DC-link Capacitor Evaluation

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Outline

- DC-Link Challenges in Traction Motor Drives
- Alternative DC-Link Approaches
- Summary

What is the Cost of Ripple Currents in a Traction Drive?

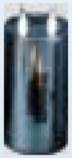
- Ripple effects the life and reduces the energy in the DC source (Battery, Fuel Cell)

- Ripple effects the performance/efficiency of the motor drive (inconsistent V_{in} = inconsistent performance)

- The capacitor provides a low impedance path for harmonics/transients (ripple)

Prime Drivers for Challenging Capacitor Requirements in Traction Motor Drives

- High inverter switching frequency – **easy filtering requirements**.
- Extended motor operation in the constant power region (six step) – **more difficult ripple (fundamentals 6th harmonic) requirements**.
- Highly transient load – **also requires high capacitance**.



FY04 Milestone

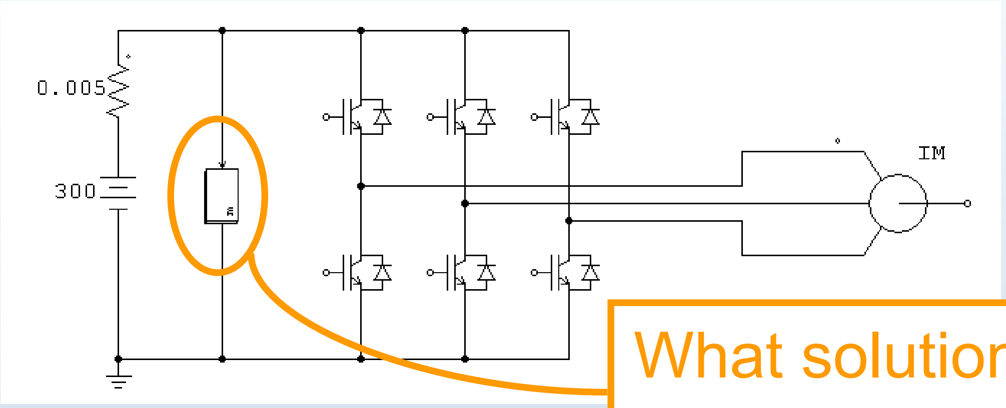
Objective: To assess subsystems' capability to meet DC-link capacitor performance, volume, weight & cost targets.

Milestone: Evaluate the performance of active filters to reduce the size/cost of capacitors/ DC-link.

Table 5. Desired DC Bus Capacitor Bank for Inverters

	2010 Typical Capacitor Bank Requirements
Capacitance, μF	2000+/- 10%
Voltage rating, VDC	600
Peak transient voltage for 50 ms	700
Leakage current at rated voltage, ma	1
Dissipation factor, %	<1
ESR, mohm	<3
ESL, nH	<20
Ripple current, amp rms	250
Temperature range of ambient air, °C	-40 to +140
Weight requirement, kg	10.8
Volume requirement, l	0.4
Cost	$30
Failure mode	Benign
Life @80% rated voltage	>10,000 hr, 20 amps rms, +85°C

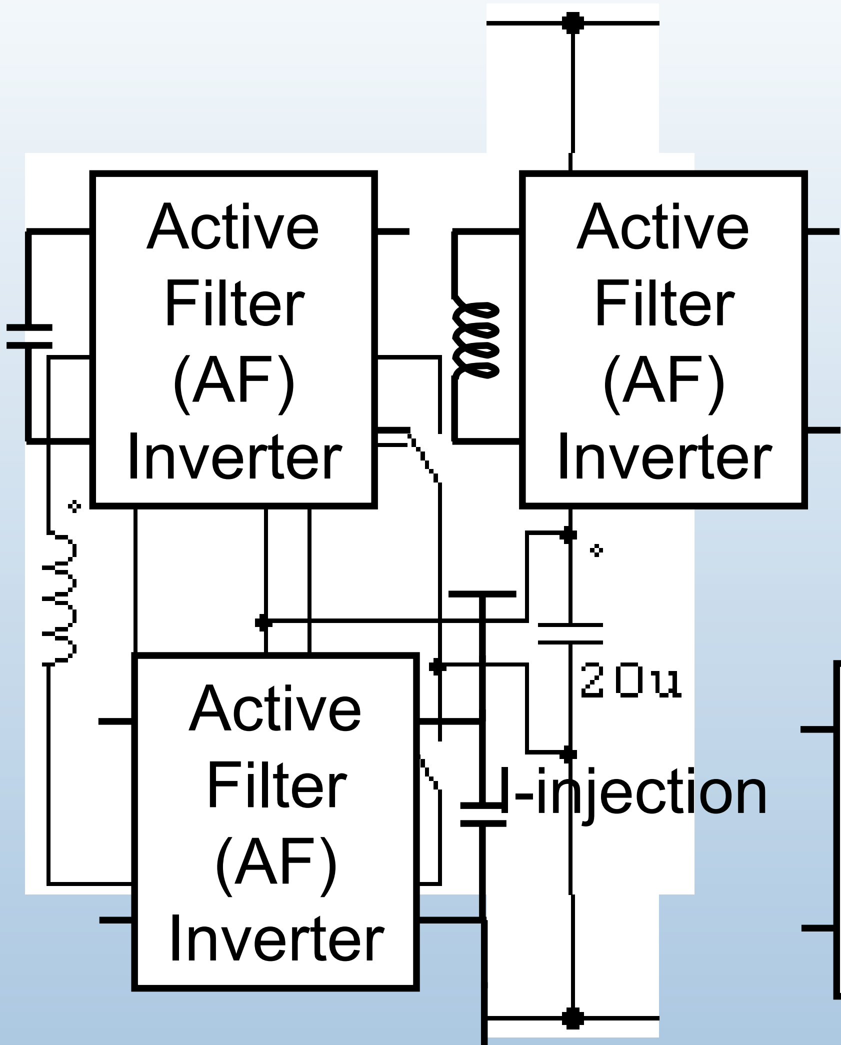
Alternative DC-link Approaches

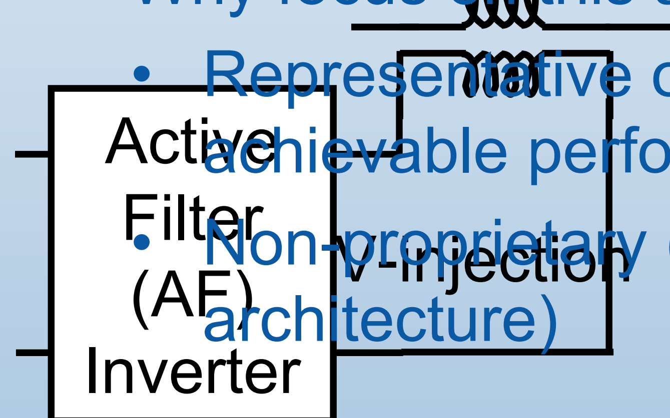


What solutions could be used in the DC-link?

- Active filter can significantly reduce capacitor requirements
- Additional architecture based solutions could reduce/eliminate capacitors

Technological Approach





Active filters evaluation:

- component sizing
- perfomance potential
- architectures

Why focus on this architecture?

- Representative of achievable performance
- Non-proprietary (well known architecture)

Active Filter Component Sizing

- Equivalent ripple circuit used for sizing components
- Inductor is 5.8mH for supplying low frequency ripple energy
- Capacitor is only 20uF
- This architecture requires large V, I switch ratings – may be costly

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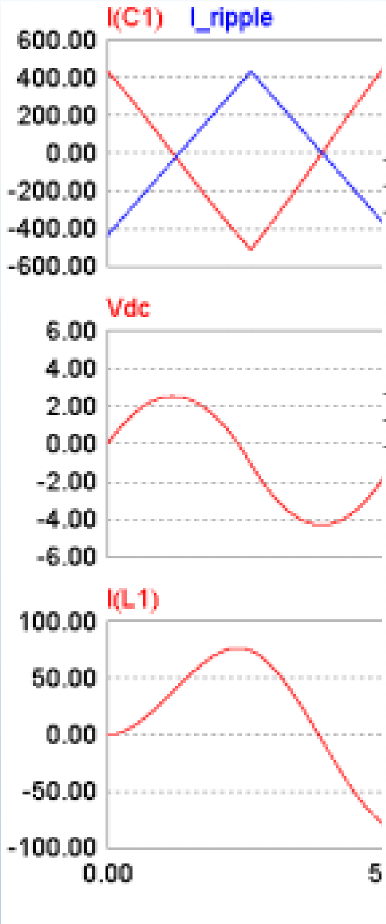
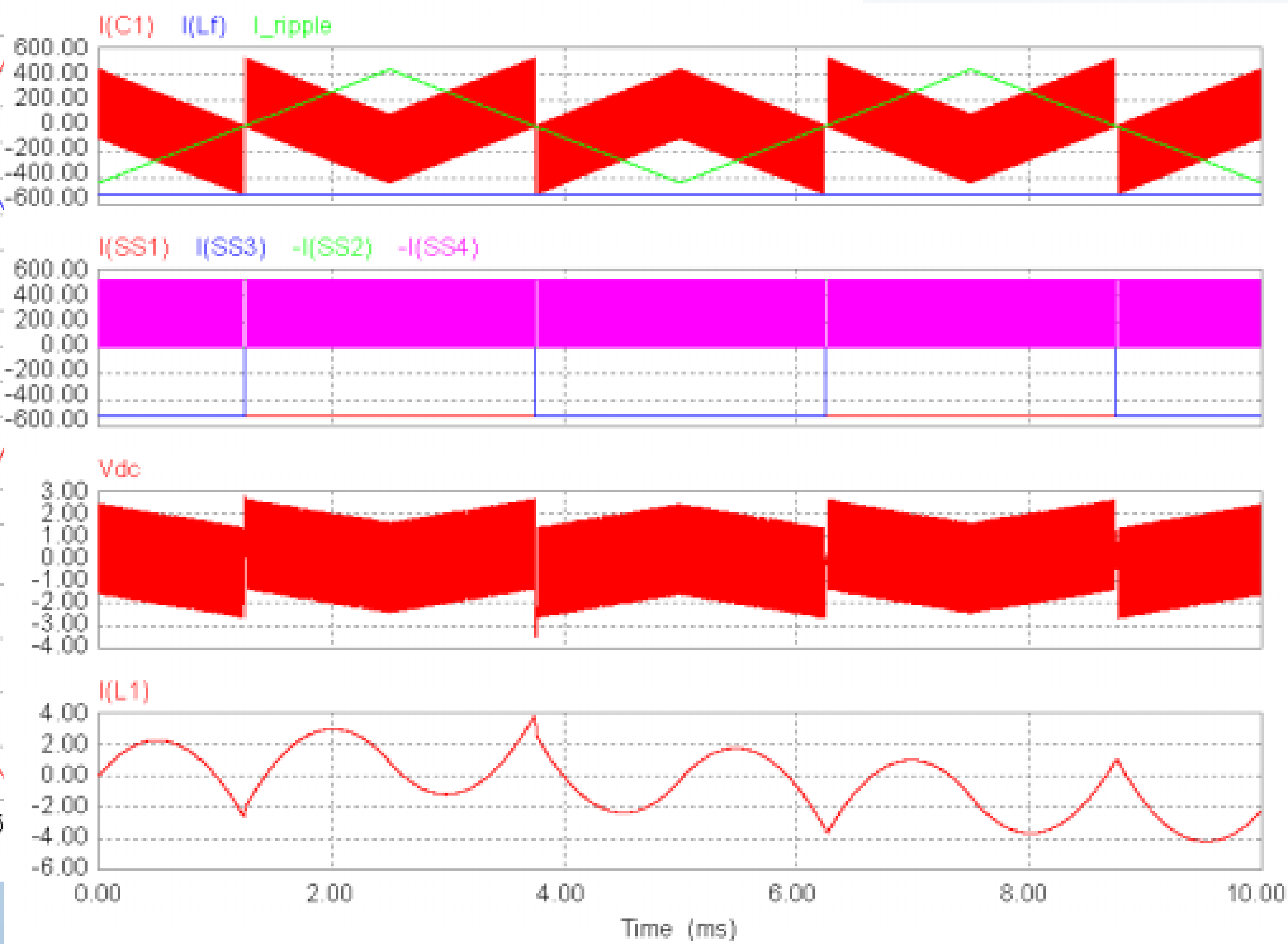
Equivalent Ripple Circuit Performance Comparison

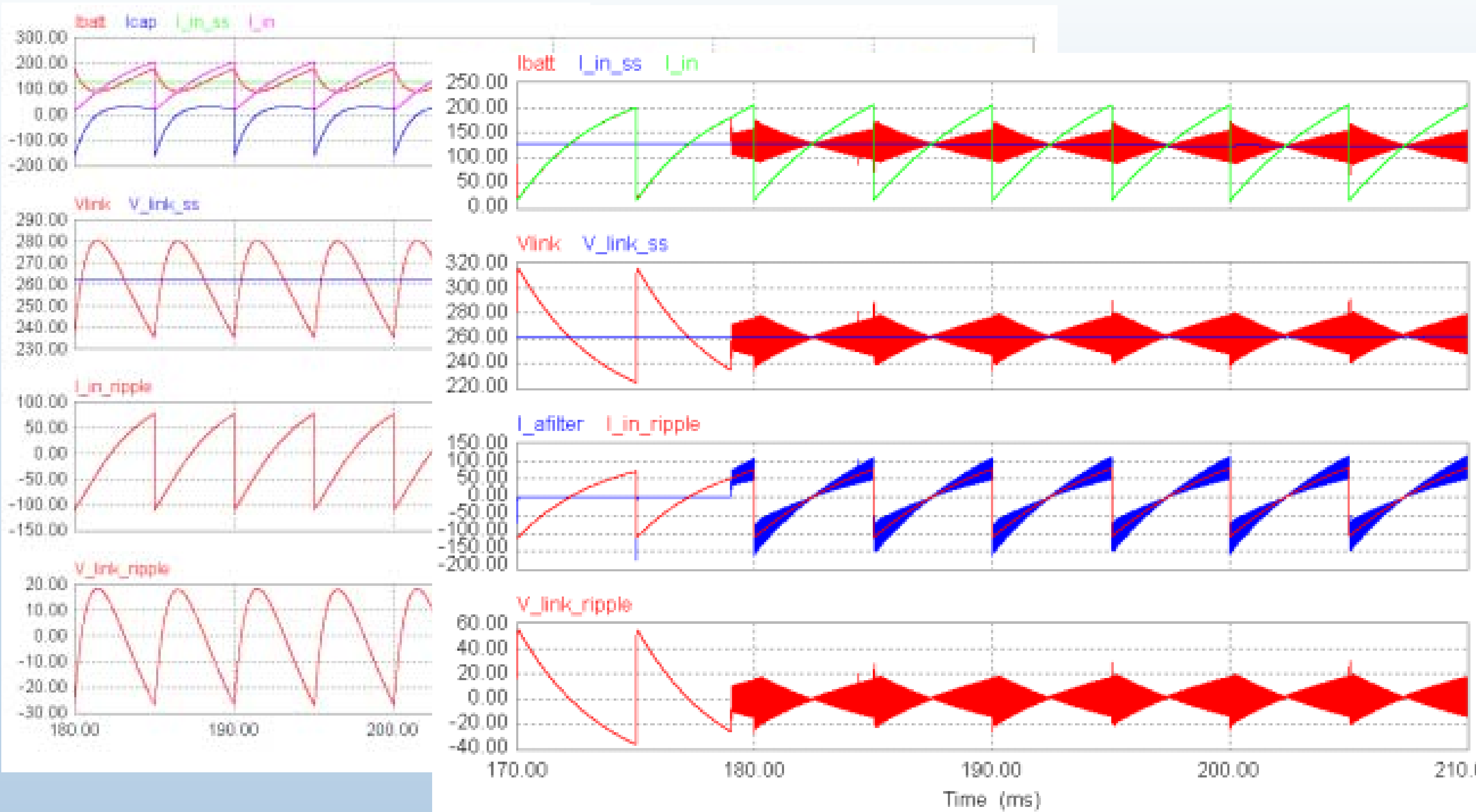




Equivalent Voltage Ripple Performance

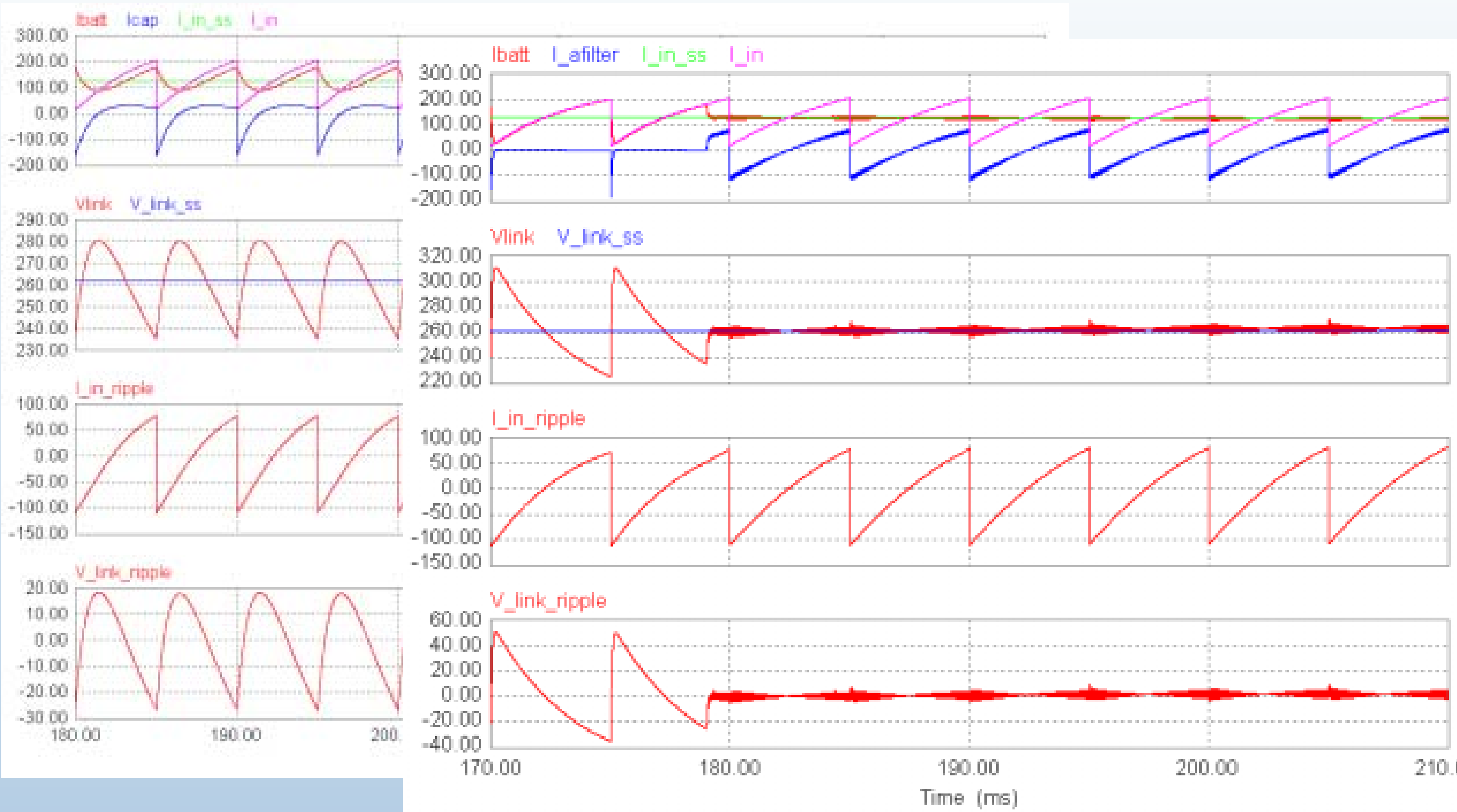
- Capacitor-only: 100,000uF -versus- AF with 20uF Capacitor

Field Weakening – Inverter Square Wave Operation



- f_e=33.3Hz, f_{ripple}=200Hz
- Cap-only: 2000uF -versus- AF w/ 20uF (f_s = 50kHz)

Field Weakening –
Filter Capacitor 5% of Targeted



- f_e=33.3Hz, f_{ripple}=200Hz
- Cap-only: 2000uF -versus- AF w/ 100uF (f_s = 50kHz)

Significance to DOE's FreedomCAR goals

- Using active filters can significantly reduce passive component requirements in the DC-link
- AF solution should be more fault tolerant, reliable, and compact
- Capacitor temperature tolerance affects failure / life more significantly than with switches

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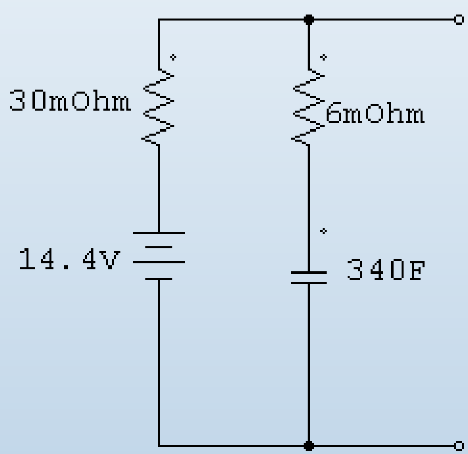
Summary of Work

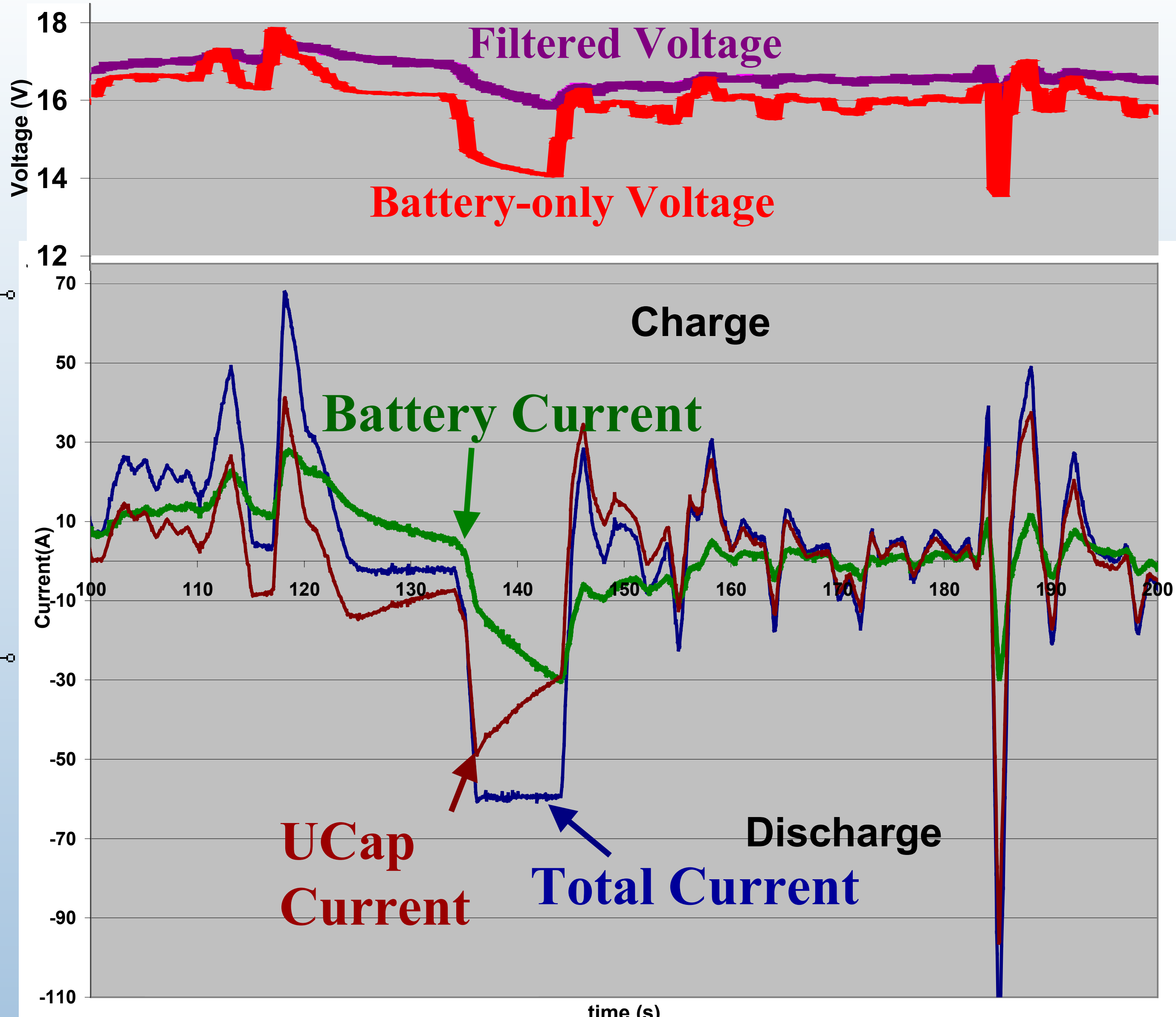
- AF passive components can be sized for lower energy requirements.
- AF architecture will be very important in determining switch sizing/cost.
- AF performance can be superior to capacitors in the DC-link.
- AF switches are already high density and capable of 125-150°C

Future Work

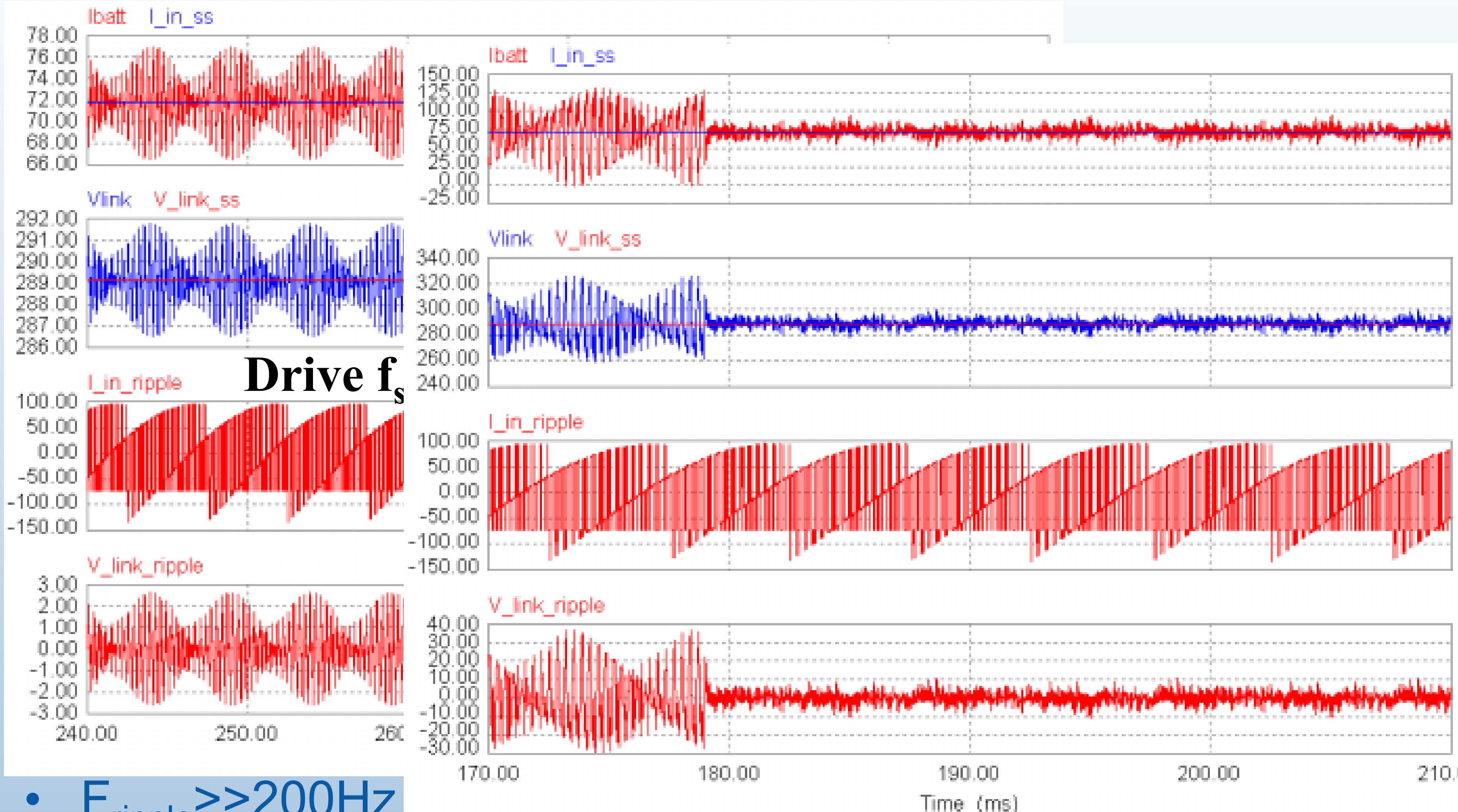
- Continue evaluating AF architectures.
- Further evaluate price potential (architecture dependent).
- Evaluate AF performance under dynamic drive cycle conditions.
- Plan to work with AF experts at Texas A&M, Illinois Institute of Technology, and Colorado School of Mines.

Appendix: Transient Behavior





Linear PWM Region – Filter Capacitor 5% of Targeted



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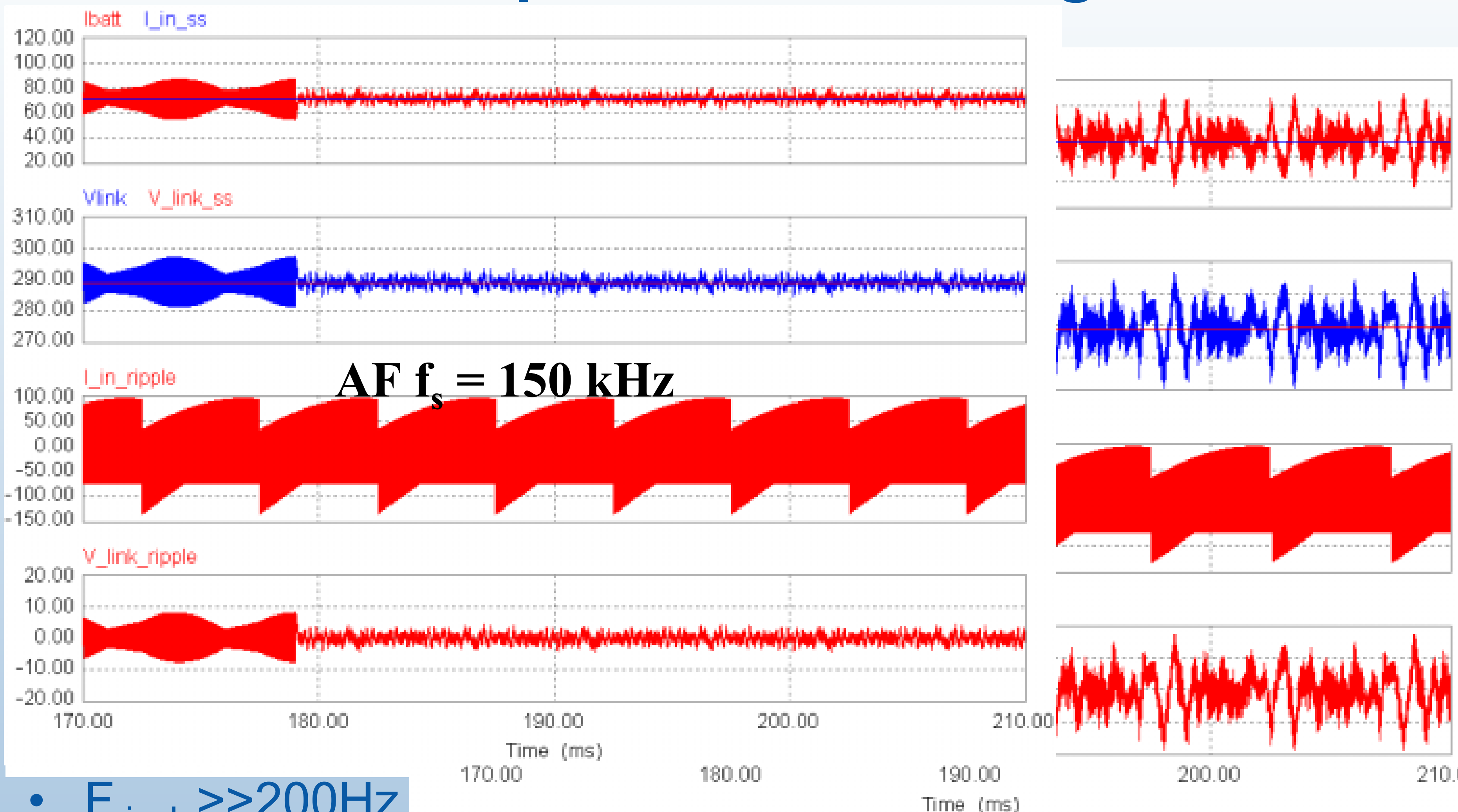

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