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W. H. BOSTICK
PULSE TRANSFORMER CIRCUIT
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FIG. 1

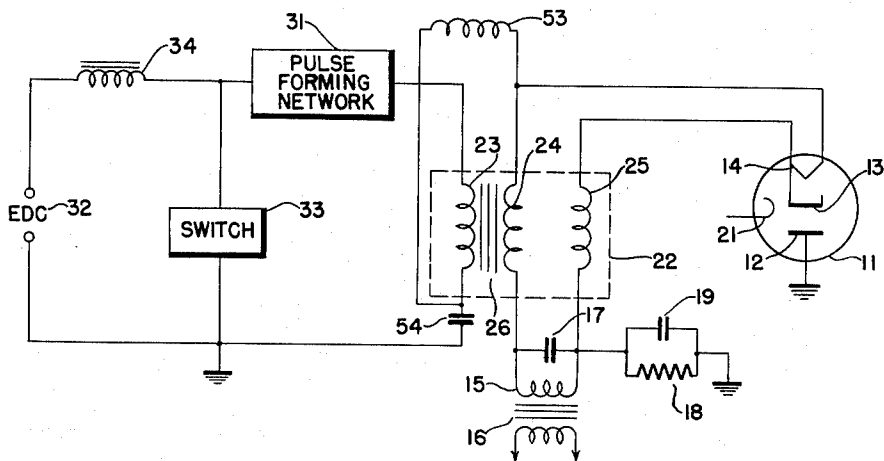


FIG. 2

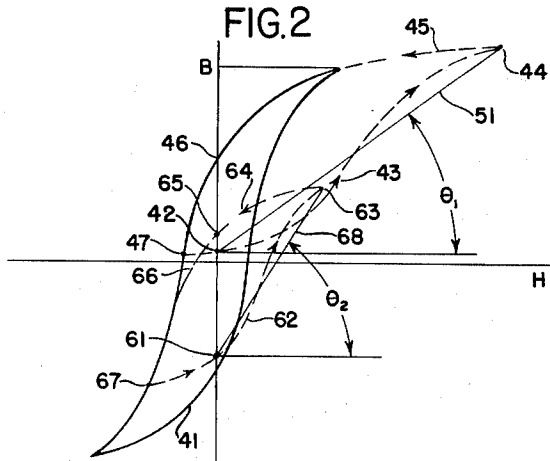


FIG. 3A

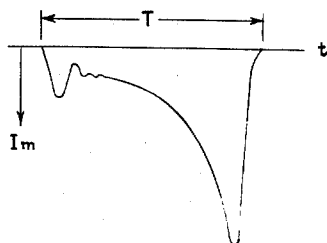
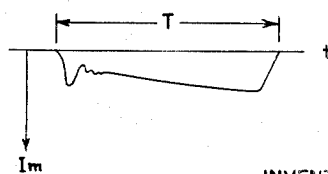


FIG. 3B



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PULSE TRANSFORMER CIRCUIT

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13 Claims. (Cl. 332-51)

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My invention relates in general to the problem of impulse signal generation and more particularly concerns a novel electrical circuit adaptable for use with an impulse modulating transformer for improving the performance thereof.

A factor which influences the operation of a transformer is the effective permeability of the magnetic core which is in turn dependent upon the magnetic characteristics of the core material itself. In impulse modulating transformers wherein a short, unidirectional voltage impulse is periodically applied to the transformer primary winding, another factor, namely the remanence, or the extent of permanent magnetization of the core, also influences the transformer performance, since the maximum practical flux density change in the core is less than the difference between the peak flux density at magnetic saturation and the remanence.

From the standpoint of efficiency it is desirable that the transformer core remanence be reduced in value between pulses, or actually made negative, so that a succeeding pulse applied to the primary winding may cause a comparatively large flux change with minimum magnetizing force, and consequently minimum primary magnetizing current.

It is therefore a specific object of my present invention to provide an electrical circuit adapted to improve the operating characteristics of a pulse modulating transformer.

Another object of my invention is to interconnect the windings of a pulse transformer so that the charging current flow between impulses in normal operation of an impulse modulating circuit properly adjusts the magnetic condition of the transformer core to a preferred value of low or negative remanence.

A further object of my invention is to provide an impulse modulating circuit wherein the normal circuit charging current between impulses readily establishes a desired transformer core magnetization without effect during the period of a pulse.

These and other objects of my present invention will now become apparent from the following specification taken in connection with the accompanying drawings in which:

Fig. 1 is a schematic diagram of a representative pulse modulation system including the features of my invention;

Fig. 2 is a graphical representation of the magnetic characteristics of a transformer core;

Fig. 3A is a reproduction of an oscillogram il-

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lustrating the wave form of magnetizing current in an impulse transformer which does not utilize the features of the circuit of Fig. 1; and

Fig. 3B is a reproduction of an oscillogram illustrating the effective change in magnetizing current characteristics which results from the utilization of the novel circuit principles illustrated in Fig. 1.

Referring now to Fig. 1, there is illustrated a circuit which, for example, may comprise the transmitter of a radio echo detection system and is adapted for the generation of comparatively short pulses of ultra high frequency energy. The high frequency generator consists of a magnetron oscillator tube 11, the anode 12 of which is grounded. The magnetron cathode 13 is directly coupled to the heater 14 which is returned electrically to the secondary 15 of a filament transformer 16. The heater transformer secondary 15 is shunted by a small capacitor 17 and is in addition returned to ground through a resistor 18 shunted by a capacitor 19.

The magnetron 11 is inoperative between impulses. However, when the potential of the cathode 13 is driven negative with respect to the grounded anode 11 by a predetermined amount, the tube will oscillate and the generated energy is coupled to suitable transmission circuits by coupling unit 21. In the circuit illustrated, the potential required for oscillation is applied to the cathode 13 by a modulating or pulse transformer 22 which comprises a primary winding 23 and a pair of secondary windings 24 and 25 the latter windings being connected to the magnetron heater leads. The windings are disposed upon a magnetic core 26 and are preferably sealed under oil in a liquid tight housing. For a more detailed discussion of the specific physical structure of a pulse transformer, reference is made by my copending application entitled "Pulse Transformer with Magnetron Well" Serial No. 608,595, filed August 2, 1945, now Patent No. 2,549,366 issued April 17, 1951.

With respect to the filament current of the magnetron 11, the bifilar secondary windings 24 and 25 act in series and have comparatively little effect thereupon. The winding direction of secondary coils 24 and 25 are such that the pulse voltage induced therein, due to transformer action, is applied to the filament and cathode leads 14 and 13 of the magnetron, and these coils divide the total space current flow through the magnetron during oscillation.

To obtain the required succession of high en-

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ergy, high frequency electrical impulses, the modulating transformer primary is correspondingly pulsed by a modulating signal generating circuit, the elements of which are a pulse forming network 31, a source of direct high potential at terminals 32 and a switching device 33. The pulse forming network may for example consist of an artificial transmission line or a simple capacitor arrangement.

The elements of the system described to this point, and not including inductor 53 and capacitor 54, comprise all those normally required for a conventional radio echo detection pulse modulation transmitter system. In operation with these circuit components only and with switch 33 open, the direct potential applied at terminals 32 results in a charging current which flows through the primary 23 of the modulating transformer 22 to charge the capacitive element of the pulse forming network 31 through the surge current limiting or charging choke 34. Closure of switch 33 discharges the pulse forming network 31 into the primary 23 of the modulating transformer in the form of a sharp, unidirectional impulse inducing a secondary voltage, negative at the cathode 13 with resultant high frequency oscillation in tube 11 as previously described.

The operating features and disadvantages of the basic pulse system described hereinabove will now be discussed in connection with Fig. 2, illustrating the magnetization characteristics of the iron core 26 of the pulse transformer shown in Fig. 1. The curve 41 is a conventional hysteresis loop, that is, a plot of the flux density in the transformer iron core as the field magnetization is varied through a cycle. In impulse transformers such as 22 in Fig. 1, the magnetic problem is somewhat less conventional due to the fact that the primary is pulsed with unidirectional signals. In this case the effect of the permanent magnetism or remanence in the iron core must be considered.

As an example, consider that the permanent magnetic field retained in the iron core after an impulse is represented by the flux density B at point 42, at zero applied field magnetizing force H. The application of the succeeding impulse increases the magnetization of the core as illustrated by the broken line 43. After reaching the peak of the pulse magnetizing force 44, the field decreases along line 45 until at zero field magnetization the remanence or permanent flux density is represented by point 46. However, the cessation of a pulse is followed by a charging current into pulse forming network 31, which in the conventional circuit flows, in the reverse direction, only through primary 23 of the pulse transformer. The effect of this charging current is to reverse the applied magnetizing force in the iron core 26 until a maximum negative value of H is obtained at point 47. As the network charging current falls off the magnetizing force again returns to zero and the original remanence 42 is restored. The path traced out in the foregoing paragraph in connection with Fig. 2 represents the magnetic cycle during the period between the initiation of one impulse and the initiation of the next impulse.

In the example described, the change in flux density equals the difference between the peak flux density obtained at point 44 and the flux density at the remanence point 42. As a result of the high remanence 42, the magnetic cycle occurs at the top of the hysteresis or magnetization curve in the range of core saturation. Ac-

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cordingly, the effective permeability given by the slope of line 51, or the tangent of angle θ_1 , is comparatively low. To cause the required change in flux density, therefore, the magnetizing force is necessarily large and as the magnetizing force is a function of magnetizing primary current, a correspondingly large magnetizing current is required during the interval of the modulating pulse with resultant poor efficiency and distortion of the pulse.

This excess magnetizing current is best illustrated in the reproduced oscillogram Fig. 3A which is a plot of the magnetizing current I_m as a function of time for the pulse period. This curve is characteristic of the "lap-type" or continuously wound strip magnetic transformer core lamination structure which has a very low equivalent air gap but results in output signal distortion due to the high flux density at remanence point 42. In a "butt-type" magnetic transformer core, the effects of saturation and permanent magnetism are somewhat reduced by a small air gap in the core but the air gap adds reluctance to the magnetic circuit. This reluctance makes it impossible to achieve with a butt-joint core an effective permeability as high as may be obtained with a lap-joint or continuously wound strip core with sufficient "reverse" magnetic field.

Returning now to Fig. 1, there is shown a preferable electrical connection for the modulating transformer 26 which eliminates the undesirable effects of excess transformer magnetizing current during the period of a high energy pulse. Thus an inductor 53 is used to interconnect the upper end of the secondary windings 24 and 25 and the lower end of the transformer primary 23. A capacitor 54 is placed in series with the return path of the primary winding 23 to ground. In the circuit illustrated, the charging current for the pulse forming network 31 flows, immediately after an impulse, through resistor 18 and through the transformer secondary windings 24 and 25 in parallel, and thence through the series circuit of inductor 53 and primary winding 23 to the pulse forming network 31. During this charging period the primary winding 23 and the secondary windings 24 and 25 are effectively in series and the combined ampere turns thereof provide a reverse magnetizing force within the iron core 26. The capacitor 54 isolates the primary 23 from ground, thus confining the flow of charging current to the desired series path. Closure of switch 33 initiates the discharge of the pulse forming network 31 into the primary 23 of the pulse transformer 22.

The capacitor 54 has comparatively no effect upon the short period impulse during the discharge. The inductor 53 has little effect upon the charging current of the pulse forming network 31. However, during the discharge period the inductor 53 effectively separates the primary and secondary windings of the pulse transformer 22 and precludes transient oscillations and the like. The effect of the novel electrical connection of the pulse transformer circuit illustrated in Fig. 1 is to greatly increase the magnetizing ampere turns which tend to reverse the magnetizing force in the transformer core 26 during the charging period.

The effect of the increase in reverse ampere turns during the charging period is shown in Fig. 2. The remanence prior to the initiation of an impulse indicated by point 61 is negative with respect to the remanence indicated at point 42 for prior art modulating circuits. During the

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period of an impulse as applied to the primary 23 of the pulse transformer, the magnetizing current increases the flux density of the core 28 from the negative value illustrated at point 61 along curve 62 to the positive value 63. As the magnetizing current falls off the flux density falls along curve 64 to point 65 which represents the point of zero magnetizing current. At this point the charging current for the pulse forming network 31 flows through the series combination of the primary and secondary transformer windings, thereby providing a negative magnetizing force of sufficient magnitude to reverse the direction of the flux within the magnetic core. This flux reversal occurs along curve 66 and reaches a maximum negative value at point 67. As the charging current of the pulse forming network falls off, the flux density rises in a positive direction from point 67 to the negative starting point 61. The effective permeability of the magnetic core during a cycle of the type just described is equal to the slope of line 68 or the tangent of angle 62.

It is evident from an inspection of Fig. 2, that the required change in flux density is obtained with a lesser change in magnetizing force in the example just described than that of the cycle previously described in connection with a conventional circuit. The effect of the increased permeability is reduced transformer primary magnetizing current during the impulse and is illustrated in the reproduced oscillogram in Fig. 3B. Here, as in Fig. 3A there is illustrated a plot of magnetizing current, as a function of time. The peak magnetizing current is much reduced from that illustrated in Fig. 3A due to the smaller field magnetizing force required as a consequence of the novel auxiliary network illustrated in Fig. 1.

In summary, the effect of guiding the charging current of the pulse forming network through both primary and secondary windings of a pulse transformer has the following advantages:

In a pulse transformer which is already constructed the magnetizing current in operation can be reduced, and the efficiency thereby increased and pulse distortion reduced. The pulse transformer can be used with a wider swing of flux density which means that it can accommodate a longer pulse or higher voltage without core saturation than it could otherwise. These advantages are more pronounced with a lap-joint or continuously wound strip core than with a butt joint core.

In designing new pulse transformers the lap-joint or continuously wound strip core may be used with a consequent larger available range of flux density and a higher effective permeability than can be achieved with the butt-joint construction which introduces the reluctance of an air gap to reduce the remanence. The larger available range of flux density permits the use of a smaller core, with consequent over-all reduction in the size of the transformer.

Although the pulse transformer auxiliary circuit has been described in connection with a particular modulation problem, that is, the modulation of an ultra high frequency generator, it is clear that the disclosure need not be thus limited and may be extended to provide similar advantages in other transformer circuits having like problems. I prefer, therefore, that this invention be limited, not by the specific disclosures hereinabove set forth, but by the prior art and the spirit and scope of the appended claims.

I claim:

1. In combination with a modulating transformer having primary and secondary windings, circuit means for generating a modulating signal, means for applying a charging current to said signal generating circuit means, and means for conducting said charging current through said transformer primary and secondary windings in series.

2. In combination with an impulse modulating transformer having primary and secondary windings upon a saturable core, an impulse generating network, a source of charging current for said impulse generating network, and means for directing said charging current through said transformer primary and secondary windings in series thereby providing a predetermined magnetization within said core.

3. An electrical circuit comprising a pulse modulating transformer having primary and secondary windings upon a saturable core, a pulse generating circuit for energizing the primary winding of said transformer with a succession of electrical pulses of comparatively short duration, an inductor, a source providing a charging current for said pulse generating circuit in the interval between said electrical pulses, said charging current flowing through said primary winding, said secondary winding and said inductor in series, said inductor being connected between said windings, said charging current providing a predetermined magnetization within said core.

4. Apparatus as in claim 3 and including a blocking capacitor in said transformer primary winding circuit for confining the flow of said charging current to said series path without effect upon said short electrical pulses.

5. In combination with a transformer having primary and secondary windings, a blocking capacitor serially connected to said primary winding and an inductor coupling the junction of said capacitor and said primary winding to said secondary winding.

6. In combination with a transformer having primary and secondary windings upon a magnetizable core, means connected to one terminal of said primary winding for blocking direct current flow therethrough, and means presenting a comparatively high impedance to transient currents connecting said terminal to said secondary winding, said last-named means presenting comparatively low impedance to direct current flow therethrough.

7. A pulse circuit including a magnetron having a cathode and an anode, a pulse modulation transformer having primary and secondary windings upon a magnetic core, and connected to apply pulses to bias said magnetron cathode to cause said magnetron to oscillate, a pulse forming network for energizing said transformer primary winding, a source of current for charging said network, and inductive circuit means for applying said charging current to said network through said primary and secondary windings in series connection to provide a predetermined state of magnetization within said core.

8. In a pulse circuit for periodically applying voltage pulses to energize a high frequency oscillator to produce short pulses of high frequency energy, a magnetron having a cathode and an anode, a pulse transformer having primary and secondary windings upon a magnetizable core and connected to apply pulses to bias said magnetron

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cathode to cause said magnetron to oscillate, a pulse generating circuit for energizing said primary winding of said transformer with a succession of electrical pulses of short duration, an inductor, a source providing a charging current for said pulse generating circuit in the interval between said electrical pulses, said charging current flowing through said primary winding and said secondary winding and said inductor in series, said inductor being connected between said windings, said charging current providing a predetermined magnetization within said core.

9. Apparatus as in claim 7 and including a blocking capacitor in said transformer primary winding circuit for confining the flow of said charging current to said series path without effect upon said short electrical pulses.

10. Apparatus as in claim 8 and including a blocking capacitor in said transformer primary winding circuit for confining the flow of said charging current to said series path without effect upon said short electrical pulses.

11. In combination with a pulse-modulating transformer having primary and secondary windings, a pulse-forming network, means for applying a charging current to said pulse-forming network, and means for conducting said charging current to said transformer primary and secondary windings in series.

12. In combination with a pulse-modulating transformer having primary and secondary windings, a pulse-forming network, a source of charging

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current, means for charging said network from said source, means for conducting said charging current through said transformer primary and secondary windings, and capacity coupling means for energizing said transformer primary winding by discharge of said pulse-forming network.

13. In combination with a pulse-modulating transformer having primary and secondary windings upon a magnetic core, a pulse-forming network, a source of charging current inductive circuit means for applying said charging current to said network through said primary and secondary windings in series connection to provide a predetermined state of magnetization within said core, and a capacity coupling circuit for energizing said transformer primary winding by discharge of said pulse-forming network through said transformer primary winding.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,860,897	Meade	May 31, 1932
2,138,653	Dome	Nov. 29, 1938
2,456,960	Lee et al.	Dec. 21, 1948
2,458,574	Dow	Jan. 11, 1949