PATENT SPECIFICATION

597,531

Application Date: June 28, 1945. No. 16562/45.

Complete Specification Left: Dec. 6, 1946.

Complete Specification Accepted: Jan. 28, 1948.

PROVISIONAL SPECIFICATION

Improvements in or relating to Electronic Integrating Apparatus

We, LEONARD ROBIN HULLS and EDMUND RAMSAY WIGAN, British Subjects, both of the Ministry of Supply, Great Westminster House, London, S.W.1, do hereby declare the nature of this invention to be as follows:—

The present invention relates to an apparatus for integrating a fluctuating voltage such as a signal voltage obtained for example from a radio receiver or audio frequency amplifier over any desired period of time. Such integrations may be required as parts of tests of the operational efficiency of radio receivers, amplifiers or microphones. The object of the invention therefore is to provide an apparatus which will give an indication of the integral of a signal voltage over a given time or in other words a measure of the area bounded by the voltage-time curve of the signal. For the integration to be useful the result obtained must at all times represent the product of the voltage and the time, that is to say that the same result must be obtained for the measurement of a voltage V existing for time t as for a voltage 2V existing for a time $t/2$ or alternatively a voltage V/2 existing for a time $2t$. Similarly if a reading M is obtained for a voltage V existing for time t, a reading 2M should be obtained for a voltage 2V existing for the same time t. These conditions must, moreover, apply whatever the absolute values of V and t, within such limits as may be set for the apparatus.

An integration could be effected by causing the signal voltage to charge a condenser through a diode, the voltage obtained in the condenser being a measure of the product of the voltage applied to the circuit and the time for which it was applied. Such an arrangement however would not comply with the conditions above discussed and would have the further disadvantage that the charging curve of the condenser is exponential in form so that an exponential relation between the final voltage on the condenser and the product of voltage and time would obtain.

According to the present invention, therefore, an apparatus for integrating a signal voltage over a given time is provided in which the signal to be integrated is caused to build up a voltage in a condenser in accordance with the magnitude and duration of said signal, the charge on the condenser being built up through a unilaterally conducting device which prevents discharge of the condenser in the absence of a signal voltage wherein means are provided for applying in series with the unilaterally conducting device and the condenser, a voltage equal to and increasing with that built up in the condenser whereby the value of the signal voltage at any instant is added to the voltage built up by the part of the integration prior to that instant.

To this end, a D.C. auxiliary voltage may be derived from an oscillatory voltage the amplitude of which is controlled by means of an amplifier the gain of which is governed by the voltage built up on the condenser during the expired portion of the integration whereby the D.C. auxiliary voltage is maintained equal to the voltage across the condenser in which the integration takes place.

An apparatus according to the invention may therefore comprise a condenser adapted to be charged by the signal voltage to be integrated, through a unilaterally conducting device, such as a diode, an oscillator, an amplifier controlled by the voltage on said condenser for amplifying an oscillatory voltage derived from said oscillator, a rectifier receiving the output from said amplifier and adapted to derive a D.C. auxiliary voltage therefrom, this voltage being injected into the network consisting of the diode, condenser and signal source, and means such as a valve voltmeter for measuring the voltage on said condenser. A single valve may be employed to effect amplification of the oscillatory voltage and to form part of a valve-voltmeter for measuring the condenser voltage.

In order that the invention may be more clearly understood an embodiment thereof will now be described by way of example, with reference to the accompanying drawings in which:—

[*Price* 1/-]

Figure 1 is a schematic block diagram of the apparatus and

Figure 2 is a more detailed circuit diagram of the integrator, omitting the oscillator.

Referring first to Figure 1, signals to be integrated are introduced through terminal 1 and feed condenser 2 and applied to the anode of a diode 3 in the cathode circuit of which is connected a condenser 4 which will therefore be charged by the signal voltages rectified in the diode 3. The voltage on the upper side of the condenser 4 is applied to a valve-voltmeter 5 to which is connected the meter 6 on which the integration readings are to be taken.

In order to provide a compensating voltage (referred to above as the " auxiliary voltage ") to raise the voltage on the anode of diode 3 in step with the rise in voltage on the upper side of condenser 4 during an integration, an oscillator 7 is provided, the operating frequency of which is not important except that preferably it will be of the same order as the signal frequencies to be integrated. The oscillator 7 feeds into an amplifier 8 the output of which is controlled in accordance with the voltage applied to the valve-voltmeter 5 and is applied to a rectifying and smoothing circuit 9 which converts it to a D.C. voltage which is applied between the anode of diode 3 and earth, to reproduce at the diode anode the same voltage as exists across the condenser 4. Resistor 10 constitutes the load for the diode 3 and the switch 11 enables the condenser 4 to be discharged prior to the commencement of an integration.

In the detailed circuit of Figure 2 the signal input terminal 20 is connected through condenser 21 to the anode of diode 22 in the cathode circuit of which is connected condenser 23, a path to earth being completed through resistor 24. The cathode of diode 22 is connected through resistor 25 to the control grid of a pentode valve 26. The cathode circuit of this valve contains a resistor 27, decoupled by condenser 28, whereby the cathode voltage will depend on the D.C. current through valve 26. This voltage is measured by a meter 29 the other side of which is connected to the slider of a variable resistor 30 which with resistor 31 forms a potentiometer chain between the RT positive and earth thus enabling the meter 29 to be set to zero deflection before the integration is commenced.

The terminals 32, 33 receive the output from an oscillator of any suitable form to set up across potentiometer 34 an oscillatory voltage a part of which is tapped off and fed through condenser 35 to the control grid of valve 26. This voltage is amplified by the valve 26 to an extent determined by the value of the grid-cathode potential of this valve at any instant. The anode circuit of valve 26 comprises the primary of transformer 36. The voltage appearing across the secondary of transformer 36 is rectified by the diode 37 to set up across resistors 38 and 39 a D.C. voltage smoothed by condenser 40. This voltage is applied through resistor 41 to the anode of diode 22. A negative D.C. bias is applied to the junction of resistors 38 and 39 from the potentiometer 42 connected across the battery 43.

A switch 44 is provided, connected across the condenser 23, to enable the condenser to be discharged prior to an integration. The variable resistor 45 enables the positive voltage on the control grid of valve 26 developed across resistor 24, to be adjusted.

Before the apparatus is used to carry out an integration it must first be set up. To do this, the following procedure is carried out.

With the meter 29 removed from the circuit and a meter connected instead in the anode circuit of valve 26, resistor 45 is adjusted until the standing current through valve 26 reaches a predetermined value which will ensure that the amplification effected by the valve will increase linearly with increasing grid potential. During this adjustment the switch 44 is closed so that condenser 23 is short-circuited. The meter may now be removed from the anode circuit of valve 26 and meter 29 is reconnected in circuit. The potentiometer 30 is then adjusted for zero reading on meter 29.

Switch 44 is now opened and potentiometer 34 adjusted to increase the oscillatory voltage fed to the control grid of valve 26 until the needle of meter 29 is seen to start moving across the scale. This will indicate that the output from valve 26 is generating a D.C. voltage across condenser 40 in excess of the standing voltage on the anode of diode 22 and is causing the build-up of a voltage in condenser 23 which, by increasing the gain of valve 26 increases the voltage fed back by this valve, the action being progressive. If now, the drift of the meter 29 across the scale is seen to decrease in speed or even stop towards the upper end of the scale it will be inferred that the output of valve 26 is not being sufficiently increased by the rising grid voltage. This is corrected by increasing the negative backing-off voltage applied through potentiometer 42 to the cathode of diode 37 and increasing the oscillator input from potentiometer 34. In this way the range of output voltages

obtained from valve 26 is increased, the starting voltage on the anode of diode 22 being restored to normal by the adjustment of the backing-off voltage.

If the movement of the meter needle is seen to accelerate towards the end of its sweep the reverse process is applied. By successive adjustments of potentiometers 34 and 42 a condition will be reached such that the movement of the meter needle is uniform throughout its travel. When this condition has been realised, the potentiometer 34 is finally adjusted until the movement of the meter needle just ceases. The apparatus is then properly set up.

Before each calibration the switch 44 is closed to discharge condenser 23 and bring the meter 29 to zero. The switch is then opened and the signal to be integrated applied to terminal 20 and at the conclusion of the signal, for example a standard phrase spoken into a microphone or at the termination of a predetermined time, the reading of meter 29 indicates the desired summation of the signal voltage fed in, in respect of magnitude and duration.

The use of the apparatus for integrations involving greater voltage-time summations than are provided for on the meter 29 in the arrangement shown may be effected quite simply by a small addition to the circuit. To this end it is necessary to discharge condenser 23 and reset the meter each time full scale deflection is reached, and the number of times full scale deflection is achieved during the entire integration must be counted. One method by which this may be achieved involves the use of a gas discharge tube of the type known as a " Thyratron ". Such a discharge tube is arranged to be fired at the instant full scale deflection is reached and on firing is caused to actuate a relay which short-circuits condenser 23 and preferably, for speedy operation, also condenser 40. An impulse is also applied by the relay to a counting device on which the number of times full scale deflection is reached will thus be recorded.

The firing of the Thyratron may be controlled by applying the voltage on condenser 40 to its grid and arranging for the discharge tube to operate when this voltage reaches that corresponding to full scale deflection of meter 29. The Thyratron may be arranged to break its own operating circuit to restore the relay to its resting condition.

Provided the operating time of the Thyratron and relay is short in relation to the time taken for full scale deflection to be built up, the error introduced by the restoration period will be negligible. By such an arrangement integrations may be carried out over lengthy periods, limited only by the capacity of the counting device.

Dated this 28th day of June, 1945.
T. BROWN,
Chartered Patent Agent,
Agent for the Applicants.

COMPLETE SPECIFICATION

Improvements in or relating to Electronic Integrating Apparatus

We, LEONARD ROBIN HULLS and EDMUND RAMSAY WIGAN, British Subjects, both of the Ministry of Supply, London, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

The present invention relates to an apparatus for integrating a fluctuating voltage such as a signal voltage obtained for example from a radio receiver or radio frequency amplifier over any desired period of time. Such integrations may be required as parts of tests of the operational efficiency of radio receivers, amplifiers or microphones. The object of the invention therefore is to provide an apparatus which will give an indication of the integral of a signal voltage over a given time or in other words a measure of the area bounded by the voltage-time curve of the signal. For the integration to be useful the result obtained must at all times represent the product of the voltage and the time, that is to say that the same result must be obtained for the measurement of a voltage V existing for time t as for a voltage 2V existing for a time $t/2$ or alternatively a voltage V/2 existing for a time $2t$. Similarly if a reading M is obtained for a voltage V existing for time t, a reading 2M should be obtained for a voltage 2V existing for the same time t. These conditions must, moreover, apply whatever the absolute values of V and t, within such limits as may be set for the apparatus.

An integration could be effected by causing the signal voltage to charge a condenser through a diode, the voltage obtained in the condenser being a measure of the product of the voltage applied to the circuit and the time for which it was

applied. Such an arrangement however would not comply with the conditions above discussed and would have the further disadvantage that the charging curve of the condenser is exponential in form so that an exponential relation between the final voltage on the condenser and the product of voltage and time would obtain.

According to the present invention, therefore, an apparatus for integrating a signal voltage over a given time is provided in which the signal to be integrated is caused to build up a voltage in a condenser in accordance with the magnitude and duration of said signal, the charge on the condenser being built up through a unilaterally conducting device which prevents discharge of the condenser in the absence of a signal voltage wherein means are provided for applying in series with the unilaterally conducting device and the condenser, a voltage equal to and increasing with that built up in the condenser whereby the value of the signal voltage at any instant is added to the voltage built up by the part of the integration prior to that instant, characterised in this that said auxiliary voltage is derived from an oscillatory voltage the amplitude of which is controlled by the voltage built up on the condenser during the expired portion of the integration whereby the D.C. auxiliary voltage is maintained equal to the voltage across the condenser in which the integration takes place.

An apparatus according to the invention may therefore comprise a condenser adapted to be charged by the signal voltage to be integrated, through a unilaterally conducting device, such as a diode, an oscillator, an amplifier controlled by the voltage on said condenser for amplifying an oscillatory voltage derived from said oscillator, a rectifier receiving the output from said amplifier and adapted to derive a D.C. auxiliary voltage therefrom, this voltage being injected into the network consisting of the diode, condenser and signal source, and means such as a valve-voltmeter for measuring the voltage on said condenser. A single valve may be employed to effect amplification of the oscillatory voltage and to form part of a valve-voltmeter for measuring the condenser voltage.

In order that the invention may be more clearly understood an embodiment thereof will now be described by way of example, with reference to the drawings accompanying the Provisional Specification in which:—

Figure 1 is a schematic block diagram of the apparatus and

Figure 2 is a more detailed circuit diagram of the integrator, omitting the oscillator.

Referring first to Figure 1, signals to be integrated are introduced through terminal 1 and feed condenser 2 and applied to the anode of a diode 3 in the cathode circuit of which is connected a condenser 4 which will therefore be charged by the signal voltages rectified in the diode 3. The voltage on the upper side of the condenser 4 is applied to a valve-voltmeter 5 to which is connected the meter 6 on which the integration readings are to be taken.

In order to provide a compensating voltage (referred to above as the "auxiliary voltage") to raise the voltage on the anode of diode 3 in step with the rise in voltage on the upper side of condenser 4 during an integration, an oscillator 7 is provided, the operating frequency of which is not important except that preferably it will be of the same order as the signal frequencies to be integrated. The oscillator 7 feeds into an amplifier 8 the output of which is controlled in accordance with the voltage applied to the valve-voltmeter 5 and is applied to a rectifying and smoothing circuit 9 which converts it to a D.C. voltage which is applied between the anode of diode 3 and earth, to reproduce at the diode anode the same voltage as exists across the condenser 4. Resistor 10 constitutes the load for the diode 3 and the switch 11 enables the condenser 4 to be discharged prior to the commencement of an integration.

In the detailed circuit of Figure 2 the signal input terminal 20 is connected through condenser 21 to the anode of diode 22 in the cathode circuit of which is connected condenser 23, a path to earth being completed through resistor 24. The cathode of diode 22 is connected through resistor 25 to the control grid of a pentode valve 26. The cathode circuit of this valve contains a resistor 27, decoupled by condenser 28, whereby the cathode voltage will depend on the D.C. current through valve 26. This voltage is measured by a meter 29 the other side of which is connected to the slider of a variable resistor 30 which with resistor 31 forms a potentiometer chain between the H.T. positive and earth thus enabling the meter 29 to be set to zero deflection before the integration is commenced.

The terminals 32, 33 receive the output from an oscillator of any suitable form to set up across potentiometer 34 an oscillatory voltage a part of which is tapped off and fed through condenser 35 to the control grid of valve 26. This voltage is amplified by the valve 26 to an extent

determined by the value of the grid-cathode potential of this valve at any instant. The anode circuit of valve 26 comprises the primary of transformer 36. The voltage appearing across the secondary of transformer 36 is rectified by the diode 37 to set up across resistors 38 and 39 a D.C. voltage smoothed by condenser 40. This voltage is applied through resistor 41 to the anode of diode 22. A negative D.C. bias is applied to the junction of resistors 38 and 39 from the potentiometer 42 connected across the battery 43.

A switch 44 is provided, connected across the condenser 23, to enable the condenser to be discharged prior to an integration. The variable resistor 45 enables the positive voltage on the control grid of valve 26 developed across resistor 24, to be adjusted.

Before the apparatus is used to carry out an integration it must first be set up. To do this, the following procedure is carried out.

With the meter 29 removed from the circuit and a meter connected instead in the anode circuit of valve 26, resistor 45 is adjusted until the standing current through valve 26 reaches a predetermined value which will ensure that the amplification effected by the valve will increase linearly with increasing grid potential. During this adjustment the switch 44 is closed so that condenser 23 is short-circuited. The meter may now be removed from the anode circuit of valve 26 and meter 29 is reconnected in circuit. The potentiometer 30 is then adjusted for zero reading on meter 29.

Switch 44 is now opened and potentiometer 34 adjusted to increase the oscillatory voltage to the control grid of valve 26 until the needle of meter 29 is seen to start moving across the scale. This will indicate that the output from valve 26 is generating a D.C. voltage across condenser 40 in excess of the standing voltage on the anode of diode 22 and is causing the build up of a voltage in condenser 23 which, by increasing the gain of valve 26 increases the voltage fed back by this valve, the action being progressive. If now, the drift of the meter 29 across the scale is seen to decrease in speed or even stop towards the upper end of the scale it will be inferred that the output of valve 26 is not being sufficiently increased by the rising grid voltage. This is corrected by increasing the negative backing-off voltage applied through potentiometer 42 to the cathode of diode 37 and increasing the oscillator input from potentiometer 34. In this way the range of output voltages obtained from valve 26 is increased, the starting voltage on the anode of diode 22 being restored to normal by the adjustment of the backing-off voltage.

If the movement of the meter needle is seen to accelerate towards the end of its sweep the reverse process is applied. By successive adjustments of potentiometers 34 and 42 a condition will be reached such that the movement of the meter needle is uniform throughout its travel. When this condition has been realised, the potentiometer 34 is finally adjusted until the movement of the meter needle just ceases. The apparatus is then properly set up.

Before each calibration the switch 44 is closed to discharge condenser 23 and bring the meter 29 to zero. The switch is then opened and the signal to be integrated applied to terminal 20 and at the conclusion of the signal, for example a standard phrase spoken into a microphone or at the termination of a predetermined time, the reading of meter 29 indicates the desired summation of the signal voltage fed in, in respect of magnitude and duration.

The use of the apparatus for integrations involving greater voltage time summations are then provided for on the meter 29 in the arrangement shown may be effected quite simply by a small addition to the circuit. To this end it is necessary to discharge condenser 23 and reset the meter each time full scale deflection is reached, and the number of times full scale deflection is achieved during the entire integration must be counted. One method by which this may be achieved involves the use of a gas discharge tube of the type known as a "Thyratron." Such a discharge tube is arranged to be fired at the instant full scale deflection is reached and on firing is caused to actuate a relay which short-circuits condenser 23 and preferably, for speedy operation, also condenser 40. An impulse is also applied by the relay to a counting device on which the number of times full scale deflection is reached will thus be recorded.

The firing of the Thyratron may be controlled by applying the voltage on condenser 40 to its grid and arranging for the discharge tube to operate when this voltage reaches that corresponding to full scale deflection of meter 29. The Thyratron may be arranged to break its own operating circuit to restore the relay to its resting condition.

Provided the operating time of the Thyratron and relay is short in relation to the time taken for full scale deflection to be built up, the error introduced by the restoration period will be negligible. By such an arrangement integrations may be carried out over lengthy periods, limited only by the capacity of the

counting device.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. An apparatus for integrating a signal voltage over a given time in which the signal to be integrated is caused to build up a voltage in a condenser in accordance with the magnitude and duration of said signal voltage, the charge on the condenser being built up through a unilaterally conducting device which prevents the discharge of said condenser in the absence of a signal voltage wherein means are provided for applying in series with said unilaterally conducting device and said condenser a D.C. auxiliary voltage equal to and increasing with the voltage built up in said condenser whereby the value of the signal voltage at any instant is added to the voltage built up by the part of the integration prior to that instant, characterised in this that said D.C. auxiliary voltage is derived from an oscillatory voltage the amplitude of which is governed by the voltage built up on said condenser during the expired portion of the integration whereby the said D.C. auxiliary voltage is maintained equal to the voltage across said condenser.

2. An apparatus as claimed in Claim 1 wherein the amplitude of said oscillatory voltage is controlled by means of an amplifier the gain of which is governed by the voltage built up on said condenser during the expired portion of the integration.

3. An apparatus as claimed in Claims 1 and 2 in which the voltage on said condenser is measured by means of a valve voltmeter.

4. An apparatus as claimed in Claim 3 wherein a single electronic valve is employed as the amplifier for said oscillatory voltage and as a part of said valve voltmeter.

5. An apparatus as claimed in any one of the preceding claims comprising means for resetting the integrator at a predetermined point in the integration and for recording each such resetting operation.

6. An apparatus as claimed in Claim 5 comprising a gaseous discharge tube adapted to operate at said predetermined point in the integration, said gaseous discharge tube being adapted to reset the integrator, operate a recorder for recording the resetting operation and terminate its own operation.

7. An apparatus for integrating a signal voltage over a given time, constructed, arranged and adapted to operate substantially as hereinbefore described with reference to Fig. 2 of the drawings accompanying the Provisional Specification.

Dated this 5th day of December, 1946.

T. BROWN,
Chartered Patent Agent,
Agent for the Applicants.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1948.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies, price 1s. 0d. each (inland) 1s. 1d. (abroad) may be obtained.

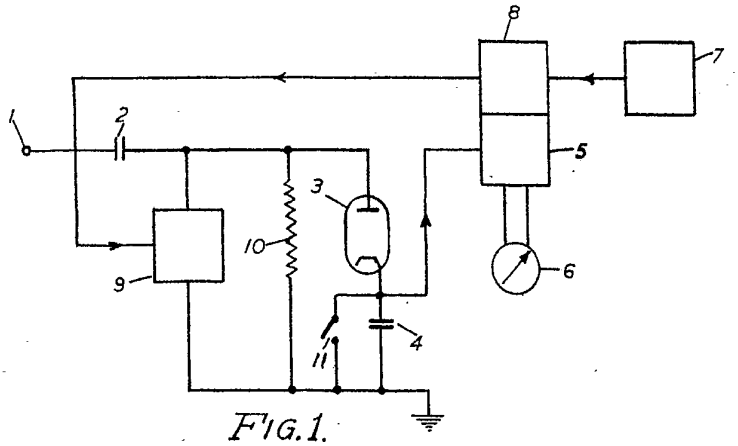

FIG. 1.

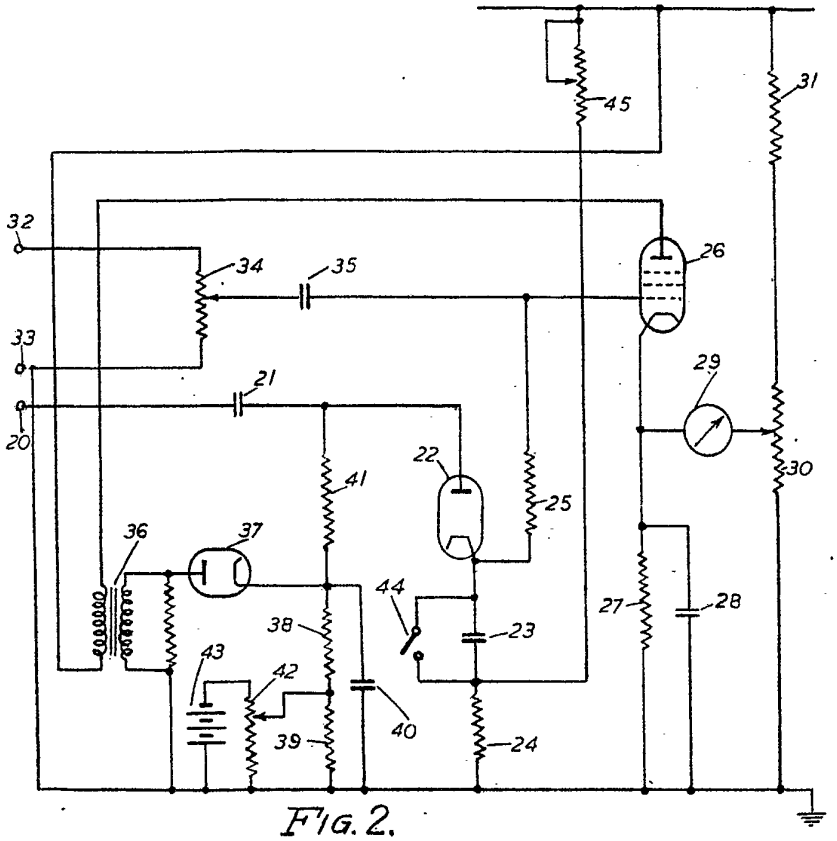

FIG. 2.

H.M.S.O.(Ty. P.)