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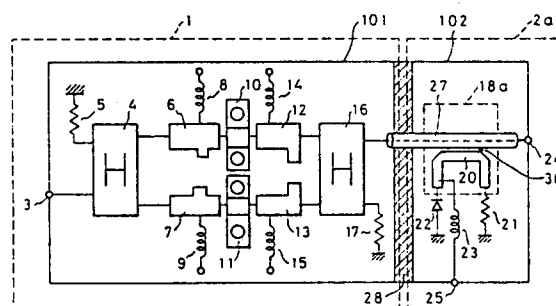
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⑤④ **Microwave power amplifier.**

⑤⑦ A microwave power amplifier having a microwave power amplifying circuit (1) and a power monitoring circuit (2).

In order to prevent power loss at connecting points, a directional coupler in the power monitoring circuit (2) is formed by a coaxial line (27) and a strip line (20). The coaxial line (27) has an opening on the outer conductor thereof so that the coaxial line and the strip line are electromagnetically coupled.

Fig.1



## Description

## MICROWAVE POWER AMPLIFIER

This invention relates to a microwave power amplifier having a microwave power amplifying circuit and a power monitoring circuit for detecting the degree of power amplification of the microwave power amplifying circuit.

The function of a microwave power amplifier is to amplify and send out an input microwave signal, and this amplifier is used in, for example, (a repeater in) a microwave multiple radio frequency transmitter (as a highpower RF amplifier).

The state of the operation of the microwave power amplifier must be constantly monitored to detect whether or not a desired power amplification is being provided. By using a DC monitor output, operation of an automatic gain controller (AGC) or automatic level controller (ALC) can be realized. To this end, in a microwave power amplifier, in addition to a microwave power circuit for carrying out a microwave power amplification, a power monitoring circuit is assembled for monitoring the degree of power amplification effected.

In one example of a microwave power amplifier, the microwave power amplifier and the power monitoring circuit are assembled within a single housing, without a shielding plate therebetween, as later described in detail with reference to Fig. 8. The power monitoring circuit in this example is formed by strip lines forming a directional coupler. This example, however, has a disadvantage in that the frequency characteristic is deteriorated due to resonance in the single housing or RF radiation coming out of a microwave power amplifying circuit.

In another example of a microwave power amplifier, the microwave power amplifying circuit and the power monitoring circuit are assembled within two separate housings, as later described in detail with reference to Figs. 9, 10, and 11, and a shielding plate is provided between the two housings. The output of the power amplifying circuit is connected through a coaxial line in the shielding plate to the input of the monitoring circuit. The monitoring circuit in this example is also constructed by strip lines forming a directional coupler. This example has an advantage in that the frequency characteristic is improved because of the separate housings. However, because a coaxial line is connected between the output strip line of the microwave power amplifying circuit and the input line of the power monitoring circuit, a considerably large power loss occurs at the connecting points between the coaxial line and the strip line.

As described above, in the above examples, if an attempt is made to improve the frequency characteristic, a large power loss occurs so that the amplification function is deteriorated; and if an attempt is made to monitor the power without deteriorating the amplification function, the frequency characteristic is deteriorated.

The present invention has been created in view of the above problems. An embodiment of the present invention may provide a microwave power amplifier

in which a power loss due to the insertion of a power monitoring circuit is small, and a power detection of microwaves with a good frequency characteristic is possible.

According to the present invention there is provided a microwave power amplifier comprising a microwave power amplifying circuit and a power monitoring circuit connected to an output of said microwave power amplifying circuit, characterised in that

said power monitoring circuit comprises:

a coaxial line for transmitting an output signal of said microwave power amplifying circuit, having an inner conductor, a dielectric supporting member covering said inner conductor, and an outer conductor covering a part of said dielectric supporting member, said outer conductor having an opening allowing radiation of electromagnetic waves from said inner conductor to outside said coaxial line, and a strip line arranged in or adjacent said opening, for electromagnetic coupling with said coaxial line through said opening to detect the output of said microwave power amplifying circuit.

Reference is made, by way of example, to the accompanying drawings in which:

Figure 1 is a general block diagram of a circuit construction of a microwave power amplifier according to an embodiment of the present invention;

Fig. 2 is a perspective view of the construction of the power monitoring circuit shown in Fig. 1;

Fig. 3 is a cross-sectional view taken along the line A-A' of Fig. 2;

Fig. 4 is a plan view of the mechanical construction of a microwave power amplifier shown in Fig. 1;

Fig. 5 is a cross-sectional view of a power monitoring circuit according to a second embodiment of the present invention;

Fig. 6 is a cross-sectional view of a power monitoring circuit according to a third embodiment of the present invention;

Fig. 7 is a general block diagram of a circuit construction of a microwave power amplifier according to a fourth embodiment of the present invention;

Fig. 8 is a general block diagram of a circuit construction of a microwave power amplifier;

Fig. 9 is a general block diagram of a circuit construction of another microwave power amplifier;

Fig. 10 is a cross-sectional view of a coaxial line between the microwave power amplifying circuit 101 and the power monitoring circuit 102 shown in Fig. 9; and

Fig. 11 is a cross-sectional view of the output end of the power monitoring circuit 102 shown in Fig. 9.

Note: Throughout the Figures, the same portions are represented by the same reference numbers.

To enable a better understanding of the embodiments of the present invention, previously proposed microwave power amplifiers will be first described with reference to Figs. 8 through 11.

Figure 8 is an example of a proposed microwave power amplifier. In Fig. 8, 1 is a microwave power amplifying circuit; and 2 is a power monitoring circuit.

In the microwave power amplifying circuit, 3 is a radio frequency (RF) input port for receiving a microwave; 4 is a branch line type 3dB hybrid circuit for branching the RF input into two outputs; and 5 is a  $50\ \Omega$  terminal resistor for the hybrid circuit 4. References 6 and 7 are input matching circuits; 8 and 9 are radio-frequency choke coils (RFCs) respectively connected to a predetermined power supply; 10 and 11 are GaAs transistors for amplifying signals; 12 and 13 are output matching circuits; 13 and 14 are RFCs; 16 is a branch line type 3dB hybrid circuit for combining the two amplified microwave signals; and 17 is a  $50\ \Omega$  terminal resistor for the hybrid circuit 16.

In the power monitoring circuit 2, 18 is a directional coupler for taking out the part of the output power of the microwave power amplifying circuit 1, and consists of a strip line 19 for transmitting the output of the microwave power amplifying circuit 1, and a strip line 20 arranged so as to be electromagnetically coupled with the strip line 19. Reference 21 is a  $50\ \Omega$  terminal resistor for the strip line 20; 22 is a detector diode for detecting a direct current component of the microwave power; 23 is an RFC; 24 is an RF output; and 25 is a DC voltage monitor output. Reference 100 is a housing in which the microwave power amplifying circuit 1 and the power monitoring circuit 2 are mounted together.

As described above, in the microwave amplifier shown in Fig. 8, since the microwave power circuit 1 and the power monitoring circuit 2 are arranged in the same housing 100, the power monitoring circuit 2 is easily influenced by the resonance of the housing 100 or the radiation power coming out of the power amplifying circuit 1. Therefore, a problem arises in that the frequency characteristic is deteriorated, and thus a correct detection of the output power is very difficult.

To obviate the above problem, another microwave power amplifier as shown in Fig. 9 has been proposed, in which the microwave power amplifying circuit 1 and the power monitoring circuit 2 are mounted respectively in two separate housings. In the Figure, 101 and 102 are the two housings for respectively mounting the microwave power amplifying circuit 1 and the power monitoring circuit 2; and 26 is a coaxial line for connecting the output strip line 90 of the microwave power amplifying circuit 1 and the strip line 19 in the power monitoring circuit 2. For simplification of the drawing, the line 90, the line between the coaxial line 26, and the strip line 19 in Fig. 9, and other lines, are not shown in full, but it should be noted that the line 90 and the other lines are also strip lines having widths similar to the strip line 19.

91 is a shielding plate provided between the

casing 1 and the casing 2.

Since the microwave power amplifying circuit 1 and the power monitoring circuit 2 are mounted in separate housings, unlike in the first example, the power monitoring circuit 2 shown in Fig. 8, is not influenced by the microwave power amplifying circuit 1. Therefore, the power monitoring circuit 2 in the second example shown in Fig. 9 can provide a good flatness frequency characteristic.

Nevertheless, a problem arises in the second example shown in Fig. 9, in that, at the connecting points between a strip line and the coaxial line, a considerably large power loss occurs. Therefore, in the construction shown in Fig. 9, even when a desired power can be obtained at the output of the microwave power amplifying circuit 1, there are a total of three changes in the transmission lines, i.e., from the strip line 90 to the coaxial line 26; from the coaxial line 26 to the strip line 19; and from the strip line 19 to the RF output terminal 24, which is usually formed by a coaxial line, and accordingly, a large power loss occurs.

This power loss will be more clearly explained with reference to Figs. 10 and 11. Figure 10 shows a cross section of the connecting points between the strip line 90 and the coaxial line 26 and between the coaxial line 26 and the strip line 19. In Fig. 10, 101a is a metal block of the housing 101; 102a is a metal block of the housing 102; 91 is a shielding plate; 103 is a dielectric substrate of alumina; 261 is a dielectric supporting member of, for example, Teflon produced by Du Pont Corporation, and 262 is an inner conductor of the coaxial line 26. The shielding plate 91 functions as an outer conductor of the coaxial line 26. The inner conductor 262 and the strip line 90 are connected by solder 263, and the inner conductor 262 and the strip line 19 are connected by solder 264. A considerably large RF power is consumed at the connecting points by the solders 263 and 264.

Figure 11 shows a cross section of the connecting point between the strip line 19 and the RF output terminal 24. In Fig. 11, an inner conductor 241 of the coaxial line, constituting the RF output terminal 24, is connected to the strip line 19 via solder 242. This solder 242 also consumes a considerable large power.

Embodiments of the present invention will be now described with reference to Figs. 1 through 7.

Figure 1 is a general block diagram of a circuit structure of a microwave power amplifier according to an embodiment of the present invention. The differences between Fig. 1 and the amplifier shown in Fig. 9 are that, in Fig. 1, in place of the strip line 19 and the coaxial line 26 in Fig. 9, a long coaxial line 27 is provided in a power monitoring circuit 2a. The coaxial line 27 transmits the amplified microwave signal from the microwave power amplifying circuit 1 to the RF output terminal 24. The outer conductor of the coaxial line 27 covers only part of the dielectric supporting member surrounding the inner conductor. Therefore, the outer conductor has an opening for partially radiating electromagnetic waves from the inner conductor to the outside of the coaxial line 27.

The opening is clearly shown in Figs. 2 and 3.

Figure 2 is a perspective view of the construction of the power monitoring circuit 2a shown in Fig. 1. Figure 3 is a cross-sectional view taken along the line A-A' of Fig. 2. In Figs. 2 and 3, 30 is the inner conductor of the coaxial line 27; 31 is a supporting member for insulation formed by fluorine-containing polymers such as Teflon produced by the Du Pont Corporation; and 32 is a block of aluminum forming the housing 102. The block 32 has a recess portion 320. On the bottom of the recess portion 320, a dielectric substrate 33 made of Teflon glass fiber or alumina is formed. The strip line 20, the terminal resistor 21, the detector diode 22, and the RFC 23 are formed on the dielectric substrate 33. Reference 34 is a ground terminal.

The recess portion 320 extends to include an opening 35 so that a part of the supporting member 31 is exposed to the outside in the recess portion 320. Accordingly, the inner conductor 30 can be electromagnetically coupled with the strip line 20, and as a result, a directional coupler 18a is formed.

Figure 4 is a plan view of the microwave power amplifier shown in Figs. 1 through 3. As shown in Fig. 4, the coaxial line 27 penetrates the block 32 of the housing 102. A part of the supporting member of the coaxial line 27 is exposed in the space of the recess portion 320 at the opening 35.

In operation, a microwave monitor power is obtained on the strip line 20 by the electromagnetic coupling through the opening 35. The detector diode 22 detects a direct current (DC) component of the monitor power. The DC component is thus obtained at a DC voltage monitoring output terminal 25.

Figure 5 shows a second embodiment of the present invention. In Fig. 5, more of the block 32a is cut away, in comparison with the embodiment shown in Fig. 3. That is, about a quarter of the surface of the supporting member 31 is exposed to the space in the recess portion 35a. According to experiments by the inventors, such a large opening has no serious influence on the characteristic impedance of the coaxial line 27. The reason for this small influence on the characteristic impedance is considered to be because almost all of the electric lines of force in the coaxial line 27 are concentrated between the inner conductor 30 and the metal block 32. That is, only a small amount of the electric lines of force is formed between the inner conductor 30 and the strip line 20, but the strip line 20 can always obtain sufficient monitoring power.

Figure 6 shows still another embodiment of the present invention. In Fig. 6, the supporting member 31a has along at least part of its length, a cross section of a sliced circle. The sliced surface (flat face) opposes the strip line 20. By this configuration, a stronger electromagnetic coupling can be established because the distance between the inner conductor 31 and the strip line 20 is made shorter. In this embodiment, an assembly consisting of a conductor substrate 32b, a dielectric substrate 33a formed on the conductor substrate 32b, and the strip line 20 is previously prepared. During manufacture of the device, a hole for inserting the supporting member 31a is made by milling, and then the supporting member 31a with the inner conductor 31

penetrating therethrough is inserted into the hole. Subsequently, the above mentioned assembly is mounted so as to abut against the surface of the recess portion 320 and the sliced surface of the supporting member 31a of the coaxial line.

Figure 7 shows a circuit construction of a microwave power amplifier according to a fourth embodiment of the present invention. In this embodiment, in contrast with the first embodiment, the monitoring microwave power obtained on the strip line 20 is directly sent out at an RF monitoring output terminal 25a. Therefore, in this embodiment, the detecting diode 22 or the RFC 23 shown in Fig. 1 are not necessary.

From the foregoing description, it will be apparent that, by providing an opening in the outer conductor of a coaxial line for transmitting the output of a microwave power amplifying circuit, and by establishing an electromagnetic coupling between the exposed coaxial line and a strip line in a power monitoring circuit, it is no longer necessary to provide, in the power monitoring circuit, a special strip line for transmitting the output power of the microwave power amplifier circuit. Therefore, the power loss incurred by connecting different types of lines is greatly reduced in comparison with previous proposals.

Further, since the power monitoring circuit and the microwave power amplifying circuit are separated by a shielding plate, the power monitoring circuit is not influenced by the microwave power amplifying circuit.

## Claims

1. A microwave power amplifier comprising a microwave power amplifying circuit (1) and a power monitoring circuit (2) connected to an output of said microwave power amplifying circuit (1), characterized in that

said power monitoring circuit (2) comprises:  
a coaxial line (27) for transmitting an output signal of said microwave power amplifying circuit (1), having an inner conductor (30), a dielectric supporting member (31) covering said inner conductor (30), and an outer conductor (32) covering a part of said dielectric supporting member (31), said outer conductor (32) having an opening (320) allowing radiation of electromagnetic waves from said inner conductor (30) to outside said coaxial line (27), and

a strip line (20) arranged in or adjacent said opening (320), for electromagnetic coupling with said coaxial line (27) through said opening (320) to detect the output of said microwave power amplifying circuit.

2. A microwave power amplifier as set forth in claim 1, wherein said opening has a size sufficient for electromagnetic coupling with said strip line whilst substantially maintaining a characteristic impedance of said coaxial line.





Fig. 3

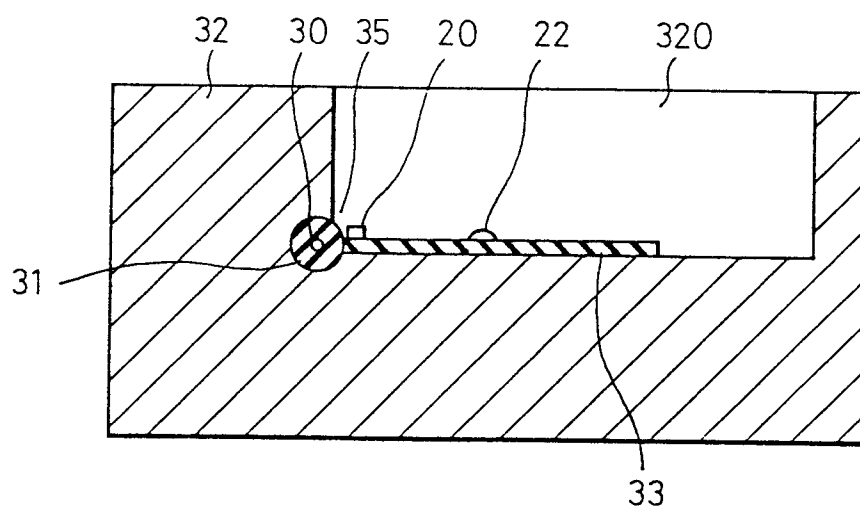


Fig. 4

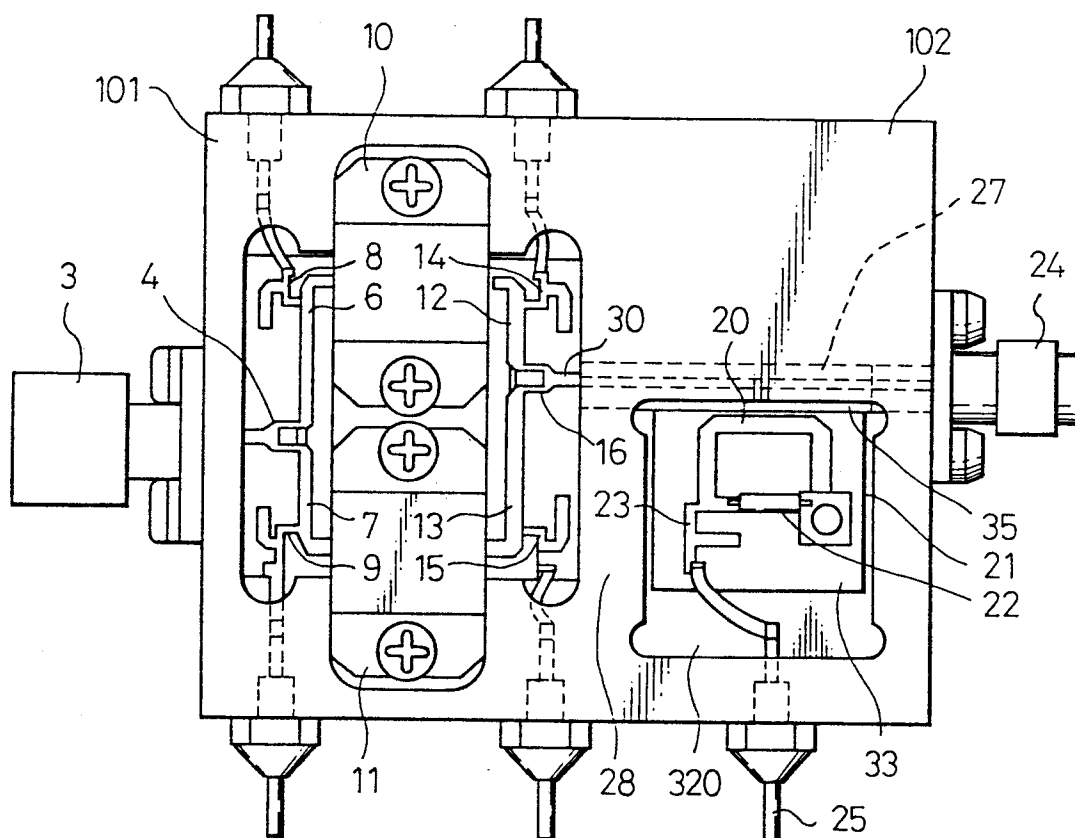




Fig. 5

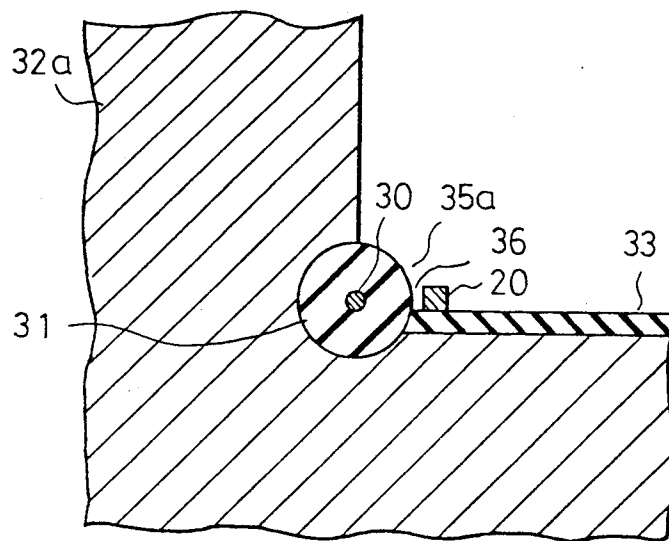


Fig. 6

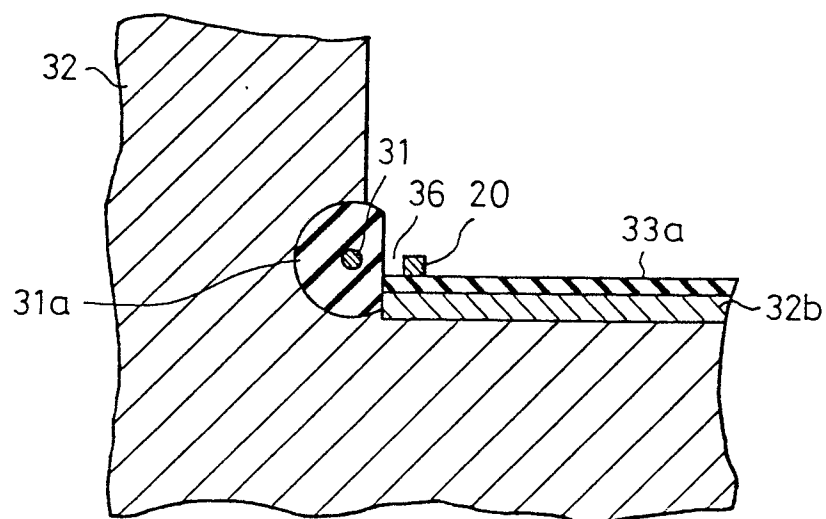


Fig. 7

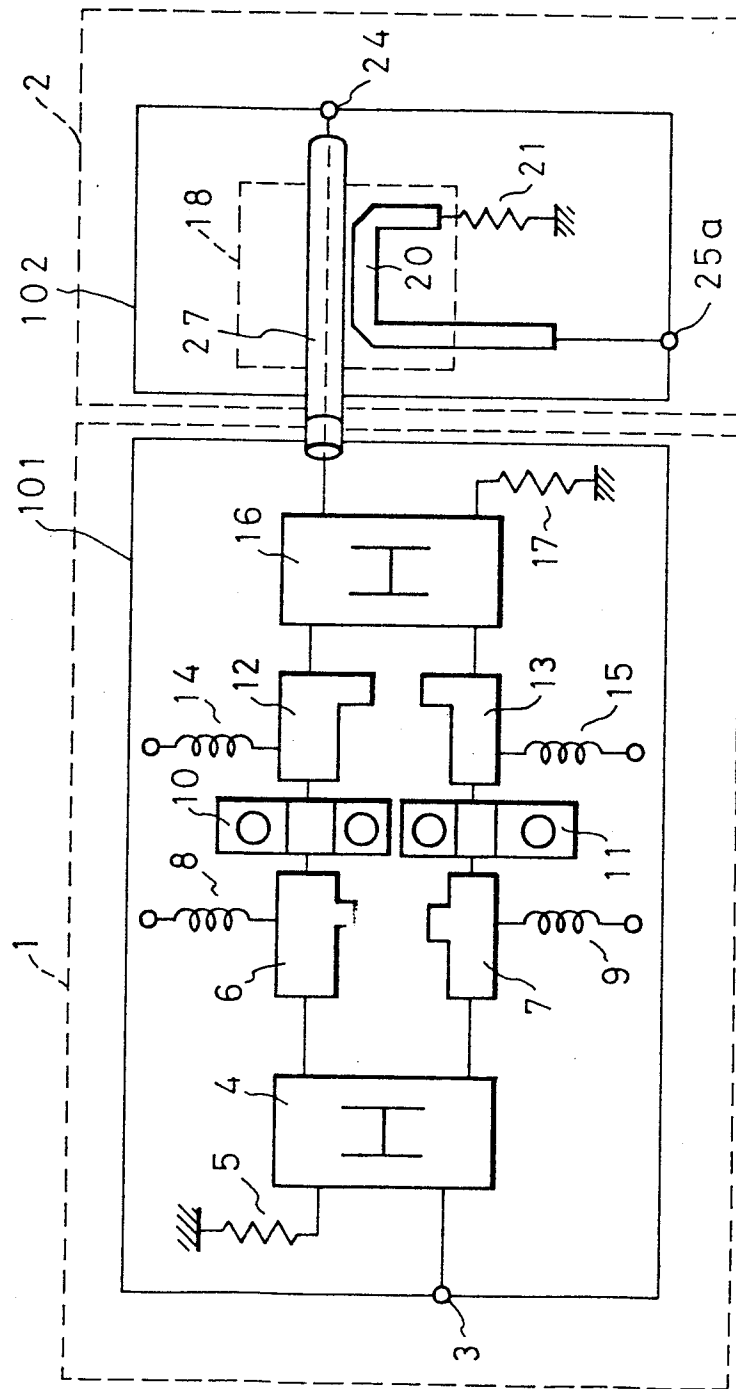
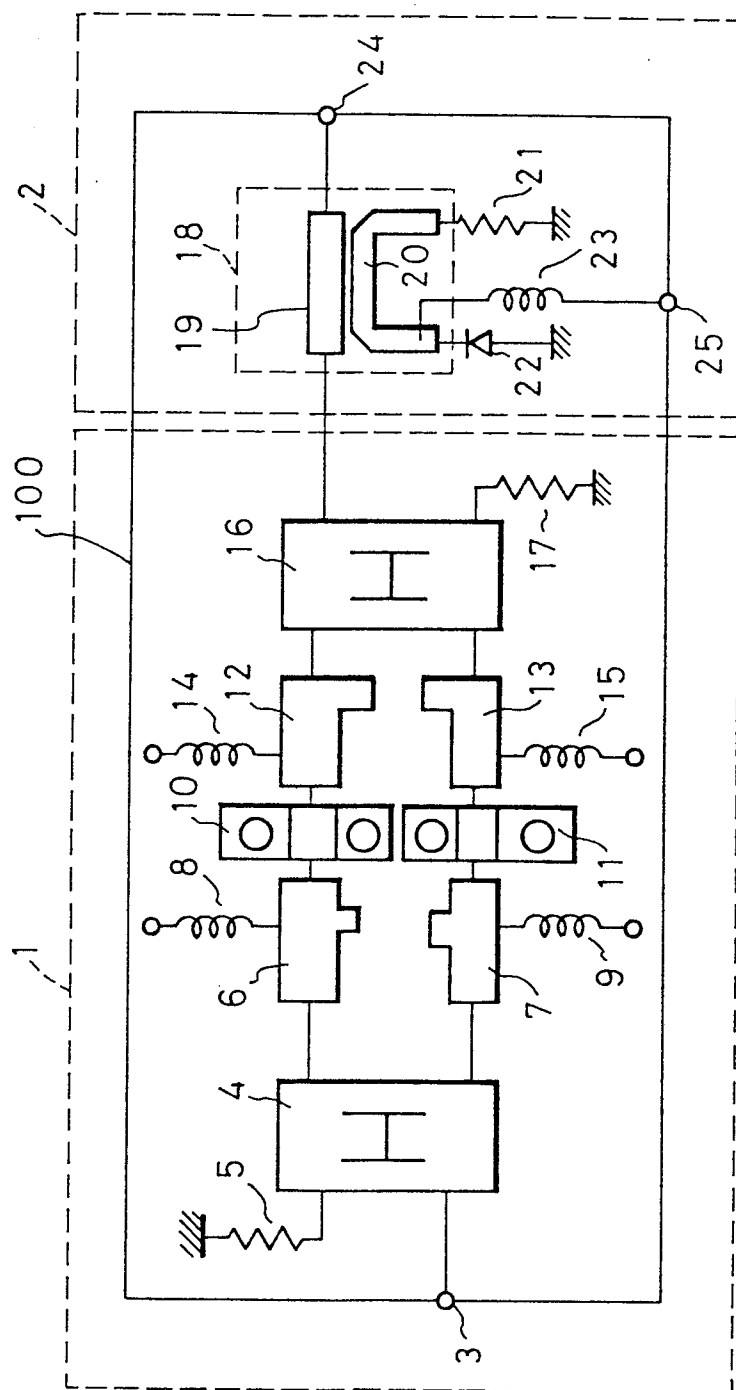


Fig. 8



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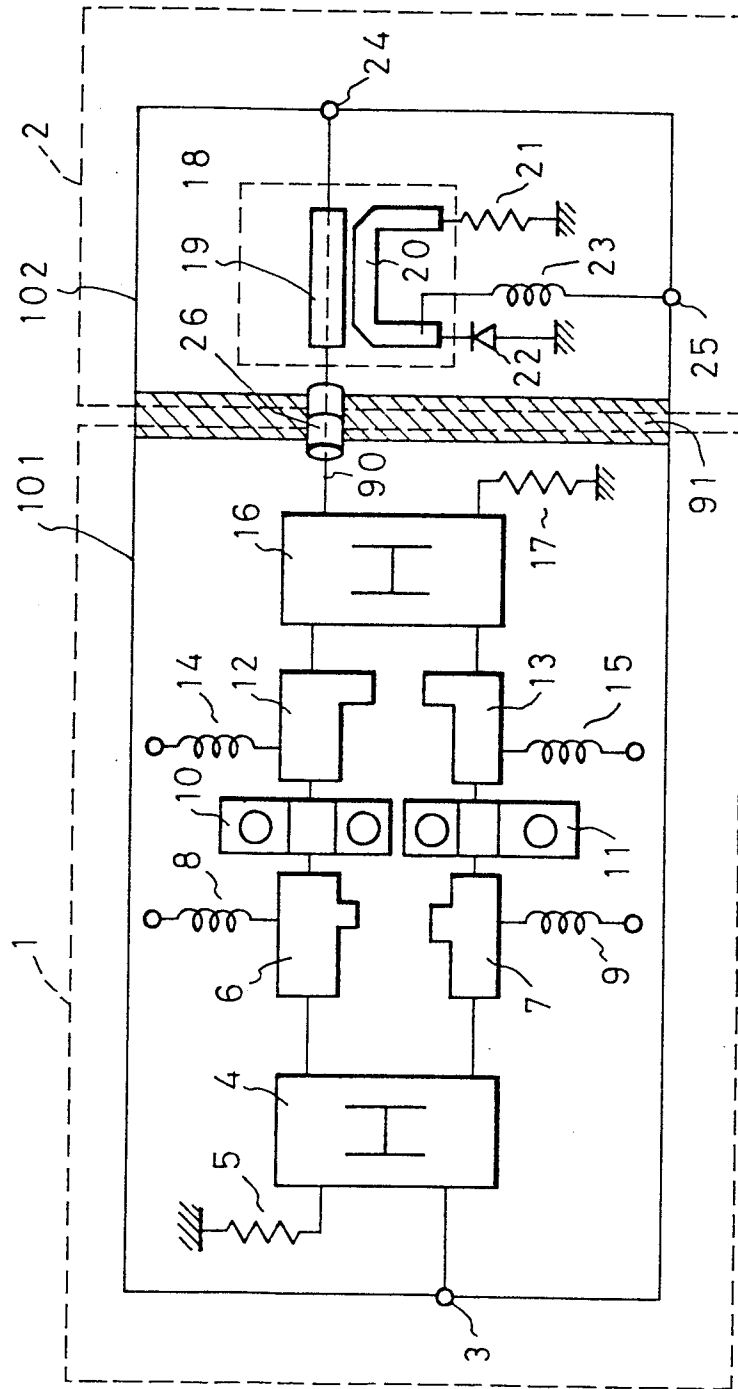


Fig.10

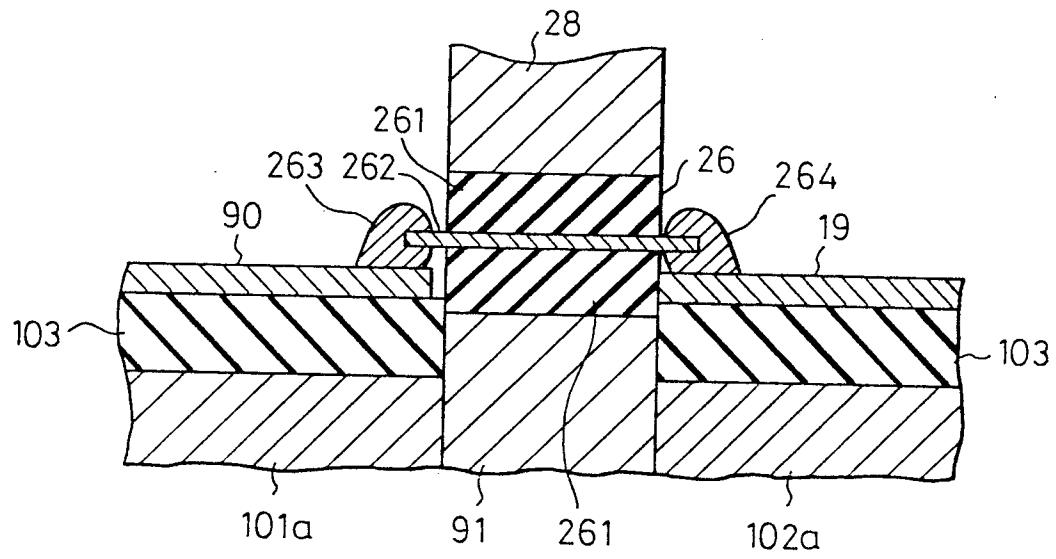


Fig.11

