

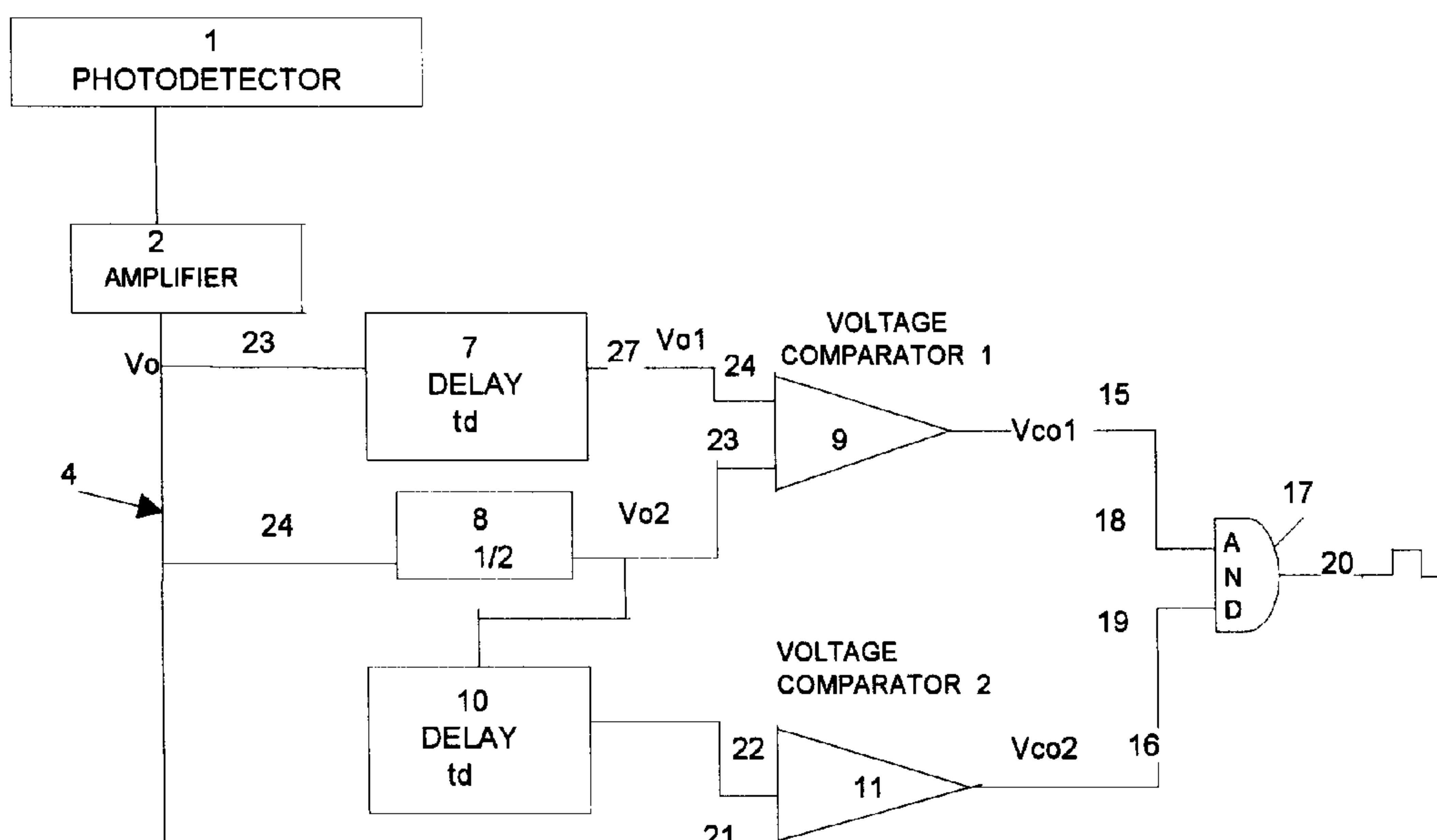
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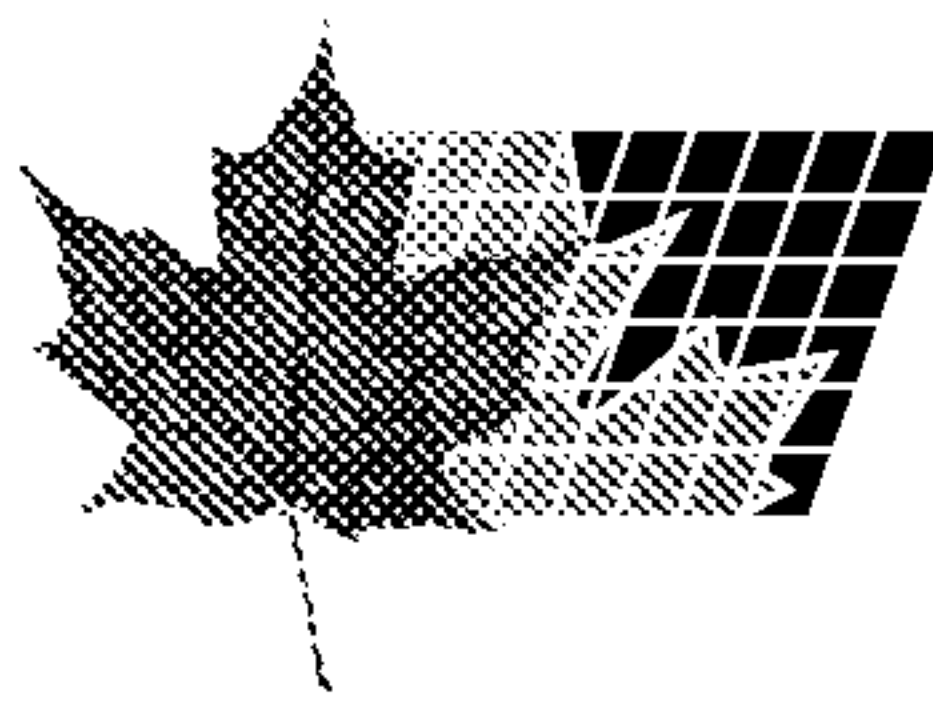
(54) **SYSTEMES DE COMMUNICATION SANS FIL A REGLAGE DE SEUIL AUTOMATIQUE**

(54) **WIRELESS COMMUNICATIONS SYSTEMS WITH SELF THRESHOLD SETTING**



(57) L'invention est un système de communication infrarouge qui comporte un photodétecteur servant à détecter des signaux infrarouges transmis par un émetteur et à les convertir en signaux électriques, un premier dispositif de retardement ayant une entrée couplée à ce photodétecteur et servant à retarder le signal de sortie de ce dernier durant une période de temps prédéterminée par rapport au temps de montée du signal électrique prévu en provenance du photodétecteur, un diviseur de tension ayant une entrée couplée au

(57) An infrared communication system is provided which includes a photodetector for detecting infrared signals from an infrared transmitter source and converting the infrared signals to electrical signals, a first delay device having an input coupled to the photodetector for delaying the signal from the photodetector for a predetermined period of time related to the rise time of an expected electrical signal from photodetector, a voltage divider having an input coupled to the photodetector for reducing the amplitude of the signal



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photodétecteur et servant à réduire l'amplitude du signal de sortie de ce dernier, un second dispositif de retardement ayant une entrée couplée à la sortie du diviseur de tension et servant à retarder le signal de sortie atténué du photodétecteur durant une période de temps prédéterminée par rapport au temps de descente du signal électrique prévu en provenance du photodétecteur, un premier comparateur de tension couplé à une sortie du premier dispositif de retardement et à une sortie du diviseur de tension qui sert à comparer les signaux reçus de ces deux unités et qui est adapté pour produire le flanc avant de sa tension de sortie à réponse à la détection du flanc avant de l'impulsion transmise par le photodétecteur, et un second comparateur de tension couplé au photodétecteur et à une sortie du second dispositif de retardement pour produire le flanc arrière d'une tension en réponse à la détection du flanc arrière de l'impulsion provenant du photodétecteur.

from the photodetector, a second delay device having an input coupled to the output of the voltage divider for delaying the reduced signal from the photodetector for a predetermined period of time related to the fall time of an expected electrical signal from the photodetector, a first voltage comparator coupled to an output of the first delay device and to an output of the voltage divider compares the signals received therefrom and adapted to generate the front edge of a voltage output in response to the detection of the front edge of a pulse from the photodetector; and a second voltage comparator having an input coupled to the photodetector into an output of the second delay device for generating back edge of a voltage output in response to detection of the back edge of a pulse from the photodetector.



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**WIRELESS COMMUNICATIONS SYSTEMS WITH
SELF THRESHOLD SETTING**

ABSTRACT

An infrared communication system is provided which includes a photodetector for detecting infrared signals from an infrared transmitter source and converting the infrared signals to electrical signals, a first delay device having a input coupled to the photodetector for delaying the signal from the photodetector for a predetermined period of time related to the rise time of an expected electrical signal from photodetector, a voltage divider having an input coupled to the photodetector for reducing the amplitude of the signal from the photodetector, a second delay device having an input coupled to the output of the voltage divider for delaying the reduced signal from the photodetector for a predetermined period of time related to the fall time of an expected electrical signal from the photodetector, a first voltage comparator coupled to an output of the first delay device and to an output of the voltage divider compares the signals received therefrom and adapted to generate the front edge of a voltage output in response to the detection of the front edge of a pulse from the photodetector; and a second voltage comparator having an input coupled to the photodetector into an output of the second delay device for generating back edge of a voltage output in response to detection of the back edge of a pulse from the photodetector.

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WIRELESS COMMUNICATIONS SYSTEMS WITH SELF THRESHOLD SETTING

Field of the Invention

The present invention relates to communications systems and more particularly to a voltage comparator circuit which makes use of both delayed and real time inputs to adjust its threshold values to respond to various inputs in order to reduce the effects of fluctuating signal strength or signals of a wide dynamic range for the duration of the communications.

Background of the Invention

Wireless or light communication systems, particularly infrared communications systems have a number of problems to deal with in effecting successful communications. One of the characteristics of wireless communications, in particularly infrared communications, is that the signal being received at a receiver may vary by many orders of magnitude because of differences in transmitter power, direction, atmospheric effects, distance, absorption, and other effects that interfere with signal transmission. In addition there is significant noise from other sources of heat and light that interfere with infrared communications, and for this purpose, special circuitry has been used to enhance the reception of the true signal being transmitted. The signal being transmitted is typically in the form of digital pulses, which would, under ideal conditions, easily be perceived by the receiver. Because of the interference that may be present, as mentioned, conventional circuits use a comparator which compares the received signal to a threshold value.

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In the infrared communication, a photodetector is used to detect infrared signals received and produces electric pulses in response to the infrared signals. The electric pulses produced by the photodetector are typically amplified and the resultant amplified digital pulse stream is compared to an internal decision threshold voltage by means of a voltage comparator and based on the comparison made, the comparator will produced an output pulse if the voltage threshold is exceeded.

In other fields of communications a fixed threshold may be satisfactory; however, in the wireless or infrared communications fields, a fixed threshold can cause numerous problems due to the wide variations in the signal. These variations will cause dead zones, fading, and pulse widths that are too wide or too narrow to be handled by the receiving circuitry. When the signal strength is too high, because of a nearby transmitter, for instance, the pulse widths being received may be too large for the receiver circuitry to handle; correspondently when the transmitter is either too weak because of positioning or distance then the pulse width determined by the comparator circuit would be too narrow for reliable processing.

U.S. Patent 4,459,311 issued October 17, 1995, assigned to Hewlett-Packard Company, Palo Alto, California, is directed to a fibre optic system of a fixed length that includes both a light source for producing optical signals, and optical fibre coupled to the light source to transmit the optical signals. A photodetector is coupled to the optical fibre to detect those optical signals and convert them to electrical signals. A delay line is coupled to the photodetector to delay the electrical signals from the photodetector for a period sufficient for the decision threshold circuit, which includes a peak detector, to detect the peak voltage of the first pulse received in a communication transmission. The threshold voltage is set to half of the peak voltage of the first digital pulse received. This threshold setting is maintained for the rest of

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the transmission. In addition, as the peak voltage is used a problem is encountered which requires compensation for a cumulative DC offset voltage.

5 As the reference is directed to a fibre optics system in which the system itself is a fixed configuration, ie: the transmitter, receiver, and optical fibre line are fixed to each other; the variations in signals expected would not result in a large change over short periods of time, eg. during the currency of a transaction. The variations indicated by the reference vary by no more than 20 dB and this variation is not generally time related. It is apparently related to the length of fibre chosen for each system, and the strength of the transmitter. So a given
10 receiver having an effective range of signal strength acceptance can be used in different fixed installations. The system disclosed apparently cannot compensate for variation in signals during a communication period as it sets its threshold only at the beginning of a communication period.

15 In the optical fibre communication system, once established the signal amplitude is constant and typically only one communication protocol is used such as SONET (SDH). However, in infrared communication, the communication distance may vary over time during the transmission. For instance in a mobile infrared telephone the users may be moving with respect to each other. The signal amplitude changes within a very large range over time and
20 the receiver expected to operate in this environment must also handle a large number of different communication protocols. This in turn poses a problem which the reference does not appear to be able to handle. In the reference the question left unsolved is how long should the peak value detected for the first pulse be kept, and when should it be updated. As we have discussed, this is not a critical problem in a fibre optic communication system
25 where one protocol is being used. However, in the infrared field and when different

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communication protocols are being used, the pulse duration and pulse separation can be widely different for the IrDA 2.4 Kbs protocol the pulse duration varies between $1.41\ \mu\text{s}$ to $85.55\ \mu\text{s}$. For the IrDA 1.152 Mb/s protocol standard the pulse duration may vary between 147.6 to 260.4 ns. This poses a serious problem for prior art systems such as the reference.

5 We have found by experimentation, that peak detection system does not work properly in infrared communications.

It is therefore desirable to use the instant signal as a basis for adjusting the threshold. Another basic problem for wireless communications is due to the base line shift caused by
10 AC coupling which is used to reduce environmental noise. Peak detection circuits cannot compensate for this, whereas, it is desirable to handle this situation as well in order to achieve successful communications flexibility.

Summary of the Invention

15 The present invention overcomes the difficulties posed by the prior art. In its preferred embodiment the invention is capable of accepting a wide input dynamic range of signals up to five orders of magnitude (50 dB) while overcoming the difficulties presented by many communications protocols such as the pulse position protocol system which is widely used in infrared communications.

20

Conventional fixed threshold settings cause the output pulse width of an amplified photodetector input to strongly depend on the input signal amplitude so that the signal may exceed the threshold required for effective communication but the communication will still fail because the output pulse is either too wide or too narrow with respect to the requirements
25 of the communication protocol being used. If a fixed threshold is used a strong signal may

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cause a very wide output pulse and may result in two pulses being merged. Conversely, if a small signal is received the resultant pulse may be too narrow.

5 The invention provides a communication system that can be useful in the infrared spectrum which includes a photodetector for detecting infrared signals from an infrared source and converting the infrared signals to electrical signals; a first delay device having an input coupled to the photodetector for delaying the signal from the photodetector for a period of time related to the rise time of an expected electrical signal from the photodetector; a voltage divider having a input coupled to the photodetector for reducing the amplitude of the signal
10 from the photodetector; a second delay device having an input coupled to the output of the voltage divider for delaying the reduced signal from the photodetector for a predetermined period of time related to the fall time of an expected electrical signal from the photodetector; a first voltage comparator coupled to an output of the first delay device and to the output of the voltage divider for comparing the signal received therefrom and adapted to generate the
15 front edge of a voltage output in response to the detection of the front edge of a pulse from said photodetector; a second voltage comparator coupled to the photodetector and to an output of the second delay device for generating the back edge of a voltage output in response to the detection of the back edge of a pulse from the photodetector.

20 In addition, the invention advantageously provides for the outputs of the first and second comparators be coupled to the inputs of an AND gate to produce an output pulse from the AND gate when the outputs of the two voltage comparators are active.

Brief Description of the Drawings

25 These and other features of the present invention will be better understood with reference to

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the following detailed description when considered in connection with the accompanying drawings in which:

Figure 1 is a generalized block diagram representation of an infrared communication circuit having a fixed threshold in accordance with the prior art;

Figure 2 is a block representation showing a specific implementation of the present invention;

Figure 3 is a block representation showing a second specific implementation of the present invention;

Figure 4 depicts input and output waveforms for the circuit of Figure 1;

Figure 5 depicts input and output from the implementation of Figure 2;

Figure 6 depicts input and output waveforms for the Figure 3 implementation.

Detailed Description of the Drawings

Referring to Figure 1, an infrared communication system having a fixed voltage threshold input V_{th} is illustrated. The system includes a photodetector 1 coupled to an amplifier 2 the output of which, V_o is fed to the input 4 of voltage comparator 3. In addition, comparator 3 is provided with a fixed threshold voltage at input 5.

When voltage comparator 3 is presented with an electrical pulse on input 4 from the amplified output of the photodetector an output V_{∞} will be produced at the output at terminal 6 in accordance with detected pulses received that exceed the fixed threshold voltage.

There has been found that such a circuit is incapable of handling a wide input dynamic range

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of up to five orders in magnitude (50 dB) may occur in infrared communications. In addition, the protocol of the pulse position modulation that is widely used in infrared communications requires a circuit output pulse width to fall within specific limitations as indicated previously. The conventional fixed threshold circuit of Figure 1 will have an
 5 output voltage pulse width (from voltage comparator 3) strongly dependent on the input signal amplitude. So that if the signal amplitude exceeds the threshold by a large amount, then communications will fail because the output pulse will be too wide to be acceptable to the infrared communication protocol. If the input pulse is too weak to exceed the threshold by a significant amount, the communication will fail because the output pulse will be too
 10 narrow to fall within the requirements of the communication protocol.

An analysis of the pulse width dependency of the circuit of Figure 1 is discussed below:

The output pulse width of V_{co} is expressed in the following formula when the fixed threshold
 15 V_{th} is set to half minimum input pulse amplitude multiplied by the system small signal gain (ie. no saturation effects).

$$PW_o = PW_i + \tau \ln \{ (2V_{in}/V_{min} - 1) * [1 - \exp(-PW_i/\tau)] \} \quad (1)$$

20 Where PW_o : output pulse width of V_{co}

PW_i : input pulse width

V_{in} : input pulse amplitude

τ : system time constant and $\tau = (2\pi BW)^{-1}$

BW: system bandwidth

25 Ln: natural logarithm

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exp: natural exponential

A detailed calculation of this is shown in Appendix A.

5 As can be seen, the output pulse width depends on the input pulse amplitude. It should be pointed out especially that when $t = T$, the input pulse period, then at the moment the next pulse starts, there is still a residual voltage, V_{re} present from the previous pulse where

$$V_{re} = [1 - \exp(-PW_i / \tau)] * \exp[-(T - PW_i) / \tau] * K * V_{in}$$

where K = system small signal gain

10 T = input pulse period

When the input pulse amplitude is large enough so that V_{re} reaches the level of V_{th} , it results in the merger of the two pulses into one, and the communication will definitely fail. This limits the system input dynamic range to

15 $V_{re} = V_{th} = K V_{min} / 2$ or

$$V_{max} / V_{min} = \exp[-(T - PW_i) / \tau] / \{2 * [1 - \exp(-PW_i / \tau)]\}$$

where V_{max} = maximum input pulse amplitude

Using 4 Mb/s IrDA protocol and a fixed threshold the dynamic range will be limited to about
20 2 orders (ie. 20 dB) of magnitude.

We have determined that one solution to the problem is to use a comparator in which the comparator threshold is not fixed but is derived from the photodetector amplifier output itself. In this way, when the input pulse received is large the threshold voltage becomes
25 high; when the input pulse received is small, the threshold voltage is reduced. In this manner

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we have determined that the output pulse width will kept constant, irrespective of the magnitude of the input pulse amplitude.

One embodiment in accordance with the invention with self threshold setting is shown in Figure 2.

It can be seen that the communication circuit of the embodiment of the invention depicted, comprises a photodetector 1 capable of detecting infrared signals from an infrared transmitter source and converting the infrared signals to electrical signals.

In this embodiment the output of the photodetector is amplified by amplifier 2 to produce a photodetector output voltage V_o on line 4.

A first delay device 7 has an input 23 coupled to the output of the photodetector on line 4 for delaying the signal from the photodetector for a predetermined period of time t_d (which is related to the rise time t_r of the expected electrical signal from the photodetector.) We have found that delay time t_d should be close to the rise time t_r , for instance if the rise time is 35 ms in the case of the 4 Mb/s IrDA protocol a time delay t_d of 20 to 50 ns will be effective. less delay can be used if signal noise is small and the offset voltages of the comparators is small.

Voltage divider 8 has an input 24 which is coupled to the photodetector output for dividing the amplitude of the signal from the photodetector by a predetermined amount. In the case of Figure 2, it is dividing the signal by half.

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A second delay device 10 has an input 26 coupled to the output 25 of voltage divider 8 for delaying the signal from the photodetector 1 for the period of time t_d .

5 The first voltage comparator 9 is coupled to output 27 of the first delay device 7 and to the output 25 of the voltage divider 8 for comparing the signals received from them at input terminals 24 and 23 of the voltage comparator 9 to generate the front edge of a voltage output V_{o1} on upper terminal 15 the response to detection of the front edge of a pulse from the photodetector 1. The second voltage comparator 11 is coupled by input terminal 21 to the photodetector 1 and by terminal 22 to the output 28 of delay device 10 for generating the
10 back edge of a voltage output V_{o2} in response to the detection of the back edge of a pulse from the photodetector 1.

The input terminal 18 and 19 AND gate 17 are coupled to the outputs 15 and 16 respectively of voltage comparators 9 and 11 and produces an output pulse on its output gate 20 in
15 response to its outputs of the voltage comparators 9 and 11 producing a suitably shaped pulse when the outputs 15 and 16 of comparators 9 and 11 respectively are active. This pulse will correspond in width with the infrared pulse received by photodetector 1 and will be relatively independent of the input amplitude received by the photodetector.

20 The output of the AND gate 17 will comprise a series of pulses in accordance with the infrared pulses detected by photodetector 1 and can be further processed by circuitry and or software which will not be described as it is not the subject of this invention for the handling of received information thereby.

25 In the embodiment of Figure 2, the amplifier output signal V_o is delayed in time and/or

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divided by 2 in amplitude to generate V_{o1} , but V_{o2} and V_{o3} .

V_{o1} has the same amplitude as V_o , but is delayed to t_d in time.

V_{o2} has the half amplitude of V_o , but is not delayed.

V_{o3} has the half amplitude of V_o , and is delayed by t_d in time.

5 V_{o1} and V_{o2} are connected to the inputs of voltage comparator 9 to generate the front edge of the circuit output pulse.

V_o and V_{o3} are connected to the inputs of voltage comparator 11 to generate the back edge of the circuit output pulse.

10 V_{o2} and V_{o3} are essentially used as the thresholds of the comparators. Their values are not preset to a fixed value, but depend on the signal amplitude itself. This is called self threshold setting.

The output pulse width is shown below:

$$PW_o = \tau * \ln \{ [2 * \exp (PW_i / \tau) - 2 + \exp (t_d / \tau)] / [2 * \exp (t_d / \tau) - 1] \} \quad (2)$$

15 where t_d : delay time for V_{o2} and V_{o3} and other variables are the same as in equation (1) above.

Equation (2) shows the circuit output pulse width is independent of the input amplitude, and accordingly all problems caused by dependence of output pulse width on input amplitude have been solved.

20 Appendix B shows the detailed derivation.

It has been determined that the delay time that will produce satisfactory results in this invention as depicted in the specific embodiment, depends on the bandwidth of the communication system designed. The delay time t_d should be approximately the same as the
25 rise time of a pulse t_r . It is well known in the art that the rise time of a pulse is defined as the

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time interval that it takes for the pulse to rise from 10% of the pulse amplitude to 90% of the final pulse amplitude. It is also well known that the communication system bandwidth determines pulse rise time and that pulse rise time can be calculated according to the formula $[t_r = 350 / \text{bandwidth}]$ in which the rise time will be determined in nanoseconds and
5 bandwidth is represented in Megahertz.

In the current IR technology, bandwidth has been kept to 10 Megahertz or less so the rise time expected in such a system for a pulse is 35 nanoseconds or longer.

10 It has been found that the amplitude ratio chosen in this embodiment for the voltage divider, namely 0.5 is a satisfactory value as it tends to keep the output pulse width approximately the same as the pulse width of the input provided to it.

15 In the high speed infrared field for which this device is adapted, the rise and fall times of pulses being transmitted are very fast so that the pulse shape approaches that of bell with curved rise and falling edges. The comparator circuit generates in response to this a shaped pulse that is suitable for use by digital processing and decoding circuits following or attached to this device.

20 Referring to Figure 3, another embodiment of the invention is shown. We have found that the output pulse width of this circuit will be kept very close to the width of the input from the photodetector. This is illustrated in Figure 6.

25 In this circuit the second comparator 11 receives as its inputs the outputs of the first delay device 7 and the second delay device 10. Delay device 10 is adapted in this embodiment to

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delay the signal by approximately $2 t_d$ (ie. Twice as much as imposed by the first delay circuit).

5 The delay devices depicted in the drawings and text have not been discussed in detail as those familiar with the art would be well able to use suitable devices in order to achieve the objectives of the invention without difficulty. Suitable delay devices would include RC filters and analog delay lines or such other devices as may be known in the art.

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APPENDIX A**Calculation of Output Pulse Width (Fixed Threshold)**

This Appendix, taken together with Figure 4, illustrates the behavior of the circuit of Figure 1.

$$V_o(t) = \begin{cases} [1 - \exp(-\frac{t}{\tau})] K V_{in} & 0 \leq t \leq PW_i \\ [1 - \exp(-\frac{PW_i}{\tau})] K V_{in} \exp(-\frac{t - PW_i}{\tau}) & PW_i < t \leq T \\ [1 - \exp(-\frac{PW_i}{\tau})] K V_{in} \exp(-\frac{T - PW_i}{\tau}) + [1 - \exp(-\frac{t - T}{\tau})] K V_{in} & T < t \leq T + PW \end{cases}$$

Where

$V_o(t)$	=	amplifier output
$\exp$	=	natural exponential function
τ	=	system time constraint, $\tau = (2\pi BW)^{-1}$
BW	=	system bandwidth
K	=	system small signal gain
V_{in}	=	input pulse amplitude
PW_i	=	input pulse width
T	=	input pulse period

Usually the threshold is preset to $\frac{1}{2} K V_{min}$, that is:

$$V_{th} = \frac{1}{2} K V_{min}$$

Where V_{th}	=	fixed threshold value
K	=	system small signal gain
V_{min}	=	minimum input pulse amplitude

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Calculation of t_1 , the cross point of the output pulse front edge and the threshold:

$$\left[1 - \exp\left(-\frac{t_1}{\tau}\right)\right] K V_{in} = V_{th} = \frac{1}{2} K V_{min}$$

$$t_1 = -\tau \ln \left(\frac{2V_{in} - V_{min}}{2V_{in}} \right)$$

Calculation of t_2 , the cross point of the output pulse back edge and the threshold:

$$\left[1 - \exp\left(-\frac{PW_i}{\tau}\right)\right] K V_{in} \exp\left(-\frac{t_2 - PW_i}{\tau}\right) = V_{th} = \frac{1}{2} K V_{min}$$

$$t_2 = \tau \ln \frac{V_{min}}{2\left[1 - \exp\left(-\frac{PW_i}{\tau}\right)\right]V_{in}} + PW_i$$

The circuit output pulse width:

$$PW_o = t_2 - t_1 = PW_i + \tau \ln \left(\frac{2V_{in}}{V_{min}} - 1 \right) \left[1 - \exp\left(-\frac{PW_i}{\tau}\right)\right]$$

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APPENDIX B**Calculation of Output Pulse Width (Circuit of Figure 2)**

This Appendix, together with the circuit of Figure 5, illustrates the behavior of the circuit of Figure 2.

The math expressions of V_o , V_{o1} , V_{o2} and V_{o3} are shown below:

$$V_o(t) = \begin{cases} [1 - \exp(-\frac{t}{\tau})] K V_{in} & 0 \leq t \leq PW_i \\ [1 - \exp(-\frac{PW_i}{\tau})] K V_{in} \exp(-\frac{t-PW_i}{\tau}) & PW_i < t \leq T \end{cases} \quad (1)$$

$$V_{o1}(t) = \begin{cases} 0 & t < td \\ [1 - \exp(-\frac{t-td}{\tau})] K V_{in} & td \leq t \leq PW_i + td \\ [1 - \exp(-\frac{PW_i}{\tau})] K V_{in} \exp(-\frac{t-PW_i-td}{\tau}) & PW_i + td < t \leq T + td \end{cases} \quad (2)$$

$$V_{o2}(t) = \begin{cases} \frac{1}{2} [1 - \exp(-\frac{t}{\tau})] K V_{in} & 0 \leq t \leq PW_i \\ \frac{1}{2} [1 - \exp(-\frac{PW_i}{\tau})] K V_{in} \exp(-\frac{t-PW_i}{\tau}) & PW_i < t \leq T \end{cases} \quad (3)$$

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$$V_{o3}(t) = \begin{cases} 0 & 0 < t < t_d \\ \frac{1}{2} [1 - \exp(-\frac{t-t_d}{\tau})] K V_{in} & t_d \leq t \leq PW_i + t_d \\ \frac{1}{2} [1 - \exp(-\frac{PW_i}{\tau})] K V_{in} \exp(-\frac{t-PW_i-t_d}{\tau}) & PW_i + t_d < t \leq T + t_d \end{cases} \quad (4)$$

(2) and (3) determine the cross-point of t_1 , the output pulse front edge:

$$K V_{in} [1 - \exp(-\frac{t_1 - t_d}{\tau})] = \frac{1}{2} K V_{in} [1 - \exp(-\frac{t_1}{\tau})]$$

$$t_1 = \tau \ln [2 \exp(\frac{t_d}{\tau}) - 1]$$

(1) and (4) determine the cross-point of t_2 , the output pulse back edge:

$$K V_{in} [1 - \exp(-\frac{PW_i}{\tau})] \exp(-\frac{t_2 - PW_i}{\tau}) = \frac{1}{2} K V_{in} [1 - \exp(-\frac{t_2 - t_d}{\tau})]$$

$$t_2 = \tau \ln \{ 2 [\exp(-\frac{PW_i}{\tau}) - 1] + \exp(\frac{t_d}{\tau}) \}$$

The circuit output pulse width PW_o is:

$$PW_o = t_2 - t_1 = \tau \ln \left\{ \frac{2 \exp(\frac{PW_i}{\tau}) - 2 + \exp(\frac{t_d}{\tau})}{2 \exp(\frac{t_d}{\tau}) - 1} \right\}$$

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While the circuitry of the invention has been described mostly in the context of infrared communications, it can be appreciated that the invention can be applied to communication systems using other wavelengths of light.

While the present invention has been described with reference to a few specific embodiments, the description is illustrative of the invention and is not to be construed as limiting the invention. Various modifications to the invention may be made by those skilled in the art without departing from the true spirit and scope of the invention as defined by the appended claims.

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

1. An infrared communications system comprising:

a photodetector including a photodetector output for detecting an infrared signal from an infrared transmitter source and converting said infrared signal to a electrical output signal output at said photodetector output, said electrical output signal having a rise time and a fall time;

a first delay device having an input coupled to said photodetector output for delaying an electrical signal from said photodetector for a predetermined period of time related to said rise time of an expected electrical signal from said photodetector, said first delay device having a first delay device output for producing a first delay device output signal;

a voltage divider having an input coupled to said photodetector output for reducing an electrical signal from said photodetector to a reduced signal, said voltage divider having a voltage divider output for producing said reduced signal as a voltage divider output signal;

a second delay device having an input coupled to said voltage divider output for delaying said reduced signal for a predetermined period of time related to said fall time of said expected electrical signal from said photodetector said second delay device having a second delay device output for producing a second delay device output signal;

a first voltage comparator having a first voltage comparator output, inputs of said first voltage comparator coupled to said first delay device output and to said voltage divider output for comparing said output signals received therefrom and adapted to generate a front edge of an output signal in response to detecting a front edge of a pulse when said electrical output signal from said photodetector is a pulse; and

a second voltage comparator having a second voltage comparator output, inputs of said second voltage comparator coupled to said photodetector output and to said second delay device output for comparing said output signals received therefrom and adapted to generate a back edge of an output signal in response to detecting a back edge of a pulse when said electrical output signal from said photodetector is a pulse.

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1 2. The system of claim 1, wherein said second voltage comparator has a second input coupled to
2 said photodetector output.

1 3. The system of claim 1, wherein said second voltage comparator has a second input coupled to said
2 first delay device output, and wherein said second delay device is adapted to delay a signal input
3 from said photodetector by a multiple of said predetermined delay time of said first delay device.

1 4. The system of claim 3, wherein said multiple is 2.

1 5. The system of claim 1 further comprising a AND gate, wherein inputs of said AND gate are
2 coupled to said first voltage comparator output and said second voltage comparator output to
3 produce an output pulse from said AND gate when said first voltage comparator output and said
4 second voltage comparator output output signals.

1 6. The system of claim 1 or claim 3, wherein said photodetector comprises:
2 a photodetector element capable of generating an electrical signal in response to detecting
3 an infrared signal; and
4 an amplifier for amplifying said electrical signal from said photodetector element to produce
5 an electrical output signal at said photodetector output.

1 7. A circuit for a light communications system having a photodetector including a photodetector
2 output for detecting an infrared signal from an infrared transmitter source and converting said
3 infrared signal to a electrical output signal output at said photodetector output, said electrical output
4 signal having a rise time and a fall time, the circuit comprising:
5 a first delay device having an input coupled to said photodetector output for delaying an
6 electrical signal from said photodetector for a predetermined period of time related to said rise time
7 of an expected electrical signal from said photodetector, said first delay device having a first delay

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8 device output for producing a first delay device output signal;

9 a voltage divider having an input coupled to said photodetector output for reducing an
10 electrical signal from said photodetector to a reduced signal, said voltage divider having a voltage
11 divider output for producing said reduced signal as a voltage divider output signal;

12 a second delay device having an input coupled to said voltage divider output for delaying
13 said reduced signal for a predetermined period of time related to said fall time of said expected
14 electrical signal from said photodetector said second delay device having a second delay device
15 output for producing a second delay device output signal;

16 a first voltage comparator having a first voltage comparator output, inputs of said first
17 voltage comparator coupled to said first delay device output and to said voltage divider output for
18 comparing said output signals received therefrom and adapted to generate a front edge of an output
19 signal in response to detecting a front edge of a pulse when said electrical output signal from said
20 photodetector is a pulse; and

21 a second voltage comparator having a second voltage comparator output, inputs of said
22 second voltage comparator coupled to said photodetector output and to said second delay device
23 output for comparing said output signals received therefrom and adapted to generate a back edge of
24 an output signal in response to detecting a back edge of a pulse when said electrical output signal
25 from said photodetector is a pulse.

1 8. The circuit of claim 7, wherein said second voltage comparator has a second input coupled to said
2 photodetector output.

1 9. The system of claim 7, wherein said second voltage comparator has a second input coupled to said
2 first delay device output, and wherein said second delay device is adapted to delay a signal input
3 from said photodetector by a multiple of said predetermined delay time of said first delay device.

1 10. The system of claim 9, wherein said multiple is 2.

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1 11. A communication system comprising:

2 a photo detector having a photo detector input for receiving communication signals from a
3 transmitting source, and having a photo detector output for providing electrical output signals;

4 a first delay line having a first delay input and a first delay output, said first delay input being
5 coupled to said detector output, said first delay line for delaying said electrical output signals by a
6 predetermined delay period;

7 a voltage divider having a divider input and a divider output, said divider input being coupled
8 to said photo detector output, said voltage divider for dividing said electrical output signals by a
9 fixed ratio;

10 a first voltage comparator having a first comparator first input, a first comparator second
11 input and a first comparator output, said first comparator first input being coupled to said first delay
12 output, said first comparator second input being coupled to said divider output;

13 a second delay having a second delay input and a second delay output, said second delay
14 input being coupled to said divider output, said second delay line for delaying said divider output
15 by said predetermined delay period; and

16 a second comparator having a second comparator first input, a second comparator second
17 input and a second comparator output, said second comparator first input being coupled to said photo
18 detector output, said second comparator second input coupled to said second delay output.

1 12. A system as recited in claim 11, further comprising an AND gate having a first AND gate input,
2 a second AND gate input and an AND gate output, said first AND gate input being coupled to said
3 first comparator output, said second AND gate input being coupled to said second comparator
4 output.

1 13. A System as recited in claim 11, wherein said divider ratio is one half.

1 14. A system as recited in claim 11, wherein said predetermined delay period has a relationship
2 to a pulse rise time expected when said electrical output signals are pulses.

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1 15. A system as recited in claim 14, wherein said relationship is equality.

1 16. A system as recited in claim 11, wherein said photo detector comprises a circuit comprising a
2 detector element and an amplifier for amplifying the output of said detector element.

1 17. A system as recited in claim 11, wherein said transmitting source is an infrared transmitter and
2 said photo detector is for detecting infrared signals.

1 18. A system as recited in claim 11, wherein said transmitting source is a wireless transmitter.

1 19. A circuit comprising:

2 a photo detector having a photo detector input for receiving communication signals from a
3 transmitting source, and having a photo detector output for providing electrical output signals;

4 a first delay line having a first delay input and a first delay output, said first delay input being
5 coupled to said detector output, said first delay line for delaying said electrical output signals by a
6 predetermined delay period;

7 a voltage divider having a divider input and a divider output, said divider input being coupled
8 to said photo detector output, said voltage divider for dividing said electrical output signals by a
9 fixed ratio;

10 a first voltage comparator having a first comparator first input a first comparator second input
11 and a first comparator output, said first comparator first input being coupled to said first delay
12 output, said first comparator second input being coupled to said divider output;

13 a second delay having a second delay input and a second delay output, said second delay
14 input being coupled to said divider output, said second delay line for delaying said divider output
15 by said predetermined delay period; and

16 a second comparator having a second comparator first input, a second comparator second
17 input and a second comparator output, said second comparator first input being coupled to said first
18 delay output, said second comparator second input being coupled to said second delay output.

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1 20. A system as recited in Claim 19, further comprising an AND gate having a first AND gate
2 input, a second AND gate input and an AND gate output, said first AND gate input being coupled
3 to said first comparator output, said second AND gate input being coupled to said second comparator
4 output..

1 21. An infrared communication system comprising:
2 a photo detector for detecting infrared signals from an infrared transmitter source and
3 converting the infrared signals to electrical signals;
4 a first delay device having a input coupled to said photo detector for delaying a signal from
5 the said photo detector for a predetermined period of time related to the rise time of an expected
6 electrical signal from said photo detector;
7 a voltage divider having an input coupled to said photo detector for reducing the amplitude
8 of said signal from said photo detector;
9 a second delay device having an input coupled to said output of said voltage divider for
10 delaying said reduced signal from said photo detector for a predetermined period of time related to
11 the fall time of an expected electrical signal from said photo detector;
12 a first voltage comparator coupled to an output, of said first delay device and to an output of
13 said voltage divider for comparing the signals received therefrom and adapted to generate the front
14 edge of a voltage output in response to the detection of the front edge of a pulse from said photo
15 detector; and
16 a second voltage comparator having an input coupled to said photo detector into an output
17 of said second delay device for generating back edge of a voltage output in response to detection of
18 the back edge of a pulse from said photo detector.

1 22. A system as recited in claim 21, wherein said second voltage comparator has a second input
2 coupled to the output of said photo detector.

1 23. A system as recited in claim 21, wherein said second voltage comparator has a second input

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2 coupled to the output of said first delay device and wherein said second delay device is adapted to
3 delay a signal input from said photo detector by a multiple of said predetermined delay time of said
4 first delay device.

1 24. A system as recited in claim 23, wherein said multiple equals 2.

1 25. A system as recited in claim 21, in which the outputs of said first and second comparators are
2 coupled to the input of an AND gate to produce an output pulse from said AND gate when the
3 outputs of said voltage comparators are both active.

1 26. A system as recited in claim 21, wherein said photo detector comprises a circuit comprising a
2 photo detector element and an amplifier for amplifying the output of said photo detector element.

1 27. A circuit for a light communication system having a photo detector for detecting light signals
2 from a light transmitter source and converting the light signals electrical signals, said circuit
3 comprising:

4 a first delay device having an input coupled to said photo detector for delaying a signal from
5 said photo detector for a predetermined period of time related to the rise time of an expected
6 electrical signal from said photo detector;

7 a voltage divider having an input coupled to said photo detector for amplitude reduction of
8 said signal from said photo detector;

9 a second delay device having an input coupled to said output of said voltage divider for
10 delaying said reduced signal from said photo detector for a predetermined period time related to the
11 fall time of an expected electrical signal from said photo detector;

12 a first voltage comparator coupled to an output of said first delay device and to an output of
13 said voltage divider for comparing the signals received therefrom and adapted to generate the front
14 edge of a voltage output in response to the detection of the front edge of a pulse from said photo
15 detector; and

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16 a second voltage comparator having an input coupled to said photo detector into an output
17 of said second delay device for generating back edge of a voltage output in response to detection of
18 the back edge of a pulse from said photo detector.

1 28. A system as recited in claim 27, wherein said second voltage comparator has a second input
2 coupled to the output of said photo detector.

1 29. A system as recited in claim 27, wherein said second voltage comparator has a second input
2 coupled to the output of said first delay device and wherein said second delay device is adapted to
3 delay a signal input from said detector by a multiple of said predetermined delay time of said first
4 delay device.

1 30. A system as recited in claim 29 wherein said multiple equals 2.

** TOTAL PAGE.009 **

18/02/2000 15:29 905 316 2294

① received

FIGURE 1

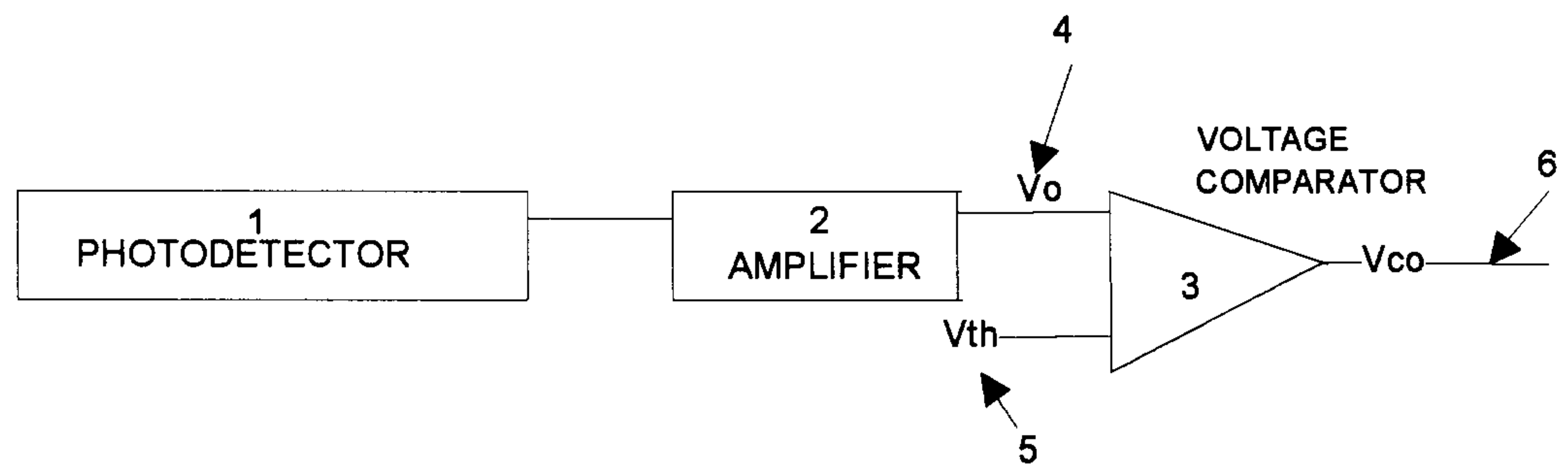


FIGURE 2

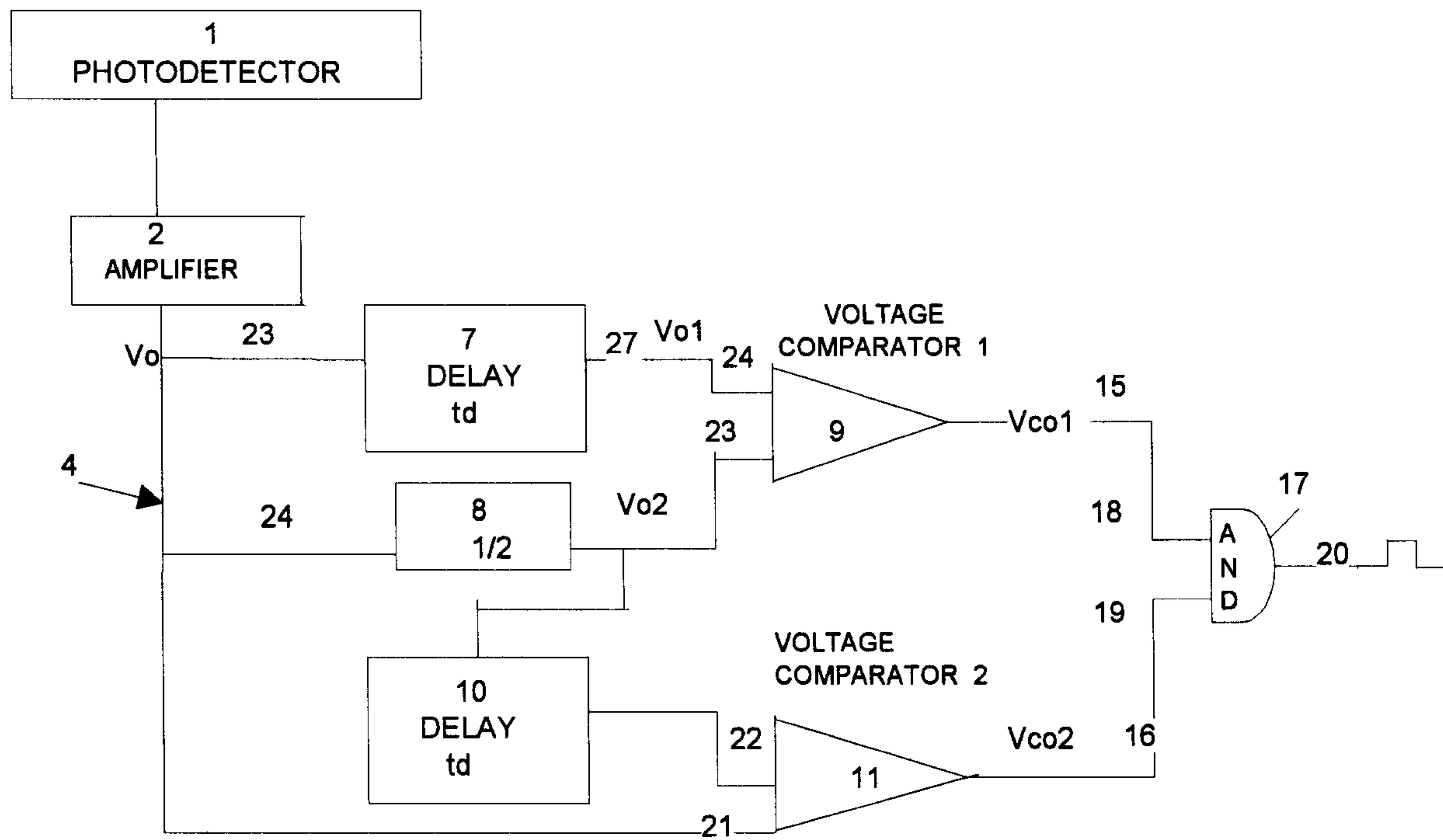


FIGURE 3

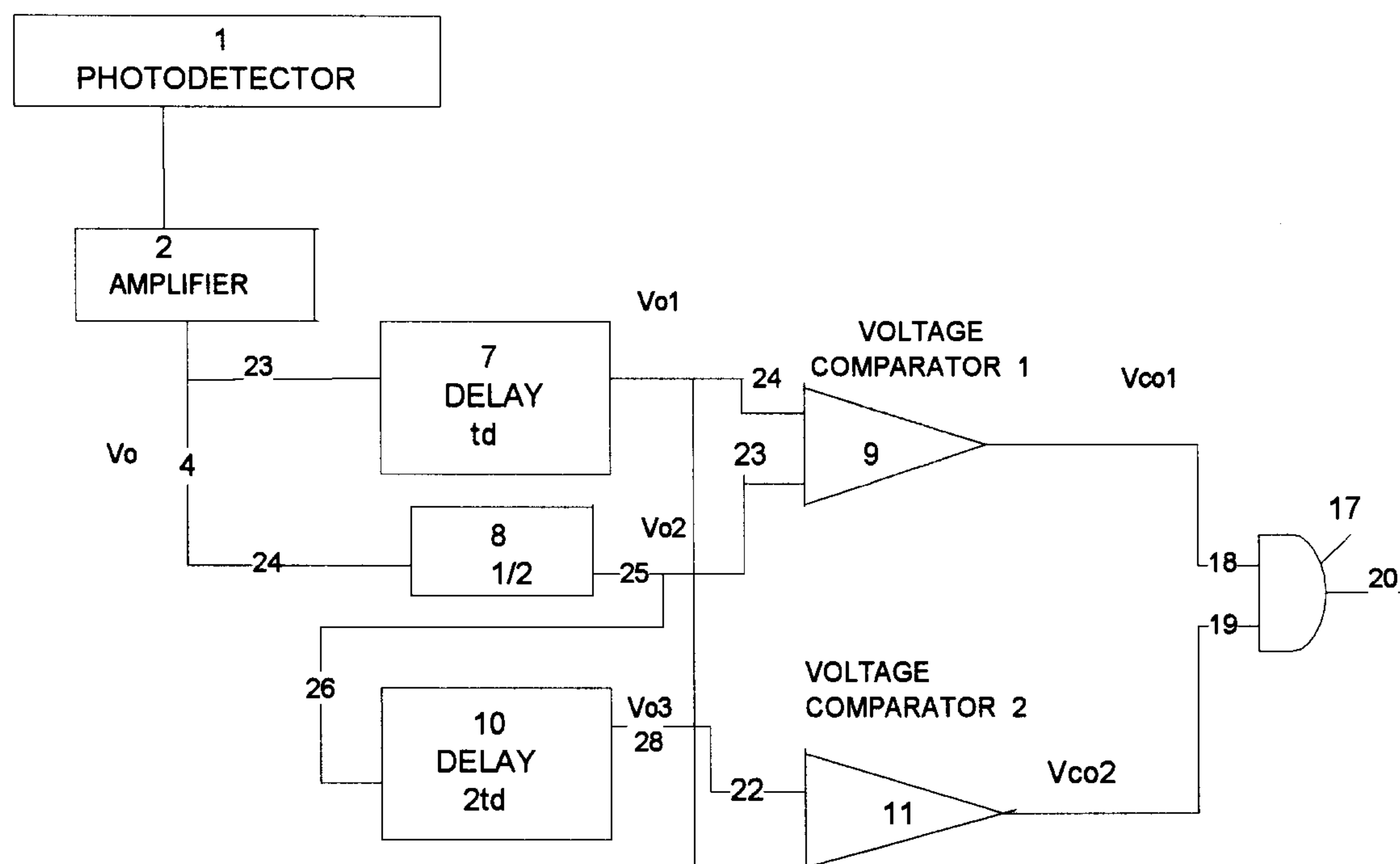


FIGURE 4

INPUT

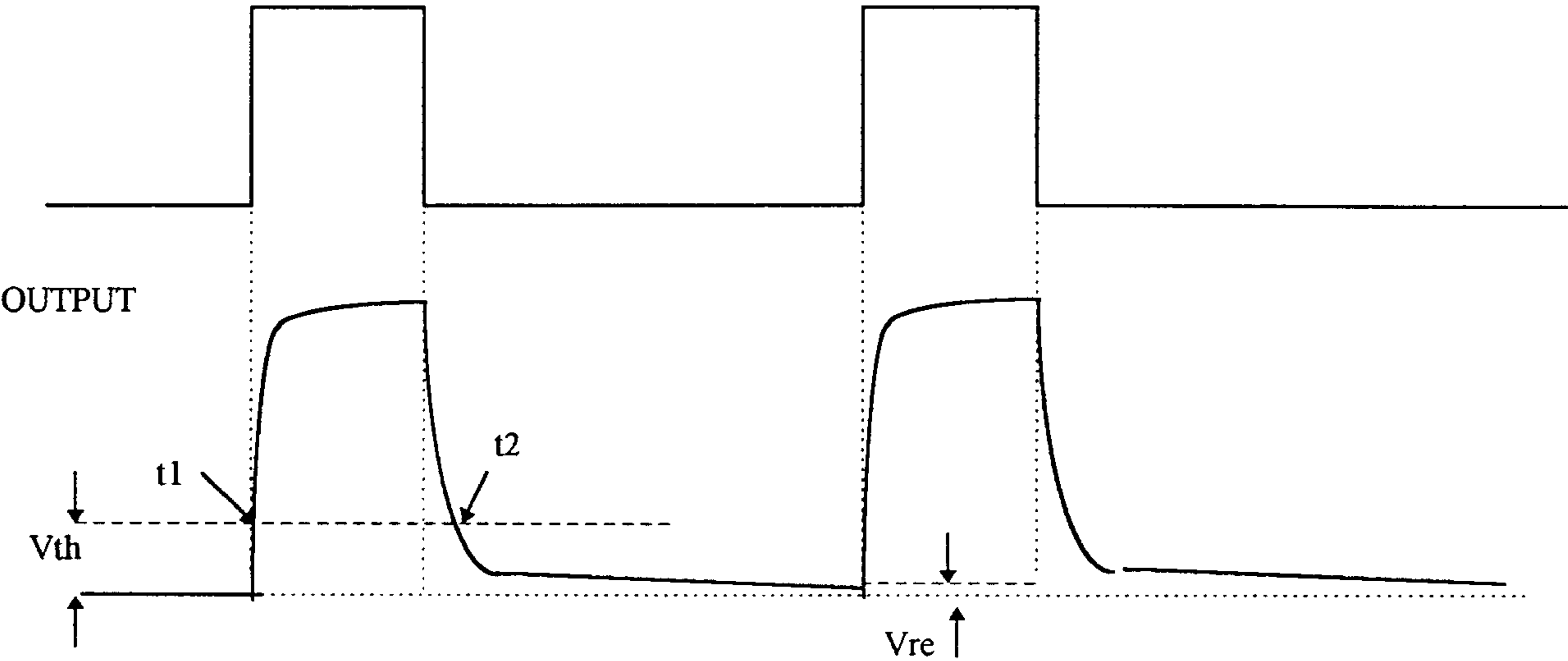


FIGURE 5

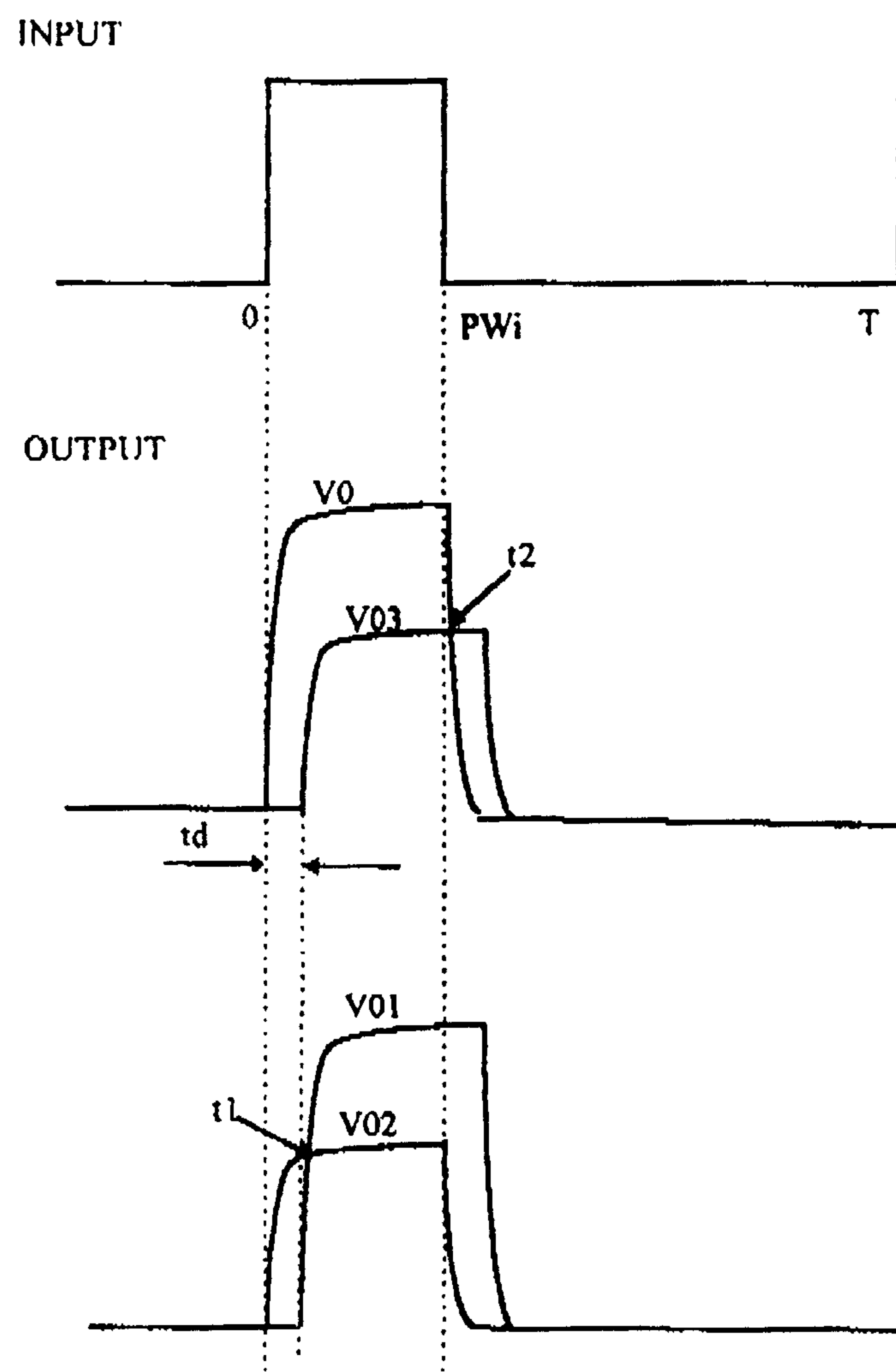


FIGURE 6

