

LB-18

LB-18 Plus 5 To Minus 15 Volts DC Converter



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+ 5 to - 15 Volts DC Converter

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+ 5 to - 15 Volts DC Converter

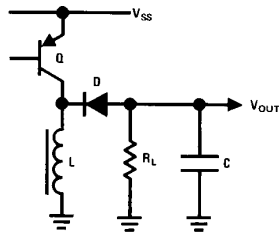
INTRODUCTION

It is frequently necessary to convert a DC voltage to another higher or lower DC-voltage while maximizing efficiency. Conventional switching regulators are capable of converting from a high input DC voltage to a lower output voltage and satisfying the efficiency criteria. The problem is a little more troublesome if a higher output voltage than the input voltage is desired. Particularly, generating DC voltage with opposite polarity to the input voltage usually involves a complicated design.

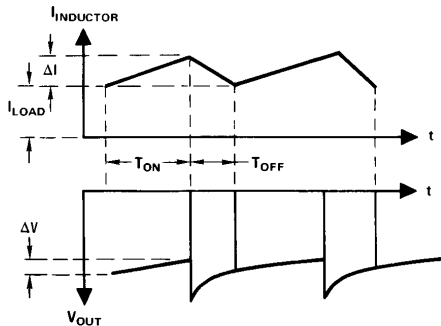
This brief demonstrates the use of the switching regulator idea for a +5 volts to -15 volts converter. The converter has an application as a power supply for MOS memories in a logic system where only +5 volts is available. However, the principle used can be applied for almost any input output combination.

OPERATION

The method by which the regulator generates the opposite polarity is explained in *Figure 1*. The transistor Q is turned ON and OFF with a given duty cycle. If the base drive is sufficient the voltage across the inductor is equal to the



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FIGURE 1. Switching Circuit for Voltage Conversion
supply voltage minus V_{SAT} . The current change in the inductor is given by:

$$\Delta I = \frac{V_{SS} - V_{SAT}}{L} \times T_{ON} \approx \frac{V_{SS}}{L} T_{ON} \quad (1)$$

Turning OFF the transistor the inductor current has a path through the catch diode and this in turn builds up a negative voltage across R_L .

The figure also shows the current and voltage levels versus time. A capacitor in parallel to the resistor will prevent the voltage from dropping to zero during the transistor ON time.

Assuming a large capacitor, we can also write the current change as:

$$\Delta I = \frac{V_{OUT} - V_D}{L} \times T_{OFF} \approx \frac{V_{OUT}}{L} \times T_{OFF} \quad (2)$$

In order to get a general idea of the operation for certain input output conditions, we will develop a set of equations.

During the transistor ON time, energy is loaded into the inductor. In the same time interval, the capacitor is drained due to the load resistor R_L .

Drop in capacitor voltage:

$$\Delta V = \frac{I_{LOAD} \times T_{ON}}{C} \quad (3)$$

During the T_{OFF} time the stored energy in the inductor is transferred to the load and capacitor. A rough estimate of T_{OFF} can be expressed as:

$$T_{OFF} = \frac{V_{SS}}{V_{OUT}} \times T_{ON} \quad (4)$$

The capacitor voltage will be restored with a average current given by:

$$I_C = \frac{\Delta V \times C}{T_{OFF}} = \frac{I_{LOAD} \times V_{OUT}}{V_{SS}} \quad (5)$$

The total inductor current during the OFF time can be written as:

$$I_{INDUCTOR} = I_{LOAD} + I_C \quad (6)$$

Inspecting *Figure 1*. We find:

$$I_C = \frac{\Delta I}{2} = \frac{V_{SS} \times T_{ON}}{2 \times L} \quad (7)$$

which yields:

$$T_{ON} = \frac{2 \times L \times I_{LOAD} \times V_{OUT}}{V_{SS}^2} \quad (8)$$

Taking into account that the efficiency is in the order of 75% the final expression is:

$$T_{ON} = \frac{1.5 \times L \times I_{LOAD} \times V_{OUT}}{V_{SS}^2} \quad (9)$$

The above equations will be applied to the regulator shown at *Figure 2*. The regulator must deliver -15 volts at 200 mA from a +5 volt supply. Using a 1 mH inductor the T_{ON} time for Q_2 is 0.18 ms from equation 9. T_{OFF} is 60 μ s from equation 4 and the oscillator frequency to:

$$F = \frac{1}{T_{ON} + T_{OFF}} \approx 4 \text{ kHz}$$

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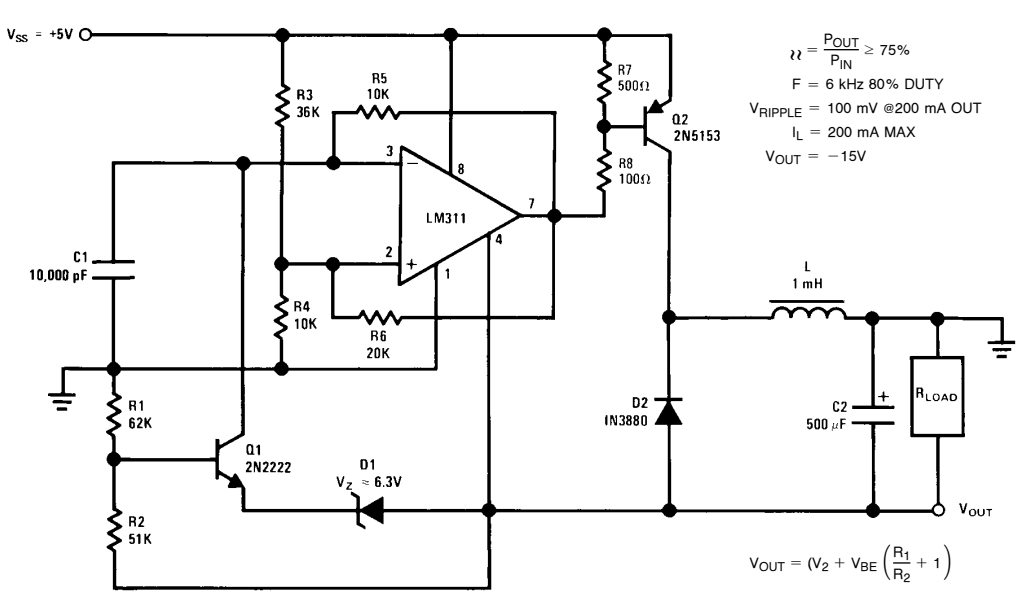


FIGURE 2. Switching Regulator for Voltage Conversion

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The LM311 performs like a free running multivibrator with high duty cycle. The IC is designed to operate from a standard single 5 volt supply and has a high output current capability for driving the switching transistor Q₂. The duty cycle is given by the voltage divider R₃ and R₄ and the frequency of C₁ in conjunction with R₅.

By setting the duty cycle higher than first calculated, the output voltage will tend to increase above the desired output voltage of 15 volts. However, an extra loop performed by Q₁ and the zener diode in conjunction with the resistor network will modify the oscillator duty cycle until the desired output level is obtained.

The output voltage is given by:

$$V_{OUT} = (V_z + V_{BE}) \left(\frac{R_1}{R_2} + 1 \right)$$


Data and results obtained with the design:

- V_{IN} = 5 volts
- V_{OUT} = - 15 volts
- I_{OUT} = max 200 mA
- Efficiency ≈ 75%
- Frequency ≈ 6 kHz 80% duty cycle
- V_{RIPPLE} ≈ 100 mV @ 200 mA load
- Line regulation: V_{IN} = 5V to 10V < 3% V_{OUT}
- I_{LOAD} = 200 mA
- Load regulation: V_{IN} = 5V < 3% V_{OUT}
- I_{LOAD} = 0 - 100 mA

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