May 4, 1965 W. B. M. CLARK ETAL 3,182,129

ELECTRONIC STETHOSCOPE

Filed Nov. 1, 1962 3 Sheets-Sheet 1

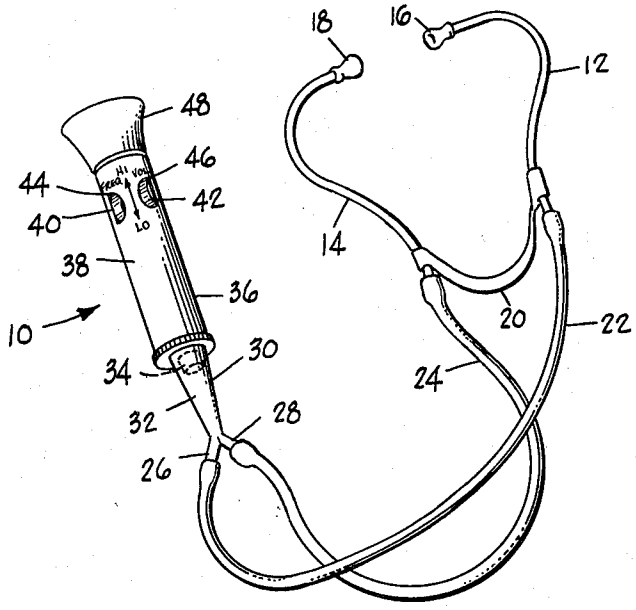


Fig. 1

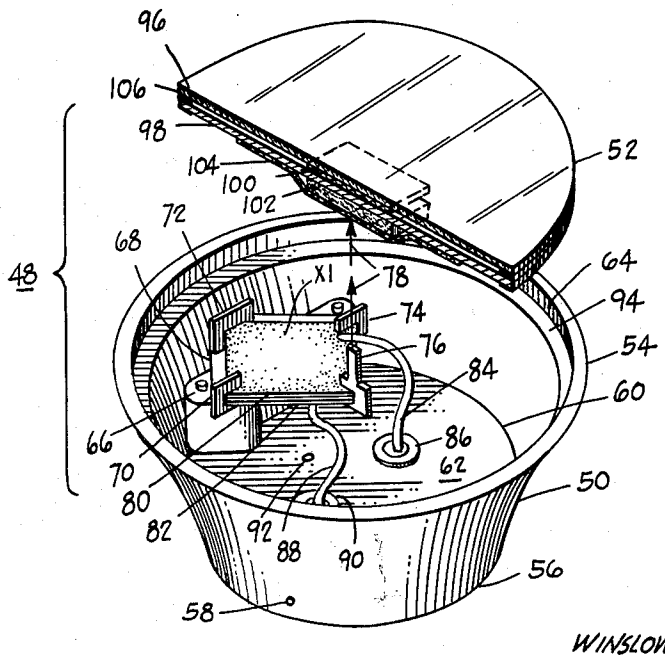


Fig. 2

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Filed Nov. 1, 1962 3 Sheets-Sheet 2

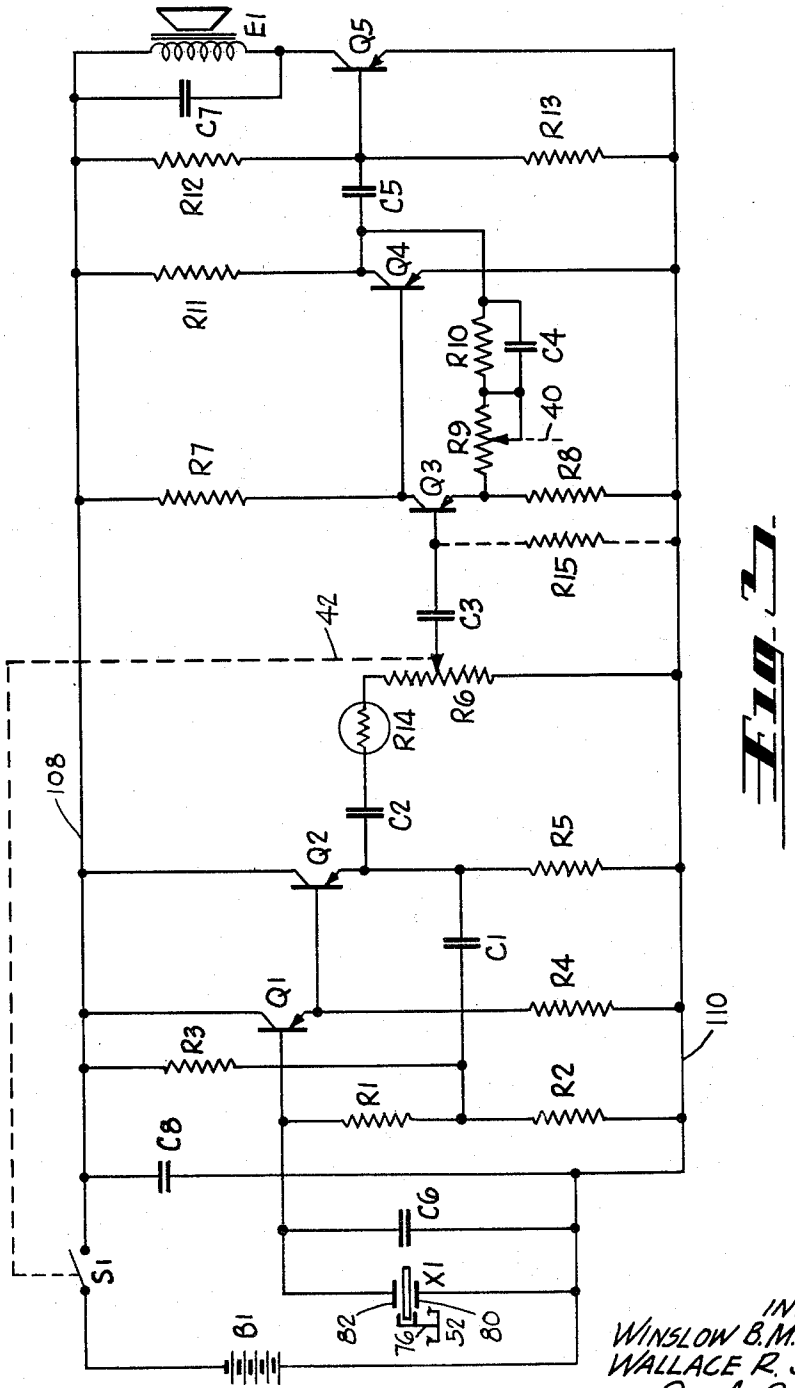


FIG. 1

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ELECTRONIC STETHOSCOPE

Filed Nov. 1, 1962 3 Sheets-Sheet 3

Fig. 4

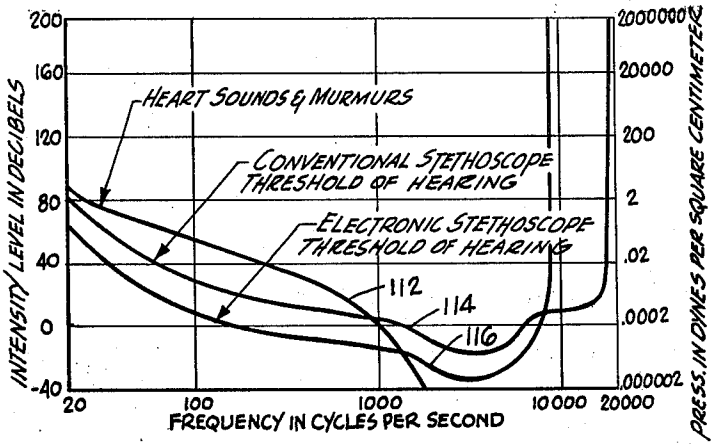
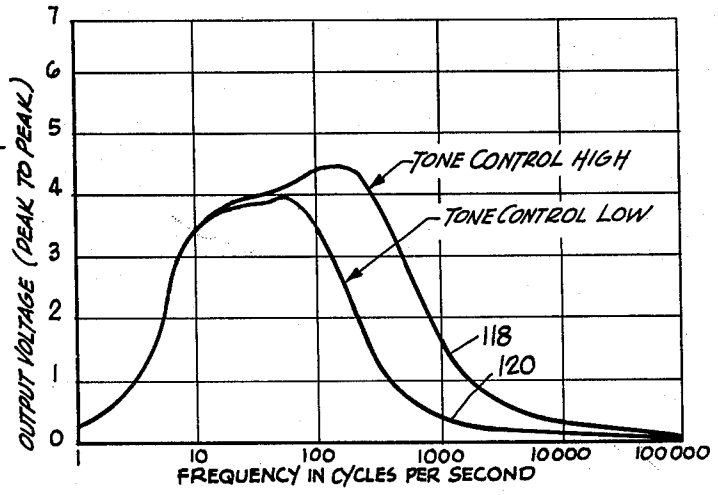


Fig. 5



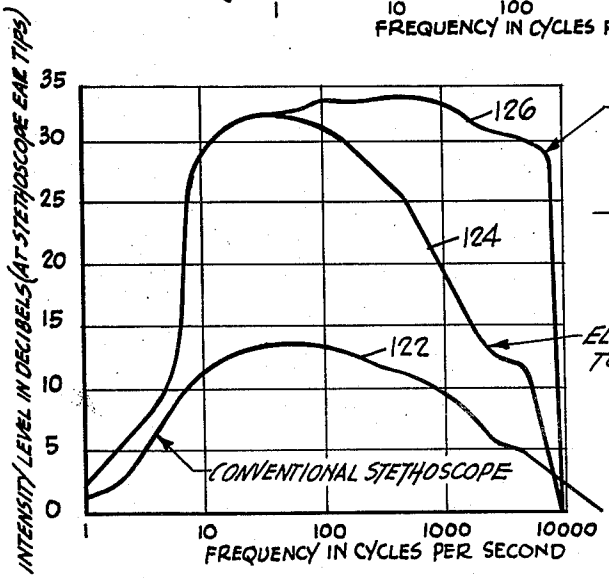


Fig. 6

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United States Patent Office 3,182,129 Patented May 4, 1965

3,182,129

ELECTRONIC STETHOSCOPE

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Filed Nov. 1, 1962, Ser. No. 234,684
8 Claims. (Cl. 179—1)

Our present invention relates generally to electronic stethoscopes and more particularly to an electronic stethoscope which is a precision, high fidelity instrument having effective and adjustable control of both volume and frequency response of the instrument.

Electronic stethoscopes have been used in the past to amplify sounds within the body of a patient but have never gained popularity or widespread usage largely because these instruments did not amplify and reproduce the sounds faithfully in such a manner as to substantially duplicate the sounds as heard through an ordinary stethoscope. The advantage obtained in being able to amplify the sounds within the body of a patient as desired was thus lost because of distortion produced in the amplification process. Further, the prior art electronic stethoscopes were quite limited in their range of frequency response and were not sufficiently versatile in performance capability to provide equally effective amplification of the lower frequency sounds, such as heart sounds, as well as the higher frequency sounds, such as lung sounds. In addition, these earlier electronic stethoscopes were bulky, heavy and unwieldy to such an extent that a sizable and separate container was usually necessary to house the electronic components except for the pickup head and the loudspeaker units which were connected to the container by suitably long leads.

In listening to internal body sounds, the higher frequency lung sounds can obscure to some extent the lower frequency heart sounds, or vice versa. If an electronic stethoscope is constructed to respond fairly equally to the higher as well as the lower frequency sounds, some diffculty may be experienced in trying to identify those sounds which are due expressly to the heart, for example. A great advantage can be achieved for diagnostic purposes if the sounds which are produced primarily by a certain organ such as the heart can be generally isolated from those sounds which are due to other organs, such as the lungs, and background room noises.

Another factor which affects the performance of an electronic stethoscope is that of ambient temperature variations. It is not feasible or practical to maintain an instrument such as a stethoscope which is used under almost any conceivable condition and environment at a single, constant temperature. However, it is an inescapable fact that electronic components and circuits are characteristically changed with ambient temperature variations. Thus, the accuracy and precision of an electronic stethoscope is normally subject to unavoidable fluctuations with variations of ambient temperature.

Bearing in mind the foregoing, it is a major object of our invention to provide a small and lightweight electronic stethoscope which is highly effective in amplifying and faithfully reproducing, over a wide frequency range, sounds originating within a person's body.

Another object of this invention is to provide an electronic stethoscope which is adjustable for selectively reproducing either higher or lower frequency body sounds more clearly, or to obtain a desired combination of relative response of the higher and lower frequency sounds to suit the particular using physician.

Another object of this invention is to provide an electronic stethoscope which has precision, high fidelity performance over a wide range of ambient temperature variations.

A further object of the invention is to provide an amplifier circuit for an electronic stethoscope wherein excellent performance involving class A circuit operation is obtainable without the need for carefully selected circuit components of suitable values and characteristics.

A still further object of the invention is to provide an electronic stethoscope having a novel pickup head structure which is responsive to body sounds over a wide frequency range but is insignificantly responsive to background room noises, especially those which are primarily airborne.

Broadly, and in general terms, the foregoing and other objects are preferably accomplished by providing an electronic stethoscope comprising a set of conventional earpieces having their respective flexible connecting tubes attached to the forked ends of a hollow Y connector, a tubular body portion having the stem of the Y connector attached to one end thereof, the body portion including a pair of volume and frequency control knobs and housing a temperature compensated amplifier circuit, and a pickup head attached to the other end of the body portion and including a diaphragm which is adapted to mechanically actuate a crystal element connected to the input of the amplifier circuit which has a loudspeaker connected at the output and positioned at the end of the body portion connecting with the stem of the hollow Y connector.

The amplifier circuit is a transistor circuit operating class A and includes the crystal input, two emitter follower stages providing an impedance match to the crystal, two following common emitter stages having a negative feedback network connecting the collector of the second stage to the emitter of the first, a thermistor included in a network coupling the low impedance output of the second emitter follower stage to the low impedance input of the first common emitter stage, and a final common emitter output stage driving a loudspeaker similar to those used in small hearing aids. The base input to the first common emitter stage does not use a return resistor in a preferred version of the amplifier circuit, and such a return resistor is only optionally used on those amplifiers which require a slight increase in gain. The amplifier circuit operates class A even though the base of the first common emitter stage is not biased with the normal divider arrangement of bias resistors, either with or without the return resistor.

The diaphragm structure of the pickup head is such that it responds to sounds covering a sufficiently wide frequency range so that the electronic stethoscope easily has a full operating range of from one to 9,000 c.p.s., approximately. The pickup head includes a substantially conventional piezoelectric crystal which is in the form of a thin square wafer, for example, having metallic foil electrodes on the two faces. The crystal is mounted on three corners and an anvil arm is affixed at one end to the remaining corner. The other, free end of the arm extends to engage the center of the inner surface or face of the diaphragm which is a disc-shaped structure mounted at the end of the pickup head.

The housing of the pickup head is a generally hollow, cylindrical structure which flares gradually outwards from a smaller end which slips over and is attached to the main tubular body portion of the electronic stethoscope. There is a wall near the smaller end of the housing, closing the hollow cylindrical structure near the smaller end thereof and providing a floor which is adapted to mount the crystal for the pickup head. Leads con-

necting with the respective metallic foil electrodes on the faces of the crystal are attached to terminals which are mounted to the floor, suitably insulated from the floor structure and extending through it. The wider open end of the housing has a recessed ledge on which is mounted the disc-shaped diaphragm to close this end with a substantially flat surface or face.

The diaphragm structure was developed in conjunction with the rest of the electronic stethoscope and comprises an outer, thin plastic (polyethelene) disc, an inner, thin and light metallic (aluminum) disc in juxtaposition therewith, a somewhat rigid surface pressure centering element (a small square of adhesive cloth tape) centered between the outer and inner discs, and a high frequency damping element (a small square felt pad) centrally attached to the inner face of the inner disc by a more rigid surface element (a square piece of adhesive cloth tape) for improving volume while retaining the high frequency damping effect of the damping element. The inner surface of the outer disc is preferably painted with an opaque (black) paint, and the free end of the anvil arm is lightly but firmly pressed against the center of the covered damping element.

Our invention will be more fully understood, and other objects and advantages thereof will become apparent from the following detailed description of a specific, illustrative example of the invention to be taken in conjunction with the attached drawings, in which:

FIGURE 1 is a perspective view of an electronic stethoscope showing the general exterior configuration or appearance of an illustrative example of our invention;

FIGURE 2 is a perspective view of the pickup head of the electronic stethoscope illustrated in FIGURE 1, the diaphragm being shown in section and separated from the wider, flared cylindrical housing end in order to illustrate the diaphragm construction and mounting of the piezoelectric crystal in the housing;

FIGURE 3 is a circuit diagram of a preferred amplifier circuit for the electronic stethoscope;

FIGURE 4 is a graph including curves which provide a comparison of performance capabilities of a conventional stethoscope and our electronic stethoscope as considered with respect to the threshold of hearing with these instruments relative to the vibratory sound spectrum of the human heart;

FIGURE 5 is a graph including curves which illustrate amplifier circuit frequency response in measured peak-to-peak output voltage, with the tone or frequency control of the electronic stethoscope adjusted to the low and high positions; and

FIGURE 6 is a graph including curves showing the response of a conventional stethoscope in comparison with that of our electronic stethoscope (set at maximum volume) to a sound source simulating a human heart, the intensity level of response being obtained at the ear tips of the stethoscopes.

FIGURE 1 shows the general appearance of a specific, illustrative example of our electronic stethoscope. The electronic stethoscope **10** provides, for example, a maximum gain of 20 decibels, approximately 100 times the sound intensity delivered by a conventional stethoscope. The amplifier circuit used has an electrical power gain of, for example, 41.8 million. As mentioned previously, the full operating frequency range is from one to 9,000 c.p.s., approximately.

The electronic stethoscope **10** has a pair of conventional earpieces **12** and **14**, having respective ear tips **16** and **18**. The earpieces **12** and **14** are held together in an opposing relationship by a connecting spring crosspiece **20**. The earpieces **12** and **14** are connected by respective flexible tubes **22** and **24** to the forked ends **26** and **28** of a hollow Y connector **30**. The stem **32** of the hollow Y connector **30** is screwed onto a hollow threaded extension **34** which extends from an end of a body portion **36** of the electronic stethoscope **10**.

The body portion **36** includes a hollow, tubular cylinder or housing **38** which houses a transistor amplifier circuit, a pair of parallel, disc-shaped control knobs **40** and **42** that rotate on a common axis running at right angles to a vertical plane containing the central axis of the tubular cylinder or housing **38**, and a battery (B1). The knobs **40** and **42** protrude above the surface of the housing **38** through respective segment openings **44** and **46** having chords which are parallel to the axis of the tubular cylinder or housing **38**. The two side faces of each of the knobs **40** and **42** lie in planes which are parallel to the chords of the segment openings **44** and **46** so that the peripheral edge surfaces extend above the surface of the tubular cylinder or housing **38** evenly with respect to each other. The knobs **40** and **42** are laterally spaced apart or separated a small distance such that both knobs can be easily rotated and adjusted by the thumb of the hand holding the body portion **36**.

The knobs **40** and **42** vary respective resistances when adjusted. The knob **40** is for tone or frequency control, and the knob **42** is for on-and-off control coupled with volume control after the instrument **10** has been turned on. By rotating the knobs **40** and **42** toward the front end of the body portion **36** of the instrument **10**, the knob **40** effectively causes decreasing rejection of the higher frequencies, and the knob **42** turns on the instrument **10** when rotated past an "on" detent, after which a red part of the knob **42** begins to appear. Further rotation of the knob **42** towards the front end of the body portion **36** increases the volume from the instrument **10** for listening at the ear tips **16** and **18**.

The electronic stethoscope **10** gain is nearly constant (± 1 db) over the frequency range of 10 to 4000 c.p.s. when the frequency or tone control knob **40** is in the full or maximum high (HI) position. A wide range of frequency rejection is available by turning the frequency control knob **40**. With the control knob **40** in full or maximum low (LO) position, all frequencies above 100 c.p.s. are reduced in the illustrative instrument **10** approximately 2.5 db per octave. The loudness at 1500 c.p.s., for example, is then one-half the loudness at 100 c.p.s.

After volume is increased to the sound level desired by rotating the knob **42** towards the "HI" direction, the frequency control knob **40** is adjusted as desired for the desired tone. Heart sounds are reproduced most effectively if the frequency control knob **40** is moved towards "LO," and lung sounds and other higher frequency sounds are reproduced more clearly by adjusting the frequency control knob **40** towards "HI." The positions of the frequency and volume control knobs **40** and **42** can be varied over a wide range to suit the particular physician.

The body portion **36** of the electronic stethoscope **10** has a pickup head **48** suitably attached at the front end thereof. In use, the front end of the pickup head **48** is placed firmly against a patient so that the entire front surface of the diaphragm is in contact with the patient. The electronic stethoscope **10** may be used through light (indoor) clothing except where there are heavy seams or substantial wrinkles in the clothing.

FIGURE 2 shows a preferred structure of the pickup head **48**. The pickup head **48** generally includes a housing **50** having a diaphragm **52** which is normally affixed to the flared end **54** of the housing **50**. The housing **50** is a generally hollow, cylindrical structure which flares gradually outwardly from the smaller end **56**. The smaller end **56** fits snugly over the forward end of the tubular cylinder or housing **38** and can be attached thereto by means of a small screw (not shown) through a small hole **58** and engaging a threaded hole suitably located in the forward end of the tubular cylinder or housing **38**.

A wall **60** is provided near the lower end **56** of the housing **50**, closing the lower end of the housing **50** and providing a floor **62** which is adapted to mount a pie-

zoelectric crystal X1 for the pickup head 48. The floor 62 has a raised pedestal 66 to which is flatly attached a mounting plate 68 having three, bent upright corners 70, 72 and 74 that are suitably cut to shape for mounting three respective corners of the square wafer crystal X1. An anvil pickup arm 76 is attached to the fourth corner of the crystal X1 such that the arm 76 extends vertically forwardly from the plane of the crystal X1. The end of the arm 76 normally presses lighly but firmly against the center of the inner surface of the diaphragm 52 as indicated by the arrows 78.

The upper or front surface of the crystal X1 has a foil electrode 80 affixed flatly thereto, and the lower or rear surface also has a similar foil electrode 82 affixed flatly thereto. The corners of the crystal X1 are cemented to the corners 70, 72 and 74 of the mounting plate 68 such that only the upper or front electrode 80 touches the mounting plate 68. A lead 84 connects the electrode 80 to terminal 86, and lead 88 connects the electrode 82 to terminal 90. The terminals 86 and 90 are suitably mounted in the wall 60 and provide connections to which an amplifier circuit in the tubular cylinder or housing 38 may be connected.

The terminal 86 can be a grounded connection, and the terminal 90 a suitably insulated connection. The anvil arm 76 is a non-conducting phenolic (Micarta) post, for example. As the arm 76 is moved by motion of the diaphragm 52, the crystal X1 will be mechanically distorted and varied. A small air hole 92 is provided in the floor 62 through the wall 60 for a vent connection when the diaphragm 52 is affixed to the flared end 54 of the housing 50.

A recessed ledge 94 and associated side wall 64 are provided around the flared end 54 to mount the dis-shaped diaphragm 52. The diaphragm 52 comprises an outer, thin plastic (polyethelene) disc 96 which is 1.75 inches in diameter and .032 inch thick, an inner, thin and light metallic (aluminum) disc 98 which is of the same diameter and thickness as the plastic disc 96, a rigid surface, pressure centering element 100 which is a one-half inch square piece of adhesive cloth tape attached to the center of the outer surface of the metallic disc 98, a high frequency damping element 102 which is a one-half inch square felt pad one-eighth inch thick, and another rigid surface element 104 which is a one inch square piece of adhesive cloth tape centrally attached to the inner surface of the metallic disc 98 holding the damping element 102 in position.

The plastic disc 96 is a solid disc, and metallic disc 98 is also a solid disc which, however, may have a few holes judiciously provided therein if desired to improve its vibratory characteristics. The plastic disc 96 is characteristically more responsively similar to the skin of a person, and conforms more closely therewith. Moreover, the disc 96 fully encloses the pickup head 48 to protect the crystal X1 from contamination and harmful exposure to detrimental vapors and atmosphere. The housing 50 and plastic disc 96 (with the diaphragm 52 in place), can be sterilized by wiping them with cotton or cloth moistened with isopropyl alcohol. The electronic stethoscope 10 should not be submerged in any liquid, of course, nor should it be exposed to temperatures in excess of 150° F. Normal operating temperature range for the instrument is from 32° to 120° F.

If a transparent or translucent plastic disc 96 is used, the inner surface is preferably painted with a dark, opaque paint so that the pressure centering element 100 will not be visible through the plastic disc 96. The one-half inch square piece of adhesive cloth tape 100 attached to the center of the outer surface of the metallic disc 98 serves to center the pressure on the center of the disc 98. The metallic disc 98 provides a stiffer backing and response member which prevents excessive deflection of the diaphragm 52 and is responsive from low to sufficienly high frequencies that the plastic disc 96 alone does not meet or reach. In fact, the frequency response was so high that the felt pad damping element 102 was found necessary to damp the high frequencies, as well as properly couple the diaphragm 52 to the anvil arm 76.

The felt pad damping element 102 damps the higher frequencies but is too resilient to connect with the anvil arm 76. The use of an adhesive cloth square 104 provides a more rigid coupling element which improves volume and simultaneously holds the damping element 102 in proper position to the center of the inner surface of the metallic disc 98. The end of the anvil pickup arm 76 can be suitably cemented in place to the adhesive cloth square 104. If the damping element 102 is reasonably dense and firm, the adhesive cloth square can be omitted, of course, and the element 102 cemented to the center of the inner surface of the disc 98 by rubber cement, for example.

A layer 106 of rubber cement is provided around the side edges of the plastic disc 96 and the metallic disc 98, around the peripheral edges of the inner and outer surfaces of the discs 96 and 98, respectively, and around the peripheral edge of the inner surface of the disc 98. This layer 106 cements the two discs 96 and 98 together and to the ledge 94 and side wall 64 around the flared end 54 of the housing 50. The rubber cement provides a cushioning effect between the discs 96 and 98, and between the diaphragm 52 and the ledge 94 and side wall 64. Thus, the diaphragm 52 is effectively floating on a layer of rubber cement.

The outer surface of the plastic disc 96 is very slightly recessed from but is substantially flush with the front edge surface of the flared end 54 when the diaphragm 52 is properly mounted in place. When the diaphragm 52 of the electronic stethoscope 10 is placed firmly against the chest of a patient, the diaphragm 52 is actuated with vibrations due to sounds within the chest that are transmitted through to the skin. The body also acts as a resonator responsive to background room noises which are transmitted, greatly damped, however, to the diaphragm 52. The resonant characteristics of the body and skin would, of course, greatly attenuate these background noises. In addition, the small amplitude resonant waves are virtually imperceptible over the main vibratory waves due to the close and loud sounds within the chest. That is, the relatively small area diaphragm and its lineal response construction produce a highly directional pickup device upon which the resonant type background noise signals are extremely ineffectual.

FIGURE 3 diagrammatically shows the crystal X1 and its connection schematically with the diaphragm 52 through the anvil pickup arm 76. A heart thump would, for example, actuate the diaphragm 52, moving the arm 76 to deflect the crystal X1. This, of course, produces a small electrical signal between the electrodes 80 and 82, and which is applied to the base of transistor Q1 connected in a first stage emitter follower circuit. The switch S1 is integral with the potentiometer R6, and is turned on (closed) by moving the knob 42 past its detent. When the switch S1 is closed, power from the battery B1 is supplied to the electronic stethoscope amplifier circuit between leads 108 and 110.

Resistors R1 and R2 are connected in series from the base of transistor Q1 to the lead 110, and resistor R3 is connected between lead 108 and the common junction between resistors R1 and R2. The collector of transistor Q1 is connected to lead 108 and the emitter is connected to lead 110 through resistor R4. The emitter of transistor Q1 is connected to the base of transistor Q2 which is connected in a second stage emitter follower circuit. The collector of transistor Q2 is connected to lead 108 and the emitter is connected to lead 110 through resistor R5. The emitter of the transistor Q2 is connected back to the common junction of resistors R1 and R2 through feedback capacitor C1.

The crystal X1 has a relatively high impedance, of

course, and the two stages of emitter followers including the transistors Q1 and Q2, respectively, provide a high input impedance for matching the crystal's impedance and also a low output impedance for matching the low input impedance of a following common emitter stage including transistor Q3. The common junction between the resistors R3 and R2 is at a fixed D.-C. level which is connected or applied to the base of the transistor Q1 through the higher resistance resistor R1. The capacitor C1 connects the output of the second emitter follower stage including the transistor Q2 also to the common junction between the resistors R3 and R2, and provides negative feedback to further improve (raise) the input impedance of the first emitter follower stage including the transistor Q1. The capacitor C6 is a high frequency rejection or by-pass element connected between the base of transistor Q1 and lead 110, and capacitor C8 is preferably connected across the battery B1 following the switch S1 and acts to reduce supply voltage drops and fluctuations.

The output of the second emitter follower stage including transistor Q2 is coupled through capacitor C2 to a series combination including thermistor R14 and potentiometer R6. The thermistor R14 is a negative temperature coefficient of resistance device which varies in resistance inversely with temperature change. Thus, as the ambient temperature of the electronic stethoscope 10 increases, the resistance of thermistor R14 decreases, and vice versa so that the resistance between the wiper of potentiometer R6 and lead 110 in proportion to the total resistance of thermistor R14 and potentiometer R6 is varied to increase the input signal to transistor Q3 with increase of ambient temperature and to decrease the input signal with decrease of ambient temperature. This compensates for the decrease or increase in gain in the amplifier stages including transistors Q1 and Q2 with increase or decrease of ambient temperature.

The wiper of the potentiometer R6 is coupled directly to the base of the transistor Q3 which is connected in a common emitter amplifier circuit. The wiper of the potentiometer R6 is mechanically connected to volume control knob 42 which first closes the switch S1 and then gradually increases the resistance between the wiper and the lead 110 as the knob 42 is rotated in the "HI" direction (FIGURE 1). The input signal to the base input of the transistor Q3 increases with the increasing resistance of potentiometer R6 and output volume will be increased.

A return resistor is not (in this invention) normally used with the transistor Q3; however, a return resistor such as resistor R15 may be optionally connected from the base of transistor Q3 to lead 110 only on those amplifiers in which a slight increase in gain is desired. Whether the return resistor R15 is used or not, class A operation of the amplifier circuit shown in FIGURE 3 is maintained. It appears that if the optional resistor R15 is not used, the leakage resistance across the capacitor C3 provides the return path. Still, class A operation is maintained without distortion. If a sine wave input signal is applied at the input of the amplifier circuit, the sine wave is maintained throughout without noticeable distortion when viewed (amplified significantly) on an oscilloscope.

The collector of the transistor Q3 is connected to lead 108 through resistor R7 and the emitter is connected to lead 110 through resistor R8. The collector of the transistor Q3 is also connected directly to the base of a transistor Q4 which is connected in another common emitter amplifier circuit. The collector of the transistor Q4 is connected to lead 108 through resistor R11 and the emitter is conneced directly to the lead 110. A negative feedback network connects the collector of the second stage common emitter amplifier Q3 to the emitter of the first stage common emitter amplifier Q4.

The negative feedback network includes a capacitor C4 connected in parallel with a resistor R10, and an adjustable resistor R9 which is connected in series with the parallel combination. The resistor R9 is varied by means of the frequency or tone control knob 40. Variation of resistor R9 varies the amount of high frequency signal components fed back largely through the capacitor C4 which is selected to pass the higher frequencies. Thus, a greater amount of higher frequency components are negatively fed back when the resistance of resistor R9 is reduced, and a smaller amount is negatively fed back when the resistance of resistor R9 is high. Accordingly, as the knob 40 (FIGURE 1) is rotated forward in the "HI" direction, the resistance of resistor R9 is increased so that a smaller amount of the higher frequency components are negatively fed back, and conversely as the knob 40 is rotated backward in the "LO" direction.

The transistors Q3 and Q4 are also connected in a temperature compensating arrangement. For example, when the temperature of the transistor Q3 increases, leakage current increases but because of the effect of the resistor R8, the current and voltage gain of this stage is effectively decreased. However, the transistor Q4 does not have a resistor similar to resistor R8 in its emitter circuit so that the current and voltage gain of the stage including transistor Q4 increases with temperature. Thus, the transistors Q3 and Q4 are mutually temperature compensating.

The output of the transistor Q4 is coupled to the base of the transistor Q5 through capacitor C5. The base of transistor Q5 is biased to a suitable quiescent operating point for class A operation by resistors R12 and R13 connected in series between leads 108 and 110, with the base of transistor Q5 being connected to the common junction between the resistors R12 and R13. The collector of the transistor Q5 is connected to lead 108 through the coil of loudspeaker E1 which is actually a magnetic earphone element similar to those used in hearing aids. The emitter is connected directly to lead 110, and a capacitor C7 is connected across the coil of the loudspeaker E1 as shown in FIGURE 3. The capacitor C7 is used to damp (bypass) the higher frequencies.

Operation of the amplifier circuit shown in FIGURE 3 is believed to be apparent from the above description. The performance, however, can be considered with respect to the illustrative circuit having components of the following types and values which has yielded a highly satisfactory electronic stethoscope. It is to be understood, of course, that the component types and values given below are merely illustrative examples, and are not to be construed as limiting on our invention.

B1	9 volts.
C1, C2, C5	5 mfd.
C3, C7	1 mfd.
C4	.1 mfd.
C6	.001 mfd.
C8	8 mfd.
E1	Telex 19225–5.
Q1, Q2, Q3, Q4, Q5	2N207B.
R1, R10, R12, R15	100 kilohms.
R2, R3	56 kilohms.
R4	470 kilohms.
R5	10 kilohms.
R6	25 kilohms (pot. with switch).
R7	220 kilohms.
R8	470 kilohms.
R9	100 kilohms (pot.)
R11	4.7 kilohms.
R13	2.2 kilohms.
R14	Victory Eng'g. Corp. 33D2.
X1	American Microphone X–206.

When the amplifier circuit of FIGURE 3 employs the optional resistor R15, it should optimumly have a value of approximately 47 kilohms instead of 100 kilohms. How-

ever, the latter value for resistor R15, if used, avoids the need for careful selection of transistors with suitable characteristics, particularly for the transistor Q3. Also, for example, when a standard signal source providing 34 microvolts peak-to-peak (15 microvolts R.M.S.) at the input of the amplifier circuit on the base of the transistor Q1 in lieu of crystal X1 (removed), substantially 34 microvolts (the figures are all peak-to-peak) appears at the emitter of transistor Q1, 33 microvolts at the emitter of transistor Q2, 28 microvolts at the top of potentiometer R6, 7.6 microvolt at the wiper thereof (volume control set for 6 volts system output), 7.4 microvolts at the base of transistor Q3 (without the resistor R15), 10 microvolts at the collector thereof, 80 microvolts at the collector of transistor Q4, and 6 volts, of course, at the collector of the transistor Q5.

FIGURE 4 is a graph generally illustrating the threshold of hearing attained with a conventional stethoscope and our electronic stethoscope, in relation to the vibratory spectrum of the human heart. The area under the curve **112** covers the vibratory spectrum of the heart, the curve **114** is a frequency plot of the threshold of hearing for a conventional stethoscope, and the curve **116** is a frequency plot of the threshold of hearing for the electronic stethoscope **10**. The intensity level of heart sounds must be above the curve **114** in order to be audible with a conventional stethoscope, and above the curve **116** for the electronic stethoscope. Thus, the area between curves **112** and **114** is the portion of the vibratory spectrum of of the heart audible with a conventional stethoscope, and the area between curves **112** and **116** is the portion audible with the electronic stethoscope. These curves are, of course, only representative and should be broadly construed. A sound (wave) pressure of .0002 dyne per square centimeter was used as the zero decibel reference.

FIGURE 5 is a graph showing amplifier circuit voltage response curves for different settings of the frequency or tone control of the electronic stethoscope **10**. Peak-to-peak output voltage is plotted against frequency. Curve **118** was obtained with the frequency or tone control knob **40** (FIGURE 1) in the maximum "HI" position wherein the resistance of resistor R9 (FIGURE 3) was 100 kilohms, and curve **120** was obtained with knob **40** in the maximum "LO" position wherein the resistance of resistor R9 was at substantially 0 ohm. Output voltage was, of course, measured from across the coil of loudspeaker E1. An input signal of 15 microvolts R.M.S. was applied to the input of the amplifier circuit of FIGURE 3 with a frequency variable source used in lieu of the crystal X1. A volume control setting of approximately midway between maximum and minimum was used.

FIGURE 6 is another graph illustrating the performance of the electronic stethoscope **10** with its frequency or tone control set at maximum high and low positions, in comparison with a conventional stethoscope. A sound source of 15 decibels was used to simulate the human heart in obtaining the curves **122, 124** and **126**. The curve **122** is a frequency plot of th eintensity level at the ear tips of a conventional stethoscope, the curve **124** is that at the ear tips of the electronic stethoscope **10** with its frequency or tone control at maximum "HI" position, and the curve **126** is that with the frequency or tone control at maximum "LO" position. The standard decibel zero reference of .0002 dyne per square centimeter was used.

The sound source used to simulate the human heart in obtaining the curves **122, 124** and **126** had its loudspeaker output suitably covered with a foam rubber pad to simulate a person's skin before the pickup heads of the conventional stethoscope and electronic stethoscope were placed against the source. The maximum intensity level point on curve **122** was established frequency-wise by varying the frequency of the sound source until the maximum level was heard at the ear tips of the conventional stethoscope. By reading the frequency setting of the source, the frequency was determined. The effect of the foam rubber pad is to reduce the known 15 decibel output of the sound source by approximately one decibel thus giving the intensity level for that frequency setting.

Other points of the curve **122** were determined by estimation at the ear tips as the frequency of the sound source was changed from point to point, the output of the sound source being a constant **15** decibels. Since the ear can detect a difference of one decibel, the curve **122** is accurate to such a degree. Corresponding points along the curves **124** and **126** were established by altering the volume control potentiometer R6 setting from maximum volume down until the intensity at the ear tips of the electronic stethoscope matches that heard with the conventional stethoscope, for each frequency setting of the sound source.

The graphs shown in FIGURES 4, 5 and 6 were derived using conservative data and poorer than average performance instruments. Even so, it is clear that the results are necessarily dependent upon the particular instruments and equipment used. Also, the results were obtained to a certain extent on the basis of individual judgment and sensitivity of response. Thus, the graphs should be considered as being primarily qualitatively representative of the performance of the electronic stethoscope **10**.

While a specific illustrative example of our invention has been described and shown in detail above, including certain types and values of the components, it is to be understood that the particular embodiment and specific data of the invention described above and shown in the drawings are merely illustrative of and not restrictive on the broad invention, and that various changes in design, structure and arrangement may be made without departing from the spirit and scope of the appended claims.

We claim:

1. An electronic stethoscope, comprising:
   - a pickup head including a diaphragm adapted to be placed in contact with a body, a piezoelectric crystal mounted in said pickup head, and means for transmitting movements of said diaphrgam to said crystal for producing an output signal therefrom;
   - an amplifier circuit including an emitter follower having an input and an output, the output signal of said crystal being applied to the input of said emitter follower, a potentiometer adapted to be connected to the output of said emitter follower and having an output, said potentiometer being manually adjustable to provide a variable signal from the output of said potentiometer, amplifying means connected to the output of said potentiometer for amplifying the variable signal therefrom, and including a feedback network which is manually adjustable for varying amount of rejection of high frequency components from the amplified output signal of said amplifying means, and output means comprising a power amplifier connected to said amplifying means, and loudspeaker means connected to said power amplifier to be driven thereby for reproducing amplified sounds corresponding to the movements of said diaphragm transmitted to said crystal, said potentiometer and said feedback network being independently adjustable during operation of said stethoscope to vary the volume and tone, respectively, of the amplified sounds from said loudspeaker means; and
   - a pair of earpieces adapted to receive the amplified sounds from said loudspeaker means.

2. An electronic stethoscope, comprising:
   - a pickup head including a diaphragm adapted to be placed in contact with a body, piezoelectric crystal mounted in said pickup head, and means for transmitting movements of said diaphragm to said crystal for producing an output signal therefrom, said diaphragm comprising an outer disc of plastic characteristics and an inner disc of metallic characteristics in juxtaposition therewith;

an amplifier circuit including an emitter follower having an input and an output, the output signal of said crystal being applied to the input of said emitter follower, a negative temperature coefficient resistance device, a potentiometer connected in series with said device in a series combination and having an output, said series combination being adapted to be connected to the output of said emitter follower and said potentiometer being adjustable to provide a variable signal from the output of said potentiometer, amplifying means connected to the output of said potentiometer for amplifying the variable signal therefrom, and including a feedback network which is adjsutable for varying amount of rejection of high frequency components from the amplified output signal of said amplifying means, and output means comprising a power amplifier connected to said amplifying means, and loudspeaker means connected to said power amplifier to be driven thereby for reproducing amplified sounds corresponding to the movements of said diaphragm transmitted to said crystal; and

a pair of earpieces adapted to receive the amplified sounds from said loudspeaker means.

3. In an electronic stethoscope, a pickup head comprising:

a housing having a first and second open end, and including mounting structure therein affixed to said housing;

a piezoelectric crystal mounted to said mounting structure and adapted to be physically distortable to produce an output signal therefrom;

a diaphragm including an outer disc of plastic characteristics, an inner disc of metallic characteristics in juxtaposition with said outer disc, and a pressure centering element positioned between said outer and inner discs, said diaphragm being mounted to said first end of said housing and closing said first end; and

means for transmitting movements of said diaphragm to said crystal to distort the same and produce an output signal therefrom.

4. In an electronic stethoscope, a pickup head comprising:

a housing having a first and second open end, and including mounting structure therein affixed to said housing;

a piezoelectric crystal mounted to said mounting structure and adapted to be physically distortable to produce an output signal therefrom;

a diaphragm including an outer disc of plastic characteristics, an inner disc of metallic characteristics in juxtaposition with said outer disc, and a high frequency damping element following said inner disc in juxtaposition therewith, said diaphragm being mounted to said first end of said housing and closing said first end; and

means for transmitting movements of said diaphragm to said crystal to distort the same and produce an output signal therefrom.

5. In an electronic stethoscope, a pickup head comprising:

a housing having a first and second open end, and including mounting structure therein affixed to said housing;

a piezoelectric crystal mounted to said mounting structure and adapted to be physically distortable to produce an output signal therefrom;

a diaphragm including an outer disc of plastic characteristics, an inner disc of metallic characteristics in juxtaposition with said outer disc, a pressure centering element positioned between said outer and inner discs, and a high frequency damping element following said inner disc in juxtaposition therewith, said diaphragm being mounted to said first end of said housing and closing said first end; and

means for transmitting movements of said diaphragm to said crystal to distort the same and produce an output signal therefrom.

6. In an electronic stethoscope, an amplifier circuit comprising:

a piezoelectric crystal adapted to be distortable according to movements of a diaphragm to produce an output signal;

an emitter follower having an input and an output, the output signal of said crystal being applied to the input of said emitter follower;

a negative temperature coefficient resistance device;

a potentiometer connected in series with said device in a series combination and having an output, said series combination being adapted to be connected to the output of said emitter follower and said potentiometer being adjustable to provide a variable signal from the output of said potentiometer;

amplifying means connected to the output of said potentiometer for amplifying the variable signal therefrom, and including a feedback network which is adjustable for varying amount of rejection of high frequency components from the amplified output signal of said amplifying means; and

output means including a power amplifier connected to said amplifying means, and loudspeaker means connected to said power amplifier to be driven thereby.

7. In an electronic stethoscope, an amplifier circuit comprising:

a piezoelectric crystal adapted to be distortable according to movements of a diaphragm to produce an output signal;

an emitter follower having an input and an output, the output signal of said crystal being applied to the input of said emitter follower;

a potentiometer adapted to be connected to the output of said emitter follower and having an output, said potentiometer being manually adjustable to provide a variable signal from the output of said potentiometer;

amplifying means including a first stage common emitter amplifier coupled directly to the output of said potentiometer, a second stage common emitter amplifier connected to said first stage common emitter amplifier, and a feedback network which is manually adjustable for varying amount of rejection of high frequency components from the amplified output signal of said amplifying means connected between the output of said second stage and the emitter of said first stage; and

output means including a power amplifier connected to said amplifying means, and loudspeaker means connected to said power amplifier to be driven thereby, said potentiometer and said feedback network being independently adjustable as desired during operation of the stethoscope to vary the volume and tone, respectively, of the amplified sounds from said loudspeaker means.

8. In an electronic stethoscope, an amplifier circuit comprising:

a piezoelectric crystal adapted to be distortable according to movements of a diaphragm to produce an output signal;

an emitter follower having an input and an output, the output signal of said crystal being applied to the input of said emitter follower;

a negative temperature coefficient resistance device;

a potentiometer connected in series with said device in a series combination and having an output, said series combination being adapted to be connected to the output of said emitter follower and said potentiometer being adjustable to provide a variable signal from the output of said potentiometer;

amplifying means including a first stage common emitter amplifier connected to the output of said potentiometer, a second stage common emitter amplifier connected to said first stage common emitter amplifier, and a feedback network which is adjustable for varying amount of rejection of high frequency components from the amplified output signal of said amplifying means connected between said first and second stages; and

output means including a power amplifier connected to said amplifying means, and loudspeaker means connected to said power amplifier to be driven thereby.

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