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(54) **POWER SEMICONDUCTOR PACKAGE WITH A COMMON CONDUCTIVE CLIP**

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(56) **References Cited**

U.S. PATENT DOCUMENTS

7,295,453 B2 11/2007 Shiraishi
7,618,896 B2 * 11/2009 Joshi H01L 23/492
257/724

(Continued)

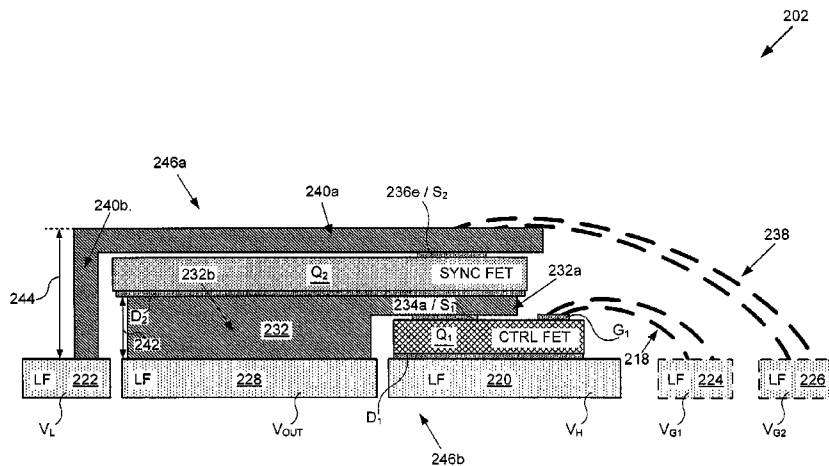
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(57) **ABSTRACT**

According to an exemplary embodiment, a stacked half-bridge package includes a control transistor having a control drain for connection to a high voltage input, a control source coupled to a common conductive clip, and a control gate for being driven by a driver IC. The stacked half-bridge package also includes a sync transistor having a sync drain for connection to the common conductive clip, a sync source coupled to a low voltage input, and a sync gate for being driven by the driver IC. The control and sync transistors are stacked on opposite sides of the common conductive clip with the common conductive clip electrically and mechanically coupling the control source with the sync drain, where the common conductive clip has a conductive leg for providing electrical and mechanical connection to an output terminal leadframe.

20 Claims, 6 Drawing Sheets



(51)	Int. Cl.		7,843,044 B2	11/2010	Takahashi	
	<i>H01L 23/00</i>	(2006.01)	7,936,054 B2	5/2011	Eom	
	<i>H01L 23/492</i>	(2006.01)	8,062,932 B2	11/2011	Herbert	
(52)	U.S. Cl.		8,299,588 B1	10/2012	Tateishi	
	CPC	<i>H01L 2224/37147</i> (2013.01); <i>H01L 2224/40095</i> (2013.01); <i>H01L 2224/40245</i> (2013.01); <i>H01L 2224/451</i> (2013.01); <i>H01L 2224/48106</i> (2013.01); <i>H01L 2224/48247</i> (2013.01); <i>H01L 2224/49111</i> (2013.01); <i>H01L 2224/73215</i> (2013.01); <i>H01L 2224/73221</i> (2013.01); <i>H01L 2224/73265</i> (2013.01); <i>H01L 2924/00014</i> (2013.01); <i>H01L 2924/01013</i> (2013.01); <i>H01L 2924/01029</i> (2013.01); <i>H01L 2924/01033</i> (2013.01); <i>H01L 2924/1306</i> (2013.01); <i>H01L 2924/13064</i> (2013.01); <i>H01L 2924/13091</i> (2013.01); <i>H01L 2924/14</i> (2013.01); <i>H01L 2924/181</i> (2013.01); <i>H01L 2924/30107</i> (2013.01)	8,426,952 B2 *	4/2013	Cho	H01L 23/49524 257/666
			8,431,927 B2 *	4/2013	Kim	H01L 29/7869 257/43
			8,860,194 B2	10/2014	Ma	
			2006/0169976 A1 *	8/2006	Kameda	H01L 23/552 257/44
			2008/0061396 A1 *	3/2008	Havanur	H01L 23/49562 257/500
			2009/0108467 A1 *	4/2009	Otreмба	H01L 23/3107 257/777
			2009/0141203 A1 *	6/2009	Son	G02F 1/136213 349/39
			2009/0160036 A1	6/2009	Grey	
			2009/0315026 A1 *	12/2009	Jeong	H01L 29/7869 257/43
			2010/0171543 A1	7/2010	Korec	
			2010/0279470 A1	11/2010	Grey	
			2012/0168926 A1	7/2012	Cho	
			2012/0181996 A1	7/2012	Gehrke	
(56)	References Cited					
	U.S. PATENT DOCUMENTS					
	7,675,148 B2	3/2010	Lim			

* cited by examiner

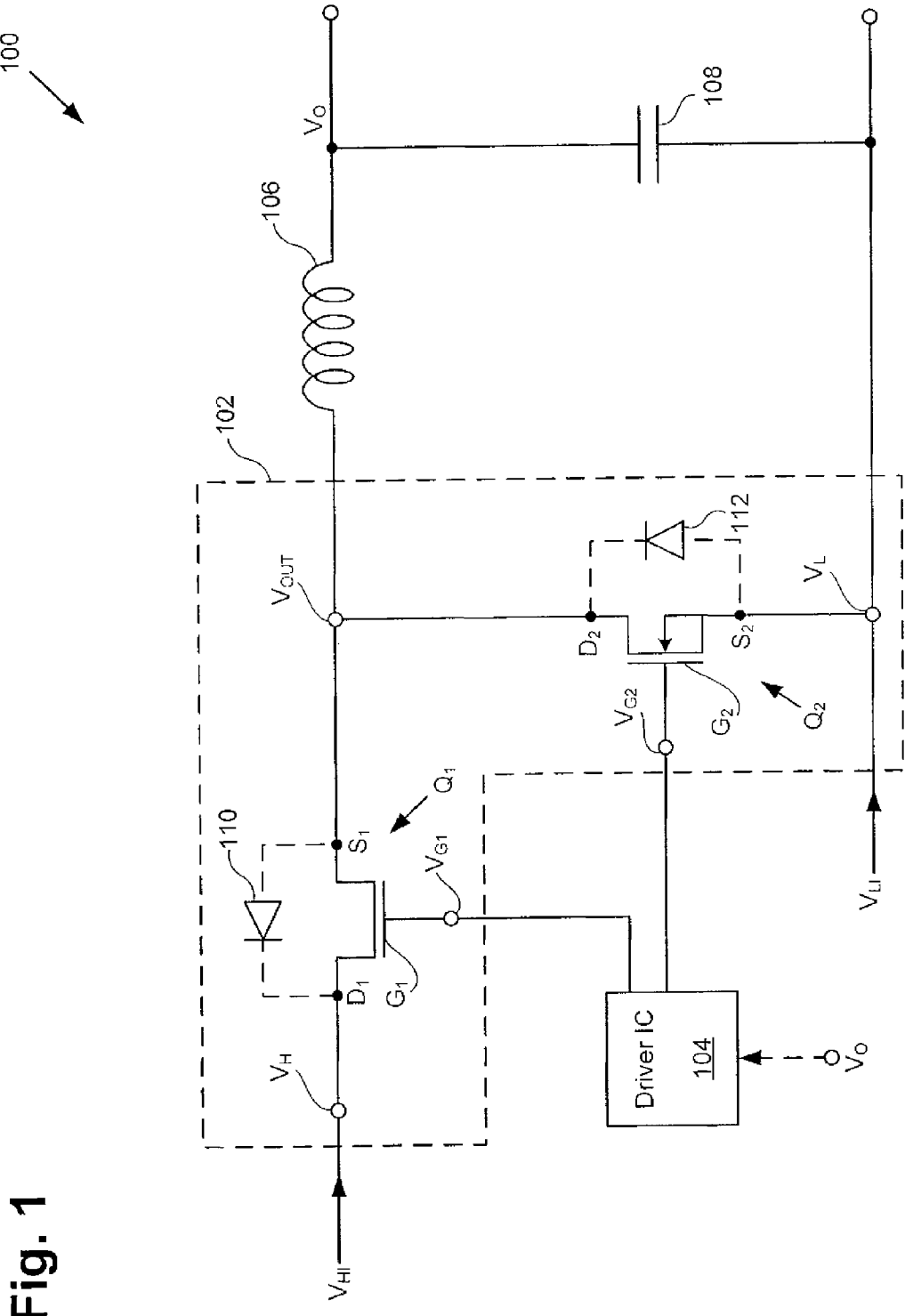


Fig. 1

Fig. 2A

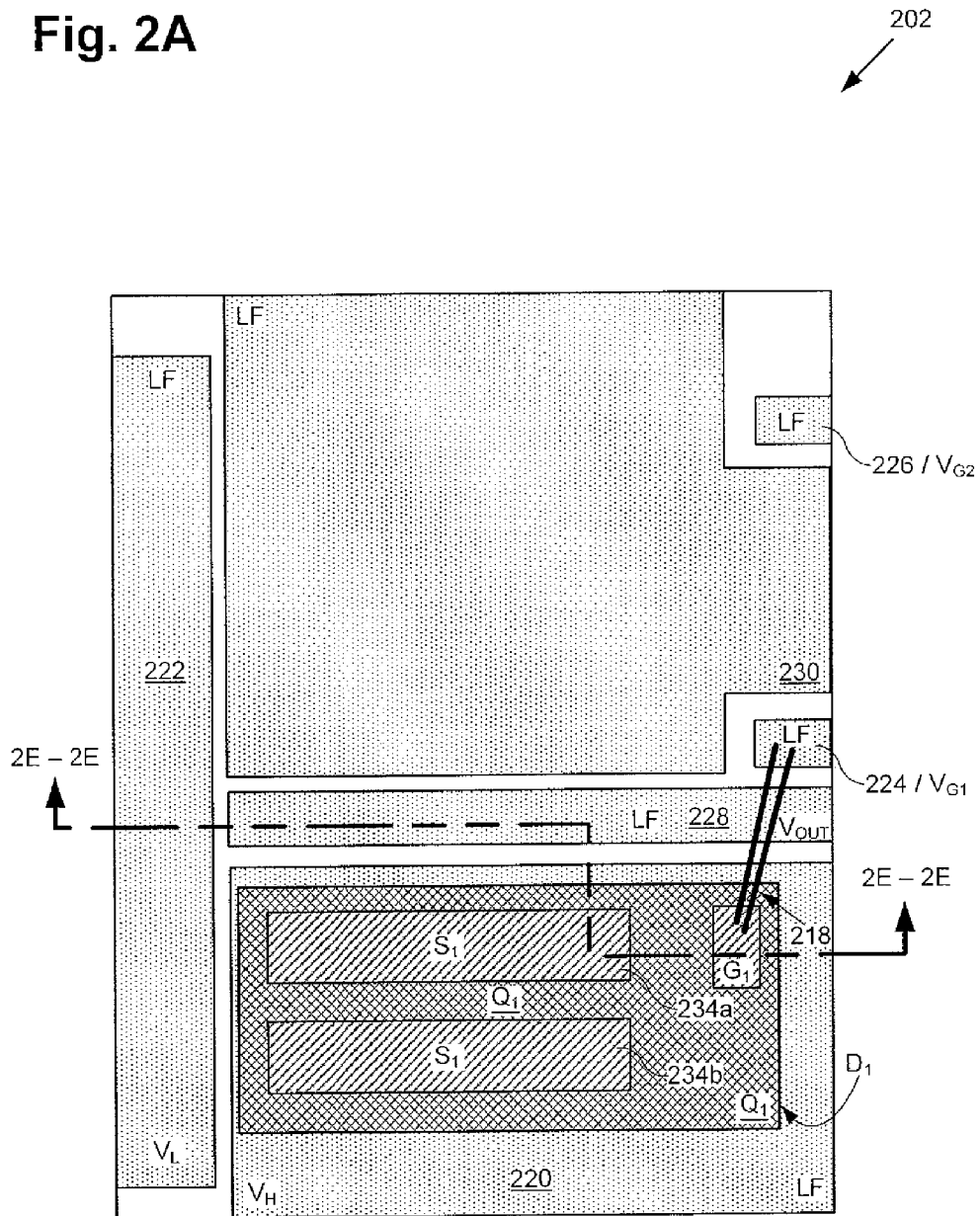


Fig. 2B

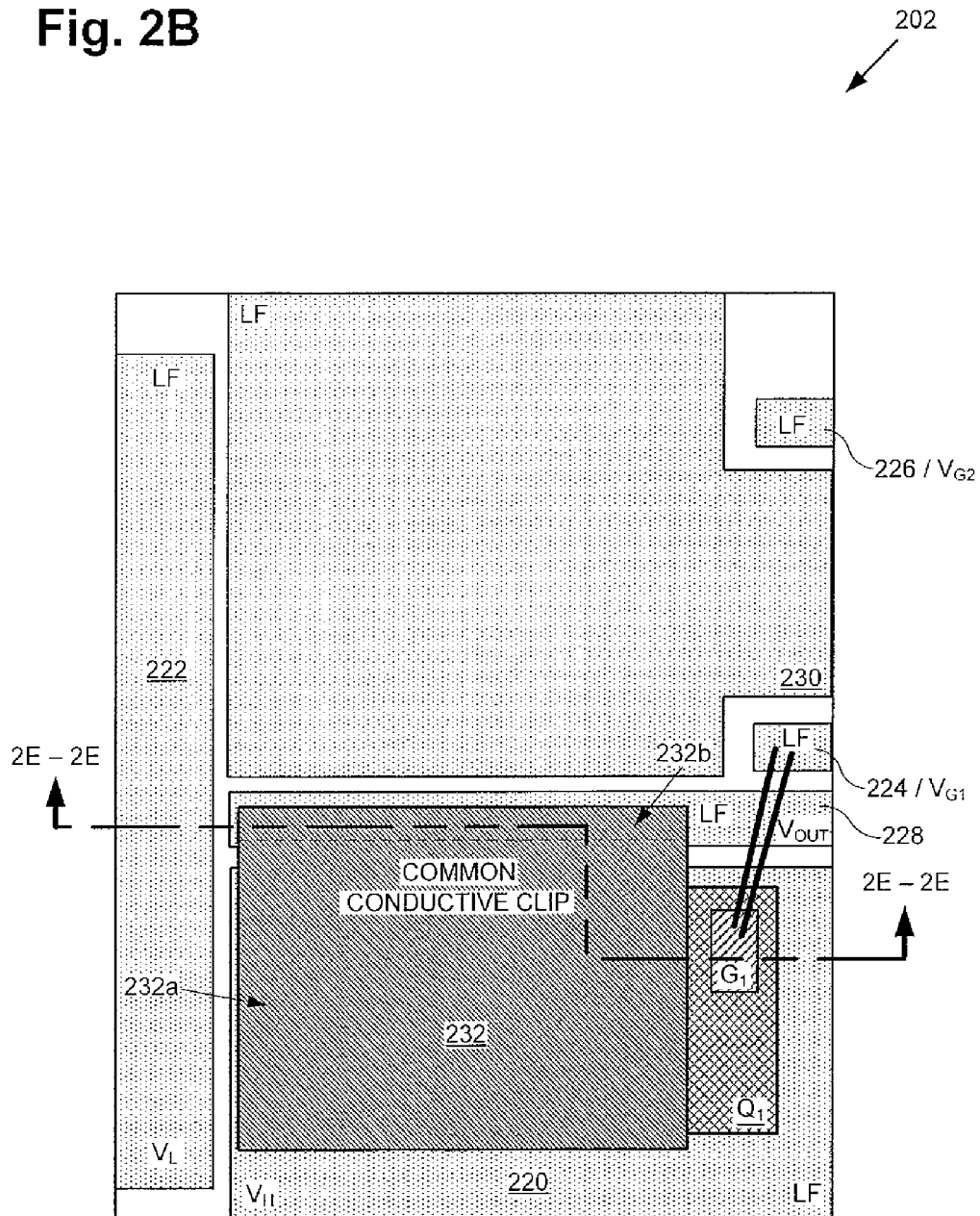


Fig. 2C

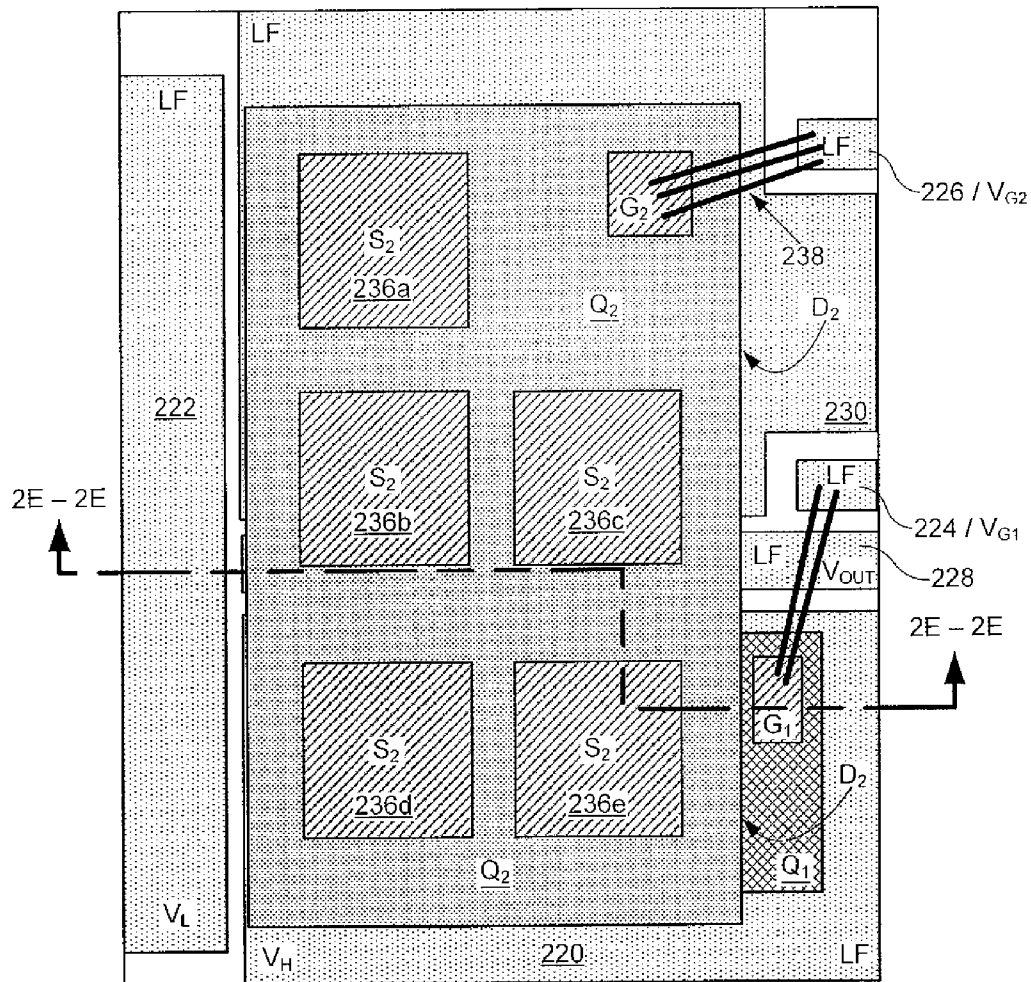


Fig. 2D

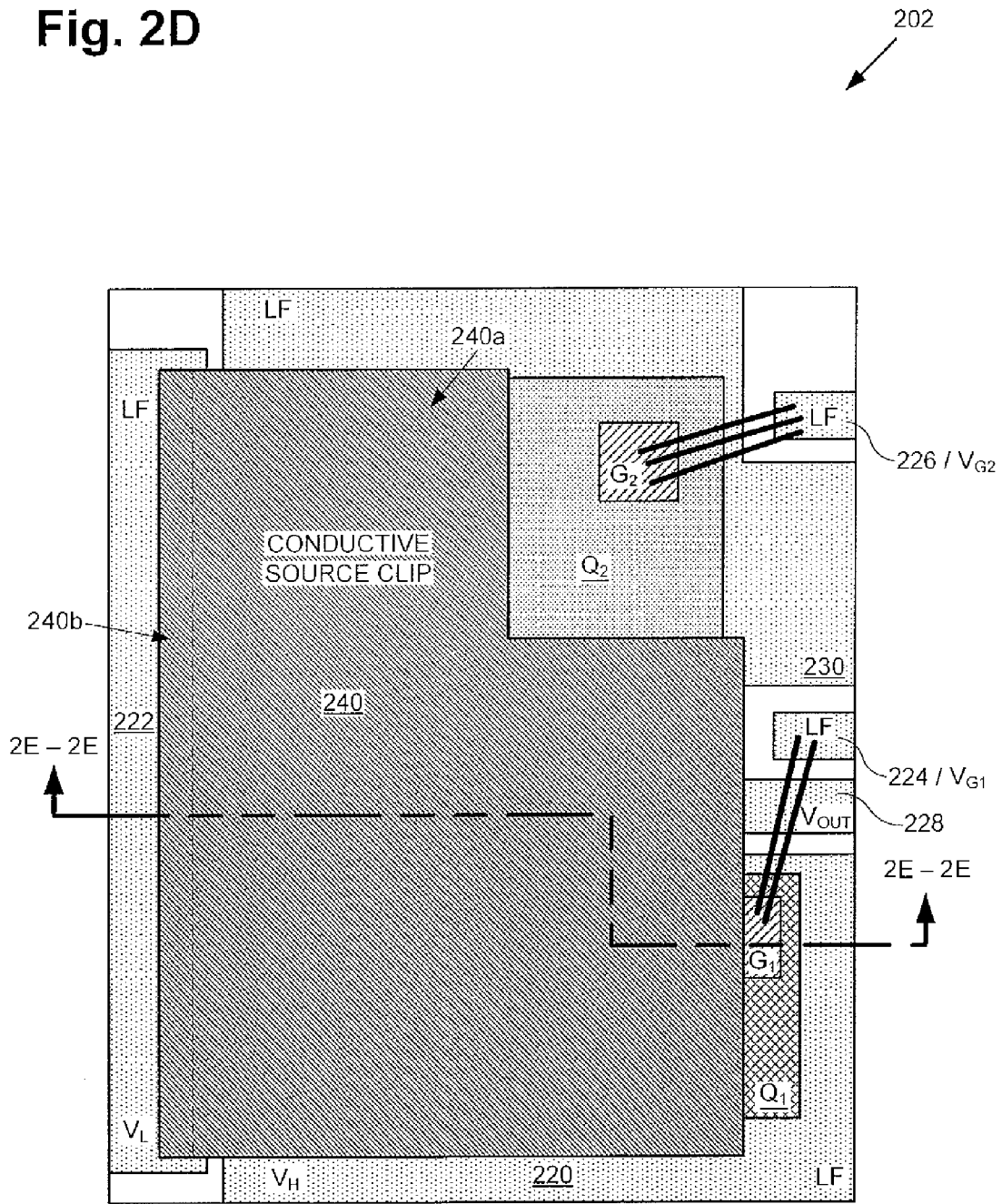
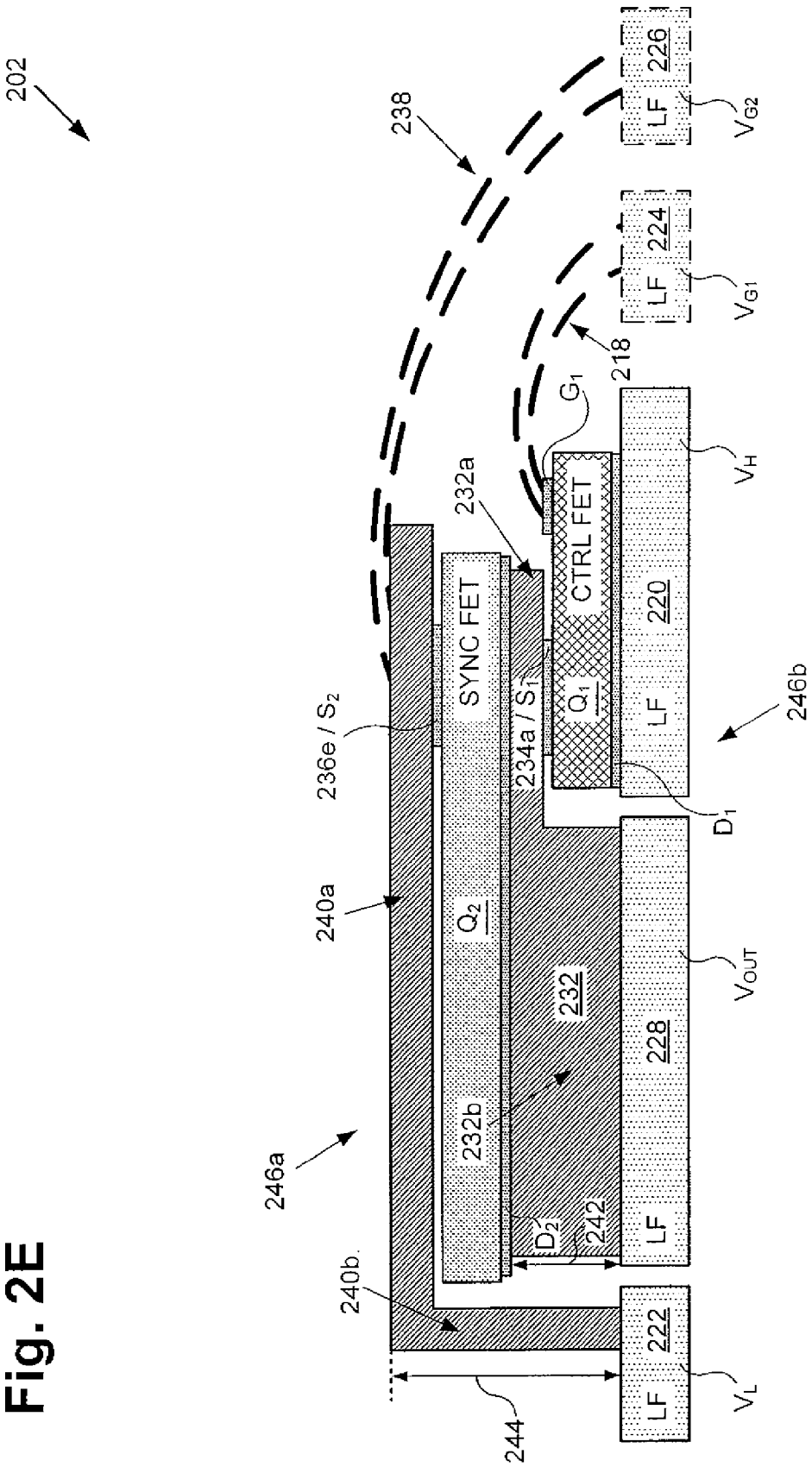


Fig. 2E



POWER SEMICONDUCTOR PACKAGE WITH A COMMON CONDUCTIVE CLIP

This is a continuation of application Ser. No. 14/221,518 filed Mar. 21, 2014, which itself is a continuation of application Ser. No. 13/279,052, filed Oct. 21, 2011, now Pat. No. 8,680,627, which in turn claims priority to U.S. provisional application Ser. No. 61/461,110, filed Jan. 14, 2011. The disclosures in the above-referenced patent applications are hereby incorporated fully by reference into the present application.

Moreover, application Ser. No. 11/986,848, filed on Nov. 27, 2007, titled "DC/DC Converter Including a Depletion Mode Power Switch," now U.S. Pat. No. 7,902,809; and pending application Ser. No. 12/928,102, filed on Dec. 3, 2010, titled "DC/DC Converter with Depletion-Mode III-Nitride Switches," and Ser. No. 12/927,341, filed on Nov. 12, 2010, titled "Semiconductor Package with Metal Straps," are hereby incorporated fully by reference into the present application.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to semiconductor devices. More particularly, the present invention relates to packaging of semiconductor devices.

2. Background Art

To allow for high efficiency power conversion, power converters, such as buck converters, commonly employ power switching circuits in which a high side power transistor and a low side power transistor are connected to form a half-bridge. One such power converter that is frequently employed is a synchronous buck converter, where the high side transistor is a control transistor and the low side transistor is a synchronous transistor. The control transistor and the synchronous transistor are typically formed on their respective separate dies, i.e. a control transistor die and a synchronous transistor die, that are connected in a package (i.e. co-packaged) to form the half bridge.

One approach to connecting the control transistor and the synchronous transistor in a package would be to arrange the control transistor and the synchronous transistor side by side on a substrate, such as a printed circuit board (PCB). However, this arrangement would result in the package having a large footprint, as the package must be large enough to accommodate footprints of the control transistor and the synchronous transistor. Furthermore, conductive traces on the PCB could be used to connect the control transistor and the synchronous transistor so as to form the half-bridge. However, the conductive traces would form long routing paths on the PCB, causing high parasitic inductance and resistance. Thus, this approach to packaging the control transistor and the synchronous transistor would result in a package having a large form factor where the package significantly degrades performance of the half bridge.

What is needed is an approach to packaging control and synchronous transistors that is capable of achieving packages having a small form factor where the packages do not significantly degrade performance of the half-bridge.

SUMMARY OF THE INVENTION

A stacked half-bridge package with a common conductive clip, substantially as shown in and/or described in connection with at least one of the figures, and as set forth more completely in the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an exemplary circuit schematic of a synchronous buck converter, according to one embodiment of the invention.

FIG. 2A illustrates a selective top view of a stacked half-bridge package, according to one embodiment of the invention.

FIG. 2B illustrates a selective top view of a stacked half-bridge package, according to one embodiment of the invention.

FIG. 2C illustrates a selective top view of a stacked half-bridge package, according to one embodiment of the invention.

FIG. 2D illustrates a selective top view of a stacked half-bridge package, according to one embodiment of the invention.

FIG. 2E illustrates a cross sectional view of a portion of a stacked half-bridge package, according to one embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

The present application is directed to a stacked half-bridge package with a common conductive clip. The following description contains specific information pertaining to the implementation of the present invention. One skilled in the art will recognize that the present invention may be implemented in a manner different from that specifically discussed in the present application. Moreover, some of the specific details of the invention are not discussed in order not to obscure the invention. The specific details not described in the present application are within the knowledge of a person of ordinary skill in the art.

The drawings in the present application and their accompanying detailed description are directed to merely exemplary embodiments of the invention. To maintain brevity, other embodiments of the invention, which use the principles of the present invention, are not specifically described in the present application and are not specifically illustrated by the present drawings.

FIG. 1 shows an exemplary circuit schematic of synchronous buck converter **100** including half-bridge **102**, which is formed in a stacked half-bridge package **102**, according to an embodiment of the invention, and is thus also referred to as "stack half-bridge package" **102** or "half-bridge package" **102** in the present application. Synchronous buck converter **100** also includes, driver integrated circuit (IC) **104**, output inductor **106**, and output capacitor **108**.

Half-bridge **102** includes control transistor Q_1 and synchronous transistor Q_2 (also referred to as "sync transistor"), high voltage input terminal V_H , low voltage input terminal V_L , output terminal V_{OUT} , control gate terminal V_{G1} , and sync gate terminal V_{G2} .

In half-bridge **102**, high voltage input terminal V_H receives high voltage input V_{H1} , which can be, for example, a direct current (DC) voltage. Low voltage input terminal V_L receives low voltage input V_{L1} , which can be, for example, ground. Also in half-bridge **102**, control gate terminal V_{G1} receives a control gate signal from driver IC **104** for driving control transistor Q_1 . Similarly, sync gate terminal V_{G2} receives a sync gate signal from driver IC **104** for driving sync transistor Q_2 . Driver IC **104** may drive control transistor Q_1 and sync transistor Q_2 utilizing any suitable method. As a specific example, in one embodiment, driver IC **104** can vary a duty cycle of the sync and control gate

signals responsive to a measurement of output voltage V_O of synchronous buck converter **100** to maintain a desired output voltage V_O , regardless of changes in high voltage input V_{HI} . It will be appreciated that in other embodiments, output voltage V_O is not measured in synchronous buck converter **100**.

Control transistor Q_1 includes control source S_1 , control drain D_1 , and control gate G_1 . Sync transistor Q_2 includes sync source S_2 , sync drain D_2 , and sync gate G_2 . In various embodiments of the present invention, control transistor Q_1 and sync transistor Q_2 can be any combination of an enhancement mode transistor and a depletion mode transistor. For example, in one embodiment, control transistor Q_1 and sync transistor Q_2 are both depletion mode transistors. Control transistor Q_1 and sync transistor Q_2 can be P-channel or N-channel transistors. Also, control transistor Q_1 and sync transistor Q_2 can be field-effect transistors (FETs). In one embodiment, at least one of control transistor Q_1 and sync transistor Q_2 is a silicon FET. However, at least one of control transistor Q_1 and sync transistor Q_2 may also comprise a non-silicon FET or any other FET in general. In one embodiment, at least one of control transistor Q_1 and sync transistor Q_2 is a metal-oxide-semiconductor field-effect transistor (MOSFET). At least one of control transistor Q_1 and sync transistor Q_2 can also be, as an example, a high electron mobility transistor (HEMT), such as a GaN HEMT.

Control transistor Q_1 has control drain D_1 for connection to high voltage input V_{HI} through high voltage input terminal V_H of half-bridge **102**. Control transistor Q_1 also has control source S_1 coupled to output terminal V_{OUT} of half-bridge **102**. Also, control transistor Q_1 has control gate G_1 coupled to control gate terminal V_{G1} of half-bridge **102** for being driven by driver IC **104**.

Sync transistor Q_2 has sync drain D_2 for connection to output terminal V_{OUT} of half-bridge **102**. Sync transistor Q_2 also has sync source S_2 coupled to low voltage input V_{L1} through low voltage input terminal V_L of half-bridge **102**. Also, sync transistor Q_2 has sync gate G_2 coupled to sync gate terminal V_{G2} of half-bridge **102** for being driven by driver IC **104**.

In some embodiments, at least one of control transistor Q_1 and sync transistor Q_2 can be connected to a diode. For example, FIG. **1** shows optional diodes **110** and **112**. In the embodiment shown in FIG. **1**, diode **110** is coupled to control source S_1 and control drain D_1 , such that diode **110** is in parallel with control transistor Q_1 . Similarly, diode **112** is coupled to sync source S_2 and sync drain D_2 , such that diode **112** is in parallel with control transistor Q_2 . In some embodiments, at least one of diodes **110** and **112** can be connected with a reverse polarity to that shown in FIG. **1**. In various embodiments, diodes **110** and **112** can be internal to or external to control transistor Q_1 and sync transistor Q_2 . As an example, in one embodiment, control transistor Q_1 and sync transistor Q_2 are MOSFETs and diodes **110** and **112** are respective body diodes of control transistor Q_1 and sync transistor Q_2 .

Control transistor Q_1 and sync transistor Q_2 are commonly included on respective dies (i.e. a control transistor die and a synchronous transistor die). The respective dies may include other components, for example, diode **110** may be on the control transistor die and diode **112** may be on the synchronous transistor die. These other components may also be provided external to the respective dies and can be, for example, on a different die.

Synchronous buck converter **100** illustrates one power converter, which can benefit from including stacked half-bridge package **102**, in accordance with embodiments of the

present invention. However, half-bridge **102** is not limited to being included in a synchronous buck converter and can be included in other types of power converters.

In accordance with embodiments of the present invention, control transistor Q_1 and sync transistor Q_2 can be connected in a stacked half-bridge package, which includes stacked half-bridge package **102**, while achieving a small footprint with low parasitic inductance and resistance. Thus, the stacked half-bridge package can have a small form factor where the stacked half-bridge package does not significantly degrade performance of half-bridge **102**.

FIGS. **2A-2D** illustrate selective top views of stacked half-bridge package **202**, corresponding to stacked half-bridge package **102** in FIG. **1**, in accordance with one embodiment of the present invention. Various features of stacked half-bridge package **202** are not shown in FIGS. **2A-2D** for clarity of description. FIG. **2E** illustrates a cross sectional view of a portion of stacked half-bridge package **202**, according to one embodiment of the invention. The cross sectional view shown in FIG. **2E** corresponds to a cross section along line **2E-2E** in FIGS. **2A-2D**.

FIG. **2A** shows control drain leadframe **220**, sync source leadframe **222**, control gate leadframe **224**, sync gate leadframe **226**, output terminal leadframe **228**, support leadframe **230**, and control transistor Q_1 of stacked half-bridge package **202**.

Control transistor Q_1 in FIGS. **2A-2E** corresponds to control transistor Q_1 in FIG. **1**. Control transistor Q_1 is over control drain leadframe **220** and includes control source S_1 , control drain D_1 , and control gate G_1 . Control source S_1 in stacked half-bridge package **202** corresponds to control source S_1 in FIG. **1**, control gate G_1 in stacked half-bridge package **202** corresponds to control gate G_1 in FIG. **1**, and control drain D_1 in stacked half-bridge package **202** corresponds to control drain D_1 in FIG. **1**. In the present embodiment, control transistor Q_1 has top and bottom surfaces, which are opposite one another. Control drain D_1 is on the bottom surface and control source S_1 and control gate G_1 are on the top surface.

FIG. **2A** shows control source S_1 and control gate G_1 are on the top surface of control transistor Q_1 , and indicates control drain D_1 on the bottom surface thereof. In the present embodiment, control drain D_1 is provided with a control drain pad that substantially covers an entirety of the bottom surface of control transistor Q_1 . Control source S_1 is provided with a plurality of control source pads **234a** and **234b** (also referred to collectively as "control source pads **234**"). Also, control gate G_1 is provided with a gate pad.

It is noted that in some embodiments, control drain D_1 , control source S_1 , and control gate G_1 are not provided as shown in stacked half-bridge package **202**. For example, control drain D_1 , control source S_1 , and control gate G_1 can be provided on different surfaces of control transistor Q_1 and can be provided using one or more pads arranged in any suitable manner. As one example, in some embodiments, a single control source pad can replace control source pads **234**.

Control drain leadframe **220**, sync source leadframe **222**, control gate leadframe **224**, sync gate leadframe **226**, output terminal leadframe **228**, and support leadframe **230** are electrically conductive and can comprise, for example, an easily solderable metal such as aluminum, and other solderable materials such as a metal alloy or a tri-metal. Control transistor Q_1 is over control drain leadframe **220**, which provides mechanical and electrical connection for control drain D_1 . In the present embodiment, control drain lead-

frame **220** of stacked half-bridge package **202** corresponds to high voltage input terminal V_H in FIG. 1.

Also in the present embodiment, at least one control gate bondwire, such as control gate bondwires **218**, provides electrical and mechanical connection for control gate G_1 . Control gate bondwires **218** provide electrical connection between control gate G_1 and control gate leadframe **224**. In the present embodiment, control gate leadframe **224** of stacked half-bridge package **202** corresponds to control gate terminal V_{G1} in FIG. 1. It is noted that some embodiments do not include control gate leadframe **224**. Furthermore, in various embodiments, something other than at least one control gate bondwire (e.g. a conductive gate clip) can provide electrical and mechanical connection for control gate G_1 .

FIG. 2B is similar to FIG. 2A, with an addition of showing common conductive clip **232** of stacked half-bridge package **202** over control drain leadframe **220** and control transistor Q_1 . Common conductive clip **232** comprises conductive material, such as a metal or metal alloy. In one embodiment common conductive clip **232** is a copper clip. Control source S_2 of control transistor Q_1 is coupled to common conductive clip **232**. Common conductive clip **232** includes conductive web **232a** and conductive leg **232b**. In FIG. 2B, a dashed line indicates a boundary of conductive web **232a** and conductive leg **232b**. In the present embodiment, conductive web **232a** is over and electrically and mechanically connected to control source S_2 of control transistor Q_1 and conductive leg **232b** is over and electrically and mechanically connected to output terminal leadframe **228**.

FIG. 2C is similar to FIG. 2B, with an addition of showing sync transistor Q_2 of stacked half-bridge package **202** over common conductive clip **232**, control drain leadframe **220**, and control transistor Q_1 . In the present embodiment, sync transistor Q_2 is on support leadframe **230**, which acts as a mechanical support for sync transistor Q_2 . In some embodiments, support leadframe **230** is not electrically conductive. Furthermore, it will be appreciated that support leadframe **230** is not required in stacked half-bridge package **202**.

Sync transistor Q_2 in stacked half-bridge package **202** corresponds to sync transistor Q_2 in FIG. 1. Sync source S_2 in stacked half-bridge package **202** corresponds to sync source S_2 in FIG. 1, sync gate G_2 in stacked half-bridge package **202** corresponds to sync gate G_2 in FIG. 1, and sync drain D_2 in stacked half-bridge package **202** corresponds to sync drain D_2 in FIG. 1. In the present embodiment, sync transistor Q_2 has top and bottom surfaces, which are opposite one another. Sync drain D_2 is on the bottom surface and sync source S_2 and sync gate G_2 are on the top surface.

FIG. 2C shows sync source S_2 and sync gate G_2 are on the top surface of sync transistor Q_2 , and indicates sync drain D_2 on the bottom surface thereof. In the present embodiment, sync drain D_2 is provided with a sync drain pad that substantially covers an entirety of the bottom surface of sync transistor Q_2 . Sync source S_2 is provided with a plurality of control source pads **236a**, **236b**, **236c**, **236d**, and **236e** (also referred to collectively as "sync source pads **236**"). Also, sync gate G_2 is provided with a gate pad.

It is noted that in some embodiments, sync drain D_2 , sync source S_2 , and sync gate G_2 are not provided as shown in stacked half-bridge package **202**. For example, sync drain D_2 , sync source S_2 , and sync gate G_2 can be provided on different surfaces of sync transistor Q_2 and can be provided using one or more pads arranged in any suitable manner. As one example, in some embodiments, a single sync source pad can replace sync source pads **236**.

Sync transistor Q_2 is over common conductive clip **232**, which is electrically and mechanically connected to sync transistor Q_2 . More particularly, sync transistor Q_2 has sync drain D_2 connected to common conductive clip **232**. Conductive web **232a** of common conductive clip **232** provides electrical and mechanical coupling of control source S_1 with sync drain D_2 .

Thus, control and sync transistors Q_1 and Q_2 are stacked on opposite sides of common conductive clip **232**, with common conductive clip **232** electrically and mechanically coupling control source S_1 with sync drain D_2 . Advantageously, a short current path is formed between control source S_1 and sync drain D_2 that has low parasitic inductance and resistance (See FIG. 2D). As such, stacked half-bridge package **202** does not significantly degrade performance of half-bridge **102** in FIG. 1. Furthermore, stacked half-bridge package **202** has a small footprint that does not incorporate footprints of control transistor Q_1 and sync transistor Q_2 individually, thereby allowing for a small form factor.

As common conductive clip **232** has conductive leg **232b** (See FIGS. 2B and 2E) for providing electrical and mechanical connection to output terminal leadframe **228**, output terminal leadframe **228** corresponds to output terminal V_{OUT} in FIG. 1. Thus, in the present embodiment, output terminal leadframe **228** is an output terminal of stacked half-bridge package **202**.

Also in the present embodiment, at least one sync gate bondwire, such as sync gate bondwires **238**, provides electrical and mechanical connection for sync gate G_2 . Sync gate bondwires **238** provide electrical connection between sync gate G_2 and sync gate leadframe **226**. In the present embodiment, sync gate leadframe **226** of stacked half-bridge package **202** corresponds to sync gate terminal V_{G2} in FIG. 1. It is noted that some embodiments do not include sync gate leadframe **226**. Furthermore, in various embodiments, something other than at least one sync gate bondwire (e.g. a conductive gate clip) can provide electrical and mechanical connection for sync gate G_2 .

FIG. 2D is similar to FIG. 2C, with an addition of showing conductive source clip **240** of stacked half-bridge package **202** over sync transistor Q_2 , common conductive clip **232**, control transistor Q_1 , and control drain leadframe **220**. Conductive source clip **240** comprises conductive material, such as a metal or metal alloy. In one embodiment conductive source clip **240** is a copper clip. Conductive source clip **240** includes source clip web **240a** and source clip leg **240b** and provides connection between sync source S_2 and sync source leadframe **222**. In FIG. 2G, a dashed line indicates a boundary of source clip web **240a** and source clip leg **240b**. In the present embodiment, sync source leadframe **222** corresponds to low voltage input terminal V_L in FIG. 1 with source clip leg portion **240b** being over and electrically and mechanically connected to sync source leadframe **222** and source clip web **240a** being over and electrically and mechanically connected to sync source S_2 of sync transistor Q_2 .

As noted above, FIG. 2E illustrates a cross sectional view of a portion of stacked half-bridge package **202** corresponding to a cross section along line 2E-2E in FIGS. 2A-2D. However, some features which are not in the cross section along line 2E-2E in FIGS. 2A-2D are included in FIG. 2E for completeness and are indicated using dashed lines. Those features are control gate bondwires **218**, control gate leadframe **224**, sync gate bondwires **238**, and sync gate leadframe **226**. Sync gate bondwires **238** are electrically connected to gate G_2 of sync transistor Q_2 , which is behind and not shown in FIG. 2E.

FIG. 2E shows that conductive source clip 240 is connected to sync source S_2 at topside 246a of stacked half-bridge package 202 and shows control drain leadframe 220, sync source leadframe 222, control gate leadframe 224, sync gate leadframe 226, and output terminal leadframe 228 at bottomside 246b of stacked half-bridge package 202. In one embodiment, hermetic sealant, such as a molding compound, can encapsulate stacked half-bridge package 202 (not shown in FIG. 2E). However, control drain leadframe 220, sync source leadframe 222, control gate leadframe 224, sync gate leadframe 226, and output terminal leadframe 228 are exposed on bottomside 246b of stacked half-bridge package 202 and thus, available for electrical connection.

FIG. 2E shows conductive leg 232b of common conductive clip 232 is of thickness 242 that is greater than that of control transistor Q_1 and that of conductive web 232b. FIG. 2E also shows source clip leg 240b of conductive source clip 240 is of thickness 244 that is greater than that of control transistor Q_1 , sync transistor Q_2 , and conductive web 232a combined. In the present embodiment, respective top and bottom surfaces of control drain leadframe 220, sync source leadframe 222, control gate leadframe 224, sync gate leadframe 226, and output terminal leadframe 228 can thereby be substantially flush with one another, as shown in FIG. 2E. As such, stacked half-bridge package 202 can easily be mounted on and electrically connected to a substrate (not shown in FIGS. 2A-2E). Furthermore, control drain leadframe 220, sync source leadframe 222, control gate leadframe 224, sync gate leadframe 226, and output terminal leadframe 228 can be of substantially a same thickness and in one embodiment, are formed from a shared leadframe.

Thus, as described above with respect to FIGS. 1 and 2A-2E, embodiments of the present invention can provide for a stacked half-bridge package including a control transistor and a sync transistor. The control transistor and the sync transistor can advantageously be connected in a half-bridge with low parasitic inductance and resistance. Furthermore, the control transistor and the sync transistor can be connected with the stacked half-bridge package having a small footprint. As such, among other advantages not specifically described herein, the stacked half-bridge package can have a small form factor, where the stacked half-bridge package does not significantly degrade performance of the half-bridge.

From the above description of the invention it is manifest that various techniques can be used for implementing the concepts of the present invention without departing from its scope. Moreover, while the invention has been described with specific reference to certain embodiments, a person of ordinary skills in the art would recognize that changes can be made in form and detail without departing from the spirit and the scope of the invention. As such, the described embodiments are to be considered in all respects as illustrative and not restrictive. It should also be understood that the invention is not limited to the particular embodiments described herein, but is capable of many rearrangements, modifications, and substitutions without departing from the scope of the invention.

The invention claimed is:

1. A power semiconductor package comprising:

a control transistor having a control drain for connection to a high voltage input, a control source coupled to a common conductive clip, and a control gate;

a sync transistor having a sync drain for connection to said common conductive clip, a sync source coupled to a low voltage input, and a sync gate;

said control and sync transistors being situated on opposite sides of said common conductive clip, said common conductive clip coupling said control source with said sync drain.

2. The power semiconductor package of claim 1, wherein a conductive web of said common conductive clip provides said coupling of said control source with said sync drain.

3. The power semiconductor package of claim 1, wherein a conductive leg of said common conductive clip is of a thickness greater than that of said control transistor.

4. The power semiconductor package of claim 1, wherein a control drain leadframe provides connection for said control drain.

5. The power semiconductor package of claim 1, wherein a conductive source clip provides connection between said sync source and a sync source leadframe.

6. The power semiconductor package of claim 5, wherein said conductive source clip comprises a source clip leg that is of a thickness greater than that of said sync transistor.

7. The power semiconductor package of claim 1, wherein a conductive source clip comprises a source clip web that is connected to said sync source and including a source clip leg that is connected to a sync source leadframe.

8. The power semiconductor package of claim 1, wherein a conductive source clip is connected to said sync source at a topside of said stacked half-bridge package.

9. The power semiconductor package of claim 1, wherein bottom surfaces of a sync source leadframe and a control drain leadframe are substantially flush with one another.

10. The power semiconductor package of claim 1, wherein top surfaces of a sync source leadframe and a control drain leadframe are substantially flush with one another.

11. The power semiconductor package of claim 1, wherein at least one control gate bondwire provides connection for said control gate.

12. The power semiconductor package of claim 11, wherein said at least one control gate bondwire provides connection between said control gate and a control gate leadframe.

13. The power semiconductor package of claim 1, wherein at least one sync gate bondwire provides connection for said sync gate.

14. The power semiconductor package of claim 13, wherein said at least one sync gate bondwire provides connection between said sync gate and a sync gate leadframe.

15. The power semiconductor package of claim 1, wherein said sync source comprises a plurality of sync source pads.

16. The power semiconductor package of claim 1, wherein said control transistor has top and bottom surfaces, said control drain being on said bottom surface and said control source and said control gate being on said top surface.

17. The power semiconductor package of claim 1, wherein said sync transistor has top and bottom surfaces, said sync drain being on said bottom surface and said sync source and said sync gate being on said top surface.

18. The power semiconductor package of claim 1, wherein respective bottom surfaces of a sync source leadframe, a control drain leadframe, a sync gate leadframe, and a control gate leadframe are substantially flush with one another.

19. The power semiconductor package of claim 1, wherein a sync source leadframe and a control drain leadframe are of substantially a same thickness.

20. The power semiconductor package of claim 1, wherein a sync source leadframe, a control drain leadframe, a sync gate leadframe, and a control gate leadframe are of substantially a same thickness.

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