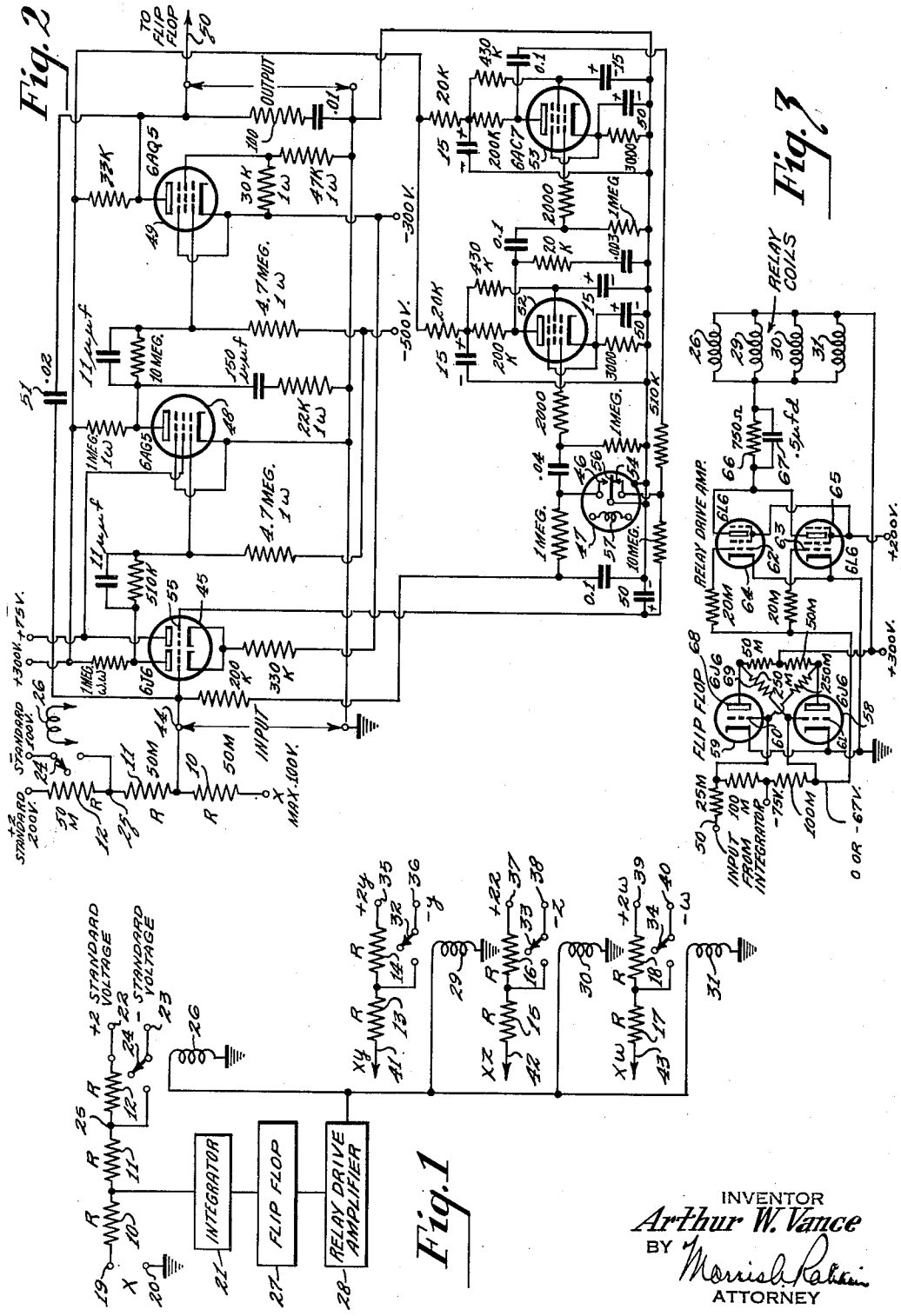
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COMPUTING DEVICE

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COMPUTING DEVICE

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6 Claims. (Cl. 235—61)

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This invention relates to computing devices which are capable of multiplying a plurality of multiplicands by the same multiplier. The multiplying device herein disclosed is similar to that disclosed in my copending application Ser. No. 91,981, filed May 7, 1949, in that it functions to produce voltages each of which is proportional to the product of a different multiplicand multiplied by the same multiplier. It is distinguished therefrom by the fact that it does not involve the use of a counter, requires only one relay for the conversion of the multiplier and is of relatively simple construction.

More particularly, the multiplying device of the present invention includes an integrator of the type disclosed in a copending application of Goldberg, Ser. No. 90,072, filed April 28, 1949, and also described in an article by Goldberg in the June 1950 issue of the "RCA Review," entitled "Stabilization of Wide-Band Direct-Current Amplifiers for Zero and Gain." To the input of this integrator is supplied a current which is the resultant difference between two currents. One of these currents

$$\frac{X}{R}$$

represents the value of the multiplier divided by a resistance R. The other of these currents

$$\frac{2E}{2R} \text{ or } \frac{-E}{R}$$

(depending on the energization of the conversion relay) represents the plus or minus value of a standard voltage E divided by R. The integral of this difference current is applied to a flip-flop or trigger circuit which has its output connected to the input of an amplifier. This amplifier delivers its output to a plurality of parallel-connected relays, one of which controls a feedback circuit of the amplifier and the others of which control circuits having outputs at which voltages proportional to the values of the different products are produced.

The principal object of the invention is the provision of an improved multiplying device and method of operation for deriving a plurality of products each equal to the same multiplier times a different multiplicand. Other objects are the provision of a multiplying device which is less complicated than those heretofore available, the provision of a multiplying device which does not involve counters or their required adjuncts, and the provision of a multiplying device wherein an extremely simple organization of elements is required for energizing a plurality of relays in response to predetermined values of a multiplier.

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The invention will be better understood from the following description considered in connection with the accompanying drawing and its scope is indicated by the appended claims.

Referring to the drawings:

Figure 1 is a block diagram showing the relation between the various parts of the improved multiplying device,

Figure 2 is a wiring diagram of the integrator, and

Figure 3 is a wiring diagram of the flip-flop and the amplifier from the output of which the various relays are energized.

Figure 1 illustrates the multiplying device as including a plurality of resistors 10 to 18 each of which may have a value of the order of 50,000 ohms. A voltage representative of the value of the multiplier x and having a maximum value of 100 volts, for example, is applied from the terminals 19—20 through the resistor 10 to the input of an integrator 21.

The input of the integrator 21 is also connected through the resistors 11 and 12 to a terminal 22 which is maintained at a voltage 2E. A terminal 23 maintained at a voltage —E is arranged to be connected through a switch 24 to the common terminal 25 of the resistors 11 and 12. Under these conditions the input current to the integrator is the difference between a current

$$\frac{x}{R}$$

and a current

$$\frac{2E}{2R}$$

or a current

$$\frac{-E}{R}$$

depending on whether the switch 24 is in its normal open position or is in its closed position as a result of energization of its operating coil 26.

The integral of this difference current builds up, due to the integrating action of the integrator 21, to a voltage such that (1) current conduction is transferred from one to the other side of a flip-flop 27, (2) the output current of a relay drive amplifier 28 is increased and (3) the relay coil 26 is energized thereby closing the switch 24 and reversing the current supplied through the resistor 11 to the input of the integrator. This condition is maintained until the integral is such as

to flip the flip-flop the other way or back to its starting position.

Connected in parallel with the coil 26 are similar coils 29, 30 and 31 which function to close the normally open switches 32 to 34. These switches are connected in similar fashion to circuits which are similar to the one to which switch 24 is connected. The similar circuits are the resistors 13 and 14, 15 and 16, 17 and 18, each of which has the value R. The first of these circuits has applied (1) to its input terminal 35 a voltage $+2y$ which is representative of twice the value of a first multiplicand and (2) to its input terminal 36 a voltage $-y$. The second circuit has applied to its terminals voltages $+2z$ and $-z$ which similarly represent the value of a second multiplicand. The third circuit has applied to its input terminals 39 and 40 voltages which similarly represent the value of a third multiplicand. As will now be explained, currents proportional to the value of the products xy, xz and xw are produced at the output leads 41, 42 and 43 of the respective multiplier circuits.

Since the gain of the integrator 21 for D. C. is infinite, the circuit must adjust itself so that the average value of the feedback current to the integrator 21 exactly equals

$$\frac{x}{R}$$

Since the standard voltages 2E and $-E$ are fixed, this means that the average conductance of the relay resistor system, through which this feedback takes place, is proportional to x. If the conductance G of this feedback relay resistor system is defined as its ability to carry current or the reciprocal of the resistance, then

$$G=\frac{x}{RE}$$

The system fails, of course when x exceeds E whereupon the relay is closed all the time. As x approaches E the relay operates less and less frequently. If $x=0$ the relay spends half the time in each position. In practice, the value of x is not allowed to exceed

$$\frac{E}{2}$$

in which case the repetition rate of the relay varies less than two to one as x varies. The natural frequency of the system is determined by the time constant of the integrator and the flip voltage of the flip-flop.

Since the conductance, or ability to carry current, of the converter relay resistor system is

$$G=\frac{x}{RE}$$

the conductance, or ability to carry current, of the resistor systems of similar relays in series or parallel which are simultaneously operated is also

$$\frac{x}{RE}$$

If these controlled relays have the same resistor systems and are excited by a voltage proportional to the other variable, as shown, the product currents are:

$$\frac{xy}{RE} \quad \frac{xz}{RE} \quad \frac{xw}{RE} \text{ etc.}$$

The output current from each of these various systems is a current proportional to the product of the two variables. This may be converted in well known fashion to a voltage.

To summarize, the current applied to the input of the integrator will have a positive or a negative polarity dependent upon whether relay contact 24 is or is not applying $-E$ to the resistor network. The time required for the output of the integrator to build up to a given voltage level, either positive or negative, or to go from a positive output level to a negative output level when the integrator input is positive, and to go from a negative output level to a positive output level, is substantially determined, in a given integrating amplifier, by the amplitude of the charging current available for the condenser connected between the input and output of the integrating amplifier (condenser 51 in Figure 2 of the drawings). This charging current is of course determined by the voltage input to the integrator. Since the flip-flop can only be turned over when the integrating amplifier attains the given voltage level, and since, between flip-flop turnovers contact 24 either rests in its open position or in its position of application of the voltage $-E$, it should be apparent that the length of time the relay remains in either of its two positions depends upon the input to the integrator. The only variable applied to the input of the system is the voltage x. It may therefore be seen that the length of time the relay contact remains longer in one of its two positions than in the other is determined by the amplitude of the applied voltage x (which one of the two positions is determined by the polarity of x). Since the ability of the relay-resistor network to pass current is determined by the operation of the relay contact, which in turn is determined by the value of x, the conductance G_1 of the network may be said to be proportional to x or equal to the product of x and a constant. This constant is

$$\frac{1}{RE}$$

Therefore,

$$G=\frac{x}{RE}$$

It is also interesting to note that the relay-resistor network consisting of relay 26 and resistors 11 and 12 are in what may be considered an electro-mechanical type of feedback network between the integrator output and its input. The average value of the feedback current through this network equals the input current or

$$\frac{x}{R}$$

since the current is the product of the conductance and the voltage or

$$GE=\frac{x}{RE}\cdot E=\frac{x}{R}$$

Identical resistor-relay networks having their relays operated identically with the operation of relay 26 will have the same conductance. If a voltage Y is applied to any one of the identical resistor-relay networks in the same manner as the voltage E was applied to the original relay-resistor network, namely as $+2Y$ and $-Y$, the average output current of the network is the product of the conductance of the system and the applied voltage or

$$\frac{xy}{RE}$$

Figure 2 shows the integrator 21 as stabilized for zero and drift in the manner disclosed in detail by the aforesaid Goldberg application. Ac-

tually, any type of integrating amplifier may be used which is stabilized for zero and drift, such as the integrating amplifier shown in the article by Ragazzini et al. in the "Proceedings of the I. R. E." for May 1947. However, the integrating amplifier which is described in the application and article by Goldberg is preferred, since it is easily stabilized. It includes an input terminal 44 from which the potential at the common terminal of the resistors 10 and 11 is applied (1) to the input of a first stage 45 and (2) to the fixed contact 46 of a chopper or vibrator 47.

The amplifier stage 45 is direct-coupled through amplifier stages 48 and 49 to an output terminal 50 which is connected to the flip-flop 27 of Figure 1. A feedback circuit including a capacitor 51 is connected from the output terminal 50 to the input terminal 44.

The chopper 47 performs two functions. First it chops or converts to A. C. any error voltage so that it may be amplified by an A. C. amplifier including amplifier stages 52 and 53. Second its fixed contact 54 is utilized to synchronously rectify the output voltage of the A. C. amplifier and apply the output as a zero and drift correction voltage to the grid 55 of the input stage 45 of the integrator. Movement of the chopper contact 56 is effected by means of a coil 57 which may be energized from a 60 cycle source. Under these conditions, the integrator is stabilized for zero and drift.

Figure 3 shows the flip-flop of Figure 1 as including a pair of tubes 58 and 59 which have their grids each cross-connected to the anode of the other so that current conduction is stable in either one or the other of the tubes and is shifted from one to the other in response to the application of a positive pulse to the grid of a nonconducting tube or to the application of a negative pulse to the grid of a conducting tube.

The grid 60 of the tube 59 is connected to the output terminal 50 of the integrator and the grid 61 of the tube 58 is connected to the grids 62 and 63 of a pair of parallel-connected amplifiers 64 and 65. These amplifiers deliver their output through a resistor 66 (shunted by a capacitor 67) to the relay coils 26, 29, 30 and 31 which have been identified in connection with Figure 1.

Assuming the tube 59 of the flip-flop 27 to be conducting, the application of a more negative voltage from the integrator 21 to the grid 60 causes current conduction to be transferred from the tube 59 to the tube 58. As a result, the voltage of the anode 68 becomes more positive. This is also true of the grids 61, 62 and 63 which are connected to the anode 68 through a 250,000 ohms resistor 69. The effect of this more positive voltage is to increase the output of the amplifiers 64 and 65 to the relay operating coils 26 and 29 to 31. This causes the relays to be operated. When conduction is transferred back to tube 59, a more negative voltage is applied to the grids 62 and 63, thus causing the amplifiers to be less conductive and the relays are released.

As explained in connection with Figure 1, the relays thereafter function in such a way that the average value of the feedback current is made exactly equal to

$$\frac{x}{R}$$

and currents representative of the values of the various products are made available at the output leads 41, 42 and 43.

From what has been said, it is evident that the ratio of the currents supplied by the relays in the plus and minus positions should be the same for each of the multiplying circuits as for the standard circuit. Obviously the illustrated type of relay may be replaced by any other type of relay adapted to perform the same function. Thus, any type of current controlling relay capable of having its effective conductance varied in response to an on and off signal will produce the desired result. It is to be understood, therefore, that the term "relay" as herein used is intended to include such devices as a D. C. balanced modulator, a diode switch, a magnetically controlled cathode ray tube, etc.

What the invention provides is a very simple time division type of multiplying device which requires a number of tubes, switches and other circuit components that is small as compared to those required by similar multiplying devices heretofore available.

What is claimed is:

1. In a device for producing a voltage proportional to the product of a multiplier x times a multiplicand y, the combination of a plurality of resistors; an integrator; means including the first of said resistors for supplying to the input of said integrator a current proportional to the value of x; a converter unit including (1) first and second fixed-voltage input leads of opposite polarity, (2) an output lead, (3) a separate pair of said resistors connected in series between said output lead and the first of said input leads and (4) a relay switch adapted to connect said second input lead to the common terminal of said series-connected resistors only when its operating coil is energized; means connecting the output lead of said converter unit to the input of said integrator; a multiplier unit having circuit components similar to those of said converter unit and having its relay coil interconnected with the relay coil of said converter unit; and means interconnecting the output of said integrator and said coils for establishing in the resistor systems of said units a conductance proportional to said value of x.

2. A device as set forth in claim 1 wherein the means interconnecting the output of said integrator with said coils are a flip-flop circuit responsive to the output of said integrator, and an amplifier responsive to the current conducting condition of said flip-flop circuit.

3. A device as set forth in claim 1 wherein the first and second input leads of said multiplier unit are charged to fixed voltages which are of opposite polarity and are proportional to the value of y.

4. In a device for producing a voltage proportional to the product of a multiplier x times a multiplicand y, the combination of an integrator; means for supplying to the input of said integrator a current proportional to the value of x; a converter unit including a pair of series-connected resistors connected to said integrator input and a relay, means coupling said relay to said integrator output to have the energization of said relay controlled from the output of said integrator, means coupled to said relay and said series connected resistors for applying to the input of said integrator a fixed voltage which has one polarity when said relay is deenergized and has the opposite polarity when said relay is energized; a multiplier unit including a relay and a pair of resistors having circuit constants similar with those of said converter unit, means coupling said multiplier relay to said integrator output to

have the energization of said relay controlled from the output of said integrator for establishing in said multiplier unit resistors a conductance proportional to the value of x; and means for applying to the resistors of said multiplying unit a voltage which is proportional to the value of y and which has its polarity determined by the open or closed condition of the relay of said multiplier unit.

5. A device as set forth in claim 4 wherein there is connected between the output of said integrator and the energizing elements of said relays a flip-flop circuit responsive to the output of said integrator, and an amplifier responsive to the current conductive condition of said flip-flop circuit.

6. In a device for multiplying a plurality of multiplicands by the same multiplier, the combination of an integrator; means for supplying to the input of said integrator a current proportional to the value of said multiplier; a converter unit including (1) a resistance network having an output lead connected to the input of said integrator and (2) a relay, means coupling said relay to said integrator output to control the energization of said relay with the output of said integrator, means coupled to said resistance network and said relay for producing at said output lead a fixed voltage which has one polarity when said relay is deenergized and has the opposite polarity when said relay is energized; a plurality of multiplier units each having a relay and a resistor network having circuit constants identical to those of said converter units, each of said multiplier units having its relay energized in the same manner as the relay of said converter unit; and means for applying to the resistance network of each of said multiplier units a voltage which is proportional to the value of a different one of said multiplicands and has its polarity determined by the opened or closed condition of the relay of said unit.

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No references cited.