An Improvement of the Sustain-driving Circuit

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Abstract

In this paper, some important driving issues pertaining to the sustain-driving circuit are examined. A new driving circuit is also proposed. The new circuit is cost effective and has a simple PCB layout in comparison to the conventional one. Some additional driving advantages are noted as well

1. Introduction

The sustain circuit is a very important part of PDP driving because this circuit manages most of the power needed in driving the PDP. Until now, several kinds of the driving circuit have been proposed, but the conventional circuit, which is known as the Weber's Energy Recovery Circuit, is still being used today.

According to the conventional method, the sustain-driving circuit consists of several major electronic power devices: the inductor, the capacitor, and the power switches. But the effects a few devices have on the clamping diode are often neglected. Usually, we are concerned about the output characteristics on the panel side of the inductor, instead of the other side.

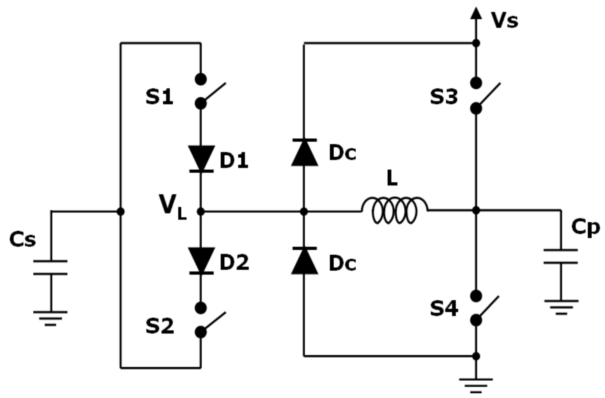

Fig.1. Conventional Energy Recovery Circuit

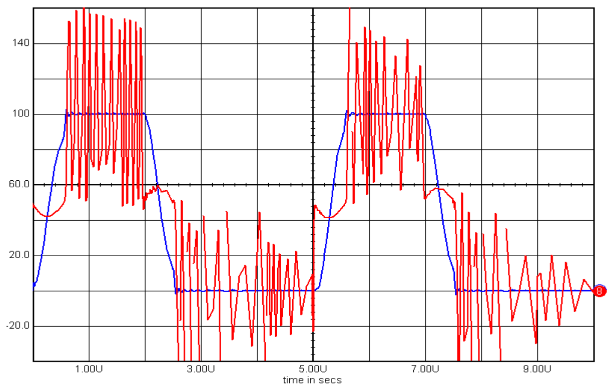

Fig.2. Simulation result of non-clamping waveform @ V_L with output waveform @ C_P

In the conventional method, the clamping diodes [Dc in Fig.1] needed to be designed on the other side of inductor in order to remove the freewheeling [Fig.2] which occurs at V_L node in Fig.1. Even though the freewheeling is not an influence on the output characteristics, it still has quite a burden with heat generation and device reliability while it is driving. In the actual circuit, usually the numbers of clamping diodes are almost the same as the energy recovery diodes' (D1, D2). This means that the clamping diodes are important devices for PDP driving.

2. Experimental

2.1. Free Resonant & Clamping

We have examined the sustain-driving circuit from this point of view, and then found a newer circuit design that is simple. Fig.3 shows the circuit that is modified from the conventional. The main difference is that the inductor (L) is moved next to the energy recovery capacitor (Cs). In spite of this modified circuit, energy recovery driving is still the same as the conventional. But there are some technical characteristics which need to be examined in the circuits.

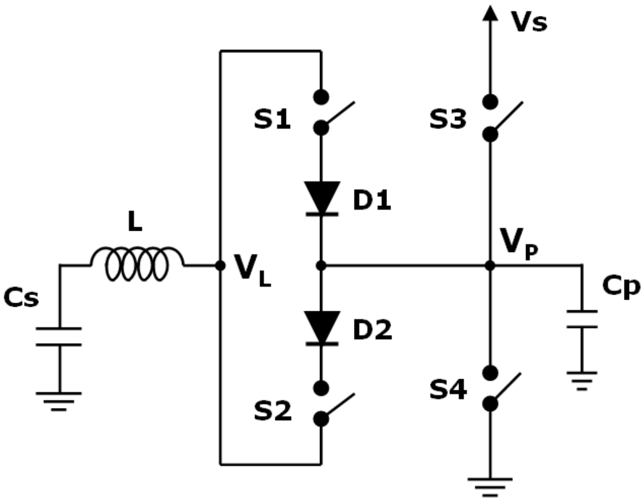

Fig.3. Proposed Circuit I

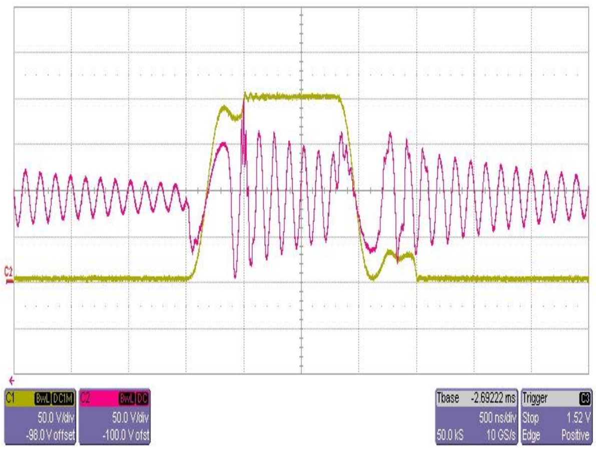

Fig.4. Driving characteristics of the Circuit (Output waveform @ V_P and V_L)

Fig. 4 shows the driving characteristics of the proposed circuit. The free resonant waveform level at V_L is located between Vs and ground level. Because one side of inductor is connected to energy recovery capacitor (Cs), it is able to maintain the Vs/2 level. This is a distinguishing point between the two methods. Accordingly, this circuit does not need to the clamping diodes. As it is mentioned above, the reason why the clamping diodes were needed was to protect the overshoot waveform when it exceeds the Vs or ground level. – So this method is named as RLC (Resonant Level Centering) driving.

But there are some issues to be examined. One of the issues is the high resonant frequency for EMI which has a regulation range that is usually between 30MHz ~ 1GHz usually. In Fig. 4, the free resonant frequency is about 8MHz, which is out of the EMI range. Also, this 8MHz is a fundamental frequency, which does not have a harmonic frequency. So this free-wheeling resonant frequency does not influence the EMI directly. Actually the EMI level of the proposed circuit is lower and better than the conventional.

The other issue is about the device reliability. Either way, the free-wheeling current that is in the inductor can influence other devices (S1, S2). This can cause heat problems or something else. So, a filtering circuit can be designed as a snubber. Fig. 5 shows the RC filtering circuit which absorbs the influencing frequency [Fig.6]. Actually, the RC filter is for specific frequency absorbing.

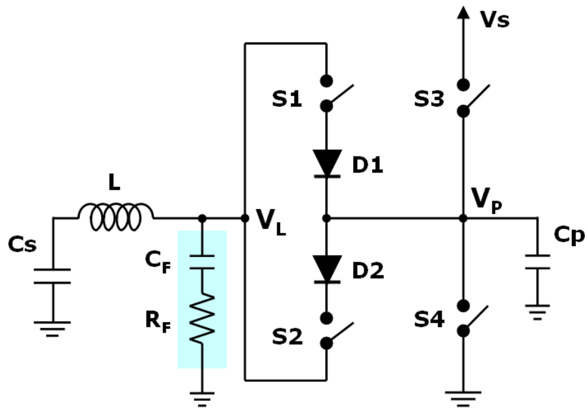

Fig.5. Proposed Circuit II

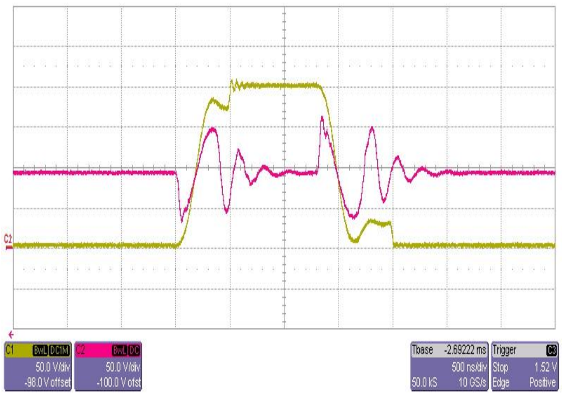

Fig.6. Driving characteristics of the circuit with the RC filter (Output waveform @ V_P and V_L)

2.2. Driving Circuit

Due to the inductor being moved, the gate driving is also more reliable than the conventional. Fig. 7 shows a conventional gate driving circuit that has a bootstrap circuit. In the conventional, the bootstrap

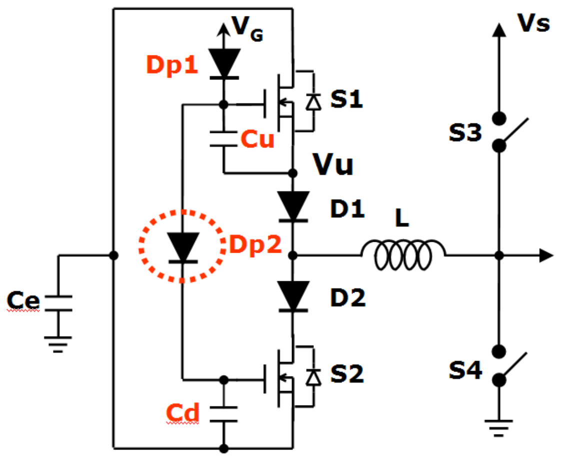

Fig.7. Gate driving in the conventional

diodes (Dp1, Dp2) are needed to charge the bootstrap capacitor (Cu, Cd). This is due to the fact that the bottom capacitor (Cd) can't charge up the voltage (V_G) itself. In detail, the upper capacitor (Cu) charges up to the V_G during the switch (S4) on for ground potential. But, there is no time to charge up for the bottom capacitor in normal conditions because the bottom capacitor is fixed on the recovery capacitor (Ce) with Vs/2 potential. So, the gate charge of the bottom capacitor has to be transferred from the upper capacitor. Also, this bootstrap circuit is processed in every sustain pulse period in a very short time.

The minimum capacitance (Cu, Cd) value can be calculated by following equations:

$$C_{D,MIN} = \frac{Q_G + Q_{RR} + I_{BST} t_{ER\_DN,ON,MAX}}{V_{BST} - V_{UVLO}} \quad \text{--- (a)}$$

$$C_{U,MIN} = C_{D,Min} + \frac{Q_G + Q_{RR} + I_{BST} t_{ER\_UP,ON,MAX}}{V_{BST} - V_{UVLO}} \quad \text{--- (b)}$$

Q_G: Gate charge of IGBT
Q_{RR}: Reverse recovery of bootstrap diode
$I_{BST} = I_{LK,D} + I_{Q,LS} + I_{Q,DRV} + I_{GS}$
$I_{LK,D}$: Leakage current of bootstrap diode
$I_{Q,LS}$: Quiescent current of level shifter
$I_{Q,DRV}$: Gate driver
I_{GS}: Leakage current between the gate-source terminals
V_{BST}: Bias voltage
V_{UVLO}: Under voltage lockout threshold of the driver

If t_{ER} is less than at least 1us, then:

$$2C_{D,MIN} \le C_{U,MIN} \quad \text{--- (c)}$$

For the actual circuit design, this condition should be considered. Moreover, if the gate-resistor is used additionally, the circuit design should consider the RC time constant more seriously. For example, Fig. 8 shows a failure mode of the gate pulse, which was omitted. Several tens of ohms values can make a difference for failure. After all, the capacitances of these bootstrap capacitors (Cu, Cd) and resistor values have to be calculated accurately in order for it not to be too big and too small.

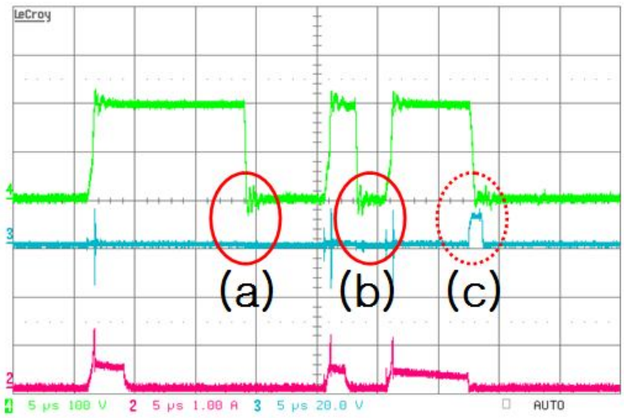

Fig.8. Gate driving failure in conventional (a),(b) : Failure mode, (c) : Normal

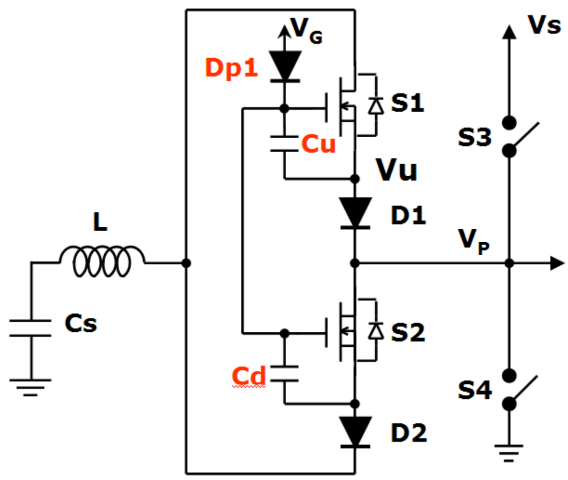

Fig.9. Gate driving in the proposed circuit

Fig. 9 shows the new gate driving circuit which is more reliable than the conventional. The bootstrap capacitors (Cu, Cd) are charged up at the same time (S4 on) with the same conditions. The positions of the devices (S2, D2) are changed reciprocally, which is not possible in the conventional without clamping.

But, the proposed circuit has no problem with wider margins so it can be said that it is more reliable.

2.3. Other Issues

The other advantage of the proposed circuit is the easy PCB layout and patterning. Due to the inductor moving, the current pattern of the major 4 switches can be laid out on the same node (Vp). There is no difference on simulation or block diagram. But, in the actual circuit design, there is quite a big advantage. If we design these switching devices all on a chip or a module, this proposed circuit structure is inevitable.

3. Results and discussion

3.1 Results

In this paper, the new and simple circuit is being proposed. The inductor is relocated and the clamping diodes can be removed. Also, there are some additional driving advantages:

1. Cost Effective Design: The clamping diodes are removed
2. It has a safer gate driving on the ER switching
3. It is easier to get to the PCB layout design

The reason for removing the clamping diodes is due to the inductor being moved toward the energy recovery capacitor. If there are no clamping diodes in the conventional circuit, freewheeling peak voltage of the inductor will surpass the sustain voltage and surpass below the ground. But in the proposed circuit, the peak voltage of the inductor stays within the certain voltage range (0V ~ Vs) for anytime because the other side of inductor is bound to the Vs/2 on the ER capacitor (Cs). Also, Table 1 shows the measurement of the voltage range on each device. There are no major differences between them.

TABLE 1. Voltage range of devices

	Conventional (V)	Proposed (V)
ER_UP Diode	207	205
ER_UP SW	119	125
ER_DN Diode	202	210
ER_DN SW	140	130

Due to the inductor moving, it will be easier to design the PCB on the output node. The four switches, which consists of the sustain/ER circuits, are combined at the same singular node. It has a very powerful effect on the PCB design for actual engineering and not for simulation. So, we can reduce the PCB area and expect to have a more efficient driving.

The driving characteristics are the same as the conventional. The RC filter is designed on one side of the inductor to absorb the free resonance of the inductor. Actually, there is no need to absorb all the frequency range. This resonant frequency can be appropriately reduced with just a C filter.

Discussion

In the proposed circuit, the efficiency and heat dissipation of the devices are not different from the conventional. This is a natural result because there were no changes in the current for the current path.

4. Summary

We have usually discussed about theoretical energy recovery circuits instead of viewing it from an actual engineering point of view. In this paper, some issues related to the conventional sustain-driving circuit were dealt with from an actual engineering point of view. In doing so, a new circuit was suggested. We expect others to try and deal with other issues from an actual engineering point of view.

5. References

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