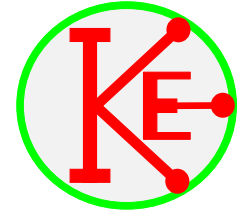


4.8 - 12V power supply



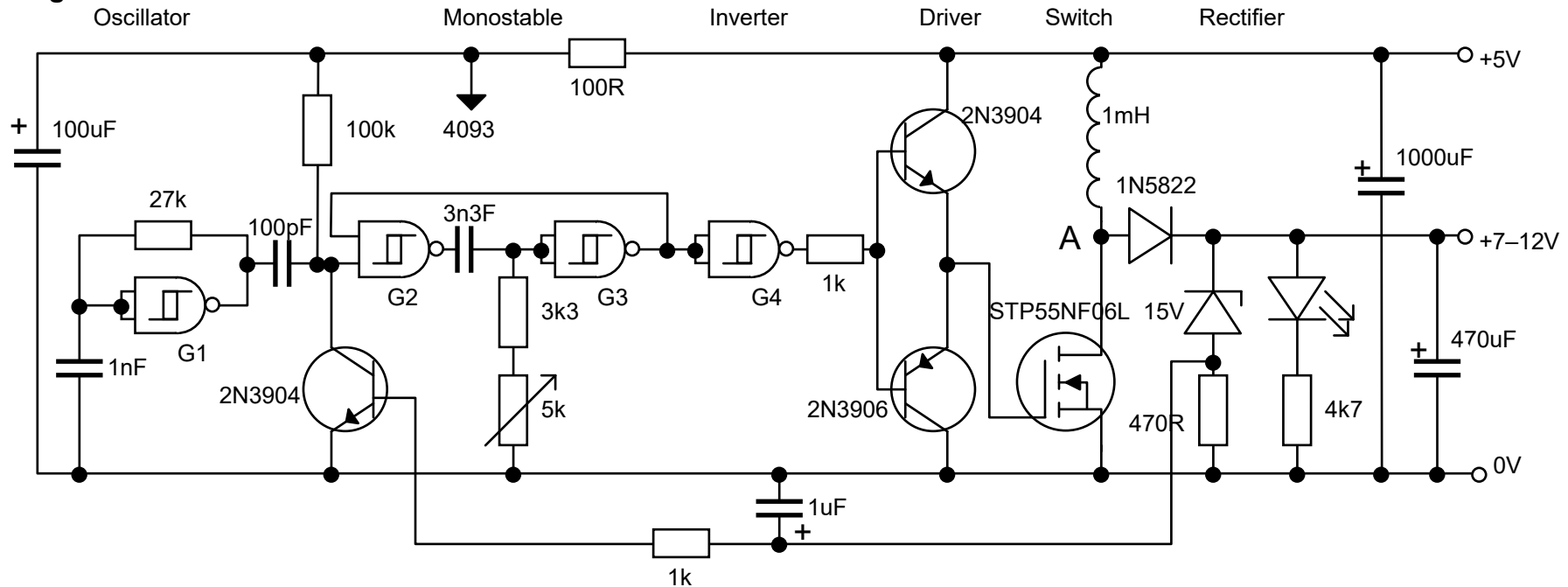
Specification

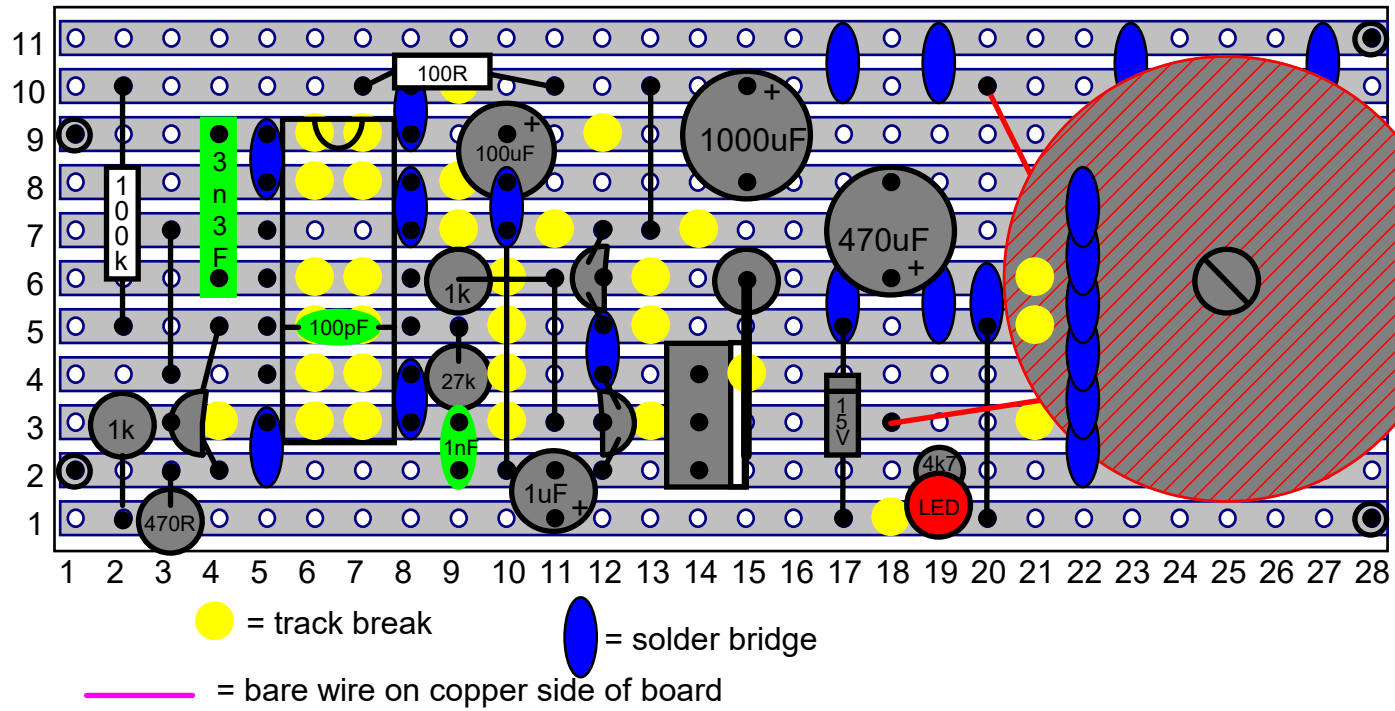
Provides a 7 - 12V output from a 4.5 - 5V supply

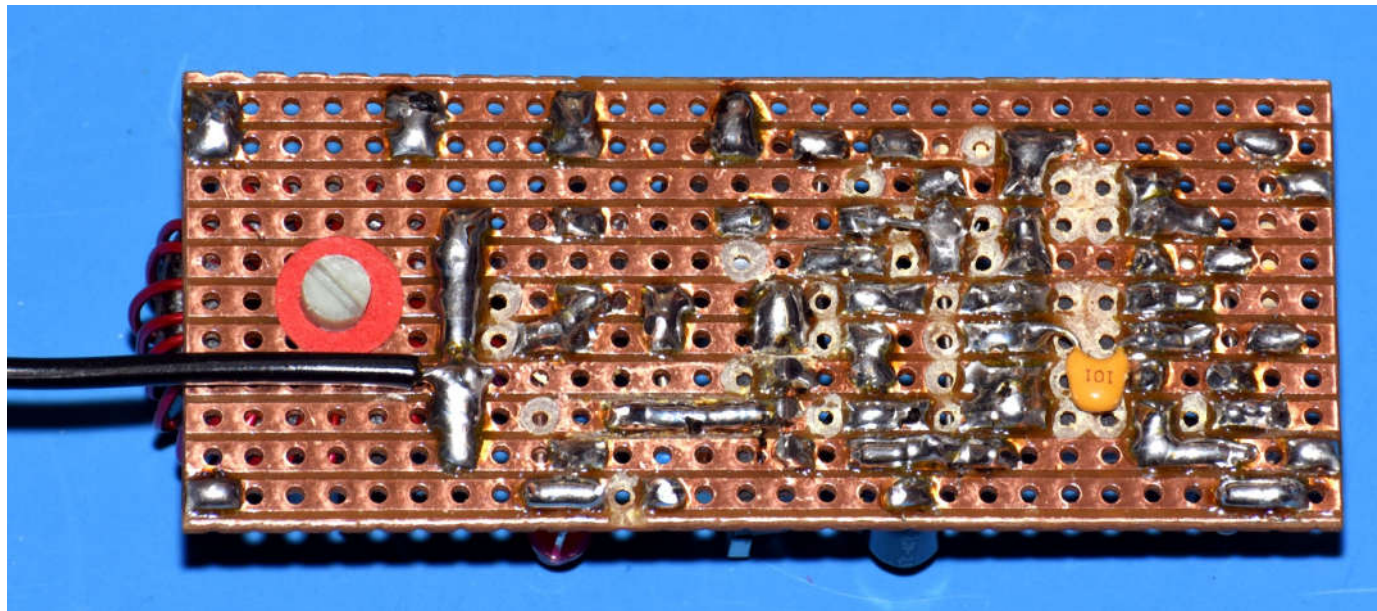
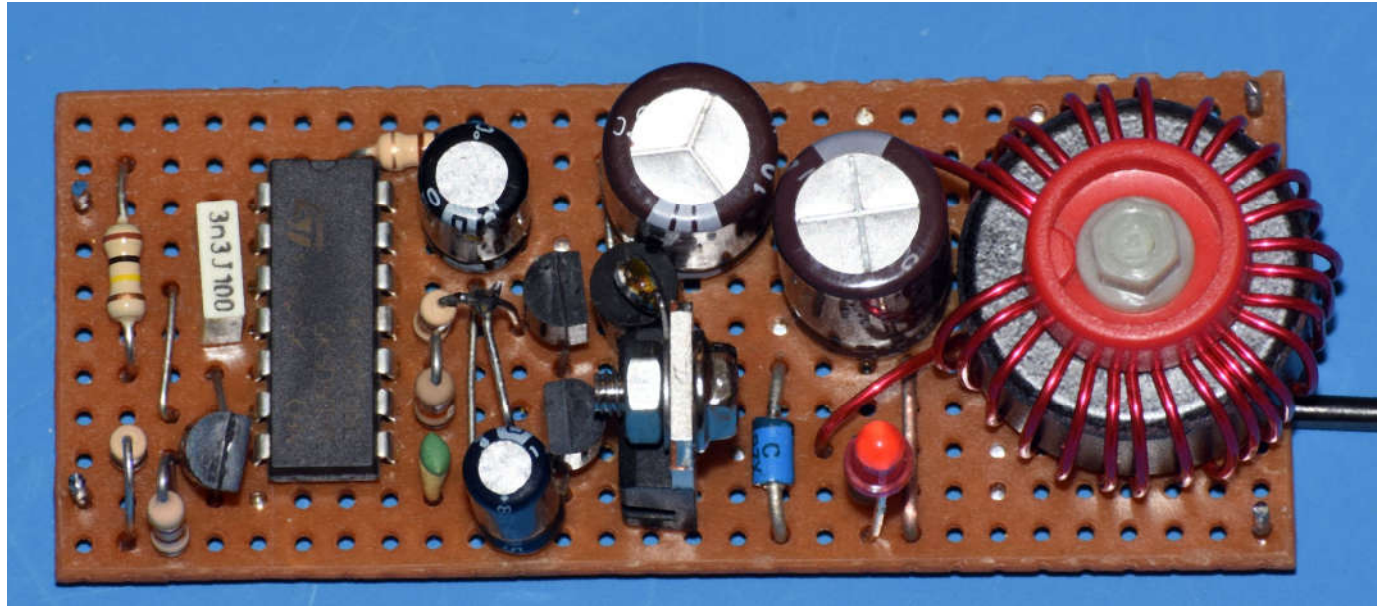
Provides a current of up to $\approx 0.5A$ at 12V (dependent on low voltage supply)

The output is limited to a maximum of $\approx 14V$.

Circuit diagram

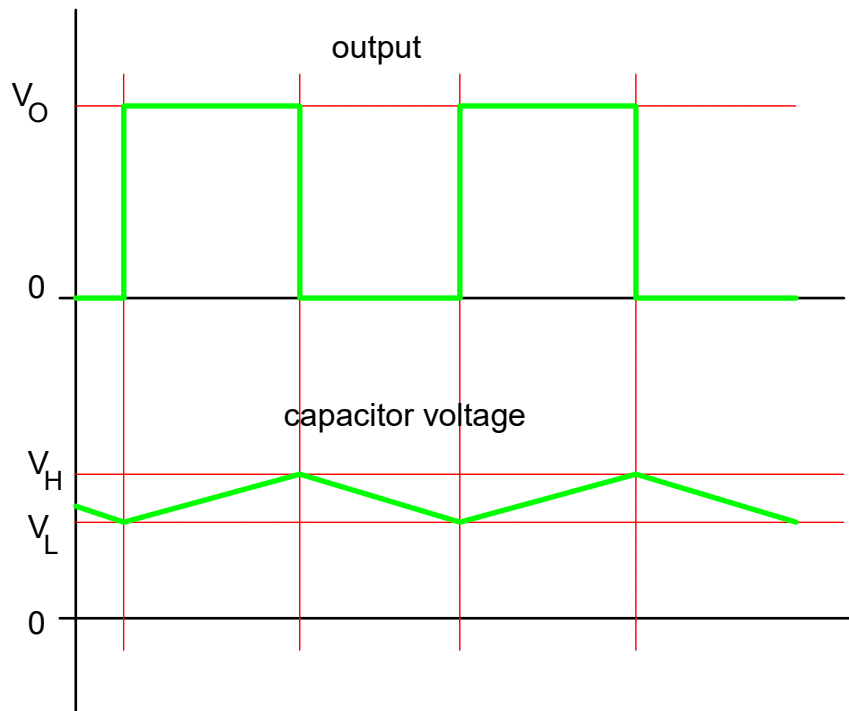






How it works**OSCILLATOR.**

This is a standard schmitt NAND gate astable. When the output of the NAND gate is high, the 1nF capacitor charges through the 27kΩ resistor until the voltage across the capacitor reaches the upper switching voltage of the Schmitt trigger (3.2V for the 4093 working on 5V). The NAND gate output then goes low and the capacitor discharges through the 27kΩ resistor until the voltage across the capacitor reaches the lower switching voltage (2.5V for the 4093 working on 5V). The output then switches high and the process repeats.



If R is the charge/discharge resistor, C is the capacitor, V_0 is the supply voltage, V_H is the upper switching voltage, V_L is the lower switching voltage

then the Period is given by $T = RC \cdot \ln \left(\frac{V_H(V_0 - V_L)}{V_L(V_0 - V_H)} \right)$

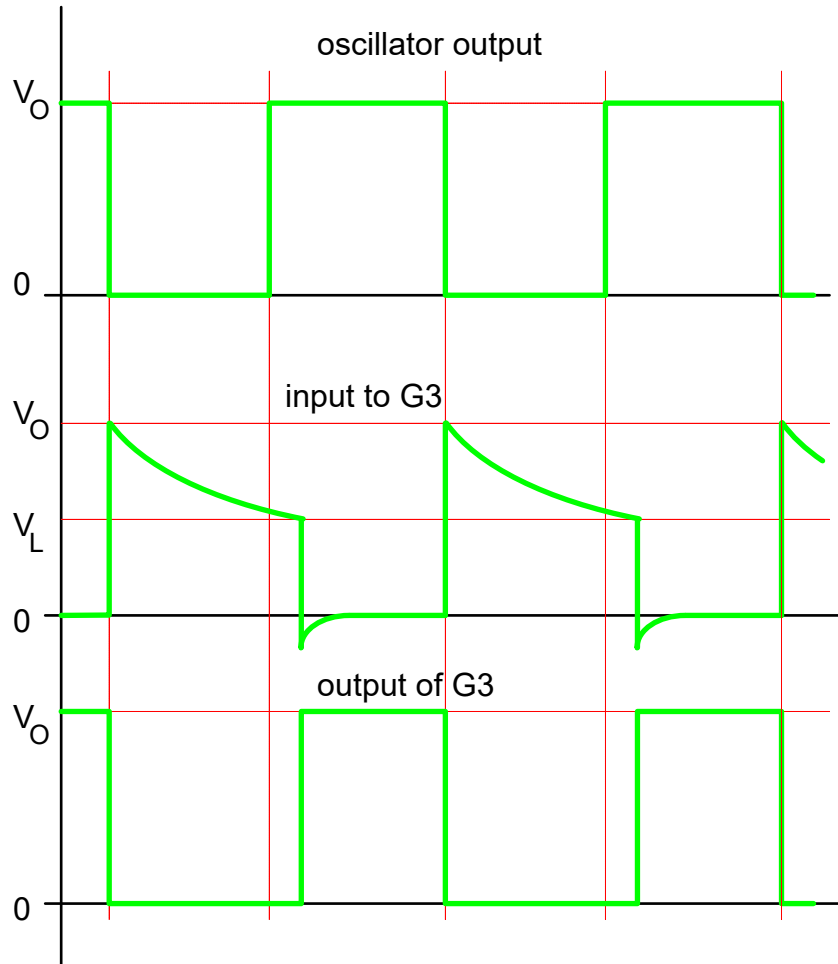
With the values used, $T = 1.55 \times 10^{-5} \text{ s}$ and the frequency is 64.4kHz.

MONOSTABLE

In the stable state, the input of gate G3 is pulled low by its input resistors, so the output is high. This makes one of the inputs of G2 high and the other input is pulled high by the 100kΩ resistor. With both inputs to G2 being high, the output is low, so the capacitor is discharged and the circuit is stable.

When the output of the oscillator goes low, the input to G2 with the 100kΩ resistor is forced low for a short time by the 100pF capacitor. The output of G2 goes high, which forces the input to G3 to become high by the 3.3nF capacitor. This makes the output of G3 low, which makes the other input to G2 low, so keeping the output of G2 high even when the input pulse from the oscillator is finished.

The 3.3nF capacitor charges through the input resistors to G3 and eventually the voltage across the input resistors becomes less than V_L . The output of G3 now becomes high. Both inputs to G2 are now also high, so G2 output goes low. This forces the capacitor to discharge through the input protection diode of G3 and the circuit returns to its stable state.



If R is the resistor at the input to G3, C is the capacitor from G2 to G3, V_O is the supply voltage, V_L is the lower switching voltage, then the time period of the unstable state is given by

$$T = RC.Ln\left(\frac{V_O}{V_L}\right)$$

INVERTER

Gate G4 has both of its inputs connected together and works as a NOT gate. This turns the output of G3 upside down.

DRIVER

Although the MOSFET has a very large input resistance ($\sim 10^9 \Omega$), it has a significant capacitance in parallel with its input. ($\sim 2\text{nF}$ for the STP55NF06L).

For the overall circuit to work efficiently, the MOSFET must switch very quickly, but unfortunately, since the output resistance of G4 is quite large ($\sim 1\text{k}\Omega$), the rise and fall time of the gate voltage of the MOSFET would be several microseconds.

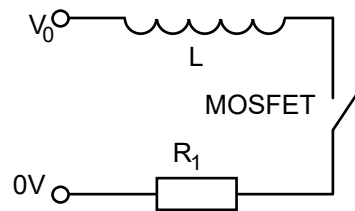
The driver provides a low resistance source for the MOSFET gate. It consists of two emitter followers, and is similar to the output of a push-pull amplifier. The output resistance of the driver is $\sim 50\Omega$ and is able to charge and discharge the gate capacitance of the MOSFET quickly ($\sim 100\text{ns}$), so keeping the circuit efficient.

A disadvantage of this driver circuit is that the output only switches between $\pm 0.7\text{V}$ of the power supply voltage, i.e. in this circuit, 0.7 to 4.3V. However, it does not affect the MOSFET as the MOSFET does not conduct until the gate to source voltage reaches $\sim 1.6\text{V}$.

SWITCH

There are two separate steps to the operation of a 'boost' powersupply.

In the first step, the MOSFET is switched on for a period of time determined by the monostable. In this time, the 1N5822 diode is reverse biased and so isolates the output circuit, while the inductor is connected directly across the battery. Current passes through the inductor and energy becomes stored in its magnetic field.



V_0 is the supply voltage, L is the inductor and R_1 is the total resistance of this part of the circuit. When the MOSFET is switched on, a current, I , starts to pass through the circuit, where

$$I = \frac{V_0}{R_1} \left(1 - \exp\left(-t/L/R_1\right) \right)$$

The changing current through the inductor produces a self induced voltage, ε , across the inductor

$$\varepsilon = -L \frac{dI}{dt}$$

The power supplied by the battery = $V_0 I = \varepsilon I + I^2 R_1$

$$\Rightarrow V_0 I = LI \frac{dI}{dt} + I^2 R_1$$

=>The energy stored in the inductor, W , during the 'on' time, t_1 is

$$W = \int_0^{t_1} LI \frac{dI}{dt} dt = L \int_0^{t_1} I dI = \frac{L}{2} [I^2]_0^{t_1}$$

$$\text{But } I = \frac{V_0}{R_1} \left(1 - \exp\left(-t/L/R_1\right) \right)$$

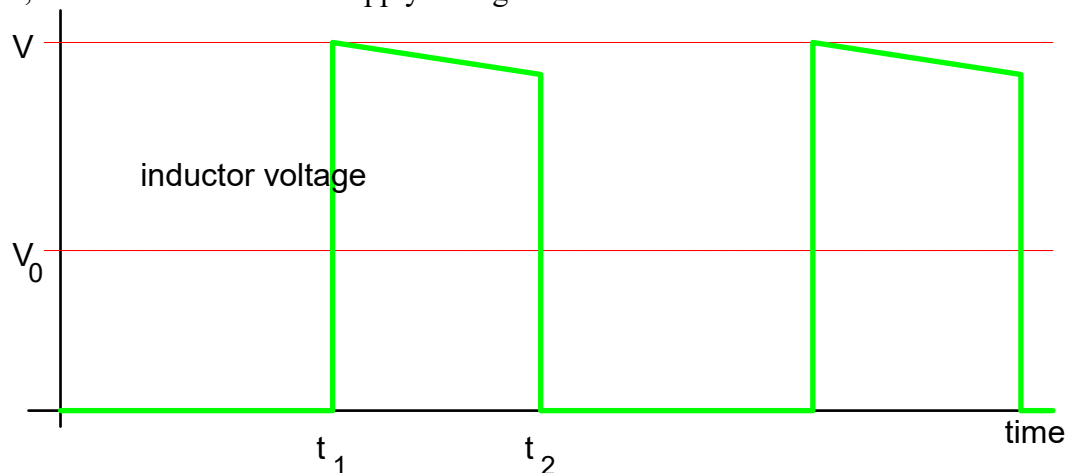
$$\Rightarrow W = \frac{L}{2} \frac{V_0^2}{R_1^2} \exp\left(\frac{-2t_1}{L/R_1}\right)$$

During this time, t_1 , the voltage at point A is virtually zero and the $470\mu\text{F}$ smoothing capacitor supplies energy to the load.

If this time is short, the current passing into the load will be reasonably constant.

If the load resistance is R_L and the current passing through this is I_L , then the energy supplied is $= I_L^2 \times R_L \times t_1$

When the MOSFET switches off, the change in current produces a negative voltage across the inductor, which now adds to the supply voltage.



During this time, the battery and inductor must supply the energy to the load and also the energy to recharge the smoothing capacitor. Energy is also lost in the rectifier diode, which for a good Schottkey diode, can be ignored

When a capacitor is charging, approximately half of the energy is wasted in the series resistance of the charging circuit. The energy supplied by the smoothing capacitor during $t_1 \approx I_L^2 \times R_L \times t_1$ so the battery and inductor must supply energy of $\approx 2 \times I_L^2 \times R_L \times t_1$ during t_2 .

During t_2 , the battery and inductor must also supply energy to the load $\approx I_L^2 \times R_L \times t_2$.

So the total energy that must be supplied by the battery and inductor during t_2

$$\approx 2 \times I_L^2 \times R_L \times t_1 + I_L^2 \times R_L \times t_2$$

and this must equal $V_0 \times I_L \times t_2 + W$

$$\Rightarrow V_0 \times I_L \times t_2 + \frac{L}{2} \frac{V_0^2}{R_1^2} \exp\left(\frac{-2t_1}{L/R_1}\right) = I_L^2 \times R_L (2 \times t_1 + t_2)$$

$$\Rightarrow \frac{L}{2} \frac{V_0^2}{R_1^2} \exp\left(\frac{-2t_1}{L/R_1}\right) = I_L^2 \times R_L (2 \times t_1 + t_2) - V_0 \times I_L \times t_2$$

If t = period of the oscillator, then $t_2 = t - t_1$

$$\Rightarrow \frac{L}{2} \frac{V_0^2}{R_1^2} \exp\left(\frac{-2t_1}{L/R_1}\right) = I_L^2 \times R_L (t + t_1) - V_0 \times I_L \times (t - t_1)$$

Re-arranging

$$\Rightarrow 0 = I_L^2 \times R_L (t + t_1) - I_L \times V_0 \times (t - t_1) - \frac{L}{2} \frac{V_0^2}{R_1^2} \exp\left(\frac{-2t_1}{L/R_1}\right)$$

This gives a quadratic equation for I_L .

The term $V_0 \times (t - t_1)$ has a small value compared to $R_L (t + t_1) \times \frac{L}{2} \frac{V_0^2}{R_1^2} \exp\left(\frac{-2t_1}{L/R_1}\right)$

so
$$I_L \approx \sqrt{\frac{\frac{L}{2} \frac{V_0^2}{R_1^2} \exp\left(\frac{-2t_1}{L/R_1}\right)}{2R_L(t+t_1)}}$$

So long as the time constant for the L/R_1 circuit is much larger than t_1 , then the actual value of L does not matter.

Similarly, the switching frequency does not matter so long as L/R_1 circuit is much larger than t_1 . However, if the switching frequency is too high, then switching the MOSFET on and off quickly becomes more of a problem (due to the gate - source capacitance) and more energy is lost in the series resistance inherent in the smoothing capacitor. The smoothing capacitor should be chosen to reduce the ripple voltage to an acceptable level and have a low 'Equivalent Series Resistance' (ESR).

The inductor charging resistor R_1 seems to make a significant difference, so a battery with a low internal resistance, an efficient input capacitor and a MOSFET with a low R_{DS} are essential for efficient operation.