PATENT SPECIFICATION 1,025,709

DRAWINGS ATTACHED.

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1,025,709

THE PATENT OFFICE LONDON

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Int. Cl.:—G 08 c //H 03 b, f.

COMPLETE SPECIFICATION.

Resistance-Capacitance Type Oscillators and Selective Amplifiers.

We, MUIRHEAD & CO. LIMITED, of Croydon Road, Elmers End, Beckenham, in the County of Kent (a Company registered under the laws of Great Britain), do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electronic oscillators and selective amplifiers, and in particular to oscillators of the so-called phase-shift or resistance-capacitance type and selective amplifiers employing a positive feedback loop connecting the output terminals of a maintaining amplifier to its input terminals, and in which the loop includes a network of resistors and capacitors. With such an arrangement, the phase-shift around the loop becomes zero at one particular frequency, for given values of the resistance and capacitance, and if the product of amplifier gain ratio and the network loss ratio exceeds unity, the system becomes self-oscillatory at that particular frequency. If the product is less than unity the circuit exhibits the characteristics of a frequency-selective amplifier. Variation of the frequency of oscillation or amplification may be achieved by varying the value of the resistance and/or capacitance in the feedback circuit.

The present invention consists in an electronic oscillator or selective amplifier which includes an amplifier and a positive feedback loop connected between the output and the input of the amplifier, said loop including a resistance and capacitance network determining the operating or oscillating frequency of the circuit, wherein the network includes at least one photosensitive element whose effective resistance depends upon the light incident upon the element, a source of light, light control means which is adjustable so that the amount of light passing from the source through the means and incident upon the element may be varied over a predetermined range with consequent variation of the operating or oscillating frequency of the circuit, and means for adjusting the light control means to pass any desired amount of light in the range so as to obtain a desired predetermined operating or oscillating frequency.

Preferably a metal filament lamp is used to provide a steady source of light, and the amount of light which is allowed to reach the element or elements is controlled by an aperture of adjustable size provided by an arrangement of masks movable relatively to one another.

Alternatively, the aperture may be of adjustable density, or both size and density may be adjusted.

Conveniently, the masks may take the form of photographic exposures on a glass or film base. In practice, the masks may be used to vary the oscillation frequency smoothly and continuously with the rotation of a control shaft and associated calibrated dial.

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It has been found that a photo-conductive cell in the form of a solid state element, composed for example of cadium sulphide, is satisfactory for use as the or each photo-sensitive element when using the aforementioned metal filament lamp.

With this arrangement the following advantages may be obtained:—

The light from a small bulb, e.g. 6 volt, 60 millamperes, is sufficient to reduce the resistance of a typical cadmium sulphide photo-conductive cell to around 100 ohms, whilst in complete darkness the resistance of the cell may be of the order of megohms In practice, a range of 100 ohms to several Kilo-ohms is usable, and thus if not less than two cells in the R-C network of the oscillator are illuminated the potentially available oscillation range will exceed 1000:1.

Secondly, this frequency range can be swept continuously, the degree of irregularity or departure from a given frequency being reducible without limit by improving the clarity and regularity of the photographic transparencies.

Thirdly, once the transparencies have been prepared and assembled into the oscillator the frequency of oscillation bears a fixed relation to the angle of rotation of the control shaft; for example, if the transparencies have been designed to give a strictly logarithmic relationship between frequency and shaft angle, this relationship will remain unchanged even if the brightness of the lamp is incorrect. Simple and cheap means are proposed for checking that the brightness of the lamp has a standard value so that the intended oscillation frequency is generated.

In order that the invention may be more easily understood, embodiments thereof will now be described with reference to the accompanying drawings in which like parts bear like reference numerals where applicable.

In the accompanying drawings:—

Figure 1 is a general view of a tuning arrangement for use in an oscillator, according to the present invention, of the Wien bridge kind and employed a fixed mask and a rotating transparency for tuning according to graded area;

Figure 2 is a vertical section through figure 1;

Figure 3 is a general view of a tuning device employing two co-operating rotating transparencies for use in an oscillator according to the present invention;

Figure 4 shows a method of driving the two discs of the apparatus of figure 2 in opposite directions;

Figure 5 is a circuit diagram, partly in schematic form, of an oscillator according to the present invention;

Figure 6 is a circuit diagram of a tuning arrangement embodying a single cell, for use in an oscillator according to the present invention;

Figure 7, 8 and 9 show further embodiments of the tuning device, for use in an oscillator according to the present invention, in which the transparencies are on film strip and are advanced by means of rollers or sprockets;

Figure 10 is a circuit diagram of an oscillator according to the invention adapted for the generation of oscillations at very low frequencies;

Figure 11 shows a method of checking the performance of the primary light source in an oscillator according to the present invention.

Figures 12 and 13 show a method of obtaining frequency modulation with an oscillator according to the present invention; and

Figures 14 and 15 illustrate means for using polarization of light to control a light beam, for use in an oscillator according to the present invention.

In carrying the invention into effect according to one convenient mode by way of example, as shown in figures 1 and 2, a disc 1 is mounted for rotation upon a shaft 2. The disc 1 is opaque except for the transparent area 3, and conveniently the disc 1 may comprise a glass disc upon which the transparency 3 is formed by any well known photographic process. An opaque mask 4 is mounted in close proximity to disc 1 and has a slot 5 formed therein. Thus, it will be seen that when disc 1 is rotated in co-operation with the opaque mask 4, there is provided a transparent aperture 6 whose area is determined by the angular position of the disc.

The slot 5 in mask 4 has a vertical height which is at least as great as the maximum radial width 7 of the transparent area 3. It is convenient to make the slot 5 in mask 4 taper slightly from top to bottom, as shown in figure 1 so that by sliding the mask downwards the area of aperture 6 is increased, the light flux incident upon photo-sensitive elements 14 and 14^1 associated with an R-C oscillator circuit is also increased and causes its frequency to be raised proportionately. In this way it is possible to compensate for different characteristics of the photo-sensitive elements. For example, if at the same illumination both elements have the same resistance R_1 and the corresponding frequency is f_1, the frequency will rise above f_1 if an element of resistance less than R_1 is substituted for either of the elements 14 and 14^1. Vertical movement of the mask 4 is intended to correct only minor errors, whilst gross errors due to large errors in element resistance at constant light flux must be corrected by more radical means, for example, by an adjustment of an iris 16 or 16^1 over the element having the lower resistance.

Light source 8 (figure 2), which conveniently may comprise a metal filament lamp fed from a constant d.c. source over terminals 9 and 9^1 is mounted at one end of a cylindrical shroud 10. The other end of the shroud 10 is closed by a translucent light diffusing disc 11 such as frosted glass. The shroud 10 is so placed that the disc 11 is positioned closely adjacent to the mask 4 and aligned with the centre line of the curved transparency 3 in disc 1. The area of disc 11 must be at least as great as the maximum area of aperture 6

On the other side of the disc 1 is located, on the centre line of the shroud 10, a further shroud 12 which conveniently may be in the form of a truncated pyramid. The end of the further shroud 12 adjacent to the disc 1 is closed by a disc 18 of translucent light-diffusing material which has an area at least as great as that of disc 11. The other end of the further shroud 12 is closed with an opaque diaphragm 13 in which are mounted in closely spaced relationship two photo-sensitive elements 14 and 14^1 of the kind herinbefore described. Conveniently, the interior walls of the shroud 12 may be provided with a reflecting surface, and a further diaphragm 15 is placed within the shroud 12 and positioned closely adjacent to elements 14 and 14^1. The diaphragm 15 is provided with irises 16 and 16^1 mounted coaxially with elements 14 and 14^1 and adjustable by means of external levers 17 and 17^1. The irises 16 and 16^1 may be of the conventional kind commonly used in cameras and similar optical devices. Thus, it will be seen that light emanating from light source 8 will be diffused by disc 11 so that aperture 6 is sensibly evenly illuminated. Light issuing from aperture 6 is further diffused by disc 18 thereby dispersing the shadows caused by the finite thickness of aperture 6 formed by the co-relationship of mask 4 and disc 1.

A scale 19 engraved on dial 20 which is externally mounted on shaft 2, co-operates with a fixed index 21 to register the shaft angle and consequently the oscillation frequency of the oscillator associated with elements 14 and 14^1.

Figure 3 shows an alternative method of light control using two discs of the form shown in figure 1. In this figure, discs 1 and 1^1 carrying transparent areas 3 and 3^1 respectively, are mounted in closely adjacent and overlapping positions as shown. The axes of the discs 1 and 1^1 are spaced apart by approximately the radius of a disc and the discs 1 and 1^1 are arranged to be rotated simultaneously about their axes in opposite directions. A simple drive is shown in figure 4 in which the disc 1 is mounted on an extension of the shaft 2. The shaft 2 is rotated by a control knob 22 which thus also rotates disc 1. A gear wheel 23 on the shaft 2 meshes with a gear wheel 23^1 on a shaft 24 carrying disc 1^1, both gear wheels having the same number of teeth. Preferably one of the gear wheels 23 or 23^1 is of the anti-backlash kind. Thus, when the control knob 22 is rotated in either direction, disc 1 is rotated at the same speed and in the same direction, while disc 1^1 is rotated at the same speed but in the opposite direction. It will be appreciated from the drawing that when the narrow ends of transparent areas 3 and 3^1 are in juxtaposition at region 25 the area of the aperture 6 so formed is sensibly zero, and that when the wide ends are in juxtaposition at region 25 the said aperture is maximum. Thus, there is provided at region 25 a variable aperture, and the mask 4 of figure 1 is not required. Obviously, an optical system which is basically similar to that shown in figure 1 may equally well be used with this arrangement, but is not shown for clarity.

The extra complication of the two discs 1 and 1^1 in figures 3 and 4 is justified when the desired frequency range of the oscillator is very wide (e.g. 1000:1), for in order to achieve such a range with the single disc 1 of figure 1, the radial width of the single track would also have to vary by a ratio of 1000:1, say from 3 inches to 0.003 inches, and at the lowest frequency, where the gap is minimum, minor errors in the gap would have a large error effect on the frequency of the oscillator. On the other hand, when two tracks in tandem having identical profiles are used, as in figure 3, variation in width from end to end would be in the ratio of about 31:1 instead of 1000:1, and the minimum width 31 times as great, e.g. 0.1 inch approximately. It follows that the tolerance on track profile is correspondingly increased.

In a commercial application, it is preferable that discs 1 and 1^1 should be interchangeable. Furthermore, to obtain a sharp delimitation it is desirable that the faces which carry the transparencies should be adjacent each other. Provision may be made for continuous rotation of the discs and shafts in the assemblies depicted in figures 1 to 4, so that a mechanical coupling may be made to cyclic automatic voltage recording devices. A flexible drive, as shown at 26 (figure 1) or a similar arrangement may be provided for this purpose.

The circuit of figure 5 shows a form of the Wien bridge oscillator in which the photo-sensitive element 14 constitutes a resistive element in series with capacitor 26 and element 14^1 constitutes a resistive element in parallel with capacitor 26^1. Capacitors 26 and 26^1 are fixed whilst the resistances of elements 14 and 14^1 are dependent on the light value of lamp 8 and the area of the variable aperture. Oscillation is maintained in the circuit by electronic amplifier 27 and a positive feedback path 28 including an output transformer 29 of the amplifier 27. The output winding 30 of the transformer 29 is loaded with a series combination of resistors 31 and 32 and is centre-tapped at 33, the centre tap being connected to ground. The feedback voltage to path 28 is taken from the junction of resistors 31 and 32. To stabilize the feedback and, consequently, the amplitude of oscillation, the resistor 32 may comprise an element such as a thermistor having a high negative temperature co-efficient of resistance. A resistive element 34 is included, as has been explained in U.K. Patent Specification No. 587,714, in order to prevent the output impedance of amplifier 27 from influencing the frequency when the input impedance of the frequency selective network consisting of elements 14 and 14^1 and capacitors 26 and 26^1 becomes very low, i.e. under strong illumination resulting in high oscillation frequencies.

The lamp 8 has, preferably, a metal filament as this makes the illumination largely immune to any small degree of ripple in the supply current which conveniently can be rectified, smoothed and stabilized alternating current. Light from lamp 8 is passed to cells 14 and 14^1 through an arrangement such as shown in figures 1 and 2 but, for clarity, this arrangement has been omitted from figure 5. In the kind of photo-sensitive element referred to hereinbefore the resistance varies inversely as the light flux reaching it, and consequently the frequency of oscillation is proportional to the area of the transparency 3 exposed as control shaft 3 is turned.

As shown in figure 6, a single cell 14^1 can be used to control the frequency of an R-C oscillator, if the points x_1, x_2 and x_3 shown therein are connected to the maintaining amplifier 27 at similarly marked points in figure 4. The values of the capacitors 26 and 26^1 and of the additional resistors 35 and 35^1 are chosen in the manner explained in U.K. Patent Specification No. 587,714. An oscillator using the network of figure 6 generates a frequency having a highly non-linear relationship to the resistance of element 14^1, the rate of rise in frequency increasing rapidly as the resistance of the element falls. The lowest frequency (highest resistance of the element) is determined by the proportions of resistor 35, 35^1 and 34 and the capacitors 26 and $26'$.

By photographing the transparency 3 onto a linear film base 37, as shown in figure 7, the accuracy with which the oscillation frequency can be set and read off from a scale 38 is greatly increased since the film strip 37 can be given any desired length. A secondary film strip 37^1 carrying a transparency 3^1 acting in co-operation with film strip 37 provides a varying aperture 39 in a similar manner to discs 1 and 1^1 in figure 3.

Referring to figure 7, the film strip 37 on which is photographed a tapering transparency 3 carries a frequency scale 38 along its upper edge. The film strip 37 is stretched between take-up spools 40 and 40^1 which may be spring loaded in opposite directions to ensure tautness of the film strip 37. The film strip 37 is advanced by means of a sprocket wheel 41 engaging corresponding sprocket holes in the film strip.

Film strip 37^1 carrying a transparency 3^1 identical with transparency 3 on film strip 37 is similarly stretched between take-up spools 43 and 43^1 and is advanced by sprocket wheel 41^1. The film strip 37 is traversed by control knob 22 over shaft 2. Shaft 2 also carries bevel wheel 45 engaging a second bevel wheel 46 attached to shaft 2^1. Thus, it will be seen that rotation of knob 22 in the direction shown causes the film strips 37 and 37^1 to move in the direction of the arrows and the aperture at 6 to be increased, whilst rotation in the opposite direction causes the aperture to be decreased. To ensure the two film strips 37 and 37^1 are in close juxtaposition where they cross, two guide plates 47 and 47^1 with cutouts 48 and 48^1 suitably placed to allow light to pass through them are provided as shown in figure 8.

An alternative embodiment, as shown in figure 9, uses a single film strip 37 co-operating with a mask, such as the mask 4 in figure 1, the film strip being traversed by friction between rollers 49 and 49^1, as shown in figure 9. Any slipping of the film cannot alter the relation between the frequency scale 38 printed on the film and the track width exposed.

The scale 38 is made visible to the operator by transmitted light from a source (not shown). It will be understood that the optical system hereinbefore described and illustrated in figure 2 is adapted to the present arrangement.

Figure 10 shows a push-pull maintaining amplifier 50 which is particularly suitable for an oscillator according to the invention when the minimum frequency to be generated is very low (say from 1 to 10 c/sec), for this amplifier does not require an output transformer to be included within the positive feed-back loop. The design of the oscillator turns on the fact that the anode potentials Ea and Eb to ground of output valves Va and Vb are necessarily very nearly equal and in anti-phase. It follows that all the pairs of elements 51 and 51^1, 52 and 52^1, and 53 and 53^1, in the two feed-back loops, generally indicated at 54 and 54^1, should be comparable with each other. Resistor 53^1 is a varistor and will adjust itself when oscillation starts to match resistor 53 provided that the frequency selective network 14 and 26, 14^1 and 26^1 is correctly proportioned. Under oscillation conditions, the voltage E_1 must equal the voltage E_2 and this requires that $R_1/R_2 = C_2/C_1 = \frac{1}{2}$ (where R_1 and R_2 are resistances of elements 14 and 14^1 respectively and C_1 and C_2 are the capacitances of elements 26 and 26^1 respectively). Since it is a requirement that R_2 is greater than R_1, element 14^1 must be arranged to receive half as much light flux as element 14 for all positions of the control shaft 2. This light reduction may be achieved conveniently by suitable adjustment of the appropriate iris 16 or 16^1. Element 52^1 is introduced (and consequently has to be balanced by element 52) in order to isolate the grid of amplifier input valve Vc from the anode voltage since a decoupling capacitor is ruled out by the low frequency requirement.

The arrangement of the active and passive parts of this circuit is such that the input impedance of the amplifier can have only a minor influence upon frequency and, similarly the frequency is little effected by phase-shift through the amplifier if the gain is high enough, but it is nevertheless helpful to apply some degree of negative feedback to keep the overall amplifier gain stable and prevent "hunting" of the varistor 53^1 serving as an amplitude controller. For this purpose, an output transformer, not included in the oscillation-loop, may be added and a feedback voltage taken from its secondary winding. It is to be understood that phase-splitting valves (not shown) connect the input valve Vc and the output valves Va and Vb of the amplifier 50.

Figure 11 illustrates a method of checking the performance of lamp 8. Besides illuminating the frequency controlling elements 14 and 14^1, lamp 8 is arranged also to illuminate comparison element 55 of the same kind as elements 14 and 14^1 which is connected in a bridge network comprising element 55, resistor 56 and potentiometer 57. The bridge is supplied with d.c. at terminals 58, and a suitable balance detector, such as a d.c. current meter, is connected between terminals y_1 and y_2. The potentiometer 57 can be adjusted by means of a slider 59 so that the detector reads zero when the lamp 8 has the correct brilliance. An audio frequency source may be used at 58 instead of a d.c. source, when headphones may take the place of the d.c. balance detector. Conveniently, the value of reistor 56 may be chosen so that the balance is achieved with the slider 59 of potentiometer 57 sensibly in the mid position. When using an audio frequency source, the circuit is in fact far more sensitive but needs additional apparatus, whereas a d.c. meter may already be available in the instrument and can be switched from its normal position to function temporarily as a bridge detector when required.

Figures 12 and 13 illustrate a simple method of applying a low frequency modulation to a fixed frequency generated by the oscillator. By way of illustration, the device is applied to the optical system shown in figure 2 and comprises a pendulum rod 60 with pendulum bob 61 suspended by a ligament 62 from a fixture 63. Below the pendulum bob 61 and attached thereto is an arcuate member 64 which is opaque at the two extremities and linearly graded in optical density to transparency at the centre. This member 64 is arranged to swing between the translucent disc 11 and the mask 4. The pendulum may be maintained in oscillatory motion and the magnitude of the swing may be controlled by any suitable means.

When the pendulum is stationary the member allows light to pass uninterrupted to elements 14 and 14^1 in the manner previously described and a fixed frequency will be generated according to the setting of the oscillator frequency control. When the pendulum is in oscillation, the light passing to the elements, and consequently the frequency, will vary sinusoidally, the magnitude of the frequency deviation from the mean (fixed) frequency being governed by the amplitude of the swing of the pendulum. The modulation frequency may be varied by changing the position of pendulum 61 on pendulum rod 60.

A further method of controlling and/or modulating the light beam and, consequently, the frequency, is by the use of two Polaroid (Registered Trade Mark) plates 65 and 66 as shown in figures 14 and 15. It can be arranged that when the planes of polarization of the two plates are parallel as in figure 14 maximum light is transmitted but when one plate is turned through 90 degrees as shown in figure 15 the planes of polarization are at right angles and no light is transmitted.

It will be understood that there have been shown and described only a few of the possible arrangements in which the principles of this invention may be embodied. Many other alternatives to the light controlling devices shown in the drawings may be made within the scope of the invention. For example, a conventional camera iris geared to open in sympathy with the rotation of shaft 2 can be used.

A valuable feature of mechanically operated masks, irises or shutters is that although the mechanism has to be designed to operate slowly when opening or closing the shutter, the rate of opening or closing need not be designed to follow any specific law for the only requirement is that the area of the transparency exposed shall be correctly related to the angle of the shaft 2. Thus, any deficiency or excess in the shutter width can always be compensated by local adjustment of the width of the transparency 3.

The proposed principle of controlling the oscillator frequency by optical means is open to a number of variants and additions, for example, a cycling variation of the oscillator frequency can be imposed by cyclic variations of the light flux delivered to the frequency controlling elements, such as 14 and 14^1, either by rotating or vibrating transparencies of graded optical density or by cyclic modulation of the voltage supplied to the primary light source, e.g. lamp 8.

Again, means well known in the art can be arranged to cause any error signal appearing at y_1—y_2 (figure 11) to modify the brightness of lamp 8 and thus automatically to maintain the oscillation frequency irrespective of mains voltage and of the optical efficiency of the lamp.

Although the invention has been described primarily with reference to an oscillator and means for varying its frequency of oscillation, it will be understood that the various measures described may also be employed in a frequency-selective amplifier to vary its selected amplifying frequency.

WHAT WE CLAIM IS:—

1. An electronic oscillator or selective amplifier which includes an amplifier and a positive feedback loop connected between the output and the input of the amplifier, said loop including a resistance and capacitance network determining the operating or oscillating frequency of the circuit, wherein the network includes at least one photo-sensitive element whose effective resistance depends upon the light incident upon the element, a source of light, light control means which is adjustable so that the amount of light passing from the source through the means and incident upon the element may be varied over a predetermined range with consequent variation of the operating or oscillating frequency of the circuit, and means for adjusting the light control means to pass any desired amount of light in the range so as to obtain a desired predetermined operating or oscillating frequency.

2. An oscillator as claimed in claim 1, wherein the product of the amplifier gain ratio and the network loss ratio exceeds unity so that the circuit is self oscillatory.

3. Apparatus as claimed in claim 1 or 2, wherein the photo-sensitive element consists of a photo-conductive cell whose resistance depends on the light incident upon it.

4. Apparatus as claimed in claim 3, wherein the photo-conductive cell is a solid state element.

5. Apparatus as claimed in claim 4, wherein the element is composed of cadmium sulphide.

6. Apparatus as claimed in any of claims 1 to 5, wherein the light control means consists of an aperture of adjustable size provided by an arrangement of masks moveable relatively to one another.

7. Apparatus as claimed in claim 6, wherein the adjustable aperture is provided by a normally fixed aperture which overlaps a portion of a moveable aperture.

8. Apparatus as claimed in claim 6, wherein the adjustable aperture is provided by the overlapping of portions of two moveable apertures.

9. Apparatus as claimed in claim 7 or 8, wherein the or each moveable aperture is provided upon a rotary disc.

10. Apparatus as claimed in claim 7 or 8, wherein the or each moveable aperture is provided upon a member mounted for linear movement.

11. Apparatus as claimed in any of claims 7 to 10, wherein the or each moveable aperture varies in width along its length.

12. Apparatus as claimed in any of claims 1 to 5, wherein the light control means consists of an aperture of variable density.

13. Apparatus as claimed in any of claims 1 to 5, wherein the variable density is provided by two polarised elements whose planes of polarization are moveable relatively to each other.

14. Apparatus as claimed in any of the preceding claims, wherein a source of light is provided for illuminating the photo-sensitive element and a comparison photo-sensitive element, which comparison element is provided with means for indicating when a desired light intensity is produced by the source.

15. Apparatus as claimed in any of the

preceding claims, wherein the network includes two photo-sensitive elements arranged to receive light from a single source of light.

16. Apparatus as claimed in claim 15, wherein means are provided for varying the ratio of the light incident upon each of the two elements.

17. Apparatus as claimed in any of the preceding claims, wherein the or each element is included in an oscillator of the Wien bridge type.

18. Apparatus as claimed in any of the preceding claims, wherein the amplifier is a push-pull amplifier.

19. Apparatus as claimed in claim 18, wherein two photo-sensitive elements are provided, one in each phase of the amplifier.

20. Apparatus as claimed in claim 19, wherein one element is arranged to receive twice as much light as the other regardless of incident intensity of the light.

21. Apparatus as claimed in any of the preceding claims, wherein means are provided for cyclically varying the incident light and thus cyclically varying the operating or oscillating frequency.

22. Apparatus as claimed in claim 21, wherein a member carried upon a pendulum is arranged to vary cyclically the incident light.

23. An electronic oscillator or selective amplifier, substantially as described with reference to any of the accompanying drawings.

24. An electronic circuit comprising a maintaining amplifier having an input and an output, a feedback loop network including resistive and capacitive elements connected between said output and said input in order to apply positive feedback to said amplifier, the product of the amplifier gain ratio and the network loss ratio exceeding unity whereby said circuit is self-oscillating at a frequency dependant upon said resistive and capacitive elements in said network, said resistive elements including a photo-sensitive element whose resistance value depends upon the light incident upon said element, and means for varying the light incident upon said element whereby said oscillatory frequency may be varied.

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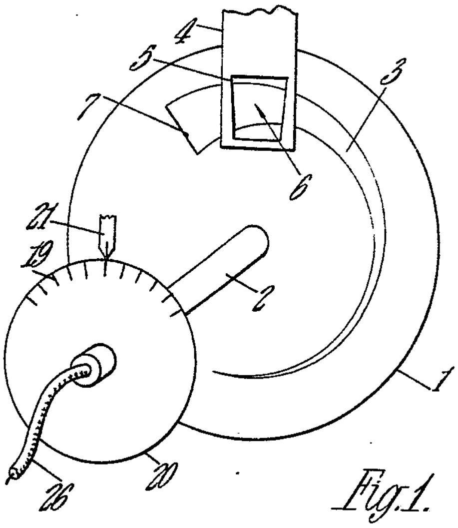
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Fig.1.

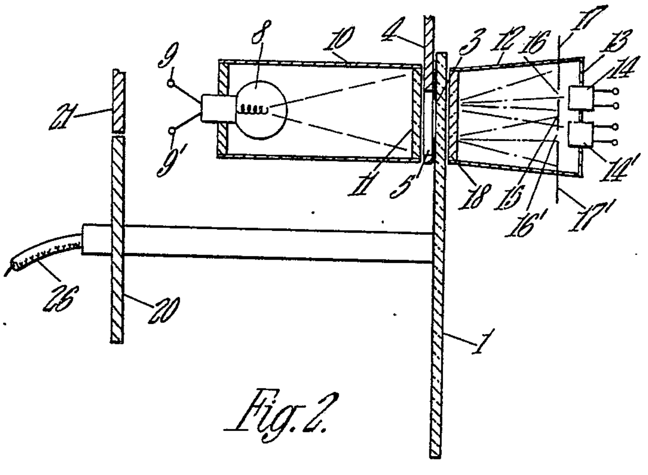
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Fig.2.

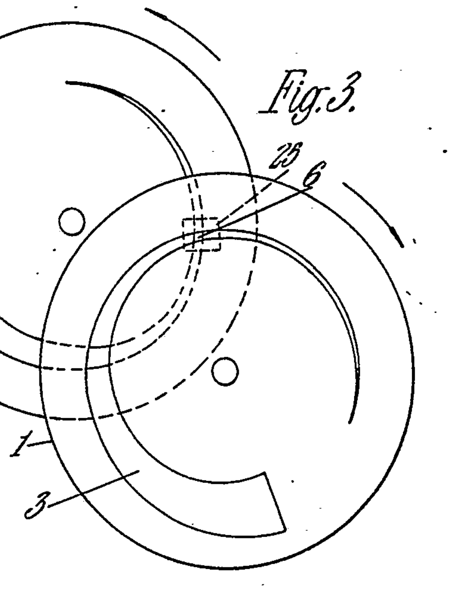

Fig.3.

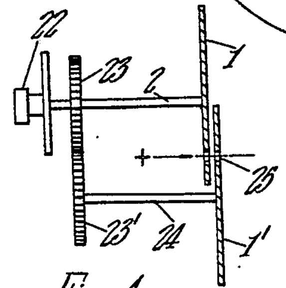

Fig.4.

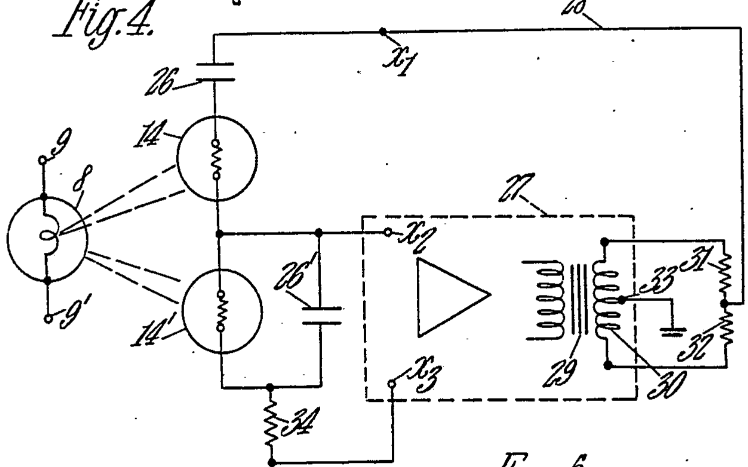

Fig.5.

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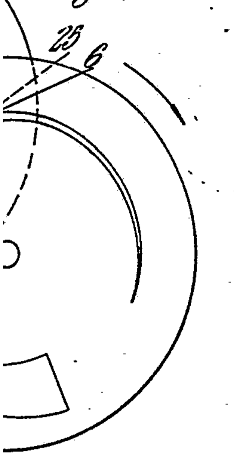
Fig.3.



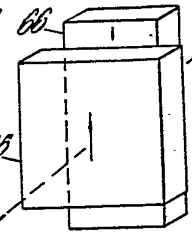


Fig.14.

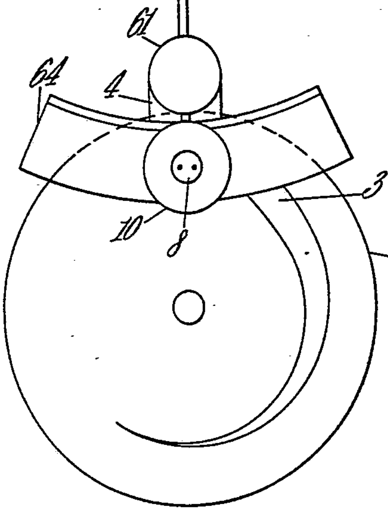


Fig.12.

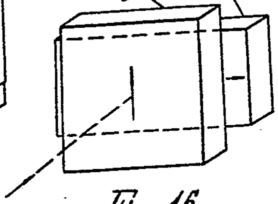


Fig.15.

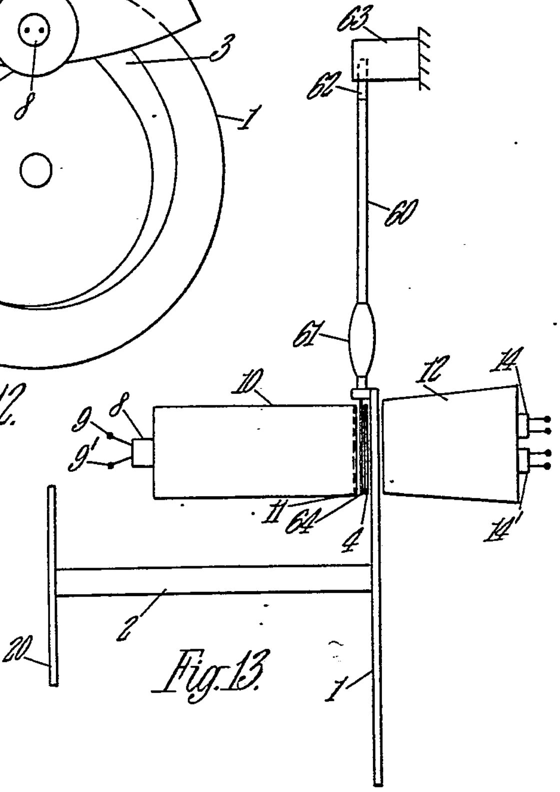
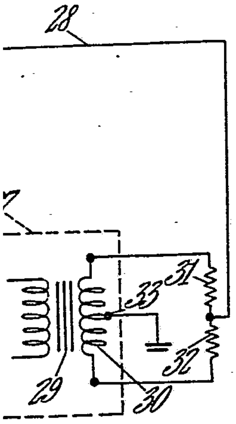


Fig.13.



ig.5.

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4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 2 & 4

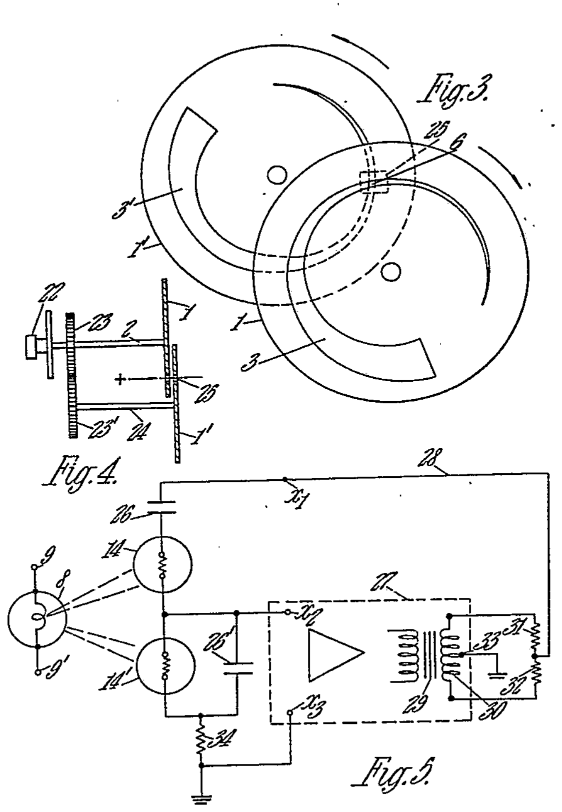


Fig.3.

Fig.4.

Fig.5.

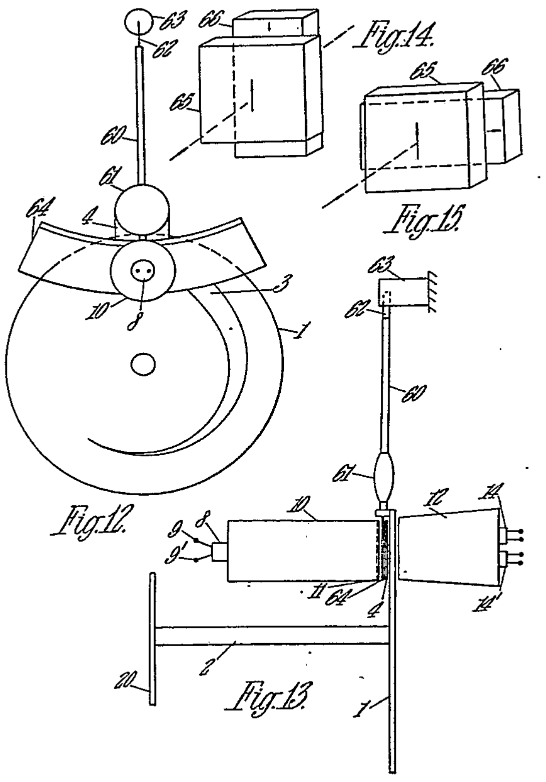
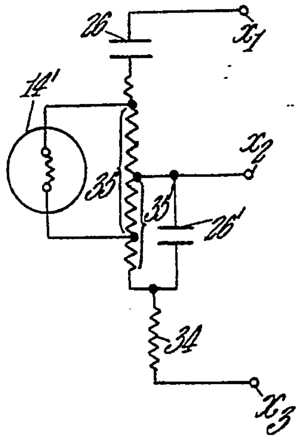


Fig.14.

Fig.15.

Fig.12.

Fig.13.



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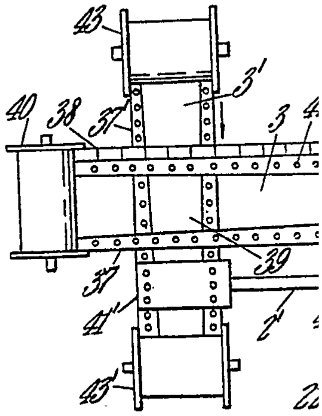


Fig.10.

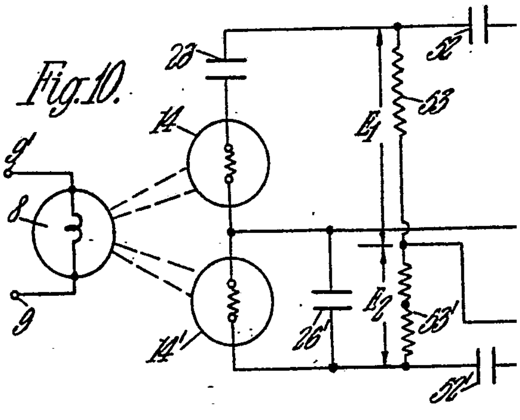
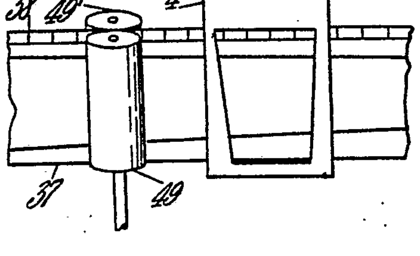
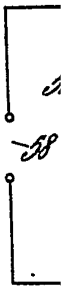


Fig.9.

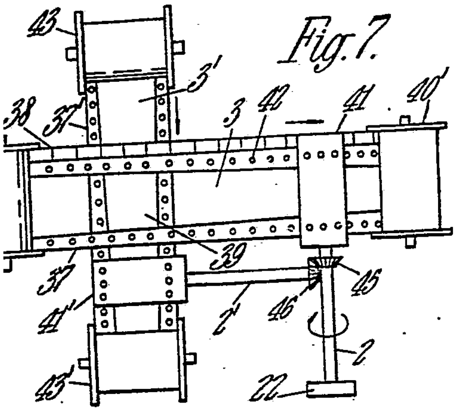




1025709 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3



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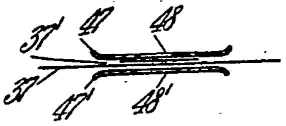


Fig.8

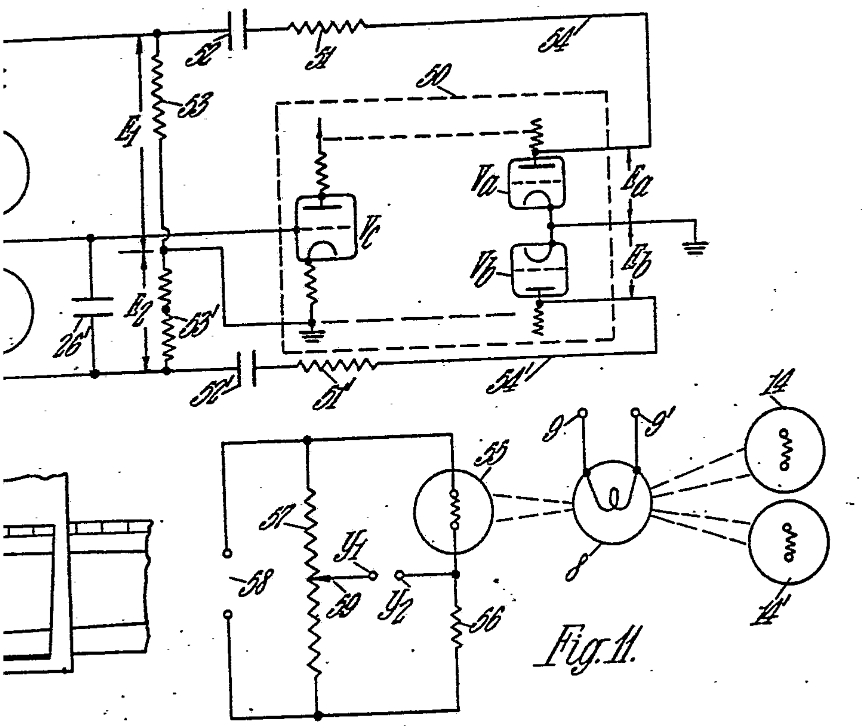
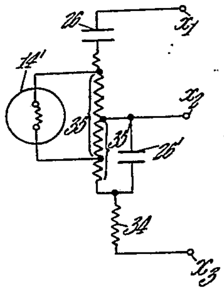


Fig.11.



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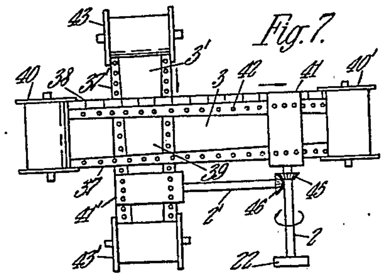

Fig.7.

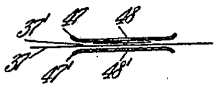

Fig.8

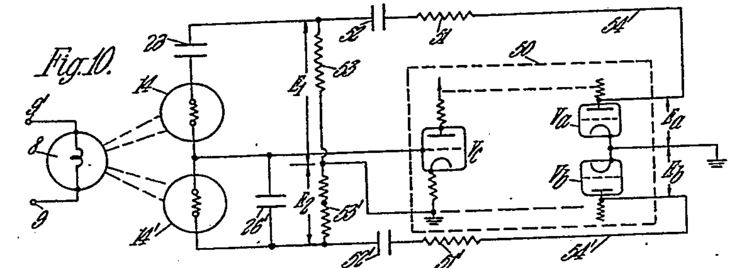

Fig.10.

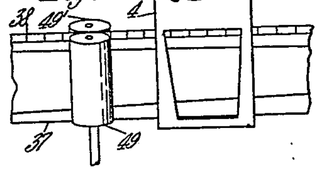

Fig.9.

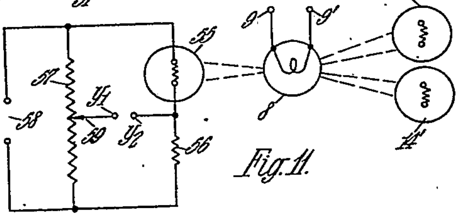

Fig.11.