Orderly Withdrawal

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1. Uninterruptible Power Supply for BASIC-Tiger®

You will know the problem from working with your PC – you are in the middle of work when suddenly there is a blackout. All data are lost, and sometimes, even worse, active programs are damaged. Therefore highly important systems in medical care, traffic etc. contain a so-called uninterruptible power supply (UPS) which switches the device to battery operation. Depending on the purpose minutes or even hours can be bridged off the mains. Such systems are usually quite complex and expensive – is it worth the effort for BASIC-Tiger®? It is in some cases, just think of long test series in a data logger, systems which control drives into possibly dangerous states etc. This application note is not about operating a BASIC-Tiger® system off the mains for hours, we could do this with a bigger buffer battery. We just want to make sure that e.g. important measured values are not lost during a blackout, but are still saved somewhere, preferably in the Tiger Flash. This requires only a few seconds – real battery operation would be over-the-top.

Let's discuss some possible solutions for our problem:

- The simplest solution would be a large buffer capacitor at the voltage regulator's output which is able to ensure operation for a few milliseconds or seconds after a blackout. It is problematic, however, that the BASIC-Tiger® has a very narrow range of operating voltage to function reliably. It would have to be a very large capacitor to be able to keep voltage at + 5 V for a longer period of time. Also it takes such a capacitor longer to get to +5 V after activating which is critical for the power-on behaviour (RESET). Another problem arises from the "reverse operation" which is dangerous for the regulator – there is (still) voltage applied to the output side, but not any more at the input side. Current seeks to flow reversely through the voltage regulator which is often prevented by a by-pass diode between input and output.
- Well, how are things going on the input side? Here a large buffer capacitor would be required which keeps up the unregulated voltage for a certain period of time in order to enable the regulator to create 5 V. We are facing the same problem here. With a very large capacitor voltage increases so slowly in front of and behind the regulator that a proper RESET is hardly possible.
- What about battery buffering at the output side? Besides those problems mentioned above the battery will be either constantly under- or overcharged. With common measures a constant operating voltage cannot be achieved.
- Success is more likely on the input side, but it is problematic that this requires batteries which provide at least 7.5 V, which is quite a waste. Nevertheless the problem of an effective and safe charging of the rechargeable battery remains.

- A convenient trade-off between capacitor and battery would be a so-called GoldCap® which is able to accumulate a lot of voltage, which is small and which is also maintenance-free. It would guarantee the BASIC-Tiger® operation for a couple of seconds. A complex charging circuitry as for rechargeable batteries is not required. However, we are facing similar problems concerning voltage permanence and charging time. Later it will become apparent that also with GoldCaps® not everything which glitters is gold…

We notice that, even using GoldCaps®, our project can only be implemented with an intelligent circuitry. In the following sections we will learn about the features of various GoldCap® versions and we will develop a UPS from this.

2. GoldCaps®: Little space - large capacity

Anybody who deals with electronics knows that conventional capacitors can only accumulate tiny amounts of voltage, speaking of pF (pico farad = 10^{-12} farad), nF (nano farad = 10^{-9} farad) or µF (micro farad = 10^{-6} Farad). The largest capacitors are electrolytic capacitors which can accumulate up to some 100 to some 1000 µF. They are polarized, i.e. they can only be loaded with voltage in one direction. Fig. 1 shows a traditional electrolytic capacitor with no less than 4,700 µF for a 6.3 V operating voltage. For a few years there are so-called GoldCap® capacitors which have the comparatively enormous capacity of up to several farads. Also GoldCap® capacitors are polarized. GoldCap® is the brand name; the technical term is multi layer capacitor. GoldCaps® are commonly used in other areas, such as in bicycle LED rear lights or as RAM buffer batteries. Could this be the right power storage for our application?

What is farad anyway? In simple words, it is the capacitor's capacity at which voltage drops by 1 V per second at a 1A discharge. Our application (BASIC-Tiger® and some peripherical devices) could manage with about 100 mA, i.e. voltage will have been dropped by about 1 V after ten seconds. Sounds good, 10 seconds should be sufficient to finish saving. One problem, however, remains. 4 V is a lot, but unfortunately 4 V is not sufficient to operate the BASIC-Tiger®. So we are left with only a fraction of the time, during which we have enough operating voltage for the BASIC-Tiger®. There is some more bad news for using GoldCaps® from the DIY box. They must never be operated at voltages exceeding 5.5 V, some can even take less! Therefore simply buffering the voltage regulator's primary side is not an option. We are, however, much more worried by the fact that standard GoldCaps® usually have a very high internal resistance – 30 Ω is a typical value for standard modules. Thus such GoldCaps® are virtually useless for our application – at 100 mA 3 V would already get lost in the capacitor.

What a shame – another failure? But as usual in technics there is another way out. GoldCaps® with a very low internal resistance (down to 0.003Ω) and a much larger capacity (up to 2.000 F at present) have been produced lately. The aim of these developments is to have efficient and small charge coupled storages e.g. for vehicles. Such GoldCaps® are the ones which we have been waiting for – large capacity and low internal resistance. What about electric strength? Unfortunately rather bad, these modules can take even less than standard GoldCaps® – 2.3 V is the common absolute upper limit. We are also disillusioned by the price which is ca. $15 for a Panasonic GoldCap® with 50 F and 0.1 Ω internal resistance (EECHW0D506, fig. 2), which looks exactly as the standard Elko (fig. 1), available for a few Cents. But this should not put us off. These GoldCaps® are going to be the basis for our BASIC-Tiger® USV. They are available on

http://www.spoerle.de/

Designation:
Supplier: Panasonic
Part Number: EEC HW0D506 50F/2,3V
Description: DOPPELSCHICHTKOND. 50F 2,3V 60'C -20+40%
D18,5XL42 MAX.RM 7,5
Information is available on:
http://www.maco.panasonic.co.jp/www-cgi/jvcr13pz.cgi?E+PZ+4+ABC0008+EECHW0D506

Fig. 1 Traditional electrolytic capacitor 4700 µF / 6.3 V

Fig. 2 Standard GoldCap® 1 F / 5.5 V with 30 Ω internal resistance (bottom) and Panasonic high-performance GoldCap® 50 F / 2.3 V with 0.1 Ω internal resistance (top)

3. The Circuitry

Our UPS is based on the GoldCaps® 50 F / 2.3 V presented above. We have already excluded simple buffering in front of or behind the standard regulator. A step-up regulator using a MAX751 which we know from a previous application note is a convenient solution for providing a consistent operating voltage of 5 V.

Please download the data sheet for more information on
http://pdfserv.maxim-ic.com/arpdf/MAX751.pdf

Since this regulator requires an input voltage of at least 2 V for safe operation at the aspired load capacity of more than 100 mA and for a sufficient power reserve, we have to connect 2 GoldCaps® in series. This reduces capacity, but their voltage is allowed to become higher than 2.3 V in total. This series connection has to be fused by over-voltage protectors on every GoldCap®, so that under no circumstances more than 2.2 V are applied to a GoldCap®. Measured LEDs, which have a similar characteristic as Zener diodes, are most suitable for this. LEDs with 2.1 V are a good choice for a series connection of GoldCaps®; this takes some experimenting. Maximum input voltage for the MAX751 is 5.25 V, thus pre-regulating the input voltage to 5 V using a 7805 is useful. The complete circuitry looks as follows:

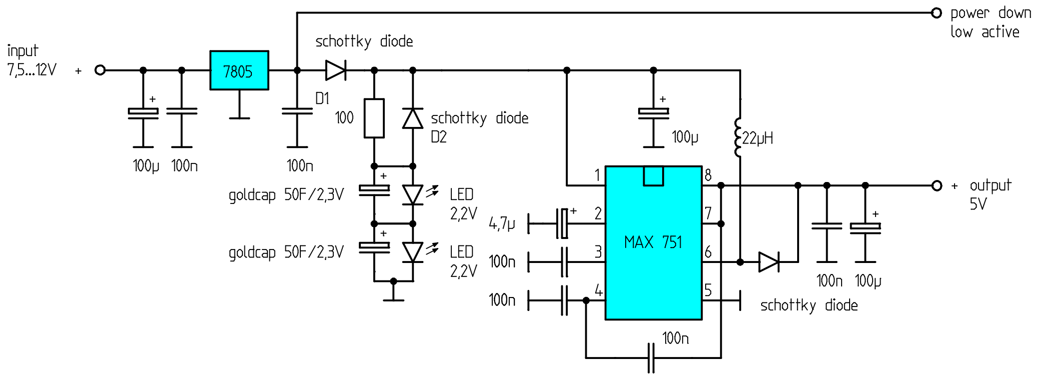

Fig. 3 Voltage supply with "power reserve" for BASIC-Tiger®

Functionality:
The first regulator (with 7805) works as we know it from the Plug & Play Lab. A constant voltage of 5 V is generated from an input voltage of 7.5 to 12 V. The series connection consisting of 2 GoldCaps® is slowly charged through diode D1 via a charging resistor (here: 100 Ω). Charging can take up to several hours depending on the charging resistor. The LEDs connected in parallel to the GoldCaps® (drop voltage has to be < 2.2 V) prevent overloading the sensitive super capacities. At the same time it is indicated that charging is finished. The 5 V voltage simultaneously reaches the input of MAX751 via diode 1, reduced by the diode's forward voltage. The MAX751 makes it a regulated 5 V voltage (i.e. Vcc for the BASIC-Tiger®) again. The lower the voltage drop at the diode, the more effective works the circuitry; this is why we suggest a Schottky diode with a very low forward voltage.

So much for normal operation. In the case of a primary blackout the following happens: The maximum voltage of charged GoldCaps® is 4.4 V (2 GoldCaps® connected in series). Immediately the GoldCaps® take over voltage supply via the second Schottky diode D2 for some 10 to 100 seconds depending on the load. A reflux via the 7805 is prevented by diode 1. As long as the GoldCap® series connection voltage is above 2.5 V the MAX751 keeps Vcc constant at 5 V.

We notice another line at the output of the 7805 which is used for signalling purposes. It carries high levels during normal operation. When deactivating the primary voltage it switches to low at once. This can be used as a logic input signal for a BASIC-Tiger® I/O pin. If a low level is detected here, data saving measures can be induced.

Some more information on the step-up regulator with the MAX751: The components coil and Schottky diode are specific special components which are best chosen according to the MAX751 data sheet. It is also important that the series connected power supply unit is able to provide sufficient high starting current. The circuitry needs it for safe oscillation build-up. When everything works normally the current is lowered considerably. Please keep in mind that when activating the primary voltage immediately an output voltage of 5 V is provided – even under load! If this is not the case, the MAX751 does not work correctly and possibly overheats. Please switch off primary voltage at once and eliminate the source of error. The following errors can occur:

- The power supply unit's current is too low
- Load at the output is too high
- Unfavourable wiring or wire diameter
- Unfavourable mass ratio

etc.

If everything goes right you will have a power supply for the BASIC-Tiger® which also tolerates a temporary blackout or allows changing batteries without losing data on battery operated devices. Also saving data in a case of blackout is unproblematic. Besides, the presented circuitry is of course also suitable for other systems which require keeping up the operating voltage for some time after switching off the power supply unit. Figures 4 and 5 show the results that were created with this circuitry. We used 40 Ω which correspond to a current of about 125 mA.

4. Safety advice

The multilayer capacitors we used in this application are very sensitive and expensive modules on an electrochemical basis. Their polarities must not be reversed and they must not be overloaded with voltage, even temporary! On the other hand they save an enormous amount of charge and they have a very low internal resistance. So never short-circuit charged GoldCaps® in order to avoid currents of several amperes flowing and destroying your screwdriver, your soldering iron and especially the expensive GoldCap® and the rest of the circuitry. Additionally such malpractice implies the danger of explosion – as there is with every standard Elko! We suggest connecting a discharging resistor of about 1 kΩ on every GoldCap® which allows a careful and permanent discharge. This also averts fireworks when accidentally putting a circuitry seemingly without voltage on a conducting pad.

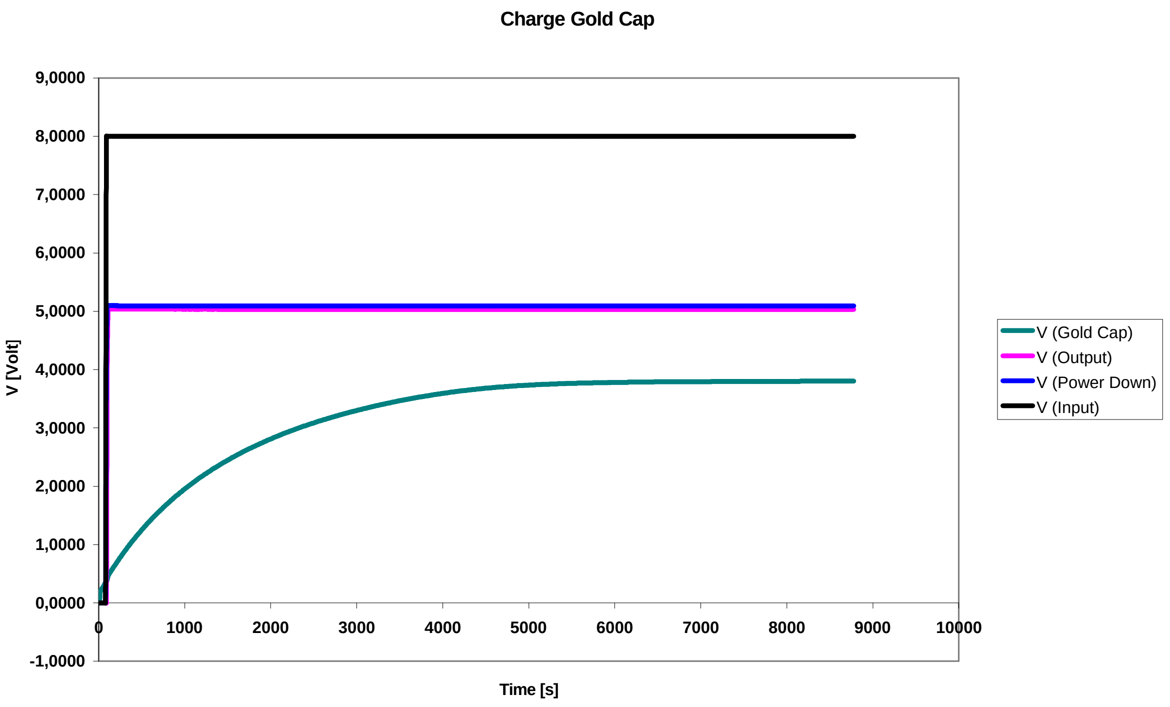

Fig. 4: Charging Gold Caps® from 5 V through 82 Ω, load at the output 40 Ω

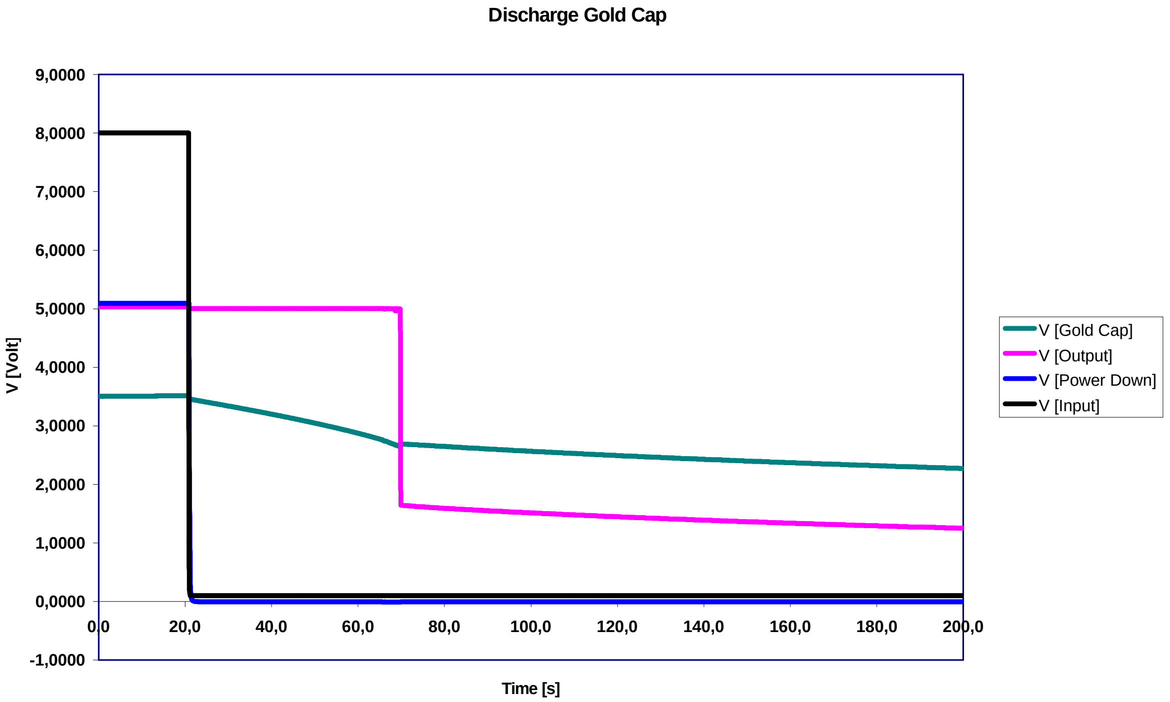

Fig. 5: Discharging GoldCaps® with 40 Ω at the output