BOOSTCAPs Start Internal Combustion Engine

Since original publication of this document, further enhancements have been made to ultracapacitor technology enabling improved performance over that listed within this application example. The product referenced is obsolete and has been replaced with newer technology. The methodologies cited within this document are unaffected.

Summary

Students at the Automobile Technology Department at Hochschule für Technik und Architektur (HTA) Biel have demonstrated that it is possible to start an internal combustion engine with BOOSTCAP™ ultracapacitors instead of a lead acid battery. These tests have been performed at a test bench and with a real car.

Figure 1: Interconnection of Boostcaps

BOOSTCAPs offer an interesting solution for a starting unit in the following applications:

- stationary engines with a charger connected to the grid (main advantage: long lifetime)
- starting aid for breakdown service (main advantage: low weight)

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Educational model

Before the relatively new technology of ultracaps could be applied, the engineers needed to know how to use these devices properly. Therefore, a simple educational model was developed in order to understand the technology better.

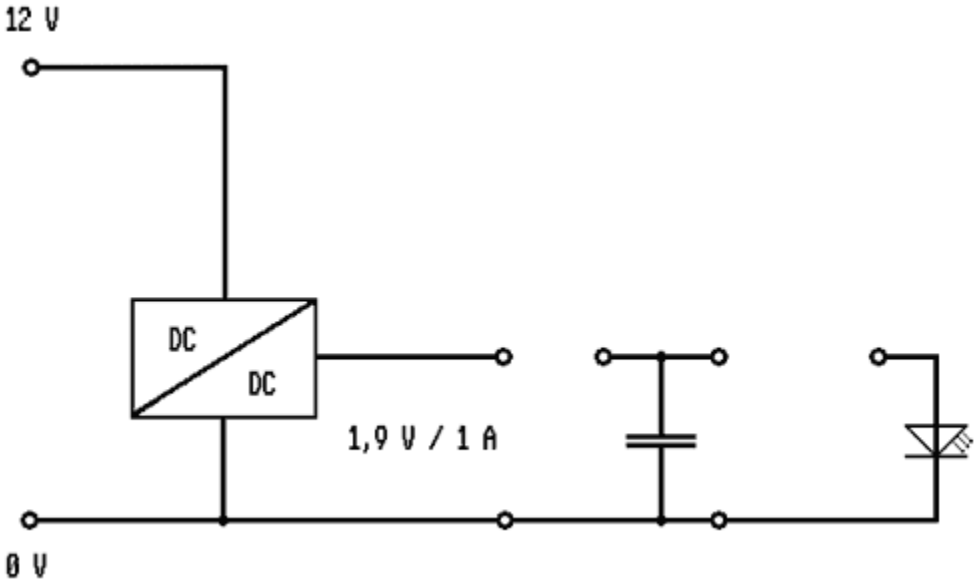

Figure 2: Educational model with a 100F Ultracap

The function is quite simple, the ultracap is charged from the DC/DC-converter. The charging current is fixed with a constant value of I = 1 A and the voltage is limited at 1.9 V. With an amp meter connected between the DC/DC-converter and the ultracap, the students will observe the charging current within about 200 s. With the help of the formula [1], the capacity of 100 Farads can be verified by calculation.

$$[1] \qquad C = \frac{Q}{U} = \frac{I * t}{U}$$

If the ultracap reaches a voltage of 1.9 V, the DC/DC-converter has to be disconnected. The ultracap can then be connected to the LED, illuminating the LED for quite a long time. After this introduction the students understand why these components could be interesting for automotive applications such as:

- capture of braking energy
- energy accumulator for hybrid vehicles
- energy accumulator for the starter

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The characteristic data for a starting process

The internal combustion engine (ICE) of a car requires a starter motor with power of about 1 kW. The open circuit voltage of a lead acid starter battery is 12.8 V and the internal resistance is about 12 mΩ.

$$[2] \qquad I_{1,2} = \frac{U_0 \pm \sqrt{U_0^2 - 4R_i P}}{2R_i}$$

$I_{1,2}$	=	current	[A]
U_0	=	open circuit voltage	[V]
R_i	=	internal resistance	[ ]
P	=	power	[W]

With this formula [2] we get the following results:

$$I_1 = 981.8 \text{ A and } I_2 = 84.88 \text{ A}$$

Because the breakaway torque needs a high current, the battery must be able to produce the value I_1 = 982 A. For this reason, a low internal resistance is of crucial importance for starter batteries.

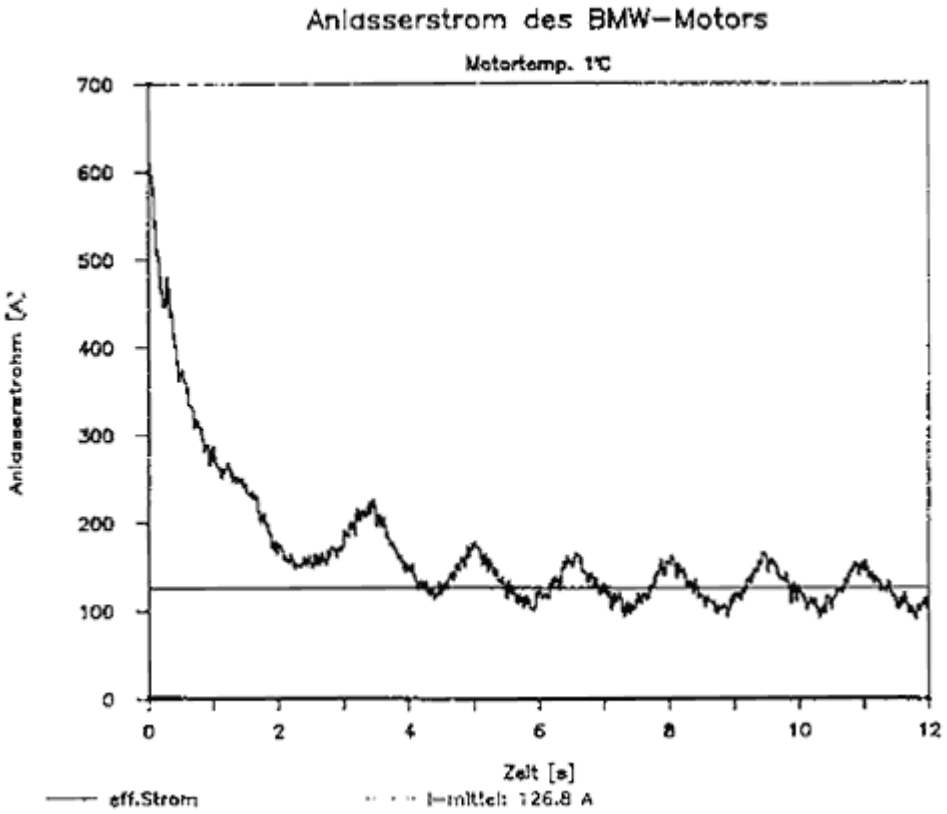

Figure 3: Current of a starter (BMW) at 1°C [2]

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Figure 3 shows the current of a starter at a temperature of 1°C. At the beginning we see a peak value of 600 A, which is important for the breakaway. The engine is moving from the static position (static friction) into a dynamic state (sliding friction).

After the breakaway, current will settle at an average of about 130 A and the oscillation of the current is produced by the compression strokes.

The time necessary to start an ICE is from 2 – 5 s. The speed of the ICE should reach at least 100 rpm [1].

Starting an ICE with a combination of battery, ultracaps and booster converter

For a diploma thesis completed at HTA Biel, the combination of battery, ultracaps and booster converter were used to start an ICE. The main goal was to reduce the weight of the starting unit (starter battery). Therefore, a small battery with a capacity of 7 Ah and a weight of about 2–4 kg was used instead of the standard lead acid starter battery which has a capacity of 40–50 Ah weighing 15 kg.

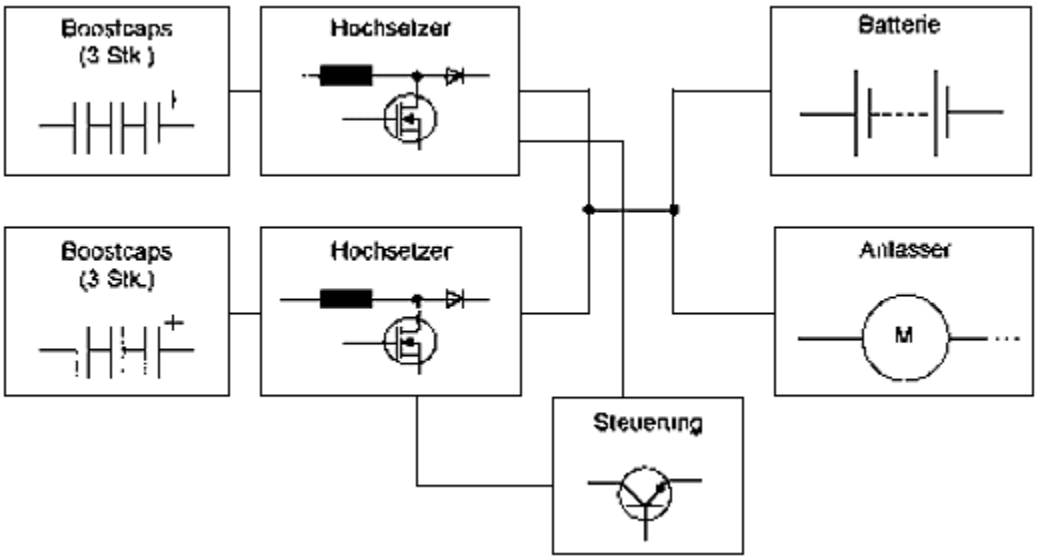

Figure 4: Block diagram of the starter unit

Two strings of 3 BOOSTCAP BCAP0005 with a capacitance of 800 F each are producing alternately a voltage of 10 V. The current within the test achieved a maximum peak of 106 A. The starting unit worked properly on the test bench.

The battery and the ultracap unit represent a current divider. Because the internal resistance of the power unit "ultracap and booster converter" was higher than the one of the battery, the peak value of the battery current was also

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higher. In combination with a battery containing a very low internal resistance this creates a problem.

Findings

With this solution the total weight of a starter unit can be reduced.

For a parallel connection of an ultracap unit and a battery, the problem of the current divider must be understood.

Starting an ICE with ultracaps

Students at HTA Biel also used a new generation of BOOSTCAPs to start the ICE without the booster converter.

For this purpose, a BOOSTCAP BCAP0007 was used with the following specifications [5]; capacitance = 1400 F, working voltage of 2.5 V and a maximum series resistance of 1.6 mΩ.

Five BOOSTCAPs were built in serial connection to a starter unit. Each BOOSTCAP has a 1 kΩ resistor in parallel connection. The whole unit weighed 1.7 kg (as compared to a lead-acid starter battery: ~15 kg).

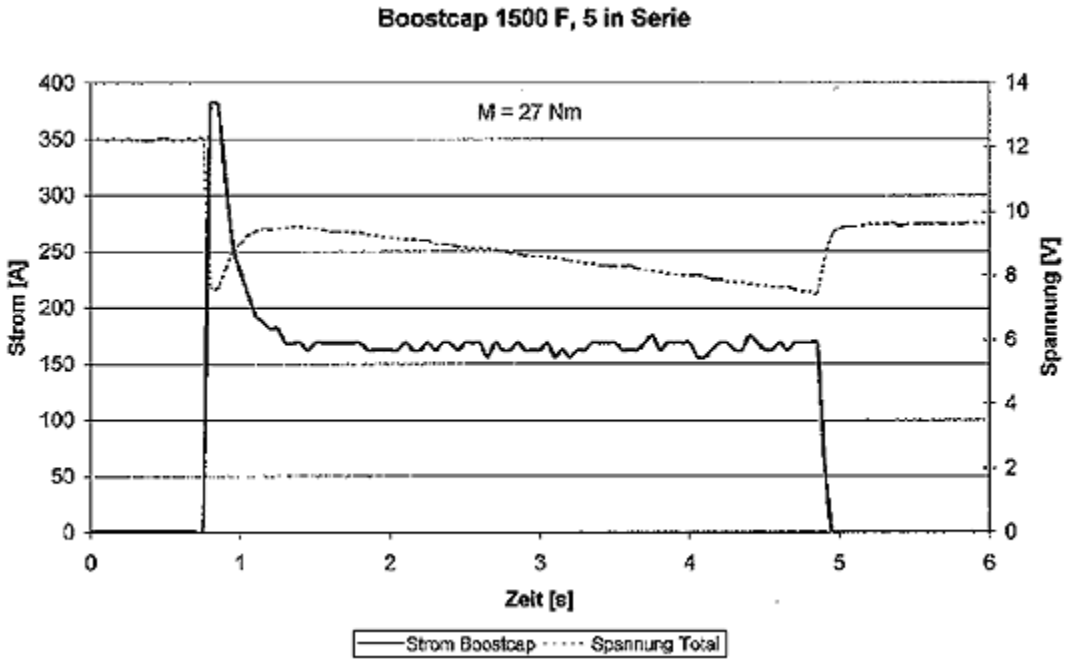

Figure 5: Current and voltage of a 1 kW starter motor measured on the test bench of HTA Biel [4]

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Because of the low internal resistance, we achieved good results both on the test bench and on a real vehicle. There is enough energy for multiple starts; with an ICE at about 20°C over ten starts were done.

Findings

BOOSTCAPs are able to start an ICE.

The weight of a starting unit with ultracaps is about 1.7 kg.

Because the total cycle life should be much higher than the one of a lead acid starter battery, this solution is very interesting for:

- ICE for stationary use
- tool for starting aid (TCS, AAA, garage)

Abbreviations Used

BOOSTCAP: double layer capacitor produced by Maxwell Technologies, Inc.

HTA: Hochschule für Technik und Architektur. Now known as HTI, Hochschule für Technik und Informatik

ICE: internal combustion engine

Ultracap: double layer capacitor

References

[1]Bosch: Kraftfahrtechnisches Taschenbuch, 23. Auflage, Vieweg-Verlag, ISBN 3-528-03876-4

[2]Marolf E. / Schwab B.: Anlassdrehmoment eines Motors (BMW), IS Biel, Abteilung Automobiltechnik, Wahlfacharbeit 1993

[3]Donatucci Domenico: Boostcap, HTA Biel-Bienne, Abteilung Automobiltechnik; Diplomarbeit 1999

[4]Bütikofer S.; Streit A.: Anlassen mit Boostcap; HTA Biel-Bienne; Abteilung Automobiltechnik; Projektarbeit 2000

[5]Maxwell Technologies, Inc.: Data sheet

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