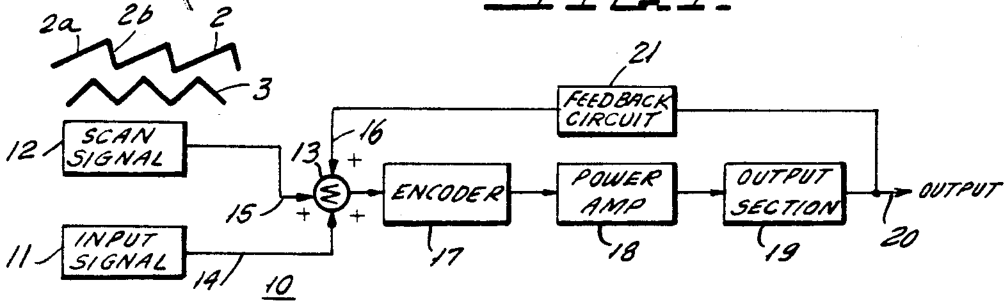
July 16, 1968 H. D. FORSTER, JR 3,393,363

AMPLIFYING MEANS EMPLOYING PULSE WIDTH MODULATION

Filed Oct. 7, 1963 7 Sheets-Sheet 1

FIG. 1.



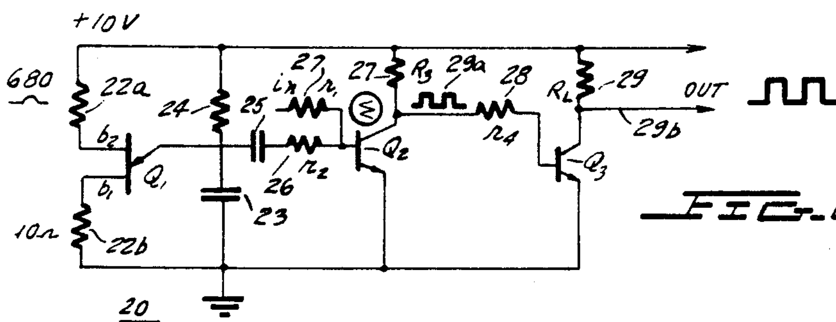


FIG. 2.

FIG. 3.

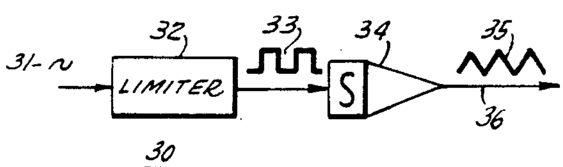
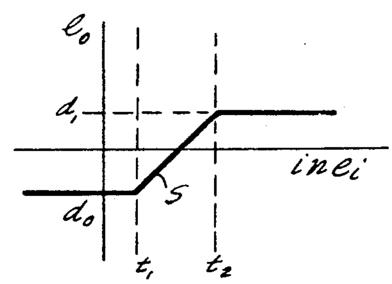


FIG. 2A.



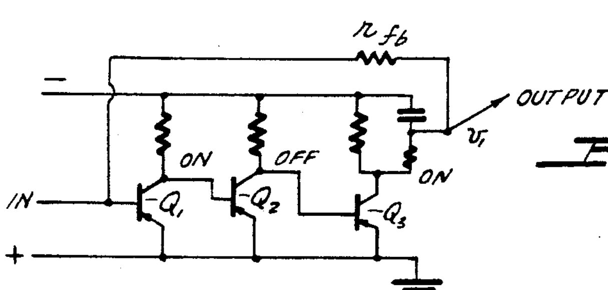


FIG. 2C.

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AMPLIFYING MEANS EMPLOYING PULSE WITH MODULATION

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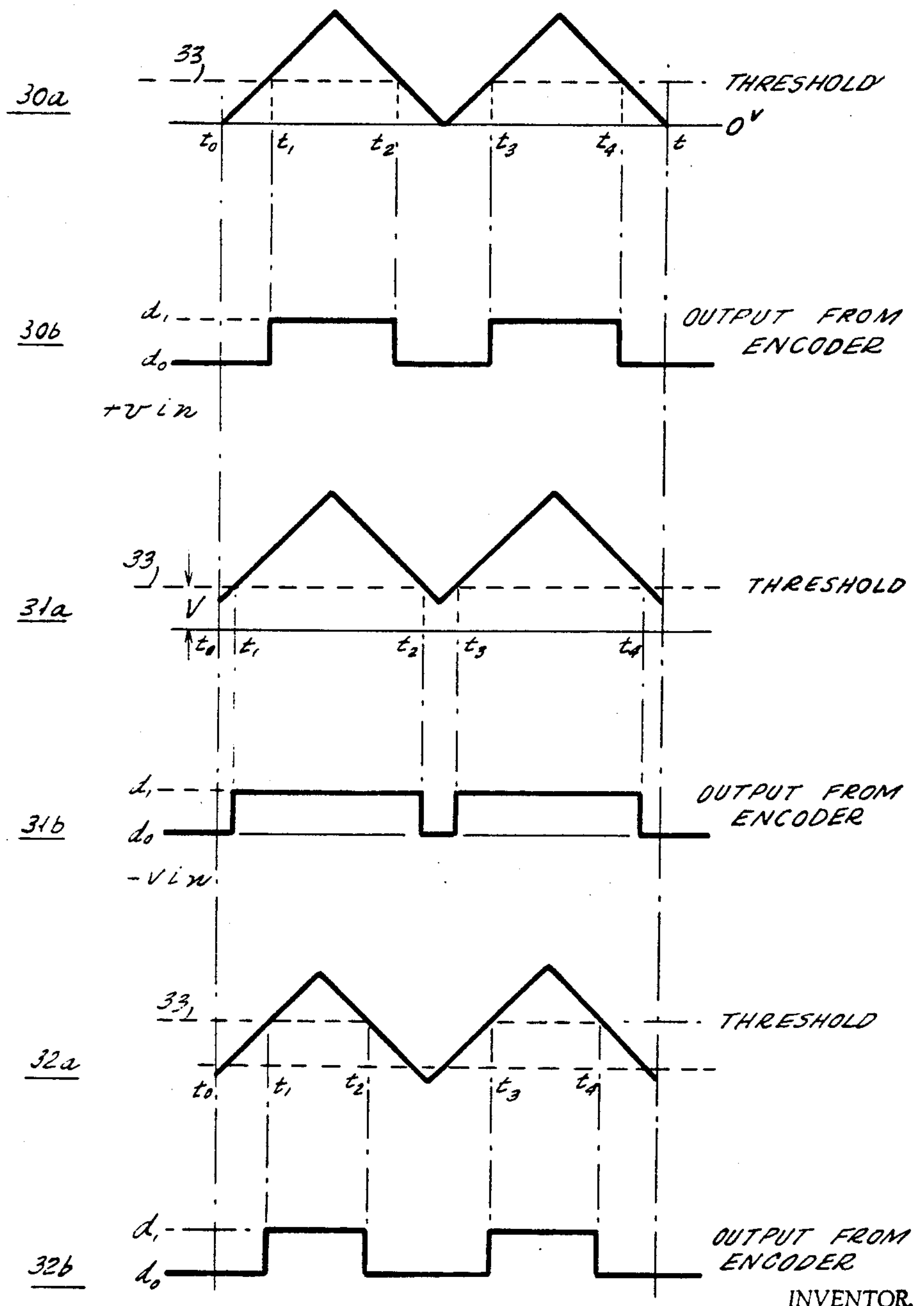
FIG. 2B.



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AMPLIFYING MEANS EMPLOYING PULSE WITH MODULATION

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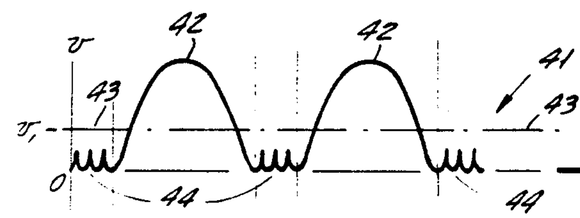

FIG. 4.

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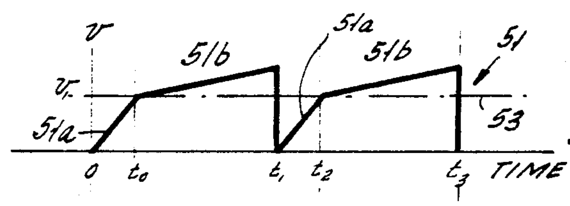

FIG. 5.

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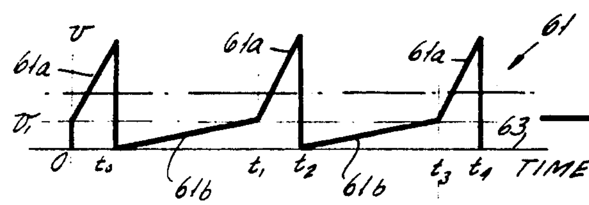

FIG. 6.

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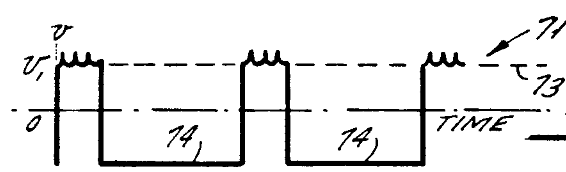

FIG. 7.

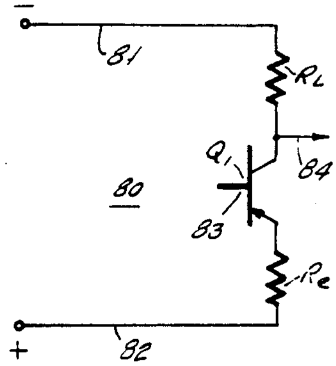

FIG. 8.

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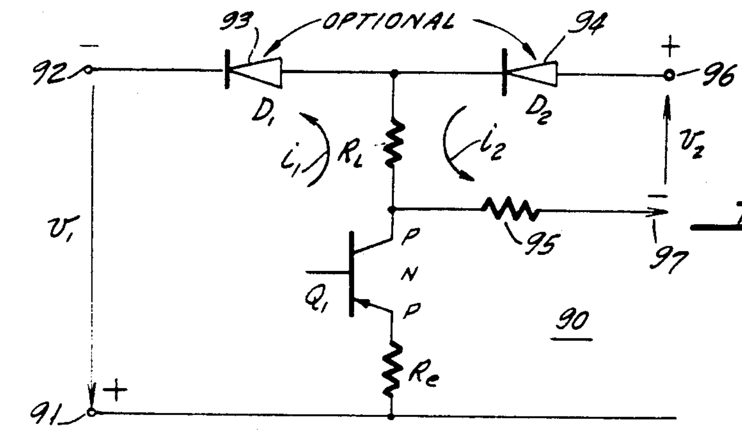

FIG. 9.

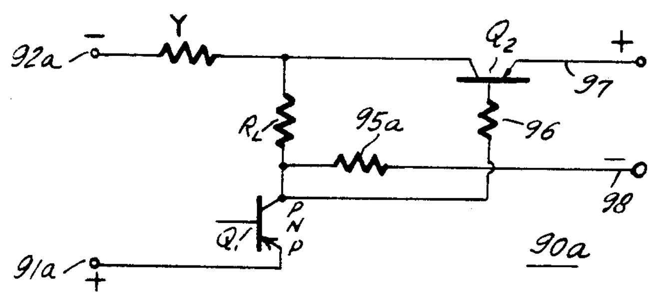

FIG. 9A.

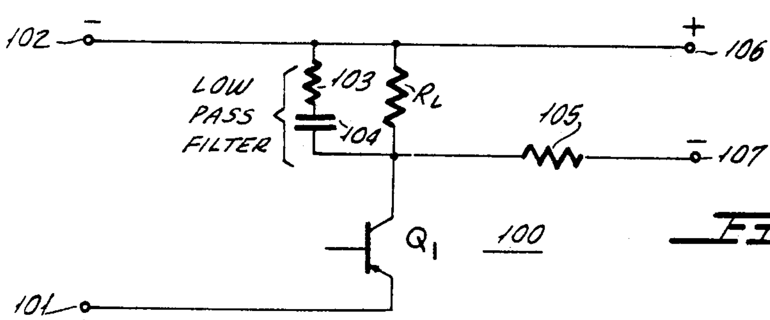

FIG. 10.

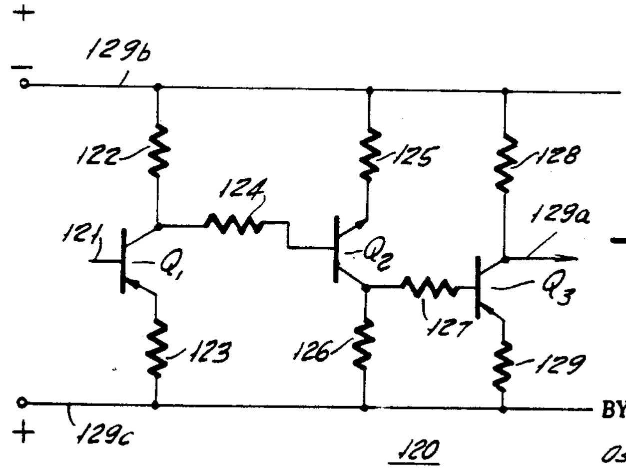

FIG. 12.

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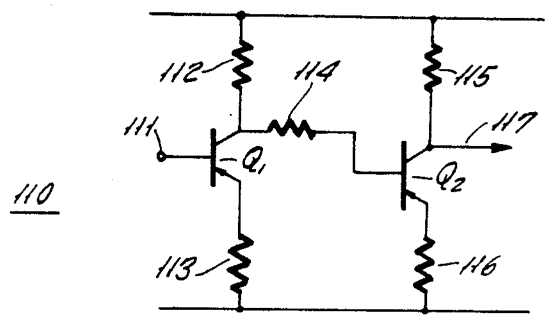

FIG. 11.

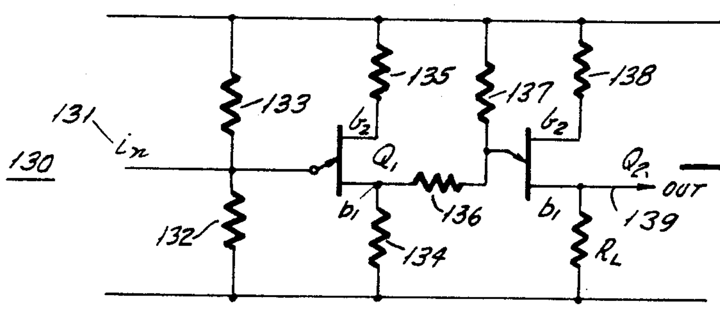

FIG. 13.

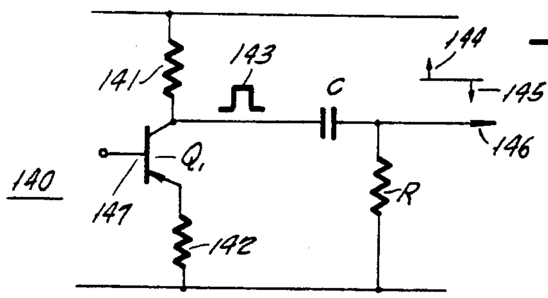

FIG. 14.

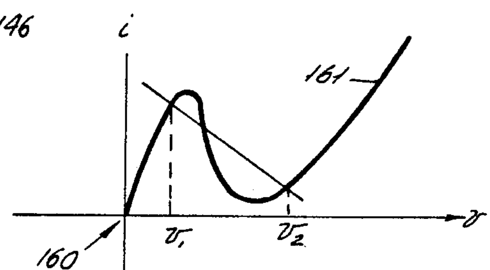

FIG. 16.

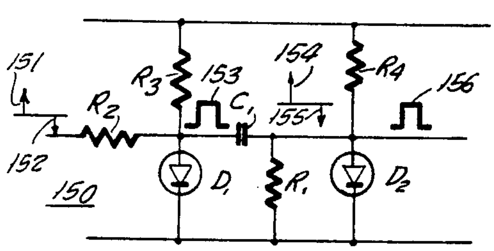

FIG. 15.

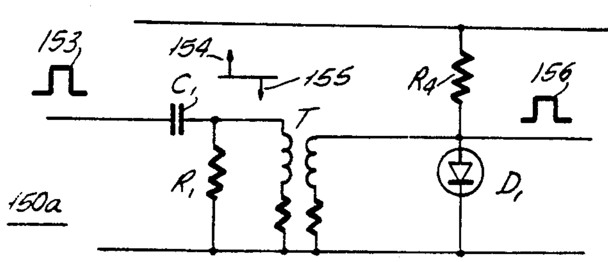

FIG. 15A.

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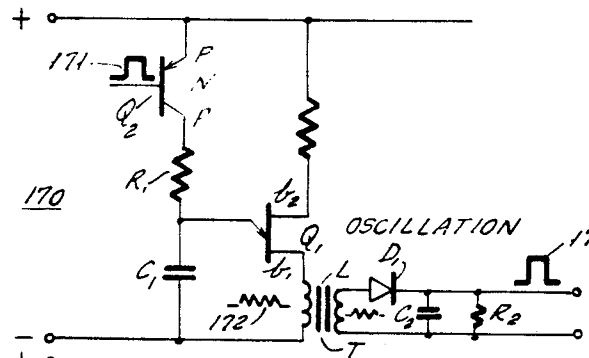

FIG. 17.

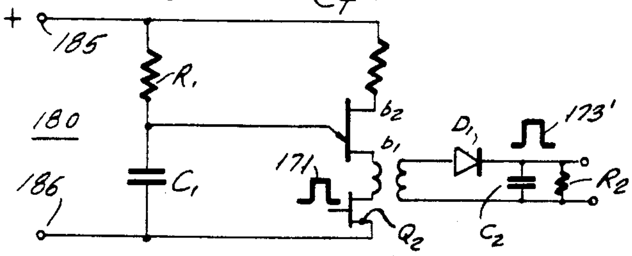

FIG. 18.

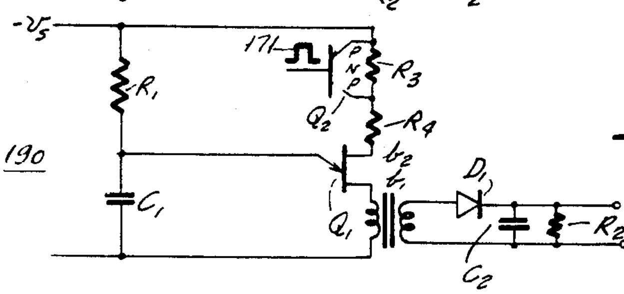

FIG. 19.

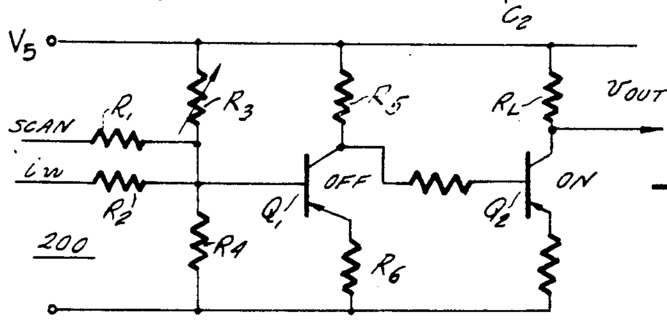

FIG. 20.

FIG. 21.

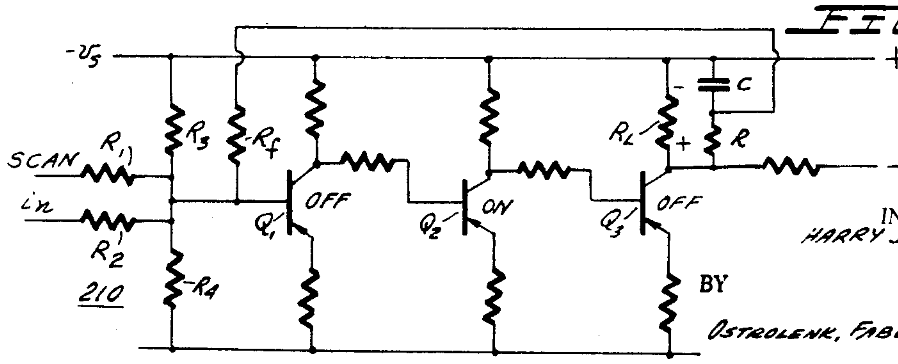

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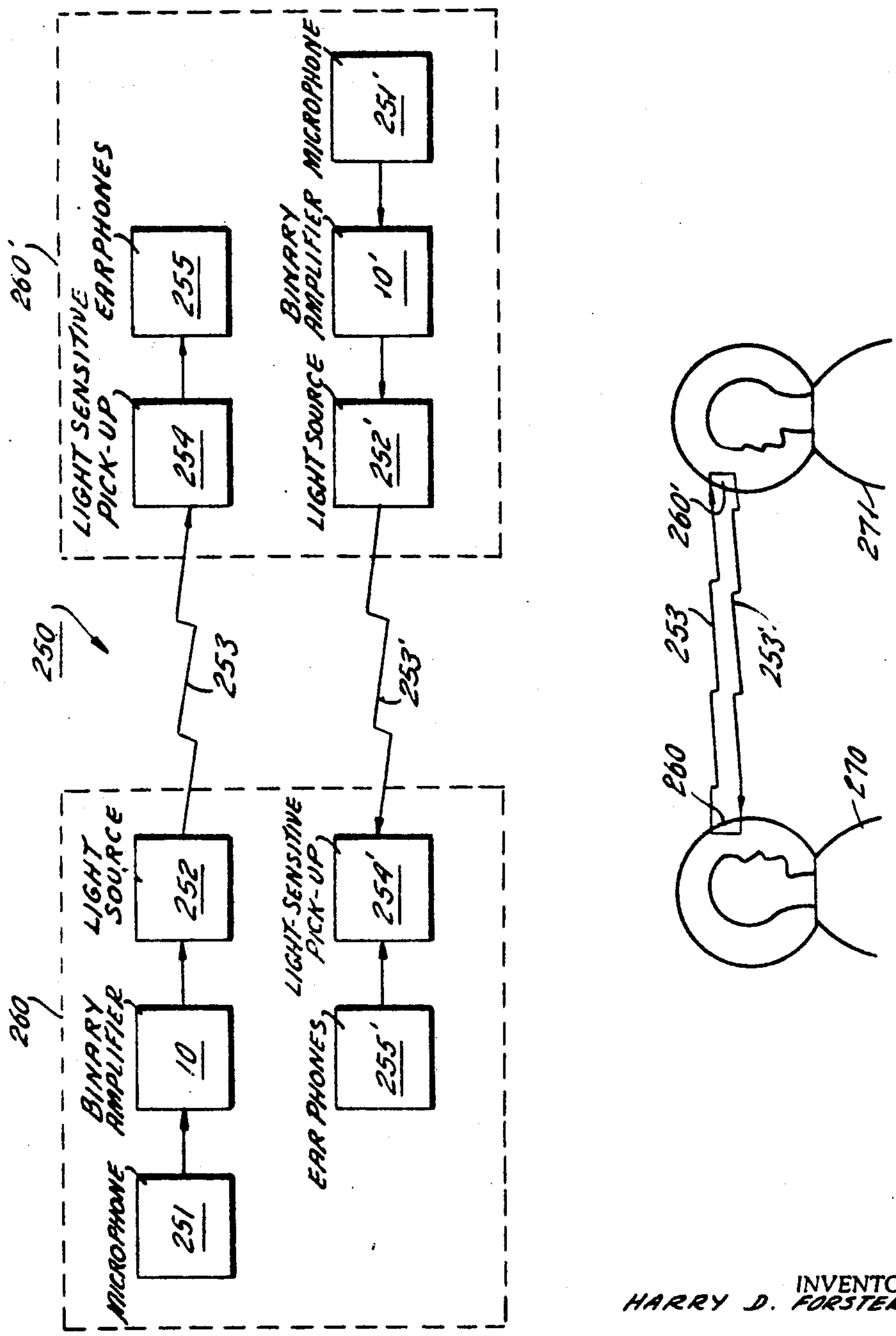
FIG. 22.



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United States Patent Office 3,393,363
Patented July 16, 1968

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3,393,363
AMPLIFYING MEANS EMPLOYING PULSE WIDTH MODULATION

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Filed Oct. 7, 1963, Ser. No. 314,193
15 Claims. (Cl. 325—38)

ABSTRACT OF THE DISCLOSURE

Solid state circuitry is disclosed for amplifying input signals in a linear fashion. Input signals are mixed or summed with a periodic signal such as, for example, a saw tooth or triangle-shaped wave-form. The resulting signal is applied to a binary circuit providing a first binary output on a predetermined threshold is achieved and a second binary output when the predetermined threshold level is not achieved. The binary output signal is then amplified and filtered to reproduce an amplified replica of the original input signal; a feedback path is provided for compensating for any drift in the circuit. Additional means may be provided to effect D.C. isolation between input and output circuits. This system may be employed as a communication means with the binary output being utilized to modulate the carrier such as a light source; receiver may be provided with light-sensitive means which then drives a transducing means converting the carrier pulses into the common form of intelligence such as, for example, audio intelligence.

The instant invention relates to electronic amplifying means, and more particularly, to amplifying means employing non-linear elements, thereby utilizing a binary concept to provide the desired amplification.

The basic approach to amplification of input signals in order to obtain a desired gain lies in the approach of using amplifier elements, such as vacuum tubes, transistors, and so forth, and operating them in the linear portions of their operation characteristic curves so as to provide an output signal having a waveshape substantially identical to the input signal such that the output signal is amplified in accordance with the gain requirements for the circuit. Such prior art approaches are not completely successful in this regard due to the fact that these devices, if they have any linear operating ranges at all, have extremely narrow linear operating ranges and attendant high power dissipation, so that a significant amount of distortion will nevertheless appear in the output waveshape, as compared with the input signal which it is desired to amplify.

The instant invention employs a concept which is totally different from such prior art approaches in that a deliberate operation of non-linearity is performed upon the input signal which it is desired to amplify.

The instant invention is comprised of electronic summing means upon which are imposed a scan signal and an input signal, thereby providing a resultant waveform having a waveshape which is non-linear relative to the input signal. The resultant waveshape is impressed upon encoder means which means has a binary operating characteristic in that it is either in a first state (i.e., "off") or a second state (i.e., "on") at any given time, and is basically incapable of being in any state other than the "on" or "off" stages.

Thus, the resulting output is comprised of substantially square pulses whose width or time duration are a function of both the scan signal and the input signal impressed upon the summing circuit. Since the significant information of such pulses reside in their pulse width or, duration, and not in their amplitude, it is then possible to amplify such pulses to any desired gain until the desired output power level is obtained. This is done by impressing the output of the encoder means upon amplification means having a suitable gain characteristic.

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The amplified input signal may now be recovered by suitable filter means having a frequency response characteristic capable of passing all frequencies of the input signal, while providing cut-off of the frequencies contained in the scan signal. It has been found that the repetition rate of the scan signal need not be greater than the frequencies contained in the input signal. Tests on the system and calculations made to date indicate that the system is usable over a range considerably greater than that heretofore believed possible by such systems. The reason for this increased bandwidth is the scan signal and general system concept. Conventional limitations were based on sampling theorems using rigid sampling periods. This circuit permits a more random sampling of the input and hence gives better performance. The exact limits are not definitely established and appear to be dependent upon the application of the system.

In numerous applications, it becomes advantageous to obtain an output signal or waveshape which bears a nonlinear relationship to the input signal. This is provided for through the employment of scan signal generating means having the capability of providing a scan signal which is designed to provide an output signal which bears a nonlinear relationship to the input signal as one example, and which may further serve to cause the encoder means to fail to produce predetermined portions of the input signal waveshape for a variety of different purposes. As one typical example, it may be desired to enhance the signal-to-noise ratio of an incoming input waveform. This may readily be done by providing a scan signal having a requisite slope so as to provide amplification of all portions of the signal above a particular threshold level, while completely cancelling or attenuating all portions of the input signal below said threshold level.

In still a further example, the inverse relationship may be obtained whereby all portions of the input signal above the threshold level are completely attenuated, while those portions of the input signal below said threshold level are amplified to the desired gain level.

One preferred manner for extracting the amplified input signal is the provision of oscillating means which is controlled by the binary output signals from the encoder means. The output of the oscillation means is then detected by suitable detector means which may then be filtered in order to extract the amplified input signal. The provision of such oscillation means, however, provides suitable isolation between input and output of the amplifying circuitry which is an undesirable characteristic, and is to be avoided whenever possible.

It is therefore one object of the instant invention to provide means for amplifying an input signal which employs novel encoder means to transform the input waveshape into binary information.

Another object of the instant invention is to provide means for amplifying an input signal which is comprised of novel binary encoder means for encoding the input signal which is summed with a suitable scan signal.

Still another object of the instant invention is to provide means for amplifying an input signal which is comprised of novel binary encoder means for encoding the input signal which is summed with a suitable scan signal where the output of the encoder circuit is related to both the scan signal and the input signal.

Still another object of the instant invention is to provide means for amplifying input signals which is comprised of novel encoding means for transforming input waveshapes into binary information, which binary signals may be suitably amplified to any desired power output level.

Another object of the instant invention is to provide means for amplifying input signals which is comprised of novel encoding means for transforming input waveshapes into binary information, which binary signals may be suitably amplified to any desired power output level and wherein the amplified binary signals are decoded by suitable filter means to obtain the amplified input signal.

These and other objects of the instant invention will become apparent when reading the accompanying description and drawings in which:

FIGURE 1 is a block diagram showing an amplifier means designed in accordance with the principles of the instant invention.

FIGURE 2 is a schematic diagram of the non-linear amplifying means of FIGURE 1.

FIGURE 2*a* is a plot showing a curve relating the input signal to the output signal of the encoder means of FIGURES 1 and 2.

FIGURE 2*b* shows a plurality of waveforms employed to facilitate the description of the instant invention.

FIGURE 2*c* shows an alternative embodiment for the circuit of FIGURES 1 and 2.

FIGURE 3 is a block diagram of an alternative embodiment of the scan generating means shown in FIGURES 1 and 2.

FIGURE 4 is a plot of a waveform of one typical input signal which may be applied to the amplifying means of FIGURES 1 or 2.

FIGURE 5 shows an alternative scan signal which may be employed in the amplifying means of FIGURE 1.

FIGURES 6 and 7 show two more alternative scan signals which may be employed in the amplifying means of FIGURE 1 for additional applications thereof.

FIGURE 8 is a schematic diagram showing one preferred output stage which may be employed in the amplifying means of FIGURE 1.

FIGURES 9, 9*a* and 10–13 show other alternative embodiments which may be employed in the output section of the amplifying means of FIGURE 1.

FIGURES 14, 15 and 15*a* show alternative embodiments which may be employed in the amplifying section of the non-linear amplifier means of FIGURE 1.

FIGURE 16 is a waveform showing the diode characteristics of the diodes employed in FIGURES 15 and 15*a*.

FIGURES 17, 18 and 19 are schematic diagrams showing alternative embodiments of circuits for providing isolation between input and output of the non-linear amplifying means of FIGURE 1.

FIGURES 20 and 21 are schematic diagrams showing two alternative arrangements for the feedback loop of the non-linear amplifying means of FIGURE 1.

FIGURE 22 is a block diagram showing one application of the amplifying circuit of the instant invention.

FIGURES 22*a* shows the manner in which spacemen may converse by utilizing the scheme of FIGURE 22.

Referring now to the drawings, FIGURE 1 is a block diagram showing the amplifier means **10** of the instant invention which is comprised of an input signal source **11** which may be any suitable input signal such as, for example, input signals in the audio range, radio frequency range, or video range, as some typical examples. A summing means **13** is provided for accepting the input signal at its input terminal **14**, a scan signal at its input terminal **15** and a feedback signal at its input terminal **16**. Summing means **13** then suitably sums all of these signals to provide a single output which is impressed upon the encoder means **17**.

The scan signal source **12** may be any suitable scan signal generating means capable of providing the desired binary output information at encoder means **17** in a manner to be more fully described. Typical examples of the scan signal are a sawtooth waveform which is the waveform **2** and a triangle waveform such as the waveform **3**.

It is possible to generate a "scan signal" by causing the device itself to act as an "oscillator." An equivalent manner of analysis is to say that the amplifier is a non-linear, astable device with controlled limit cycles. The pulse width is controlled by the control of the limit cycle. An example is shown in FIGURE 2*c*. Suppose that Q_1 of FIGURE 2*c* is "on," then so is Q_3. The voltage v_1 is therefore going toward ground potential. This reduces the current fed back through r_{fb} and hence tends to turn Q_1 off thereby yielding the opposite effect. If the input signal is also applied to the base of Q_1 then the points where Q_1 turns on and off are controlled by the input thus developing "pulse width" information.

The summation of the inputs to summing circuit **13** (FIGURE 1) are impressed upon a non-linear encoder circuit **17** having a characteristic substantially as that shown in FIGURE 2*a* such that its output is at a voltage level d_0 when the input signal is below a first threshold level t_1, and further so that the output level is at d_1 when the input signal is greater in magnitude than the threshold level t_2. By using a scan signal such as, for example, the scan signal **2** or **3** of FIGURE 1, the width of the output signal derived from encoder means **17** may be controlled within any desired limits so that the amplitude of the input signals from signal source **11** are converted into pulse width information at the output of encoder means **17** With the information in pulse width as opposed to signal amplitude form, the output signals may then be amplified by the amplifying means **18** which need not be perfectly linear since the only portion which need be preserved in the output signal of encoder means **17** is the width of the pulse and not the height. After amplifying to a suitable power output level, the amplified binary information is then impressed upon an output section **19** which is utilized to filter out from the binary information the desired portion, or portions, of the input signal from signal source **11**. It should further be understood that the filter means may not be required in many applications. In order to provide relatively constant gain for the non-linear amplifying means of FIGURE 1, a feedback loop **21** is provided so as to control variations in gain or attenuation which may occur between summing means **13** and output terminal **20**. In addition, the gain can be used to control D.C. level and to help in filtering the output, and to do frequency response shaping or any other function generally performed by a feedback circuit.

Theory of operation

The objective of the circuit **10** of FIGURE 1 is to transform an input signal e_1 into a binary signal and then to ultimately recover the desired signal from the transformed binary information. The functional dependence of the binary signal upon the input is determined by the scan signal developed by scan signal generating means **12**.

The device which converts the continuous signal derived from input signal source **11** to the binary signal is the encoder means **17** which has the transfer function, as shown in FIGURE 2*a*. As the input signal impressed upon the encoder means increases from a minus quantity to zero and then from zero to a plus quantity, the output for encoder means **17** changes from d_0 to d_1. It will be noted that at the threshold level t_1, the output of encoder **17** moves along positive slope S until threshold level t_2 is attained, at which time the output remains constant at d_1. While it is somewhat advantageous to have the slope of the portion S of the waveform shown in FIGURE 2*a* as being perfectly vertical, it is not necessary that the encoder have a perfect binary transfer function, and it may be imperfect, as is shown in FIGURE 2a.

The effect of the scan signal which is summed with the input signal is to cause the summed signal to scan across the threshold levels of the encoder. One example is shown in FIGURE 2b for a triangular scan signal. A change in the level or amplitude of the input signal causes a corresponding change in the level of the output by changing the level produced by the pulses. The amount by which the output changes as a function of the input varies as a function of the slope of the scan signal. Referring more particularly to FIGURE 2b, the first plot **30**a shows a triangular waveform summed with an input signal at a time when the input signal voltage level is zero volts. At this time, the triangle waveform rests directly upon the time axis which is a zero volt reference level. At time t_0, the triangular waveform has a value of zero volts, but as time increases the value of waveform **30**a increases in a positive direction. At time t_1, the value of the triangular waveform output reaches the threshold level of the encoder means **17** at which time the output of the recoder **17** changes from the voltage level d_0 to the voltage level d_1, as shown by waveform **30**b. Between the times t_1 and t_2 the value of the triangular waveform is greater than the threshold level **33** so that the output of encoder **17** remains at the voltage level d_1. At time t_2, the voltage level of triangular waveform **30**a decreases below the threshold level **33**, causing the encoder output **17** to drop to the voltage level d_0, as shown by waveform **30**b. Between the times t_2 and t_3, the voltage level of the triangular waveform **30**a remans below the threshold level **33**, causing the output of encoder **17** to remain at voltage level d_0. In a like manner, between times t_3 and t_4, the voltage level of triangular waveform **30**a exceeds the threshold level **33**, causing the output of encoder **17** to be at the level d_1 during this time period.

Considering the waveforms **31**a and **31**b, it can be seen that the triangle waveform **31**a has been "lifted," due to the summation of the triangle waveform with a substantially constant voltage (relative to the scan signal) of a magintude V. In this particular instance, the encoder will generate an output, as shown by waveforms **31**b at time t_1, wherein time t_1 occurs almost immediately after time t_0 due to the fact that at t_1, the summation of the triangle waveform **31**a with the constant voltage V, exceeds the threshold level **33**. Thus, the time t_1 in the waveform **31**a occurs substantially before the time t_1 in the waveform **30**a. In a like manner, the triangular waveform does not go below the threshold level **33** until time t_2 which can be seen to occur after the time t_2 of the waveform **30**a. This forms the square pulse having a time duration t_2-t_1, as shown by waveform **31**b, which is substantially greater than the time duration of the first square pulse shown in waveform **30**b. In a like manner, the second square pulse is formed during the times t_3 to t_4, and is substantially identical to the first time pulse. Since the square pulses of waveforms **30**b and **31**b have substantially the same magnitudes, the information which they carry is contained within their pulse widths, or time duration, and it is the time duration which is employed as the means for relating the binary pulses to the amplitude of the input signal source. While the waveforms of FIGURE 2b show a scan signal of a frequency greater than the frequency or repetition rate of the input signal it should be understood that in many applications the scan signal may be chosen to have a repetition rate which is equal to or less than the repetition rate of the input signal.

As still a further example, the waveform **32**a which is another triangle waveform, is shown summed with a negative voltage, so that is forms the two square pulses shown in waveform **32**b which are substantially narrower than both the pulses shown by waveform **30**b and waveform **31**b. This is due to the fact that the summation of the constant voltage with the triangle waveform **32**a does not exceed the threshold levels **33** until the time t_1 which occurs substantially later than the times t_1 in the examples of **30**a and **31**a, and further, the resultant waveform of **32**a goes below the threshold level of time t_2, and further the resultant waveform **32**a drops below the threshold level **33** at a time t_2 which occurs substantially before the times t_2 of the waveforms **30**a and **31**a, causing the two square pulses of waveform **32**b to be formed which are substantially narrower in pulse width (i.e., time duration) than the square pulses or binary pulses of wave forms **30**b and **31**b.

The scan signal

The scan signal is the primary determinant of the system, and controls the application thereof. Its form, therefore, ascertains the use of the system. The uses can generally be classified as:

(1) Linear amplitude operations.
(2) Non-Linear amplitude operations.
(3) Scan fundamental operations.

A linear operation is one in which the output desired is a linear function of the input signal. A non-linear operation is one in which the desired output amplitude is a non-linear function of the input signal amplitude.

In some applicatios such as, for example, the driving of an A-C servo motor, the primary objective is to maintain a fundamental frequency component in the output signal and to operate upon this fundamental frequency component so as have complete control of the driven device (i.e., the servo motor). One method of doing this is to utilize the frequency of the scan signal as the desired output frequency fundamental and to operate upon this fundamental frequency so as to control the output thereof. This is defined as a "scan fundamental operation."

Each of the following applications utilize a different form of scan signal generator:

Linear amplitude operation

A scan signal having a waveform that is linear with time may be used as the scan signal in an application where it is desired to have an output whose amplitude is a linear function of the input amplitude. The two simplest linear forms are the "ramp" and the "triangle." These signals may be generated by any conventional means such as, for example, a sawtooth generator, a triangle generator, etc.

A typical circuit which may be employed for the block diagram of FIGURE 1 is shown in schematic form in FIGURE 2. The scan signal generator which, in this case, is a sawtooth generator, is comprised of a unijunction transistor Q_1 having tow base electrodes b_2 and b_1 connected through respective resistances **22**a and **22**b to a positive 10 volt source and ground potential respectively. The emitter electrode of the unijunction transistor Q_1 is connected to the common terminal between series connected resistor and capacitor elements **24** and **23** respectively, the opposite terminals of which are connected to the positive 10 volt source and ground potential. The operation is such that when the emitter of unijunction transistor Q_1 has a very small current, capacitor **23** begins charging thereby forming the positive going ramp of the sawtooth scan signal (see segment **22**a of waveform **22** in FIGURE 1). After a predetermined time, capacitor **23** charges so that the common terminal between capacitor **23** and resistor **24** reaches a voltage level causing the emitter to b_1 resistance to drop rapidly. At this time, transistor Q_1 causes capacitor **23** to discharge through unijunction transistor Q_1 and resistor **22**, thereby forming the negative going portion of the sawtooth waveform (see portion **22**b of waveform **22** in FIGURE 1). This sawtooth waveform, which is the scan signal, is passed through series connected capacitor **25** and resistor r_2 to the base electrode of transistor Q_2. Also connected in common with the base of transistor Q_2 is a resistor r_1 which receives the input signal from the input signal source, such as the source **11**, as shown in FIGURE 1.

The arrangement of resistors **26** and **27** connected in common with the base electrode of transistor Q_2 provides the summation circuit **13** of FIGURE 1. The resultant waveform is, therefore, used to drive the transistor Q_2 in a bi-stable manner (transistor Q_2 serving as the encoder means **17**) so as to form the square pulses **29***a* at the collector electrode transistor Q_2. These pulses are passed through resistor **28** to the base electrode of transistor Q_3 which suitably amplifies these binary pulses shown at **29***c* which appear at the output terminal **29***b*. The purpose of FIGURE 2 is to show the use of the unijunction scan generator in a typical circuit and its intergration with the remainder of the non-linear amplifying means circuitry.

It should also be noted at this point that it is not necessary to provide a scan generator for each amplifying means. It is possible to use a single scan generator for driving many amplifier circuits in common. In such situations, the scan signal can be viewed as another input signal to the amplifying means.

To obtain a linear scan, it is also possible to employ a triangle waveform scan signal rather than the ramp or sawtooth (see waveforms **2** and **3** of FIGURE 1). FIGURE 3 shows a block diagram embodiment **30** for obtaining a triangle waveform scan signal. The arrangement is comprised of limiting means **32** for receiving an A-C signal **31** at its input terminal, and providing the square pulses **33** at its output terminal due to the limiting action. The square pulses **33** are impressed upon an integrating circuit **34** which, due to its inherent characteristics, forms the triangle waveform **35** at its output terminal **36**. Thus, output terminal **36** may be connected to the base electrode of transistor Q_2 as a substitute for the sawtooth waveform scan generating means comprising unijunction transistor Q_1 of FIGURE 2. The circuitry of FIGURE 3 is of a highly advantageous arrangment, since the input signal in the limiting means **32** is usually available from a variety of locations such as any suitable nearby power supply source, etc.

Non-linear amplitude operation

While the following examples are by no means intended to be an exhaustive treatment of the variety of non-linear applications, it is felt that the following examples will suffice in order to obtain an understanding of non-linear operation for the amplifying means of FIGURES 1 and 2.

In the section on the theory of operation, the effect of the scan signal slope upon the system gain was considered. The general concept for non-linear operation is to have a scan signal whose slope is non-linear with respect to time. The output is then a function of the amplitude of the input signal to the encoder. Consider the following examples:

Let it be assumed that an input signal shown by the waveform **41** in the plot **40** of FIGURE 4 is comprised of information pulses such as, for example, the pulses **42**, and is further comprised of the low level noise components **44**, wherein a high content of such low level noise is present.

In order to minimize the effect of the noise level upon the information signal, it is possible to employ a scan signal, such as the scan signal waveform **51**, shown in the plot **50** of FIGURE 5. The scan signal waveform **51** is comprised of two portions during each cycle wherein a first portion **51***a* which occurs between the time $0–t_0$ and $t_1–t_2$ has a substantially steep slope. The portion **51***b* occurs within the times $t_0–t_1$ and $t_2–t_3$ of the two cycles of the scan signal, shown in FIGURE 5. It can be seen that the portion **51***b* has a smaller slope which is significantly less than the slope of portion **51***a*. The breakpoint between the two slopes **51***a* and **51***b* occurs at times t_0 and t_2 and is designated by the gain transition level phantom line **53**. The input waveform **41** and the scan signal waveform **51** are impressed upon the amplifier of the instant invention in such a manner that the scan signal has a reverse polarity from that shown in the waveform of FIGURE 5 so that it is subtracted from the input waveform **41**. Consider first the noise segments, **44**, of the input waveform **41**. The combination of the input, **41**, and the scan waveform, **51**, is such that it never causes the gain transition level **53** to pass the threshold of the encoder. The effect is therefore that of a substantially steep slope scan signal **51***a*, thereby giving little gain to the input. Consider now inputs that are sufficiently large so that their combination with the scan signal will cause the portion **51***b* of the scan to be employed. This will occur for all inputs in excess of level **43**. When such portions of input **41** as the pulses **42** occur they exceed level **43** and are effectively scanned by segments **51***b* and therefore have a higher gain. Whereas the scan signal waveform **51** is shown to occur substantially in synchronism with the input waveform **41**, such that its steep slope portions **51***a* are in alignment with the noise level portions **44** and its relatively small slope portions **51***b* are in alignment with the signal level portions **42**, it should be understood that when operating the amplifier circuit in this manner it is not at all necessary that synchronism occur between the scan signal waveform **51** and the input waveform **41** since the scan signal acts to effectively reduce the noise level present in the input waveform, regardless of both the phase and frequency relationship between the scan signal and the input signal waveforms.

The reverse situation which may occur from that given above is that wherein the desired signal is contained in the low level information while the high level information is that which is undesirable or unwanted. Thus, considering the plot of FIGURE 4, in this example, the information desired to be derived from the input waveform **40** is the low level signal portions **44** whereas the high level portions **42** in this particular example are either undesired or unwanted.

In this situation, the scan signal waveform **61** of the plot **60**, shown in FIGURE 6 is employed. The scan signal waveform **61** is comprised of two waveform portions **61***a* and **61***b* wherein the portion **61***a* which occurs between time $0–t_0$; $t_1–t_2$; and $t_3–t_4$ and has a substantially steep slope. The portion **61***b* occurs between the time $t_0–t_1$; $t_2–t_3$ and has a substantially small slope. In this instant the scan and information signal waveform are impressed upon the amplifier circuit in an additive fashion. Considering the low lever portion **44** of FIGURE 4 and the scan signal portion **61***a* of FIGURE 6, it can be seen that the resultant waveform will be substantially greater in magnitude than the low level portion **44** and will lie well above the cut-off level **63** of the amplifier. Considering the high level portion **42** of FIGURE 4 and the scan signal portion **61***b* of FIGURE 6, it can be seen that the resultant signal occurring due to a summation of these two portions will be increased only slightly above the original high level signal portion **42**. Thus the resultant waveform permits the user a vastly improved opportunity for observing and examining the low level portion **44** of the input signal waveform **41**. Again, it should be noted, as was stated previously, with respect to the scan signal **51** of FIGURE 5, that phase and frequency synchronism is neither required nor desired as between the scan signal waveform **61** and the input waveform **41** of FIGURES 6 and 4, respectively.

In the selection of the slope of the scan signal portion **61***a* and **61***b* of scan signal **61**, the objective is to increase the gain of the amplifier to as high a level as possible without saturating the amplifier, the effect of which would be to cancel or diminish the function for which the scan signal **61** is employed.

In addition to the amplifying function recited above where it may be desired to either increase or diminish the effect of low level noise, the encoding capabilities of the amplifier which is comprised of a waveform having square pulses of equal amplitude and varying pulse widths. Such output waveforms would be similar to those shown in the plots **30*b*, 31*b*** and **32*b*** of FIGURE 2*b* described previously.

The scan signals **51** and **61**, shown in FIGURES 5 and 6, may be generated by any suitable scan signal generator, such as, for example, the scan signal generator identified by the name waveform synthesizer and manufactured by the Exact Electronics Corporation of Hillsborough, Oreg. It should be understood that any other suitable scan signal generator or waveform synthesizer may be employed since the specific generator employed lends no novelty to the circuitry of the instant invention.

A still different concept of non-linear scan signals can be obtained when considering the time perspective. Suppose, for example, that periodic data of the form shown in FIGURE 4 is being imposed upon the non-linear amplifying circuit of FIGURE 1, and that only a certain time portion of the incoming waveform is to be amplified. A scan signal of the form **71**, shown in the plot **70** of FIGURE 7 may be employed, which scan signal is synchronized with the clock frequency rate of the input signals. If the lower levels **74** of the scan signal are sufficient to keep the encoder means off, then the only portions of the input signal amplified will be those portions where the normal scan signal appears. In this manner, portions of any predetermined length may be deleted (i.e., attenuated) from the incoming data signals. Those portions which are to be amplified, however, may be either non-linear, linear, or a combination thereof.

Output stages

The output stage **19** of FIGURE 1 is a design which depends upon the intended use of the amplifying means **10**. The most fundamental amplifying means is that shown in FIGURE 8, which amplifying means **80** is comprised of a transistor Q_1 receiving the output from the encoder means at its base electrode **83**, having its collector and emitter electrodes connected through respective resistors R_L and R_e to the voltage source terminals **81** and **82**, respectively. The output is taken at point **84** from the collector electrode. The embodiment **80** of FIGURE 8 assumes that either the load filters out any unwanted signal introduced by the scan signal, or that the spurious signals are used by the load as in the scan fundamental operating mode.

An alternative embodiment **90** is shown in FIGURE 9, and is employed primarily as means for compensating for a D-C level which may be introduced into the load. With the arrangement **90** of FIGURE 9 the transistor Q_1 has its collector and emitter electrodes connected to the resistors R_L and R_e, respectively. The terminals **92** and **91** of the voltage source are connected to the resistors R_L and R_e respectively, with suitable diode means **93** being connected between the terminal **92** and the resistor R_L. The second voltage source is connected at terminals **96** and **97** through a diode **94** and a resistor **95**. This power source is connected and polarized in such a manner so as to counteract a D-C level established by the fundamental circuit. The output as seen by the load can now go positive or negative.

A modified embodiment **90*a*** of the circuit **90**, shown in FIGURE 9 is shown in FIGURE 9*a* and is comprised of transistors Q_1 and Q_2 wherein transistor Q_1 is connected to the first voltage source via terminals **92*a*** and **91*a***, and the second voltage source is connected at terminal **97** which is in electrical series with the emitter electrode of transistor Q_2, the collector electrode of which is connected to the terminal **92*a*** through resistor Y. The base electrode of transistor Q_2 is connected to the collector electrode of transistor Q_1 and operates to control the power supply connected to terminals **97** and **98** in such a way that when transistor Q_2 is conducting, transistor Q_1 is off, and vice versa. This arrangement also enables the output as seen by the load to go either positive or negative. Assuming that R_L is driven by two sources v_1 and v_2, the current through R_L is $i_1 - i_2$; by superposition the sum of the currents due to v_1 and v_2, the objective of FIGURES 9 and 9*a* is to show that this current can be controlled by diodes D_1 and D_2. In FIGURE 9 when, D_2 is closed; with D_1 open the current is i_2. When Q_1 conducts, the current is $i_1 - i_2$. If $i_1 > i_2$ then the effect of being conductive Q_1 is to reverse the direction of i_2. In FIGURE 9*a*, both Q_1 and Q_2 are used. They are connected so that when Q_1 conducts Q_2 is in cut-off and $i_L = i_1$; and when Q_2 conducts Q_1 is cut-off and $i_L = i_2$, thereby effecting a change in direction of i_L.

Bridge circuits can also be utilized for the bi-directional outputs. In some circuits, it may be desirable, however, to remove the high frequency components before they are admitted to the load. In such situations, a low pass filter may be added so that only the desired frequencies go to the load means. FIGURE 10 shows an embodiment **100** which may be employed with the bi directional circuit of FIGURE 9 and which is comprised of a transistor Q_1 which contains, in addition to the resistor R_1 in its load circuit, a low pass filter means comprised of the resistor and capacitor elements **103** and **104**, respectively, which elements cooperate to form a low pass filter means to filter out all unwanted high frequencies. It should be understood that other situations may exist where filters of different pass bands may be desired other than the low pass filter of FIGURE 10, and the output circuit or stage **100** of FIGURE 10 may employ filters of other pass band characteristics other than the low pass band filter shown therein.

Power amplifier stage

The amplifying stage or section **19** of FIGURE 1 may utilize the circuit arrangement **110**, as shown in FIGURE 11 of the drawings. In this arrangement, the binary pulses from the encoder means **17** are impressed upon the base electrode **111** of a transistor Q_1. The level of the pulse is amplified and applied to the base of transistor Q_2 through the resistance means **114** which, in turn, provides a second stage of amplification amplifying the already amplified signal output from transistor Q_1 and providing this second stage of amplification at its output terminal **117**. It has been found to be advantageous, but not absolutely necessary, to utilize the bi-level aspect of the transformed signal to drive the individual stages into or out of saturation, or nearly so. Operating in this manner causes less power to be dissipated in the active transistor devices Q_1 and Q_2. It also eliminates D-C biasing problems common to conventional amplifiers. The combination of this type of operation and the scan signal concept permits the use of a D-C amplifier with directly coupled stages, thereby eliminating the problem of D-C shift. The stability of the amplifier, therefore, is determined primarily by the scan signal and, hence, is an A-C and not a D-C problem.

The amplifier stages do not have to appear as shown in FIGURE 11. An alternative arrangement such as the schematic embodiment **120** shown in FIGURE 12 may be employed. This arrangement employs NPN and PNP transistors Q_2 and Q_3–Q_1, respectively, such that the collector electrodes of the PNP transistors Q_1 and Q_3 are connected to the negative voltage bus **129*b***, while the collector electrode of the NPN transistor Q_2 is connected to the positive voltage bus **129*c***. This complementary symmetry arrangement has been found to be highly advantageous.

The circuitry **130** of FIGURE 13 teaches the employment of unijunction transistors, such as the transistors Q_1 and Q_2 to provide a unijunction operation. The output of the encoder means **17** is impressed upon the input terminal **131** which is connected through the voltage divider circuit comprised of resistors **133** and **132** to the control electrode of unijunction transistor Q_1. As the input voltage is raised with the control electrode of unijunction transistor Q_1, it is triggered and fired, thereby raising the voltage at the base electrode b_1 of transistor Q_1 due to the increased voltage drop across resistor **134**. This causes the voltage level at the control electrode of unijunction transistor Q_2 to be raised sufficiently enabling transistor Q_2 to fire, thereby increasing the voltage drop across the load resistor R_L. By dropping the input voltage at input terminal **131**, this causes the reverse action to take place.

The same general concept of operation can be obtained with any device capable of bi-level operations. Other such typical devices are relays, silicon controlled rectifiers, trigistors, and diodes, to name just a few.

Variations in the system become obvious when it is observed that the significant information of the transformed signal is in the time of transition. Hence only this transition time, or its equivalent, need be transmitted and amplified.

FIGURE 14 shows a schematic diagram **140** which exemplifies this concept. The bi-level signal which is obtained as the output signal from the encoder means **17** of FIGURE 1 is impressed upon the base electrode **147** of transistor Q_1. The signal which is suitably amplified and shown at **143** then appears at the output or collector electrode of transistor Q_1. The signal is then impressed upon a differentiation circuit comprised of the capacitor and resistor elements C and R to produce the output pulses **144** and **145**. Amplification or transmission of these pulses is sufficient for maintenance of all the desired information of the signal. It is not necessary to produce the pulses in the specific manner shown in FIGURE 14, nor need they be in the opposite directions, as shown therein. Only their position in time relation need be maintained.

A direct continuation of the concept employed in FIGURE 14 is shown in the embodiment **150** of FIGURE 15 which employs diode amplifying means. In the circuit **150**, the tunnel diodes D_1 and D_2 (or their equivalent) are used for amplification purposes.

FIGURE 16 shows a plot **160** which presents the curve **161** representing the tunnel diode current-voltage characteristic. Let it be assumed that the diodes D_1 and D_2 are in their lower voltage state v_1. A positive pulse **151** is then applied through resistor R_2 to the anode electrode of diode D_1. This drives the diode D_1 through the negative resistance region to its second stable operating point at voltage level v_2. The voltage across diode D_1 thereby appears as the waveform **153** at the anode electrode of diode D_1 due to the bi-stable characteristic of diode D_1. This output voltage is suitably differentiated by the differentiation network comprised of capacitor and resistor C_1 and R_1 respectively so as to form the positive pulse **154** which it should be noted has a greater magnitude than the pulse **151**. The pulse **154** is then employed to switch the following stage containing tunnel diode D_2 to generate the output **156**. The negative pulses **152** and **155** are employed to reverse the procedure so as to form the trailing edges of the square pulses **153** and **156** respectively. Power gain is obtained by the increased voltage and current levels in the successive diode stages.

FIGURE 15*a* shows an alternative embodiment **150*a*** which may be substituted for the embodiment **150** of FIGURE 15. In the circuit **150*a***, a transformer means T is provided which receives an input waveform **153** which is differentiated to form pulses **154** and **155** by the differentiation circuit C_1–R_1, thereby impressing these pulses upon the primary winding of transformer T. The secondary winding or transformer winding T is connected across the anode and cathode electrodes of the tunnel diode D_1 which generates the output **156** is substantially the same manner as that described with respect to the diodes D_1 and D_2 of FIGURE 15. The transformer T thereby serves to provide a voltage gain in the embodiment of FIGURE 15*a*, as well as providing D-C isolation between the input and output stages of FIGURE 15*a*. An obvious extension of the embodiment **150*a*** of FIGURE 15*a* would thereby be the use magnetic amplifiers having suitable characteristics to provide substantial gain in addition to providing the isolation function of the device of FIGURE 15*a*.

As another operating concept, let it be assumed that a bi-level signal is applied to a device such as a voltage tuned klystron whereby F.M. modulation results. Suppose, however, that the range of oscillation is between both levels. The resulting output is then a pulse of varying frequency marking the crossover. This is then all the information necessary for complete reconstruction of the signal. Such pulses are of a "chirp" nature which, according to the articles entitled:

(1) Klystron & Microwave Triodes; Rad Lab Series #7, McGraw-Hill, 1948. Chapter 16, page 441, shows the basic concept of the encoding process. FIGURE 16.1 in particular gives the output power and frequency spectrum for two types of input signals of interest.

(2) Radar Engineering; Fink, McGraw-Hill, 1947, page 424, FIGURES 305 and 306, shows a more specific form for accomplishing the above object. Any state of the art circuit is sufficient.

The coding can also be in the form of "modeing." That is, at both levels of the input signal, the klystron oscillates, but at two different modes.

Input-output isolation

In the circuits discussed so far, it can be seen that a common continuous path occurs between input and output. Such a situation is not permissible in most circuit arrangements due to D-C level problems imposed, as well as other problems. Returning to a consideration of FIGURE 15*a*, this embodiment provides an indication as to one method of isolation between input and output. Another method which may be employed is that of triggering an oscillator on and off, in accordance with the binary level of the output derived from the encoder means **17** of FIGURE 1. Three such embodiments are set forth in FIGURES 17 through 19 respectively. Considering first FIGURE 17, the output of encoder means **17** of FIGURE 1 forms pulses such as, for example, the pulse **171** impressed upon the base electrode of transistor Q_2. Transistor Q_2 is arranged to operate as an amplifying means which impresses its output upon the control or trigger electrode of a unijunction transistor Q_1. The operation of FIGURE 17 is essentially that of the unijunction relaxation oscillator. When Q_2 is on, Q_1 oscillates as normal. When Q_2 turns off the oscillation of Q_1 closes. The transformer T in the b_1 lead of Q_1 is used for coupling of the A.C. components of the oscillation. FIGURES 17, 18 and 19 show that control of the oscillator can be had by placing Q_2 in any of the three legs of Q_1. A detector circuit comprised of diode D_1 and parallel connected capacitor and resistor C_2–R_2 forms a square wave output pulse **173** which is basically the envelope of the waveshape **172**. Employing this embodiment not only preserves the identity of the square wave **171** which can be seen is substantially identical to the output waveshape **173**, but further provides isolation between input and output.

The embodiment **180** of FIGURE 18 differs from the arrangement **170** of FIGURE 17 in that the control transistor Q_2 is connected in series relationship with the unijunction transistor Q_1 in such a manner that when the square pulse **171** is present, this completes the series circuit between positive and negative voltage busses **185** and **186** respectively, enabling oscillation to occur in substantially the same manner as that described with reference to FIGURE 17 to provide an output **173'** substantially identical to the output **173** contained in FIGURE 17.

The embodiment **190** of FIGURE 19 differs from the arrangement **180** of FIGURE 18 in that the transistor Q_2 has its emitter and collector electrodes connected so that the transistor Q_2 is in parallel with a resistor element R_3. When the square pulse **171** is impressed upon the base electrode of transistor Q_2, this effectively short-circuits resistor R_3 to a degree sufficient to permit oscillations to occur. Any one of the embodiments **170, 180** or **190** may be employed as the isolating means for the non-linear amplifying circuitry of FIGURE 1.

Feedback

Feedback around the entire circuit may be accomplished as in any other circuit arrangement. There are, however, some unique feedback characteristics which are inherent in the system of the instant invention. FIGURE 20 demonstrates one of these for a simplified version of the non-linear amplifying means. FIGURE 20 shows an embodiment **200** having a summing circuit which is comprised of resistors R_1, R_2, R_3 and R_4. The encoder is comprised of transistor Q_1 and the amplifier stage is comprised of transistor Q_2 with the load appearing as resistor R_L. The summed, or resultant, voltage that is fed into the base electrode of the encoder transistor Q_1 is developed across resistor R_4 and is due to the currents present in resistors R_1, R_2 and R_3. Suppose, for example, that the supply voltage V_S diminishes somewhat. It would be expected that the voltage drop across R_L would also decrease. The drop in supply voltage V_S, however, reduces the current in resistor R_3. This lowers the net voltage at the base of transistor Q_1. Hence transistor Q_1 will be cut off for a longer portion of the scan period. This thereby causes transistor Q_2 to be on for a longer portion of the scan period, causing an increase in the D-C level of the output. This makes apparent the ability of resistor R_3 to control the D-C level of the output signal.

An alternative form of overall feedback is shown in the schematic circuit **210** of FIGURE 21, which arrangement will compensate for any type of drift. To outline this operation, suppose, for example, that the output across the load resistor R_L becomes too positive. This means that the voltage across capacitor C will also go positive. The current fed back through the resistor R_f is thereby reduced. This reduces the voltage drop across resistor R_4, thereby causing transistor Q_1 to be off for a longer period of the scan cycle, and likewise causing transistor Q_3 to be off for a longer portion of the cycle, thereby causing the level across the load resistor R_L to go more negative. It should be noted that the polarity of the feedback depends on the phase of the stage fed back relative to the encoder means. For example, the encoder means being transistor Q_1, is amplified by an amplifier stage comprised of first transistor Q_2 and then a second amplifier stage comprised of transistor Q_3. The first amplifier stage has as an inherent characteristic the phase inversion of the signal impressed upon its base electrode which inversion is the 180° phase inversion. By placing this completely inverted signal through a second stage of amplification, a second phase inversion of 180° occurs, thereby shifting the ultimate output signal after its original phase condition. By adding a third stage, or by removing one of the two amplifying stages, this arrangement may be employed to change the polarity of the feedback.

One scheme of application for the instant invention is of the arrangement **250** shown in FIGURE 22. The arrangement **250** is comprised of a first location **260** which utilizes the amplifier circuit **10** of the instant invention which is substantially similar to the schematic arrangement **10** of FIGURE 1. The block **251** represents a suitable microphone or speaker means capable of converting voice into electrical signals. The electrical signals are impressed upon the amplifier **10** and are employed as the input waveforms. As previously described, the amplifier **10** generates square pulses of substantially equal magnitude, but of varying pulse widths. These signals are impressed upon a light source **252** and act to modulate light signals so that the light source **252** generates light signals of equal intensity but of varying time duration. These light signals represented by the line **253** are directed to a remote location **260'** which is provided with a suitable light or photo-sensitive pickup means **254**. The photo-sensitive pickup means **254** is capable of converting the light pulses or flashes which impinge on the photosensitive means and converting them to electrical signal pulses of substantially identical waveshape to the output of amplifier **10** at location **260**. These square pulses are impressed upon suitable speaker means, such as, for example, ear phones which are capable of converting the square pulses into sound. The speaker means is identified by the block designated **255**. There is no necessity to decode the equal magnitude square pulses of varying time duration since the ear phones coupled to the light detection means **254** load the light detection means **254** sufficiently to act as a decoding means, thus avoiding the need for any filter means to decode the incoming signals.

Remote location **260'** may be provided with a transmission circuit comprised of a microphone or speaker **251'**, amplifier circuit **10'** and a light generating means **252'** substantially identical to the elements **251**, **10** and **252** respectively, of location **260**. Likewise, location **260** may be provided with suitable light sensitive pickup means **254'** and ear phone means **255'** substantially identical to the elements **254** and **255** of location **260'**.

The arrangement of FIGURE 22 may be advantageously employed in the field of space exploration. Let it be assumed that spacemen are deployed to regions of the universe beyond the atmospheric layers of the earth or other planets and well into space. It will be under such conditions substantially impossible for two or more such spacemen to communicate to one another due to the fact that the space is substantially devoid of air or atmosphere so that there is no suitable means which exists for carrying voice signals from one location to another. In order to enable such voice communication to be carried out, each spaceman, such as, for example, the spaceman **270** and **271** of FIGURE 22*a*, is provided with a facility **260** or **260'** substantially identical to those shown in FIGURE 22. For voice communication to take place, spaceman **270** merely speaks into the microphone **251**, which signals are coded by the amplifier **10**, the output of which is used to modulate the light source **252**. The modulated light **253** is then received by the photo-sensitive pickup **254** provided in the facility **260'** of spaceman **271**. The modulated light is converted into electrical signals which are in turn converted by the ear phones **255** into suitable sound signals. Spaceman **271** may converse with spaceman **270** in substantially the same manner by speaking into microphone **251'**, which voice signals are ultimately transmitted and then decoded at facility **260** by ear phones **255'**. This arrangement thus makes it quite simple for individuals to converse with one another in environments where the amount of air present to propogate voice signals is extremely small. It should be understood that the above arrangement is merely exemplary and that the invention is not limited to voice amplications.

It can therefore be seen that the instant invention provides an amplifying means for suitably amplifying input signals through the employment of a non-linear or binary coding concept, which, even through introducing nonlinetarity to the input signals by transducing them into binary signals, nevertheless, is capable of producing an output signal which is substantially an exact replica of the input signal amplified to a suitable level.

Although this invention has been described with respect to preferred embodiments thereof, it should be understood that many variations and modifications will now be obvious to those skilled in the art, and it is preferred, therefore, that the scope of this invention be limited not by the specific disclosure herein, but only by the appended claims.

The embodiments of the invention in which an exclusive privilege or property is claimed are defined as follows:

1. Amplifying means comprising an input signal source; scan signal generating means for generating a scan signal; summing means having three input terminals for summing the instantaneous output signals of said scan signal generating means applied at a first input terminal and said input signal source applied at a second input terminal; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; filter means connected to the output of said first amplifying means, the output of said filter means being an amplified replica of the output of said input signal source; feedback means connected between said filter means output and the third input terminal of said summing means.

2. Communication means for transmitting information between two or more remote locations wherein each location is provided with first means for generating electrical signals representative of the information to be transmitted, said first means comprising means for converting audio information into electrical signals;

amplifying means of the type described in claim **1** for encoding said electrical signal;

transmitting means operated by said amplifying means for generating light pulses;

receiver means at each location comprising light-sensitive means for converting light pulses depending upon said light sensitive means into electrical signals; and means for converting said electrical pulses into audio information.

3. The amplifying means of claim **1** further comprising first and second bias means; first and second diode means coupling said first and second bias means respectively, to said first amplifying means being connected with their polarities arranged to permit generation of either positive or negative polarity output signals.

4. The amplifying means of claim **1** further comprising first and second bias means coupled to said first amplifying means;

transistor means coupled between said first amplifying means and said first bias means;

impedance means coupled between said second bias means and said first amplifying means;

second impedance means coupled between said first amplifying means and said transistor means selectively operating said transistor means to permit generation of output signals of either positive or negative polarity.

5. Amplifying means comprising an input signal source; scan signal generating means for generating a scan signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; filter means connected to the output of said first amplifying means; said scan signal generating means including means for generating an output waveform adapted to prevent the magnitude of said summing means resultant output signal from achieving said threshold level for selecting only portions of said input signal to be amplified.

6. Amplifying means comprising an input signal source; scan signal generating means for generating a scan signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein the said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; filter means connected to the output of said first amplifying means, the output of said filter means being an amplified replica of the output of said input signal source; said first amplifying means comprising a first differentiation circuit for converting said encoding means output signal into impulses spaced at predetermined intervals and means for converting said impulses into an amplified replica of the output signal of said encoding means.

7. Amplifying means comprising an input signal source; scan signal generating means for generating a scan signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshhold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; filter means connected to the output of said amplifying means, the output of said filter means being an amplified replica of the output of said input signal source; said first amplifying means comprising a transistor amplifier stage for amplifying the output of said encoding means; a differentiation circuit connected to said transistor amplifier stage for converting the amplified binary output signals into impulses spaced at predetermined time intervals, the length of said time intervals being substantially equal ot the width of said binary signals.

8. Amplifying means comprising an input signal source; scan signal generating means for generating a scan signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a secondary binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; filter means connected to the output of said amplifying means, the output of said filter means being an amplified replica of the output of said input signal source; said first amplifying means comprising a first differentiation circuit connected to the output of said encoder means for converting the binary output signal into impulses spaced at predetermined time intervals; a first amplifier stage comprised of tunnel diode means for converting said impulses into binary signals; the binary output signals of said first amplifier stage being amplified replicas of said encoding means binary output signals.

9. Amplifiying means comprising an input signal source; scan signal generating means for generating a scan signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; filter means connected to the output of said amplifying means, the output of said filter means being an amplified replica of the output of said input signal source; said first amplifying means comprising a first differentiation circuit connected to the output of said encoder means for cnoverting the binary output signals into impulses spaced at predetermined time intervals; a first amplifier stage comprised of tunnel diode means for converting said impulses into binary signals; the binary output signals of said first amplifier stage being amplified replicas of said encoding means binary output signals; a second differentiation circuit connected to the output of said first amplifier stage for converting said binary output signals into impulses spaced at predetermined intervals; a second amplifier stage comprising tunnel diode means for converting said impulses into binary signals, the binary output signals of said second amplifier stage being amplified replicas of the binary output signals of said first amplifier stage.

10. Amplifying means comprising an imput signal source; scan signal generating means for generating a scan signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; filter means for averaging the output of said amplifying means, the output of said filter means being an amplified replica of the output of said input signal source; input-output isolation means connected between said first amplifying means and said filter means comprising a control stage having its input connected to the output of said first amplifying means; oscillator means; said control stage being connected to said oscillator means for enabling operation thereof upon receipt of a first binary signal from said first amplifying means; detector means for converting said oscillator output signals into binary signals; transformer means inductively coupling said oscillator means to said detector means; the output of said detector means generating binary signals which are amplified replicas of the binary output signals of said first amplifying means; said transformer means being adapted to isolate the amplifier means output from its input.

11. Amplifying means comprising an input signal source; scan signal generating means for generating a scan signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; said scan signal generating means including means for generating a non-linear output waveform having a portion of each cycle of said output waveform adapted to prevent the magnitude of said summing means resultant output signal from achieving said threshold level for selecting only portions of said input signal to be amplified.

12. Amplifying means comprising an input signal source; scan signal generating means for generating a scan signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoding means; said first amplifying means comprising a transistor amplifier stage for amplifying the output of said encoding means; a differentiation circuit connected to said transistor amplifier stage for converting the amplified binary output signals into impulses spaced at predetermined time intervals, the length of said time intervals being substantially equal to the width of said binary signals; tunnel diode means for amplifying and converting said impulses into binary signals.

13. Amplifying means for reducing noise level in an input signal comprising first means for receiving said input signal; scan signal means for generating a repetitive waveform, said scan signal waveform having a substantially steep slope during a first portion of each cycle of said repetitive waveform; and having a slope substantially less than the slope of said first portion during the remaining portion of each cycle of said repetitive waveform; and means for subtracting said scan signal from said input signal to generate an output signal in which the noise level content is substantially reduced.

14. Means for converting signal amplitude information into pulse width information comprising amplifier means; summing means having first and second inputs, said first input receiving output signals containing said signal amplitude information the output of said summing means being amplified by said amplifier means; feedback means connecting the output of said amplifier means to the second input of said summing means to reduce the effect of the input signal upon said amplifier means by providing negative feedback; said amplifier means comprising a transistor connected in common emitter fashion and having series connected resistor and capacitor means in series with the collector of said transistor; said feedback means being connected between said resistor and capacitor and said summing means second input.

15. Amplifying means comprising an input signal source; scan signal generating means for generating a periodic signal; summing means for summing the instantaneous output signals of said scan signal generating means and said input signal source; encoding means for encoding the resultant instantaneous output signal of said summing means into binary signals wherein said encoding means generates a first binary condition when said summing means instantaneous output signal exceeds a predetermined threshold level and a second binary condition when said summing means instantaneous output signal does not exceed said predetermined threshold level; first means for amplifying the output of said encoder means; filter means; input-output isolation means connected between said first amplifying means and said filter means comprising a control stage having its input connected to the output of said first amplifying means; oscillator means; said control means being connected to said oscillator means for enabling operation thereof upon receipt of a binary signal from said first amplifying means; detector means for converting said oscillator output signals into binary signals; means capacitively coupling said oscillator means to said detector means; the output of said detector means generating binary signals which are amplified replicas of the binary output signals of said first amplifying means; said coupling means being adapted to isolate the amplifier means output from its input.

(References on following page)

References Cited

UNITED STATES PATENTS

2,391,776	12/1945	Fredendall	325—38 X
2,471,168	5/1949	Posthumus	332—15
3,090,929	5/1963	Thompson	332—9
3,149,293	9/1964	Farkas	332—15
3,167,720	1/1965	Sharma	332—15 X
3,170,125	2/1965	Thompson	332—15 X
2,990,516	6/1961	Johannessen	332—15 X
3,260,912	7/1966	Gregory	332—15 X
3,290,503	12/1966	Staufenberg et al.	250—199
3,187,273	6/1965	Chasek	307—88.5

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