Transient Recognition Control for Fuel Cell Systems

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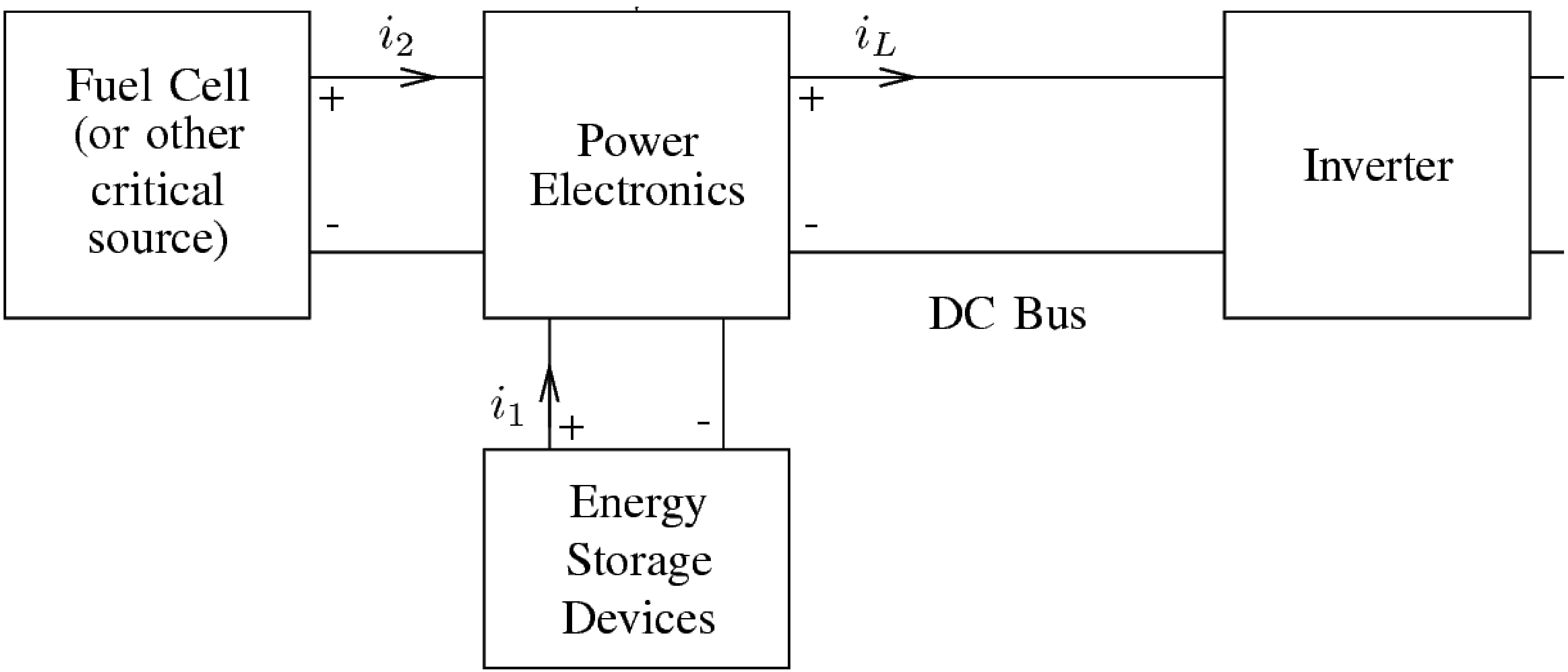
Outline

- What's the problem?
- Transient recognition control
- Sequential cluster-weighted modeling
- Simulation results
- FPGA implementation
- FPGA results
- Power electronics
- Future directions

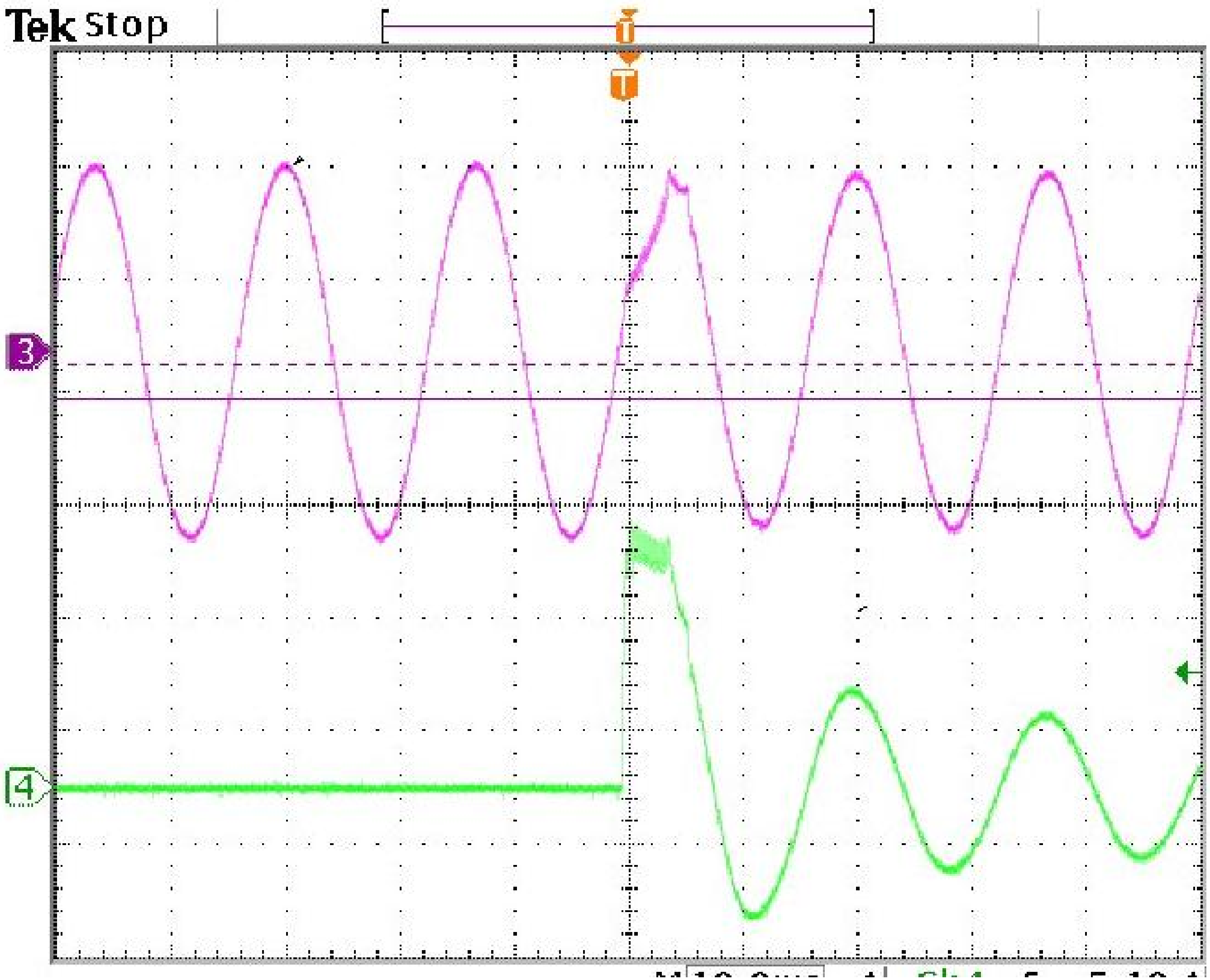


Allocation of power from different sources should be a *control* decision

Transient Recognition Control
The load following problem

Inverter output 500W FC

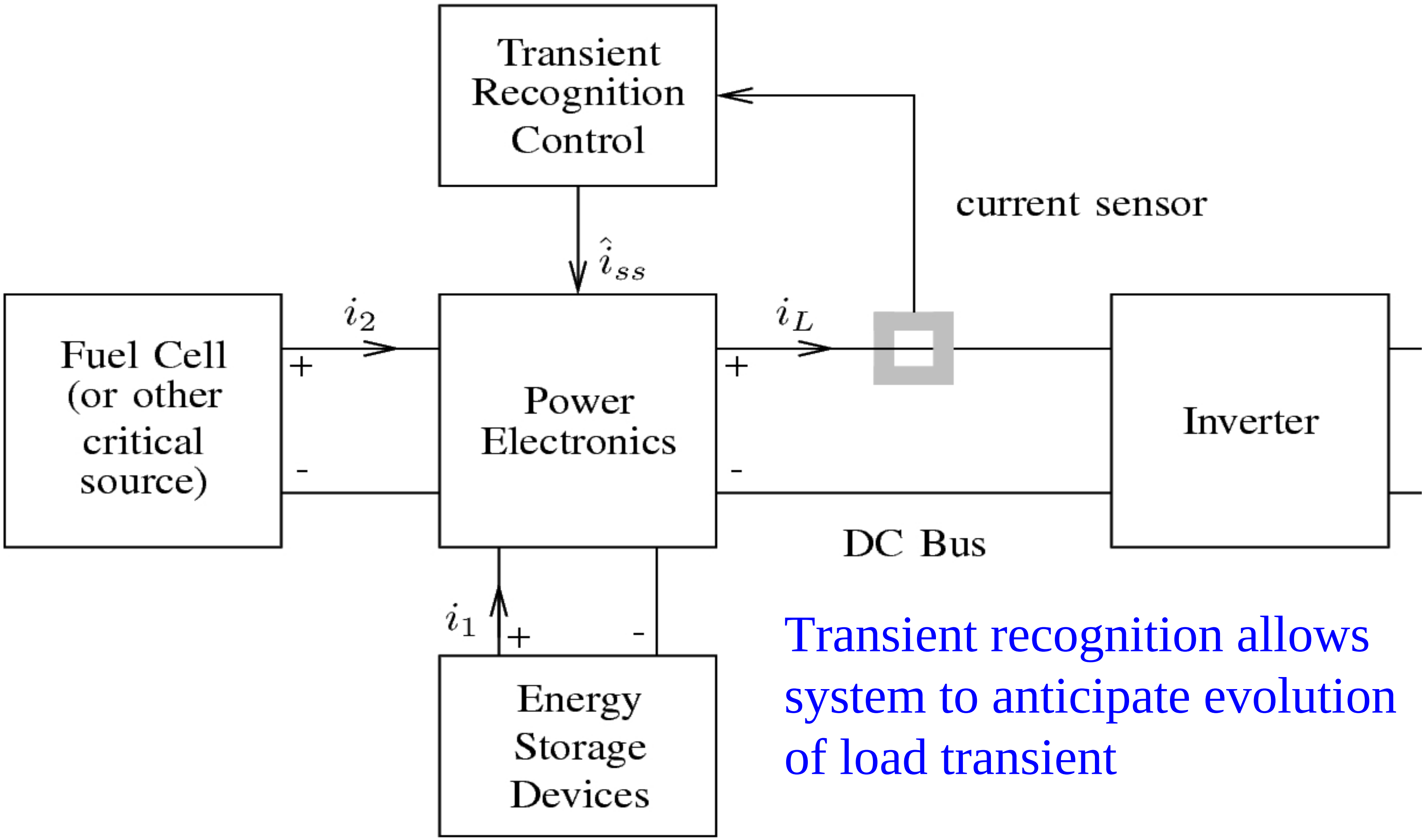
Current, 100W lightbulb



- Transients typically impulsive
- Transient excitation may degrade FC
- Transient distortion may cause load/FC interaction

Conventional controls are a compromise solution

Transient Recognition Control



Transient recognition allows system to anticipate evolution of load transient

Transient Recognition Control for Hybrid Fuel Cell Systems, IEEE Transactions on Energy Conversion

$$\langle \hat{y} | \vec{x}_n \rangle = \frac{\sum_{m=1}^{M} f(\vec{q}_m, \vec{\beta}_m) p(\vec{x}_n^{(1:K)} | c_m) P(c_m)}{\sum_{m=1}^{M} p(\vec{x}_n^{(1:K)} | c_m) P(c_m)}$$

$$\vec{q}_m = \left(\vec{x}_n^{(1:K)^T} \quad \vec{\mu}_m^{(K+1:D)^T} \right)^T$$

Prediction is sequential, probabilistic interpolation of local models

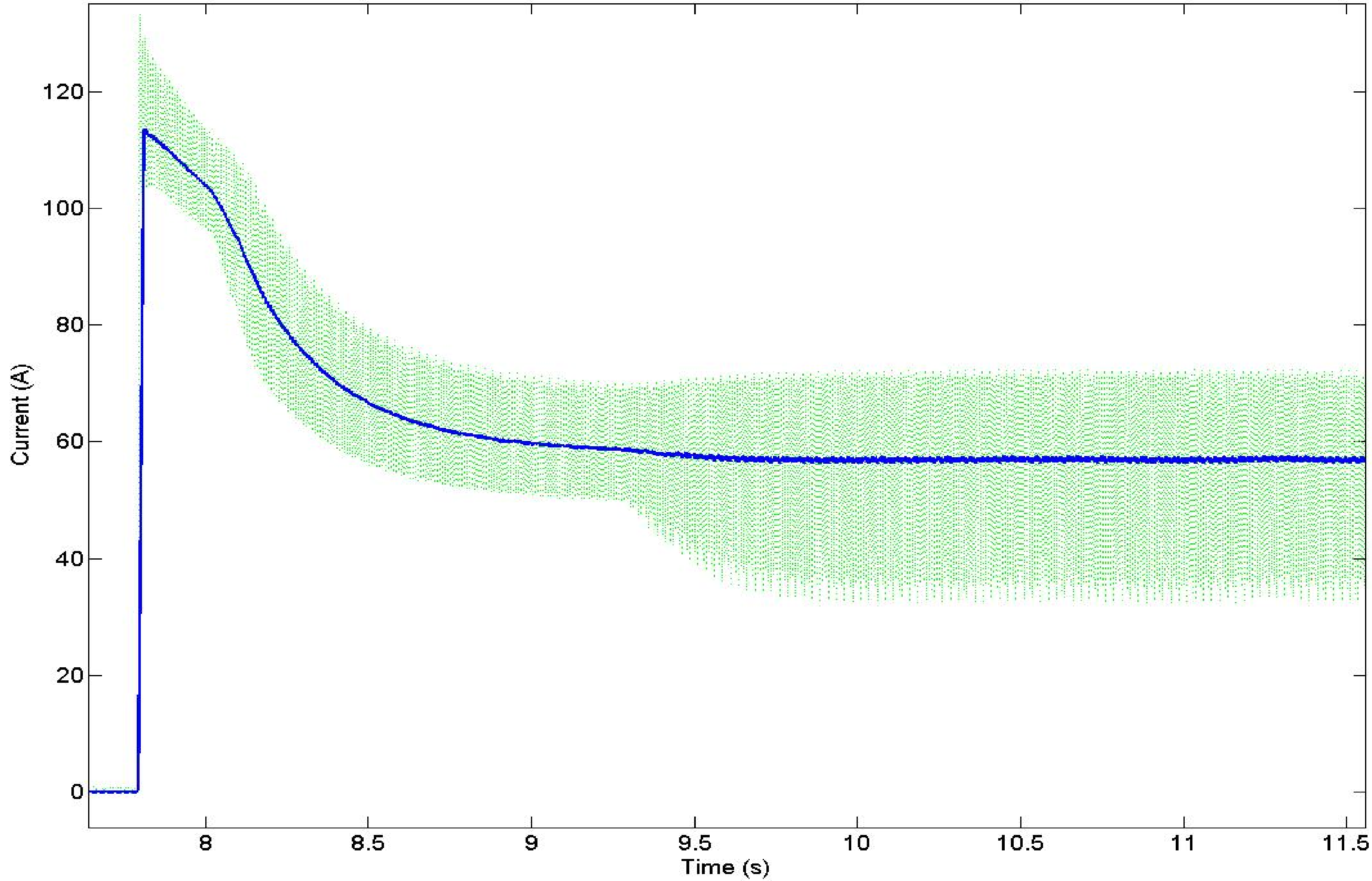
Transient Recognition Control
Sequential Cluster Weighted Modeling (SCWM)

$$f(\vec{x}_n, \vec{\beta}_m) = \vec{\beta}_m^T \cdot \vec{x}_n = \sum_{d=1}^{D} \beta_{m,d} \cdot x_{n,d}$$

$$p(\vec{x}_n | c_m) = \prod_{d=1}^{D} \frac{1}{\sqrt{2\pi\sigma_{m,d}^2}} \exp\left[\frac{-(x_{n,d} - \mu_{m,d})^2}{2\sigma_{m,d}^2}\right]$$

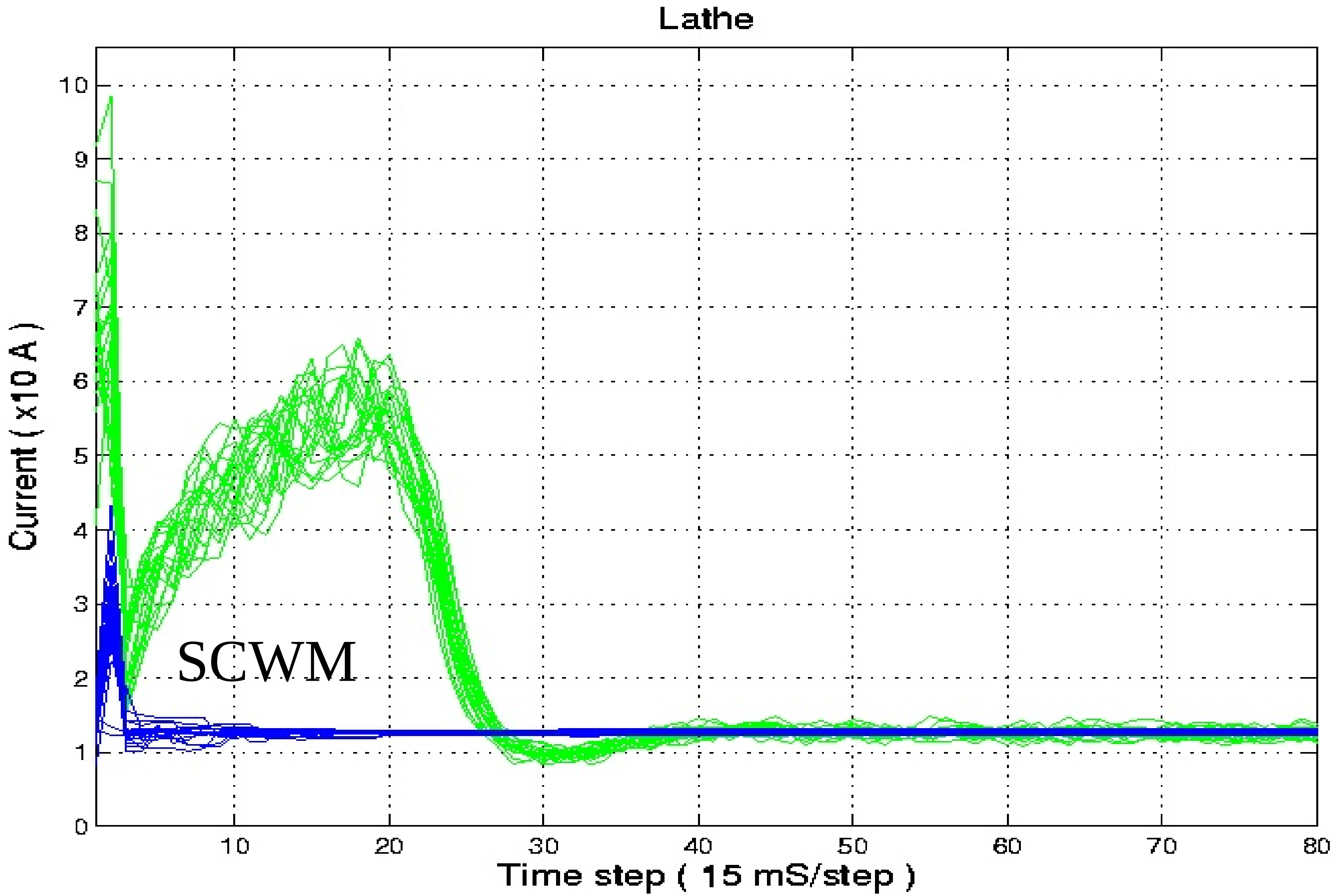
Update allows SCWM to adapt

Filtering inverter ripple



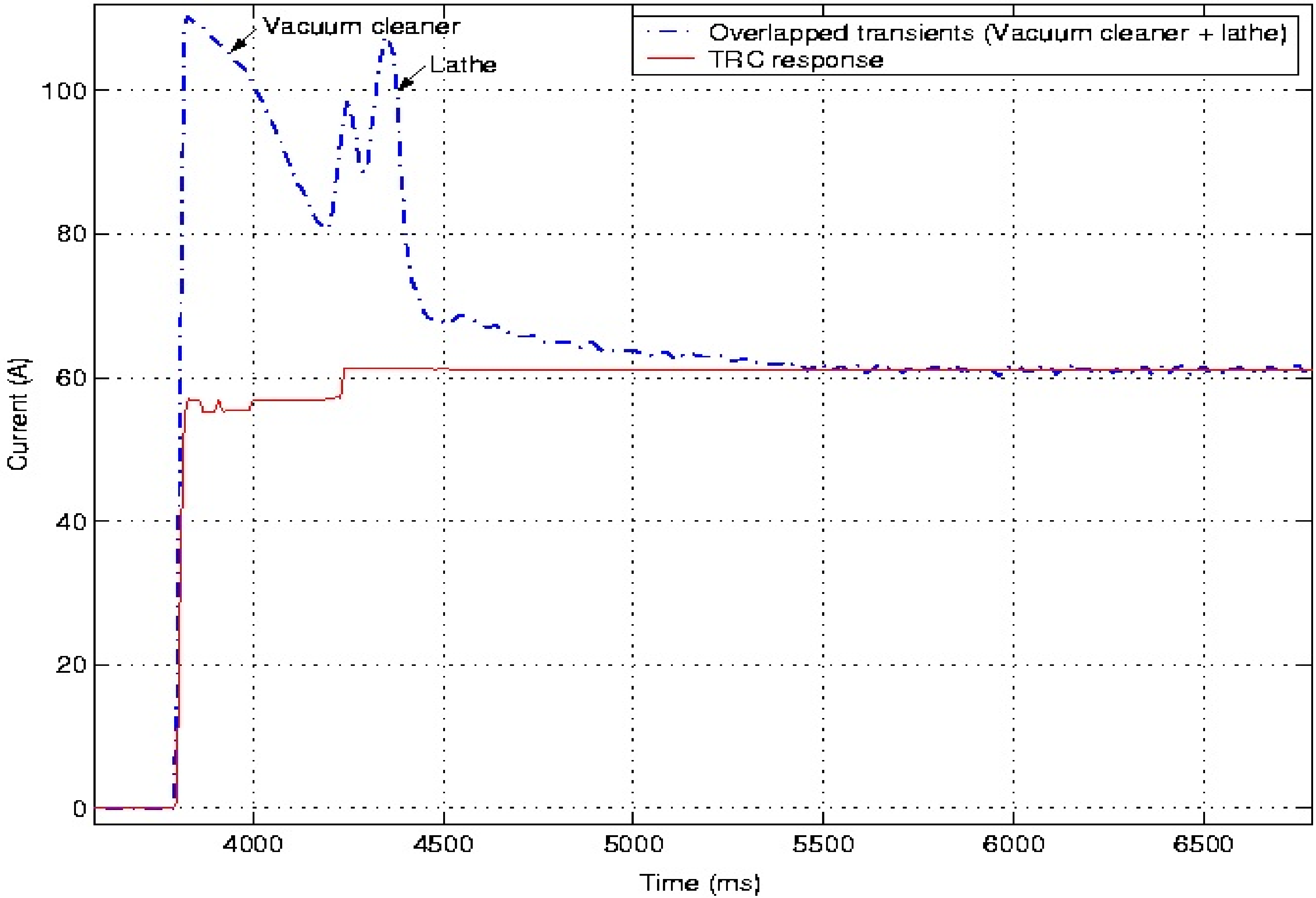
Pre-filtering eliminates inverter ripple

SCWM Lathe Transient Prediction

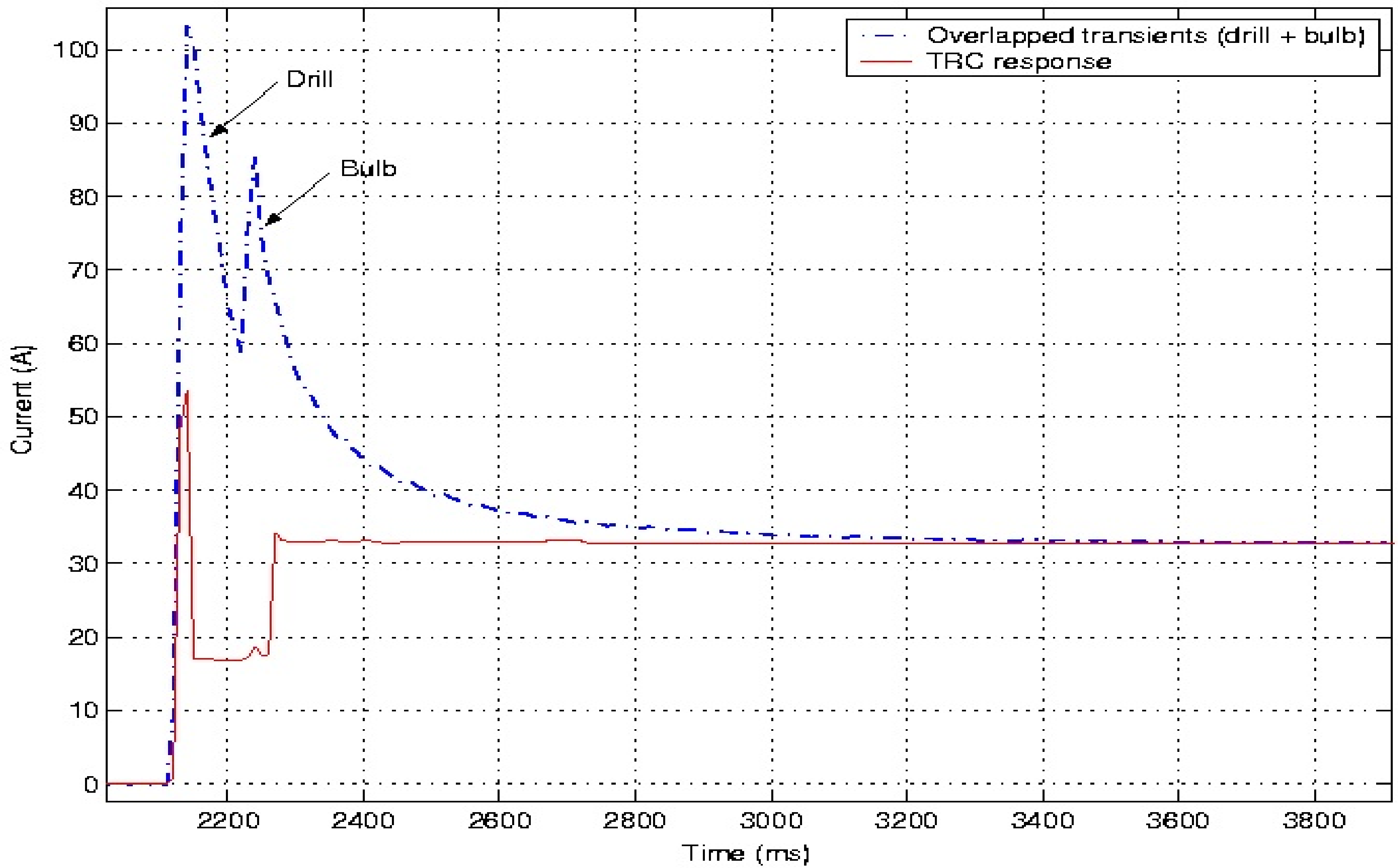


Physically similar load transients differ by scale factors

Transient Recognition Control
Transient overlap resolution

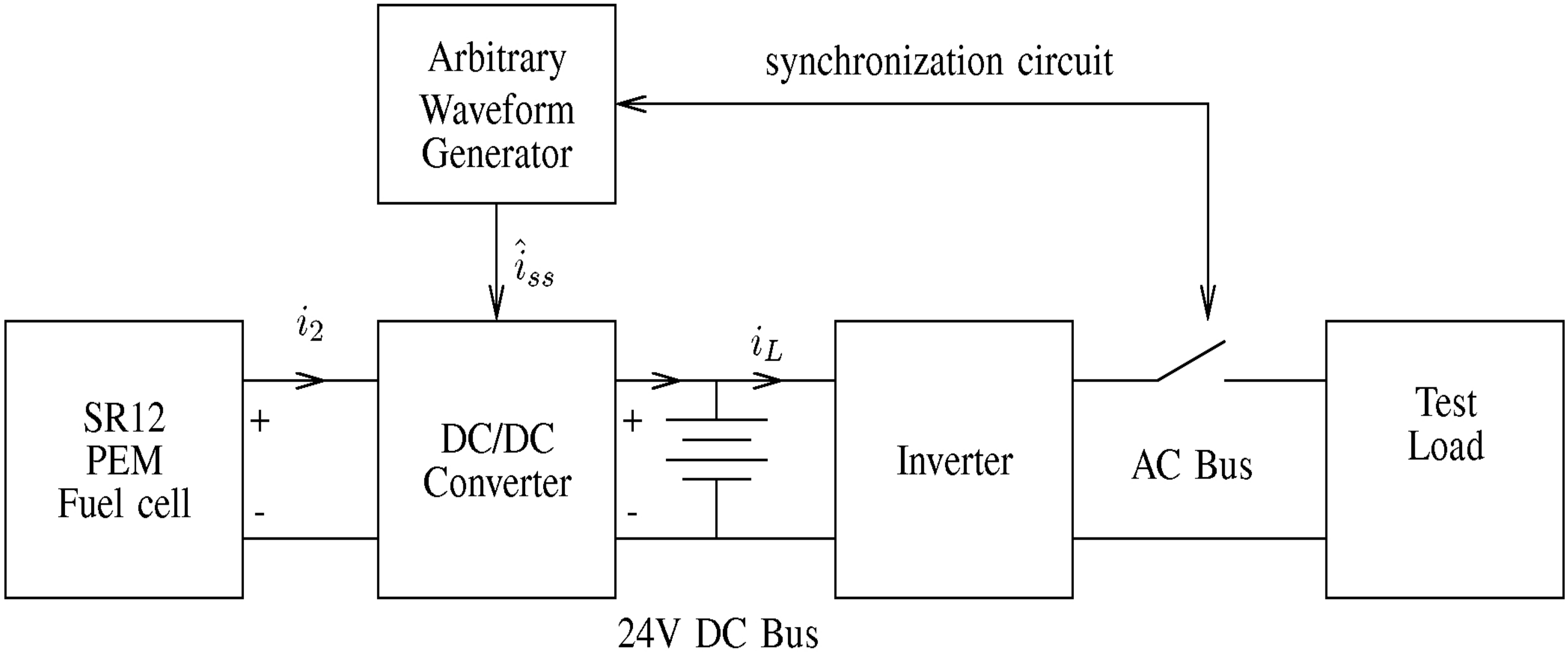


Transient Recognition Control
Transient overlap resolution



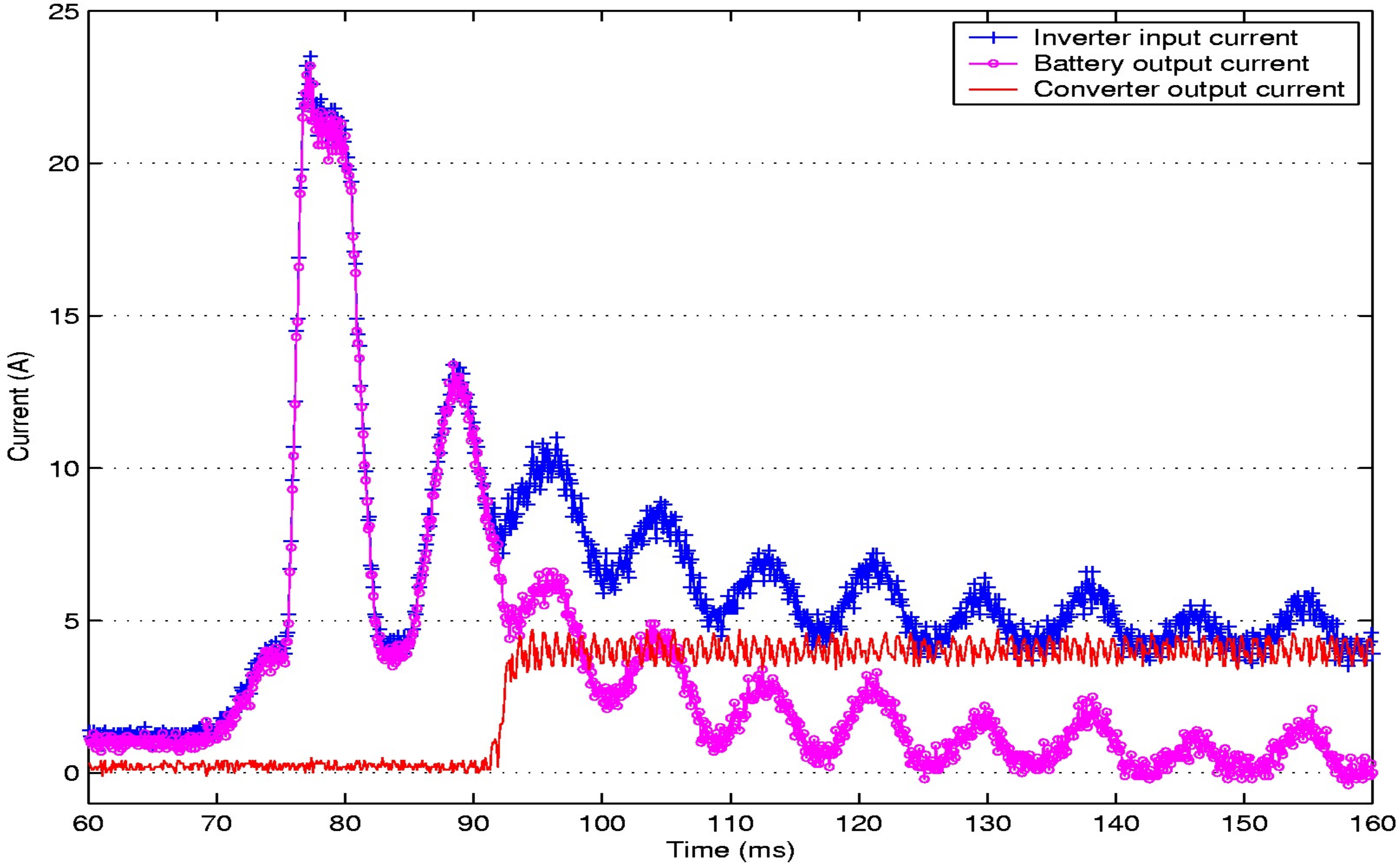
SCWM likelihood calculation helps resolve overlap

Transient Recognition Control
Test setup

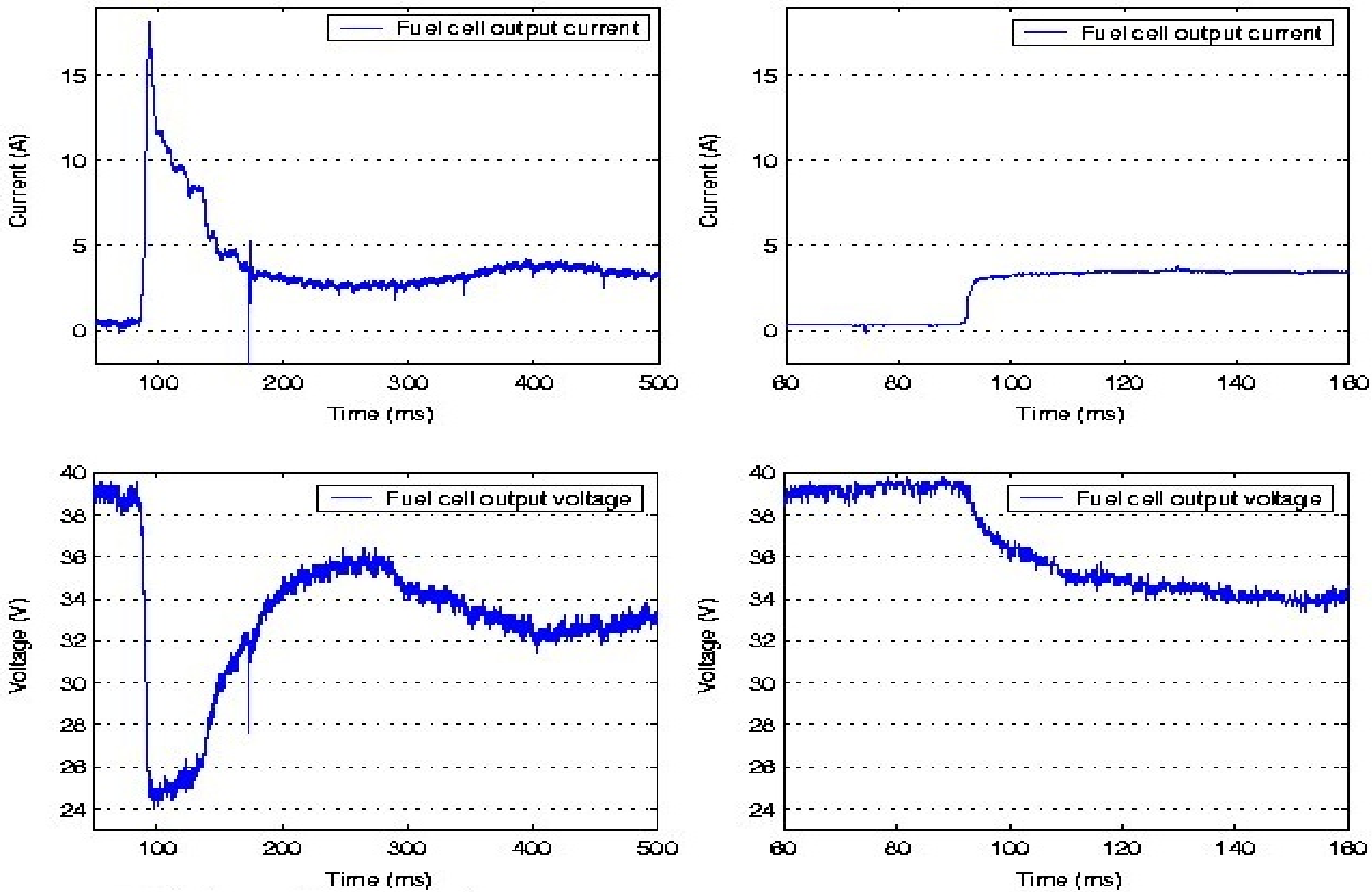


SCWM responses precomputed and stored in AWG

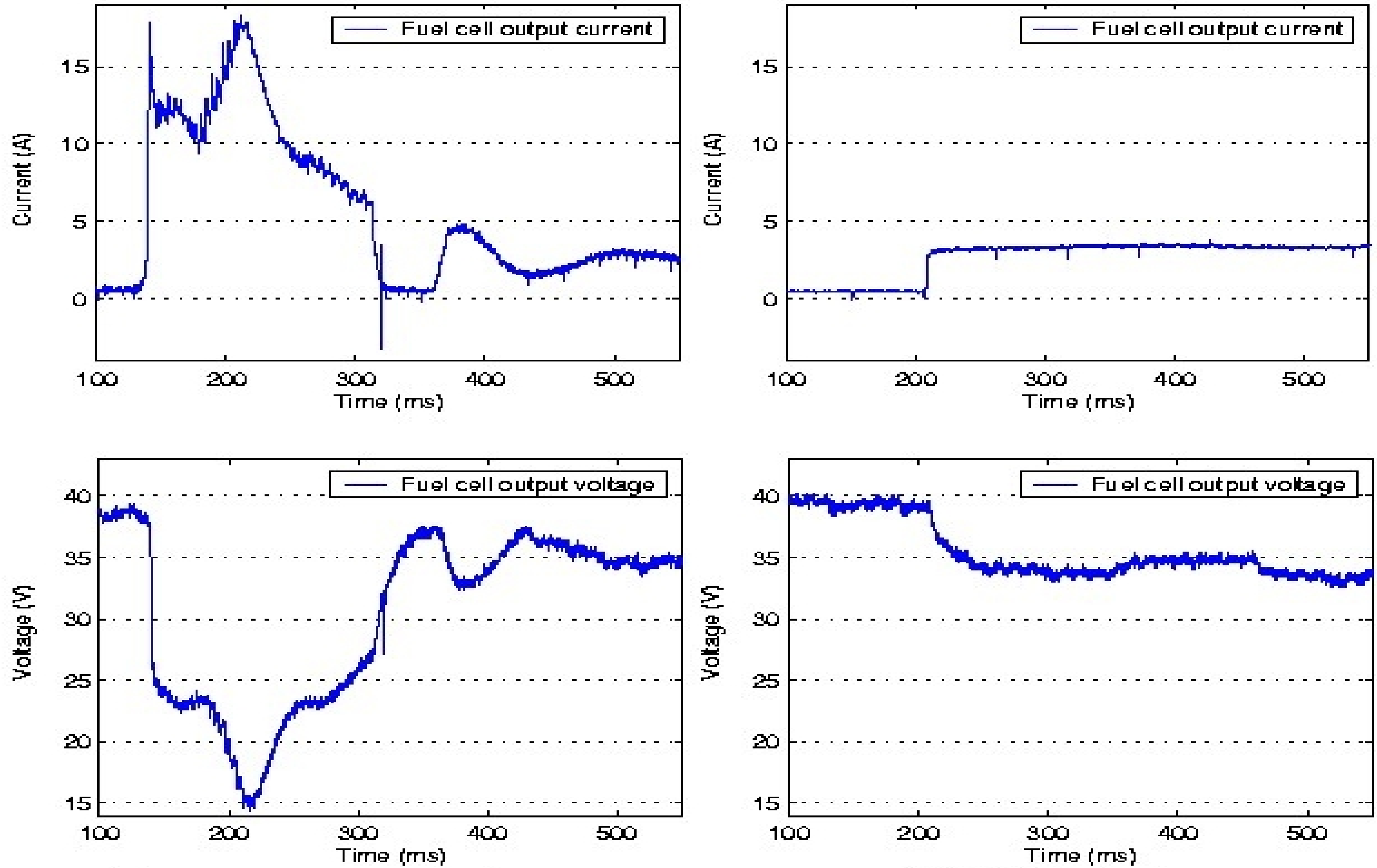
Transient Recognition Control
DC-link currents



Transient Recognition Control
Transient impact at fuel cell terminals

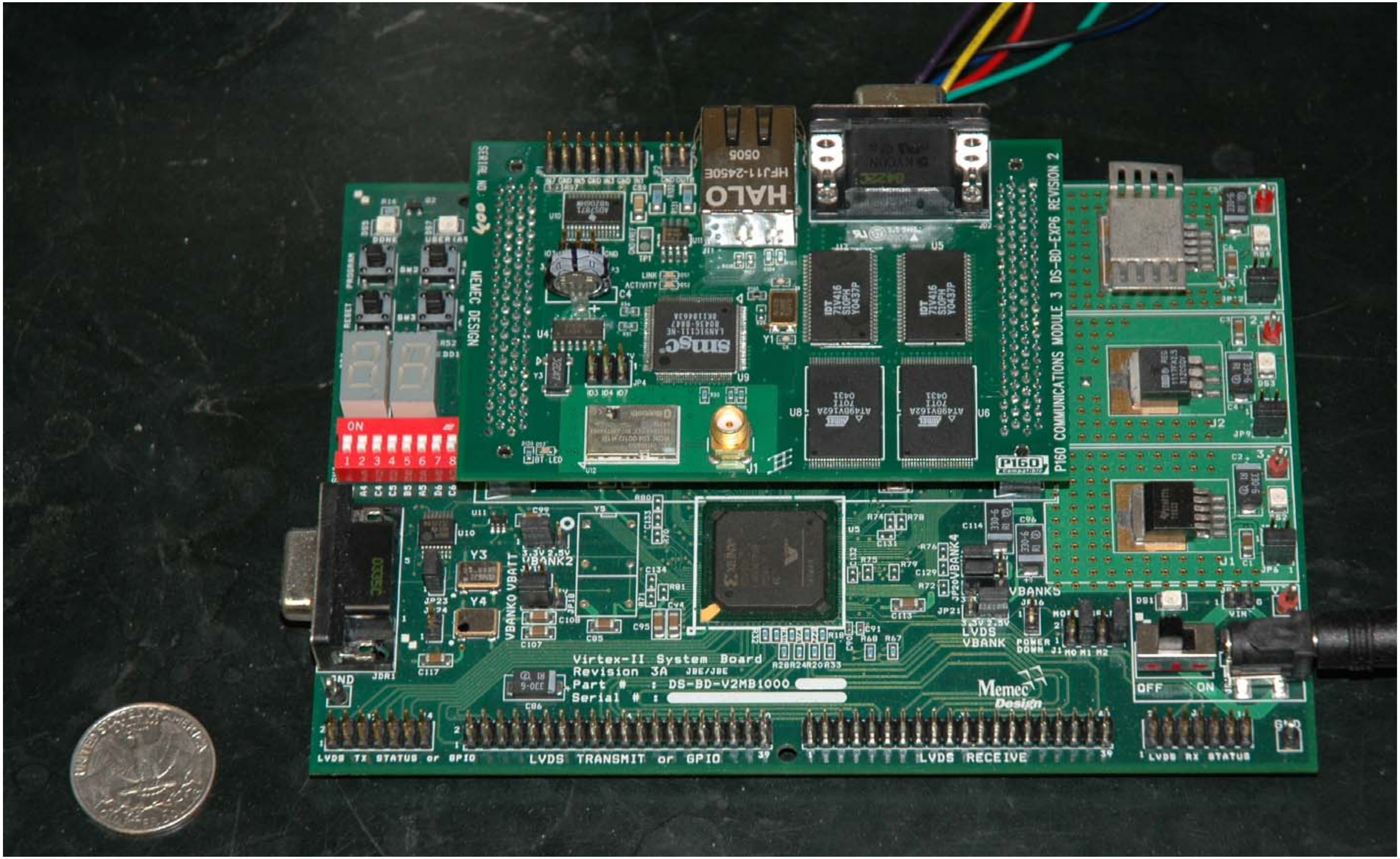


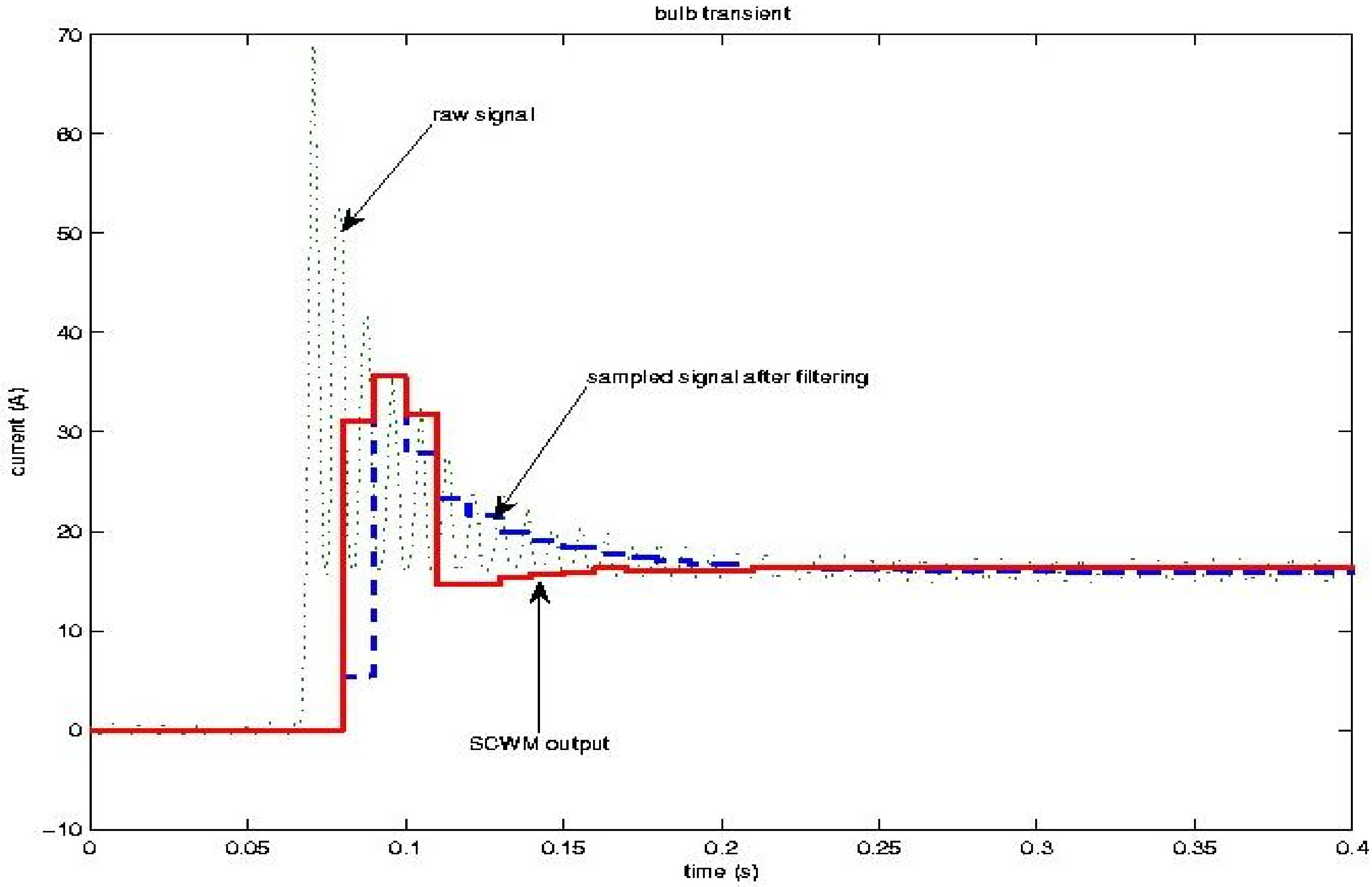
Transient Recognition Control
Transient impact at fuel cell terminals



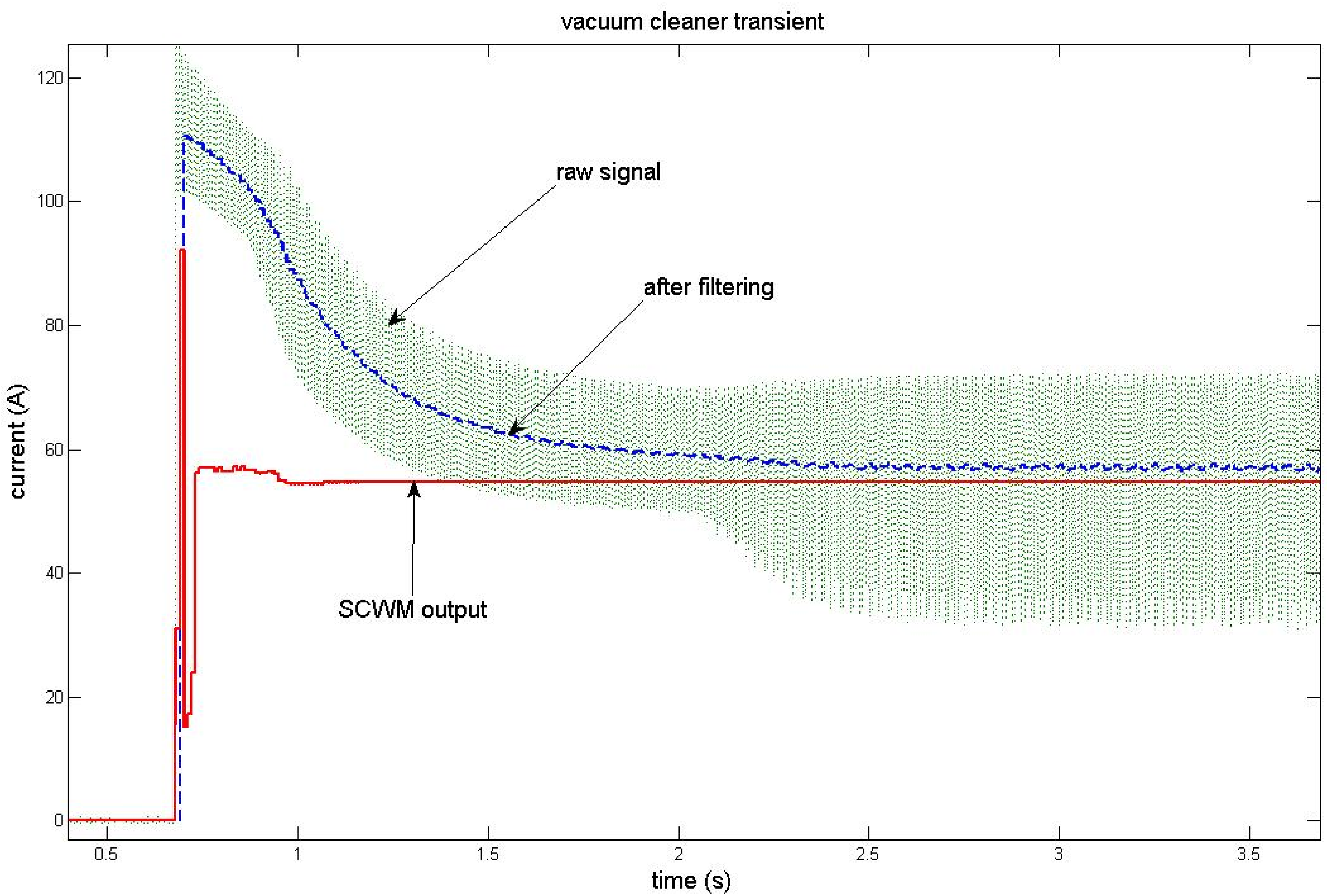
TRC mitigates transient effect at fuelcell terminals

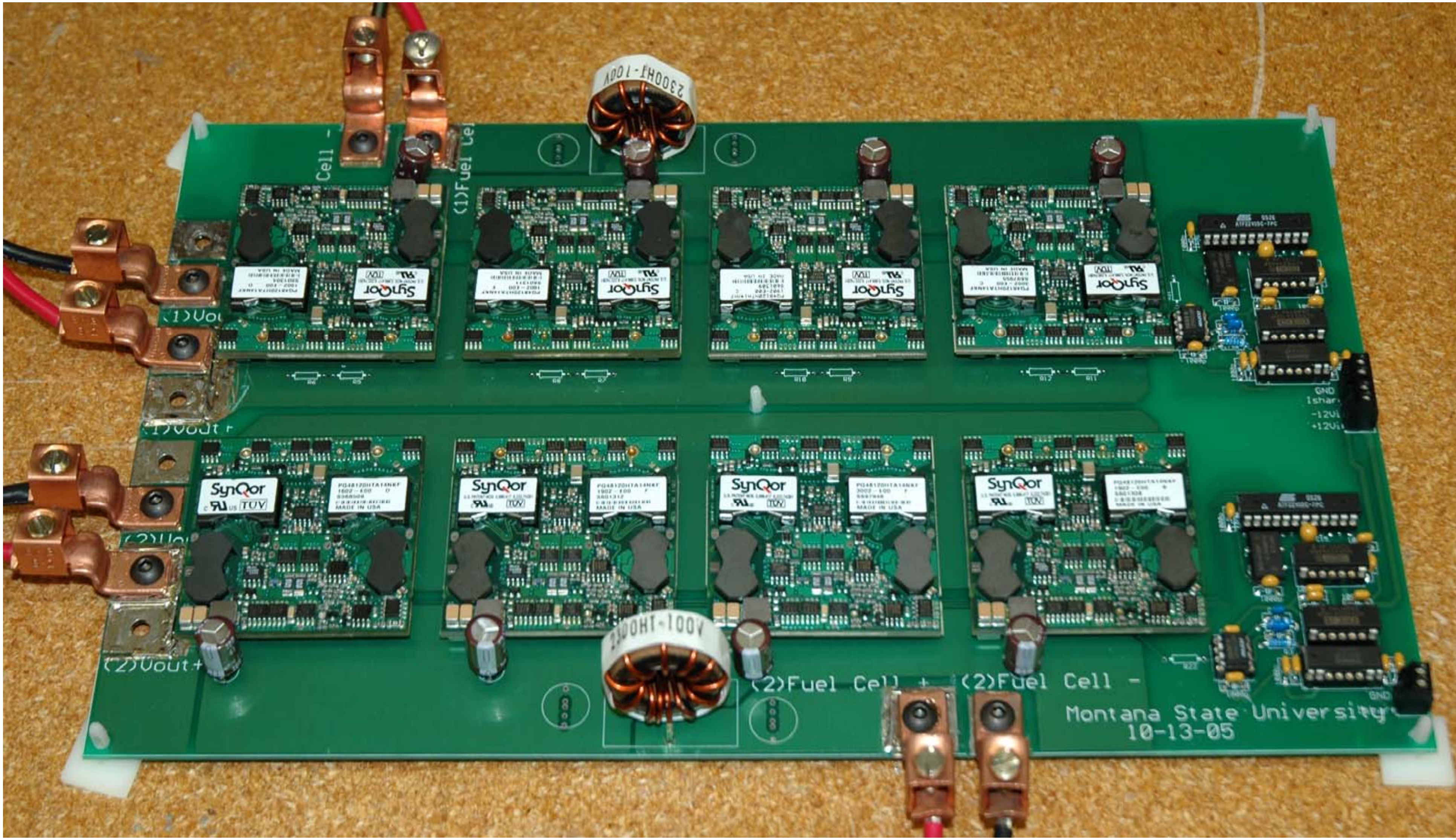
Transient Recognition Control
Virtex-II FPGA Implementation



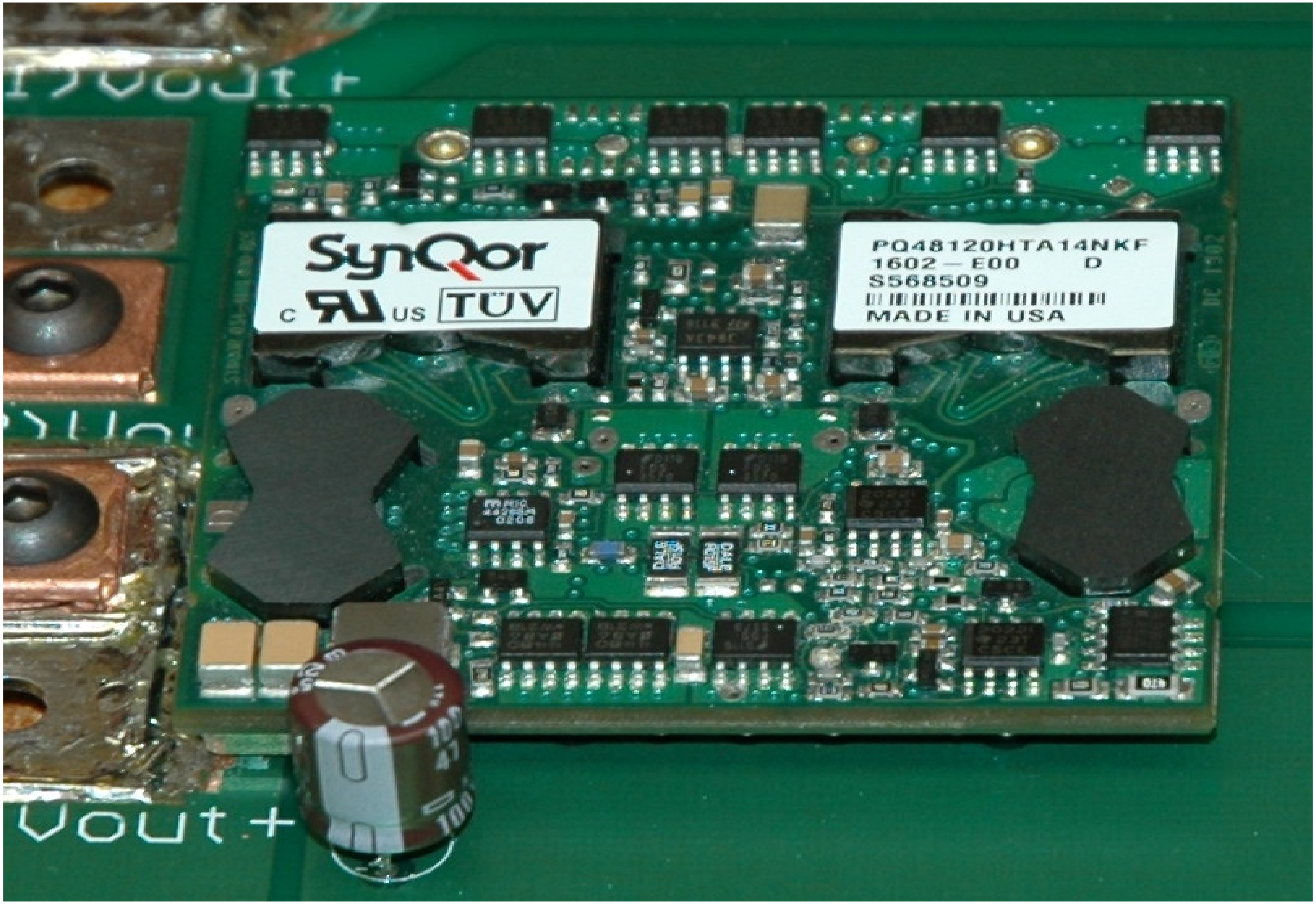

bulb transient
raw signal
sampled signal after filtering
SCWM output
current (A)
time (s)
70
60
50
40
30
20
10
0
−10
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4

Transient Recognition Control
Virtex-II Hardware Co-simulation



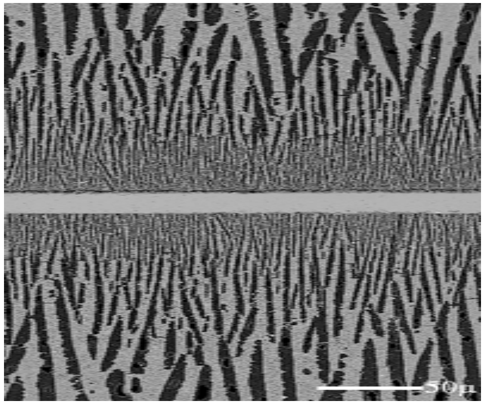


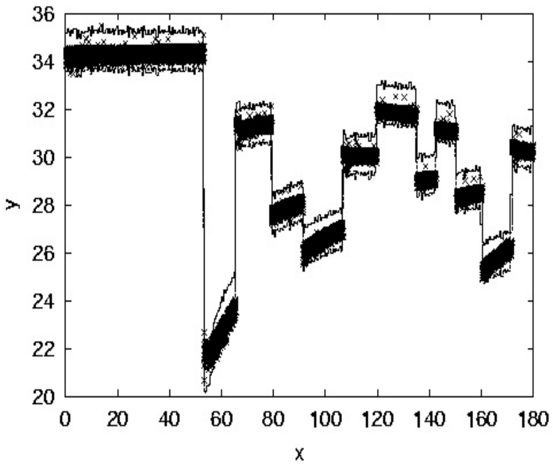
Current sharing control integrates with TRC.



500W in a half-brick, no heat sink

Full-stack simulator

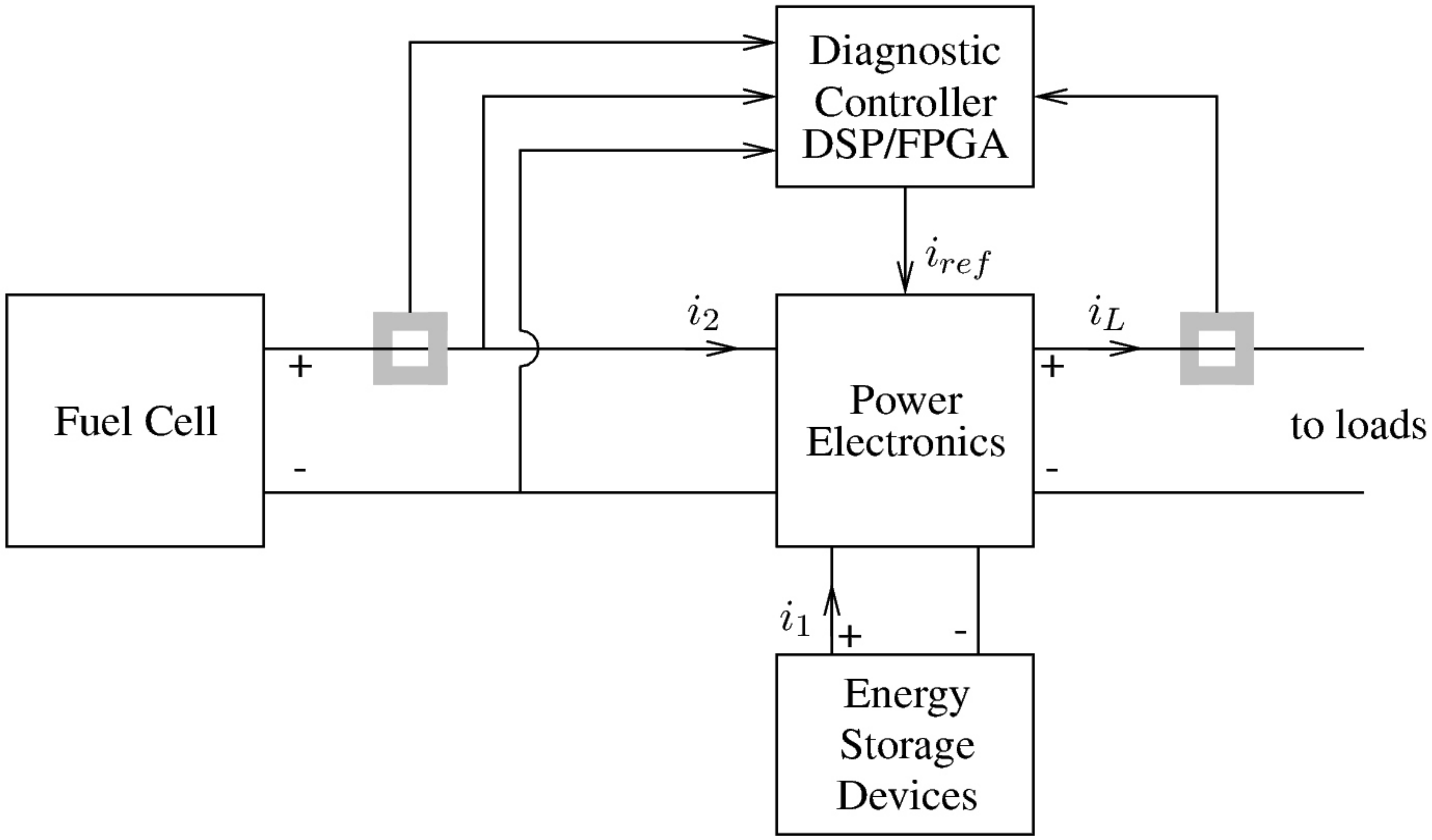




50V, 75A
3500 W
4-quadrant
> 100 kHz

Accelerated test platform for full-scale electronics and controls

Diagnostic control?



Continuously diagnose fuel cell and adapt control response

Closing thoughts

- TRC can mitigate transient effects at FC terminals
- SCWM is a useful model for implementing TRC
- TRC is feasible using FPGA techniques
- Simplified TRC?

Can appropriate controls ease materials/BOP problems?

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