SERIES SWITCHING MOTOR CONTROLLER

A new architecture electric vehicle controller

Eric Gullichsen
g@pataphysics.to

US8386102

SERIES SWITCHING MOTOR CONTROLLER

Simple

Inexpensive

Efficient

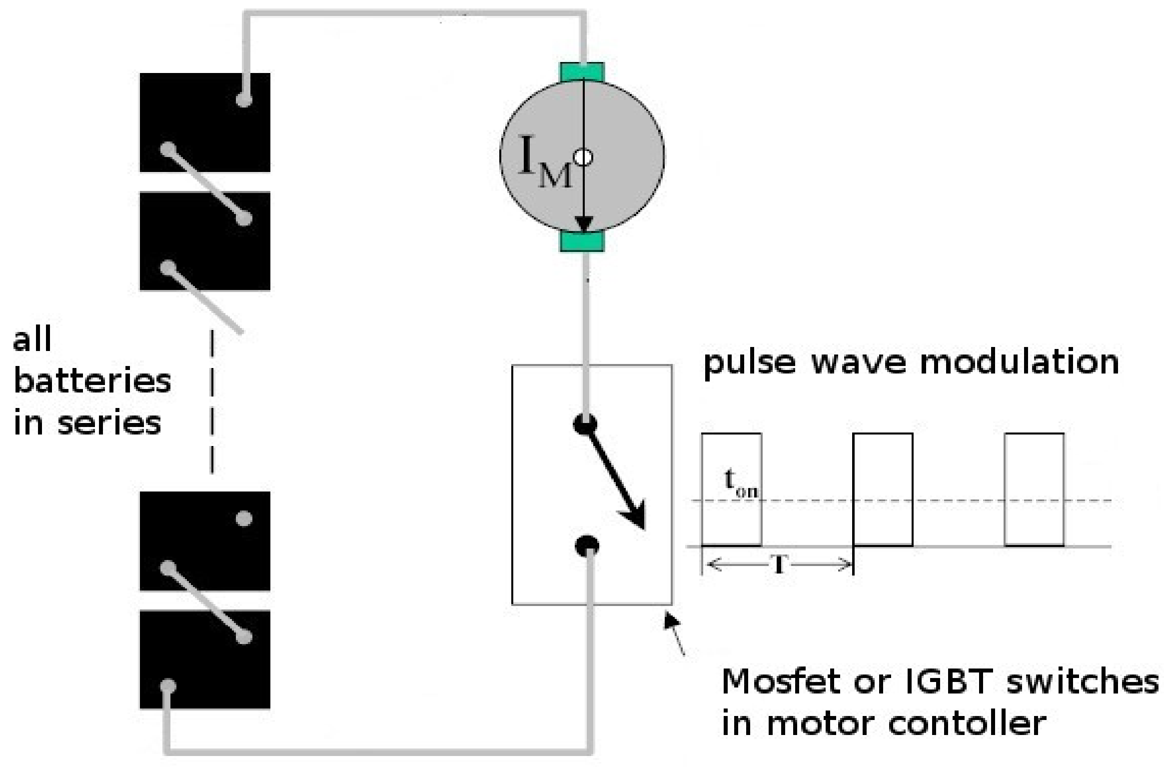
Robust

Very different from existing technology

US Patent 8386102

Conventional EV architecture

- All batteries hardwired in series
- PWM chopper (or multiphase equivalent)



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Conventional EV architecture

Disadvantages of conventional technology:

- ► Complex and expensive
- ► Switching losses (requiring cooling systems and yet more complexity)
- ► Fragile, single point of failure
- ► Cascading failure mode

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Conventional EV architecture

Very high power, switched at high frequency by tiny semiconductor junctions.

"Putting this all together, it is amazing to consider that a bunch of tiny pieces of silicon, totaling less area than a business card, can turn on and off tens of thousands of times per second, and control the flow of over 900 amps of current to the Roadster motor."
(http://my.teslamotors.com/roadster/technology/power-electronics-module)

Series Switching Controller

A new and radically different approach:

"A computer-controlled switching system activates switches to add/remove discrete battery modules from a series string.

An algorithm decides which batteries should be switched into the power circuit."

(US Patent 8386102)

Series Switching Controller

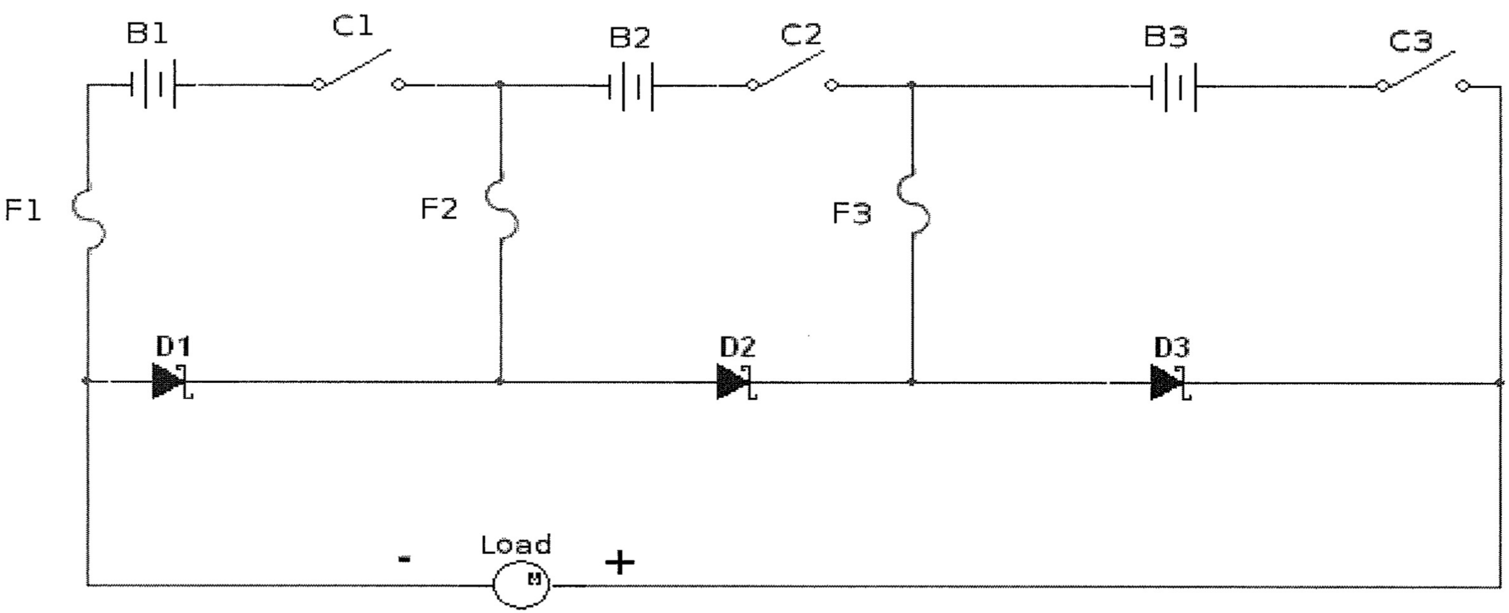

Fig. 3

Advantages of patented technology

- Simple
- Very low-cost components (electromechanical)
- No high frequency switching
- Distributed architecture
- Completely modular
- Failure tolerant
- Safe, fully optoisolated

Advantages of patented technology

- Highly efficient: needs no active cooling

  100% efficient at full throttle

- Arbitrary operating voltage, no current limit
- Achieves both top and bottom cell balancing

  Top balancing:

  One shunt regulator per cell, switches in a resistive load to dissipate cell charging current

  Bottom balancing:

  Switching algorithm equalizes rate of discharge of all modules

Advantages of patented technology

- Cost Savings through component elimination:

  No need for accessory battery

  (Use any battery for 12 volt power.)

- Elimination of battery charger:

  In semiconductor implementations, series string switching to phase match rectified AC charging input

First Proof of Concept Implementation

Impractical due to Peukert's law

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Switcher Mark 5: Lithium Iron battery and Ultracapacitor

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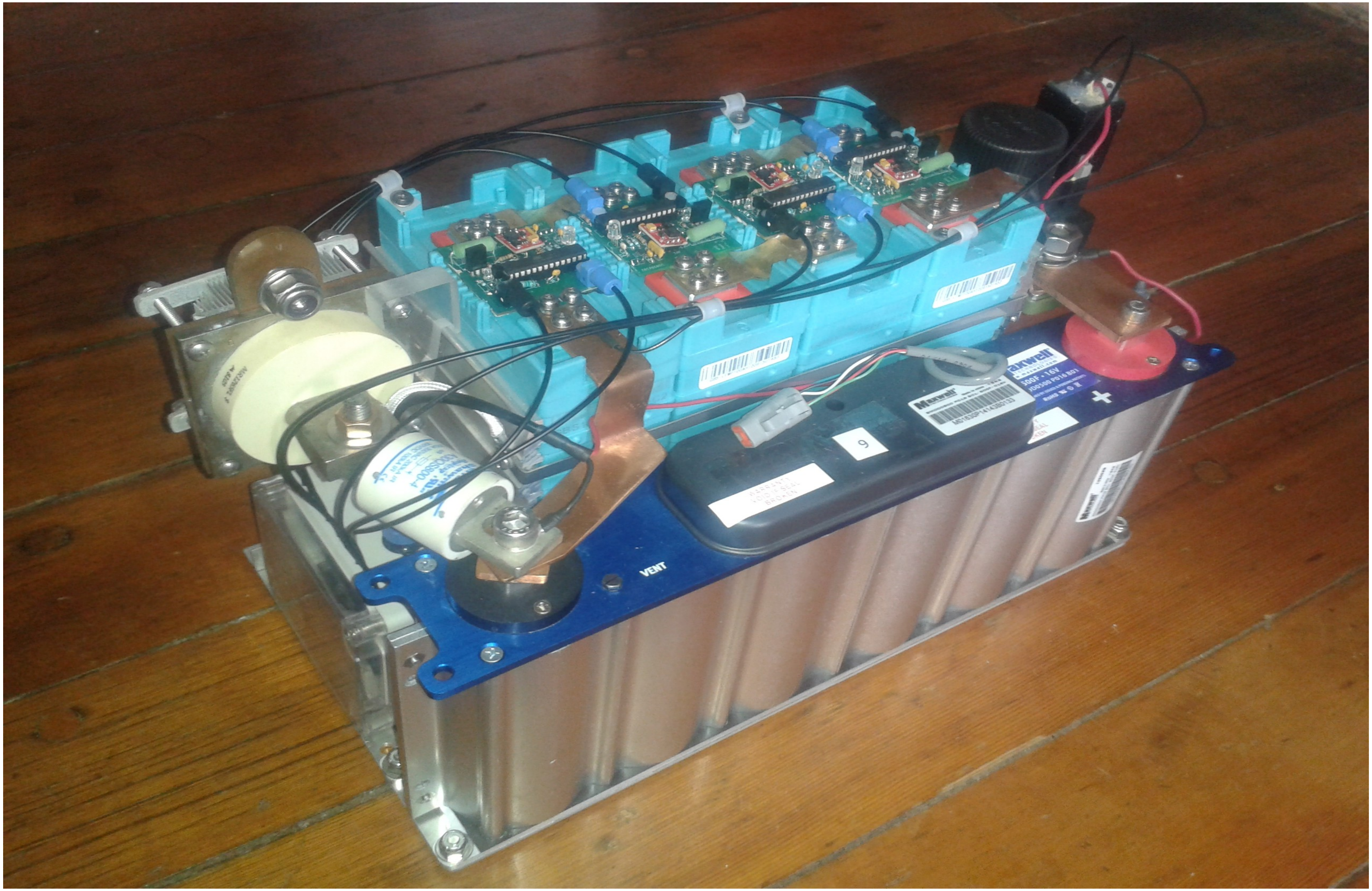
Switcher Mark 5: Lithium Iron battery and Ultracapacitor



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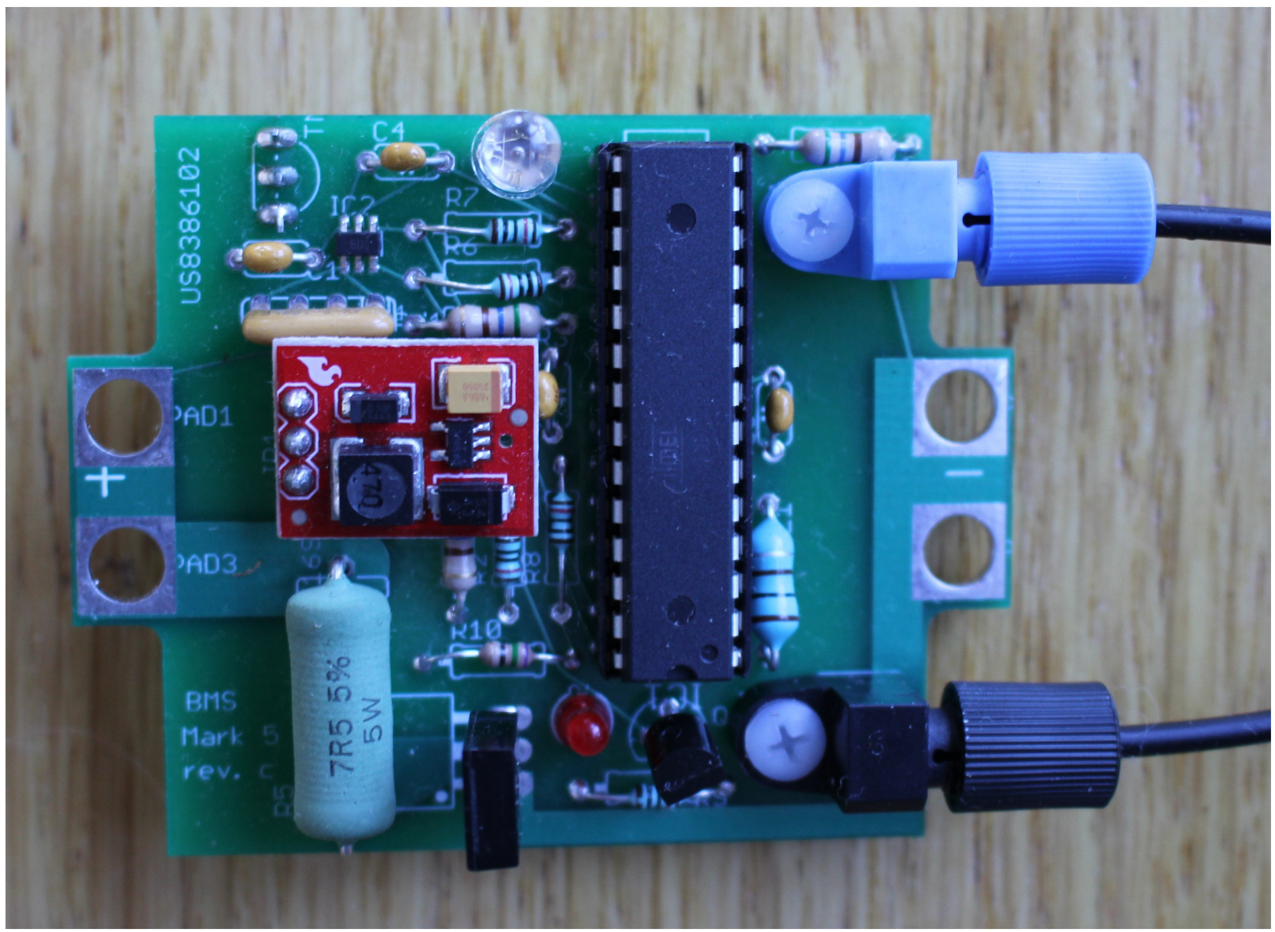
Switcher Mark 5: Lithium Iron battery and Ultracapacitor

Ultracapacitor passive parallelization

- GBS LiFeMnPO4 battery (12.8 V, 100 Ah, 10 C)
- Maxwell BMOD0500 ultracapacitor (16 V, 500 F)
- BMS: One micro per cell, to measure voltage and temperature
- Low-cost plastic optical fiber data link to mux
- Xbee 802.15.4 radio link to main computer

BMS Subsystem

One per cell



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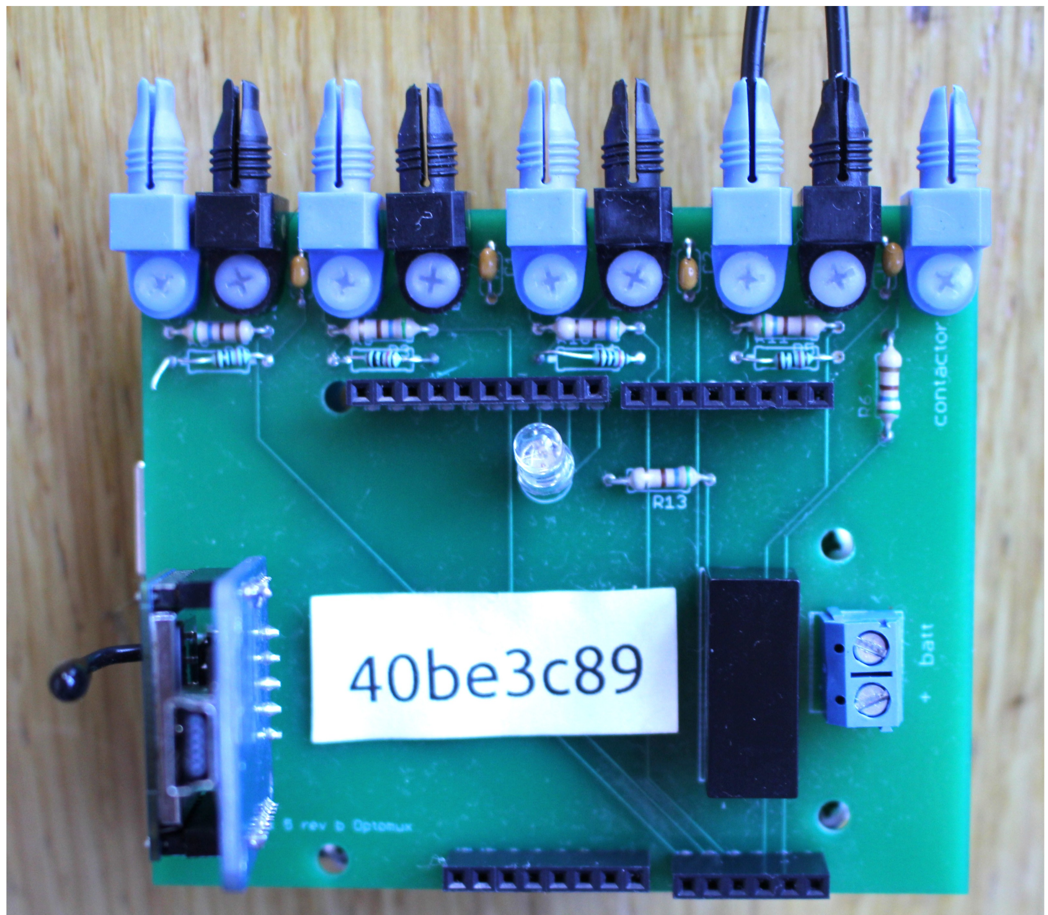
Optical Mutiplexer and Xbee link

One per module



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Optional Ultracapacitor

Ultracap used in pulsed mode

Battery and ultracap have similar internal resistances (~2 millohm)

Hardwired in parallel with the battery, no buck/boost converter needed.

"Power and Life Extension of Battery Ultracapacitor Hybrids"
(IEEE Transactions on Components and Packaging Technologies, Vol. 25, No. 1, March 2002)

Optional Ultracapacitor

$$i_{UC}(t) = \frac{(V_{UC_0} - V_B) + I_o R_B}{R_B + R_{ESR}} e^{-t/\tau}$$

and $$i_B(t) = I_o - i_{UC}(t)$$

where:

V_{UC_0} = the initial UC voltage

$R_B = R_C + R_{OV}$

$\tau = C(R_B + R_{ESR})$

C = Capacitance of the UC

V_O = Output Voltage, constant

V_B = Battery Voltage, constant

I_o = Output current, constant

$i_{UC}(t)$ = UC current

$i_B(t)$ = Battery current

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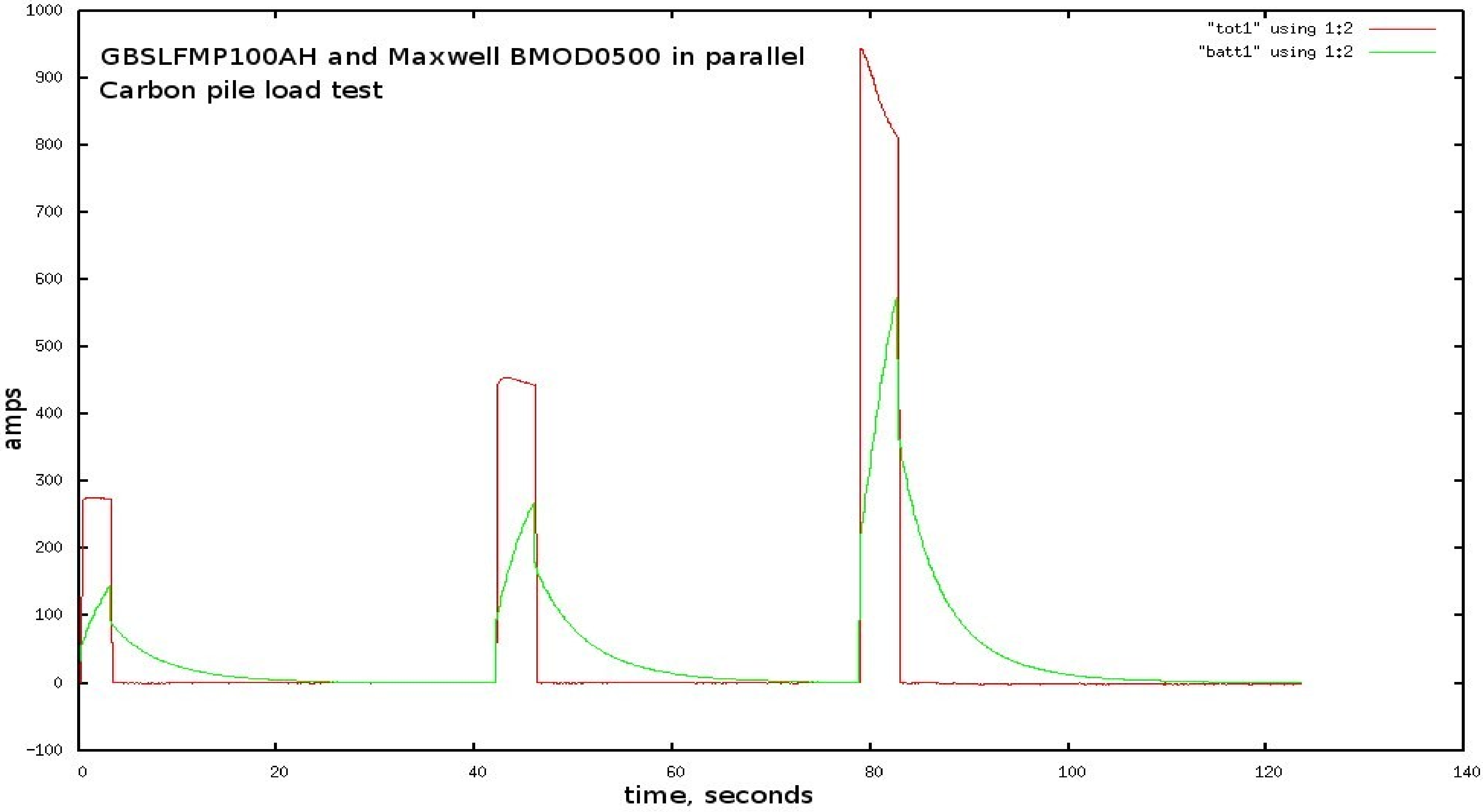
Optional Ultracapacitor



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Optional Ultracapacitor

"We have analytically demonstrated that a battery ultracapacitor hybrid power source can supply a pulsed load with higher peak power, smaller internal losses and greater discharge life of the battery, than can the battery-powered system alone."

Conclusion

Inexpensive, simple, reliable, efficient controller.