

July 9, 1946.

H. GOLDBERG ET AL.

2,403,716

COMBINED AMPLIFIER AND POWER SUPPLY CIRCUIT

Filed Feb. 7, 1944

2 Sheets-Sheet 1

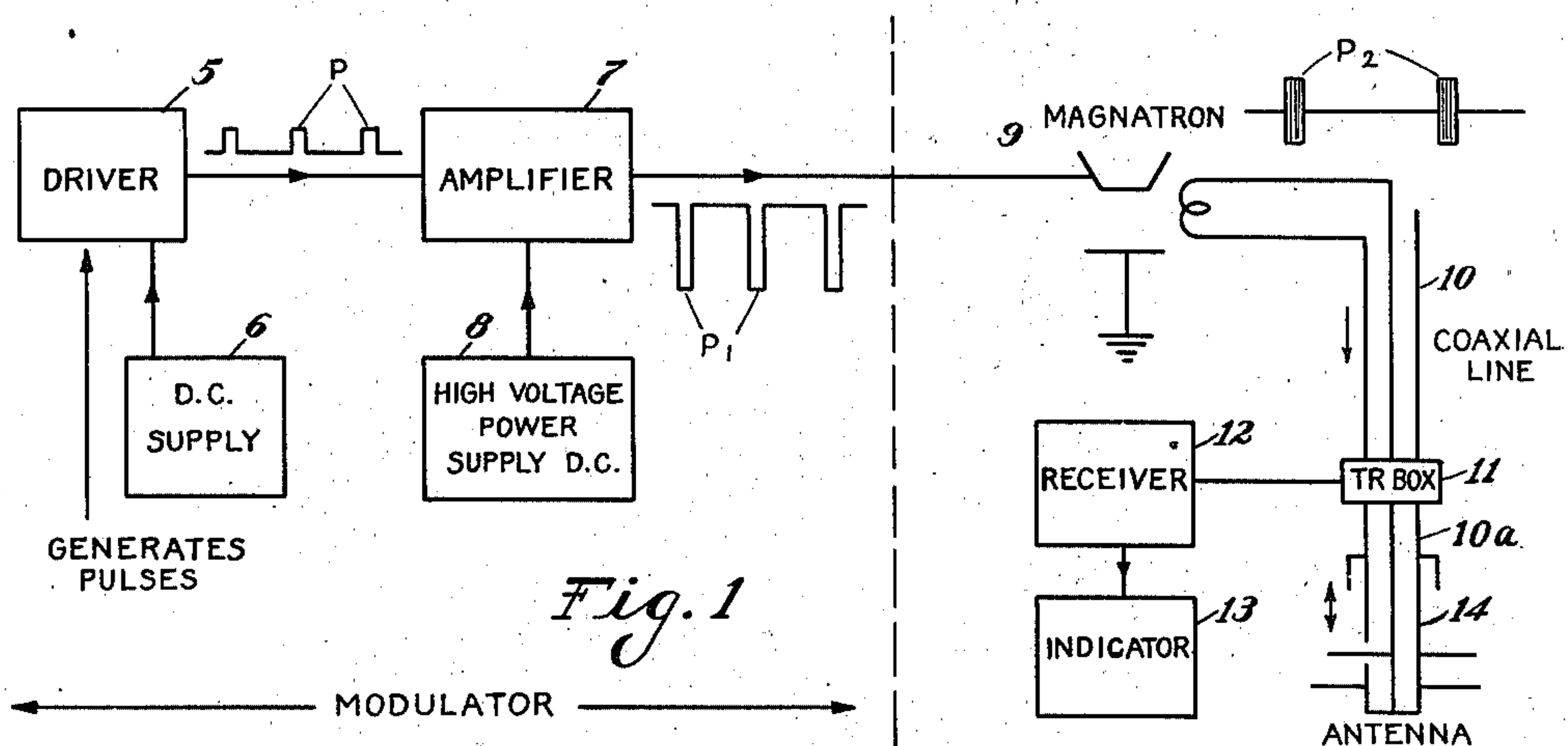


Fig. 1

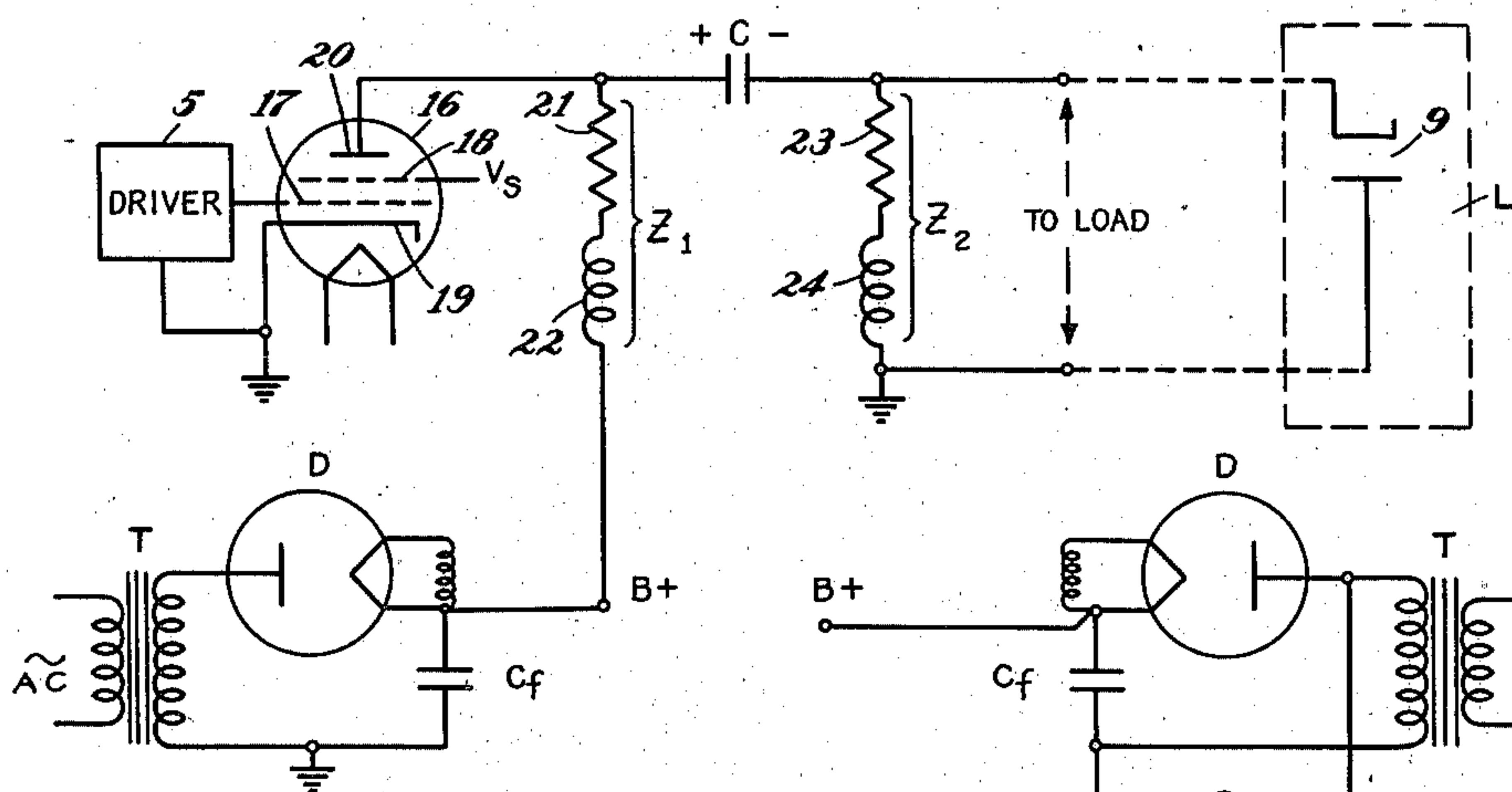


Fig. 2

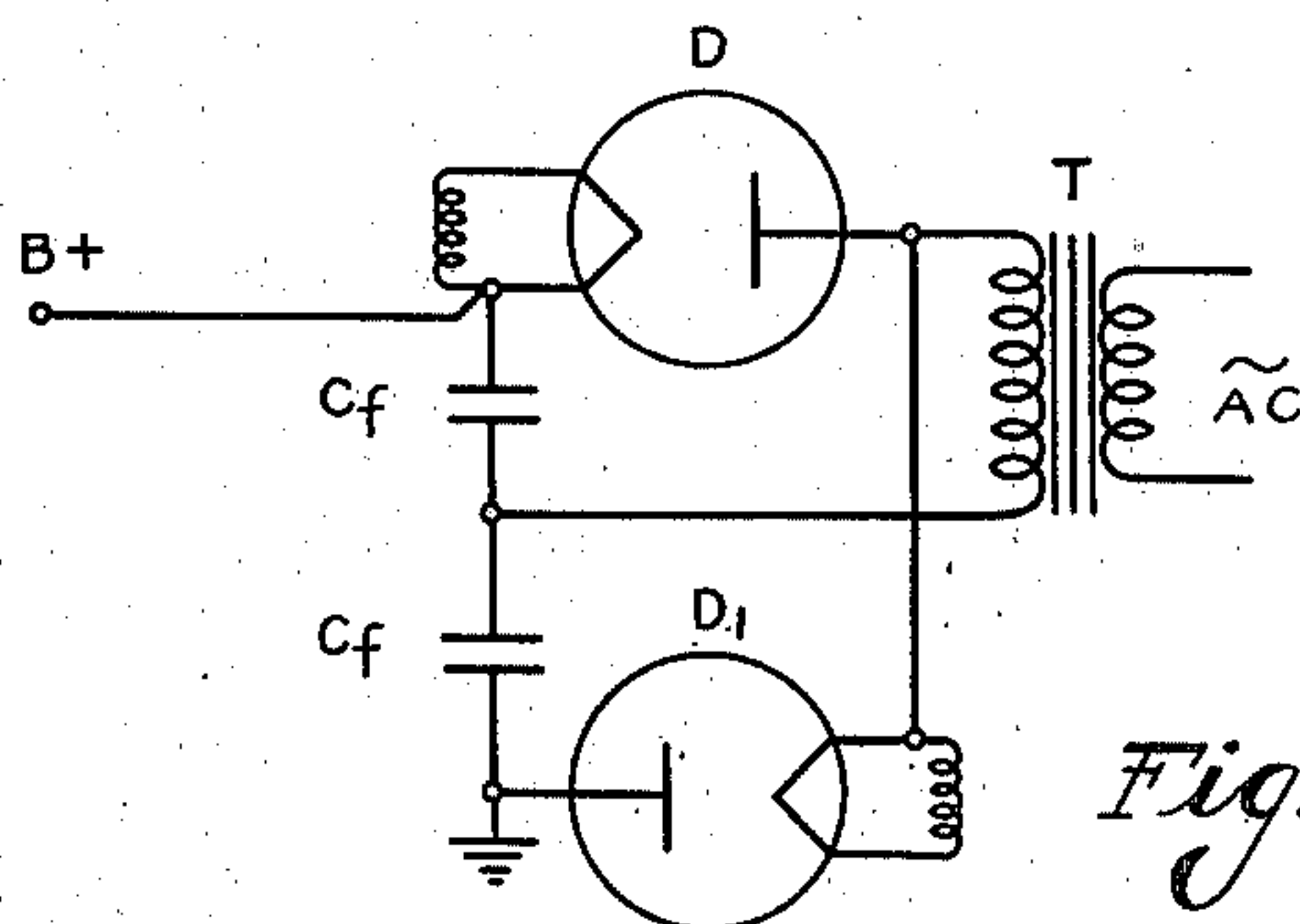


Fig. 3

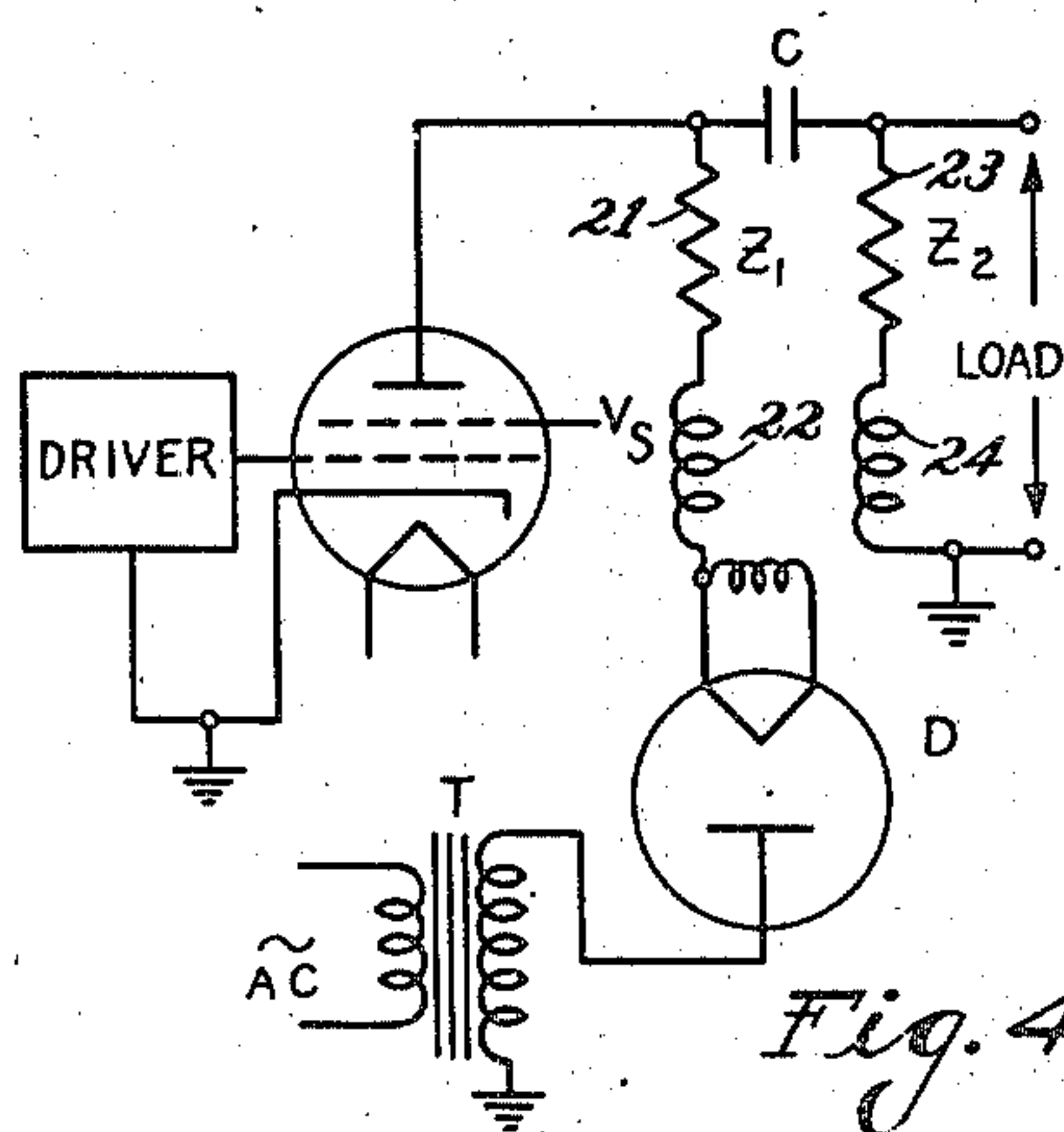


Fig. 4

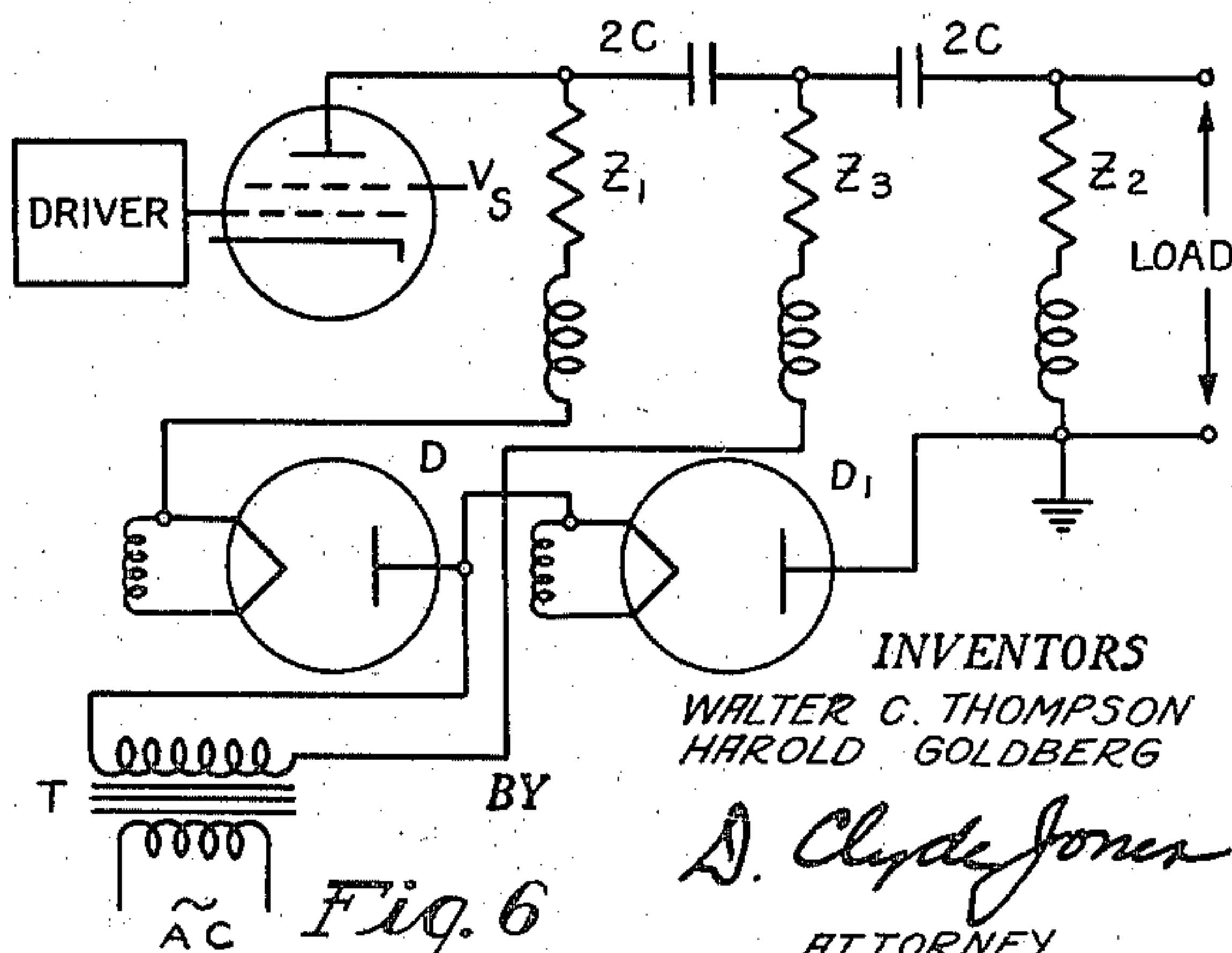


Fig. 6

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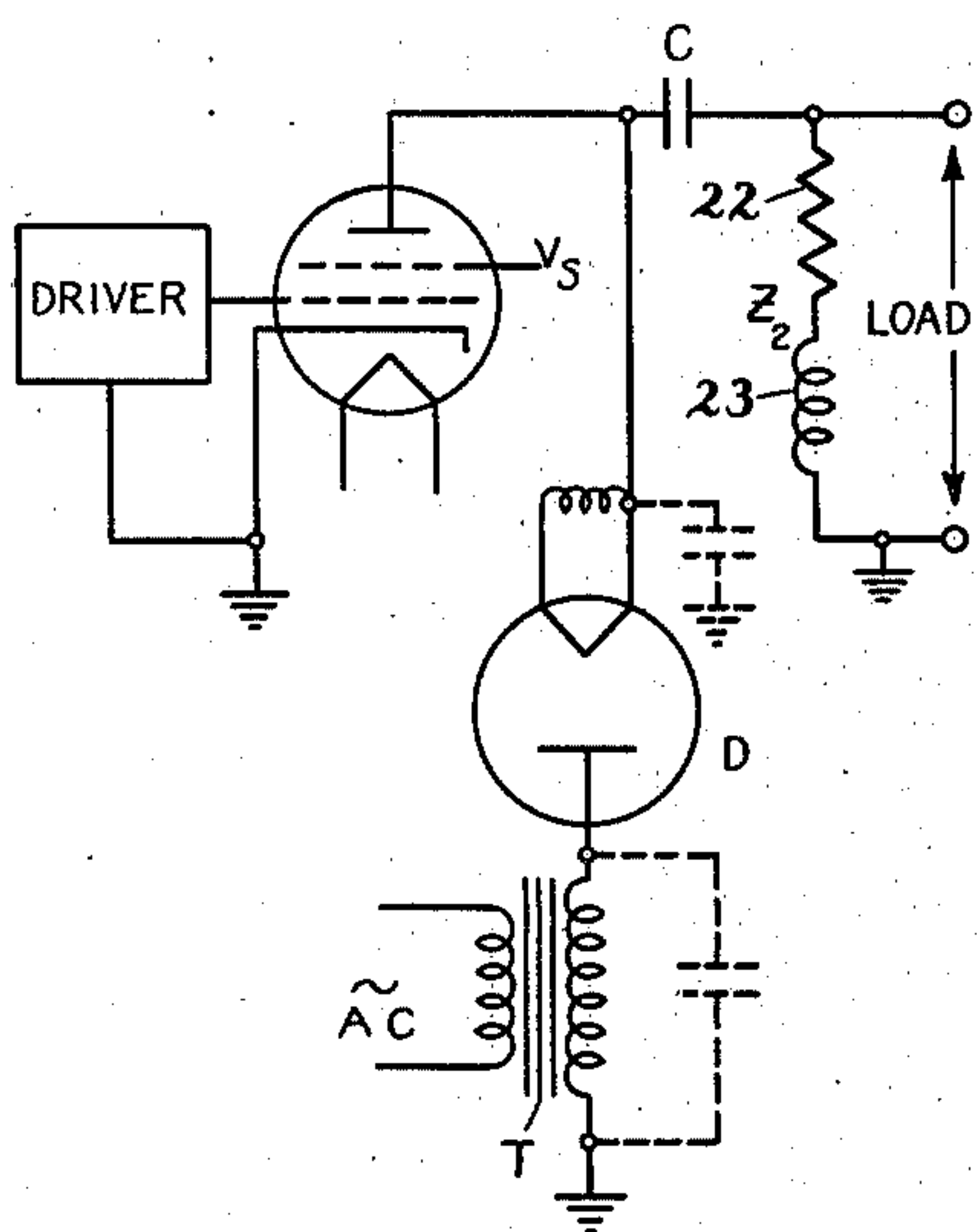


Fig. 5

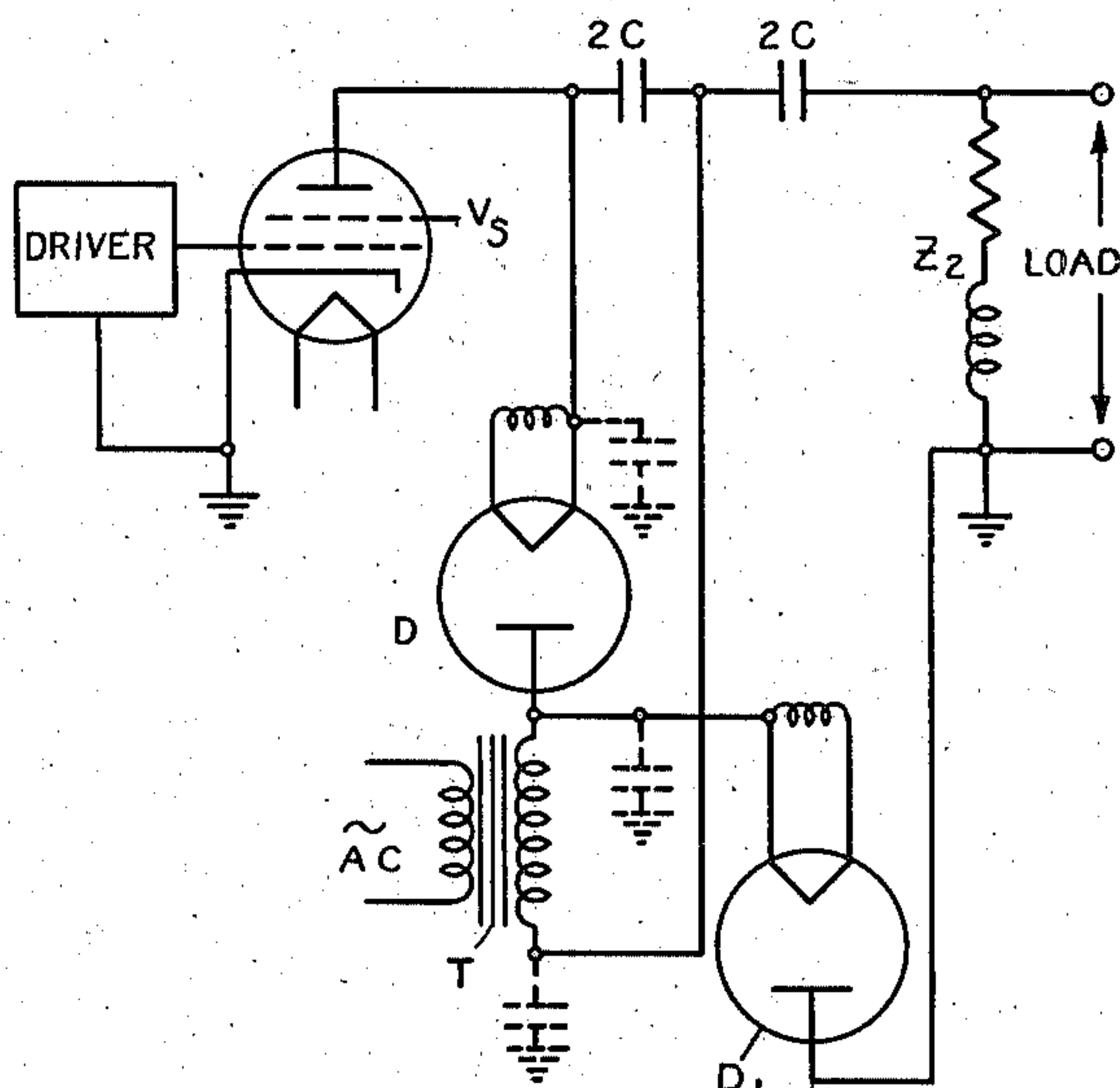


Fig. 7

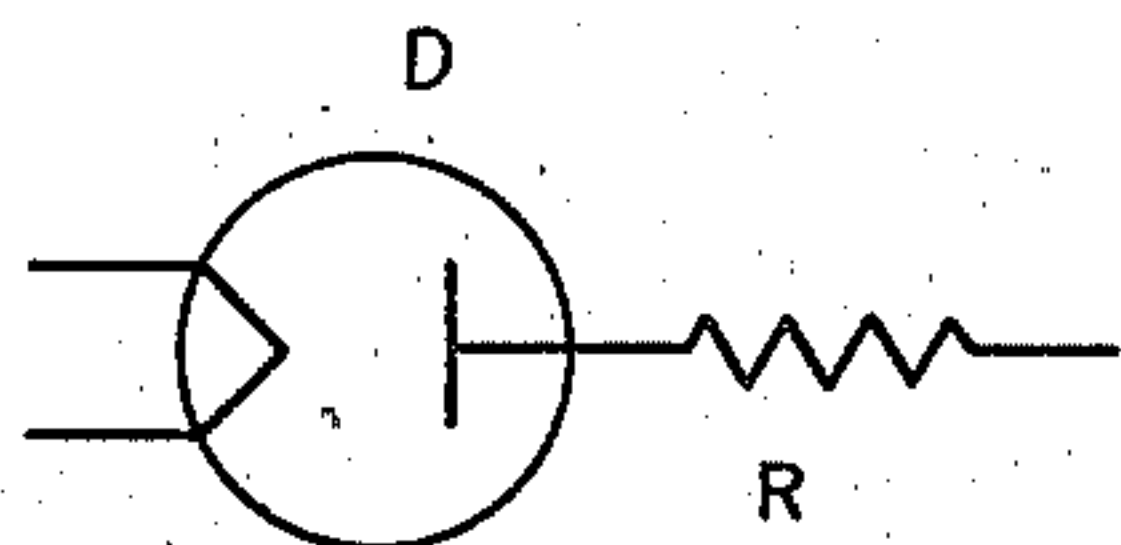


Fig. 8

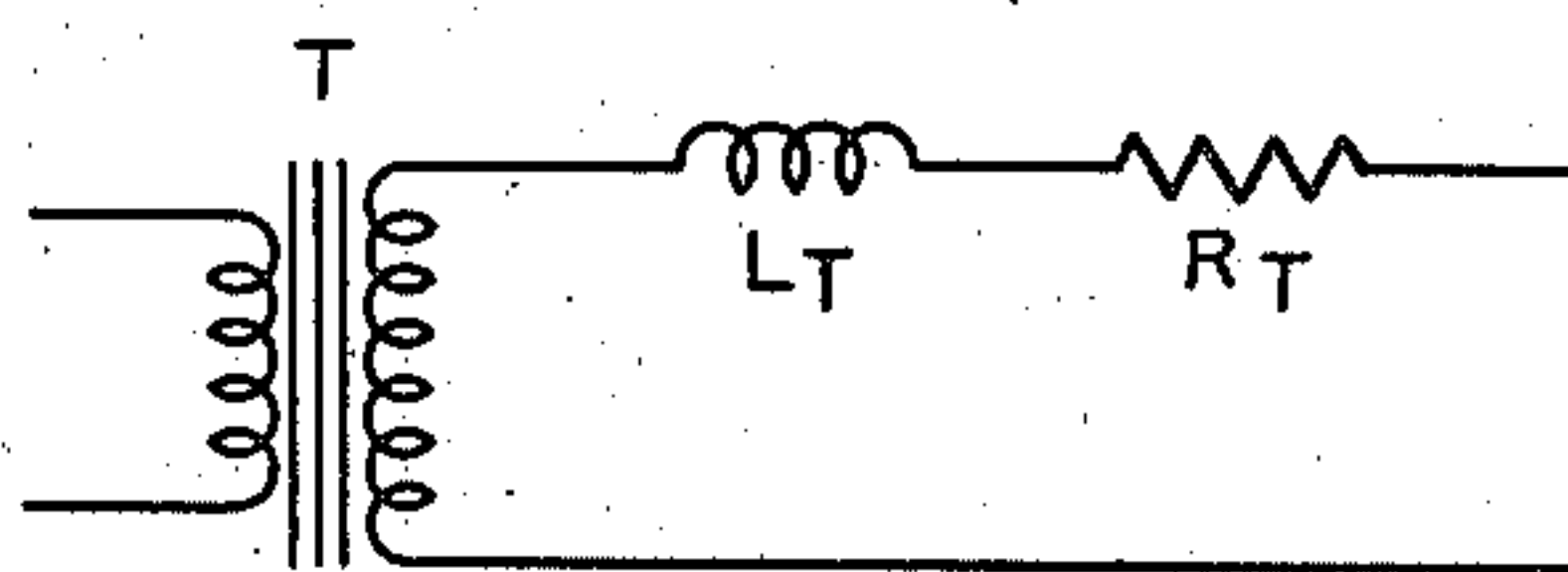


Fig. 9

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COMBINED AMPLIFIER AND POWER
SUPPLY CIRCUIT

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This invention relates to combined amplifier and power supply circuits.

In a radio locator and especially in a radio locator of the pulse echo type, there is utilized a so-called driver which applies periodic pulses of relatively high voltage, such as nine hundred volts, to the grid of an electron tube included in a so-called amplifier-clipper. A high voltage power supply unit supplies to the amplifier-clipper, a high anode voltage. For example, in one particular locator this anode voltage is of the order of fifteen thousand volts and the amplifier-clipper supplies to the load, a clipped and squared pulse at twelve thousand volts and twelve amperes.

In the past the power supply and amplifier units utilized what was considered to be the irreducible minimum of components. However, in accordance with the present invention, the number of components used in said units has been substantially reduced by having certain of these components perform not only their conventional functions but also the functions usually performed by certain components eliminated in the present novel construction. This reduction is extremely useful particularly in equipment for use in airplanes. For example, in one type of equipment, it was impossible, prior to the discovery of the present invention, to design a thoroughly reliable modulator unit for use under the severe conditions imposed by the necessity of operating such equipment in aircraft flying at high altitudes under extreme conditions of temperature and humidity.

For a clearer understanding of the invention, reference is made to the following description and claims when taken with the drawings in which:

Fig. 1 is a diagrammatic showing of a radio locator system having a modulator including a combined amplifier-clipper and power supply of the present invention indicated at the left of the broken line and having at the right of this broken line a given load such as a transmitter with its related means for transmitting exploring pulses and a receiver with its indicator for the returning or reflected exploring pulses;

Fig. 2 is a showing of a conventional amplifier-clipper with its half wave power supply;

Fig. 3 is a showing of a full wave doubler rectifier which can be substituted for the half wave rectifier of Fig. 2;

Figs. 4 and 5 are successive steps in the improvement in the circuit arrangement of Fig. 2;

Figs. 6 and 7 are successive steps in the improvement in the circuit arrangement of Fig. 2 when the half wave rectifier thereof is replaced by the full wave rectifier of Fig. 3; and

Figs. 8 and 9 are diagrams useful in setting forth the electrical characteristics of a rectifier tube and a transformer, respectively.

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In Fig. 1, there is illustrated a diagrammatic showing of a radio locator system in which the present invention is incorporated. At the left of the broken line in this figure, there is illustrated a modulator comprising a driver 5 (which generates control pulses P) with its direct current supply 6 together with the combined amplifier-clipper circuit 7 and power supply circuit 8 of the present invention. The amplifier-clipper delivers pulses P1. The portion of the locator system at the right of the broken line, but forming no part of the present invention, comprises a magnetron transmitter 9 to deliver radio frequency exploring pulses P2 and also comprises a receiver 12 with its indicator 13 together with a transmitter and receiver switch unit 11 for alternately connecting the transmitter and the receiver to a coaxial line 10a and thence to an antenna assembly 14.

The present invention is particularly directed to the amplifier-clipper circuit 7, together with a high voltage direct current power supply 8. A conventional form of these circuits using a half wave rectifier, is shown in Fig. 2. Likewise, a conventional form of these circuits results when the full wave doubler rectifier shown in Fig. 3 is substituted for the half wave rectifier which is disconnected at terminal marked B+ and the B+ connection of the full wave rectifier is connected to that terminal.

In accordance with known practice, the half-wave rectifier (Fig. 2) comprises a diode D, a filter condenser Cf and an iron core transformer T connected to an alternating current source A. C., as shown. Also in accordance with known practice, the full wave rectifier doubler of Fig. 3, comprises the two diodes D and D1, filter condensers Cf, Cf and the iron core transformer T connected to a source of alternating current A. C., as shown. No explanation of the operation of these rectifier circuits or their relative advantages is necessary since they are well known.

The amplifier-clipper (Fig. 2) includes a tetrode 16 having a control grid 17, a screen grid 18, a cathode 19 and an anode 20, the screen grid being normally supplied with a voltage Vs. It will be understood that a triode or pentode tube may be used instead of the tetrode 16. When in use, the tetrode or amplifier tube 16 is ordinarily biased to cut-off, so that during the time that no pulse P is supplied to the grid 17 thereof by the driver 5, the amplifier tube does not conduct, and the coupling capacitor C charges with the polarity shown, to approximately the voltage B supplied by the power supply. When a pulse P from driver 5 causes the grid 17 of the amplifier tube 16 to become positive to the point of saturation, this tube is rendered conducting. Condenser C begins to discharge through anode 20 and cathode 19 of the tube 16 and through the parallel com-

combination of Z2 and the load L, which includes the magnetron 9. This produces a voltage across the parallel combination of Z2 and the load L equal to the condenser voltage less the anode space drop between anode 20 and cathode 19 in the amplifier tube. During this time, the power supply or rectifier tends to discharge through Z1 and the amplifier tube 16 but the discharge current is kept small by reason of the impedance Z1. When the driver pulse P ends, the amplifier tube 16 is again rendered non-conducting so that the condenser C stops discharging. At the same time, the voltage across the load L drops to approximately zero, and condenser C, whose voltage dropped during the time it was discharging, is recharged by the power supply through impedance Z1 and the parallel combination of the load L and impedance Z2.

Impedance Z1, may be a pure inductance, or pure resistance, or a combination of both, the latter being shown herein and respectively designated Z1 and Z2. Ordinarily, wire wound resistors of the inductive type may be used. The function of impedance Z1 is to prevent the discharge of the power supply unit 8 during the pulse. This impedance must not, however, be made of a size such that the charging current to condenser C gives rise to excessively large power losses. Impedance Z2 is also a combination of inductance Z3 and resistance Z4. It is needed only when the load is a unilateral or a very non-linear device such as a magnetron 9. Such a load acts in similar fashion to a diode, and if it were not for impedance Z2, condenser C could never be charged by the power supply 8.

Since it is usually desirable that the modulator deliver a flat-topped output pulse, it is necessary that the voltage across condenser C shall not fall more than some small percentage of the voltage to which it is initially charged. This means that the total charge "IΔT" delivered to the load L during the pulse (where I is the peak current and ΔT is the duration of the pulse) must be a small percentage of the total charge in the condenser at the beginning of the pulse. If the drop is small, it is given, approximately, by

$$\Delta e = \frac{I\Delta T}{C}$$

Thus if the requirements on the output pulse are known, the minimum value of condenser C can be determined.

Since the charging of the power supply filter condenser Cf takes place at the power line frequency or a multiple of it, the voltage across condenser Cf and across condenser C will have a power line ripple component. The amount of ripple will depend, to a large degree on the total capacitance of C plus Cf, and the average load current. For minimum ripple, the total capacitance must be made as large as possible. It should be noted that while the ripple is a function of the total capacitance, the drop in output voltage during each pulse is a function of the coupling capacitance, C, only.

In general, the obstacles to small size and weight in a modulator or pulser of this kind are the inevitable large sizes of high voltage components. Generally speaking, the smallest and lightest design will also be the most efficient if the design is achieved by the elimination of elements which dissipate power or else by the use of elements in their most useful condition.

If only a certain volume of high voltage capacitors may be accommodated, the best design is one

which utilizes all of the capacitance in C and none in Cf. Such an improved circuit design shown in Fig. 4, is the conventional circuit using the half wave rectifier power supply but omitting the condenser Cf, which is employed in all conventional circuits. The operation is exactly as described before except that condenser C is recharged directly through the agency of the transformer and rectifier but without the cooperation of condenser Cf. The power line ripple is equivalent to that of a conventional circuit using a total capacitance equal to condenser C but the output pulse performance is equivalent to a conventional circuit with a coupling capacitor equal to C. Thus both the benefits of high coupling capacitance and adequate filtering are obtained. A conventional circuit with the total capacitance of C divided between condensers C and Cf will have the same ripple but poorer pulse performance.

The combined amplifier and full-wave doubler rectifier of Figs. 2 and 3 cannot be modified in the manner shown in Fig. 4. Here the form of circuit improvement, that is, in the case of the full wave rectifier, is not merely effected by the elimination of the filter condenser Cf. Instead, the coupling capacitor C has been replaced by two capacitors 2C, 2C in series, of half the voltage rating and double the capacitance. These capacitors serve both as coupling and filter capacitors. The combination in practice requires the same volume and weight as the single capacitor C since high voltage capacitors are usually built by connecting low voltage capacitors in series. The circuit performance is as previously described except that the coupling capacitor network is charged directly through the full wave rectifier doubler circuit. Impedance Z3 serves a purpose similar to that served by impedance Z1. The advantages of the circuit are those already given for the half wave circuit of similar design.

It has been discovered that the circuit arrangements of Fig. 4 and Fig. 6 can be further improved by the elimination of impedance Z1, in the arrangement of Fig. 3 and by the elimination of impedances Z1 and Z3 from the arrangement of Fig. 6, provided that certain of the retained components have appropriate characteristics. This is possible since a rectifier tube has an inherent dynamic impedance and a power transformer has an inherent leakage inductance. In other words, a rectifier tube may be represented as an ideal rectifier D in series with a resistance R (Fig. 8) and a power transformer may be represented as an ideal transformer T with the secondary winding thereof in series with the resistance RT and the leakage inductance LT of this winding (Fig. 9). It is possible, therefore, by proper choice of components to substitute these inherent circuit elements for Z1 in Fig. 4 to give the half wave rectifier of Fig. 5 and for Z1 and Z3 in Fig. 6 to provide the rectifier doubler circuit of Fig. 7. It should be noted, however, that this substitution cannot be done in the conventional circuits of Figs. 2 and 3 but is possible only after the filter condenser or condensers Cf, Cf have been removed.

The capacitances and connections represented by dotted lines (Figs. 5 and 7) are the unavoidable stray capacitances inherent in the transformers. For short pulses, it is necessary to design the transformers so that these stray capacitances are kept small. It is also necessary that the transformers be designed to stand pulse voltages since the transformers are actually pulsed

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in these improved circuits but are not pulsed in the conventional circuits of Fig. 2 and 3. For use with certain magnetron loads, it is sometimes necessary to restore impedance Z_3 into the doubler circuit Fig. 7 for the purpose of damping out certain undesirable transients. The circuits shown in Figs. 5 and 7, allow better performance than the conventional devices (Figs. 2 and 3) with fewer components, and with smaller size, and with a weight reduction of as much as twenty pounds in certain models, as compared with prior devices.

What we claim is:

1. In an arrangement of the class described, an amplifier including an electron tube provided with a cathode, an anode and a control grid, said electron tube being normally biased to cut off, means including said grid for intermittently rendering said tube conducting, a load circuit, a capacitor coupling said anode to said load, a power supply unit including a diode rectifier, and a conductive connection substantially devoid of any physical impedance element linking said diode rectifier to said anode.

2. In an arrangement of the class described, an amplifier including an electron tube provided with a cathode, an anode and a control grid, means including said grid for rendering said tube conducting, a load circuit, a capacitor coupling said anode to said load, a power supply unit including a diode rectifier, and a conductive connection substantially devoid of any physical impedance element, linking said unit to said anode, the inherent impedance of said diode rectifier alone serving to limit the current flow through said connection.

3. In an arrangement of the class described, an amplifier including an electron tube provided with a cathode, an anode and a control grid, said electron tube being normally biased to cut off, means for periodically applying positive voltage to said grid to render said electron tube conducting, a load circuit, a capacitor coupling said anode to said load, a power supply device including a diode conductively connected to said capacitor and serving to supply charging current to said capacitor, said capacitor being the sole physical capacitance element for coupling said amplifier to said load and for filtering out the ripple component from the power supplied by said rectifier.

4. In an arrangement of the class described, an amplifier including an electron tube provided with a cathode, an anode and a control grid, said electron tube being normally biased to cut off, means for periodically applying positive voltage to said grid to render said electron tube conducting, a load circuit, a capacitor coupling said anode to said load circuit, and a power supply unit including a rectifier and a transformer, said rectifier being provided with a cathode and with a plate, said transformer comprising a primary winding connected to a source of alternating current and a secondary winding included in the connection from said plate to a low reference potential, said rectifier cathode being conductively connected to said capacitor whereby said device serves to supply charging current to said capacitor, said capacitor being the sole physical capacitance element for coupling said amplifier to said load and for filtering out the ripple component from the power supplied by said rectifier.

5. In an arrangement of the class described, an amplifier including an electron tube provided with a cathode, an anode and a control grid,

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said electron tube being normally biased to cut off, means for periodically applying positive voltage to said grid to render said electron tube conducting, a load circuit, a capacitor coupling said anode to said load circuit, and a power supply unit including a rectifier and a transformer, said rectifier being provided with a cathode and with a plate, said diode being conductively connected to said anode through a connection devoid of inductance or resistance elements, said transformer comprising a primary winding connected to a source of alternating current and a secondary winding having one terminal thereof connected to said plate, the cathode return of said electron tube and the low potential side of said load as well as the remaining terminal of said secondary winding being at a common potential, the stray capacitances of said unit being reduced to a low value.

6. In an arrangement of the class described, an amplifier including an electron tube provided with a cathode, an anode and a control grid, said electron tube being normally biased to cut off, means for periodically applying positive voltage to said grid to render said electron tube conducting, a load circuit, two capacitors connected in series so that their voltages add, said capacitors serving to couple said anode to said load circuit, a rectifier including a transformer and two diodes, each having a cathode and a plate, said transformer having a primary winding and a secondary winding, said primary winding being connected to an alternating current source, one terminal of said secondary winding being conductively connected to the common terminals of said capacitors, the other terminal of said secondary winding being joined by a conductive connection to the plate of the first diode and to the cathode of said second diode, the cathode of the first diode being joined by a conductive connection to said anode, the plate of said second diode being joined by a conductive connection to the low potential side of said load circuit, at least two of said conductive connections being devoid of inductor or resistor elements.

7. In an arrangement of the class described, an amplifier including an electron tube provided with a cathode, an anode and a control grid, said electron tube being normally biased to cut off, means for periodically applying positive voltage to said grid to render said electron tube conducting, a load circuit, two capacitors connected in series so that their voltages add, said capacitors serving to couple said anode to said load circuit, a rectifier unit including a transformer and two diodes, each having a cathode and a plate, said transformer having a primary winding and a secondary winding, said primary winding being connected to an alternating current source, one terminal of said secondary winding being conductively connected to the common terminals of said capacitors, the other terminal of said secondary winding being joined by a conductive connection to the plate of the first diode and to the cathode of said second diode, the cathode of the first diode being joined by a conductive connection to said anode, the plate of said second diode being joined by a conductive connection to the low potential side of said load circuit, at least two of said conductive connections being devoid of inductor or resistor elements, the stray capacitances of said unit being reduced to a low value.

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