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VARIABLE TIME DELAY MEANS

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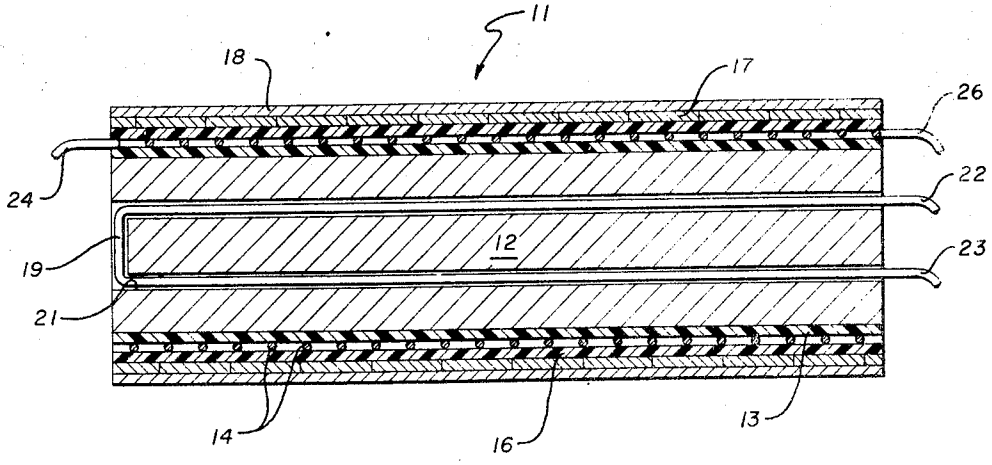
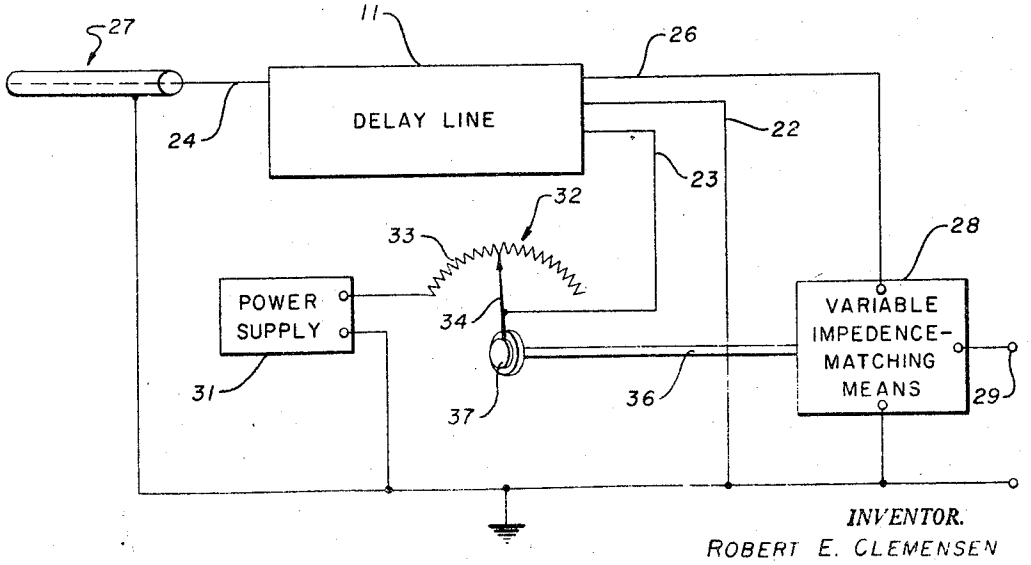


Fig. 1.

Fig. 2.



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VARIABLE TIME DELAY MEANS

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The present invention relates to improved variable time delay method and means having a precisely controllable time delay.

There have been developed various methods and means for delaying electrical signals whereby same may be employed with desired phase or time relationships; however, the majority of such methods provide only an invariable time delay. While this is satisfactory in many circuits, there are other circumstances where varying conditions or parameters require a controllable time delay. A number of different means for varying the time delay of a delay device are known; however, disadvantages have been discovered in the application thereof which has limited the utility of same.

It is an object of the present invention to provide an improved variable time delay method and means.

It is another object of the present invention to provide a time delay line including a magnetic core having a precisely controllable permeability.

It is a further object of the present invention to provide time delay means having a magnetic core with a wide permeability range and means electrically varying same for controlling time delay.

It is yet another object of the present invention to provide a variable delay line including a winding about a magnetic core with means electrically varying the core permeability and impedance matching means coupled to the coil and variable with core permeability.

It is still another object of the present invention to provide an improved variable delay line having a coil wound about a magnetic core and control means electrically varying the core permeability throughout the length thereof together with variable impedance matching means coupled to said coil and controlled by said control means.

Numerous other possible objects and advantages of the invention will become apparent from the following description of the invention taken together with the accompanying drawing, wherein:

Figure 1 is a longitudinal section taken at a central plane of a delay line constructed in accordance with the invention; and

Figure 2 is a schematic representation of a time delay system embodying the method and means of the invention.

The present invention operates to vary the time constant or time delay of an inductive circuit by varying the permeability of the linking magnetic circuit thereof. There is associated with an electrical circuit a magnetic circuit having a variable permeability so that the inductance of the electrical circuit is variable. It will be appreciated that the inductance of a coil is proportional to the permeability of the core thereof and further that the time constant of the coil is proportional to the square root of the inductance. Thus the time delay is proportional to the square root of the permeability, and also as the characteristic impedance of inductive circuit is proportional to the square root of the inductance, it, too, is proportionate to the square root of the permeability. By varying the permeability of the magnetic portion of an inductive circuit there is thus produced a like variation in time delay and characteristic impedance of the circuit.

In order for a core material to be suitable for permeability variations as noted above, it should have certain properties, such as low initial magnetism, and should be easily magnetized to saturation with a relatively small number of ampere turns. The material should not absorb excessive amounts of signal power, as by eddy currents, and should be capable of being magnetized to a high degree compared to the value of initial magnetization. Additionally, the material should have low retentivity, low hysteresis loss and require negligible coercive force, as well as being capable of following the same magnetization pattern an infinite number of times. One core material particularly well adapted for use in the present invention is cubic ferrite.

Considering now the structural details of the present invention and referring to the accompanying drawing, there is shown in Fig. 1 thereof a delay line **11** comprising a central elongated core **12** formed of a magnetic material having the above-listed properties. About this core **12** is wrapped a layer of insulation **13** and a winding **14** is wound about the core upon this insulation. A second layer of insulation **16** is wrapped about the winding **14** and an isolating shield **17** formed thereabout as by a winding of flat conductor wound about the insulating layer **16**. A final external protective coating **18**, as for example a vinyl resin sheath, envelops the shield **17** about same. Each of the successive layers of the delay line is tightly wound upon each other so as to form a compact unit.

The winding **14** of the delay line **11** is wound helically about the magnetic core **12** and is adapted to carry signals that are to be delayed. There is additionally provided a second winding **19** linking the magnetic core and adapted to carry a control current whereby the permeability of the coil may be varied and, consequently, the time delay of the signal winding **14** controlled. The second winding **19** is wound longitudinally of the core and is disposed in slots or apertures **21** formed therein; there being shown only a single turn for convenience of illustration. The slots **21** may be formed as bores internally of the magnetic core or may be disposed on the core periphery. The second winding **19**, as shown, has two end leads **22** and **23** extending from the same end of the delay line **11**, while the signal winding **14** has an input lead **24** at one end of the line and an output lead **26** at the other end of the delay line.

Considering now the time delay system of the invention as illustrated in Fig. 2 of the drawing, the input lead **24** of the delay line is connected to a signal source, not shown, as by the central conductor of a coaxial cable **27** having the outer conductor thereof grounded. The output lead **26** of the delay line signal winding **14** is connected to the input of a conventional variable impedance-matching means **28** which has the output thereof connected to an output terminal **29**. The output signal is taken between the output terminal **29** and ground as the input signal appears between the central conductor of the coaxial cable and the grounded outer conductor thereof.

Energization of the second or control winding of the delay line **11** is accomplished by a power supply **31**. One terminal of the power supply **31** is connected to one lead **23** of the second winding **19** of the delay line through a rheostat **32** while a ground return path is provided between the other winding lead **22** and the other power supply terminal. The rheostat **32** includes a resistor **33** with a contact **34** controllably slideable thereover and

connected to the lead 23. Movement of the contact 34 over the resistor 33 to vary the current flow from the power supply 31 through the second delay-line winding 19 may be accomplished by mounting the contact 34 upon a rotary mounted shaft 36 having a control knob 37 thereon. This shaft 36 also extends into said variable impedance-matching means 28 for varying the impedance thereof. As the permeability of the delay line core 12 varies directly with the characteristic impedance of the line, a direct variation of matching impedance and permeability is required and same is here obtained from a single control shaft simultaneously varying control current to the delay line and the value of the variable matching impedance.

Considering now the operation of the invention, a signal is fed to the delay line 11 through input means such as a coaxial cable 27 having the central conductor thereof connected by the lead 24 to the signal winding 14 of the delay line. After passing through the signal winding 14 of the delay line, the signal is applied to the variable impedance-matching network 28. The signal is delayed in passing through the delay line an amount determined by the time constant thereof. The time constant being directly proportional to the permeability of the delay line core 12, this permeability is varied to control the time delay. By turning the rheostat knob 37, the contact 34 is displaced along the resistor 33 to thereby vary the resistance in circuit with the power supply 31 and the control winding 14 of the delay line. In this manner the current through the control winding 14 is varied to control the permeability of the core 12. The time delay of the delay line 11 varies with the core permeability, as noted above, and also the characteristic impedance varies directly therewith so that it is necessary to match impedances to prevent reflections. In the present invention a matching impedance network is provided in circuit with the delay line at the output of the signal winding thereof and the impedance of this network is varied directly with the core permeability by means of the shaft 36. The characteristic impedance of the delay line is thus matched by the impedance 28 throughout all variations thereof as the delay line time constant is controlled and consequently no interfering signal reflections are produced at the delay line output, as would result from impedance discontinuities.

What is claimed is:

1. A delay line comprising a cylindrical magnetic core having axial openings therethrough, an insulated control winding wound longitudinally of said core in the openings thereof, a first layer of the insulation wound about said core and control winding, a signal winding helically wound circumferentially about said core upon said insulation, a second layer of insulation wound about said signal winding, an electric shield formed of electrically conducting material enveloping said second layer of insulation, and a protective coating disposed about said shield covering the exterior surface thereof.

2. Time delay means comprising a cylindrical magnetic core, a signal winding wound about said core, a control winding wound longitudinally of said core and adapted to carry a variable current for controlling more permeability, variable power supply means connected across said control winding for energizing same, a variable impedance-matching means connected to the output of said signal winding, and control means simultaneously and similarly varying said power supply means and said impedance-matching means.

3. Time delay means comprising a magnetic core having a high permeability, a signal winding wound about said core and having an input adapted to receive signals to be controllably delayed and an output, a control winding linking said core, a power supply connected across said control winding and having control means varying the output thereof, variable impedance-matching means having an input connected to the output of said signal winding and an output, and control means including a shaft operatively connected to the control means of said power supply and to said variable impedance-matching means for varying the power supply output to the control winding and the matching impedance in direct proportion.

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