# INTELLIGENT AND PRECISION CONTROL LABORATORY


Faculty:

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Research Focus:

- **Developing a general framework for the design of intelligent and yet high precision/performance control algorithms**
- **Applying to the integrated design of intelligent and precision mechatronic systems**
- **Nonlinear observer design and neural network learning for virtual sensing, modeling, prognostics, fault detection, diagnostics, and adaptive fault-tolerant control; Data fusion.**


Sponsors and Donors:

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affiliated with

**Ruth & Joel Spira Laboratories for Electro-Mechanical Systems**

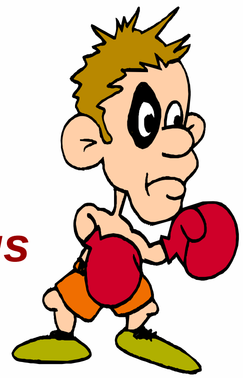
**Ray W. Herrick Laboratories**

# NONLINEAR ADPTIVE ROBUST CONTROL THEORY

***Essence***

**Good Body and Instinct**

***Fast Instantaneous Reaction*** !



**Brain Power**

***Good Learning Ability !***

⇓

**Seamless integration of the fast reaction to immediate feedback information *(e.g., nonlinear high-gain robust control)* and the slow learning utilizing large amount of stored past feedback information that is available in the modern computer based control systems *(e.g., adaptive control)* to maximize the achievable control performance with built-in intelligences**

# Essence of Adaptive Robust Control Strategy

- Nonlinear ***local high-gain*** robust feedback for fast instance reaction to maximize the attenuation of various model uncertainties for a guaranteed robust performance
- ***Controlled*** parameter adaptation and learning to achieve a fine tuned high performance
- By-product of learning process such as ***accurate parameter estimates*** to add ***built-in machine intelligences***

$\Rightarrow$

A well-built **BRAIN**

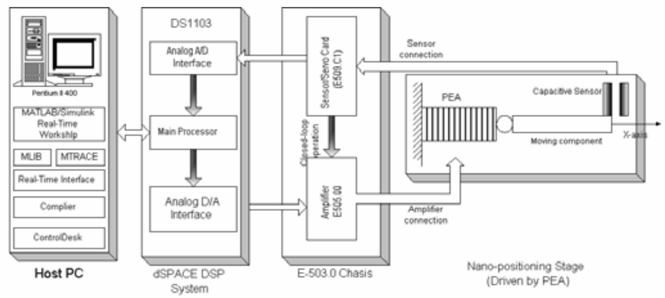
for

**Intelligent** and **Precision** ***Mechatronic*** **Systems**

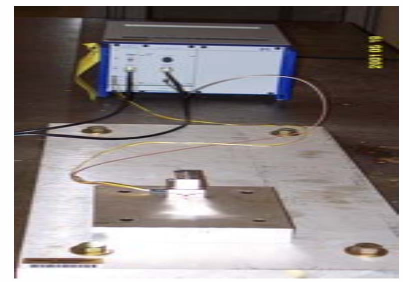
# APPLICATIONS

- **Precision Control of Electro-Magnetic Motor Driven Mechanical Systems for *Precision Manufacturing***
- **Ultra-Precision Control of Piezo-Electrical Actuator Driven Mechanical Systems for *Nanotechnology***

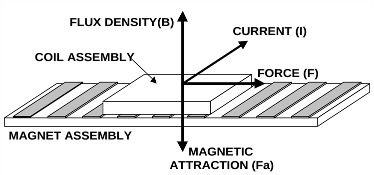
**High-Speed Linear Motor Drives**

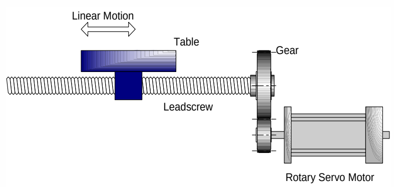



Nano-positioning Stage (Driven by PEA)

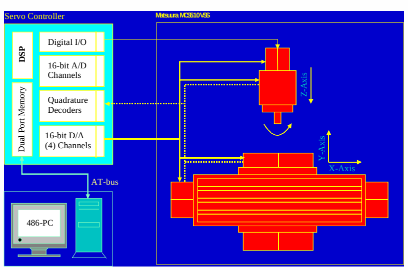


**Nano-positioning Stage**



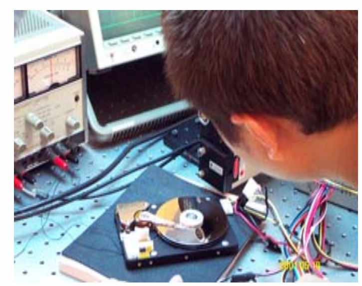




**Micro-Pump**



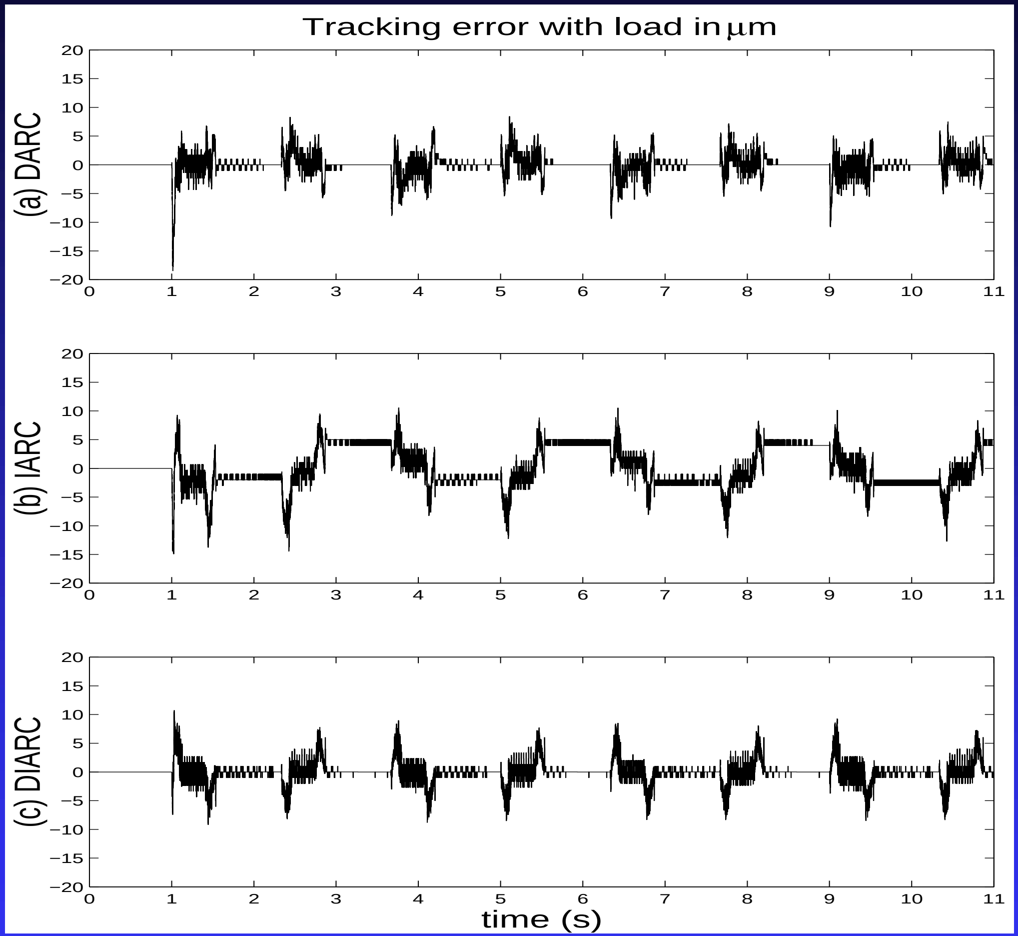

**Machine Tools**


**Laser Micro-Machining**

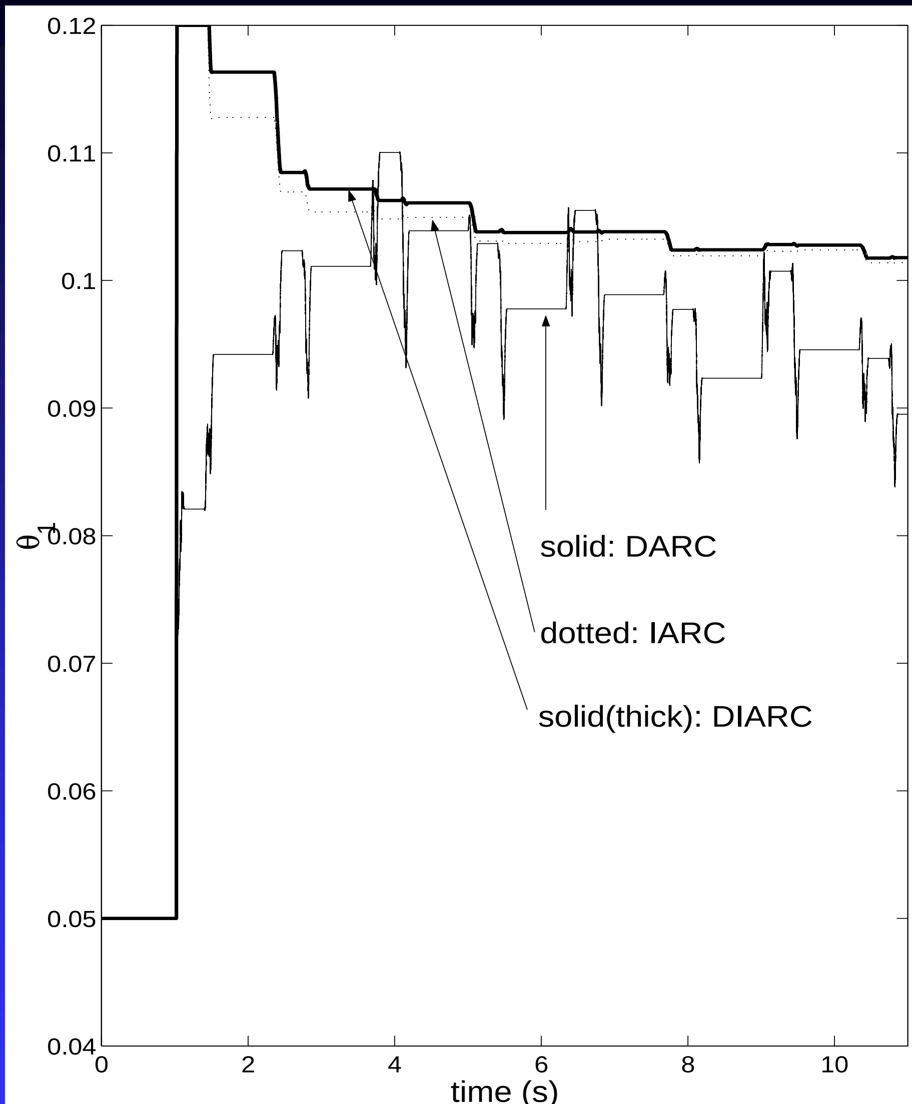


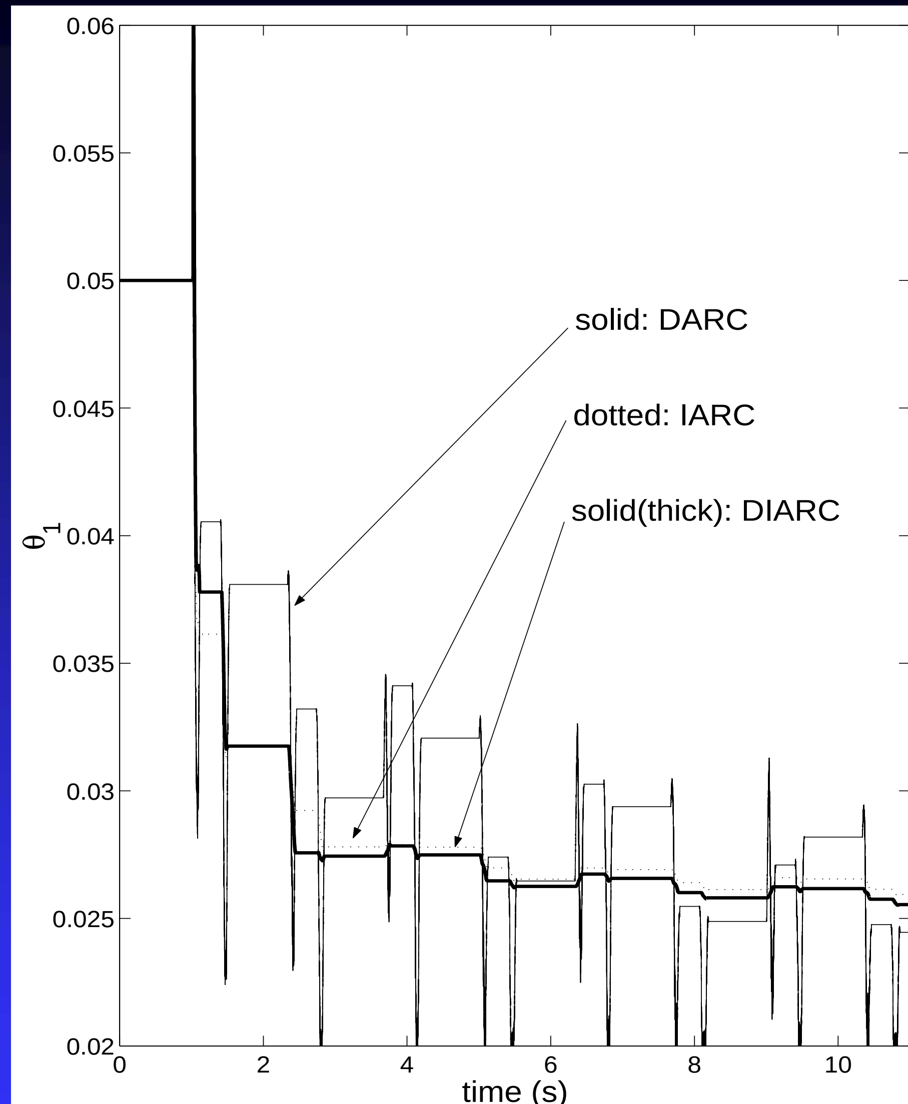
**Ultra-High Density Dual Stage Hard Disk Drives (HDD)**

# Tracking Errors for Point-to-Point Trajectory $(a_{max} = 12 m/\sec^2, v_{max} = 1 m/\sec)$




**The above results demonstrate the excellent robust tracking performance of the proposed ARC algorithms – Tracking errors are mostly within 10 μm with final tracking error around the encoder resolution of 1 μm for both loaded and unloaded cases**



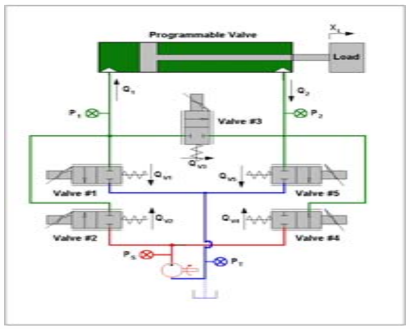



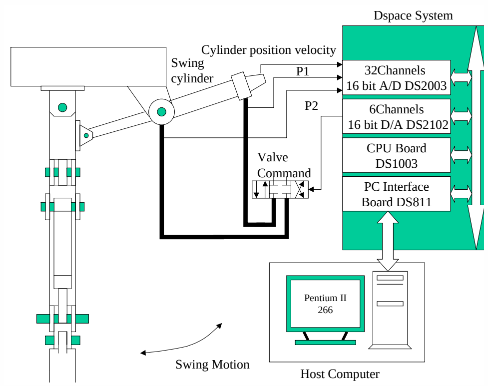

**The above plots show the accurate parameter estimation capability of the proposed DIARC and IARC – estimates of the inertia load converge to their actual values for both loaded and unloaded cases**

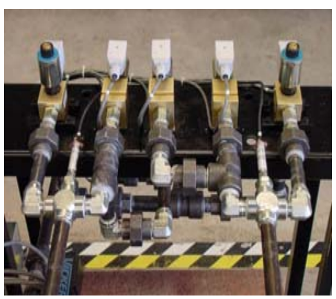
# APPLICATIONS

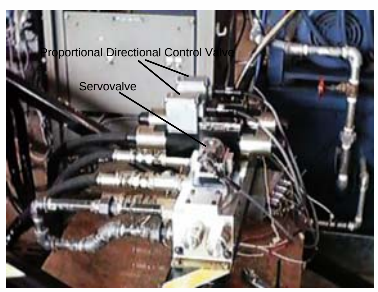
- **Energy Saving Control of Electro-Hydraulic Actuator Driven Systems with *Novel Programmable Valves***
  - Hydraulic Servo-systems
  - Hydraulic Excavators
  - …

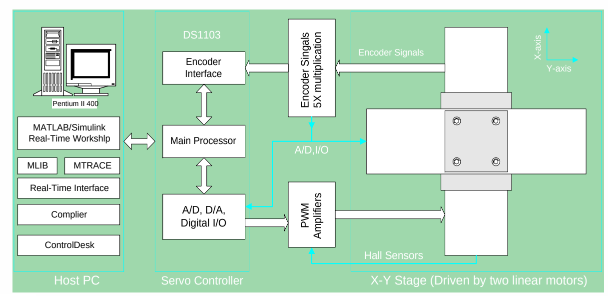
- **Coordinated Control of Multi-DOF Mechanical Systems and Multiple Robots for *Factory Automation***
  - Trajectory Tracking Control of Robot Manipulators
  - Motion and Force Control of Robot Manipulators
  - Coordinated Control of Multiple Robot Manipulators



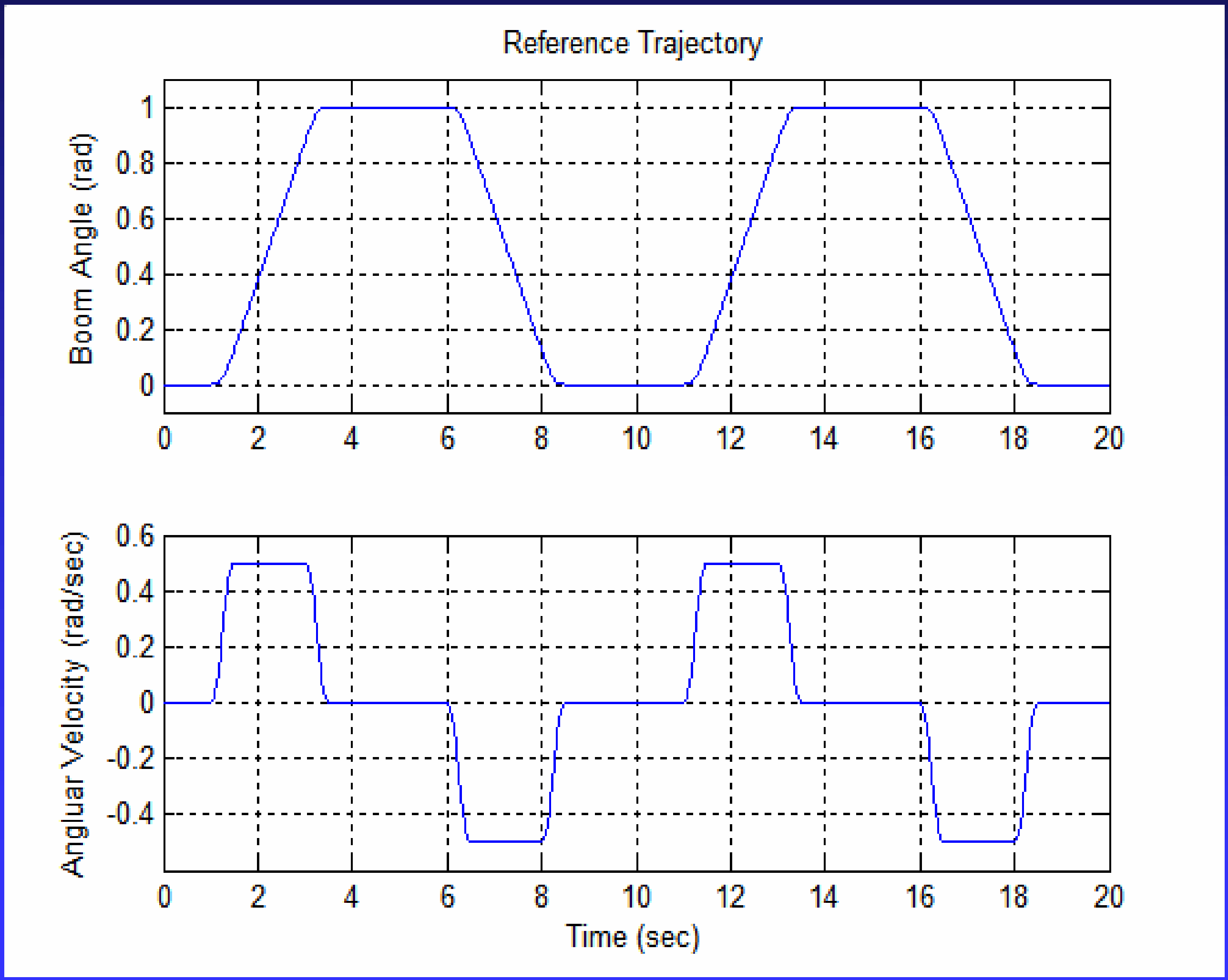


# COORDINATED CONTROL EXPERIMENTS

## Automated Modeling and Energy Saving Adaptive Robust Control of Electro-Hydraulic Systems with Programmable Valves

# Comparative Experiments




- PDC valve

  Vickers KBFDG4V-5-2C50N-Z-PE7-H7-10

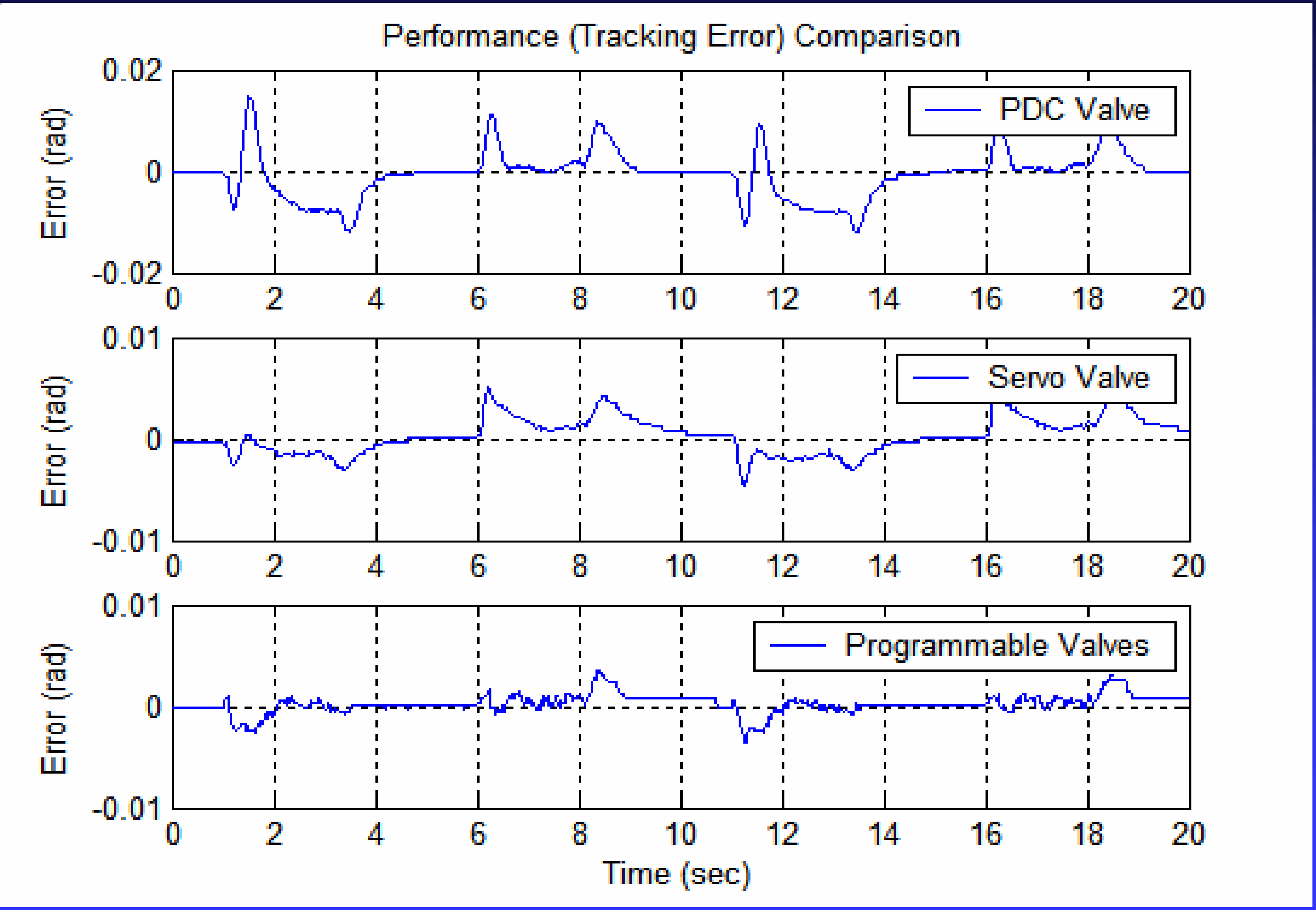
- Servo valve

  Parker BD760AAAN10

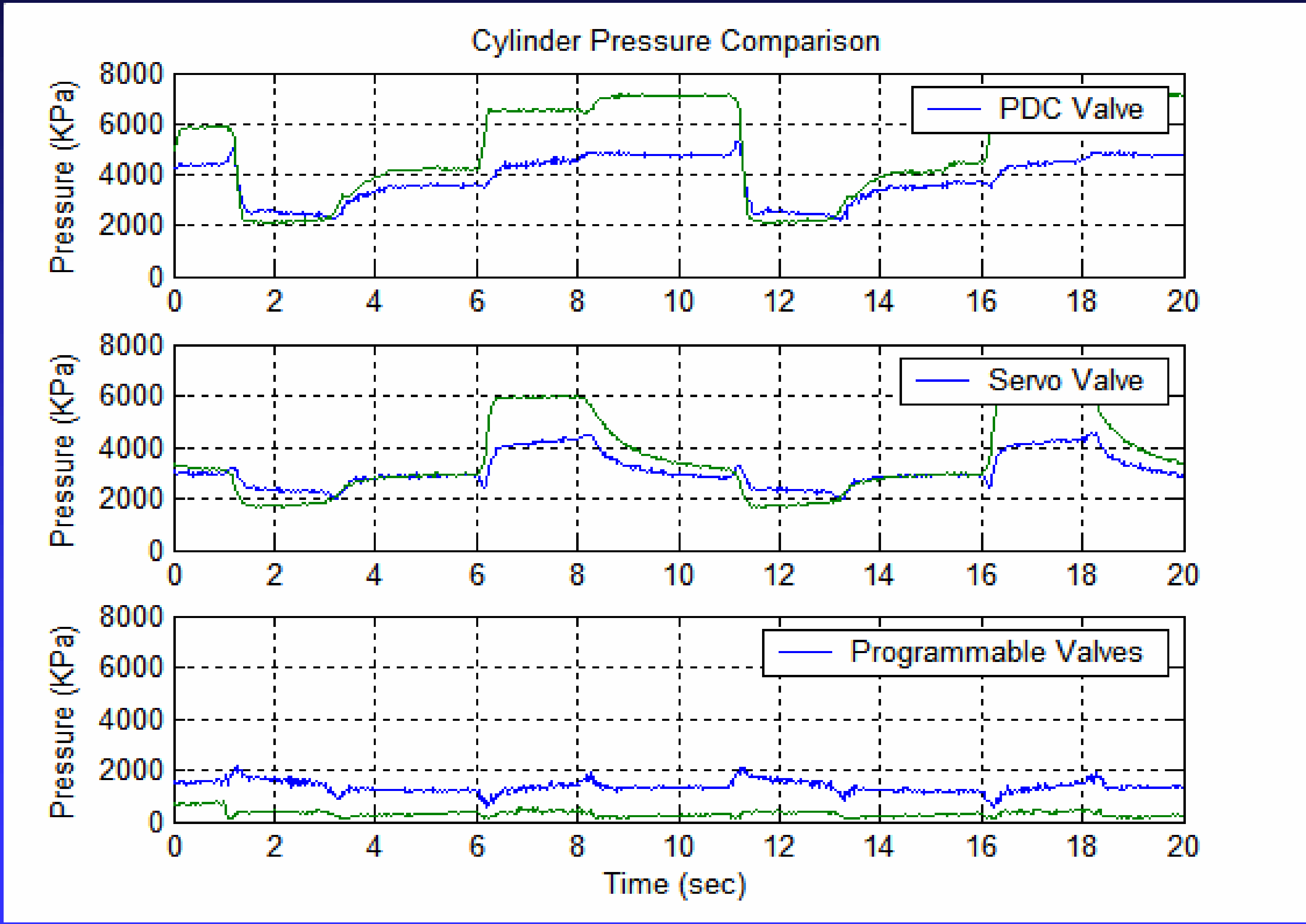
- Programmable valves

  Vickers EPV10-A-8H-12D-U-10

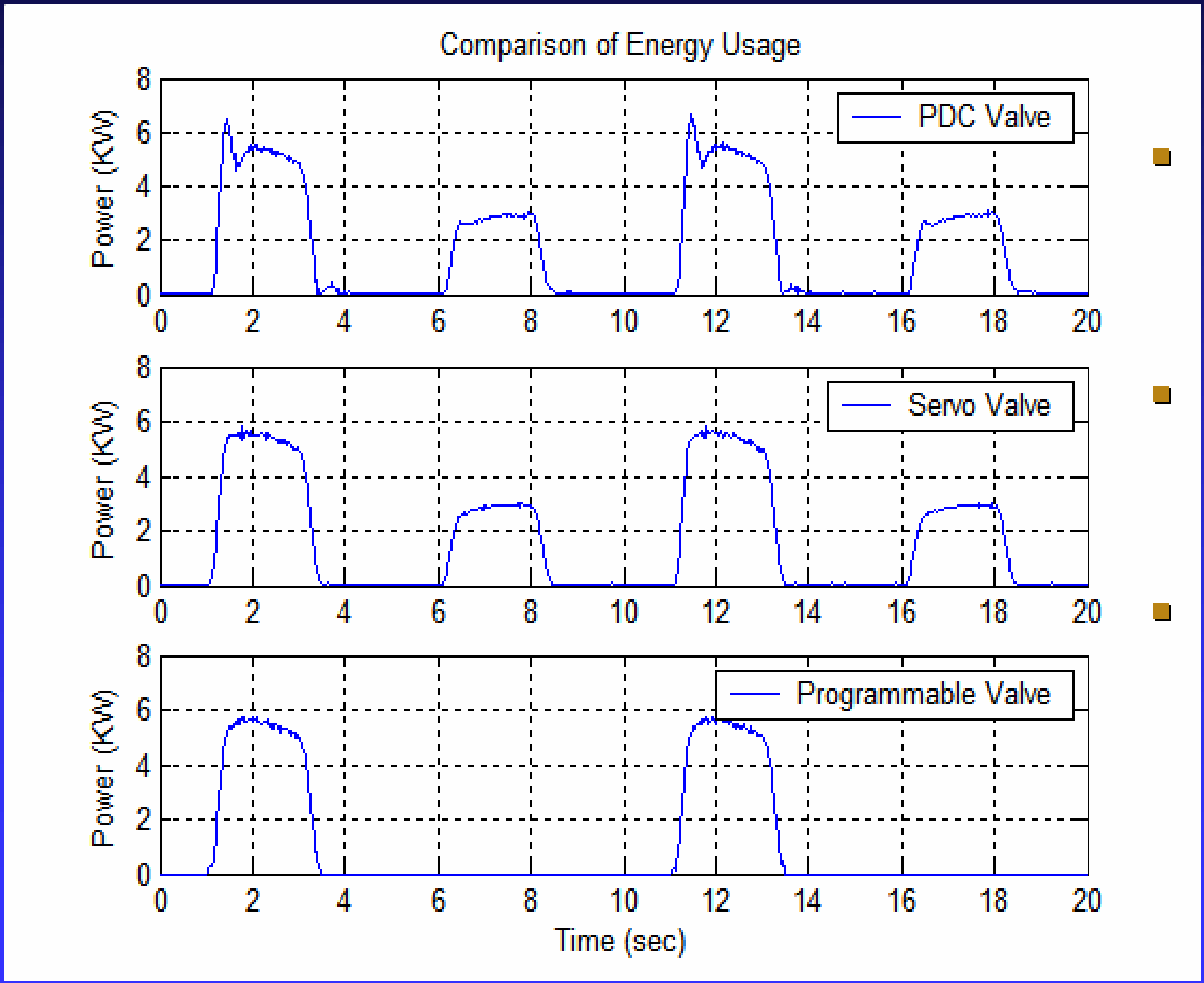
# Comparison of Performance



# Comparison of Cylinder Pressures



# Comparison of Energy Usage
## ( Constant Supply Pressure Ps=1000psi)

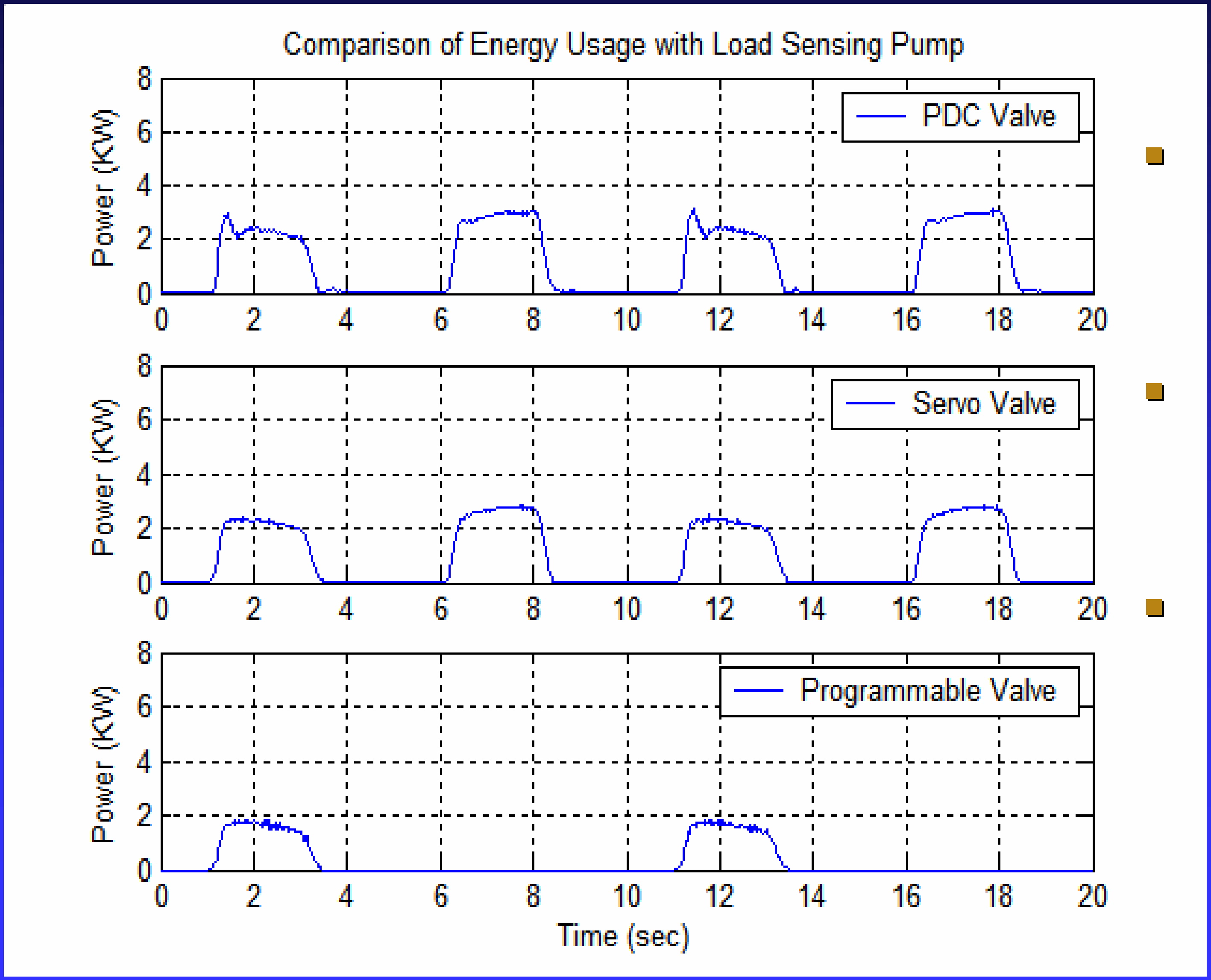



- 32.4 KJ
- 32.7KJ
- 21.3KJ

34% less than PDC

35% less than Servo

# Comparison of Energy Usage
## (Ps=Working Pressure + 500KPa)



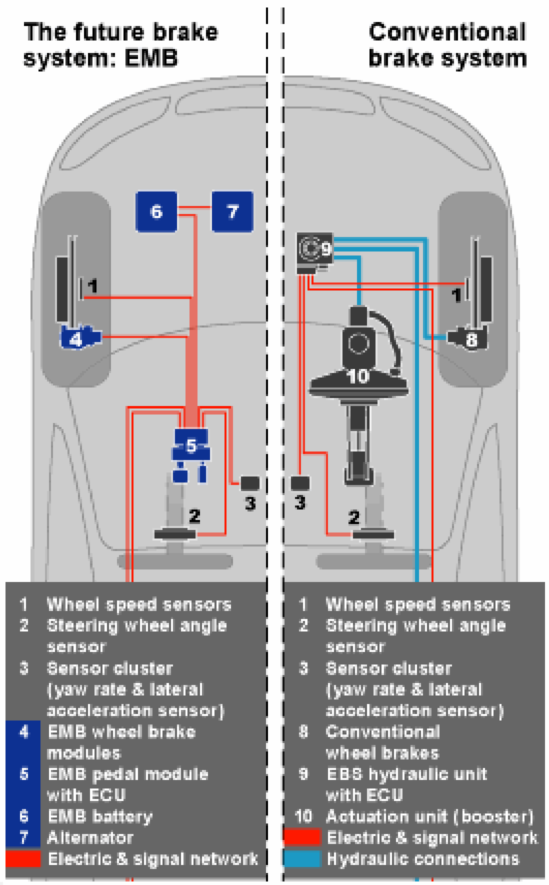

- 20.9 KJ
- 19.3KJ
- 6.4KJ

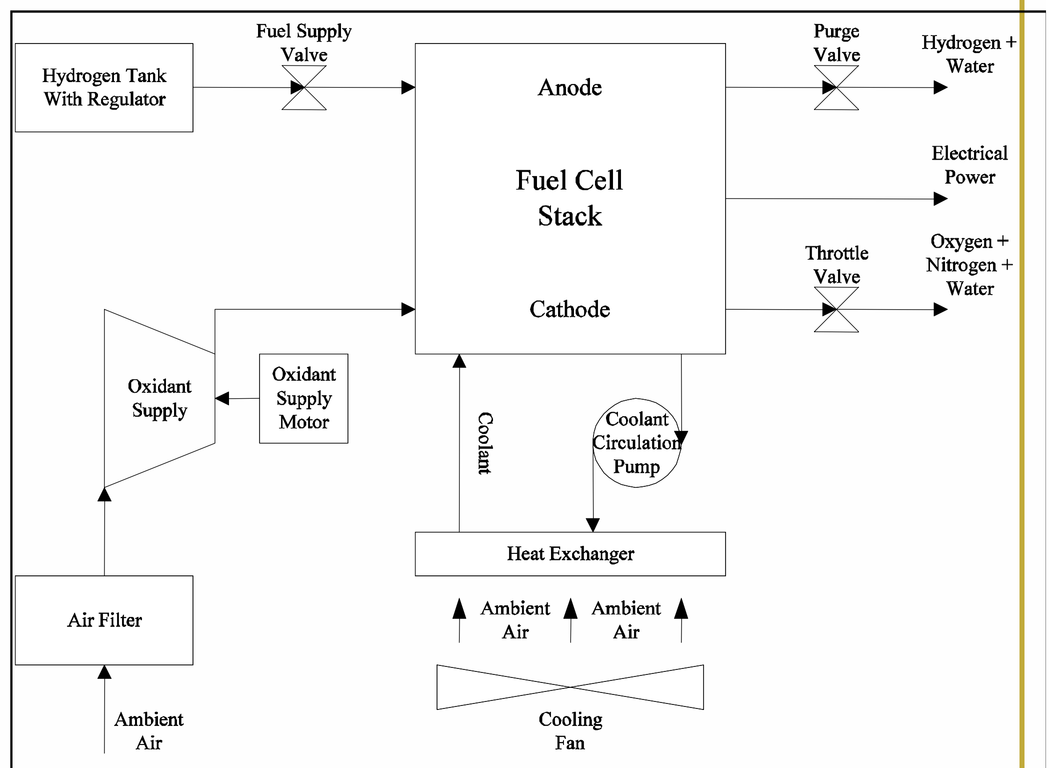
69% less than PDC

67% less than Servo

# AUTOMOTIVE APPLICATIONS

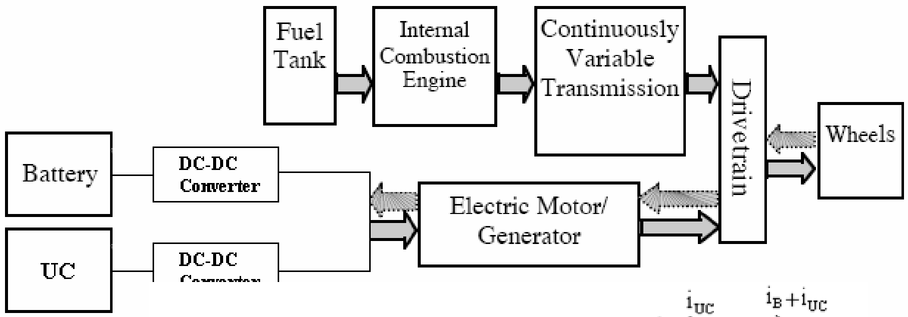
- **Modeling and Control of Electro-Mechanical Brake Systems for *Brake-by-wire and System Level Drive-by-wire Applications***
- **Modeling and Control of Proton Exchange Membrane (PEM) Fuel Cells Systems for *Optimization of Net Power Output***

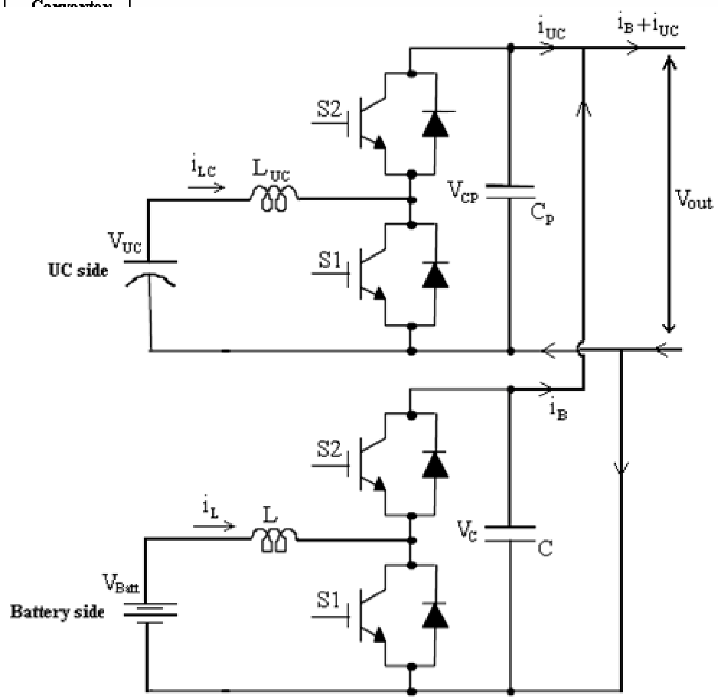


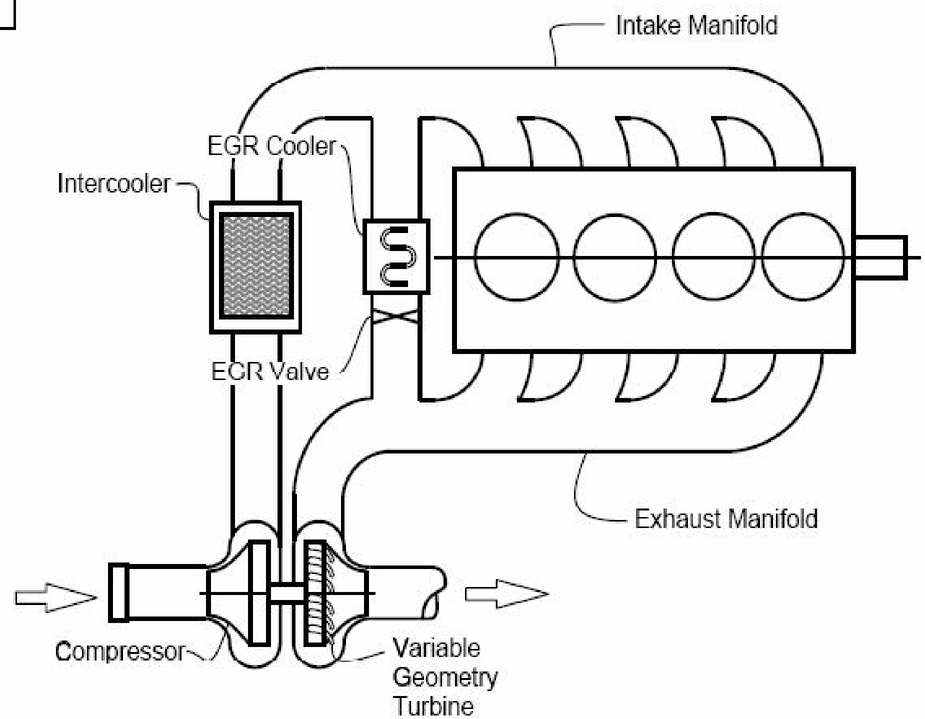
# AUTOMOTIVE APPLICATIONS

- **Power Management and Control of Hybrid Electric Vehicles**




- **Nonlinear Adaptive Robust Control of Turbocharged Diesel Engines**



# OTHER APPLICATIONS

Active Noise Controls (with Prof. Kai Ming Li)

Nonlinear Adaptive Robust Control of Surgical Bio-medical Devices (with Prof. Bill Peine)

Fault Diagnosis scheme for early, robust and reliable detection of sensor and actuator faults

Condition Monitoring algorithms for Preventive Maintenance of electro-hydraulic and electro-mechanical systems