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"SEMICONDUCTOR INTEGRATED CIRCUIT DEVICE".

The present invention relates to a semiconductor integrated circuit device (hereinafter referred to as an IC) and, more specifically deals with an IC in which an amplifier circuit is formed therein.

In an IC having elements that are formed on a substrate, it is necessary that the substrate is fixed to earth potential so that the substrate is separated from the elements by the pn junction.

On the other hand, the reference potential wiring (earth) of the circuit formed in the IC must be fixed to earth potential by providing on the substrate a wire bonding pad for earthing the circuit, and connecting the pad to an externally drawing lead of the IC (hereinafter often referred to as external connecting pin of the IC) using a metal connector.

In general, the number of external connecting pins of the IC is determined depending upon the

construction of the package forming the IC. It is desired to minimize the number of external connecting pins (external connecting terminals) in the circuit which is produced in an integrated circuit form. From such a point of view, the wire bonding pad for earthing the circuit and the wire bonding pad for earthing the substrate has previously been formed on the substrate in the form of a common wire bonding, and the common pad has been connected to an external connecting pin of the IC via a metal connector so as to be maintained at the earth potential of an electronic device which consists of a printed board.

However, we have found the fact that when the IC is employed for an audio amplifier circuit, the distortion factor of the audio amplifier circuit is deteriorated by the internal resistance possessed by the metal connector which connects the common wire bonding pad to the external connecting pins. In other words, since a heavy current such as output current flows from a reference potential to earth potential in the circuit which is constructed in the form of an integrated circuit, the reference potential undergoes variation in the IC due to the internal resistance of the metal connector, whereby the potential of the substrate is also varied.

Variation in the substrate potential caused by the output current, reduces the quality of the output in the audio amplifier circuit by increasing the distortion.

If illustrated in further detail with regard to the IC which contains an audio amplifier circuit having at least an output amplifier circuit portion and an input amplifier circuit portion, a reference potential line in the output amplifier circuit portion is separated from a reference potential line in the output amplifier circuit portion in the IC in order that the input side is not affected by the variation in the reference potential caused by a heavy current in the output amplifier circuit portion, and wire bonding pads and external connecting leads are provided to individually earth them.

In this case, when the substrate is connected to the wire bonding pad for earthing in the output amplifier circuit, the output current flows through the metal connector on the output side and through the external connecting lead. However, since the metal connector contains internal resistance, the reference potential line in the output amplifier circuit undergoes variation due to the output current, and the substrate potential also undergoes the same variation. Variation in the substrate potential is fed back by way of

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parasitic capacitance which is formed between a region where the input-stage transistor is formed and the substrate in the above-mentioned region, and the thus fed-back signals are superimposed on the input signals which causes the distortion to increase.

On the other hand, when the substrate is connected to the wire bonding pad for earthing the input amplifier circuit, the leakage current flows into the substrate via a pnp lateral transistor which forms a quasi-complementary push-pull circuit. The leakage current flows through the metal connector on the input side and through the external connecting lead. Here, since the metal connector contains resistance, the reference potential line in the input amplifier circuit portion is varied by the leakage current which flows into the substrate, and the distortion is increased.

It is therefore an object of the present invention to provide a semiconductor integrated circuit device for use in audio amplifier circuits, which circuits is designed to decrease the distortion.

According to the present invention there is provided a semiconductor integrated circuit device for amplifier circuits including: a semiconductor substrate in which amplifier circuits are formed in an integrated

circuit form; a first wire bonding pad which is formed on said semiconductor substrate to earth at least one of said amplifier circuits; an external terminal which is separated from said semiconductor substrate and which is electrically connected to said first wire bonding pad via a first conductor; a second wire bonding pad which is formed on said semiconductor substrate being separated from said first wire bonding pad, and which earths said semiconductor substrate; and a second conductor which electrically connects said second wire bonding pad to said external terminal.

The present invention will now be described in greater detail by way of example with reference to the accompanying drawings, wherein:-

Figure 1 is a circuit diagram of one preferred form of semiconductor integrated circuit device;

Figure 2 is a plan view of the semiconductor integrated circuit device shown in Figure 1;

Figure 3 is a cross-sectional view on an enlarged scale of the semiconductor integrated circuit device shown in Figure 2, taken along the line III-III;

Figure 4 is a cross-sectional view on an enlarged scale of the semiconductor integrated circuit device shown in Figure 2, taken along the line IV-IV; and

Figure 5 is a plan view of a second embodiment of a semiconductor integrated circuit device.

The circuit and construction of the IC shown in Figures 1 and 2 is for audio amplifiers.

The IC is a monolithic integrated circuit which consists of a single silicon semiconductor substrate. The portion surrounded by a chain dotted line is formed in a semiconductor chip. Symbols P_1 to P_8 denote external connecting leads, i.e., external connecting pins which are provided in the package of the IC.

Referring to Figure 1, the audio amplifier circuit consists of an input amplifier circuit A_1 for amplifying the input signals, a drive circuit A_2 which receives the output of the input amplifier circuit and which drives a subsequent stage, and an output amplifier circuit A_3 which is driven by the drive circuit and which produces output signals.

The input amplifier circuit A_1 constitutes a differential amplifier circuit which includes pnp transistors Q_1 to Q_4, and is used as a buffer amplifier for the drive circuit A_2 which is connected in the subsequent stage.

Darlington-connected pnp transistors Q_1 and Q_2 are earthed at their collector electrodes. Input

signals V_{IN} are applied to the base electrode of the transistor Q_1 through an external connection lead P_2.

Similarly, Darlington-connected pnp transistors Q_3 and Q_4 are earthed at their collector electrodes, and the base electrode of the transistor Q_4 is biased to zero volts (earth potential).

The emitter electrode of the transistors Q_2 is connected to the emitter electrodes of transistors Q_5 and Q_6 through respective resistors R_{10} and R_{11}, whilst the emitter electrode of the transistor Q_3 is connected to the emitter electrodes of transistors Q_8 and Q_7 through respective resistors R_{12} and R_{13}. The transistors Q_5 and Q_8 constitute a differential amplifier.

The collector electrode of a constant-current transistor Q_9 is connected to commonly connected base electrodes of the transistors Q_6 and Q_7.

The base electrode of the constant-current transistor Q_9 has a constant voltage applied thereto from diode-connected transistors Q_{12} and Q_{13} which are connected in series, whereby the collector electrode is supplied with a constant current which is determined by the resistor R_2 that is connected to the emitter electrode of the constant-current transistor Q_9. The constant current is supplied to the commonly connected base

electrodes of the transistors Q_6 and Q_7 which form part of the differential amplifier.

A voltage source V_{cc} is applied to the commonly connected collector and base electrodes of the diode-connected transistor Q_{12} via transistors Q_{10} and Q_{11}. The voltage source V_{cc} is also applied to the resistor R_2 which is connected to the emitter electrode of the constant-current transistor Q_9, and to load resistors R_1 and R_3 of the differential transistors Q_5 and Q_8 respectively, via transistors Q_{10} and Q_{11}.

The load resistors R_1 and R_3 are provided for the collector electrodes of the differential transistors Q_5 and Q_8, in order to obtain amplified output signals of opposite phases.

Diode-connected transistors Q_6 and Q_7 and resistors R_{11} and R_{12} that are provided between the base electrodes of the differential transistors Q_5 and Q_8 and the emitter electrodes of the transistors Q_2 and Q_3 and operate so that the apparent current amplification factor of the differential transistors Q_5 and Q_8 is set to be nearly unity.

The drive circuit A_2 consists of a biasing circuit which includes transistors Q_{14} to Q_{16}, a differential circuit which includes a feed-back transistor

Q_{18}, and a driver circuit which includes transistors Q_{20} and Q_{21} connected in Darlington configuration, and drives the output amplifier circuit A_3 which is placed in the subsequent stage.

Emitter electrodes of a pnp transistor Q_{17} and an npn transistor Q_{18} are commonly connected, the collector electrode of the transistor Q_{17} is earthed via a resistor R_{15}, and the collector electrode of the transistor Q_{18} is connected to the junction between the transistor Q_{10} and the transistor Q_{11}.

One of the amplified outputs obtained from the input amplifier circuit A_1 is applied to the base electrode of the transistor Q_{17}, and an output signal is produced on the collector electrode of the transistor Q_{17}.

The transistor Q_{18} operates to feed back a direct current, and its base electrode is connected to a middle-point potential of the output amplifier circuit A_3 through a terminal P_4 via a feedback circuit which consists of resistors R_8 and R_9 and a capacitor C_3 that are connected outside the IC, whereby the middle-point potential of the output amplifier circuit A_3 is controlled to a predetermined potential.

The above feedback circuit operates as a

negative feedback circuit for alternating currents.

Referring to the Darlington pair consisting of the transistors Q_{20} and Q_{21}, the base electrode of the transistor Q_{20} has applied to it, the output signal from the collector electrode of the transistor Q_{17} of the differential circuit. Output signals are produced on the collector electrodes of the transistors Q_{20} and Q_{21} with the constant-current transistor Q_{19} as the load.

A capacitor C_1 which is connected between the base electrode of the transistor Q_{20} and the collector electrode of the transistor Q_{21} is provided to prevent oscillation of the circuit.

The output amplifier circuit A_3 consists of a quasi-complementary push-pull circuit.

Transistors Q_{26} and Q_{27} connected in Darlington configuration have applied to their base electrodes, the output signals of the drive circuit A_2, and produce positive A.C. output signals on their emitter electrodes.

A transistor Q_{28} for obtaining negative A.C. output signals operates in a complementary manner with respect to the transistors Q_{26} and Q_{27}, and has applied to its base electrode, an output signal of the drive circuit A_2 via a pnp transistor Q_{23} which forms an inverter stage.

Diodes D_1 to D_3 and a transistor Q_{24} constitute a circuit for biasing the output transistors Q_{23}, Q_{28}, Q_{26} and Q_{27}.

An audio output signal is obtained from a point at which the emitter electrode of the transistor Q_{27} is connected to the collector electrode of the transistor Q_{28}, via an external terminal P_8.

In this circuit, reference potentials of the input amplifier circuit A_1 and the drive circuit A_2 are earthed via an earthing wire bonding pad 3 (Figure 2) on the input side and via an external terminal P_3, a reference potential of the output amplifier circuit A_3 is earthed via an earthing wire bonding pad 6 (Figure 2) on the output side and via an external terminal P_6, and the substrate is earthed via a wire bonding pad 6' (Figure 2) for the substrate and via the external terminal P_6.

The IC construction of the audio amplifier circuit is illustrated in Figure 2.

In Figure 2, the same portions as those of Figure 1 are denoted by the same symbols.

A portion surrounded by a broken line A_1 denotes the input amplifier circuit portion, a portion surrounded by a broken line A_2 denotes the drive circuit

portion, and a portion surrounded by a broken line A_3 denotes the output amplifier circuit portion.

Reference numerals 1 to 8 denote wire bonding pads which are connected to predetermined external terminals P_1 to P_8 via metallic connector wires 11 to 18. An earthing wire bonding pad 3 is provided on the input side, and an earthing wire bonding pad 6 is provided on the output side.

The IC construction also includes a semiconductor chip 20, and a tub 10 for securing the semiconductor chip 20.

Figure 3 is a cross-sectional view on an enlarged scale of a pnp transistor forming region which is formed in the input amplifier circuit portion of the semiconductor chip along the line III-III of Figure 2, and Figure 4 is a cross-sectional view on an enlarged scale of the wire bonding pad for substrate formed in the output amplifier circuit portion along the line IV-IV of Figure 2.

The semiconductor chip shown includes a substrate 21 (P-SUB), an n-type well region 22 for forming elements that is separated from a p^+-type isolation region 21' by a pn junction, a p-type region 23 formed in the well region 22, an n^+-type region 24 formed in the

well region 22 or in the p-type region 23, a first insulation layer 25, a first aluminium layer 26 which serves as an electrode for the elements that are formed on the substrate, and which is used for effecting predetermined circuit connection, a second insulation film 27 which is provided on the first aluminium layer, and a second aluminium layer 28 for effecting predetermined circuit connections. The second aluminium layer 28 is insulated from the first aluminium layer 26 by the second insulation film 27, and is connected to the first aluminium layer 26 through holes that are formed in the second insulation film 27.

A section 9' of the first aluminium layer 26 and the second aluminium layer 28 are connected by a conductor 9 as shown in Figure 3, and the extension thereof is connected to the aluminium layer 28 of Figure 4 through a conductor IV.

The pnp transistors Q_1 to Q_4 formed in the input amplifier circuit portion A_1 are the substrate-type pnp transistors in which the n-type well region 22 serves as a base region, the p-type region 23 serves as an emitter region, and the substrate 21 serves as a collector region.

The second aluminium layer denoted by 6' serves

as a wire bonding pad for the substrate. A metallic connector wire 16' is provided for connecting the wire bonding pad 6' to the external terminal P_6 which is earthed. The metallic connector wire 16' is made of gold wire.

The substrate 21 is connected to the wire bonding pad 6' for the substrate via the first aluminium layer, and is earthed.

According to the embodiment illustrated in Figures 1 to 4, the output current from the output transistor Q_{28} which constitutes the output amplifier circuit A_3 flows through the earthing wire bonding pad 6, the metallic connector wire 16 and the external terminal P_6.

Therefore, the potential of the earthing wire bonding pad 6 varies relative to the potential of the external terminal P_6, depending upon the resistance (for example, 50 miliohms) of the metallic connector wire 16.

However, the earthing wire bonding pad 6 is connected to the external terminal P_6 in such a manner that a wire bonding pad 6' for the substrate is separately provided, and the wire bonding pad 6' for substrate is connected to the external terminal P_6 through a second metallic connector wire 16'.

Since the wire bonding pad 6' for the substrate is connected to the external terminal P_6, variation in voltage is not transmitted to the substrate no matter how it is varied by the resistance in the metallic connecter wire and the output current of the output circuit. Consequently, the potential in the substrate is not varied by the above-mentioned variation in voltage, and no variation is fed back to the input signals by the parasitic capacitance which exists between the base region 22 of the pnp transistors Q_1 to Q_4 in the circuit portion A_1 and the substrate in the region where the pnp transistors Q_1 to Q_4 are formed. Therefore, the input signals can be prevented from being distorted.

Furthermore, a parasitic vertical transistor with its collector serving as a p-type substrate is formed in the pnp lateral transistor Q_{23} which constitutes the output amplifier circuit A_3. When there is a leakage current $\underline{i}$ as indicated by a broken line in Figure 1, the leakage current $\underline{i}$ flows from the substrate to earth via the wire bonding pad 6' for the substrate, the metallic connector wire 16' and the external terminal P_6, so that the potential in the substrate varies primarily due to the great resistance of the substrate. With reference to the pnp transistors Q_1 to Q_4 which are formed in the

input amplifier circuit A_1 that is susceptible to the substrate potential, the substrate in the region where the pnp transistors Q_1 to Q_4 are formed is connected to the wire bonding pad 6' which is earthed through aluminium conductors 9' and 9 that have resistance which is much smaller than that of the substrate.

Accordingly, the variation in the substrate in the section where the pnp transistors of the input amplifier circuit are formed, is very little affected by the leakage current $\underline{i}$ which flows into the substrate of the pnp lateral transistor Q_{23}. Therefore, the input signals are less distorted by the feed back through the parasitic capacitance.

Furthermore, the wire bonding pad 6' to which is connected the substrate is separated from the earthing wire bonding pad 6 which is maintained at a reference potential of the output side and separated from the earthing wire bonding pad 3 which is maintained at a reference potential on the input side. The wire bonding pad 6' is connected to the external terminal P_6 on the output side. Therefore, the leakage current $\underline{i}$ which flows into the substrate, does not flow through the wire bonding pad 3 for earthing on the input side, through the metallic connector wire 13 or through the external

terminal P_3 on the input side. Consequently, the reference potential lines of the input amplifier circuit A_1 and the drive circuit A_2 are not varied by the resistance of the metallic connector wire 13 or of the external terminal P_3; the input signals can be prevented from being distorted.

Figure 5 illustrates a second embodiment in the audio amplifier circuit of Figure 1, i.e., illustrates on an enlarged scale a portion of the semiconductor chip of the integrated circuit, and the same portions as those of Figures 1 to 4 are denoted by the same reference numerals.

In Figure 5, the semiconductor chip includes an earthing wire bonding pad to which is connected the reference potential of the input amplifier circuit A_1 and the drive circuit A_2, an external terminal P_3 which is connected to earth potential, a metallic connector wire 13 which connects the earthing wire bonding pad 3 to the externally drawing lead P_3, a first aluminium conductor 9' which is connected to the substrate, a wire bonding pad 3' for the substrate which is connected to the first aluminium conductor 9' and a metallic connector wire 13' which connects the wire bonding pad 3' for the substrate to the external terminal

P_3.

The wire bonding pad 3' to which is connected the substrate is separated from the earthing wire bonding pads 3 and 6 on the input side and on the output side, and is connected to the external terminal P_3 via the metallic connector wire 13'.

Therefore, even when the output current of the transistor Q_{28} in the output amplifier circuit A_3 flows through the metallic connector wire 16 and through the external terminal P_6, the substrate potential does not undergo variation, and the input signals are not distorted.

Furthermore, when the leakage current $\underline{i}$ flows from the pnp lateral transistor Q_{23} which constitutes the output amplifier circuit A_3 into the substrate, the potential varies very little in the substrate in the region where the pnp transistors Q_1 to Q_4 of the input amplifier circuit A_1 are formed, and the input signals are prevented from being distorted, since the substrate in the region where the pnp transistors Q_1 to Q_4 of the input amplifier circuit A_1 are formed is earthed via the first aluminium conductor 9', via the metallic connector wire 13' and via the external terminal P_3 on the input side, that have resistances which are extremely small compared with the resistance of the

substrate between the region where the pnp lateral transistor Q_{23} is formed and the region where the pnp transistors Q_1 to Q_4 are formed.

In an alternative form of application, even when the pnp transistor in the input amplifier circuit A_1 is a lateral pnp transistor, variation in the substrate potential is fed back to the input signals by the parasitic capacitance between the base region and the substrate. By applying the principles outlined above distortion can be avoided.

CLAIMS.

1. A semiconductor integrated circuit device for amplifier circuits including: a semiconductor substrate in which amplifier circuits are formed in an integrated circuit form; a first wire bonding pad which is formed on said semiconductor substrate to earth at least one of said amplifier circuits; an external terminal which is separated from said semiconductor substrate and which is electrically connected to said first wire bonding pad via a first conductor; a second wire bonding pad which is formed on said semiconductor substrate being separated from said first wire bonding pad, and which earths said semiconductor substrate; and a second conductor which electrically connects said second wire bonding pad to said external terminal.

2. A semiconductor integrated circuit device for amplifier circuits according to Claim 1, wherein said device further includes an element forming region for forming a pnp transistor that constitutes said amplifier circuit, said element forming region being formed in said semiconductor substrate, and a third conductor which electrically connects the semiconductor substrate in which is formed said element forming region to said second wire bonding pad.

3. A semiconductor integrated circuit device for amplifier circuits according to Claim 2, wherein said amplifier circuit includes an output amplifier circuit portion and an input amplifier circuit portion which is connected to the input side of said output amplifier circuit portion, and said element forming region forms at least a portion of said input amplifier circuit portion.

4. A semiconductor integrated circuit device for amplifier circuits according to Claim 3, wherein said external terminal is provided for earthing said output amplifier circuit portion.

5. A semiconductor integrated circuit device for amplifier circuits according to Claim 3, wherein said external terminal is provided for earthing said input amplifier circuit portion.

6. A semiconductor integrated circuit device for amplifier circuits according to any one of the preceding Claims 2 to 5, wherein said third conductor is electrically connected to said semiconductor substrate in which is formed said element forming region, and is composed of a metal layer which is formed on said semiconductor substrate between the element forming region and said second wire bonding pad.

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7. A semiconductor integrated circuit device for amplifier circuits constructed substantially as herein described with reference to and as illustrated in Figures 2 to 4 or Figure 5 of the accompanying drawings.

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