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(54) Title: METHOD AND APPARATUS UTILIZING ELECTRODERMAL RESPONSE AND THE LIKE AS A CONTROL MEANS

(57) Abstract

A specific embodiment of the method and apparatus utilizing a personal computer (10) having a game paddle input port (E1, E2, E3). According to the method and apparatus of this invention, the time rate of change in the electrodermal response and the like of a biologic individual is sensed independently of the absolute value of the electrodermal response or the like and continuously adjusted toward a time rate of change approaching the average time rate of change which the biologic individual can conciously achieve in such electrodermal response and the like. The resultant time rate of change is utilized as the input (24, 25) to a computer (10) in order to provide the control means.

METHOD AND APPARATUS UTILIZING
ELECTRODERMAL RESPONSE AND THE
LIKE AS A CONTROL MEANS

Field of the Invention

5   This invention relates to methods of and
apparatus for sensing responses in autonomic systems
of biologic individuals and more particularly to a
method and apparatus utilizing electrodermal response
and the like in biologic individuals as a control
10   means.

Background of the Invention

All living individuals, i.e., plants and
animals, are known to have complex systems for
automatically maintaining their biological balances
15   substantially independently of their central nervous
system. Such systems are called "autonomic systems"
and in warm blooded animals, for example, such systems
are known to control such things as the body
temperature, respiration rate and heart beat of the
20   animal, for purposes which are fairly well understood.
However, both plants and animals have been found to
have autonomic systems controlling their electrodermal
response for purposes which are not fully understood.
Furthermore, it has been found that the
25   central nervous system of human beings can consciously
and subconsciously control their autonomic systems
including their electrodermal response. The conscious
and subconscious control of respiration rate by the
central nervous system is a common experience of all
30   mankind. In recent years bio-feedback devices have
enabled human experience of the conscious and
subconscious control of such autonomic systems as heart

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beat, blood pressure, temperature, and electrodermal response, for example.

However, the conscious and subconscious control of such autonomic systems by the central nervous system as experienced in the prior art is often erratic, at best, particularly for electrodermal control. This is due, in part, to the fact that such autonomic systems are subject to simultaneous autonomic control which is by nature a primary effect, whereas the conscious and subconscious control of such autonomic systems by the central nervous system is a secondary effect. In other words, although a human being may be able to consciously achieve an electrodermal response through the central nervous system, such response will tend to stimulate a counteracting autonomic response. Such autonomic response may be larger than the conscious response and may be followed by further autonomic responses directed toward restoring the original balance of the system. In addition, the individual may simultaneously exhibit an autonomic electrodermal response of many times such conscious response due to environmental effects such as the weather, temperature, atmospheric pressure, etc. Finally, a simultaneous subconscious electrodermal response through the central nervous system due to loud noises, personal psychological condition, etc., may occur which may either reinforce or counteract the conscious electrodermal response.

One object of this invention is to provide a reliable method and apparatus for utilizing "conscious" (i.e., "intentional" or "voluntary") electrodermal response and the like as a control means.

Summary of the Invention

According to this invention, electrodermal response and the like of a biologic individual is utilized by programming an electrical device to

5   respond in a desired humanly perceptible fashion to changes in the sense and amplitude of an electrical control signal only in a given range. A value characteristic of the state of an autonomic system, for example, the galvanic skin resistance of the

10   individual, is then sensed and converted to an electrical signal, the absolute value of which changes in sense and amplitude with changes in the sensed value characteristic of the state of the autonomic system and such electrical signal is continuously

15   adjusted in absolute value toward a given electrical value with a given time rate of change approaching the average time rate of change which can be achieved in the value characteristic of the state of the autonomic system by the central nervous system of a biologic individual. The resultant time rate of change in the

20   absolute value of the electrical signal is converted to an electrical signal within the given range and used as the electrical control signal for the electrical device.

Brief Description of the Drawing

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This invention will be more fully understood from the following detailed description of the method when read in conjunction with the appended drawing showing a preferred embodiment of the apparatus wherein:

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FIG. 1 is a perspective view of a stylized
personal computer having a control means according to
a preferred embodiment of this invention connected
thereto.

5   FIG. 2 is a block diagram of the apparatus
of this invention.

FIG. 3 is a schematic diagram of a circuit
for amplifying galvanic skin response and the like
suitable for use in apparatus according to one
10   embodiment of the teaching of this invention.

FIG. 4 is a graph of conventional
resistance values at the GSR input of apparatus
according to this invention plotted on the ordinate
against time plotted on the abscissa.

15   FIG. 5 is a graph of the effective output
resistance values of the apparatus corresponding to
the input resistance values of FIG. 4 plotted on
the ordinate against time on the abscissa.

FIG. 6 is a graph similar to FIG. 4 showing
20   idealized GSR values for a first biologic individual
in solid line and for a second biologic individual in
broken line.

FIG. 7 is a graph similar to FIG. 5 but
showing the position of an image on the face plate of
25   a monitor in values of FIG. 6.

Detailed Description of the Invention

Referring to the drawing an apparatus
according to a preferred embodiment for practicing
the method of this invention is shown. Thus, in
30   FIG. 1, a conventional personal computer system 10 is
shown as comprising a computer circuitry and keyboard
unit 12 with a pair of disc or tape drives 13 and 14
and a cathode ray tube monitor 16 electrically
connected thereto. Such system may be a personal
35   computer system as manufactured and sold by the Apple,

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Atari, or Commodore computer manufacturing companies
having a game paddle input port as is well known in
the art. Such game paddles conventionally comprise
simple variable resistors or potentiometers adapted to
provide resistance values between about zero and

5   about 150,000 ohms at the input port to the computer
system. As is well known in the art, the circuitry 12
of the computer system may be programmed to respond
to manual adjustment of the resistance value of the

10   game paddle to produce a desired display on the
cathode ray tube monitor 16. This is conventionally
done by prerecording the program on a disc or tape
which is then inserted into one of the disc or tape
drives 13 and 14 to program the circuitry 12 of the

15   computer system. Such prerecorded programs may
comprise a game of some sort, for example, having a
controllable element such as an image of a ball or
other character which can be caused to move about on
the face plate of the cathode ray tube monitor by

20   manually changing the setting of the variable
resistor or potentiometer of the game paddle.
Although a wide variety of mechanical elements for
effecting the change in the resistance value of game
paddles known in the prior art have been used, all

25   of such game paddle devices comprise essentially a
resistance element having a first wire connecting one
end thereof to one input terminal of the game paddle
input port, and a second wire connecting a movable
tap on the resistor to another input terminal of the

30   game paddle input port.
         According to the embodiment of this
invention shown in the drawing, the conventional game
paddle is replaced by a pair of wires electrically
connected to a circuit including a pair of electrode

35   members preferably having a coating of noble metal

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thereon. One of such electrode members may be
considered connected to one input terminal of the game
paddle input port and the other of such electrode
members may be considered connected to the other
5   input terminal of the game paddle input port. By
placing the contact members in galvanic contact with
the skin of a human individual, the skin resistance of
such human individual may be considered to be imposed
upon the game paddle input port to the computer
10   system 10.

        For example, as shown in FIG. 1, a device 20
comprising a body 21 of insulating material and a pair
of close spaced metallic electrode members 22 and 23
mounted thereon is substituted for the game paddle.
15   If the electrode members 22 and 23 are, in fact,
directly electrically connected to the game paddle
input port of the computer system 10 by means of a
pair of wires 24 and 25 each connected to a different
one of the electrode members 22 and 23, it has been
20   found that certain individuals can simply place a
first of their fingers on one of the electrode
members 22 and a second of their fingers on the
other electrode member 23 and successfully substitute
voluntary variations in their galvanic skin
25   resistance for manual changes in a game paddle in
controlling a preprogrammed computer system 10.
However, such control is undependable at best and
impossible for many individuals.

        The fact that the resistance value present
30   between the electrodes 22 and 23 will vary in time,
when such electrodes are in continuous galvanic
contact with the skin of a human individual is known
in the art as the galvanic skin response (GSR) or
Psycho galvanic reflex (PGR) or electrodermal reflex
35   (EDR). All of these terms refer to the phenomena

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involving changing electrical properties of the skin
of a biologic individual including at least two
distinct classes one of which is resistance present
between two spaced points on the skin surface and the
5   other of which is a potential difference between two
spaced points on the skin surface. For the purposes of
this invention, such phenomena will be referred to
collectively as "electrodermal response".

Apparatus for measuring and recording
10 electrodermal response accompanying emotional and
other stresses of a subject have come into widespread
use, particularly in connection with such response
accompanying psychologically induced stresses in what
has come to be popularly known as a "lie detector".
15 Although much is known about electrodermal response,
much information is still lacking as to variables
affecting such response. For discussion of some of
the problems reference is made to Chapter One of the
book entitled "TECHNIQUES IN PSYCHOPHYSIOLOGY" edited
20 by Irene Martin and Peter H. Venables, published by
John Wiley and Sons in 1980. (See also the article
titled "Skin Resistance and Galvanic Skin Response"
published by Robert Edelberg et al in the Archives
of General Psychiatry, Volume 7, September 1962, at
25 pages 163 and 169 and an article titled "Problems in
Measurement of Electrodermal Phenomena - Choice of
Method and Phenomena - Potential, Impedance,
Resistance" by T.W. Forbes, published in
Psychophysiology, Volume 1, No. 1, July 1964, at
30 pages 26 to 30.

In the prior art, electrodermal response
although quick and transient, was known as a
sensitive indicator of sympathetic activity level
occurring in response to such influences as
35 frightening stimuli or other emotional stress. The

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electrodermal response was believed to be
involuntary in the sense that subjects could not
suppress it readily, if at all, although it was
recognized that a subject could voluntarily produce
5   an electrodermal response by deep breathing or moving.
Applicants have found that through the use of the
proper method and apparatus it is possible to learn to
control the electrodermal response with improved
reliability and further, that voluntary electrodermal
10 response can be utilized reliably and effectively as
a control resistance at the game paddle input port of
a computer, for example.

Thus, referring to FIG. 1 of the drawing,
in order for an individual to play a game, for
15 example, programmed into the computer system 10 under
the control of electrodermal response the individual
must first achieve a galvanic skin resistance within
the range of a conventional game paddle which may
be 0 to 150,000 ohms, for example. Although galvanic
20 skin resistance less than 150,000 ohms may be
exhibited by any individual under appropriate
circumstances and may be achieved by certain
individuals voluntarily and at any time, normal
galvanic skin resistance is somewhat higher and in
25 many individuals may remain at or above 200,000 ohms.
In addition, the relative ability to change galvanic
skin resistance varies widely between individuals.
Certain individuals may be able to achieve wide
variations in their galvanic skin resistance while
30 others will only be able to effect relatively small
changes in their galvanic skin resistance.
Furthermore, the galvanic skin resistance of an
individual will tend to "drift" rather than remain at
and about a given level over an extended period of
35 time.

If a particular individual can achieve a
galvanic skin resistance less than 150,000 ohms so
that it is within the range of an ordinary game
paddle, then the computer can be programmed so that
5   relatively small changes in galvanic skin resistance
will produce the full range of control normally
requiring tens of thousands of ohms variation.
However, this requires that the individual not only be
capable of causing a very large initial change in
10   galvanic skin resistance but that the individual be
capable of making very small voluntary changes in
galvanic skin resistance of the order of a few ohms
after the necessary value below 150,000 ohms is
reached. It has been found that certain individuals
15   can achieve such fine voluntary control. However,
even those individuals are subject to involuntary
drifting of their galvanic skin resistance by
hundreds or thousands of ohms to values greater than
150,000 ohms due to external stimuli beyond their
20   control.
            According to this invention, the
electrodes 22 and 23 are not directly connected to
the imput port of the computer 10. Instead, the
device 20 includes a circuit 26 interposed between
25   the electrodes 22, 23 and the wires 24, 25,
respectively, as indicated by the block diagram in
FIG. 2. As shown in FIG. 2, a third wire 27 is
connected between the circuit 26 and the computer 10
in order to establish a common ground therebetween.
30   According to this invention, the circuit 26
senses the resistance present between electrodes 22,
23 and produces an electrical signal which changes in
sense and amplitude directly with changes in the
resistance sensed between the electrodes 22, 23. The
35   circuit 26 includes means which continuously adjusts

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the absolute value of such electrical signal toward a
given electrical value with a given time rate of
change. Finally, the circuit 26 includes means for
converting the resultant electrical value to
5   corresponding resistance value within the range of a
conventional game paddle which may be 0 to
150,000 ohms, for example.

Thus, if the electrodes 22, 23 are not in
contact with the skin of a biologic individual, the
10   resistance therebetween will be very high, approaching
infinity. The resulting electrical signal produced
by the circuit 26 would tend to be very high but for
the fact that the circuit 26 automatically adjusts
such signal toward a given value. Such given value is
15   then converted to a resistance value which is within
the range of a conventional game paddle and preferably
toward the middle of such range although it could be
toward the upper or lower end of the range as desired.
If a very low resistance is connected between the
20   electrodes 22, 23, a correspondingly low electrical
signal will be produced by the circuit 26 which will
again be adjusted to the given value required to
produce a resistance value within the range of a
conventional game paddle. It will be understood that
25   the resistance value produced in either case will be
substantially the same value.

For ease of understanding, it may be
assumed that the computer is programmed to produce a
very simple game in which an image of a ball is
presented on the faceplate of the cathode ray tube
30   monitor 16 which image may be moved up and down on the
faceplate of the monitor 16 by means of a conventional
game paddle connected to the computer 10. For example,
adjustment of the game paddle to its 0 resistance
35   setting may move the image of the ball to the extreme

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bottom of the monitor 16 while adjustment of the game
paddle to its maximum resistance setting will move
the image of the ball to the extreme top of the
monitor 16 with intermediate adjustments of the game
5   paddle producing intermediate positions of the image
of the ball. If the game paddle is then replaced by
the circuit 26 and electrodes 22, 23 according to
this invention with a low resistance connected
between the electrodes 22, 23, the image of the ball
10 will first move to the bottom of the faceplate of
the monitor 16 and then upwardly until it reaches the
preselected intermediate position. Similarly, if the
low resistance is then removed from between the
electrodes 22, 23, the image of the ball will move to
15 the top of the faceplate of the monitor 16 and then
return to the preselected intermediate position where
it will remain so long as the very high resistance
therebetween is unchanged.

     If two adjacent fingers of the hand of a
20 human individual are placed in contact with the
electrodes 22 and 23, respectively, the image of the
ball will first move to the bottom of the faceplate
of the monitor 16 and then it will begin to move
erratically between intermediate positions on the
25 faceplate of the monitor 16. It has been found that
the human individual by observing the faceplate of
the monitor 16 can learn to cause the ball to move
predominantly in one direction or the other or to
remain stationary in a given position through
30 appropriate voluntary control of the electrodermal
response by the central nervous system.

     At this point it should be noted that
applicants' apparatus is not a "lie detector" or a
"bio feedback" device as proposed in the prior art
35 based on electrodermal response. This fact is due to

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a fundamental difference between applicants' method
and apparatus and the teaching of the prior art.
Thus, according to applicants' method and apparatus,
the position of the image of the ball on the
5   faceplate of the monitor 16 does not have any
relationship to a particular general or overall
psychological state of the human individual using
the apparatus whereas it would be necessary for each
position of the image on the faceplate of the
10 monitor 16 to correspond to a particular general or
overall psychological state of the human individual
using the apparatus in order for it to operate as a
"lie detector" or "bio feedback" device in
accordance with the teaching of the prior art. This
15 is due to the fact that applicants' apparatus is
designed to continuously adjust the signal
representative of the electrodermal response of the
human individual using the apparatus toward a given
value in order to enable the individual to accomplish
20 an intended purpose (i.e., position the image of the
ball at a particular place or cause it to move in a
particular direction on the faceplate of the
monitor 16.)
          More particularly, "lie detector" devices
25 and "bio feedback" devices of the prior art have
included a manually adjustable control which was used
to establish a given relationship between the
operation of such devices and a particular
psychological state of the subject. Changes in the
30 psychological state of the subject from such given
state are then monitored with information as to the
given psychological state always being carefully
maintained even though it was subsequently necessary
to manually readjust the device in order to keep the
35 electrodermal response within therrange of the

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device. This is true even though certain of the
prior art "lie detector" devices and "bio feedback"
devices included means for automatically readjusting
the device to keep the electrodermal response within
5   the range of the device. By necessity, such
readjustment had to be accomplished with a substantial
time delay in order to avoid loss of information with
respect to the given general or overall psychological
state to which the response was to be related.
10   According to applicants' invention, the
particular general or overall psychological state of
the human individual using the apparatus is totally
unimportant. Thus, no time delay is required in
connection with the readjustment action according to
15   applicants' invention. Instead, it is necessary that
the time rate of the readjustment action approach the
average time rate of change in electrodermal response
that can be achieved by voluntary control through the
central nervous system of the human individual using
20   the apparatus. Thus, according to applicants'
invention, a particular position of the image on the
faceplate of the monitor 16 may be achieved in a
multiplicity of psychological states thereby insuring
that the human individual using the apparatus has
25   continuous control over the position of the image on
the faceplate.
             Referring to FIG. 3 of the drawing, a
preferred embodiment of the circuit 26 for use in
accordance with the teaching of applicants' invention
30   is shown. The circuit 26 includes a first operational
amplifier 30 connected across the electrodes 22 and 23
to provide a constant current flow therebetween
regardless of the resistance value present
therebetween. The varying voltage thus present at
35   the output of the first operational amplifier 30 is

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connected to the input of the second operational
amplifier 32 through an RC network 34. The second
operational amplifier 32 amplifies the voltage
present at the input thereof. The time constant of
the RC network 34 is selected to provide a time rate
of change which approaches the average time rate of
change in electrodermal response which may be
attained by the central nervous system under the
conscious control of the subject.

The circuit 26 as shown in FIG. 3 is
specifically adapted for connection to the game paddle
input port of a computer as currently manufactured by
the Apple Computer Company under the type designation
"Apple II". In such a computer a five volt power
supply with respect to the computer ground is
available for connection to one end of the variable
resistor of the game paddle through the wire 24 with
the other end of the variable resistor connected to
the computer ground through the wire 27 and the
adjustable tap of the variable resistor connected to
the input port through the wire 25.

In the circuit 26 according to the
embodiment of the invention shown in FIG. 3, all of
the points labeled A are connected to the five volt
power supply through the wire 24, all of the points
labeled C are connected to the computer ground
through the wire 27 and the point labeled B is
connected to the game paddle input port through the
wire 25. As shown at the left side of FIG. 3, a
first transistor circuit 36 is connected between the
five volt power supply and computer ground through the
wires 24 and 27, respectively. As shown at the right
of FIG. 3, a second transistor circuit 38 is
connected between the five volt power supply and the
game paddle input port through the wires 24 and 25,

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respectively.

    Thus the first transistor citcuit comprises
a transistor 40 having its collector 41 connected to
the five volt power supply and its emitter 42
5   connected through a resistor. 43 to computer ground.
A capacitor 44 is connected in parallel with a pair of
series connected resistors 45 and 46 between the
collector 41 and emitter 42 if the transistor 40.
The base 47 of the transistor 40 is connected to the
10   junction 48 between the resistors 45 and 46. The
first transistor circuit 36 functions to provide a
constant reference voltage of about two and one-half
volts at the output 49 thereof and to smooth out any
voltage fluctuations which may be present in the
15   voltage supplied by the computer 10. The reference
voltage output 49 of the transistor circuit 36 is
taken between the emitter 42 of the transistor 40
and the resistor 43 and is connected directly to one
input 51 of the operational amplifier 30.
20   One of the electrodes 22 is directly
connected to the other input 52 of the operational
amplifier 30. The other electrode 23 is directly
connected to the output 53 of the operational
amplifier 30. A resistor 54 of large resistance value
25   is connected between the electrode 22 and computer
ground thus limiting the current flow between the
electrodes 22 and 23 to a very low value in order to
reduce toward minimum any possibility that such
current flow might stimulate or otherwise affect the
30   autonomic system or central nervous system of the
subject whose electrodermal response is to be
utilized.

    Thus the operational amplifier 30 will
cause a given small current flow through the galvanic
35   skin resistance of a subject in contact with the

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electrodes 22 and 23 regardless of the value of such
skin resistance. The voltage at the output 53 of the
operational amplifier 30 will fluctuate as required
to maintain the given small current flow between the
5   electrodes 22 and 23 regardless of variations in the
galvanic skin resistance present between the
electrodes 22 and 23.

A capacitor 56 is connected across the
electrodes 22 and 23 and a capacitor 58 is connected
10 between the output 53 of the operational amplifier 30
and computer ground. The capacitors 56 and 58
function to filter out noise and spurious responses
which may be present between the output of
operational amplifier 30 and computer ground 27.

15   The voltage present at the output 53 of
the operational amplifier 30 is coupled to the
operational amplifier 32 through the RC network 34.
The RC network 34 comprises a capacitor 60 having one
terminal connected to the output 53 of the
20 operational amplifier 30. The other terminal of the
capacitor 60 is connected to the input 51 of the
operational amplifier 30 through the series
connected resistors 62 and 64. The junction between
the series connected resistors 62 and 64 is
25 connected through a resistor 66 to the adjustable
center tap 67 of a potentiometer 68. The
potentiometer 68 has its opposite ends connected to
the five volt power supply and computer ground
through the wires 24 and 27, respectively.

30   The other terminal of the capacitor 60 is
also directly connected to one input 71 of the
operational amplifier 32. The other input 72 of
operational amplifier 32 is connected to the
output 73 thereof through a resistor 74 and to the
35 reference voltage at 49 through a resistor 75. A

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capacitor 76 is connected in parallel with the
resistor 74. The output 73 of the operational
amplifier 32 is connected through a resistor 78 to
the second transistor circuit 38.

5   The second transistor circuit 38 comprises
a transistor 80 having its collector 81 connected to
the game paddle input port through wire 25. The
emitter 82 of the transistor 80 is connected to the
five volt power supply through a resistor 84. The
10   base 86 of the transistor is connected both to the
five volt power supply through resistor 88 and to the
output 73 of the second operational amplifier 32
through the resistor 78. The function of the second
transistor circuit 38 is to present a variable
15   resistance value at the game paddle input port of
the computer 10 which simulates the variable
resistor of a conventional game paddle. Thus the
voltage applied to the base 86 of the transistor 80
of the transistor circuit 38 will determine the value
20   of the effective resistance presented by the
transistor circuit 38 to the game paddle input port
of the computer 10.

The RC network 34 in combination with the
operational amplifier 32 functions as a slope
25   detector with respect to changes in the resistance
present between the electrodes 22 and 23. In other
words, the RC network 34 and operational amplifier 32
with its associated circuitry apply a voltage to the
base 86 of transistor 80 which is representative of
30   the time rate of change in the resistance value
present between the electrodes 22 and 23 as will be
more fully described hereinafter. It will be
understood that if the resistance value between the
electrodes 22 and 23 is constant, no signal will be
35   coupled through the capacitor 60 to the input 71

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of the operational amplifier 32. In such
condition, the center tap 67 of the variable
resistor 68 is adjusted to provide a voltage which
when amplified by the operational amplifier 32 and
5   applied to the base 86 of the transistor 80 through
the resistor 78 will cause the transistor circuit 80
to produce an effective resistance value within the
range of a conventional game paddle. For example,
the transistor 80 and resistors 84, 88 may be selected
10 so that an appropriate adjustment of the center
tap 67 will produce a given resistance value between
the five volt power supply at wire 24 and the game
paddle input port at wire 25 which is located at or
about the middle of the range of a conventional game
15 paddle. Changes in the electrical resistance value
present between the electrodes 22 and 23 will then
produce changes in the effective resistance value
present between the five volt power supply and the
game paddle input port as more fully described with
20 reference to FIGS. 4 through 7.

In an embodiment of this invention as
actually constructed and successfully operated, the
electrical and electronic components of the circuit 26
as shown in FIG. 3 of the drawing were as follows:

25 Operational amplifier 30)	(National LM 358
)	(
Operational amplifier 32)	(Dual Op-amp.
Transistor 40	Motorola 2N4400
Resistor 43	I.R.C. 1.5K ohm
Capacitor 44	Mallory 4.7 MFD
30 Resistor 45	I.R.C. 10K ohm
Resistor 46	I.R.C. 19K ohm
Resistor 54	I.R.C. 3.3 MEG.
Capacitor 56	Mallory 4.7 MFD
Capacitor 58	Mallory .1 MFD
35 Capacitor 60	Sprague 100 MFD

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Resistor 62	I.R.C. 4.7K ohm
Resistor 64	I.R.C. 220 ohm
Resistor 66	I.R.C. 220K ohm
Potentiometer 68	I.R.C. 100K ohm
Resistor 74	I.R.C. 1 MEG ohm
Resistor 75	I.R.C. 560 ohm
Capacitor 76	Mallory .1 MFD
Resistor 78	I.R.C. 100K ohm
Transistor 80	Motorola 2N 4402
Resistor 84	I.R.C. 1.5K ohm
Resistor 88	I.R.C. 51K ohm

Referring to FIGS. 4 and 5 of the drawing,
a pair of corresponding conceptual graphs of
resistance values plotted on the ordinate with
respect to time plotted on the abscissa are shown.
Thus the graph of FIG. 4 represents a resistance
value changing in time between the electrodes 22
and 23. The graph of FIG. 5 represents the
resulting changing effective resistance of the
transistor circuit 38 at corresponding points in
time according to this invention.

It is emphasized that according to the
teaching of this invention, the base line
resistance value shown in FIG. 4 has no significance
whatever other than to aid in the understanding of
the following description and may be hundreds of
thousands of ohms. No matter what the absolute
value of such base line is, so long as it remains
constant, the resulting resistance value of the
transistor circuit 38 will be a value at or about
the middle of the resistance range of a conventional
game paddle as represented by the base line in
FIG. 5.

If the resistance present between the
electrodes 22 and 23 increases as represented by the

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graph segment 91 of FIG. 4, a resulting increase in
the given resistance value of the transistor
circuit 38 will occur as represented by the graph
segment 101 in FIG. 5. According to this invention,
5   the slope of the segment 91 of FIG. 4 will determine
the height reached by the segment 101 above the base
line of FIG. 5. If the resistance present between
the electrodes 22 and 23 then decreases as
represented by the graph segment 92 of IFG. 4, the
10   resistance value of the transistor circuit 38 will
decrease as shown by the graph segment 102 in FIG. 5.
As shown by the graph segment 102, the decrease in
resistance value of the transistor circuit 38 will
initially have a slope greater than the slope of the
15   segment 92 and again, the amount by which the
effective resistance of the transistor circuit 38
decreases below the base line of FIG. 5 will be
directly proportional to the slope of the graph
segment 92 of FIG. 4. If the resistance value
20   between the electrodes 22 and 23 then remains constant
for a period of time as represented by the graph
segment 93 of FIG. 4, the effective resistance value
of the transistor circuit 38 will return to the given
resistance value of the base line of FIG. 5 as
25   indicated by the graph segment 103.

       If the resistance value present between
the electrodes 22 and 23 then increases at a high
slope as represented by the graph segment 94 in FIG.4,
The effective resistance value of the transistor
30   circuit will increase rapidly to a higher value
representative of the higher slope of the graph
segment 94 as indicated by the graph segment 104 of
FIG. 5. Again, if the resistance value present
between the electrodes 22 and 23 remains constant as
35   indicated by the graph segment 93' of FIG. 4, the

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effective value of the transistor circuit 38 will
decrease toward the given base line value as shown
by the graph segment 103' of FIG. 5.

     If the resistance value between the

5   electrodes 22 and 23 again increases as shown by the
graph segment 91' with a slope identical to the graph
segment 91, the resultant effective resistance of the
transistor circuit 38 represented by the graph
segment 101' in FIG. 5, will approach a value

10 identical to that represented by the graph
segment 101 of FIG. 5.

     More importantly, if the resistance value
present between the electrodes 22 and 23 changes with
a given slope over an extended period of time as

15 represented by the graph segment 95 in FIG. 4, the
effective resistance value of the transistor
circuit 38 will attain a given constant value as
represented by the graph segment 105 in FIG. 5. As
represented by the graph segment 93" of FIG. 4, if

20 the resistance value present between the electrodes
22 and 23 attains a given value and then remains
constant, the effective resistance value of the
transistor circuit 38 will tend to return to its
given base value as represented by the graph

25 segment 103" of FIG. 5.

     Graph segments 96, 91" and 97 of FIG. 4
considered in conjunction with graph segments 106,
101" and 107 of FIG. 5 illustrate that if the
resistance value present between the electrodes 22

30 and 23 increases with a given slope and then such
slope decreases, the effective resistance value
of the transistor circuit 38 will first increase to
a high value corresponding to the initial slope
and then decrease to a lower values corresponding

35 to the decreasing slopes.

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Graph segments 98 and 99 of FIG. 4 in
conjunction with graph segments 108 and 109 of
FIG. 5 illustrate that an exponential increase or
decrease in the resistance present between the
5   electrodes 22 and 23 will result in a modified
exponential increase or decrease in the resistance
value of the transistor circuit 38.

It is pointed out that the graph shown in
FIG. 5 is an idealized approximation intended to
10   illustrate the effects of the time constant of the
RC network 34. In the circuit 26 according to the
embodiment of this invention shown in FIG. 3, the
RC network 34 has a time constant slightly less
than one-half second. Such time constant approaches
15   the average reaction time of the human central
nervous system to visual stimuli where
discrimination between more than two qualities is
required. Thus, referring to graph segment 93''' in
FIG. 4 and corresponding graph segment 103''' in
20   FIG. 5, the time rate of change at which a given
absolute value present between the electrodes 22
and 23 is accommodated to tend to provide an
effective resistance value for the transistor
circuit 38 corresponding to the base line value
25   shown in FIG. 5 approaches the average time rate
of change which can be made in the resistance value
present between the electrodes 22, 23 by the central
nervous system of an individual.

Referring to FIG. 6, a graph representing
30   the galvanic skin resistance of a first individual
imposed upon the electrodes 22 and 23 plotted on the
ordinate against time on the abscissa is represented
by the solid line 110. Similarly, a graph of the
galvanic skin resistance of a second individual
35   plotted on the ordinate against time on the abscissa

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is represented by the broken line 120.

Referring to FIG. 7, the position of an
image on the face plate of the cathode ray tube
monitor 16 of the computer 10 according to this
5   invention is plotted on the ordinate against time on
the abscissa. The solid line 130 represents the
position of the image in response to the galvanic
skin resistance of the first individual shown by the
solid line 110 in FIG. 6 and the broken line 140 in
10   FIG. 7 represents the position of the image in
response to the galvanic skin resistance of the
second individual represented by the broken line 120
in FIG. 6. Thus referring to the extreme left hand
side of FIGS. 6 and 7, it will be understood that
15   according to the teaching of this invention as
described hereinabove, if the galvanic skin
resistance of the two individuals remains constant
for a period of time, the image on the face plate will
be substantially centered regardless of the relative
20   absolute values of their galvanic skin resistance.
When the galvanic skin resistance of the first
individual increases with a given slope as indicated
by the graph segment 111 in FIG. 6, the image on the
face plate will move upwardly to a given position
25   where it will remain as indicated by the graph
segment 131 in FIG. 7 so long as the given slope is
maintained. If the slope is increased as indicated
by the graph segment 112, the image on the face plate
will move upwardly to a new position as indicated by
30   the graph segment 132 in FIG. 7 where it will remain
until the slope again changes as indicated by the
graph segment 113 in FIG. 6 at which time it will
move to a new position as indicated by the graph
segment 133 in FIG. 7.
35   Graph segments 114 and 115 in FIG. 6

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illustrate further increases in the galvanic skin
resistance of the first subject at different slopes
until a fairly high galvanic skin resistance is
attained as indicated by the graph segment 116.

5   Similarly, graph segments 134 and 135 illustrate the
position of the image on the face plate corresponding
to the slopes of the segments 114 and 115. The graph
segment 136 in FIG. 7 in conjunction with the graph
segment 116 of FIG. 6 illustrates that the image will

10   tend to return to center when the galvanic skin
resistance of the first individual remains constant
even though it is now at a much higher absolute
value.

        Graph segments 121 through 126 of the

15   graph 120 in FIG. 6 are mirror images of graph
segments 111 through 116 of graph 110. Similarly,
graph segments 141 through 146 of FIG. 7 are mirror
images of graph segments 131 through 136.

        It will be seen that although there is a

20   wide difference between the absolute values of the
galvanic skin resistance of the first individual as
represented by graph setment 116 and the galvanic
skin resistance of the second individual as represented
by the graph segment 126, the image on the face plate

25   of the cathode ray tube monitor will nevertheless tend
to return to about the middle of the face plate.
Furthermore, it will be seen that the first and second
individuals can achieve identical control of the
image in spite of the wide disparity between their

30   galvanic skin resistances. In other words, it will
be seen that, since graph segments 117 and 118 have
the same slope as graph segments 127 and 128 in
FIG. 6, the resultant position of the image on the
face plate will be identical as indicated by graph

35   segments 137 and 147, 138 and 148 of FIG. 7. Thus,

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if the first and second individuals have the same
intention, they can achieve the same position of the
image on the face plate regardless of the state of
their respective galvanic skin resistances.

5   Alternatively, graphs 110 and 120 may
represent the galvanic skin resistance of the same
individual at two different times. First when the
individual's autonomic system is causing his galvanic
skin resistance to increase over a period of time as
10   represented by graph 110. Graph 120 would indicate
that at a different time, the individual's
autonomic system was causing a decrease in the
galvanic skin resistance of the individual.

According to this invention, it has been
15   found that individuals can modify the slope of an
increase or decrease in galvanic skin resistance at
will, thereby enabling the individual to control the
position of an image on the face plate of the cathode
ray tube monitor reliably and with repeatable
20   certainty. The same signal which controls the position
of the image on the face plate of the cathode ray tube
monitor 16 can be used to control the position of other
instrumentalities such as robots or robotic devices,
for example.

25   It is pointed out that the changes in the
effective resistance of the transistor circuit 38
according to this invention need not extend throughout
the full range of a conventional game paddle. Instead,
appropriate programming of the computer 10 can be used
30   to amplify much smaller changes in the resistance
value to enable the full range of control of the
position of the image on the face plate of the cathode
ray tube monitor. In this regard, it is noted that
the resistor 74 may be selected to provide a desired
35   gain in the operational amplifier 32 and thus the

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range of variation in the effective resistance of the
transistor circuit 38. In the embodiment of this
invention shown in the drawing, a gain of about 2000
has been found to be preferable. A higher gain will

5   make the circuit so sensitive that even the heartbeat
of the individual can be detected. Lower gains tend
to require excessive concentration on the part of the
individual in order to effect a time rate of change
in galvanic skin resistance sufficient to produce the

10   desired positioning of the image on the face plate.
      It is believed that those skilled in the
art will make obvious modifications in the
specific circuit 26 as shown in the drawing and
specifically described hereinabove without departing

15   from the scope of applicants' method and apparatus
as taught above and claimed in the following claims.

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Claims

1. The method of utilizing electrodermal
response and the like of a biologic individual as a
control means comprising the steps of:

5   a) programming an electrical device to
respond in a desired humanly perceptible fashion to
changes in the sense and amplitude of an electrical
control signal only in a given range;

        b) sensing a value characteristic of the
10 state of the said electrodermal response and the
like;

        c) converting said sensed value into an
electrical signal which changes in sense and
amplitude with changes in said sensed value;

15   d) continuously adjusting said electrical
signal toward a given electrical value with a time
rate of change approaching the average time rate of
change which can be achieved by the central nervous
system of said biologic individual in said value

20 characteristic of the state of said electrodermal
response and the like;

        e) converting the resultant time rate of
change in said electrical signal to an electrical
output signal having a value corresponding to a zero

25 resultant time rate of change at about the middle of
said given range and which varies directly in sense
and amplitude with changes in said resultant time
rate of chjange with a difference between the minimum
and maximum values thereof that is a substantial

30 portion of said given range; and

        f) utilizing said electrical output signal
as said electrical control signal to said electrical
device.

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2. Apparatus utilizing electrodermal
response and the like of a biologic individual as a
control means comprising in combination;

a) an electrical device programmed to
5   respond in a desired humanly perceptible fashion to
changes in the sense and amplitude of an electrical
control signal only in a given range at the input
thereto;

b) means sensing a value characteristic of
10   the state of said electrodermal response and the like;

c) means converting said sensed value into an
electrical signal which changes in sense and amplitude
with changes in said sensed value;

d) means continuously adjusting said
15   electrical signal toward a given electrical value with
a time rate of change approaching the average time
rate of change which can be achieved by the central
nervous system of said biologic individual in said
value characteristic of the state of said
20   electrodermal response and the like:

e) means converting the resultant time
rate of change in said electrical signal to an
electrical output signal having a value corresponding
to a zero resultant time rate of change at about the
25   middle of said given range and which varies directly
in sense and amplitude with changes in said resultant
time rate of change with a difference between the
minimum and maximum values thereof that is a
substantial portion of said given range; and

30   f) means coupling said electrical output
signal to said input of electrical device to provide
said electrical control signals thereto.

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      3. In combination with a computer having a
game paddle input port, which computer is
pre-programmed to respond to changes in resistance at
said game paddle input port in a given range. a

5   control device comprising: .

        a) a pair of spaced skin contact members;

        b) first electrical circuit means
connected between said pair of galvanic skin contact
members; said first electrical circuit means sensing

10   the resistance value established between said
galvanic skin contact members by contact thereof with
spaced points on the skin of a biologic individual
and producing an electrical output signal
representative of said sensed resistance value;

15   c) second electrical circuit means
continuously adjusting said electrical output signal
of said first electrical circuit means toward a
given value with a given time rate of change
approaching the average time rate of change which

20   can be achieved by the central nervous system of said
biologic individual in said resistance value
established between said galvanic skin contact members
to produce a composite electrical output signal; and

        d) third electrical circuit means

25   responsive to the said composite electrical output
signal of said second electrical circuit means
producing a resistance value. in said given range at
said game paddle input port of said computer
representative of said composite electrical output

30   signal.

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4. The combination of claim 3 wherein said
first electrical circuit means establishes a constant
current flow between said galvanic contact members
when said galvanic skin contact members are in contact
5   with the skin of a biologic individual and said
electrical output signal of said first circuit means
is the voltage difference between said galvanic skin
contact members.

5. The combination of claim 4 wherein said
10 second means of said electrical circuit comprises an
RC network detecting the slope of the time rate of
change in said voltage difference to produce said
composite electrical output signal.

6. Apparatus for utilizing changes in the
15 response of an autonomic system of a biologic
individual to control a computer having an input
means, saud cinputer being pre-programmed to perform
selected operations in response to signals in a
given range applied to said input means thereof;
20 said apparatus comprising:
a) sensor means for sensing a time
varying absolute value representative of the state of
said autonomic system;
b) first circuit means having an input and
25 an output with said input thereof connected to said
sensor means, said first circuit means being adapted
to produce a time varying electrical signal
corresponding to said sensed time varying absolute
value of said autonomic system;
30   c) second circuit means having an input
and an output with the input thereof connected to the
output of said first circuit means; said second
circuit means being adapted to continuously adjust

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Claim 6 - continued.

said electrical signal at said output of said first
electrical circuit means toward a given value with a
time rate of change approaching the average time rate
5   of change that said biologic individual can achieve
in said response of said autonomic system to produce
a composite time varying electrical signal at the
output thereof;

        d)   third circuit means having an input and
10   an output with the input thereof connected to the
output of said second circuit means; said third circuit
means being adapted to convert said composite time
varying electrical signal at said output of said
second circuit means to said signals in said given
15   range with a given value corresponding to a zero time
rate of change in said composite time varying signal
corresponding to a value toward the middle of said
given range and a difference between maximum and
minimum values which is at least a substantial
20   portion of said given range; and

        e)   means connecting the output of said
third circuit means to said input means of said
computer.

        7.   Apparatus for utilizing the electrodermal
25   response of a biologic individual to control an
electrical device having an input and programmed to
respond in a humanly perceptible fashion to changes
in the sense and amplitude of an electrical control
signal only in a given range at said input comprising:
30   a)   a pair of electrodes adapted to be
connected to said individual at spaced locations;

        b)   means for establishing a constant
electrical current flow between said electrodes;

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Claim 7 - continued

       c) a first operational amplifier having
two inputs and an output;

       d) means connecting one of said

5   electrodes to one input of said operational
amplifier through the capacitor of an RC network
having an RC time constant of about one-half second;

       e) resistor means connecting the output
of said first operational amplifier to the other

10   input thereof to establish a given gain through said
operational amplifier, and

       f) means for converting the output of
said operational amplifier to an electrical control
signal in said given range and applying said control

15   signal to said input of said electrical device.

       8. Apparatus as claimed in claim 7 wherein
said means for establishing a constant current flow
between said electrodes comprises a second operational
amplifier having two inputs and an output, said one of

20   said electrodes being connected to said output of
said second operational amplifier, the other of said
electrodes being connected to one of said inputs of
said second operational amplifier and a constant
voltage source having one side connected to said one

25   input of said second operational amplifier through a
resistor and the other side directly connected to
the other input of said operational amplifier.

       9. Apparatus as claimed in claim 8
wherein the resistance of said RC network is

30   connected between said other input of said second
operational amplifier and said one input of said
first operational amplifier.

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10. Apparatus as claimed in Claim 9
wherein said control signal is a resistance value
and said means for converting the output of said first
operational amplifier to said electrical control
5   signal and applying it to said input of said
electrical device comprises a transistor having its
base connected to said output of said first
operational amplifier with its emitter and collector
connected to said input of said electrical device.

10   11. Apparatus as claimed in claim 9
wherein said constant voltage source comprises a
second transistor having the emitter and collector
thereof connected in series with a first resistor
across a power supply, second and third resistors
15   connected in series across said power supply in
parallel with said series connected transistor and
first resistor, and a capacitor connected across
said power supply in parallel with said series
connected second and third resistors, the junction
20   between said second and third resistors being
connected to the base of said second transistor
and said other input of said second operational
amplifier being connected to the junction between
said first resistor and the emitter of said second
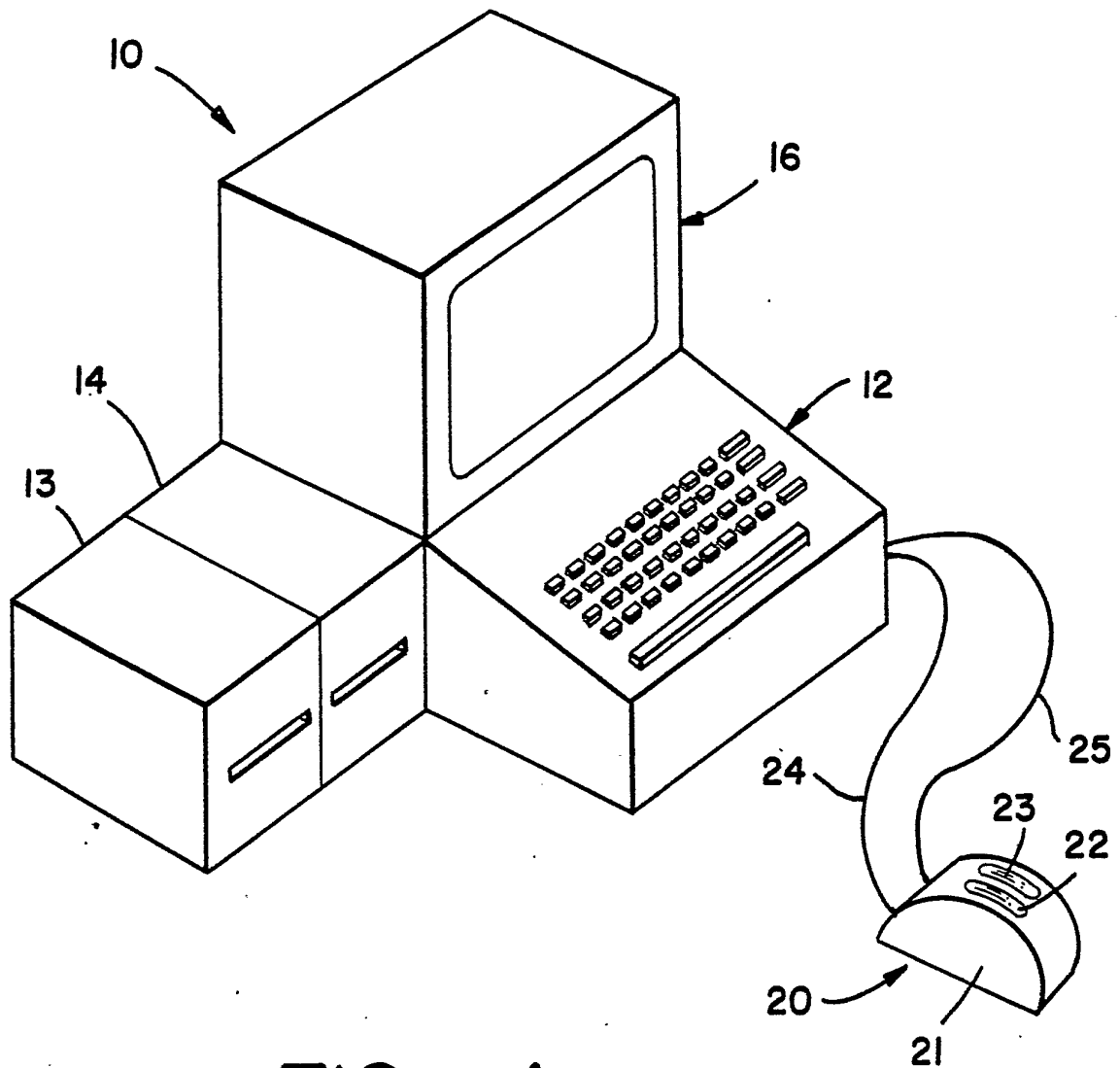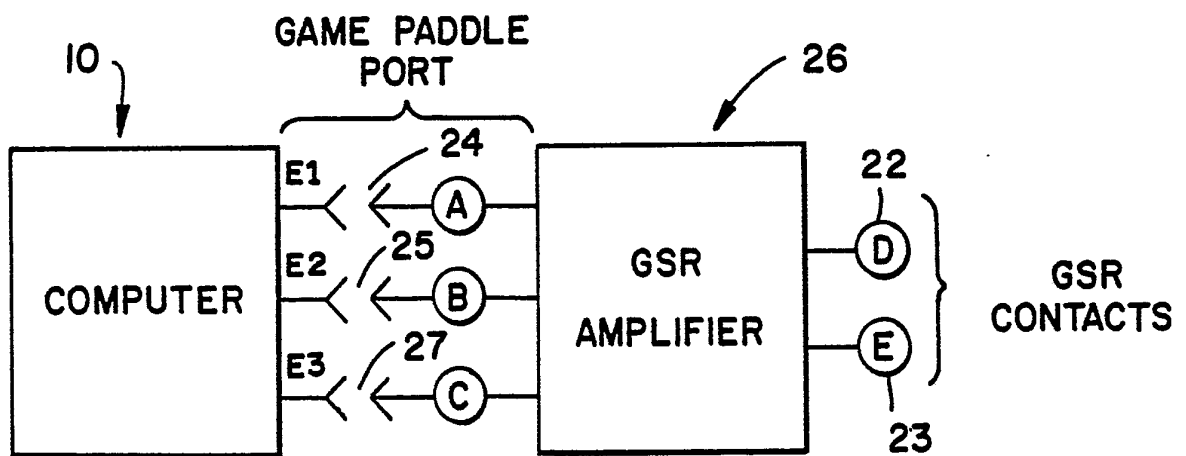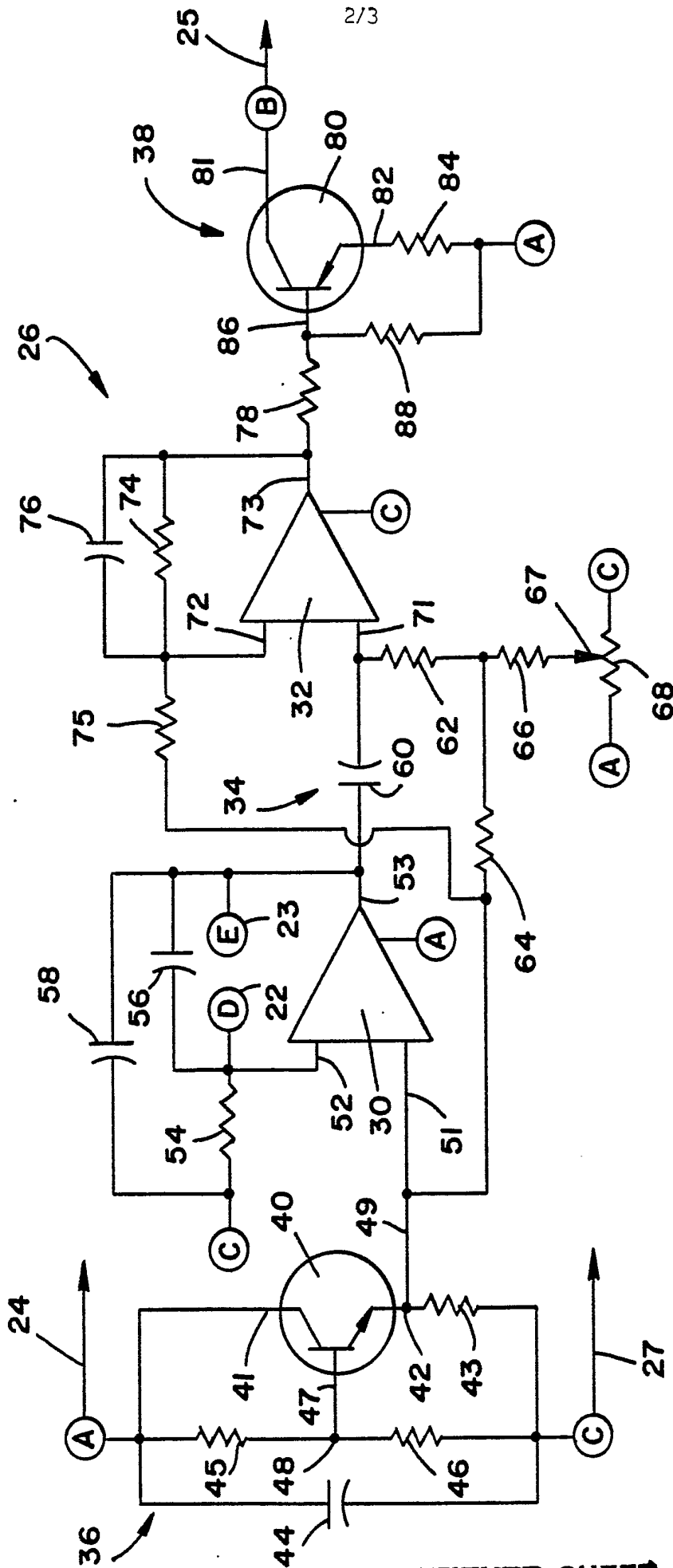25   transistor.

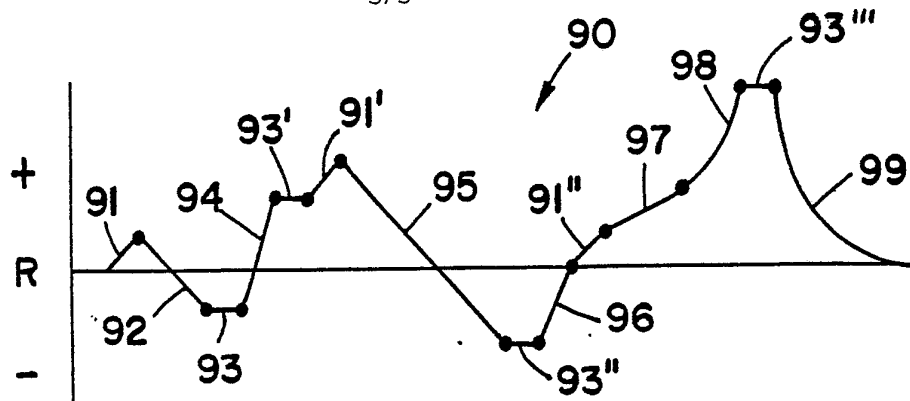## SUBSTITUTE SHEET

FIG _ 1

FIG _ 2

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FIG – 3

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FIG_4
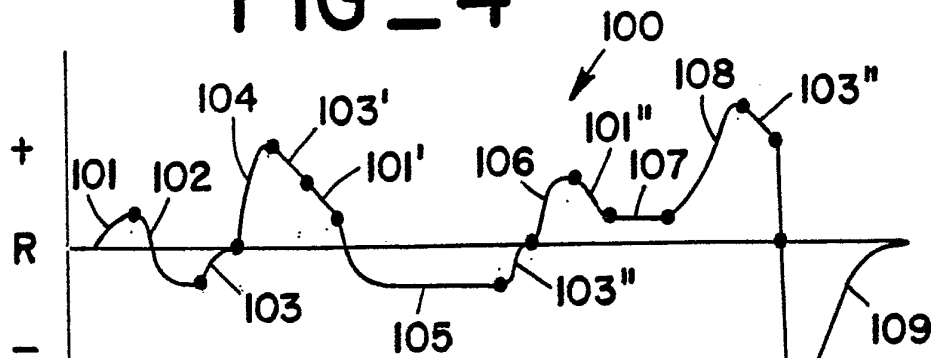
FIG_5
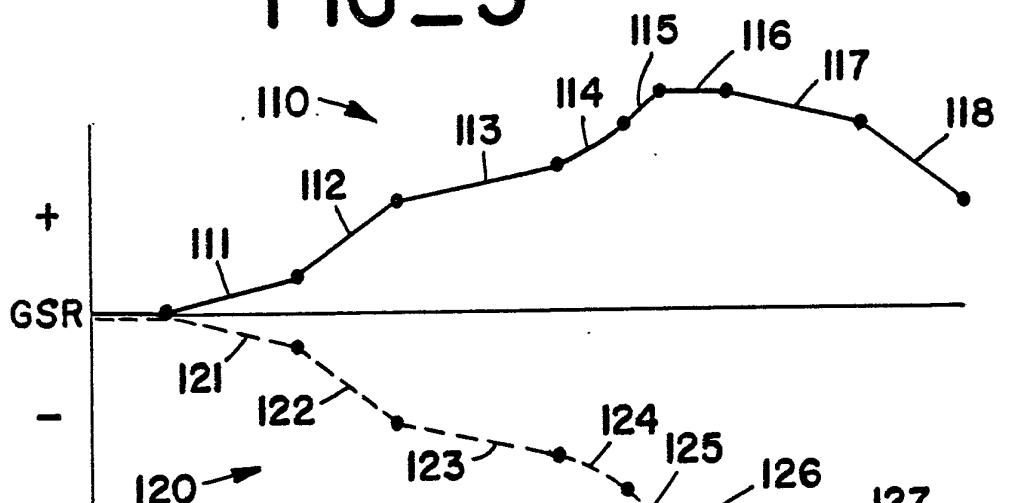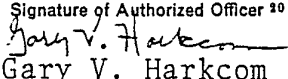
FIG_6

FIG_7

INTERNATIONAL SEARCH REPORT

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 3

According to International Patent Classification (IPC) or to both National Classification and IPC

INT. CL. 4   G06F 15/42, 15/44; A 61 B 5/05
U.S. CL.   364/413; 128/734; 273/85G

II. FIELDS SEARCHED

Minimum Documentation Searched 4

Classification System	Classification Symbols
U.S.	364/200,410,413,415,417,900; 324/62R,63,65R; 128/630, 734,902,905; 273/1GC, 85G

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched 5

III. DOCUMENTS CONSIDERED TO BE RELEVANT 14

Category *	Citation of Document, 16 with indication, where appropriate, of the relevant passages 17	Relevant to Claim No. 18
A	US, A, 4,461,301, (Ochs), 24 July 1984	1-11
A	US, A, 4,358,118, (Plapp), 09 November 1982	1-11
A	US, A, 4,149,716, (Scudder), 17 April 1979	1-11
A	US, A, 3,727,604, (Sidwell), 17 April 1973	1-11
A	US, A, 3,870,034, (James), 11 March 1975	1-11
A	US, A, 3,841,316, (Meyer), 15 October 1974	1-11
A	US, A, 4,088,125, (Forgione et al.), 09 May 1978	1-11

* Special categories of cited documents: 15

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search 2	Date of Mailing of this International Search Report 2
30 October 1985	0 8 NOV 1985

International Searching Authority 1	Signature of Authorized Officer 10
ISA/US	*Jauy V. Harken* Gary V. Harkcom

Form PCT/ISA/210 (second sheet) (October 1981)