Design and Development of Driver Protection Circuit of Self Turn off Devices Applies to Electric Vehicle Fast-Change Mode

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Abstract. In this paper, based on the design of the chip UAA4002 one for electric vehicle fast charge mode of self-turn-off device driver protection circuitry to power transistor, for example, study design optocoupler isolation circuit, control circuit, anti-saturation circuit, composite buffer circuit, Further integration of the formation of self-turn-off device drivers, isolation, protection circuit, which has a simple circuit structure, function, high reliability, low switching losses, fast response.

1. Introduction
At present, the world's social and economic development is facing severe challenges such as shortage of fossil energy supply and deteriorating ecological environment. Energy and environmental issues have become a major strategic issue that countries urgently need to solve [1]. Electric vehicles have the advantages of energy saving and environmental protection [2-3]. Vigorously developing electric vehicles and realizing the comprehensive transformation of transportation energy have been widely established in the world as effective ways and important measures for implementing energy sustainable utilization strategies and low-carbon economic transformation [2], [4-5].

According to the development strategy of electric vehicles in China and the current demand for electric vehicles, fast charging will become the main way of energy supply for electric vehicles [4, 6]. Therefore, the development of infrastructures such as chargers that support the rapid charging mode of electric vehicles is a key path to optimize the allocation of electric vehicles for charging and replacing resources, and is the basic link for promoting the development of the electric vehicle industry [7-9].

The change of the charging mode of the electric vehicle puts forward higher requirements on the reliability and response speed of the self-shutdown device such as the high-power transistor used in the charger [8, 10-11], and at the same time, in order to improve the efficiency of the charger, it is necessary to reduce the self. Turn off the switching losses of the device and simplify the structure of its drive protection circuit as much as possible [12].

The function of the self-shutdown device driving protection circuit such as a high-power transistor is to amplify the control signal current outputted by the control circuit to ensure that the self-shutdown device can be reliably turned on and off [13-14]. The base driving mode of the self-shutdown device directly affects its working condition, and some characteristic parameters can be improved or damaged. The driving protection circuit should be matched with the main circuit to ensure that the self-shutdown device is quasi-saturated at any time during the conduction period. State, when turned off, can quickly add a large enough reverse bias voltage, and have enough protection function [13, 15].
Most self-shutdown devices use a base drive circuit with reverse bias or a base drive circuit topology with overload and short circuit protection [16-18]. The clamp diode and the potential compensation diode in the base drive circuit with reverse bias enable the self-shutdown device to be in a critical saturation state when turned on [16, 19], and the Zener diode and the reverse bias diode can be self-shutdown. The device accelerates off at the off-state, but the regulation value of the Zener diode is difficult to determine. The effect of too low reverse bias is not obvious. If it is too high, the power component will be damaged and high-frequency parasitic oscillation may occur [17, 20]. The thermal capacity of the self-shutdown device is generally small, and the overcurrent capability is very low. When it is operated in the inverter system, due to its long turn-off time, it is easy to cause the bridge arm short-circuit fault [20-21], and with overload, The short-circuit-protected base drive circuit uses state-recognition protection with low sensitivity for monitoring under mild overload conditions [18, 22]. The above discrete component drive protection circuits have the disadvantages of many components, complicated circuits, poor stability and inconvenient use.

Based on the chip UAA4002, this paper designs a self-shutdown device drive protection circuit suitable for the fast charging mode of electric vehicles. It has the advantages of simple circuit structure, perfect function, high reliability, small switching loss and fast response speed.

2. Drive protection circuit design

2.1. Power Electronics Drive Protection Principle

(1) Drive: The driver receives the control signal output from the control system, and after processing, sends a drive signal to the switch tube to control the on/off state of the switch device.

(2) Overcurrent and overvoltage protection: including device protection and system protection, protect the switching device in the main circuit to prevent overcurrent and overvoltage damage to the switching device.

(3) Buffering: Prevent over-voltage and over-current of the switch tube during turn-on and turn-off, and reduce switching loss.

(4) Filtering: Filter out the AC component of the output voltage or current to obtain smooth DC power, filter out unwanted harmonics, and improve the power quality obtained by the power supply and output to the load.

(5) Heat dissipation: The power consumption of the switching device and other components is radiated, the thermal power of the switching device is reduced, and the junction temperature of the switching device is lowered.

(6) Control: Real-time and adaptive control of power electronic circuits, integrated reference and feedback signals, after processing, provide switching devices with turn-on and turn-off signals, power-on, power-off and protection signals.

2.2. Circuit overall structure design

This paper takes high-power transistors as an example to design its driving, isolation and protection circuits. As shown in FIG. 2, the driving protection circuit includes a positive and negative power supply, an optocoupler isolation circuit, a control circuit, an anti-saturation circuit, a high power transistor, and a composite buffer circuit.

The control signal of the circuit is input into the anode of the original LED of the optocoupler device after the RC filter, and the cathode of the LED is grounded via the resistor. The emitter of the phototransistor is directly connected to the input end of the chip UAA4002 in the control circuit, and the negative power supply is connected through the resistor and the switch, and the positive power supply is connected to the collector of the phototransistor through the switch. The positive and negative power supplies are respectively connected to the positive and negative power supply pins of the chip UAA4002, and respectively connected to the collectors of the subsequent upper and lower pairs of tubes, and the upper and lower pairs are respectively connected. The tube is respectively connected to the anti-saturation circuit through the current limiting resistor, and the anti-saturation circuit is connected in
parallel between the base and the collector of the high-power transistor. In the control circuit, the chip UAA4002 is connected through the resistor and the subsequent RC filter. The base of the two-way pair tube is internally grounded by the peripheral circuit and the emitter of the high-power transistor. The negative power supply is connected to the emitter of the high-power transistor through the switch and the resistor, and the composite buffer circuit is directly connected in parallel at high power. Between the collector and emitter of the transistor.

2.3. Optocoupler isolation circuit design
The optocoupler isolation circuit includes a RC filter, an optocoupler device, and a resistor. The RC filter uses a resistor-capacitor parallel structure, and then connects the anode of the original LED of the optocoupler device. The cathode of the LED is grounded through a resistor, and the optocoupler device is coupled. The collector of the square phototransistor is connected to the positive power supply through a switch, and the emitter is connected to the negative power supply through a resistor and a switch, and is directly connected to the subsequent control circuit, as shown in FIG.

2.4. Control circuit design
The control circuit mainly includes the chip UAA4002 and its peripheral circuits, the upper and lower pairs of tubes and their additional circuits. The chip UAA4002 is connected to the bases of the upper and lower pairs of tubes through resistors and RC filters, and the positive and negative power pins are directly connected. Positive and negative power supply, the input end is directly connected to the emitter of the phototransistor of the optocoupler device, and the internal tuning ends are respectively grounded by the chip peripheral circuit and the emitter of the high power transistor, and the emitters of the upper and lower tubes are respectively connected. Positive and negative power supply, the collector is
connected to the subsequent anti-saturation circuit through the resistor-capacitor filter and then through the current limiting resistor.

2.5. Anti-saturation circuit design
The anti-saturation circuit adopts a Beck clamp circuit topology, which is directly connected in parallel between the base and the collector of the high-power transistor, and is connected with the control circuit through a current limiting resistor, which includes three branches, and the first branch includes one clamping diode, the diode uses a fast recovery diode to connect the current limiting resistor and the collector of the high power transistor; the second branch includes two series-connected potential compensation diodes, each of which uses a fast diode, connected to the current limiting resistor and large The base of the power transistor; the third branch includes an anti-parallel diode directly in parallel with the second branch, as shown in FIG.

2.6. Composite buffer circuit design
The composite buffer circuit adopts a composite structure of an open absorption circuit and a shutdown absorption circuit, and is directly connected in parallel between the collector and the emitter of the high power transistor, and includes an inductor, a resistor, a capacitor, a diode, and the inductor is connected in series to the collector of the high power transistor. The resistor and the capacitor are connected in series and connected to a branch composed of a high-power transistor and an inductor. The diode is connected between the branch of the high-power transistor and the inductor and the branch composed of the resistor and the capacitor, and the inductor and the resistor constitute an open-through absorbing circuit. At the same time, it is combined with resistors and capacitors to form a shutdown absorption circuit, as shown in Figure 5.

![Figure 3. Schematic diagram of anti-saturation circuit](image1)

![Figure 4. Schematic diagram of complex circuit](image2)
2.7. Circuit implementation diagram
The above-mentioned optocoupler isolation circuit, control circuit, anti-saturation circuit and composite buffer circuit are designed. The schematic diagram of the self-shutdown device drive protection circuit suitable for the electric vehicle fast charge mode is shown in Fig. 6.

![Circuit implementation diagram](image)

Figure 5. Schematic diagram of achievement

3. Experiment

3.1. Control circuit power-on, the waveform of each port when the main circuit is not powered

![Waveform](image)

Figure 6. The waveform of each port when control circuit power-on but the main circuit is not powered

From the waveform of "control circuit power-on, main circuit is not powered", it can be seen that the OUTPUT terminal of the control circuit outputs the PWM waveform with the frequency of 128.099KHz, the RT/CT terminal is the triangular waveform, the supply voltage is 11.9V, and the control circuit works normally.
3.2. When the input voltage=220V, each voltage waveform

Figure 7. The $V_{ds}$ and $I_{ds}$ of GTR

Figure 8. The output $V_{out}$ of DC coupling and AC coupling when rated load

Figure 9. The voltage of transformer primary and second when rated load

Figure 10. The voltage of rectifier diode and snubber when rated load
Figure 11. The output of TL431-1 and TL431-3 feet when rated load and 50% rated load

Figure 12. The output of UAA4002-COMP when rated load and 50% rated load

It can be seen from the input voltage $V_{in}=220V$, the MOS tube $V_{ds}$ voltage waveform that at the moment of turn-off, the overshoot voltage and oscillation at both ends of the GTR are small, because the input voltage is increased and the input current is reduced under certain power conditions. Therefore, after the switch is turned off, the $dI/dT$ caused is reduced, so that the voltage overshoot across the switch tube is reduced. The voltage across the GTR has an overshoot voltage because the leakage inductance of the primary side of the transformer is large, so a high $dV/dT$ is generated at both ends of the leakage inductance, and the absorption capacitor voltage is large, and the absorption circuit diode fails to conduct in time. The generated induced voltage is directly applied across the GTR, resulting in a higher $V_{ds}$. After the GTR is turned off, $V_{ds}$ generates a slight oscillation. This may be because the primary leakage inductance resonates with the capacitance $C_{ds}$ at both ends of the tube, causing voltage oscillation. On the other hand, it may be due to the long connection line during the soldering process. And a loop is formed between the lines, causing the circuit to oscillate.

The current $I_{ds}$ flowing across the GTR is close to a horizontal straight line, but there are some current spikes, indicating that the filtering is not complete, and there are some high-frequency components, which can be improved by adjusting the parameters of the filter circuit, such as appropriately increasing the capacitance value.
Through the rated load, the output DC voltage $V_{out}$ (DC coupled) 5V waveform and the rated load, the output DC voltage $V_{out}$ (AC coupled) 5V waveform comparison shows that the AC component of the output waveform of the control circuit accounts for a small proportion, indicating that the driving effect is good, the circuit stability and output accuracy are ideal.

When the input voltage $V_{in}=220V$, it can be seen from the primary side voltage waveform of the transformer that the filtering effect is ideal, and the high frequency component is less. It proves that the filter capacitor is selected reasonably, and the purpose of filtering out the high frequency component is basically achieved, and the secondary side voltage has some spikes. The filter effect can also be improved, such as increasing the filter capacitor.

The clamp voltage $V_c$ waveform of the absorption capacitor under rated load has oscillation. Because the capacitance value is chosen to be large, the voltage change across the capacitor during charging is small. The energy stored in the absorption capacitor can be absorbed in one switching cycle. The release of the circuit is completed, which has a certain inhibitory effect on alleviating the voltage overshoot at both ends of the GTR.

It can be seen from the pin waveforms of TL431-1 and TL431-3 that the reference voltage and sampling voltage of the Zener diode are generally 2.5V, which ensures that the final output voltage can be controlled by negative feedback and PWM. The required 5V voltage. As the input voltage increases, the waveforms of the TL431-1 and TL431-3 pins become worse and the burrs increase. The possible cause is that the intermittent oscillation effect occurs after the duty ratio drops to a certain value, resulting in a worse output effect. In practical applications, try to avoid too low duty cycle, or take certain measures to make up for it, such as adding high frequency choke coil or decoupling capacitor at the input end.

4. Conclusion

Based on the UAA4002 chip research, this paper designs a self-shutdown device drive protection circuit suitable for electric vehicle fast charge mode, including the overall structure of the circuit and the optocoupler isolation circuit, control circuit, anti-saturation circuit and composite buffer circuit. Turn off the device drive protection circuit.

The circuit has the advantages of simple structure, easy implementation, high reliability, ideal driving effect, high system efficiency, fast response, flexible adjustment, complete protection functions, etc., and has broad application prospects and market potential.

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