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Capacitor module having a metal sheet between adjacent capacitors

Abstract

A capacitor module that includes: a plurality of capacitors each including: a first electrode and a second electrode that face each other, and a side surface joining the first electrode and the second electrode, the side surface having a pair of flat portions that face each other, and a pair of curved portions joining the pair of flat portions to each other, the plurality of capacitors being arrayed in a row such that the flat portions of adjacent capacitors face each other; at least one metal sheet arranged in any of spaces between the flat portions of the adjacent capacitors, the at least one metal sheet being in contact with the first electrode of at least one of the adjacent capacitors; a first bus-bar electrically connected to the at least one metal sheet; and a second bus-bar electrically connected to each of the second electrodes of the plurality of capacitors.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS (1) The present application is a continuation of International application No. PCT/JP2021/018752, filed May 18, 2021, which

claims priority to Japanese Patent Application No. 2020-093502, May 28, 2020, the entire contents of each of which are incorporated herein by reference.

FIELD OF THE INVENTION

(1) The present invention relates to a capacitor module.

BACKGROUND OF THE INVENTION

(2) Patent Document 1 discloses a configuration of a capacitor having a plurality of unit capacitors, where one electrode of each of unit capacitors is connected to a different element electrode plate.

Patent Document 1: JP5989533

SUMMARY OF THE INVENTION

(3) The capacitor described in Patent Document 1 still leaves room for improvement in terms of compatibility between heat dissipation and simplification of configuration.

(4) It is therefore an object of the present invention to provide a capacitor module having a simplified configuration as well as improved heat dissipation.

(5) A capacitor module according to an aspect of the present invention comprises: a plurality of capacitors each including: a first electrode and a second electrode that face each other, and a side surface joining the first electrode and the second electrode, the side surface having a pair of flat portions that face each other, and a pair of curved portions that face each other and join the pair of flat portions to each other, the plurality of capacitors being arrayed in a row such that the flat portions of adjacent capacitors of the plurality of capacitors face each other; at least one metal sheet arranged in any of spaces between the flat portions of the adjacent capacitors, the at least one metal sheet being in contact with the first electrode of at least one of the adjacent capacitors; a first bus-bar electrically connected to the at least one metal sheet; and a second bus-bar electrically connected to each of the second electrodes of the plurality of capacitors.

(6) According to the present invention, there can be provided a capacitor module having a simplified configuration as well as improved heat dissipation.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. 1 is a perspective view showing a capacitor module according to a first embodiment of the present invention.

(2) FIG. 2 is a perspective view of the capacitor module of FIG. 1, with a case removed.

(3) FIG. 3A is a perspective view showing a capacitor of the capacitor module of FIG. 1.

(4) FIG. 3B is a perspective view showing a capacitor of the capacitor module of FIG. 1.

(5) FIG. 4 is a side view of the capacitor module of FIG. 1.

(6) FIG. 5 is a perspective view showing a metal sheet of the capacitor module of FIG. 1.

(7) FIG. 6 is a perspective view showing a first bus-bar of the capacitor module of FIG. 1.

(8) FIG. 7 is a perspective view of the capacitor module of FIG. 1, seen from a different direction.

(9) FIG. 8 is a perspective view of a capacitor module according to a first variant of the first embodiment.

(10) FIG. 9 is a side view of a capacitor module according to a second variant of the first embodiment.

(11) FIG. 10 is a perspective view of a capacitor module according to a third variant of the first embodiment.

(12) FIG. 11 is an enlarged view of a part of a first bus-bar according to a fourth variant of the first embodiment.

(13) FIG. 12 is a side view of a capacitor module according to a second embodiment.

(14) FIG. 13 is a perspective view of a capacitor module according to a variant of the second embodiment.

DETAILED DESCRIPTION OF THE INVENTION

Background to the Invention

(15) In the capacitor described in Patent Document 1, the unit capacitors each have a capacitor element and an element electrode plate, each element electrode plate being connected to one electrode of each capacitor element. Each element electrode plate is arranged adjacent to each capacitor so that heat generated from the capacitor element can be dissipated by the element electrode plate.

(16) On the other hand, due to the configuration connecting one element electrode plate to one capacitor element, the number of the element electrode plates may be excessive depending on the arrangement of the capacitor elements. When the number of the element electrode plates is excessive, there are problems that the configuration becomes cumbersome and that the assembly process becomes complicated.

(17) Thus, the inventors investigated a capacitor module having a simplified configuration as well as improved heat dissipation and arrived at the following invention.

(18) A capacitor module according to an aspect of the present invention comprises: a plurality of capacitors each including: a first electrode and a second electrode that face each other, and a side surface joining the first electrode and the second electrode, the side surface having a pair of flat portions that face each other, and a pair of curved portions that face each other and join the pair of flat portions to each other, the plurality of capacitors being arrayed in a row such that the flat portions of adjacent capacitors of the plurality of capacitors face each other; at least one metal sheet arranged in any of spaces between the flat portions of the adjacent capacitors, the at least one metal sheet being in contact with the first electrode of at least one of the adjacent capacitors; a first bus-bar electrically connected to the at least one metal sheet; and a second bus-bar electrically connected to each of the second electrodes of the plurality of capacitors.

(19) According to this configuration, the metal sheets arranged between the flat portions can cover all of the first electrodes of the plurality of capacitors. This achieves the simplified configuration while improving heat dissipation by the metal sheets.

(20) The metal sheet may bend in different directions so as to come into contact with the first electrodes of both of the adjacent capacitors.

(21) This configuration allows each metal sheet to come into contact with two first electrodes. This facilitates design changes such as arranging the metal sheet in all of the spaces between the flat portions, or thinning out the number of the metal sheets to be arranged. Since the specifications of the metal sheets can be unified, mass production of the metal sheets becomes possible, enabling suppression of the production costs.

(22) The metal sheet may comprise a main body arranged between the respective flat portions of the adjacent capacitors; one or more first electrode contact portions extending from the main body and contacting the first electrode of one capacitor of the adjacent capacitors; one or more second electrode contact portions extending from the main body and contacting the first electrode of a second capacitor of the adjacent capacitors, wherein the one or more first electrode contact portions and the one or more second electrode contact portions are alternately disposed at intervals; and a bus-bar contact portion extending from the main body and contacting the first bus-bar.

(23) This configuration ensures well-balanced arrangement of the electrode contact portions.

(24) The bus-bar contact portion may be located at a position up to which the main body extends from between the respective flat portions of the adjacent capacitors toward between the respective curved portions of the adjacent capacitors.

(25) According to this configuration, as compared with the case where the bus-bar contact portion is disposed at a position extended toward the second electrode, the distance between the bus-bar contact portion and the second electrode can be increased. Short circuit between the bus-bar contact portion and the second electrode can thus be prevented.

(26) The bus-bar contact portion may lie between the curved portions.

- (27) This configuration enables the bus-bar contact portion to be arranged in a dead space between the curved portions. This contributes to size reduction of the capacitor module.
- (28) The number of the plurality of capacitors may be $2n+1$ (n is a natural number), and the number of the metal sheets may be $n+1$ to $2n$.
- (29) According to this configuration, each of the first electrodes can be connected to the metal sheet arranged between the adjacent capacitors with a smaller number of metal sheets than the number of the capacitors. This achieves simplification of the configuration and suppression of the production costs.
- (30) The number of the plurality of capacitors may be $2n$ (n is a natural number greater than or equal to 2), and the number of the metal sheets may be n to $2n-1$.
- (31) According to this configuration, each of the first electrodes can be connected to the metal sheet arranged between the adjacent capacitors with a smaller number of metal sheets than the number of the capacitors. This achieves simplification of the configuration and suppression of the production costs.
- (32) The number of the plurality of capacitors may be m (m is a natural number greater than or equal to 3), and the number of the metal sheets may be $m-1$.
- (33) This configuration enables the metal sheet to be arranged in all of the spaces between the flat portions. This can improve heat dissipation of the capacitor module.
- (34) A first embodiment according to the present invention will hereinafter be described with reference to the accompanying drawings. In the drawings, elements are shown in an exaggerated manner for ease of explanation.

First Embodiment

(35) [Overall Configuration]

(36) FIG. 1 is a perspective view showing a capacitor module 1 according to the first embodiment of the present invention. FIG. 2 is a perspective view of the capacitor module 1 of FIG. 1, with a case 91 removed. FIGS. 3A and 3B are perspective views showing a capacitor 11 of the capacitor module of FIG. 1. FIG. 4 is a side view of the capacitor module 1 of FIG. 1. FIG. 5 is a perspective view showing a metal sheet 51 of the capacitor module 1 of FIG. 1. FIG. 6 is a perspective view showing a first bus-bar 54 of the capacitor module 1 of FIG. 1. FIG. 7 is a perspective view of the capacitor module 1 of FIG. 1, seen from a different direction. X, Y, and Z directions in the diagrams represent height, lateral, and longitudinal directions, respectively, of the capacitor module 1.

(37) The capacitor module 1 comprises, as shown in FIGS. 1 and 2, four capacitors 11 to 14, three metal sheets 51 to 53, the first bus-bar 54, and a second bus-bar 55. In the capacitor module 1, the case 91 made of resin houses the four capacitors 11 to 14, the metal sheets 51 to 53, a part of the first bus-bar 54, and a part of the second bus-bar 55, with the interior of the case 91 being filled with sealing resin (not shown).

(38) The case 91 has an opening 92 provided at a position facing a bottom surface 93. The case 91 is made of an insulating material, for example, a synthetic resin such as polyphenylene sulfide (PPS resin) or polybutylene terephthalate (PBT resin).

(39) The sealing resin is filled in the interior of the case 91 to seal constituent elements of the capacitor module 1. The sealing resin is a thermosetting resin, and, for example, can be an epoxy resin. It may be a urethane resin.

(40) <Capacitors>

(41) The capacitors 11 to 14 are film capacitors formed by winding a dielectric film. The capacitors 11 to 14 are formed by winding the dielectric film on which surface a metal deposition film is formed and pressing a roll of the dielectric film into a flat shape. In this embodiment, the four capacitors 11 to 14 are included in the capacitor module 1. The capacitors 11 to 14 have a similar configuration, and therefore the capacitor 11 will be described herein.

(42) The capacitor 11 has, as shown in FIGS. 3A and 3B, a first electrode 21, a second electrode 31,

and a side surface **41**. The first electrode **21** and the second electrode **31** are (end face) electrodes arranged so as to face each other. The side surface **41** is a side surface joining the first electrode **21** and the second electrode **31**. The side surface **41** has a pair of flat portions **41a** facing each other and a pair of curved portions **41b** joining the pair of flat portions **41a** together.

(43) The dielectric film of the capacitor **11** can be, for example, a plastic film such as polyethylene terephthalate, polypropylene, polyphenylene sulfide, or polyethylene naphthalate. The metal deposition film formed on the surface of the plastic film can be Al, Zn, or the like. The first electrode **21** and the second electrode **31** are formed, for example, by thermal spraying Zn or the like at the ends of the wound dielectric film.

(44) As shown in FIGS. **2** and **4**, the capacitors **11** to **14** are arrayed in a row inside the case **91** such that the flat portions **41a** to **44a** face each other. That is, the flat portion **41a** and the flat portion **42a** face each other, the flat portion **42a** and the flat portion **43a** face each other, the flat portion **43a** and the flat portion **44a** face each other. The capacitors **11** to **14** are arrayed such that a gap distance between the flat portions **41a** to **44a** is approx. 0.5 mm to 4.0 mm. The capacitors **11** to **14** are arranged such that, among the curved portions **41b** to **44b**, the curved portions **41b** to **44b** on one hand face the opening **92**, while the curved portions **41b** to **44b** on the other face the bottom surface **93**.

(45) <Metal Sheet>

(46) As shown in the figures, the metal sheets **51** to **53** are conductive members that electrically connect the first electrodes **21**, **22**, **23**, and **24** of the capacitors **11**, **12**, **13** and **14**, respectively, and the first bus-bar **54**. As shown in the figures, the metal sheets **51**, **52**, and **53** have, respectively, main bodies **61**, **62**, and **63**, electrode contact portions **71** (**71a**/**71b**), **72** (**72a**/**72b**), and **73** (**73a**/**73b**), and bus-bar contact portions **81**, **82**, and **83**.

(47) As shown in FIGS. **2** and **4**, the metal sheets **51** to **53** are arranged such that the main bodies **61** to **63** lie in spaces between the flat portions **41a** to **44a** of the capacitors **11** to **14**. That is, the metal sheets **51** to **53** are arranged respectively between the respective flat portions **41a** and **42a** of the adjacent capacitors **11** and **12**, between the respective flat portions **42a** and **43a** of the adjacent capacitors **12** and **13**, and between the respective flat portions **43a** and **44a** of the adjacent capacitors **13** and **14**. In this embodiment, the main body **61** of the metal sheet **51** is arranged in a space **S1** between the flat portion **41a** and the flat portion **42a**. Similarly, the main body **62** of the metal sheet **52** is arranged in a space **S2** between the flat portion **42a** and the flat portion **43a**. Furthermore, the main body **63** of the metal sheet **53** is arranged in a space **S3** between the flat portion **43a** and the flat portion **44a**. That is, in the capacitor module **1**, the three metal sheets **51** to **53** are arranged for the four capacitors **11** to **14**.

(48) Since the metal sheets **51** to **53** have a similar configuration, the configuration of the metal sheet **51** will be described with reference to FIG. **5**.

(49) The main body **61** of the metal sheet **51** is a portion arranged in the space **S1** between the flat portion **41a** and the flat portion **42a**. When sealing resin is filled in the interior of the case **91**, with the main body **61** of the metal sheet **51** arranged in the space **S1**, the sealing resin is filled in the space **S1** as well. At this time, the sealing resin enters between the main body **61** and the flat portion **41a** and between the main body **61** and the flat portion **42a**, leading to improvement in thermal conductivity.

(50) The metal sheet **51** includes the electrode contact portions **71** extending from the main body **61** to contact the first electrodes **21** and **22**. The electrode contact portions **71** are configured by bending a part of an end in the longitudinal direction (**Z** direction) of the main body **61** in the lateral direction (**Y** direction). This embodiment includes, as shown in FIG. **5**, four electrode contact portions **71** (two electrode contact portions **71a** and two electrode contact portions **71b**). The electrode contact portions **71a** are bent to contact the first electrode **21** of the capacitor **11** from the main body **61**. The electrode contact portions **71b** are bent to contact the first electrode **22** of the capacitor **12** from the main body **61**. That is, the electrode contact portions **71a** and the

electrode contact portions **71b** bend in different directions so that the metal sheet **51** comes into contact with both the first electrodes **21** and **22** of the two capacitors **11** and **12**.

(51) In this embodiment, the electrode contact portions (first electrode contact portions) **71a** contacting the first electrode **21** of the capacitor **11** and the electrode contact portions (second electrode contact portions) **71b** contacting the first electrode **22** of the capacitor **12** are alternately disposed spaced apart in the height direction (X direction). Alternate disposition of the electrode contact portions **71a** and the electrode contact portions **71b** ensures well-balanced arrangement of the electrode contact portions **71**. It also enables the electrode contact portions **71a** and the electrode contact portions **71b** to come into even contact with the first electrode **21** and the first electrode **22**. The arrangement of the electrode contact portions **71a** and the electrode contact portions **71b** is not limited thereto as long as the configuration allows connections to both the first electrode **21** of the capacitor **11** and the first electrode **22** of the capacitor **12**.

(52) The electrode contact portions **71** are electrically connected to the first electrodes **21** and **22** by soldering. Not all electrode contact portions **71** need to be soldered. For example, one of the two electrode contact portions **71a** and one of the two electrode contact portions **71b** may be soldered, and the remainders may be brought into mere contact with the first electrodes **21** and **22**, respectively, without soldering. By appropriately selecting the electrode contact portions **71** to be soldered, it is possible to reduce the influence of heat during soldering on the characteristics of the capacitor module **1**. By soldering all of the electrode contact portions **71** to the first electrodes **21** and **22**, it is possible to improve the reliability in connection between the metal sheet **51** and the first electrodes **21** and **22**.

(53) The metal sheet **51** includes, as shown in FIGS. **2** and **5**, the bus-bar contact portions **81** extending from the main body **61** to contact the first bus-bar **54**. The bus-bar contact portions **81** are portions inserted into holes **64a** (see FIG. **6**) disposed at an embedded portion **64** of the first bus-bar **54** that will be described later. The bus-bar contact portions **81** are configured as protruding portions that further protrude in X direction from a part of an end in X direction of the main body **61**.

(54) In this embodiment, as shown in FIG. **4**, the bus-bar contact portions **81** are provided at a position up to which the main body **61** extends from the space **S1** between the flat portions **41a** and **42a** toward a space **S4** between the curved portions **41b** and **42b**. That is, the bus-bar contact portions **81** are provided at a position up to which the main body **61** extends from between the respective flat portions **41a** and **42a** of the adjacent capacitors **11** and **12** toward between the respective curved portions **41b** and **42b** of the capacitors **11** and **12**. Similarly, the bus-bar contact portions **82** are provided at a position up to which the main body **63** extends from the space **S2** toward a space **S5**, and the bus-bar contact portions **83** are provided at a position up to which the main body **63** extends from the space **S3** toward a space **S6**. The bus-bar contact portions **81** to **83** are electrically connected to the first bus-bar **54** by soldering.

(55) The metal sheets **51** to **53** can be formed by, for example, pressing a metal sheet of approx. 0.3 mm to 0.5 mm in thickness. The metal sheets **51** to **53** are made of a thinner metal than the first bus-bar **54** that will be described later. Since they are made of a low-cost metal thinner than the first bus-bar **54**, the production costs can be reduced by connecting the first electrodes **21** to **24** of the capacitors **11** to **14** via the metal sheets **51** to **53** to the first bus-bar **54**.

(56) Since the four capacitors **11** to **14** are arrayed in a row, the three spaces **S1** to **S3** are provided between the flat portions. In the embodiment, as shown in FIG. **4**, the metal sheets **51** to **53** are arranged in the three spaces **S1** to **S3**, respectively. Due to the arrangement of the metal sheets **51** to **53** in the three respective spaces **S1** to **S3**, the capacitor module **1** can have improved heat dissipation. Such an arrangement of the metal sheets **51** to **53** enables the first electrodes **21** to **24** of the capacitors **11** to **14** to be connected to the first bus-bar **54** by using a less number of the metal sheets **51** to **53** than the number of the capacitors **11** to **14**, leading to a simplified configuration of the capacitor module **1**. By arranging the metal sheets **51** to **53** in the spaces **S1** to **S3**, respectively,

currents flowing through the metal sheets **51** to **53** can efficiently cancel magnetic fields caused by currents flowing through the capacitors **11** to **14**, allowing the capacitor module **1** to have a low ESL.

(57) Sealing resin is filled in the spaces **S1** to **S3** between the flat portions. Heat generated from the capacitors **11** to **14** is transmitted through the sealing resin to the metal sheets **51** to **53**. Since the metal sheets **51** to **53** are electrically and mechanically connected to the first bus-bar **54**, heat of the capacitors **11** to **14** can be efficiently radiated to the outside of the capacitor module **1** from an exposed portion **74** of the first bus-bar **54** that is exposed to the outside of the sealing resin.

(58) In this embodiment, as shown in FIG. 2, the metal sheet **51** is in contact with both the first electrodes **21** and **22** of the capacitors **11** and **12**, respectively. Similarly, the metal sheet **52** is in contact with both the first electrodes **22** and **23** of the capacitors **12** and **13**, respectively, and the metal sheet **53** is in contact with both the first electrodes **23** and **24** of the capacitors **13** and **14**, respectively. In other words, the first electrode **21** of the capacitor **11** is in contact with the metal sheet **51**, the first electrode **22** of the capacitor **12** is in contact with the metal sheet **51** and the metal sheet **52**, the first electrode **23** of the capacitor **13** is in contact with the metal sheet **52** and the metal sheet **53**, and the first electrode **24** of the capacitor **14** is in contact with the metal sheet **53**. That is, among the capacitors **11** to **14**, the capacitor **12** and the capacitor **13** arranged inside are each in contact with two metal sheets, while the capacitor **11** and **14** arranged outside are each in contact with one metal sheet.

(59) In this embodiment, as shown in FIGS. 2 and 4, the three metal sheets **51** to **53** are arranged for the four capacitors **11** to **14**. When arraying the capacitors **11** to **14** in a row such that the flat portions **41a** to **44a** face each other, the number of the spaces **S1** to **S3** between the flat portions becomes 3. Since in this embodiment the metal sheets **51** to **53** are arranged in the spaces **S1** to **S3**, respectively, the number of the metal sheets becomes 3 if the number of the capacitors is 4. That is, the number of the metal sheets becomes at most one less than the number of the capacitors.

(60) <First Bus Bar>

(61) The first bus-bar **54** is a plate-shaped conductive member electrically connected to the first electrodes **21** to **24** of the capacitors **11** to **14**. The first bus-bar **54** is formed from a conductive member of approx. 0.3 mm to 2 mm in thickness. As shown in FIG. 2, the first bus-bar **54** and the first electrodes **21** to **24** are electrically connected via the metal sheets **51** to **53**.

(62) As shown in FIGS. 2 and 6, the first bus-bar **54** has the three embedded portions **64** and the exposed portion **74**. The embedded portions **64** are portions connected to the bus-bar contact portions **81** to **83** of the metal sheets **51** to **53** and are embedded in the interior of the sealing resin within the case **91**. The exposed portion **74** is a portion exposed to the outside of the case **91**.

(63) As shown in FIG. 6, each of the embedded portions **64** has the holes **64a**. The bus-bar contact portions **81** to **83** of the metal sheets **51** to **53** are inserted into the holes **64a** so that the first bus-bar **54** and the metal sheets **51** to **53** are electrically connected by soldering. Connections between the first bus-bar **54** and the metal sheets **51** to **53** are not limited to soldering, and can be done by, for example, welding or a mechanical method such as caulking.

(64) In this embodiment, as shown in FIG. 4, the embedded portions **64** of the first bus-bar **54** are arranged at a higher position than the capacitors **11** to **14** in the height direction (X direction). Specifically, the embedded portions **64** are arranged at a position closer to the opening **92**, than a position **H1** of the top of the curved portions **41b** to **44b** of the capacitors **11** to **14** arranged toward the opening **92**. By arranging the embedded portions **64** at this position, connections between the first bus-bar **54** and the metal sheets **51** to **53** can be done at a position apart from the second electrodes **31** to **34**. This can prevent short circuit between the first bus-bar **54** and the second electrodes **31** to **34**.

(65) <Second Bus Bar>

(66) As shown in FIG. 7, the second bus-bar **55** is a plate-shaped conductive member electrically connected to the second electrodes **31** to **34** of the capacitors **11** to **14**. The second bus-bar **55** is

formed from a conductive member of approx. 0.3 mm to 2 mm in thickness. The second bus-bar 55 has an exposed portion 65 exposed to the outside of the case 91, and an electrode contact portion 75 in contact with the second electrodes 31 to 34. The second bus-bar 55 and the second electrodes 31 to 34 are electrically connected by soldering.

(67) The exposed portion 74 of the first bus-bar 54 and the exposed portion 65 of the second bus-bar 55 are arranged with an interval V1 of approx. 0.5 mm. By reducing the interval V1 between the exposed portion 74 of the first bus-bar 54 and the exposed portion 65 of the second bus-bar 55 to some extent, the capacitor module 1 can implement a low ESL. Accordingly, the exposed portion 74 and the exposed portion 65 are preferably arranged such that the size of the interval V1 becomes approx. 0.5 mm.

Effects

(68) According to the capacitor module 1 of the first embodiment, the following effects can be provided.

(69) The capacitor module 1 comprises the four capacitors 11 to 14, the three metal sheets 51 to 53, the first bus-bar 54, and the second bus-bar 55. The capacitors 11 to 14 have respectively the first electrodes 21 to 24, the second electrodes 31 to 34, and the side surfaces 41 to 44. The first electrodes 21 to 24 and the second electrodes 31 to 34 are respectively arranged so as to face each other. The side surfaces 41 to 44 join the first electrodes 21 to 24 and the second electrodes 31 to 34, and include respectively the pairs of flat portions 41a to 44a, each pair facing each other, and the pair of curved portions 41b to 44b joining respectively the flat portions 41a to 44a on one hand and the flat portions 41a to 44a on the other. The capacitors 11 to 14 are arrayed in a row such that the flat portions 41a to 44a face each other. The metal sheets 51 to 53 are arranged in corresponding ones of the spaces between the flat portions 41a to 44a of the adjacent capacitors 11 to 14 and are respectively in contact with at least the first electrodes 21 to 24 on one hand of the adjacent capacitors 11 to 14. The first bus-bar 54 is electrically connected to the metal sheets 51 to 53. The second bus-bar 55 is electrically connected to each of the second electrodes 31 to 34. The first electrodes 21 to 24 of the capacitors 11 to 14 are each electrically connected to the metal sheets 51 to 53.

(70) Such a configuration enables the metal sheets 51 to 53 arranged (in the spaces S1 to S3) between the flat portions 41a to 44a to cover all of the first electrodes 21 to 24 of the capacitors 11 to 14. This makes it possible to simplify the configuration of the capacitor module 1 while improving heat dissipation of the capacitor module 1 by the metal sheets 51 to 53.

(71) Due to the arrangement of the metal sheets 51 to 53 in the spaces S1 to S3, magnetic fields caused by currents flowing through the interiors of the capacitors 11 to 14 can be efficiently cancelled, allowing the capacitor module 1 to have a low ESL.

(72) The metal sheets 51 to 53 bend in different directions so as to come into contact with the respective first electrodes 21 to 24 of adjacent two capacitors 11 to 14.

(73) Such a configuration allows each of the metal sheets 51 to 53 to come into contact with the first electrodes 21 to 24 of the two capacitors 11 to 14. This facilitates design changes such as arranging the metal sheet in all of the spaces S1 to S3 between the flat portions 41a to 44a, or thinning out the number of the metal sheets to be arranged. By unifying the specifications of the metal sheets 51 to 53, mass production of the metal sheets 51 to 53 becomes possible, enabling the production costs to be suppressed.

(74) The metal sheets 51 to 53 have the main bodies 61 to 63, the electrode contact portions 71 to 73, and the bus-bar contact portions 81 to 83. The main bodies 61 to 63 are arranged between the respective flat portions 41a to 44a of the adjacent capacitors 11 to 14. The electrode contact portions 71 to 73 extend from the main bodies 61 to 63 to contact the first electrodes 21 to 24. The bus-bar contact portions 81 to 83 extend from the main bodies 61 to 63 to contact the first bus-bar 54 and are provided at a position up to which the main bodies 61 to 63 extend from (the spaces S1 to S3) between the flat portions 41a to 44a toward (the spaces S4 to S6) between the curved

portions **41b** to **44b**.

(75) Such a configuration enables connections between the first bus-bar **54** and the metal sheets **51** to **53** to be performed at a position apart from the second electrodes **31** to **34**. This can prevent short circuit between the first bus-bar **54** and the second electrodes **31** to **34**.

(76) The number of the capacitors **11** to **14** is m (m is a natural number greater than or equal to 3), and the number of the metal sheets **51** to **53** is $m-1$. In this embodiment, the number of the capacitors **11** to **14** is 4, and the number of the metal sheets **51** to **53** is 3.

(77) By virtue of such a configuration, the metal sheets **51** to **53** can be arranged in the spaces **S1** to **S3**, respectively, between the flat portions **41a** to **44a**. This can improve heat dissipation of the capacitor module **1** while simplifying the configuration.

(78) [Variants]

(79) Although in the first embodiment, the example including the four capacitors **11** to **14** has been described, the number of the capacitors is not limited to 4, but 3 or more capacitors can be disposed.

(80) Although in the first embodiment, as shown in FIG. 4, the example has been described where the embedded portions **64** of the first bus-bar **54** are arranged at the same position in the height direction (X direction), this is not limitative. The three embedded portions **64** of the first bus-bar **54** need not necessarily be arranged at the same position in the height direction (X direction). Also in cases where the positions in the height direction differ, the same effects as in the first embodiment can be provided.

(81) Although in the first embodiment, the example has been described where the pairs of curved portions **41b** to **44b** of the capacitors **11** to **14** are arranged such that each pair face the opening **92** and the bottom surface **93**, respectively, of the case **91**, the arrangement of the capacitors **11** to **14** is not limited thereto. FIG. 8 is a perspective view of a capacitor module **1a** according to a first variant of the first embodiment. As shown in FIG. 8, the capacitors **11** to **14** may be arranged such that the first electrodes **21** to **24** are arranged toward the bottom surface **93** while the second electrodes **31** to **34** are arranged toward the opening **92**.

(82) Such a configuration can provide the same effects as in the first embodiment.

(83) Although in the first embodiment, as shown in FIG. 4, the example has been described where the embedded portions **64** of the first bus-bar **54** are arranged at a higher position than the position **H1** of the top of the curved portions **41b** to **44b** of the capacitors **11** to **14** arranged toward the opening **92**, this is not limitative. FIG. 9 is a side view of a capacitor module **1b** according to a second variant of the first embodiment. As shown in FIG. 9, embedded portions **64b** of a first bus-bar **54b** may be arranged at a lower position than the position **H1** of the top of the curved portions **41b** to **44b** of the capacitors **11** to **14**. That is, the embedded portions **64b** of the first bus-bar **54b** are arranged respectively in the spaces **S4** to **S6** between the curved portions **41b** to **44b**.

(84) Since the spaces **S4** to **S6** between the curved portions **41b** to **44b** become dead spaces within the case **91**, the dead spaces can be effectively used by positioning the embedded portions **64b** at this position. This contributes to size reduction of the capacitor module **1**.

(85) The first bus-bar **54** may include a cooling portion on which a thermal pad is arranged. FIG. 10 is a perspective view of a capacitor module **1c** according to a third variant of the first embodiment. In the capacitor module **1c**, a first bus-bar **54c** includes a cooling portion **76** extending from an exposed portion **74c**, on which cooling portion **76** a thermal pad **77** is arranged. Due to such a configuration, the first bus-bar **54c** can be cooled over a larger area, leading to further improvement in heat dissipation of the capacitor module **1c**.

(86) The thermal pad may be arranged on the first bus-bar **54** of the capacitor module **1** of the first embodiment. Specifically, the thermal pad is arranged on the exposed portion **74** of the first bus-bar **54** so that the first bus-bar **54** can be cooled. This achieves further improvement in heat dissipation of the capacitor module **1**.

(87) The embedded portions **64c/64d** of the first bus-bar may have different shapes. FIG. 11 is an

enlarged view of a part of a first bus-bar **54d** according to a fourth variant of the first embodiment. As shown in FIG. **11**, a recessed portion **66** may be disposed at a part of each of the embedded portions **64d** of the first bus-bar **54d** that extend from an exposed portion **74d**. By disposing the recessed portion **66** in the vicinity of the holes **64a** receiving the bus-bar contact portions **83** of the metal sheet **53**, escape of heat during soldering can be suppressed.

Second Embodiment

(88) A capacitor module **2** according to a second embodiment of the present invention will be described.

(89) In the second embodiment, difference from the first embodiment will be mainly described. In the second embodiment, constituent elements identical or equivalent to those in the first embodiment will be described with the same reference numerals. In the second embodiment, descriptions overlapping with those in the first embodiment will be omitted.

(90) FIG. **12** is a side view of a capacitor module **2** according to the second embodiment.

(91) In the second embodiment, as shown in FIG. **12**, the number of metal sheets **151** and **152** differs from that in the first embodiment. Specifically, among the spaces **S1** to **S3** between the flat portions, the metal sheet **151** is arranged in the space **S1** and the metal sheet **152** is arranged in the space **S3**. The metal sheets **151** and **152** can be connected respectively to first electrodes of the adjacent two capacitors. For this reason, without arranging the metal sheets in all of the spaces **S1** to **S3**, the metal sheets **151** and **152** may be arranged such that the metal sheets **151** and **152** are connected to respective corresponding ones of all the first electrodes **21** to **24**. In this embodiment, an electrode contact portion **171a** of the metal sheet **151** is connected to the first electrode **21** of the capacitor **11**, while an electrode contact portion **171b** is connected to the first electrode **22** of the capacitor **12**. Similarly, an electrode contact portion **172a** of the metal sheet **152** is connected to the first electrode **23** of the capacitor **13**, while an electrode contact portion **172b** is connected to the first electrode **24** of the capacitor **14**. In case of arranging the two metal sheets **151** and **152**, a first bus-bar **154** has two embedded portions **164** that extend from exposed portion **174**.

(92) Since in this embodiment, the number of the capacitors **11** to **14** is 4, three spaces **S1** to **S3** are provided between the flat portions. Accordingly, the number of the metal sheets to be arranged can be at most one less than the number of the capacitors. In cases where the number of the capacitors is even, the number of the metal sheets to be arranged can be at least one-half of the number of the capacitors. That is, when the number of capacitors is $2n$ (n is a natural number greater than or equal to 2), the number of the metal sheets is n to $2n-1$. In this embodiment, with $n=2$, the number of the capacitors is $2n=4$ and the number of the metal sheets is $n=2$.

(93) In cases where the number of the capacitors is odd, i.e., the number of the capacitors is $2n+1$ (n is a natural number), the minimum number of the metal sheets is $n+1$ and the maximum number of the metal sheets is $2n$. For example, with $n=2$, the number of the capacitors is $2n+1=5$, while the minimum number of the metal sheets is $n+1=3$ and the maximum number of the metal sheets is $2n=4$.

(94) [Effect]

(95) According to the capacitor module **2** of the second embodiment, the following effect can be presented.

(96) The number of the plurality of capacitors is $2n+1$ (n is a natural number) and the number of the metal sheets is $n+1$ to $2n$.

(97) The number of the plurality of capacitors is $2n$ (n is a natural number greater than or equal to 2) and the number of the metal sheets is n to $2n-1$.

(98) Reduction in the number of the metal sheets leads to a simplified configuration of the capacitor module **2**.

(99) [Variant]

(100) Although in the second embodiment, the example has been described where the metal sheets **51** to **53** are arranged almost over the entire surfaces of the flat portions **41a** to **44a** of the

capacitors **11** to **14**, this is not limitative. FIG. **13** is a perspective view of a capacitor module **2a** according to a variant of the second embodiment. In FIG. **13**, the case **91** and the capacitor **14** are not shown.

(101) As shown in FIG. **13**, metal sheets **51a** and **52a** are formed to have a length in the longitudinal direction (Z direction) shorter than that of the metal sheets **51** to **53** of the first embodiment. The longitudinal length of the metal sheets **51a** and **52a** may be a short length of the order of one-half of the longitudinal length of the capacitors **11** to **14**. Such a configuration enables the metal sheets **51a** and **52a** to be arranged at central portions on the capacitors **11** to **13**, which portions generate the most heat by ripple current flowing through the capacitors **11** to **13**. By arranging the metal sheets **51a** and **52a** in the vicinity of the central portions of the capacitors **11** to **13**, heat dissipation effect can be improved.

(102) The first bus-bar **154a** and the second bus-bar **155a** may have different shapes. Specifically, as shown in FIG. **13**, an exposed portion **174a** of the first bus-bar **154a** and an exposed portion **165a** of the second bus-bar **155a** are formed extending in the height direction (X direction). Such an arrangement of the first bus-bar **154a** and the second bus-bar **155a** can also present the same effects as in the first embodiment.

(103) Although the present invention has been fully described in relation to the preferred embodiments while referring to the accompanying drawings, it is apparent for those skilled in the art that various modifications and alterations are possible. Without departing from the scope of the present invention defined by the appended claims, such modifications and alterations should be construed as being encompassed therein.

(104) The present invention is useful for capacitors used in various types of electronic equipment, electric equipment, industrial equipment, vehicle devices, etc.

EXPLANATIONS OF REFERENCE NUMERALS

(105) **1**, **1a** to **1b**, **2**, **2a** capacitor module **1a** capacitor module **11** to **14** capacitor **21** to **24** first electrode **31** to **34** second electrode **41** to **44** side surface **41a** to **44a** flat portion **41b** to **44b** curved portion **51** to **53** metal sheet **54** first bus-bar **55** second bus-bar **61** to **63** main body **64** embedded portion **71** to **73** electrode contact portion **81** to **83** bus-bar contact portion

Claims

1. A capacitor module comprising: a plurality of capacitors each including: a first electrode and a second electrode that face each other; and a side surface joining the first electrode and the second electrode, the side surface having a pair of flat portions that face each other, and a pair of curved portions that face each other and join the pair of flat portions to each other, the plurality of capacitors being arrayed in a row such that the flat portions of adjacent capacitors of the plurality of capacitors face each other; only a single metal sheet arranged in any of spaces between the flat portions of the adjacent capacitors, the single metal sheet comprising: one or more first electrode contact portions extending from the single metal sheet and contacting the first electrode of one capacitor of the adjacent capacitors; one or more second electrode contact portions extending from the single metal sheet and contacting the first electrode of a second capacitor of the adjacent capacitors, wherein the one or more first electrode contact portions and the one or more second electrode contact portions extend in opposite directions relative to the single metal sheet; a first bus-bar electrically connected to the single metal sheet; and a second bus-bar electrically connected to each of the second electrodes of the plurality of capacitors, wherein the first bus-bar is configured as a different member from the single metal sheet and is electrically connected to the single metal sheet.
2. The capacitor module of claim 1, wherein the metal sheet bends in different directions so as to come into contact with the first electrodes of both of the adjacent capacitors.
3. The capacitor module of claim 1, wherein the metal sheet comprises: a main body arranged

between the respective flat portions of the adjacent capacitors; one or more first electrode contact portions extending from the main body and contacting the first electrode of one capacitor of the adjacent capacitors; one or more second electrode contact portions extending from the main body and contacting the first electrode of a second capacitor of the adjacent capacitors, wherein the one or more first electrode contact portions and the one or more second electrode contact portions are alternately disposed at intervals; and a bus-bar contact portion extending from the main body and contacting the first bus-bar.

4. The capacitor module of claim 3, wherein the bus-bar contact portion is located at a position up to which the main body extends from between the respective flat portions of the adjacent capacitors toward between the respective curved portions of the adjacent capacitors.

5. The capacitor module of claim 4, wherein the bus-bar contact portion lies between the curved portions.

6. The capacitor module of claim 3, wherein the bus-bar contact portion lies between the curved portions.

7. The capacitor module of claim 1, wherein a number of the plurality of capacitors is $2n+1$, and a number of the metal sheets is $n+1$ to $2n$, wherein n is a natural number.

8. The capacitor module of claim 1, wherein a number of the plurality of capacitors is $2n$, and a number of the metal sheets is n to $2n-1$, wherein n is a natural number greater than or equal to 2.

9. The capacitor module of claim 1, wherein a number of the plurality of capacitors is m , and a number of the metal sheets is $m-1$, wherein m is a natural number greater than or equal to 3.

10. The capacitor module of claim 1, wherein the first bus-bar includes a first exposed portion and the second bus-bar includes a second exposed portion, and the first exposed portion and the second exposed portion are arranged with an interval of approx. 0.5 mm therebetween.

11. The capacitor module of claim 1, wherein the first bus-bar includes an exposed portion, and a cooling portion extending from the exposed portion.

12. The capacitor module of claim 11, further comprising a thermal pad arranged on the cooling portion.

13. A capacitor module comprising: a plurality of capacitors each including: a first electrode and a second electrode that face each other; and a side surface joining the first electrode and the second electrode, the side surface having a pair of flat portions that face each other, and a pair of curved portions that face each other and join the pair of flat portions to each other, the plurality of capacitors being arrayed in a row such that the flat portions of adjacent capacitors of the plurality of capacitors face each other; only a single metal sheet arranged in any of spaces between the flat portions of the adjacent capacitors, the single metal sheet comprising: one or more first electrode contact portions extending from the single metal sheet and contacting the first electrode of one capacitor of the adjacent capacitors; one or more second electrode contact portions extending from the single metal sheet and contacting the first electrode of a second capacitor of the adjacent capacitors, wherein the one or more first electrode contact portions and the one or more second electrode contact portions extend in opposite directions relative to the single metal sheet; and a bus-bar contact portion extending from the single metal sheet, wherein the bus-bar contact portion lies between the curved portions of the adjacent capacitors; a first bus-bar electrically connected to the bus-bar contact portion of the single metal sheet; and a second bus-bar electrically connected to each of the second electrodes of the plurality of capacitors.
