

**United States
Murata**

[15] 3,682,160

[45] Aug. 8, 1972

[54] **PHYSIOLOGICAL SIGNAL
TRANSMITTER FOR USE INSIDE THE
BODY**

[72] Inventor: **Norio Murata**, Hirakata-shi, Japan

[73] Assignee: **Matsushita Electric Industrial G.
Ltd.**, Kadoma, Osaka, Japan

[22] Filed: **Oct. 16, 1969**

[21] Appl. No.: **866,818**

[52] U.S. Cl. 128/2 P, 331/66, 331/173,
340/248

[51] Int. Cl. A61f 5/00

[58] Field of Search 128/2 R, 2.1 A, 2.1 P, 2.06 R,
128/419 R, 419 P, 2.1 R; 204/195; 325/118;
340/248 P, 253 P; 331/65, 66, 173

[56] **References Cited**

UNITED STATES PATENTS

3,218,638 11/1965 Honig.....128/2.1 P
3,231,834 1/1966 Watanabe 128/2.1 P

OTHER PUBLICATIONS

Mackay et al. "Nature," Vol. 179, June 15, 1957 pp.

1,239-1,240

Nagumo et al. "IRE Transactions on Bio-Medical
Electronics" Vol. BME-9, July, 1962, pp. 195-199

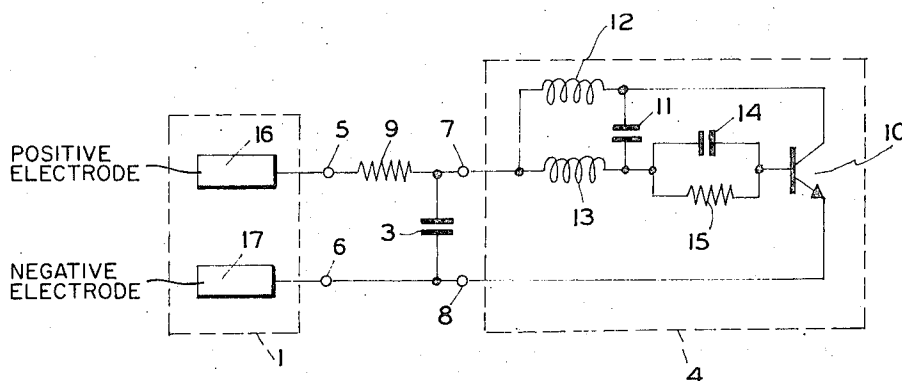
Primary Examiner—William E. Kamm

Attorney—Wenderoth, Lind & Ponack

[57] **ABSTRACT**

A miniature medical transmitter detects a physiological variable in a human body and transmits a signal to a receiver placed at the outside of a human body, more particularly to an orally swallowable miniature transmitter for measuring pH value or any other variable in a gastro-intestinal tract. The transmitter comprises detecting means for generating a voltage relating to a physiological variable in a human body, limiting network means, a storing capacitor and oscillator means, and its operation is based on an arrangement wherein the voltage from the detecting means activates the oscillator means and, at the same time, modulates the oscillator means. Accordingly, the transmitter does not require conventional power supply means such as battery means and external energy sender means placed outside the body.

17 Claims, 17 Drawing Figures



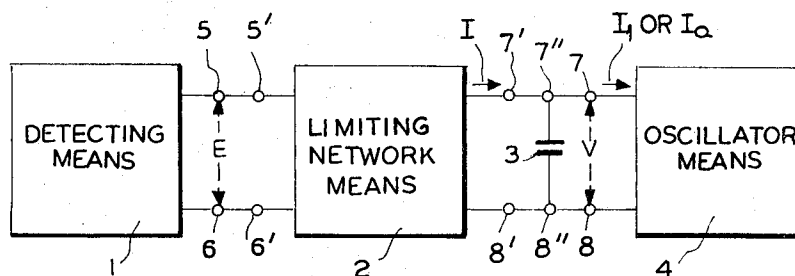


FIG. 1

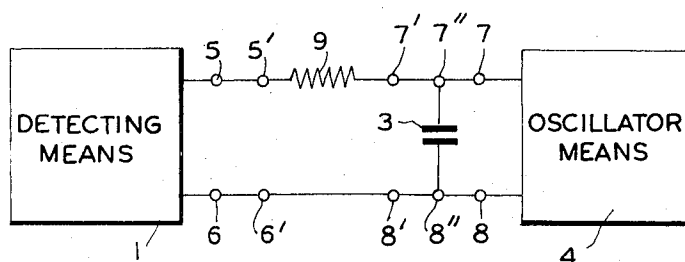


FIG. 2

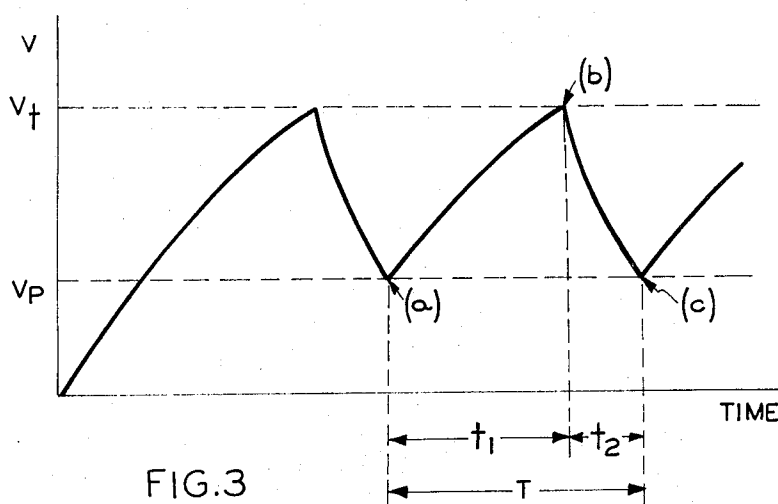


FIG. 3

INVENTOR
NORIO MURATA

BY *Wendroth, Lund & Ponack*
ATTORNEYS

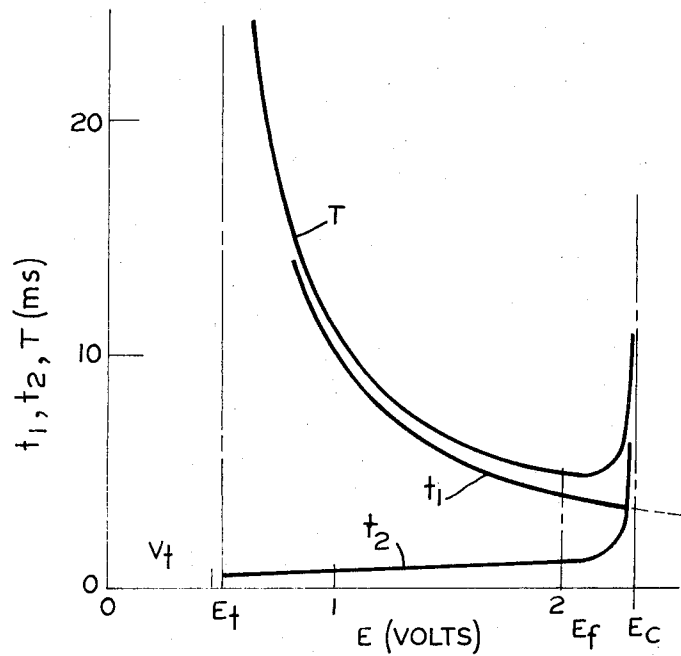


FIG.4

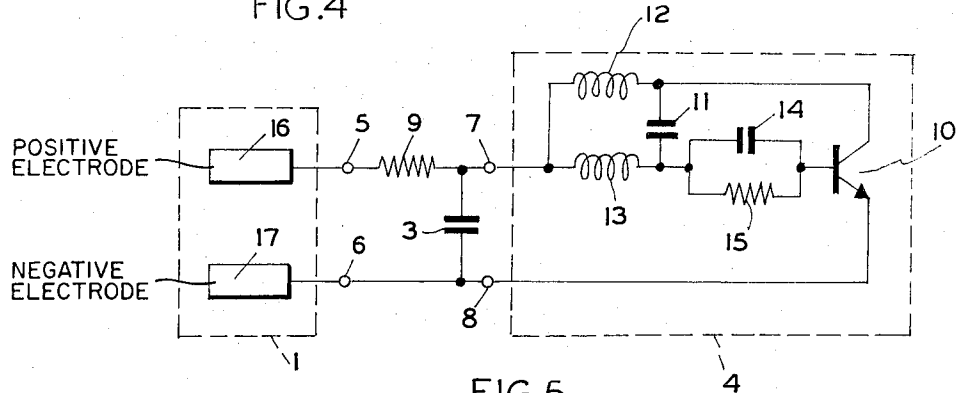


FIG.5

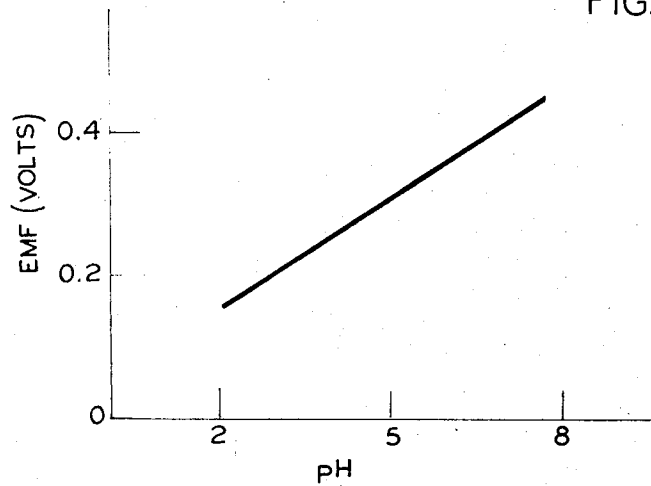


FIG.7

INVENTOR
NORIO MURATA

BY *Wendroth, Lund & Tonack*
ATTORNEYS

FIG. 6a

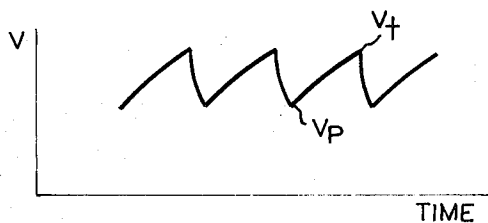


FIG. 6b

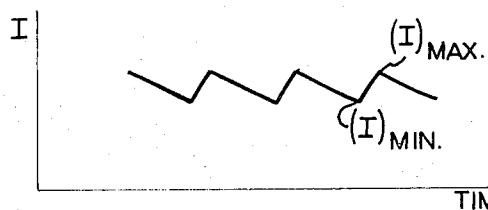


FIG. 6c

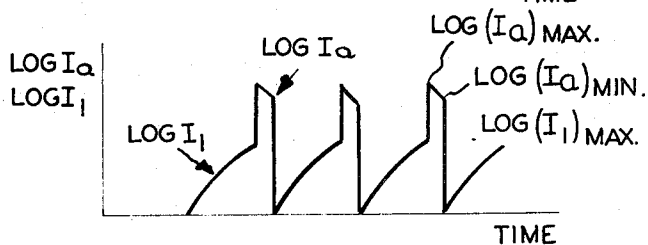


FIG. 6d

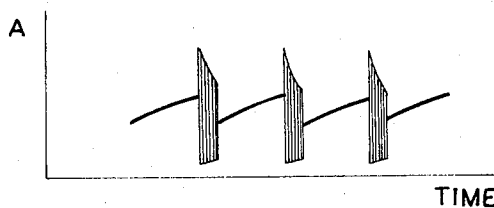
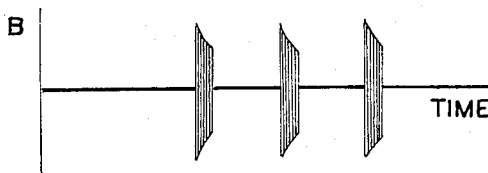


FIG. 6e



INVENTOR
NORIO MURATA

BY *Wendroth, Lind & Ponack*
ATTORNEYS

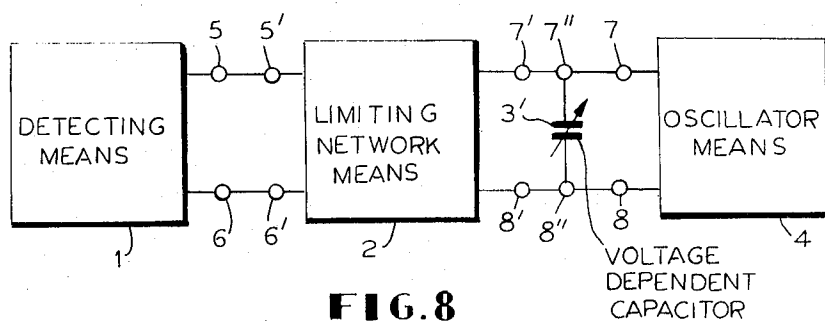


FIG. 8

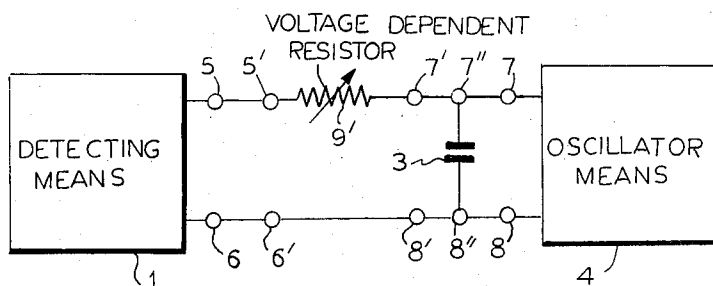


FIG. 9

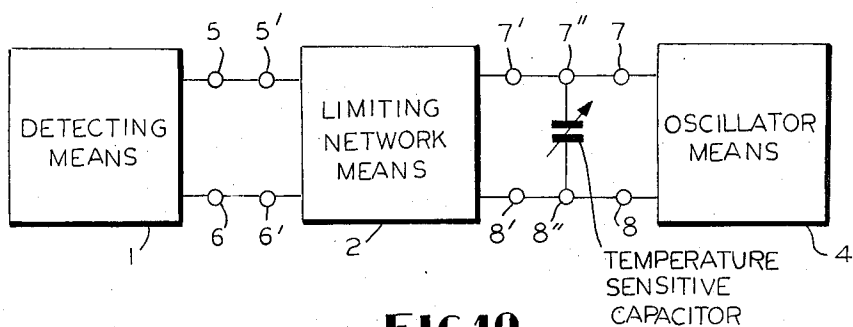


FIG. 10

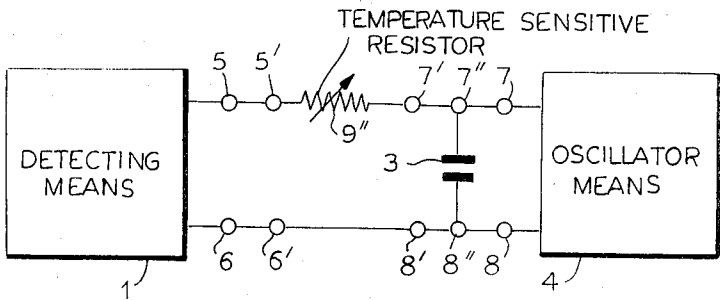


FIG. 11

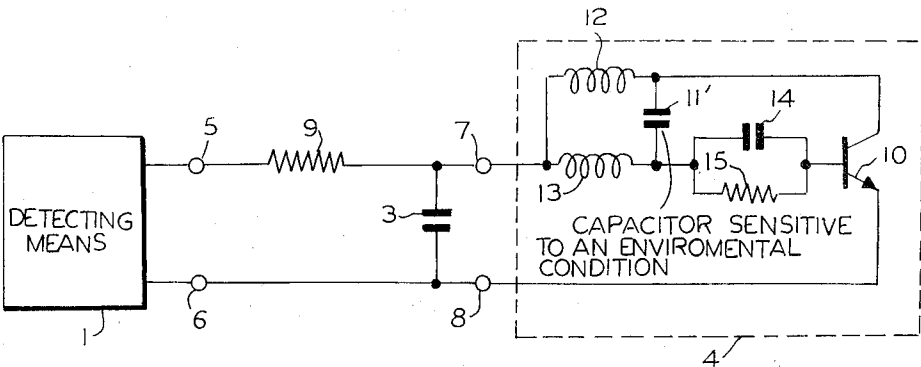


FIG. 12

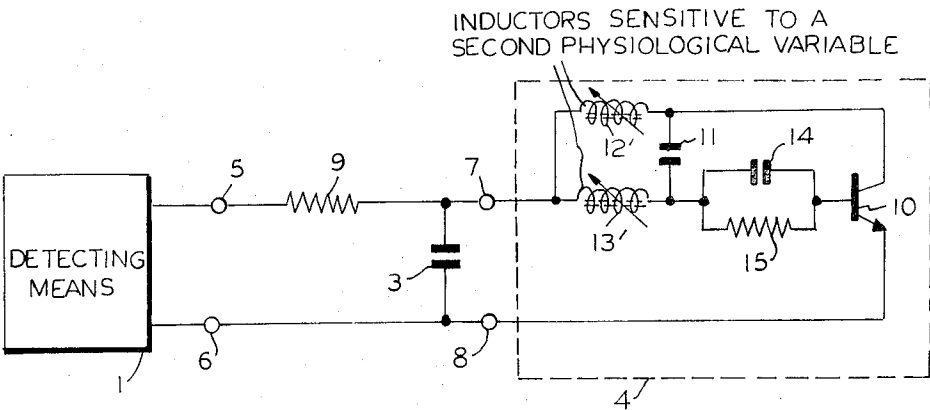


FIG. 13

PHYSIOLOGICAL SIGNAL TRANSMITTER FOR USE INSIDE THE BODY

BACKGROUND OF THE INVENTION

This invention relates to a miniature medical transmitter for detecting a physiological variable in a human body and for transmitting a signal to a receiver placed at the outside of a human body, more particularly to an orally swallowable miniature transmitter for measuring pH value or any other variable in a gastro-intestinal tract.

The physiological variables in human body such as pH value and pressure in the stomach have been heretofore measured by using a stomach tube which is swallowed by patients. Besides being painful, the stomach tube makes it difficult to measure the pH value or pressure in the intestine. Recently, such disadvantages have been successfully improved by using radio telemetering capsules. They have provided useful information for research in the medical field. For instance, a broad review on these devices can be obtained by the following literatures.

1. Mackay: Radiotelemetering from within the Human Body.

IRE Transactions on Medical Electronics, Vol. ME-6, No. 2, pp. 100-105, June 1959.

2. Nagumo et al.: Echo Capsule for Medical Use (A Batteryless Endoradiosonde).

IRE Transactions on Bio-Medical Electronics, Vol. BME-9, No. 3, pp. 195-199, July 1962.

3. U.S. Pat. No. 3,133,537, Muth, May 19, 1964

The conventional devices for measuring a physiological variable in a human body wirelessly are activated by a battery or the like included therein or by energy supplied from the outside wirelessly. The use of battery or the like is apt to make the device larger and more complicated. A device activated by energy supplied from the outside needs an external energy sender and is usually operated in a shielded room for the operation.

Accordingly, it is an object of the invention to provide a medical transmitter which is capable of measuring a physiological variable of a human body without using a conventional battery or the like as an integral part of the medical transmitter.

It is another object of the invention to provide a medical transmitter which is capable of measuring a physiological variable of a human body without using an external energy sender placed outside the body in order to activate the medical transmitter.

These and other objects of this invention will be apparent upon consideration of following detailed description taken in conjunction with the accompanying drawings, wherein:

FIG. 1 is a block diagram illustrative of the medical transmitter for measuring a physiological variable in a human body in accordance with the present invention,

FIG. 2 is an embodiment of the medical transmitter according to FIG. 1,

FIG. 3 is a voltage waveform in the medical transmitter according to FIG. 2,

FIG. 4 is a graph showing the relationship between a voltage due to a physiological variable and various time intervals produced by the medical transmitter according to FIG. 2,

FIG. 5 is one embodiment of a preferable circuit diagram of the medical transmitter according to the present invention,

FIG. 6 is a series of waveforms generated by the medical transmitter of FIG. 5,

FIG. 7 is a graph showing the relationship between pH and electromotiveforce (EMF) of an antimony electrode with reference to a saturated calomel electrode, and FIGS. 8-13 illustrate modified embodiments of the medical transmitter according to the present invention.

A medical transmitter according to the present invention comprises detecting means for generating a voltage relating to a physiological variable in a human body, limiting network means, a storing capacitor and oscillator means, and its operation is based on the novel arrangement wherein the voltage from the detecting means activates the oscillator means and, at the same time, modulates the oscillator means.

Referring now to FIG. 1, the medical transmitter adapted for transmission of an electric signal corresponding to a physiological variable in a human body, in accordance with the present invention, comprises detecting means 1 having two detecting terminals 5 and 6 provided with detected voltage E relating to the physiological variable; limiting network means 2 which has two input terminals 5' and 6' connected with the two detecting terminals 5 and 6 and which has two output terminals 7' and 8' provided with a limiting current, I therefrom; a storing capacitor 3 of a capacitance, C₀, which is connected at two terminals 7'' and 8'', with the two output terminals 7' and 8'; and oscillator means 4 which has two energizing terminals 7 and 8 connected with the two terminals 7'' and 8'' of the storing capacitor 3 and which contains no battery or the like. The oscillator means 4 starts to generate an oscillation in an oscillation frequency, f, when a voltage between the two energizing terminals 7 and 8 rises up to a starting voltage V_s; and the oscillator means 4 stops the oscillation when the voltage between the two energizing terminals 7 and 8 falls down to a stopping voltage, V_p. The oscillator means 4 has a leakage current I₁ to flow therethrough upon the cease of the oscillation and an actuating current I_a to flow therethrough during the oscillation, whereby the following relation holds:

$$0 < (I_1)_{\max} < (I)_{\min} < (I)_{\max} - (I_a)_{\min} < (I_a)_{\max} < C_0 \cdot f \cdot (V_s - V_p) \quad (1)$$

where (I₁)_{max} is a maximum value of the leakage current I₁, (I)_{min} and (I)_{max} are a minimum value and a maximum value of the limiting current I, respectively, and (I_a)_{min} and (I_a)_{max} are a minimum value and a maximum value of the actuating current I_a, respectively.

For convenience, the voltage between the two energizing terminals 7 and 8 will be defined as an energizing voltage, V. It is necessary that the limiting network means 2 be a passive four terminal network containing no battery or the like. Generally, the limiting current I, the leakage current I₁ and the actuating current I_a are defined as variables with time as explained hereinafter.

An oscillator means 4 satisfying the following conditions

$$(I_1)_{max} < (I_a)_{min} \quad (2)$$

$$V_t > V_p \quad (3)$$

can accomplish a medical transmitter satisfying the relation (1) by controlling the detected voltage E and the limiting network means 2. The medical transmitter satisfying the relation (1) always operates in an intermittent oscillation. When the oscillator means 4 supplied with an energizing voltage V lower than the starting voltage V_t is not oscillating, a limiting current I is larger than a leakage current I_1 . Accordingly, the storing capacitor 3 continues to be charged by a current due to a difference between a limiting current I and a leakage current I_1 until an energizing voltage V rises up to the starting voltage V_t and then an oscillation takes place in the oscillator means 4.

When the oscillator means 4 supplied with an energizing voltage V higher than the stopping voltage V_p is oscillating, an actuating current I_a is larger than a limiting current I . Accordingly, the storing capacitor 3 continues to discharge a charge stored in the storing capacitor 3 at a current due to a difference between an actuating current I_a and a limiting current I until an energizing voltage V falls down to the stopping voltage V_p , and then the oscillation ceases.

The relation, $(I_a)_{max} < C_o \cdot f(V_t - V_p)$, which is derived from the relation (1) makes it possible for the oscillator means 4 to repeat many cycles of the oscillation having oscillation frequency f during a time interval when the oscillator means 4 is oscillating. Therefore, the medical transmitter according to the present invention always operates in an intermittent oscillation.

For convenience, a time interval when the oscillator means 4 is not in oscillation and a time interval when the oscillator means 4 is oscillating will be defined as a non-oscillating period t_1 and an oscillating period t_2 , respectively. A time interval which is the sum of the non-oscillating period t_1 and the oscillating period t_2 will be defined as an intermittent oscillation period, T .

A non-oscillating period t_1 and an oscillating period t_2 are a function of the limiting current I which is a function of the detected voltage E . Therefore, the intermittent oscillation period T of the medical transmitter is also clearly a function of the detected voltage E . Accordingly, the medical transmitter according to the present invention transmits an electric signal corresponding to a physiological variable in a human body.

In order to transmit an electric signal corresponding exactly to a physiological variable, the intermittent oscillation period T of the medical transmitter is required to be much shorter than a time interval corresponding to one cycle of the highest frequency in a physiological variable. The use of an oscillation frequency f of medium frequency or more can easily satisfy this requirement, because the highest frequency of a physiological variable is usually not more than about 100Hz.

Referring to FIG. 2, in which the limiting network means 2 consists of a limiting resistor 9 having resistance R_o , the relation (1) is reduced to

$$V_t + (I_1)_{max} \cdot R_o < E < V_p + (I_a)_{min} \cdot R_o \quad (4)$$

$$0 < (I_a)_{max} < C_o \cdot f(V_t - V_p) \quad (5)$$

and the relation (2) is reduced to

$$(I_a)_{min} >> (I_1)_{max} + (V_t - V_p)/R_o \quad (6)$$

In the medical transmitter satisfying the above relations (4) and (5), an energizing voltage V has, for example, a waveform as shown in FIG. 3. In this figure, a time interval (a) to (b) is the non-oscillating period t_1 , a time interval (b) to (c) is the oscillating period t_2 , a time interval (a) to (c) is the intermittent oscillation period T .

Referring to FIG. 4, the non-oscillating period t_1 is infinite at a critical voltage E_t higher than the starting voltage V_t . When the leakage current I_1 increases with an increase in the energizing voltage V , the critical voltage E_t is equal to

$$E_t = V_t + (I_1)_{max} \cdot R_o$$

When $E > E_t$, the higher detected voltage E results in the higher limiting current I and accordingly, in the shorter non-oscillating period t_1 . The oscillating period t_2 is infinite at a voltage, which will be defined as transition voltage E_c . When the actuating current I_a decreases with a decrease in the energizing voltage V , the transition voltage E_c is equal to

$$E_c = V_p + (I_a)_{min} \cdot R_o$$

When $E < E_c$, the lower detected voltage E results in the lower limiting current I and accordingly, in the shorter oscillating period t_2 . Finally, the oscillating period t_2 tends to a finite value when the detected voltage E tends to the critical voltage E_t .

As a result, the intermittent oscillation period T is infinite when the detected voltage E is equal to the critical voltage E_t or to the transition voltage E_c . Referring again to FIG. 4, the intermittent oscillation period T is insensitive to a slight change in the detected voltage E at a turnover voltage E_f , near which a decrement in the t_1 caused by a slight increase in the E is equal to an increment in the t_2 caused by the slight increase in the E . When a detected voltage E is within the range,

$$E_t < E < E_f \quad (7)$$

the intermittent oscillation period T becomes shorter as the detected voltage E increases. When a detected voltage E is within the range,

$$E_f < E < E_c \quad (8)$$

the intermittent oscillation period T becomes longer as the detected voltage E increases. For $E > E_c$, the oscillator means 4 ceases the intermittent oscillation and sustains a continuous oscillation. For $E < E_t$, no oscillation occurs. Both ranges as specified by (7) and (8) make it possible to transmit an electric signal corresponding to a physiological variable.

It has been discovered according to the invention that the use of the former range, i.e. $E_t < E < E_f$ results in better stability of the intermittent oscillation period T of the medical transmitter than that of the latter range, i.e. $E_f < E < E_c$ when the following relations hold:

$$V_t > (I_1)_{max} \cdot R_o \quad (8)'$$

$$(I_a)_{min} > 10 (I_1)_{max} \quad (8)''$$

A medical transmitter explained with reference to FIG. 1 is satisfactorily accomplished by using any available and suitable transistor tuned oscillator satisfying the relations (2) and (3). When the transistor tuned oscillator is employed for the medical transmitter hav-

ing a diagram shown by FIG. 2, an arrangement for $E_f = 0.5$ volts and $E_r = 2.0$ volts satisfies a combination of a higher stability of the T and a wider measurable range, and makes it possible to measure stably a detected voltage E satisfying the following relation in accordance with the present invention.

$$0.5 \text{ volts} < E < 2.0 \text{ volts} \quad (9)$$

Referring to FIG. 5, wherein similar references designate the components similar to those of FIG. 1 and FIG. 2, a detecting means 1 comprises a positive electrode 16 and a negative electrode 17, and satisfies the relation (9). The detecting means 1 is connected, at the detecting terminals 5 and 6, to a transistor tuned oscillator 4 through the limiting resistor 9 and the storing capacitor 3. The storing capacitor 3 is connected between the two energizing terminals 7 and 8. The limiting resistor 9 is connected between the detecting terminal 5 and the energizing terminal 7.

The transistor tuned oscillator 4 is a transistor Hartley oscillator which will oscillate, if a battery is connected to the two energizing terminals 7 and 8, and it consists of an NPN transistor 10, a tuning capacitor 11 having capacitance C , tuning inductors 12 and 13 having self-inductances L_1 and L_2 , respectively, a feedback capacitor 14 having capacitance C_b and a base biasing resistor 15 having resistance R_b . The tuning capacitor 11 and the tuning inductors 12 and 13 act as a tuning circuit which determines the oscillation frequency f of the transistor tuned oscillator 4.

In order to make it possible to satisfy the relation (8)' and (3), an inductance ratio L_2/L_1 is designed to be at least 1, which is larger than the ratio appearing in a conventional transistor Hartley oscillator.

While the transistor tuned oscillator 4 is not in oscillation, a small dc current corresponding to the leakage current I_l which relates to a static characteristic of the transistor 10 flows mainly into a collector of the transistor 10 through the inductor 12, and partly into a base of the transistor 10 through the inductor 13 and the base biasing resistor 15. The storing capacitor 3 can be charged up so that an energizing voltage V gradually rises up, because the resistance R_0 of the limiting resistor 9 is determined to enable supplying a limiting current I much larger than the leakage current I_l . With the rise of the energizing voltage, the leakage current I_l may increase, and an amplification factor of the transistor 10 may also increase.

When the energizing voltage V reaches the starting voltage V_t , the amplification factor of the transistor 10 grows so large that the transistor tuned oscillator 4 is made to oscillate. When once the oscillation occurs, a dc current component flowing to the transistor 10 turns into the actuating current I_a and is much larger than the leakage current I_l , because of a non-linearity of an emitter-base characteristic of the transistor 10. Then a charge stored in the storing capacitor 3 is discharged through the transistor tuned oscillator 4, because the resistance R_0 of the limiting resistor 9 is determined to supply a limiting current I much smaller than the actuating current I_a . The energizing voltage V gradually lowers while the actuating current I_a is decreasing.

When the energizing voltage V falls down to the stopping voltage V_p , the amplification factor becomes so small that the transistor tuned oscillator 4 is unable

to sustain the oscillation. Thus the transistor tuned oscillator 4 stops the oscillation and turns into the initial state where only a slight current corresponding to the leakage current I_l flows into the transistor tuned oscillator 4.

With such a process the medical transmitter of FIG. 5 generates the intermittent oscillation.

The operation of the medical transmitter of FIG. 5 will be more apparent by referring to FIG. 6. The energizing voltage V fluctuates between V_t and V_p as shown in FIG. 6 (a), and the limiting current I fluctuates between $(I)_{min}$ and $(I)_{max}$ as shown in FIG. 6 (b). The current flowing to the transistor tuned oscillator 4 changes over a wide range and its waveform has two jumps at the beginning and the end oscillation as shown in FIG. 6 (c), where the ordinate is scaled in logarithm. A voltage A between the collector and the emitter of the transistor 10 changes as shown in FIG. 6 (d), and a voltage B across the tuning capacitor 11 changes as shown in FIG. 6 (e).

As an example, a medical transmitter having E_t of 0.5 volts and E_r of 2.0 volts can be formed by using components listed in Table 1 and its main performance indices actually measured are shown in Table 2. The t_1 , t_2 and T versus the E relations of the medical transmitter are shown in FIG. 4.

It should be understood that a transistor tuned oscillator defined herein is not limited to the Hartley oscillator, but any other transistor tuned oscillator such as a Colpitts or other tuned-collector oscillator is essentially satisfactory.

The transistor tuned oscillator 4 shown in FIG. 5 has a tuning capacitor 11 intentionally inserted therein. However, it is also possible to utilize a tuning circuit having no tuning capacitor inserted therein. For example, one may use a tuning circuit consisting of the tuning inductors 12 and 13, a stray capacitance in the tuning inductors 12 and 13 and others, and an electrode to electrode capacitance of the transistor 10.

TABLE 1

limiting resistor, 9	(R_0)	100	k Ω
storing capacitor, 3	(C_0)	0.22	μ F
transistor, 10		2SC829	
tuning capacitor, 11	(C)	2	pF
inductance ratio	(L_2/L_1)	16	
Q value of the tuning coil		90	
feedback capacitor, 14	(C_b)	560	pF
base biasing resistor, 15	(R_b)	50	k Ω
oscillation frequency	(f)	2	MHz

TABLE 2

starting voltage,	V_t	0.467	V
stopping voltage,	V_p	0.194	V
maximum value of the leakage current,	$(I_l)_{max}$	0.3	μ A
minimum value of the actuating current,	$(I_a)_{min}$	22	μ A
maximum value of the actuating current,	$(I_a)_{max}$	480	μ A
critical voltage,	E_t	0.499	V
transition voltage,	E_c	2.35	V
turnover voltage,	E_f	2.08	V

The employment of a pH sensor of the aforesaid detecting means 1 in any of FIGS. 1, 2 and 5 achieves a medical transmitter adapted for transmission of an electrical signal corresponding to a pH value in a gastro-intestinal tract. When the transmitter explained

with reference to FIG. 5 is used for measurement of the pH value, the pH sensor for use in the detecting means 1 is preferably provided with a detected voltage within a range between 0.5 and 2.0 volts.

The pH sensor usually comprises two electrodes, i.e. one is a pH sensitive electrode and the other is a reference electrode as is well-known. The operable pH sensor as the detecting means 1 shown in FIG. 5 comprises, as a pH sensitive electrode, a member selected from the group consisting of an antimony electrode, a molybdenum electrode, a tungsten electrode, a germanium electrode and a silicon electrode, and as a reference electrode, a member selected from the group consisting of a zinc electrode, a manganese electrode, a mangesium electrode, and a zinc-magnesium alloy electrode. The medical transmitter using this pH sensor has a rather high sensitivity for high pH values and therefore is suitable for measurement of the pH value in intestines.

On the other hand, a pH sensor suitable for measurement in the stomach comprises, as a pH sensitive electrode, a member selected from the group consisting of an antimony electrode, a molybdenum electrode, a tungsten electrode, a germanium electrode and a silicon electrode, and as a reference electrode, a member selected from the group consisting of a vanadium pentoxide electrode, a nickel sesquioxide electrode, a manganese dioxide electrode and a lead dioxide electrode. The medical transmitter using such a pH sensor is characterized by a rather high sensitivity for low pH values.

Among those operable pH sensors, a combination of an antimony electrode and a zinc electrode has the most stable relation between the pH value and the detected voltage.

Referring to FIG. 7, an antimony electrode generates an electromotive force of about -0.15 volts and of about -0.45 volts in a solution having pH2 and a solution having pH8, respectively. The electromotive force referred to herein is measured as a reference to that of a saturated caromel electrode. The electromotive force of the antimony electrode varies by about 0.05 volts per unit pH in the range of pH2 to pH8 which covers pH values in the gastro-intestinal tract.

On the other hand, the electromotive force of the zinc electrode shows little change with pH and is about -1.1 volts in the range of pH2 to pH8.

Accordingly, a pH sensor consisting of the antimony electrode and the zinc electrode generates detected voltages E of 0.95 volts and 0.65 volts at pH2 and pH8, respectively. The detected voltage E varies by about 0.05 volts per unit pH in the pH range to 2 to 8.

A reference electrode consisting of an element selected from the group of a zinc electrode, a magnesium electrode, a manganese electrode and a zinc-magnesium alloy electrode has a negative voltage with respect to the pH sensitive electrode mentioned above. Therefore, a reference electrode consisting of such a metal electrode should be connected to the terminal 6 when the transistor 10 is NPN type, and should be connected to the terminal 5 when the transistor 10 is PNP type.

On the contrary, a reference electrode consisting of an element selected from the group of a vanadium pentoxide electrode, a nickel sesquioxide electrode, a man-

ganesse dioxide electrode and a lead dioxide electrode has a positive voltage with respect to the pH sensitive electrode mentioned above. Therefore, a reference electrode consisting of such a metal oxide electrode should be connected to the terminal 5 when the transistor 10 is NPN type, and should be connected to the terminal 6 when the transistor 10 is PNP type.

The electric signal from the medical transmitter is picked up by an antenna and is amplified by a conventional high frequency amplifier. The amplified signal is then, for instance, converted to an analog voltage corresponding to the intermittent oscillation period T and finally is indicated on a meter or recorded on a chart. As a result, a physiological variable in a human body can be measured wirelessly.

In general, the storing capacitor 3 can employ any element adapted to store an electric charge. Thus, for example, a voltage dependent capacitor as well as a voltage independent capacitor can also be utilized for the storing capacitor 3. Referring to FIG. 8, the storing capacitor is a voltage dependent capacitor 3', and the voltage dependent capacitor can improve linearity in the charging characteristic. Accordingly, stability of the intermittent oscillation period T can be improved, especially the stability at a region of the detected voltage E near the critical voltage E_c .

The limiting network means 2 can also comprise voltage dependent elements. Referring to FIG. 9, the limiting network means is a voltage dependent resistor 9', and the use of the voltage dependent resistor makes it possible to control a relationship between a physiological variable and an intermittent oscillation period T .

An undesirable temperature dependence of the intermittent oscillation period T , if it exists, can be compensated by use of a storing capacitor comprising a temperature sensitive capacitor and/or by use of limiting network means comprising temperature sensitive elements. Referring to FIG. 10, the storing capacitor comprises a temperature sensitive capacitor 3'' capable of compensating a temperature dependence of the intermittent oscillation period of the medical transmitter. Referring to FIG. 11, the limiting network means comprises a temperature sensitive resistor 9'' capable of compensating a temperature dependence of the intermittent oscillation period of the medical transmitter. In the medical transmitter as specified by Table 1, for example, the intermittent oscillation period T is shortened by a temperature rise due to a change of transistor characteristics. This shift of the intermittent oscillation period T can be reduced to a negligibly small value by use of a storing capacitor or a limiting resistor characterized by a temperature coefficient of about $+10,000$ ppm/ $^{\circ}\text{C}$.

When the detecting means 1 has a considerable internal resistance, the internal resistance should be taken into account in the design of the limiting network means.

The medical transmitter according to the present invention can transmit another electric signal in addition to the signal resulted from the detecting means. Referring to FIG. 12, the transistor tuned oscillator 4 has a tuning capacitor 11' having a variable capacitance sensitive to an environmental condition surrounding the medical transmitter, so that the oscillation frequency

varies with the environmental condition. As a result, two kinds of physiological variables may be simultaneously transmitted as the functions of the intermittent oscillation period T and the oscillation frequency f .

When the tuning capacitor 11' of FIG. 12 is a temperature sensitive capacitor, the oscillation frequency f changes proportionally with a temperature change of the environment around the medical transmitter. Thus, the medical transmitter can transmit the electric signal concerning the temperature as well as the signal resulted from the detecting means.

Referring to FIG. 13, the transistor turned oscillator 4 has a tuning inductor 12' and/or 13' having a variable inductance sensitive to a second physiological variable, so that the oscillation frequency f varies as a function of the second physiological variable.

In the medical transmitter as shown in FIG. 13, use of the tuning inductors 12' and 13' having a movable magnetic core with a pressure in the environment surrounding the medical transmitter, causes the inductances of the tuning inductors 12' and 13' to change with the pressure which is a second physiological variable. Thus, the oscillation frequency f changes in accordance with the pressure change.

It is readily apparent that a medical transmitter according to the present invention can measure a physiological variable of a human body without using a battery or the like and an external energy sender.

While certain representative embodiments and details have been shown by the purpose of illustrating the invention, it will be apparent to those skilled in the art that various changes and modifications may be made therein without departing from the spirit or scope of invention.

What is claimed is:

1. A medical transmitter adapted for transmission of an electric signal corresponding to a physiological variable in a human body, which comprises detecting means having two detecting terminals provided with a detected voltage E relating to said physiological variable; limiting network means which has two input terminals connected with said two detecting terminals and which has two output terminals provided with a limiting current I therefrom; a storing capacitor of a capacitance, C_0 , which is connected with said two output terminals; and oscillator means which has two energizing terminals connected with two terminals of said storing capacitor and energizable by an electric charge stored in said storing capacitor which functions as a power source for said oscillator means, said oscillator means for starting oscillation in an oscillation frequency f when a voltage between said two energizing terminals rises up to a starting voltage V_i and for stopping said oscillation when said voltage between said two energizing terminals falls down to a stopping voltage V_p , and said oscillator means having a leakage current I_1 adapted to flow therethrough upon the cessation of said oscillation and an actuating current I_a to flow therethrough during oscillation, said oscillating means having the following operating characteristic:

$$0 < (I_1)_{max} < (I)_{min} < (I)_{max} < (I_a) < (I_a)_{max} < C_0 \cdot f(V_{ia} - V_p)$$

where $(I_1)_{max}$ is a maximum value of said leakage current I_1 , $(I)_{min}$ and $(I)_{max}$ are a minimum value and a

maximum value of said limiting current I , respectively, and $(I_a)_{min}$ and $(I_a)_{max}$ are a minimum value and a maximum value of said actuating current I_a , respectively; whereby said oscillator means is intermittently oscillating with an intermittent oscillation period which is variable with a change in said detected voltage.

2. A medical transmitter defined by claim 23, wherein said limiting network means comprises a limiting resistor having resistance R_0 .

3. A medical transmitter defined by claim 2, wherein said oscillator means comprises a transistor tuned oscillator.

4. A medical transmitter defined by claim 3, wherein said detecting means comprises a pH sensor.

5. A medical transmitter defined by claim 4, wherein said pH sensor has a pH sensitive electrode comprising an antimony electrode, and a reference electrode comprising a zinc electrode.

6. A medical transmitter defined by claim 4, wherein said pH sensor has a pH sensitive electrode comprising an antimony electrode, and a reference electrode comprising a manganese electrode.

7. A medical transmitter as claimed in claim 4, wherein said pH sensor has a pH sensitive electrode comprising an antimony electrode, and a reference electrode comprising a magnesium-zinc alloy electrode.

8. A medical transmitter as claimed in claim 4, wherein said pH sensor has a pH sensitive electrode comprising an antimony electrode, and a reference electrode comprising a manganese dioxide electrode.

9. A medical transmitter as claimed in claim 4, wherein said pH sensor has a pH sensitive electrode comprising an antimony electrode and a reference electrode comprising a vanadium pentoxide electrode.

10. A medical transmitter defined by claim 3, wherein said transistor tuned oscillator has a tuning capacitor having a variable capacitance sensitive to an environmental condition surrounding said medical transmitter.

11. A medical transmitter defined by claim 10, wherein said tuning capacitor is a temperature sensitive capacitor.

12. A medical transmitter defined by claim 3, wherein said transistor tuned oscillator has a tuning inductor, an inductance of which is variable depending upon a second physiological.

13. A medical transmitter defined by claim 12, wherein said second physiological variable is pressure and said tuning inductor has a magnetic core movable with a change in said pressure.

14. A medical transmitter defined by claim 1, wherein said storing capacitor is a voltage dependent capacitor.

15. A medical transmitter defined by claim 1, wherein said limiting network means comprises voltage dependent elements.

16. A medical transmitter defined by claim 1, wherein said storing capacitor consists essentially of a temperature sensitive capacitor capable of compensating a temperature dependence of said intermittent oscillation period of said medical transmitter.

17. A medical transmitter defined by claim 1, wherein said limiting network means comprises temperature sensitive elements capable of compensating a

temperature dependence of said intermittent oscillation period of said medical transmitter.

* * * * *

5

10

15

20

25

30

35

40

45

50

55

60

65