United States Patent

Browning

[15] **3,704,948**

[45] **Dec. 5, 1972**

[54] **METHOD AND APPARATUS FOR TRANSMITTING INFORMATION**

[72] Inventor: **Iben Browning,** Sunnyvale, Calif.

[73] Assignee: **Longshots, Inc.,** Mountain View, Calif.

[22] Filed: **Oct. 7, 1966**

[21] Appl. No.: **585,098**

Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 523,114, Jan. 26, 1966, abandoned.

[52] **U.S. Cl.** **355/80**

[51] **Int. Cl.** **G03b 27/72**

[58] **Field of Search** 355/71, 80, 133

[56] **References Cited**

UNITED STATES PATENTS

3,455,633	7/1969	Land	355/77
2,985,086	5/1961	Craig	355/80 X

Primary Examiner—John M. Horan

Attorney—Limbach, Limbach & Sutton

[57] **ABSTRACT**

An analog-to-digital conversion method and apparatus is disclosed wherein a random noise signal is mixed with an analog signal to produce an output signal of binary pulses, the probability of occurrence of which pulses is proportional to the waveform of the analog signal. More generally, a random information matrix is modulated with an analog information matrix such as a photograph to reduce contrast and produce a continuous "gray scale" with greater definition in the output.

9 Claims, 9 Drawing Figures

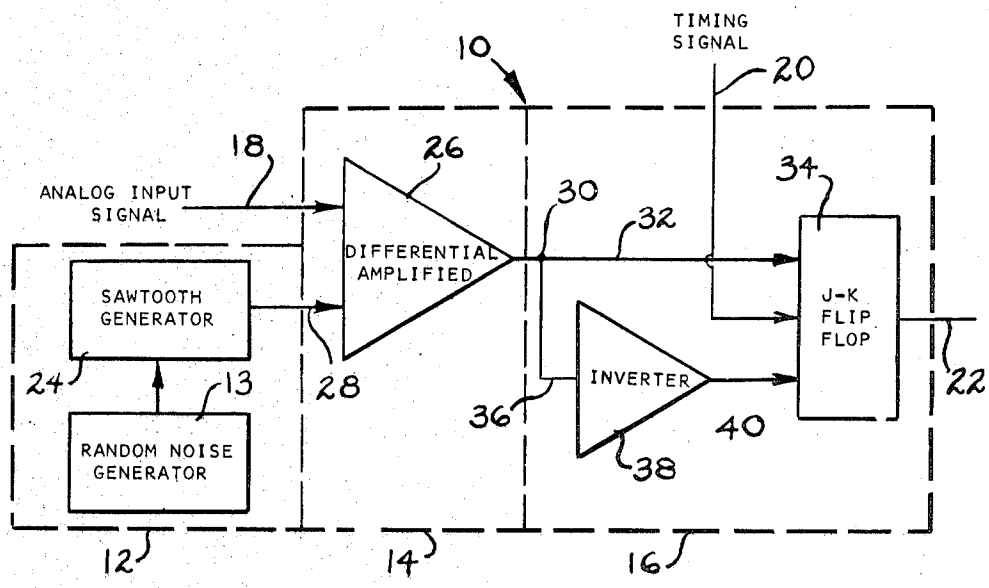


FIG. 1

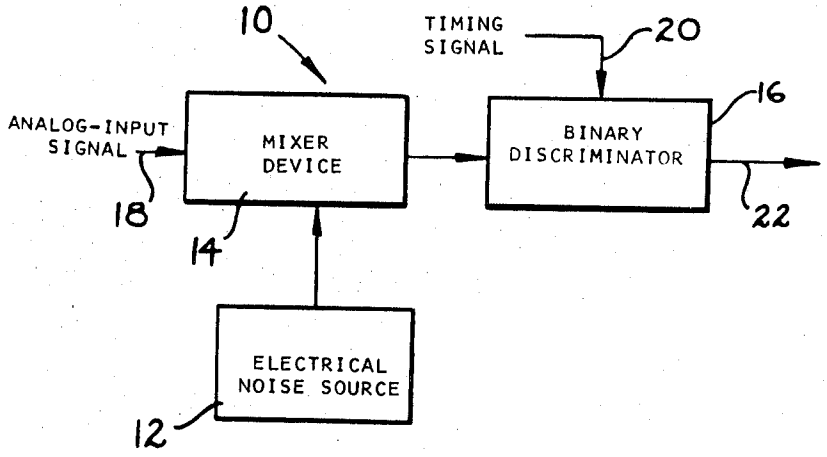
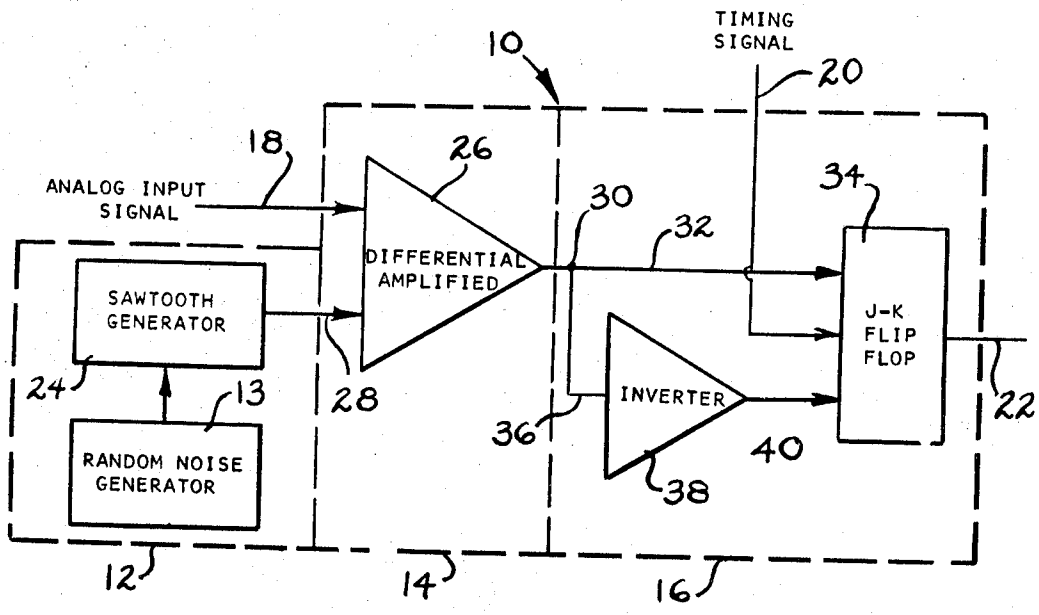


FIG. 2



INVENTOR
IBEN BROWNING

BY

ATTORNEY

FIG. 3

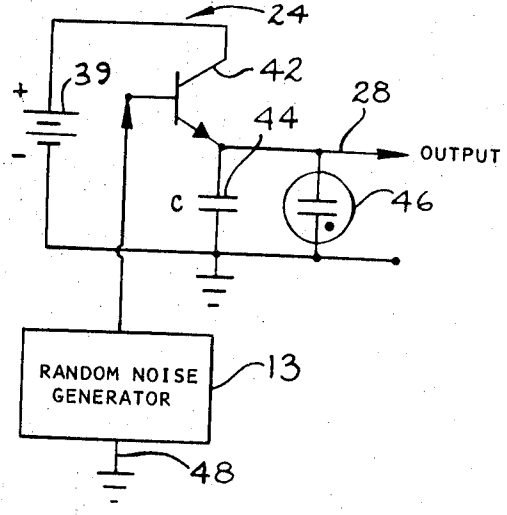


FIG. 5

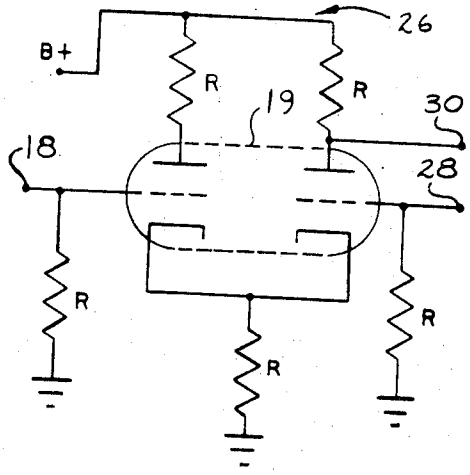


FIG. 4

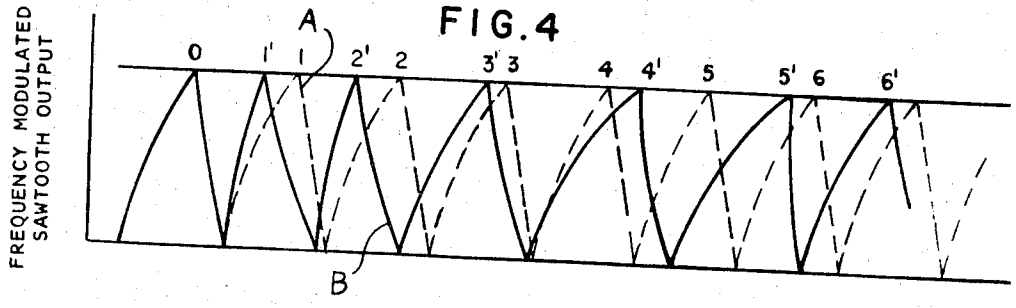
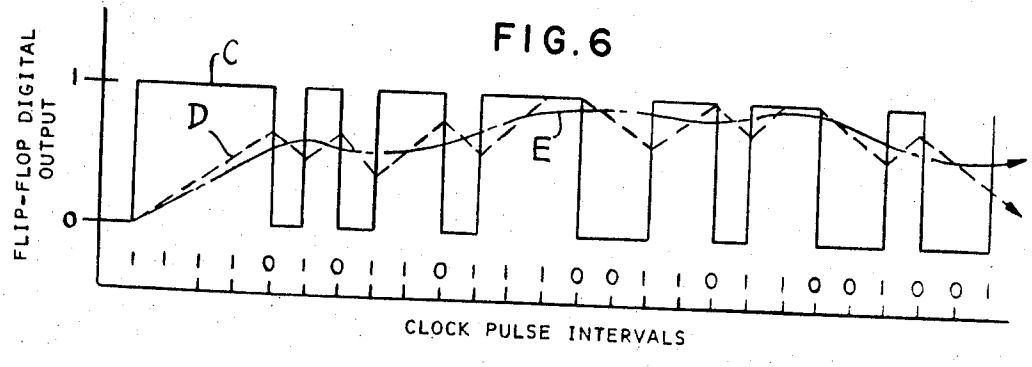


FIG. 6



INVENTOR
IBEN BROWNING
BY
ATTORNEY

FIG. 7

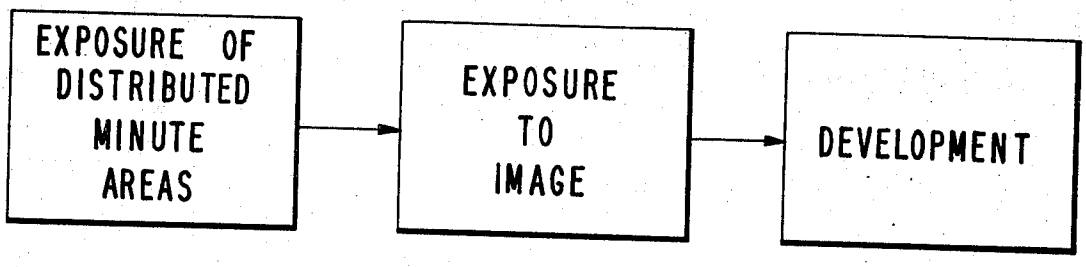


FIG. 8

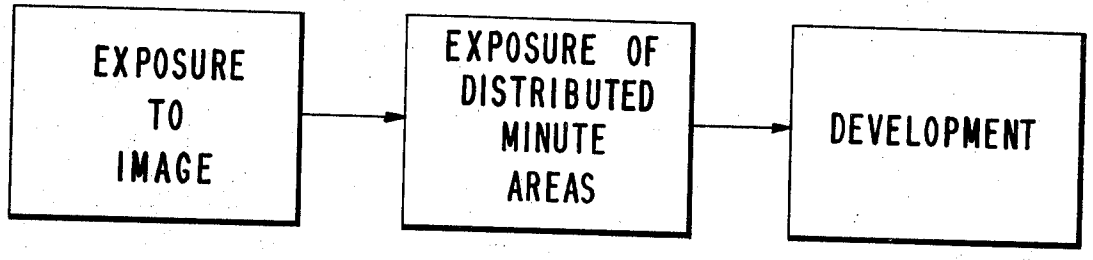
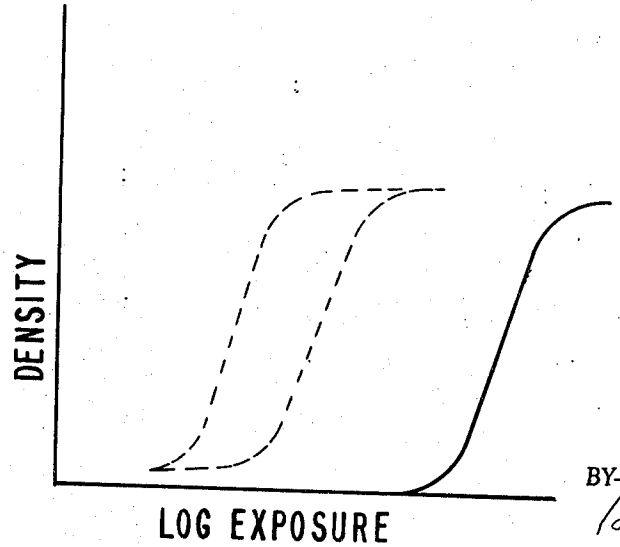


FIG. 9



INVENTOR.
IBEN BROWNING
BY Townsend and Townsend
ATTORNEYS

METHOD AND APPARATUS FOR TRANSMITTING INFORMATION

The application is a continuation in part application of my application, Ser. No. 523,114, filed Jan. 26, 1966, titled Analog-to-Digital Apparatus now abandoned.

The present invention is directed to a method and apparatus for transmitting information and beneficially changing the amount of information transmitted and/or the time required to obtain such information in an information matrix and, more particularly, to analog-to-digital information apparatus and photographic recording method and apparatus for accomplishing the above.

Broadly stated, the present invention, to be described in greater detail below, is directed to a method and apparatus of beneficially changing the amount of information and/or the time required to obtain such information in an information matrix comprising the steps of combining a random distribution of information producing signals and an analog signal matrix formed from information and producing a composite information matrix of such signals and signal matrix.

One aspect of the present invention relates to analog-to-digital information apparatus wherein a random noise signal is uniquely combined with an analog information signal for subsequent conversion to digital information signals characterized as having an infinite "-gray-scale."

In general, analog information conversion systems of the type encompassed by the present invention may be readily applicable to electrical, pneumatic, mechanical, optical, photographic and hydraulic systems which are responsive or adaptable to analog-to-digital conversion techniques. Prior art technology and space exploration are changing rapidly such that the need for apparatus and techniques to process analog information is greater than heretofore imagined. This is especially true in the field of analog-to-digital telemetry. Well known analog-to-digital conversion apparatus of the prior art has been used with digital computers for processing data derived from such conversion and therefore are rather complicated.

For example, it has been found highly desirable to convert the analog signal produced by a television camera in space exploration to a useful digital form which can be reconstituted on earth as substantially the same analog signal from which it was derived without the loss of gray-scales. In general, in the prior art, such conversion has been accomplished by measuring the energy level of the analog waveform at any instant during a complex sampling process. The sampled signal represents a series of instantaneous measurements at preselected frequencies. The energy level measured for the waveform at any instant of the sampling process is usually expressed in the form of a digital code consisting of a string of zeros (0) and ones (1), commonly termed binary digital coding, which are numerical representations of the instantaneous amplitude of points along the analog waveform.

From such a string of ones and zeros, representing an analog waveform, it is possible to reconstitute an analog signal which approximates the original analog waveform. However, the quality of such a reconstituted waveform, in terms of gray-scale, depends entirely upon how well the information contained in the original analog signal waveform was retained during the conversion and reconversion processes. Stated differently, if the specific digital representation of the analog signal is only an approximation, then the reconstituted signal will be only an approximation of less desirable quality.

For example, a television camera may scan a scene that is composed of surfaces that cover the spectrum between black and white, i.e., having infinite shades of gray in between evidencing the voltage amplitude variations in the analog waveform. These infinite scales of gray between black and white may be readily recorded as an analog waveform, but a digital coded representation of the same waveform is infinitely more difficult to produce, since generally only the black or white represented by ones or zeros respectively, are generated as bits of information with which to work.

Therefore, to derive a signal of infinite shades of gray, it is necessary to provide a formidably large or an infinite number of bits of information. However, to generate such formidably large number of bits with prior art techniques would be prohibitive in terms of cost per bit of information. For example, to obtain an infinite gray scale of digital coded representations of an analog signal, it would be necessary to assign a code number to every point along the analog waveform ranging from black to white, and sample the analog at an infinite number of intervals. Since the number of points between black and white is infinite, it would be rather impractical, if not impossible, to devise an economical and uncomplicated processing system to accomplish the desired end.

One known prior art system has been proposed which utilizes pulse-code modulation coding of an analog signal waveform which generates several million bits (megabits) per second of coded information. With black and white images, each coded bit corresponds to a shade of gray. Thus, with the foregoing approach, the system requires seven-digit binary coding in order to produce sufficient levels of gray to reproduce only a good quality analog waveform. It is believed that up to nine digits per binary code may be required under certain conditions to produce an acceptable reconstituted quality analog waveform. Other problems which may make this approach unattainable, are limitations in the electronic devices, materials, circuits, systems designs, time jitter of systems and the like, associated with the prior art. Thus, it will be appreciated that heretofore system approaches and techniques must of necessity be complicated, costly and unreliable and therefore, makes it virtually impossible to attain the desired ends.

The present invention obviates the foregoing and other disadvantages of the prior art techniques and apparatus by providing an uncomplicated and economical apparatus for the conversion of analog signal information to binary digital form through the use of a noise signal and preferably a random noise signal which is mixed or superimposed on the analog signal for the production of a resultant binary digital output signal having an infinite gray-scale associated therewith. In accordance with an illustrative embodiment of the invention, there is provided a technique and apparatus for producing a binary digital output signal derived from a composite analog and noise signal which has gray-scale characterized as substantially the same

quality as the original analog waveform without coding the output signal. That is, reconstituted analog waveforms, which are derived from the binary digitized signal, have unusual quality in terms of gray-scale being devoid of prior art sharp-contrasts of black and white, and lacking the requirement of removing or filtering the noise signal as has been the practice in the prior art.

Accordingly, it is the broad object of this aspect of the invention to provide a unique technique and apparatus for converting a composite analog signal waveform and noise signal to a non-coded digital signal.

Another object of this aspect of the present invention is to provide a unique technique and apparatus for converting analog signals having a random noise signal combined therewith to form a binary digitized signal for producing a reconstituted analog signal having infinite shade of gray.

Yet another object of this aspect of the present invention is to provide an apparatus for producing a non-coded digitized signal from an analog signal having a random noise signal component which may be converted directly into a binary digital signal by means of binary discrimination without the removal of the noise signal component.

Another object of this aspect of the present invention is to provide an apparatus which produces signal of an infinite number of clip levels from an analog signal mixed with a random noise signal to thereby produce a binary digital form which may be reconstituted as an analog signal essentially in its original form.

In accordance with another aspect of the present invention, a method is provided for effectively reducing the otherwise resultant contrast in an image formed on a photosensitive sheet wherein the sheet is exposed for a given time to the primary image being photographed and also a multitude of distributed minute regions of the sheet are exposed with various light energies and the double exposed photosensitive sheet is developed to produce a photocopy with a lower contrast than if the exposure of the minute regions were not made.

Presently, a problem exists with recording information using high contrasts and typically high speed photosensitive sheets. Since the sheet can either be a photonegative or photopositive sheet, film, or copy paper, the word "sheet" is used hereinafter to mean any one of such or similar types of material. When taking or printing a picture using a high contrast photosensitive sheet, a great deal of resolution and, therefore, information is lost because only a short change in the total exposure period will make the difference between a dark image or light image produced. Consequently, the high contrast picture typically produced does not provide good resolution of the tones of the image being photographed which lie in the broad range between dark and light. The problem is fully brought out in situations where it is necessary to use a high speed, high contrast film due either to the light conditions or time available for making the photograph but where a lower contrast image would be more beneficial.

For such situations as outlined immediately above, the present invention not only permits the production of a lower than otherwise possible contrast reproduction, but also permits a reduction in the time required to record the image. In accordance with the present invention as applied for photographing an image, the high contrast film is exposed from various light energies in the multitude of distributed minute regions either before or after the exposure for recording the individual event. The duration of this pre or post exposure serves as part of the time that is necessary with the particular photosensitive sheet being utilize to produce a desirable image exposure. When the actual image being copied is exposed on the sheet, the time necessary to complete that exposure is correspondingly less than would otherwise be necessary because of the average exposure time of the multitude of distributed minute regions. Thus, the critical time required for exposing the sheet to the image is reduced. The exposure of the distributed minute regions of the sheet can be done when time is not critical either before or after the primary time exposure.

Besides the reduced exposure time for the actual image, a lower contrast image is recorded than otherwise would be the case and, therefore, the criticality of the exposure time to the actual image is also avoided. If the present invention is not employed, those portions of the actual image which are either of slightly greater or slightly less than medium intensity will turn out as either a bright or a dark area indistinguishable from even greater or less intense portions. By utilizing the present invention in each of the corresponding portions of the reproduced image corresponding to the aforementioned portions of the actual image, a predominant number of the multitude of distributed minute regions is exposed with an intensity which corresponds with the detailed intensities of the actual image thereby providing a lower than otherwise expected contrast reproduction. The result will be a reproduced image somewhat grainy but providing lower contrast and, therefore greater resolution than an image produced on the same sheet in the conventional manner. The grainy effect is dependent upon the size of the minute regions and can be reduced so as to be substantially unnoticeable to the naked eye.

The method in accordance with the present invention effectively changes the sensitometric curves for the photosensitive sheet. In conventional high speed, high contrast film, the gamma factor is high so that the sensitometric curve for the film is very steep and the latitude is limited. With a limited latitude, high contrast results from the fact that small changes in exposure result in large changes in density. The present invention effectively broadens the sensitometric curve and in any given region reduces the slope of the curve so that less than normally expected contrast results.

The exposure of the minute regions can be accomplished in a number of different ways. In accordance with one aspect of the present invention, an uneven surface is illuminated so that light and dark areas result and an image of this surface is projected onto the photosensitive sheet to produce the distributed areas of various intensities. The surface may be a layer of sandlike particles or the like.

In accordance with another aspect of the present invention, a screen can be utilized to mask portions of the photosensitive sheet to produce the distributed regions of different intensities. This screen can be of any suitable material such as, metal, paper or cloth and the size and distribution of the apertures of the screen selected

to produce the desired effect depending upon spacing of the screen from the sheet, the photosensitive characteristics of the sheet and the desired effect to be produced on the sheet.

While the invention can be accomplished with a single exposure to expose the desired minute regions of the sheet, a number of exposures can be made to accomplish this. For example, in accordance with another aspect of the present invention, a plurality of exposures are made to expose minute regions of the sheet and the relationship between the sheet and the screen or uneven surface is changed in each exposure so that the distribution of the exposed minute regions is truly random.

The novel features which are believed to be characteristic of the invention both as to its organization and method of construction or operation, together with further objects and advantages thereof, will be better understood from the following description considered in connection with the accompanying drawings in which one or more embodiments of the invention are illustrated by way of example. It is to be expressly understood, however, that the drawings are for the purpose of illustration and description only and are not intended as a definition of the limits of either the apparatus or method of operation of the invention.

FIG. 1 is a simplified block diagram of one aspect of the invention;

FIG. 2 is a schematic block diagram illustrating a more detailed embodiment of the invention;

FIG. 3 is a circuit diagram of a sawtooth generator connected to a random noise generator used in FIG. 2;

FIG. 4 illustrates two wave shapes to assist in an explanation of the invention;

FIG. 5 is a circuit diagram of a differential amplifier used in FIG. 2;

FIG. 6 illustrates binary digital waveform representative of a converted analog signal and the running average thereof;

FIG. 7 is a block diagram illustrating the steps of the method in accordance with the present invention;

FIG. 8 is a view similar to FIG. 7 showing an alternative embodiment of the present invention;

FIG. 9 is a sensitometric curve of a high speed, high contrast film illustrating in phantom the effect of use of the present invention.

While the present invention is broadly directed to a method of beneficially changing the amount of information and/or the time required to obtain such information in an information matrix and comprises the steps of combining a random distribution of information producing signals and an analog signal matrix formed from information and then producing a composite information matrix of such signals and signal matrix, the invention is particularly suited for and will be described for purposes of illustration with respect to both an analog-to-digital information apparatus wherein a random noise signal is uniquely combined with an analog information signal for subsequent conversion to digital information signals and a method for effectively reducing the otherwise resultant contrast in an image formed on a photosensitive sheet.

With reference now to FIG. 1, wherein like or corresponding parts are designated by the same reference characters throughout the several views, there is shown for brevity a simplified block diagram 10 of the invention as applicable to an analog-to-digital apparatus which comprises an electrical noise source 12 connected to a mixer device 14 and a binary discriminator device 16 connected to the output of mixer 14. An input conductor 18 is provided at mixer 14 to receive an analog signal and an input conductor 20 is provided at binary discriminator 16 to receive a timing signal. The output from the combination is taken from binary discriminator 16 by conductor 22.

Before a detailed discussion of FIG. 1 is given it is appropriate at this point to discuss noise source 12, mixer device 14 and binary discriminator 16 in some detail. More particularly, a discussion of noise source 12 is believed to be especially necessary since the use of this element of the invention is essential to the uniqueness of the combination.

To begin, the noise source 12 in FIG. 1, is, for brevity, shown as an electrical noise source. However, it is believed that the basic concepts of the present invention are readily applicable to other fields of science such as pneumatic, mechanical, optical, photographic and hydraulic systems. It is to be understood that specific elements for use in these other fields would be compatible with the specific field of concern.

With respect to the electric noise generator 12, any suitable noise source may be used, preferably provided its output noise signal is "random". It is extremely important to understand what is meant by random and why it is essential to the unobviousness of the present invention. In the process of perfecting the present invention it was discovered that it is possible, contrary to heretofore known prior art beliefs, to combine an electrical noise signal with an analog signal through the use of various mixing devices and subsequently passing the composite signal through a suitable discriminating device to produce a binary digital output of bits such that the output statistical average of ones and zeros per unit of time is equal to the average amplitude of the input analog signal in the same unit of time. As discussed briefly hereinabove, this approach is not conventional in the prior art since heretofore, the presence of a noise signal as an integral part of the resulting useful output signal has been considered per se undesirable. Thus, according to the present invention no attempt is made to remove or filter out the noise signal. To the contrary, it has been found that the presence of the noise as taught by the invention is essential.

As used in the specification and claims, the term "electrical noise signal" is understood to encompass noise of various types. Such types may include, but is not limited thereto, random, pseudo-random, programmed and the like. However, it has been found that "random" is preferred. In the specification and claims "random" is understood to mean a mode which may produce a Gaussian or bell-shaped distribution of frequencies; or a linear distribution of frequencies between some upper and lower limits. The frequencies may be partitioned either according to frequency of occurrence, or energy content to provide means for controlling the character or nature of the random signal depending upon the specific nature of the problem sought to be solved.

With respect to the mixer device it is sufficient to state that any suitable mixer device which is capable of

mixing a noise signal and an analog signal to produce a composite signal to which the binary discriminator is responsive will be adequate. Stated differently, once the character of the binary digital signal is determined mixer may be devised to meet such a need. Thus, the requirements of the binary digital discrimination are important in determining the design of the mixer. A typical design of a suitable mixer device is shown in FIGS. 2 and 5 and will be discussed in greater detail with reference thereto.

As for the binary digital discriminator it is sufficient to state that the nature of the output signal from the device may be dictated by an associated system utilized therewith to reconstitute the analog signal. An example of a discriminator found useful in executing the present invention is shown in FIG. 2. The basic criteria for a design of a suitable discriminator is that is must be capable of sampling, discriminating and developing an output signal in binary form from a signal which is a composite of an analog and random noise signal. With the foregoing in mind a more detailed discussion of discriminator 16 will be given hereinbelow.

With reference now to FIG. 2, there is shown a more specific block diagram 10 of an embodiment of the invention which includes electrical noise source 12 which comprises a random noise generator 13 the output of which is connected to a sawtooth generator 24. The output of electrical noise source 12 and an analog signal are fed to mixer 14, consisting of a differential amplifier 26, respectively by conductors 28 and 18. The output of mixer amplifier 26 is fed to a pair of electrical conductors connected at a junction 30, one conductor 32 is connected directly to a flip-flop circuit 34 while the other conductor 36 is connected to an inverter 38 the output of which is in turn connected to flip-flop 34 through another conductor 40. Also connected to flip-flop 34 is an output taken off through conductor 22 when a timing signal is applied via conductor 20.

Continuing with the description of the invention, attention will now be given to the various elements of the combination shown in FIG. 2. The random noise generator 13 represents a preferred type of noise generation where the noise is random as compared with other forms, such as pseudo-random or programmed noise for examples. As indicated hereinabove, one of the unique features of the present invention resides in the use of a random noise signal which is uniquely combined with an analog signal.

More particularly, in this embodiment the use of a random noise signal permits an analog signal to be combined with a random noise frequency modulated signal, such as a sawtooth wave, in such a manner that the composite analog and sawtooth signal has an overall resultant waveform or characteristic envelope which is determined by that of the original analog signal. It should be noted here that there is no necessity to filter out the effects of the random noise in order for the composite signal to be useful, as utilized in the present invention.

The random noise frequency modulated sawtooth signal which is combined with an analog signal in differential amplifier 26 will be more clearly understood by referring to FIG. 3. In FIG. 3 which illustrates a form of electrical noise source 12, the output of noise generator 13 is connected to the base of transistor 42 of sawtooth generator 24. Sawtooth generator 24 is similar to a simple relaxation oscillator circuit where the resistance (R) of the RC time constant has been replaced by transistor 42. In this unique arrangement noise generator 13 drives transistor 42 such that the IR drop thereacross and the charging rate of a capacitor 44 connected between the emitter thereof and ground changes to conform with the output voltage waveform of electrical noise source 12. The foregoing mode of operation causes frequency modulation of the sawtooth waveform output having a rate of change in the waveform which is determined by the frequency distribution of the noise signal and a deviation from the natural relaxation frequency determined by the amplitude of the noise. The effect just discussed may be seen by referring to FIG. 4 which shows a normal waveform designated A shown as a broken line and a random noise frequency modulated waveform designated B shown as a solid line illustrating the effects of noise amplitude on the frequency of the sawtooth output of generator 24.

Returning to FIG. 3 it may be seen that the output from sawtooth generator 24 is taken from conductor 28 connected to a terminal of a gas discharge device 46 which is connected in parallel with capacitor 44. The other respective terminals of gas discharge device 46 and capacitor 44 are connected to ground to complete the circuit with noise generator 13, which has one of its terminals 48 grounded. Continuing with the description FIG. 2, the analog signal applied to conductor 18 and the FM sawtooth signal from conductor 28 of generator 24 are added algebraically in differential amplifier 26. Depending upon the polarity of the resultant signal, differential amplifier may be driven to saturation or cut off.

FIG. 5 illustrates one form of differential amplifier 26 which may be used satisfactorily to provide the desired addition of analog and frequency modulated sawtooth signals of the types encompassed by the present invention.

It should be noted at this point that mixer 14 employs a differential amplifier in the illustrated embodiment. In the embodiment shown, it is to be understood that the applied analog signal is a low level signal necessitating amplification thereof. Thus, the use of the particular differential amplifier shown in FIG. 5 is not to be construed as a limitation of the invention. In general, the output signal from differential amplifier 26 is characterized as a series of pulses which are not of uniform spacing or duration, but are of uniform amplitude when the amplifier is driven to saturation. When the amplifier is driven to saturation or cut off the pulses also may be flat on top.

The signal derived from differential amplifier 26 is applied to flip-flop 34 along two branches. One branch conductor 32 is directly from amplifier 26, the other branch is from junction 30 along conductor 36 through inverter circuit 38 and from there to flip-flop 34 through conductor 40. A timing signal is also fed to flip-flop 34 through conductor 20.

Flip-flop 34 is a conventional J-K type, known to those versed in the digital circuitry art and no detailed discussion will be given thereof. It suffices to say the function of the circuit is that of producing a binary

digital output voltage representing a one or zero depending upon the polarity of the input voltage applied along conductors **32** and **40**. The timing signal applied along conductor **20** is utilized to establish clock pulse intervals or time base during which the polarity of the input signal from differential amplifier **26** is determined. That is, if the polarity is representative of a preselected magnitude during a given time interval a one (1) is indicated, if it is not, a zero (0) is indicated. Thus, the output of the J–K flip-flop is a series of ones or zeros depending upon the polarity of the input signal thereto.

A binary digital output is derived from the foregoing process which is shown by way of illustration in FIG. **6**. As shown in FIG. **6** a digital output is illustrated as a series of square pulses of varying widths designated C. The width of a positive pulse or the absence of a pulse in a space is determined by the number of ones (1) present for the positive pulses and number of zeros (0) for the absence of pulse. Thus, a binary digital signal having four ones (1–1–1–1) is a pulse of four units in width. Particular attention should be given to the resultant signal noting that the binary representation is not a "binary coded" signal.

Also shown in FIG. **6** is a dashed line designated D which is an average of the pulses shown, while the other curve designated E, which is a running average of binary digital voltage signal of Curve C, may be produced by feeding a signal such as Curve C into a standard prior art integration circuit. Curve E is illustrative of essentially the original analog waveform which would be reconstituted by feeding it to an integration circuit and displaying the waveform. In actual practice it has been found that the higher the frequency of clock pulses, the closer the binary digital sample will be resulting in reconstituted analog waveform of an excellent infinite gray-scale. Thus, providing a simplified technique for further enhancement of the infinite gray-scale.

As applicable to the analog-to-digital apparatus just described, the invention is unique in that it uses a noise signal mixed with an analog signal which in effect produces a random fluctuation of the amplitude of analog signal, while maintaining the general format or envelop character of the original analog waveform, which in turn retains or preserves all of the informational aspects of the original analog signal. Next, and contrary to the belief in the prior art, none of the noise signal mixed with or added to the analog signal is filtered out. There is no necessity to do so, since the presence of such noise enhances the opportunity of obtaining an infinite gray scale simply when one was impractical, if not impossible, in the prior art.

Finally, the simplicity with which the foregoing results can be obtained is exemplified by the fact that no complicated and costly binary coding circuits or techniques are needed as is required in the prior art to approach an infinite gray scale. The simplicity of the type of circuitry required is illustrated in the fact that it has been found that the binary discriminating device **16** shown in FIG. **1** may be in its simplest form a one-shot multivibrator, producing ones when "on" and zeros when "off." That is, so long as the output signal produces binary bits representing the resultant probability of the composite noise and analog signals which is proportional to the amplitude of the original analog input signal.

Refer now to the drawing with particular reference to FIGS. **7** and **8**, the aspects of present invention, as applied to the production of a photocopy of less than otherwise resultant contrast, includes the steps of exposing a multitude of minute areas of a photosensitive sheet with various amounts of light energy. In one embodiment of the invention, the minute areas are randomly distributed across the photosensitive sheet. The effect of this exposure is to provide a certain exposure to each minute region of the sheet which differs from the exposure of immediately adjacent minute regions.

The exposure of minute regions of the photosensitive sheet can be accomplished in a number of different ways, either by use of a screen type member which will produce a light distribution as desired or a matrix which when focused onto the photosensitive sheet will produce the desired light distribution. By way of example in accordance with one aspect of the present invention, the exposure of randomly distributed minute regions is accomplished by illuminating a layer of sandlike particles spaced a finite distance from a lens which is oriented with respect to the photosensitive sheet so as to be effectively focused at infinity. By exposing the photosensitive sheet with the image produced of the layer of sandlike particles, the photosensitive sheet is exposed with randomly distributed regions of various light intensities.

The total light intensity of the most intensely exposed minute regions is less than the exposure time that would reach the toe or lower inflection point of the sensitometric curve for the particular photosensitive sheet.

Another way of producing the desired exposure is to pass light through a screen onto the sheet. This exposure is made with the screen spaced a distance from the sheet to produce areas of confusion between intensely exposed areas so that a wide variation in light exposures is produced and the pattern of the screen is not well defined. The screen can be made of metal, paper or fabric and the size of the apertures selected in accordance with the spacing from the photosensitive sheet, the size and distance of the light source, the particular characteristics of the sheet, and the desired effect to be produced on the sheet.

After the distributed minute regions have been exposed with various intensities and before the film is developed, the image to be recorded is projected onto the photosensitive sheet in any suitable manner characterized by the type of sheet, be it photopositive or photonegative film, photocopy paper, etc. Then after the sheet has been at least doubly exposed, the sheet is developed in the prescribed manner well known in the art so that the desired reproduction is made.

So long as the total exposure of both the minute regions and the actual image is of a desired time duration it does not matter whether the exposure of the minute regions is made before or after the exposure of the image to be reproduced. Thus, as shown in FIG. **8**, the exposure of the actual image on the photosensitive sheet can be made before the exposure of the distributed minute regions.

While the invention has been described with reference to a single exposure of the sheet through the screen or to the illuminated surface, a number of exposures can be utilized. In accordance with one embodiment of the present invention, a number of such exposures are made with the relative position between the

film and the screen or illuminated surface changed for each exposure to produce a more nearly random pattern of exposed distributed minute regions.

FIG. 9 is a sensitometric curve which illustrates the effect of use of the present invention. The conventional curve for high speed type film such as, Eastman high contrast positive film, type 5363, is shown in heavy lines. By using a double exposure with the multitude of distributed minute regions, the latitude for the high speed exposure is cut down by the exposure of the minute regions but the latitude has a greater tolerance due to the various intensities of the exposed minute regions since in any one general region of the photograph, both high and low exposed minute areas exist. Any given region on the sensitometric curve extends between the limits indicated in phantom. It can be analogized that the use of the present invention effectively reduces the gamma factor for this film.

While reference is made above to the random distribution of the minute exposed regions it is important to note that the beneficial effects of a random distribution are achieved so long as the distribution of areas is random with respect to the image.

Although the foregoing invention has been described in some detail by way of illustration and example, for purposes of clarity and understanding it is understood that certain modifications can be practiced within the spirit of the invention as limited only by the scope of the appended claims.

What is claimed is:

1. The method of beneficially changing the amount of information and/or the time required to obtain information in an information matrix representative of an image comprising the steps of combining a random distribution of random intensity signals and an analog signal matrix formed from the image and producing a composite information matrix of said signals and signal matrix.

2. The method of claim 1 where the information is an image and the composite information matrix is a reproduction of that image on a photosensitive sheet and including producing the random intensity signals by exposing with various amounts of light energy a multitude of randomly distributed minute regions of the sheet and producing the analog signal matrix by exposing the sheet for a time with the image.

3. The method of claim 1 wherein the information is an image, the random intensity signals are a noise signal and the analog signal matrix is an analog input signal and said step of producing a composite information matrix includes mixing said noise signal with said analog input signal to produce an output signal corresponding to the algebraic sum of said noise and analog input signals and discriminating the composite output signal for conversion to a binary digital output signal corresponding to the waveform of the analog input signal.

4. Method of producing a reduced contrast photocopy with a photosensitive sheet comprising steps of exposing said sheet for a time with the image being photographed, exposing a multitude of distributed minute regions of the sheet with various amounts of light energy unrelated to the image and after at least such double exposure developing the sheet to produce a photograph with lower contrast than if the exposure of minute regions were not made.

5. The method in accordance with claim 4 wherein said step of exposing a multitude of minute regions of the sheet includes the step of projecting light onto the film through a screen having minute apertures.

6. Method in accordance with claim 4 wherein the step of exposing a multitude of minute regions includes exposing randomly distributed minute regions across the film.

7. The method of producing a reduced contrast photocopy comprising the steps of: exposing a multitude of randomly distributed minute regions of a photosensitive sheet with various amounts of light energy, exposing the sheet with an image to be reproduced and developing the, at least doubly exposed, sheet to produce on the sheet a developed image with lower contrast than if the exposure of minute regions were not made.

8. The method in accordance with claim 7 wherein said step exposing distributed minute regions includes multiple exposures of the sheet with an illumination pattern to expose a multitude of distributed minute regions of the sheet with various amounts of light energy, and changing the relation between the illuminating pattern and the film for each exposure.

9. The method of producing a reduced contrast photocopy with a photosensitive sheet comprising the steps of exposing said sheet for a time with the image being photographed, exposing a multitude of randomly distributed minute regions of the sheet with various amounts of light energy unrelated to the image including imaging a defocused illuminated layer of sandlike particles on the sheet and after at least such double exposure developing the sheet to produce a photograph with lower contrast than if the exposure of minute regions were not made.

* * * * *