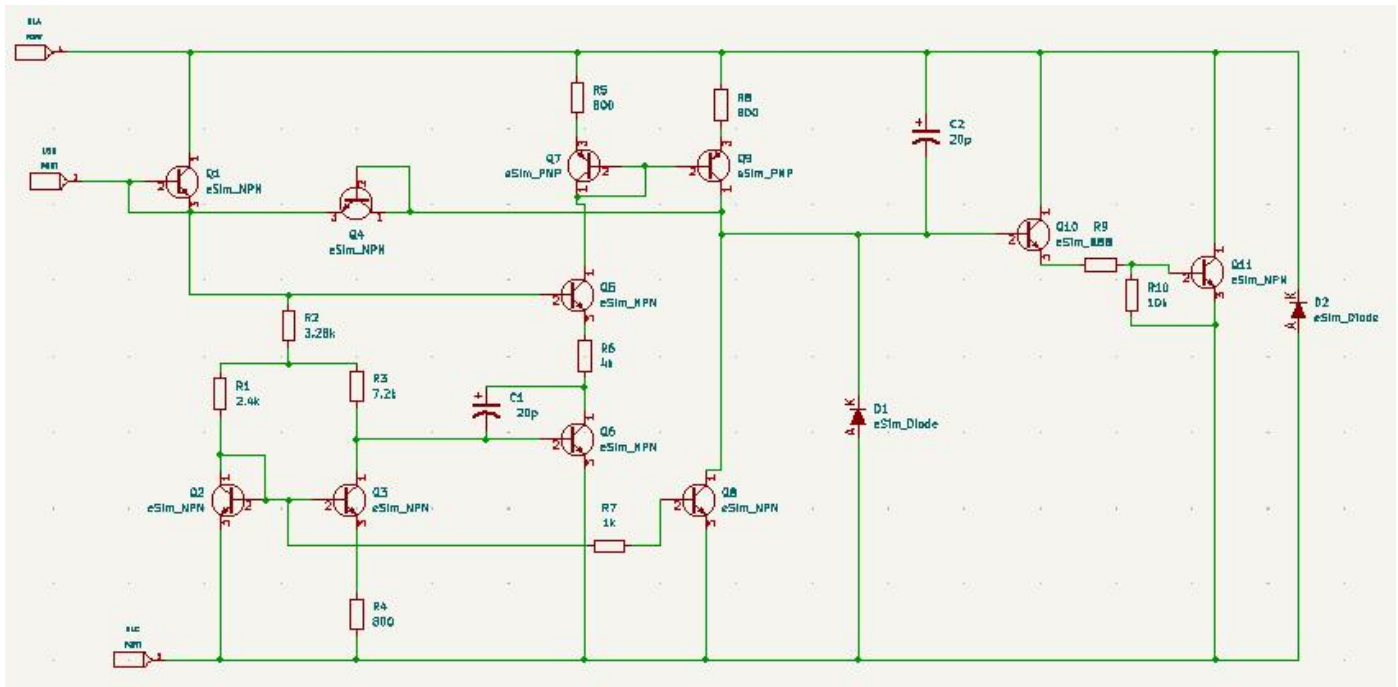


Title of the circuit : Precision Programmable Shunt Regulator-TL431

Theory/Description :

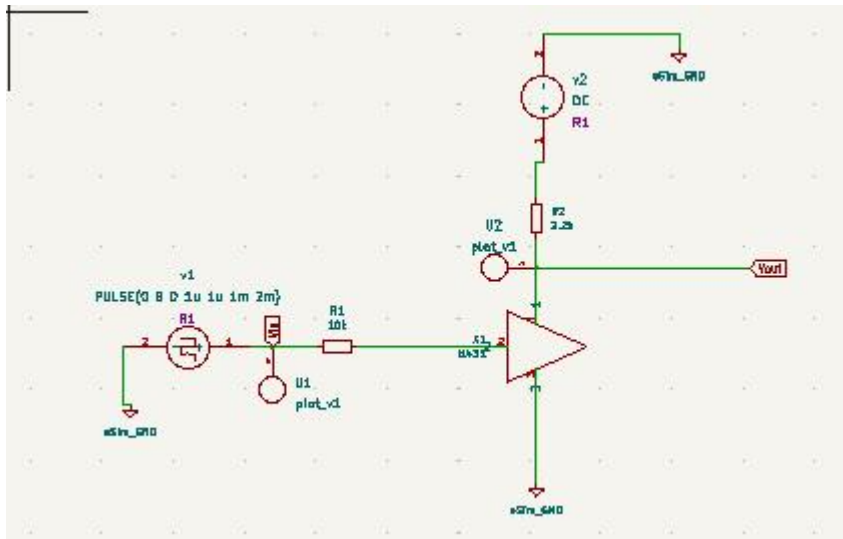
The TL431 is a precision programmable shunt regulator that provides a highly stable and accurate reference voltage. It contains an internal 2.5 V bandgap reference and an error amplifier, which together allow the device to compare the voltage at the reference (REF) pin with the internal reference. By using external resistors, the output voltage can be set. When the REF voltage is below the reference level, the device turns off and draws minimal current. Due to its high accuracy, low temperature drift, and adjustable output capability, the TL431 is widely used in voltage regulation, feedback control, and precision reference applications.



Working:

The TL431 operates as a precision programmable shunt regulator by comparing the voltage at its reference (REF) pin with an internal 2.5 V reference voltage. When the voltage at the REF pin is less than 2.5 V, the internal error amplifier remains inactive and the device draws only a small leakage current, so the cathode voltage rises toward the supply voltage through the series resistor. When the REF pin voltage exceeds 2.5 V, the internal amplifier activates the output transistor, causing the TL431 to conduct and sink current from the cathode to the anode. As a result, the cathode voltage decreases until the REF pin voltage is regulated back to 2.5 V. By using an external resistor divider network, the threshold or output voltage can be programmed to desired values. Thus, the TL431 maintains a stable and accurate voltage and can also function as a voltage comparator in control and regulation circuits.

Test Circuit

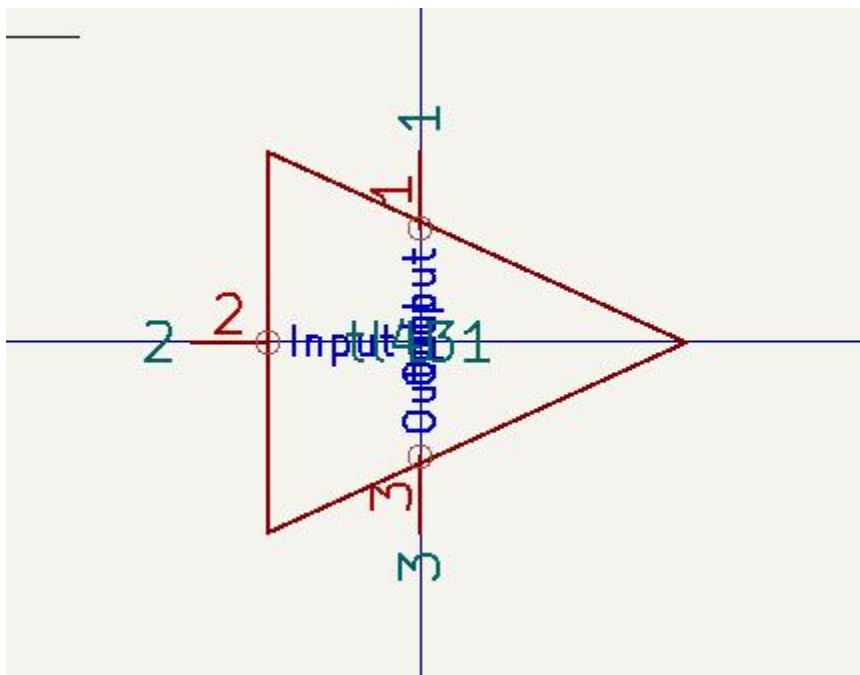


In this test circuit, the TL431 is used as a precision shunt regulator to observe its voltage switching behavior. The supply voltage is applied to the cathode of the TL431 through a series resistor, while the anode is connected to ground. An input signal is applied to the reference (REF) pin to control the operation of the device.

When the voltage at the REF pin is less than the internal reference voltage of 2.5 V, the TL431 remains in the OFF state and draws minimal current. As a result, the cathode voltage rises toward the supply voltage through the series resistor, producing a high output voltage at Vout. When the REF pin voltage exceeds 2.5 V, the internal error amplifier activates the output transistor, causing the TL431 to conduct and sink current from the cathode to the anode. This reduces the cathode voltage, resulting in a low output voltage at Vout.

Thus, the output voltage V_{out} switches between high and low levels depending on the input signal applied to the REF pin. By plotting V_{out} in transient analysis, the dynamic response and switching behavior of the TL431 can be clearly observed and verified.

SYMBOL



The TL431 is a three-terminal precision programmable shunt regulator with three pins: Cathode (Pin 1), Reference (Pin 2), and Anode (Pin 3).

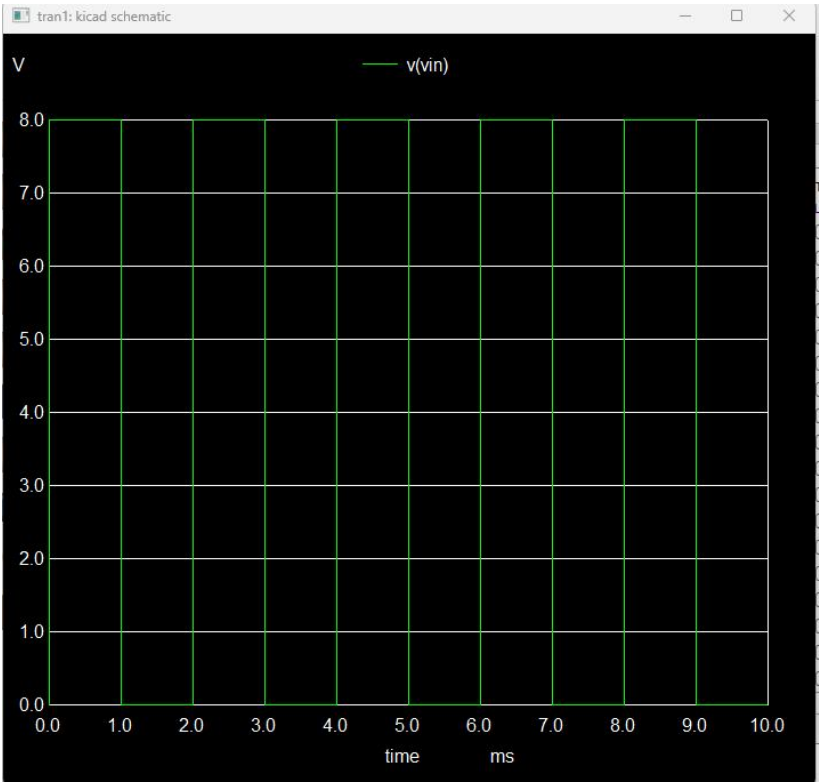
Pin 1 (Cathode) acts as the output terminal of the device. The output voltage V_{out} is measured at this pin, and the TL431 sinks current from the cathode when it is activated.

Pin 2 (Reference) is the control input pin. The voltage applied at this pin is compared with the internal 2.5 V reference voltage, which determines the operating state of the TL431.

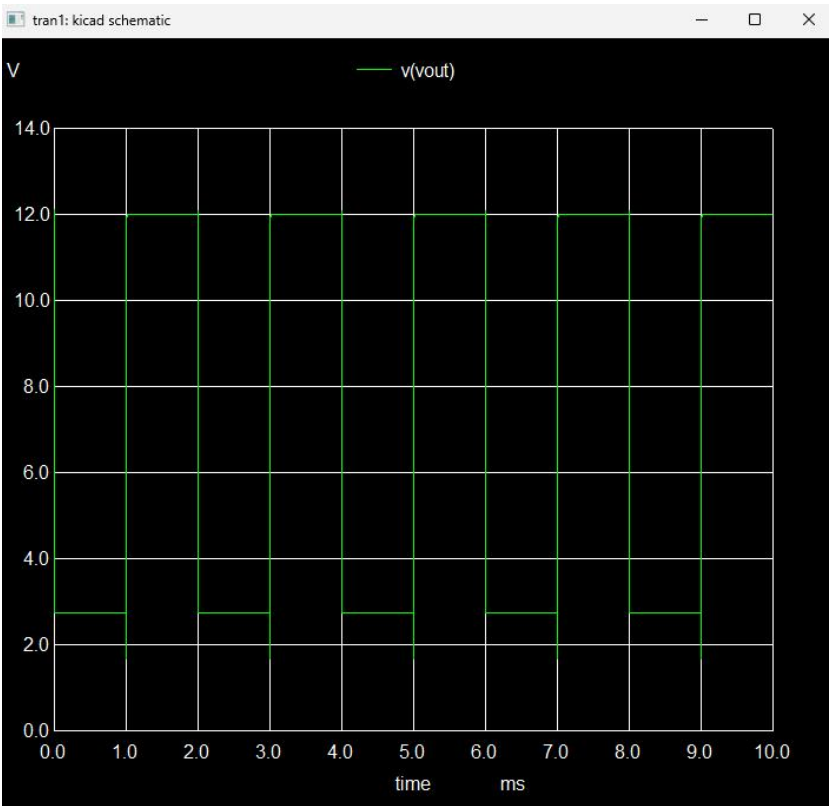
Pin 3 (Anode) is the ground or neutral terminal. It provides the return path for current and is typically connected to the circuit ground.

Thus, the TL431 operates by controlling the current flow between the cathode and anode based on the voltage applied at the reference pin.

INPUT SIGNAL WAVEFORM:



OUTPUT SIGNAL WAVEFORM:



The output waveform shows the switching behavior of the TL431 based on the input voltage at the reference pin. When the input voltage is below 2.5 V, the TL431 remains OFF and the output voltage rises toward the supply voltage. When the input voltage exceeds 2.5 V, the TL431 turns ON and the output voltage drops to a lower level. Thus, the waveform indicates the transition of the TL431 between OFF and ON states, confirming its operation as a precision shunt regulator.

SOURCE/REFERENCE:

TL431, TL432 Precision Programmable Reference
<https://www.ti.com/lit/ds/symlink/tl431.pdf>