Clamp Diodes: Principles, Functions, and Applications

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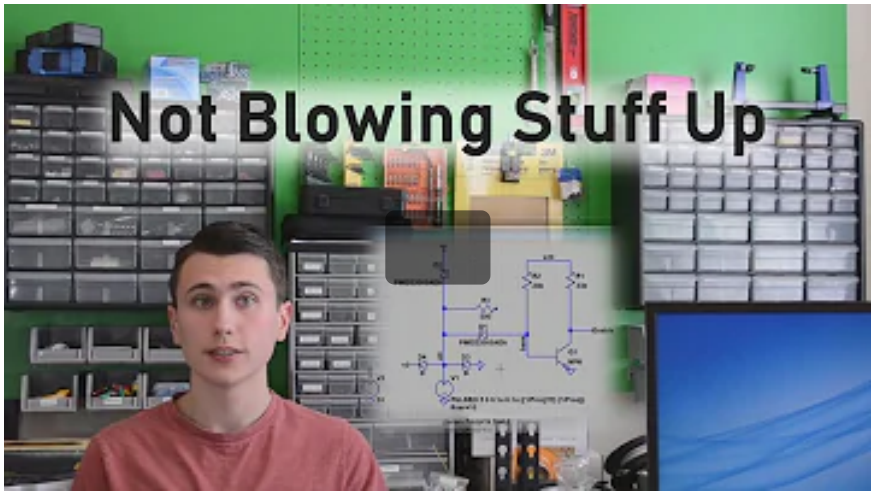
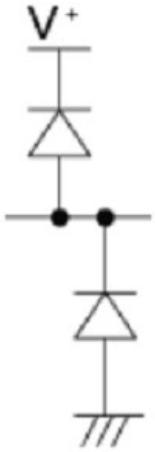
Clamp means jamming the position. In circuit, is means controlling the voltage. Clamp Diode is a kind of diode that is used to limit the potential of a certain point in the circuit, controlling the input voltage to a peak value to a predetermined voltage, without changing the signal. The working principlealso the unidirectional conductivity of the diode.



Clamping Diodes - Things not Blowing Up

Catalog

I. Principles



The circuit configuration of clamp diodes

What is the principle of **clamping diodes**? To understand this question, you must first understand clamping circuit. A circuit that can fix a certain part of the input and output signal waveform at a selected level is called a clamp circuit. If you want to change the clamp level, you can connect a DC potential in the circuit. If you want to clamp the bottom of the pulse, you can reverse the diode on the side. The following figure shows the input signal clamping circuit of a typical integrated **operational amplifier** block.

The clamping diode protection circuit consists of two diodes in **reverse series**. Only one diode can be turned on at a time, and the other is in the off state. As a result, the forward and reverse pressure drop of it will be clamped to the forward conduction of the diode. The voltage drop is below 0.5-0.7, so as to **protect the circuit**.

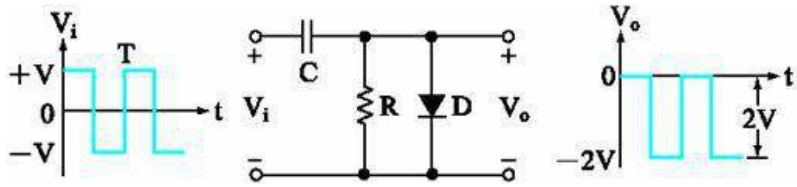
The function of the clamping circuit is to keep the top or bottom of the periodically changing waveform at a **certain DC level**. Take a common diode clamp circuit as an example, suppose the input signal, at zero time, uO(0+)=+E, uO produces a positive transition with amplitude E. After that, between 0 and t1, the diode D is turned on, the charging current of the capacitor C is very large, and uC quickly becomes equal to E, causing uO=0. At t1, ui(t1)=0, and uO has an amplitude -E jump again. During t1~t2, D is turned off, and the charging capacitor C can only be discharged through R. Usually, the value of R is very large, causing uC drops very slowly, and uO changes very little. At t1, uI(t2) = E, and uO have a jump of the amplitude E. During t2 to t3, D is turned on and capacitor C is recharged. Unlike the period from 0 to t1, there is a large amount of charge stored on the capacitor at this time, so the charging duration is shorter, and uO decreases to zero more quickly. Repeat the above process later, the waveforms of uO and uC. It can be seen that the top of uO is basically limited to zero level, so the circuit is called a zero-level positive peak (or top) clamp circuit.

Connect the diode reversely to clamp the bottom of the input rectangular wave at zero level, forming a zero-level negative peak (or bottom) clamp circuit.

Triode clamp circuit, if its BE junction is also seen as a diode, then, in terms of the principle of clamping, the circuit shown is exactly the same, except that the circuit also has an amplifying effect.

To get to know the priciples of clamp diodes better, here are the introductions of the principles of two different ciucuits:

1. Negative clamp diode circuit



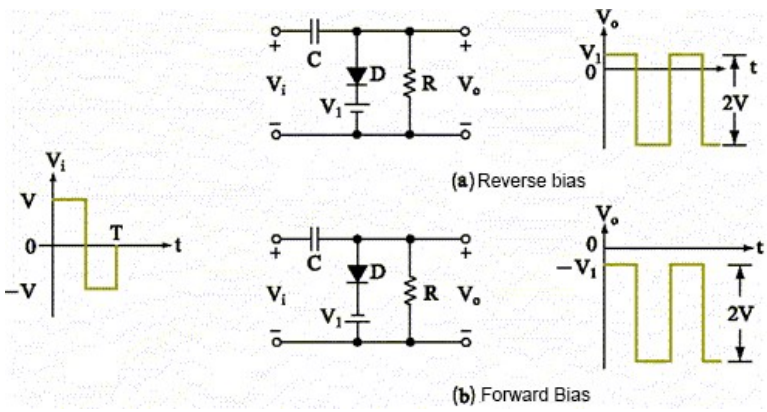
The circuit configuration of the negative clamp diode circuit

Working Principle:

When Vi is positive for half a cycle; charging starts, and the capacitor C is charged to the value of V. At this time, the clamp diode is turned on, Vo=0V.

When Vi is a negative half cycle, stop charging, the voltage on the capacitor is -V, and the negative half cycle voltage -V is added at the same time, Vo=-2V.

2. Bias type clamp diode circuit



The circuit configuration of the bias type clamp diode circuit

Working principle:

When Vi is positive for half a cycle, the diodes DON, C are charged to the value of V (positive left, negative right), Vo=+V1(a) or -V1(b).

When Vi is a negative half cycle, the diode DOFF, RC time constant is large enough, Vo=VC+Vi (negative half cycle)=2V.

II. Functions

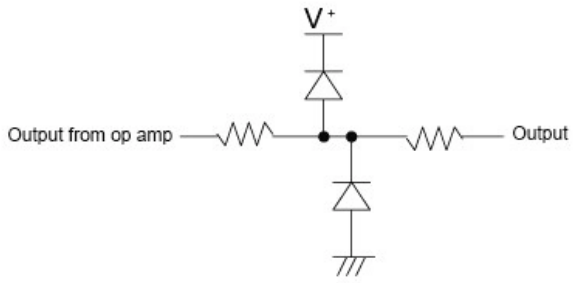
In the clamping circuit, the cathode of the diode is **grounded**, and the positive terminal circuit is clamped below zero potential;

1. When the cathode of the diode is grounded, and the potential of the positive terminal circuit is higher than the ground, the diode will conduct and pull its potential down, that is, the positive terminal circuit is clamped to zero potential or below (ignoring the tube voltage drop).

2. When the anode of the diode is grounded, and the potential of the negative circuit is higher than the ground, the diode will be cut off, and its potential will not be affected by the diode;

3. In the clamping circuit, if the cathode of the diode is connected to +5V, the positive terminal circuit is clamped below the +5V potential;

4. In the clamp circuit, if the anode of the diode is connected to +5V, the negative terminal circuit will be clamped above the +5V potential.



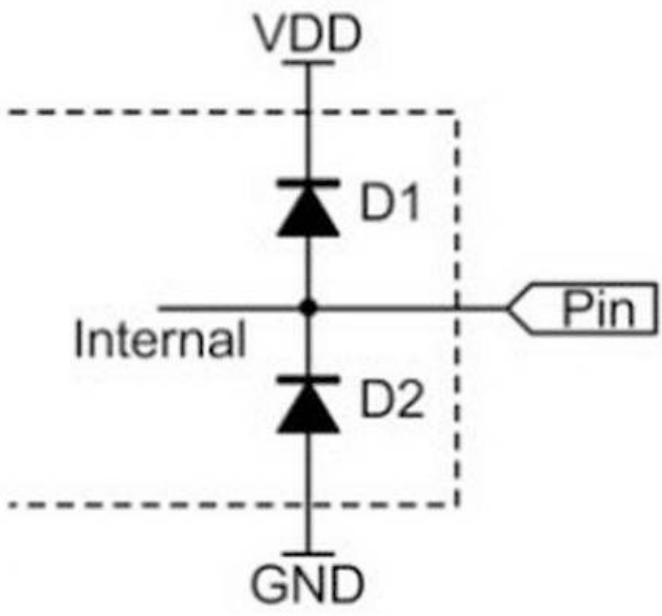
The function of the clamping circuit

Clamp diodes are 1N5177 Schottky diodes because their forward conduction voltage is equal to about 0.4V, which is lower than the forward conduction voltage of the op-amp input electrostatic discharge (ESD) protection diode; therefore, the clamping diode will be before the ESD diode Start to conduct current. The overvoltage protection resistor ROVP limits the forward current flowing through the clamping diode, keeping it below the maximum current rating, and preventing damage from excessive current. The feedback loop resistor RFB is used because any input bias current on the non-inverting input will flow through the ROVP and produce an input voltage error-increasing the RFB value can eliminate the error because it will produce a **similar voltage** at the inverting input.

III. Applications

1. Used to protect GPIO

The clamping diode circuit is used in the internal circuit structure of GPIO, as shown in the figure below. Its function is to prevent the voltage input from the external I/O pin from **being too high or too low** to cause damage to the internal circuit. If the signal input from Pin (assuming any input signal has a certain internal resistance) voltage exceeds VDD plus the conduction voltage drop of the upper diode (driving 0.7V), the diode will be turned on and the excess current will be drawn to VDD , And the real signal voltage input to the internal will not exceed VDD+0.7V. Similarly, if the signal voltage input from Pin is lower than VSS, the actual input internal signal voltage will be clamped to about VSS-0.7V due to the effect of the lower diode.



The circuit configuration of GPIO

The reference power supply VDD of the GPIO pulled up by the cathode of the clamp diode D1, and the anode of the clamp diode D2 is connected to GND.

When the output voltage is greater than VDD; D1 turns on, D2 turns off, and the voltage of Pin is VDD (ignoring the turn-on voltage drop of the diode);

When the input voltage is less than GND; D1 is off, D2 is on, and the voltage of Pin is GND (ignoring the conduction voltage drop of the diode);

Therefore, the input voltage range can be controlled between [GND, VDD] to protect Pin from damage. How to determine whether the GPIO is damaged? Methods as below:

First, **adjust the multimeter to the diode position**, connect the red test lead to the GND of the motherboard, and connect the black test lead to the test GPIO pin. At this time, it is to measure whether the diode D2 is damaged. The test value is the conduction value of the diode, and the general range is 0.4-0.6V. Beyond this range is diode breakdown.

Secondly, **connect the red test lead to the test GPIO pin** and the black test lead to GND. At this time, it is to measure whether the diode D1 is damaged.

Adding clamping diodes can protect the input and output ports of the microcontroller. As shown above, adding two Schottky diodes as clamping diodes can effectively prevent the GPIO from being broken down by static electricity. When the voltage is greater than VDD, D1 is turned on, and the static electricity is released to VDD through D1; when the voltage is less than GND, D2 is turned on, and the static electricity is released to GND through D2. Because of the need to quickly discharge static electricity, Schottky diodes or fast switching diodes are generally selected as clamping diodes.

2. Other Uses

Clamping circuits are also often used in various display devices. In the oscilloscope and radar display, a clamp circuit is used to restore the DC component of the scanning signal to solve the problem of image position movement on the screen caused by the change of scanning speed. In the TV system, a clamp circuit is used to keep the top of the sync pulse of the full TV signal at a fixed voltage to overcome the level fluctuation caused by the loss of the DC component or interference, so as to realize the separation of the TV sync signal.

Clamp diodes will generate a **clamp voltage**. The object it limits can be an object that needs overvoltage protection, such as the MOS tube in a switching power supply. A clamping network is needed to limit the voltage between the D and S poles to protect the MOS from damage.