Model Railway Static Grass spreader

Specification

Produces an output voltage of ~6kV off load.
Output is via a 20MΩ resistor to minimise the risk of electric shock.
Operates from 9V either from an internal PP3 or an external supply.
Different size sieves can be attached to the spreader.
The case is made from 42mm waste pipe fittings.

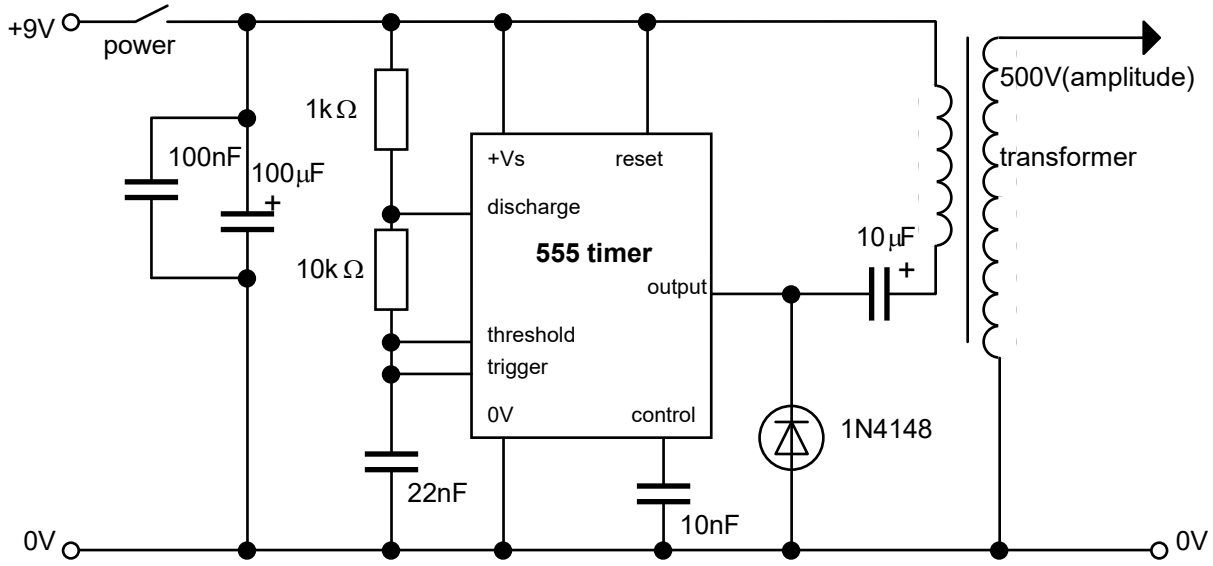
Circuit description and diagram

The circuit consists of two main sections, the oscillator and the voltage multiplier.

The oscillator is needed to change the direct current from the battery into an alternating current which can be passed into a step up transformer to produce a high voltage.
The step up transformer can either be a standard miniature 4.5V mains transformer operated in reverse or transformer that has been liberated from old equipment.
Transformers used to produce the high voltage for the cold cathode lamps in LCD monitors and televisions are also suitable.
The one used in this device was liberated from a laser printer and had a step up ratio of 1 : 150 when operating at a frequency of 3.1kHz.

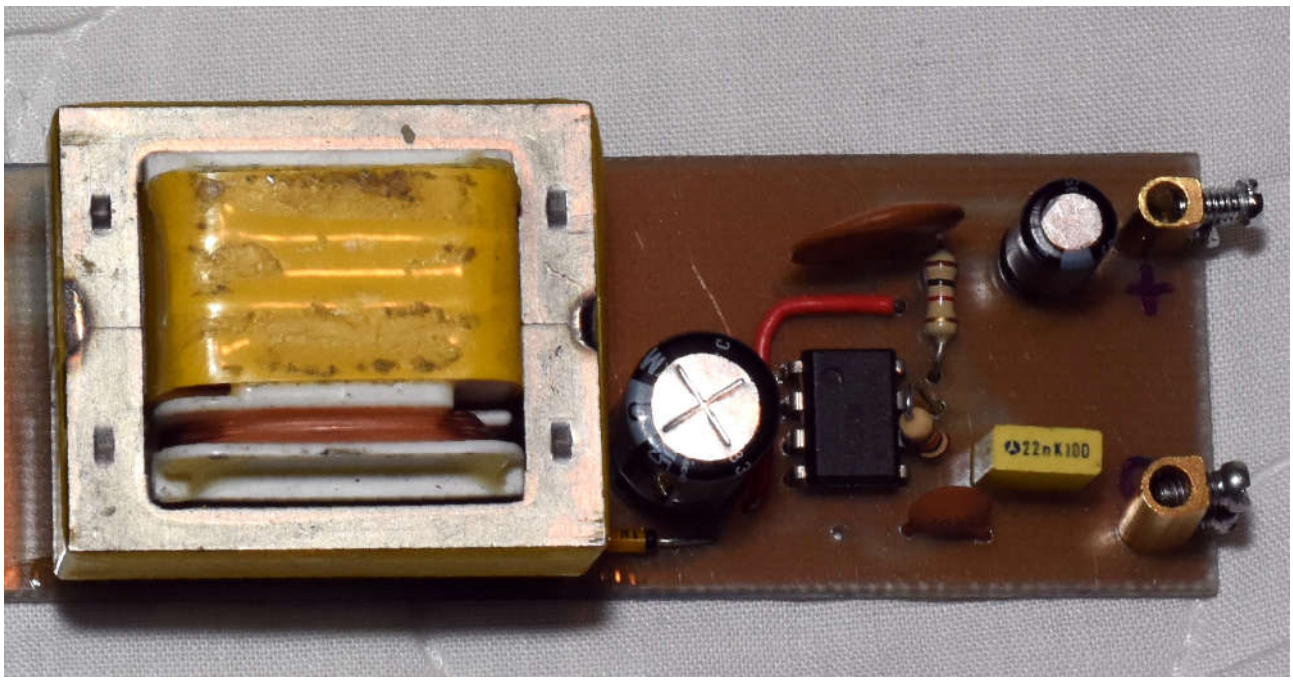
The oscillator

The original oscillator was designed around a one transistor Colpitt's oscillator. The primary coil of the transformer had an inductance of around 260µH and so needed a capacitance of approximately 10µF to be resonant at 3.1kHz. Such non electrolytic capacitors are physically large and expensive and so a 555 timer astable was used instead. A 555 will sink/source 200mA and was found to be able to power the primary coil of the transformer.
The circuit below is a standard 555 astable. (See the ELEC2 support booklet for full details.)
The 1N4148 diode stops any negative pulses from the transformer damaging the oscillator circuit.



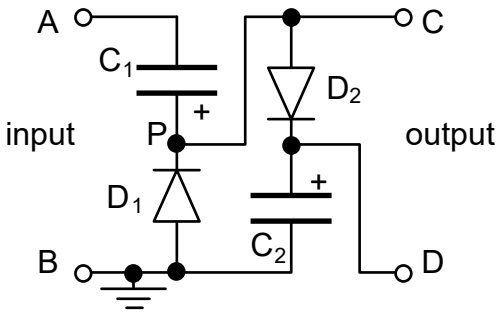
NOTES:-

From a batch of 10 NE555s, 4 worked very well with this circuit.
Another 4 worked well until the transformer secondary coil had to supply current, when they started to oscillate at a much higher frequency (9 - 25kHz).
The other two would not oscillate reliably in this circuit.



The voltage multiplier

This is an electric circuit that generates a high direct voltage from a low alternating voltage or pulsing direct voltage input. It was named after the British and Irish physicists John Cockcroft and Ernest Walton, who in 1932 used this circuit design to power their particle accelerator, performing the first artificial nuclear disintegration in history.
The basic voltage multiplier circuit is shown below.



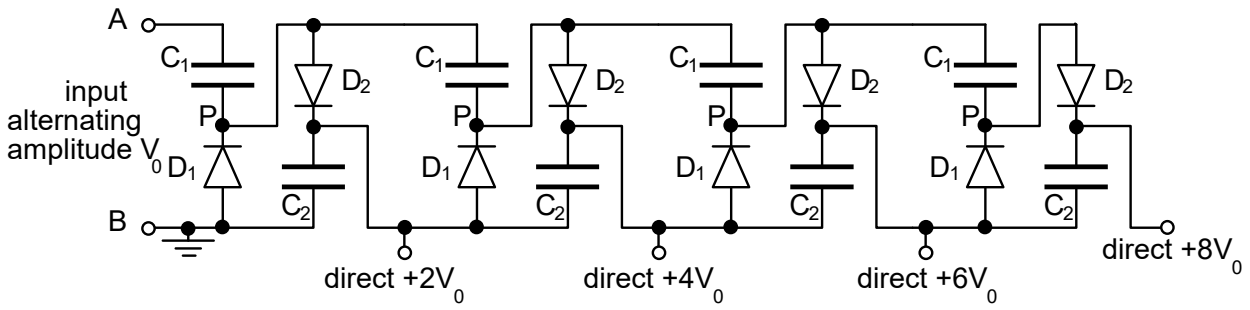
How it works

Consider:-

an alternating voltage of amplitude V_0 connected to the input terminals, A and B,
the capacitors C_1 and C_2 fully discharged,
and V_0 large compared to the forward voltage of the diodes.

When A is negative with respect to B, D_1 will conduct and C_1 will charge to V_0 with respect to A.
Point P is now positive with respect to A.
As A now becomes positive with respect to B, the voltage at point P increases and approaches $2\times V_0$.
D_1 does not conduct, but D_2 now conducts and capacitor C_2 starts to charge, also approaching $2\times V_0$.
Terminal D now has a direct voltage of $+2V_0$ with respect to point B.
In practice, it will take a few cycles of the alternating input to achieve $2V_0$.
At terminal C, there is an alternating voltage of amplitude V_0 superimposed onto a direct voltage of V_0 with respect to terminal B.
The circuit, therefore provides a half wave rectified output with a voltage of $2V_0$.

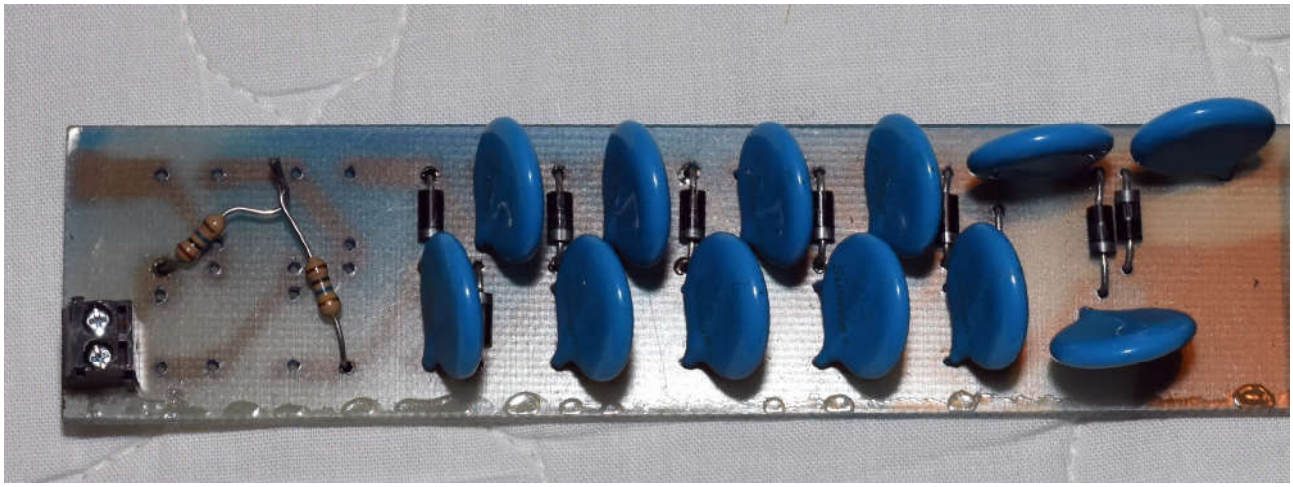
This basic voltage multiplier unit can be cascaded together to produce very large direct voltages.
The circuit diagram below shows four units.



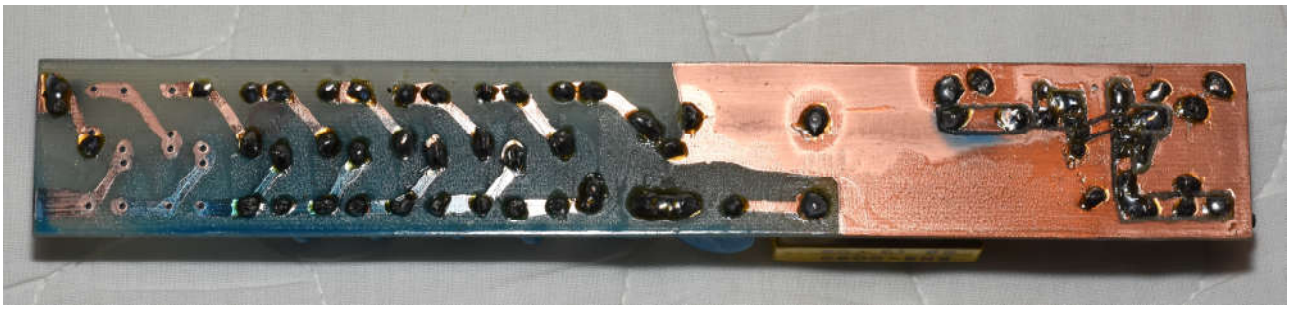
All voltages measured with respect to point B

The grass spreader has six basic units cascaded together giving an output of ~6kV off load
All of the diodes are UF4007 and the capacitors are 10nF, 2kV ceramic.

The voltage multiplier is shown below.



The input from the transformer is at the right hand side and the output is taken from the left hand side via the two 10MΩ resistors.
The complete circuit was made onto a fibre glass printed circuit board, the copper side is shown below. The oscillator section is on the right.



Casing

The casing was made from 40mm Floplast, solvent weld, black waste pipe, from Screwfix.
All of the fittings were a tight push fit and so were not solvent welded to enable modifications etc to be carried out as necessary. Floplast 40mm Access plugs were used for the ends and these were joined to the central piece of pipe with straight connectors.
The plastic used for these pipe fittings is a very good insulator, which is useful when there is 6kV around!

At the front of the unit, two metal connectors from a terminal strip were fixed to the Access plug, so that different sieves could be attached to the unit.

The Access plug at the rear of the unit contains the PP3 battery, the 4mm socket for the ground lead and a 2.1mm power socket, so that the unit can be externally powered.
The 'red' push to make power button was fitted into the plastic tube holding the circuit board.

After the unit has been switched on, it is worth touching the ground lead to the sieve to ensure that the sieve and the internal circuit is discharged. Failure to do this can result in an electric shock!

In use, the area to be grassed is covered with a thin layer of glue and a connection from the ground lead is made to the glue. Some model grass is put into the sieve attached to the unit away from the area to be covered with grass.
The unit is then moved to the area to be grassed and powered, while gently shaking the unit with the sieve over the area.
The picture below shows a sample of 4mm grass put onto a piece of double sided sticky tape fixed to a piece of aluminium.