the harmonic oscillator and the relaxation oscillator.

Harmonic oscillator

The harmonic oscillator produces a sinusoidal output. The basic form of a harmonic oscillator is an electronic amplifier with the output attached to a narrow-band electronic filter, and the output of the filter attached to the input of the amplifier. When the power supply to the amplifier is first switched on, the amplifier's output consists only of noise. The noise travels around the loop, being filtered and re-amplified until it increasingly resembles the desired signal.

A piezoelectric crystal (commonly quartz) may be coupled to the filter to stabilise the frequency of oscillation, resulting in a crystal oscillator.

There are many ways to implement harmonic oscillators, because there are different ways to amplify and filter. For example:

- Armstrong oscillator
- Hartley oscillator
- Colpitts oscillator
- Clapp oscillator
- Pierce oscillator (crystal)
- Phase-shift oscillator
- RC oscillator (Wien Bridge and "Twin-T")
- cross-coupled LC oscillator
- Vačkář oscillator

Relaxation oscillator

The relaxation oscillator is often used to produce a non-sinusoidal output, such as a square wave or sawtooth. The oscillator contains a nonlinear component such as a transistor that periodically discharges the energy stored in a capacitor or inductor, causing abrupt changes in the output waveform.

Square-wave relaxation oscillators can be used to provide the clock signal for sequential logic circuits such as timers and counters, although crystal oscillators are often preferred for their greater stability.

Triangle-wave or sawtooth oscillators are used in the timebase circuits that generate the horizontal deflection signals for cathode ray tubes in analogue oscilloscopes and television sets. In function generators, this triangle wave mays then be further shaped into a close approximation of a sine wave.

Other types of relaxation oscillators include the multivibrator and the rotary traveling wave oscillator

WAVE GENERATORS play a prominent role in the field of electronics. They generate signals from a few hertz to several gigahertz (10^9 hertz). Modern wave generators use many different circuits and generate such outputs as SINUSOIDAL, SQUARE, RECTANGULAR, SAWTOOTH, and TRAPEZOIDAL waveshapes. These waveshapes serve many useful purposes in the electronic circuits you will be studying. For example, they are used extensively throughout the television receiver to reproduce both picture and sound.

One type of wave generator is known as an OSCILLATOR. An oscillator can be regarded as an amplifier which provides its own input signal. Oscillators are classified according to the waveshapes they produce and the requirements needed for them to produce oscillations.

CLASSIFICATION OF OSCILLATORS (GENERATORS)

Wave generators can be classified into two broad categories according to their output waveshapes, SINUSOIDAL and NONSINUSOIDAL.

Sinusoidal Oscillators

A sinusoidal oscillator produces a sine-wave output signal. Ideally, the output signal is of constant amplitude with no variation in frequency. Actually, something less than this is usually obtained. The degree to which the ideal is approached depends upon such factors as class of amplifier operation, amplifier characteristics, frequency stability, and amplitude stability.

Sine-wave generators produce signals ranging from low audio frequencies to ultrahigh radio and microwave frequencies. Many low-frequency generators use resistors and capacitors to form their frequency-determining networks and are referred to as RC OSCILLATORS. They are widely used in the audio-frequency range.

Another type of sine-wave generator uses inductors and capacitors for its frequency-determining network. This type is known as the LC OSCILLATOR. LC oscillators, which use tank circuits, are commonly used for the higher radio frequencies. They are not suitable for use as extremely low-frequency oscillators because the inductors and capacitors would be large in size, heavy, and costly to manufacture.

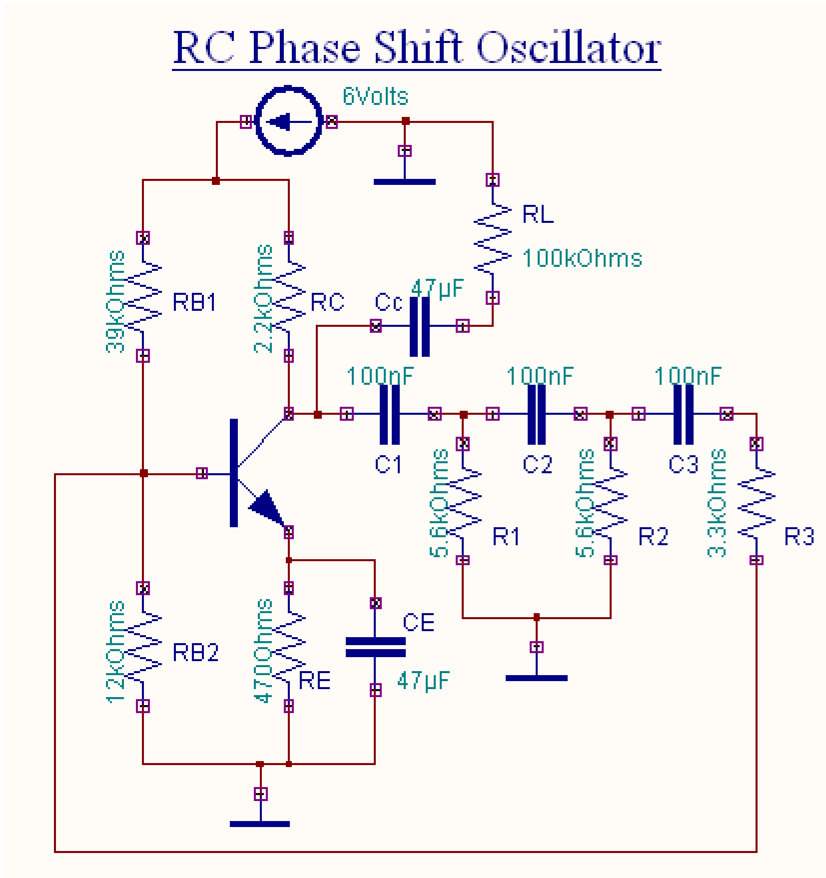
A third type of sine-wave generator is the CRYSTAL-CONTROLLED OSCILLATOR.

The crystal-controlled oscillator provides excellent frequency stability and is used from the middle of the audio range through the radio frequency range.

RC Phase Shift Oscillator

An oscillator is a circuit, which generates ac output signal without giving any input ac signal. This circuit is usually applied for audio frequencies only. The basic requirement for an oscillator is positive feedback. The operation of the *RC Phase Shift Oscillator* can be explained as follows. The starting voltage is provided by *noise*, which is produced due to random motion of electrons in resistors used in the circuit. The noise voltage contains almost all the sinusoidal frequencies. This low amplitude noise voltage gets amplified and appears at the output terminals. The amplified noise drives the feedback network which is the phase shift network. Because of this the feedback voltage is maximum at a particular frequency, which in turn represents the frequency of oscillation. Furthermore, the phase shift required for positive feedback is correct at this frequency only. The voltage gain of the amplifier with positive feedback is given by

$$A_f = \frac{A}{1 - A\beta}$$



From the above equation we can see that if $A\beta = 1 \quad A_f = \infty$. The gain becomes infinity means that there is output without any input. i.e. the amplifier becomes an oscillator. This condition $A\beta = 1$ is known as the *Barkhausen criterion* of oscillation. Thus the output contains only a single sinusoidal frequency. In the beginning, as the oscillator is switched on, the loop gain $A\beta$ is greater than unity. The oscillations build up. Once a suitable level is reached the gain of the amplifier decreases, and the value of the loop gain decreases to unity. So the constant level oscillations are maintained. Satisfying the above conditions of oscillation the value of *R* and *C* for the phase shift network is selected such that each *RC* combination produces a phase shift of 60°. Thus the total phase shift produced by the three *RC* networks is 180°. Therefore at the specific frequency f_O the total phase shift from the base of the transistor around the circuit and back to the base is 360° thereby satisfying *Barkhausen criterion*. We select $R_1=R_2=R_{3*}=R$ and $C_1=C_2=C_3=C$

The frequency of oscillation of RC Phase Shift Oscillator is given by

$$f_o = \frac{1}{2\pi RC\sqrt{6}}$$

At this frequency, the feedback factor of the network is $\beta = \frac{1}{29}$. In order that $|A\beta| < 1$ it is required that the amplifier gain $|A| > 29$ for oscillator operation

OSCILLATORS

What are oscillator basics?

Some people regard the design of RF Oscillators and oscillator basics in particular, to be something akin to a "black art" and after many years of swearing at "cranky" oscillators I'm not all too sure they are all that wrong. I suggest you ensure you remember this old saying:

"Amplifiers oscillate and oscillators amplify" - unknown

Introduction to oscillator basics

When I was a kid, yes I can remember back to the late 1940's, we collected all manner of junk. Cool was anything remotely electrical and, of course bicycle dynamos, lamps or motors were even "extra cool".

We as precious little seven year olds conceived - all budding nuclear physicists that we were - of this real smart idea, obviously nobody had ever thought of this before.

"Why don't we connect a motor to a generator, so the motor drives the generator, providing electricity for the motor, which continues to drive the generator and it'll go on, and on, and on for a hundred years and we'll become rich and world famous!"

Of course we had no concept of frictional losses (I think that's right) way back then. Nor had the words "perpetual motion" passed our ears.

The whole point of that little story is to crudely demonstrate the principle of how an oscillator works. If you can follow that childishly naive concept then you will kill them in this.

Principles of Oscillator operation

Every oscillator has at least one active device (smarties don't complicate matters for me - just read on) be it a transistor or even the old valve. This active device and, for this tutorial we'll stick to the humble transistor, acts as an amplifier. There is nothing flash about that. For this first part of the discussion we will confine ourselves to LC Oscillators or oscillator basics and I'll keep the maths to an absolute minimum.

At turn on, when power is first applied, random noise is generated within our active device and then amplified. This noise is fed back positively through frequency selective circuits to the input where it is amplified again and so on, a bit like my childhood project.

Ultimately a state of equilibrium is reached where the losses in the circuit are made good by consuming power from the power supply and the frequency of oscillation is determined by the external components, be they inductors and capacitors (L.C.) or a crystal. The amount of positive feedback to sustain oscillation is also determined by external components.

Hartley Oscillator

I decided to use the [Hartley Oscillator]() for the simple reason it's my favourite. Recently it was discussed that your favourite oscillator was likely the one which worked best for you and I think that is quite true. So here it is in it's most simplified form.

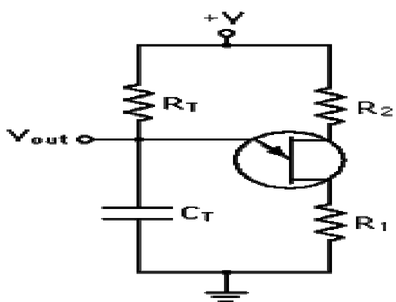


Figure 1 - schematic of a hartley oscillator

Colpitts Oscillator

The basic Colpitts oscillator circuit look like this and you will see some similarities.

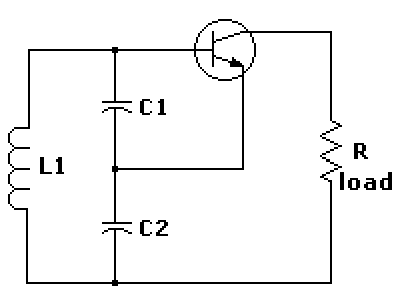


Figure 2 - schematic of a collpitts oscillator

If you consider positive feedback is applied to compensate for the losses in the tuned circuit, the amplifier and feedback circuit create a negative resistor. When Z1 and Z2 are capacitive, the impedance across the capacitors can be estimated from a formula I won't lay on you here because it includesbeta, hie, as well as X_{C1} and X_{C2}. Suffice to sayit can be shown that the input impedance is a negative resistor in series with C1 and C2. And the frequency is in accordance with:

$$fo = \frac{1}{2\pi [LC_1C_2/(C_1+C_2)]^{1/2}}$$

Figure 3 - formula - colpitts oscillator

Frequency or Phase Stability of an Oscillator

Frequency or phase stability of an oscillator is customarily considered in the long term stability case where frequency changes are measured over minutes, hours, days even years. Of interest here are the effects of the components changes, with ambient conditions, on the frequency of oscillation. These might be caused by changes in the input voltage, variations in temperature, humidity and ageing of our components.

Never underestimate the effects of these variations on the frequency of operation. I've gone nuts working on so called precision designs, with precision components, where the frequency wandered at random over several kilohertz over several minutes. Needless to say I'd "messed up".

Short term stability is also of great interest and, again I could lay some real heavy maths on you but I won't. I'll simply say it can be mathematically proven that the higher the circuit Q, the higher this stability factor becomes. The higher the circuit Q, the better the ability the tuned circuit can filter out undesired harmonics **AND** noise.

Reducing Phase Noise in Oscillators

1. Maximize the Qu of the resonator.

2. Maximize reactive energy by means of a high RF voltage across the resonator. Use a low LC ratio.

3. Avoid device saturation and try to use anti parallel (back to back) tuning diodes.

4. Choose your active device with the lowest NF (noise figure).

5. Choose a device with low flicker noise, this can be reduced by RF feedback. A bipolar transistor with an unby-passed emitter resistor of 10 to 30 ohms can improve flicker noise by as much as 40 dB. - see emitter degeneration

6. The output circuits should be isolated from the oscillator circuit and take as little power as possible.

Effects of ambient changes on stability in oscillators

A frequency change of a few tens of hertz back and forth over a couple of minutes would mean nothing to an entertainment receiver designed for the FM Radio band. Such a drift in an otherwise contest grade receiver designed to receive CW (morse code) would be intolerable. It's a question of relativity.

Minimizing Frequency drift in oscillators

These are random and not in any particular order.

1. Isolate the oscillator from succeeding stages with a well designed buffer stage followed by a stage of amplification. Large signals can often then be reduced by a 3 or 6 dB attenuator which also has the benefit of presenting a well defined load impedance to the amplifier. If the stage is feeding a mixer, as is most often the case, then another benefit is the mixer (you are using double balanced mixers?), also see a source impedance of 50 ohms.

2. Ensure the mechanical stability of your oscillator is such that mechanical vibration can have no effect on components, especially those frequency determining components.

3. Supply the oscillator with a clean well regulated supply. If using varactor tuning, doubly ensure the tuning DC voltage is as clean as possible, a few hundred micro volts of noise can be imposed on the oscillator signal. Use back to back diodes for the variable element. Air variables are hard to come by although they offer far superior Q figures. DC tuning tends to be more versatile.

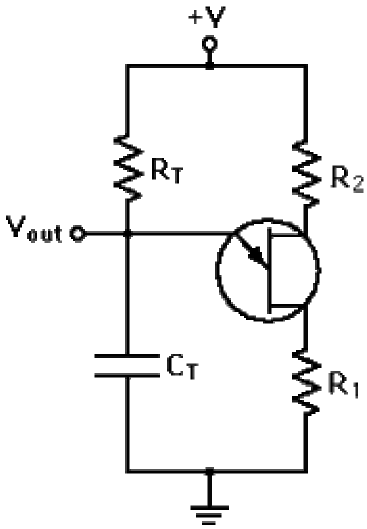
4. Minimize circuit changes from ambient variations by using NPO capacitors, polystyrene are dearer but excellent, silvered mica in my opinion are not what many people believe and are highly over rated.

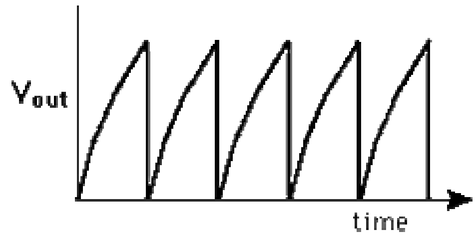
5. The inductor should be air wound on a coil form with a configuration to maximize Qu. If you must use a toroid, where possible try to use the 6 type as it offers the best Q. Sometimes, for other reasons you might have to use a slug tuned form.

6. Parallel a number of smaller value NPO capacitors rather than using one large one in frequency determining components. For trimmers try and use an air variable. Keep an eye out for small value N750, N1500 capacitors, < 15 pF, when available and are found to be dirt cheap. These are sometimes useful in taming drift in an oscillator.

7. Bipolar or FETS for active device seems to be a matter of personal preference and I've seen some ferocious arguments over that one. Consensus seems to come down in favour of FETS. Me, I'm a bipolar man because FETS hate me pure and simple.

UJT Relaxation Oscillator

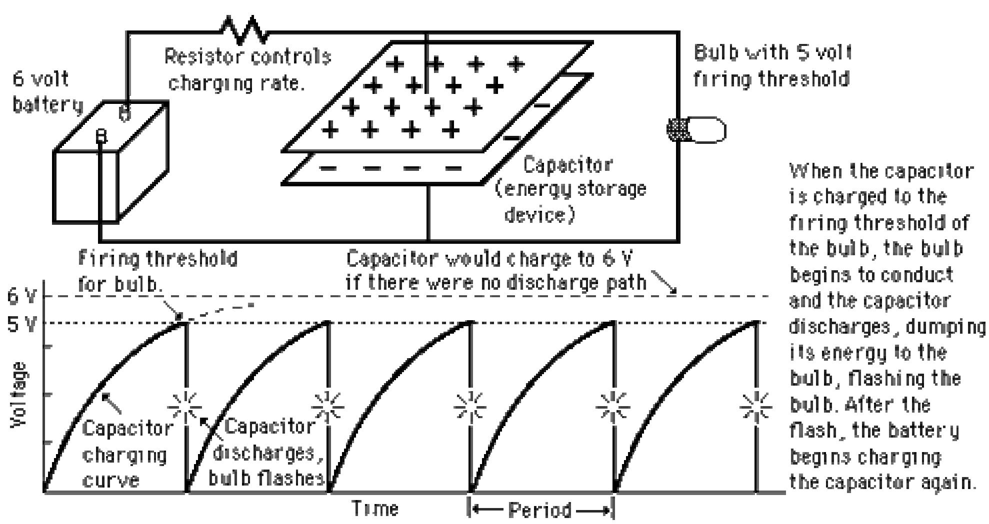




The negative resistance characteristic of the unijunction transistor makes possible its use as an oscillator.

Relaxation Oscillator Concept

The concept of a relaxation oscillator is illustrated by this flasher circuit where a battery repeatedly charges a capacitor to the firing threshold of a bulb, so that the bulb flashes at a steady rate.



A relaxation oscillator is a repeating circuit (like the flasher circuit illustrated above) which achieves its repetitive behavior from the charging of a capacitor to some event threshold. The event discharges the capacitor, and its recharge time determines the repetition time of the events. In the simple flasher circuit, a battery charges the capacitor through a resistor, so that the values of the resistor and the capacitor (time constant) determine the flashing rate. The flashing rate can be increased by decreasing the value of the resistance.

One of the reasons for the importance of the relaxation oscillator concept is that some neural systems act like relaxation oscillators. For example, the bundle of nerve fibers called the SA node (sino-atrial node) in the upper right hand part of the heart acts as the natural pacemaker of the heart, firing at a regular rate. The rate of this relaxation oscillator is variable, and can be increased in response to exertion or alarm. Other nerve cells recharge like a capacitor, but then wait for some kind of stimulus to fire. In response to some kind of trauma, it might be that the firing threshold is lowered enough to "self fire" and act as a relaxation oscillator. This is an intriquing possibility for explaining the ringing in the ears after a loud concert.