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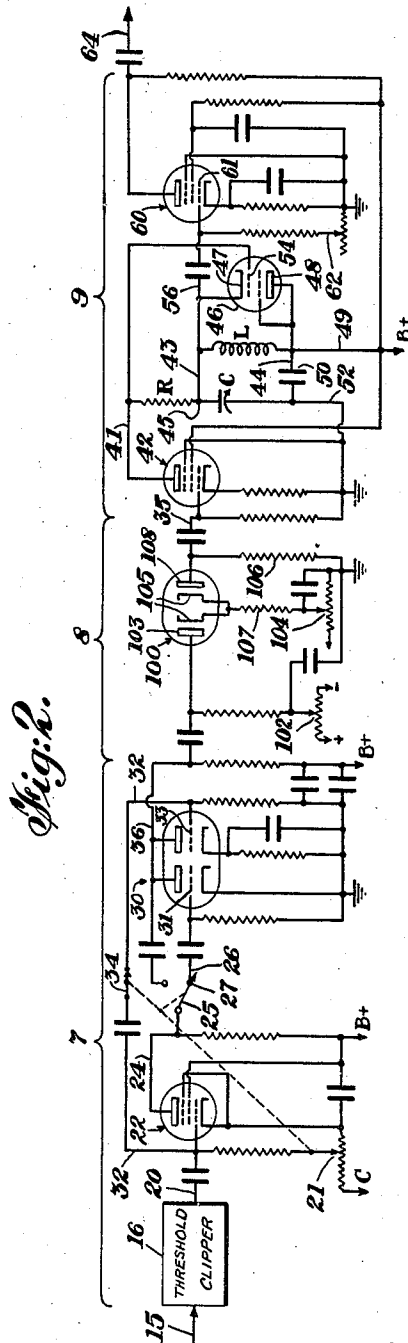
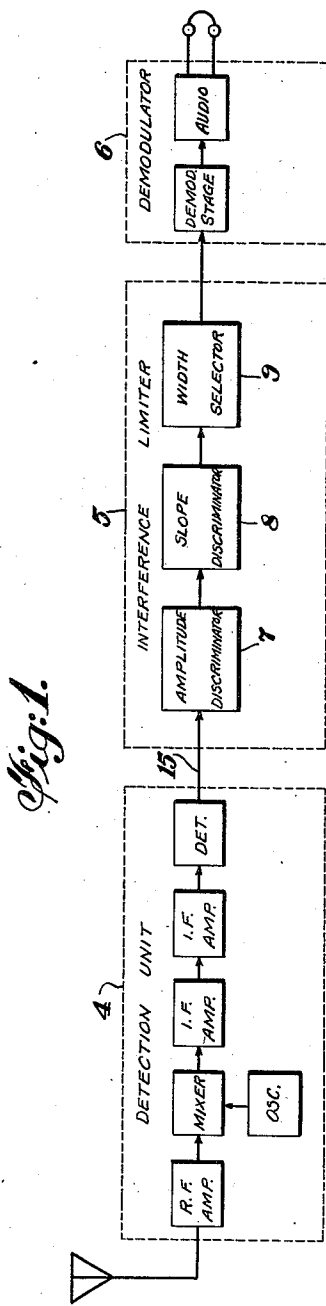
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2,434,937

SELECTIVE FILTERING SYSTEM

Filed May 24, 1943

2 Sheets-Sheet 1



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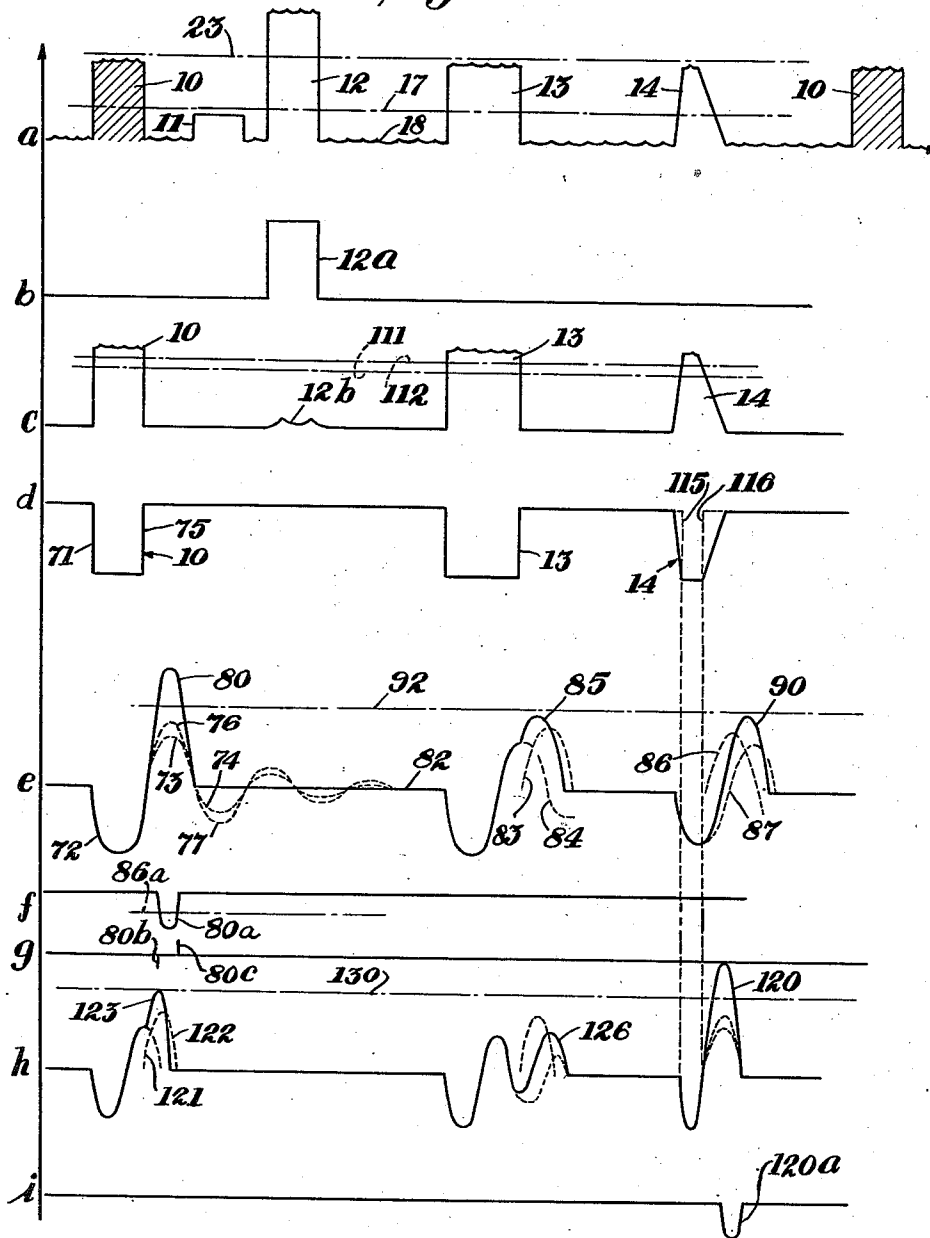
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2 Sheets-Sheet 2

Fig. 3.



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SELECTIVE FILTERING SYSTEM

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Application May 24, 1943, Serial No. 488,182

13 Claims. (Cl. 178—44)

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This invention relates to communication systems utilizing trains of pulses for conveyance of intelligence and more particularly to a selective filtering system for receivers intended for reception of time modulated signals.

Our present application covers a species of our invention disclosed in our copending application entitled "Filtering system," Serial No. 488,180, filed May 24, 1943. As stated in our aforesaid application, radio and telegraph communication systems using time modulated pulses for transmission of intelligence may, with the presence of jamming pulses and/or pulses conveying other channels of intelligence, result in interference at the receiver unless special precautions are made.

Where pulses carrying intelligence are transmitted at a given frequency or a given time relationship, interfering or pulses of other channels of communication, except in the case of superposition, can be eliminated by blocking. A system providing such blocking to eliminate unwanted pulses is disclosed in the copending application of E. Labin Serial No. 386,282, filed April 1, 1941, now Patent No. 2,406,019, granted August 20, 1946. Should the pulses carrying the intelligence be transmitted at irregular timing or even at different repetition rates, this frequency or time selection method of blocking is not entirely satisfactory. This is particularly so in the case of a large degree of time modulation and where, as in the case of war time communication, it is desirable to change the formation of the pulse train from time to time in order to confuse the enemy.

It is an object of our invention, therefore, to provide a receiver with a pulse filtering system for limiting interference which system is easy and simple to operate.

Another object of our invention is to provide a method and means to eliminate those pulses differing in amplitude, width and/or slope (build up and decay time) from a selected pulse shape.

The above and other objects of the invention will become more apparent upon consideration of the following detailed description to be read in connection with the accompanying drawings, in which:

Fig. 1 is a block diagram of a radio receiver provided with a pulse filtering system according to our invention;

Fig. 2 is a schematic wiring diagram of the pulse filtering system by which interference pulses are eliminated in the receiver; and

Fig. 3 is a graphical illustration of the operating steps of the filtering system.

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The receiver system shown in Fig. 1 comprises a detection unit 4, an interference limiter or pulse filtering system 5 and a demodulator 6. The detection unit is conventional with the exception that a wider frequency pass band is provided than normal in order to accommodate the pulse signals. The unit comprises the usual R. F. amplifier, oscillator, mixer, I. F. amplifier stages and diode detector. These stages operate in the usual manner for reception of time modulated pulses the same as for amplitude modulator signals.

If the pulses are transmitted on wire lines, either as direct current pulses or as carrier frequency pulses, the detection unit 4 may be omitted or modified accordingly.

In order to effectively jam a time modulation system, the only efficient means is to utilize pulse transmission. This is because the utilization of a continuous carrier for jamming purposes is overcome by time modulated systems by virtue of the high peak power of the time modulation system. A continuous carrier, in order to jam pulse signals must have a power at least 14 decibels above the average power of the time modulation transmitter.

Assuming that a series of wanted time modulation pulses and unwanted enemy jamming pulses, which differ from the time modulated pulses in several characteristics at the receiving location, are received by the receiver of Fig. 1. The jamming signals are not likely to be identical in shape to the time modulated pulses. The present invention makes use of this difference in pulse shape to eliminate the enemy jamming pulses or any other unwanted pulses. The interference limiter 5 is provided with an amplitude discriminator 7 to eliminate those pulses differing in amplitude from the wanted pulse, a slope discriminator 8 to eliminate or at least transform those pulses differing in slope (build-up and decay time) from the wanted pulse so that they may be eliminated by a subsequent filtering operation such as performed by the width selector 9. The width selector 9, of course, eliminates all pulses differing in width from the width of the wanted signal pulse. These pulse shape discriminating and selecting stages are arranged in tandem relationship. That is to say, the received pulses are applied to the filtering stages in succession.

The demodulator 6 converts the time displaced pulses to amplitude varying pulses by any known means. A suitable demodulator unit for this purpose is disclosed in the copending application of

D. D. Grieg Serial No. 459,959, filed September 28, 1942, now Patent No. 2,416,306, granted Feb. 25, 1947. The signal increments thus converted from time modulated pulses to amplitude modulated pulses are readily applicable in the usual manner to an audio stage for audible reception.

Referring to Figs. 2 and 3 of the drawings, curve *a* of Fig. 3 represents an input wave or train of pulses of various shape characteristics. Pulse 10 is a wanted signal pulse which appears at a given repetition rate and is time displaced by intelligence being transmitted. Pulses 11 and 12 differ in amplitude from the pulse 10, the pulse 11 being less and the pulse 12 being greater. These two pulses are selected of the same width as pulse 10 for purposes of illustrating the selective feature of the amplitude discriminator 7. Pulse 13 is of the same amplitude as pulse 10 but is of greater width. Pulse 14 is also of the same amplitude as pulse 10 but is of different shape in that the leading and trailing edges are sloped at different build-up and decay times.

This train of pulses after having passed through the detection unit 4 is applied to the interference limiter 5. The input 15 of the amplitude discriminator 7 feeds the pulses to a threshold clipper 16 which preferably is adjusted to clip the pulses at an amplitude level 17, curve *a*, Fig. 3, at an amplitude level slightly greater than the amplitude of the small pulse 11 but less than the amplitude of pulse 10. This clipping operation eliminates the smaller pulses such as pulse 11 and any noise fluctuation 18 that might be present between the successive pulses.

The output 20 of the threshold clipper 16 is applied to a second threshold and amplifying clipper 22 which preferably is adjusted by a control resistor 21 to threshold clip the pulses at a level 23. This level is greater than the amplitude of pulse 10 but less than the amplitude of the larger pulse 12. The output of the clipper stage 22 is taken from the plate connection 24 so that the upper portion of the pulse thus clipped is inverted in phase and amplified as indicated at 12*a*. This inverted energy 12*a* is applied to an input connection 26 of grid 31 of a mixer stage 30 through a movable switch contact 25 and a terminal 27.

The mixer stage 30 comprises a conventional double triode tube. While the plate output of the clipper 22 is applied to grid 31 of the mixer, the output energy of clipper 16 is also applied to the mixer through a connection 32 and switch 34 to grid 33. The output at the anode connection 36 is illustrated by curve *c*. It will be observed that the large pulse 12 as well as the small pulse 11 is eliminated. This elimination may result in some small disturbance 12*b* but this, as will be seen hereinafter, will be eliminated by the operation of a subsequent filtering stage.

When the interfering noise or pulses are below amplitude level 17 curve *a*, there is no need of the clipping operation of tube 22 or the mixing of mixer stage 30. The switch arm 25 may then be moved to its upper contact, opening switch 34 and shifting the bias of tube 22 to operate as a normal amplifier. The opening of switch 34 effectively by-passes the mixer stage 30.

Curve *c*, however, still contains pulse 13 which differs in width from pulse 10 and pulse 14 which differs in slope from pulse 10. It will be noted that the base of the pulse 14 is substantially the same width as pulse 10. The pulse width selector 9 serves to eliminate pulses differing in width from the pulse 10 and also those pulses

having slower build-up and decay times such as the pulse 14. Should it be desirable, however, to eliminate pulse 10 in preference to pulse 14 a re-shaping of pulse 14 will then be desirable. This re-shaping is accomplished by the gate function of the slope discriminator 8, the details and operation of which will be hereinafter described. For the present let it be assumed that the device 8 is so adjusted as to pass the pulses 10, 13 and 14 substantially as shown in curve *c*.

The width selector 9 is preferably of the character disclosed in our copending application Serial No. 487,072 filed May 15, 1943, entitled "Pulse selecting and eliminating system." Other forms of width selector that may be used are disclosed in the copending application of E. Labin Serial No. 467,509, filed December 1, 1942, now Patent No. 2,418,127, granted April 1, 1947.

The output connection 35 of the shape discriminator 8 is applied to a limit clipping tube 42 which limits the amplitude of the pulses 10, 13 and 14 to substantially the same amplitude. This tube also operates to invert the pulses from positive to negative as indicated by curve *d*. This output energy of tube 42 is applied through a resistor *R* to a shock excitable L-C circuit 45. The condenser *C* is adjustable so that the circuit may be tuned to a frequency the period of which is twice or some other proper multiple of the duration of the wanted pulse 10. The coil *L*, of course, may also be made adjustable either in place of the adjustment of condenser *C* or to operate in conjunction therewith.

Connected across the tunable circuit 45 is a vacuum tube 46 the cathode 47 of which is connected to the input side 43 of the circuit 45 while the anode 48 is connected to the opposite side 44 of the circuit. The anode connection at this side of the circuit is also connected through lead 49 to a positive potential B+. A condenser 50 separates the lead connection 49 from a ground lead 52. The condenser 50 operates as a coupling condenser and the capacitance thereof does not affect appreciably the adjustment of the condenser *C*.

The energy output of the anode connection 41 of the tube 42 is also applied to a grid 54 of the tube 46 so as to block conduction between the cathode 47 and the anode 48 while pulse energy is applied to the circuit 45. The undulations occurring in the circuit 45 are taken off through a connection 56 for application to a threshold clipper and amplifier stage 60. The bias on the grid 61 of the clipper stage 60 is controlled by adjustment of a resistor 62.

The operation of the width selector portion of the circuit of Fig. 2 is indicated by the curves *d*, *e* and *f*. The curve *d* represents the anode voltage across the resistor *R*. Curve *e* represents the oscillations produced at the output 56 of the circuit 45 in response to the pulse energy of curve *d*. Curve *f* represents the pulse output at 64 from the clipper stage 60 after the undulations have been threshold clipped.

When the leading edge 71 of the wanted pulse 10 is applied to the circuit 45, an undulation 72, curve *e* is produced. The circuit 45 will oscillate tending to produce in response to the edge 71 a damped wave according to the undulations 72, 73, 74, etc. When the trailing edge 75 of the pulse 10 is applied to the circuit 45, a further shock excitation occurs in the opposite direction producing undulations 76, 77, etc. The undulations 73 and 76 are in time relation since the circuit is tuned to a period equal to twice the dura-

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tion of the pulse 10 and they combine to produce a maximum undulation 80. The succeeding pairs of undulations produced by the leading and trailing edges of the pulse 10 tend to produce a damped oscillation but all oscillations beyond the trailing edge of the undulation 80 are damped out by the tube 46. The damping function of this tube is controlled by the potential applied across the cathode and anode connections thereof and to the grid 54. The grid 54 receives a potential corresponding to the voltage across the resistor R when the pulse is applied to the circuit 45. This potential being negative (curve d) blocks conduction in the tube so that the "Q" of the circuit 45 will remain high and the circuit will respond to the leading and trailing edges of the pulse to initiate the oscillation. The connection of the cathode 47 and the anode 48 across the circuit 45 is such that the polarity of the undulation 80 is such that it blocks the tube against conduction. Thus, the tube remains blocked for the duration of the undulation 80 and when the polarity commences to change from positive to negative this change immediately produces conduction in the tube 46 thereby shunting the low resistance of the tube across the circuit 45. This so lowers the "Q" of the circuit as to absorb energy that would normally produce the next succeeding undulation thereby suppressing the further tendency of the circuit to produce oscillations. This results in a substantially zero output as indicated at 82 following the undulation 80 and until the leading edge of the next succeeding pulse is applied to the circuit. It will be clear that this damping operation of the tube 46 suppresses trailing oscillations for each of the pulses so that they will not interfere or adversely affect the oscillations produced by later occurring pulses.

The pulse 13 being wider than the pulse 10, the leading edges thereof are further apart than the time corresponding to one-half of the period at which the circuit 45 is tuned. This results in the production of oscillations 83 and 84 which are out of step thereby producing an undulation 85 of lower amplitude than the undulation 80.

Pulse 14, while of the same width at the base as pulse 10, is of different width at the crest thereof. The build-up and decay slopes of the pulse being less steep than the leading and trailing edges 71 and 75 of pulse 10 do not shock excite the circuit 45 with as great a force. As shown in curve e, the leading and trailing edges of the pulse 14 produce oscillations 86 and 87 which are out of step. These oscillations combine to produce a maximum undulation 90 which, however, is of less amplitude than the undulation 80.

The clipping operation of tube 60 being adjusted as indicated by the level 92 eliminates the undulations 85 and 90 producing an output undulation 80a which corresponds to the peak portion of undulation 80. When the undulation is limited as indicated by level 86a and differentiated, positive and negative pulses 88c and 88b are produced either one of which may be used to represent the wanted pulse 10. It is this final pulse output that is applied to the demodulator stage 6 for inversion from time modulated to amplitude modulated signals.

Referring back to curves c and d and the slope discriminator 9 of Fig. 2, it will now be explained how the circuit may be adjusted to select pulses shaped like pulse 10 and to eliminate other pulse shapes. The gate function of the slope discriminator 8 is performed by a diode-double-limiter tube 100 of the character disclosed in our co-

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pending application entitled "Indicating and calibrating means" Serial No. 437,530, filed April 3, 1942. The tube 100 is provided with a potentiometer 102 by which a bias of desirable positive or negative magnitude, as the case may be, can be applied to the anode 103. A second potentiometer 104 supplies adjustably controlled negative bias to the cathodes 105. A load resistor 106 is connected between the anode and ground. In operation, the anode 103 is biased with respect to the cathodes 105 and ground so as to permit the space discharge path between these elements to conduct for only a portion of the voltage swing of the applied pulse. This results in a clipping operation at a level such as 142, curve c, whereby the clipped potential of the input pulse appears across the biasing resistor 107, associated with the potentiometer 104. The cathodes 105, however, are normally biased negatively so that there is a normal conductive path provided between the electrodes 105 and the anode 108. It follows that the pulse appearing across the resistor 107 will be conducted through the discharge path, that is, from the cathodes 105 to the anode 108, as long as the magnitude of this voltage is less than the anode potential. This produces a second limiting level 111 above the limiting level 112 produced by the first conductive path.

It will be clear from the foregoing description that the double limiting operation of the tube 100 provides a gate the levels of which are adjustable throughout the height of the pulses. By varying the amount of the negative bias applied to the cathodes 105, the spread of the gate may be adjustably selected. If it is desired to change the effective position of the gate, adjustment of the potentiometer 102 will serve this purpose without changing the spread of the gate.

Should it be desirable to select pulse 14 and eliminate pulses 10 and 13, a slice of each pulse may be obtained at a height on the pulse 14 where its width is different from the pulse 10. When these sliced portions of the pulses are amplified in tube 42, the pulses 10 and 13 will be substantially as shown in curve d but pulse 14 will now assume the shape indicated by the leading and trailing edges 115 and 116. When this pulse shape is applied to the circuit 45, the leading and trailing edges 115, 116 will, when the circuit 45 is tuned to the period which is an even multiple of the timing between the edges 115 and 116, produce a maximum undulation 120. The pulse 10, however, now being wider than the period between the edges 115 and 116 of pulse 14 will produce oscillations 121 and 122 which are out of step thereby resulting in an undulation 123 which is of less amplitude than the undulation 120. Likewise, the wider pulse 13 will produce an undulation 126 which is of even smaller amplitude. By properly clipping at a level 130, the undulation 120 is selected as indicated at 120a (curve f) and the undulations 123 and 126 are eliminated. The pulse 120a may be re-shaped similarly as indicated in curve g for the pulse 80a.

From the foregoing description, it will be clear that the receiving system of Fig. 1 by means of the filtering stages of the interference limiter 5 will eliminate for most practical purposes jamming and other interfering signals or pulses that may be received. While pulses of a shape identical to the wanted pulses and of identical amplitudes can not be eliminated by this system, the

probability of identical amplitudes is very small, and furthermore it will be understood that the pulse shape used for conveying messages may be varied from time to time so that the enemy will be unable to effectively jam the system.

It will also be recognized that the filtering system of our invention may be used in conjunction with multi-channel telegraphy as well as in a radio receiver.

While we have shown and described the principles of our invention in connection with specific apparatus, we recognize that various changes and modifications may be made therein without departing from the invention. It is our aim, therefore, to cover in the appended claims all such changes and modifications as fall within the scope of the invention.

We claim:

1. A method of selectively filtering a train of pulses to eliminate those pulses differing in amplitude and width characteristics from a given pulse shape, comprising threshold clipping the pulses at an amplitude greater than the smaller amplitude pulses but less than the amplitude of said given pulse shape, thereby eliminating said smaller pulses, threshold clipping and inverting in phase at least a part of that portion of those pulses extending above the amplitude of said given pulse shape, mixing the inverted pulse energy with the pulse energy obtained by the first-mentioned clipping operation, whereby those pulses of amplitude greater than said given pulse shape are eliminated, shock exciting a resonant circuit by means of the leading and trailing edges of the remaining pulses, the oscillations initiated by the edges of each pulse combining to form an undulation following the trailing edge of the pulse, damping out the oscillations normally following said undulation so that oscillations produced by one pulse will not affect the oscillations produced by the next pulse, tuning the resonant circuit to a period equal to a given multiple of the width of the given pulse shape so that the oscillations set up by the edges of the pulses of width corresponding to the width of said given pulse shape provide undulations of maximum amplitude and the oscillations produced by the edges of pulses of greater and lesser width form undulations of amplitude less than said maximum undulation, and threshold clipping the undulations to eliminate those corresponding to those greater and lesser width pulses.

2. A method of selectively filtering a train of pulses to eliminate those pulses differing in width and slope characteristics from a given pulse shape comprising gate clipping to obtain a slice of each pulse at a level where the given pulse shape differs in width from the widths of the other pulses, shock exciting a resonant circuit with the pulse slices, the oscillations initiated by the edges of each pulse slice combining to form an undulation following the trailing edge of the pulse slice, damping out the oscillations normally following said undulation so that oscillations produced by one pulse will not affect the oscillations produced by the next pulse slice, tuning the resonant circuit to a period equal to a given multiple of the width of the slice taken from the pulses of said given pulse shape so that the oscillations set up by the edges of pulse slices of greater and lesser amplitude and the oscillations produced by the edges of pulse slices of greater and lesser width form undulations of amplitude less than said maximum undulation, and threshold clipping the undulations to eliminate those corre-

sponding to those greater and lesser width pulse slices.

3. A system for selectively filtering a train of pulses to eliminate those pulses differing in amplitude and width characteristics from a given pulse shape, comprising a first means to threshold clip the pulses at an amplitude greater than the smaller amplitude pulses but less than the amplitude of said given pulse shape, a second means to threshold clip and invert in phase at least a part of that portion of those pulses extending above the amplitude of said given pulse shape, a mixer, means to supply the output of said first and second clipping means to said mixer so that the inverted pulse energy substantially eliminates the larger pulses, a pulse width discriminator, and means to apply the output of said mixer to said width discriminator thereby eliminating those pulses differing in width from said given pulse shape.

4. The system defined in claim 3 wherein the width discriminator comprises a shock-excitable resonant circuit responsive to the leading and trailing edges of the pulses to establish oscillations, means to damp out the oscillations normally following the first undulation formed by the combined oscillations, tuning the resonant circuit to a period equal to an even multiple of the width of the given pulse shape so that the oscillations set up by the edges of the pulses of width corresponding to the width of said given pulse shape provide undulations of maximum amplitude and the oscillations produced by the edges of pulses of greater and lesser width form undulations of amplitude less than said maximum undulation, and means to threshold clip the undulations to eliminate those corresponding to the greater and lesser width pulses.

5. The system defined in claim 3 wherein the means for conducting the pulses from the mixer to the width discriminator comprises a gate clipping device, means to control the breadth of the gate, and means to control the level at which the gate clipping operation is performed on the pulses whereby said given pulse shape may have given slope characteristics and the pulses differing therefrom are eliminated.

6. A system for selectively filtering a train of pulses to eliminate those pulses differing from one or more of the given amplitude, given slope and given width characteristics of a given pulse shape, comprising filter means to pass energy of those pulses having said given amplitude characteristic, filter means to pass energy of those pulses having said given slope characteristic and to translate them into pulses of said given width, filter means to pass energy of those pulses having said given width characteristic, and means to correlate the operations of the several filter means to produce final output pulses having a timing according to those pulses of said train having said given shape characteristics, said means for correlating the operations of the several filter means including means for connecting said filter means in tandem relation whereby the width filter means operates on the pulse energy output of the other filter means.

7. A system for selectively filtering a train of pulses to eliminate those pulses differing from one or more of the given amplitude, given slope and given width characteristics of a given pulse shape, comprising first filter means to pass energy of those pulses having said given amplitude characteristic and to translate the slope characteristic

into a width characteristic, and second filter means including a resonant circuit connected to the output of said first filter means to pass pulse energy of those pulses passed by said first filter means having said given width characteristic.

8. A system for selectively filtering a train of pulses of substantially the same base width to eliminate those pulses differing in slopes of the edges thereof from the slopes of the edges of a given pulse shape, comprising means for clipping the train of pulses between two selected clipping levels relative to the base of the pulses to obtain a slice of each pulse, the pulses differing in slope from said given pulse shape producing pulse slices differing in width from the width of the pulse slices obtained from pulses of said given shape, a pulse width discriminator, and means to apply the pulse slices from said clipping means thereby eliminating those pulse slices differing in width from the pulse slices clipped from the pulses of said given pulse shape.

9. A method of selectively filtering a train of pulses to eliminate those pulses differing from one or more of the given amplitude, given slope and given width characteristics of a given pulse shape, comprising subjecting energy of the train of pulses to a first filtering operation to pass energy of those pulses having said given amplitude characteristic, subjecting the pulse energy output of said first filtering operation to a second filtering operation to pass pulse energy between two selected clipping levels to obtain pulses of duration different from said given width characteristic for those pulses varying in width and slope from said given shape, and subjecting the pulse energy output of said second filtering operation to a third filtering operation to pass energy of those pulses having said given width characteristic.

10. A method of selectively filtering a train of pulses of substantially the same base width to eliminate those pulses differing in the slopes of the edges thereof from the slopes of a given pulse shape, comprising: gate clipping at a given level above the base of the pulses to obtain a slice of each pulse, the pulses differing in slope from said given pulse slopes producing pulse slices differing in width from the widths of the pulse slices obtained from pulses of said given shape, and subjecting the pulse slices to a filtering operation to eliminate those pulse slices differing in width from the pulse slices clipped from pulses of said given pulse shape.

11. A method of selectively filtering a train of pulses to eliminate those pulses differing in one or more of the following characteristics; amplitude, slope and width characteristics from a given pulse shape comprising: threshold clipping the pulses at an amplitude greater than the smaller amplitude pulses but less than the amplitude of said given pulse shape, thereby eliminating said smaller pulses, threshold clipping and inverting in phase at least a part of that portion of those pulses extending above the amplitude of said given pulse shape, mixing the inverted pulse energy with the pulse energy obtained by the first-mentioned clipping operation, whereby those pulses of amplitude greater than said given pulse shape are eliminated; then eliminating pulses having different slopes than that of said given pulse including gate clipping to obtain a slice of

each of the remaining pulses at a given level with respect to the bases of the pulses, the pulses differing in slope from said given pulse slopes producing pulse slices differing in width; and thereafter filtering the pulse slices to eliminate those pulse slices differing in width from the pulse slices taken from pulses of said given pulse shape.

12. A system for selectively filtering an original train of differently shaped pulses to produce a new train of desired pulses corresponding to a given shape comprising: means to eliminate those pulses of undesired amplitude, means to eliminate those pulses of undesired slope by changing their base width from that base width of the desired pulses, means coupled to the output of the last-named means to eliminate those pulses of undesired width, and means to correlate the results from the above-mentioned means to produce said new train of desired pulses.

13. A method of selectively filtering a train of pulses to eliminate those pulses differing from one or more of the given amplitude, given slope and given width characteristics of a given pulse shape, comprising: subjecting energy of the train of pulses to a first filtering operation to pass energy of those pulses having said given amplitude characteristic, subjecting the pulse energy output of said first filtering operation to a second filtering operation including a clipping operation to produce pulse energy between two selected clipping levels to obtain pulses of different duration for those pulses varying in width and slope from said given shape, subjecting the pulse energy output of said second filtering operation to a third filtering operation to pass energy of those pulses having said given width characteristic, said third filtering operation including shock exciting a resonant circuit by means of the leading and trailing edges of the pulses from said second filtering operation, the oscillations initiated by the edges of each pulse combining to form an undulation following the trailing edge of the pulse, damping out the oscillations normally following said undulation so that oscillations produced by one pulse will not affect the oscillations produced by the next pulse, tuning the resonant circuit to a period equal to a given multiple of the width of the given pulse shape so that the oscillations set up by the edges of the pulses of width corresponding to the width of said given pulse shape provide undulations of maximum amplitude, and the oscillations produced by the edges of pulses of greater and lesser width form undulations of amplitude less than said maximum undulation, and threshold clipping the undulations to eliminate those corresponding to those greater and lesser width pulses.

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