

IR-1263

- 1 -

HIGH VOLTAGE DRIVERS WHICH AVOID $-V_s$ FAILURE MODESRELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application Serial No. 60/004,981 filed on
 5 October 10, 1995.

BACKGROUND OF THE INVENTION

The present invention relates to level shifted high voltage MOSgate device drivers and, more particularly, to MOSgated device drivers with improved
 10 immunity to deleterious effects of commutating currents.

Level shifted high voltage MOSgated device drivers are well known for the drive of bridge connected MOSgated devices, such as IGBTs and power MOSFETs. A family of such devices are sold under the type numbers
 15 IR21XX, which are high voltage integrated circuit (HVIC) devices, which each drive two such MOSgated devices per leg of a bridge. Figures 1 and 2 show typical configurations for an IR21XX driver (for example, an IR2155) for high side and low side IGBTs 10 and 11
 20 respectively, which are associated with fast recovery diodes 12 and 13, respectively. The H_o and L_o outputs at pins 4 and 2, respectively, turn devices 10 and 11 sequentially on and off to control power flow to the output circuit (not shown).

25 In operation, when the top device 10 is turned off, the current I_{10} commutates to the bottom diode 13, as I_{13} , as shown in Figure 3. The current I_{13} flows through

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the inherent inductances L_{s1} and L_{s2} in series with diode 13, causing the voltage at V_o to go to $-V_a$. This negative voltage can cause the driver IC 20 to malfunction or blow-up. This problem is even more intense under short circuit conditions.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide level shifted high voltage MOSgated device drivers that are built to withstand the deleterious effects of commutating currents.

The foregoing and other objects of the invention are realized by constructing the device such that the internal inherent inductances L_{s1} and L_{s2} have lower values, which is attained by keeping shorter conductor lengths and positioning the D_s and common (COM) connection in a manner which reduces the inductance path. Furthermore, the device's C_b capacitance is increased in order to reduce the voltage developing on this capacitor. Further expedients involve increasing the size of the C_{vcc} capacitor to hold the C_{vcc} voltage as stiff as possible, to ensure that the internal IC diode D_s cannot turn on earlier. Very approximately, the capacitance C_{vcc} should have a value ten times the total of all C_b capacitors in the system.

The invention further attains its objectives by reducing the resistance R_b and the bootstrap path as much as possible, to cause reduced current flow through the substrate diode. Finally, the invention contemplates providing a resistor R_{com} to increase the resistance in the path of the substrate diode D_s and to reduce the charging of C_{vcc} and the substrate current.



Other features and advantages of the present invention will become apparent from the following description of the invention which refers to the accompanying drawings.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic of a prior art circuit showing a driver IC connected to drive a pair of high voltage devices;

10 Fig. 2 is a circuit schematic illustrating the operation of the circuit of Fig. 1;

Fig. 3 is a schematic showing the path of the commutating current when the top transistor device is turned off;

15 Fig. 4 illustrates an embodiment of the present invention;

Fig. 5 is a circuit showing another feature of the present invention;

20 Fig. 6 is a plot of the capacitor voltage at different capacitance values, to show the reduced peak voltage on the capacitor at higher capacitance values.

DETAILED DESCRIPTION OF THE INVENTION

25 To better describe the problem solved by the instant invention, reference is made to Figure 4 which shows the relevant circuit components and the significant parasitic components. The circuit components include bootstrap diode D_b (22) and a capacitor C_{VCC} (26). Also shown is the parasitic substrate diode D_s (24) of the IC and the input C_{VCC} capacitor (26). There are two modes of failure when V_o goes to $-V_s$.

30 In the first, the bootstrap diode D_b (22) of Figure 4 starts to conduct and charges capacitor C_b (28).



If the voltage on capacitor C_b (28) exceeds the avalanche rating at the top driver (shown as a zener diode 30), then it destroys the IC 20. In the second mode, the bootstrap capacitor C_b (28) can also charge up through the parasitic IC substrate diode D_s (24). If significant current flows through diode D_s (24), the IC can malfunction, be damaged or destroyed.

In the prior art, not enough attention has been paid to the component layout which causes the L_{s1} and L_{s2} inductors to increase. Moreover, the C_b capacitor has been sized to hold up the driver voltage for the maximum pulse ON time and not for reducing the voltage buildup.

Prior art solutions to these problems have included adding a current limiting resistance to the bootstrap path and adding resistors, such as resistor 32 and high voltage diodes, such as diode 34 (Figure 5) to limit the amount of $-V_s$. This, however, causes a gate voltage spikes and requires additional high voltage diodes.

In accordance with the present invention:

(a) The values of inductance L_{s1} and L_{s2} are reduced by keeping short conductor lengths and by positioning the V_s connection 38 and "com" connection 36 in Figure 4 to reduce the inductance path;

(b) The capacitor C_b (28) value increased to cause the capacitance voltage to rise to a reduced value, as shown in Figure 6. For a size 3 IGBT die (available from International Rectifier Corporation of El Segundo, CA), and laying out the parts on an IMS substrate, a capacitance of $0.47 \mu F$ is preferably used;

(c) The size of the C_{VCC} capacitor 26 is increased to hold the V_{CC} supply (Figure 4) as "stiff" as



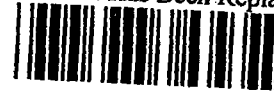
possible since, if there are dips in the V_{CC} voltage during bootstrap charging, the internal IC diode D_s (24) can turn on earlier. Preferably, capacitor C_{VCC} (26) should have a value of ten times the total of all C_s capacitors in the system;

(d) The resistance R_s (40) in the bootstrap path is reduced as much as possible. Resistor R_s (40) limits the charging of capacitor C_s (28) which causes increased current flow through the parasitic substrate diode, which can cause a malfunction. The recommended resistor value is 0 ohms;

(e) A resistor R_{COM} (42) can be added in line 41 in Figure 4 to increase the resistance in the path of substrate diode D_s (24). Resistor R_{COM} (42) also reduces the charging of capacitor C_s (26) and the substrate current.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.



WHAT IS CLAIMED IS:

1. A driving circuit for high power devices, the circuit comprising:

a MOSgate driver and a power switching circuit, the power switching circuit including a first MOSgate transistor and a second MOSgate transistor, the MOSgate driver being connected to and serving to alternately turn on the first and second MOSgate transistors;

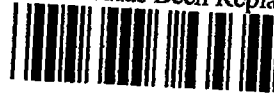
the power switching circuit having a voltage output node between the first MOSgate transistor and the second MOSgate transistor, and the second MOSgate transistor having associated therewith a recovery diode and inherent inductances L_{s1} and L_{s2} ;

the MOSgate driver comprising an integrated circuit and including an external capacitor C_p connected between a circuit node V_i and a circuit node V_o of the MOSgate driver circuit, the MOSgate driver circuit further including a common node and a series circuit including a charging capacitor C_{vcc} , a resistor R_i and a diode D_i connected between the common node and the V_i node; and

the MOSgate driver circuit and the power switching circuit being connected as close as possible to one another to obtain short conductor lengths between the nodes V_i and V_o and between the common node and another common node of the power switching circuit, to thereby reduce the values of the inductances L_{s1} and L_{s2} .

2. The circuit of claim 1, in which the capacitor C_p has an increased value, substantially in excess of a capacitance needed to hold up a voltage of





5 the first MOSgate transistor for a maximum pulse ON time, said increased value being determined by the inductances L_{31} and L_{32} and also by the size and type of said MOSgate transistors.

3. The circuit of claim 1, in which a capacitance of the capacitor C_1 has a value greater than about 0.47 μ F, for IR size 3 "k" type IGBTs.

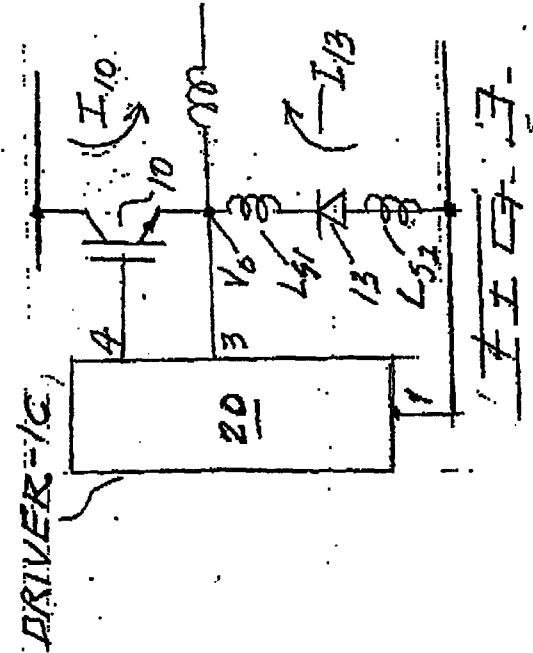
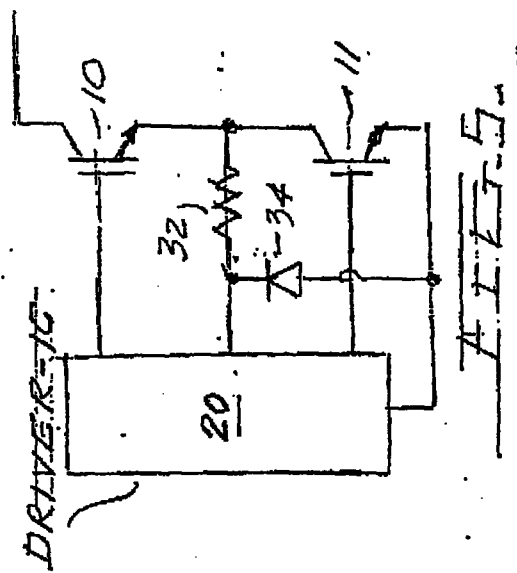
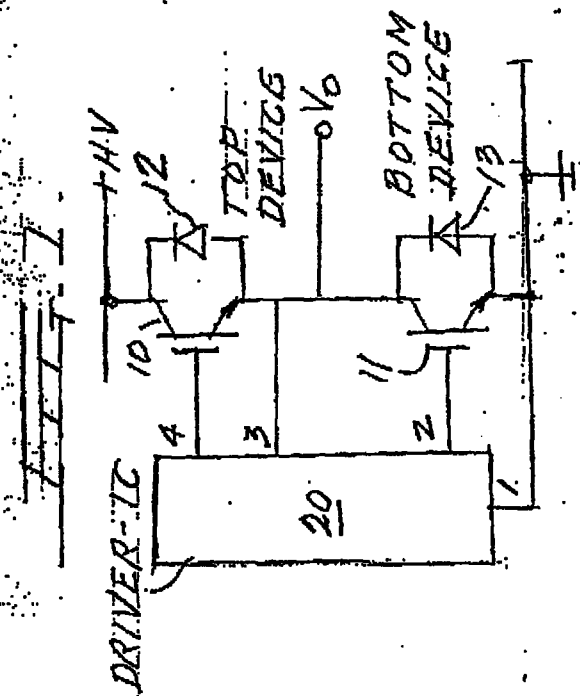
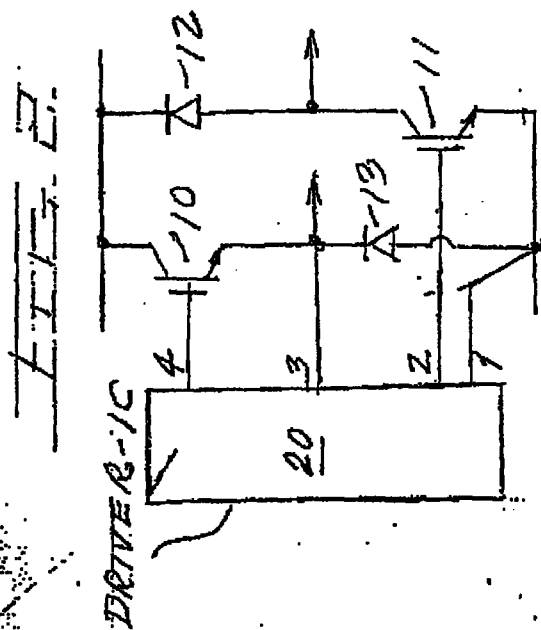
4. The circuit of claim 1, in which the capacitor C_{VCC} has a value of at least about ten times the value of the capacitor C_1 in the circuit.

5. The circuit of claim 1, in which the value of the resistor R_1 is reduced to as little as possible.

6. The circuit of claim 5, in which the value of resistor R_1 is about 0 ohms.

7. The circuit of claim 1, including a resistor R_{COM} of about 1 to 20 ohms between the common node of the MOSgate driver circuit and the common node of the power switching circuit.





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FIG 5

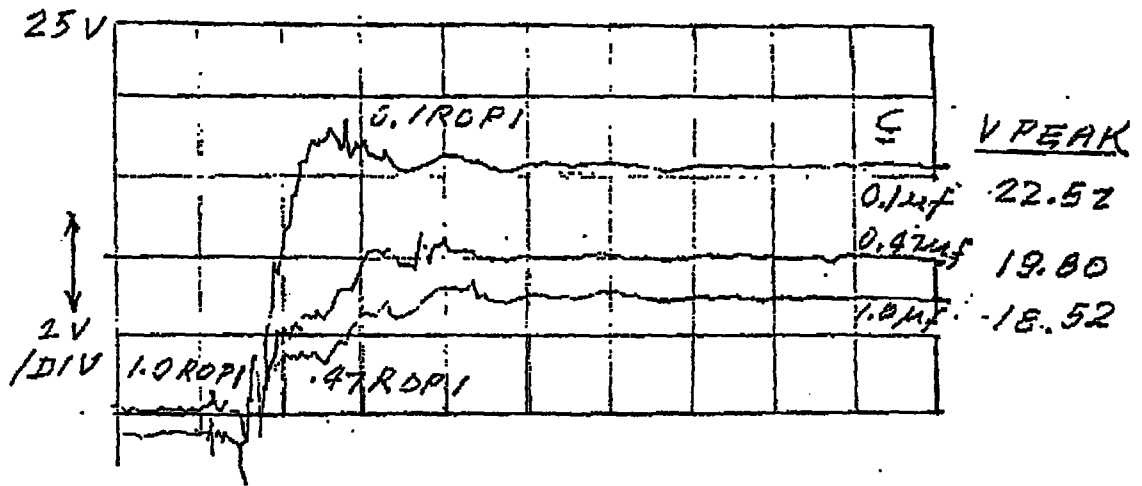
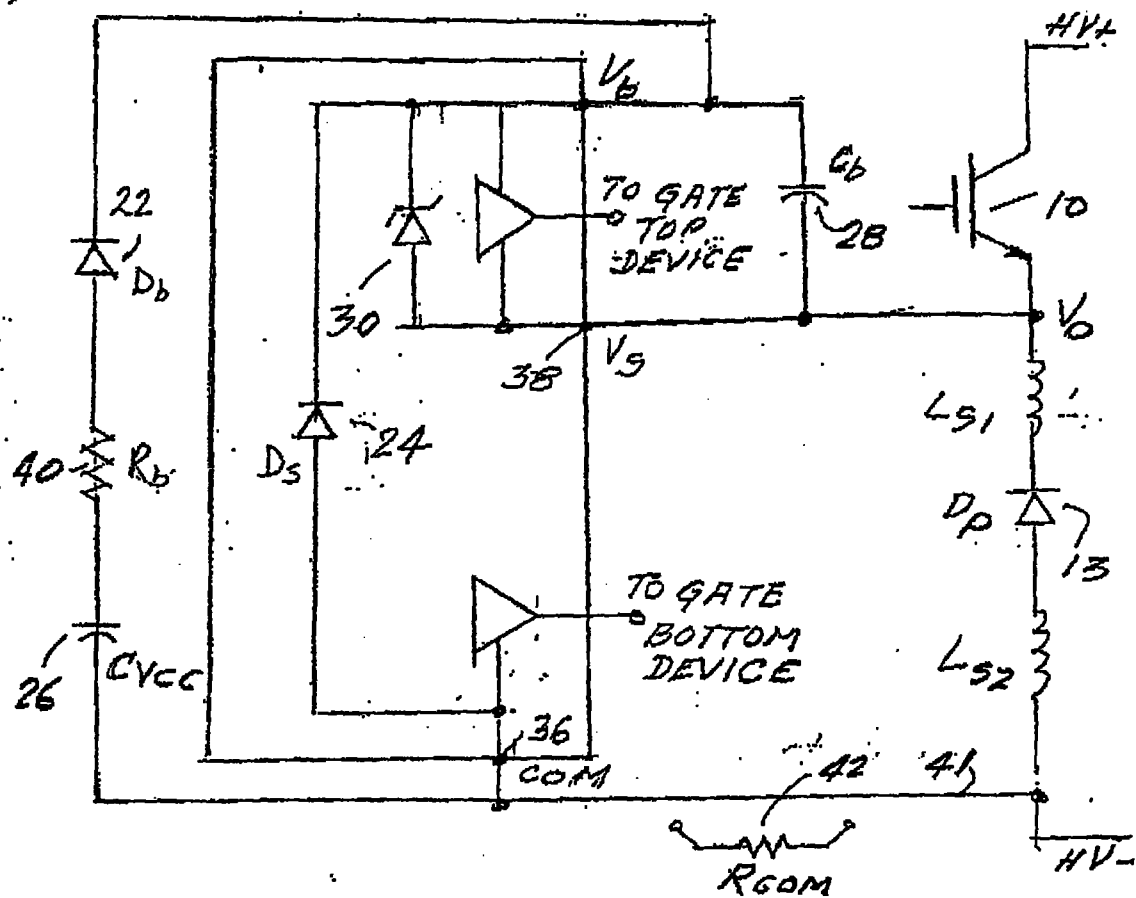


FIG 4



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HIGH VOLTAGE DRIVERS WHICH AVOID $-V_s$ FAILURE MODESABSTRACT OF THE DISCLOSURE

In a level shifted high voltage MOSgate device driver which drives MOSgate devices such as IGBTs and power MOSFETs, effects of negative voltage swings caused by currents commutating through L_{s1} and L_{s2} inductances in the power circuits are avoided due to several measures. First, the values of the inductances L_{s1} and L_{s2} are reduced by keeping short conductor lengths, by other layout/wire bonding techniques to reduce the values of the L_{s1} and L_{s2} inductances. The external, charging capacitor C_s value is increased substantially to reduce the voltage buildup on the internal circuitry. A typical value is $0.47 \mu F$, for a given circuit, IGBT and layout combination. The size of the C_{VCC} capacitor is selected to keep the supply voltage as stiff as possible. Preferably, C_{VCC} is at about ten times the value of the sum of the C_s capacitance in the circuit. The resistance R_s in the bootstrap path is reduced as much as possible, preferably to zero. Finally, a resistor R_{COM} is optionally added between the common nodes of the driver circuit and the power device circuit.

FIGURE 1



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- 1 -

HIGH VOLTAGE DRIVERS WHICH AVOID -V_o FAILURE MODESRELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application Serial No. 60/004,981 filed on October 10, 1995.

BACKGROUND OF THE INVENTION

The present invention relates to level shifted high voltage MOSgate device drivers and, more particularly, to MOSgated device drivers with improved immunity to deleterious effects of commutating currents.

Level shifted high voltage MOSgated device drivers are well known for the drive of bridge connected MOSgated devices, such as IGBTs and power MOSFETs. A family of such devices are sold under the type numbers IR21XX, which are high voltage integrated circuit (HVIC) devices, which each drive two such MOSgated devices per leg of a bridge. Figures 1 and 2 show typical configurations for an IR21XX driver (for example, an IR2155) for high side and low side IGBTs 10 and 11 respectively, which are associated with fast recovery diodes 12 and 13, respectively. The H₀ and L₀ outputs at pins 4 and 2, respectively, turn devices 10 and 11 sequentially on and off to control power flow to the output circuit (not shown).

In operation, when the top device 10 is turned off, the current I₁₀ commutates to the bottom diode 13, as I₁₃, as shown in Figure 3. The current I₁₃ flows through

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Date: 29 JAN 1997

the inherent inductances L_{S1} and L_{S2} in series with diode 13, causing the voltage at V_0 to go to $-V_0$. This negative voltage can cause the driver IC 20 to malfunction or blow-up. This problem is even more intense under short circuit conditions.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide level shifted high voltage MOSgated device drivers that are built to withstand the deleterious effects of commutating currents.

The foregoing and other objects of the invention are realized by constructing the device such that the internal inherent inductances L_{S1} and L_{S2} have lower values, which is attained by keeping shorter conductor lengths and positioning the D_0 and common (COM) connection in a manner which reduces the inductance path. Furthermore, the device's C_0 capacitance is increased in order to reduce the voltage developing on this capacitor. Further expedients involve increasing the size of the C_{VCC} capacitor to hold the C_{VCC} voltage as stiff as possible, to ensure that the internal IC diode D_s cannot turn on earlier. Very approximately, the capacitance C_{VCC} should have a value ten times the total of all C_0 capacitors in the system.

The invention further attains its objectives by reducing the resistance R_0 and the bootstrap path as much as possible, to cause reduced current flow through the substrate diode. Finally, the invention contemplates providing a resistor R_{COM} to increase the resistance in the path of the substrate diode D_s and to reduce the charging of C_{VCC} and the substrate current.

Other features and advantages of the present invention will become apparent from the following description of the invention which refers to the accompanying drawings.

5 BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic of a prior art circuit showing a driver IC connected to drive a pair of high voltage devices;

10 Fig. 2 is a circuit schematic illustrating the operation of the circuit of Fig. 1;

Fig. 3 is a schematic showing the path of the commutating current when the top transistor device is turned off;

15 Fig. 4 illustrates an embodiment of the present invention;

Fig. 5 is a circuit showing another feature of the present invention;

20 Fig. 6 is a plot of the capacitor voltage at different capacitance values, to show the reduced peak voltage on the capacitor at higher capacitance values.

DETAILED DESCRIPTION OF THE INVENTION

To better describe the problem solved by the instant invention, reference is made to Figure 4 which shows the relevant circuit components and the significant parasitic components. The circuit components include
25 bootstrap diode D_b (22) and a capacitor C_{VCC} (26). Also shown is the parasitic substrate diode D_s (24) of the IC and the input C_{VCC} capacitor (26). There are two modes of failure when V_o goes to $-V_e$.

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If the voltage on capacitor C_b (28) exceeds the avalanche rating at the top driver (shown as a zener diode 30), then it destroys the IC 20. In the second mode, the bootstrap capacitor C_b (28) can also charge up through the parasitic IC substrate diode D_s (24). If significant current flows through diode D_s (24), the IC can malfunction, be damaged or destroyed.

In the prior art, not enough attention has been paid to the component layout which causes the L_{s1} and L_{s2} inductors to increase. Moreover, the C_b capacitor has been sized to hold up the driver voltage for the maximum pulse ON time and not for reducing the voltage buildup.

Prior art solutions to these problems have included adding a current limiting resistance to the bootstrap path and adding resistors, such as resistor 32 and high voltage diodes, such as diode 34 (Figure 5) to limit the amount of $-V_e$. This, however, causes a gate voltage spikes and requires additional high voltage diodes.

In accordance with the present invention:

(a) The values of inductance L_{s1} and L_{s2} are reduced by keeping short conductor lengths and by positioning the V_e connection 38 and "com" connection 36 in Figure 4 to reduce the inductance path;

(b) The capacitor C_b (28) value increased to cause the capacitance voltage to rise to a reduced value, as shown in Figure 6. For a size 3 IGBT die (available from International Rectifier Corporation of El Segundo, CA), and laying out the parts on an IMS substrate, a capacitance of $0.47 \mu F$ is preferably used;

(c) The size of the C_{vcc} capacitor 26 is increased to hold the V_{cc} supply (Figure 4) as "stiff" as

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possible since, if there are dips in the V_{CC} voltage during bootstrap charging, the internal IC diode D_s (24) can turn on earlier. Preferably, capacitor C_{VCC} (26) should have a value of ten times the total of all C_b capacitors in the system;

(d) The resistance R_b (40) in the bootstrap path is reduced as much as possible. Resistor R_b (40) limits the charging of capacitor C_b (28) which causes increased current flow through the parasitic substrate diode, which can cause a malfunction. The recommended resistor value is 0 ohms;

(e) A resistor R_{COM} (42) can be added in line 41 in Figure 4 to increase the resistance in the path of substrate diode D_s (24). Resistor R_{COM} (42) also reduces the charging of capacitor C_b (26) and the substrate current.

Although the present invention has been described in relation to particular embodiments thereof, many other variations and modifications and other uses will become apparent to those skilled in the art. It is preferred, therefore, that the present invention be limited not by the specific disclosure herein, but only by the appended claims.

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REPLACEDWHAT IS CLAIMED IS:

1. A driving circuit for high power devices, the circuit comprising:

a MOSgate driver and a power switching circuit, the power switching circuit including a first MOSgate transistor and a second MOSgate transistor, the MOSgate driver being connected to and serving to alternately turn on the first and second MOSgate transistors;

the power switching circuit having a voltage output node between the first MOSgate transistor and the second MOSgate transistor, and the second MOSgate transistor having associated therewith a recovery diode and inherent inductances L_{s1} and L_{s2} ;

the MOSgate driver comprising an integrated circuit and including an external capacitor C_b connected between a circuit node V_b and a circuit node V_s of the MOSgate driver circuit, the MOSgate driver circuit further including a common node and a series circuit including a charging capacitor C_{VCC} , a resistor R_b and a diode D_b connected between the common node and the V_b node; and

the MOSgate driver circuit and the power switching circuit being connected as close as possible to one another to obtain short conductor lengths between the nodes V_s and V_o and between the common node and another common node of the power switching circuit, to thereby reduce the values of the inductances L_{s1} and L_{s2} .

2. The circuit of claim 1, in which the capacitor C_b has an increased value, substantially in excess of a capacitance needed to hold up a voltage of



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5 the first MOSgate transistor for a maximum pulse ON time, said increased value being determined by the inductances L_{s1} and L_{s2} and also by the size and type of said MOSgate transistors.

3. The circuit of claim 1, in which a capacitance of the capacitor C_1 has a value greater than about 0.47 μF , for IR size 3 "k" type IGBTs.

4. The circuit of claim 1, in which the capacitor C_{VCC} has a value of at least about ten times the value of the capacitor C_1 in the circuit.

5. The circuit of claim 1, in which the value of the resistor R_1 is reduced to as little as possible.

6. The circuit of claim 5, in which the value of resistor R_1 is about 0 ohms.

7. The circuit of claim 1, including a resistor R_{COM} of about 1 to 20 ohms between the common node of the MOSgate driver circuit and the common node of the power switching circuit.



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HIGH VOLTAGE DRIVERS WHICH AVOID $-V_s$ FAILURE MODES

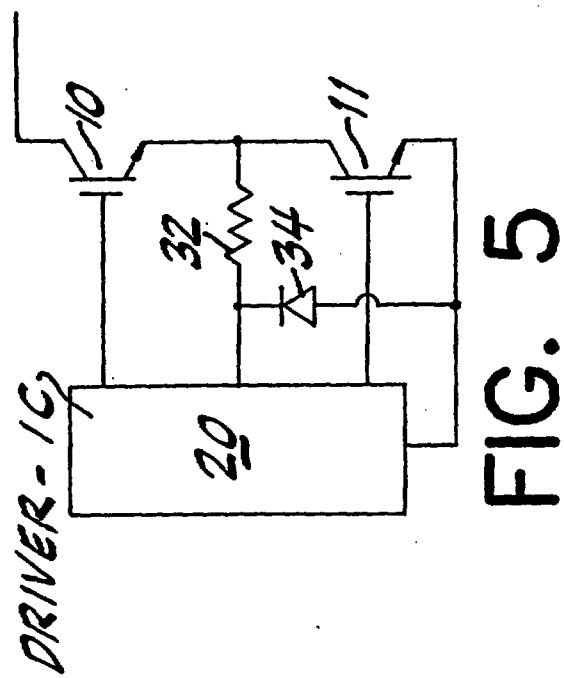
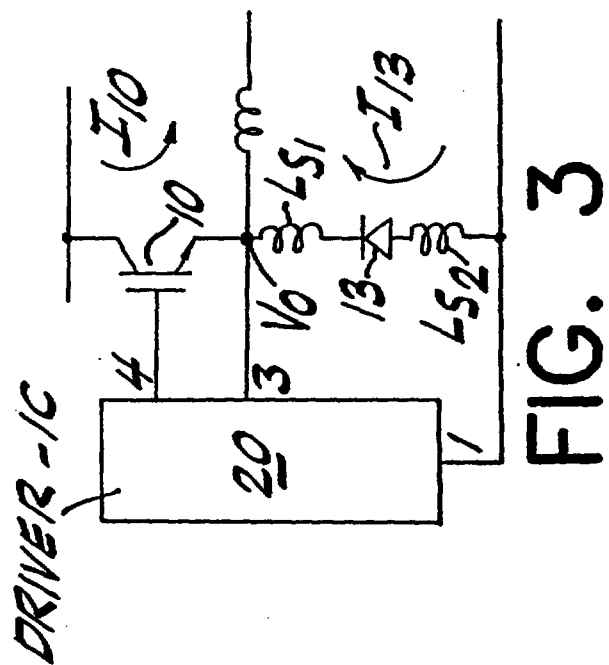
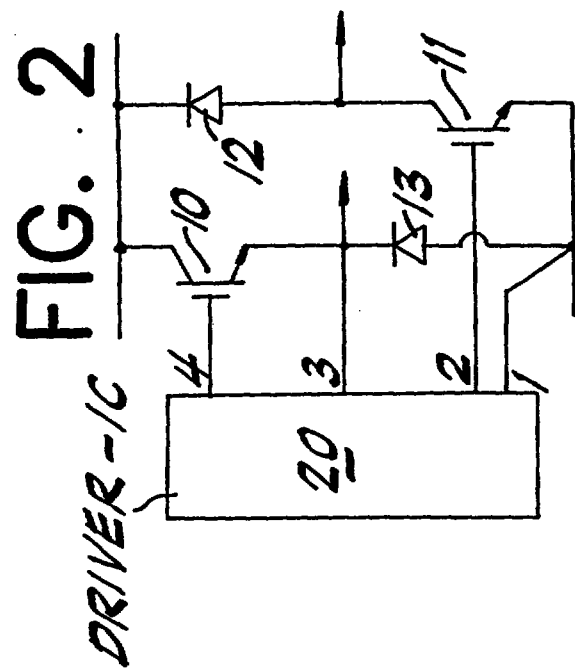
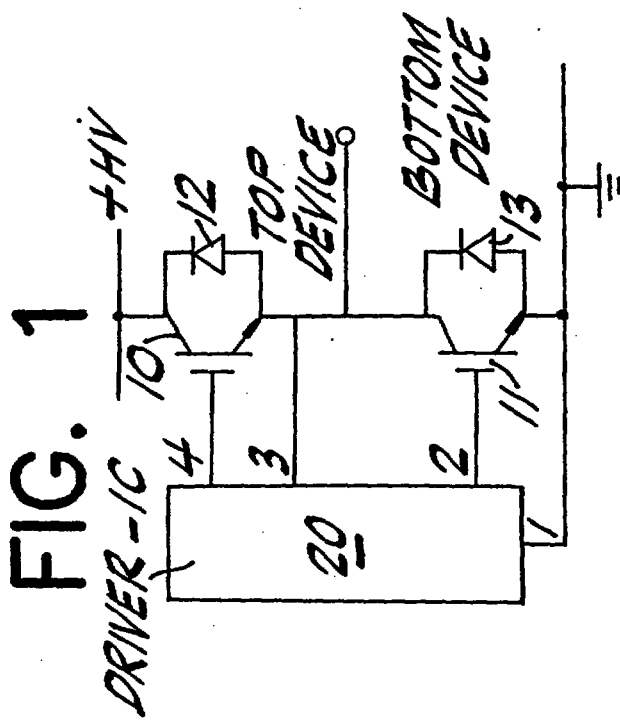
ABSTRACT OF THE DISCLOSURE

In a level shifted high voltage MOSgate device driver which drives MOSgate devices such as IGBTs and power MOSFETs, effects of negative voltage swings caused by currents commutating through L_{s1} and L_{s2} inductances in the power circuits are avoided due to several measures. First, the values of the inductances L_{s1} and L_{s2} are reduced by keeping short conductor lengths, by other layout/wire bonding techniques to reduce the values of the L_{s1} and L_{s2} inductances. The external, charging capacitor C_b value is increased substantially to reduce the voltage buildup on the internal circuitry. A typical value is $0.47 \mu F$, for a given circuit, IGBT and layout combination. The size of the C_{VCC} capacitor is selected to keep the supply voltage as stiff as possible. Preferably, C_{VCC} is at about ten times the value of the sum of the C_b capacitance in the circuit. The resistance R_b in the bootstrap path is reduced as much as possible, preferably to zero. Finally, a resistor R_{COM} is optionally added between the common nodes of the driver circuit and the power device circuit.

Figure 1

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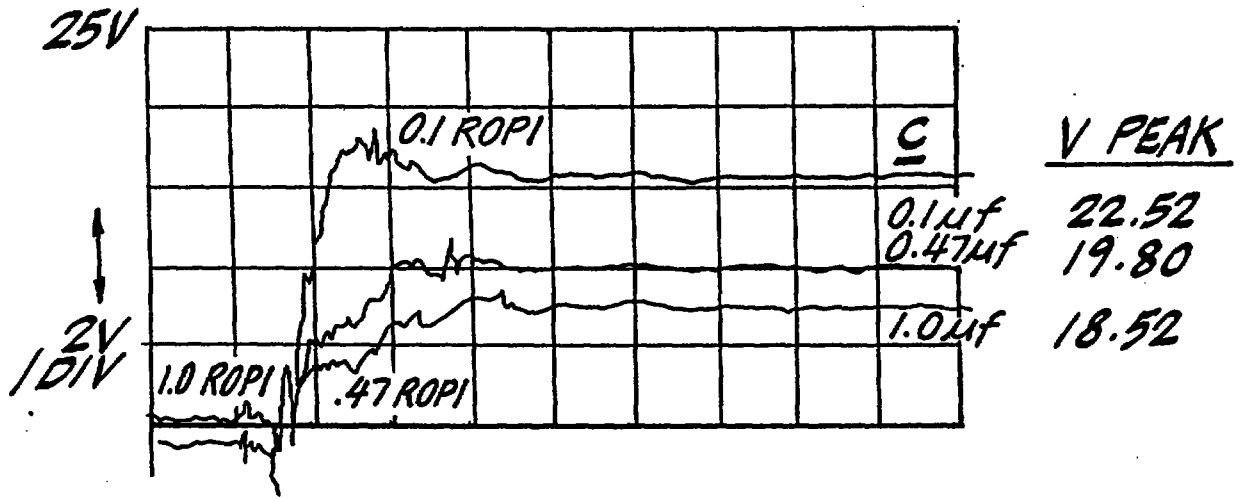


FIG. 6

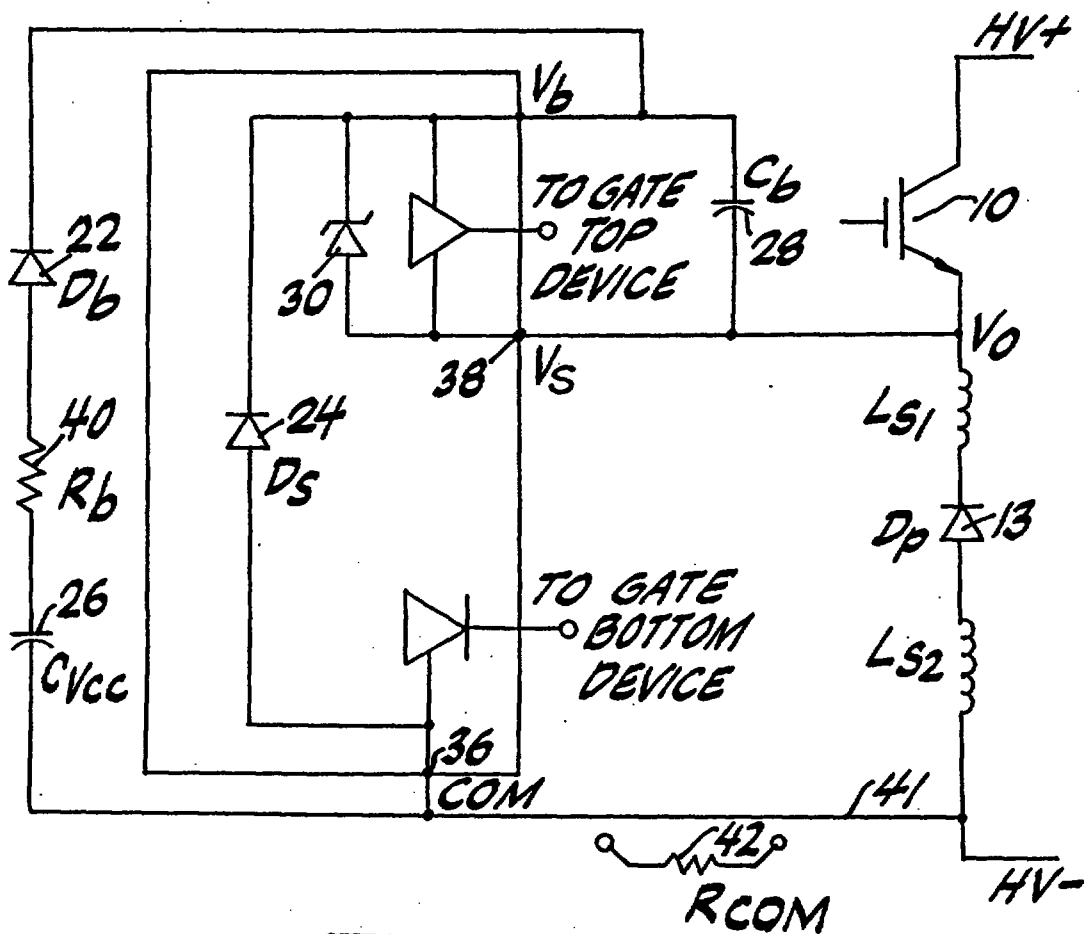


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WHAT IS CLAIMED IS:

1. A driving circuit for high power devices, the circuit comprising:

a MOSgate driver and a power switching circuit, the power switching circuit including a first MOSgate transistor and a second MOSgate transistor, the MOSgate driver being connected to and serving to alternately turn on the first and second MOSgate transistors;

the power switching circuit having a voltage output node between the first MOSgate transistor and the second MOSgate transistor, and the second MOSgate transistor having associated therewith a recovery diode and inherent inductances L_{S1} and L_{S2} ;

the MOSgate driver comprising an integrated circuit and including an external capacitor C_b connected between a circuit node V_b and a circuit node V_s of the MOSgate driver circuit, the MOSgate driver circuit further including a common node and a series circuit including a charging capacitor C_{VCC} , a resistor R_b and a diode D_b connected between the common node and the V_b node; and

the MOSgate driver circuit and the power switching circuit being connected as close as possible to one another to obtain short conductor lengths between the nodes V_s and V_o and between the common node and another common node of the power switching circuit, to thereby reduce the values of the inductances L_{S1} and L_{S2} .

2. The circuit of claim 1, in which the capacitor C_b has an increased value, substantially in excess of a capacitance needed to hold up a voltage of



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WHAT IS CLAIMED IS:

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1. A driving circuit for high power devices, the circuit comprising:

a MOSgate driver and a power switching circuit, the power switching circuit including a first MOSgate transistor and a second MOSgate transistor, the MOSgate driver being connected to and serving to alternately turn on the first and second MOSgate transistors;

the power switching circuit having a voltage output node between the first MOSgate transistor and the second MOSgate transistor, and the second MOSgate transistor having associated therewith a recovery diode and inherent inductances L_{S1} and L_{S2} ;

the MOSgate driver comprising an integrated circuit and including an external capacitor C_b connected between a circuit node V_b and a circuit node V_s of the MOSgate driver circuit, in which the capacitor C_b has an increased value, substantially in excess of a capacitance needed to hold up a voltage of the first MOSgate transistor for a maximum pulse ON time, said increased value being determined by the inductances L_{S1} and L_{S2} and also by the size and type of said MOSgate transistors, the MOSgate driver circuit further including a common node and a series circuit including a charging capacitor C_{VCC} , a resistor R_b and a diode D_b connected between the common node and the V_b node; and the MOSgate driver circuit and the power switching circuit being connected as close as possible to one another to obtain short conductor lengths between the nodes V_s and V_o and between the common node and another common node of the power switching circuit, to thereby reduce the values of the inductances L_{S1} and L_{S2} .

2. The circuit of claim 1, in which a capacitance of the capacitor C_b has a value greater than about 0.47 μF , for IR size 3 "k" type IGBTs.

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3. The circuit of claim 1, in which the capacitor C_{VCC} has a value of at least about ten times the value of the capacitor C_b in the circuit.

4. The circuit of claim 1, in which the value of the resistor R_b is reduced to as little as possible.

5. The circuit of claim 4, in which the value of resistor R_b is about 0 ohms.

6. The circuit of claim 1, including a resistor R_{COM} of about 1 to 20 ohms between the common node of the MOSgate driver circuit and the common node of the power switching circuit.



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