Progress Report

to

National Fluid Power Association

By

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This report summarizes the work done on a hydraulics project partially funded by a gift from NFPA. The main objective of this project was to build an electro-hydraulic (EH) training apparatus using Independent Metering Valves (IMV). The advantage of IMV system is the capability to simulate various basic hydraulic functions, such as closed center, open center, load sensing, regeneration etc..., by means of different software configurations. The main idea of IMV is based on independently controlling valves flow orifices in real-time control software (like Matlab/Simulink). The unique flexibility of the IMV concept, in which modifications are made on the control algorithm, makes possible to demonstrate a variety of hydraulic configurations without any hardware change.

The hydraulic hardware set-up is based on electronically controlled variable displacement pump with load sensing system, actuators with position sensors, line pressure sensors, independently metered valves for each cylinder. The independently metered valves used in this research are proportional control solenoid poppet and spool valves.

Five distinct metering modes exist in literature: Powered Extension, High Side Regeneration Extension, Low Side Regeneration Extension, Powered Retraction, and Low Side Regeneration Retraction. Regeneration flow refers to pumping the fluid from one end of the cylinder to the other end to achieve precise motion control with the use of no or minimum flow contribution from the pump.

This research is focused on analyzing the following,

I. Study and analyze the five metering modes,

II. Analyze the performance between the poppet valve setup (Fig. 2) and spool valve setup (Fig.3) in IMV configuration,

III. Focus on the energy savings potential of independent metering valve configuration,

IV. And finally exploit the IMV configuration for further capabilities.

The control system architecture block diagram (Fig. 1) and the schematic diagram (Fig. 2 and Fig. 3) of the hydraulic setup is shown below. The original concept of IMV requires five bidirectional proportional valves. Instead, in Figure 2 the setup has five unidirectional proportional valves (SP1, SP2, SP3, SP4 and SP5) with the addition of two On/Off (SV1 and SV2) valves to facilitate regeneration capability. Similarly, in Figure 3 the setup has four proportional self pressure compensated spool valves (ZL1, ZL2, ZL3 and ZL4) arranged in an IMV configuration. From the Control side, a CAN card is used to send CAN messages to the Electronic Valve Drivers (Current Amplifiers) which in turn send command signals to the valves. From the software aspect Matlab/Simulink software is used: xPC Target Matlab module transfers the Simulink control logic model to the CAN Card which is responsible for the real-time control of the valves.

The system flexibility can then be either directed to teaching of various basic to advanced hydraulic configurations and EH control strategies or towards the research on optimization of hydraulic controls in a way not possible with conventional single spool four way valves. Also, Independent metering has the potential of achieving precise motion control with energy saving by monitoring the pressure in both actuator chambers.

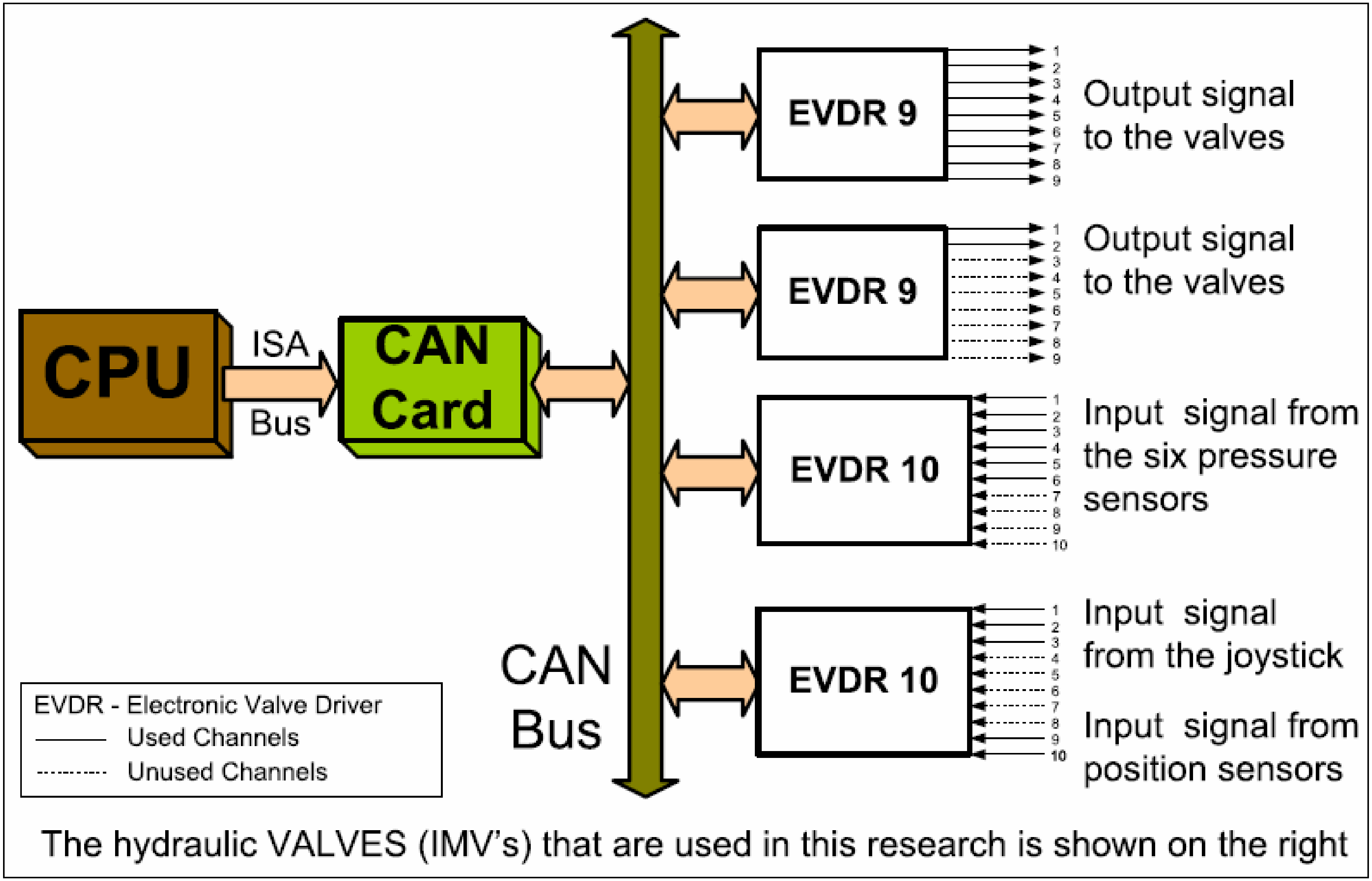
The hydraulic/electronic hardware that is required to make this setup completely functional is as follows,

S.No	Component	Cost of One	No. required	Total Cost
1	3-way Diverter Ball Valve	$82.64	7	$578.48
2	Pressure Sensors	$200.00	6	$1,200.00
3	Hoses/fittings/mounting/machining/ electrical wiring/misc			$3,000.00
	TOTAL			**$4,778.48**

The valves, machined valve manifolds and the electrical hardware has been donated by Hydraforce Inc. in Lincolnshire, IL. The company has provided their full support with the hydraulic hardware and electrical hardware.

The company will be providing us with the Electronic Valve Drivers (Current Amplifiers) and CAN hardware once we have our hydraulic hardware installed.

The complete setup hydraulic circuit diagram is shown in Figure 4. Once the hardware is built we will be able to work on different control strategies that can be implemented to control the valves in Matlab/Simulink.



CPU
ISA
Bus
CAN
Card
CAN
Bus
EVDR 9
Output signal
to the valves
EVDR 9
Output signal
to the valves
EVDR 10
Input signal from
the six pressure
sensors
EVDR 10
Input signal
from the joystick
Input signal from
position sensors
EVDR - Electronic Valve Driver
Used Channels
Unused Channels
The hydraulic VALVES (IMV's) that are used in this research is shown on the right

Figure 1

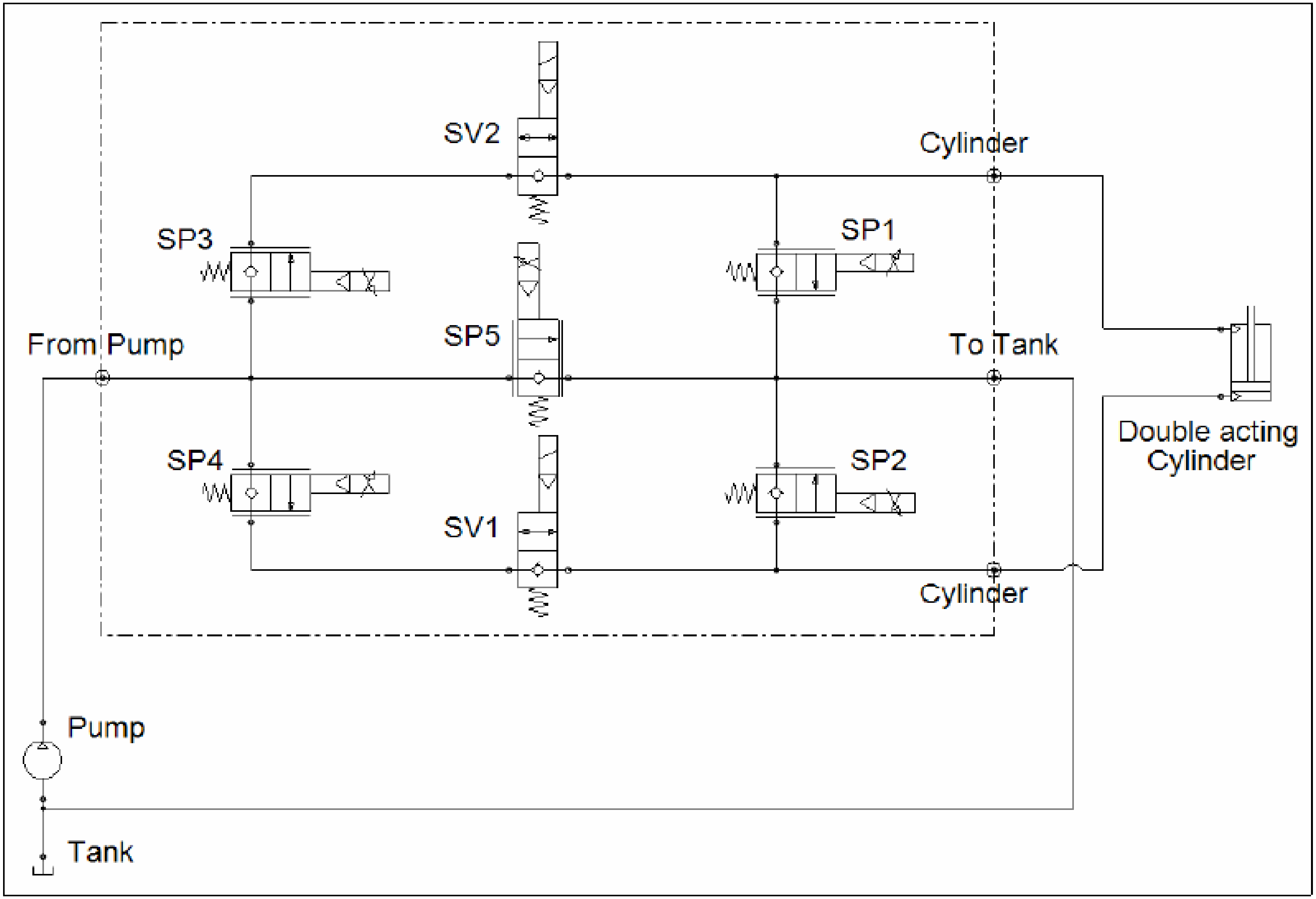

SV2
Cylinder
SP3
SP1
SP5
From Pump
To Tank
SP4
SP2
Double acting Cylinder
SV1
Cylinder
Pump
Tank

Figure 2

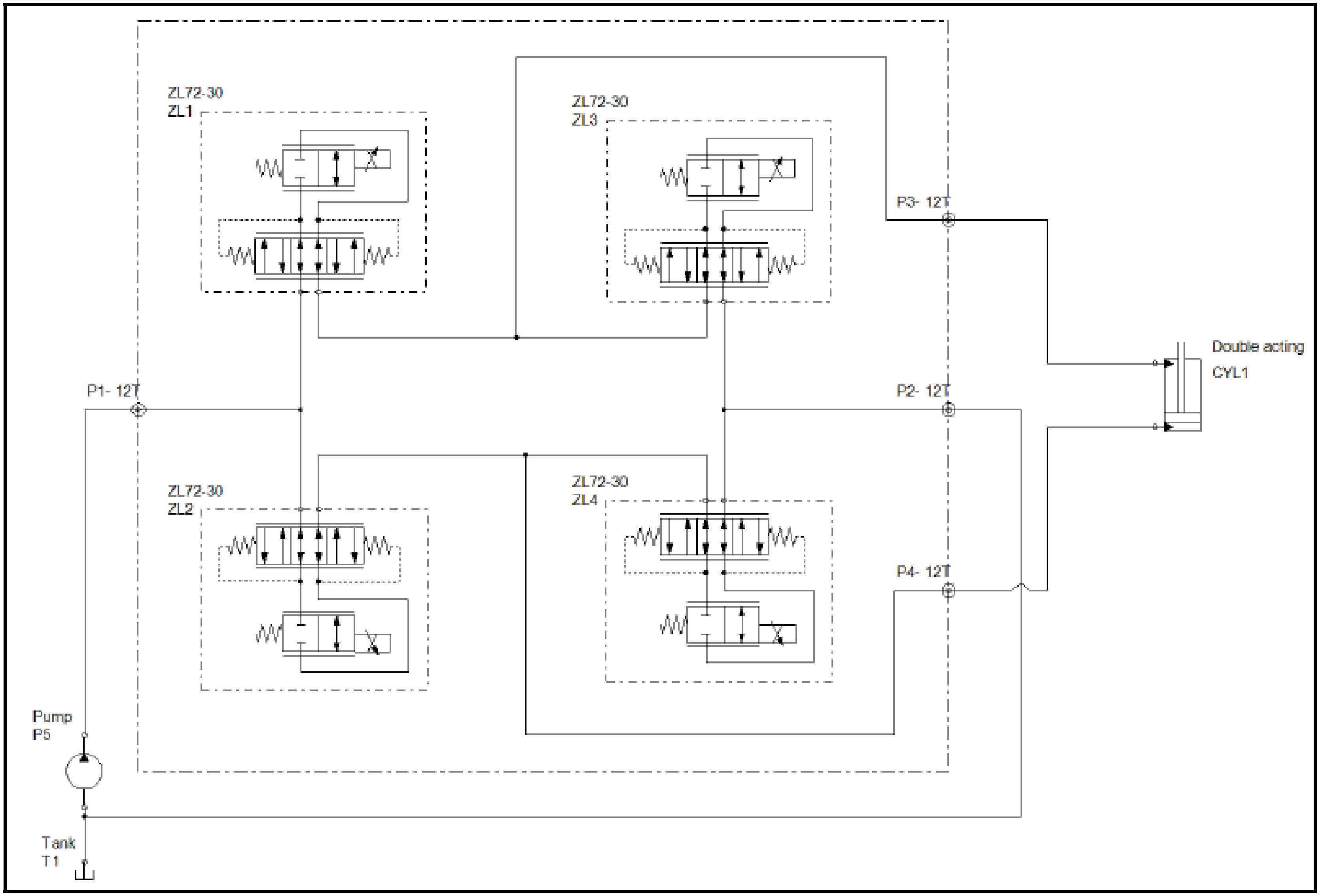
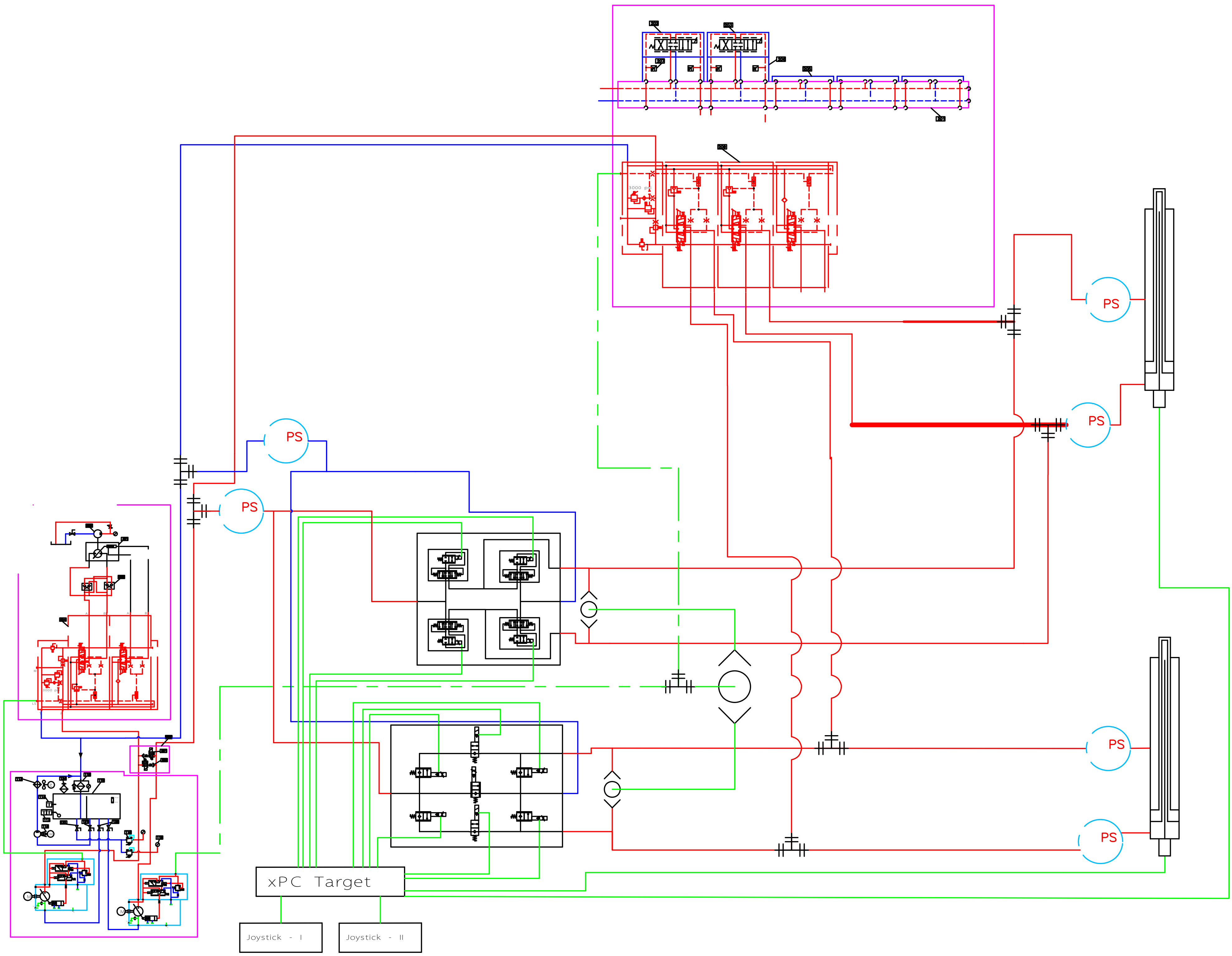

ZL72-30
ZL1
ZL72-30
ZL3
P3- 12T
Double acting
CYL1
P1- 12T
P2- 12T
ZL72-30
ZL2
ZL72-30
ZL4
P4- 12T
Pump
P5
Tank
T1

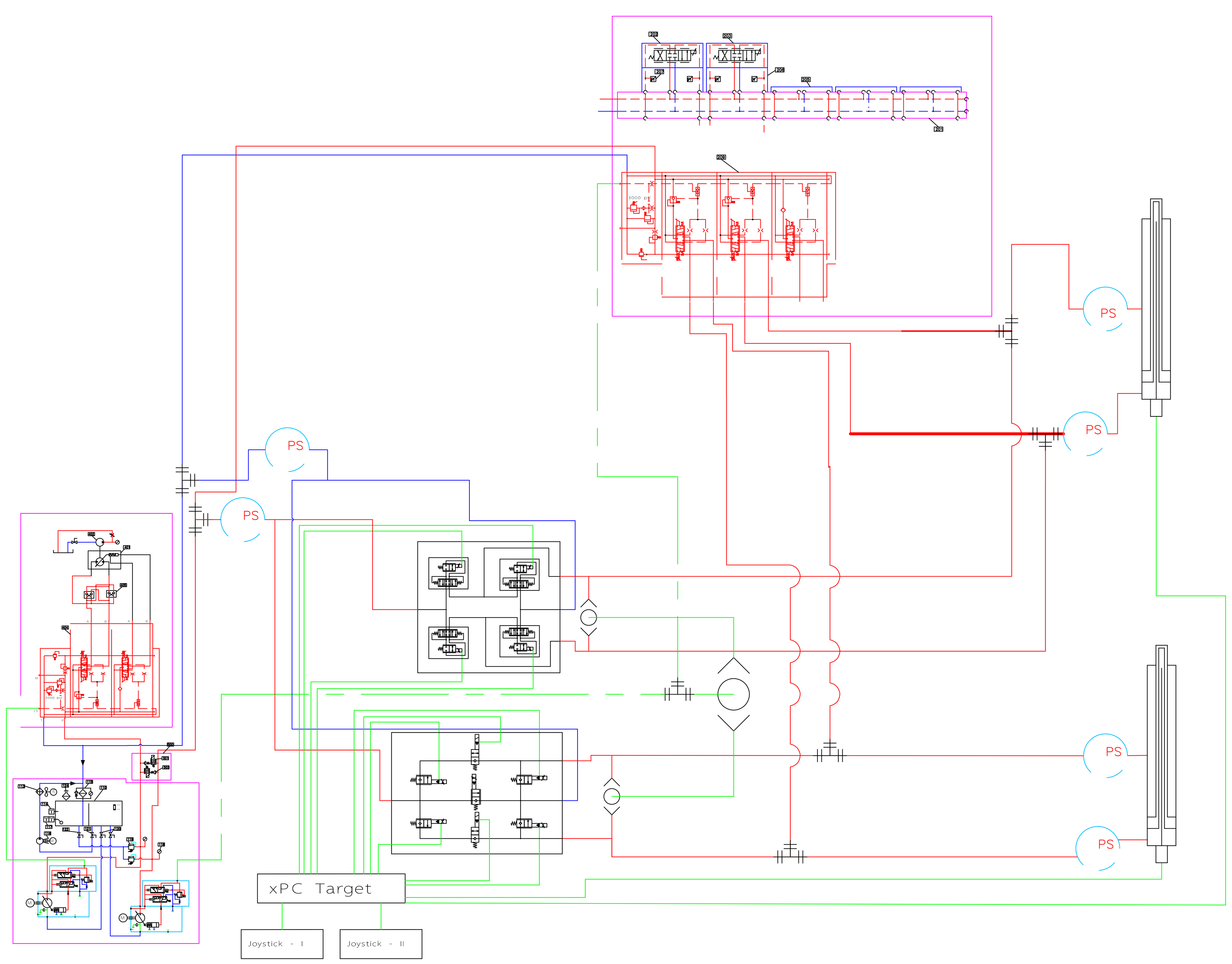
Figure 3

Figure 4



PS
PS
PS
PS
PS
PS
PS
PS
xPC Target
Joystick - I
Joystick - II

REVISIONS				
ZONE	REV	DESCRIPTION	DATE	APPROVED



SIZE	FSCM NO.	DWG NO.	REV
SCALE		SHEET	