TL431 Applications and Switched Mode Power Supplies (SMPS)

Introduction to Switched Mode Power Supplies (SMPS)

- **What is an SMPS?**
    - SMPS are efficient power converters that take in high-voltage AC (mains) and convert it into lower DC voltages, often used for powering devices like phones, laptops, and various household electronics.
    - SMPS can achieve high efficiency (e.g., 84%) and are widely appreciated for their performance.
    - This video explores how a specific component, the **TL431**, is used in SMPS and other electronic applications.

Introduction to the TL431

- **What is the TL431?**
    - The **TL431** is a **precise programmable reference voltage** IC, often used in feedback systems for voltage regulation.
    - It can be used in many applications such as comparators, voltage regulation, and feedback loops in power supplies.

Basic Operation of the TL431

- **Functional Block Diagram**:
    - The TL431 consists of a **comparator**, a **transistor**, a **diode**, and a **voltage reference** (typically 2.495V).
    - It operates with a supply voltage between **Vref** (the reference pin) and **36V**, requiring a small current (1mA).
    - The IC has three key pins:
        - **Ref Pin**: The reference pin, which sets the comparison voltage.
        - **Anode Pin**: Connected to GND.
        - **Cathode Pin**: Typically connected to a resistor linked to a supply voltage.

TL431 in Basic Circuit Configurations

- **Comparator Mode**:
    - When the reference voltage (**Ref Pin**) is lower than the internal reference voltage (typically 2.495V), the output stays high.
    - When the reference voltage exceeds 2.495V, the output transistor switches on, pulling the output voltage low.
    - In this configuration, the TL431 acts as a comparator.
- **TL431 as a Zener Diode**:
    - When the reference pin is connected to the cathode pin, the TL431 behaves like a **2.5V zener diode**.
    - As the input voltage increases, the voltage across the TL431 stays regulated at **2.5V**.
    - This is useful for voltage regulation as TL431 provides better stability than regular zener diodes.

Adjustable Zener Diode Using TL431

- **Adjustable Voltage**:
    - By adding a voltage divider between the **cathode**, **ref pin**, and **anode**, the reference voltage can be adjusted.
    - This allows you to create an **adjustable zener diode**. For example, a **5V zener diode** can be created using appropriate resistors.
    - The TL431 allows for better stability and precision compared to traditional zener diodes.

Various Applications of TL431

- **Battery Protection Circuit**:
    - The TL431 can be used in **battery over-discharge protection** circuits to disconnect the load when the battery voltage drops below a certain threshold.
- **Constant Current Sink**:
    - The TL431 can also be used as a **precision constant current sink**, adjustable by using a potentiometer.

Switched Mode Power Supply (SMPS) and Feedback Loop Theory

- **Basic Feedback Loop**:
    - A **flyback converter** circuit can use the TL431 in its feedback loop to regulate the output voltage.
    - The feedback system works by comparing the output voltage (via a voltage divider) to the reference voltage (set by the TL431).
    - The error amplifier processes the voltage difference and adjusts the **PWM (pulse width modulation)** signal to control the output voltage.
    - **Negative feedback** ensures the output voltage is stable.

Implementation of TL431 in SMPS

- **SMPS Feedback Circuit**:
    - In a typical SMPS, the TL431 is used in combination with an **optocoupler** to isolate the feedback loop.
    - The voltage divider should set the reference voltage at **2.5V** for a 5V output.
    - The TL431 regulates the voltage by adjusting the current passing through the optocoupler LED, ensuring stability.
    - Key components involved:
        - Voltage divider (2 resistors of 500Ω each).
        - Resistor for current-limiting (around 650Ω).
        - Capacitor for feedback stability (typically 100nF).
- **Building a DIY SMPS**:
    - The video details how the creator built a **DIY low-voltage SMPS** using the TL431.
    - The feedback loop controls the **PWM signal** to ensure the output voltage stays stable.
    - The final circuit was assembled on a **perfboard**, but it required programming to generate a sawtooth signal for the PWM circuit.
    - Results showed that the feedback system worked well and stabilized the output voltage.

Conclusion

- **TL431 in DIY Electronics**:
    - The **TL431** is a versatile and powerful component that can be used in various applications, including:
        - Voltage regulation (as a zener diode).
        - Feedback circuits (SMPS, battery protection).
        - Constant current regulation.
    - The **DIY SMPS project** using the TL431 demonstrated the practical use of this IC in voltage regulation and feedback systems.
- **Recommendation**:
    - The TL431 offers an easy-to-implement, reliable solution for power supply regulation and can be used in many custom electronics projects.