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TIME INTERVAL TO PULSE HEIGHT CONVERTER

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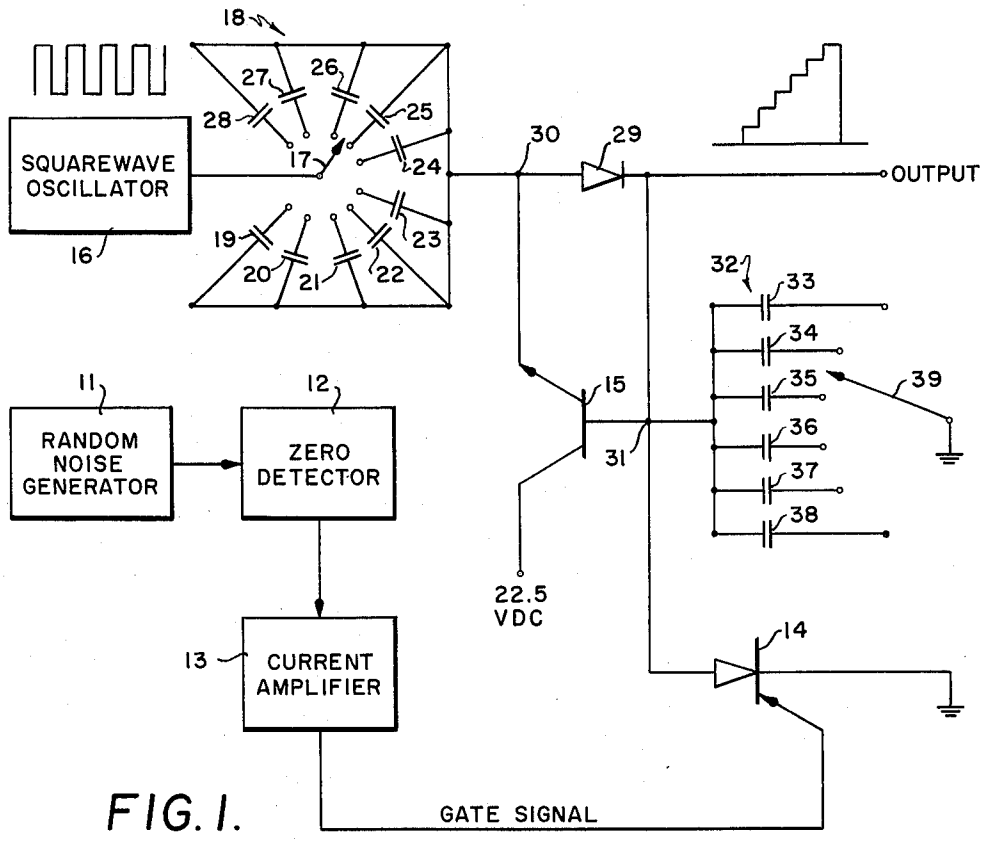


FIG. 1.

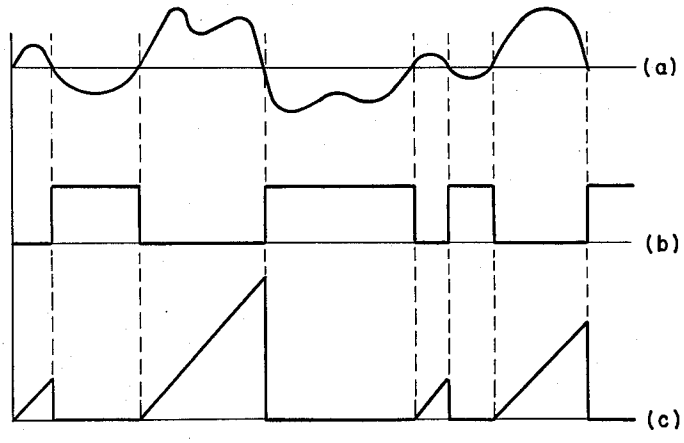


FIG. 2.

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TIME INTERVAL TO PULSE HEIGHT CONVERTER

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates generally to signal processing systems and in particular is an electronic circuit for converting the time intervals between consecutive zero-voltage crossings of a random or other input signal to an output signal having a waveform with consecutive amplitudes respectively proportional thereto.

In the past, sawtooth generators involving the timely charging and discharging of a capacitor have been employed for purposes somewhat similar to the purposes of this invention. However, the linearity in such devices usually leaves something to be desired, and, moreover, for most practical purposes, they are not readily adaptable for being used as a processor of random signals.

Waveform generators that provide an output signal which, when plotted against linear time, is formed by a succession of steps have also been employed satisfactorily for many practical purposes but they are usually considerably more complex from a circuit standpoint and are not structurally combined in such manner as to produce results that are identical with the results produced by the subject invention.

Accordingly, this invention overcomes many of the disadvantages of the prior art, in that it produces a series of step signals having a more linear slope trend, it may be used to process random as well as other signals having zero-voltage crossings and convert the consecutive time intervals thereof to signals having amplitudes respectively proportional thereto, and it is a wave form generator that is considerably less complex than comparable prior art generators.

It is, therefore, an object of this invention to provide a method and means for converting time intervals between zero-voltage and other predetermined voltage level crossings of input signals to output signals having amplitudes proportional thereto, respectively.

Another object of this invention is to provide a stairstep signal generator having improved slope trend linearity.

Still another object of this invention is to provide a method and means of converting the time intervals between zero-crossings of random signals within a broad frequency band to a signal having amplitudes respectively proportional thereto.

A further object of this invention is to provide an improved time interval to pulse height converter.

A further object of this invention is to provide an improved electronic generator for producing a signal having sawtooth characteristics, the slope of which is formed of stairstep signals having identical amplitudes and a substantially constant slope trend.

Another object of this invention is to provide a pump type sawtooth signal generator having a controllable pumping rate for producing variable slope stairstep sawtooth waveforms at predetermined or random time intervals.

Another object of this invention is to provide an improved method and means for studying the distribution

of time intervals between two consecutive zero-crossings of a random or other predetermined electrical signal.

Another object of this invention is to provide a time interval to pulse height converter having a relatively wide operable range of time intervals.

Another object of this invention is to provide an improved staircase signal generator that produces very small and accurate stairstep signals, with the steps thereof having substantially equal amplitude and disposed to form a ramp of substantially constant slope.

Another object of this invention is to provide a time interval to pulse height converter that is easily and economically manufactured, maintained, and operated.

Other objects and many of the attendant advantages will be readily appreciated as the subject invention becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawing wherein:

FIG. 1 is a combination block and schematic circuit diagram of the subject invention; and

FIG. 2 is a graphical representation of various and sundry signal waveforms that may typically occur at particular locations within the device of FIG. 1.

Referring now to FIG. 1, there is shown a random noise generator **11** which, in this particular embodiment, provides the input signal to be analyzed for consecutive zero-crossing time intervals. It should be understood, however, that any other suitable input signal, such as a pseudorandom, random, predetermined, uniform, or otherwise, may be supplied or used as the input signal to the invention. The output of random noise generator **11** is applied to the input of a conventional zero detector **12**. Of course, the input thereof would of necessity be the input to the invention, in event some other signal were being analyzed. A current amplifier **13** is coupled to the output of zero detector **12**. The output of amplifier **13** constitutes the gating signal, and it, therefore, has a current level that is appropriate for controlling the operation of a silicon controlled rectifier. This gate signal output from amplifier **13** is thus applied to the control element or gate of a rapid acting switch means, such as, for example, a 2N1843 silicon controlled rectifier **14**. The cathode of rectifier **14** is connected to ground, and the anode thereof is connected to the base of a 2N335 transistor **15**. The collector of transistor **15** is connected to a predetermined direct current voltage, preferably of the order of +22.5 volts.

A squarewave signal generator **16** has the output thereof coupled to the movable arm of a rotary switch **17**. The stationary contacts thereof are respectively connected to one of the plates of each capacitor making up a bank of capacitors **18** of varying capacitances. Said bank of capacitors may, for instance, include a 300 $\mu\mu$f. capacitor **19**, a 260 $\mu\mu$f. capacitor **20**, a 390 $\mu\mu$f. capacitor **21**, a 470 $\mu\mu$f. capacitor **22**, a 510 $\mu\mu$f. capacitor **23**, a 680 $\mu\mu$f. capacitor **24**, a 780 $\mu\mu$f. capacitor **25**, an 820 $\mu\mu$f. capacitor **27**, and a 1200 $\mu\mu$f. capacitor **28**. The other plates of each of the aforementioned capacitors **19** through **28** are interconnected and coupled to the anode of a IN277 diode **29**. The emitter of transistor **15** is connected to said interconnected capacitor plates and diode **29** by means of an electrical junction **30**. The cathode side of diode **29** constitutes the output of the invention and is also connected to the base of transistor **15** by means of an electrical junction **31**. Also connected to electrical junction **31** is another bank of capacitors **32** comprising, for example, a .047 μf. capacitor **33**, a .068 μf. capacitor **34**, a 0.15 μf. capacitor **35**, a 0.22 μf. capacitor **36**, a 0.33 μf. capacitor **37**, and a 0.47 μf. capacitor **38**. The aforesaid capacitors **33** through **38** are respectively connected

to the fixed contacts of another rotary switch **39**, the movable arm of which is connected to ground.

The operation of the invention will now be discussed briefly in connection with FIGS. 1 and 2 as follows:

Any appropriate input signal, such as the typical random signal shown in FIG. 2(*a*), is either supplied by the random noise generator or some other signal source, and it is applied to the input of zero detector **13**. Although primarily intended to contain zero voltage crossings, it should be understood that this input signal may be appropriately biased at some other voltage level to place the control voltage crossings at any preferred voltage level, since so doing would be obvious to the skilled artisan having the benefit of the teachings presented herewith. Zero detector **13** determines the zero or other bias voltage crossings of said input signal. In this particular illustration, it forms negative squarewave type signals having time intervals equal to the time interval between consecutive zero crossings of the random signal. Such signal is represented by the waveform of FIG. 2(*b*) and, of course, this is the typical type of output signal obtained from zero detector **13**. This signal is then amplified to a more useful current level by conventional current amplifier **13** before being applied as the gate signal to switching silicon controlled rectifier **14**.

Squarewave oscillator **16** is preferably of the variable frequency type, and it produces a train of rectangular pulses of predetermined amplitude and frequency which are used as the pumping voltages. For most practical purposes, pumping frequencies of twenty to one hundred kilocycles per second are satisfactory; however, any other frequency may be employed if desired. The respective capacitors of capacitor banks **18** and **32** are preferably selected in accordance with the formula:

$$SA=\frac{Q_{18}Vin}{Q_{32}}$$

where

SA is the step amplitude in volts;
Q_{18} is the voltage charge on the selected capacitor (C_{18}) of capacitance bank **18**;
V*in* is the pumping voltage of oscillator **16**; and
Q_{32} is the voltage charge on the selected capacitor (C_{32}) of capacitance bank **32**.

Accordingly, in this manner, an optimum slope trend of the sawtooth portion of the output signal may be obtained.

As the train of input pulses are applied, the positive going leading edge of the first pulse causes diode **29** to conduct, thereby causing C_{18} and C_{32} to be connected in series, as said pulses are applied thereto. This, in turn, causes C_{18} and C_{32} to receive the same charge, but since C_{18} has a much smaller capacitance than C_{32}, most of the voltage appears across C_{18}. On the negative trailing edge of the first pulse, the potential at junction **30** falls sufficiently to cut off diode **29** and thus isolate C_{32} from the input pumping voltage. Transistor **15** conducts on the negative trailing edge and acts as an emitter follower to effectively discharge C_{18} to the same potential as C_{32}, thus maintaining junction **30** at substantially the same potential as junction **31** throughout the discharge period of C_{18}. This effectively removes the bias voltage from diode **29** and places both sides of it at a voltage level equal to the first incremental step voltage retained by C_{32}. Hence, on arrival of the pulse train's second pulse, the positive going leading edge thereof must add another identical voltage increment to C_{32}, as it again charges both C_{18} and C_{32}, before diode **29** is again cut off by the negative-going trailing edge thereof. The process then repeats as before and continues to add incremental voltages to C_{32} and, hence, to the sloping portion of the sawtooth output signal, until such time as it is discharged by the application of a discharging gate signal.

In this particular embodiment, rapid acting silicon controlled rectifier **14** acts as an extremely efficient and satisfactory switching means for discharging C_{32}. As herein employed, it may be considered an open switch until it is closed by the gate signal which, of course, has suitable voltage and current characteristics. A typical representation of a waveform that may be used for such purpose is depicted in FIG. 2(*b*), which is obviously obtained from the processing of the random waveform of FIG. 2(*a*) by zero detector **12** and current amplifier **13**. FIG. 2(*c*) shows a typical representation of the output signal having sawtooth type pulse heights that are respectively proportional to the consecutive time intervals between the positive-going zero crossings of the waveform of FIG. 2(*a*) and the negative rectangular portions of the waveform of FIG. 2(*b*). Obviously, it would be well within the purview of one skilled in the art, having the benefit of the teachings presented herewith, to make the negative-going portions of the input random or other signal to be the controlling factor.

Also, as indicated by FIG. 2(*c*), the fall-time of each of the ramp pulses was sufficiently rapid to prevent their adversely affecting the slopes of the immediately succeeding pulses. Moreover, it has been determined that linearity occurs for time intervals corresponding to frequencies of ten to five thousand cycles per second. Of course, the proper adjustment of the voltage of the train of pulses, the capacitances of C_{18} and C_{32}, and the pumping rate will enable longer or shorter time intervals to be effectively employed and/or analyzed.

Obviously many modifications and other embodiments of the subject invention will readily come to the mind of one skilled in the art having the benefit of the teachings presented in the foregoing description in accompaniment with the associated drawing. Therefore, it is to be understood that the invention is not to be limited thereto and that said modification and embodiments are intended to be included within the scope of the appended claims.

What is claimed is:

1. A time interval to pulse height converter comprising in combination,
- a squarewave oscillator,
- a first variable capacitor connected to the output of said squarewave oscillator,
- a second variable capacitor,
- a diode interconnecting said first and second variable capacitors,
- a transistor having a base, a collector, and an emitter, with the emitter thereof coupled to the junction of said first variable capacitor and said diode, the base thereof coupled to the junction of said second variable capacitor and said diode, and the collector thereof coupled to a predetermined positive direct current voltage,
- a silicon controlled rectifier having an anode, a cathode, and a gate, with the anode thereof connected to the base of said transistor, the cathode thereof connected to a ground, and the gate thereof adapted for receiving a gating signal.

2. The invention according to claim **1** further characterized by a zero detector effectively connected to the gate of said silicon controlled rectifier.

3. The invention according to claim **2** further characterized by a random noise signal generator connected to the input of the aforesaid zero detector.

4. A time interval to pulse height converter comprising in combination,
- a zero detector,
- a current amplifier coupled to the output of said zero detector,
- a ground,
- a silicon controlled rectifier having an anode, a cathode, and a gate, with the cathode thereof connected to said ground, and the gate thereof coupled to the output of the aforesaid current amplifier,

a squarewave signal generator,
a first bank of capacitors,
a first selector switch coupled between said first bank of capacitors and said squarewave generator for selectively connecting a predetermined capacitor thereof thereto,
a second bank of capacitors,
a second selector switch coupled between said second bank of capacitors and said ground for selectively connecting a predetermined capacitor thereof thereto,
a diode connected between and in series with said first and second banks of capacitors, and
a transistor having an emitter, a collector, and a base, with the emitter and base thereof connected in parallel with said diode, the base thereof also coupled to the anode of the aforesaid silicon controlled rectifier, and the collector thereof connected to a predetermined direct current voltage.

5. The invention according to claim **4** further characterized by a predetermined signal source connected to the input of the aforesaid zero detector for supplying an electrical signal having zero-voltage crossings thereto.

6. The device of claim **5** wherein said predetermined signal source is a pseudorandom noise generator.

7. The device of claim **5** wherein said predetermined signal source is a random noise generator.

8. The device of claim **5** wherein said predetermined signal source is a generator for producing an electrical output signal having zero-voltage crossings and predetermined time intervals therebetween.

9. Means for converting the time interval between the consecutive zero voltage crossings of an input random noise signal to an output signal having pulse amplitudes respectively proportional thereto comprising in combination,
a squarewave oscillator means for generating a train of squarewave pulses,
a transistor pump circuit connected to the output of said squarewave oscillator means for producing a linear stairstep sawtooth voltage signal in response to said train of squarewave pulses,
a ground, and
a silicon controlled rectifier having an anode, a cathode, and a gate, with the anode thereof connected to said transistor pump circuit, the cathode thereof coupled to said ground, and the gate thereof adapted for receiving a gating signal.

10. Means for converting the time interval between the consecutive zero voltage crossings of an input random noise signal to an output signal having pulse amplitudes respectively proportional thereto comprising in combination,
a squarewave oscillator means for generating a train of squarewave pulses,
a transistor pump circuit connected to the output of said squarewave oscillator means for producing a linear stairstep sawtooth voltage signal in response to said train of squarewave pulses,
a ground,
a silicon controlled rectifier having an anode, a cathode, and a gate, with the anode thereof connected to said transistor pump circuit, the cathode thereof coupled to said ground, and the gate thereof adapted for receiving a gating signal,
a zero detector having an input and an output with the input thereof adapted for receiving the aforesaid input random noise signal that is to be converted to an output signal having pulse amplitudes respectively proportional thereto, and
a current amplifier interconnecting the output of said zero detector and the gate of the aforesaid silicon controlled rectifier.

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