# Hydraulic Systems Digitalization

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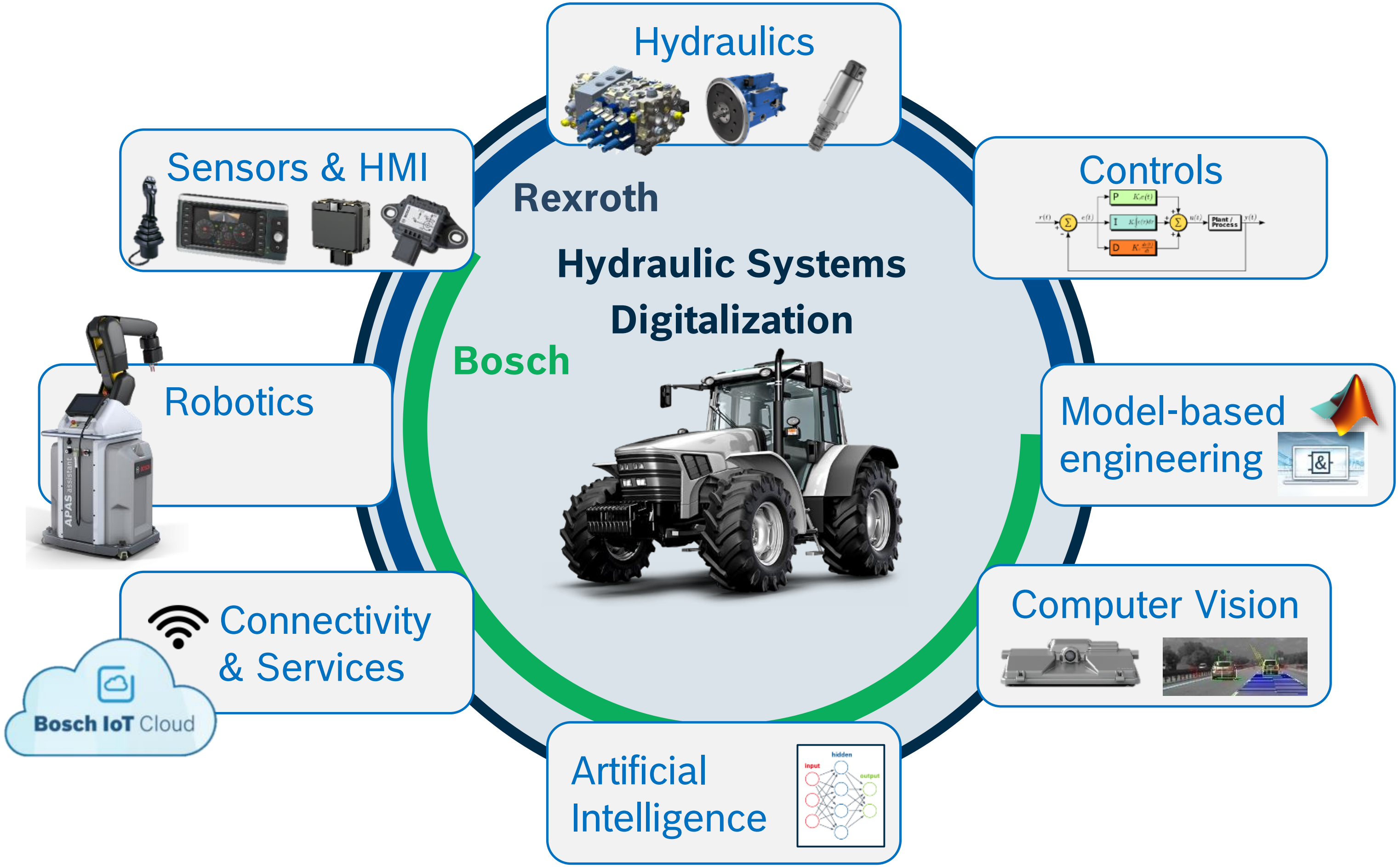
rexroth
A Bosch Company

# Hydraulic Systems Digitalization
## Unleashing Hydraulics Through Electronics



Hydraulics

Controls

Model-based engineering

Computer Vision

Artificial Intelligence

Connectivity & Services

Robotics

Sensors & HMI

**Rexroth**

**Hydraulic Systems Digitalization**

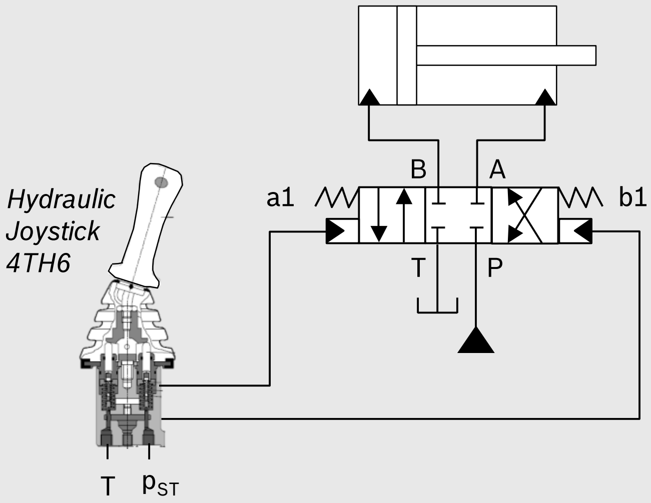
**Bosch**

Bosch IoT Cloud
APAS assistant
hidden
input
output
Plant / Process

# 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

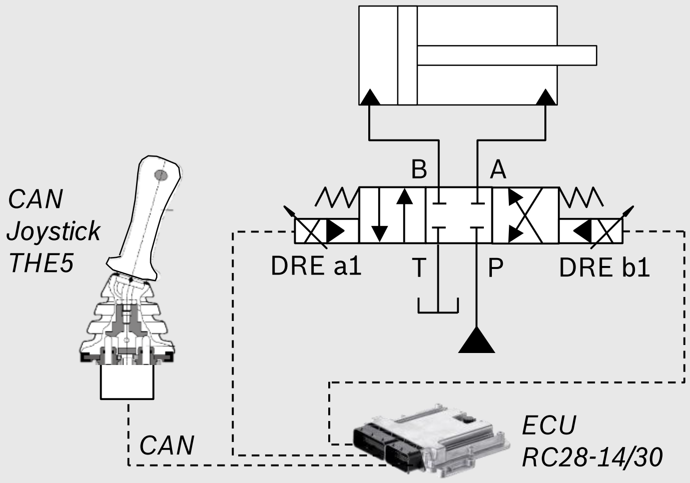

Hydraulic Joystick 4TH6
a1
B
A
b1
T
P
T
$p_{ST}$

**No possibility to manipulate driver demand**

**vs.**

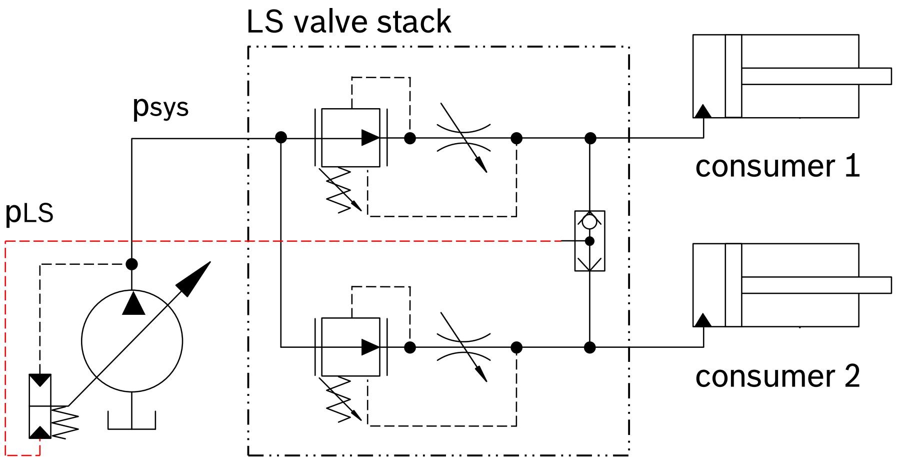
### Electro-Hydraulic Pilot Control (EH System)

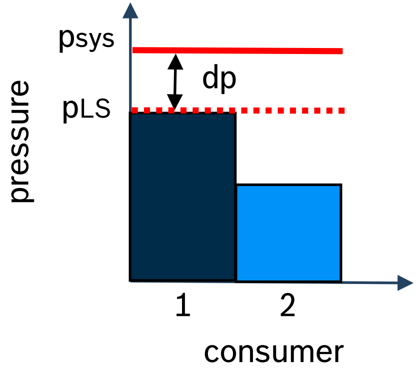
- Driver demand is given by electronic joystick
- Software computes the actuation currents for DREs


CAN Joystick THE5
B
A
DRE a1
T
P
DRE b1
CAN
ECU RC28-14/30

**Driver demand can be manipulated by software**

# Traditional Load Sensing Hydraulics
## Working Principle

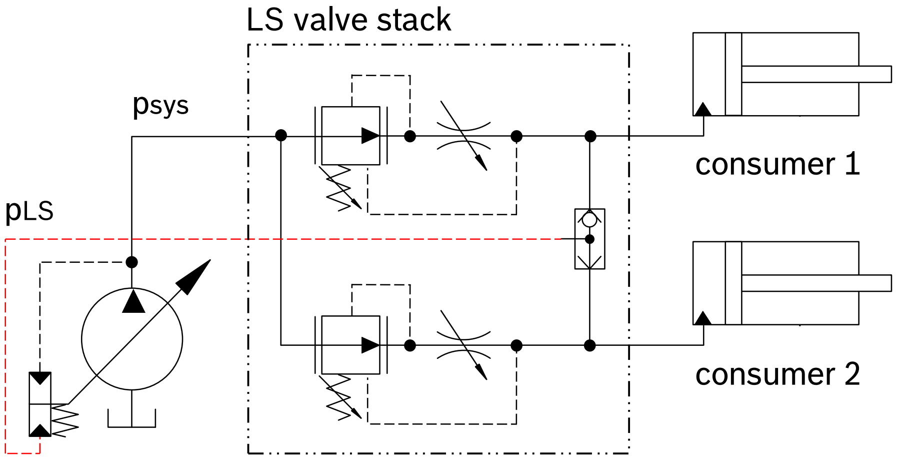


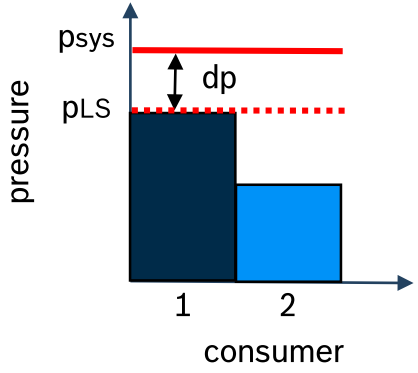


- Pump operates in a closed-loop control with reference on the highest load pressure
- This load pressure generally exhibits large changes
- Additional uncertainties exist in the system (i.e. changes in temperature, natural frequencies and damping).

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

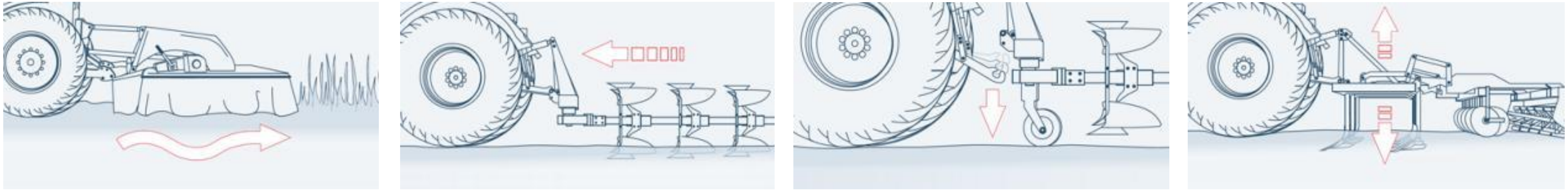
# Traditional Load Sensing Hydraulics
## Working Principle


LS valve stack
psys
pLS
consumer 1
consumer 2



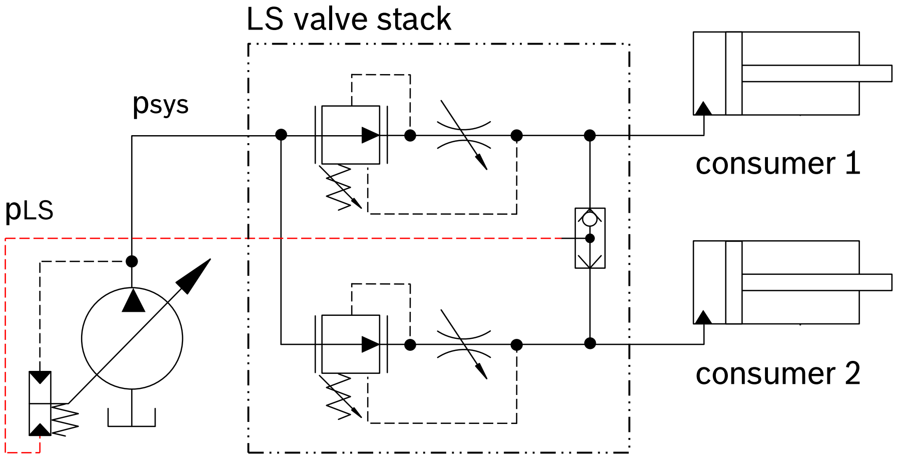
In **tractor applications**, one setting has to cover:

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

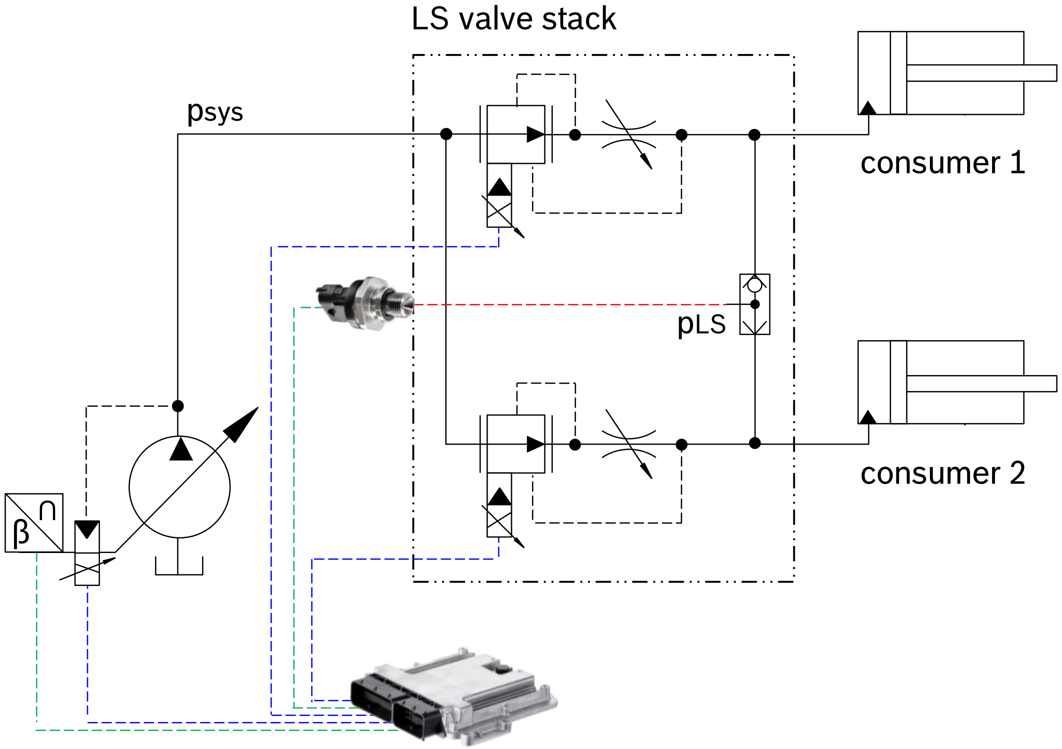


# Load Sensing Hydraulics
## Architecture Comparison

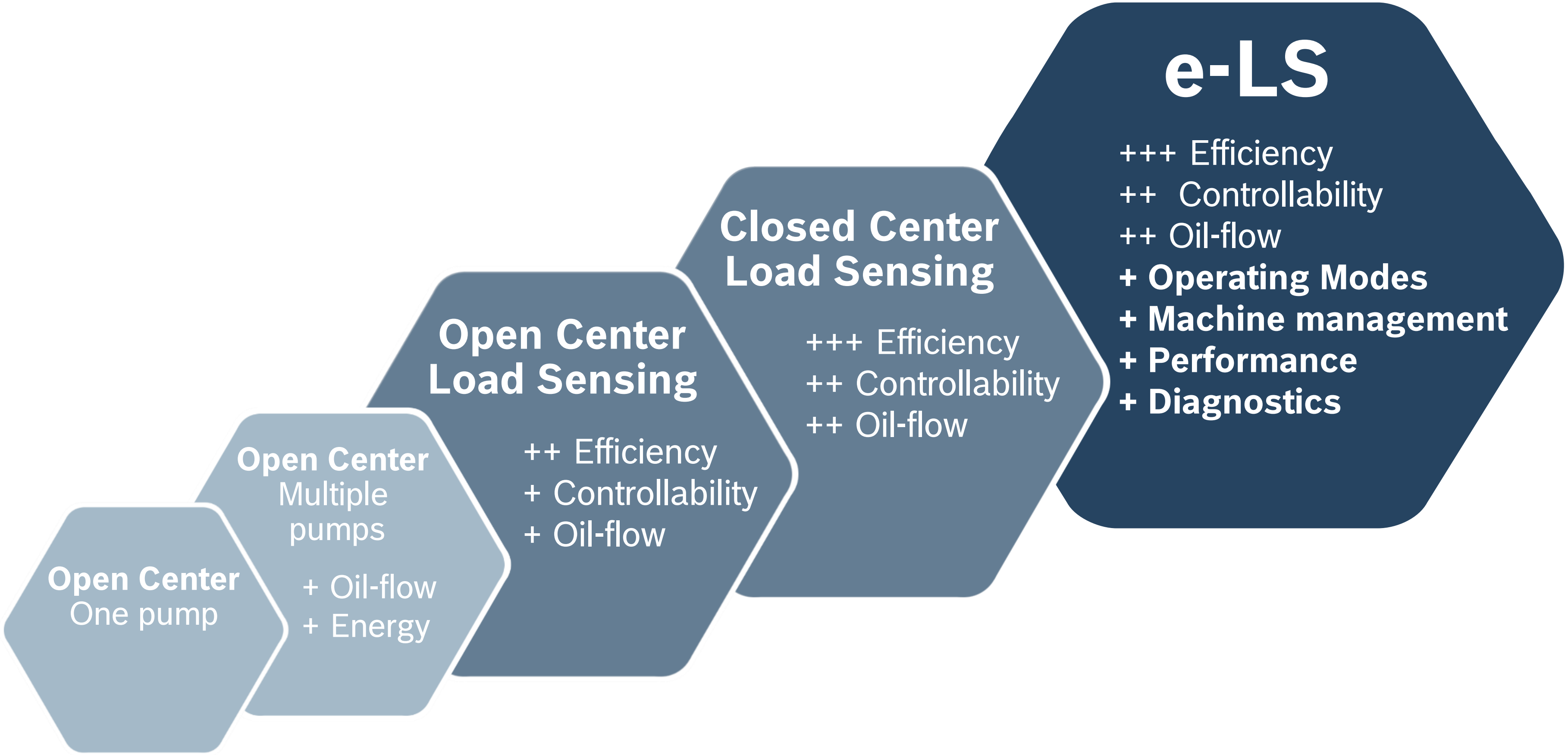
### Hydraulic Load Sensing (traditional)


LS valve stack
psys
pLS
consumer 1
consumer 2

### Electronic Load Sensing


LS valve stack
psys
consumer 1
pLS
consumer 2
β
∩

# e-LS Advances Load-Sensing Systems



**Open Center**
One pump

**Open Center**
Multiple
pumps

+ Oil-flow
+ Energy

**Open Center**
**Load Sensing**

++ Efficiency
+ Controllability
+ Oil-flow

**Closed Center**
**Load Sensing**

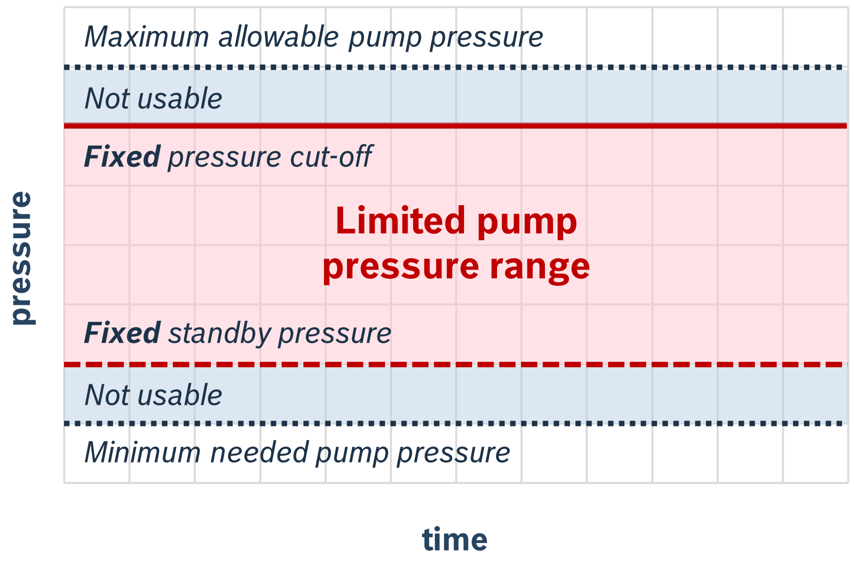
+++ Efficiency
++ Controllability
++ Oil-flow

**e-LS**

+++ Efficiency
++ Controllability
++ Oil-flow
**+ Operating Modes**
**+ Machine management**
**+ Performance**
**+ Diagnostics**

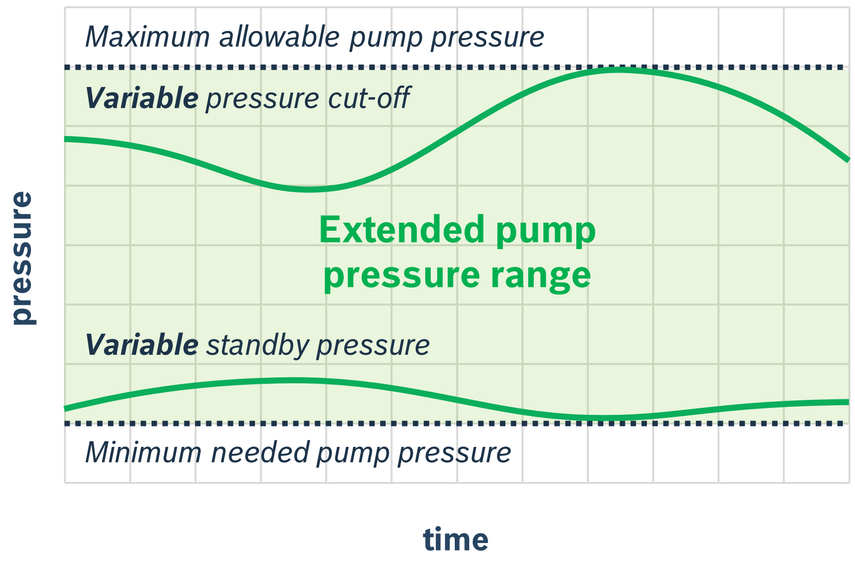
# Load Sensing Hydraulics
## Pump Pressure Settings Comparison

### Hydraulic Load Sensing (traditional)


Maximum allowable pump pressure
Not usable
Fixed pressure cut-off
Limited pump pressure range
Fixed standby pressure
Not usable
Minimum needed pump pressure
pressure
time

- No possibility to vary pump settings on demand

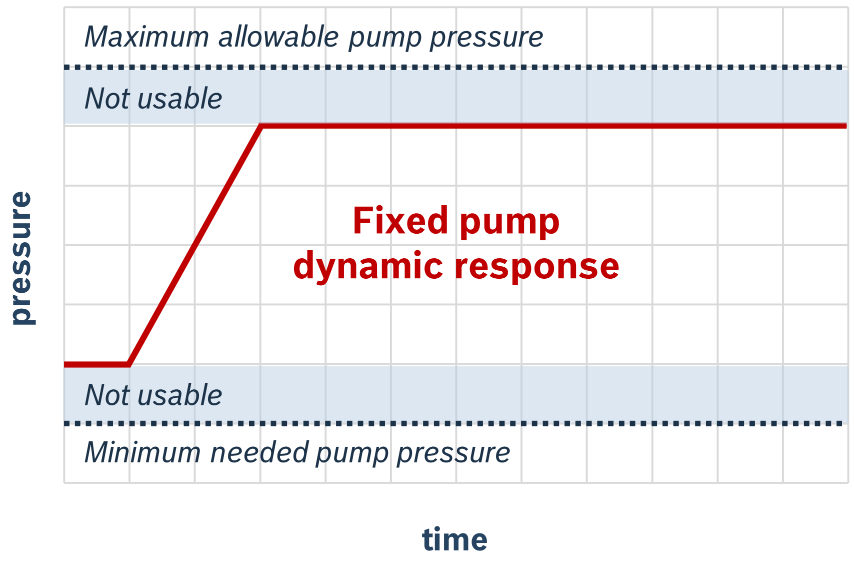
### Electronic Load Sensing


Maximum allowable pump pressure
Variable pressure cut-off
Extended pump pressure range
Variable standby pressure
Minimum needed pump pressure
pressure
time

+ Maximum system pressure is defined by software
+ Possibility of pressure/force limitation for single machine functions (e.g. gripper force limitation)
+ Lower standby pressure

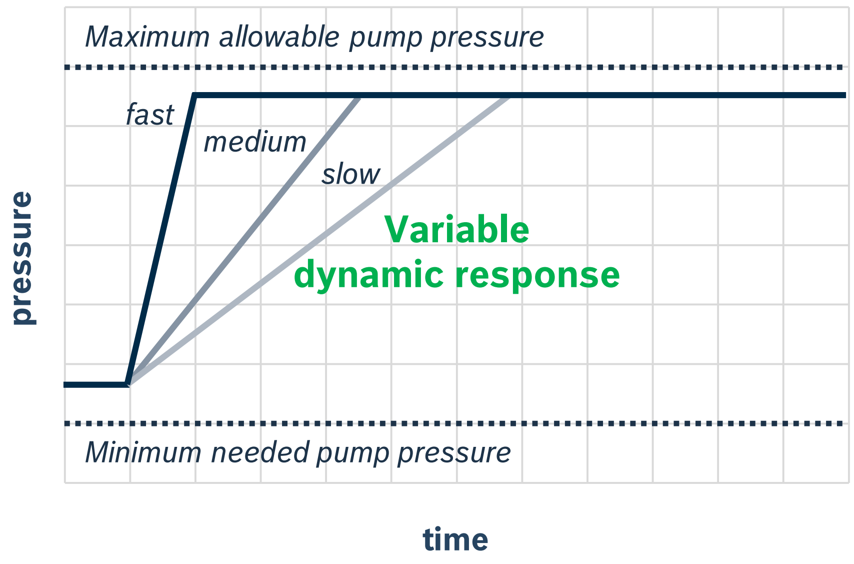
# Load Sensing Hydraulics
## Pump Dynamic Behavior Comparison

### Hydraulic Load Sensing (traditional)



- No possibility to vary pump settings on demand

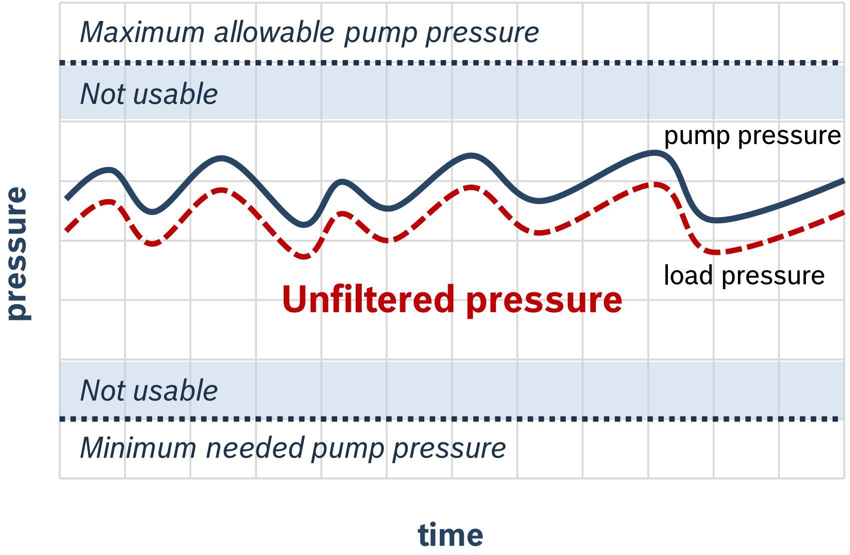
### Electronic Load Sensing



+ Avoid oscillations
+ Smooth reaction for high controllability
+ Fast reaction for aggressive maneuvers

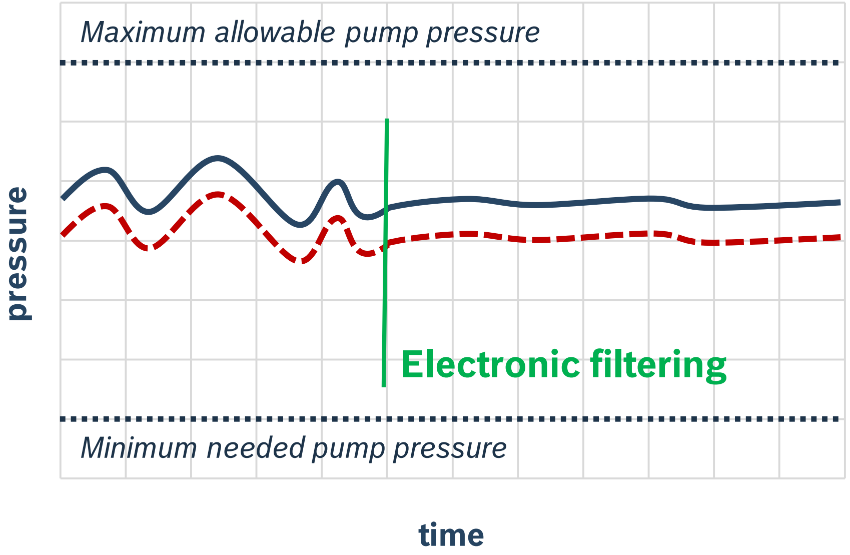
# Load Sensing Hydraulics
## Pressure Behavior Comparison

### Hydraulic Load Sensing (traditional)



- No possibility to vary pump settings on demand

### Electronic Load Sensing

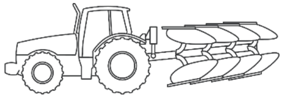


+ Avoid oscillations
+ Smooth reaction for high controllability
+ Fast reaction for aggressive maneuvers

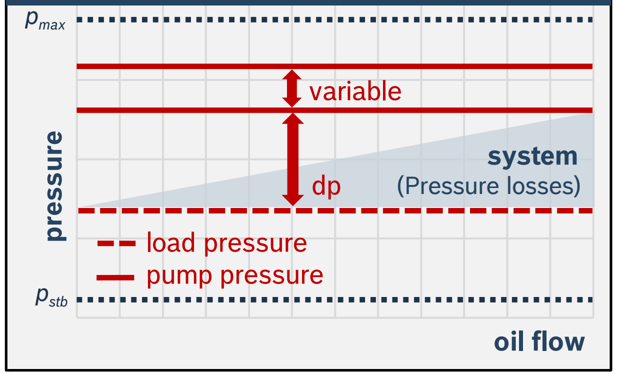
# Electronic Load Sensing (eLS)

## Various Operation Modes for Different Use Cases

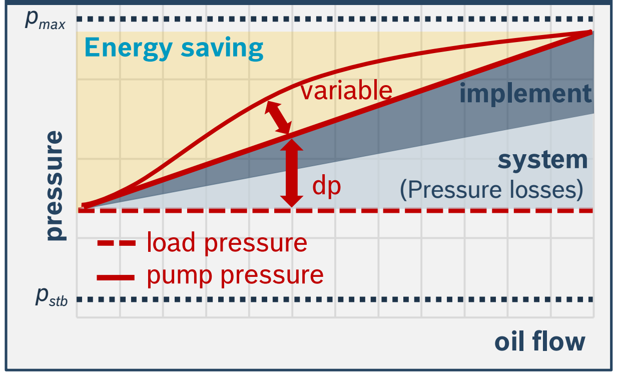
**Mode 1**



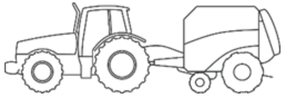
### Constant Differential Pressure



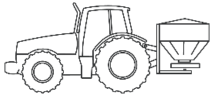
### Variable Differential Pressure



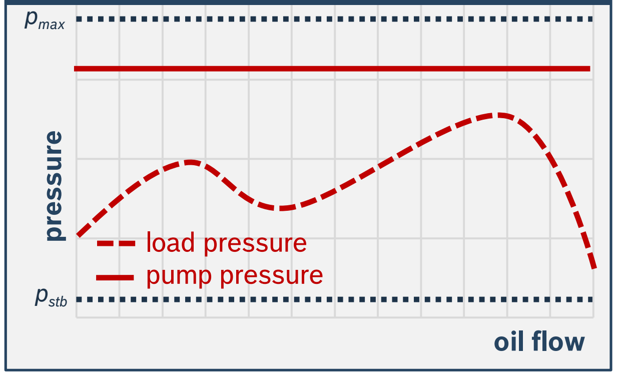
**Mode 2**



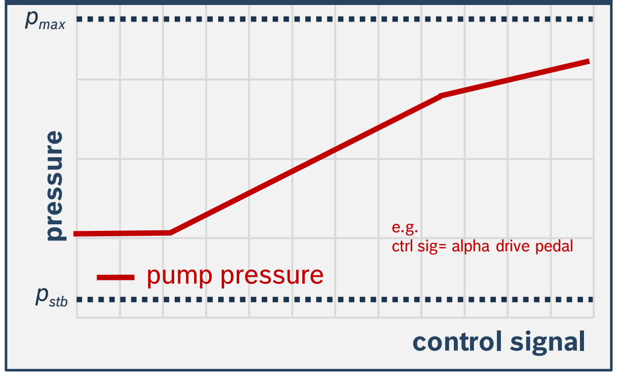
**Mode 3**



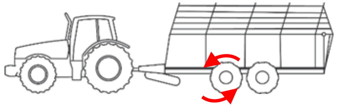
### Constant Pressure Control



### Active Pressure Control



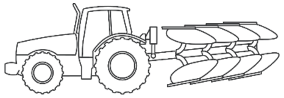
**Mode 4**

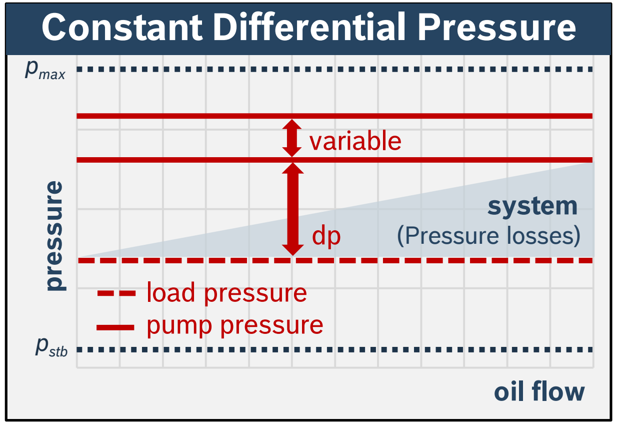


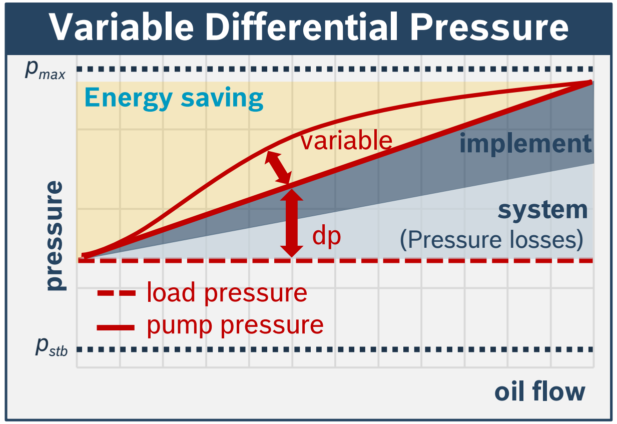
# Electronic Load Sensing (eLS)

## Various Operation Modes for Different Use Cases

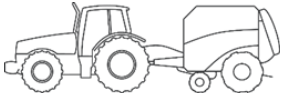
**Mode 1**



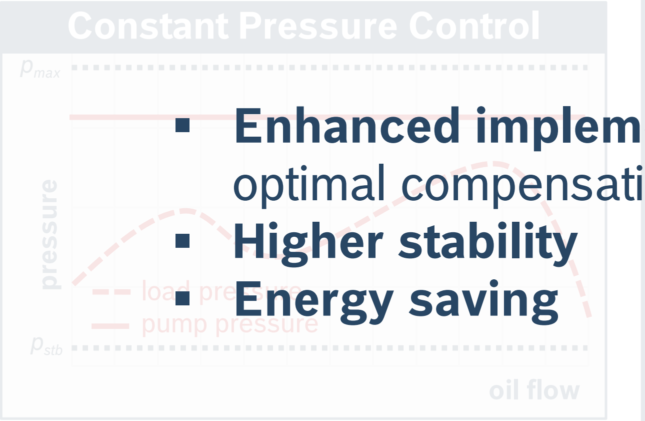

**Constant Differential Pressure**


**Variable Differential Pressure**

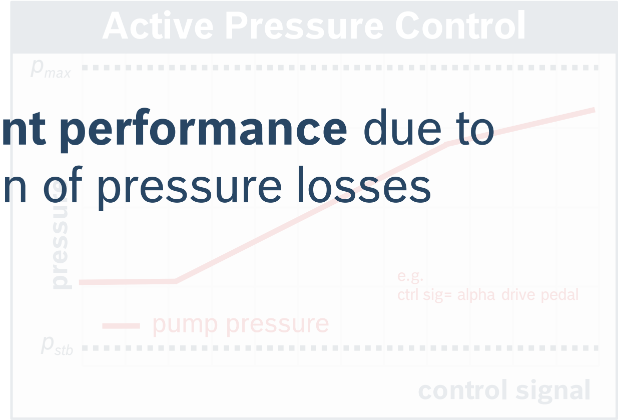
**Mode 2**



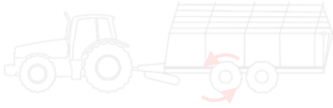
**Mode 3**


**Constant Pressure Control**

- **Enhanced implement performance** due to optimal compensation of pressure losses
- **Higher stability**
- **Energy saving**


**Active Pressure Control**

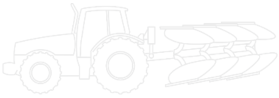
**Mode 4**

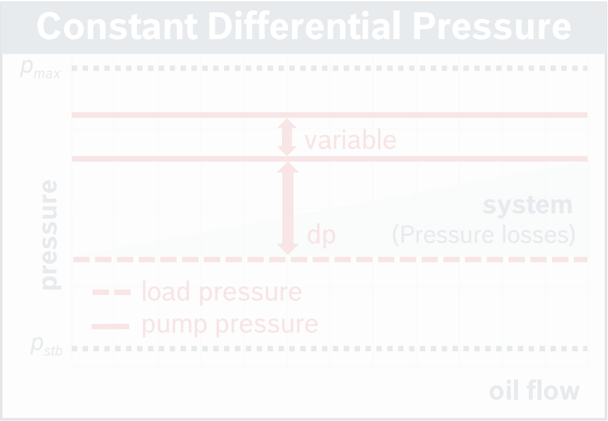


# Electronic Load Sensing (eLS)

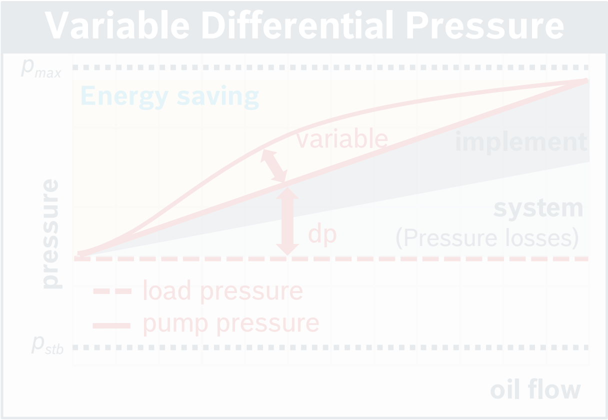
## Various Operation Modes for Different Use Cases

**Mode 1**

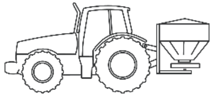


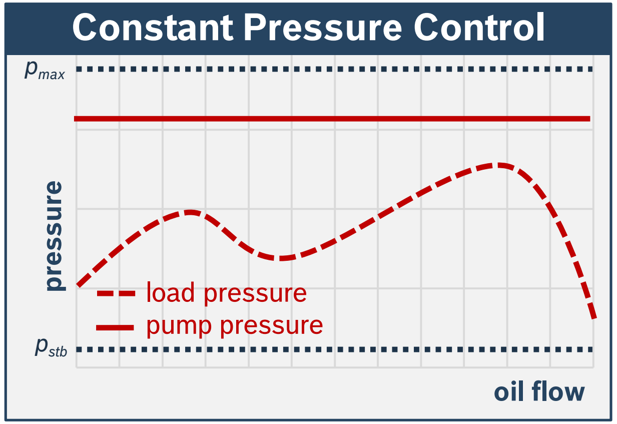

Constant Differential Pressure
$p_{max}$
variable
system
(Pressure losses)
dp
pressure
load pressure
pump pressure
$p_{stb}$
oil flow

**Mode 2**

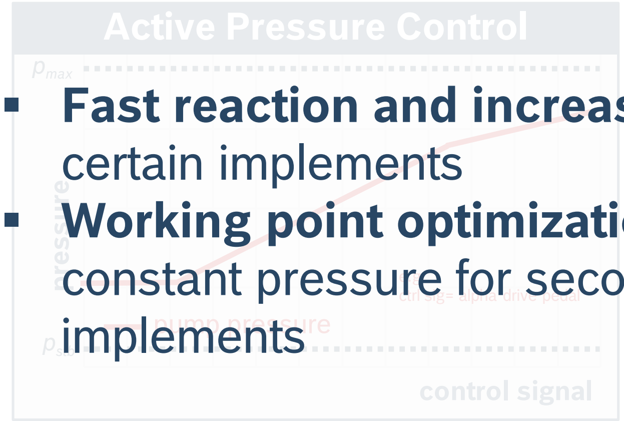

Variable Differential Pressure
$p_{max}$
Energy saving
variable
implement
system
(Pressure losses)
dp
pressure
load pressure
pump pressure
$p_{stb}$
oil flow

**Mode 3**




Constant Pressure Control
$p_{max}$
pressure
load pressure
pump pressure
$p_{stb}$
oil flow

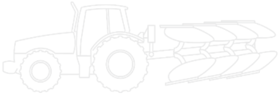
**Mode 4**

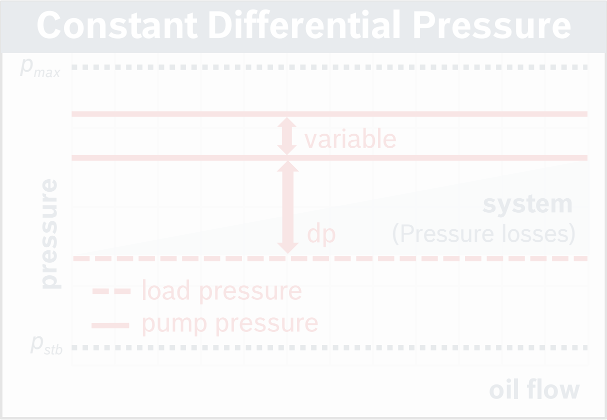

Active Pressure Control
$p_{max}$
pressure
pump pressure
$p_{stb}$
control signal

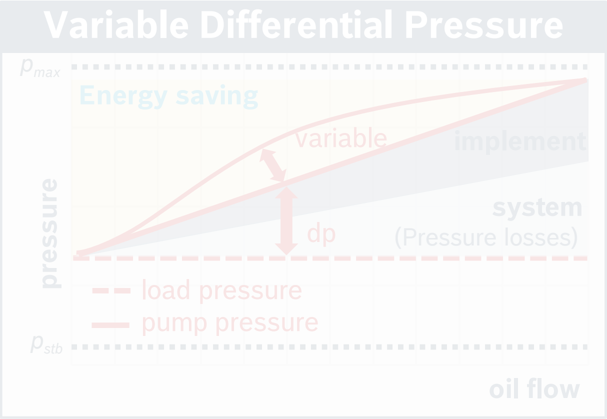
- **Fast reaction and increased stability** for certain implements
- **Working point optimization** with adjustable constant pressure for secondary controlled implements

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

Mode 1

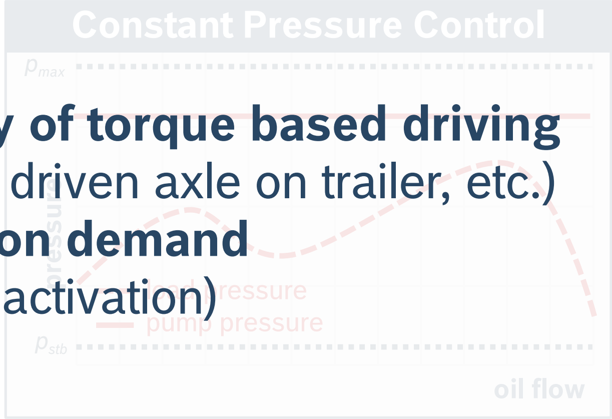




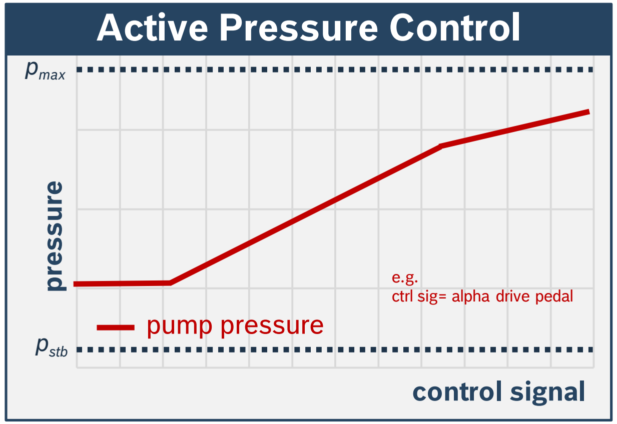


Mode 2

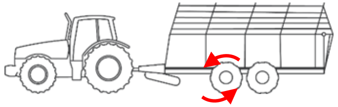
Mode 3



- **Possibility of torque based driving**
  (additional driven axle on trailer, etc.)
- **Pressure on demand**
  (front axle activation)

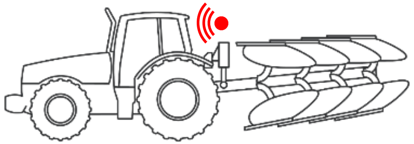


**Mode 4**



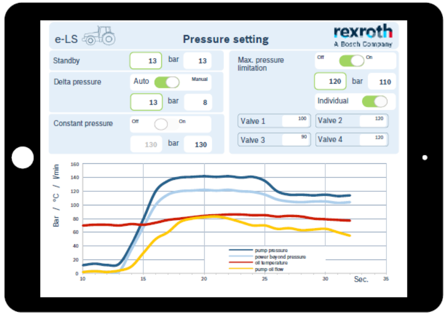
# Load Sensing Hydraulics
## Selecting the Optimized Settings for Each Individual Implement

**Automatic**



**Remote**

eLS



e-LS

Pressure setting

Standby: 13 bar 13

Delta pressure: Auto ● Manual; 13 bar 8

Constant pressure: Off ○ On; 130 bar 130

Max. pressure limitation: Off ● On; 120 bar 110

Individual ●

Valve 1: 100

Valve 2: 120

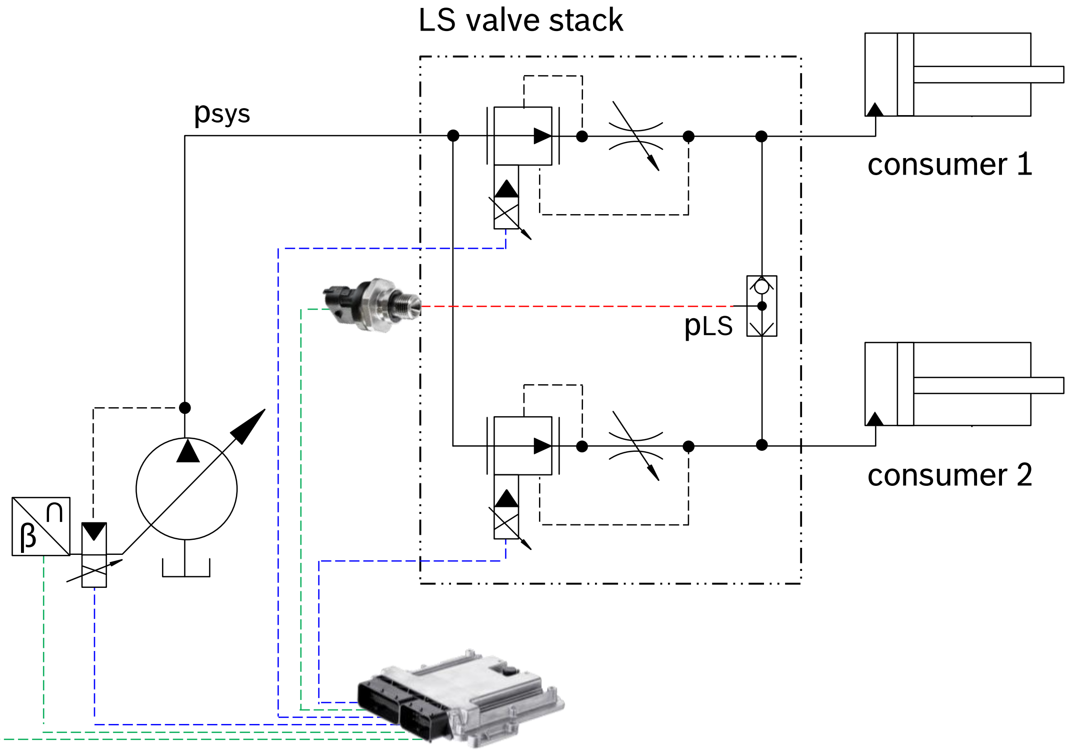
Valve 3: 90

Valve 4: 120

rexroth
A Bosch Company
Bar / °C / l/min
160
140
120
100
80
60
40
20
0
10
15
20
25
30
Sec.
35
pump pressure
power beyond pressure
oil temperature
pump oil flow

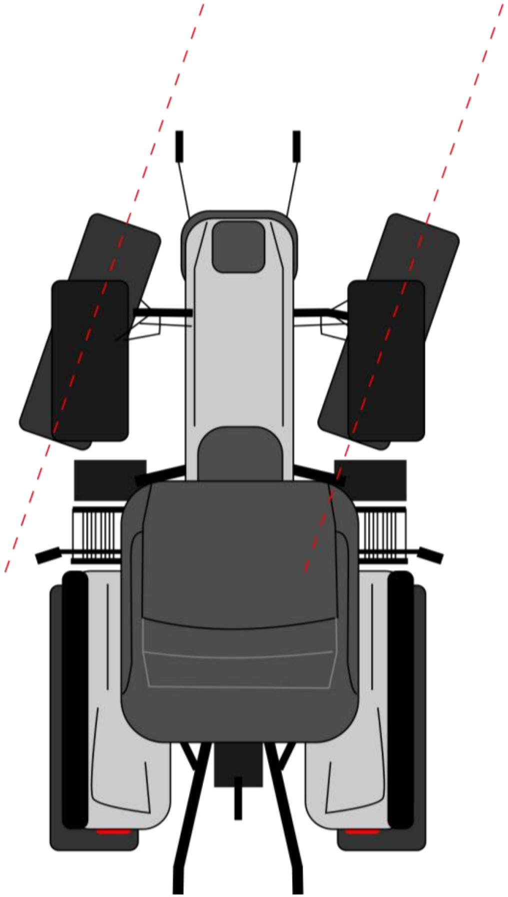
**Manual**

## Electronic Load Sensing

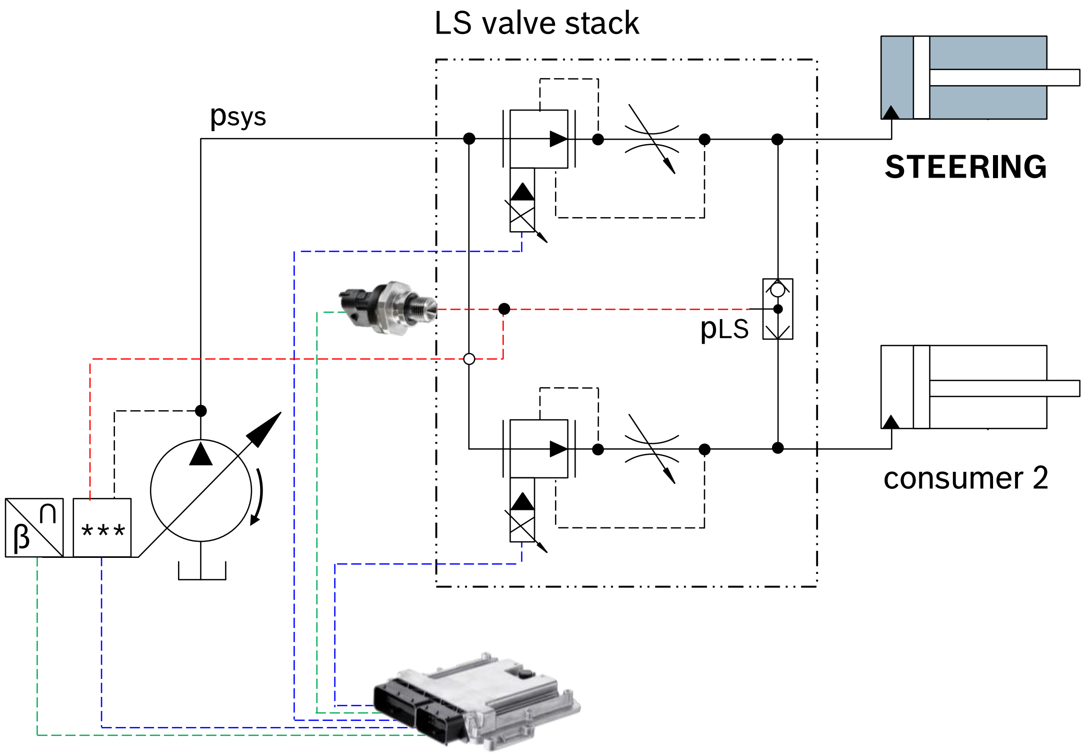


LS valve stack
psys
consumer 1
pLS
consumer 2
β

# Load Sensing Hydraulics
## eLS with Steering



## Electronic Load Sensing


LS valve stack
psys
STEERING
pLS
consumer 2
β
∩
***

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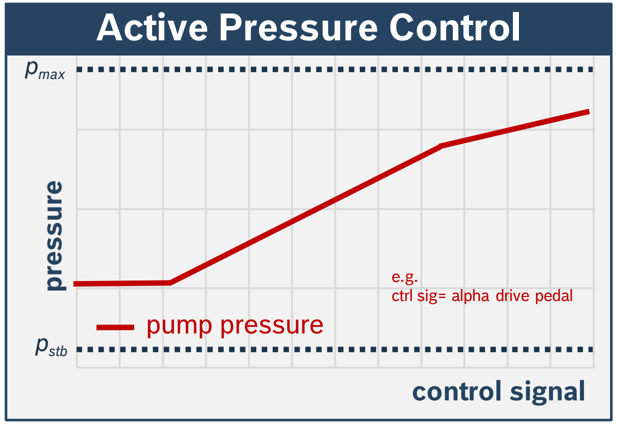
# Practical Examples

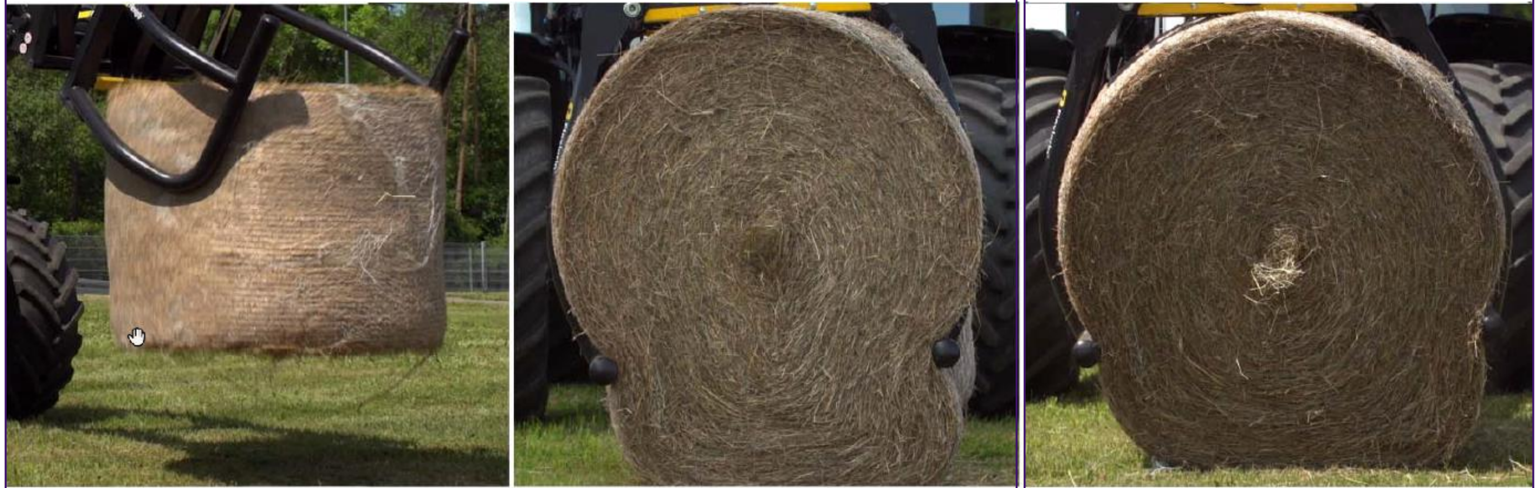
# Electronic Load Sensing (eLS) Hydraulics



Griper Control

Hydraulic Load Sensing (LS)

Electronic Load Sensing (eLS)



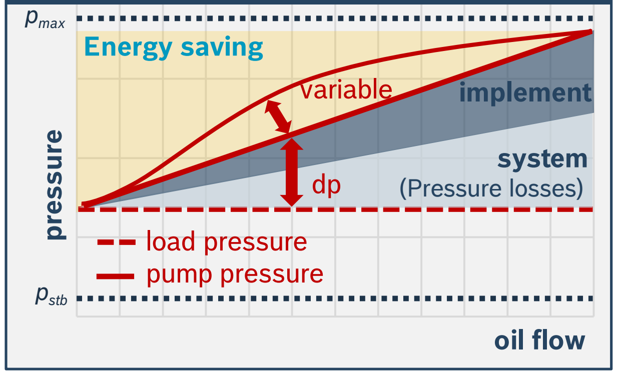
Pressure Too Low

Pressure Too High

Optimal and repeatable pressure setting

# Electronic Load Sensing (eLS) Hydraulics

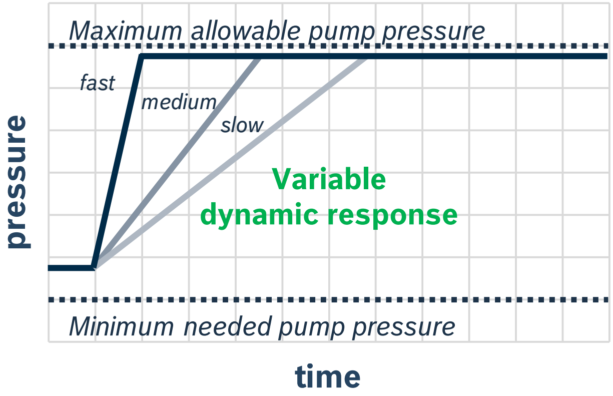
**Variable Differential Pressure**



Hydraulic Load Sensing (LS)

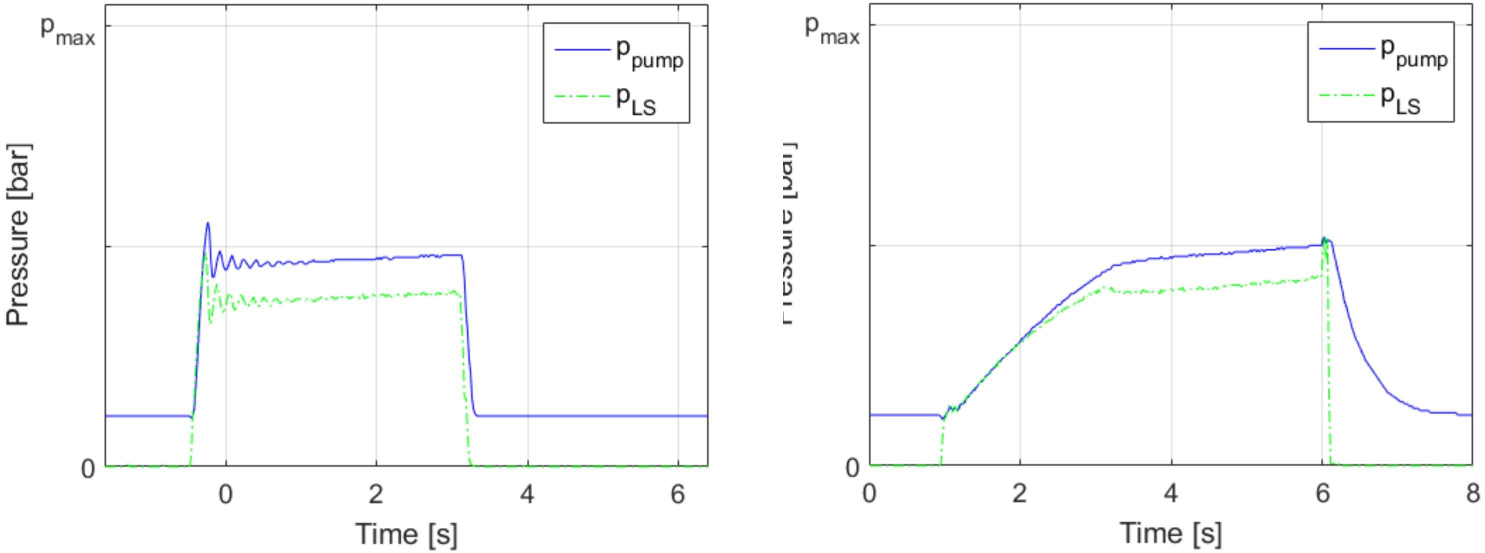
Electronic Load Sensing (eLS)

# Electronic Load Sensing (eLS) Hydraulics

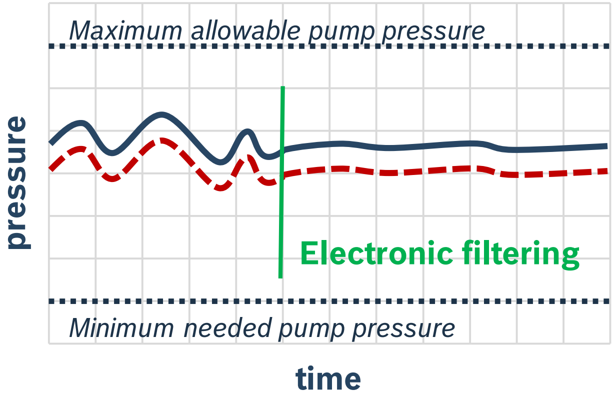

Maximum allowable pump pressure
fast
medium
slow
Variable dynamic response
pressure
Minimum needed pump pressure
time

Front-loader Lifting Control

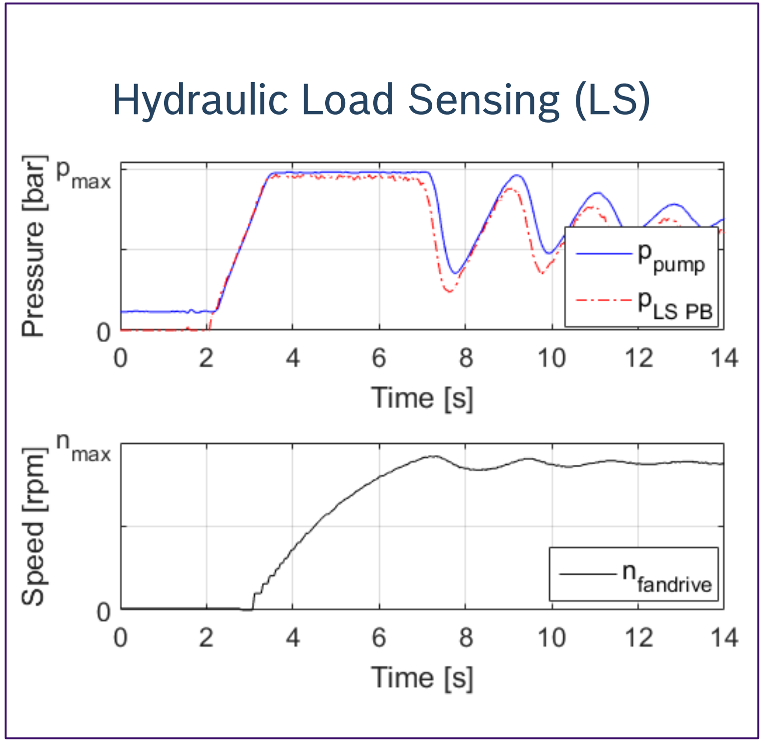
Electronic Load Sensing (eLS)



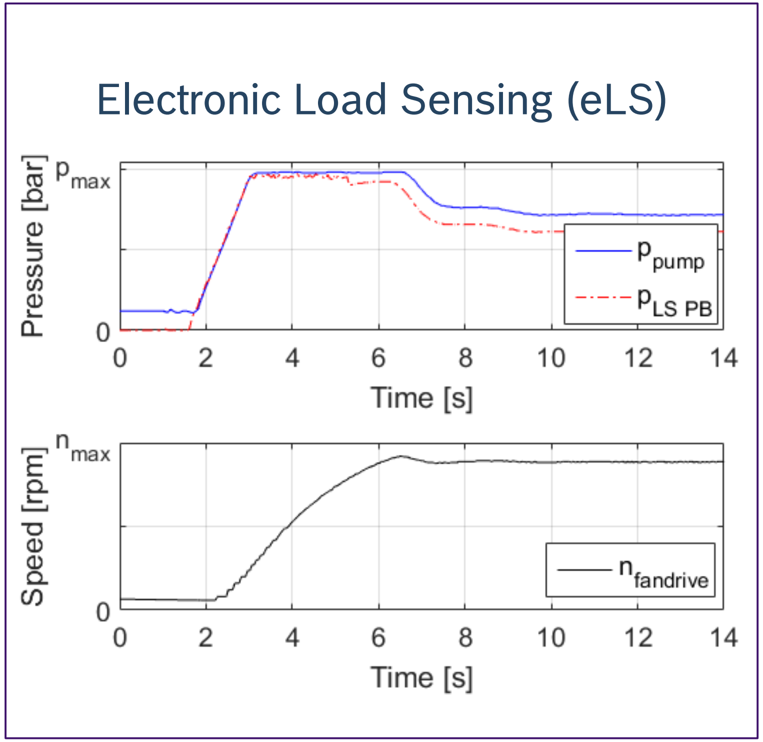
# Electronic Load Sensing (eLS) Hydraulics


Maximum allowable pump pressure
pressure
Electronic filtering
Minimum needed pump pressure
time

Fan Control



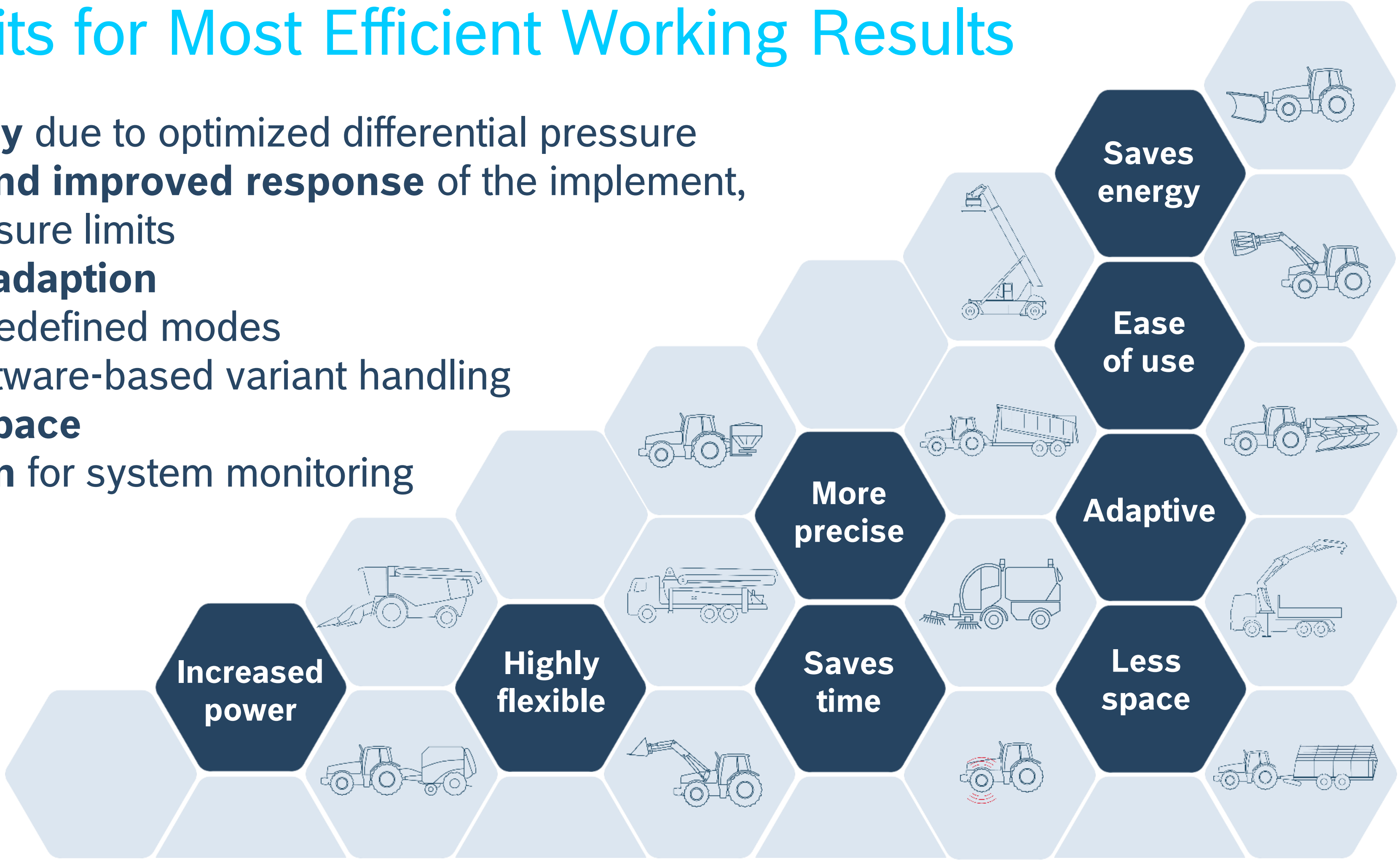
Hydraulic Load Sensing (LS)



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
Increased power
Highly flexible
Saves time
Less space

# Thank You!

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