Actuator 2 – Hydraulic and Pneumatic Actuation

ME490A
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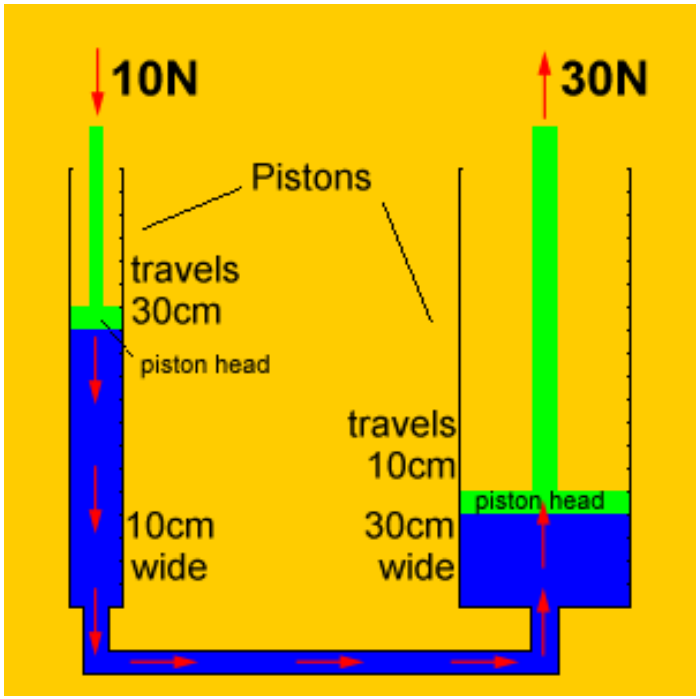
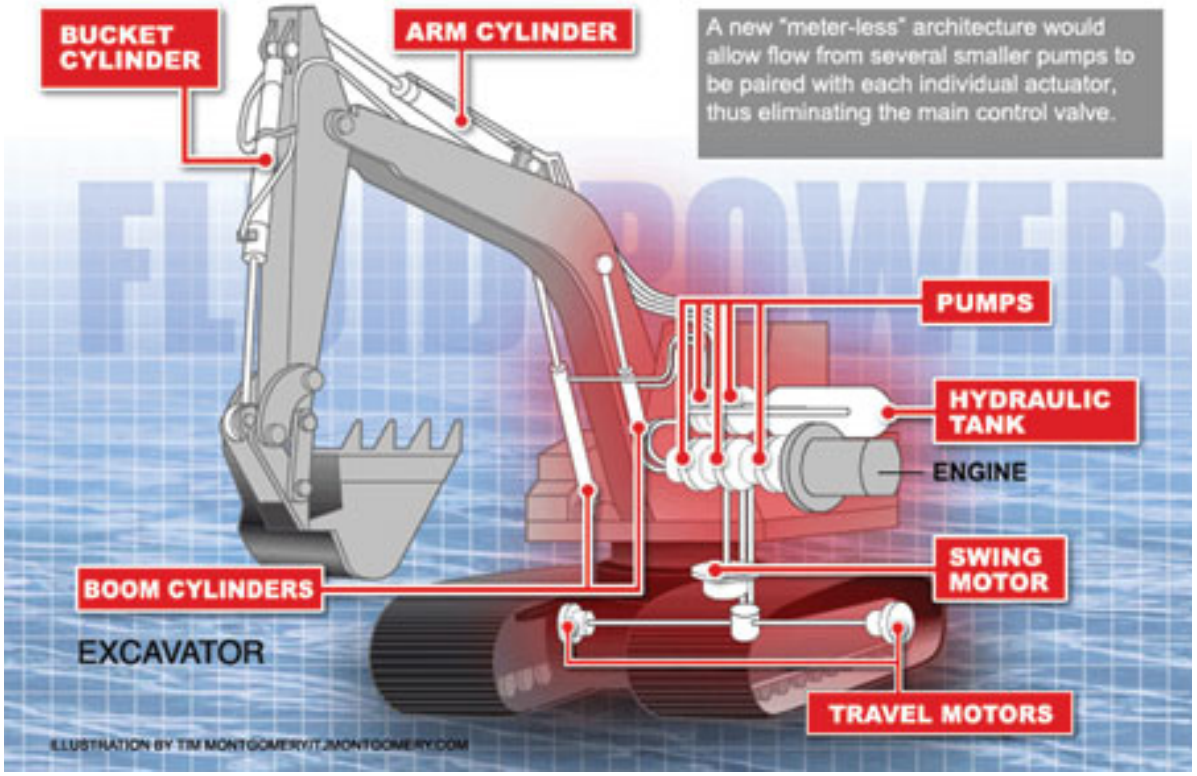
Adapted from a presentation by Dr. Kee Moon

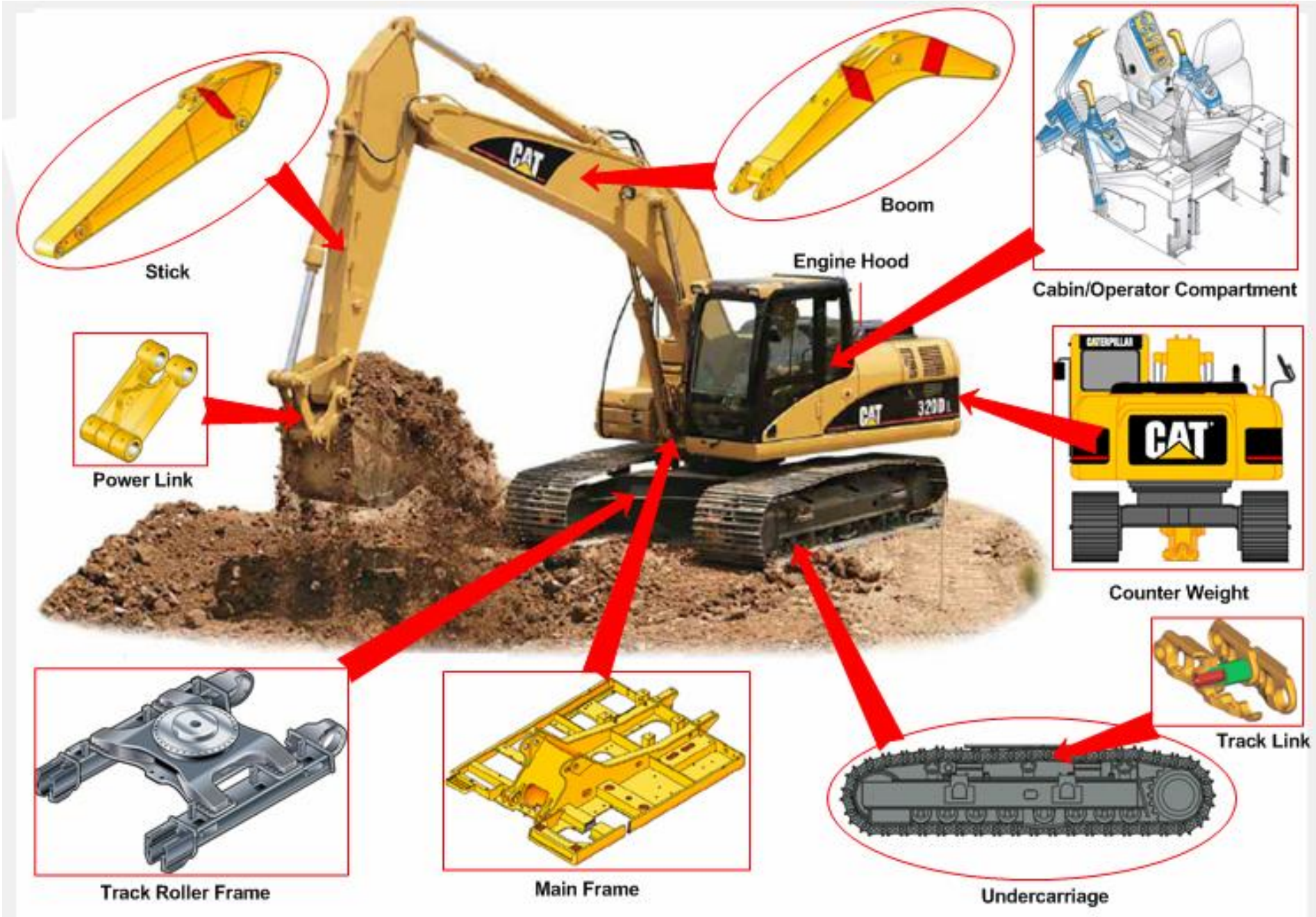
Excavators


10N
30N
Pistons
travels
30cm
piston head
travels
10cm
piston head
10cm
wide
30cm
wide

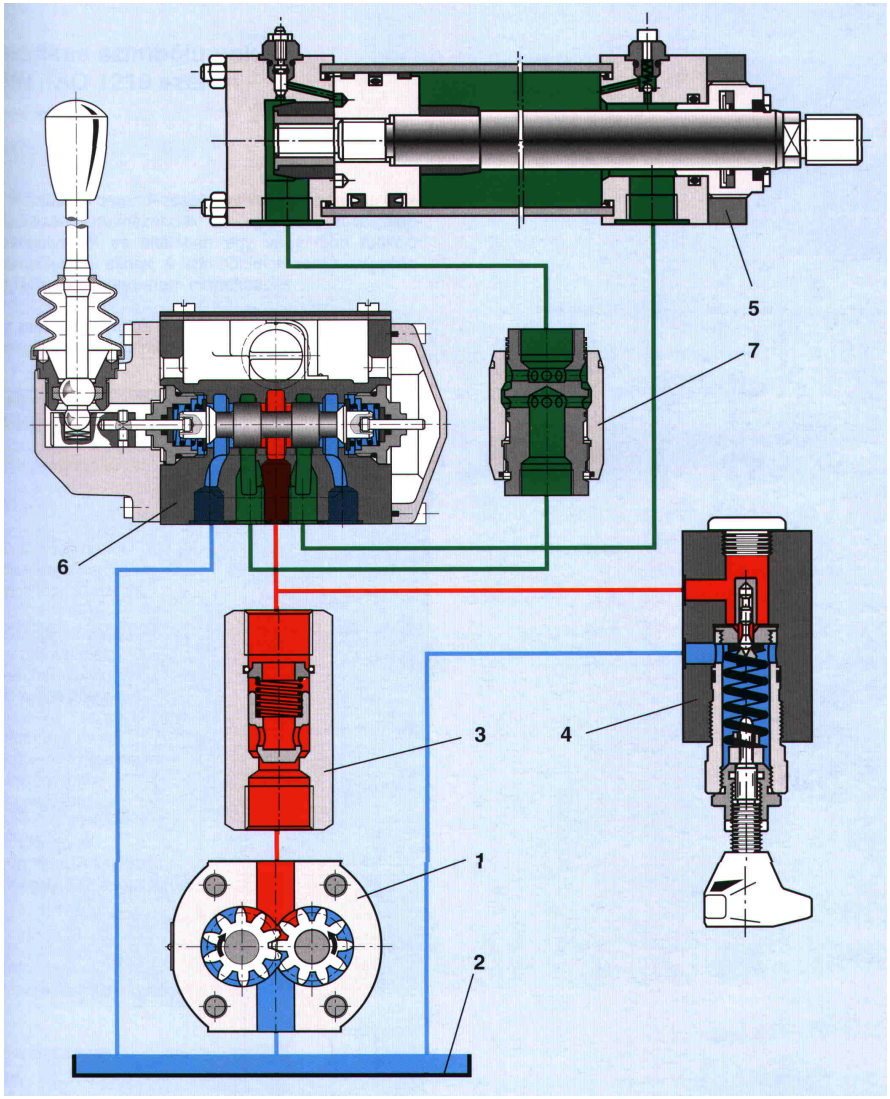

LIEBHERR

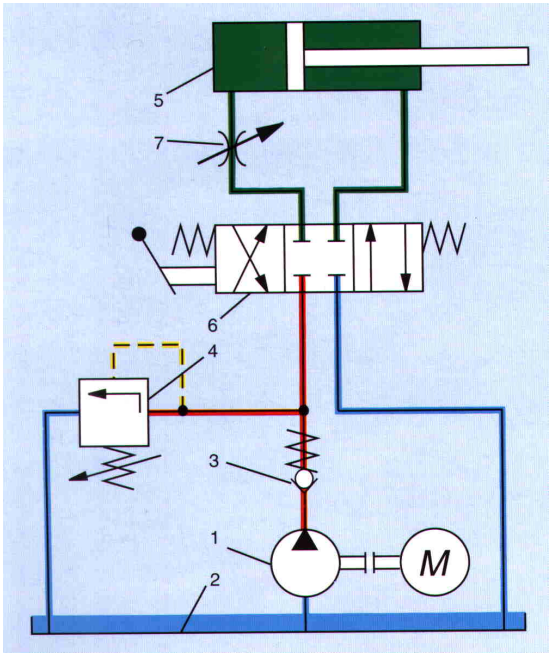
Excavator hydraulics



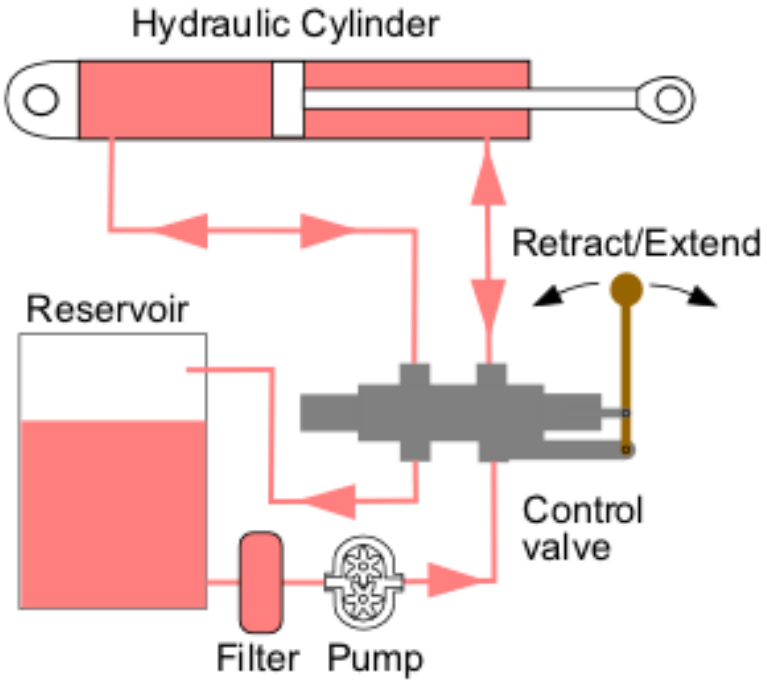

Stick
Boom
Engine Hood
Cabin/Operator Compartment
Power Link
Counter Weight
Track Link
Track Roller Frame
Main Frame
Undercarriage

A typical hydraulic system





1 – pump
2 – oil tank
3 – flow control valve
4 – pressure relief valve
5 – hydraulic cylinder
6 – directional control valve
7 – throttle valve



http://www.youtube.com/watch?v=wm-E_YNv0ek

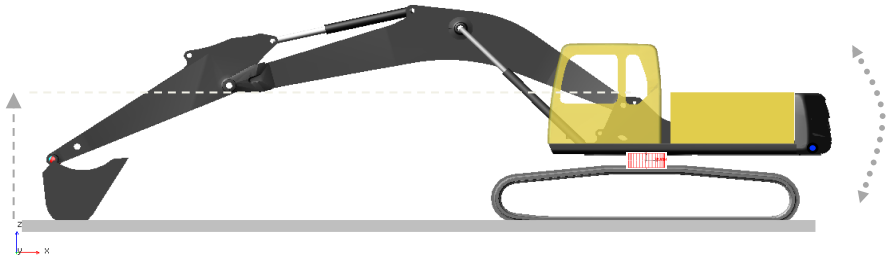
Advantages of hydrostatic drives

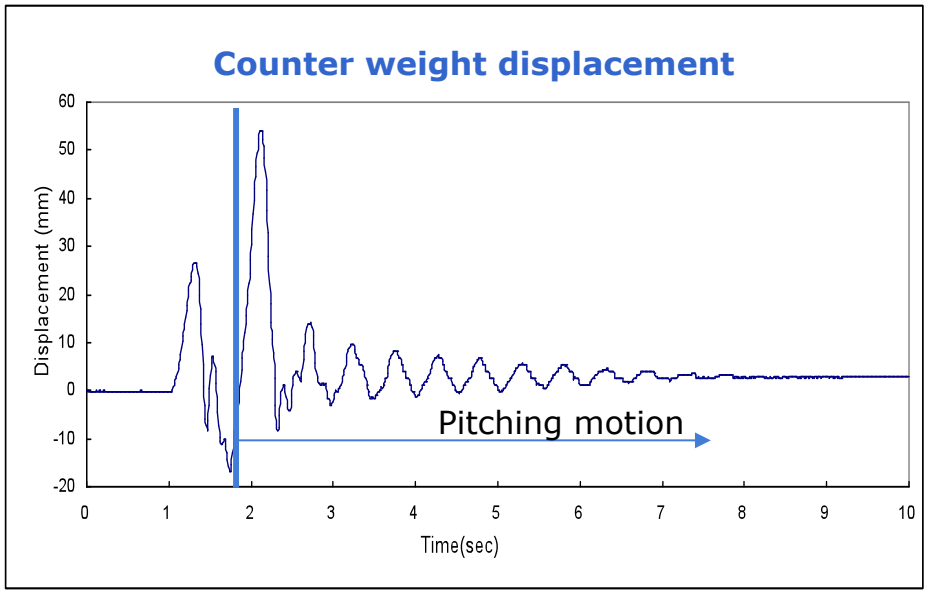
- Simple method to create linear movements
- Creation of large forces and torques, high energy density
- Continuously variable movement of the actuator
- Simple turnaround of the direction of the movement, starting possible under full load from rest
- Low delay, small time constant because of low inertia
- Simple overload protection (no damage in case of overload)
- Simple monitoring of load by measuring pressure
- Arbitrary positioning of prime mover and actuator
- Large power density (relatively small mass for a given power compared to electrical and mechanical drives)
- Robust (insensitive against environmental influences)

Disadvantages of hydrostatic drives

- Working fluid is necessary (leakage problems, filtering, etc.)
- It is not economic for large distances

A New Excavator without vibration problem?





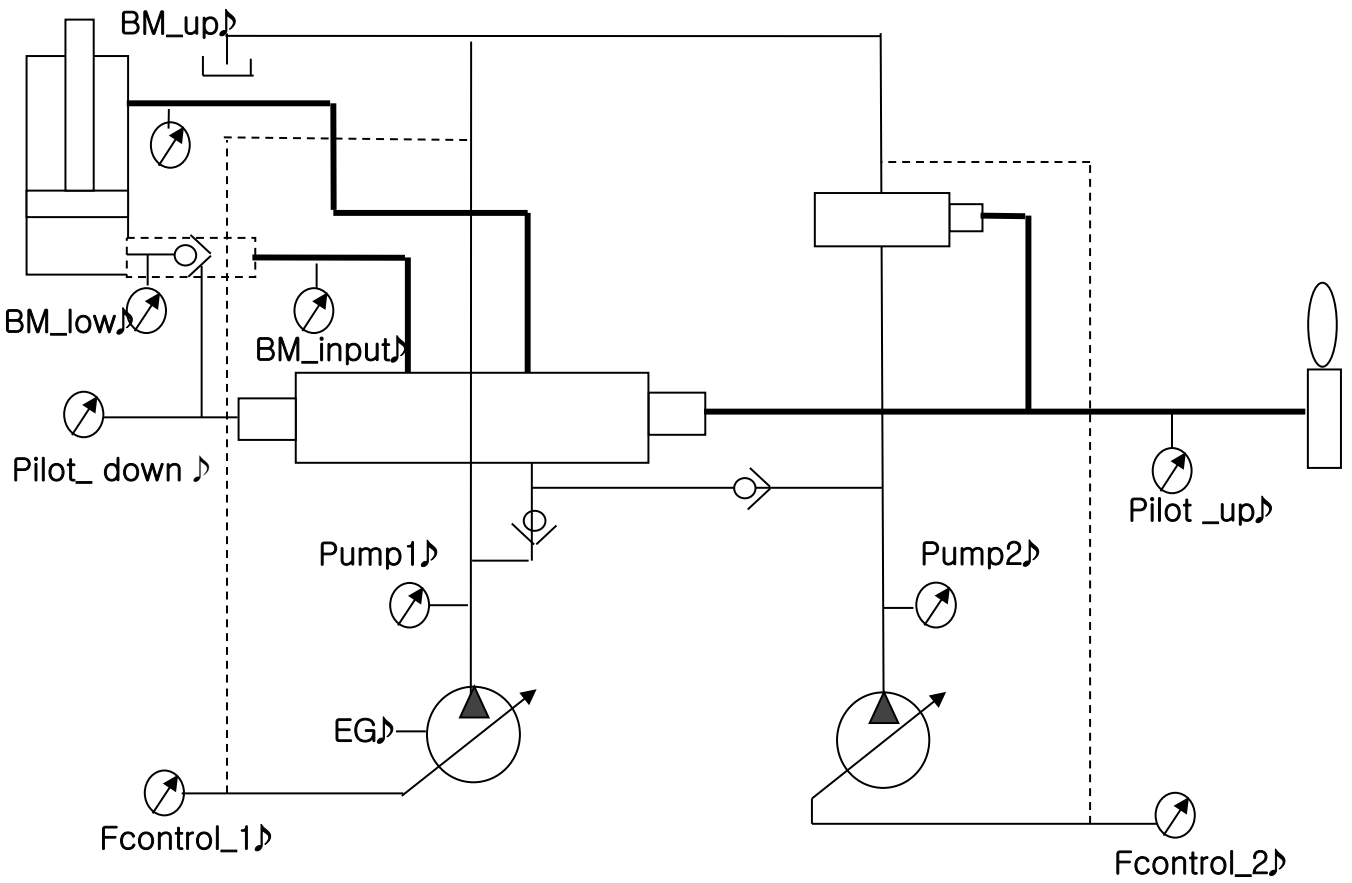
Conventional pitching test:

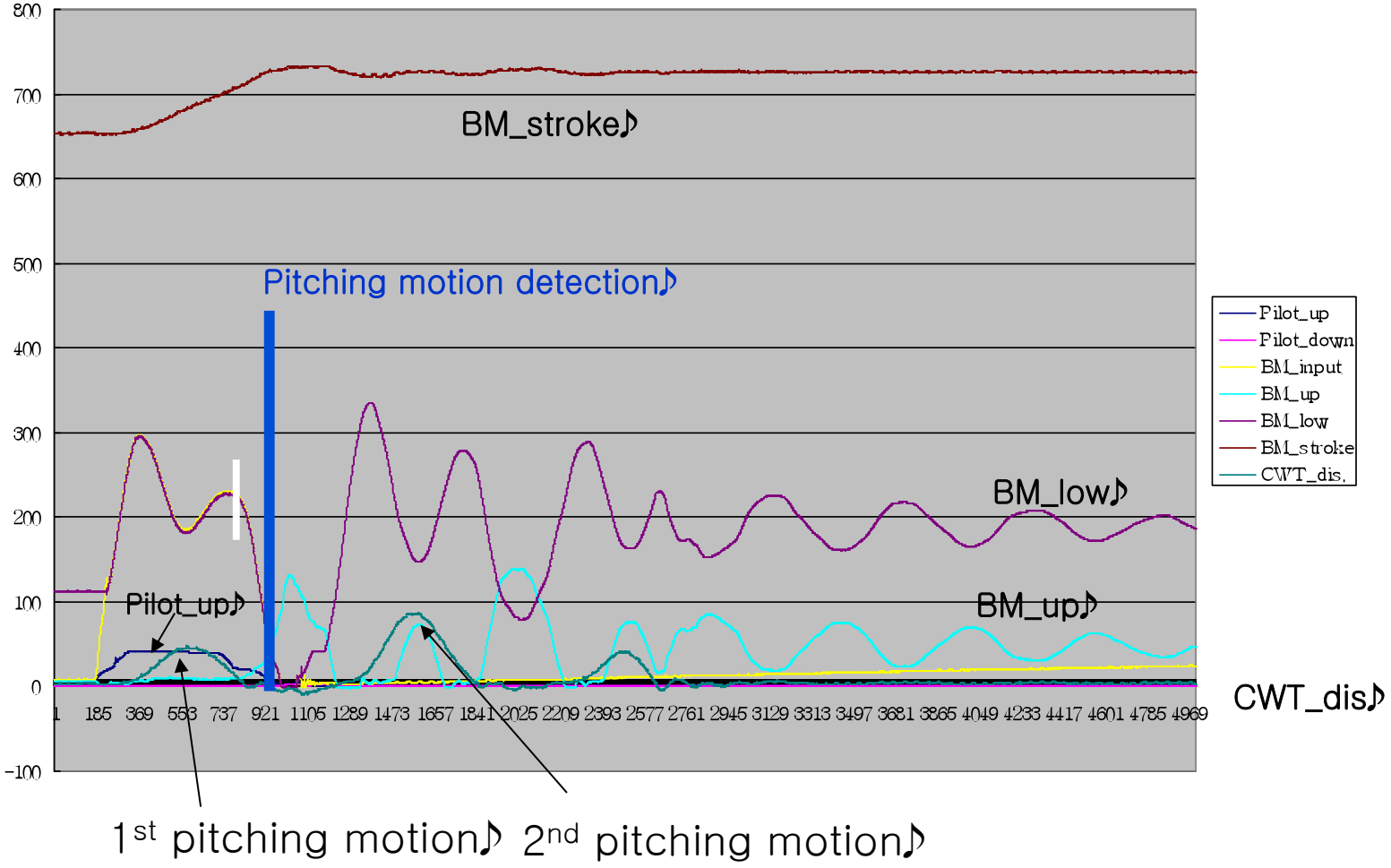
experimental result (ec290)

Max. CWT displacement:

55mm, ~1.5 Hz.

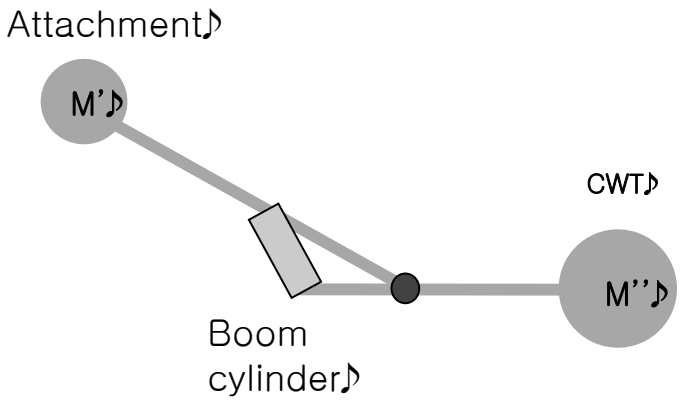
- Sensor distribution map for the pitching data acquisition




800
700
600
500
400
300
200
100
0
-100
1 185 369 553 737 921 1105 1289 1473 1657 1841 2025 2209 2393 2577 2761 2945 3129 3313 3497 3681 3865 4049 4233 4417 4601 4785 4969
BM_stroke♪
Pitching motion detection♪
BM_low♪
Pilot_up♪
BM_up♪
CWT_dis♪
Pilot_up
Pilot_down
BM_input
BM_up
BM_low
BM_stroke
CWT_dis.
1st pitching motion♪
2nd pitching motion♪

- Pitching motion mechanism – boom lifting mechanism
- Frequency response of the system
- Time delay analysis
- Optimum sensor locations to detect pitching motion :
  Boom_upper and Boom_lower chamber pressures

- Pitching motion mechanism



Energy flow ♪

Kinetic energy of the attachment♪

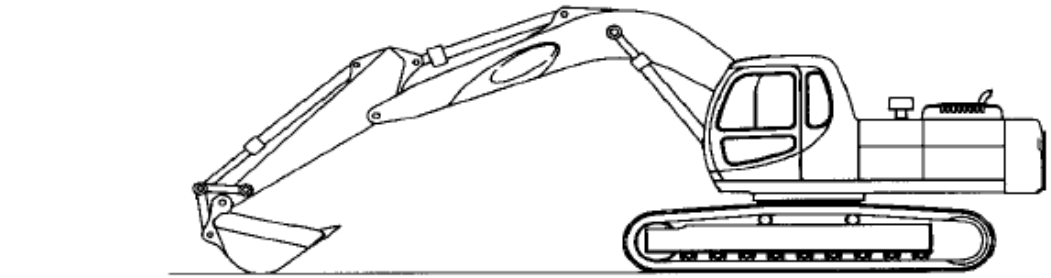
↕

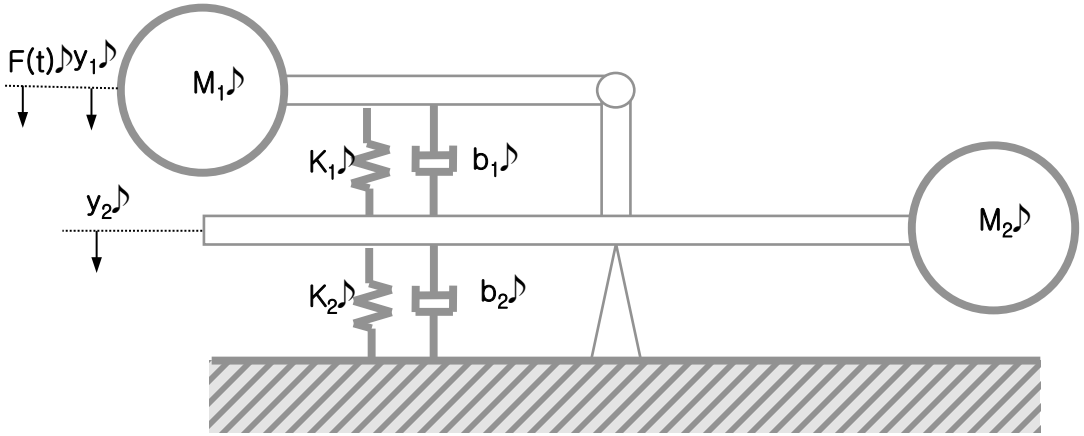
Potential energy of the boom cylinder♪

↕

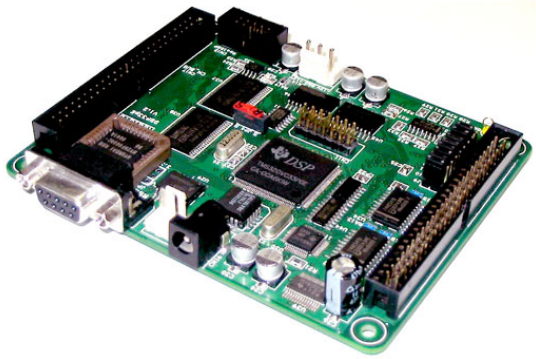
Kinetic energy of the CWT♪

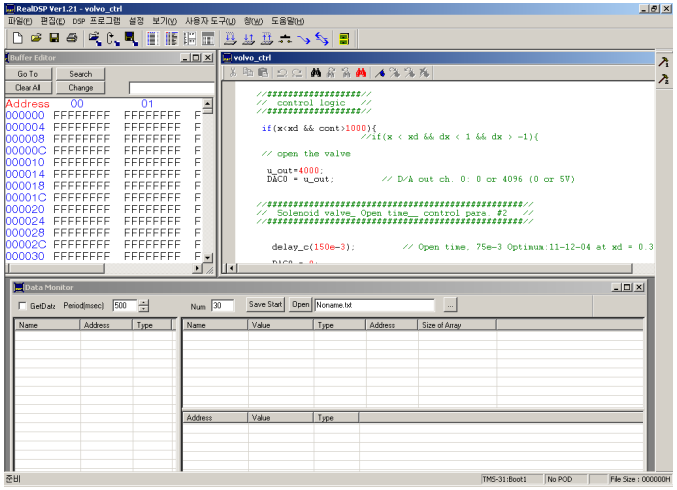
- Prototype schematic diagram to represent the pitching motion



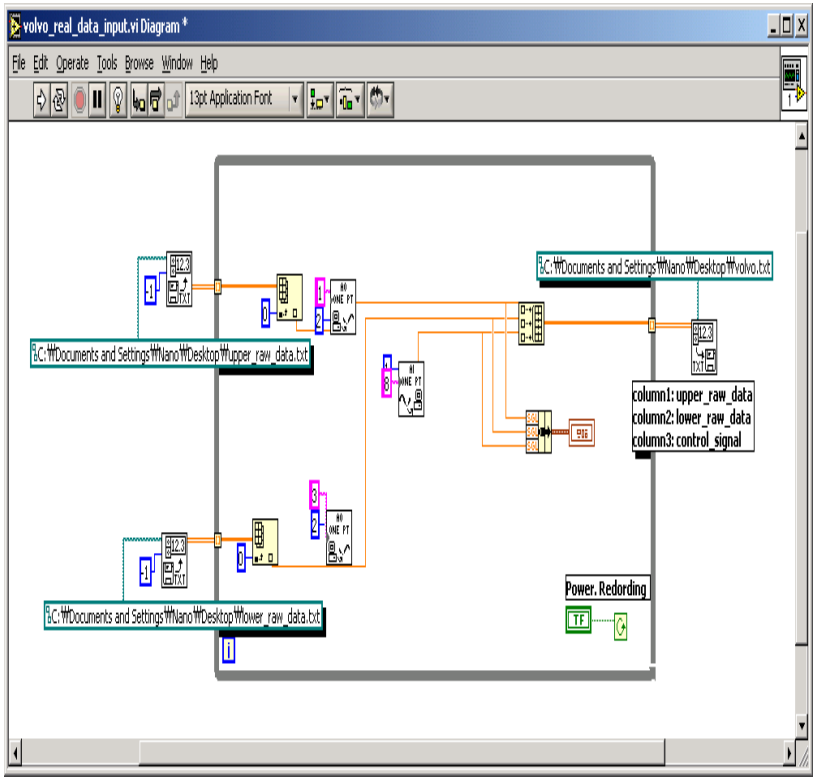


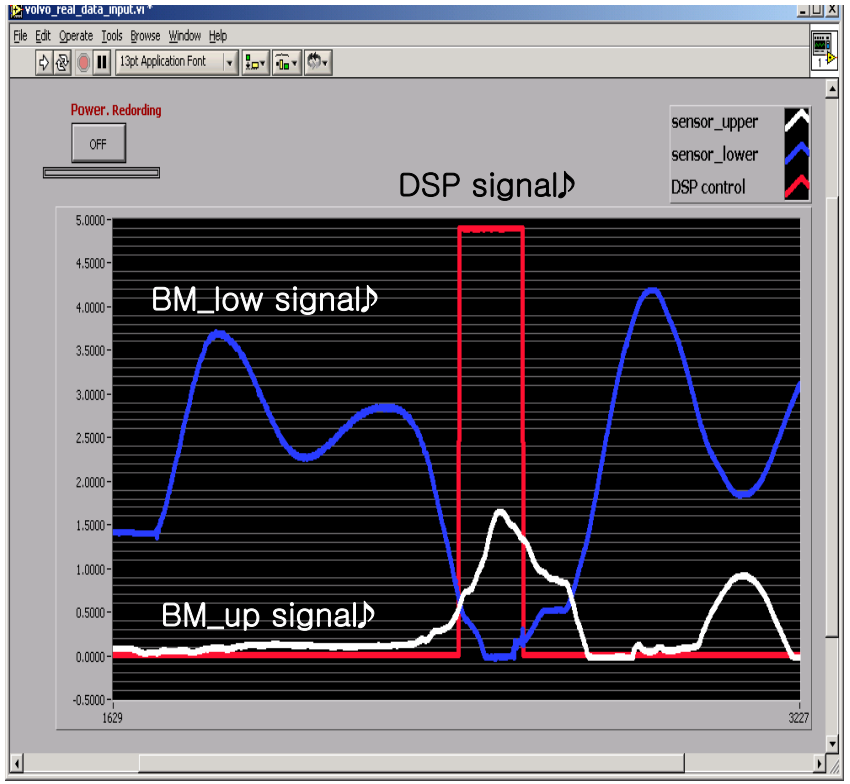
- TI TMS320 chip,
  Realsys-DSP33-PLUSE
- ADC:12bit 8Ch DAC :12bit 2Ch
- ~$1000
- Appropriate for experimental implementation
- C program
- Inexpensive DSP is desirable
  VOLVO custom design

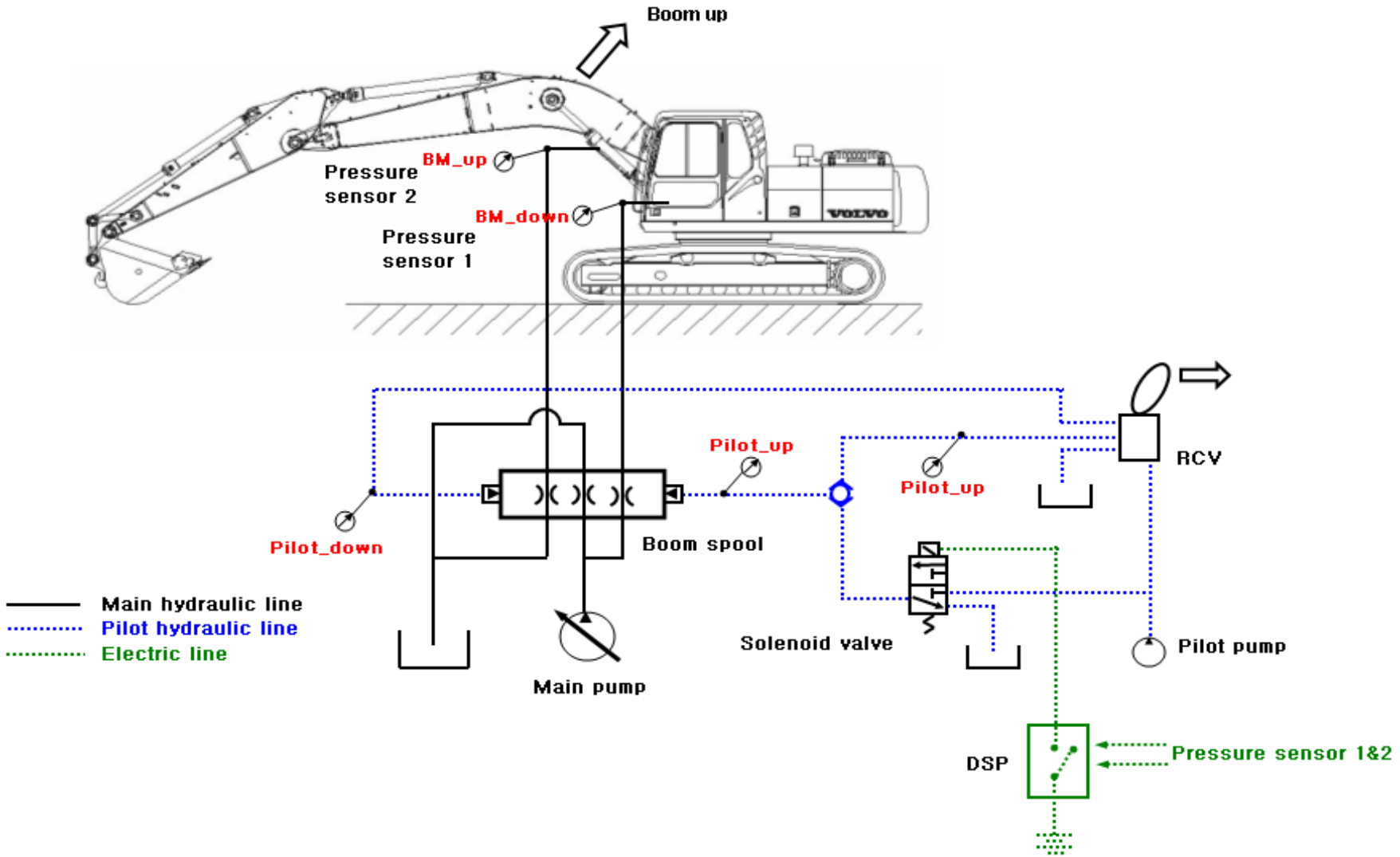




- Simulated sensor signals to the DSP
  - Voltage signal from D/A converter to the DSP
- To test the control program of the DSP
  - Voltage signal from DSP to A/D converter
  - Various control environments

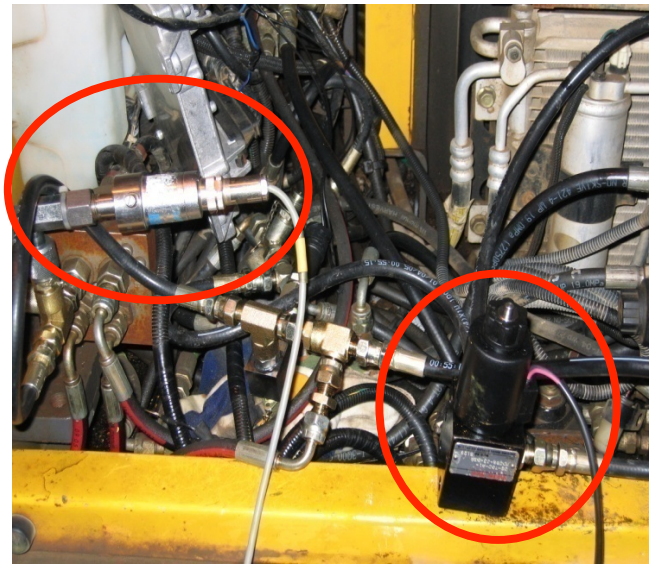




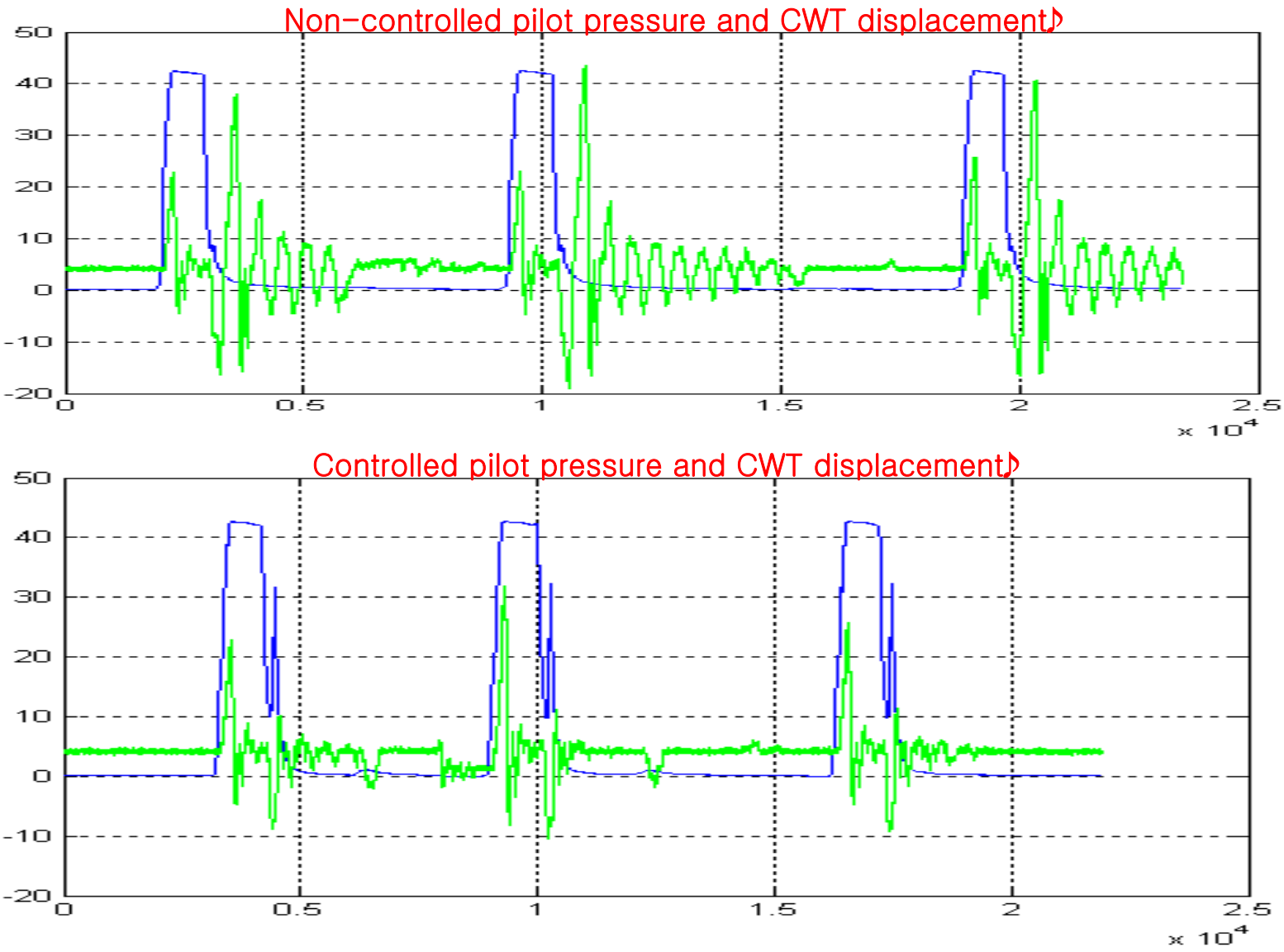

Boom up
BM_up
Pressure sensor 2
BM_down
Pressure sensor 1
Pilot_up
Pilot_up
RCV
Pilot_down
Boom spool
Solenoid valve
Pilot pump
Main pump
DSP
Pressure sensor 1&2
Main hydraulic line
Pilot hydraulic line
Electric line

- Pressure sensors
  - Boom-up chamber
  - Boom-low chamber
- Boom stroke sensor

- DSP controller



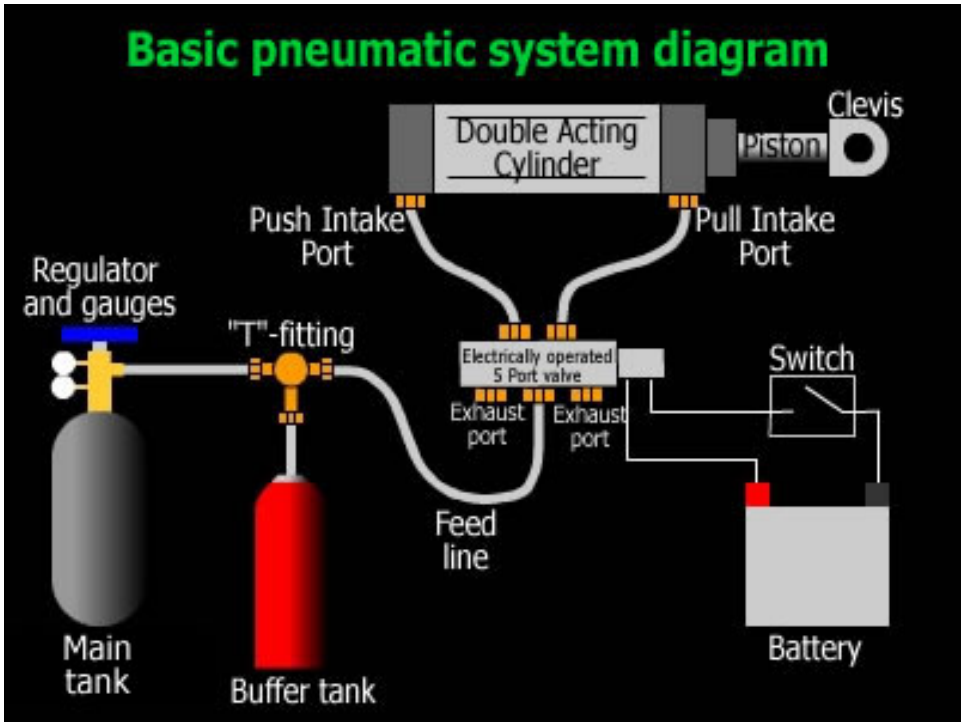
- Solenoid actuation controlled by DSP

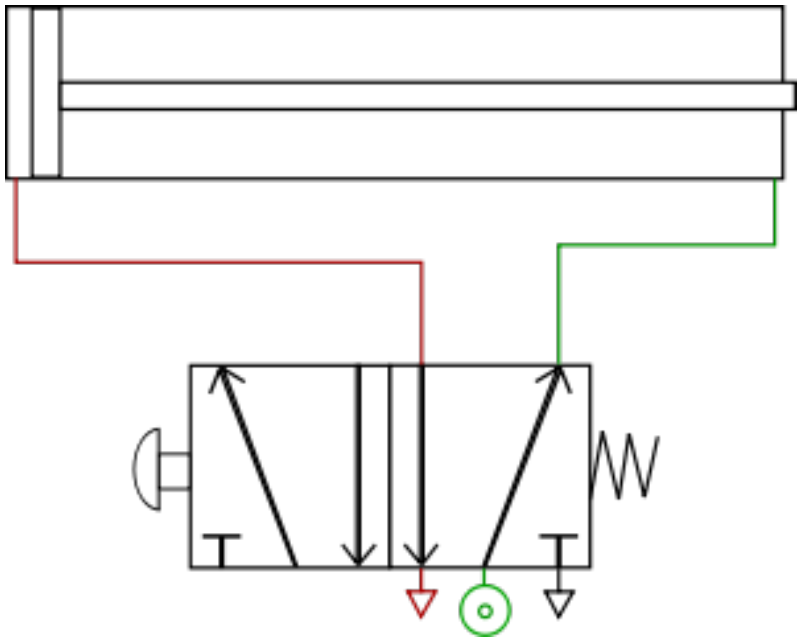

Non-controlled pilot pressure and CWT displacement
50
40
30
20
10
0
-10
-20
0
0.5
1
1.5
2
2.5
x 10^4
Controlled pilot pressure and CWT displacement
50
40
30
20
10
0
-10
-20
0
0.5
1
1.5
2
2.5
x 10^4

What are pneumatics

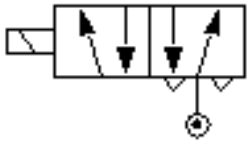
- Mechanisms which use air pressure to apply mechanical force and displacement (work)
- The pneumatic devices we use are basically binary actuators – either retracted or extended

Pneumatic Actuation

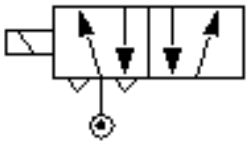


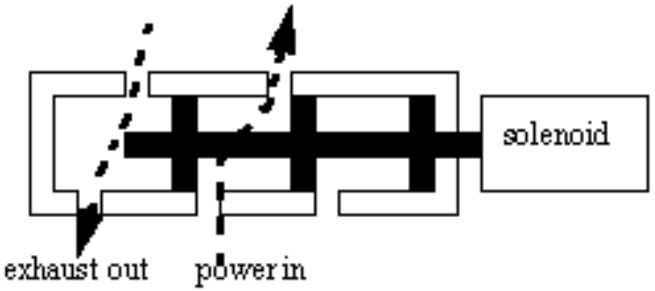


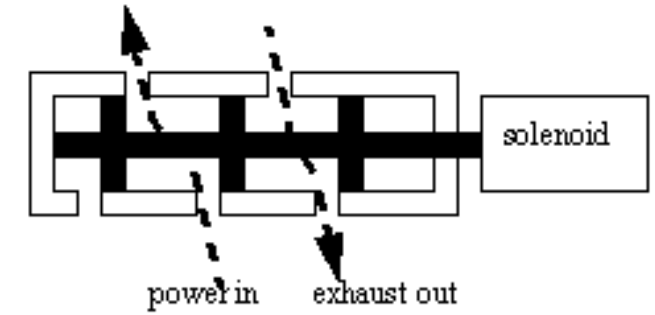
Pneumatic Control Valve



The solenoid has two positions and when actuated will change the direction that fluid flows to the device. The symbols shown here are commonly used to represent this type of valve.



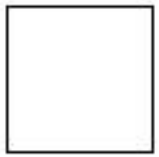


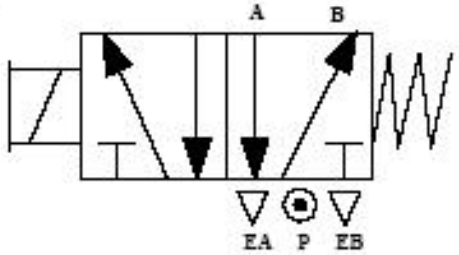


Reading Pneumatic Schematic Symbols

The Block

The block symbolizes the possible valve functions or positions. Example: A 5/2 valve schematic will be illustrated with 2 blocks describing two valve functions or positions. A 5/3 valve schematic will show three blocks describing 3 possible valve functions or positions.



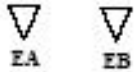


The Arrows

The Arrow symbols illustrate the direction of gasses flowing into and out of the valve ports. Gas is pressure is supplied from port P. Depending on which of the valve blocks is in function, the gas is directed to port A or B as shown by the arrows.

The Actuator (Solenoid) Symbol

Pneumatic valves can be operated in several ways. Hand operated (including levers and push and or push pull buttons) ; Air piloted (Operated remotely by pneumatic signals); Solenoid (directly actuated with electronic signals)



Exhaust Port Symbol

The inverted triangle symbol denotes an exhaust port. The letters EA indicate this is the exhaust port for the A circuit. Ebin turn indicates the exhaust port for the B circuit.

5/2 Valve has 5 ports and 2 possible conditions

1.) B is pressurized and A is exhausted.
2.) A is pressurized and B is exhausted.

When the solenoid is NOT energized the B port is pressurized. The spring symbol defines the valve position at rest.

The Return Spring

The spring symbol defines the "at rest" position of the solenoid valve. The spring "Pushes" from the side it is drawn on and places the right side block diagram of the valve in function.

The T Symbol

This symbol indicates that a port is closed and is neither passing or exhausting gas.

Pressure or Air Supply Symbol

This symbol indicates the air supply port. In addition to this symbol the letter P or the number 1 also indicates the air supply port.

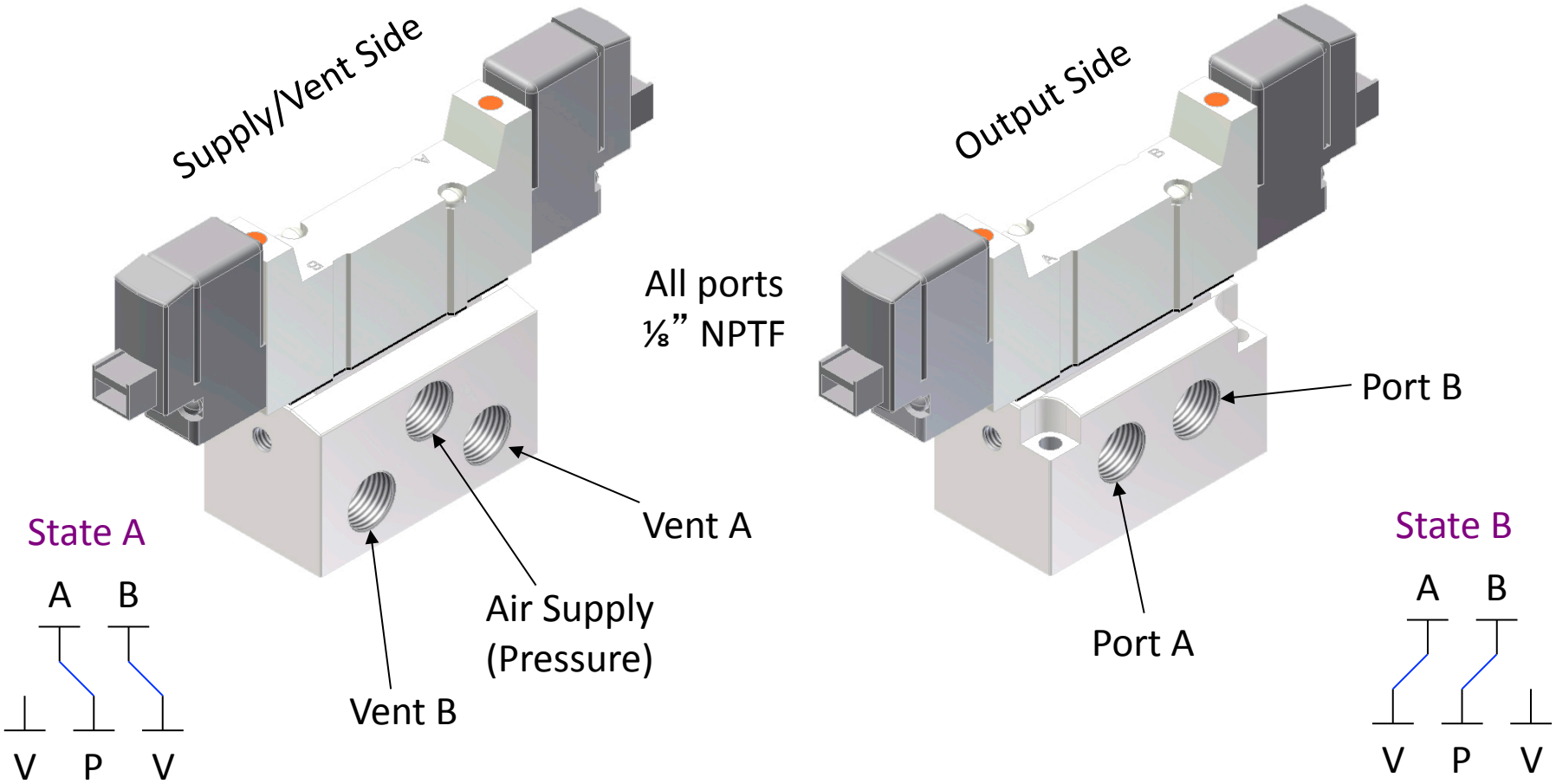
Strengths

- Simple
- Easy to control
- Can apply a lot of force from a small, light package
- Force is limited by air pressure and cylinder diameter
- No adverse consequence if cylinder is stopped (no stalled motors) or reversed – compressed air is a spring

Drawbacks

- Cylinders can be subject to damage
- Repair impossible

The pneumatic system
(the solenoid valve)



The pneumatic system *(device control)*