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LIN Mechatronics Applied to HVAC Expansion Valves

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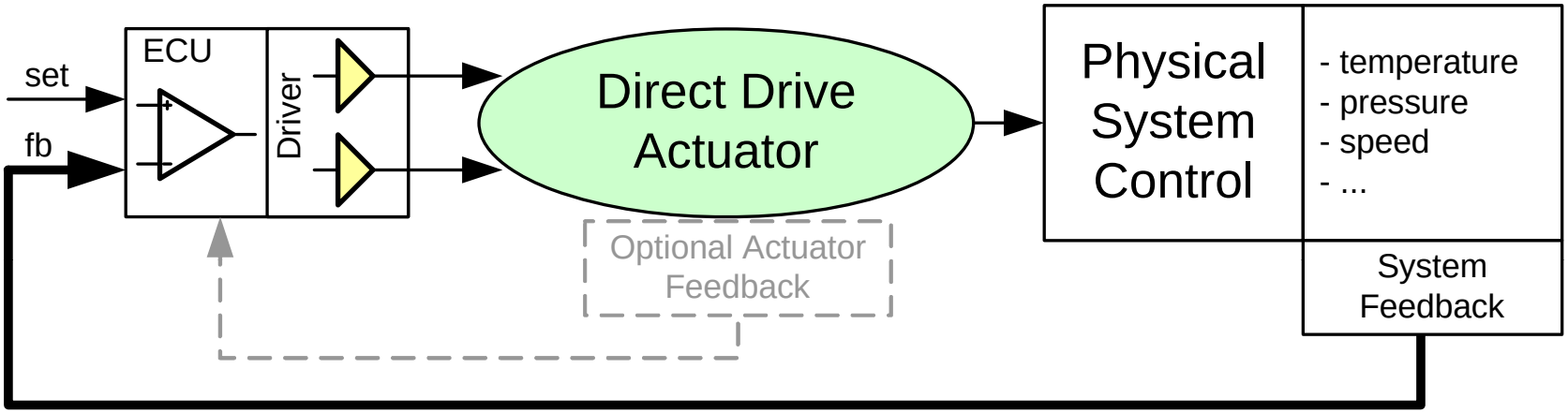
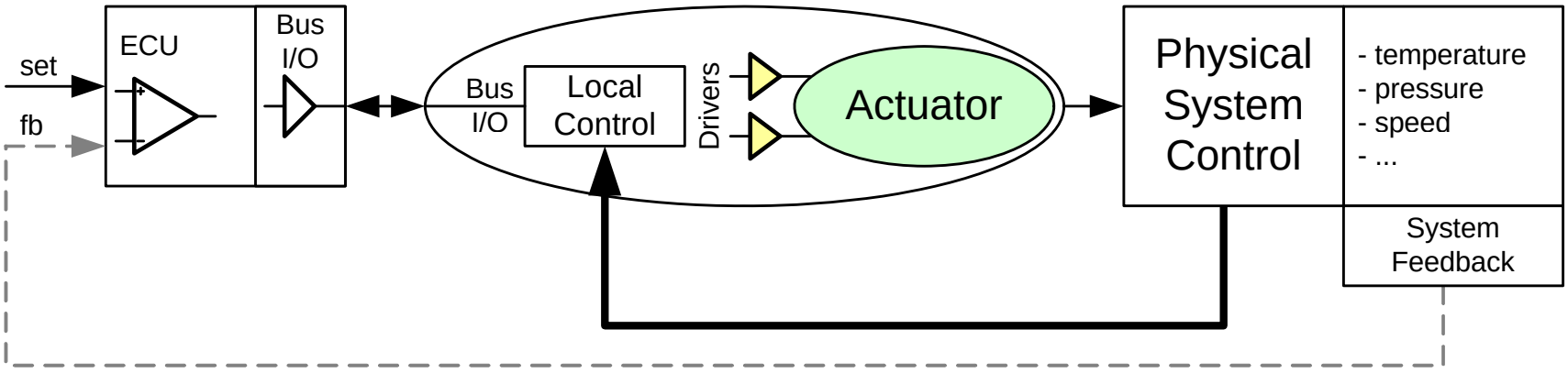
- Balanced Features in Actuator Systems
  - Direct Drive & Mechatronics
  - Direct Drive Examples
  - Mechatronics Examples
- Automotive Stepper Motor Actuators & Common Issues
- Emerging Stepper Motor Technologies
  - Software Complexity
  - Stall/Steploss Detection
  - Resonance
- Climate Control Systems
  - Automotive Air-conditioning System and EXV
  - Stepper motor EXV
  - LIN Mechatronic EXV
- Conclusion

Actuators have Balanced Cost-Features-Quality

- Direct Drive Actuators are typically operated in a closed loop on system level.
- For Mechatronic Actuators, feedback loop is often locally or indirectly on system level.

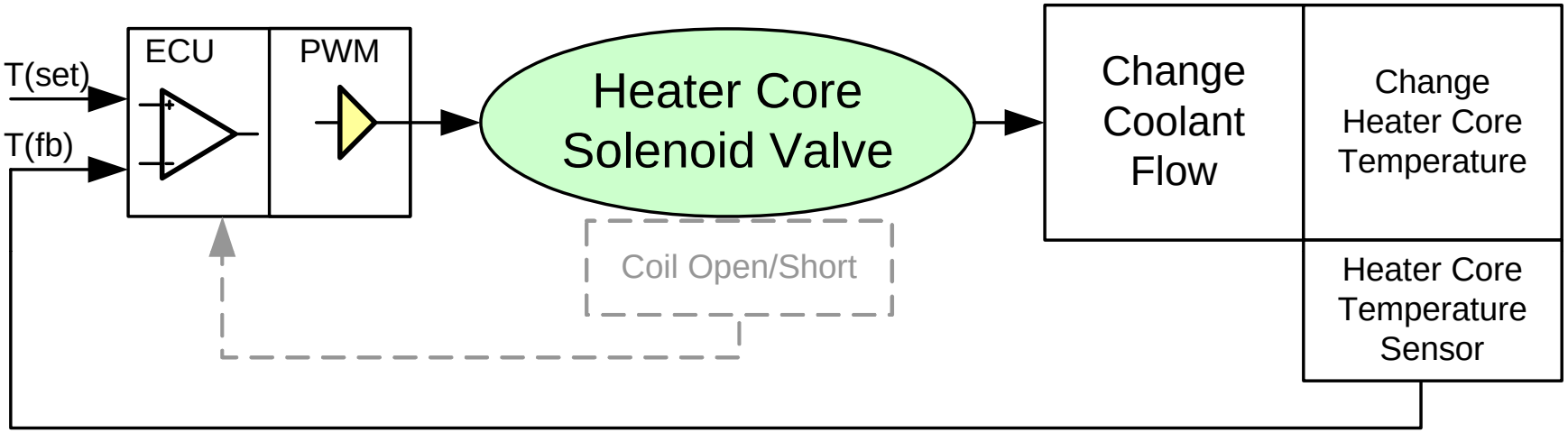


Mechatronic Actuator

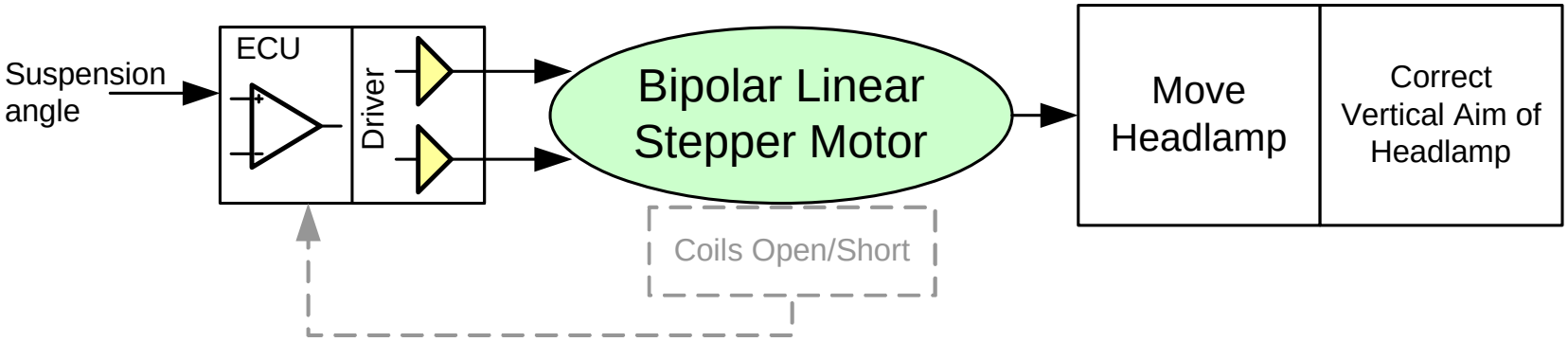


Examples of Direct Drive Actuators

- **HVAC Heater Core Solenoid Valve : closed loop**

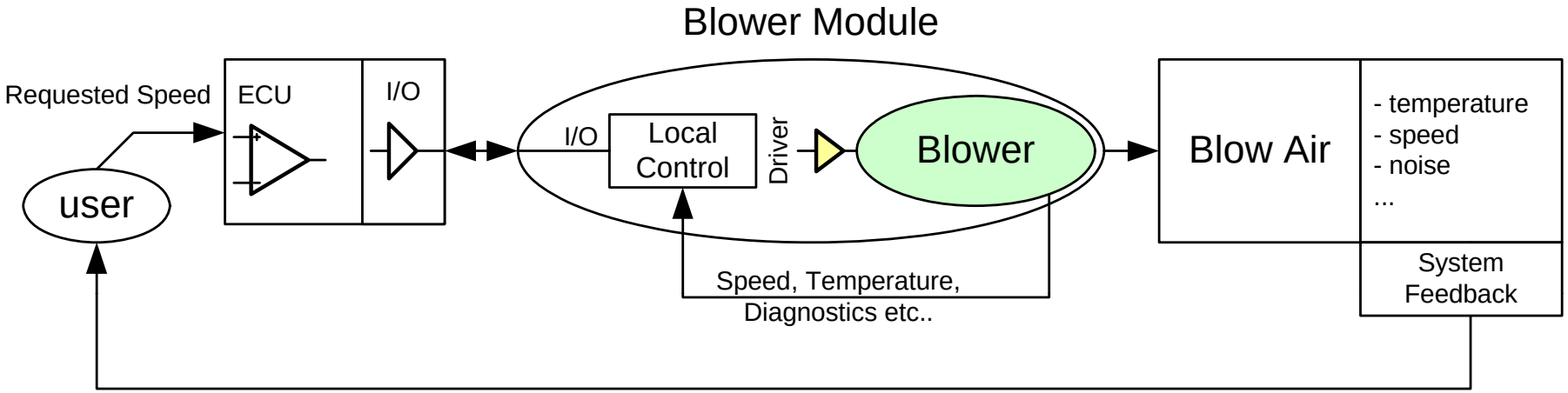


- **HID Headlamp leveling : open loop**

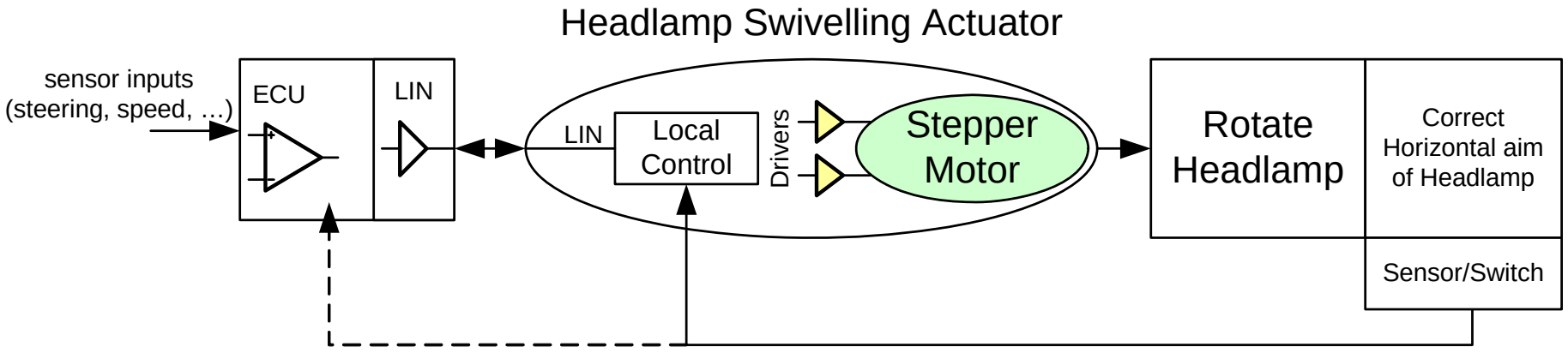


Examples of Mechatronic Actuators

- **Fan HVAC blower : local closed loop**



- **HID Headlamp Swiveling : local closed loop**



Automotive Stepper Motor Actuators

- Some actuators benefit from stepper motor technology :
  - Headlamp adjustment
  - HVAC air flaps
  - Idle speed Control & LPG Expansion valves

- For other applications, stepper motors are sometimes labeled as “not suitable” :
  - Motors require complex software to operate
  - Open Loop, but additional sensor needed to detect step-loss
  - Risk of resonance resulting in noise, vibration and step-loss

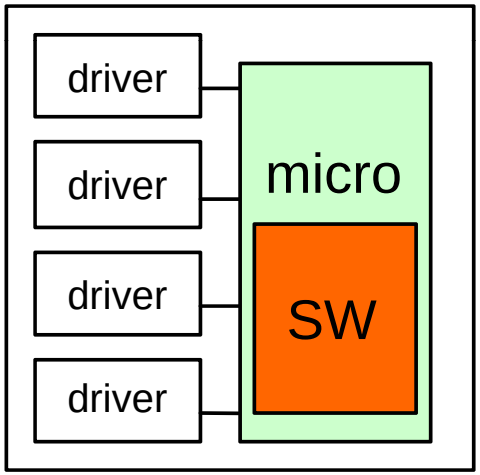
- Following slides show how we can counter these objections.

Drive Stepper Motors with Simple Software

…and use Stepper Motor Drivers with Command Interface and Positioner :

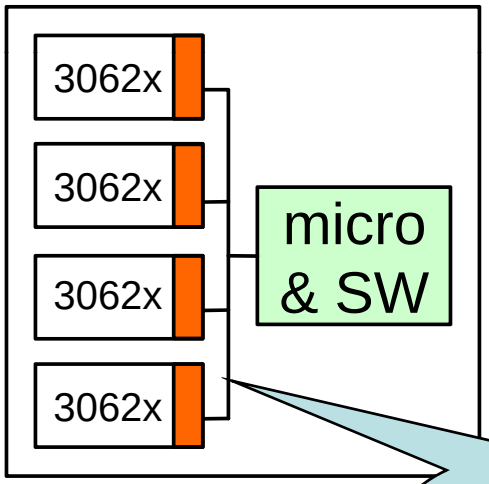
- Software architecture can be made modular and extendable to multiple axis
- Software is easier to qualify
- Software is tolerant for late-minute changes of motion parameters

Past Architecture



☹ *Large Micro*
☹ *Complex SW*
☹ *Not Modular*

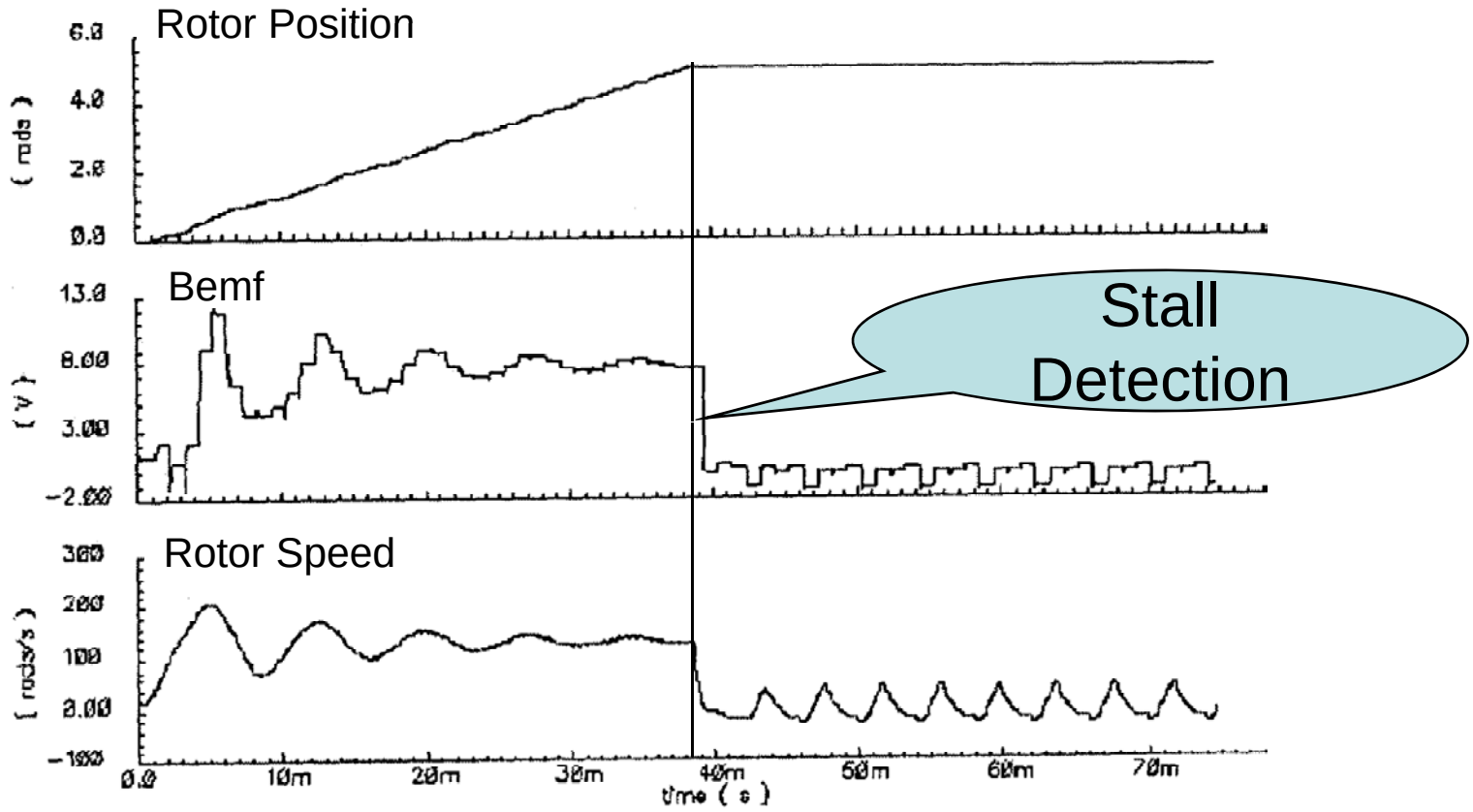
Actual Architecture



Both LIN & I^2C bus versions are in automotive production

☺ *Small Micro*
☺ *Simple SW*
☺ *Simple HW*
☺ *Modular*

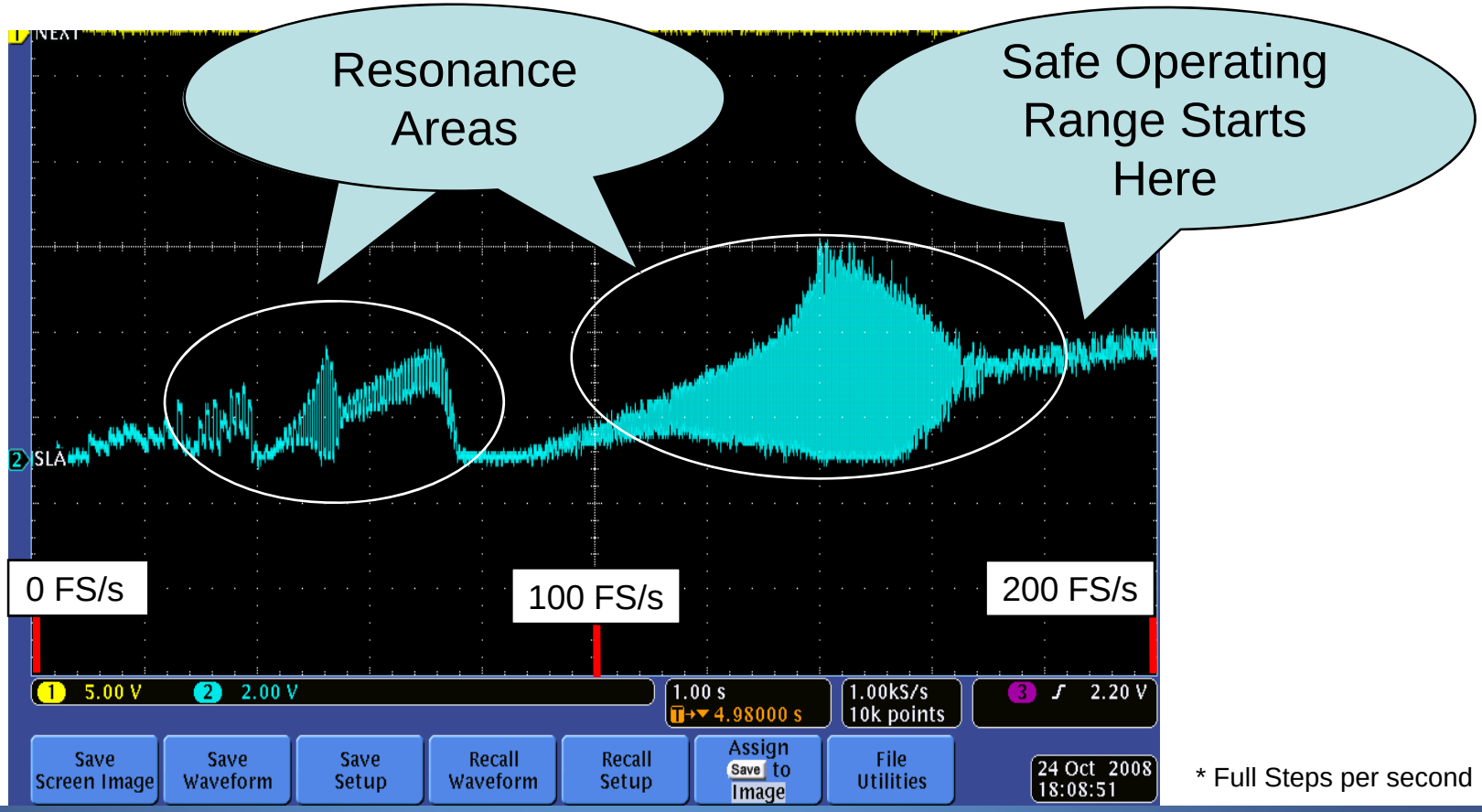
Sensorless Step-Loss Detection through Bemf



- Motor Speed and Load of Rotor is reflected in Back-Emf (Bemf)
- Evaluation of Bemf Yields Reliable Sensorless Stepless Detection
- Principle is integrated in products and in automotive production
- More Flexible Implementation is available through “Speed and Load Angle” pin

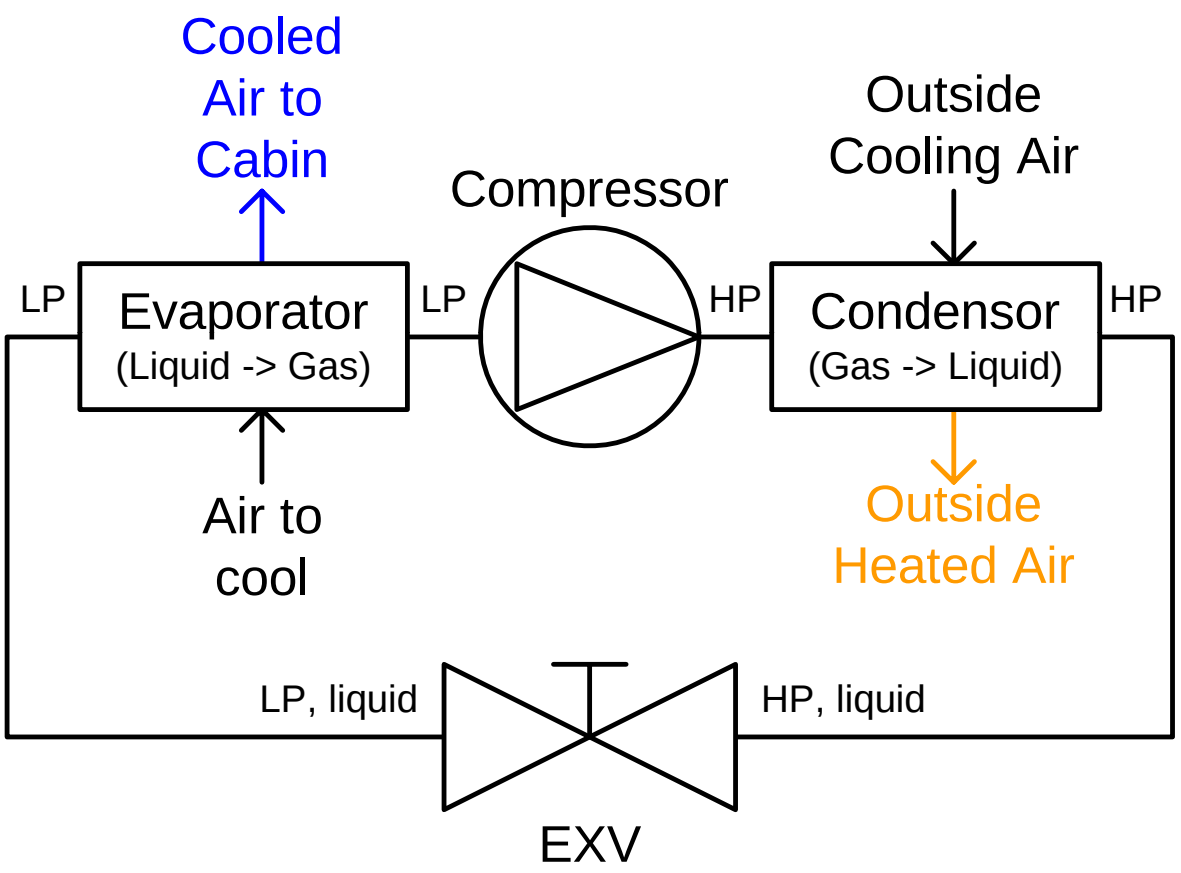
Resonance Characterization and Avoidance

- Operate motor and observe SLA pin (NCV70521) on an oscilloscope.
- Example below is a frequency sweep of a stepper motor (0 .. 200 FS/s*)
- Resonance should not be a problem : it can be characterized and avoided



* Full Steps per second

Automotive Air-Conditioning System



- Compressor Activity is Reduced when Evaporator Works More Efficient
- Evaporator Efficiency Depends on Wetting of Surfaces and Liquid/Gas Ratio
- Expansion Valve (EXV) is a key contributor to evaporator- and system efficiency

Mechanical Expansion Valve Types

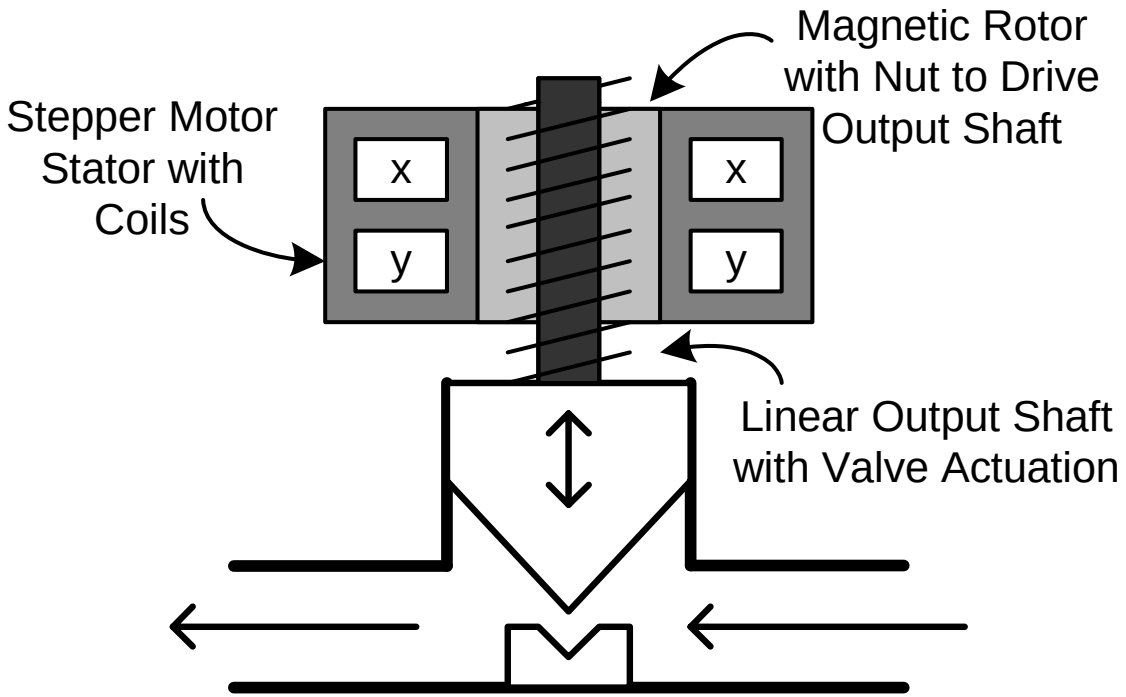
1. Thermostatic Expansion Valves :
   - Mechanical control device that works through pressure equalization
   - Modulates refrigerant flow to maintain a fixed superheat at evaporator output
   - Potential Issue : superheat is not flexible

2. Fixed Orifice Valve :
   - Passive valve (narrow tube) that feeds limited amounts of refrigerant
   - Valve bleeds also when engine stops
   - Potential Issue : fuel economy for start-stop

➔ Both Valve types have their advantages and flaws. In any case, better control of refrigerant flow is possible for next generation HVAC systems.

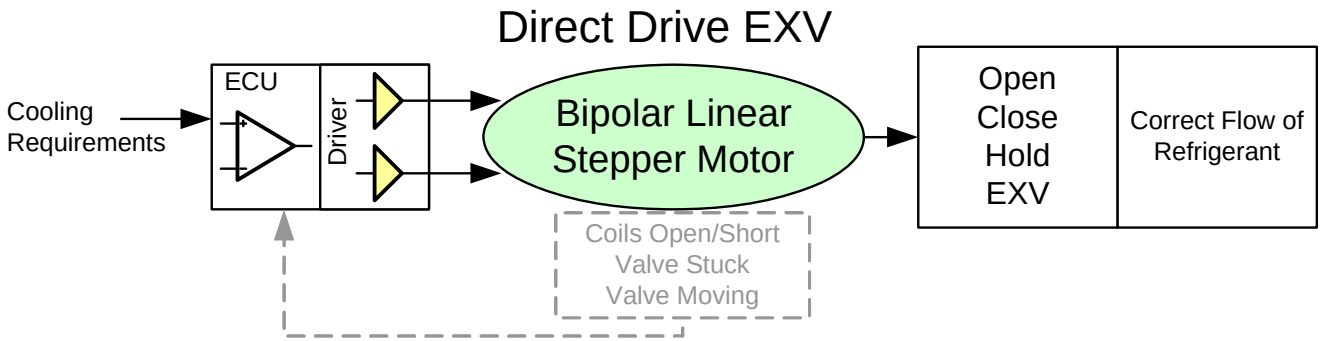
Electro-Mechanical Expansion Valve

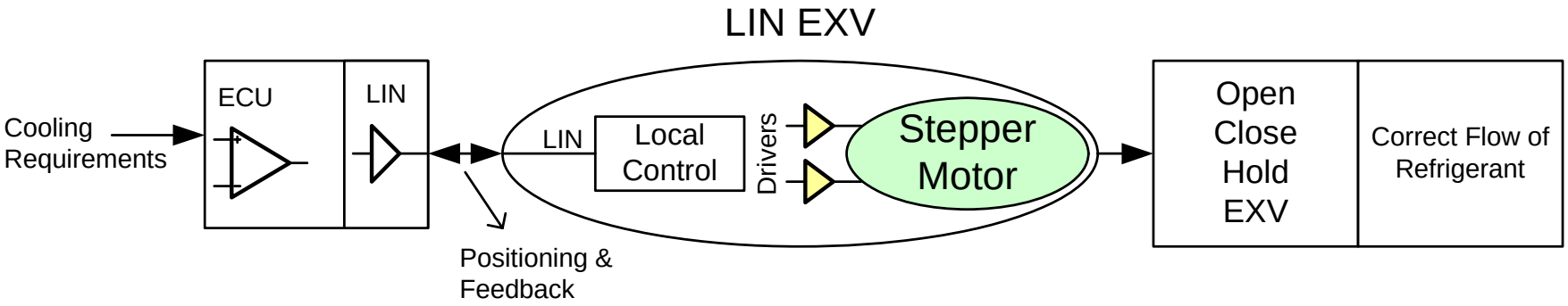
- Linear Stepper Motors are Best Candidates :
  brushless, sensorless, accurate positioning and stable hold function
- Actuator of Choice in Domestic and Industrial Refrigerators
- Available Intelligent Stepper Motor Drivers allow Full Control of EXV



EXV Controls Refrigerant Flow

Balanced Control for EXV's





- Sensorless and Semi-Closed Loop Operation provides Balanced Control
- Both Direct Drive and LIN Mechatronic solutions will work
- LIN bus allows modular approach between Tier-1 and Tier-2

Conclusion

- Examples of balanced direct-drive and mechatronic actuators have been shown

- Emerging and silicon integrated techniques related to automotive stepper motor actuators include :
  - Modular hardware architecture reduces software complexity
  - Motor used as Sensor (Bemf) Allows to Improve Control at no Additional Cost
  - Actuator Resonance Issues can be Characterized and Avoided

- Next generation HVAC systems equipped with electro-mechanical expansion valves will benefit from these stepper motor technologies

- LIN Mechatronic expansion valves allow re-balancing of system performance, cost and quality.