Aug. 28, 1962 K. J. GERMESHAUSEN 3,051,918

TRANSMISSION-LINE TRANSFORMER

Filed Nov. 18, 1955

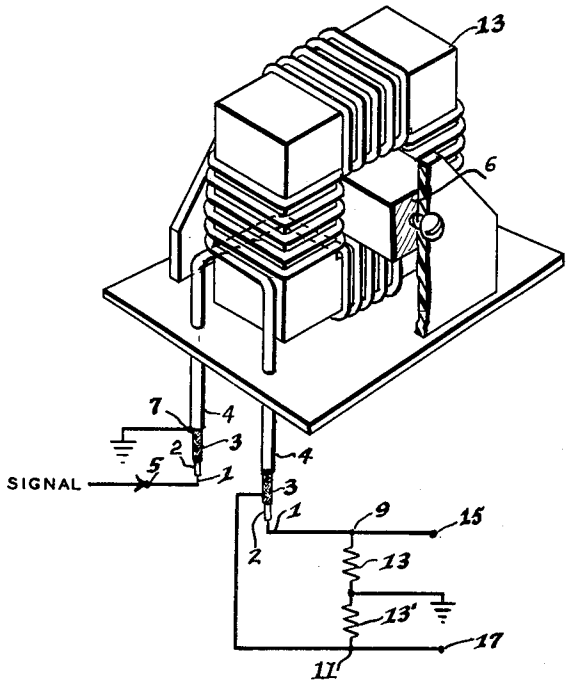


FIG. 2

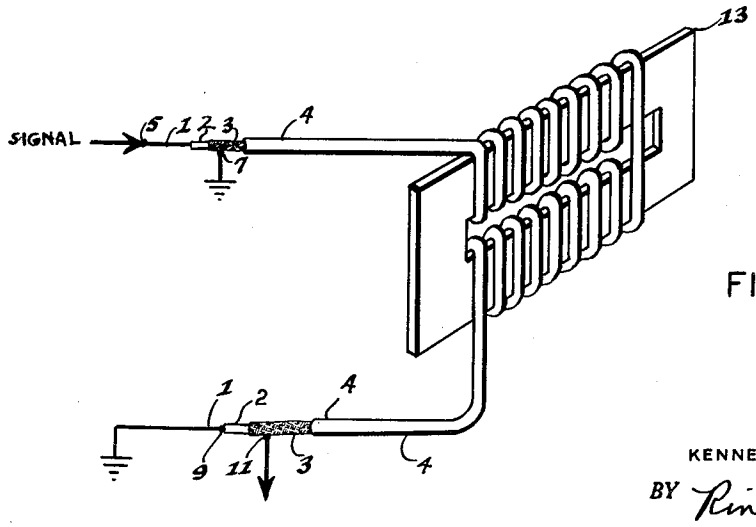


FIG. 1

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United States Patent Office 3,051,918 Patented Aug. 28, 1962

3,051,918

TRANSMISSION-LINE TRANSFORMER

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Filed Nov. 18, 1955, Ser. No. 547,595
3 Claims. (Cl. 333—31)

The present invention relates to polarity, impedance and voltage transformers and, more particularly, to transformers of the transmission-line type.

Transmission lines and similar devices have previously been utilized for the purpose of transforming the polarity of signals or transforming impedances or voltages from one level to another at opposite ends of the lines. Unfortunately, however, such devices are inherently narrow-band devices. Since it has not heretofore been possible successfully to achieve broad banding with the aid of the transmission-line type of transformer, resort has been had to other and more complex types of transformers. In accordance with the present invention, on the other hand, transmission lines may now be utilized as transformer elements over wide frequency bands and, in particular, over broad high-frequency bands.

An object of the present invention, therefore, is to provide a new and improved transformer of the transmission-line type having a very wide band-pass.

Other and further objects will be explained hereinafter and will be more particularly pointed out in the appended claims.

The invention will now be described in connection with the accompanying drawing FIG. 1 of which is a perspective view of a transmission-line transformer constructed in accordance with the present invention; and

FIG. 2 is a similar view of a modification.

In the system of FIG. 1, a transmission line comprising two conductors **1** and **3** is shown, for purposes of illustration, as of the preferred coaxial construction, the conductor **1** being the inner conductor and the conductor **3**, the outer coaxially disposed conductor. An insulating sleeve **2** separates the inner and outer conductors **1** and **3**, and the outer conductor **3** is provided with an external insulating covering **4**, as is well known. The transmission line **1**, **3** is provided at one end with a pair of input terminals **5** and **7**, and, at the other end, with a pair of corresponding output terminals **9** and **11**. The input terminal **5** is connected to the upper end of inner conductor **1** and the input terminal **7** is connected to the outer conductor **3**, being preferably grounded, as shown. The word "ground" as used in this specification and claims is intended to connote not only actual earthing, but also chassis or other reference potential. The output terminal **9**, corresponding to the input terminal **5**, is shown connected to the lower end of the inner conductor **1** and is preferably grounded, as illustrated. The output terminal **11**, corresponding to the input terminal **7**, is shown connected to the lower end of the outer conductor **3** and is at floating potential. In accordance with the present invention, the transmission line **1**, **3** is coiled transversely and continuously about the upper and lower legs of a preferably annular or ring-like magnetic core **13**, as of rectangular contour. The magnetic core **13** is constituted of a ferrite or similar material. The outer conductor **3** is, of course, insulated from the core **13** by the outer covering **4**.

When a signal, such as, for example, a voltage pulse having a wide range of frequency components, is applied to the input terminals **5** and **7**, the signal will pass along the transmission line **1**, **3** to the output terminals **9** and **11**. Since the inner-conductor output terminal **9** is terminated in a ground connection, as before stated, and the outer-conductor output terminal **11** is at floating potential, as

distinguished from the floating inner-conductor input terminal **5** and the grounded outer-conductor input terminal **7**, the signal would be reflected from the output terminal **11** back along the conductor **3** to the input terminal **7**. Since the input terminal **7** is grounded, a short-circuit condition is presented that causes the signal to return along the conductor **3** back to the output terminal **11**, arriving in opposite polarity to the polarity of the original signal at the output terminal **11**. Cancellation of signal at the output terminal **11** would thus result. This is obviated by introducing a delay into the transit time of the signal from the output to the input and back to the output again. The capacitance-to-ground and the inductance presented by the line determines the amount of time delay. Additional inductance is introduced through the expedient of the coiling or winding of the transmission line **1**, **3** as previously explained, transversely about the magnetic core **13**. The winding of the coaxial line **1**, **3** upon the core **13** may therefore be considered as presenting a high-impedance long-delay path for the reflected signal from the output terminals **9**, **11**. If the applied signal is of a particular polarity (say positive) with respect to input terminal **7**, the signal at the output terminals **9**, **11** will be of the same polarity with respect to output terminal **11**. However, since both input terminal **7** and output terminal **9** are at ground potential, it follows that output terminal **11** will be of opposite polarity (negative) with respect to ground or the output terminal **9**. Thus polarity inversion is obtained.

From another point of view, the coiling of the conductor upon the iron core may be considered as increasing the inductance in the path of the shielded cable, since when the device is used as a pulse inverter the shield represents a direct-current short circuit across the input to the device. The impedance of this short-circuit at the higher frequencies must be raised if the device is to be operated properly. The impedance may be raised by increasing the inductance in the shorting path and this is done by the wrapping or coiling of the conductor around the iron core, as before explained.

The result of this construction is materially to increase the low-frequency response of the transmission line and hence the length of voltage pulses utilizable therewith, thereby providing wide or broad-band operation of the transmission line as a polarity inverter or transformer.

The capacitance-to-ground is reduced by maintaining the assembly away from close proximity to grounded surfaces such as shields, and the like, the resulting reduction in delay time being compensated for by the increased inductance provided by the coiling of the line. This construction also results in still a further advantage since it greatly increases the impedance of the conductor **3** to ground, thereby preventing excessive loading of the signal arriving at the terminal **11**.

The polarity inverter or transformer of FIG. 1 is particularly adapted for operation with an unbalanced system. It is of particular utility as a polarity inverter for pulses, such as those utilized for the purpose of triggering thyratrons or other pulsed devices, or for transient signals that are to be oscillographically observed in the study of fast, wide-band transients and the like. The present invention, however, is equally applicable for providing unbalanced-to-balanced signal connections, as shown in FIG. 2. The output terminal **9** is there shown connected to ground through a terminating resistor **13**. The output terminal **11** is similarly connected to ground through a similar resistor **13'**. Between the further output terminals **15** and **17**, connected, respectively, to the output terminals **9** and **11**, a pair of balanced outputs with respect to ground is thus achieved, effecting a transformation from the unbalanced input terminals **5**, **7** to the balanced output terminals **15**, **17**. This is useful for

such purposes as providing a balanced signal for television or other receivers from an unbalanced coaxial-line input, or where similar balanced and unbalanced conditions must be met. Wide-band high-frequency operation is again obtained by the expedient of coiling or winding the transmission line 1, 3 about the magnetic core 13. In the system of FIG. 2, the sides as well as the top and bottom legs of the core 13 are employed for the continuous coiling or winding of the line 1, 3, as is a core of greater thickness than the substantially planar core of FIG. 1. This, of course, increases the value of the introduced inductance. The core 13 may be mounted upon an insulating block 6, as shown in FIG. 2.

In actual practice, the present invention requires a number of turns of the line 1, 3 about the magnetic core 13, usually in the neighborhood of ten or twenty turns, more or less. The low-frequency cut-off or the maximum duration of a transient signal that the transformer of the present invention will pass is determined primarily by the number of turns on the core 13 and by the magnetic properties of the core. The number of turns required to give the desired inductive impedance can be easily computed by the same well-known methods used in the design of pulse transformers. The high-frequency-limit of the device, however, is determined by the transmission-line attenuation characteristics and the length of transmission line used.

As an illustration, twenty turns of conventional coaxial line wound upon a transformer core having a cross-sectional area of about 3 to 4 square centimeters and a total core length of about 8 to 10 inches, have been found to operate as a transformer in the manner, above described, having a wide frequency band-pass of from approximately 500 kilocycles up to frequencies of the order of 1000 megacycles. This transformer has been found successfully to operate not only with transient signals having a maximum duration of about one microsecond, but, also, to pass faithfully substantially square relatively narrow pulses of 10 millimicroseconds duration, thus illustrating the broad-band wide-frequency characteristics of the invention.

The transmission line need not, of course, be of the coaxial-line type, though this is preferred in view of the ease of coiling and insulating the line from the magnetic core 13. Other types of transmission lines, including the open-wire type, may, of course, also be utilized, as may magnetic cores of different configurations.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention, as defined in the appended claims.

What is claimed is:

1. Apparatus for inverting the polarity of short-duration wide-bandwidth electrical impulses comprising:

a source of unbalanced short-duration wide-bandwith impulses having its output referenced to ground;

a load adapted to receive the inverted impulses;

a coaxial transmission line having a center conductor, and an outer conductor insulated from the center conductor, one of said conductors having a first input terminal at one end of the transmission line and a first output terminal at the other end of the transmission line, and the other of said conductors having a second input terminal at the said one end of the transmission line and a second output terminal at the said other end;

means for connecting the said source to the said first input terminal;

means for connecting the said load to the said second output terminal;

means for connecting the first output terminal to the second input terminal through ground; and

a closed magnetic core about which said coaxial transmission line is coiled a plurality of times intermediate the said input and output terminals, said core being insulated from the conductors of the transmission line.

2. Apparatus as claimed in claim 1 and in which the said first output terminal and the said second input terminal are connected to a common ground.

3. Apparatus as claimed in claim 2 and in which the said source is connected to the said center conductor of the coaxial transmission line, and in which load is connected to the said outer conductor.

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