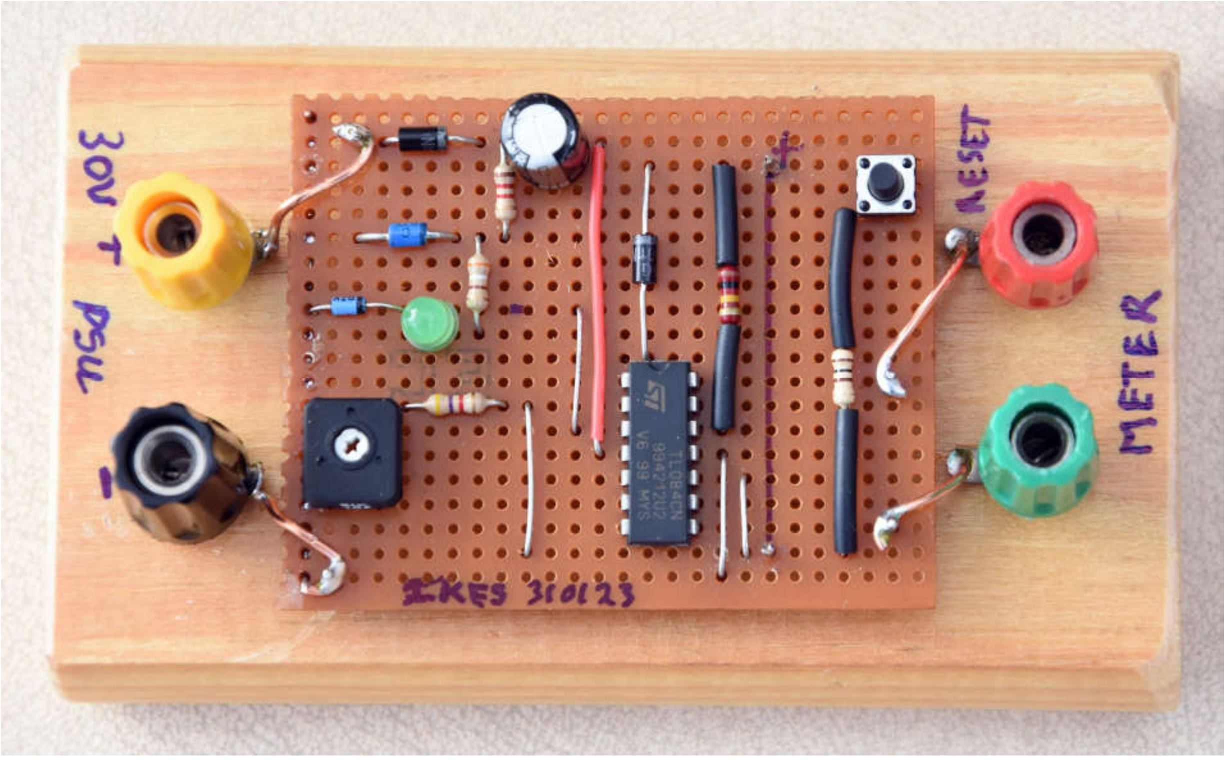
Constant Current Generator
For capacitor charging.



The test capacitor is connected across the solder pins joined by the blue line,
with the positive side connected to the top (+) pin.

The charge stored in a capacitor (coulombs) when charging = current (amps) × time (seconds).

$$Q = I \times t$$

The charge stored in a capacitor (coulombs) = capacitance (farad) × p.d. across the capacitor (volts)

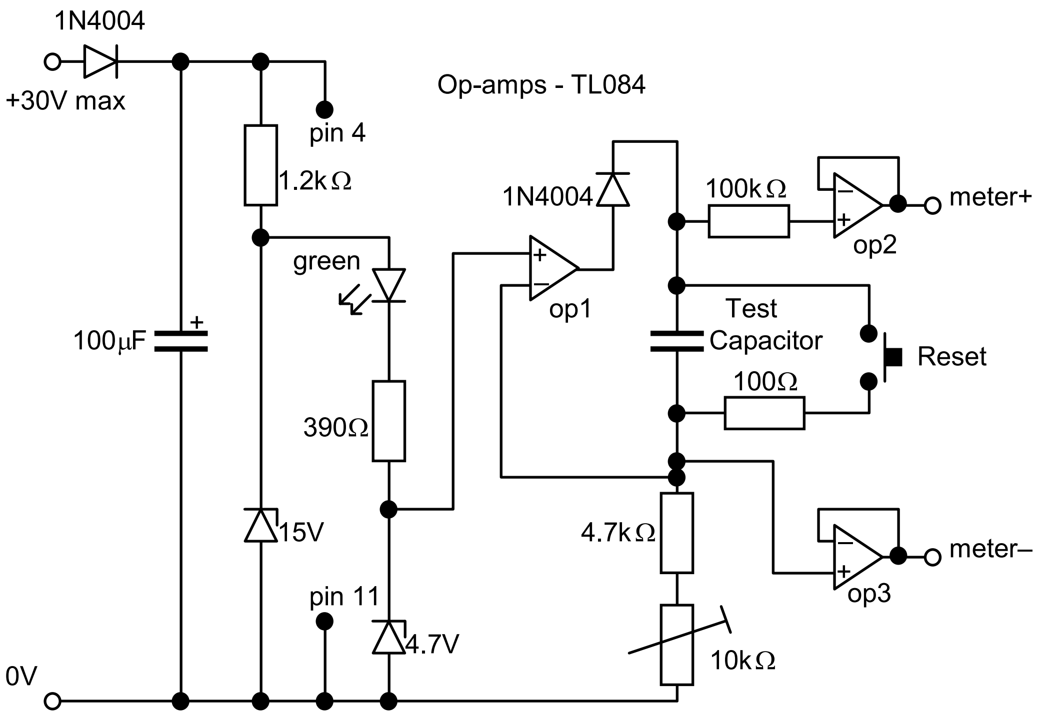
$$Q = C \times V$$

Combining these together gives $I \times t = C \times V$

$$\Rightarrow V = t \times (I/C) \quad \text{(eqn 1)}$$

If the current charging the capacitor is kept constant, then a graph of p.d. against time will be a straight line with a gradient of current / capacitance.

The circuit diagram below gives a constant current over a wide range of p.d.s across the test capacitor.



How it works

The maximum supply voltage is 30V and the 1N4004 diode in the power supply line protects against the power supply being connected incorrectly.

The 15V and 4.7V zener diode circuits give a stable 4.7V reference voltage. The green LED acts as an indicator to show that the circuit is powered.

Op-amp1 is connected as a comparator between the 4.7V reference and the p.d. across the 4.7kΩ and 10kΩ resistors. The output of op-amp 1 supplies the charging current for the test capacitor, and continually adjusts the current to ensure that there is 4.7V across the 4.7kΩ and 10kΩ resistors. This current will be constant until the maximum output voltage of the op-amp is reached.

The 1N4004 diode in the output of op-amp1 stops the capacitor discharging through op-amp1 when it is charged and the power supply is disconnected from the circuit.

Op-amps 2 and 3 are connected as voltage followers which isolate the meter from the test capacitor. This prevents the internal resistance of the meter from affecting the charging current.

The Reset switch discharges the test capacitor to repeat the test. The 100Ω resistor limits the discharge current from the capacitor and protects the contacts of the switch.

Using the Reset switch will only discharge the capacitor to a p.d. equal to the charging current × 100Ω. For a charging current of 0.5mA, the p.d. will be 0.05V. This can be reduced to zero by using a wire connected briefly across the test capacitor at the start of a test.

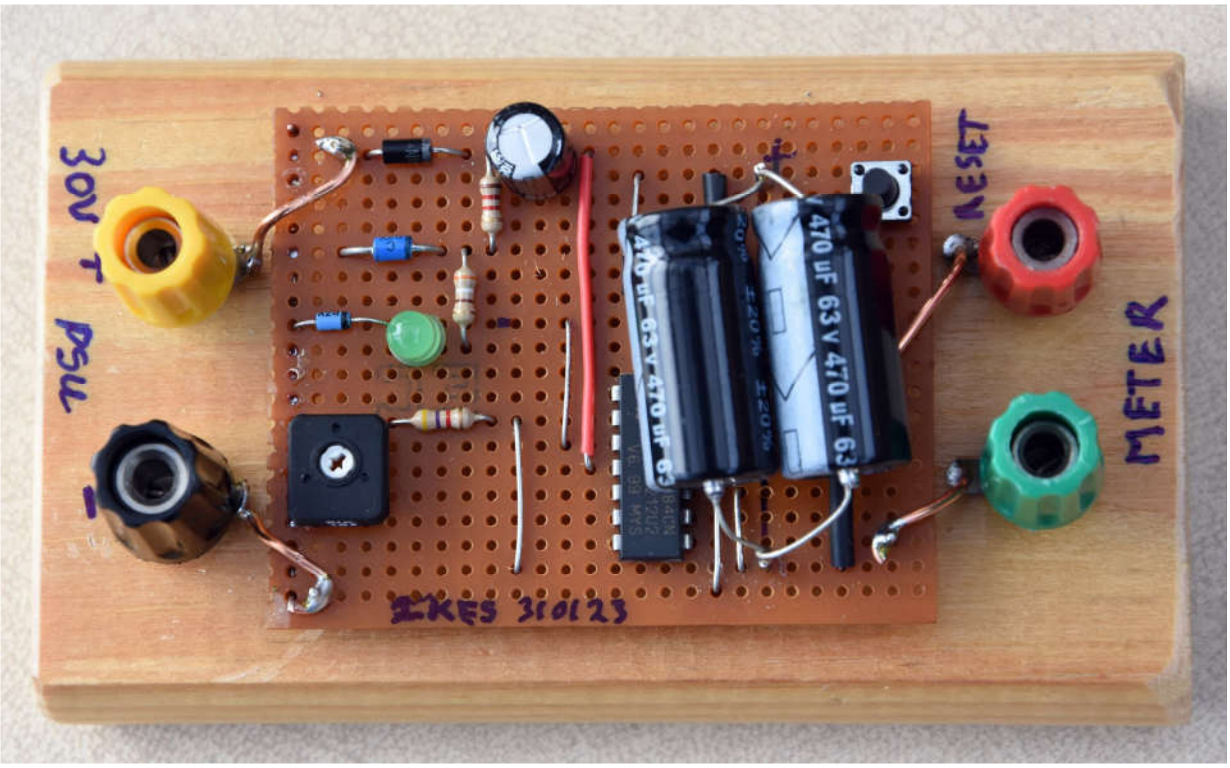
Using the circuit

The test capacitor is connected to the circuit, with the positive side connected to the terminal marked with a +. It should have a working voltage of 35V or more.
The circuit is connected to the power supply and a suitable voltmeter.
The charging current is set by holding the reset switch pressed and adjusting the 10kΩ preset resistor.
To make a set of measurements, a stop clock should be started as the reset button is released. Watching the stop clock and the meter and recording results is difficult and so it is much easier to either use a data logger or make a video recording (on a mobile phone) of the timer and voltmeter. The video can then be replayed and paused as necessary to make the measurements.

Modifications and Uncertainties

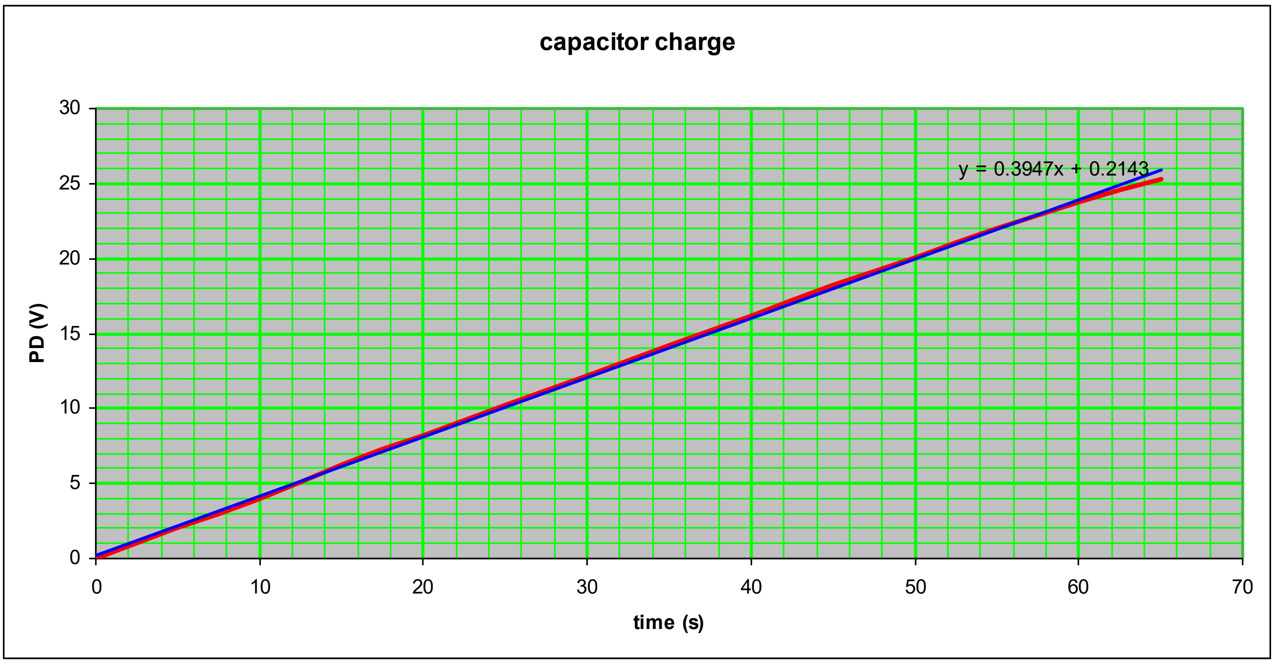
The constant current can be changed by changing the values of the 4.7kΩ and 10kΩ resistors and the op-amps will sink and source maximum currents of ≈ 5mA.
Electrolytic capacitors have a natural leakage current (a few μA) and so the charging current should be at least 100 times larger to keep uncertainties to around 1% or less.
Digital meters can struggle with displaying a constantly changing voltage, updating their displays around three times a second. This can lead to incorrect readings. Data loggers often incorporate a sample and hold circuit and may give more faithful measurements than cheap digital voltmeters.
To ensure an accurate current is set, the 100Ω resistor in the reset circuit should have a 1% tolerance (or better).
Making measurements from a video recording or data logger gives more accurate measurements (and is less stressful) than making measurements directly.

In practice.



The picture shows two 470µF 63Vwkg capacitors wired in parallel and connected to the constant current circuit. The combined capacitance was measured as ≈910µF.
The current was set to ≈0.36mA.
The measurements below were taken from a video recording of the capacitor charging.
(http://www.ikes.16mb.com/e_vid/cap_charge1.mp4)

time (s)	p.d. (V)
0	0
5	2.0
10	4.0
15	6.2
20	8.2
25	10.2
30	12.2
35	14.2
40	16.2
45	18.2
50	20.1
55	22.0
60	23.8
65	25.3



From the trend line, the gradient is 0.395 Vs^{-1}
=> From eqn 1 $C = I / \text{gradient} = 0.36 \times 10^{-3} / 0.395 = 911\mu F$
which is consistent with the measured value.

A high resolution version of the video (~100MB) is available on request).