Aug. 8, 1933. H. SCHUMACHER 1,921,844

CRYSTAL CONTROLLED OSCILLATOR

Filed Feb. 10, 1931

Fig. 1

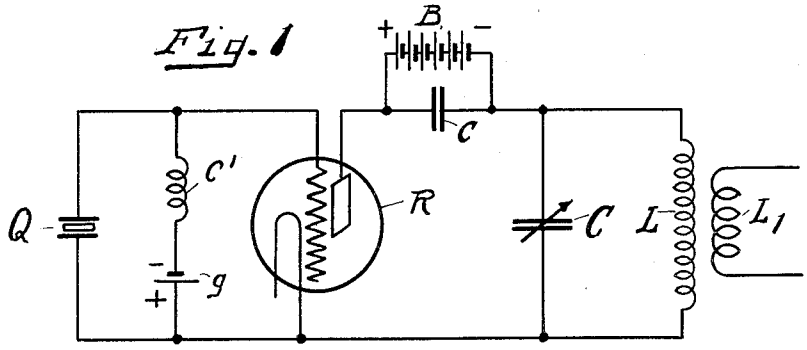


Fig. 2

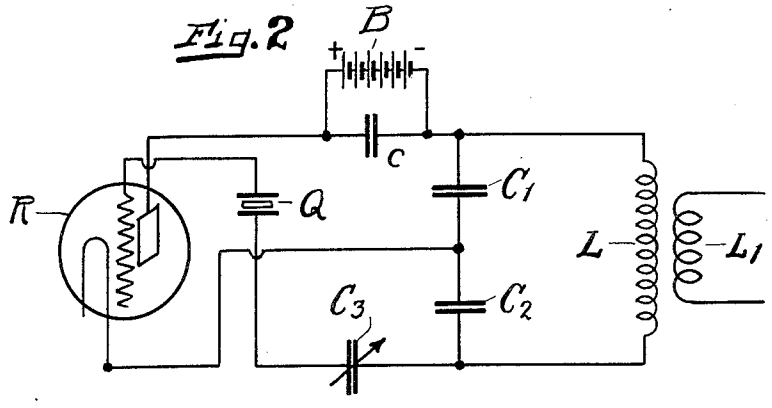
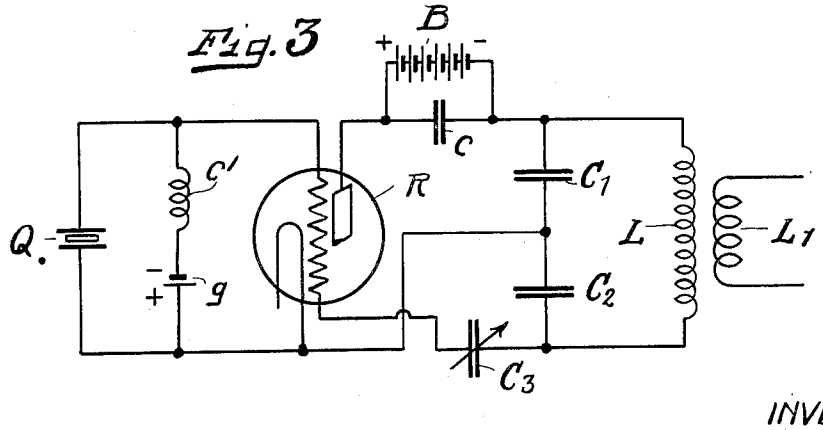


Fig. 3



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Patented Aug. 8, 1933 1,921,844

UNITED STATES PATENT OFFICE

1,921,844

CRYSTAL CONTROLLED OSCILLATOR

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Application February 10, 1931, Serial No. 514,781, and in Germany February 11, 1930

3 Claims. (Cl. 250—36)

My invention relates to crystal controlled oscillators for generating high frequency electric oscillations, as used for commercial communication, broadcasting and other purposes. Oscillators of the vacuum tube type with a piezo crystal, such as a quartz crystal for controlling and producing sustained electric oscillations have a number of advantages and are at present extensively used in practice, especially on account of the highly stabilized frequency obtained and the maintenance of the frequency of the oscillations within very close limits.

There are instances, however, where even higher stability and constancy of frequency or wave length is required than could be secured by crystal oscillator circuits of the usual design known in the art up to date. Accordingly, an object of my invention is the provision of a crystal oscillator circuit which possesses increased stability and which maintains the frequency of the oscillations constant within extremely small limits, as compared to prior arrangements.

Another object of my invention is to eliminate or minimize to a considerable extent the effects of variations of the operating conditions or constants of the system on the stability and constancy of the crystal oscillations, such as primarily the effect of variations of the supply voltages, such as of the filament current and plate current supply.

With this aim in view, a more specific object of my invention consists in the provision of means in connection with a crystal controlled vacuum tube oscillator which operates through the inherent capacity feed back via the anode-grid electrode capacity, whereby the amount of feed back may be readily adjusted to its critical and most favorable operating value for obtaining the maximum stability and constancy of frequency of the oscillations.

Another further object of my invention is the provision of a compensating or neutralizing circuit, commonly referred to as neutrodyne circuit, associated with a vacuum tube crystal oscillator for adjusting the inherent feed back capacity of the tube to its critical and most efficient value for obtaining a maximum of frequency constancy and stability of the system.

These and further objects of my invention will become more apparent as the following detailed description proceeds, taken with reference to the accompanying drawing, which by way of example illustrates practical embodiments of the novel features of the invention.

Figure 1 illustrates, for the purpose of better understanding, a crystal oscillator circuit of the type as commony used up to date.

Figure 2 shows an improved circuit in accordance with the invention.

Figure 3 illustrates an alternative method of practicing my invention.

Similar reference characters designate similar parts throughout the different views of the drawing.

Referring more particularly to Figure 1, I have shown a vacuum tube R of normal construction, comprising a cathode, control grid and plate electrode and an oscillator output circuit comprised by an inductance L and variable capacity C in parallel to each other and connected between cathode and anode electrodes. The anode current is supplied by a high-potential battery B inserted in the anode lead and shunted by a capacity C for by-passing for the high frequency currents, in a manner well known. The crystal Q, which may be a quartz crystal consisting of a suitably cut quartz plate with electrodes arranged at both sides, is connected between the cathode and grid electrode. In place of a quartz crystal as shown, any other known type of electro-mechanical oscillating device, such as a magneto-strictive element may be used, as is obvious in accordance with the spirit of the invention. I have also shown a grid battery *g* in series with a choke coil C' connected between grid and cathode, the choke coil serving to avoid any possible loss of radio frequency voltage through the grid return provided by biasing battery *g*. This circuit operates, as is well known, in that a mechanical or electric vibration, once started at some point of the system, will continue because the plate inductance is connected by a variable condenser and the circuit is otherwise arranged to become regenerative by the familiar method which utilizes the self capacity of the tube elements for the purpose of feed back. As is known, of course, there must be the proper relation between the crystal's own natural frequency of vibration and the frequency or rate at which the first storage or energy changes in value, in order to excite the crystal and cause it to move to its greatest limits.

Experiments and practical experience have shown that such a circuit as hitherto used in the art in many cases does not produce the desired stability of the oscillations and is very easily and readily affected by sudden variations of the supply voltages, such as of the anode supply B and the filament heating supply volt-

age, which in most cases are taken directly from power lines. The invention is based on the reasoning that in the hitherto known circuit no attention is paid to the value of the feed back, which in the case of Figure 1 is provided via the inherent grid anode capacity of the tube. By experiments, it was found that by providing means for varying the effective inherent feed back capacity, the constancy of the oscillations, as well as the stability of the oscillator, can be considerably increased. This is quite obvious, as it may be understood that either a too large or a too small amount of feed back current exerts an unfavorable effect on the operation of the oscillator mechanism.

Accordingly, the new idea underlying the invention consists in providing means whereby the feed back self capacity may be readily adjusted to an optimum value with regard to maximum stability and constancy of the oscillations. Preferred embodiments of this idea are shown by Figures 2 and 3, in which a compensating or neutralizing circuit operating according to the Wheatstone bridge principle and known in receiving circuits as neutrodyne circuit is provided, which however, contrary to the usual neutrodyne methods in receivers, serves not to completely neutralize or suppress the effects of the inherent capacity, but to effect neutralization to a certain extent only corresponding to the optimum effective value of the feed back.

Referring to Figure 2, this is obtained in that the piezo electric crystal is inserted in the grid circuit of the tube R, which is furthermore provided with a neutralizing circuit for neutralizing the inherent grid-anode capacity. In this particular arrangement, which as experiments show, produces extremely favorable results, the adjustment of the grid circuit is such that the grid anode capacity is close to that value at which complete neutralization would take place. The tube R operates on the oscillatory circuit consisting of inductance L and two capacities C_1 and C_2. The mid-point of these capacities is connected in the usual manner of neutrodyning circuits to the filament of the tube. The grid circuit includes the quartz crystal Q and the variable neutralizing condenser C_3 which is adjusted in such a manner that the balance of the bridge system, which is completed by the inherent capacity between the grid and anode, is just not complete as yet. With such a circuit, extremely constant oscillations are produced with grid currents of very low intensity. This latter requirement is generally made in crystal oscillators, as a maximum output will be obtained from the circuit when a minimum of grid current flows. A further advantage of this circuit consists in its extraordinary independence of variations of the heating and plate voltages.

Referring to Figure 3, this shows a circuit similar to Figure 2, with the exception of the quartz crystal being connected in parallel to the grid and cathode, instead of in series with the lead from the neutralizing condenser C_3.

The invention is especially useful in such instances where the highest possible requirements are made as to the production of a practically absolutely constant frequency and also where extreme stability of the oscillator is of paramount importance. This is, for instance, the case in common frequency broadcasting, where a number of transmitting stations, suitably distributed over a surface area, broadcast a single program, each operating on the same common frequency, whereby the individual radiated frequencies have to be kept constant and stable within extremely close limits, in order to prevent interference in the receiving sets which, on account of their position, simultaneously receive from at least two of such single wave stations. Another field where the invention presents great advantages is for measuring purposes where alternating or high frequency currents are used, such as for determining capacities, inductances, phase shifts and the like and where, as is known, the highest requirements are made as to constancy and stability of the measuring currents, in order to insure accurate results.

Although I have described my invention with particular reference to the exemplifications illustrated, I wish it to be understood that modifications and variations may be made, coming within its broader aspects and its wider scope, as expressed in the appended claims.

What I claim is:—

1. In a high frequency oscillator, comprising a vacuum tube having filament, grid and plate electrodes, an output circuit connected between said grid and said plate electrode, a connection from said filament to a tap point on said output circuit, a compensating condenser connected in the lead from said grid electrode to said output circuit in series with an electromechanical oscillating control device.

2. In a high frequency oscillator, comprising a vacuum tube having filament, grid and plate electrodes, an output circuit connected between said grid and said plate electrode, a connection from said filament to a tap point on said output circuit, a compensating condenser connected in the lead from said grid electrode to said output circuit in series with a piezo electric control device.

3. In a crystal controlled oscillator, comprising a vacuum tube having cathode, grid and plate electrodes, an output oscillatory circuit connected between said plate and grid electrodes, a connection from said cathode to an intermediate point on said oscillatory circuit and a piezo electric control crystal and a variable compensating condenser being inserted in the lead from said output circuit to said grid electrode.

HANS SCHUMACHER.