Class #23
Digital Hydraulics

• Reading Questions
• Digital Hydraulic Pump
• Switch-Mode Hydraulic Pump
• Switched-Inertance Hydraulic Circuits
Reading Questions

• Reading: Linjama, “Digital Fluid Power – State of the Art”

• Reading: Yuan et al., “A Review of Switched Inertance Hydraulic Converter Technology”

• Project Check-in
Digital Hydraulics

Definition: Using on-off valves for control - often fast switching valves.

Digital Displacement Pump

Digital Displacement Pump Exercise

1. Pressure and flow ripple

2. Valve transition required for 30 Hz pump freq? How does this compare to the response of a servovalve?
Switch-Mode Pumps and Motors

a) Check Valve → Hydraulic Accumulator → High Pressure Rail → On-Off Valve

b) Hydraulic Accumulator → High Pressure Rail → Motor

c) Check Valves → Pump/Motor → 3-way Rail → High Pressure Rail → On-Off Valve
Switch-Mode Pump

a. Sketch the pressure through a switching cycle

\[ P(t) \]

Valve Opens  |  Valve Closes  |  Valve Opens

b. \( V_{\text{switched}} = 100 \text{ cm}^3, P_{\text{high}} = 20 \text{ MPa} \), what is flow rate to compress the switched volume?

c. \( Q_{\text{pump}} = 0.001 \text{ m}^3/\text{s}, f = 100 \text{ Hz} \), what fraction of the pump flow rate is consumed in fluid compression? Is this an energy loss?

2. \( P_{\text{charge}} = 15 \text{ MPa}, V_{\text{accum}} = 1 \text{ lit}, \text{Duty} = 50\% \), what is the flow ripple?

3. Step to 25 MPa, how should the duty cycle be controlled? Response time with load flow rate of 30 lit/min?
Switch-Mode Pump

- How to manage compressible energy loss?
Soft Switch Concept

Soft Switch Mechanism
Illustrating Soft Switch Operation
Modeling Dynamics & Energy Losses

- Pressure Dynamics
  - Switched Volume
  - Back of Soft Switch
- Spring-Mass-Damper Dynamics
  - Soft Switch Piston
  - Check Valves
- Flow Resistances
- Leakage
Experimental Results
Control of Multiple Actuators from Single Pump

• Valve Control
  – Fixed Pump
  – Pressure Compensated Pump
  – Load Sensing Pump

• Transformers
Digital Transformers: Switched Inertance Hydraulic Systems

Boost Converter  Buck Converter