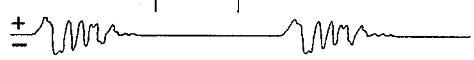
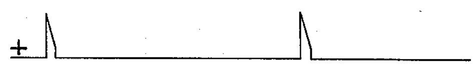
March 6, 1951 | T. G. BARNES | 2,544,482

APPARATUS FOR TIMING THE INTERVAL BETWEEN IMPULSES

Filed May 29, 1946

Fig. 9.





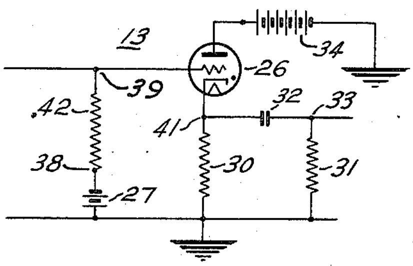


Fig. 8.

Fig. 10.

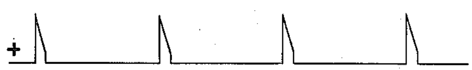
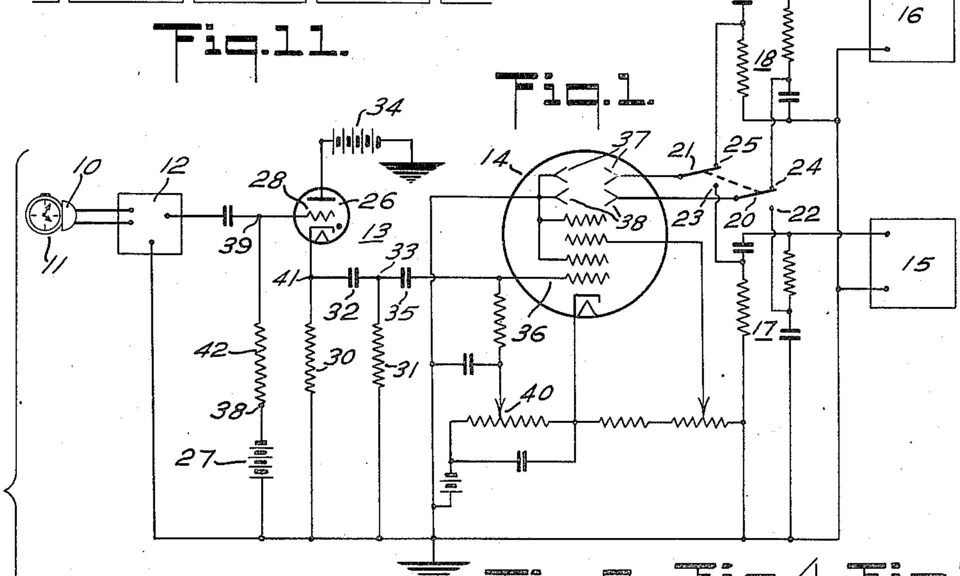


Fig. 11.

Fig. 1.



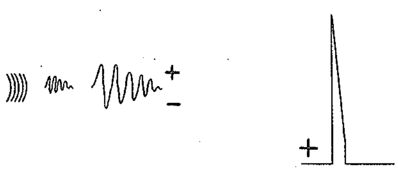


Fig. 7.

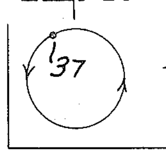


Fig. 4.

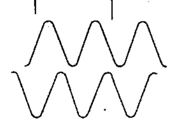


Fig. 3.

Fig. 6.

Fig. 5.

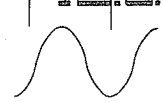


Fig. 2.

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APPARATUS FOR TIMING THE INTERVAL BETWEEN IMPULSES

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3 Claims. (Cl. 73—6)

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The present invention relates to testing apparatus and more particularly to a watch rate synchronizing system and its associated components.

Some of the objects of the present invention are: to provide a novel watch rate synchronizing system; to provide a system for comparing the frequency of watch ticks with a standard of frequency whereby a watch can be adjusted to synchronize with the selected standard; to provide as a component of a watch rate synchronizing system a novel peaking circuit; to provide a synchronizing system including a plurality of frequency standards capable of being selectively controlled; to provide a system for synchronizing a periodically operating device producing sound waves which are transformed into an electrical succession of pulses to be utilized in comparison with a standard of frequency; to provide a novel self-excited pulse generator; to provide a novel peaking and blocking circuit arranged to function as a single sweep circuit for a cathode ray oscilloscope; and to provide other improvements as will hereinafter appear.

In the accompanying drawings Fig. 1 represents a watch rate indicator network embodying one form of the present invention; Fig. 2 represents a pulse form derived from an amplified watch tick signal; Fig. 3 represents a wave derived from a high frequency alternating voltage source serving as a standard of comparison; Fig. 4 represents two separate continuous A. C. voltages of the same frequency but 90° out of phase with each other; Fig. 5 represents a wave derived from a low frequency alternating voltage; Fig. 6 represents two separate continuous A. C. voltages of the same frequency but 90° out of phase with each other; Fig. 7 represents the pattern produced on a cathode ray tube by the network of Fig. 1 with its applied signal; Fig. 8 represents a novel form of peaking circuit forming a part of the present invention; Fig. 9 represents a wave form of an incoming signal as delivered to the peaking circuit of Fig. 8; Fig. 10 represents the peaked output voltage from the circuit of Fig. 8; and Fig. 11 represents the output voltage wave as derived from the circuit of Fig. 8 functioning as a self-excited pulse generator.

Referring to the drawings and more particularly to Fig. 1, the network shown is arranged for testing the rate of a watch or other periodically operating device and comprises generally a sound pick-up device such as an electro-acoustic transducer 10 for receiving the ticks of a watch 11 and translating such ticks into electrical signals suitably amplified by an amplifier 12, as shown

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in Fig. 9. The amplified signal is delivered to a peaking circuit 13 having its output voltage in the form of a single positive pulse impressed on the grid (Z axis) of a cathode ray tube 14. The X axis and the Y axis of the deflecting plates of the tube 14 are energized by selecting a low frequency alternating voltage source 15 or a high frequency alternating voltage source 16, the former having its output split into two separate continuous voltages 90° out of phase by a resistance-capacity phase splitter network 17, and the latter having its phase output split into two separate continuous voltages 90° out of phase by a resistance-capacity phase splitter network 18, so that, in use of either source, the pattern produced by the tube 14 is a circular path, as shown in Fig. 7. The selection of the two sources of voltage is in accordance with the positions of two manually shiftable interconnected switches 20 and 21, arranged to contact the respective shift phase terminals 22 and 23, and 24 and 25.

Generally considered therefore, the invention changes the tick of a watch into an electrical wave which is sharpened into a single positive pulse of very short duration, for example 0.00001 second and impressed on the grid (Z axis) of the cathode ray tube 14. The result is a bright spot as indicated on the circle of Fig. 7, the spot occupying an arc on the circle of only 0.01 of the whole circle since it takes 0.001 second for the complete circle to be described by the revolving beam, and the duration of the intense beam is 0.00001 second, while the standard alternating voltage source is 1000 cycles per second.

Most watches tick every fifth of a second when accurately set so that if the watch is adjusted correctly the second tick will occur when the beam has just completed its 200th revolution and the second bright spot will appear in precisely the same position as the first. Hence, if the watch is accurately adjusted the spot will appear to remain in the same place on the circle. If the rate is slow the spot will drift around the circle in the same direction as that in which the beam is being described.

In order to sharpen the electric wave resulting from the watch tick so that only a spot is visible on the circle, and also to block out all other noise, such as that in the "tail" of the tick noise, so that only one pulse is received by the screen of the cathode ray tube for each tick, the peaking circuit 13 is provided as one means of producing a pulse which is positive and of such relatively large magnitude as to intensify the beam and produce a bright spot on the screen. This peaking circuit 13 includes a gas tube 26, such as the "884 thyratron" which is biased beyond cut off by the voltage across the negative or C source battery 27. When a positive voltage from the watch tick strikes the control grid 28 the tube fires. The cathode resistor 30 is large enough to prevent the tube from firing, but resistor 31 is small enough to allow the tube to fire. Capacitor 32 begins to charge through resistor 31 the instant the tube fires and the plate current through the tube decays as the capacitor charges until the point is reached where the gas in the tube deionizes. The discharge of this capacitor then takes place through resistor 30. Since resistor 30 is a larger resistor than resistor 31, the rate of discharge of the capacitor is less than the rate of charge.

As long as the capacitor 32 is discharging through resistance 30 the plate voltage across tube 26 is reduced and the grid bias is increased by the voltage across resistor 30. Both effects block the tube from firing on signals of the same magnitude as those which previously fired the tube. The circuit thus acts to sharpen a pulse, block subsequent disturbances for a period and then reset itself for another pulse.

The result of this action is an output voltage across resistor 31 which is peaked as shown in Fig. 10. The pulse is almost vertical on the initial face for the instant the tube fires point 33 is brought up from ground potential to the potential of the B+ on the supply 34 less the tube drop, which is small. For example, if the gas tube is an "884" with a tube drop of about 20 volts and the B+ supply voltage 34 is +105 volts, the initial potential at 33 is +85 volts.

The potential of point 33 decays as the capacitor is charged. This is shown by the slant side of the pulse. The rate of decay of this potential is determined largely by the time constant of capacitor 32 and resistor 31. The time interval during which incoming signals are blocked from triggering the gas tube is determined largely by the time constant of capacitor 32 and resistor 30. By proper selection of these three elements the pulse duration and the time interval for blocking out succeeding signals can be varied widely.

In the watch rate indicator a reasonable period of the pulse duration might be 0.00001 second and the time interval for blocking signals might be 0.1 second. This could be approximately obtained by using a capacity 32 of 0.01 microfarad and a resistance 31 of 1000 ohms in the charging circuit and a resistance 30 of 10 megohms in the discharging circuit.

By reference to Fig. 1 of the drawings the aforesaid peaking circuit 13 is shown in the complete network to produce watch tick indication as compared to a known standard. Thus, the sound energy of the tick of the watch 11 is changed into an electrical wave by the transducer 10, traverses the amplifying circuit 12 to be impressed upon the grid 28 of the gas tube 26. No cathode current is flowing in the tube 26 before the wave of Fig. 9 reaches it, but at the onset of the positive portion of the electrical wave the tube 26 triggers or fires through the peaking circuit 13, including the capacitor 32 and resistor 31. The values of the capacitor 32 and the resistor 31 are preferably such that the duration of the pulse is very short. The function of the resistor 30 is to discharge the capacitor 32 slowly, extinguish the current in the tube 26 after the pulse, and to block any subsequent interfering noise until time for the onset of the next tick. Hence, the resistor 30 must have a large value of resistance compared with the value of the resistor 31. The action of the peaking circuit thus produces the large sharp positive pulse of Figs. 2 and 10, which is sent to the Z axis of the cathode ray tube 14, namely by way of a capacitor 35 and intensity grid 36, and serves to intensify the beam momentarily and put a bright pip 37 on the screen of the cathode ray tube 14.

For the purpose of checking the frequency of the watch ticks, it is preferred to employ two frequency standards, such as shown at 15 and 16, of which the low frequency standard 15 is for a rough set on the watch, while the high frequency standard is for precision setting or synchronizing of the watch rate.

The steady state alternating voltage of the low frequency standard source 15 (see Fig. 5) is split into two steady state alternating voltages 90° out of phase with each other by the resistance-capacity phase splitting network 17 (see Fig. 6). This set of alternating voltages is used when switches 20 and 21 are in positions 22 and 23 respectively, for the rough setting. These switches are mechanically connected to operate together.

Similarly, the steady state alternating voltage from the high frequency standard source 16 (see Fig. 3) is split into two steady state alternating voltages 90° out of phase with each other (see Fig. 4). This set of alternating voltages is used when switches 20 and 21 are in positions 24 and 25 respectively for the precision adjustment.

One set of alternating voltages (depending upon whether it is the rough adjustment or the precision adjustment) is sent onto the deflecting electrodes of the cathode ray tube 14. The alternating voltage impressed across the pair of deflecting plates 37 (say the horizontal or X-axis) is of the same frequency but 90° out of phase with the alternating voltage impressed across the other pair of deflecting electrodes 38 (say the vertical or Y-axis). The result is that the beam of the cathode ray tube 14 describes a circle on its screen with a frequency exactly equal to that of the standard frequency source being used.

The intensity of the beam, however, is adjusted by potentiometer 40 so that the circle is either just visible or not quite visible. Only the pips from the peaking circuit will show up brightly on the screen.

If the frequency of the watch tick is adjusted to an integral submultiple of the standard frequency, the spot will always appear at the same point on the circle. If the frequency of the watch tick is slightly off from the integral submultiple of the standard frequency it will appear to drift around the circle. The greater this rate differs from an integral submultiple the faster it will drift (the larger jumps it takes around the circle).

It would be desirable to pole the split phase voltages so that the beam revolves counter-clockwise on the screen. If the watch rate is slightly slow, the spot drifts counter-clockwise. If the watch rate is slightly fast, the spot drifts clockwise.

While the watch rate can be effectively checked by a single frequency standard, it is preferable to use two, for the following reasons. If the frequency of the watch tick is greatly off from the correct integral submultiple of the standard frequency, the spot may appear at widely separated points on the circle as it makes its sequence of appearances (about five per second), or it may even appear in the wrong cycle of the revolutions of the beam. Thus, there might be this 360° ambiguity due to the wrong submultiple setting of the watch tick rate.

For example, if the precision standard frequency were 1000 cycles per second and the watch tick frequency five cycles per second, the beam would revolve 200 times around the circle between pips. There might be the possibility of setting the watch rate at some other submultiple of the standard frequency, e. g. it might be set fast by 1 part in 200, i. e. 0.5% fast, so that the beam only made 199 revolutions between pips. Yet the appearance on the screen would be the same as if the watch were set correctly. Hence, it is desirable to have some lower frequency standard to adjust the rate of the watch to better than 1 part in 200 in our illustration. This lower frequency standard might well be the 60 cycle A. C. power supply which might normally be used to power the system anyway. The 60 cycle A. C. power supply from the utility companies is usually more accurate than the requirement in this instance.

If 60 cycles is used as the low frequency standard, there will be only 12 revolutions of the beam between pips. There should be no difficulty in setting the watch tick rate correct to this submultiple, $\frac{1}{12}$ of the standard frequency. For a watch to be off 1 part in 12 would mean that it was off two hours per day. Such a discrepancy could be observed in less than one minute by comparing with an accurate watch. Hence, any 360° ambiguity in the spot appearance could be eliminated by comparing this watch with a reasonably accurate one for a period of about a minute.

With the 60 cycle standard the synchronizing of the watch should be better than 0.1%. A discrepancy of 0.1% would mean an error in time between ticks of 0.0002 seconds. Since the period of the low frequency standard is $\frac{1}{60}$ second the displacement of the second pip from the first pip would be 0.012 of the distance around the circle, or the spot would drift (i. e. progress in five jumps) 0.06 of the way around the circle per second. This drift rate would be readily discernable for it is about four times the rate of rotation of the second hand on a watch and that rate of motion is readily discernable. In fact, this rough adjustment could be made still more accurately if the low frequency standard were more accurate than 0.1%. Hence the rough adjustment should set the watch rate well within the range to be handled by the precision high frequency standard.

In the case of a 1000 cycle per second frequency for the precision standard, if the watch tick rate were off by 1 part in 100,000 (or 0.001%) it would show up on the screen with a drift rate of once around the circle in 100 seconds. This drift rate which indicates an error in setting of the watch would be noticed very quickly. In this instance it means that an error in the watch rate of less than 1 second per day is readily detected.

While in the foregoing the frequency of watch ticks is to be standardized, it will be apparent that other troubles in a watch can be analyzed such, for example, as using the scatter or separation of alternate spots when the net drift is removed as a means for diagnosing the unbalance in the escapement mechanism. The change in the rate of the watch with different orientations could be observed by setting the rate correct with one orientation of the watch in space, then changing the orientation and observing whether or not the spot began to drift and if so in what direction and what its rate of drift is.

It might be desirable to view the actual wave form of the ticks and other noises. The cathode ray tube could be employed with only a few modifications to show this wave form.

In watches or other time pieces having a tick rate different from the standard of five per second, the system can be adjusted to set the watch until the proper drift rate is obtained. The drift rate could be tabulated for any frequencies in terms of the time taken for the spot to drift through a given arc on the circle. This arc could be marked on the screen of the cathode ray tube and an ordinary timepiece used to get the time of drift.

In connection with the novel peaking circuit **13**, it should be noted that this may function as a self-excited pulse generator by using a potential at point **38** which is less negative than the cut-off bias, in which case the circuit will generate its own pulses, as in the peaking-blocking use the duration of the pulse depends upon the capacitor **32** and the resistor **31**, while the repetition time, i. e., from the beginning of one pulse to the beginning of the next, depends upon the capacitor **32** and the resistor **30**. Fig. 11 shows the output voltage of such a pulse generator.

In order to modulate the frequency of the circuit **13** when used as a pulse generator, the repetition time may be changed by impressing a different potential on the grid **39**. This is due to the fact that the period between pulses depends upon the time required for the cathode **41** to drop to a difference between points **41** and **39** equal to the striking potential. If point **39** is raised to a more positive potential, the repetition time is shortened. Similarly, if the potential of point **39** is lowered or made more negative, the repetition time is lengthened. Hence, the frequency of the pulses can be modulated by merely applying a varying voltage across the grid resistor **42**.

Furthermore, the peaking and blocking circuit **13** may be used as a single sweep circuit for a cathode ray oscilloscope. If transient phenomena are to be observed it is desirable to have the sweep initiated at the outset of the transient phenomena and have only a single sweep which lasts for the duration of the transient. This peaking circuit will accomplish this if the bias is set very near the cut-off point and the time constant which determines the slant side of the pulse is adjusted correctly. In order to have the single sweep begin at the left edge of the screen, the spot should be positioned off to the right such a distance that the spot will take on its starting position on the left at the instant it is triggered into action.

Having thus described my invention, I claim:

1. In a system for synchronizing periodic sound waves with a selected frequency as a standard of comparison, the combination of a cathode ray tube, means comprising a selected frequency source applied to the X and Y axes of said tube for producing a predetermined pattern on the screen of said tube, means for transforming successive sound signals from a device under test into a corresponding succession of positive voltage pulses, and means comprising a peaking circuit including a single gas tube having a plate directly connected to a direct current source to impress said impulses upon the Z axis of said cathode ray tube to produce varia-

tions in intensity of the cathode ray beam, whereby the apparent relative motion or absence of apparent relative motion of the point of changed intensity on said pattern indicates the relation of the frequency of the pulses to the selected frequency.

2. In a system for synchronizing periodic sound waves with a selected frequency as a standard of comparison, the combination of a cathode ray tube, means comprising a selected frequency source and a phase splitting circuit applied to the X and Y axes of said tube for producing a predetermined pattern on the screen of said tube, means for transforming successive sound signals from a device under test into a corresponding succession of positive voltage pulses, and means comprising a peaking circuit including a single gas tube having a plate directly connected to a direct current source to impress said impulses upon the Z axis of said cathode ray tube to produce variations in intensity of the cathode ray beam, whereby the apparent relative motion or absence of apparent relative motion of the point of changed intensity on said pattern indicates the relation of the frequency of the pulses to the selected frequency.

3. In a system for synchronizing periodic sound waves with a selected frequency as a standard of comparison, the combination of a cathode ray tube, means comprising a selected frequency source applied to the X and Y axes of said tube for producing a predetermined pattern on the screen of said tube, means for transforming successive sound signals from a device under test into a corresponding succession of positive voltage pulses, means comprising a peaking circuit to impress said impulses upon the Z axis of said tube to produce variations in intensity of the cathode ray beam, said peaking circuit including a resistor and two capacitors arranged to provide a resistive path to ground and preventing extraneous noises from obscuring the synchronism between said device frequency and the frequency standard, whereby the apparent relative motion or absence of apparent relative motion of the point of changed intensity on said pattern indicates the relation of the frequency of the pulses to the selected frequency.

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