Hydraulic Systems Digitalization

Enrique Busquets
Engineering Manager – Mobile Systems and Electronics
Hydraulic Systems Digitalization
Unleashing Hydraulics Through Electronics

Hydraulics

Sensors & HMI

Rexroth

Robotics

Controls

Model-based engineering

Connectivity & Services

Bosch IoT Cloud

Artificial Intelligence

Computer Vision

Bosch
Hydraulic Systems Digitalization
Unleashing Hydraulics Through Electronics

Hydraulic Pilot Control (Non-EH System)
- Driver demand is given by hydraulic pilot pressure
- No electronics, no software

Electro-Hydraulic Pilot Control (EH System)
- Driver demand is given by electronic joystick
- Software computes the actuation currents for DREs

Driver demand can be manipulated by software

No possibility to manipulate driver demand

Driver demand can be manipulated by software
Traditional Load Sensing Hydraulics

Working Principle

- Pump operates in a closed-loop control with reference on the highest load pressure
- This load pressure generally exhibits large changes
- Additional uncertainties exist in the system (i.e. changes in temperature, natural frequencies and damping).

A fixed setting of the pump’s control parameters must be a compromise across all operating conditions
Traditional Load Sensing Hydraulics

Working Principle

In **tractor applications**, one setting has to cover:

- Multiple different implements
- Varying working conditions & processes
- Individual driver preferences
Load Sensing Hydraulics

Architecture Comparison

Hydraulic Load Sensing (traditional)

Electronic Load Sensing
e-LS Advances Load-Sensing Systems

Closed Center Load Sensing
+++ Efficiency
++ Controllability
++ Oil-flow
+ Operating Modes
+ Machine management
+ Performance
+ Diagnostics

Open Center Load Sensing
+++ Efficiency
++ Controllability
++ Oil-flow

Open Center Multiple pumps
+ Oil-flow
+ Energy

Open Center One pump
+ Oil-flow
+ Energy

Open Center Load Sensing
++ Efficiency
+ Controllability
+ Oil-flow
Load Sensing Hydraulics
Pump Pressure Settings Comparison

**Hydraulic Load Sensing (traditional)**

- Maximum allowable pump pressure
  - Not usable
  - **Fixed** pressure cut-off
  - **Fixed** standby pressure
- Minimum needed pump pressure

**Electronic Load Sensing**

- Maximum allowable pump pressure
  - **Variable** pressure cut-off
  - **Variable** standby pressure
- Minimum needed pump pressure

- No possibility to vary pump settings on demand
- + Maximum system pressure is defined by software
  + Possibility of pressure/force limitation for single machine functions (e.g. gripper force limitation)
  + Lower standby pressure
Load Sensing Hydraulics
Pump Dynamic Behavior Comparison

Hydraulic Load Sensing (traditional)

- No possibility to vary pump settings on demand

Electronic Load Sensing

+ Avoid oscillations
+ Smooth reaction for high controllability
+ Fast reaction for aggressive maneuvers
Load Sensing Hydraulics
Pressure Behavior Comparison

Hydraulic Load Sensing (traditional)

- No possibility to vary pump settings on demand

Electronic Load Sensing

+ Avoid oscillations
+ Smooth reaction for high controllability
+ Fast reaction for aggressive maneuvers
Electronic Load Sensing (eLS)
Various Operation Modes for Different Use Cases

**Mode 1**
Constant Differential Pressure

- \( P_{\text{max}} \)
- Load pressure
- Pump pressure
- \( P_{\text{lab}} \)
- Oil flow
- \( \Delta P \) (Pressure losses)

**Mode 2**
Variable Differential Pressure

- \( P_{\text{max}} \)
- Load pressure
- Pump pressure
- \( P_{\text{lab}} \)
- Oil flow
- \( \Delta P \) (Pressure losses)

**Mode 3**
Constant Pressure Control

- \( P_{\text{max}} \)
- Load pressure
- Pump pressure
- \( P_{\text{lab}} \)
- Oil flow

**Mode 4**
Active Pressure Control

- \( P_{\text{max}} \)
- Pump pressure
- \( P_{\text{lab}} \)
- Control signal

- Example: \( \text{ctrl sig} = \alpha \) drive pedal

Energy saving
Electronic Load Sensing (eLS)
Various Operation Modes for Different Use Cases

Mode 1
- Constant Differential Pressure
- $p_{\text{max}}$
- $p_{\text{stb}}$
- $p_{\text{max}}$
- $\Delta p$
- load pressure
- pump pressure
- (Pressure losses)
- oil flow

Mode 2
- Variable Differential Pressure
- $p_{\text{max}}$
- $p_{\text{stb}}$
- $p_{\text{max}}$
- $\Delta p$
- load pressure
- pump pressure
- (Pressure losses)
- oil flow

Mode 3
- Constant Pressure Control
- $p_{\text{max}}$
- $p_{\text{stb}}$
- $p_{\text{max}}$
- $\Delta p$
- load pressure
- pump pressure
- (Pressure losses)
- oil flow

Mode 4
- Active Pressure Control
- $p_{\text{max}}$
- $p_{\text{stb}}$
- control signal

- Enhanced implement performance due to optimal compensation of pressure losses
- Higher stability
- Energy saving
Electronic Load Sensing (eLS)
Various Operation Modes for Different Use Cases

Mode 1: Constant Differential Pressure
- \( p_{\text{max}} \) constant differential pressure
- \( p_{\text{stb}} \) system pressure
- \( p_{\text{load}} \) load pressure
- \( p_{\text{pump}} \) pump pressure
- \( \Delta p \) (Pressure losses)

Mode 2: Variable Differential Pressure
- \( p_{\text{max}} \) variable differential pressure
- \( p_{\text{stb}} \) system pressure
- \( p_{\text{load}} \) load pressure
- \( p_{\text{pump}} \) pump pressure
- \( \Delta p \) (Pressure losses)

Mode 3: Constant Pressure Control
- \( p_{\text{max}} \) constant pressure
- \( p_{\text{stb}} \) system pressure
- \( p_{\text{load}} \) load pressure
- \( p_{\text{pump}} \) pump pressure

Mode 4: Active Pressure Control
- Fast reaction and increased stability for certain implements
- Working point optimization with adjustable constant pressure for secondary controlled implements

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Electronic Load Sensing (eLS)  
Various Operation Modes for Different Use Cases

<table>
<thead>
<tr>
<th>Mode 1</th>
<th>Mode 2</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Constant Differential Pressure</strong></td>
<td><strong>Variable Differential Pressure</strong></td>
</tr>
<tr>
<td>$p_{\text{max}}$</td>
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<tr>
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<td>$p_{\text{load}}$</td>
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<tr>
<td>$p_{\text{pump}}$</td>
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<tr>
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<td>$\text{oil flow}$</td>
</tr>
<tr>
<td>$\text{variable}$</td>
<td>$\text{variable}$</td>
</tr>
<tr>
<td>$\text{system (Pressure losses)}$</td>
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</tr>
<tr>
<td>$dp$</td>
<td>$dp$</td>
</tr>
</tbody>
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<td>$\text{oil flow}$</td>
<td>$\text{control signal}$</td>
</tr>
</tbody>
</table>

- **Possibility of torque based driving**  
  (additional driven axle on trailer, etc.)
- **Pressure on demand**  
  (front axle activation)
Load Sensing Hydraulics
Selecting the Optimized Settings for Each Individual Implement

Automatic

Remote

Manual

Electronic Load Sensing

LS valve stack

consumer 1

consumer 2

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Load Sensing Hydraulics
eLS with Steering

Electronic Load Sensing

LS valve stack

STEERING

consumer 2

psys

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Practical Examples
Electronic Load Sensing (eLS) Hydraulics

Active Pressure Control

Hydraulic Load Sensing (LS)

Electronic Load Sensing (eLS)

Griper Control

Pressure Too Low
Pressure Too High
Optimal and repeatable pressure setting
Electronic Load Sensing (eLS) Hydraulics

Variable Differential Pressure

Hydraulic Load Sensing (LS)

Electronic Load Sensing (eLS)
Electronic Load Sensing (eLS) Hydraulics

Variable dynamic response

Maximum allowable pump pressure

Minimum needed pump pressure

fast

medium

slow

Pressure [bar]

Time [s]

Front-loader Lifting Control

Electronic Load Sensing (eLS)
Electronic Load Sensing (eLS) Hydraulics

Fan Control

Hydraulic Load Sensing (LS)

Electronic Load Sensing (eLS)
Electronic Load Sensing (eLS)
Enhanced Benefits for Most Efficient Working Results

- **Improved Efficiency** due to optimized differential pressure
- **Increased power and improved response** of the implement, due to variable pressure limits
- **Individual system adaption**
- **Easy to use** with predefined modes
- **High flexibility**, software-based variant handling
- **Less installation space**
- **Connectivity option** for system monitoring

- **Saves energy**
- **Ease of use**
- **More precise**
- **Adaptive**
- **Less space**
- **Saves time**
- **Increased power**
- **Highly flexible**
Thank You!

Enrique Busquets
Enrique.Busquets@bosch.com