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Electronic device capable of suppressing high ground impedance, and method for manufacturing the electronic device

Abstract

An electronic device that is capable of keeping the impedance (ground impedance) between a printed circuit board and a shield case low. The electronic device includes a printed circuit board that has ground layer(s) which is conductive and is provided at a location in the thickness direction of the printed circuit board, and the shield case which is disposed on one side of the printed circuit board and consists of a hollow body that has conductivity. A through hole(s) passing through the ground layer is formed in the printed circuit board. A projecting portion(s), which is inserted into the through hole(s), is formed in a projecting manner in the shield case. In a state of being inserted in the through hole(s), the projecting portion(s) is electrically connected to the ground layer via solder.

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Background/Summary

BACKGROUND OF THE INVENTION

Field of the Invention

(1) The present invention relates to an electronic device that is capable of suppressing high ground impedance, and a method for manufacturing the electronic device.

Description of the Related Art

(2) In recent years, as wireless communication devices have become widespread, a shield case that shields a wireless communication device from electromagnetic waves or the like has been known. Japanese Patent No. 3067326 discloses a technique in which, to mount the shield case on a board land, the board land and the shield case are joined together by reflow soldering. Japanese Laid-Open Patent Publication (Kokai) No. 2010-192756 discloses positioning of the shield case.

(3) According to Japanese Patent No. 3067326, when, for example, an attempt is made to downsize a wireless communication device, there is room for improvement in the shielding effect achieved by the shield case. Specifically, the attempt is made to downsize the wireless communication device, as the downsize thereof, the area of a ground layer land pattern on a surface layer of a board is reduced accordingly, and it is feared that it will be difficult to secure (form) a sufficient area of the ground layer land pattern, depending on the size of the downsized wireless communication device. Japanese Laid-Open Patent Publication (Kokai) No. 2010-192756 has a problem that if the impedance (ground impedance) between the ground layer land pattern, whose area cannot be secured to a sufficient level, and the shield case is high, the shielding effect of the shield case will decrease. Thus, there is a demand for an electronic device capable of keeping the impedance between the shield case and the ground layer low. It is noted that Japanese Laid-Open Patent Publication (Kokai) No. 2010-192756 neither discloses nor suggests a configuration for keeping the impedance low.

SUMMARY OF THE INVENTION

(4) The present invention provides an electronic device that is capable of suppressing the high impedance (ground impedance) between a printed circuit board and a shield case, and a method for manufacturing the electronic device.

(5) Accordingly, the present invention provides an electronic device including a printed circuit board comprising at least one ground layer that has conductivity, wherein the at least one ground layer is provided at a location in a middle in a thickness direction of the printed circuit board, and a shield case that is placed on one side of the printed circuit board and consists of a hollow body that has conductivity, wherein at least one through hole passing through the at least one ground layer is formed in the printed circuit board, at least one projecting portion to be inserted into the at least one through hole is formed in a projecting manner in the shield case, and in a state of being inserted in the through hole, the projecting portion is electrically connected to the at least one ground layer via solder.

(6) According to the present invention, the high impedance (ground impedance) between the printed circuit board and the shield case can be suppressed.

(7) Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 is a block diagram showing an example of a configuration of an electronic device according to a first embodiment of the present invention.

(2) FIG. 2 is an exploded perspective view of a wireless communication device which the electronic device in FIG. 1 has.

(3) FIG. 3A is a cross-sectional view taken along a plane [A] enclosed by dashed dotted lines in FIG. 2.

(4) FIG. 3B is a flowchart showing a manufacturing process for the wireless communication device which the electronic device in FIG. 1 has.

(5) FIG. 4 is a cross-sectional view showing a configuration of a comparative example (an example of a prior art) which is compared with the present invention.

(6) FIG. 5 is a cross-sectional view showing the relationship between the sizes of layers of a printed circuit board and size of through holes in FIG. 3A.

(7) FIG. 6 is an exploded perspective view of a wireless communication device which an electronic device according to a second embodiment of the present invention has.

(8) FIG. 7 is a plan view and a cross-sectional view of a wireless communication device which an

electronic device according to a third embodiment of the present invention has.

(9) FIG. 8 is an exploded perspective view of a shield case which an electronic device according to a fourth embodiment of the present invention has.

DESCRIPTION OF THE EMBODIMENTS

(10) The present invention will now be described in detail below with reference to the accompanying drawings showing embodiments thereof. It is to be understood, however, that configurations in the embodiments described below are only illustrative, and the scope of the present invention is not intended to be limited by the configurations in the embodiments.

(11) Referring to FIG. 1 to FIG. 5, a description will now be given of a first embodiment of the present invention. FIG. 1 is a block diagram showing an example of a configuration of an electronic device 1 according to the first embodiment of the present invention. As shown in FIG. 1, the electronic device 1 has a wireless communication device 10 and a control device (controller board) 22, which controls the wireless communication device 10.

(12) The wireless communication device 10 has a wireless communication IC 11, a printed circuit board 12, a shield case 13, an antenna 14, and an external interface (I/F) 15. The wireless communication IC 11 is an electronic component that carries out communications using communication standards such as Wi-Fi (registered trademark) and Bluetooth (registered trademark). The wireless communication IC 11 is mounted on the printed circuit board 12. The shield case 13 is disposed on a surface of the printed circuit board 12 and on the same side as the wireless communication IC 11. The shield case 13 is comprised of a box-shaped hollow body that has conductivity, and shields the wireless communication IC 11 inside thereof. The antenna 14 is an antenna for wireless communication and provided on the surface of the printed circuit board 12 and on the same side as the wireless communication IC 11. The antenna 14 is electrically connected to a circuit pattern 128 on the printed circuit board 12. The external interface 15 is, for example, a USB device interface and mounted on the surface of the printed circuit board 12 and on the same side as the wireless communication IC 11. The external interface 15 is electrically connected to the circuit pattern 128 on the printed circuit board 12.

(13) The control device 22 has a controller 21 and an external interface (I/F) 25. The controller 21 is capable of communicating with the external interface 15 of the wireless communication device 10 via the external interface 25 and controls the wireless communication device 10.

(14) FIG. 2 is an exploded perspective view of the wireless communication device 10 which the electronic device 1 in FIG. 1 has. FIG. 3A is a cross-sectional view taken along a plane [A] enclosed by dashed dotted lines in FIG. 2. As shown in FIG. 2 and FIG. 3A, the printed circuit board 12 is a laminate with a plurality of layers. In the present embodiment, the printed circuit board 12 has a core material (core layer) 31 disposed in the center of the printed circuit board 12 in a thickness direction, a prepreg 32 disposed on the front surface of the core material 31 (the upper side of the core material 31 as viewed in FIG. 3A), and a prepreg 33 disposed on the back surface of the core material 31 (the lower side of the core material 31 as viewed in FIG. 3A). The printed circuit board 12 also has an L1 layer 34, an L2 layer 35, an L3 layer 36, and an L4 layer 37, all of which have conductivity. It is noted that although in the present embodiment, the L1 layer 34 through the L4 layer 37 are made of, for example, copper foil, they have only to be made of a conductive material and they are not limited by copper foil. The L1 layer 34 is provided on the front surface (one side) of the prepreg 32 (the upper side of the prepreg 32 as viewed in FIG. 3A). The L1 layer 34 has the circuit pattern 128, which is electrically connected to the wireless communication IC 11, and a land pattern 123, which is electrically connected to the shield case 13 and functions as a first ground layer (front-side ground layer). A copper plating layer 38 is provided on the land pattern 123. The L2 layer 35 is provided between the prepreg 32 and the core material 31, that is, at a location different from that of the land pattern 123 in the thickness direction of the printed circuit board 12 (i.e., at a location in the middle in the thickness direction of the printed circuit board 12). The L2 layer 35 has a ground pattern 124, which is electrically

connected to the shield case **13** and functions as a second ground layer (middle ground layer). The L3 layer **36** is provided between the core material **31** and the prepreg **33**, that is, at a location in the middle in the thickness direction. The L4 layer **37** is provided on the back surface of the prepreg **33** (the lower side of the prepreg **33** as viewed in FIG. 3A), and electrically connected to the shield case **13** and functions as a third ground layer (back-side ground layer). A copper plating layer **39** is provided on the L4 layer **37**.

(15) As shown in FIG. 2, the wireless communication IC **11** is disposed in an area enclosed by the land pattern **123** on the printed circuit board **12**. The antenna **14** and the external interface **15** are disposed outside the land pattern **123** on the printed circuit board **12**. In the present embodiment, the antenna **14** is a pattern antenna, and the external interface **15** is, for example, a USB device interface.

(16) As shown in FIG. 3A, a through hole **121** and a through hole **122** are formed in the printed circuit board **12**. The through hole **121** and the through hole **122** pass through the land pattern **123** (the L1 layer **34**), the prepreg **32**, the ground pattern **124** (the L2 layer **35**), the core material **31**, the prepreg **33**, and the L4 layer **37**. It is noted that although in the present embodiment, the number of through holes are formed in the printed circuit board **12** is two, this is not limitative, and the number of through holes may be, for example, one, or three or more.

(17) A connecting portion **301A**, which connects the land pattern **123** (including the copper plating layer **38**) and the ground pattern **124** together, and a connecting portion **302A**, which connects the ground pattern **124** and the L4 layer **37** together, are provided in an inner peripheral portion of the through hole **121**. The connecting portion **301A** and the connecting portion **302A** are each made of a conductive material such as copper. Thus, the land pattern **123** and the ground pattern **124** are electrically connected together via the connecting portion **301A**, and the ground pattern **124** and the L4 layer **37** are connected together via the connecting portion **302A**. The connecting portion **301A** and the connecting portion **302A** constitute a cylindrical ground portion (conductor post) **30A**, which passes through the printed circuit board **12** in the thickness direction. A space **360** is formed between the ground portion **30A** and the L3 layer **36**, and the ground portion **30A** is apart from the L3 layer **36**.

(18) As with the through hole **121**, a connecting portion **301B**, which connects the land pattern **123** and the ground pattern **124** together, and a connecting portion **302B**, which connects the ground pattern **124** and the L4 layer **37** together, are provided in an inner peripheral portion of the through hole **122**. The connecting portion **301B** and the connecting portion **302B** are each made of a conductive material such as copper. Thus, the land pattern **123** and the ground pattern **124** are electrically connected together via the connecting portion **301B**, and the ground pattern **124** and the L4 layer **37** are connected together via the connecting portion **302B**. The connecting portion **301B** and the connecting portion **302B** constitute a cylindrical ground portion (conductor post) **30B**, which passes through the printed circuit board **12** in the thickness direction. As with the ground portion **30A**, a space **361** is formed between the ground portion **30B** and the L3 layer **36**, and the ground portion **30B** is apart from the L3 layer **36**.

(19) In plan view of the printed circuit board **12**, the wireless communication IC **11** is located between the through hole **121** and the through hole **122** (see FIG. 2). The wireless communication IC **11** is covered with the shield case **13** from the front side. The shield case **13**, which is a box-shaped member with a top **133**, a side wall **134**, and an opened bottom, is constructed by punching out, by e.g., press work, a conductive plate material (for example, a tin plate (SPTE, tin plated steel plate) with a thickness of 0.2 mm) into a desired shape to form a base metal and then bending the base metal. In a lower edge portion of the side wall **134**, a leg portion (projecting portion) **131** and a leg portion (projecting portion) **132** are formed such that they project downward. As shown in FIG. 3A, the leg portion **131** is inserted into the through hole **121**. In the state of being inserted in the through hole **121**, the leg portion **131** is electrically connected to the ground portion **30A** (including the land pattern **123**, the ground pattern **124**, and the L4 layer **37**), which is comprised of

the connecting portion **301A** and the connecting portion **302A**, via solder **130A**. The solder **130A** is provided over the entire length and entire circumference of the inner peripheral portion of the through hole **121**. The leg portion **132** is inserted into the through hole **122**. In the state of being inserted in the through hole **122**, the leg portion **132** is electrically connected to the ground portion **30B** (including the land pattern **123**, the ground pattern **124**, and the L4 layer **37**), which is comprised of the connecting portion **301B** and the connecting portion **302B**, via solder **130B**. The solder **130B** is provided over the entire length and entire circumference of the inner peripheral portion of the through hole **122**. With this configuration, a sufficient contact area between the printed circuit board **12** and the shield case **13** can be secured, and therefore, the high impedance (ground impedance) between the printed circuit board **12** and the shield case **13** can be suppressing. In particular, a low-impedance conduction path is secured by a path indicated by a dotted line in FIG. 3A, and hence the wireless communication IC **11** is electrostatically shielded.

(20) A conductive material (electrical conductor) such as iron is used for the shield case **13** so as to also serve as a magnetic shield that shields the effects of a magnetic field (electromagnetic induction), an electromagnetic shield that shields the effects of an electromagnetic wave, and an electrostatic shield that shields the effects of an electric field (electrostatic induction). For example, in the case where the conductive material is used for the shield case **13** as the magnetic shield, the conductive material satisfactorily acts as the magnetic shield because magnetic lines of force are canceled by an overcurrent occurring in the conductive material at high frequencies such as the 2.4 GHz frequency band and the 5 GHz frequency band used for wireless communications such as Wi-Fi (registered trademark) and BLE.

(21) The electromagnetic shield is intended to shield an electromagnetic wave that propagates a combination of alternating electric field and magnetic field. In a case where the antenna **14** is a dipole antenna, for the wireless communication IC **11**, consideration should be given to the electromagnetic shield in a near field that is relatively close to the antenna **14**. In the near field, an electric field component is dominant, and the surge impedance is very high. In the case where the conductive material is used for the shield case **13** as the electromagnetic shield, the return loss is high because surge impedance in the conductive material is only about 1Ω as compared to the surge impedance of 377Ω , in the air, and therefore, the conductive material satisfactorily acts as the electromagnetic shield.

(22) In the case where the conductive material is used for the shield case **13** as the electrostatic shield, current noise caused by an electric field of a noise (electrostatic induction) propagates to the ground portion **30A** and the ground portion **30B** via the shield case **13** that is earthed in consideration of parasitic capacitance. As a result, an internal circuit portion of the wireless communication IC **11** shielded by the shield case **13** is protected from the electric field of noise. Here, consideration should be given to the ground impedance of the shield case **13** in order to reduce the effects of the noise current flowing through the electrostatic shield. The reason is that as the ground impedance decreases, the noise current decreases accordingly, and the noise voltage also decreases, leading to an improvement in the shielding effect.

(23) In plan view of the printed circuit board **12**, the through hole **121** and the through hole **122** are circular (see FIG. 2). It is noted that although the diameter of the through hole **121** and the diameter of the through hole **122** are the same in the present embodiment, this is not limitative, and they may be different. The leg portion **131**, which is inserted into the through hole **121**, has a circular column shape, and its diameter is sufficiently smaller than that of the through hole **121**. The leg portion **132**, which is inserted into the through hole **122**, is also has a circular column shape, and its diameter is sufficiently smaller than that of the through hole **122**. As a result, the leg portion **131** can be easily inserted into the through hole **121**, and the leg portion **132** can be easily inserted into the through hole **122**. Therefore, the printed circuit board **12** and the shield case **13** can be assembled speedily together. Moreover, with this configuration, the shield case **13** can be positioned with respect to the printed circuit board **12**, and hence the shield case **13** can be

prevented from coming into contact with a undesired pattern so that shorts can be prevented.

(24) Referring to FIG. 3B, a description will now be given of a manufacturing method for the wireless communication device **10** (the electronic device **1**). FIG. 3B is a flowchart showing a manufacturing process for the wireless communication device **10** which the electronic device **1** in FIG. 1 has. As shown in FIG. 3B, the manufacturing process for the wireless communication device **10** includes a through hole forming process, an electronic component connecting process, and a shield case connecting process, and they are performed in this order. In the through hole forming process, first, the printed circuit board **12**, in which the through hole **121** and the through hole **122** have not yet been formed is prepared. Next, the printed circuit board **12** is subjected to machining in which the through hole **121** and the through hole **122** are formed. After the machining, the inner peripheral portion of the through hole **121** and the inner peripheral portion of the through hole **122** are subjected to plating, forming the ground portion **30A** and the ground portion **30B**. Moreover, the copper plating layer **38** and the copper plating layer **39** can also be formed in the plating.

(25) In the electronic component connecting process, first, the wireless communication IC **11** is prepared. Next, the wireless communication IC **11** and the circuit pattern **128** on the printed circuit board **12** are connected together via solder. In the shield case connecting process, first, the shield case **13** is prepared. Next, the leg portion **131** of the shield case **13** is inserted into the through hole **121**, and the leg portion **132** of the shield case **13** is inserted into the through hole **122**. Then, solder is supplied between the leg portion **131** and the ground portion **30A** to connect the leg portion **131** and the ground portion **30A** together via the solder. Solder is also supplied between the leg portion **132** and the ground portion **30B** to connect the leg portion **132** and the ground portion **30B** together via the solder.

(26) It is preferable, after any process among the through hole forming process, the electronic component connecting process, and the shield case connecting process, to carry out a process for connecting the external interface **15** and the printed circuit board **12** together via solder. As a result of the processes described above, the wireless communication device **10** in which the high impedance between the printed circuit board **12** and the shield case **13** is suppressed can be obtained.

(27) FIG. 4 is a cross-sectional view showing a configuration of a comparative example (an example of a prior art), which is compared with the present invention. As shown in FIG. 4, a wireless communication device **10'**, which is the comparative example, is configured such that the leg portion **131** and the leg portion **132** are omitted from the shield case **13** as distinct from the wireless communication device **10** according to the present invention. It is noted that in the wireless communication device **10'** as the comparative example, a low-impedance conduction path is secured by a path indicated by a dotted line, and hence the wireless communication IC **11** is electrostatically shielded, as with the wireless communication device **10** according to the present invention.

(28) Here, comparing the path indicated by the dotted line in FIG. 3A (the present invention) and the path indicated by the dotted line in FIG. 4 (the prior art) with each other, thick lines between the shield case **13** and the ground pattern **124** are different. Specifically, in the configuration shown in FIG. 3A, a thick-line path A and a thick-line path B are formed, whereas in the configuration shown in FIG. 4, there is no thick-line path A, and only a thick-line path B is formed. Therefore, in the configuration shown in FIG. 3A, the shield case **13** has the thick-line path A, which is extended by the leg portion **131** and the leg portion **132**, as a circuit parallel with the thick-line path B. As a result, low impedance can be achieved. It is noted that an ordinary through hole has a larger diameter than that of a through-via, and the resistance value of the thick-line path B itself is low as well.

(29) FIG. 5 is a cross-sectional view showing the relationship between the sizes of the layers of the printed circuit board **12** and the size of the through hole **121** (**122**) in FIG. 3A. The printed circuit

board **12** in FIG. 5 is an ordinary printed circuit board with a thickness h of 1.6 mm. For example, the thickness of the core material **31** is 1100 μm , the thickness of the prepreg **32** is 200 μm , and the thickness of the prepreg **33** is 200 μm . For example, the thickness of the L1 layer **34** is 18 μm , the thickness of the L2 layer **35** is 35 μm , the thickness of the L3 layer **36** is 35 μm , the thickness of the L4 layer **37** is 18 μm , the thickness of the copper plating layer **38** is 25 μm , and the thickness of the copper plating layer **39** is 25 μm . The thickness of the ground portion **30A** is 25 μm (the thickness of the round portion **30B** is the same).

(30) For FIG. 5, the relationship between the resistance value R , and the through hole diameter $2r_{\text{sub}0}$, the coating thickness $2r_{\text{sub}1}$, the plate thickness h , and the conductor's conductivity σ , can be expressed by Equation 1 below. It is noted that conductivity of copper $\rho_{\text{sub}cu}$ is expressed by $\sigma_{\text{sub}cu}=6.0 \times 10^{sup.7}$ [S/m].

[Math1]

$$(31) \quad R = \frac{h}{\sigma_{\text{CU}} (r_0^2 - r_1^2)} \quad \text{Equation 1}$$

(32) For example, for the configuration shown in FIG. 4, in a case of a through-via with a drill diameter of 0.6 mm, assuming that the length $L_{\text{sub}B}$ of the thick-line path B from the L1 layer **34** to the L2 layer **35** is 200 $\mu\text{m}+25 \mu\text{m}+18 \mu\text{m}+35 \mu\text{m}$, the resistance value $R_{\text{sub}BVH}$ of the through-via is expressed by $R_{\text{sub}BVH}=0.0041$ [m Ω].

(33) On the other hand, for the configuration shown in FIG. 3A, in a case of the through hole **121** with a drill diameter of 0.7 mm, the resistance value $R_{\text{sub}BTH}$ of the through hole **121** on the thick-line path B from the L1 layer **34** to the L2 layer **35** is expressed by $R_{\text{sub}BTH}=0.0030$ [m Ω]. Assume that the shield case **13** is made of a tin steel plate with a thickness $t=76 \mu\text{m}$, and the leg portion **131** has a thickness $W=0.4$ mm. Assuming that a high-frequency electric current flows on the surface of the shield case **13** due to the skin effect, and the length $L_{\text{sub}A}$ of the thick-line path A is 200 $\mu\text{m}+25 \mu\text{m}+18 \mu\text{m}+35 \mu\text{m}$, the resistance value $R_{\text{sub}ASPTE}$ is expressed by Equation 2 below. It is noted that the conductivity of tin $\sigma_{\text{sub}SPTE}$ is expressed by $\sigma_{\text{sub}SPTE}=9.2 \times 10^{sup.6}$ [S/m].

$$R_{\text{sub}ASPTE}=\rho_{\text{sub}SPTE} \times L_{\text{sub}A} / (W \times t)=0.0010 \text{m}\Omega \quad \text{Equation 2}$$

(34) Assuming that a parallel circuit has only the resistance value of the thick-line path A and the resistance value of the thick-line path B so as to simplify the explanation, for the configuration shown in FIG. 3A, the combined resistance value R is expressed by $R=1$

$(1/R_{\text{sub}ASPTE}+1/R_{\text{sub}BTH}=0.00075$ [m Ω]. Thus, the impedance as low as about 18% relative to the resistance value $R_{\text{sub}BVH}=0.0041$ [m Ω] in FIG. 4 can be implemented. It is noted that there is also a path via the solder **130A** and the through hole **121** between the thick-line path A and the thick-line path B in FIG. 3A, and hence the actual impedance is much lower. As described above, in the wireless communication device **10** according to the present embodiment, the impedance is kept lower than that in the comparative example **10'**. Although in the above description, a calculation example for one through hole and one leg portion is taken, the impedance can be further reduced by using a plurality of through holes and a plurality of leg portions.

(35) A description will now be given of a second embodiment. FIG. 6 is an exploded perspective view of a wireless communication device which an electronic device **10** according to the second embodiment of the present invention has. As shown in FIG. 6, the printed circuit board **12** has a through hole **125** and a through hole **126**. In plan view of the printed circuit board **12**, the through hole **125** and the through hole **126** are each oval. The direction of the long diameter of the oval shape of the through hole **125** and the direction of the long diameter of the oval shape of the through hole **126** are the same. The shield case **13** has a leg portion **135** to be inserted into the through hole **125**, and a leg portion **136** to be inserted into the through hole **126**. The leg portion **135** and the leg portion **136** each has a plate-like shape.

(36) Generally, in a case where the shield case **13** is subjected to sheet-metal working with an ordinary sheet-metal press machine, it is feared that it will be difficult to implement the leg portion

131 and the leg portion **132**, which has a circular column shape with a thickness of, for example, 0.4 mm, with high precision. Accordingly, in the present embodiment, the shield case **13** is provided with the leg portion **135** and the leg portion **136**, which have a plate-like shape with a width of, for example, 1.0 mm. By adopting this design, the leg portion **135** and the leg portion **136** can be easily implemented with high precision by the shield case **13** being machined with an ordinary sheet-metal press machine. In this case, the through hole **125** and the through hole **126** are formed so as to have an oval shape with, for example, a long diameter of 1.4 mm and a short diameter of 0.7 mm. As a result, the through hole resistance value $R_{\text{sub.BTH}}$ on the thick-line path B from the L1 layer **34** to the L2 layer **35** further decreases. Specifically, $R_{\text{sub.BTH}}=0.00000013$ [$\text{m}\Omega$]. As the width of the leg portion **135** and the leg portion **136** increases, the resistance value $R_{\text{sub.ASPTE}}$ on the thick-line path A further decreases as well. Specifically, as the width of the leg portion **135** and the leg portion **136** increases to 1.0 mm, $R_{\text{sub.ASPTE}}=0.00040$ [$\text{m}\Omega$] holds. When their combined resistance value R_2 is calculated in the same manner as in the first embodiment, $R_2=(1/R_{\text{sub.ASPTE}}+1/R_{\text{sub.BTH}})\approx R_{\text{sub.BTH}}=0.00000013$ [$\text{m}\Omega$] holds. Thus, the impedance can be kept at further low.

(37) A description will now be given of a third embodiment. FIG. 7 is a plan view and a cross-sectional view of a wireless communication device which an electronic device according to the third embodiment of the present invention has. As shown in FIG. 7, a processed portion **127**, which has been subjected to thermal land processing, is provided around the through hole **125** (the same holds for the through hole **126**). For the oval through hole **125**, thermal capacity during soldering is large, and thus the solderability is improved by the processed portion **127**. It is noted that the processed portion **127** may be provided not only in the L1 layer **34** but also in any of the L2 layer **35**, the L3 layer **36**, and the L4 layer **37** or all of them.

(38) A description will now be given of a fourth embodiment. FIG. 8 is an exploded perspective view of a shield case which an electronic device according to the fourth embodiment of the present invention has. As shown in FIG. 8, the shield case **13** is configured so as to be divided into a plurality of members, i.e., a shield case upper portion (upper member) **137** and a shield case lower portion (lower member) **138** in the thickness direction of the printed circuit board **12**. The shield case upper portion **137** and the shield case lower portion **138** are assembled by, for example, projections and depressions engaging. One out of the shield case upper portion **137** and the shield case lower portion **138** which is located on the printed circuit board **12** side, that is, the shield case lower portion **138** which is on the lower side as viewed in FIG. 8, has the leg portion **131** and the leg portion **132**. The shield case upper portion **137** is removably mounted on the shield case lower portion **138**. As a result, in the shield case **13**, even if the shield case lower portion **138** is fixed to the printed circuit board **12**, the shield case upper portion **137** can be removed from the shield case lower portion **138**. Thus, for example, inspections such as a visual inspection and a camera inspection can be easily performed for the wireless communication IC **11**.

(39) Moreover, to fix the shield case **13** to the printed circuit board **12**, first, the shield case lower portion **138** is fixed to the printed circuit board **12** with the shield case upper portion **137** and the shield case lower portion **138** separated from each other. This can reduce the thermal capacity in soldering described above, and pretreatment such as preheating of the shield case **13** can be omitted, making low-cost fixing possible. Then, after the shield case lower portion **138** is fixed to the printed circuit board **12**, the shield case upper portion **137** is mounted to the shield case lower portion **138**. Although in the present embodiment, the shield case **13** is comprised of two members, the number of members constituting the shield case **13** is not limited to two, and may be, for example, three or more.

Other Embodiments

(40) Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-

transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)TM), a flash memory device, a memory card, and the like.

(41) While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

(42) This application claims the benefit of Japanese Patent Application No. 2022-51124 filed on Mar. 28, 2022, which is hereby incorporated by reference wherein in its entirety.

Claims

1. An electronic device including: a printed circuit board comprising at least one ground layer that has conductivity, wherein the at least one ground layer is provided at a location in a middle in a thickness direction of the printed circuit board; and a shield case that is placed on one side of the printed circuit board and that is comprised of a hollow body that has conductivity, wherein at least one through hole passing through the at least one ground layer is formed in the printed circuit board, at least one projecting portion to be inserted into the at least one through hole is formed in a projecting manner in the shield case, in a state of being inserted in the through hole, the projecting portion is electrically connected to the at least one ground layer via solder, the printed circuit board comprises a front-side ground layer that has conductivity and is different from the ground layer, wherein the front-side ground layer is provided on the one side, the projecting portion is electrically connected to the front-side ground layer via the solder, the printed circuit board comprises a connecting portion that has conductivity, wherein the connecting portion is provided in an inner peripheral portion of the through hole and electrically connects the at least one ground layer and the front-side ground layer to each other, and the projecting portion is electrically connected to the connecting portion via the solder.
2. The electronic device according to claim 1, wherein the solder is provided over the entire length and entire circumference of the inner peripheral portion of the through hole.
3. The electronic device according to claim 1, wherein the through hole is circular or oval in plan view of the printed circuit board.
4. The electronic device according to claim 1, wherein the projecting portion has a circular column shape or plate-like shape.
5. The electronic device according to claim 1, wherein a portion of the printed circuit board around the through hole is subjected to thermal land processing.
6. The electronic device according to claim 1, wherein the shield case comprises a plurality of members capable of being separated from each other in the thickness direction of the printed circuit board, and among the plurality of members, a member located on the printed circuit board side has

the at least one projecting portion.

7. The electronic device according to claim 1, wherein with the at least one projecting portion inserted in the at least one through hole, the shield case is positioned with respect to the printed circuit board.

8. The electronic device according to claim 1, further including an electronic component disposed on the one side of the printed circuit board and covered with the shield case.

9. The electronic device according to claim 8, wherein two through holes are formed, and in plan view of the printed circuit board, the electronic component is located between the two through holes.

10. An electronic device comprising: a printed circuit board; and a shield case that is disposed on one side of the printed circuit board and that is comprised of a hollow body that has conductivity, wherein at least one through hole passes through the printed circuit board, and a ground portion that has conductivity is formed in an inner peripheral portion of the through hole, at least one projecting portion to be inserted into the at least one through hole is formed in a projecting manner in the shield case, and in a state of being inserted in the through hole, the projecting portion is electrically connected to the ground portion via solder.

11. A manufacturing method for an electronic device including a printed circuit board comprising at least one ground layer that has conductivity and is provided at a location in a middle in a thickness direction of the printed circuit board, and a shield case that is placed on one side of the printed circuit board and that is comprised of a hollow body that has conductivity, the manufacturing method comprising: forming at least one through hole, which passes through the at least one ground layer, in the printed circuit board, and in a state in which at least one projecting portion formed in a projecting manner in the shield case is inserted into the at least one through hole, electrically connecting the projecting portion to the ground layer via solder, wherein the printed circuit board comprises a front-side ground layer that has conductivity and is different from the ground layer, wherein the front-side ground layer is provided on the one side, the projecting portion is electrically connected to the front-side ground layer via the solder, the printed circuit board comprises a connecting portion that has conductivity, wherein the connecting portion is provided in an inner peripheral portion of the through hole and electrically connects the at least one ground layer and the front-side ground layer to each other, and the projecting portion is electrically connected to the connecting portion via the solder.
