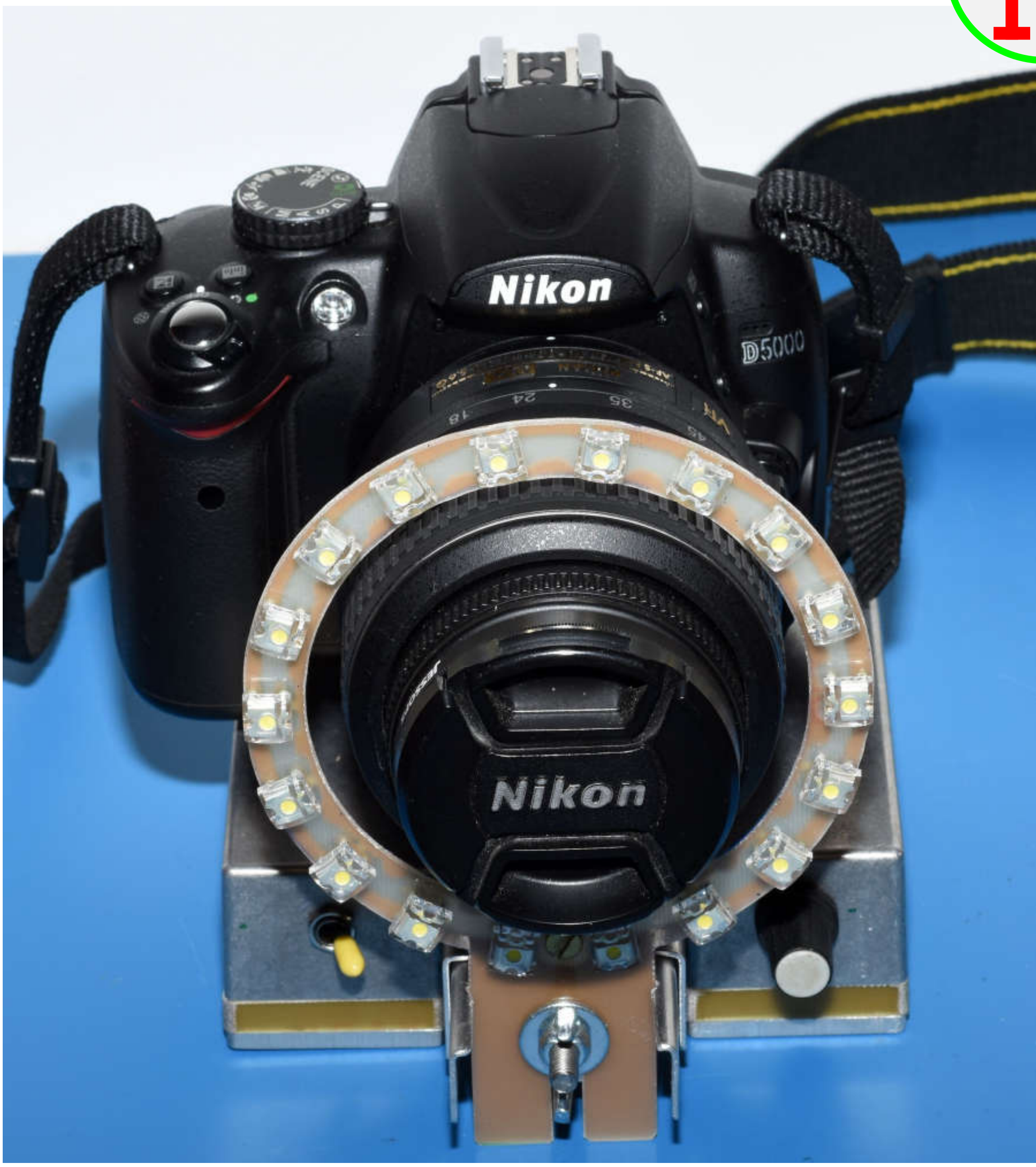
Ring lamp.



Macro photography is when the image created is larger than the original object. This often involves having the lens near to the object which results in a narrow range of distances that are actually in focus (small Depth of Field). This effect can be limited by using a large F number for the aperture, e.g F16 or F22, but this will severely reduce the amount of light reaching the sensor. This is overcome by using a slow shutter speed and /or a high speed setting of the sensor of the camera. Slow shutter speeds are fine if the object is stationary and a tripod can be used to support the camera. The higher the speed of the sensor, the more noise is introduced into the picture.
The slow shutter speed and high sensor setting can all be solved by using flash, but when the lens is very close to the object, it often casts a shadow since the flash gun is offset from the lens position.

The ring lamp is a circle of LEDs that surround the lens and illuminate the object so eliminating any shadow from the lens.

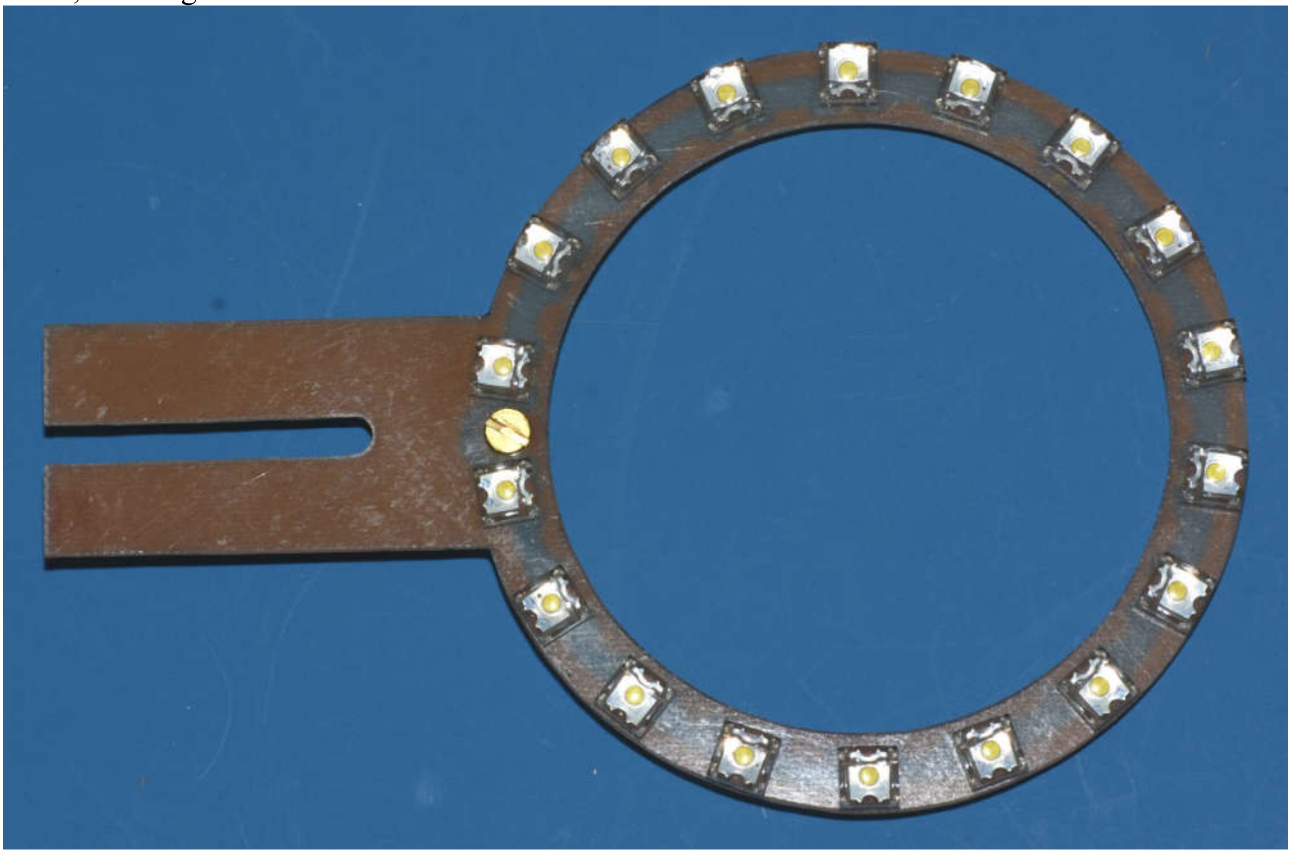
The ring lamp iteslf consists of 18 × 7.6mm square LED modules each having a viewing angle of 120° and a luminous intensity of up to 30 lumens. The colour temperature of the LEDs is nominally 6500K, which is a little 'whiter' than natural day light. The LED modules are mounted on a fibre glass printed circuit board disc. Each LED module has a 100Ω surface mount resistor connected in series to help limit the current to the rated value of 30mA, and produced its rated output with a 12V power supply.
When operating at full power, the ring lamp will give about 500 lumens of light. At full power, the ring lamp has a power consumption of 12 × 0.03 × 18 = 6.48W. Of this, 1.62W is wasted as heat in the resistors, giving a lamp power of 4.86W. In use, the ring lamp will be found to improve an exposure by up to four F stops, especially when the object is very close to the ring lamp.
However, it is useful to compare the ring lamp power to the power output from a flash gun.
Many flash guns charge a 200μF capacitor up to around 400V and then discharge this through the flash tube. The energy dissipated in the flash tube is around 8 Joules. But this energy is often given out in around 1/1000 second, giving an equivalent power of 8kW!! The ring lamp will therefore not make as larger a difference to exposures as a flash gun!

The ring lamp was designed to be portable and attached to the camera. To enable this it was decided to power the ring lamp from a battery made from four rechargeable AA cells. This battery only provides around 5V when fully charged and so an electronic boost power supply is used to increase the voltage to a maximum of 12V. Because of the way the circuit works, a control is included to vary the brightness of the LEDs which also helps to conserve energy in the battery.

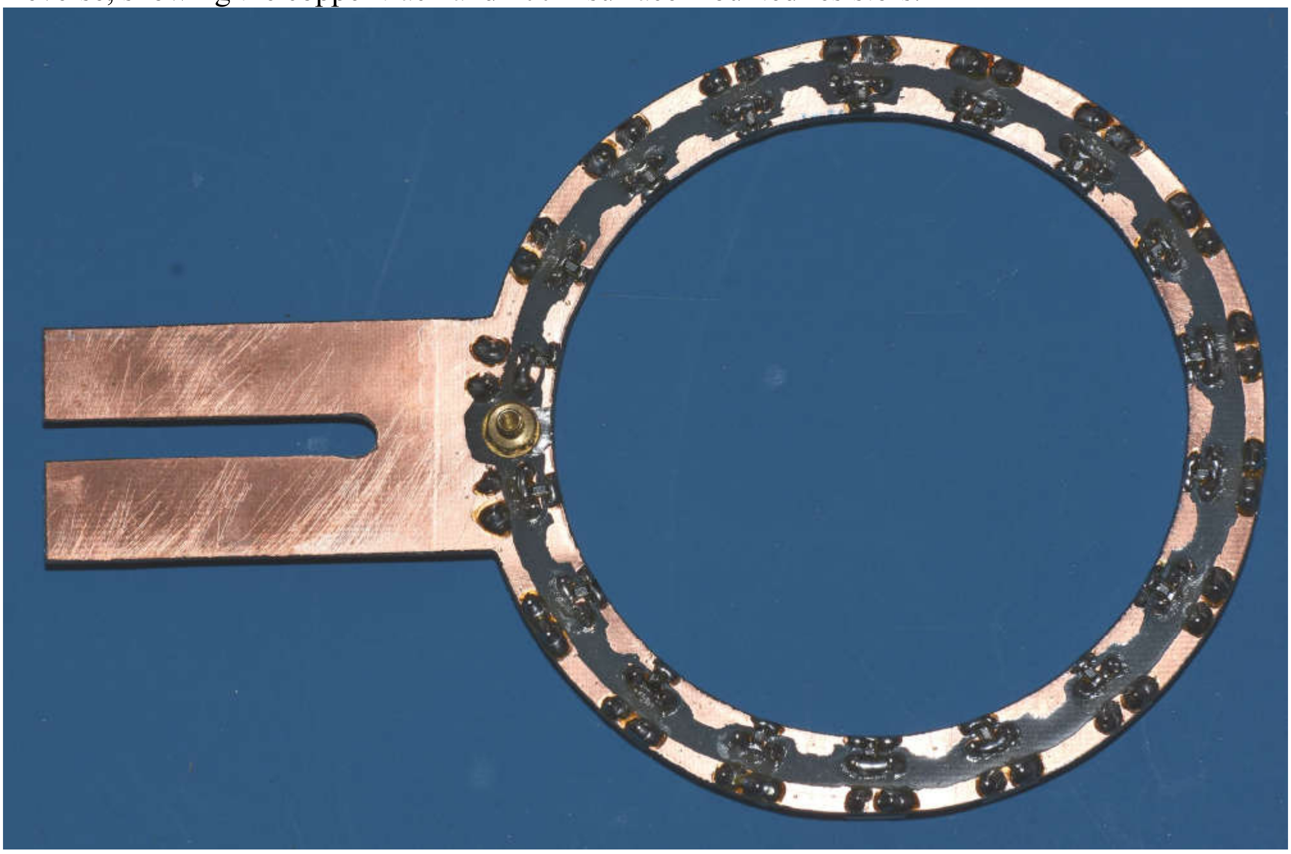
The ring lamp unit is attached to the camera by the tripod mounting.
The tripod mounting hole has a ¼ inch UNC thread with 20 threads per inch.
By chance, this is almost the same thread as a ¼ inch British Whitworth thread (though the thread angle is slightly different) and so can be used.

The Ring Lamp.

Front, showing the LEDs



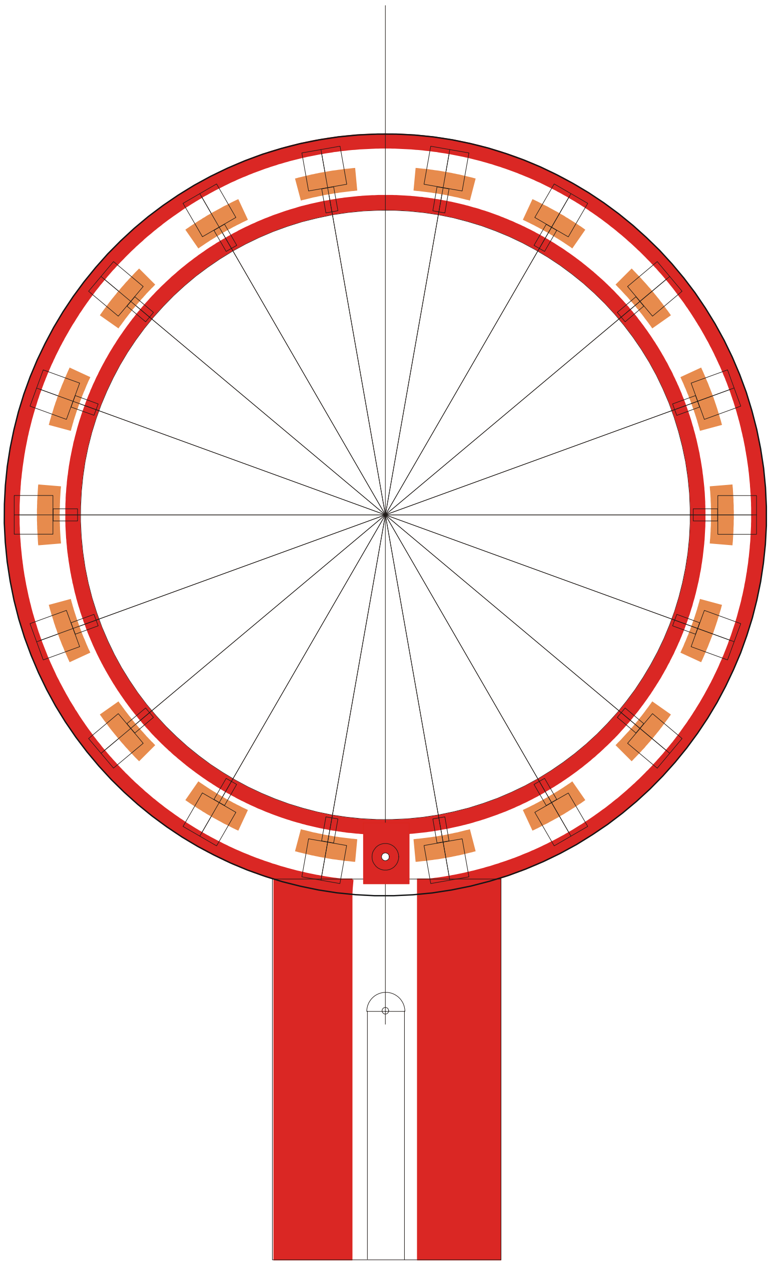
Reverse, showing the copper track and 100Ω surface mounted resistors.



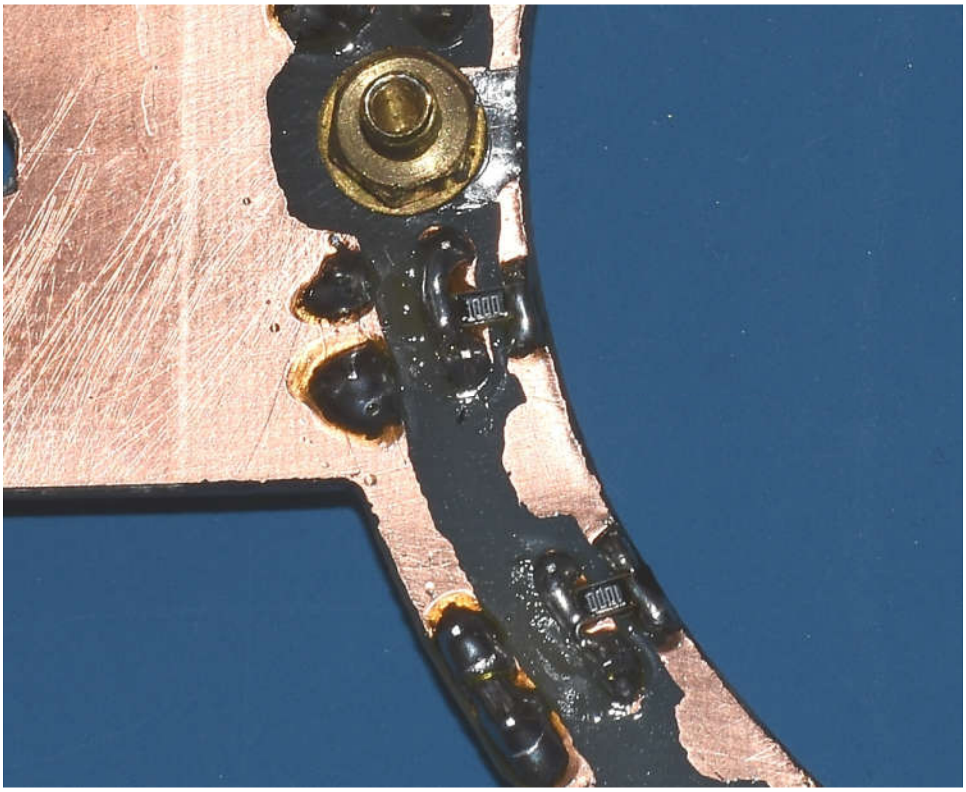
The ring lamp was cut from a 100mm × 160mm piece of fibre glass printed circuit board.
It was helpful to draw concentric circles of the radius listed at the top of the diagram as a guide to marking out the copper track and position of the LEDs.

50mm, 40mm, 42mm, 48mm
43mm 46mm

100mm 80mm
82mm@2mm 89mm@3mm 98mm@2mm



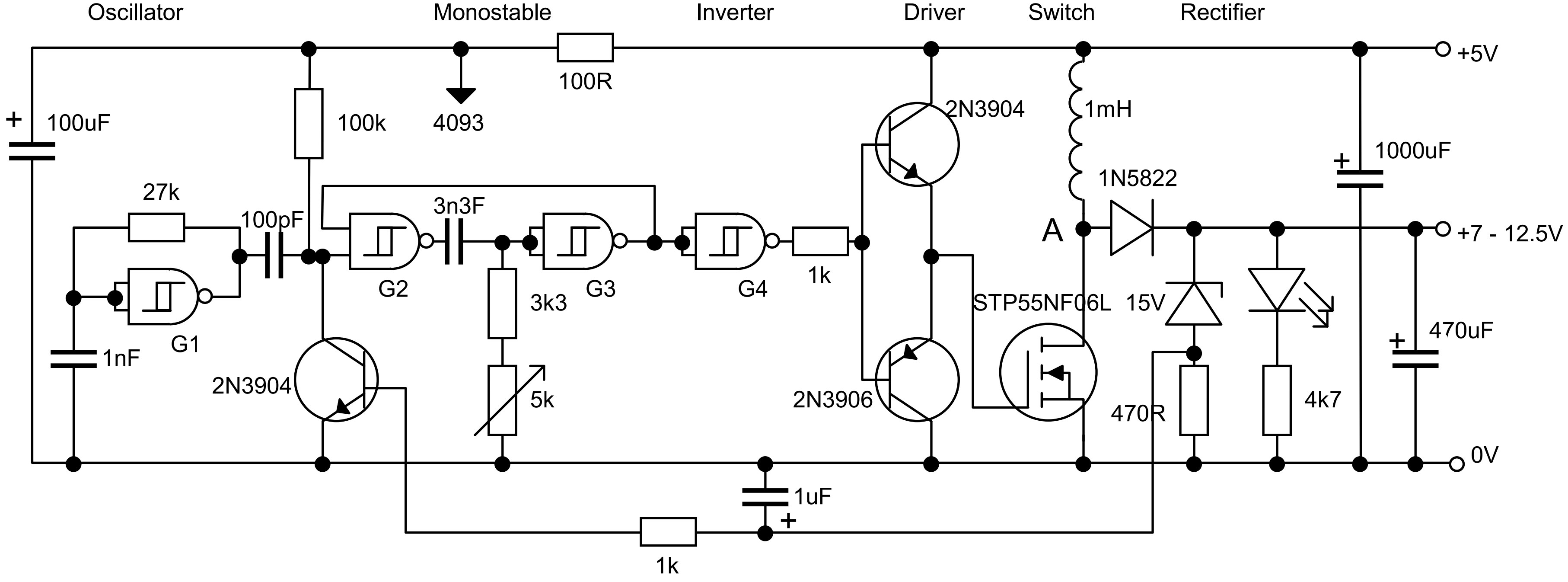
The inner and outer copper track width were 2mm and the sections of the middle track were 3mm wide.
A fretsaw was used to cut out the ring lamp circuit board and the copper side was thoroughly cleaned with an abraisive rubber and propanone.
A printed copy of the ring lamp diagram was stuck onto the copper side of the board and a centre punch used to mark the corner of each LED and the two other holes.
The ring lamp diagram was removed and the copper again cleaned. An etch resistant pen was then used to colour all of the areas corresponding to the red and orange sections in the diagram.
After etching in ferric chloride solution and washing, 1mm holes were drilled at every centre punch mark. The two larger holes were enlarged to 3.5mm and then the lower one to 5mm.
A 5mm slot was cut from the 5mm hole to the bottom of the board.
The copper was again cleaned and then the ring section was sprayed with printed circuit board lacquer, the lower section with the 5mm slot was polished with Brasso.

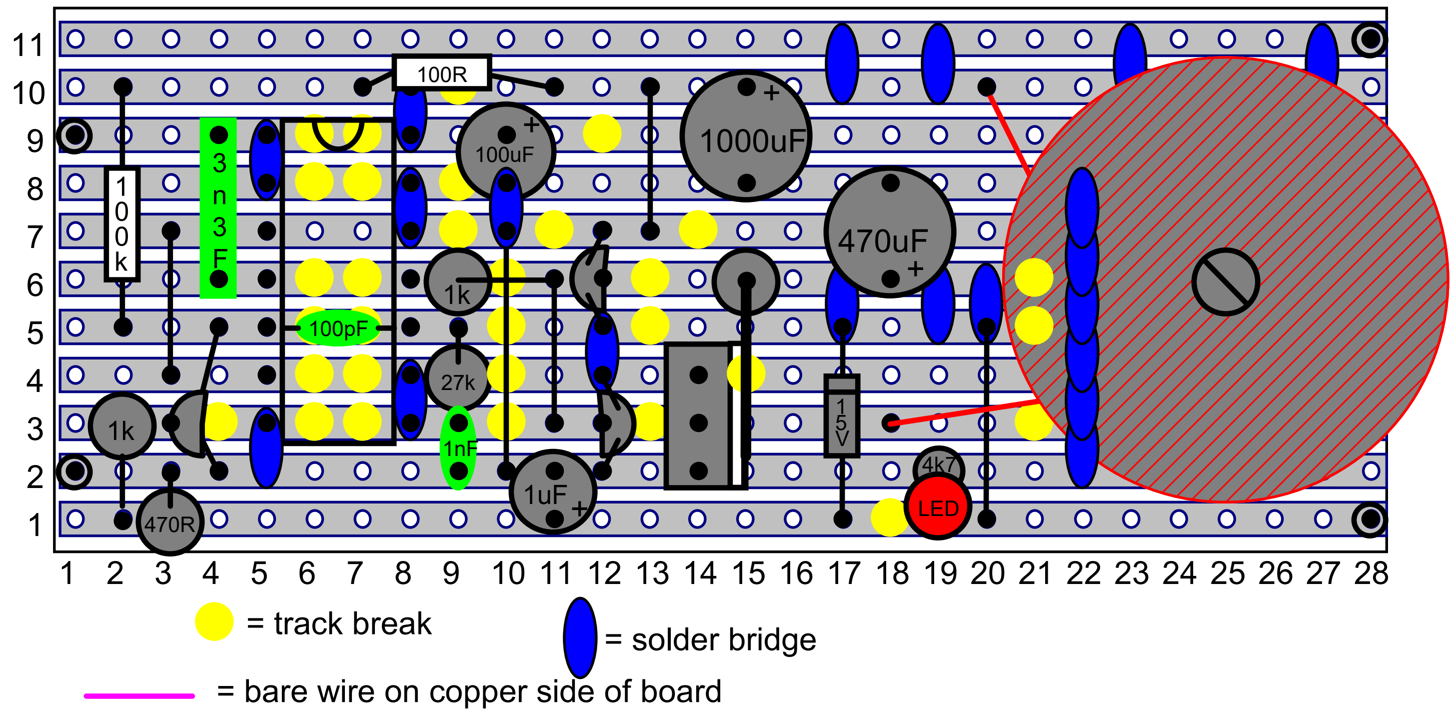


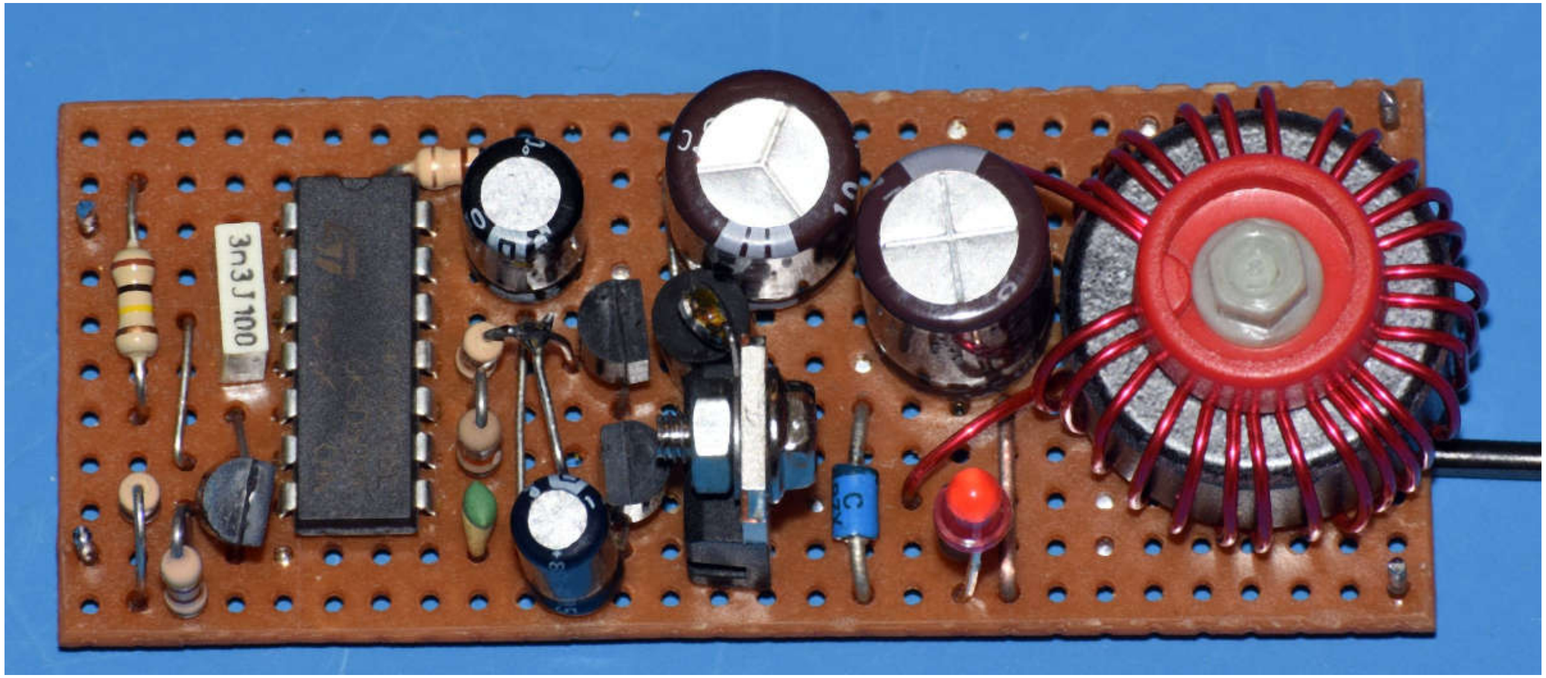
The LEDs are soldered in place, with the cathode (negative) to the outer ring. The 100Ω resistors are soldered between the anodes of the LEDs (positive) and the inner ring, as seen in the picture above. The connection to the inner ring was made from a brass 3.5mm (4BA) bolt, which was drilled in the centre to act as a socket for a 2mm plug. The copper board around the 3.5mm hole was coated in a thin layer of solder to ensure a good contact with the brass bolt.

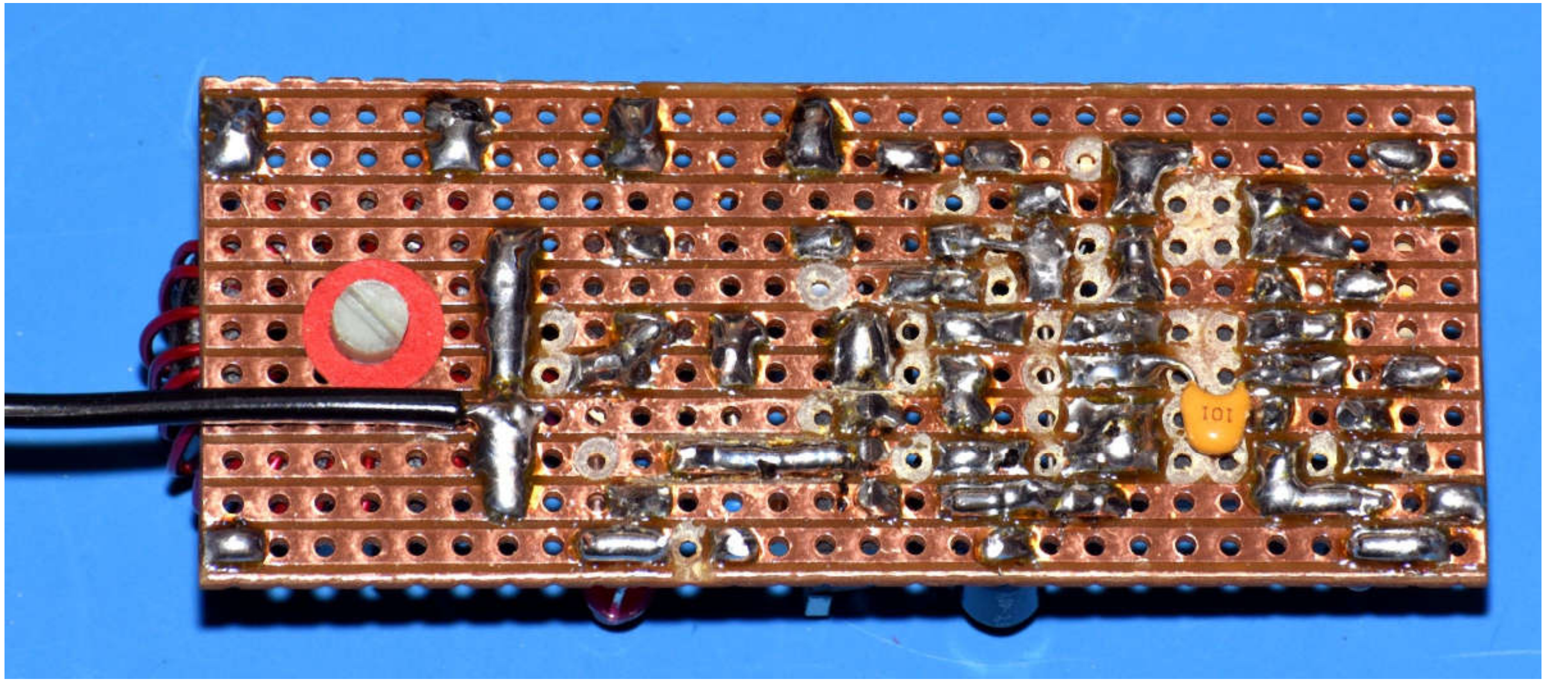
Power supply construction

Circuit diagram




100R
100k
3n3F
100pF
100uF
1000uF
470uF
1k
27k
1nF
1uF
470R
15V
4k7
LED
= track break
= solder bridge
= bare wire on copper side of board


3n3J100

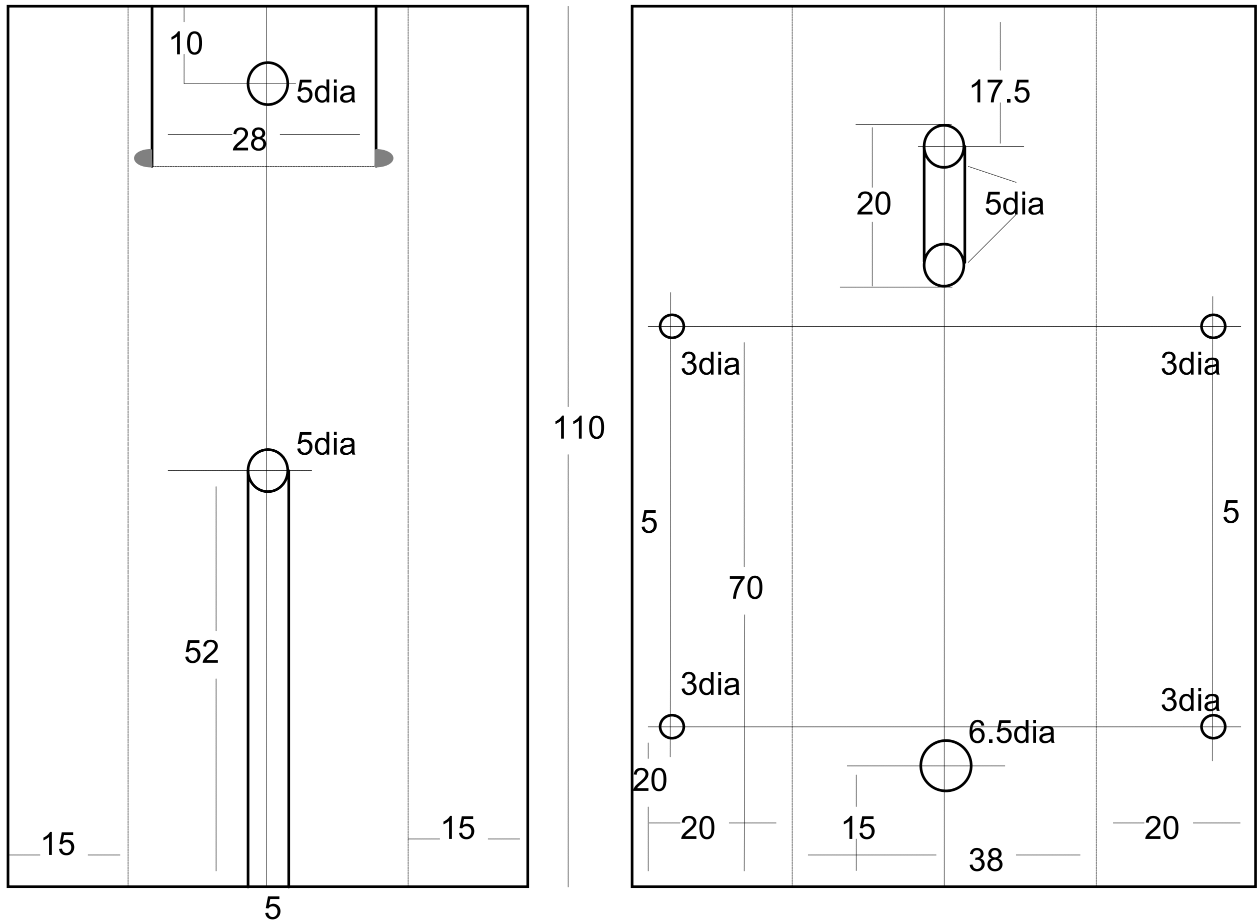


Hardware

The frame is made from 1mm Aluminium sheet and consists of an inner and outer section.
All sizes are in mm.

Inner

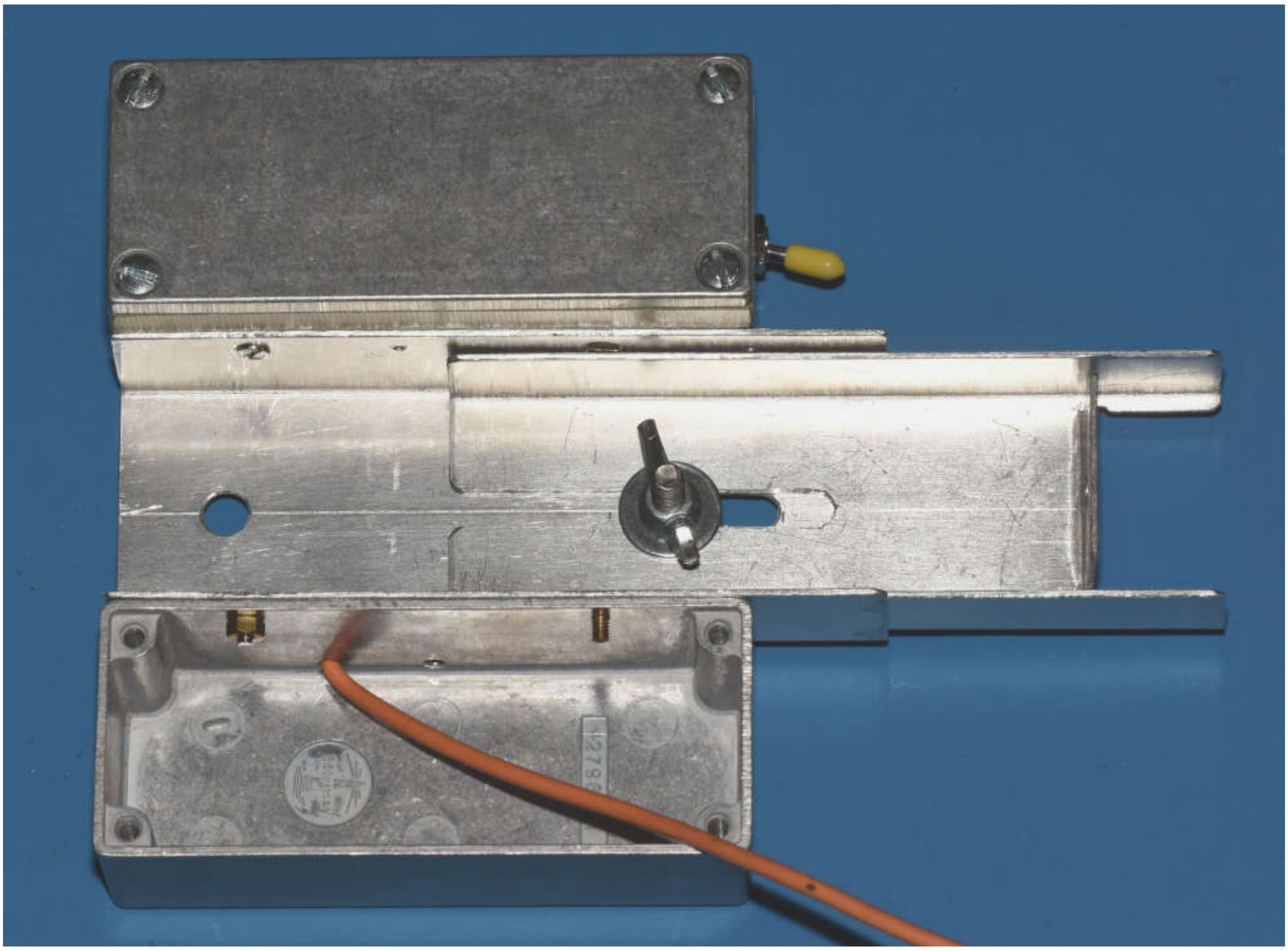
Outer



The inner section is on the left and the outer one on the right.
The 3mm holes on the sides of the outer section are counter sunk on the inside, to allow the inner section to fit correctly

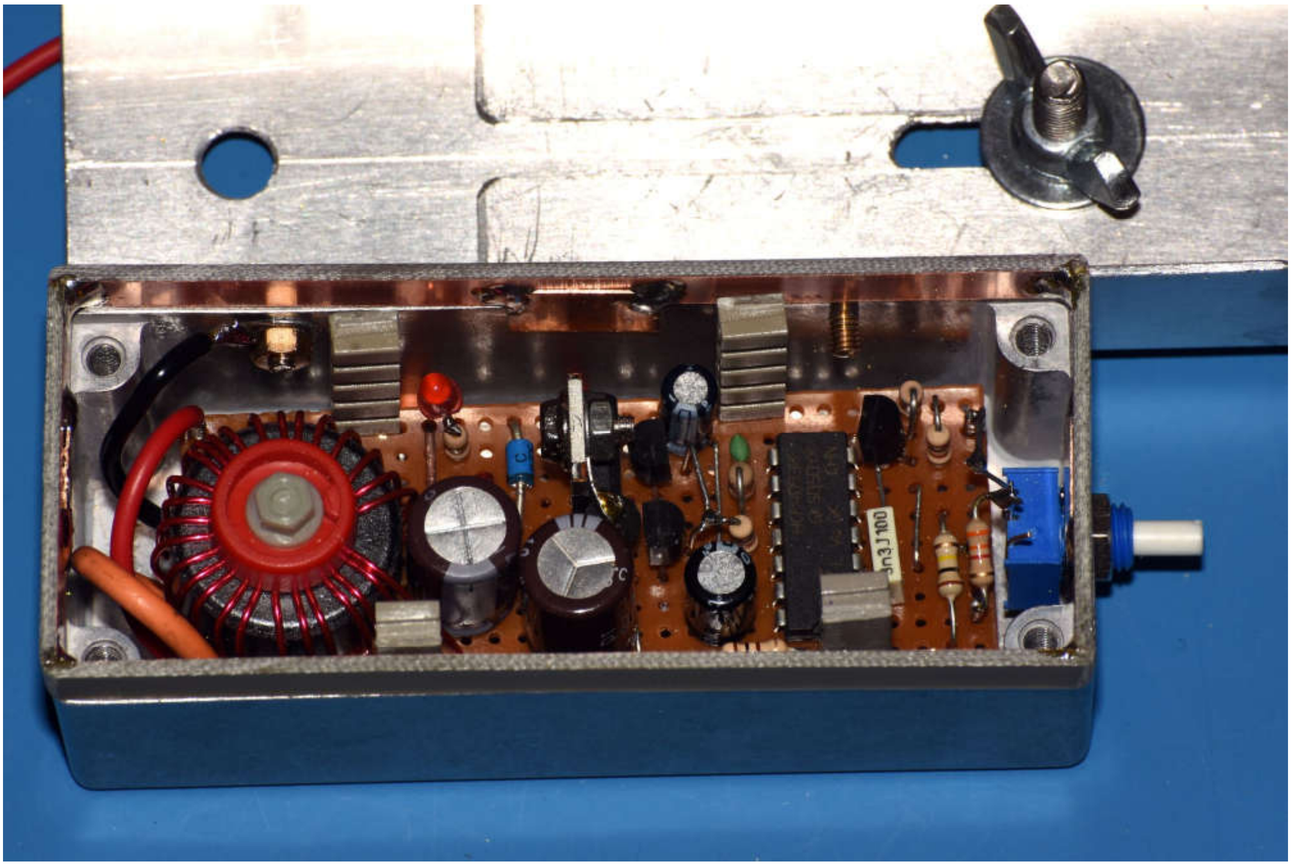
The power supply electronics and the battery are enclosed in separate Eddystone cases 92 × 38 × 31mm. These are drilled and attached to the outer section with 3mm counter sunk bolts and nuts.

The top of the diecast box (without the lid) is level with the edge of the outer section of the frame. To allow power to pass from the battery to the power supply electronics, the positive supply wire passes through a 3mm hole, drilled into the side of each diecast box at the bottom, 35mm from the end. The diecast boxes and the aluminium frame carry the negative supply.



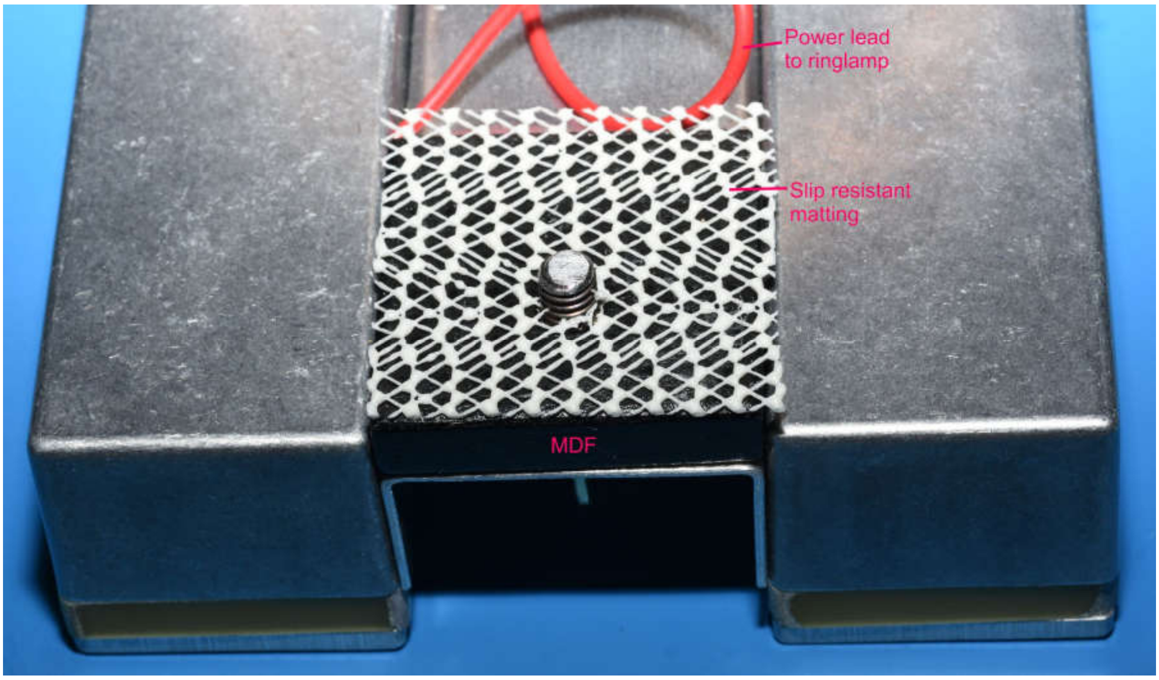
The diecast box with the lid attached holds the batteries.
The empty diecast box shows the positive wire from the battery box. This passes over the outer section of the frame.
A second 3mm hole, 45mm from the end is drilled in the power supply electronics box to carry the output to the ringlamp. This can be seen in the photograph above.

The battery holder is deeper than 31mm and so does not quite fit into the diecast box. This is remedied by making an extension rectangle from 6mm wide fibre glass printed circuit board (pcb), soldered and glued at each corner.
Two 92 × 6mm and two 35 × 6mm strips of pcb material was used for each rectangle.
The four M3.5 bolts supplied with each box were now not long enough and so were replaced with 25mm long M3.5.
A small piece of thin sheet copper was soldered onto each side of the extension rectangle to help it to fit correctly onto the diecast box. These can be seen in the photograph below.



Camera mount

This was made from a piece of MDF 40mm × 40mm ×10mm.
A 6.5mm hole is drilled in the centre, 15mm from the side, for the tripod bolt to pass through.
A grove 3mm deep is filled across the MDF block to allow the positive power supply wire to pass between the two diecast boxes and allow the MDF to fit flat onto the aluminium channel joining the two boxes.
The MDF is glued onto the aluminium channel and a 40mm square piece of 'slip resistant' mat is glued onto the top of the MDF. This matting ensures that the camera is held firm onto the ringlamp hardware. This can all be seen in the picture below.

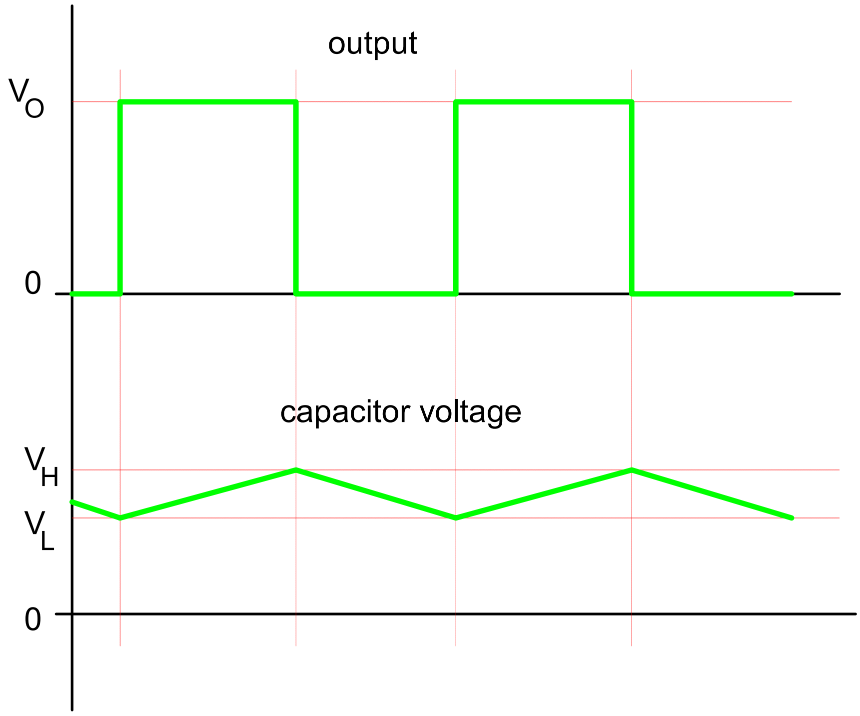



Nikon

How the power supply 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 $T = RC.Ln\left(\frac{V_H(V_0 - V_L)}{V_L(V_0 - V_H)}\right)$

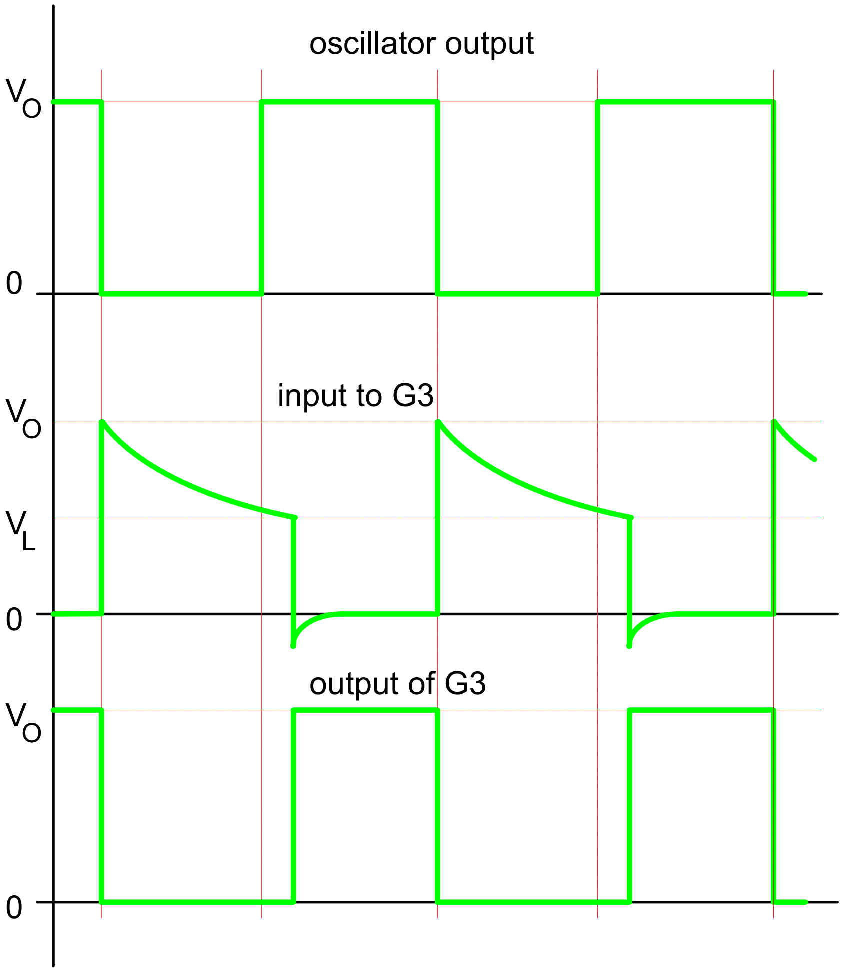
With the values used, $T = 1.55 \times 10^{-5}$s and the frequency is 64.4kHz.

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. The 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 that VL. 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_0 is the supply voltage, V_L is the lower switching voltage, then the time period of the unstable state is given by

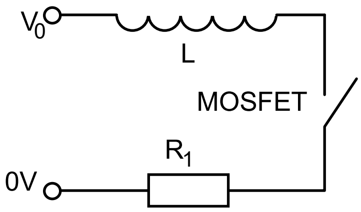
$$T = RC.Ln\left(\frac{V_0}{V_L}\right)$$

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 (~$10^9\Omega$), it has a significant capacitance in parallel with its input. (~2nF 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 (~1kΩ), 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 ~50Ω and is able to charge and discharge the gate capacitance of the MOSFET quickly (~100ns), so keeping the circuit efficient.
A disadvantage of this driver circuit is that the output only switches between ±0.7V 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 ~1.6V.

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 = εI + I^2R_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

$$W = \int_0^{t1} LI\frac{dI}{dt}dt = L\int_0^{t1} I.dI = \frac{L}{2}\left[I^2\right]_0^{t1}$$

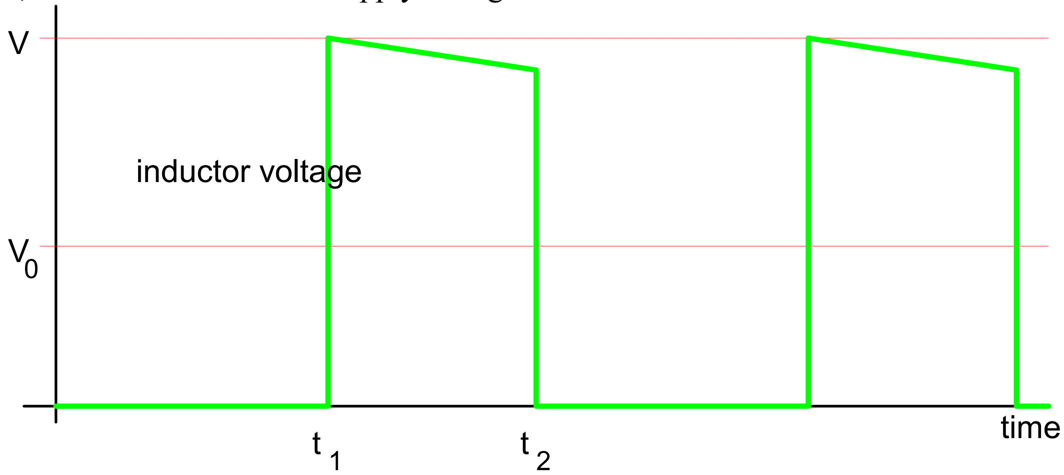
But $I = \frac{V_0}{R_1}\left(1 - \exp\left(-t/_{L/R_1}\right)\right)$

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

During this time, t_1, the voltage at point A is virtually zero and the 470μF 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 been 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 $t_1 \approx I_L^2$ x R_L x t_1 so the battery and inductor must supply energy of ≈ 2 x I_L^2 x R_L x t_1 during t_2.
During t_2, the battery and inductor must also supply energy to the load $\approx I_L^2$ x R_L x t_2.
So the total energy that must be supplied by the battery and inductor during t_2

$$\approx 2 \text{ x } I_L^2 \text{ x } R_L \text{ x } t_1 + I_L^2 \text{ x } R_L \text{ x } t_2$$

and this must equal V_0 x I_L x t_2 +W

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

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

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

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

Re-arranging

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

This gives a quadratic equation for I_L.

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

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

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. This is to ensure that the the inductance does not saturate.
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.