Switching Regulator Basics
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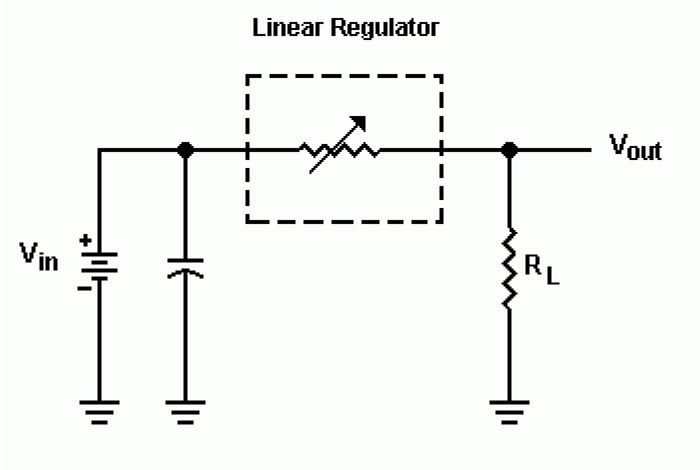
Although most power supplies used in amateur shacks are of the linear regulator type, an increasing number of switching power supplies have become available to the amateur. For most amateurs the switching regulator is still somewhat of a mystery. One might wonder why we even bother with these power supplies, when the existing linear types work just fine. The primary advantage of a switching regulator is very high efficiency, a lot less heat and smaller size.

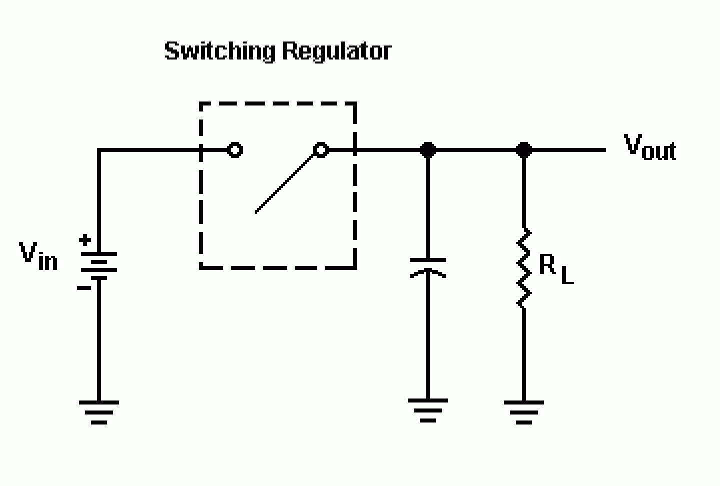
To understand how these black boxes work lets take a look at a traditional linear regulator at right. As we see in the diagram, the linear regulator is really nothing more than a variable resistor. The resistance of the regulator varies in accordance with the load resulting in a constant output voltage



The primary filter capacitor is placed on the input to the regulator to help filter out the 60 cycle ripple. The linear regulator does an excellent job but not without cost. For example, if the output voltage is 12 volts and the input voltage is 24 volts then we must drop 12 volts across the regulator. At output currents of 10 amps this translates into 120 watts (12 volts times 10 amps) of heat energy that the regulator must dissipate. Is it any wonder why we have to use those massive heat sinks? As we can see this results in a mere 50% efficiency for the linear regulator and a lot of wasted power which is normally transformed into heat.

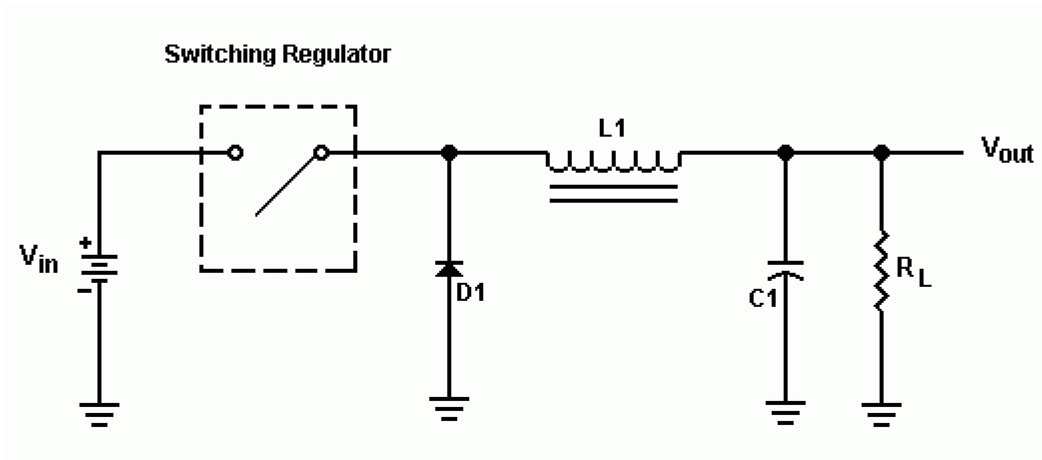
Now lets take a look at a very basic switching regulator at right.

As we see can see, the switching regulator is really nothing more than just a simple switch. This switch goes on and off at a fixed rate usually between 50Khz to 100Khz as set by the circuit.



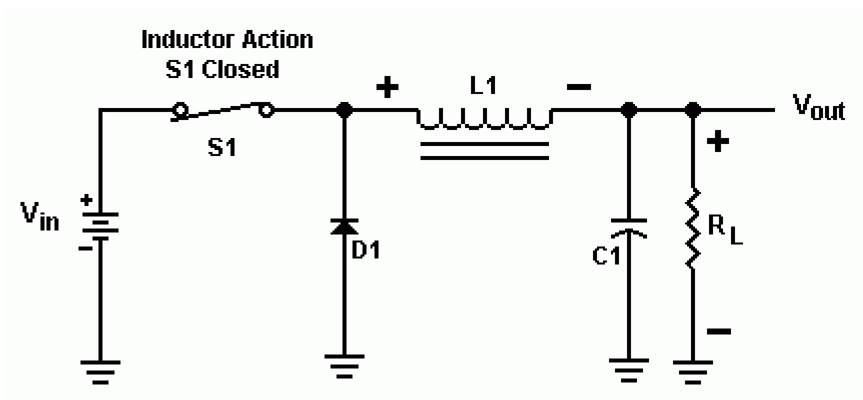
The time that the switch remains closed during each switch cycle is varied to maintain a constant output voltage. Notice that the primary filter capacitor is on the output of the regulator and not the input. As is apparent, the switching regulator is much more efficient than the linear regulator achieving efficiencies as high as 80% to 95% in some circuits. The obvious result is smaller heat sinks, less heat and smaller overall size of the power supply.

The previous diagram is really an over simplification of a switching regulator circuit. An actual switching regulator circuit more closely resembles the circuit below:

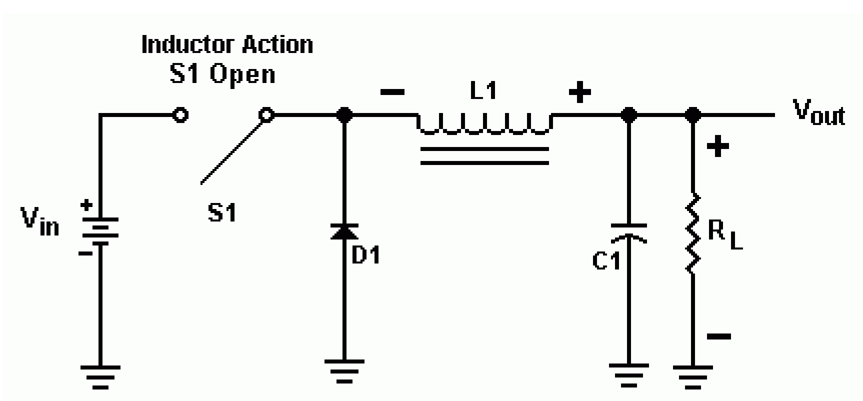


As we see above the switching regulator appears to have a few more components than a linear regulator. Diode D1 and Inductor L1 play a very specific role in this circuit and are found in almost every switching regulator. First, diode D1 has to be a Schottky or other very fast switching diode. A 1N4001 just won't switch fast enough in this circuit. Inductor L1 must be a type of core that does not saturate under high currents. Capacitor C1 is normally a low ESR (Equivalent Series Resistance) type.

To understand the action of D1 and L1, lets look at what happens when S1 is closed as indicated below:



As we see above, L1, which tends to oppose the rising current, begins to generate an electromagnetic field in its core. Notice that diode D1 is reversed biased and is essentially an open circuit at this point. Now lets take a look at what happens when S1 opens below:



As we see in this diagram the electromagnetic field that was built up in L1 is now discharging and generating a current in the reverse polarity. As a result, D1 is now conducting and will continue until the field in L1 is diminished. This action is similar to the charging and discharging of capacitor C1. The use of this inductor/diode combination gives us even more efficiency and augments the filtering of C1.

Because of the unique nature of switching regulators, very special design considerations are required. Because the switching system operates in the 50 to 100 kHz region and has an almost square waveform, it is rich in harmonics way up into the HF and even the VHF/UHF region. Special filtering is required, along with shielding, minimized lead lengths and all sorts of toroidal filters on leads going outside the case. The switching regulator also has a minimum load requirement, which is determined by the inductor value. Without the minimum load, the regulator will generate excessive noise and harmonics and could even damage itself. (This is why it is not a good idea to turn on a computer switching power supply without some type of load connected.) To meet this requirement, many designers use a cooling fan and or a minimum load which switches out when no longer needed.

Fortunately, recent switching regulator IC's address most of these design problems quite well. Because of lowered component costs as well as a better understanding of switching regulator technology, we are starting to see even more switching power supplies replacing traditionally linear only applications. It is no doubt that we will see fewer linear power supplies being used in the future.

In this article we addressed basic switching regulator design concepts and it is hoped that amateurs will begin to look at switching regulators much more seriously when they decide to replace an old power supply. In a future construction article, we will review an actual switching regulator circuit.

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