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Schlatter

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[45] **Oct. 30, 1973**

[54] **FUNCTION GENERATOR AND COMPONENTS THEREOF**

[75] Inventor: **Gerald Lance Schlatter,** Boulder, Colo.

[73] Assignee: **International Telephone and Telegraph Corporation,** New York, N.Y.

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Related U.S. Application Data

[62] Division of Ser. No. 124,070, March 15, 1971.

[52] **U.S. Cl.**..... **235/197,** 235/151.34, 235/183

[51] **Int. Cl.**..... **G06g 7/18,** G06g 7/26, G06g 7/57

[58] **Field of Search**..... 235/197, 193, 184, 235/183, 180, 151.34, 193.5; 73/194 E; 328/160, 144, 34, 58

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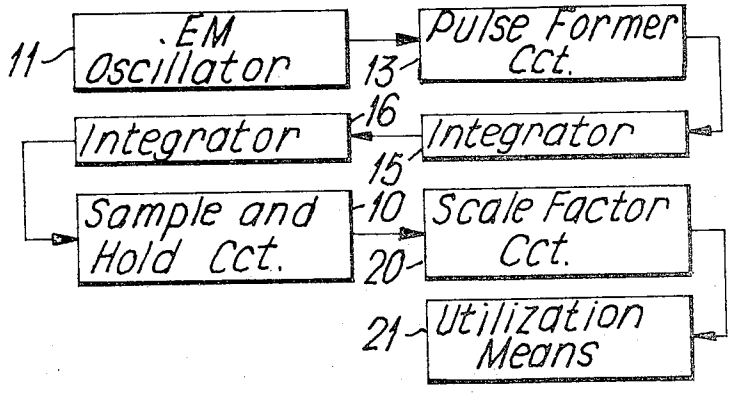
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Primary Examiner—Joseph F. Ruggiero
Attorney—C. Cornell Remsen, Jr. et al.

[57] **ABSTRACT**

A vibration densitometer that computes and transmits the difference between actual density and a known, constant reference density. A pulse former circuit produces a pulse train useful in producing a linear density difference analog. Two integrators and one sample and hold circuit are employed in the computation. A single one shot actuates both integrators and the sample and hold circuit. A scale factor circuit is employed for calibration and to convert the difference analog to an analog of absolute density. The difference density analog makes possible the computation and transmission of density data with an extraordinarily high degree of accuracy. However, the difference density analog is produced with a very small, unique system.

8 Claims, 8 Drawing Figures



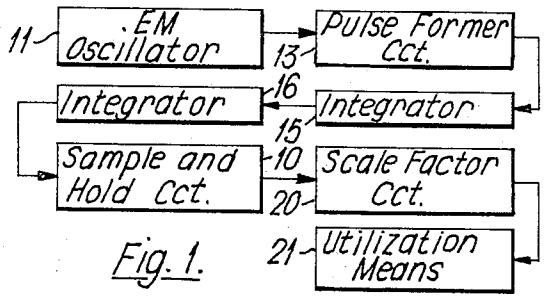


Fig. 1.

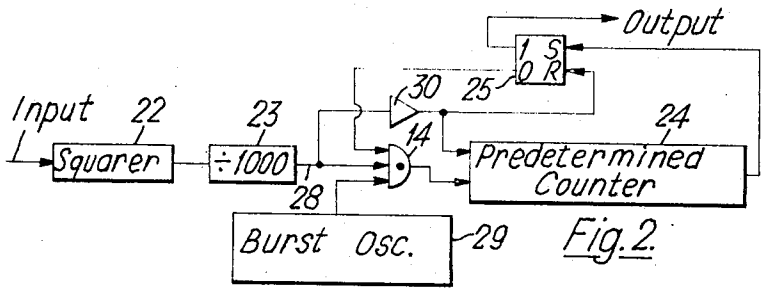


Fig. 2.

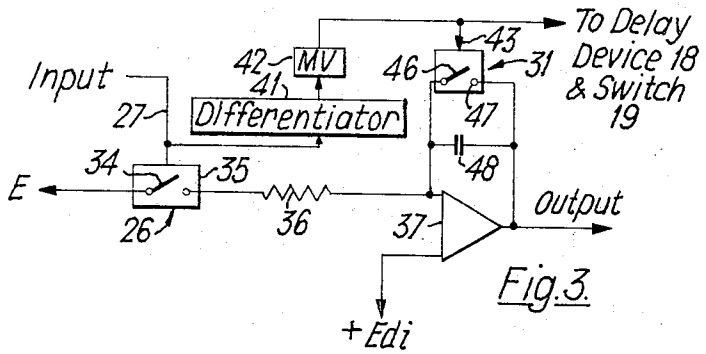


Fig. 3.

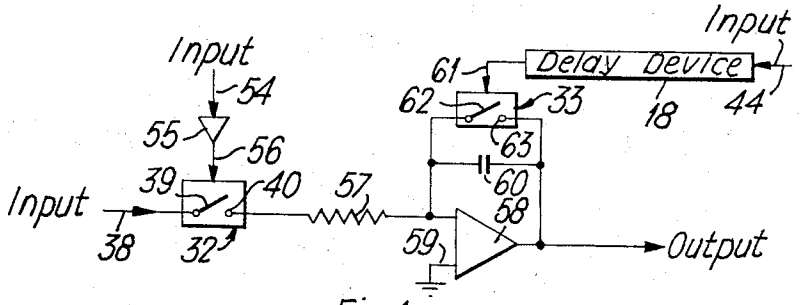


Fig.4.

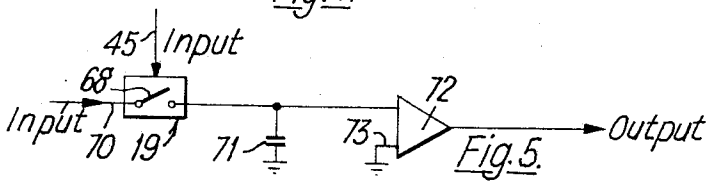


Fig.5.

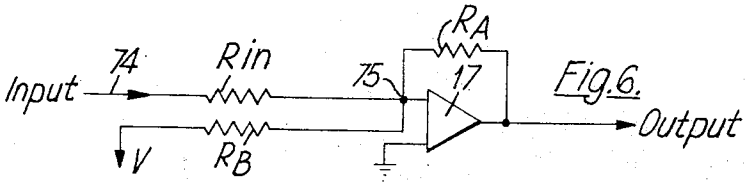


Fig.6.

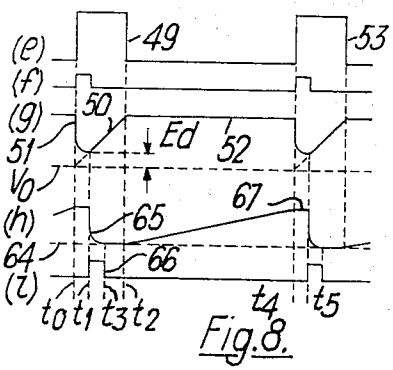


Fig.8.

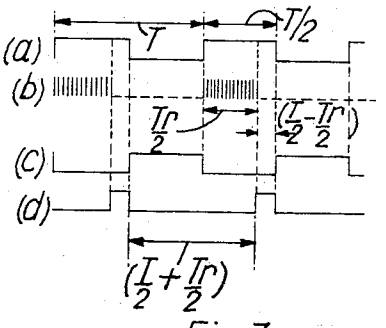


Fig.7.

FUNCTION GENERATOR AND COMPONENTS THEREOF

This is a division of copending application Ser. No. 124,070, filed March 15, 1971. The benefit of the filing date of said copending application is, therefore, hereby claimed for this application.

BACKGROUND OF THE INVENTION

This invention relates to devices for producing an electrical output signal which is a predetermined function of an input signal thereto, and more particularly, to analog computer systems or the like and subsystems thereof.

Although the device of the present invention will have application in fields other than those disclosed herein, the invention has been found to possess considerable utility when employed as a vibration densitometer of the type disclosed in copending application Ser. No. 65,371, filed Aug. 20, 1970, by C.E. Miller and G. L. Schlatter for DENSITOMETER.

The output analogs of prior art vibration densitometers have been relatively inaccurate. Moreover, the equipment required to produce such analogs has been very complicated.

SUMMARY OF THE INVENTION

In accordance with the device of the present invention, the above-described and other disadvantages of the prior art are overcome by providing means to produce a density difference signal in accordance with the difference between the density of a fluid and a known, constant density. Computation and data transmission accuracy is thereby improved. Further, several unique circuits are employed to make the output analog directly proportional to the density difference. These circuits require very few, inexpensive component parts. A scale factor circuit is also a feature of the invention. The scale factor circuit makes calibration possible, and a return to absolute density, if desired.

The above-described and other advantages of the present invention will be better understood from the following detailed description when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings which are to be regarded as merely illustrative:

FIG. 1 is a block diagram of one embodiment of the system of the present invention;

FIG. 2 is a block diagram of a pulse former circuit shown in FIG. 1;

FIG. 3 is a schematic diagram of an integrator shown in FIG. 1;

FIG. 4 is a schematic diagram of another integrator shown in FIG. 1;

FIG. 5 is a schematic diagram of a sample and hold circuit shown in FIG. 1;

FIG. 6 is a schematic diagram of a scale factor circuit shown in FIG. 1; and

FIGS. 7 and 8 are graphs of groups of waveforms characteristic of the operation of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the drawings in FIG. 1, a pulse former circuit 13, a first integrator 15, a second integrator 16, a sample and hold circuit 10, a scale factor circuit 20, and utilization means 21 are connected in succession from an electromechanical oscillator 11.

A vibration densitometer is, what may be described as, an electromechanical oscillator. A structure adapted to be vibrated is thus immersed in a fluid, and driven at its own natural resonant frequency. The said natural resonant frequency changes according to a predetermined function of the fluid density.

In accordance with the foregoing, oscillator 11 may include all of the structure illustrated in FIGS. 1 through 6, inclusive of said copending application. It may also include all of the blocks shown in FIG. 7 of said copending application except linearization circuit 109 and indicator 110.

In driving the structure to be vibrated in said copending application, a tracking filter is employed. The output of the tracking filter may be employed as the input to circuit 13 shown in FIG. 1 in the instant application.

Utilization means 21 may be simply an indicator, if desired. The indicator may simply be a voltmeter calibrated in density. However, utilization means may also be any conventional rate of mass flow or total mass flowmeter or other device that requires a density analog input that is provided by scale factor circuit 20. Further, current analogs may be employed simply by connecting a voltage to current converter anywhere that the same is desired in the system of FIG. 1. As will be apparent, utilization means 21 is not limited to a device to indicate density, but may be employed in a mass flowmeter or other device requiring a controlling input voltage or current which changes in accordance with fluid density.

As shown in FIG. 2, a squarer 22, a frequency divider 23, an AND gate 14, a predetermined counter 24 and a flip-flop 25 are connected from the output of oscillator 11 to a switch 26 in FIG. 3. The "1" output of flip-flop 25 is connected to an input lead 27 of switch 26. All the switches disclosed herein may be electromechanical or electrical, but preferably are electronic switches including, but not limited to, transistor switches. Thus, the signal on input lead 27 of switch 26 closes switch 26 when the 1 output of flip-flop 25 is high.

If the output of the said tracking filter is fairly square, squarer 22 need not be employed. In this case, the output of the tracing filter may be connected either directly to the input of divider 23, or directly to the input lead 28 of gate 14. If the tracking filter is connected to the input lead 28, divider 23 may thus be eliminated. Divider 23 is thus optional. As shown, divider 23 divides by 1,000. This number, too, is also optional.

A burst oscillator 29 is connected to a second input of gate 14. The "0" output of flip-flop 25 is connected to a third input of gate 14. The output of gate 14 is connected to the input of counter 24. An inverter 30 is connected from lead 28 to the reset input of flip-flop 25. The output of inverter 30 is also connected to the reset input of counter 24.

The operation of the pulse former circuit 13 of FIG. 2 may, perhaps, be best understood from the waveforms shown in FIG. 7. Pulse former circuit 13 converts waveform *a* to waveform *d*. The output of divider 23 is indicated by waveform *a*. The output of gate 14 is indicated by waveform *b*. Gate 14 passes a burst of pulses from oscillator 29 to counter 24 over a period which may be called $T_r/2$. The high output of divider 23 keeps gate 14 open. Initially, flip-flop 25 is in the 0 state and

thus does not inhibit gate 14. Counter 24 then counts burst pulses counter 24 stops counting a period of time $T_r/2$ after the leading edge of of each output pulse of divider 23. Counter 24 may be adjustable as to its predetermined count, if desired. Burst oscillator 29 produces pulses at a high stable, constant frequency.

Once the burst of pulses has been counted, counter 24 sets flip-flop 25 to the 1 state. The 0 output of flip-flop 25 then goes low and inhibits gate 14. No further pulses are then introduced to counter 24 until the leading edge of the next output pulse from divider 23. The output of inverter 30 is shown in waveform *c*. When waveform *a* goes low, waveform *c* goes high, and both counter 24 and flip-flop 24 are reset. The 1 output of flip-flop 25 is thus illustrated in waveform *d*.

As will be evident from the following description, the vertical input leads to switches 26, 31, 32, 33 and 19 represent the actuating input lead. As described previously, the actuating input lead carries a voltage which, when high, causes the switch to close. Switch 26 effectively has an arm 34 and a contact 35. A constant voltage, E, is connected to arm 34. A resistor 36 is connected between contact 35 and one input of a differential amplifier 37. The other input of differential amplifier 37 is connected to a constant voltage, E_{dt}. The input to switch 26 on lead 27 is connected from the 1 output of flip-flop 25 shown in FIG. 2, as stated previously. The output of amplifier 37, as in FIG. 3, is connected to an input lead 38 connected to an effective arm 39 of the switch 32, switch 32 having an effective contact 40.

In FIG. 3, a differentiator 41 is connected from lead 27 to a monostable multivibrator 42. The output of multivibrator 42 is connected to the actuating lead 43 of switch 31. The output of multivibrator 42 is also connected to an input lead 44 of a delay device 18 shown in FIG. 4, and to an actuating input lead 45 of switch 19 shown in FIG. 5.

In FIG. 3, switch 31 has an effective arm 46, and a contact 47. A capacitor 48 is connected from the output of amplifier 37 to the input thereof to which resistor 36 is connected. Arm 46 is connected to one electrode of capacitor 48, and contact 47 is connected to the other electrode thereof.

In the operation of the first integrator 15, shown in FIG. 3, the input to switch 26 on lead 27 closes switch 26 each time and a length of time that flip-flop 25 is in the 1 state. That is, switch 26 is closed during the widths of the pulses indicated in waveform *d*. The integrator of FIG. 3, therefore, integrates during at least a portion of this time. However, due to the fact that integration is performed not only during the pulses of waveform *d*, but also during the time between those pulses, one of the first and second integrators 15 and 16 of FIGS. 3 and 4, respectively, must reset during its own integration interval. It is the first integrator 15 of FIG. 3 that does this.

Differentiator 41 produces an output pulse at the leading edge of each of the pulses in waveform *d*. Multivibrator 42 then produces an output pulse having a leading edge coincided with the leading edge of each of the pulses of waveform *d* and having a trailing edge occurring before the trailing edges of the pulses of waveform *d*. The output of multivibrator 42 is indicated by waveform *f* in FIG. 8. Waveform *e* is the same as waveform *d* although the scale thereof has been changed for clarity.

Receipt by switch 31 of the multivibrator output causes the capacitor 48 to discharge. Capacitor 48 is thus shunted through switch 31.

If capacitor 48 were completely discharged, at a time, t_t shown in FIG. 8, the integrator would integrate from the zero line, V_o, starting at time, t_1, since it is the object of the integrator of FIG. 3 to produce a maximum output at a time t_2, which is directly proportional to the time width of pulse 49 shown in FIG. 8, an error would be introduced because the time $(t_1 - t_0)$ would be omitted.

In accordance with the device of the present invention, this error is eliminated by preventing the output of amplifier 37 from falling below a predetermined constant voltage, E_d, by supplying a suitable bias to amplifier 37, i.e. E_{dt}. This provides the bias sufficient to maintain $E_d = St_r$, where S is the slope of line 50, and $t_r = t_1 - t_0$. Note that t_r is also the pulse width of the output pulses of multivibrator 42 shown in FIG. 3. Note that the line 50 thus extends precisely through the point t_0, V_o and makes the integration accurate for the entire width of pulse 49.

In accordance with the foregoing, as shown in FIG. 8, the output of amplifier 37 drops along the line 51, integrates along the line 50 and remains constant at 52 over a period between the trailing edge of pulse 49 and the leading edge of pulse 53. The output of amplifier 37 remains constant during the interval along the line 52 because during this period switch 26 is opened.

In FIG. 4, an input lead 54 is connected from the 1 output of flip-flop 25. An inverter 55 is connected from lead 54 to the actuating input lead 56 of switch 32. As stated previously, input lead 38 is connected from the output of amplifier 37. A resistor 57 is connected from switch contact 40 to one input of an amplifier 58. The other input is grounded at 59. As before, a capacitor 60 is connected from the output to the input of amplifier 58 which is connected to resistor 57. A delay device 18 is connected from an input lead 44 to an actuating input lead 61 of switch 33. Switch 33 has an effective pole 62, and a contact 63. Pole 62 is connected to one electrode of capacitor 60. Contact 63 is connected to the other electrode of capacitor 60. The output of delay device 18 is indicated by waveform *i* in FIG. 8. However, the pulse width and location of the output pulses of delay device 18 need not be exactly the same as that of waveform *i*.

Since reset occupies a portion of the widths of pulses 49 and 53 for the first integrator 15 of FIG. 3, no special precautions need be taken in connection with the second integrator 16 of FIG. 4. Thus, the output pulses of delay device 18 provide for reset. The outputs of amplifiers 37 and 58 are shown in waveforms *g* and *h*, respectively. The output of amplifier 58 drops to zero volts at 64 on a line 65 produced by reset pulse 66. The output of amplifier 58 then stays at zero volts between t_3 and t_2 and integrates from t_2 to t_4. The inverted pulse input on lead 56 terminates the integration and the output of amplifier 58 remains constant at the line 67 between times t_4 and t_5.

First and second integrators 15 and 16, respectively, effectively integrate for periods from t_0 to t_2, and from t_2 to t_4, respectively. Thus, switch 26 is closed for the period from t_0 to t_2, and switch 32 is closed from t_2 to t_4.

Second integrator 16 shown in FIG. 3, integrates at a rate directly proportional to the constant voltage, E.

Thus, first integrator **15** shown in FIG. **4**, integrates at a rate directly proportional to the voltage upon input lead **38**, this voltage being the output voltage of amplifier **37** in FIG. **3**. The voltage on input lead **38** is integrated between t_2 and t_4 because switch **32** is closed during this time. Sample and hold circuit **10**, shown in FIG. **5**, includes switch **19** having an effective arm **68** and an effective contact **69**. An input lead **70** to switch **19** is connected from the output of amplifier **58**, shown in FIG. **4**. Switch **19** has an actuating input lead **45** connected from the output of multivibrator **42** shown in FIG. **3**. The sample and hold circuit **10** of FIG. **5** thus samples the amplitude of waveform *h* between t_0 and t_1, between t_4 and t_5, etc. Note that switch **19** is closed over the duration of the pulses of waveform *f*. The entire circuit **10** of FIG. **5** may be conventional. A capacitor **71** is connected from switch contact **69** to ground. An amplifier **72** has one input connected from switch contact **69** and another input which is grounded over a lead **73**.

Scale factor circuit **20** is shown in FIG. **6** including an input lead **74** which is connected from the output of amplifier **72** in FIG. **5**. The circuit of FIG. **6** includes input resistors R_{in} and R_B, a feedback resistor R_A and an amplifier **17**.

Resistor R_{in} is connected between input lead **74** and a junction **75**. Resistor R_B is connected from a point of potential V to junction **75**. Resistor R_A is connected from the output of amplifier **17** to junction **75**. In equations 8 and 9 to follow, the resistance R_A of resistor R_A may be adjusted or selected to take care of the appropriate constant A in both of the equations 8 and 9. The resistance R_B of resistor R_B and/or the potential V may be adjusted or selected to accurately provide for the constants B, and d_r in equations 8 and 9. The output of amplifier **17** is then connected to utilization means **21**, as described previously.

THEORY OF OPERATION

One of the objects of the invention is to produce a D.C. voltage at the output of circuit **10** directly proportional to the fluid in which the densitometer probe is immersed.

If *f* is the resonant frequency of the oscillator **11**, period, T, can be defined as,

$$T = 1/f \tag{1}$$

The densitometer of the present invention very accurately reproduces the equation,

$$d = AT^2 + B \tag{2}$$

where,

d is density, and

A and *B* are constants.

See copending application Ser. No. 65,371 filed Aug. 20, 1970, by C.E. Miller and G.L. Schlatter for DENSITOMETER for the proof.

If d_r is some known, fixed density for a period, T_r. then,

$$d_r = AT_r^2 + B \tag{3}$$

Subtracting equation 3 from equation 2,

$$d - d_r = A(T^2 - T_r^2) \tag{4}$$

Factoring and dividing by four,

$$d - d_r = 4A\,[(T/2) - (T_r/2)]\,[(T/2) + (T_r/2)] \tag{5}$$

In FIG. **7**, the output of divider **23** is indicated at waveform *a*. Note that each pulse has a period, T, and that each pulse has a width T/2. In effect, pulse former **13** subtracts a known, constant pulse width from the first portion of each of the pulses *a*. Call this portion $T_r/2$. The output pulses of gate **14** are shown at *b*. Waveform *c* is *a* inverted. Pulses *d* appear at the output of pulse former **13**.

Note that the period between the trailing edges of pulses *d* is T. The period between the trailing edge of the first and the leading edge of the next is thus,

$$T - [(T/2) - (T_r/2)\,] = [(T/2) + (T_r/2)] \tag{6}$$

Integrators **15** and **16** thus perform the computation,

$$[(T/2) - (T_r/2)]\,[(T/2) + (T_r/2)\,] \tag{7}$$

which is directly proportional to $d - d_r$. By adding the known constant, d_r, it is possible to arrive at absolute density. Use of d_r makes possible a more accurate computation and signal transmission because only the difference $d - d_r$ is computed and transmitted, and not absolute density, *d*.

Note that,

$$d = A(T^2 = T_r^2) + D_r \tag{8}$$

where,

$$d_r = AT_r^2 + B \tag{9}$$

Equation 8 gives the output of amplifier **17** in terms of a voltage directly proportional to *d*.

As stated previously, a voltage to current converter may be employed anywhere in the system of FIG. **1**. Such a converter may employ a Darlington circuit or otherwise. By this reference hereto, said copending application, in its entirety, is incorporated herein as fully set forth herein hereat.

As stated previously, counter **24** may be adjustable to adjust the predetermined count thereof. Note will be taken that the input signal to the scale factor circuit **20** of FIG. **6** on lead **74** is a D.C. voltage which is directly proportional to $d - d_r$. On the other hand, the output of amplifier **17** is a D.C. voltage directly proportional to d only.

The work "spaced" as used herein is hereby defined to include pulse spacing from center to center. However, this definition does not exclude a spacing which is measured in some other way.

The word "densitometer" is hereby defined for use herein and in the claims to include a device which may

or may not have utilization means 21 as described herein.

From FIGS. 3 and 8, and from the foregoing, it will be appreciated that there is an integrator in FIG. 3. The integrator of FIG. 3 may include all the parts shown connected from resistor 36, switch pole 46 and switch contact 47. The integrator of FIG. 3 thus has a first input connected from one side of resistor 36 to the upper input of amplifier 37. Switch 26 can be closed on receipt of an input pulse over lead 27. The leading edge of the input pulse thus can occur at a time $t = t_o$. See FIG. 8. In this case, t is the variable time. The term t_o may be a constant, if desired, and may be equal to zero, if so considered.

The integrator of FIG. 3 has a second input at 43, and an output marked with the legend "output."

Switch 31 in FIG. 3 may be considered to be "reset means." This reset means is actuable and connected to the said integrator input at 46 and 47 to lower the output signal magnitude at the integrator output from a predetermined magnitude such as is illustrated at the maximum output of g at $t = t_o$ in FIG. 8, to E_d at $t = t_1$, where t_1, by inspection of FIG. 8, is les than t_2, and $t = t_2$ at the trailing edge of the pulse 49 in FIG. 8.

The phrase "operator means" may include, but may or may not be limited to, multivibrator 42 shown in FIG. 3. Multivibrator 42 is responsive to input pulses on lead 27 through differentiator 41 and is connected to the reset means of switch 31 at 43. The multivibrator 42 thus actuates switch 31 during the period t_o to t_1 as shown in FIG. 8. Multivibrator 42 deactuates switch 31 at least during the period $t = t_1$ to $t = t_2$, by inspection of FIG. 8.

The said integrator has a construction such that when switch 31 is deactuated, the output signal of the said integrator is directly proportional to the time integral of whatever signal is impressed upon the integrator input from resistor 36 in FIG. 3. The said integrator thus produces a signal at the output thereof and so labeled in FIG. 3, which signal is E_d in magnitude at $t = t_1$ and which is $E_d + E_e$ at $t = t_2$, where $E_e = s\ (t_2 - t_1)$.

What is claimed is:

1. A function generator comprising: first means to produce one train of pulses of a width T/2, also spaced T/2; second means connected from said first means to receive said pulse train and to convert it to another pulse train of the same period, T, but of a pulse width, $[(T/2) - (T_r/2)]$, where T_r is a constant, the time between the trailing edge of one pulse in the other train to the leading edge of the next succeeding pulse therein thereby being $[(T/2) + (T_r/2)]$; and third means connected from said second means to receive said other pulse train and to produce an output signal directly proportional to the product, $[(T/2) - (T_r/2)]\ [(T/2) + (T_r/2)]$.

2. A function generator comprising: first means to produce one train of pulses of a width T/2, also spaced T/2; second means connected from said first means to receive said pulse train and to convert it to another pulse train of the same period, T, but of a pulse width, $[(T/2) - (T_r2)]$, where T_r is a constant, the time between the trailing edge of one pulse in the other train to the leading edge of the next succeeding pulse therein thereby being $[(T/2) + (T_r/2)]$; a first integrator connected from said second means to receive said other pulse train and to integrate to a maximum amplitude directly proportional to $[(T/2) - (T_r/2)]$ during each pulse of said other train, and a second integrator connected from both said second means and said first integrator to receive the outputs thereof and to integrate to a maximum amplitude directly proportional to the product, $[(T/2) - (T_r/2)]\ [(T/2) + (T_r/2)]$ during each interval between each pair of immediately adjacent pulses in said other train, the output of said second integrator increasing linearly for each said interval, $[(T/2) + (T_r/2)]$, at a rate directly proportional to the output signal magnitude of said first integrator.

3. The invention as defined in claim 2, wherein said first integrator includes first and second electrically operable switches, a differentiator, a multivibrator, an amplifier, a resistor and a capacitor, said first switch being connected from said second means to be closed thereby drawing each pulse output of said second means, means to supply a constant D.C. voltage to one side of said first switch, said resistor being connected from the other side of said first switch to one input of said smplifier, said differentiator being connected from said second means to the input of said multivibrator to supply an input pulse thereto approximately at the leading edge of each output pulse of said second means, said multivibrator producing an output pulse beginning approximately with the leading edge of each output pulse of said second means and lasting for a length of time less than the pulse width of the output pulses of said second means, said second switch being connected from the output of said multivibrator and being actuable to close during the output pulse thereof, said multivibrator being a monostable multi-vibrator, said capacitor being connected from the output to the input of said amplifier to which said resistor is connected, said second switch being connected in parallel with said capacitor, bias means connected to the other input of said amplifier to prevent the output thereof from falling below a D.C. voltage E_d, where $E_d = St_r$, and S is the constant rate of change of magnitude of the output signal of said amplifier, t_r being the pulse width of the output pulse of said multivibrator, integration thereby being performed from the time $t = t_r$ at an initial amplitude of E_d, said second integrator including third and fourth electrically operable switches, an inverter connected from said second means to said third switch to close the same during the time between the pulses appearing at the output of said second means, said second integrator also having a resistor, a capacitor and an amplifier, said first integrator amplifier having its output connected to one side of said third switch, said second integrator resistor being connected between the other side of said third switch and one input of said second integrator amplifier, the other input of said second integrator amplifier being grounded, said second integrator amplifier to which said second integrator resistor is connected, said fourth switch being connected in parallel with said second integrator capacitor, a delay device connected between said multivibrator output and said fourth switch to close said fourth switch sometime after said second switch has closed, and to open said fourth switch before said third switch is closed, said fourth switch being closed a sufficient amount of time to discharge said second integrator capacitor for each cycle of the output of said second means.

4. Integration apparatus comprising: an integrator having a first input adapted to receive a pulse having a leading edge at $t = t_o$, where t is the variable time, said

integrator having a second input and an output; reset means connected to said integrator second input and actuable to change the magnitude of the signal appearing at said integrator output when it is different from E_d between $t = t_o$ and $t = t_1$, and operator means responsive to said pulse and connected to said reset means to actuate said reset means between t 32 t_o and $t = t_1$ in a manner to cause it to change said integrator output signal to be equal to E_d at $t = t_1$, where t_1 is less than t_2, and $t = t_2$ at the trailing edge of said pulse, said operator means deactuating said reset means during the entire period of $t = t_1$ to $t = t_2$, said integrator having a construction such that when said reset means is deactuated, the output signal of said integrator is directly proportional to the time integral of the magnitude of whatever signal is impressed upon said integrator first input, said integrator producing a signal at the output thereof which is $E_d + E_d$ at $t = t_2$, where $E_e = S(t_2 - t_1)$, at least one of said means and said integrator having constructions such that $E_d = S(t_1 - t_o)$, said one means determining the time interval $(t_1 - t_o)$, S being the rate of change of the magnitude of the output signal of said integrator with respect to time during the period $t = t_1$ to $t = t_2$.

5. A function generator comprising: a differential amplifier; a capacitor connected from the input to the output of said amplifier; a first electrically actuable switch connected in shunt across said capacitor; a second electrically actuable switch; a resistor connected fron one side of said second switch to one input of said amplifier; means to supply a D.C. source of potential to the other side of said second switch; source means to supply pulses to said second switch to close it over the duration of each pulse; a monostable multivibrator having an on time shorter than said pulses; a differentiator connected from said source means to said multivibrator to turn it on at the leading edge of each pulse, the output of said multivibrator being connected to said first switch to close it during said on time; and means to supply a source of potential to the other amplifier input such that the output thereof does not fall below $E_d = St_r$, where S is the integrating slope and t_r is said on time, even though said capacitor is completely discharged at the end of each on time interval.

6. The invention as defined in claim **5**, wherein said D.C. source of potential is constant.

7. A function generator comprising: first means to produce one train of pulses of a width T/2, also spaced T/2; and second means connected from said first means to receive said pulse train and to convert it to another pulse train of the same period, T, but of a pulse width, $[(T/2) - (T_r/2)]$, where T_r is a constant, the time between the trailing edge of one pulse in the other train to the leading edge of the next succeeding pulse therein thereby being $[(T/2) + (T_r/2)]$, said second means including an AND gate having one input connected from said first means to receive said one pulse train, a burst oscillator for supplying pulses at a constant rate greater than the pulse repetition frequency of said one train of pulses, the output of said oscillator being connected to another input of said AND gate, a predetermined counter connected from the output of said AND gate to receive the output pulses thereof, a flip-flop having a set input connected from said counter, an inverter connected from said first means to the reset inputs of said counter and said flip-flop, the 0 output of said flip-flop being connected to a third input to said AND gate, the 1 output of said flip-flop providing said pulses of width, $[(T/2) - (T_r/2)]$.

8. A function generator comprising: a differential amplifier; a capacitor connected from one input of said amplifier to the output thereof; an electrically actuable switch connected in shunt across said capacitor; first means including at least first and second leads for supplying input pulses on both of said leads having coincident leading and trailing edges, said first lead being connected to said one amplifier input; second means connected from said second lead to said switch to impress pulses thereon having widths less than those of said input pulses, the leading edges of said second means pulses coinciding with those of said input pulses, said switch being normally open in the absence of said second means pulses; and third means to supply a potential to the other input of said amplifier such that the output thereof does not fall below E_d, where $E_d = St_r$, and where S is the integrating slope and t_r is the pulse width of said second means pulses, even though said capacitor is completely discharged each time the trailing edge of one said second means pulses occurs.

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