

K. SCHLESINGER

METHOD OF DIVIDING FREQUENCY

Fig. 4.

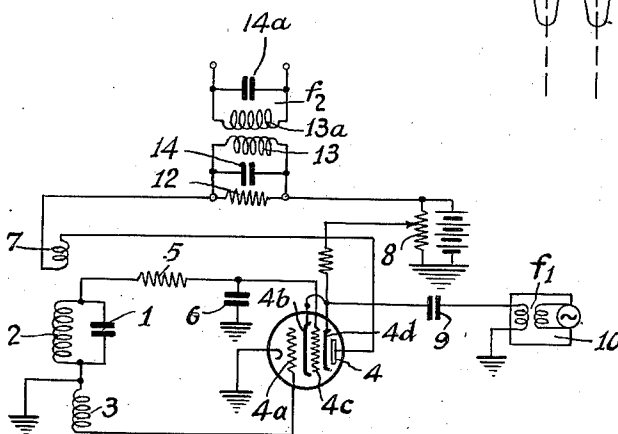
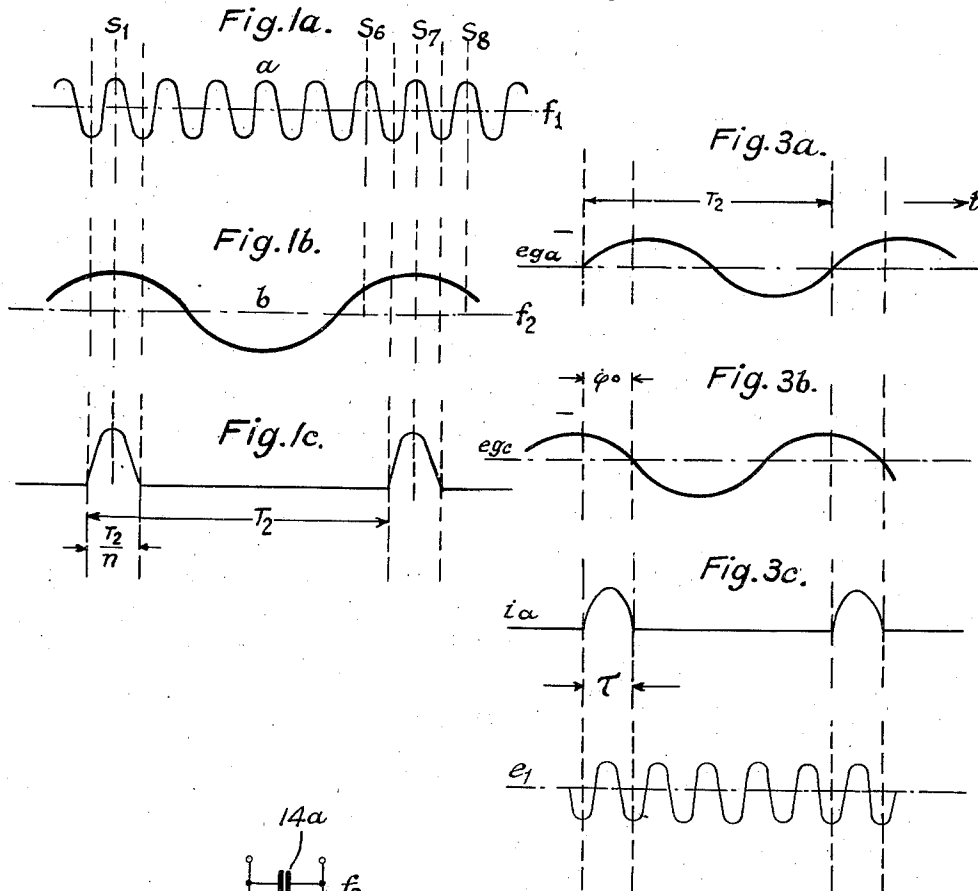


Fig. 2.

Inventor:

Miss Willerup.

UNITED STATES PATENT OFFICE

2,252,442

METHOD OF DIVIDING FREQUENCY

Kurt Schlesinger, Berlin, Germany, assignor to
Radioaktiengesellschaft D. S. Loewe, Berlin-
Steglitz, Germany, a company of Germany

Application November 5, 1938, Serial No. 239,155
In Germany March 22, 1938

5 Claims. (Cl. 250—36)

The large part played by frequency division in all synchronisation problems is well known. Cascade connections of up to a value of three powers of ten or more are required for direct wave broadcasting on the transmission of pictures by way of leads and for television purposes. The operation of these systems, which are employed at the transmission end, must naturally be perfectly reliable. In the case of a divider cascade no stage should make an error, even occasionally, in the frequency or in the phase, so that the complete transmission will not be interfered with.

Unfortunately practically all of the connection systems known heretofore fail to comply entirely with these conditions as to reliability. Two faults occur, the phase error and the frequency error.

In the accompanying drawing:

Figure 1a shows the curve of a controlling oscillation of a frequency divider. Figure 1b shows the curve of the oscillation of the controlled system the synchronisation of which is indefinite.

Fig. 1c shows a curve of a controlled oscillation formed to prevent an incorrect synchronisation.

Figure 2 shows the circuit connection of a frequency divider according to the invention.

Figures 3a-3d show the derivation of the oscillation according to the Figure 1c from the natural oscillation of the controlled system as compared with the controlling oscillation, and

Fig. 4 shows several frequency dividing stages coupled together.

In Figure 1a there is shown by *a* the rapid control oscillation of the frequency f_1 and by *b* the slow controlled oscillation of the frequency f_2 . The divider ratio of $f_2:f_1=1:7$.

On the basis of Fig. 1 there can now be explained the occurrence of the phase error and the frequency error. The oscillations S_1 and S_7 of the Figure 1a are intended to synchronise the operated system. When the sensitivity of response of the controlled system has chronologically the same disposal as the sine wave of Fig. 1b, the operative condition with respect to the sixth or eighth period of the curve *a* is obviously not much poorer than that as regards the desired seventh period, as the condition of oscillation of the curve *b* has only been changed to little extent for small timed deviations of this nature from zero. It frequently occurs, therefore, in practice that a frequency divider of this kind jumps about in the phase on the basis of some small variation in its operative conditions and can be synchronised by an earlier or later

period of the control oscillation. In a divider ratio

$$\frac{f_1}{f_2} = n$$

there then occurs in certain circumstances an operation by the oscillations $n-1$ and $n+1$, a synchronised television image, for example, being continuously displaced by

$$\frac{1}{n}$$

of its width. The probability of a jumping about of this kind is naturally all the greater, the greater the desired frequency division has been selected to be. Small differences in frequency on the part of the controlled oscillator lead to a continuous operation on the incorrect wave, immediately they reach an amount of

$$\pm \frac{1}{n}$$

It has been attempted to gain freedom from these uncertain factor by developing two fundamentally different connection systems:

- (1) RC systems or RL systems,
- (2) CL systems.

(1) Systems with condenser and resistance determine their frequency by a current or potential value in conjunction with a condenser. They are well protected against errors in phase, but are greatly dependent on operating potentials and currents, and accordingly also on the tubes. They must, therefore, usually be operated by accumulators and are very sensitive to fluctuations in the potential of the mains.

(2) Systems with normal oscillatory circuit CL are in the frequency extremely independent of mains potentials and tubes, but are liable to the phase error according to Figs. 1a, 1b.

The fundamental idea of the invention set forth in the following consists in producing the synchronisation sensitivity for the controlled system only during a short fraction of the controlled oscillation, viz., during a period of the control oscillation, i. e., only during the time

$$\frac{T_2}{n}$$

Designation: Shortening of the period of response.

In Fig. 1c there is shown an ideal response curve for a system of the kind in question. The

system switches itself for output only during the brief period

$$\frac{T_2}{n}$$

if T_2 is its natural period. The result is that a premature or delayed ignition of the synchronism by the two adjacent periods of the control oscillation of the controlled system cannot take place, as the system is disconnected from the circuit automatically before the arrival of the neighbouring periods. In this way a jumping about of the controlled system in its phase would be out of the question. There remains the possibility of the frequency error, which would consist in displacement of the period duration T_2 of the controlled oscillation to the value

$$T_2 \left(1 \pm \frac{1}{n} \right)$$

In this connection there is employed the second fundamental idea according to the invention:

The controlled system is built up as reaction-coupled oscillator, and in the reaction-coupling channel there is included a conductance which is controlled in full range by the control oscillation. In this way it is accomplished that the oscillations of the controlled system are capable of existing at all only so far as the synchronisation signals arrive in the correct phase or correct frequency. The controlled system, therefore, in accordance with the invention, is designed as a "dependent oscillator."

The idea according to the invention accordingly resides in a combination made up of the shortening of the period of response and the dependent oscillator.

This idea can be realised in very different ways. One of the most simple connection systems is that according to Fig. 2. There is to be recognised in the first place an oscillatory circuit comprising the capacity 1 and the self-induction 2. This oscillatory circuit is tuned to the slow frequency f_2 . Its potential time curve can be in accordance with Fig. 1b (sine wave). First there is produced from this simple sine oscillation an impulse curve according to Fig. 1c. Particularly suitable for this purpose is a method, the so-called phase shifting, which has already been described by the applicant on Patent 2,190,504. An auxiliary coil 3 inductively coupled with the coil 2 produces an auxiliary potential, which is shifted by 180° . This is conducted to the first grid 4a of a hexode 4 direct, i. e., without phase shift. On the other hand the terminal potential of the oscillatory circuit is conducted to the third grid 4c of the same hexode by way of a phase shifter, which consists of the resistance 5 and the condenser 6. The potential of the third grid 4c is accordingly retarded by a phase slip, which is adjustable at 5, 6, in relation to the phase of the first grid 4a. These phase conditions are illustrated in Fig. 3.

In Fig. 3a the potential e_3 at the auxiliary coil 3 is at the same time the potential e_{4a} at the grid 4a. On the other hand, in Fig. 3b, e_{4c} is a potential which is phase shifted by the angle φ_0 and at the same time turned by 180° , such as reaches the third grid 4c, i. e. e_{4c} . A plate current can only flow when the two grids are simultaneously positive. In Fig. 3c it is to be recognised when this occurs. Fig. 3c accordingly represents the plate current i_a dependent on the time. In this case, therefore, by phase shifting, there has been produced from a sine oscillation

according to Fig. 3a a shortening of the time of response, viz., an impulse oscillation according to Fig. 3c. In this way there has been fulfilled the first condition relative to the invention. The angle τ is so adjusted that the impulse duration becomes

$$\tau = \frac{T_2}{n}$$

T_2 is the period of the oscillation circuit 1, 2. There must now be fulfilled the second condition according to the invention: the dependent oscillator. For this purpose there is performed the following: The anode circuit of the hexode 4 is reaction-coupled to the grid circuit. For this purpose there is employed, for example, the coil 7 or any other known kind of reaction coupling. Experience has shown that the reaction coupling energy merely requires to prevail during the very brief time of the desired period T_2 . It is not necessary to introduce reaction coupling energy into the grid circuit for the entire duration of the period. Fundamentally, therefore, the hexode can oscillate in powerful fashion, although only brief current impulses flow in its plate circuit, i. e., in the reaction coil 7. In order to act on these oscillations from the control oscillation a valve must be provided in the reaction channel. For this purpose there can be employed in simple fashion the screening grids 4b and 4a. The screening grids 4b, 4d receive their bias from a potentiometer 8. This bias is selected to be so low that the oscillations of the system can exist weakly or not at all. Oscillations from the control transmitter 10 are conducted to the screening grids by way of a condenser 9. 10 has the frequency $f_1 = n \cdot f_2$. It is to be recognised now that the oscillations of 4 are produced and are capable of being upheld if, and only if, a positive period of the control oscillations (represented in Fig. 3d) arrives just at the moment when the two grids 4a and 4c are positive. This means that the system 4 attempts to maintain its oscillations continuously, and in this connection must so adjust itself that its transmission phase always coincides with a positive half-wave of the control oscillation. A jumping about in an adjacent period is prevented by the method of shortened time of response, and a jumping about in an incorrect natural wavelength is prevented by the fact that the oscillations of the controlled system must cease if they do not coincide with a sub-harmonic f_1 . In Fig. 3 there are shown the conditions with respect to a frequency division of 1:6.

Numerous modifications of the connection system in Fig. 2 are conceivable without departing from the idea according to the invention. The supply of the control potential can take place inductively instead of capacitatively, there being included a transformer in place of the working resistance 11. The system according to Fig. 2 supplies at the n -resistance 12 potential impulses of negative sign on the lines of Fig. 3c. If it is desired to obtain sine oscillations, there can be included in place of 12 a simple or coupled oscillatory circuit 13, 14, 13a, 14a. Its impedance exerts no appreciable reaction on the system, as the tube 4 is a screening grid tube. In this form of connection the system is suitable for the building up of cascades; a sine oscillation of the frequency f_1 is introduced at 10, and a like oscillation of the reduced frequency f_2 is obtained at 14a. At this terminal, therefore, there can readily be connected a further divider

system, which is connected in exactly the same manner as that described. Figure 4 shows cascades of these frequency dividers connected in series and very high divider factors brought about. This is of particular importance in television in obtaining a large number of lines. For example 441 is equal to $7 \cdot 7 \cdot 3 \cdot 3$, and consists, therefore, of four dividers in the described connection with the stated single prime factors. Naturally there can be employed for coupling and transmission purposes in place of the switching elements also tubes, and preferably screening grid tubes, with which there can be obtained complete freedom from reaction and at the same time considerable sensitivity. Measures of this kind are quite well known to the skilled man. There can also be included an RC system in place of the LC system as shown. Finally, the hexode can be replaced in equivalent fashion by a triode, without the operation of the whole differing from the behaviour set forth in Figs. 1 and 3.

What I claim as new and desire to secure by Letters Patent is:

1. A frequency divider comprising a source of high frequency oscillations, a circuit tuned to a subharmonic of said high frequency, means to cause oscillations to take place in said tuned circuit at its tuned frequency, means to transform the oscillations of said circuit into impulses of a duration being substantially equal to one period of said high frequency oscillations, impulse control means to cause the arising of said impulses, only when an oscillation of said high frequency is applied to said impulse control means, and means to excite said tuned circuit by said impulses.

2. A frequency divider comprising a source of high frequency oscillations, a circuit tuned to a subharmonic of said high frequency, means including a tube having cathode, at least two grids and an anode for causing oscillations to take place in said tuned circuit at its frequency, means to transform the oscillations of said circuit into impulses of a duration being substantially equal to one period of said high frequency oscillations, including said tube, means for applying high frequency oscillations to one of said grids and said impulses to the other of said grids, an output circuit between said anode and said cathode, means for coupling said tuned circuit to said output circuit.

3. A frequency divider comprising a source of high frequency oscillations, a circuit tuned to a

subharmonic of said high frequency, a tube having a cathode, at least three grids, an anode and an output circuit between said cathode and said anode, means for applying the oscillations of said tuned circuit on the one hand between the cathode and one of said grids and on the other hand between the cathode and another grid in nearly opposite phase so that an impulse of substantially the width of a high frequency oscillation appears in said output circuit, means for applying said high frequency between said cathode and a third grid so that only when an oscillation of said high frequency is applied an impulse can arise, the output circuit of said tube being back-coupled to said tuned circuit.

4. A frequency divider comprising a tube having a cathode, three grids and an anode, means for applying high frequency oscillations to one of said grids, a circuit tuned to a subharmonic of said high frequency connected between a second of said grid and said cathode, and phase shifting means between said second grid and said tuned circuit, an output circuit between said anode and said cathode and a circuit between said third grid and said cathode, means for coupling said tuned circuit to said output circuit and to said third grid circuit, said phase shifting means being proportioned so that the phases of the subharmonic voltages on the second and third grid are sufficiently less than 180° out of phase so that an impulse of substantially the width of a high frequency impulse appears in said output circuit at subharmonic frequency intervals.

5. A frequency divider consisting of a source of high frequency oscillations and a multiple of frequency dividing stages coupling circuits, each stage having input and output and comprising a circuit tuned to a subharmonic of said high frequency, means to cause oscillations to take place in said tuned circuit at its frequency, means to transform said oscillations into impulses of a duration being substantially equal to one period of said high frequency oscillations, impulse control means to cause the arising of said impulses, only when an oscillation of said high frequency is applied to said impulse control means, and means to excite said tuned circuit by said impulses, the input of the second and following of said stages being coupled to the output of each preceding stage via one of said coupling circuits forming the impulses in the output circuit of each stage into sinusoidal oscillations.

KURT SCHLESINGER.