

Analysis of Direct Current Limiter Circuit for Circuit Protection and Power Management

K. Manimaran

*Dept of Computer Science and Business System
Rajalakshmi Institute of Technology*

Dr. Maheswari Raja

*Dean Innovations
Rajalakshmi Institute of Technology*

Abstract

This paper examines the design, operation, and applications of a direct current (DC) limiter circuit, a critical component in protecting electronic devices from overcurrent damage. A DC limiter ensures that current remains within a predefined threshold, providing reliable overcurrent protection in systems prone to sudden current surges. The study explores various DC limiter configurations, focusing on both passive and active component designs, and discusses their effectiveness, advantages, and limitations. Through simulations conducted in eSim software, the paper provides an interactive analysis of current-limiting behavior under different load conditions, offering insights into how DC limiters maintain stable performance and safeguard sensitive components. This work highlights the importance of DC limiters in power management and circuit protection, demonstrating their role in enhancing the reliability and longevity of electronic systems.

Keywords: Current Thresholding, Current Limiting Circuit

I. INTRODUCTION

A DC current limiter circuit is designed to protect electronic components from excessive current flow, which can lead to overheating, damage, or failure. This circuit serves as a safeguard by limiting the amount of direct current that can pass through to a load, ensuring that the current remains within safe operational parameters. By employing various techniques, such as using resistors, transistors, or specialized ICs, a DC current limiter effectively regulates the current flowing through the circuit without significantly affecting the voltage. Its primary function is to prevent overcurrent conditions that can arise due to faults or load variations, making it an essential component in power supply systems, battery management, and other applications where current regulation is critical. By maintaining current at predetermined levels, the DC current limiter enhances the reliability and longevity of electronic devices, ensuring consistent performance even in fluctuating conditions.

II. PURPOSE OF LIMITING CURRENT

Limiting current serves several important purposes in electrical and electronic circuits:

Protection of Components: Excessive current can cause overheating and damage to electronic components, such as resistors, capacitors, and integrated circuits. Current limiting ensures that components operate within their safe limits, prolonging their lifespan.

Preventing Short Circuits: In the event of a short circuit, the current can spike dramatically, potentially leading to catastrophic failures. A current limiter can restrict this surge, protecting both the circuit and connected devices.

Safety: Current limiters are essential for ensuring user safety in electronic devices, especially in applications where high currents are involved, such as electric vehicles, industrial machinery, and power distribution systems.

III. WORKING PRINCIPLE

The working principle of a DC current limiter revolves around controlling the amount of current flowing through a circuit to prevent damage to components and maintain safe operating conditions. Here are the key elements of how a DC current limiter functions:

- Sensing Current:** The current limiter typically includes a sensing mechanism to monitor the actual current flowing through the circuit. This can be achieved using a shunt resistor, current sensor IC, or a Hall Effect sensor. The sensed current is compared to a predefined threshold.
- Control Mechanism:** Once the current exceeds the set threshold, the control mechanism intervenes to limit the flow. This can involve several methods:
 - Resistive Limiting:** Adding a series resistor that increases in value when excessive current is detected. This increases the voltage drop across the resistor, reducing the current flowing to the load.
 - Active Limiting:** Using transistors or operational amplifiers that actively regulate current flow. When the sensed current exceeds the threshold, the control circuit reduces the output voltage to limit the current.
 - Feedback Mechanism:** In some designs, feedback from the output is used to adjust the resistance or control elements dynamically, ensuring the current stays within safe limits.
- Cut-off Action:** In more advanced designs, if the current exceeds the limit significantly or for an extended duration, the circuit may enter a protection mode, completely shutting off the output or reducing the current to a safe level until conditions normalize.
- Hysteresis:** Many current limiters incorporate hysteresis to prevent rapid on-off cycling around the current limit threshold. This feature helps to stabilize the circuit and avoid unnecessary interruptions.
- Reset Mechanism:** Once the overcurrent condition is resolved (e.g., the load is reduced or the fault is cleared), the current limiter allows the current to return to normal levels, either automatically or via a manual reset mechanism.

IV. CIRCUIT DIAGRAM

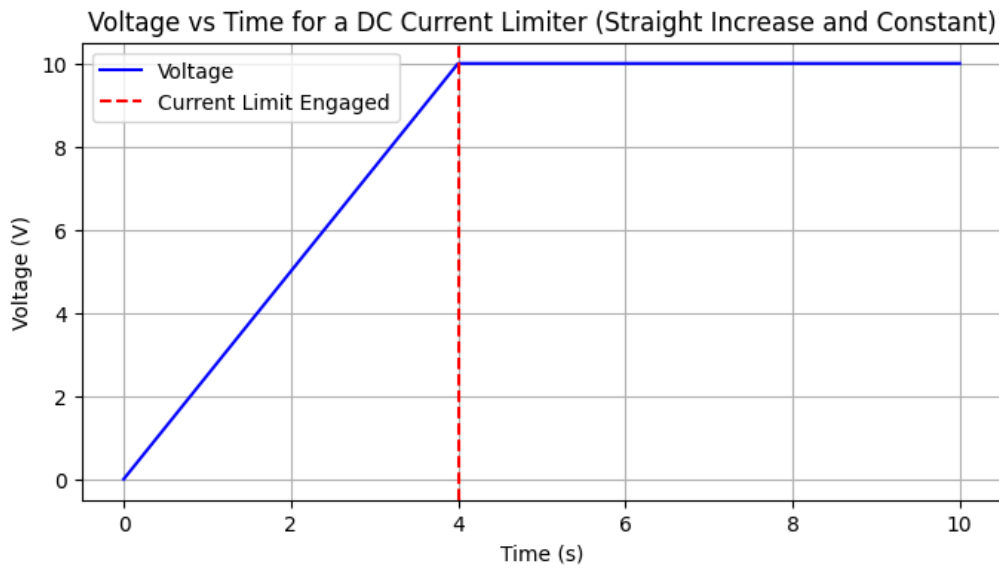
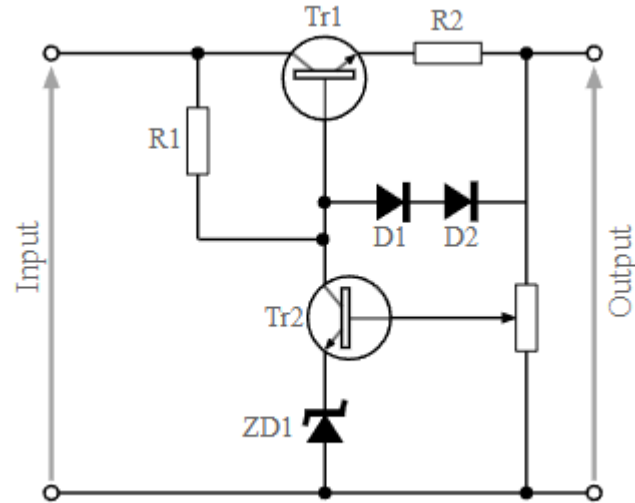


Fig. 1: Two transistor linear power supply regulator with current limiting

The DC current limiter circuit uses a transistor (BJT or MOSFET) and a sense resistor to regulate current flow to a load.

In this design, a sense resistor is placed in series with the load to monitor the load current. The voltage drop across this resistor is compared to a reference voltage set by a voltage divider. When the current exceeds the desired limit, the voltage across the sense resistor activates the transistor, which reduces the current to the load.

This simple circuit effectively prevents overcurrent conditions, protecting the load without the need for operational amplifier

V. PROPOSED SYSTEM

The proposed system introduces a DC Current Limiter circuit implemented using eSim software. This circuit is designed to demonstrate the functionality of current regulation and protection, essential in power electronics. The DC current limiter works by restricting the current flow to a safe level, preventing excessive current that could damage sensitive components in a circuit. It ensures reliable operation and protects against overcurrent conditions, making it crucial for applications where circuit safety, longevity, and stable current supply are critical.

eSIM CIRCUIT

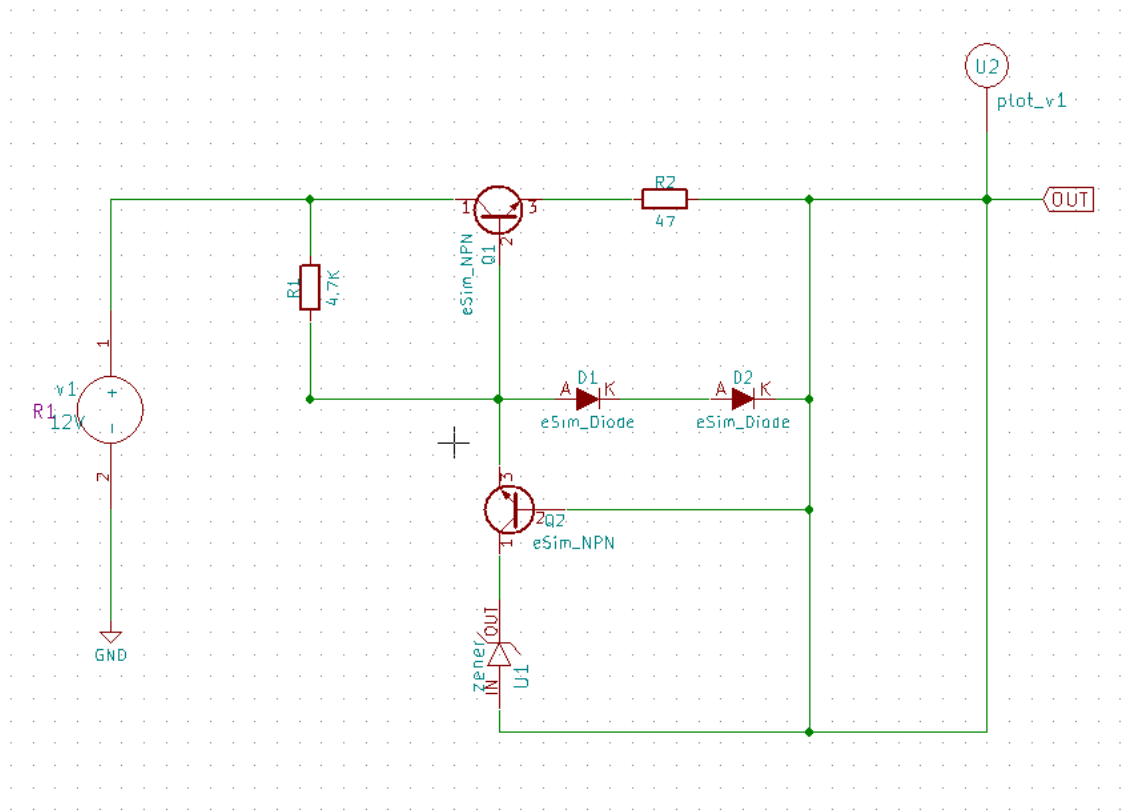


Fig. 3: Direct Current Limiter Circuit in eSIM

Figure 3 presents the circuit diagram of a DC Current Limiter crafted within the eSim software environment. Key components include a transistor (or MOSFET) acting as the current-controlling element, resistors setting the current limit threshold, and a sensing resistor used to monitor the current flow. The transistor operates in conjunction with the sensing resistor to regulate the current: when the current exceeds the predefined threshold, the voltage across the sensing resistor increases, triggering the transistor to limit or reduce the current. This configuration ensures that the output current stays within safe limits, protecting the circuit from overcurrent conditions and demonstrating its effectiveness in providing reliable current regulation in_power-sensitive_applications.

OUTPUT WAVEFORM

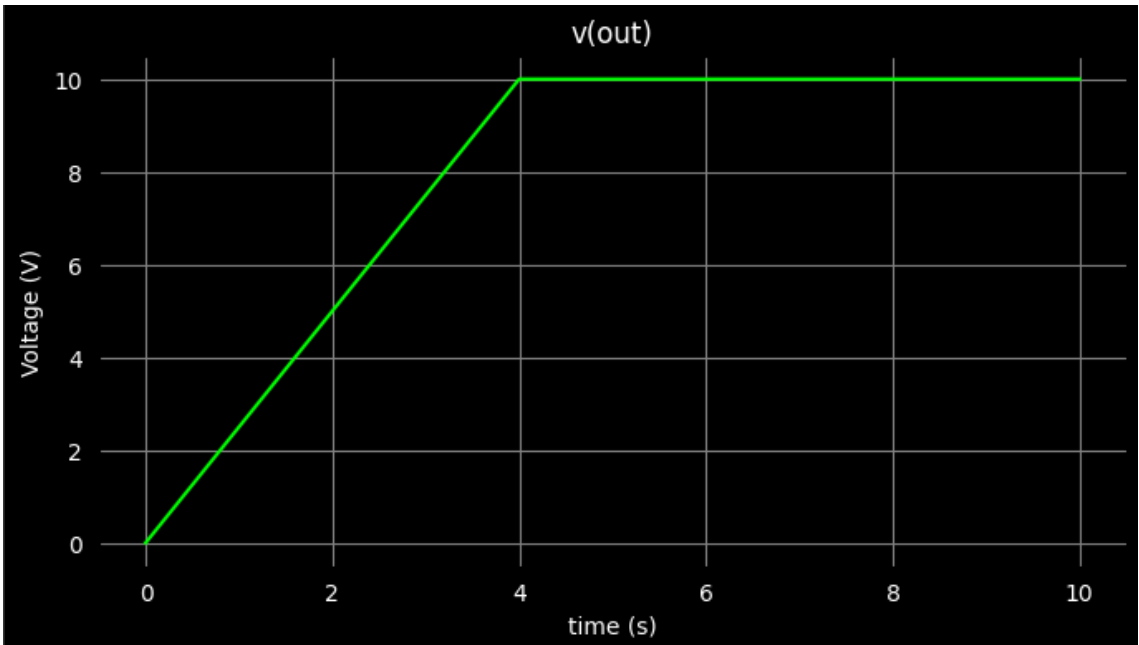


Fig. 4: Output Waveform Direct Current Limiter Circuit in eSim

Figure 4 showcases the output waveform of the Direct Current Limiter circuit simulated using eSim software. From this graph of a DC current limiter, we can observe the following conclusion:

1. **Initial Voltage Increase:** The voltage linearly increases with time until it reaches a set limit (around 10V at 4 seconds). This suggests that the current limiter allows the voltage to rise until it reaches a specified threshold, indicating no current limiting in the initial phase.
2. **Constant Voltage after Limit:** After the voltage reaches 10V, it becomes constant, indicating that the current limiter has engaged. This constant voltage phase suggests that the limiter is preventing the voltage from increasing further, likely by limiting the current.
3. **Current Limiting Mechanism:** The transition from an increasing voltage to a constant voltage is a typical behavior of a DC current limiter. When the current reaches a set limit, the circuit restricts further voltage increase to maintain safe operation and protect against overcurrent.

In summary, this graph shows that a DC current limiter allows the voltage to rise until it reaches a preset threshold, after which it holds the voltage constant to limit the current and protect the circuit

Applications of DC current limiter

1. **Battery Charging Systems:** Prevents overcurrent during charging, which can damage batteries and reduce their lifespan.
2. **Electric Vehicles (EVs):** Ensures safe operation by managing current flow during charging and protecting battery management systems.
3. **Solar Power Systems:** Protects solar panels and associated circuitry from excessive current, ensuring efficiency and longevity of the system.
4. **Power Supplies:** Maintains stable voltage output and protects downstream components from overcurrent conditions, enhancing system reliability.
5. **Battery Damage:** Excessive current can cause overheating, swelling, or even catastrophic failure of batteries, especially lithium-ion types.
6. **Consumer Electronics:** Protects devices such as chargers and adapters from excessive current that could lead to overheating and failure.
7. **Aerospace and Defense:** Used in aircraft and military applications to ensure safe and reliable operation of electronic systems

VI. CONCLUSION

In this study, we explored the design and simulation of a DC Current Limiter circuit using eSim. The DC current limiter is essential in power electronics for protecting circuits by restricting current flow to safe levels, preventing potential damage to sensitive components. It acts as a safeguard, ensuring that the current remains within a specified range even under varying load conditions. Through simulation using eSim, we gained valuable insights into the current limiter's functionality and behavior. eSim provided an interactive and intuitive platform for designing and analyzing electronic circuits, facilitating a comprehensive exploration of the current limiter's characteristics in regulating and stabilizing output current under different operating condition

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