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(54) **LOW INDUCTANCE CAPACITOR ASSEMBLY**

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USPC **361/328**; 361/330

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None
See application file for complete search history.

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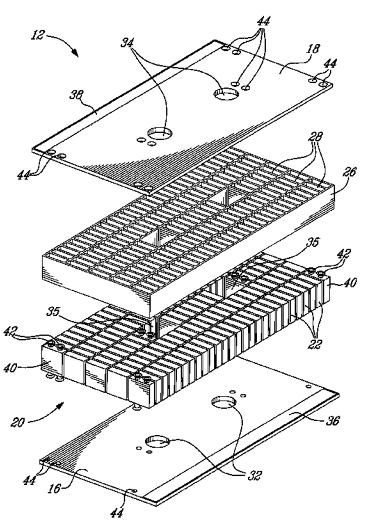
(57) **ABSTRACT**

A low-inductance capacitor assembly (**12**) is provided. The capacitor assembly (**12**) includes a positive terminal plate (**16**), a negative terminal plate (**18**) and an array (**20**) of capacitors (**22**) disposed between and electrically coupled to the positive terminal plate (**16**) and the negative terminal plate (**18**). A passage (**30**) extends through the positive terminal plate (**16**), the negative terminal plate (**18**) and through a void (**35**) formed within the array (**20**) of capacitors (**22**). The passage (**30**) may allow routing of a conductor (**14**) through the capacitor assembly (**12**).

21 Claims, 5 Drawing Sheets



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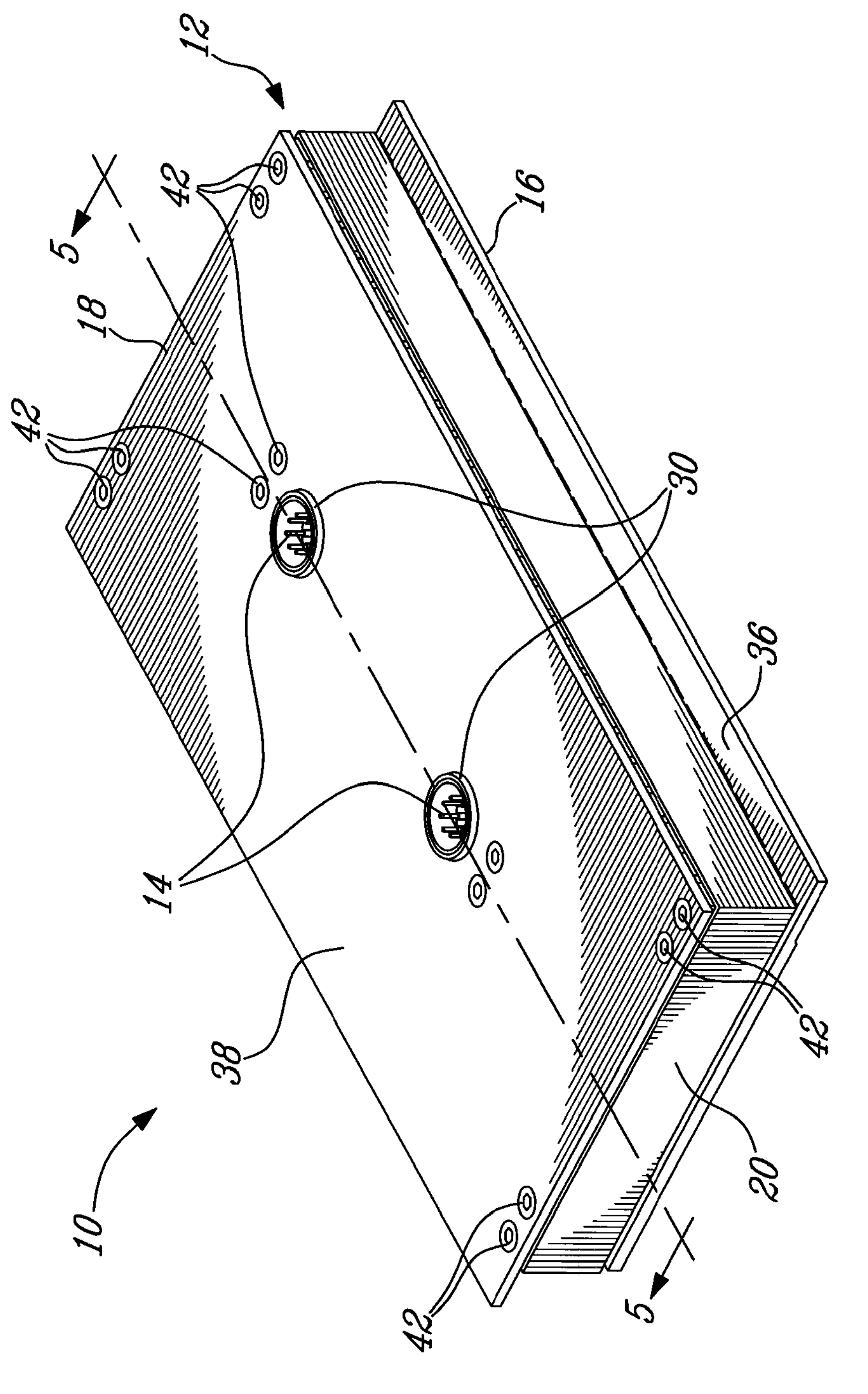

Fig-1

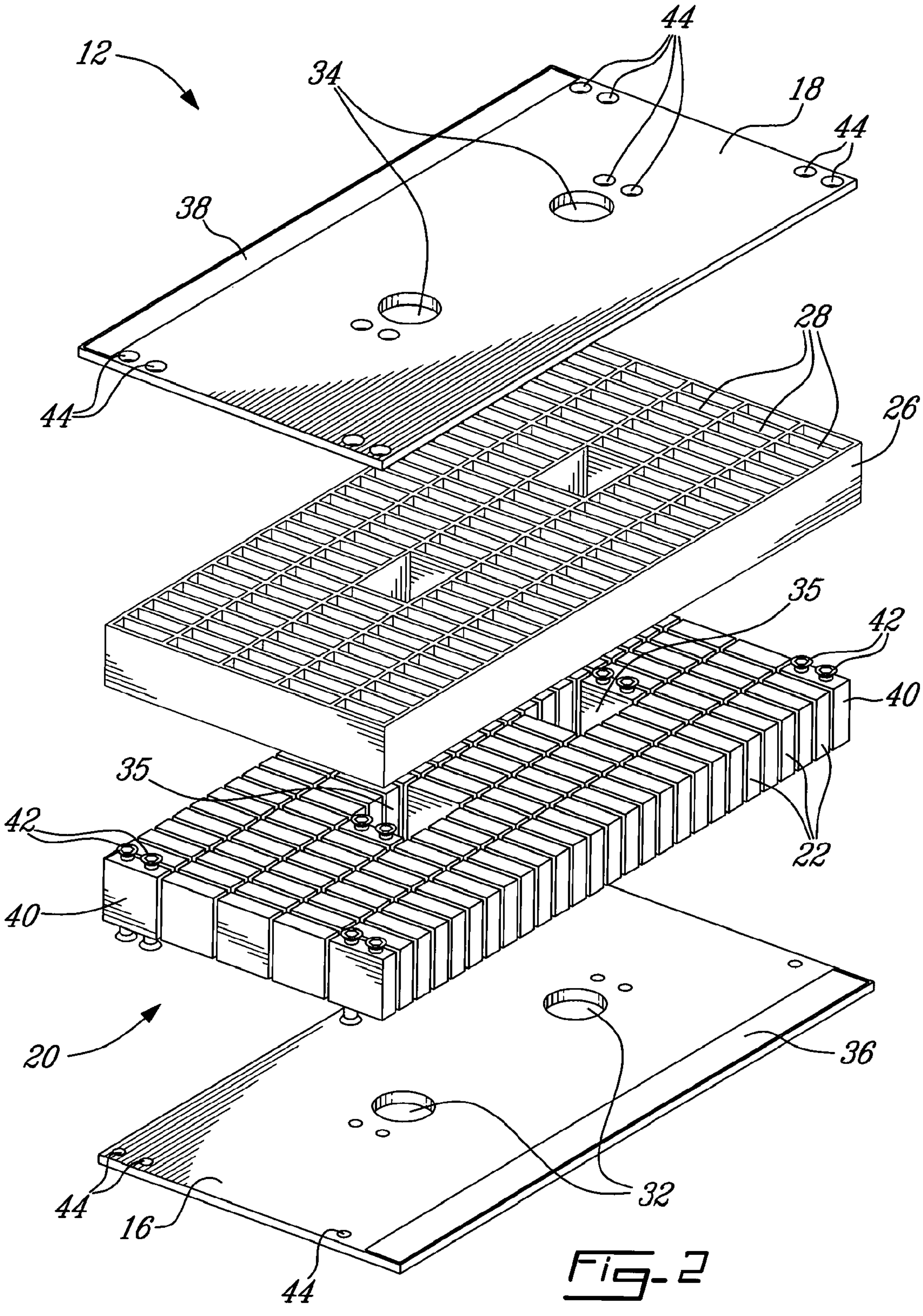

Fig-2

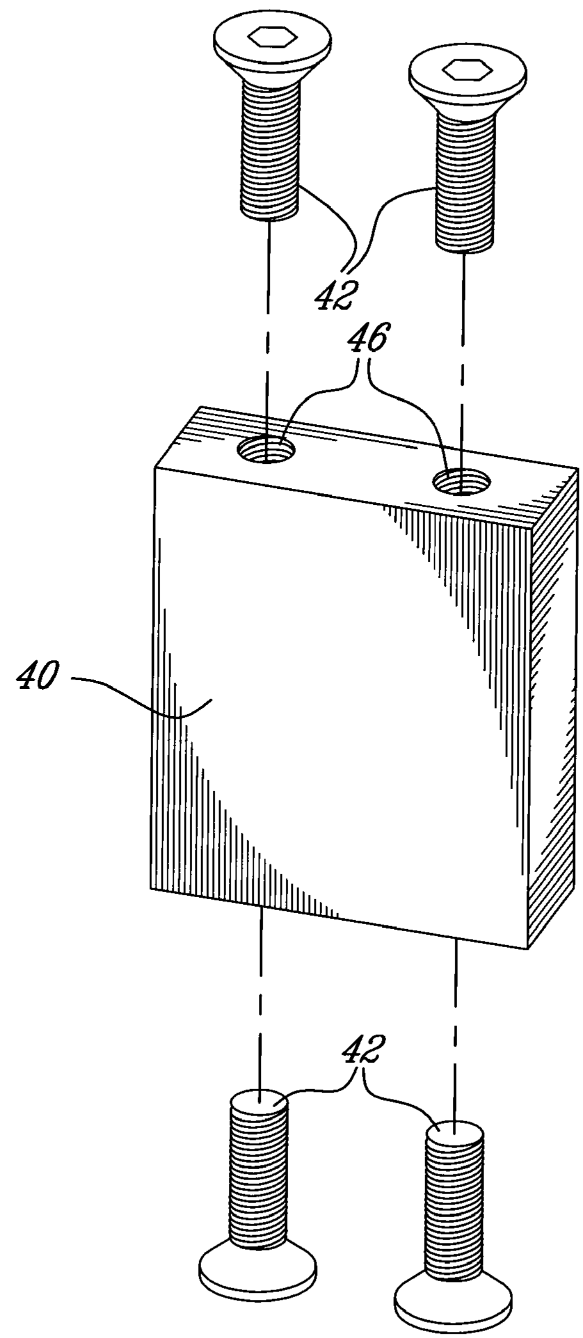

Fig-3

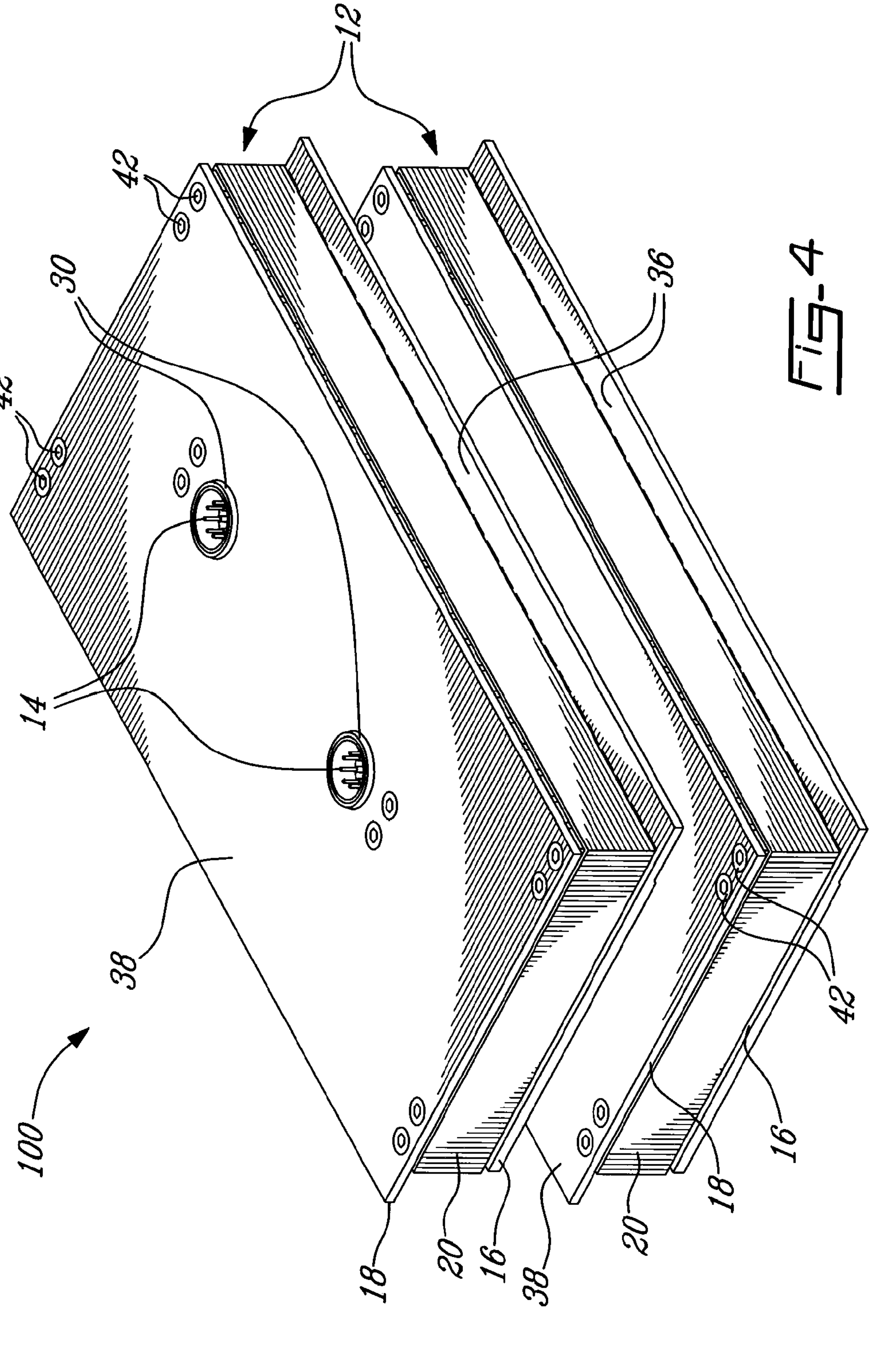

Fig-4

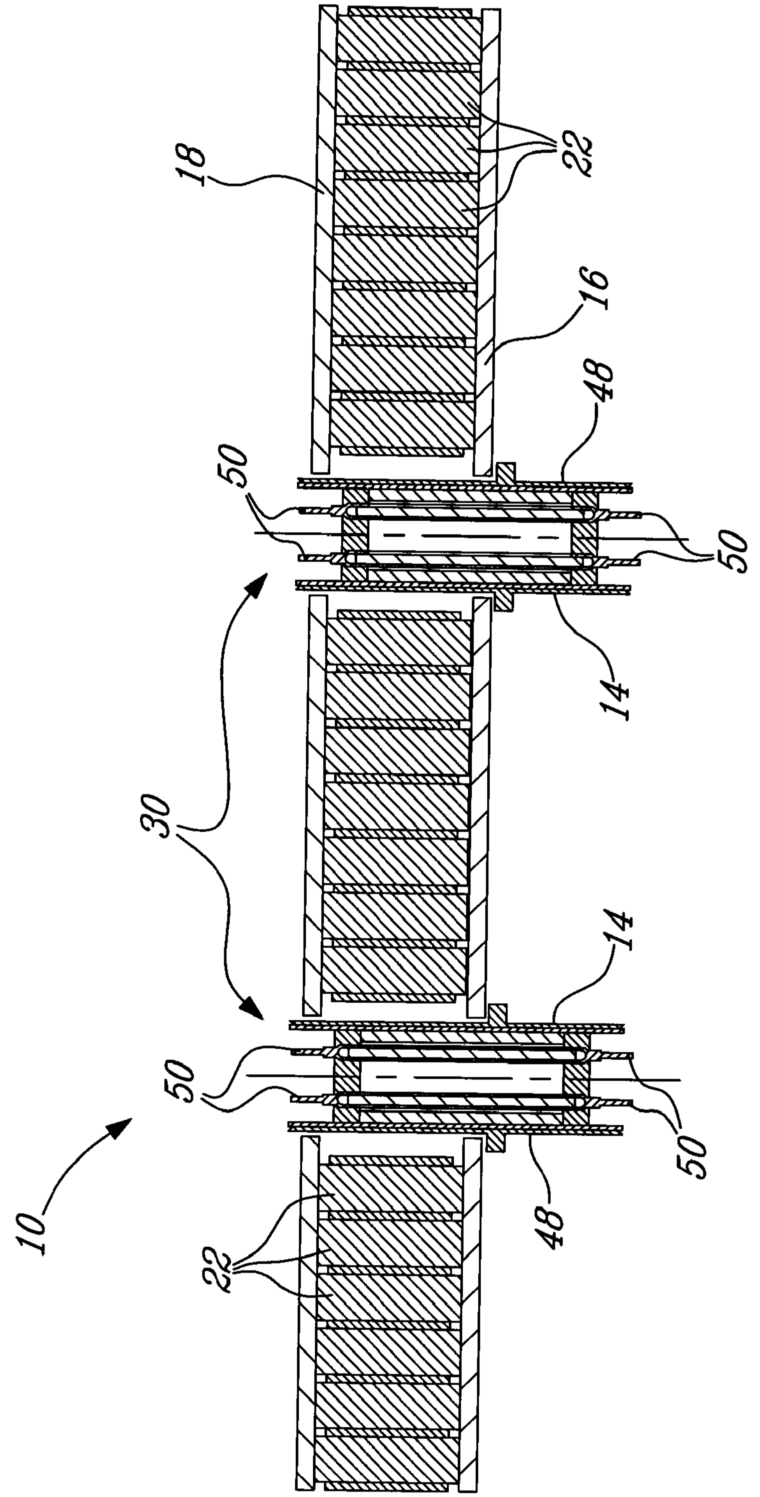

Fig-5

LOW INDUCTANCE CAPACITOR ASSEMBLY

TECHNICAL FIELD

The disclosure relates generally to capacitors, and more particularly to low-inductance capacitor assemblies.

BACKGROUND OF THE ART

Power switching circuits are used in aerospace applications, including in electrical motor drives for starter/generators as parts of gas turbine engines. For optimal control of switching speeds and pulse rise times, it can be important to reduce or otherwise control the inductance associated with capacitors. In addition, conventional capacitors typically used in high-power switching circuits are relatively bulky and require relatively large packaging envelopes.

In aerospace applications, the smallest possible envelope for equipment is nearly always desired, in order to reduce weight and drag of the overall vehicle. Other design objectives for equipment onboard aircraft include increasing reliability while reducing size, weight and cost.

Improvement in packaging, and control of switching speeds and pulse rise times of low-inductance capacitors and capacitor assemblies is therefore desirable.

SUMMARY

The disclosure describes capacitors, and in particular low-inductance capacitors and capacitor assemblies.

Thus, in one aspect, the disclosure provides a capacitor assembly which may comprise: a positive terminal plate and a negative terminal plate; an array of capacitors disposed between and electrically coupled to the positive terminal plate and the negative terminal plate; and at least one passage extending through the positive terminal plate, the negative terminal plate and through a void formed within the array of capacitors.

In another aspect, the disclosure provides a capacitor installation which may comprise: a first terminal plate having a first opening and a second terminal plate having a second opening; an array of capacitors disposed between and electrically coupled to the first terminal plate and the second terminal plate, the array of capacitors forming a void cooperating with the first opening and the second opening to form a passage; and a conductor or other system component extending through the passage.

In a further aspect, the disclosure provides a capacitor assembly which may comprise: a positive terminal plate and a negative terminal plate; a non-conductive matrix disposed between the positive plate and the negative plate, the matrix comprising a plurality of through sockets; and a plurality of capacitors inserted in respective sockets within the matrix, the capacitors being electrically coupled to the positive terminal plate and the negative terminal plate.

In a further aspect, the disclosure provides a method of assembling a capacitor assembly. The method may comprise: disposing an array of capacitors between a positive terminal plate and a negative terminal plate, the array of capacitors including a void cooperating with a first opening in the positive plate and a second opening in the negative plate to form a passage; electrically coupling the capacitors with the positive terminal plate and the negative terminal plate; and mechanically securing the capacitors between the positive terminal plate and the negative terminal plate.

In a further aspect, the disclosure provides a method of assembling a capacitor assembly. The method may comprise:

positioning a plurality of capacitors in respective sockets formed within a non-conductive matrix; and electrically coupling the capacitors to a positive terminal plate and to a negative terminal plate.

Further details of these and other aspects of the subject matter of this application will be apparent from the detailed description and drawings included below.

DESCRIPTION OF THE DRAWINGS

Reference is now made to the accompanying drawings, in which:

FIG. **1** shows a perspective view of a capacitor installation, including a capacitor assembly, in accordance with an embodiment disclosed herein;

FIG. **2** is a perspective exploded view of the capacitor assembly of FIG. **1**;

FIG. **3** is a perspective view of a mechanical connector from the capacitor assembly of FIG. **1**;

FIG. **4** is a perspective view of a capacitor installation including two capacitor assemblies in accordance with another embodiment disclosed herein; and

FIG. **5** is a cross-sectional view of the capacitor installation of FIG. **1** taken along line **5-5** in FIG. **1**.

DETAILED DESCRIPTION OF EMBODIMENTS

Various aspects of embodiments of the disclosure are described through reference to the drawings.

FIG. **1** illustrates a low-inductance capacitor installation **10** in accordance with the disclosure herein. Capacitor installation **10** comprises capacitor assembly **12**, and conductor or other structure or component **14** extending through capacitor assembly **12**. Capacitor installation(s) **10** may for example be secured to a circuit board and/or other electrical or electronic component(s) such as an associated power bus (not shown). Capacitor installation(s) **10** may be used, for example, in applications where a high current and a low inductance are required. For example, capacitor installation **10** may be used in a direct current (DC) link circuit of a motor drive, switched power circuitry such as DC-DC converters, and/or inverters and high frequency motor drives. Capacitor installation(s) **10** may also be used in motor drive circuitry for a starter-generator of a gas turbine engine in an aircraft application.

Capacitor assembly **12** may comprise a plurality of terminal plates, such as for example first (e.g., positive) terminal plate **16**, second (e.g., negative) terminal plate **18**; and one or more capacitor arrays **20**, each composed of a plurality of capacitors **22**, disposed between positive the plates **16**, **18**. Array(s) **20** of capacitors **22** (see, e.g., FIG. **2**) may be disposed in any desired or otherwise suitable arrangement(s) to accommodate systems configuration, co-location, installation, etc. Array(s) **20** may be of one, two, or in appropriate circumstances three dimensions. For example, as shown in FIGS. **1** and **2**, a two-dimensional array **20** may comprise a plurality of capacitors **22** disposed in rectangular, circular or any other suitable or otherwise desired regular or irregular two-dimensional configuration(s). Array(s) **20** may be one-dimensional and may comprise a plurality of capacitors **22** arranged in a single row (e.g., along a line). Array(s) **20** may be two-dimensional and comprise two or more rows of capacitors **22** disposed side-by-side. Array **20** may not necessarily be planar such that some of capacitors **22** may have different elevations to accommodate various shapes (e.g. contours) of terminal plates **16**, **18**.

Array(s) **20** may also be provided in three-dimensional arrays wherein, for example, two or more two-dimensional arrays **20** may be superimposed (e.g., stacked) between terminal plates **16** and **18**. In this arrangement, the two or more two-dimensional arrays **20** could be separated by shared, common terminal plate(s), or may stacked with distinct, or separated terminal plates separated by, for example, sheets or other forms of insulating materials.

The shape(s) of terminal plates **16**, **18** and/or array(s) **20** may be selected or otherwise determined to accommodate a wide range of installation/space constraints, and may for example one or more comprise cutouts **30** to avoid interfering with proximate or through-disposed components of the same or other systems. Accordingly, capacitor assembly(ies) **12** may provide a relatively simple and flexible packaging option for providing a large number of capacitors **22** having a relatively large capacitance and excellent response characteristics within a relatively small space. For example, capacitor assembly(ies) **12** may be positioned in relatively close proximity to associated components and circuitry such as switching devices.

Terminal plates **16** and **18** may be substantially planar or may have one or more planar region(s). Alternatively or in addition, terminal plates **16** and **18** may have one- or two-dimensional curved or rounded region(s) to accommodate installation constraints. Terminal plates **16** and **18** may comprise any suitable conductive material(s) such as, for example, aluminum-based material and/or copper-based material.

Each capacitor **22** within an array **20** may be electrically coupled to a positive terminal plate **16** and a negative terminal plate **18**. Electrical coupling of capacitors **22** with positive terminal plate(s) **16** and/or negative terminal plate(s) **18** may be achieved through the application of an electrically-conductive epoxy such as a silver-based epoxy. Alternatively or in addition, capacitor(s) **22** may be electrically coupled to terminal plate(s) **16** and/or **18** by soldering, or by using any other suitable method(s) and/or device(s) for producing electrical connections.

Conductive epoxy(ies) or other form of electrical coupling(s) between capacitor(s) **22** and plate(s) **16**, **18** may provide structural support and/or stiffening. For example, such coupling mechanisms may provide support for capacitors **22** between terminal plates **16** and **18**. Coupling of capacitor(s) **22** directly to terminal plate(s) **16**, **18** may allow capacitor assembly(ies) **12** to have relatively low inductance(s). The use of electrically-conductive epoxy(ies) may also allow (i.e. compensate) for dimensional variations, within a certain range, of capacitors **22**.

A desired capacitance value of a capacitor assembly **12** may be achieved by the selection of an appropriate number and value of capacitors **22** within a capacitor assembly **12**. The use of a plurality of capacitors **22** in a parallel arrangement can allow a capacitor assembly **12** to be used in high current and/or high-frequency applications.

Capacitors **22** may comprise a plurality of pre-fabricated chip capacitors of dielectric type such as, for example, ceramic or plastic film chip capacitors. Any suitable type(s) of chip capacitor(s) **22** could be used. Capacitors **22** within an array **20** may all have substantially identical capacitances and therefore the total capacitance of capacitor assembly **22** may be a multiple of the capacitance of one capacitor **22**. Alternatively, it may be appropriate to mix capacitors **22** of different types and/or capacitances within capacitor assembly(ies) **12** to obtain specific characteristics and/or behavior of capacitor assembly(ies) **12**.

Capacitor assembly(ies) **12** may also have favorable heat dissipation characteristics. For example, terminal plates **16** and/or **18** may comprise material(s) of relatively good electrical and thermal conductivity. The geometric configuration of terminal plates **16** and **18** may be selected to provide a relatively large surface area through which heat may be dissipated. Suitable heat-dissipation means such as, for example, cooling fin(s) may also be incorporated into or otherwise thermally connected to at least one of terminal plates **16** and **18** to further increase heat dissipation by convection if desired.

FIG. **2** illustrates an exploded view of a low-inductance capacitor assembly **12** such as that shown in FIG. **1**. Individual capacitors **22** within an array **20** may be disposed within matrix **26**. Matrix **26** may comprise a frame-like member including a plurality of through sockets **28** into which capacitors **22** may be inserted. Matrix **26** may comprise electrically and/or thermally non-conductive material(s) such as, for example, suitable light-weight polymeric material(s), composite material(s) and/or electrically and/or thermally insulated metal(s). Depending of the type(s) of material selected, matrix(ces) **26** may provide fire resistant and/or heat resistant barrier(s) between adjacent capacitors **22**.

Matrix(ces) **26** may be useful, for example, when assembling a capacitor assembly **12** and may also facilitate the automated assembly/positioning of a capacitor assembly **12**. Accordingly, matrix **26** may serve as a support frame for positioning individual capacitors **22** during an automated operation using, for example, vibrator technology for filling matrix **26** with capacitors **22**. A matrix **26** may also serve as an electrical insulator between adjacent capacitors **22**. A matrix **26** may also isolate capacitors **22** within array **20** from each other and, for example, prevent an exploding capacitor **22** from damaging adjacent capacitors **22**.

A capacitor assembly **12** may comprise one or more passages **30** extending through capacitor assembly **12**. Passage(s) **30** may for example comprise an opening **32** in a positive plate **16**, opening **34** in a negative plate **18**, and cooperating void(s) **35** within an array **20**. Passage(s) **30** may be located within a periphery of a capacitor assembly **12** such that, for example, one or more individual capacitors **22** are disposed so as to encircle a structure **14** and thereby allow the structure **14** to pass through the array **20** while maintaining advantages of the multiple-capacitor array. For example, passage(s) **30** may be located within a generally central region of a positive terminal plate **16** and a negative terminal plate **18**. Accordingly, passage(s) **30** may extend through array **20**, for example, inside a periphery of array **20**. Void(s) **35** may each correspond to a location within array **20** where at least one capacitor **22** has been omitted.

Accordingly, depending on the configuration of array **20** and the number of capacitors **22** within array **20**, void(s) **35** may be surrounded by neighboring capacitors **22** within array **20**. Openings **32** and **34** and void **35** may be substantially aligned to form a substantially straight (e.g. orthogonal or oblique relative to terminal plates **16** and/or **18**) passage through capacitor assembly **12**. Alternatively, openings **32** and **34** and void(s) **35** may be, for example, relatively positioned offset from each other to form a curved passage **30** for routing flexible cabling through capacitor assembly **12**. Passage(s) **30** may allow the routing of structure **14**, which may for example include various forms of wiring, cabling, conduit, fasteners, connector, other system component, etc. through capacitor assembly **12**.

Capacitor assembly(ies) **12** may used in applications where low inductance and high power is desirable. Accordingly, capacitor **12** may be used in high frequency, high efficiency switching applications. For example, capacitor assembly **12** may be used in power switching circuitry in high-power motors such as starter/generators in gas turbine applications. The packaging flexibility of a capacitor assembly **12** in accordance with the disclosure may allow for the shape/configuration of capacitor assembly **12** to be selected based on the space available for installation.

Capacitor assembly **12** may be mechanically and electrically connected to an associated power bus or other electrical/electronic components or conductors via a positive connection **36** on a positive terminal plate **16** and/or a negative connection **38** on a negative terminal plate **18** without intermediate conductor(s) which could potentially increase impedance. Either or both of positive and negative connections **36**, **38** may comprise a contact area along an edge of positive terminal plate **16** and on negative terminal plate **18** respectively. Positive and/or negative connections **36**, **38** may comprise mounting holes (not shown) for securing a capacitor assembly **12** to an associated power bus using suitable threaded or other types of fasteners and/or using one or more clamps (not shown). Alternatively or additionally, positive and/or negative connections **36**, **38** may be mechanically and/or electrically connected to associated bus work by soldering or by using any other suitable method(s) and/or device(s) of producing electrical connections. For example, a capacitor assembly **12** may be used in a gate drive circuit and positioned adjacent to or immediately above a switching device such as a metal oxide semiconductor field effect transistor (MOSFET) (not shown). Accordingly, conductor(s) **14** may include one or more wires associated with the operation of the MOSFET.

FIG. **3** illustrates a mechanical connector **40** which may be used to secure an array **20** of capacitors **22** between, for example, a positive terminal plate **16** and a negative terminal plate **18** to provide structural support if required. A plurality of mechanical connectors **40** may be secured between plates **16**, **18** using for example fasteners **42** extending through holes **44** in plates **16**, **18** and threaded into corresponding threaded holes **46** in mechanical connectors **40**. Any other suitable method(s) and device(s) could be used to secure mechanical connectors **40** between terminal plates **16**, **18**. Any suitable number of mechanical connectors **40** may be used to provide adequate support. In the embodiment shown, where array **20** is of rectangular shape, mechanical connectors **40** may for example be provided in each corner of array **20** as well as within a central region of array **20**, for example, adjacent to passage(s) **30**. The shape and size of each mechanical connector **40** may be substantially similar to that of capacitors **22** so that mechanical connectors **40** may also be contained within respective sockets **28** extending through matrix **26**. Mechanical connectors **40** may comprise a non-conductive material with sufficient strength to provide adequate structural support within capacitor assembly **12**.

FIG. **4** illustrates a low-inductance capacitor installation, generally shown at **100**, in accordance with another exemplary embodiment of the disclosure herein. Capacitor installation **100**, may comprise two or more capacitor assemblies **12** disposed relatively proximate to each other or otherwise associated with each other. For example, capacitor assemblies **12** of installation **100** may be in a stacked relationship or otherwise disposed to allow a common structure **14** through both (or more) capacitor assemblies **12**. Capacitor installation(s) **100** may for example be secured to a circuit board and/or other electrical or electronic component(s). For example, capacitor assemblies **12** may each be connected to respective power buses and/or respective circuitry (not shown). Alternatively, capacitor assemblies **12** may, for example, be connected to a common power bus and/or common circuitry (not shown). Two or more capacitor assemblies **12** could be electrically coupled together in a series or a parallel configuration.

FIG. **5** illustrates a cross-sectional view of capacitor installation **10** of FIG. **1**. Structure(s) **14** may extend through one or more passages **30** and may include a feed through connector having connector body **48** and one or more conductor pins/wires **50** disposed in connector body **48**. Conductor pin(s) **50** may be used to transmit electrical signal(s) through capacitor assembly(ies) **12**. Connector body(ies) **48** and pin(s) **50** may be configured to interface with other electrical/electronic component(s) (not shown) by direct connection and/or via cooperating connectors (not shown).

During assembly of capacitor assembly **12**, array(s) **20** of capacitors **22** may be disposed between one or more plates **16**, **18**; electrically coupled to a positive terminal plate **16** and a negative terminal plate **18**; and mechanically secured between plates **16**, **18**. An electrically conductive epoxy such as a silver-based epoxy may be used in order to electrically couple capacitors **22** to positive terminal plate **16** and/or the negative terminal plate **18**. Conductive epoxy(ies) may also provide some structural support between capacitors **22** and terminal plates **16** and **18**. The conductive epoxy may be applied to contact face(s) of positive terminal plate **16** and/or negative terminal plate **18** prior to disposing capacitors **22** between terminal plates **16** and **18** and also before mechanically securing terminal plates **16** and **18** together via mechanical connectors **40**, if required, to form a sandwich structure. Other means of producing an electrical connection between capacitors **22** and terminal plates **16** and **18** such as soldering may also be used. The use of conductive epoxy may compensate for some dimensional variations of capacitors **22** within array **20**.

Assembly of capacitor assembly(ies) **12** may be performed manually, semi-automatically or may be fully automated using suitable automation machinery/robotics. To facilitate positioning and distributing of capacitors **22** within array **20**, non-conductive matrix **26** may be used to serve as a guide or template. Individual capacitors **22**, such as chip capacitors for example, may be automatically positioned (e.g. inserted) within sockets **28** during an automated operation using vibrator technology. For example, capacitor(s) **22** may be disposed within such matrix(ces) **26** prior to attachment of either or both of plates **16**, **18**.

Void(s) **35** cooperating with respective opening(s) **32** in positive plate **16** and also with opening(s) **34** in negative plate **18** to form passage(s) **30** may be formed in array **20** by omitting at least one capacitor **22** from array **20** so as to permit the routing of cabling/conduit through array **20**. Passage(s) **30** may extend through a socket **28** of matrix **26**, which may be sized accordingly. Alternatively, passage(s) **30** may be formed through capacitor assembly **12** comprising a continuous array **20** of contiguously-disposed capacitor(s) **22** by drilling or other method of material removal following assembly of capacitor assembly **12**.

The above description is meant to be exemplary only, and one skilled in the art will recognize that changes may be made to the embodiments described without departing from the scope of the invention disclosed. Modifications which fall within the scope of the present invention will be apparent to those skilled in the art, in light of a review of this disclosure, and such modifications are intended to fall within the appended claims. Except to the extent necessary or inherent in the processes themselves, no particular order to steps or stages of methods or processes described in this disclosure is intended or implied.

What is claimed is:

1. A capacitor assembly comprising:
a positive terminal plate and a negative terminal plate;
an array of capacitors, the capacitors being disposed between and electrically coupled to the positive terminal plate and the negative terminal plate in parallel; and
at least one passage extending through the positive terminal plate, the negative terminal plate and through a void formed within the array of capacitors, the void including a location where at least one capacitor is omitted from the array of capacitors.

2. The capacitor assembly as defined in claim **1**, wherein the array of capacitors includes a two-dimensional array of capacitors.

3. The capacitor assembly as defined in claim **2**, wherein the capacitors include chip capacitors.

4. The capacitor assembly as defined in claim **3**, comprising a non-conductive matrix through which the capacitors are disposed.

5. The capacitor assembly as defined in claim **1**, comprising an electrically-conductive epoxy electrically coupling at least one of the capacitors to at least one of the positive terminal plate and the negative terminal plate.

6. The capacitor assembly as defined in claim **1**, comprising at least one mechanical connector secured between the positive terminal plate and the negative terminal plate.

7. The capacitor assembly as defined in claim **1**, comprising a non-conductive assembly matrix through which the capacitors are disposed.

8. The capacitor assembly as defined in claim **7**, comprising an electrically-conductive epoxy electrically coupling the capacitors to the positive terminal plate and the negative terminal plate.

9. The capacitor assembly as defined in claim **8**, wherein the capacitors include chip capacitors.

10. The capacitor assembly as defined in claim **9**, wherein the void is surrounded by capacitors within the array of capacitors.

11. A capacitor installation comprising:
a first terminal plate having a first opening and a second terminal plate having a second opening;
an array of capacitors, the capacitors being disposed between and electrically coupled to the first terminal plate and the second terminal plate in parallel, the array of capacitors forming a void cooperating with the first opening and the second opening to form a passage, the void including a location where at least one capacitor is omitted from the array of capacitors; and
a conductor or other system component extending through the passage.

12. The capacitor installation as defined in claim **11**, wherein the void is surrounded by capacitors within the array of capacitors.

13. The capacitor installation as defined in claim **11**, comprising a non-conductive assembly matrix through which the capacitors are disposed.

14. The capacitor installation as defined in claim **11**, wherein a connector extends through the passage.

15. A capacitor assembly comprising:
a positive terminal plate and a negative terminal plate;
a non-conductive matrix disposed between the positive plate and the negative plate, the matrix comprising a plurality of through sockets;
a plurality of capacitors inserted in respective sockets within the matrix, the capacitors being electrically coupled to the positive terminal plate and the negative terminal plate in parallel; and
at least one mechanical connector secured between the positive terminal plate and the negative terminal plate; the mechanical connector being inserted in one of the sockets of the matrix.

16. The capacitor assembly as defined in claim **15**, comprising an electrically-conductive epoxy electrically coupling at least one of the capacitors to at least one of the positive terminal plate and the negative terminal plate.

17. The capacitor assembly as defined in claim **15**, wherein the capacitors include chip capacitors.

18. The capacitor assembly as defined in claim **17**, wherein the sockets are arranged in a two-dimensional array.

19. A capacitor assembly comprising:
a positive terminal plate and a negative terminal plate;
an array of capacitors disposed between and electrically coupled to the positive terminal plate and the negative terminal plate; and
at least one passage extending through the positive terminal plate, the negative terminal plate and through a void formed within the array of capacitors, the void including a location where at least one capacitor is omitted from the array of capacitors.

20. A capacitor installation comprising:
a first terminal plate having a first opening and a second terminal plate having a second opening;
an array of capacitors disposed between and electrically coupled to the first terminal plate and the second terminal plate, the array of capacitors forming a void cooperating with the first opening and the second opening to form a passage, the void including a location where at least one capacitor is omitted from the array of capacitors; and
a conductor or other system component extending through the passage.

21. A capacitor assembly comprising:
a positive terminal plate and a negative terminal plate;
a non-conductive matrix disposed between the positive plate and the negative plate, the matrix comprising a plurality of through sockets;
a plurality of capacitors inserted in respective sockets within the matrix, the capacitors being electrically coupled to the positive terminal plate and the negative terminal plate; and
at least one mechanical connector secured between the positive terminal plate and the negative terminal plate, the mechanical connector being inserted in one of the sockets of the matrix.

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