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WATTMETER

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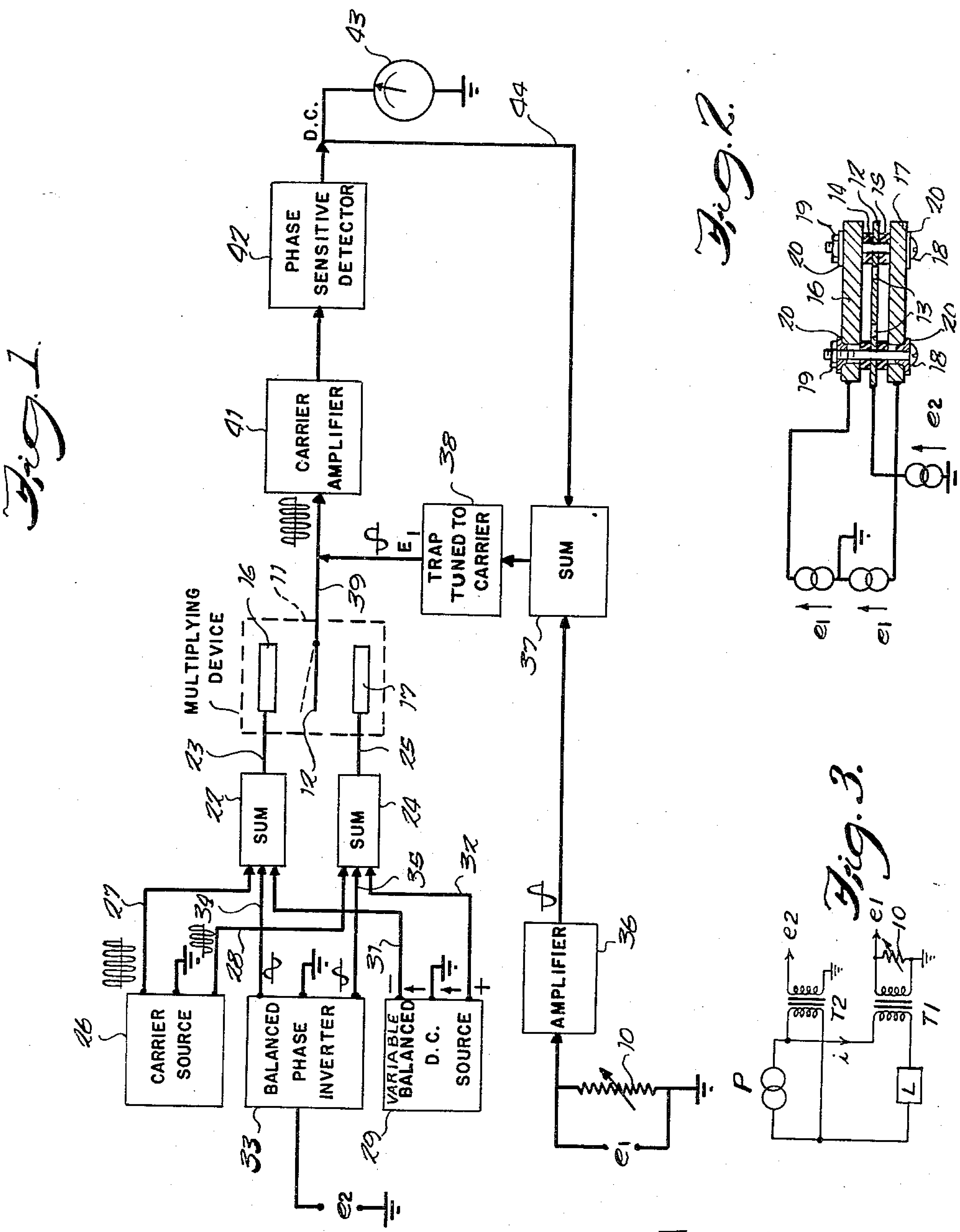

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WATTMETER

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This invention relates to wattmeters, and more particularly to wattmeters usable at higher alternating current frequencies.

It is an object of this invention to provide a new and improved wattmeter.

Another object of this invention is to provide a wattmeter which is rugged, dependable and does not require any rotating parts in the wattage sensing portion of the device.

A still further object of this invention is to provide an improved multiplying device in combination with the wattage determining portion of the device.

Other and further objects of the invention will be apparent by reference to the following description taken in conjunction with the accompanying drawing, wherein:

Figure 1 is a functional block diagram of the invention; and

Figure 2 is a cross-sectional view of the electrostatic multiplying device used in the wattmeter.

Fig. 3 is a functional diagram showing how the voltage and current components of the power transmitted from an electrical source to a load are derived for application to the wattmeter of Fig. 1.

Referring now more particularly to Figure 1, there is shown a wattmeter of this invention for measuring the power transmitted from an electrical source to a load, having two input voltages e_1 and e_2. The input voltage e_1 is developed across a resistor 10 and is proportional to the current transmitted to the load whose power consumption is to be determined. The input voltage e_2 is proportional to the voltage applied to the load whose power consumption is to be measured.

The heart of the wattmeter is an electrostatic multiplying device 11. Referring momentarily to Figure 2 for a detailed showing of this device, it is seen that a deflectable electrically conducting element or diaphragm 12, which may be made of a thin, metallic foil with vent holes 13 piercing its surface, has a pair of spaced insulating spacers 14 on one side adjacent its periphery and a pair of spaced insulating spacers 15 on its other side adjacent its periphery. These spacers 14 and 15 may be made of any well-known insulating material, such as fibre-board. An electrically conducting member or metallic end plate 16 contacts the insulating spacers 14 on the side remote from the diaphragm 12. A second electrically conducting member or metallic end plate 17 contacts the insulating spacers 15 on the side remote from the diaphragm 12. A pair of bolts 18 and nuts 19 firmly hold together the layered structure consisting of the end or charge plates 16 and 17, the spacers 14 and 15 and the diaphragm 12. The bolts 18 and nuts 19 are insulated from the end plates by washers 20. Provision is made for applying input voltages to the diaphragm 12 and each of the end plates 16 and 17.

In order to clearly illustrate the manner in which this structure performs the process of multiplication, let it be assumed that a time-varying input signal $2e_1$ is applied between the end plates 16 and 17 having instantaneous polarities as shown by the arrow heads in Figure 2. Let there further be applied a second time-varying input signal e_2 between the diaphragm 12 and the neutral of the first signal voltage $2e_1$. The potential difference between the diaphragm 12 and the plate 16 produces a force on diaphragm 12 in an upward direction, i. e. toward the plate 16, due to the difference between e_1 and e_2. This can be expressed as

$$f\ \text{up}=k_1(e_1-e_2)^2 \qquad (1)$$

The potential difference between the diaphrgam 12 and the lower plate 17 produces a downward force

$$f\ \text{down}=k_2(e_1+e_2)^2 \qquad (2)$$

The net downward force on the diaphragm is then

$$f=k_2(e_1+e_2)^2-k_1(e_1-e_2)_2 \qquad (3)$$

where k_1 and k_2 are constants determined by the geometry of the physical structure. If, by reason of the geometry of the system, k_1 is equal to k_2, then

$$f=4ke_1e_2 \qquad (4)$$

Equation 4 shows that the force deflecting the diaphragm 12 is a function of the product of the voltages e_1 and e_2. Stating this differently, an instantaneous force is produced acting on the deflectable element or diaphragm 12 which is proportional to the product of the instantaneous signal voltages e_1 and e_2. Due to the mass compliance and damping of the system, this force is integrated and produces an average deflection, depending upon the average value of the product of the two signal voltages.

Since the deflection of the diaphragm 12 is a function of the force applied to the diaphragm, either a mechanical or electrical means for measuring or sensing the deflection of the diaphragm could be used. If a mechanical sensing means is used, the deflection must of necessity be relatively large. This would modify the geometry of the system to the extent that k_1 no longer equals k_2 and errors are accordingly, introduced.

Therefore, in the preferred embodiment, an electrical method of sensing is used in which the average force due to e_1 and e_2 is opposed by a force $4kE_1E_2$ (where E_1 is the value of the D. C. signal produced by the phase sensitive detector and applied to the diaphragm 12 and E_2 is the value of each of the balanced D. C. voltages applied to the summing circuits 22 and 24). This force is very nearly equal to the average value of the force $4ke_1e_2$, because of the feedback loop to be described hereafter. As a result the deflection of the diaphragm 12 is very small, being only that necessary to produce the required error voltage to excite the feedback loop.

In particular, a carrier source having two outputs of equal amplitude but opposite polarities, both outputs being balanced to ground, has one of its output voltages applied to the plate 17. The diaphragm 12 together with the plates 16 and 17 forms a capacitive voltage divider so that, if the diaphragm 12 is deflected from its center position, the capacitive arms of the divider are unbalanced and the diaphragm will pick up one of the two carrier output voltages. If the deflection of the diaphragm 12 is toward the plate 16, then the diaphragm will pick up the carrier voltage applied to that plate, the other carrier voltage being picked up if the deflection is in the direction of the plate 17.

From the above discussion it is clear that the actual physical deflection of the diaphragm is extremely small (approaching zero), but that the tendency to be deflected as counteracted by the high-gain feedback loop can be accurately observed from the magnitude of the feedback loop voltage providing this counteracting force.

Referring now again to Figure 1, the output of the summing amplifier 22 is applied through a lead 23 to the plate 16 of the multiplying device 11. A summing circuit 24 has its output connected through a lead 25 to the plate 17 of the multiplying device 11. Each of the summing networks 22 and 24 has three inputs which may have voltages applied to them to be summed by their respective networks to be applied to their respective plates 16 and 17.

A carrier source 26 providing two balanced phase opposed output voltages on its output leads 27 and 28 has its output voltages applied, one each, to an input of the summing network 22 and 24. The balanced output voltages of the carrier source 26 are balanced to ground in the same manner as the output voltages from a balanced D. C. source 29 which appear on conductors 31 and 32. Conductor 31 is connected to the input of the summing network 22, while conductor 32 is connected to an input of the summing network 24. The proportional wattmeter input voltage e_2 is applied to the input of a phase inverter 33. The two phase opposed output voltages of the phase inverter 33 are applied, one through a conductor 34, to the summing network 22, the other through a conductor 35 to a summing network 24. The current proportional wattmeter input voltage e_1 is applied to the input of an amplifier 36. The output of the amplifier 36 is applied to one of the inputs of a summing network 37. The output of the summing network 37 is applied to a wave trap 38 which is tuned to the frequency of the carrier source 26. The output of the carrier amplifier 41 is applied to the input of a phase sensitive detector 42, the constant or slowly varying D. C. output of which indicates by its amplitude and polarity the amount of force necessary to counterbalance the force due to the product of e_1 and e_2. A power calibrated voltmeter 43 is connected to the output of the detector 42. The output of the detector 42 is also applied through a lead 44 to the second input of the summing network 37.

If the diaphragm 12 is initially centered between the plates 16 and 17, no carrier voltage is applied to the carrier amplifier. If signal voltages e_1 and e_2 are now applied to the two inputs of the wattmeter, a deflection of the diaphragm 12 takes place resulting in a D. C. voltage out of the phase detector 42 having a magnitude and polarity depending upon the deflection of the diaphragm 12. If this D. C. voltage is now applied with proper polarity to the diaphragm 12 in the presence of balanced D. C. voltages on the end plates, as is done through the feedback loop of conductor 44, a force is developed due to the D. C. product which opposes the average force due to the signal voltages. As is well known from feedback theory, a sufficiently large loop gain as provided by carrier amplifier 41 will minimize the error between these products to a very small value. If the output from the balanced D. C. source 29 and the size of the resistor 10 are held fixed, the voltmeter reading of meter 43 becomes a direct measure of the average value of the instantaneous signal product or the power. A number of power scales for the meter 43 may be readily provided by adjusting the size of resistor 10, by varying the output voltage of the balanced D. C. source 29 or by varying a combination of both.

Fig. 3 illustrates how the input voltages e_1 and e_2 applied to amplifier 36 and phase inverter 33 respectively, are derived. In Fig. 3 a power source P is connected in series with a load L and the primary of a transformer T1. The secondary of transformer T1 is connected across resistor 10. The input voltage e_1 is developed across resistor 10 and is proportional to the current i transmitted to load L. Connected in parallel with the load L is the primary of a second transformer T2. The input voltage e_2 is developed across the secondary coil of transformer T2, one end of which is grounded, and is proportional to the voltage applied to load L.

The output reading obtained at meter 43 is proportional to the average value of e_1e_2 and, therefore, is proportional to the average value of power. If the meter 43 is calibrated in terms of power, the meter will provide a direct indication of the average value of the power consumed by the load.

While there has been shown and described an invention in connection with certain specific embodiments, it will, of course, be understood that it is not intended nor wished to be limited thereto since it is apparent that the principles herein disclosed are susceptible of numerous other applications, and modifications may be made in this circuit arrangement and in the instrumentalities employed, without departing from the spirit and scope of this invention as set forth in the appended claims.

I claim as my invention:

1. A wattmeter for measuring the high frequency power transmitted from an electrical source to a load having an input voltage and input current proportional to the transmitted voltage and current comprising an electrostatic multiplying device having a diaphragm disposed in spaced relation between two plates, a first summing means having its output connected to one of said plates, a second summing means having its output connected to the other of said plates, a carrier source having a pair of balanced output voltages connected respectively to the inputs of said first and second summing means, said first proportional input voltage being applied to a balanced phase inverter having a pair of balanced output voltages, said phase inverted output voltages being applied respectively to the inputs of said first and second summing means, a balanced voltage source having its output voltages applied to said first and second summing means respectively, said first proportional input current being coupled to one of the inputs of a third summing means, the output of said third summing means being fed to a carrier-tuned trap circuit, said carrier tuned trap circuit being connected to said diaphragm of said multiplying device, said diaphragm being connected to the input of a carrier amplifier, a detector connected to the output of said carrier amplifier, the output of said detector being connected to the other of the inputs of said third summing means, and a meter connected at the output of said detector to give a direct reading in units of power.

2. A wattmeter according to claim 1 in which said balanced voltage source output can be adjusted to provide a number of ranges of power measurement.

3. A wattmeter for measuring the power transmitted from an electrical source to a load having an input voltage and input current proportional to the transmitted voltage and current comprising an electrostatic multiplying device having a deflectable means positioned between two plates, a first and second combining means having their outputs connected respectively to one of each of said plates, a carrier source having a pair of phase-opposed output voltages connected respectively to the inputs of said first and second combining means, means for deriving two phase-opposed voltages from said proportional input voltage, said two phase-opposed voltages being applied to said first and second combining means respectively, said proportional input current being coupled to one of the inputs of a third combining means, the output of said third combining means being fed to a carrier blocking circuit, said carrier blocking circuit being connected to said deflectable means of said multiplying device, said deflectable means being connected to the input of a carrier amplifier, a detector connected to the output of said carrier amplifier, the output of said detector being connected to the other of the inputs of said third combining means, and means to provide a visible indication of the amount of transmitted power.

4. A wattmeter according to claim 3 including means for providing a number of ranges of power measurement.

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