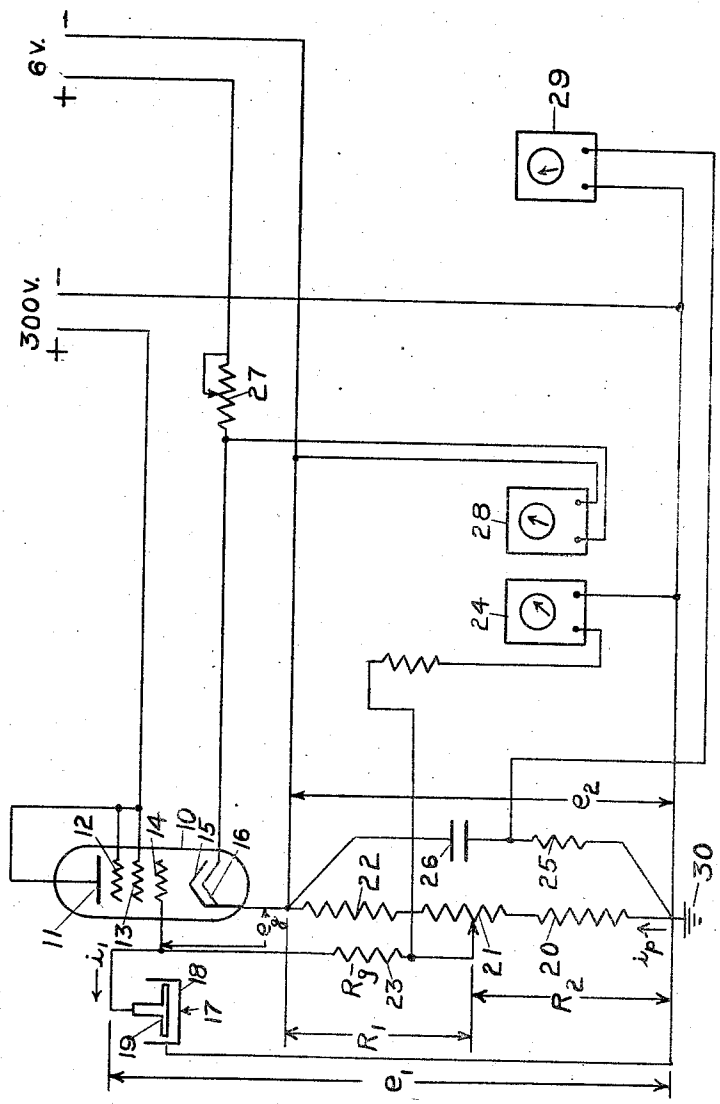
Feb. 19, 1946. F. M. WIENER ET AL 2,395,309

DIRECT READING SOUND PRESSURE METER

Filed Sept. 30, 1943



FRANCIS M. WIENER
ROBERT L. WALLACE JR.
INVENTORS

BY J. J. Fitzgerald
ATTORNEY

Patented Feb. 19, 1946

2,395,309

UNITED STATES PATENT OFFICE

2,395,309

DIRECT READING SOUND PRESSURE METER

Francis M. Wiener and Robert L. Wallace, Jr., Cambridge, Mass., assignors to United States of America, as represented by the Secretary of the Navy

Application September 30, 1943, Serial No. 504,488

3 Claims. (Cl. 181—0.5)

This invention relates in general to acoustical apparatus and in particular to an improved device for reading sound pressures directly.

It is the general object of our invention to provide a device which, when placed in a sound field, will produce a voltage at its output proportional to the sound pressure and of such magnitude that it can be read on a high impedance voltmeter. The output impedance of the device is low enough so as not to introduce any appreciable error due to the finite impedance of the voltmeter.

A more specific object is to provide a device of the character described, utilizing a high impedance condenser type microphone as the sound responsive element and in which a novel circuit arrangement is utilized to provide a high impedance input to an amplifier to which the microphone is connected, and which also furnishes a suitable biasing potential for the microphone to measure its open circuit voltage, which is proportional to the sound pressure.

These and other objects of our invention will become apparent from the detailed description to follow and from the accompanying drawing, the single figure of which shows schematically a preferred embodiment of our invention.

Referring now to the drawing, the numeral 10 designates an amplifier tube which may be, for example, an RCA type 6J7 or 1620. Tube 10 is connected as a triode cathode follower and includes a plate 11, suppressor grid 12, screen grid 13, control grid 14, cathode 15 and a cathode heater 16.

A condenser type microphone is shown at 17, and is preferably a Western Electric type 640-A. It has one plate 19 connected to control grid 14 of tube 10. The other plate 18 which is the movable member of the microphone is connected to the lower end of a plurality of serially arranged resistors 20, 21 and 22. The upper end of resistor 22 is connected to cathode 15. The positive side of a 300 volt "B" supply source is connected to plate 11 of tube 10 and the negative side thereof is connected to the lower end of resistor 20 and ground 30.

The values of resistors 20, 21 and 22 are so chosen that a 200 volt biasing potential for the microphone 17 will be obtained across resistor 20 and the tapped portion of the resistor 21. The remainder of resistors 21 and 22 furnish approximately 2 volts for the bias on tube 10. Satisfactory values for these resistors which are preferably wire wound are as follows: Resistor 20—0.1 megohm, resistor 21—400 ohms and resistor 22—1000 ohms.

As the biasing potential across microphone 17 should remain constant in order for the sound pressure reading to be consistently accurate, we preferably include a voltmeter 24 which is connected across the tapped portion of resistor 21 and resistor 20. The potentiometer arrangement of resistor 21 is so adjusted as to vary current flow through the resistors until voltmeter 24 reads 200 volts, which thus establishes the desired 200 volt bias on microphone 17. A proper tube bias of about —2 volts is provided for tube 10 so that no grid current flows.

The bias circuit for the microphone 17 also includes a 20 megohm resistor 23. It prevents the charge generated by the motion of the movable plate 18 of the condenser microphone 17 from leaking off. It is very important for the proper functioning of the circuit for other reasons also, which will be discussed later.

Also connected across resistor 21 to 22 inclusive, is a 2 megohm resistor 25 and a .5 microfarad condenser 26. The condenser 26 keeps the direct current potential of about 200 v. between cathode and ground from appearing across resistor 25, and vacuum tube voltmeter 29, whereas its impedance for alternating currents is very small so that effectively the full output voltage e_2 appears across resistor 25. A rheostat 27 is included in the cathode heater circuit to regulate current flow therein, and another voltmeter 28 may be also connected in this circuit across the cathode heater 16 if desired. A high impedance electronic voltmeter 29 such as the Ballantine electronic voltmeter model 300 is connected as shown. This type of voltmeter produces at its output about 1 millivolt for a sound pressure level of 70 decibels (re .0002 dynes/cm.^{2}), and its scale may be calibrated to read directly in decibels sound pressure.

The operation of the device is as follows: When the microphone 17 is placed in a sound field, the alternating sound pressure of which it is desired to measure, a periodic motion of plate 18 is produced which generates the open circuit voltage of the microphone. This open circuit voltage is applied across the high impedance input of tube 10 and associated circuit, and produces an output voltage e_2 across the resistor combination 20, 21 and 22, which essentially appears in the scale reading of the high impedance voltmeter 29 which as heretofore indicated, may be calibrated to read directly in units of sound pressure.

That the voltage measured by voltmeter 29 is

substantially equal to the voltage caused by the change in distance between plates 18 and 19 of microphone 17 is shown to be so by the following mathematical analysis:

Let e_1, e_2, e_g, i_1, and i_p represent small signal variational voltages and currents respectively.

$$e_2+e_g=e_1 \quad (1)$$

$$e_2=Ri_p+R_2i_1 \quad (2)$$

Where

$$R\equiv R_1+R_2$$

But

$$i_1<<i_p$$

So

$$e_2\doteq Ri_p=\frac{R\mu e_g}{R+r_p} \quad (3)$$

Where

μ=amplification factor
r_p=plate resistance
} of tube 10

From (1) and (3)

$$e_2\cdot\left[1+\frac{R+r_p}{R\mu}\right]=e_1 \quad (4)$$

And

$$e_2=\frac{e_1}{1+\left(\frac{1}{\mu}\right)+\left(\frac{1}{RS_p}\right)} \quad (5)$$

Where s_p=plate transconductance of tube 10

In the circuit shown in the drawing

$R\doteq 100{,}000$ ohms
$\mu\doteq 20$
$S_p\doteq 1700\times 10^{-6}$ amperes/volt

Hence

$$e_2\doteq\frac{e_1}{1.05}=0.95e_1$$

independent of frequency.

To measure the open circuit voltage of a high impedance device, such as the condenser type microphone 17 whose impedance at 100 C. P. S. is about 3×10^7 reactive ohms, the input impedance of the measuring device must be a multiple of that value.

That this is accomplished by this device is shown by the following mathematical analysis:

Since

$$i_1<<i_p$$

$$i=\frac{e_1-\left(\frac{R_2}{R}\right)e_2}{R_g} \quad (6)$$

And the input impedance Z_{in} from grid 14 to ground 30 becomes

$$Z\equiv\frac{e_1}{i_1}=R_g\frac{1}{1-\left(\frac{R_2}{R}\right)\left(\frac{e_2}{e_1}\right)} \quad (7)$$

Now, in the circuit shown

$$\frac{R_2}{R}\doteq 0.99$$

$$R_g=2\times 10^7 \text{ ohms}$$

and

$$\frac{e_2}{e_1}\doteq 0.95$$

$$Z_{in}=3.3\times 10^8 \text{ resistive ohms.}$$

It is thus shown that for the circuit constants chosen here e_1 substantially equals the open circuit voltage generated by the microphone for frequencies above 100 C. P. S.

Since it is seen from (7) that the input impedance is proportional to R_g, the frequency range can be extended towards lower frequencies by increasing R_g, i. e. resistor 23.

By similar calculations, it can be shown that the output impedance of the device, measured between cathode 15 and ground 30 is very low for the circuit constants given, namely of the order of 1000 ohms or less.

Summary

(1) The device measures the open circuit voltage of a condenser microphone 17, which is proportional to the sound pressure acting upon it by means of a high impedance voltmeter 29, substantially independent of frequency over a wide audio frequency range. The voltmeter can be calibrated directly in terms of sound pressure.

(2) The performance of the device is substantially independent of changes in the characteristics of the vacuum tube 10.

(3) The output impedance of the device is sufficiently low to permit the reading of the voltmeter 29 at a location distant from the point of location of the microphone and amplifier without elaborate precautions and errors due to the finite impedance of the voltmeter.

(4) In a preferred embodiment of the invention, the microphone and amplifier are housed in a case of suitably small dimensions so as not to disturb appreciably the sound field to be measured.

(5) An insert resistor for precision measurement of the open circuit voltage generated by the microphone can be easily installed by breaking the lead between point 18 in the diagram and ground 30.

(6) Despite the fact that a very high input impedance for alternating signals is realized, the resistance for direct current from the fixed plate 19 of the condenser microphone 17 has the magnitude of R_g which, from (7) is seen to be smaller than said input impedance, by a factor of approximately 16. Thus the effect of leakage in the condenser microphone is generally reduced compared with devices of similar kind known to the art prior to this invention. Moreover, the presence of leakage in the microphone reducing the value of the effective bias voltage across the condenser microphone from the existing voltage across resistor R_2 is indicated by a change in deflection of voltmeter 24 when the microphone is alternately connected and disconnected from the circuit.

(7) To make the deflection of voltmeter 29 independent of frequency for microphones whose open circuit voltage is not independent of frequency for a given sound pressure, an equalizing network can be inserted into the circuit between the output terminals of the device and voltmeter 29, compensating for the response-frequency characteristic of the microphone.

Having thus fully described our invention, we claim:

1. In apparatus for measuring the intensity of a sound field, a space discharge tube having a cathode, control grid and plate, a source of unidirectional potential, an impedance, means connecting said source of potential in circuit with said plate and cathode through said impedance, a high impedance condenser microphone adapted to be placed in said sound field, a high impedance connecting said microphone into the plate-cathode circuit of said tube whereby the alternating potential produced across the condenser plates of said microphone when the latter is placed in said

sound field will effect a substantially equivalent alternating potential across first said impedance, and means adapted to measure last said potential.

2. The combination in claim 1 and further including means utilizing the drop in potential across at least a portion of first said impedance for impressing a unidirectional biasing potential on the condenser plates of said microphone.

3. In apparatus for measuring the intensity of a sound field, a space discharge tube having a cathode, control grid and plate, a source of unidirectional potential, an impedance, means connecting said source of potential in circuit with said plate and cathode through said impedance, a high impedance condenser microphone adapted to be placed in said sound field, circuit means connecting one condenser plate of said microphone to the grid of said tube and also to one point on first said impedance through a second and high impedance, circuit means connecting the other condenser plate of said microphone to another point on first said impedance whereby a biasing potential for the microphone is supplied and whereby the alternating potential produced across the plates of said microphone when placed in said sound field will produce a substantially equivalent alternating potential across first said impedance, and means adapted to measure last said potential.

FRANCIS M. WIENER.
R. L. WALLACE, Jr.