Robotic Backhoe with Haptic Display
Design Overview

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Robotic Backhoe with Haptic Display
Summary

The John Deere Company has expressed interest in developing haptic controls for their earthmoving equipment. The overall purpose of this project will be to develop a testbed for evaluating various haptic feedback control schemes as applied to a hydraulic backhoe, to be used as a tool in the development of haptic user interfaces for John Deere.

The project will involve several phases. In the first phase, haptic control will be applied to a single cylinder/degree of freedom on the backhoe, utilizing position feedback from a sensor mounted to the backhoe and controlled by the PHANTOM manipulator. Once the concept has been proven on one cylinder, the project will progress to the second phase, to include feedback and control of all four of the backhoe’s links. Subsequent phases may explore the use of alternative haptic user interfaces, as well as the incorporation of GPS navigation into the system.

This design overview outlines the plans for the Robotic Backhoe with Haptic Display at the Georgia Institute of Technology, Fluid Power and Motion Control Center. This design is based upon goals set at the meeting at the John Deere Research Center in Dubuque, Iowa on May 29, 2003.
Operator has the option of three control interfaces:
1. Existing manual controls
2. PHANTOM Haptic manipulator
3. PVG32 Manual controls

*Linear position transducer for Phase 1 / 1-dof operation only. Another position measurement solution will be necessary for Phase 2 / 4-dof control.
Hose Couplers

High pressure filter
Hydac DF60

Diverter valve
Hydac 3-way
(bypasses PVG block if necessary)

Existing valve block
with added tees for new connections
Gresen V20
Connect Sauer-Danfoss PVG valves to gage manifolds with hard tubing & Swagelock fittings (not shown)

Connect quick-disconnect couplers to Gresen valve tees with flexible hose & SAE O-ring seal fittings (not shown)

Tubing sizes: 1” supply & return ½” cylinder lines
Connect to pump / supply via Power Beyond Sleeve here

Connect to tank via Gresen outlet port here

Existing Gresen V20 valve block connected in series with Sauer-Danfoss PVG valve block: remains fully functional
Valve / Gage / Controller Assembly

- 3000 psi gage (supply) - WIKA
- 2000 psi gages (cap & rod each cylinder) - WIKA
- Pandora Enclosure
  - PC/104 CPU
  - 32MB Flash memory
  - 50W power supply
  - PC interface
- Pressure transmitters - WIKA Type S-10
- Valve mount made from 3/8" aluminum plate
- Return port
- Supply port
- SAE O-ring seal fittings
- Gage manifolds made from 2" x 2" aluminum bar stock
- Diamond Systems
Valve/gage/controller assembly designed to remove easily for service and storage.
Haptic manipulator and control computer can be interchanged for left-handed operators.
Table Assembly

- 1" x ½" rectangular tubing frame
- 12 gage (0.1046") steel tabletop
- Existing controls remounted for use as performance datum during evaluation of haptic improvements
- ¼" steel plate support
Position Sensor Mounting (temporary)

- Magnetic reflector
- Sensor mounts strapped to cylinders with worm-drive clamps (not shown)
- Steel pipe, cut & welded
- Transducer
- Measurement length
ROBOTIC BACKHOE
Hydraulic Circuit

Phase 1: Single DOF Control (Dipperstick)

- Bucket
- Stick
- L or R Stabilizer
- Boom
- Swing

Sauer-Danfoss PVG 32

Gresen V20 valve bank (existing)

Engine & pump
Signal Processing

Operator

PHANTOM Manipulator

PHANTOM Driver

Controller (Target Computer)

Backhoe dynamics

Position Sensors (4)

Pressure sensors (9)

Vale commands

PVG Valve Driver

PVG Valves

Host Computer

Program C code (offline)

Pressure signals

Oil flow

Visual feedback

Force input

Haptic feedback

Joystick encoder signals

Joystick motor signals

Position signals

Backhoe position

Operator

PHANTOM Manipulator

PHANTOM Driver

Controller (Target Computer)

Backhoe dynamics

Position Sensors (4)

Pressure sensors (9)

Vale commands

PVG Valve Driver

PVG Valves

Host Computer

Program C code (offline)

Pressure signals

Oil flow

Visual feedback

Force input

Haptic feedback

Joystick encoder signals

Joystick motor signals

Position signals
Other Components

Components required for the functioning system but not represented in this CAD model:

- Hard tubing & fittings between PVG valves and pressure gage manifolds
- Flexible hose between couplers and Gresen block tees
- Positions sensors on swing, boom, and bucket cylinders
- Tempsonics signal amplifier
- Connection to existing electrical system / auxiliary 12V car battery
- 110VAC Inverter for computer & PHANTOM
- Sensor & valve wiring
- Cables for computer and PHANTOM

See Bill of Materials for more detail
# Robotic Backhoe with Haptic Display

## Bill of Materials

### Valves

<table>
<thead>
<tr>
<th>Item</th>
<th>Supplier</th>
<th>Part#</th>
<th>Unit Qty (1 dof)</th>
<th>Qty (4 dof)</th>
<th>Unit $</th>
<th>Total $</th>
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<tr>
<td>Proportional valve, PVES (PVG 32)</td>
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### Tubing & Hoses

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<tr>
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<td>Straight Thread Red/Exp, 7/8 SAE F x 1-1/16 SAE M</td>
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### Swagelock Fittings

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<th>Total $</th>
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<tr>
<td>Male Connector, 1&quot; tube x 1-1/16-12 SAE straight thread</td>
<td>Georgia Valve &amp; Fitting</td>
<td>S-1610-1-12ST (Swagelock)</td>
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<td>Male Connector, 1/2&quot; tube x 7/8-14 SAE straight thread</td>
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### Aluminum

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### Steel

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<tr>
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<tr>
<td>High pressure in-line</td>
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<tr>
<td>body</td>
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<td>Programming computer</td>
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<td>Control computer</td>
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<td>Jupiter-MM 50W power</td>
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<tr>
<td>FlashDisk / IDE extender</td>
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<td>ACC-I DEEEXT</td>
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<td>board</td>
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<td>Pandora Enclosure, 5.0&quot;</td>
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Operator’s Perspective
Please disregard the position of the operator's feet!

To view a trenching animation of this CAD model, download the following files in .mpg format:

[ trench_des1.mpg | trench_des2.mpg | trench_des3.mpg ]