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J. D. CORDER

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MULTIPLYING DEVICE

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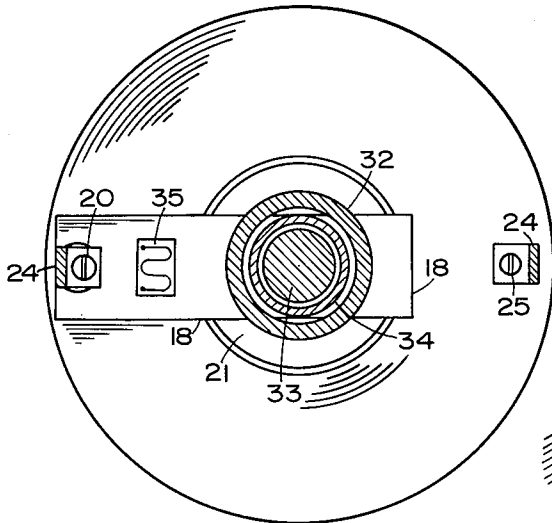


FIG. 2

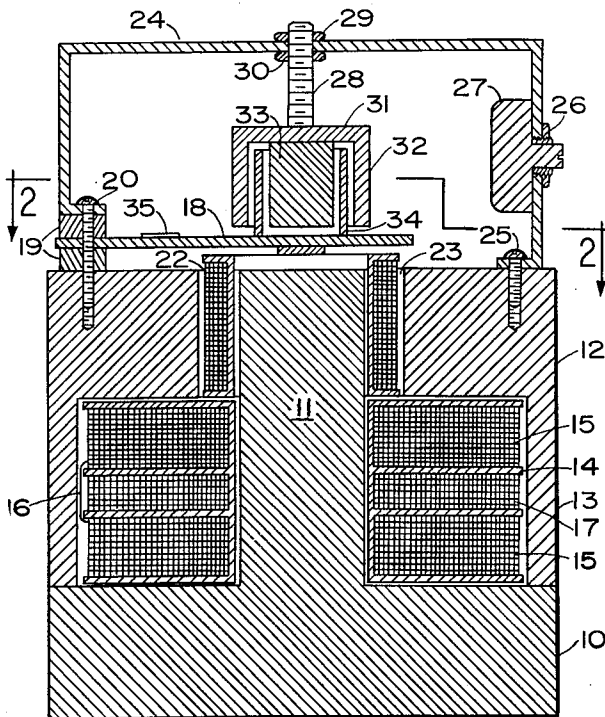


FIG. 1

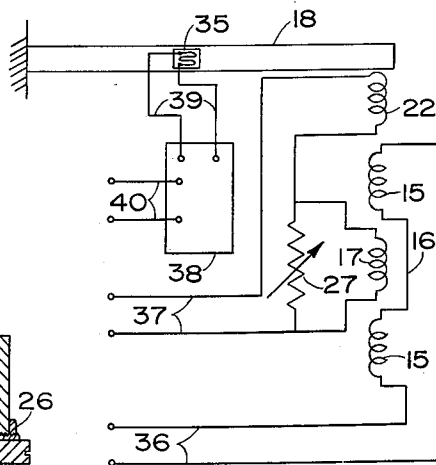


FIG. 3

INVENTOR.
JOHN DWIGHT CORDER
BY

Paul H. Johnson

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MULTIPLYING DEVICE

John Dwight Corder, 226 Harrison St., Lewisburg, Pa.

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9 Claims. (Cl. 235-194)

This invention relates to a device for the multiplication of electric signals. More particularly, this invention relates to a device for the electromechanical multiplication of electrical signals for use with analog computers.

Many applications in electronic computers involve equations requiring the multiplication of two variable quantities. These variable quantities are represented by proportionate voltage values. To obtain the product of two variables their representative voltages must be multiplied, producing a single new variable voltage, which, at all times, is the product of the two input voltages.

One type of multiplier in use is the servo-driven potentiometer type. This type of multiplier is capable of relatively high accuracy but is limited in its application by its rather slow response.

Others working in this field have provided numerous types of electronic multipliers which have a much higher speed response but are less accurate and dependable and are more complicated.

Therefore, an object of my invention is to overcome the objections in other types of multipliers.

Another object of my invention is to provide an electromechanical type of multiplier with a speed response higher than the potentiometer type.

Another object of my invention is to provide a multiplier that is relatively less complicated and more dependable than the electronic types.

Another object of my invention is to provide a multiplier which will be relatively simple and inexpensive to manufacture.

These and other objects and a better understanding of my invention can be had by referring to the following specifications and claims, taken in conjunction with the following drawings in which:

FIG. 1 is a cross sectional view of the multiplier.

FIG. 2 is a cross sectional view taken along the line 2-2 of FIG. 1.

FIG. 3 is a diagram showing schematically the circuit arrangement of the invention.

Referring now to FIG. 1 and FIG. 2 the numeral 10 represents a circular base, having a center piece 11. A top plate 12 having an integrally formed shell 13 fits on the base 10. All of these components are made of high permeability metal having a low hysteresis loss in the presence of an alternating electromagnetic field.

Slideably mounted on the center piece 11 is a primary coil form 14, having three sections adapted for receiving windings of magnet wire. The two outer sections of the primary coil form 14 contain the windings of the stationary coil 15. Although the windings of stationary coil 15 are in two sections, they are connected by a jumper 16 to form, in effect, a single coil. Wound on the inner section of primary coil form 14 is a neutralizing coil 17 which is electrically separated from the two sections of the stationary coil 15.

A cantilever beam 18 is supported to the top plate 12 by spacers 19 and a screw 20. A moveable coil form 21, made of aluminum or some similar light weight material, is supported to the cantilever beam 18. Wound within the moveable coil form 21 is moveable coil 22. The moveable coil 22 surrounds, but does not touch center piece 11. Thus, moveable coil 22 is free to move up and down small distances within the air gap 23 existing between the center piece 11 and top plate 12, bending cantilever beam 18 as it moves.

A bracket 24, disposed across the top of the multiplier,

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is affixed by screws 20 and 25. Supported to the bracket 24, by nut 26, is a diverter rheostat 27, similar to Ohmite Manufacturing Company's catalog number CLV 1031.

Also supported to bracket 24, by stud 28 and screws 29 and 30, is a dampening base 31. The dampening base 31 has an integrally formed flange 32 and is composed of high permeability metal. Affixed to dampening base 31, and within flange 32 is a cylindrical permanent magnet 33. Supported to the cantilever beam 18, and disposed in the annulus between the dampening base flange 22 and the permanent magnet 33 is a dampening shell 34, composed of aluminum or a similar light weight metallic material.

Affixed to the cantilever beam 18 at a point between the dampening shell 34 and the supporting spacers 19 is a strain gage 35. The strain gage 35 is bonded to the cantilever beam 18 by an adhesive material such as an epoxy base cement.

Referring now to FIG. 3 the electrical relationship of the components of the invention are shown diagrammatically. The two segments of stationary coil 15 are connected with jumper 16. Moveable coil 22, affixed to cantilever beam 18 is in series electrically with neutralizing coil 17. The diverter rheostat 27 is electrically paralleled with neutralizing coil 17.

One of the electrical input signals to be multiplied is applied directly across stationary coil 15 by conductors 36. The other electrical input signal to be multiplied is applied across the moveable coil 22 in series with neutralizing coil 17 by conductors 37.

The strain gage 35, affixed to cantilever beam 18, is electrically connected to a strain gage measuring system 38 by conductors 39. Various strain gage measuring systems 38 are commercially available. Although not shown on the drawing, it is within the purview of my invention that the strain gage measuring system 38 can be compactly built and physically incorporated with the structure of my invention to form a completely self contained multiplying system. The product of the signals introduced on conductors 36 and 37 is obtained on conductors 40 as the output of the strain gage measuring system 38.

Operation

One of the signals to be multiplied is fed by conductors 37 into moveable coil 22 and neutralizing coil 17. As current flows through moveable coil 22 an electromotive force is established, tending to develop lines of magnetic flux in center piece 11. Neutralizing coil 17 is wound in the opposite direction of moveable coil 22 so that current flowing in the neutralizing coil 17 tends to develop lines of magnetic flux in a direction in the center piece 11 opposite to that of the moveable coil 22. Neutralizing coil 17 has more turns of wire than does the moveable coil 22. Thus only a part of the current which flows through the moveable coil 22 need flow through the neutralizing coil 17 to counteract and neutralize the magnetic flux tended to be induced by the moveable coil 22. By adjusting the diverter rheostat 27 a proper ratio of resistance with the impedance of neutralizing coil 17 may be obtained so that a correct proportion of current flows through the neutralizing coil 17 to balance the electromagnetic force developed by the moveable coil 22. Once the diverter rheostat 27 has been adjusted it is not necessary that it be readjusted. Regardless of the amount or wave shape of the current flowing in moveable coil 22, the portion of the current flowing in neutralizing coil 17 will eliminate any magnetic flux tended to be developed in the center piece 11.

The other signal to be multiplied is fed into stationary coil 15 by conductors 36. As current flows through stationary coil 15, electromagnetic force is generated to produce magnetic flux lines in center piece 11. The complete

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path of the generated flux is through center piece 11, the base 10, shell 10, top plate 12, the air gap 23 and back to center piece 11. Due to the geometric construction of the multiplier the magnetic flux generated by stationary coil 15 is concentrated in the air gap 23.

When a voltage is impressed on conductors 36 current flows in stationary coil 15, producing magnetic flux in air gap 23. If a voltage is simultaneously impressed on conductors 37, an electromotive force is developed by current flowing through moveable coil 22 at a right angle to the flux in the air gap 23. The reaction of the electromagnetic forces causes the moveable coil 22 to exert a physical force on the cantilever beam 18. The force will be either up or down depending on the polarity of voltages impressed on conductors 36 and 37.

Within its elastic limits, the stress developed by moveable coil 22 on the cantilever beam 18 will result in the creation of a directly proportional strain in the cantilever beam 18. The amount of the strain is detected by strain gage 35 bonded to the cantilever beam 18. By calibrating properly, the output at conductors 40 of the strain gage measuring system 38 is adjusted to be a voltage which is the product of the input voltage at conductors 36 and 37. The stress exerted by the moveable coil 22 will at all times be a product of the electromotive force generated by stationary coil 15 times the electromotive force generated by moveable coil 22. This stress is converted directly into strain in the cantilever beam 18, where it is detected by strain gage 35 and converted into a voltage equivalent by the strain gage measuring system 38. Therefore the output voltage at conductors 40 is a product of the input voltages at conductors 36 and 37.

When the voltage at conductors 36 is zero, no stress is exerted on the cantilever beam 18 because there is no magnetic flux in the air gap 23, regardless of the voltage on conductors 37. Conversely, when the voltage is zero on conductors 37, no stress is exerted on the cantilever beam 18 because there is no electromotive force developed by moveable coil 22 to react with the flux in the air gap 23, regardless of the value of the voltage on conductors 36. This is in conformity with the mathematical relationship that the product of zero times any quantity is zero.

The cantilever beam 18 will have a natural oscillating frequency determined by such factors as the length, the cross sectional area, the modulus of elasticity of the material and the weight of the moveable coil 22 affixed to it. According to the application of the multiplier, it may be desirable to diminish the effect of the cantilever beam's natural oscillation. This is accomplished by providing a dampening system in association with the cantilever beam 18. Several dampening means suggest themselves, however, by way of example, I have shown a method of providing pure velocity dampening. The dampening shell 34, affixed to the cantilever beam 18, is disposed to move up and down within the annulus between permanent magnet 33 and dampening flange 32 as the cantilever beam 18 tends to oscillate. As the dampening shell 34 moves, it cuts the lines of magnetic flux created by permanent magnet 33. This sets up a counter-electromotive force within the dampening shell 34, opposing the direction of movement in the magnetic field created by permanent magnet 33, retarding the movement and thereby stopping the oscillation of cantilever beam 18. By nuts 29 and 30 on stud 28, the dampening base 31 can be raised or lowered, changing the volume of dampening shell 34 in the flux field of permanent magnet 33 and thereby varying the amount of dampening to adapt the multiplier to various applications.

The optimum sensitivity of the strain gage 35 depends upon a small force exerted by moveable coil 22 producing a large amount of strain or "bend" in the cantilever beam 18. This would indicate a long, thin and narrow configuration of high flexibility material for the cantilever beam 18. However, this configuration would tend to pro-

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duce a cantilever beam 18 having a low natural frequency of oscillation. In order to prevent the natural oscillatory frequency of the cantilever beam 18 being a deterrent to accuracy of results of the multiplier, the natural frequency should be several times higher than the anticipated operating frequency. A high natural frequency of the cantilever beam 18 would require parameters tending toward a short, wide and thick beam of flexible material. Therefore, high natural frequency is obtained at the expense of sensitivity. I have discovered a mathematical derivation giving a figure of merit of any proposed cantilever beam 18 with given parameters, as follows:

$$K = \sqrt{\frac{M}{BDLE}}$$

where K is the figure of merit; M is the total weight of the moveable coil form 21, the moveable coil 22 and the dampening shell 34, in slugs; B is the width of the cantilever beam 18 in inches; D is the thickness of the cantilever beam 18 in inches; L is the length of the cantilever beam 18 in inches; and E is Young's modulus of elasticity of the material of which the cantilever beam 18 is constructed.

Although I have described my invention with a certain degree of particularity, it is understood that many changes may be made in the details of construction and operation of my multiplier without departing from the spirit and scope of my invention.

I claim:

1. A device for the multiplication of electrical signals comprising, in combination; a stationary coil; a diverter coil mounted in path of magnetic flux of said stationary coil; a moveable coil mounted within path of magnetic flux created by said stationary coil and said diverter coil; and means of converting force exerted by said moveable coil to an electrical signal.

2. A device for the multiplication of electrical signals comprising, in combination; a stationary coil; a diverter coil mounted in path of magnetic flux of said stationary coil; a beam; a moveable coil affixed to said beam and disposed within the path of magnetic flux created by said stationary coil and said diverter coil; and means of detecting strain in said beam resulting from stress exerted by said moveable coil.

3. A device according to claim 2 above wherein said diverter coil and said moveable coil are connected in a series electrical relationship wherein current flowing through said diverter coil flows through said moveable coil.

4. A device according to claim 3 above including means of proportioning percentage of current flowing through said moveable coil which will flow through said diverter coil.

5. A device according to claim 4 above wherein said means of proportioning percentage of current flowing through said moveable coil which will flow through said diverter coil includes a diverter rheostat placed electrically in parallel with said diverter coil.

6. A multiplying device having conductors for receiving signal currents inputs to be multiplied comprising, in combination; a base; a center piece integrally formed with said base; a top plate having a hole disposed to be mounted around said center piece providing an air gap between said center piece and the top plate; a shell integrally formed with said top plate disposed to be supported on said base; said base center piece, top plate and shell being of magnetic material; a stationary coil mounted within said shell around said center piece adapted for receiving one of the said signal currents to be multiplied; a diverter coil mounted within said shell and around said center piece; a beam affixed to said top plate; a moveable coil affixed to said beam disposed around said center piece and adapted for movement within said air gap between said center piece and said top plate and adapted to receive one of the said signal currents to be multiplied;

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means of diverting a portion of said signal which flows through said moveable coil through said diverter coil; a dampening means associated with said beam; a strain gage means affixed to said beam; and a strain gage measuring system electrically associated with said strain gage whereby signal current product of said signal current inputs may be obtained.

7. A device according to claim 6 wherein said means of diverting a portion of said signal current which flows through said moveable coil through said diverter coil includes; a diverter rheostat; said diverter coil connected electrically in series with said moveable coil; and said diverter rheostat connected electrically in parallel with said diverter coil.

8. A device according to claim 6 above wherein said dampening means includes a cylindrical dampening shell of metallic material affixed to said beam; a damp-

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ening base; means of supporting said dampening base adjacent said dampening shell; a dampening flange integrally affixed to said dampening base disposed externally around said dampening shell; said dampening base and dampening flange being composed of magnetic material; and a permanent magnet affixed to said dampening base within said dampening flange and disposed to protrude within said dampening shell.

9. A device according to claim 8 above wherein said means of supporting said dampening base adjacent said dampening shell includes adjustable means whereby amount of said permanent magnet protruding within said dampening shell may be varied.

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