RUTGERS
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Switching Voltage Regulator and Current Limiter

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Abstract

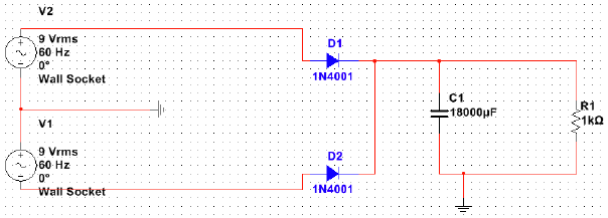
One of the main hazards in electrical or electronic circuits is over-current, or an excessive amount of current being delivered to the load due to a short circuit.

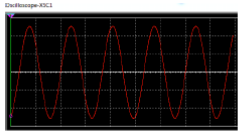
Circuits can be protected from over-current by implementing a current limiting circuit. A current limiter sets a maximum load current by using sensing resistors along with transistors that act as on and off switches.

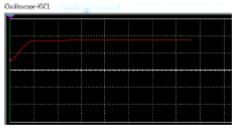
Our project explores how current can be limited independent of the input voltage by passing signals through various circuits including a transformer, rectifier, filter, and regulator.

Transformer / Full Wave – Half Bridge Rectifier with Filter

A full wave bridge rectifier using two diodes can be used with a balanced AC source and center tapped transformer. Each half of the transformer windings becomes two separate sources.

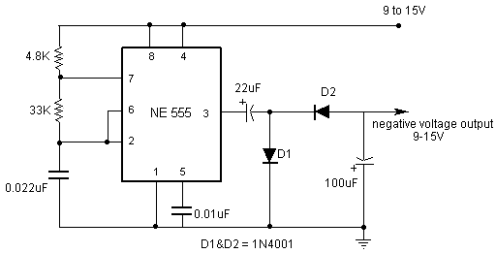



Unrectified AC Voltage Sinusoid


Rectified DC Voltage

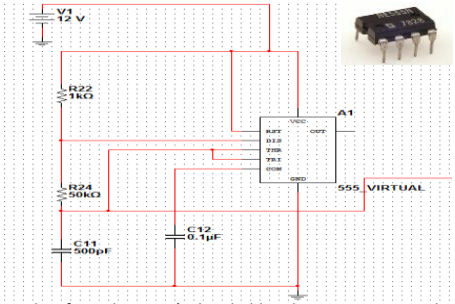
Voltage Inverter

In many circuits an internal adjustable voltage is needed. This circuit shows how a voltage inverter can be created using the 555 timer IC and a bit of external circuitry. The circuitry below can receive a +9 V input and produce a -9 V output which can be useful, as a negative voltage is needed to power the op amp in the current limiter.

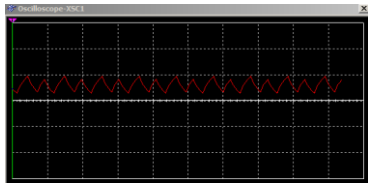


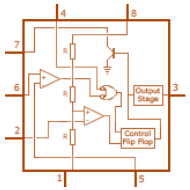
555 Timer

The 555 timer is a popular and easy-to-use integrated circuit chip with many applications. In this project, a 555 timer is used to generate a pulse as an input to the switching regulator.



The output is taken from the timer's threshold and trigger pin instead of the output pin so that the result is a triangle wave rather than a square wave.



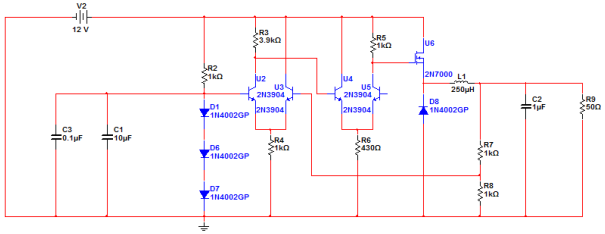


Switching Regulator

This circuit is a switching regulator, which is designed to be more efficient than its linear counterpart by incorporating a power MOSFET (2N7000), fast-switching diode (F1UP20), and an inductor (250 uH). Its purpose is to transfer energy, bit-by-bit, from a 12 V input to an 8 V output. Because energy is transferred in segments, it has high efficiency, typically in the 85% or > range.

When the switch is closed, L1 opposes the rising current and generates an electromagnetic field in its core. D8 becomes reversed biased and at this point, the switch operates as an open circuit.

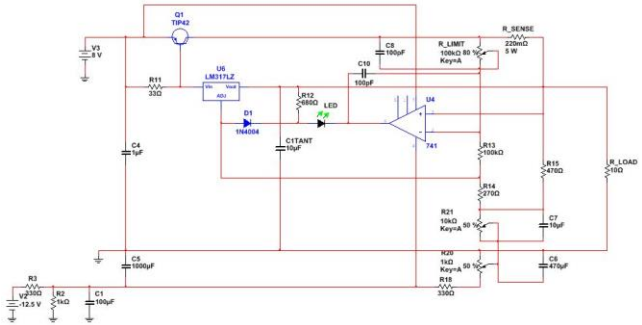
When the switch is open, L1's electromagnetic field discharges and generates a current in the reverse polarity. D8 conducts until the electromagnetic field in L1 has been depleted.



Current Limiter

This circuit is used to impose a max load current, protecting it from over-current in the case of a short circuit load. It takes two inputs, a positive DC voltage from the voltage regulator, and another negative DC voltage from the voltage inverter to power the operational amplifier. An LM317 chip is used because it has built-in over-current as well as over-temperature protection.

Adjustable current limiting is provided by the op amp 741, which used as a comparator. This IC monitors the voltage across R_SENSE. If this voltage exceeds a certain level, set by the potentiometer R_LIMIT, the output goes low, dragging down the ADJ pin of the LM317 and thus the output voltage.



Current Limiting Test

The current limit is tested by using a load resistance of 10 ohms and lowering it to 1 ohm by 1 ohm increments. As resistance is decreased, the current should gradually increase until it hits a certain max limit. Once it hits the maximum load current, the LED lights up, indicating the limit has been reached. From this point on, any further reduction in load resistance will continue to produce a constant max load current.

The short-circuit test is performed by replacing the load resistance with a wire. Without a current limiter, this would result in over-current and the load circuit would be damaged. However, as shown below, even with a short-circuit the output load current is still under the set maximum limit of 1 A.