SuperCap Battery

Power from a GoldCap

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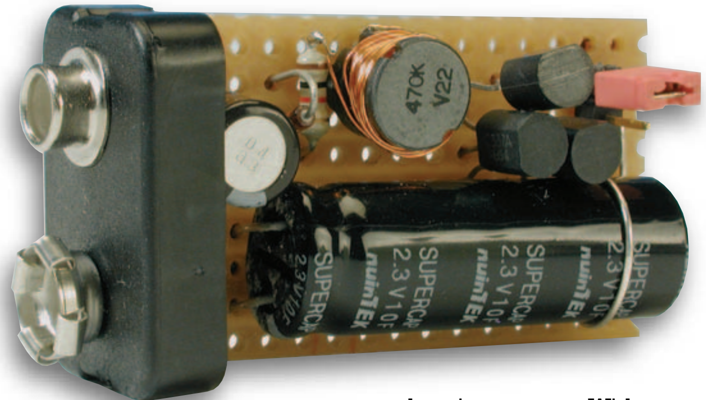
GoldCap capacitors offer an interesting alternative power source when compared to conventional disposable or even rechargeable batteries. They can be charged very rapidly and can also deliver a high peak output current. Their voltage rating however is quite low so a little electronic assistance is necessary to raise the output voltage to a more useful level.

PP3 (6F22) type 9 V batteries are often used in small portable equipment that require very little current and may only be used intermittently. Under these conditions its often the case that the battery is flat just when you urgently need to use the equipment. NiCd rechargeable cells are not a good choice in these applications because their self-discharge characteristics are much worse than dry cells and often there is no charge left after a long time in storage. Capacitors offer an interesting alternative power storage device, they can be charged very quickly and they retain their charge for years. SuperCaps are small outline capacitors offering huge storage capacity measured in farads rather than the microfarads (μF) that we are used to. The maximum supply voltage of 2.3 V means that some form of voltage multiplier is necessary to increase voltage up to a more useful 9 V. Using a 10 F, 2.3 V SuperCap specified here, the complete circuit can be built into a package the same size as a PP3 cell.

Compared to rechargeable cells a capacitor can handle a very high peak current for both charging and discharging and has a very low self-discharge characteristic (it keeps its charge). A capacitor is an almost ideal energy storage medium as can witnessed for example by its universal use in camera flash equipment. There are no batteries (dry or rechargeable) of the equivalent size that can deliver so much energy in such short a time. Also there are very little loses involved in the charge/discharge cycle. Now the bad news; unlike a battery a capacitor has a very simple formula relating its voltage to charge stored so that when charge is removed, output voltage falls. In this respect a rechargeable cell is much more user-friendly, it keeps the output voltage relatively constant over the discharge cycle until the charge is used up when the output voltage falls more sharply. A capacitor will therefore need some form of voltage regulation circuit before it can act more like a battery.



The switching regulator

The circuit shown here in **Figure 1** uses a small outline SuperCap with a capacitance of ‘just’ 10 F (yes that’s 10,000,000 μF!) with a maximum operating voltage of 2.3 V. A switching voltage regulator is used to pump up the capacitor voltage to 9 V. A small switch or jumper is fitted to the circuit to ensure that the capacitor retains its charge over time. An LM317T voltage regulator (IC1) is used on the input to ensure that the capacitor can be recharged from a wide range of voltage sources whilst protecting the capacitor from over-voltage. This IC has built-in over-current and over-temperature protection. The circuit can be charged from a standard mains adapter where the internal resistance of the adapter will limit the charging current. With an input current of 1 A the capacitor will be fully charged in 20 s!

The rest of the circuit is a switching regulator containing a small ferrite coil or choke (L1). The 470 µH choke consists of approximately 20 turns of enamelled copper wire wound around a ferrite core. The resistance of the winding should be less than 1 Ω. The two ends of the winding are soldered to connecting pins in the body of the choke. **Figure 2** shows the second winding of 20 turns that needs to be wound over the top of the existing winding to provide feedback for the oscillator (wind in the same direction as the first winding). Alternatively the existing winding can be removed from the choke and replaced by a 40 turn centre-tapped winding of enamel coated copper wire (0.5 mm diameter or 24/26 SWG is suitable). The choke has now been converted into a small transformer. Oscillator operation has proved to be reliable and runs with an input voltage as low as 0.5 V.

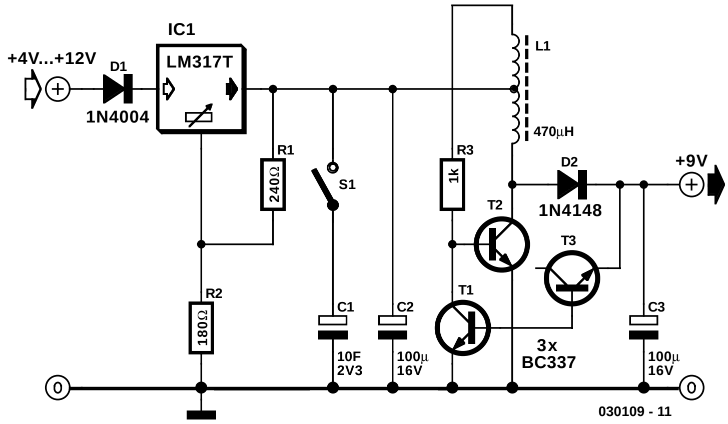


Figure 1. Circuit diagram of the Goldcap rechargeable.

The output voltage is regulated to provide approximately 9 V. Transistor T3 uses its reverse biased base-emitter junction to act as a zener diode, providing a voltage reference to regulate the output. The zener voltage of a small signal NPN transistor is around 8 V in this configuration (an 8 V zener diode could be substituted for T3). The circuit produces an output of 8.5 V with an input voltage of 2.3 V while at 0.7 V the output falls to 8.4 V.

Two of the most important criteria for any switching regulator are its output current capability and its efficiency. A 1 kΩ load resistor was used for testing. The circuit took 50 mA with an input voltage of 2.3 V giving a power consumption figure of 115 mW. The output voltage of 8.5 V is the same as the output voltage with no load. Current in the load is 8.5 mA giving an output power of 72.3 mW and this equates to an efficiency of 63 %.

Output current is about 1 mA with a load resistance of 8.2 kΩ. The output voltage remains constant until the SuperCap voltage falls to 1 V by which time the capacitor will have given up 80 % of its stored energy. As the voltage continues to fall the output also sinks until at 0.6 V the output voltage is 4.8 V.

As with any switching regulator, the input current increases as the input voltage falls. This type of regulator is more efficient than a standard linear regulator so that smaller loads result in lower power consumption. Under no-load conditions the converter consumes just 2 mA with an input voltage of 2.3 V. Lightly loaded, the circuit will run for up to three hours before it needs recharging.

The SuperCap used in this circuit is produced by the Korean company NuinTEK and has a package outline 10 mm diameter by 30 mm. Farnell stock a similar SuperCap produced by Panasonic, this device is a little larger with a body diameter of 18 mm and will not unfortunately fit into a PP3 outline. Alternatively there are 10 F GoldCaps rated at 2.5 V, these are more generally available but the case size is again bigger than the NuinTEK capacitor.

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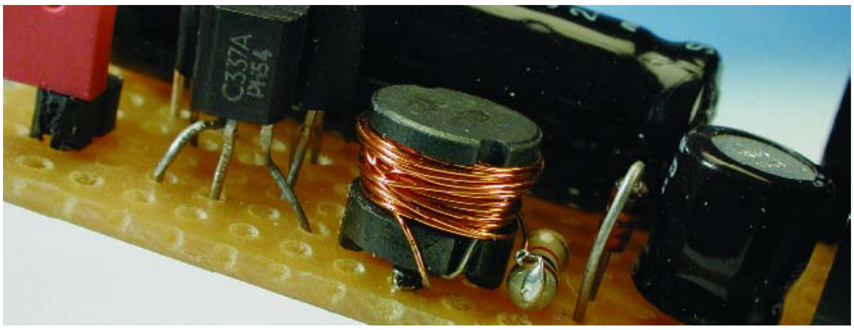


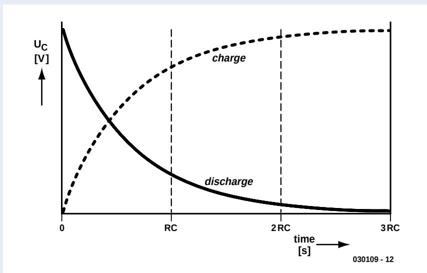
Figure 2. Coil L1 winding details.

Capacitance measurement

Most capacitance meters are not capable of measuring capacitors of 1 F and more, so what can you do when you need to measure a SuperCap or GoldCap capacitor? Well the answer is not that difficult, all you need is a timer (a watch will do), a voltmeter and a load resistor.

The voltage stored on a capacitor does not fall linearly when it is connected to a constant resistance but exponentially. The curve gets flatter with time because as the voltage falls so the current in the load gets smaller causing less and less charge to be taken from the capacitor. Theoretically it will never be totally discharged, with time the discharge curve can approach but never actually achieve zero volts. This simple capacitor/resistor circuit is said to have a time constant $\tau = R \cdot C$. Where τ is seconds, R ohms and C farads. After each time constant the output voltage falls by 37% of its starting value and in practice falls to within 1% of its final value after 5 time constants. A 10 F SuperCap together with a 100 Ω resistor has a time constant $\tau = 100\ \Omega \times 10\ F = 1000\ s$ (16 Minutes and 40 Seconds). Armed with this information we can now start measuring!

Starting with the capacitor charged up to 2 V we can work out the value of capacitance by measuring the time it takes for the voltage to fall by 37% (37% of 2 V equals 0.74 V so the voltage across the capacitor will be 1.26 V after one time constant) now plugging this time into the formula $C = \tau/R$ will give us the value of C. In our test the voltage took 1200 s to fall to 1.26 V so the capacitance measured is 12 F.



Don't be tempted to use too low a value of load resistance to speed up the test; you could end up burning your fingers (literally). The SuperCap can deliver a peak current of around 6 A, this equates to a lot of power (heat) dissipated in low resistance loads. The capacitor is also not a perfect device and like all capacitors has a certain amount of internal series resistance. The smaller the value of load resistance the greater will be the effect of dissipation in this internal resistance.