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METHOD AND APPARATUS FOR COUNTING ELECTRICAL IMPULSES

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2 Sheets-Sheet 1

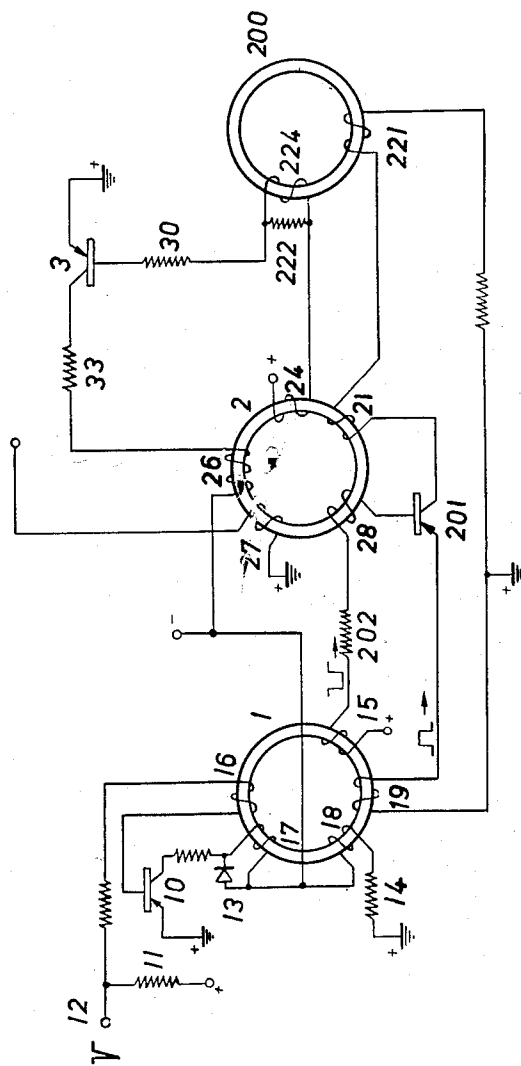


Fig. 1

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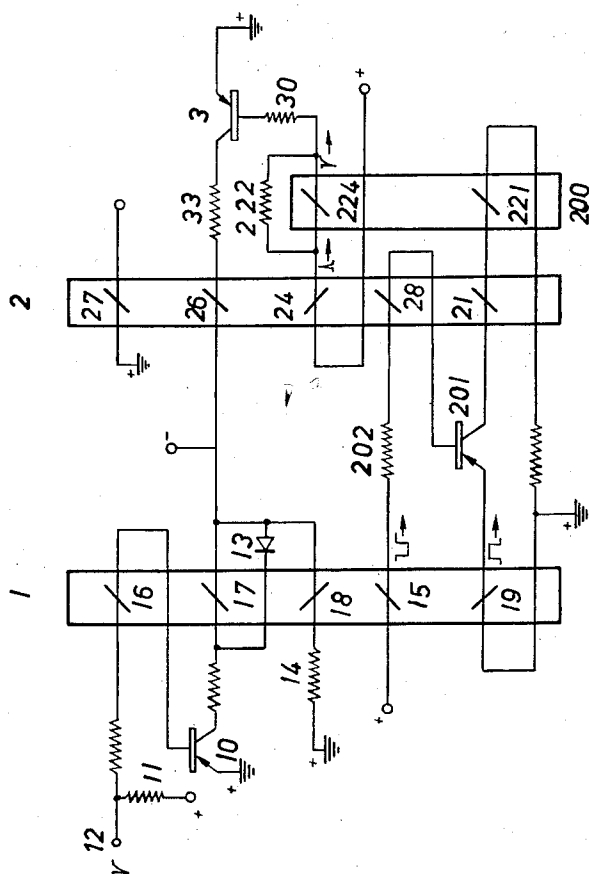


Fig. 2

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METHOD AND APPARATUS FOR COUNTING ELECTRICAL IMPULSES

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4 Claims. (Cl. 235—92)

The invention refers to a counting arrangement for counting electrical pulses by means of constructional elements which are outstanding as to their simplicity, accuracy and practically unlimited life. All these conditions are not fulfilled by such devices using high vacuum tubes and similar constructional elements. Therefore, it has already been proposed to use magnetic elements, especially magnetic transformers.

Such so-called counting transformers are magnetic switching elements wherein by utilization of their magnetic remanence, their flux density can be quantitatively accumulated in that the magnetic flux level existing from time to time can be built up or down stepwisely by the impulses to be counted. For optimum operation, magnetic materials which have a substantially rectangular hysteresis loop are preferably used. The counting procedure is such that the pulses to be counted, each of which has an exact voltage-time value measured in volt-seconds, are applied to an input winding of the transformer core and operate to reversely magnetize the core through a stepwise changing of its magnetic flux level from a condition of saturation in one direction to saturation in the opposite direction. With such counting transformers, through the above-mentioned stepwise magnetization, exact digital values can be accumulated and digitally exact output values can be taken out.

In order to indicate that the counting transformer has reached its fully saturated condition and thus its counting capacity, one output winding can be used as a signal producing winding. These signals differ in the saturated condition of the transformer quantitatively from those in the unsaturated condition of the transformer, and indeed are so much the stronger the nearer the hysteresis loop of the core approaches a rectangle. However, the hysteresis loops of ordinary magnetic materials are not absolutely rectangular, but have sloping portions near the transition zones from unsaturated condition to saturated condition. These transition zones, however, are of decisive importance, since the indicating pulses occurring upon reaching one or the other end of the counting range are produced in them. As soon as a magnetic core in the above-described counting of counting steps, preferably ten counting steps, is reversely magnetized from its original saturated condition to its opposite saturated condition in order to count further a resetting pulse must be furnished to return the counting transformer to its original magnetic condition. Moreover, a carry-over pulse, is required for the counting element of the next higher stage. It is therefore an important requirement that an absolutely clear end signal be produced at one or both ends of the counting range of the counting transformers.

The principal object of the invention is to provide simple and particularly reliable means for resetting the counting transformer to its original condition of saturation after having stepwisely reached its condition of opposite saturation by means of the pulses to be counted. For this purpose the pulse voltages induced in the input circuit

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of the counting transformer will be compensated by simultaneously induced, but oppositely directed pulse voltages in a compensation circuit during stepwise remagnetization of the counting transformer.

Other objects of the invention will become apparent from the following detailed description of the invention with respect to the accompanying drawings, in which

Fig. 1 shows a conventional schematic diagram of the invention,

Fig. 2 shows a schematic diagram of the arrangement shown in Fig. 1.

In Figures 1 and 2, one form of the invention is shown, in which the resetting of the counting transformers is achieved in a new manner. In this arrangement there is provided an additional resetting transformer of a core with two windings for each decade of the counting arrangement. This transformer has a core of low hysteresis material, preferably of non-saturable soft iron which has the smallest possible amount of residual magnetism.

The arrangement shown in Figures 1 and 2 consists of a pulse forming stage 1, having five windings 15 to 19, a counting transformer 2 representing the first decade of the counting arrangement and having five windings 21, 24, 26, 27, 28. Coupled with the counting transformer 2 there is a resetting transformer 200 with two windings 221, 224.

The compensation circuit mainly consists of the windings 24 and 224. Because the core of the resetting transformer 200, as above mentioned, is of soft iron and therefore has a poor hysteresis loop, this core will be brought in a condition of a higher magnetization when the winding 221 is energized by a pulse from the transformer 1. The core 200 at once falls back to its normal condition if the pulse in the winding 221 has ended. Every pulse through the winding 221 therefore causes a pulse in the winding 224 and the winding-sense being so, that this pulse is negative. During the counting steps of transformer 2 a positive pulse is formed in the winding 24 of this transformer. Both pulses which occur at the same time when the counting pulse goes through windings 21—221 meet at the conductor leading to the base of the transistor 3. The circuit is so adjusted that the positive pulse from winding 24 with respect to its amplitude slightly predominates the negative pulse from the winding 224. Thus the transistor 3 (for this example a p-n-p transistor) remains blocked because the base remains positive. Normally, that means when no counting takes place, the transistor 3 is blocked because its base over the winding 24 is connected to the positive current source. At the end of the 9th reverse magnetizing step of the transformer 2 positive saturation of its core will be nearly reached. The 10th counting pulse over winding 21 will therefore cause no pulse in the winding 24. The same counting pulse causes, over the winding 221, the negative pulse in the winding 224 which now stands alone at the base of the transistor 3. The negative pulse causes the transistor 3 to become conducting. The resetting current flows over the transistor 3 and resistor 33 to the reset winding 26, thus bringing the transformer 2 back to its negative saturation.

The transformer 2, the true counting transformer, is so interconnected with the resetting transformer 200, that at the common output of this interconnection circuit, at the end of the counting procedure, a uniform output signal is provided which on the one hand, effects the resetting of the counting transformer 2 in the condition of negative magnetic remanence, and, on the other hand releases a carry-over signal for the next counting stage 4, in one of the output windings arranged thereon.

The transformer 1, serving solely as pulse forming stage, has merely the function, with the help of its output winding 19, to give off pulses to the counting trans-

former 2 which has a predetermined voltage-time integral. The value of these voltage-time integrals corresponds quantitatively to the flux change which the core of the counting transformer 2 undergoes during each individual pulse. If the entire flux change in the core of the counting transformer 2 between negative and positive saturation amounts to $\Delta\phi$ in volt seconds, then the value of the voltage-time integral of each pulse at the output of the pulse forming stage 1 or at the input of the counting stage 2, in a decimal system for example, must be

$$\frac{\Delta\phi}{10}$$

in volt-seconds.

The transformer 1 is provided with four windings 16-19. The winding sense of the above-mentioned windings is shown in the drawings. The circuit arrangement of the pulse forming stage 1 further comprises the transistor 10. The winding 16 has one end connected to the input terminal 12 from which negative counting pulses are conducted. The emitter terminal of transistor 10 is connected over ground to the positive pole of a direct current voltage source, (not illustrated). The winding 17 is connected at one end to the collector terminal of the transistor 10 and, at the other end, to a supply conductor connected with the negative pole of the voltage source. The winding 17 is shunted by a diode 13. The winding 18 is connected at one end to the above-mentioned negative pole supply conductor and at its other end to the positive pole of the voltage source over a resistor 14. The output winding 19 is connected to the first counting stage 2 through transistor 301 and winding 21.

In addition to the four windings there is provided another winding 15 which is connected to the base of a switching transistor 201 over a resistor 202 and a winding 28 on the counting transformer 2. The counting transformer 2, which has a core of magnetic material with an approximately rectangular hysteresis loop, can operate in the decimal system, or in combined stages in any other counting system. When applying the biquinary counting system for instance the first counting stage will be reset after five counting steps and the second counting stage after two counting steps, so that both counting stages together will operate as a decimal counter. Naturally the counting module can also be varied to any other counting system.

The counting transformer 2 has an input winding 21, a compensation winding 24, a reset winding 26 and an output winding 27. One terminal of the output winding 19 of the pulse forming stage 1 is connected to the input winding 21 of the counting transformer 2, the other terminal of the input winding 21 being connected to the output winding 19 of the pulse forming stage 1 over the resistance 22.

Similarly to the connections between the output winding of the pulse forming stage 1 with the input winding of the counting stage 2, the output winding 27 of this transformer is connected to the input winding of the transformer of the next counting stage.

Before the beginning of the counting procedure, the transistors are in blocked condition, which is effected through the above-described positive pre-voltage being applied to their base terminals, as shown in the drawings.

At the beginning the transformer 1 is in its condition of negative saturation, since its winding 18 carries a continuously negative current. The pulses to be counted are supplied with negative polarity at the input terminal 12 of the counting apparatus. Every negative counting pulse flows through the winding 16 of the forming transformer 1, but does not, however, change the magnetic condition of the core of this transformer since it is already in the condition of negative saturation. However, the above-mentioned pulses make the base terminal of the transistor 10 extraordinarily negative, so that an elec-

tric current begins to flow in said transistor, which current flows through the winding 17. Thereupon, magnetic feed-back coupling is effected upon the winding 16, which results in a further increase of the base terminal potential in the negative direction, so that now the transistor 10 is acceleratingly (practically within a microsecond) set into fully conducting condition. The magnetic field produced in the winding 17 by means of the collector current begins, at the instant in which its field strength reaches and oversteps the coercivity field strength of the core of the transformer 1, to reverse magnetize this core, and indeed so long as the induced voltages in the windings 16 and 17 hold the transistor 10 conducting in mutual feed-back coupling. During this time a voltage is simultaneously produced in the winding 18, which voltage opposes the source voltage. At the same time, a positive secondary pulse voltage is induced in the winding 19, which is conducted to the input winding 21 of the transformer 2 as formed pulses.

At the end of the positive reverse magnetization procedure in the transformer 1, that is, as soon as its core is positively saturated, no more voltages are induced in its winding 16 to 19, so that the negative rest voltage again comes into operation in the winding 18, which back magnetizes the core of the transformer 1 into negative saturation.

Upon disappearance of the induced voltages in the windings 16 and 17 the transistor 10 again becomes blocked. The voltage induced in the winding 19 during the back magnetization presents, during the operation time of the voltage integral

$$\int \frac{E}{n} dt$$

a value which corresponds in volt-seconds to the flux difference between negative and positive saturation remanence in the transformer 1. The output pulse of the winding 19 thus has a constant value of voltage time which, being precisely defined and quantitatively fixed, determines the reverse magnetization step, that is, the flux change per counting step in the counting transformer 2. The voltage time integral at the output of the winding 19 corresponds therefore, for each counting step, to a full reverse magnetization of the core of the forming transformer 1; however, in decimal counting systems, only to the tenth part of the entire flux change which the core of the counting transformer 2, experiences in running through the decade, i.e. in reverse magnetizing from the negative into the positive saturation remanence condition. There are therefore required, at the output 19 of the transformer 1 or at the input 21 of the transformer 2, ten formed pulses for fully reverse magnetizing the core of the counting transformer 2. With a lesser number of pulses, the transformer 2, proceeding from the negative remanence condition, remains on a changed flux level between the negative and positive saturation remanence which corresponds quantitatively to the number of pulses received.

The pulses to be counted, which are introduced at the input end of the pulse forming stage 1 and which may be of any possible shape and voltage-time-integral shall be called counting pulses in the following, whereas the negative pulses leaving the output winding 19 of this stage have an equal voltage-time-integral and will in the following be called driving pulses. These driving pulses are delivered to the input winding 21 of the counting transformer 2. Each pulse changes the magnetic flux level of the core of the transformer 2 by one tenth of the total flux difference between the condition of negative saturation, which had been assumed as the initial condition of this transformer, to the opposite condition of positive saturation.

The input winding 21 of the transformer 2 is switched in series with a winding 221 on the resetting transformer 200, while the compensation winding 24 of

the counting transformer 2 is switched in series with a winding 224 on the resetting transformer 200. The other terminal of the winding 224 is connected to the base of the transistor 3 over the resistor 30. Connected in parallel to the winding 224 there is a resistor 222. The emitter of the transistor 3 is connected to a source of positive voltage, whereas the collector is connected to the resetting winding 26 of the counting transformer 2 over a resistor 33.

The transistor 201 operates as a one-way directive switch, and is especially necessary when coupling is not from a forming stage to a counting stage, as in the above-described case, but from a preceding counting stage to a next following counting stage. The transistor 201 serves merely as a transistor switch, and is blocked in its normal condition. Thus in conducting the transistor 201 couples in one direction, from the transformer 1 to the transformer 2 in the example shown in Figures 1 and 2. The pulse pair occurring at the windings 19, 15 of the transformer 1 controls the base terminal of the transistor 201 negatively and the emitter terminal positively. The transistor 201 becomes instantaneously conducting, the base current flowing through the winding 28 and the collector current flowing through the winding 21 of the transformer 2.

The core of the transformer 2 will thus become reversely magnetized by an amount $\Delta\phi$ which corresponds to the input side integral

$$\int \frac{E}{n} dt$$

and, as already described, each counting pulse provides a reverse magnetizing step which produces a tenth part of the entire flux difference between negative and positive saturation remanence of the core of the transformer 2.

A positive pulse is effected in the compensation winding 24 at the instant of each reverse magnetizing step, which is connected with the base circuit of the transistor 3. This positive pulse is not able to influence the normally blocked condition of the transistor 3. At the same time the switch transistor 201 energizes the winding 221 of the transformer 200 in such a way that a negative pulse is effected in the winding 224 in the base conductor of the transistor 3. The positive pulse from the winding 24 and the negative pulse from the winding 224 are so adjusted with respect to their amplitudes that the positive pulse slightly predominates, and thus the transistor 3, which for example is a p-n-p transistor, remains blocked. A negative pulse which is simultaneously induced in the winding 26 at the collector side of the transistor 3 does not influence the latter, since it is kept in the blocked position by the cooperation of the winding 24 and 224.

During each positive remagnetization step of the transformer 2 a negative output pulse is effected on the output winding 27, which can be connected with the input winding of the next following counting transformer. These output pulses, however, effect counting operations only when they are positive, as already explained with regard to the corresponding working of the windings 15 and 28 and the transistor 201.

At the end of the ninth reverse magnetizing step of the transformer 2, positive saturation of its core will be nearly reached. The tenth input pulse therefore effects no, substantially no more flux change, since the induction runs on the upper horizontal branch of the rectangular hysteresis loop. On the base terminal side of the output of the winding 24 no pulse or only a weak positive pulse is therefore effected at the instant of this counting step, so that the output winding 224 of the transformer 200 gives its negative pulse practically uncompensated in the base control conductor of the transistor 3, which therefore becomes conducting. Thereupon the winding 26 becomes conducting and back-magnetization of the transformer 2 is effected. The conductivity of the transistor 3 is accelerated, as already described above in the

case of transistor 10, through the amplifying characteristic of the transistor and through the positive feed-back coupling of the collector terminal side of the winding 26 to the base terminal side winding 24 of the transformer 2.

As will be apparent from the foregoing description, the transistor 3 remains conducting until the full back-magnetization of the transformer 2, and blocks itself again upon departing from the full back-magnetization condition. During the back-magnetization procedure, the output winding 27 gives a positive carry-over or transfer pulse to the next following counting transformer stage not shown in Figures 1 and 2. The transistor 201 remains blocked during the back-magnetization, since on the winding 28 a voltage is now induced in the counter-acting direction from the winding 26 and no more from the winding 21. Thus, after the tenth counting step, the core of the transformer 2 is again driven back into the negative condition of remanence and the transistors 10, 201 and 3 find themselves again in blocked condition. The counting transformer of the next stage has received a carry-over pulse and a further counting procedure can go on the same way as described above.

While we have described some preferred embodiments of our invention, it is to be understood that this disclosure is for the purpose of illustration only and that various omissions, or changes in arrangement of parts, as well as the substitution of equivalent elements for those herein shown and described, may be made without departing from the spirit and scope of the invention as set forth in the appended claims.

We claim:

1. In a device for counting electrical pulses the combination comprising a counting transformer having a core with substantially rectangular hysteresis characteristic, means for effecting the condition of magnetic saturation of said transformer in one direction, input circuit means operative to stepwisely remagnetize said counting transformer to its condition of magnetic saturation in the other direction in response to pulses applied to said input circuit, an auxiliary transformer with a substantially non-saturable characteristic, compensation circuit means arranged on said auxiliary transformer, one of said counting transformers and one of said auxiliary transformers being connected to form one stage of a multi-stage counting arrangement.

2. In a device for counting electrical pulses, the combination comprising a counting transformer having a core with substantially rectangular hysteresis characteristic, a substantially non-saturable auxiliary transformer, means for effecting the condition of magnetic saturation of said counting transformer in one direction, input circuit means inductively coupled with said counting transformer and said auxiliary transformer operative to stepwisely remagnetize said counting transformer from its condition of magnetic saturation in said one direction to the condition of magnetic saturation in the other direction in response to pulses applied to said input circuit, a first control winding on said auxiliary transformer, a second control winding on said counting transformer, said input circuit means being operable to induce a first control pulse in said first control winding in response to each pulse received in said input circuit, said input circuit means being operable to induce a second control pulse of opposite polarity with respect to the polarity of said first control pulse in said second control winding when said counting transformer is in a non-saturated condition, and circuit means connecting said first and second control windings in series and operative in response to the value of the difference in voltage between said first and second pulses to render said one direction magnetic saturation effecting means operative.

3. The device for counting electrical pulses as defined in claim 2 wherein said one direction magnetic saturation means comprises a magnetizing winding on said counting transformer, a transistor, a source of D.-C.,

voltage, said magnetizing winding being connected between the negative terminal of said voltage source and the collector terminal of said transistor, the emitter terminal of said transistor being connected to the positive terminal of said source, said first and second control winding connecting means comprising a source of positive potential applied through said first and second control windings to the base terminal of said transistor, whereby said magnetizing winding will become energized for effecting said one direction magnetic saturation of said counting transformer.

4. The device for counting electrical pulses as defined in claim 3 including an output winding on said counting transformer for issuing carry-over pulses induced therein through energization of said magnetizing winding.

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