

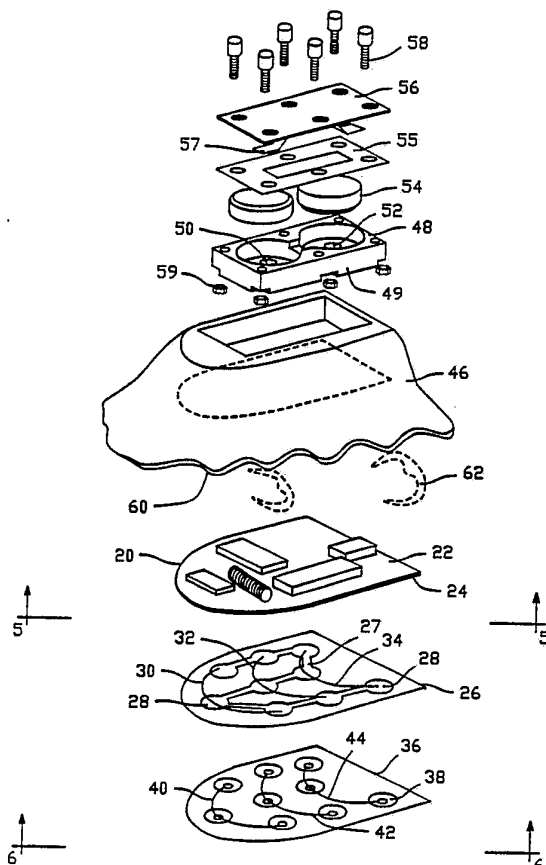


INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁵ : H04Q 9/00	A1	(11) International Publication Number: WO 93/07726 (43) International Publication Date: 15 April 1993 (15.04.93)
(21) International Application Number: PCT/US92/08524 (22) International Filing Date: 7 October 1992 (07.10.92) (30) Priority data: 774,675 11 October 1991 (11.10.91) US (71) Applicant: NEW ABILITIES SYSTEMS, INC. [US/US]; 765 Christine Drive, Palo Alto, CA 94303 (US). (72) Inventors: FORTUNE, Daniel ; 3962 Nelson Court, Palo Alto, CA 94306 (US). ORTIZ, John, E. ; 192 Garden Street, East Palo Alto, CA 94306 (US). TRAN, Hien, Ngoc ; 2848 Mattison Lane, Santa Cruz, CA 95065 (US). (74) Agents: HAYNES, Mark, A. et al.; Fliesler, Dubb, Meyer & Lovejoy, Four Embarcadero Center, Suite 400, San Francisco, CA 94111-4156 (US).		(81) Designated States: AU, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, SE). Published <i>With international search report.</i>

(54) Title: TONGUE ACTIVATED COMMUNICATIONS CONTROLLER**(57) Abstract**

A tongue activated communications controller (10) for use by disabled or other persons to control a wide variety of devices, and which includes a dental appliance (12) fitted to the user's palate, and a keyboard (36) with a plurality of tongue activatable switches (38) for generating a signal depending upon which switch has been selected, and upon the status of a battery voltage level. The communications controller (10) includes a radio frequency transmitter (12) which uses magnetic flux linkage for transmitting the signal. The communications controller further includes a receiver (16) for converting the transmitted signal into digital form, and also includes a microprocessor based controller unit (18) for processing the received data, and for communicating with the attached devices which the user wishes to control. Data is sent from the transmitter using a fixed transmission time, digital pulse code modulation technique to achieve ultra low power consumption in the transmitter.



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TONGUE ACTIVATED COMMUNICATIONS CONTROLLER

CROSS-REFERENCE TO OTHER APPLICATIONS

5 This is a continuation-in-part application of now
revived patent application, Serial No. 07/285,771, filed
December 16, 1988.

This application is related to Mr. Dan Fortune's
earlier filed and now abandoned patent application, filed
July 18, 1983, Serial No. 06/514,973.

10

BACKGROUND OF THE INVENTIONField of the Invention

15 This invention relates to the field of communications
controllers and more particularly to the field of such
controllers which are activated with a user's tongue.

Previous Art

20 A significant portion of persons who do not have the
use of their limbs are isolated from daily functioning in
society. Some of these persons may have suffered
traumatic injuries to their spinal cord, such as during
automobile accidents or sport injuries and the like;
others may have had diseases of the neuromuscular and
central nervous system. In these types of diseases,
25 cognitive function most often remains intact. It has
been found that often these pathologies do not affect the
function of the user's tongue. The tongue remains
accessible as a communications link after all limb
control has been lost, even in such progressive
30 neuromuscular diseases such as multiple sclerosis.

The number of such disabled people is increasing in
the general population. Thus, there is an increased need
for new devices that allow the disabled person to work
and to have a near-normal lifestyle. With a faster and

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more aesthetically acceptable communications controller, it is possible for the disabled person to become a productive part of society. There has been a great amount of recent development in this area, particularly in the area of computer controllers for operating mechanical devices.

Current devices exist for hands free computer input. These devices include a mouth stick controller which is a device clenched in the user's teeth and operated by gross head motions to perform various mechanical tasks. This device is utilized primarily by high level quadriplegics and can be wielded with adequate proficiency after some practice. However it requires a high degree of mobility to accomplish specific tasks and is often awkward to use and leads easily to deterioration of teeth and oral occlusion. Additionally, a mouth stick controller has the limitation that the patient must be in extremely close proximity, in fact a mouth stick controller extends from the mouth to the device being operated.

Voice recognition systems are known. However, further refinement is necessary to produce a reliable method of data communication even for a person having an unimpaired voice. In many cases, quadriplegics have partial paralysis of the diaphragm and larynx. Their speech articulation and volume are severely hampered. Therefore, voice recognition systems, which require good articulation and volume, are not well suited to a broad range of physically impaired persons. Additionally, voice recognition systems present difficulty in environments where multiple users coexist.

Other devices proposed to assist the disabled person include many forms of single switch computer control. This type of control is slow to operate and requires many levels of programming. Typically, a single switch

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actuation device requires an action such as "sip" and "puff" breathing, eyebrow motion, or chin movements to control or to operate a computer, to actuate an environmental control or to achieve personal mobility.

5 Disabled persons with a great degree of mobility and who have a capacity to operate more than one switch desire increased and faster access to a computer. Currently, single switch driven software does not achieve the desired speed that can be obtained by multiple switch

10 inputs.

Another relevant device is an ultra-sonic head controller. This device is limited to the user that is able to produce at least small and precise head movements necessary for keying a computer via ultra-sonic position

15 detectors. The computer recognizes the position of the head and deviations in head positions are interpreted as an analog signal. An example of an ultrasonic device is the Personics View Control System (VCS), which is currently commercially available. The Personics system

20 includes three ultra sonic transducers housed in a headset to receive a signal transmitted from a control unit. By comparing the signal received at three points on the headset, changes in the angle and rotation of the head are tracked.

25 Yet another device which is designed for persons of limited mobility is an eye switch apparatus which is an infrared emitter and detector pair mounted on standard eye-glasses. This system operates by emitting small, low power, infrared beams. The reflectivity of the surfaces

30 in front of the emitter can be sensed. For example, when the eyelid opens or closes, an electronics unit activates a relay which serves as a switch. Virtually any body surface can reflect the beam, giving a wide range of threshold levels and possible methods of operation.

35 However, there is a distinct lack of speed in the use of

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such a device and there is the disadvantage of triggering this type of device unintentionally, such as during normal eye blinking.

5 The devices currently known are quite limited in the variety of devices they can control. Additionally, presently known devices require physical movements from the disabled user that may not be possible. What is needed is a device which can be used by a large number of persons having limited mobility and which can operate a
10 broad range of devices. The device must not require difficult physical movements for persons suffering from progressive neuromuscular disorders and quadriplegia due to spinal injuries and the device should be aesthetically pleasing.

15 Low power frequency modulated (FM) radio transmitters are well known in the field of system application controllers and in the communications field. For example, residential wireless telephones, garage door openers, remote controlled toys and various games are
20 applications of frequency modulated radio transmitters to control applications in and around the home.

Presently, miniaturization allows the same FM technology which is used in the home to be used in an intra-oral transmitter intended to help the disabled.
25 However, some difficulties remain. Included in these difficulties are: (1) the need to use carrier frequencies of approximately 88 Mhz to reduce the size of the electric field antenna; (2) the need to continuously transmit the carrier frequency; and (3) limitations on
30 the size of the battery imposed by the small size of these devices. Problems (1) and (2), above, result in excessive battery drain, while problem (3) places a limit on battery life.

The existing devices do not employ some means of
35 communicating to the user the fact that battery output is

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marginal. This combination of high battery drain and nonreporting of battery status creates a reliability problem. At least one device uses a circuit which turns off the carrier frequency and resets the logic circuits when no user operable switch is activated. But this circuit still requires power to perform its function and thus battery drain remains a major problem.

The use of high frequency, electric field transmission also creates an additional problem: interference between other users who are in the immediate vicinity (20 to 1000 feet). Some applications embed an ID code in every transmission to protect against such interference. This approach increases the battery drain, and lacks a practical method of changing the ID code to prevent interference from a user having the same code.

SUMMARY OF THE INVENTION

It is a general object of this invention to provide a tongue activated communications controller which enables persons of limited mobility to operate various devices reliably.

It is a further object of this invention to provide such a tongue activated communications controller which is well suited for use by persons having quadriplegia due to spinal cord injuries and neuromuscular disorders.

It is yet a further object of this invention to provide a tongue activated communications controller which has an improved battery life, and a shelf life approaching that of the battery itself.

It is an additional object of this invention to provide a tongue activated communications controller which has decreased size and weight, improved reliability and safety, can be used in numerous applications by disabled and non-disabled persons, and is resistant to interference from adjacent users.

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In accordance with the above objects, a tongue activated communications controller in accordance with this invention comprises:

an intra-oral transmitting assembly including:

5 a two sided circuit board, the first side having
 electronic means for transmitting an electrical
 signal and the second side having a keyboard
 with a plurality of tongue activatable
10 positions, the activated positions encode a
 signal for transmission; and a wireless
 transmitter having an inductor defining an
 antenna for enhanced transmission of the encoded
 signals, the inductor having one or more
15 windings around the perimeter of the printed
 circuit board; and

 receiving means for receiving the encoded signals
 from the transmitting assembly including computing means
 for decoding the encoded signals and for forming a set of
 instructions for operating a device from the decoded
20 signals and means for sending the instructions to the
 device for operation.

In another preferred embodiment the tongue activated communications controller comprises:

an intra-oral transmitting assembly including:

25 a keyboard having a plurality of
 tongue-activated switches, each switch having an
 interval of switch activation defined by the
 depression of the switch; an encoding means for
 receiving input from all the tongue-activated
30 switches and, during an interval of switch
 activation, for generating a waveform which is
 a function of the specific switch activated; and
 a magnetic coupling means for receiving the
 waveform from the encoding means and, during
35 the interval of switch activation, for

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generating a time-varying magnetic field whose properties are a function of the waveform and a receiving means for receiving the time-varying magnetic field generated by the intra-oral transmitting assembly, the receiving means including:

5 a decoding means for converting the received time-varying magnetic field into a waveform which is a function of the specific switch activated and

10 a control means for converting the waveform of the decoding means into appropriate action,

whereby upon tongue activation of one of the switches an appropriate action is taken.

In another preferred embodiment, the intra-oral transmitting assembly, comprises:

15 a keyboard having a plurality of tongue-activated switches, each switch having an interval of switch activation defined by the depression of the switch;

20 an encoding means for receiving input from all the tongue-activated switches and, during an interval of switch activation, for generating a waveform which is a function of the specific switch activated; and

25 a magnetic coupling means for receiving the waveform from the encoding means and, during the interval of switch activation, for generating a time-varying magnetic field whose properties are a function of the waveform, whereby upon tongue activation of one of the switches a time-varying magnetic field is created whose properties are uniquely determined by the switch which is activated.

30 The invention as defined herein includes a keypad having a plurality of switches which identify and invoke differently coded instructions. In this way, the user can effectively operate a motorized wheel chair, a computer or a variety of other devices. The separate
35 keypad switches enable the user through the use of

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his/her tongue to accurately and easily identify each desired switch. Thus, an unskilled user using the separate keypad switches, even for the first time, can accomplish the desired activity with little or no training.

The addition of magnetic coupling enables the user to use the same battery over an extended period of time. This addition of the magnetic coupling will allow such long battery life even under heavy usage.

Additionally, the transmitter assembly can be encapsulated into the dental appliance and, because of the ultra low power usage, have a shelf life as long as that of the battery.

The addition of the magnetic coupling also allows low power transmission without causing interference with other devices which may be operating in close proximity.

It is an advantage of the present invention to provide a tongue activated communications controller which is easily used by persons having limited physical mobility.

It is an additional advantage of the present invention to provide such a tongue activated communications controller which can be made to operate a broad range of devices.

It is an additional advantage of this invention to provide such a tongue activated communications controller which can be used by large numbers of persons having quadriplegia due to spinal cord injuries and neuromuscular disorders.

It is an additional advantage of this invention to provide a tongue activated communications controller which has an improved battery life, and a shelf life approaching that of the battery itself.

It is yet an additional advantage of this invention to provide a tongue activated communications controller

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which has decreased size and weight, improved reliability and safety, can be used in numerous applications by disabled and non-disabled persons, and is resistant to interference from adjacent users.

5

BRIEF DESCRIPTION OF THE DRAWINGS

For a further understanding of the objects and advantages of the present invention, reference should be made to the following detailed description, taken in
10 conjunction with the accompanying drawing, in which like parts are given like reference numerals and wherein:

Fig. 1 is a schematic illustration of the tongue activated communications controller in accordance with this invention illustrating usage with a personal
15 computer, a wheelchair as well as additional applications.

Fig. 2 is a partial sectional schematic view of the tongue activated communications controller in accordance with this invention installed in the mouth of the user.

Fig. 3 is a perspective view of the assembled tongue
20 activated communications controller.

Fig. 4 is an exploded perspective view of the tongue activated communications controller of Fig. 3.

Fig. 5 is an enlarged bottom view of the assembled tongue activated communications controller illustrating
25 the electrical circuit of the keypad.

Fig. 6 is an enlarged bottom view of the tongue activated communications controller of Fig. 3.

Fig. 7 is an enlarged cross-sectional view of the keyboard in accordance with this invention.

Fig. 8 is an electrical circuit schematic of the
30 tongue activated communications controller in accordance with this invention.

Fig. 9 is a side perspective view of a second embodiment of the tongue activated communications

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controller in schematic illustrating a fixed inductor wrapped around the perimeter of a PC board.

Fig. 10 is an electrical circuit schematic of a second embodiment of the transmitter circuit of the tongue activated communications controller in accordance with this invention.

Fig. 11 is a timing diagram illustrating encoded transmission from the tongue activated communications controller in accordance with this invention.

Fig. 12 is a schematic illustration of the encoded signal being received by the tongue activated communications controller in accordance with this invention.

Fig. 13 is a flow chart of the software enclosed in the smart box in accordance with this invention.

Fig. 14 is a schematic illustration of an alternate tongue activated communications controller for transmission by means of a magnetic field.

Fig. 15 is a pictorial diagram showing a typical installation of the tongue activated communications controller for transmission by means of a magnetic field.

Fig. 16 is an exploded perspective view of the intra-oral transmitting assembly for transmission by means of a magnetic field.

Fig. 17 is a block diagram of the major elements of the alternate intra-oral transmitting assembly for transmission of Fig. 16.

Fig. 18 is an electrical schematic diagram of the alternate intra-oral transmitting assembly of Fig. 16.

Fig. 19 is a timing diagram of the alternate intra-oral transmitting assembly of Fig. 16 depicting normal battery voltage operation.

Fig. 20 is a timing diagram of the alternate intra-oral transmitting assembly of Fig. 16 depicting low battery voltage operation.

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DETAILED DESCRIPTION OF THE INVENTION

Two embodiments of the tongue activated communications controller will be described below. It will be appreciated that many other embodiments are possible within the spirit and scope of this invention. With particular reference to Fig. 1, there is shown the overall schematic of the tongue activated communications controller, in accordance with this invention, generally designated by the numeral 10. The tongue activated communications controller 10 (hereinafter TACC) is illustrated as interfacing with either a personal computer and/or a wheelchair and/or additional applications. The TACC 10 includes an intra-oral transmitter assembly 12. The intra-oral transmitter assembly 12 fits into the mouth of a user and is held in place therein by press fit. It may also be desirable for the intra-oral transmitter assembly 12 to be held in place in a user's mouth by clasps as illustrated in phantom in Figs. 3 and 4. After installation, the user can transmit encoded signals illustrated by waves 14 to a receiver 16. It is preferable that the transmission be wireless to increase the flexibility of movement of an associated transmitter, however hard-wired embodiments of the TACC are within the scope of this invention. The signals are encoded and are transmitted by the TACC in binary form. The receiver 16 receives the encoded binary signals and communicates with a smart box 18 which decodes the signals. The smart box 18 comprises a microcomputer; for example, a Z-80 microprocessor or a 4 bit micro-controller would be suitable. The smart box 18 decodes the encoded binary signal and determines which switch on the keyboard has been depressed. The smart box 18 sends a control signal to the desired device for carrying out the appropriate action, such as inputting to

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5 a personal computer or directing the motion of a wheelchair. The smart box 18 includes the software for monitoring the received signal and converting it to the appropriate control signal as will be more fully appreciated hereinafter.

10 With particular reference to Figs. 2-4, there is shown the details of the intra-oral transmitter assembly 12. The intra-oral transmitter assembly 12 includes a PC board 20. The PC board 20 is a two-sided board having a first side 22 with transmitter electronics and a second side 24 with the electrical circuit for the keyboard. Thus, the PC board in accordance with this invention includes both the transmitter electronics and circuitry for switching from one keyboard position to another.

15 The first side 22 includes an encoder 96, a transmitter 98, a timer 100, an oscillator 102 and a voltage regulator 104. A detailed description of the above elements is set forth below with reference to Fig. 8. The particular electrical devices are preferably low power, high speed semiconductors and are preferably a combination of CMOS integrated circuits and discrete devices. These types of semiconductor devices are preferred because they are compatible with the speed of the 2 MHz crystal oscillator 102.

25 The intra-oral transmitter assembly further includes an adhesive spacer 26 having a plurality of openings 28 and a keyboard membrane 36 including a plurality of conductive key pad members 38. The keyboard membrane 36 is bonded to the PC board 20 using the adhesive spacer 26. The adhesive spacer 26 is an acrylic adhesive which creates a water tight seal between the keyboard membrane 36 and the PC board 20. The adhesive spacer 26 has channels 27 to permit the movement of air trapped within the channels 27 and the openings 28 as one of the

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conductive key pad members 38 is depressed by the user's tongue.

5 The adhesive spacer 26 spaces the membrane 36 away from the second side 24 to prevent short circuiting of the keyboard. Therefore, the adhesive is made from an insulating material, such as an acrylic based adhesive. Additionally, the adhesive spacer 26 acts as a moisture barrier to prevent corrosion and disfunctioning of the electrical circuits. This is especially important since
10 much of the life of the intra-oral transmitter assembly 12 is spent in a moist or wet environment.

In the preferred embodiment, there are three rows of openings 28. The rows have an arc shaped design, designated by the lines having reference numerals 30, 32
15 and 34 for each of the first, second and third rows, respectively. The arc shaped design accommodates the conductive key pad members 38. The conductive key pad members 38 are similarly divided into three rows 40, 42 and 44, designating the first, second and third rows
20 respectively. As will be appreciated from the more detailed explanation found with reference to Fig. 6, the conductive key pad members 38 are generally flat and each includes a nipple 92 which protrudes away from the second side of the PC board. Pressure from the tip of a user's
25 tongue deforms the pad members 38 and pushes the conductive surface of the pad members 38 through the opening 28 of the adhesive spacer 26 and into electrical contact with the second side 24 of the PC board as best shown in Fig. 7.

30 The intra-oral transmitter assembly 12 is encapsulated by an encapsulant 46 made of methyl methacrylate. As shown more clearly in Figs. 2 and 3, the methyl methacrylate encapsulates the PC board 20 the adhesive spacer 26 and the keyboard membrane 36. The
35 bottom of the operating surface of the keyboard membrane

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36 which includes the nipples 92 is exposed for access by the user's tongue and not encapsulated.

5 The encapsulant 46 has a recess defining a battery compartment 48. Within the compartment 48 are two electrically conductive pads 50 and 52 which are electrically connected to the voltage regulator. A pair of batteries 54 are placed in electrical contact with the pads 50 and 52. In order to protect the user the batteries 54 are sealed in the battery compartment 48 by
10 a gasket 55 and a cover 56. The cover 56 is placed over the batteries 54 for securing the batteries 54 into electrical contact with the pads 50 and 52. The cover 56 includes an electrical contact 57 for bridging the two batteries. The cover 56 is secured to the battery
15 compartment 48 by use of screws 58 and nuts 59 in the battery compartment.

The cover 56 is made from fiberglass and is mounted almost flush with the encapsulant 46. In the preferred embodiment, the encapsulant encapsulates the cover 56.
20 This ensures a comfortable fit of the intra-oral transmitter assembly 12 to the roof of the mouth of the user.

The battery compartment 48 has walls 49 made of A-Butyl Styrene. This provides a double insulation in
25 combination with the encapsulant to limit any passage of fluids or gases between the inside of the battery compartment 48 and the user's mouth.

The encapsulant further has teeth interface members 60 which comprise the shaped outside edges of the
30 encapsulant 46. The edges are shaped in the form of the profile of the inside of the teeth and gums in the mouth of the user. In order to accomplish this, the encapsulant 46 is cast into an impression of the user's mouth, using standard dental techniques. This allows the
35 intra-oral transmitter assembly 12 to be press fit to

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conform to teeth and gum and the roof of the mouth of the user. Additionally, this procedure ensures that the fit of the intra-oral transmitter assembly 12 will be comfortable and secure within the user's mouth.

5 In some mouths, additional security is desirable. As shown in phantom in Figs. 3 and 4, a clasp 62 can be embedded in the encapsulant 46 and secured to the teeth using standard dental techniques.

10 With particular reference to Fig. 5, there is shown the second side 24 of the PC board 20 having the electrical circuit for the keyboard. The circuitry is divided into three arc shaped rows 64, 66 and 68. The arc shaped rows 64, 66 and 68 are compatible with the earlier described first, second and third rows, 30, 32 and 34, respectively, of the adhesive spacer 26 and the
15 first, second and third rows, 30, 32 and 34, respectively, of the keyboard membrane 36. Thus, the conductive key pad members 38 of the keyboard membrane 36 align with the openings 28 of the adhesive spacer 26
20 which are aligned with the switches 63.

Each switch 63 is approximately 0.175 inch in diameter. The switches 63 are divided into three rows. The first row comprises switches 70, 72 and 74, which are consecutively numbered switches 1, 2 and 3. The second
25 row comprises switches 76, 78 and 80, which are numbered switches 4, 5 and 6. The third row comprises numbered switches 82, 84 and 86 which are switches 7, 8 and 9, respectively.

Each of the switches 63 is generally round in shape.
30 The center-to-center spacing of adjacent switches is approximately equal and is approximately 0.3 inch. This is true except for the center-to-center spacing of switch 2 to switch 4, which is somewhat larger, approximately 0.37 inch.

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As can be seen from Fig. 5, each of the switches 63 is electrically connected by conductive lines 88 and holes 89 in the PC board 20 to the first side 22 of the PC board 20. Thus, when an electrical connection is made across the switch 63, a signal for that switch is sent to the first side 22 keyboard electronics and transmitted by the intra-oral transmitter assembly 12 to the receiver 16.

With particular reference to Fig. 6, there is shown the bottom side of the keyboard membrane 36. The keyboard membrane 36 is made from mylar and has conductive ink applied to it to create pad members 38. The conductive ink provides a conductive path across one of the switches 63 when one of the corresponding pad members 38 is depressed. The adhesive spacer 26 spaces the keyboard membrane 36 away from the PC board 20 sufficiently (approximately 0.002 inch) so that no electrical contact is made until one of the pad members 38 is depressed. The channels 27 facilitate the depression of the pad members 38 by allowing the displacement of air between the pad members 38 and the PC board 20.

As shown most clearly in Fig. 7, each of the pad members 38 have a nipple 92. The nipple 92 is in the form of a Braille raised dot as to both diameter and shape made with a Braille slate stylus. This provides the user with accurate tactile feedback.

Similar to the switches 63, the pad members 38 are 0.175 inch in diameter. Adjacent pad members 38 are spaced apart 0.3 inch, center-to-center. The distance between the middle pad in the first row 40 and the middle pad in the second row 42, which corresponds to switches 2 and 4 are somewhat larger than the 0.3 inch center to center spacing and match exactly the spacing of switches 2 and 4. The nipples 92 are formed so as to facilitate

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the detection of one of the pad members 38 with the tongue. Approximately 0.50 ounce of force is required to depress one of the pad members 38 to make electrical contact such that a circuit for switch 63 is completed.

5 With respect to Fig. 8, there is shown the electrical circuit schematic for the intra-oral transmitter assembly 12. As shown, the assembly 12 includes a keypad 94, an encoder 96, a transmitter 98, a timer 100, an oscillator 102 and a voltage regulator 104. The oscillator 102
10 preferably oscillates at a fixed frequency of MHz.

The keypad 94 comprises the second side 24 switches 1 through 9 as shown in the Fig. 8. When one of the switches 63 is closed, an electrical signal is sent to the encoder 96. The signal received is encoded using a
15 decade counter 106; for example, if switch 3, designated by the numeral 74, is closed, an electrical signal is received at Q4 of the decade counter designated by the numeral 108. This is also pin position 10 of the decade counter 106.

20 The signal is encoded and sent to an output of the decade counter designated by Q1 and the reference numeral 110. This is also known as pin position 2 of the decade counter.

The encoded output of the decade counter, Q-1, 110,
25 is sent to the first NAND gate 112 of the oscillator 102. The encoded signal sent to the first NAND gate 112 is mixed with a carrier signal created by the oscillator 102.

The oscillator 102 uses a second NAND gate 114, a
30 crystal and appropriate discrete components to generate a 2 MHz carrier signal. The carrier signal is then sent through conductive line 116. The carrier signal is then mixed with the encoded signal at the first NAND gate 112. The output of the mixed signal is sent to the transmitter
35 98 over conductive line 118.

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The transmitter 98 transmits at 2 MHz frequency using the carrier signal created by the oscillator 102. In the embodiment of the transmitter 98 shown in Fig. 8, the transmitter 98 has a variable inductance and can be adjusted to tune the resonant frequency of the transmitter 98 to the carrier signal of 2 MHz.

The receiver 16 detects the encoded signal from the intra-oral transmitter assembly 12 and filters out the carrier signal. The encoded modulated signal, which remains, is passed to the smart box 18 and decoded to determine which switch on the keyboard has been depressed. The smart box 18 translates the encoded modulated signal into a control signal for controlling and operating various devices, as shown in Fig. 1. The control signal may be analog or digital in nature. The operation of the receiver 16 and smart box 18 will be more fully appreciated with reference to Figs. 11 - 13.

The frequencies of the various modulating signals transmitted by the intra-oral transmitter assembly 12 are determined by the timer 100. The voltage regulator 104 reduces the battery voltage potential of nominally 6V to a potential of 3.3V. This provides the power to the semiconductor devices, the decade counter 106 and NAND gates 111. The 3.3V potential also represents the binary high for the digital logic. The 3.3V potential is sent over conductive line 120 to the decade counter enable 122 of the decade counter 106. This is also known as pin position 14 of the decade counter 106.

Thus, when the voltage regulator 104 provides the 3.3V signal, the decade counter 106 is enabled and the clock input 124 is tied to the timer 100. As can be seen, the clock input 124 is tied to the output of the timer 100 by conductive line 126 and the voltage regulator output is tied to the decade counter enable 122 by conductive line 120. Thus, when the clock is enabled,

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an encoding signal corresponding to one of the switches 63, namely the switch depressed, is sent from the decade counter 106 to the oscillator 102 and then transmitted.

5 With particular reference to Fig. 9, there is shown a second embodiment of the intra-oral transmitter assembly generally denoted by the numeral 130. In the second embodiment, there is a groove 132 having a depth within the range of .25 inch to .10 inch around the perimeter of the PC board 20. The wire is wound around
10 the PC board replacing the variable inductance surface mounted component of the earlier described embodiment. Magnet wire 133 of 39 gage is tightly wound around groove 132 and is held in place thereby. Wrapping the magnet wire 133 creates an inductor having a fixed value, in the
15 preferred embodiment, the value ranges between 2.8 uH and 10 uH. Unlike the first embodiment the inductance can not be varied after assembly. However, the inductance can be measured on a case by case basis. The magnet wire 133 is connected to the first side 22 of the PC board in
20 the same location where the variable inductor was found in the first embodiment 12.

As can be appreciated, a new transmitter circuit, generally designated by the numeral 135, is necessary to accommodate the second embodiment of the intra-oral
25 transmitter assembly 130. The corresponding circuit diagram is shown in detail in Fig. 10. The transmitter assembly 130 includes a fixed inductor 134 which comprises the magnetic wire 133 wound around the PC board groove 132, as described earlier. The inductor 134 is a
30 fixed value that ranges between 2.8 uH and 10 uH. The transmitter assembly 130 further includes a pair of 1000 Pf capacitors and a tuning capacitor 136. The tuning capacitor 136 is inserted into the
circuit to assure that the tuned resonant frequency of
35 the transmitter matches the 2 MHz carrier. The value of

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the tuning capacitor 136 is selected accordingly. This ensures the signal is accurately received by the receiver 16.

When the signal is transmitted, it is done so by a wireless transmission. If it was desirable for there to be a hard wire between the intra-oral transmission assembly 12 and the smart box 18, the signal would be tapped directly from the output of the decade counter 106. In this embodiment no transmitter or oscillator would be necessary.

Fig. 11 illustrates the encoding of the signal transmitted by either of the intra-oral transmitter assemblies 12 or 130. The timer sends out a clock signal represented by pulse line 140. When none of the switches 63 has been activated, no signal is sent out from the decade counter 106. This is schematically represented by a straight pulse line 142. When one of the switches 63 is depressed a unique pulse line is generated. For example, when switch 1 has been depressed, a pulse line 144 is created. Pulse line 144 is a square wave line having a period of $2T$, where T is one timer period. This form of modulation is called pulse coded modulation.

Coded pulse line 144 is then combined with the 2 MHz carrier and forms pulse line 145. Pulse line 145 is then transmitted to the receiver 16 where the carrier is filtered out and the signal decoded.

When switch 2 is depressed, a pulse line 146 having a period of $3T$ ($1T$ high and $2T$ low) is created. Pulse line 146 is combined with the 2 MHz carrier to form pulse line 147 and is then transmitted to receiver 16. Similarly, when switch 3 is depressed a $4T$ ($1T$ high and $3T$ low) pulse line 148 is created. Again, it is combined with the carrier and transmitted. The remaining switches 63 follow the same pattern.

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Fig. 12 illustrates receipt of the wireless transmission of the signal from either of intra-oral transmitter assemblies 12 or 130. As described above, the receiver filters out the carrier portion of the signal. The receiver 16 is a modified AM receiver which has been tuned to the carrier frequency of 2 MHz. This is done by adjusting the core and changing the capacitors to stabilize the reception by minimizing drift. The receiver 16 uses an amplitude modulation detection scheme to recover the encoded signal.

The receiver 16 sends the demodulated, encoded signal to a comparator 150 which converts the wave form into binary format. The comparator 150 sends the signal to a digital filter 152 which converts the encoded signal into a square wave. The digital filter 152 sends the resulting, filtered signal to the smart box 18.

The smart box 18 comprises a standard microcomputer architecture. The preferred embodiment of the smart box includes a single board computer which has a plurality of input and output ports, e.g. Prolog, STD-7000 System 7806 Z-80A Multifunction CPU card 7904 TTL Decoded I/O Utility Card. The smart box 18, using the software described in detail below, generates a control signal for controlling and operating various devices. The control signal may be digital or analog or a modified digital signal. The control signal may be altered as needed using the smart box and the system software.

In order to generate the correct signal, the smart box 18 uses the system software to determine which switch has been depressed and activates its own corresponding switch to direct the desired device to perform the desired function.

The system software referenced above will now be described with reference to Fig. 13. At the top level of the software, there are two software loops operating at

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all times. The main routine is called TOP, generally designated by the numeral 154. TOP performs initial and preparatory routines and then enters into a repeating loop. Within this repeating loop the computer executes
5 the MAP-SWITCH 158 subroutine which selects the mapping of the switch position identification for different keyboard layouts. Upon completion of MAP-SWITCH 158, TOP 154 enters another subroutine called RUN-MODES 160. After executing RUN-MODES 160, the software checks for
10 keyboard inputs in another subroutine called ?TERMINAL 162. If a key is activated on a programmer's computer, the Main Event loop within TOP 154 ends. This programmer's computer is connected to the smart box 18 only during programming and testing. Otherwise, the Main
15 Event loop repeats, continuing with the MAP-SWITCH subroutine. The Main Event loop is comprised of MAP-SWITCH 158, RUN-MODES 160 and ?TERMINAL 162. The TOP 154 routine remains within the RUN MODES 160 as long as one of the pad members 38 is depressed to cause
20 activation of one of the switches 63.

At regular .512 msec intervals, the computer halts whatever it is doing in the TOP routine and executes another routine called TICKER, generally designated by the numeral 164. TICKER 164 is the interrupt service
25 routine which reads the binary signal from the receiver 16 and updates the clock variables to reflect the time between each low to high transition edge of the pulse line as described with reference to Fig. 11. The TICKER 164 routine prepares data to be sent out to those devices
30 which require repeating outputs, for example, a Macintosh computer mouse port. In other cases, routines within RUN-MODES 160 send out control information directly without using TICKER 164, for example wheelchair controllers. The TICKER 164 routine calculates the
35 length of time between successive low to high transition

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edges and stores information in the software variables NEW-CLOCK and OLD-CLOCK. These variables are read into RUN-MODES 160 to determine which of the switches 63 has been closed.

5 There are several software subroutines within the smart box 18.

As shown in Fig. 13, there is an initialization subroutine called INITS, designated by the reference numeral 156, which performs the functions of initializing
10 variables and configuring the timers in the smart box 18 necessary for the interrupt service routine. INITS 156 also performs a one time initialization of variables handled regularly within the interrupt service routine, TICKER 164 and establishes the location of TICKER 164 in
15 memory. The TICKER 164 routine runs whenever its interrupt is encountered and handles all timing calculations.

Additionally, INITS 156 performs the functions of preparing the variables used in identifying each switch
20 63, configuring the variables that control the acceleration behavior of a device such as a computer mouse and configuring the motorized wheelchair controller so that the wheelchair is stationary upon initial operation.

25 The MAP-SWITCH 158 contains a simple one-to-one table which changes the logical identity associated with each switch so that the switches 1 through 9 can be mapped anywhere on the keypad.

The RUN-MODES 160 selects one of the available
30 operation modes which the smart box 18 operates. For example, the modes in the smart box 18 are ?TEST, MOUSE or CHAIR. ?TEST configures the operation of the intra-oral transmitter assembly 12 into a test mode; MOUSE converts operation of the intra-oral keypad into a
35 Macintosh mouse emulation; and CHAIR converts the

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operation of the intra-oral keypad into the directional control of a powered wheelchair. Other additional operational modes can be added as required and then the smart box will behave in one of these modes as desired.

5 In the CHAIR mode, the user depresses one of the conductive key pad members 38 to control a motorized wheelchair. In a preferred embodiment a DUFCO controller is used and the CHAIR subroutine produces the output necessary to operate such a controller. The user can
10 move one of 8 directions; forward, forward right, right, or send a stop signal.

 The CHAIR mode includes a lower level subroutine entitled, TACC-KEY? which examines the switch closure data from either one of the transmitter assemblies 12 or
15 130 to determine which switch if any, has been closed. There are several error suppression algorithms within the TACC-KEY? subroutine to minimize the effect of key bounce and transmission signal degradation.

 The CHAIR-mode includes another lower level
20 subroutine entitled, RUN-CHAIR, which reads which switch the user has closed and performs a table look-up to determine which bits (binary values) to set high or low in the output signal. This output signal is composed of a four bit word: a forward bit, a reverse bit, a left bit
25 and finally a right bit. These bits determine the direction that the wheelchair moves. All acceleration and velocity ramping is handled by the DUFCO wheelchair controller hardware. These bits form a command instruction for the wheelchair controller and when
30 outputted, the wheelchair controller responds with movement.

 An additional low level CHAIR subroutine is entitled, STOPCHAIR which sets the four bit signal sent to the DUFCO wheelchair controller to zero. This instructs the
35 wheelchair to stop.

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The mouse mode includes low level routines which translate switch closure into Macintosh mouse emulation. The algorithm for performing this emulation is set forth in Appendix A, which represents the source code for the
5 above software, is attached hereto and made part hereof.

Another embodiment of the tongue activated communications controller 10 uses a magnetic field for transmissions. The TACC 10 shown in block diagram form in Fig. 17 includes an intra-oral transmitting assembly
10 12 having nine tongue activatable switches 63, a battery 54, an encoder 96 for generating a signal which identifies the activated switch and reports the status of the battery 54 voltage level and a transmitter circuit 98 for generating a radio frequency (RF) magnetic field
15 corresponding to the resulting encoder signal.

The tongue activated communications controller 10 also includes a receiver 16 (Fig. 14) responsive to the magnetic field generated by the intra-oral transmitting assembly 12, and a smart box 18 for decoding the received
20 signal, displaying system status to the user (see, for example, Fig. 15) and generating and monitoring appropriate signals and signalling sequences for control and monitoring of such things as a motorized wheelchair, bed, lights, environmental controls, computer, TV, VCR
25 and numerous other devices.

Fig. 14 also shows communication between the smart box 18 and various device "links" by means of both radio frequency (RF) link or infrared (IR) link. An typical application of an IR link between the smart box 18 and a
30 desktop computer is depicted in Fig. 15.

The intra-oral transmitting assembly 12 is shown in block diagram form in Fig. 17 and is shown schematically in Fig. 18 of the drawing.

Electrical power is supplied by a single 3.0 volt
35 battery 54. The negative terminal of battery 54 is

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connected to the common ground return designated by the inverted triangle symbol. The positive terminal of the battery 54 is distributed to the various circuits shown in Fig. 18. The positive voltage level is designated as VCC.

5 Battery 54 has bypass capacitors 196 which are connected between the positive and negative terminals of battery 54 and provide bypass for high frequency switching transients.

10 A keyboard 94 having tongue activatable switches, SW1 70 through SW9 86, is also shown schematically in Fig. 18.

Each of the switches 63 in the preferred embodiment is a momentary, single-pole, single-throw switch having a normally open pair of contacts which are bridged by a conductive key pad member 38 when the switch is activated. Each switch can be activated by tongue depression of the associated nipple 92 which is located on the keyboard membrane 36.

20 A first contact of each switch contact pair is returned to VCC through the common pullup resistor 174. The resulting signal is biased at the high level when no switch is activated.

25 The second contact of switches, SW1 70 through SW8 84, is connected to one of the active Q output signals of a decade counter 106, which is a 74HC4017 high-speed CMOS integrated circuit and receives operating power from the battery 54.

30 The second contact of switch SW9 86 is returned directly to the common ground as shown by the inverted triangle symbol.

35 The clock input at pin 14 of the decade counter 106 is returned to VCC. When the reset input at pin 15 of the decade counter 106 is at the high level, active output signal Q0 will be ON and the remaining active

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output signals, Q1 through Q9, of the decade counter 106 will be OFF. Once the reset input is at the low level, the sequencing of the decade counter 106 can begin. The enable input will be used as a clock to advance the state of the decade counter 106.

Timer 100 output signal Q12 is connected to the enable input pin 13 of the decade counter 106. The interval from a high-level-to-low-level transition of the Q12 output signal to the next such transition defines a clock period of the decade counter 106. The state of the decade counter 106 is defined by the level of each of its Q output signals. The state of the decade counter 106 will advance at each high-to-low transition of timer 100 output signal Q12.

The decade counter 106 could more accurately be referred to as a "ring" counter because of its output behavior.

The reason for making a comparison between the decade counter 106 and a "ring" counter is that the active Q output signals of the decade counter 106 are not in binary-coded format, as might be expected. Rather, at each high-to-low transition of timer 100 output signal Q12, the Q1 through Q9 output signals of the decade counter 106 successively turn ON then OFF for one clock period each.

The first time the timer 100 output signal Q12 changes from the high to the low level, the Q0 output signal of the decade counter 106, which has been ON since reset, will turn OFF and the Q1 output signal will turn ON. At the next such transition of the timer 100 output signal Q12, the decade counter 106 output signal Q1 will turn OFF and the output signal Q2 will turn ON, followed by Q3, then Q4, Q5, etc., until the ninth clock pulse, during which decade counter 106 output signal Q9 will be ON.

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When a keyboard switch 63 is activated, a specific Q output signal of the decade counter 106 will be connected to the reset input of the decade counter 106 and the reset input of the oscillator 102 and timer 100 through the bridged pair of contacts of the activated switch. The common signal thus formed is returned to VCC through the pullup resistor 174 and comprises a common reset signal. Pullup resistor 174 insures that a high level is present at the reset input of the oscillator 102, timer 100 and decade counter 106 during the time that no keyboard switch 63 is activated. Thus, the decade counter 106 always begins its cycle having its Q0 output signal ON and its Q1 through Q9 output signals OFF.

The above description discloses the operation of the decade counter 106 only in general terms. More specifically, the output signals of the decade counter 106 will advance only to the point at which one of the decade counter 106 Q output signals is coupled through the activated keyboard switch 63 back to the common reset input signal.

At that point in the sequence of operation, the decade counter 106 will be reset to its initial state. This action will cause the active Q output signal to return to the low level which will be passed through the activated keyboard switch 63 to the reset input of the oscillator 102, timer 100 and decade counter 106.

Once the common reset signal has returned to the low level, the decade counter 106 will be allowed to resume counting at the next transition of timer 100 output signal Q12 from the high to the low level.

The oscillator 102 and timer 100 are implemented using a high speed, low power CMOS device, the 74HC4060 and receive operating power from the battery 54.

When the common reset signal is at the high level, the oscillator 102 output signal at pin 9 and each of the

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Q output signals of the timer 100 will be at the low level. As a result, the oscillator 102 and the timer 100 are disabled when no keyboard switch 63 is activated.

5 The 2.0 Megahertz (hereinafter "MHz") crystal 198 and the biasing network comprised of capacitors 188 and 190 and resistors 170 and 172, are connected to the oscillator 102 X2 and X1 inputs, pin 10 and pin 11 respectively.

10 When the oscillator 102 is disabled because no keyboard switch 63 is activated, the crystal 198 does not oscillate. This feature permits the intra-oral transmitting assembly 12 to reduce further the current drawn from the battery 54 when no keyboard switch 63 is activated and the oscillator 102 is disabled. The
15 crystal 198 is biased by the biasing network so that upon the reset input changing from the high to the low level, an output signal is available at oscillator 102 pin 9 within approximately one half micro-second. The result of thus disabling the oscillator 102 is an increase in
20 battery life.

The oscillator 102 output signal at pin 9 will be a squarewave having a fundamental frequency of 2.0 MHz when the oscillator 102 is enabled by the activation of any keyboard switch 63.

25 The timer 100 output signals, Q4 through Q14, are each squarewaves having a fundamental frequency equal to one half that of the next lower numbered output signal. Timer 100 output signal Q4 has a fundamental frequency one sixteenth that of the oscillator 102 output signal at
30 pin 9. Thus, timer 100 output signal Q12 at pin 1 will have a fundamental frequency of approximately 0.488 Kiloherztz. The period of the squarewave at timer 100 output signal Q12 will be 2.048 millisecond.

35 If one of the tongue activatable keyboard switches 63 is still depressed, the above described cycle will

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repeat. The cycle will continue to repeat until all the keyboard switches 63 are released. If a keyboard switch 63 is released during a cycle, the cycle will terminate.

5 The circuit 104 shown in the upper left corner area of Fig. 18 includes FET's 184 and 186 and resistors 176, 178, 180 and 182. One end of each of the resistors 176, 180 and 182 is connected directly to the positive terminal of the battery 54. Circuit 104 monitors the battery voltage with respect to the common ground return.

10 The nominal battery voltage is approximately 3.0 volts. If the battery voltage falls below a threshold of approximately 2.0 to 2.2 volts, the circuit 104 will generate a low level output signal. The circuit 104 thus implements the logical compliment of a "low battery
15 detect" function.

If the battery voltage is less than the threshold voltage, the transmitted magnetic field of the intra-oral transmitting assembly 12 will be modified and thus able to communicate the "low battery" status.

20 In the preferred embodiment, the output signal Q1 of the decade counter 106 will be at the high level for 2.048 millisecond during each cycle of keyboard switch activation. The output signal Q1 of the decade counter 106 is ANDed at NAND gate 204 with the output signal of
25 the "low battery" detect circuit 104.

When the battery voltage exceeds the threshold defined above, the output signal of NAND gate 204 will be the logical compliment of the output signal Q12 of the timer 100. Since the transition from the high to the low
30 level of the output signal Q12 of the timer 100 is used to advance the state of the decade counter 106 and since the output signal of NAND gate 204 is ANDed with the output signal Q1 of the decade counter 106, the output signal of inverter 114 will represent the first 1.024

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millisecond of the 2.048 millisecond duration of the output signal Q1 of the decade counter 106.

But when the battery voltage is less than the threshold voltage, the output signal of NAND gate 204 will be at the high level. This circumstance will result in the output signal of inverter 114 being at the high level for the full 2.048 millisecond duration of the output signal Q1 of the decade counter 106.

The output signal of inverter 114 is ANDed with the 2.0 MHz squarewave output signal from the oscillator 102 pin 9. These two signals are ANDed together by NAND gate 202. The output signal of NAND gate 202 drives the resonant circuit comprised of capacitors 192, 194, trimmer capacitor 136 and inductor 134.

RF choke 200 is placed in series between the output signal of NAND gate 202 and the resonant circuit. Choke 200 acts as a charging choke and reduces the current required to charge the resonant circuit by 50 percent, thus helping to further reduce battery drain.

The resonant circuit described above has a resonant frequency of 2.0 MHz. Minor variations in the values of the components of the resonant circuit can be compensated for by adjustment of trimmer capacitor 136.

Inductor 134 is wound within the slot 132 (Fig. 10) at the periphery of the printed circuit board 20 upon which the electronic circuits are mounted. Both the width and depth of the slot 132 as well as the wire gauge of inductor 134 are carefully controlled to reduce the stray capacitance in inductor 134. Such stray capacitance represents additional losses which draw current from the battery 54 not utilized in the generation of the magnetic field.

Inductor 134 is wound in recess 132 around the periphery of the printed circuit board 20, and has 14 turns of no. 32 AWG enameled magnet wire arranged in

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seven layers of two turns each. The depth of the recess is 0.12 inch and the width of the recess is 0.03 inch.

Because of the manner in which inductor 134 is constructed, the cross-sectional area of inductor 134 is large, resulting in a magnetic field having lower flux density than would a similar inductance wound upon a small ferrite core. Also, careful layout of the components of the electronic assembly 90 upon the PC board 20 further reduces stray capacitance.

There is an advantage which accrues to the use of a magnetic field having lower flux density as is the case in the present invention. That advantage is a decrease in directional sensitivity between the orientation of the intra-oral transmitting assembly 12 and that of the receiver 16.

A typical operation of the intra-oral transmitting assembly 12 will now be described with respect to Figs. 18, 19 and 20.

When one of the keyboard switches, SW1 70 through SW9 86, is depressed, the magnetic field generated by the current flowing in inductor 134 of the intra-oral transmitting assembly 12 will be a function of the specific keyboard switch activated and also a function of the status of the battery voltage.

The resulting magnetic field (Fig. 19, line "Pulse Line SW1 & Carrier" and line "Pulse Line SW3 & Carrier") will comprise a burst of pulses at the 2.0 MHz rate which is of 1.024 millisecond duration, repeated at intervals dependent upon which switch is activated, when the battery voltage exceeds the threshold voltage. The resulting magnetic field (Fig. 20, line "Pulse Line SW1 & Carrier" and line "Pulse Line SW3 & Carrier") will comprise a burst of pulses at the 2.0 MHz rate and being of 2.048 millisecond duration, repeated at appropriate

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intervals, when battery 54 has a voltage below the threshold voltage.

Because the "low-battery detect" circuit 104 does not modify the overall length of the cycle, as was discussed
5 above, the repetition rate of the pulsed magnetic field does not change as a function of battery voltage. Only the width of the burst of 2.0 MHz pulses changes, being either 1.024 millisecond or 2.048 millisecond in duration.

10 Each cycle of the resulting magnetic field can be thought of as being comprised of the burst of 2.0 MHz pulses followed by a period of quiescence equal to a number of intervals of 1.024 millisecond duration which depends upon both the specific keyboard switch activated
15 and the battery voltage.

In example 1, assume the following: the battery voltage exceeds the threshold voltage and switch SW1 70 has been activated. While switch SW1 70 remains activated, the following cycle repeats.

20 The oscillator 102, the timer 100 and the decade counter 106 are permitted to sequence. The first time the timer 100 output signal Q12 (Fig. 19, TIMER line) moves from the high to the low level, the decade counter 106 output signal Q0 moves from the high to the low level
25 and output signal Q1 turns ON.

The presence of a low level at pin 12 of NAND gate 204 results in the last half of the decade counter 106 output signal Q1 being gated off at the input to pin 10 of NAND gate 202. This circumstance results in the
30 resonant circuit being driven by a burst of 2.0 MHz pulses for a period of 1.024 millisecond.

At the next transition of the timer 100 output signal Q12 from the high to the low level, the decade counter 106 output signal Q1 turns OFF and output signal Q2 turns
35 ON. This change is coupled through the activated

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keyboard switch SW1 70 to the reset inputs of the oscillator 102, the countdown 100 and the decade counter 106.

5 Because the reset inputs to these two integrated circuits operate as asynchronous inputs, the decade counter 106 output signal Q2 returns to the low level within the circuit delay of approximately 80 nanoseconds. The specific pulse width of output signal Q2 of the decade counter 106 is a function of the delay between the
10 reset input and the Q2 output signal of the decade counter and is also a function of stray circuit capacitance and of the battery voltage level. It will be appreciated that the specific pulse width is not critical to the proper operation of the present invention.

15 The return of the decade counter 106 output signal Q2 to the low level allows the cycle just described to repeat because the common reset signal is at the low level. The cycle will continue to repeat until switch SW1 70 is deactivated. A keyboard switch is deactivated
20 by removing the tongue pressure from the nipple 92 associated with the particular switch.

 The cycle which occurs when the battery voltage exceeds the threshold and switch SW1 70 is activated, comprises a burst of 2.0 MHz magnetic pulses having
25 duration of 1.024 millisecond followed by a period of 3.072 millisecond duration of no magnetic pulses. This cycle will repeat if switch SW1 70 continues to be activated.

 In example 2, assume the following: the battery
30 voltage is below the threshold voltage and any tongue activated switch 63 has been activated.

 The result is the generation of a magnetic field (Fig. 20, line "Pulse Line SW1 & Carrier" and line "Pulse Line SW3 & Carrier") comprising a burst of pulses at the
35 2.0 MHz rate but of 2.048 millisecond duration. In all

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other respects, the cycle resulting from activation of keyboard switch SW1 70 when the battery voltage is below the threshold voltage will be identical to the cycle which results when the battery voltage exceeds the threshold voltage. Thus, it is seen that low battery voltage doubles the burst pulse duration and does not change the overall duration of the cycle. The burst pulse width is a function only of the battery voltage while the burst pulse repetition rate is a function of the specific keyboard switch activated (Fig. 19, line "Pulse Line SW1 & Carrier" and Fig. 20, line "Pulse Line SW1 & Carrier").

In a third example, it will be assumed that keyboard switch SW3 74 is activated and that the battery voltage exceeds the threshold voltage. Under these assumptions, the resulting cycle will begin with a 1.024 millisecond burst of 2.0 MHz pulses, followed by an interval of 1.024 millisecond plus 4.096 millisecond of no magnetic field (the duration of the last half of decade counter 106 output signal Q1, plus the cumulative duration of output signals Q2 and Q3, each being 2.048 millisecond in duration), followed by an approximately 80 nanosecond interval of no magnetic field (during which the decade counter 106 output signal Q6 will be at the high level and the oscillator 102, the countdown 100 and the decade counter 106 will be reset). This cycle will continue to repeat so long as keyboard switch SW3 74 is activated.

Thus, it will be seen that in the preferred embodiment the cycle of the resulting magnetic field (assuming the battery voltage exceeds the threshold voltage) will be one of the following:

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SW1 1.024 msec burst plus 3 x 1.024 msec quiescence;
 SW2 1.024 msec burst plus 5 x 1.024 msec quiescence;
 SW3 same 7 x same
 SW4 same 9 x same
 5 SW5 same 11 x same
 SW6 same 13 x same
 SW7 same 15 x same
 SW8 same 17 x same
 SW9 same 19 x same.

10

It will be appreciated that the effects of the approximately 80 nanosecond interval can be safely ignored.

Operation of the intra-oral transmitting assembly 12 is slightly different for keyboard switch SW9 86. As shown in Fig. 18, when activated, keyboard switch SW9 86 connects the reset inputs of the oscillator 102, the timer 100 and the decade counter 106 to the common ground. When keyboard switch SW9 86 is activated, the two integrated circuits are allowed to operate continuously and without reset because no decade counter 106 Q output signal is coupled through the activated keyboard switch to the reset inputs. When the Q9 output signal of the decade counter 106 is ON and the Q12 output signal of the timer 100 is changing from the high to the low level, the Q9 output signal of the decade counter 106 will turn OFF and the Q0 output signal of the decade counter 106 will turn ON. The decade counter 106 will continue to thus cycle through each of its states without reset until the keyboard switch SW9 is deactivated.

30

Inductor 134 of the resonant circuit of the intra-oral transmitting assembly 12 acts as the primary coil of an air core RF transformer. The secondary coil of this air core RF transformer is located in the

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receiver 16 which is depicted in block diagram form in Fig. 14.

5 The present invention relies upon use of the magnetic field produced by a current loop (inductor 134) rather than the electric field radiated from an antenna for coupling the output of the intra-oral transmitting assembly 12 to the receiver 16.

10 This feature embraces a number of advantages. Among these are (1) use of the relatively small inductor 134 rather than a significantly larger electric field antenna; (2) operation at the relatively low carrier frequency of 2.0 MHz rather than operation at an approximately 88 MHz; (3) use of an AM receiver 16, which in the preferred embodiment is a broadcast band AM receiver modified to operate at the 2.0 MHz carrier
15 frequency; (4) the savings in operating power resulting from the use of the lower carrier frequency, the relatively low duty cycle and the use of the charging choke 200 to drive the resonant circuit; and (5)
20 improvement in non-interference between the output of the intra-oral transmitting assembly 12 and other adjacent transmitting assemblies.

The savings in operating power is a direct result of the use of a low carrier frequency, 2.0 MHz, a low duty
25 cycle and the use of the charging choke 200. The power consumed is a direct, linear function of carrier frequency and stray capacitance. And the use of the charging choke 200 limits the current supplied to the resonant circuit to 50 percent of what the current would
30 be without the choke 200 while producing the same magnetic field strength.

The present invention, by the physical arrangement of the parts in the layout of the printed circuit board 20 and in particular, the arrangement of the inductor 134 in
35 slot 132 at the periphery of the printed circuit board

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20, minimizes the stray capacitance, thus further reducing power drawn from the battery.

Earlier designs of intra-oral transmitting assemblies have relied upon use of frequency modulated (FM) transmission at carrier frequencies at or near 88 MHz. The electric field antennas at such frequencies, though quite small, require large amounts of electrical power. The result is a significant decrease in the life of the battery.

The improvement in non-interference of the preferred embodiment results from the fact that the magnetic field strength falls off as the reciprocal of the third power of the distance separating transmitter and receiver. Whereas the electric field strength, relied upon by the existing devices, falls off as the reciprocal of the distance separating transmitter and receiver. Thus, when one is able to use the magnetic field rather than the electric field, effective isolation without the need for additional circuitry or shielding is possible over relatively short distances.

It is true that both the electric and the magnetic fields are present in the preferred embodiment when a keyboard switch is activated. However, the tongue activated communications controller 10 uses the air core RF transformer to effectively couple the magnetic field. The invention does not efficiently couple the electric field because no attempt is made to implement an electric field antenna of the necessary size.

The radiated power of the magnetic field, measured at a distance of three meters from the transmitting assembly is approximately 0.25μ Amp/meter.

In the preferred embodiment depicted in Fig. 18 and described above, the preferred battery 54 is a lithium "button" type battery having a 3.0 Volt output level at 30 mAmp-hour. The average current drain using such a

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battery is less than 0.5μ Amp when no keyboard switches are activated and averages less than 500μ Amp when a keyboard switch is activated. The low battery drain, when no keyboard switch is activated, results in a shelf
5 life for the intra-oral transmitting assembly 12 nearly equal to that of the lithium battery, approximately 10 years.

It is within the scope and spirit of the present invention that the discrete components and the integrated
10 circuits which comprise the electronic assembly 98 can be replaced with a single, custom integrated circuit which is designed to perform the following functions: encoding the activated keyboard switch and battery voltage status into a digital signal; combining the digital signal with
15 a carrier frequency just above the AM broadcast band of frequencies; and generating a magnetic field corresponding to the combined signals for communicating with an AM receiver.

Use of the custom integrated circuit will reduce
20 operating power to approximately 40% of its present value.

The transmitter assembly 90 is easily detachable from the dental appliance. Thus, the transmitter assembly 90, including its battery 54 is an easily replaceable,
25 disposable item.

The receiver 16 as implemented in the preferred embodiment of the present invention is a standard AM broadcast band receiver which is modified to permit operation at the 2.0 MHz carrier frequency.

30 The modifications are (1) change a capacitor value in the local oscillator circuit of receiver 16 to allow the local oscillator to be compatible with the 2.0 MHz carrier frequency, and (2) change the value of a capacitor associated with the ferrite core antenna of the

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receiver 16 to permit reception of the 2.0 MHz RF magnetic field.

An electrical signal which is output by the modified AM receiver 16 is used as an input to the smart box 18.

5 The electrical signal as it enters the smart box 18 corresponds to the output of the encoder 96 of the intra-oral transmitting assembly 12. The 2.0 MHz carrier signal has been removed by the demodulation process of receiver 16 and only an equivalent of the digital signal
10 remains.

 The smart box 18 is implemented using a standard off-the-shelf programmable micro-controller having microcode and with appropriate interface and support
15 circuits. The demodulated receiver input is fed directly into the programmable micro-controller.

 The micro-controller is programmed by means of microcode which includes instructions to the micro-controller to measure the pulse width and pulse
20 repetition rate of the incoming signal. If either parameter is too far outside acceptable limits, the incoming signal is ignored as it may result from interference.

 The pulse-width check also allows checking of the status of the intra-oral transmitting assembly 12 battery
25 voltage level. The pulse repetition rate check is used also to determine which of the intra-oral transmitting assembly 12 keyboard switches is activated.

 When the activation of a specific keyboard switch is detected by this process, the information is passed to
30 another part of the microcode of the micro-controller. There it is compared with the current state of the system and results in appropriate change of system state or system output.

 A concurrent process, operating in the smart box 18
35 and implemented by a part of the microcode, is constantly

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displaying the system state to the user, or to operate an audio alarm for the benefit of the visually impaired. In the preferred embodiment, the display is a liquid crystal display of approximately 4 lines of 20 characters each.

Finally, a third concurrent process implemented by the microcode is operating at all times in the programmable micro-controller. That is the interface and control function with external devices.

Depending upon the options installed in the smart box 18, a subprocess of the micro-controller program monitors signals received from, and generates signals and signalling sequences appropriate to communicate with, various devices. Typical devices are depicted in Fig. 14.

Thus, the smart box 18 is limited only by the number and type of interfaces provided. Both infra red (IR) and radio frequency (RF) coupling to external devices, as well as direct wired coupling, is understood to be embraced within the scope and spirit of the present invention.

One application which deserves special attention is the typing input to a computer.

Special software is loaded into the computer such that it may be called into operation from the tongue-activated transmitting assembly. A typical operation would be as follows: a top level menu would be displayed to the user upon the smart box 18 display (for example, mounted on the wheelchair as shown in Fig. 15); from this menu of possible applications, the user would activate the tongue activatable keyboard switch which corresponded to the computer application.

Then by depressing a sequence of tongue activatable keyboard switches, the user would bring up the special

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typing program on the computer with which the user was in communication and control.

5 In essence, the special program displays a square matrix of sub menus. The user would then activate the keyboard switch corresponding to the sub menu which contains the computer activity he desires to use. This stepping downward through levels of nested menus can be of any desired degree of complexity.

10 The typing application can be implemented using a 3 by 3 matrix, each sub menu of which is a 3 by 3 matrix. This degree of nesting provides for reaching one of 81 targets and requires a sequence of two tongue activations to reach any target. Each target corresponds to a typing symbol (e.g., the letters of the alphabet, numbers, 15 special symbols and control functions such as backspace, delete, enter, etc.) which may be selected and executed using sequences of two tongue depressions.

The typing application can thus be implemented using an intra-oral transmitting assembly 12 having exactly 9 20 switches. Other arrangements are clearly possible.

It should be noted that the wheelchair control feature requires a minimum of 9 switches. The nine switches correspond to the following wheelchair commands: forward, forward right, right, backward right, backward, 25 backward left, left, forward left and stop.

While the foregoing detailed description has described several embodiments of the tongue activated communications controller 10 in accordance with this invention, it is to be understood that the above 30 description is illustrative only and not limiting of the disclosed invention. Particularly, any number of devices, including environmental controls, computers, telephones, musical instruments and other devices could be operated by the tongue activated communications controller 10 in accordance with this invention. It will 35

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be appreciated that all such embodiments are within the scope and spirit of this invention. Thus, the invention is to be limited only by the claims as set forth below.

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CLAIMS

What is claimed is:

1. A tongue activated communications controller, comprising:

5 an intra-oral transmitting assembly including:

a two sided circuit board, the first side having electronic means for transmitting an electrical signal and the second side having a keyboard with a plurality of tongue activatable positions, the activated positions
10 encode a signal for transmission; and

a wireless transmitter having an inductor defining an antenna for enhanced transmission of the encoded signals, the inductor having one or more windings around the perimeter of the printed circuit board; and

15 receiving means for receiving the encoded signals from the transmitting assembly including computing means for decoding the encoded signals and for forming a set of instructions for operating a device from the decoded signals and means for sending the instructions to the
20 device for operation.

2. A controller as set forth in Claim 1, wherein the first side of the printed circuit board includes a means for encoding.

25

3. A controller as set forth in Claim 1, wherein the keypad has nine discrete switches.

4. A controller as set forth in Claim 3, wherein
30 the keypad has three arc-shaped rows and each row having three switches.

5. A controller as set forth in Claim 1, wherein the second side of the printed circuit board includes a
35 keyboard membrane having an operational surface with a

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plurality of switches and an adhesive spacer between the printed circuit board and the keyboard membrane and wherein the printed circuit board, adhesive spacer and keyboard membrane are encapsulated by an encapsulant with the operational surface of the keyboard membrane exposed.

5

6. A controller as set forth in Claim 5, wherein the printed circuit board is bonded to the keyboard membrane.

10

7. A controller as set forth in Claim 5, wherein the operational surface for the keyboard membrane includes a plurality of spaced apart, separate conductive pads for making electrical contact with the printed circuit board.

15

8. A controller as set forth in Claim 7, wherein each pad has a nipple which can be depressed by a human tongue.

20

9. A controller as set forth in Claim 8, wherein each of the nipples is a Braille nipple and provides tactile feedback for a human tongue.

25

10. A controller as set forth in Claim 5, wherein the encapsulant having an outer edge which define means for interfacing with the teeth and forming a press-fit connection therewith.

30

11. A controller as set forth in Claim 5, wherein a clasp is embedded into the encapsulant for securing the intra-oral transmitting assembly in the mouth of a user.

35

12. A controller as set forth in Claim 5, wherein the encapsulant is made from methyl methacrylate.

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13. An intra-oral transmitting assembly including:
a keyboard having a plurality of tongue-activated
switches, each switch having an interval of switch
5 activation defined by the depression of the switch;

an encoding means for receiving input from all the
tongue-activated switches and, during an interval of
switch activation, for generating a waveform which is a
function of the specific switch activated; and

10 a magnetic coupling means for receiving the waveform
from the encoding means and, during the interval of
switch activation, for generating a time-varying magnetic
field whose properties are a function of the waveform,
whereby upon tongue activation of the one of the switches
15 a time-varying magnetic field is created whose properties
are uniquely determined by the switch which is activated.

14. An intra-oral transmitting assembly as set forth
in Claim 13, further including an electrical source.
20

15. An intra-oral transmitting assembly as set forth
in Claim 25, wherein the electrical source further
comprises at least one electrical battery.

25 16. An intra-oral transmitting assembly as set forth
in Claim 13, wherein the assembly is fitted to the palate
of the user.

17. An intra-oral transmitting assembly as set forth
30 in Claim 13, wherein the encoding means generates a
digital waveform.

18. An intra-oral transmitting assembly as set forth
in Claim 16, wherein the digital waveform has an ON level

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and an OFF level and defines a sequence having discrete time intervals.

19. An intra-oral transmitting assembly as set forth
5 in Claim 18, wherein the digital waveform assumes the ON level for a first predetermined number of discrete time intervals then assumes the OFF level for a second predetermined number of discrete time intervals and wherein the sequence thus defined is repeated throughout
10 the interval of switch activation.

20. An intra-oral transmitting assembly as set forth
in Claim 19, wherein the time-varying magnetic field is a function of the logical product of the digital waveform
15 received from the encoding means and a second digital waveform having ON and OFF levels and a transition, the transition defined as a change of level, the second digital waveform having a plurality of transitions throughout each sequence of the digital waveform received
20 from the encoding means.

21. An intra-oral transmitting assembly as set forth
in Claim 20, wherein the second digital waveform is a squarewave having a predetermined frequency generated by
25 a crystal-controlled oscillator and having a second discrete time interval defined as the duration of one complete cycle of the squarewave.

22. An intra-oral transmitting assembly as set forth
30 in Claim 21, wherein the each discrete time interval of the digital waveform received from the encoding means has a duration which is a predetermined multiple of the second discrete time interval of the squarewave.

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23. An intra-oral transmitting assembly as set forth in Claim 19, further having means for connecting an electrical source having a voltage level.

5 24. An intra-oral transmitting assembly as set forth in Claim 23, wherein the voltage level is monitored by a low-voltage detection means for producing an output if the voltage level is less than a predetermined voltage.

10 25. An intra-oral transmitting assembly as set forth in Claim 24, wherein the output of the low-voltage detection means is an input to the encoding means and wherein the digital waveform generated by the encoding means is modified if the voltage level of the electrical
15 source is less than the predetermined voltage.

26. An intra-oral transmitting assembly as set forth in Claim 25, wherein the ON-level of the digital waveform generated by the encoding means is two discrete time
20 intervals in duration if the voltage level is less than the predetermined voltage.

27. A tongue-activated control system, comprising:
an intra-oral transmitting assembly including:
25 a keyboard having a plurality of tongue-activated switches, each switch having an interval of switch activation defined by the depression of the switch;

an encoding means for receiving input from all
30 the tongue-activated switches and, during an interval of switch activation, for generating a waveform which is a function of the specific switch activated; and

a magnetic coupling means for receiving the waveform from the encoding means and, during the interval
35 of switch activation, for generating a time-varying

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magnetic field whose properties are a function of the waveform and

5 a receiving means for receiving the time-varying magnetic field generated by the intra-oral transmitting assembly and further comprising:

a decoding means for converting the received time-varying magnetic field into a waveform which is a function of the specific switch activated and

10 a control means for converting the waveform of the decoding means into appropriate action, whereby upon tongue activation of one of the switches an appropriate action is taken.

28. A tongue-activated control system as set forth
15 in Claim 27, wherein the receiving means is an AM receiver.

29. A tongue-activated control system as set forth
in Claim 28, wherein the AM receiver is a broadcast-band
20 AM receiver modified to operate at a carrier frequency of 2.0 MHz.

30. A controller as set forth in Claim 1, wherein
each tongue activatable position comprises a discrete
25 switch.

31. A controller as set forth in Claim 30, having at
least nine discrete switches.

30 32. A controller as set forth in Claim 1, wherein
the perimeter of the printed circuit board has a recess.

33. A controller as set forth in Claim 33, wherein
the recess has a first wall and a second wall and has a

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width w defined by the distance between the first and second walls.

5 34. A controller as set forth in Claim 33, wherein the conductor has a diameter d and wherein the width of the recess equals at least one diameter of the conductor.

10 35. A controller as set forth in Claim 34, wherein the inductor comprises one or more turns of a conductor wound within the recess.

15 36. A controller as set forth in Claim 35, wherein the conductor is enameled solid wire having a size of 32 AWG.

20 37. A controller as set forth in Claim 35, wherein the conductor is wound within the recess in layers, each layer having a number of turns n equal to the width of the recess measured in conductor diameters.

25 38. A controller as set forth in Claim 37, wherein the inductor comprises 14 turns of the conductor.

30 39. An intra-oral transmitting assembly as set forth in Claim 13, wherein the intra-oral transmitting assembly includes a dental appliance, having a removable module, and wherein the removable module includes the keyboard, the encoding means, and the magnetic coupling means.

35 40. An intra-oral transmitting assembly as set forth in Claim 39, wherein the removable module has a replaceable electrical source.

41. A controller as set forth in Claim 37, wherein the recess has a bottom wall and has a depth D defined by

- 51 -

the distance between the periphery of the printed circuit board and the bottom wall, and wherein the depth of the recess is 0.12 inch and the width of the recess is 0.03 inch.

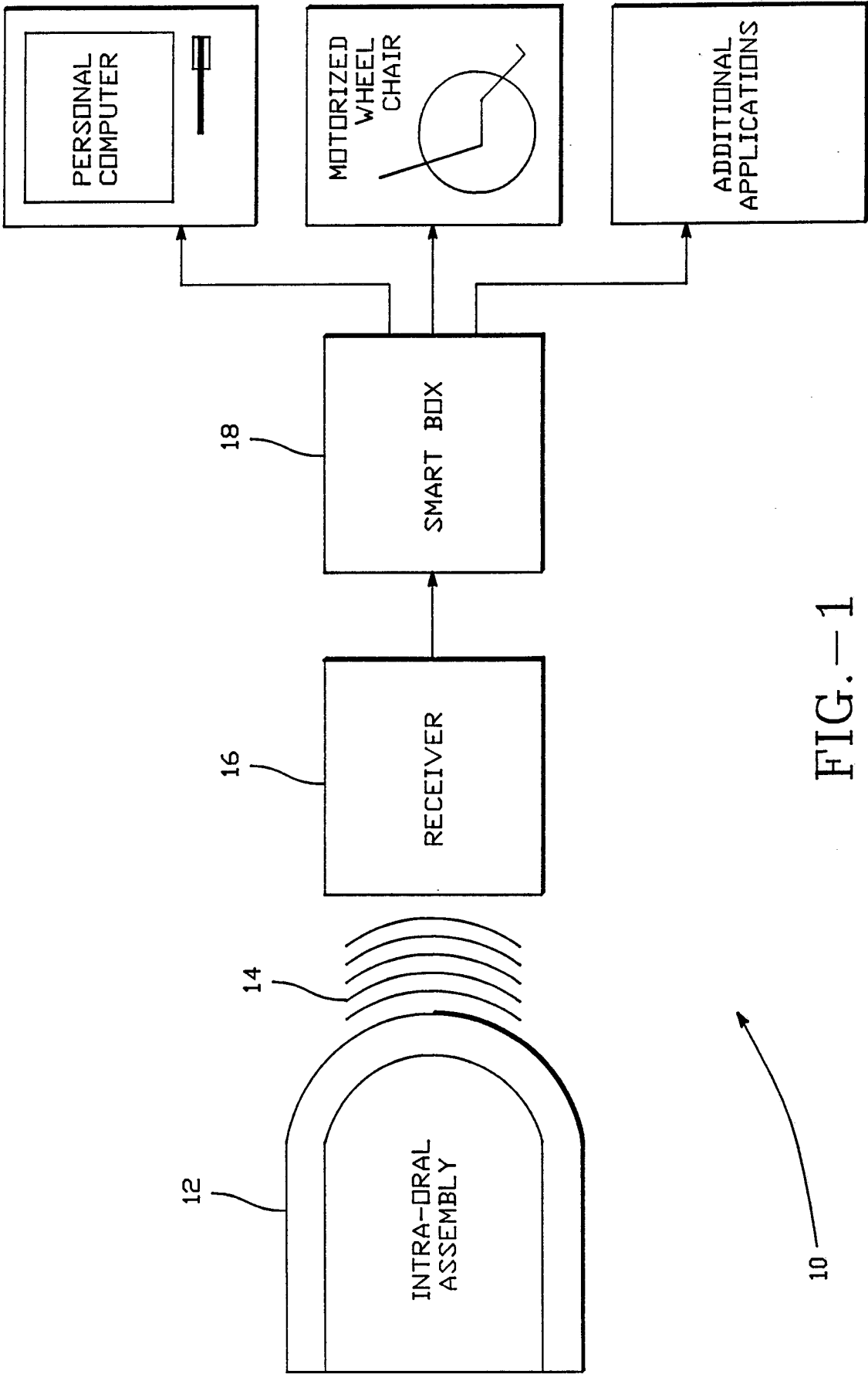


FIG.—1

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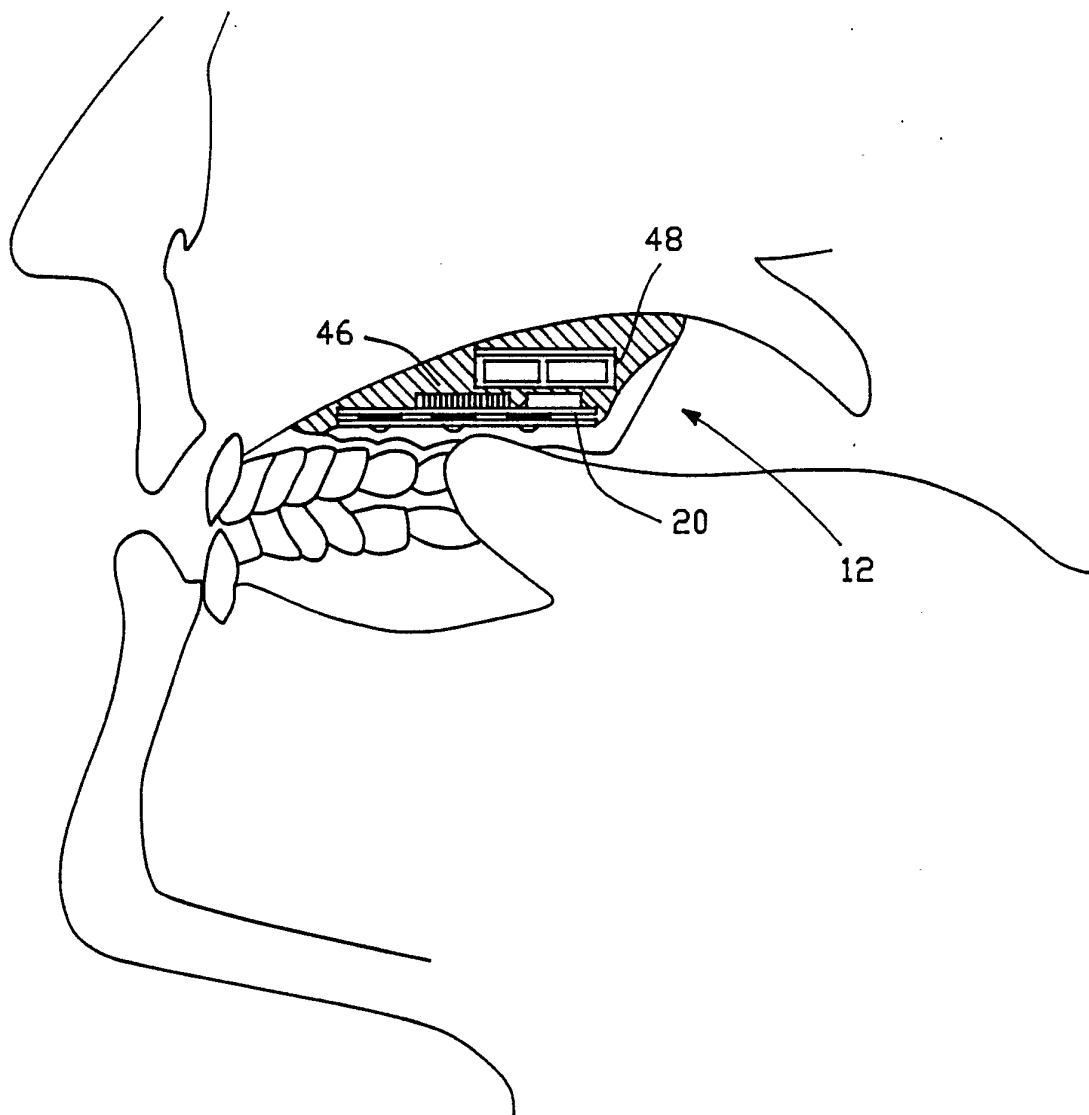


FIG.-2

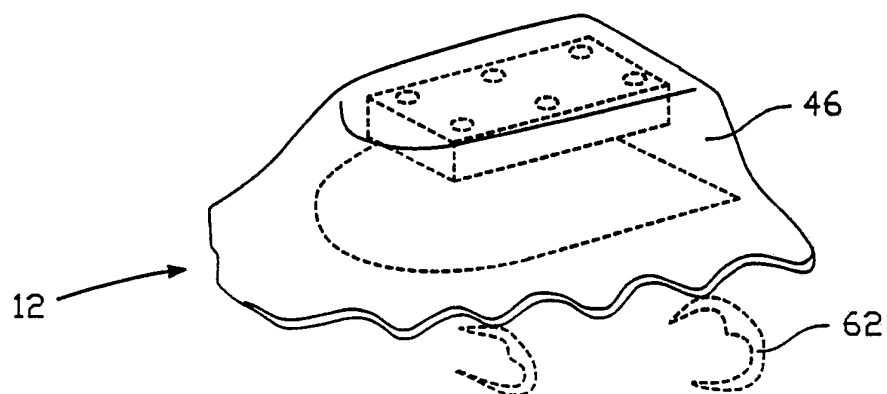


FIG.-3

SUBSTITUTE SHEET

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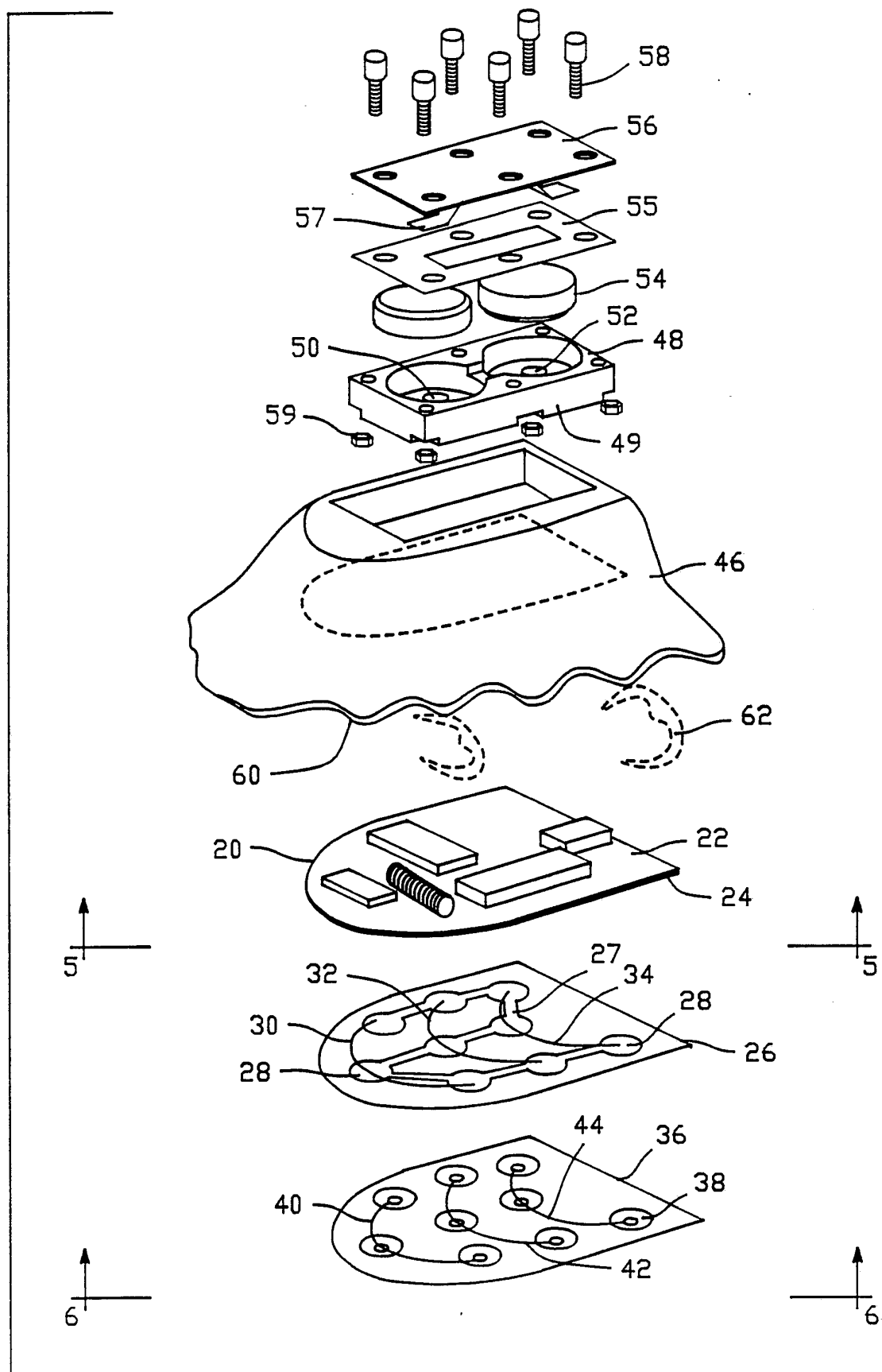


FIG.-4

SUBSTITUTE SHEET

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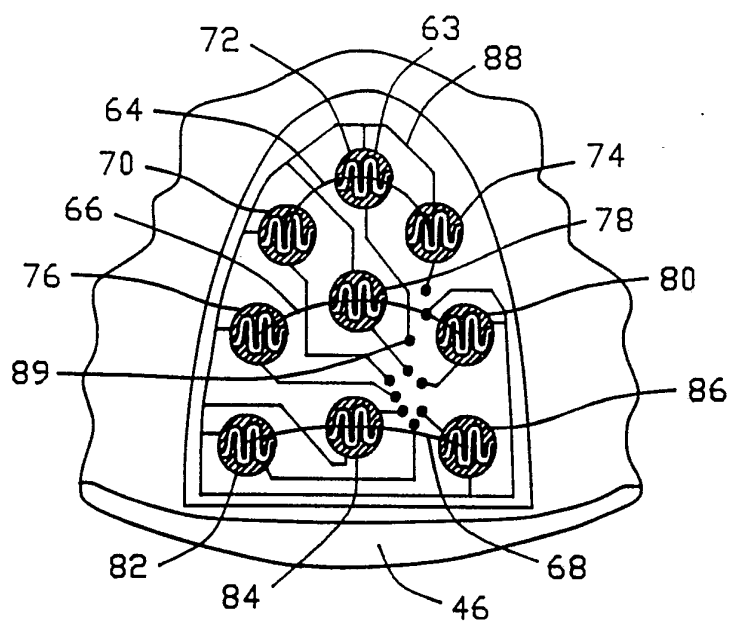


FIG.-5

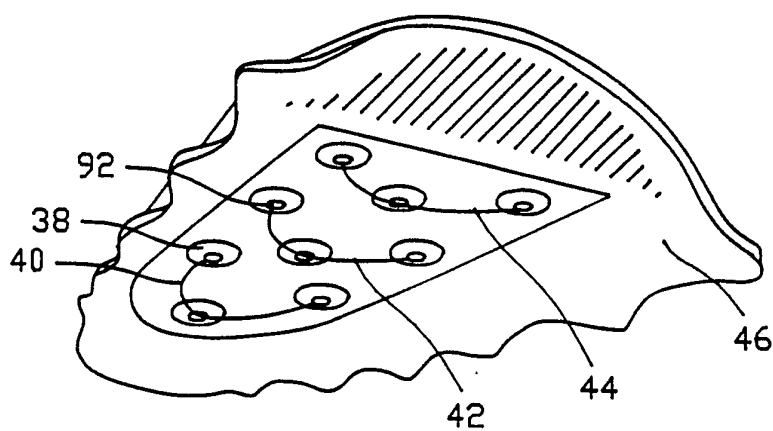


FIG.-6

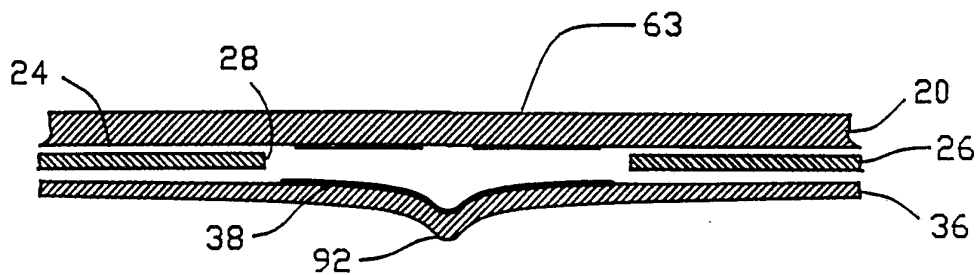


FIG.-7

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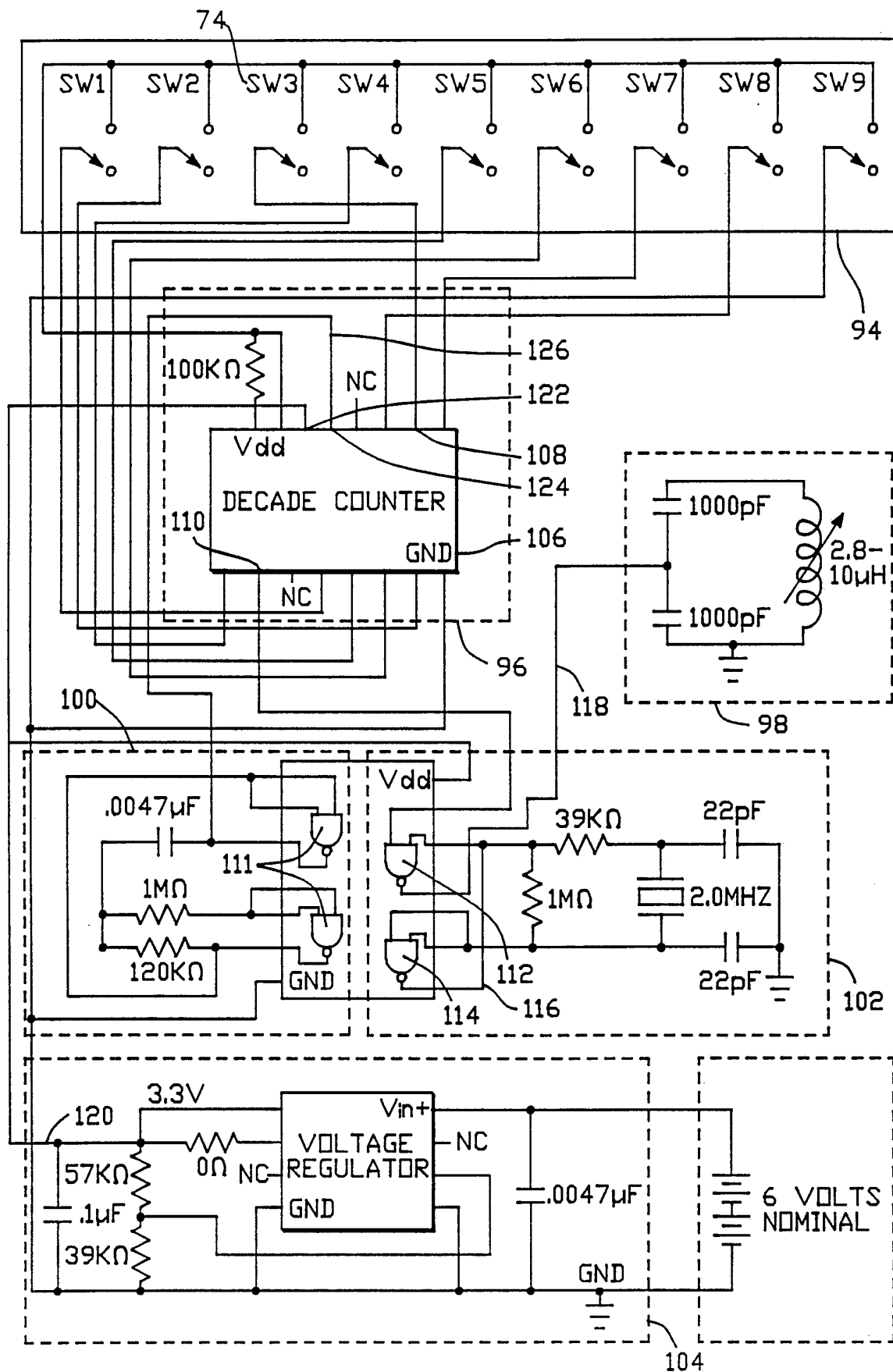


FIG. -8

SUBSTITUTE SHEET

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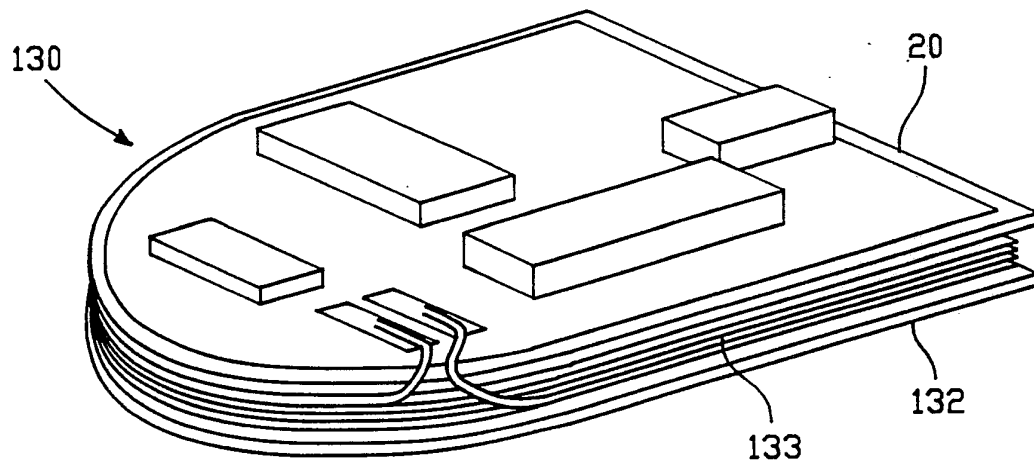


FIG.-9

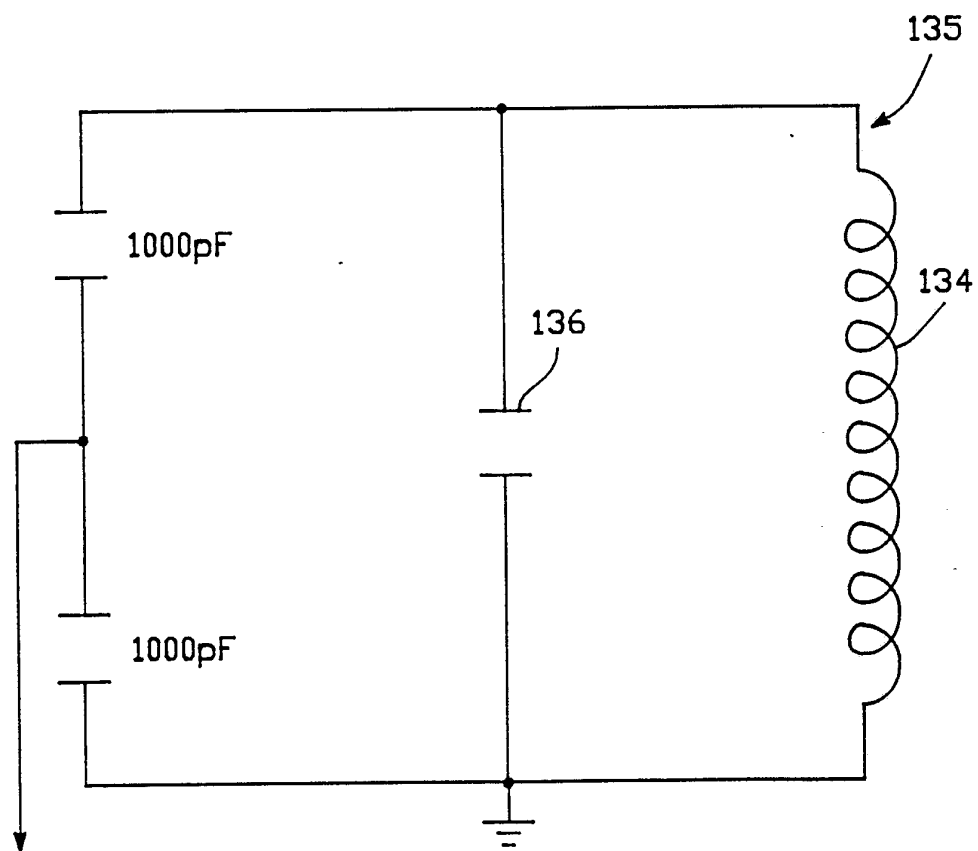


FIG.-10

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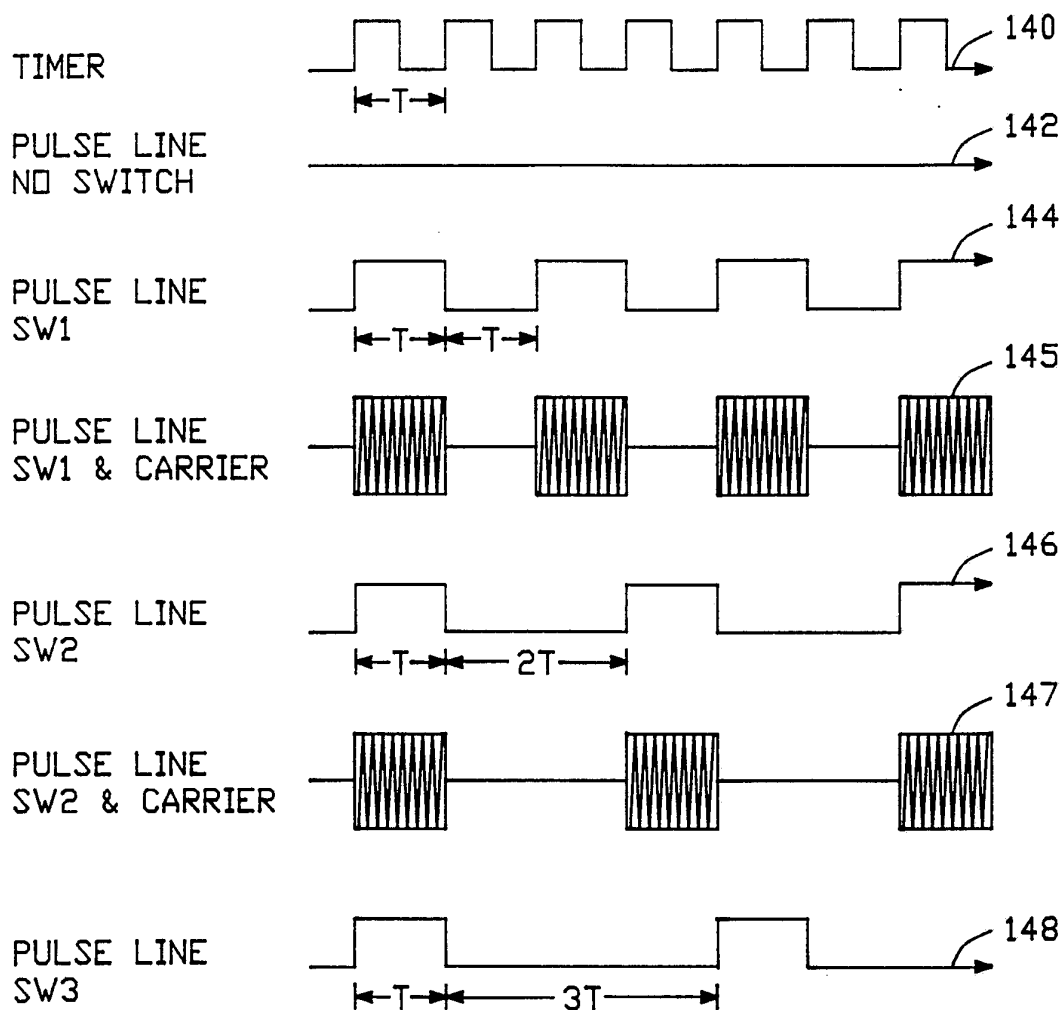


FIG.-11

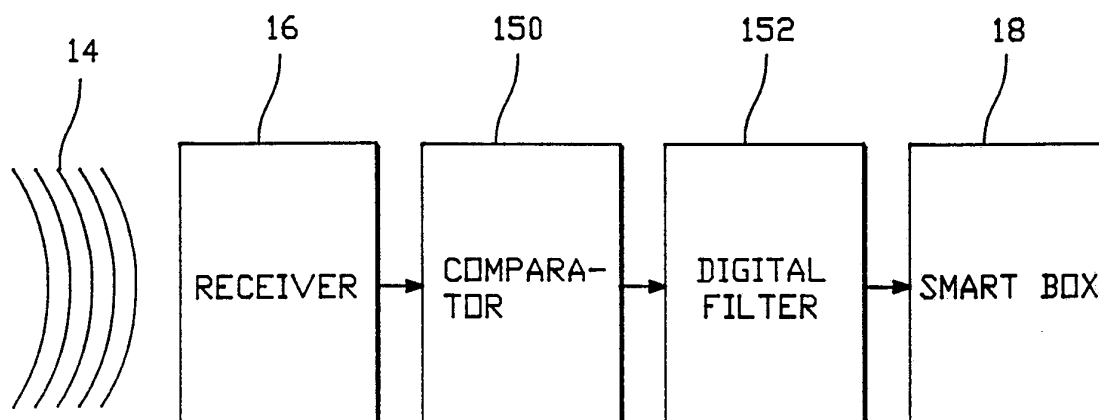


FIG.-12

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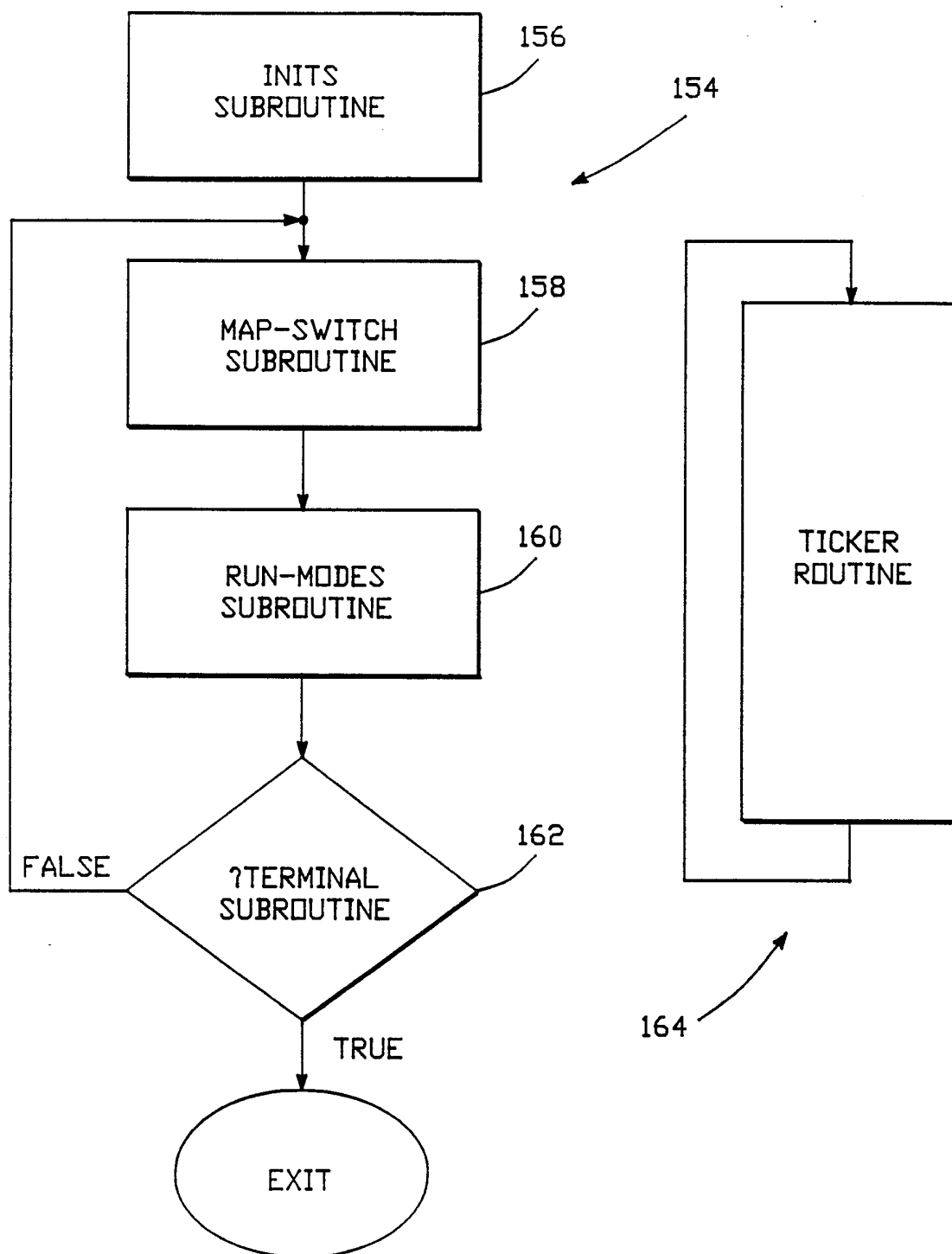


FIG.-13

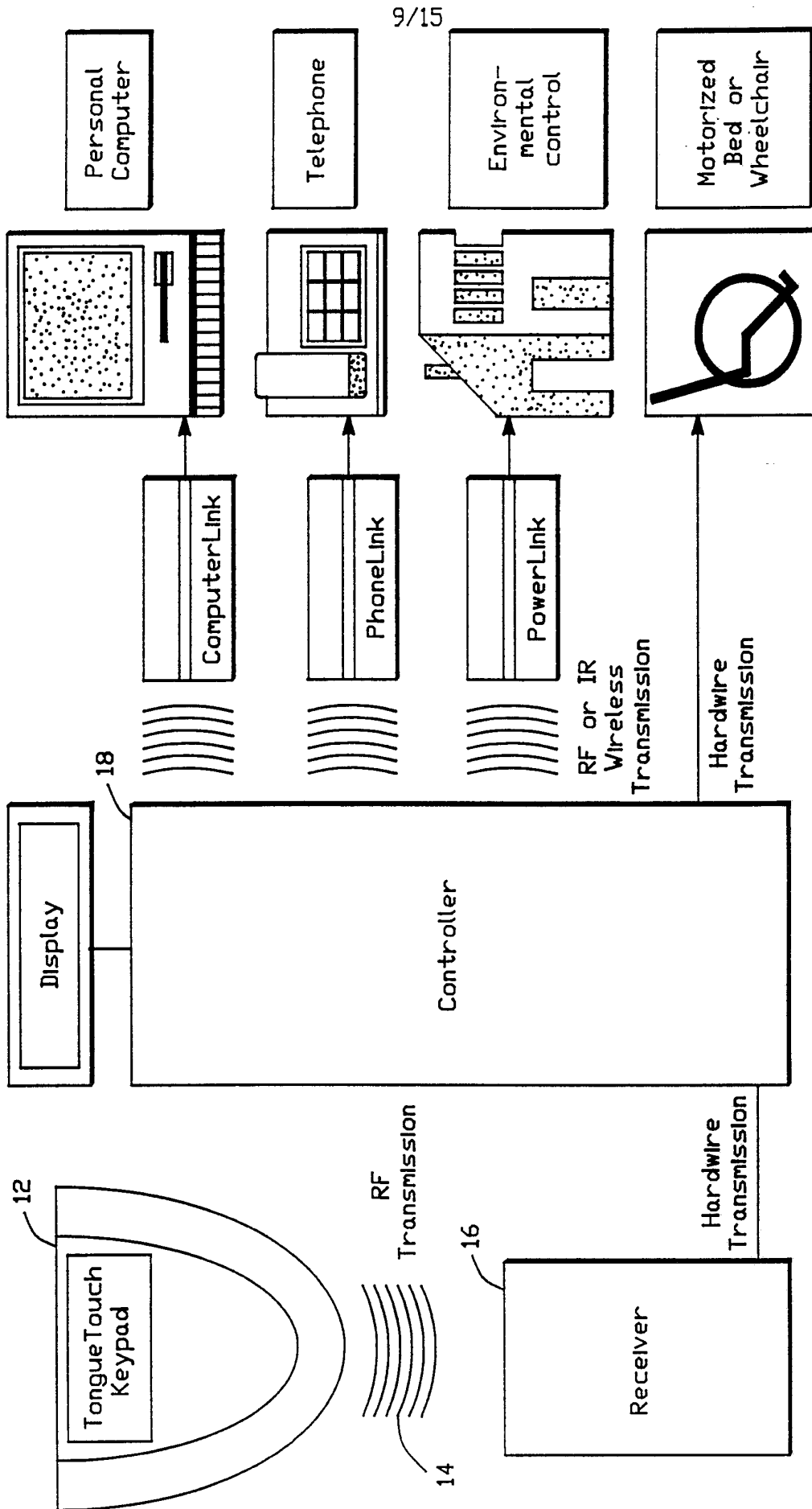


FIG. - 14

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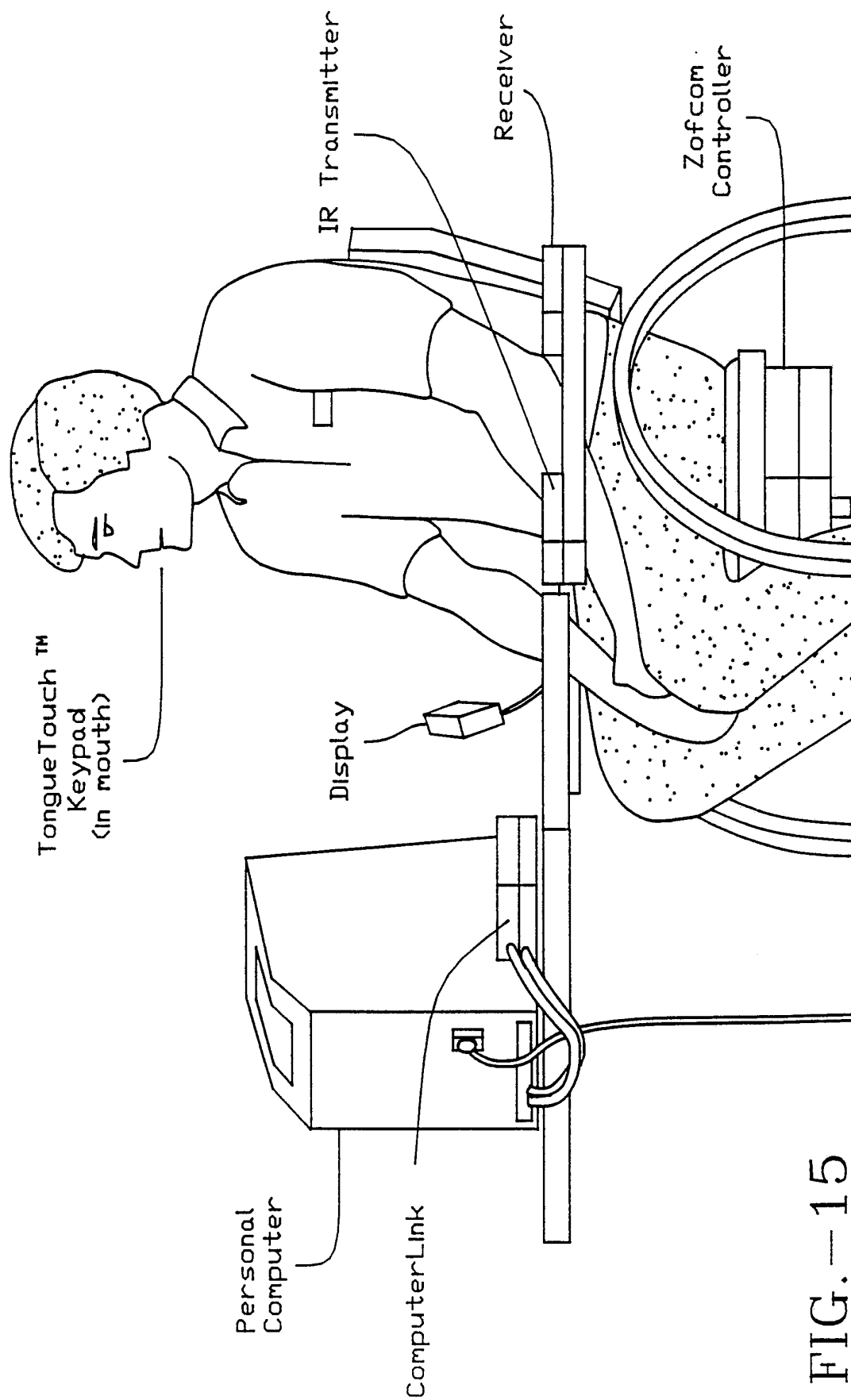


FIG. — 15

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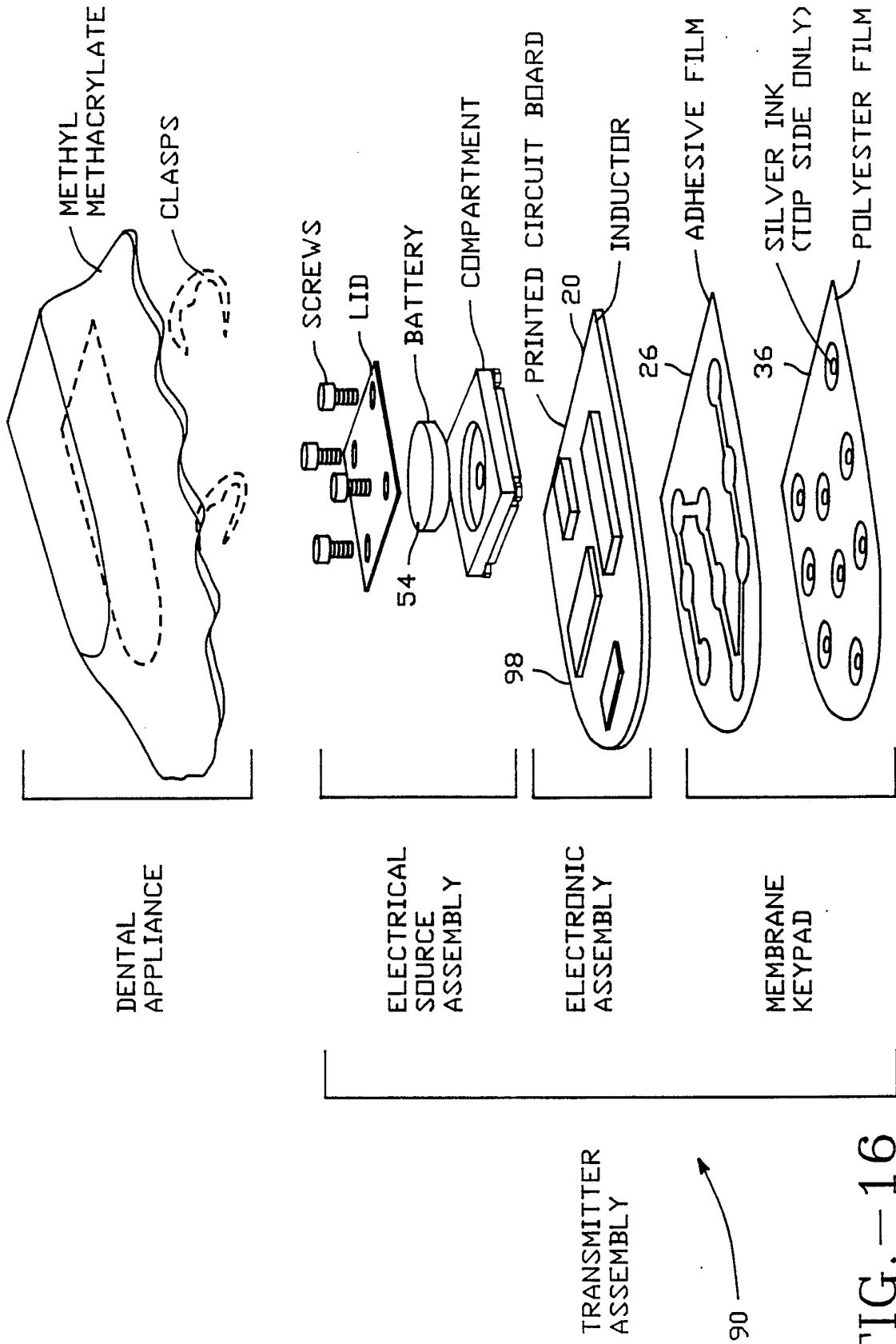


FIG.-16

BLOCK DIAGRAM OF THE INTRA-ORAL TRANSMITTER

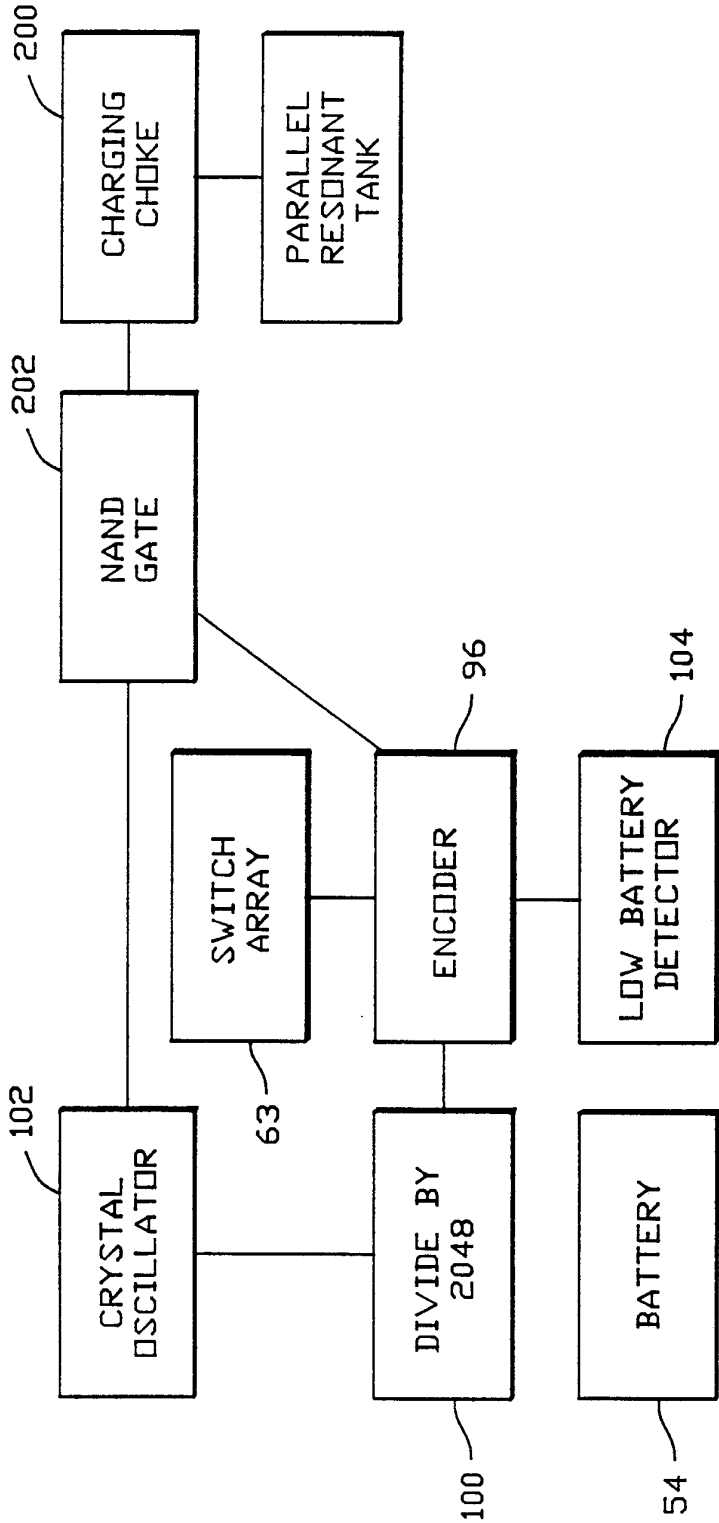


FIG.-17

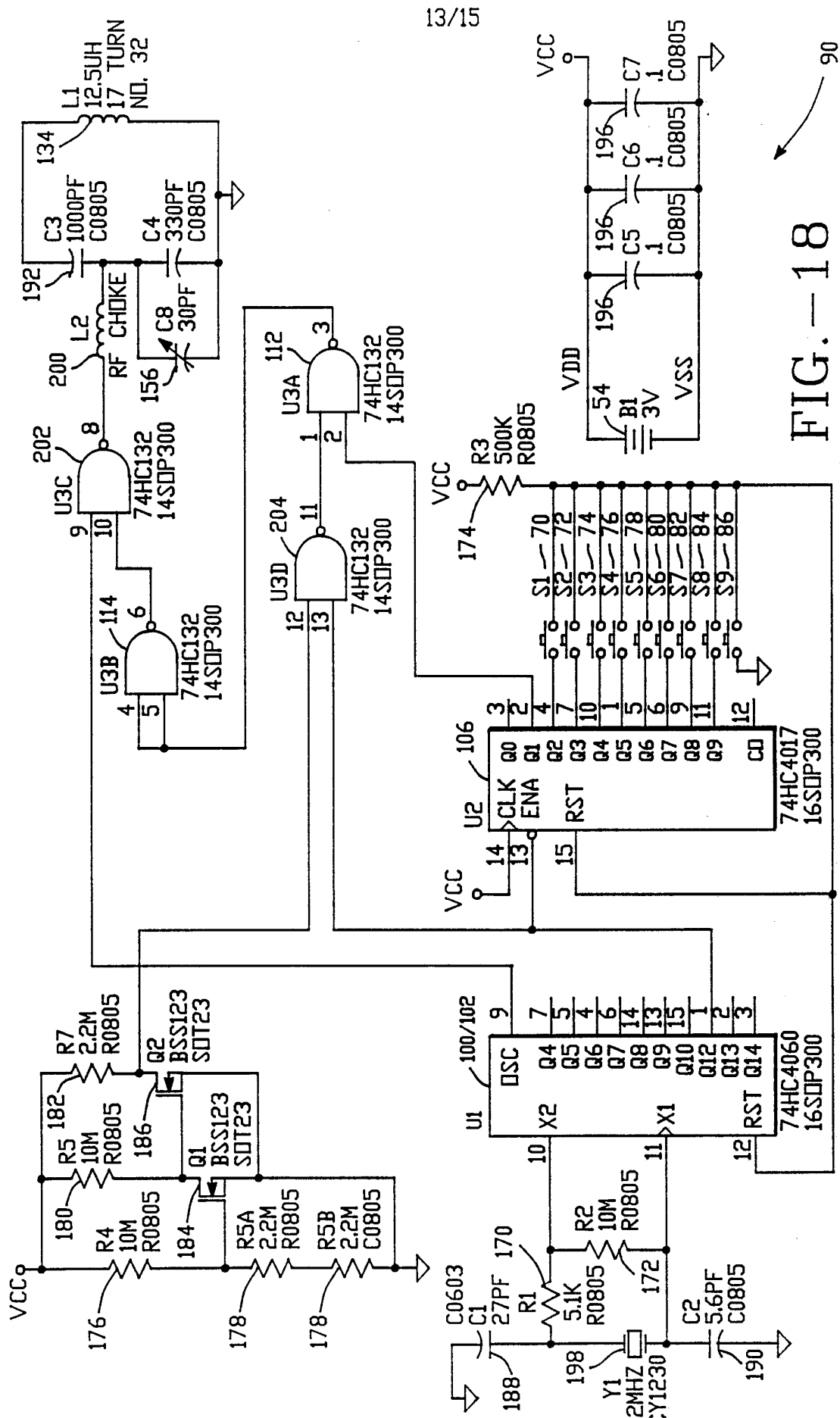


FIG. -18

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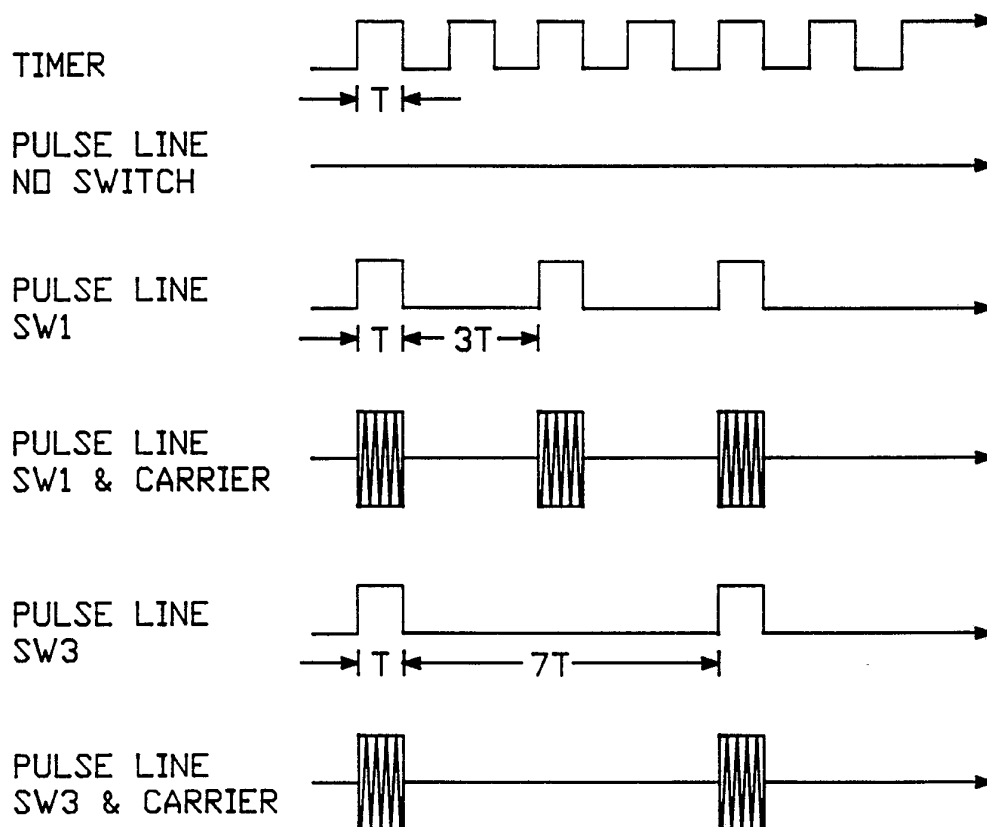


FIG.—19

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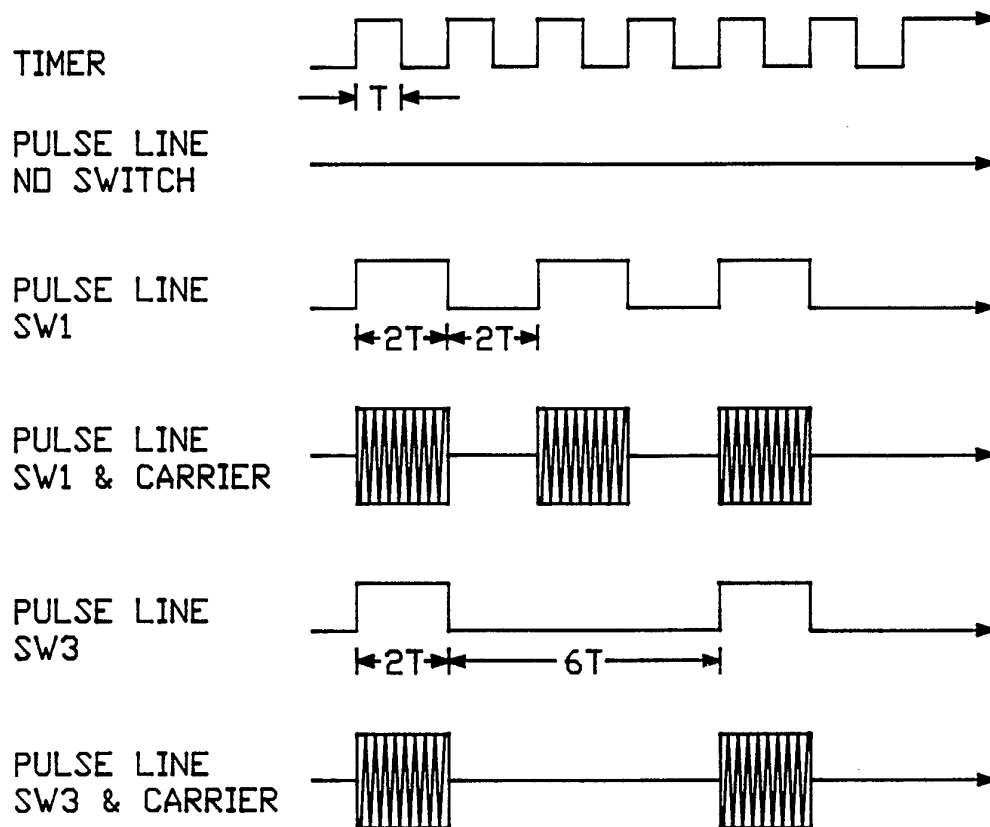


FIG.-20

INTERNATIONAL SEARCH REPORT

PCT/US92/08524

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04Q 9/00

US CL :340/825, 190

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
<u>X</u> Y	US, A, 4,605,927 (KATZ, ET AL) 12 AUGUST 1986; Note col. 6, lines 17-34	<u>13,14,16-20</u> 23,27,1-12, 15,21,22,24- 26,28-32, 39,40
Y	US, A, 4,353,064 (STAMM) 05 OCTOBER 1982; See Abstracts, col. 2, lines 45-65, col. 4, lines 25-51.	1-2,15,21,22 24-26,28-32, 39,40



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	*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
A document defining the general state of the art which is not considered to be part of particular relevance	*X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
E earlier document published on or after the international filing date	*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
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)	*&* document member of the same patent family
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	

Date of the actual completion of the international search

13 DECEMBER 1992

Date of mailing of the international search report

14 JAN 1993

Name and mailing address of the ISA/US
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INTERNATIONAL DIVISION

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/08524

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,243,846 (LENEARTS ET AL) 06 JANUARY 1981; See Abstract, col. 1, lines 10-33; col. 2, lines 22-38; col. 3, lines 33-53.	1-2,15,21, 22-24-26, 28-32,39,40
Y	US, A, 4,334,542 (TAKINISHI ET AL) 15 JUNE 1982; See Abstract col. 1, lines 61 - col. 2, line 61.	3-4
Y	US, A, 4,263,485 (CORWIN) 21 APRIL 1981; See Abstract, col. 2, line 47 - col. 3, line 53	5-12
Y	US, A, 4,616,213 (DANISH) 07 OCTOBER 1986; See Abstract, col. 7, lines 55-65.	8-12
Y	US, A, 4,539,699 (KATZ ET AL) 08 SEPTEMBER 1985; See Abstract, col. 3, lines 23-68; col. 4, lines 30-49.	39, 40
A	US, A, 4,629,424 (LAUKS ET AL) 16 DECEMBER 1986; See Abstract, col. 5, lines 1-3; col. 6, lines 33-41.	1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US92/08524

B. FIELDS SEARCHED

Minimum documentation searched

Classification System: U.S.

340/825, 190. 825.56, 825.64, 825.69, 825.72, 407; 341/21, 22, 176; 400/87; 434/112, 113; 128/774, 777; 455/41, 100; 200/DIG. 2, 513; 381/70