NFPA

Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

Final Presentation
Cal Poly
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Intro

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Manufacturing

Vehicle Construction & Final Product

Overview

New bike chassis: Frame, Seat, and Handlebars

New Hydraulic Circuit Designed and Assembled

Experimentation with gear ratio's and shifting

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Frame

- All frame pieces cut, welded and drilled on campus
  - All pieces TIG welded except for pedal and front wheel tubes
    - C-clamps and welding magnets were used as primary fixturing
    - Various amperages utilized for welding differing wall thicknesses
    - Pedal and front wheel tubes MIG welded
  - Cleaned and painted after manufacturing

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Handlebars

- Handlebars were also cut and welded on campus
  - Water-TIG for welding
    - Challenges of welding aluminum discussed in future slide
  - 90° vice for tube welding used for handle pieces

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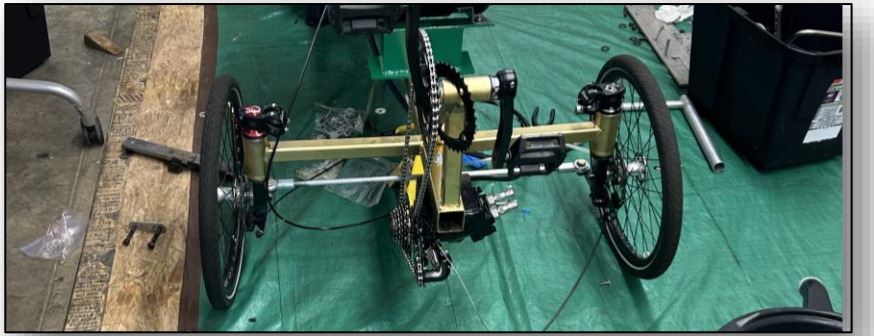
Seat & Steering

- Sourced a new seat with retrofitted attachment to the frame
  - Lightweight, comfortable, and easy to mount
  - Removed excess parts and drilled new holes

- Ackermann steering recycled from last team
  - Worked well previously, decided to use it again



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Hydraulics

- All Hydraulic components were sourced or reused; none were made in house.
- Contractors Maintenance in San Luis Obispo, cut all hydraulic lines to length and provided fittings.
- New attachment brackets were made.

Front Power Transfer

- Interchangeable sprocket attached to the pedals
- 7-speed cassette
- Custom-mounted derailleur
- Shifter connected to our pneumatic system

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Rear Power Transfer

- Flip-flop hub facilitating both free and fixed-wheel sprockets

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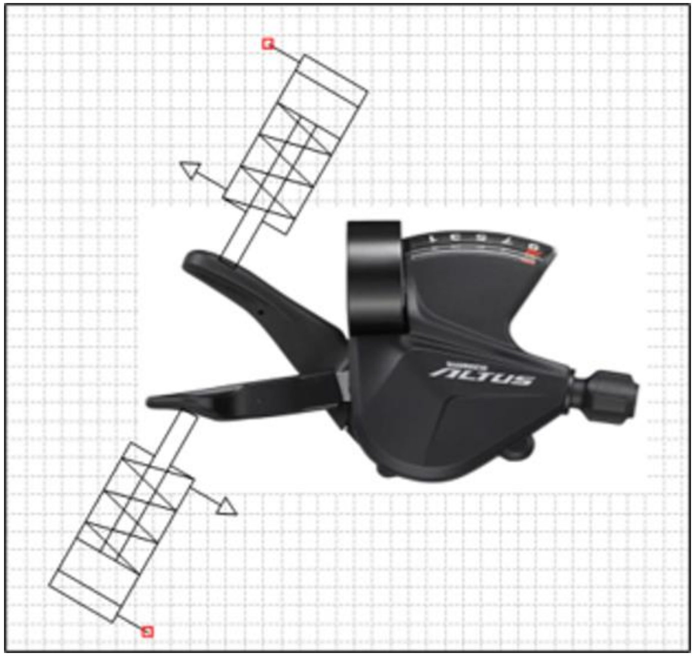
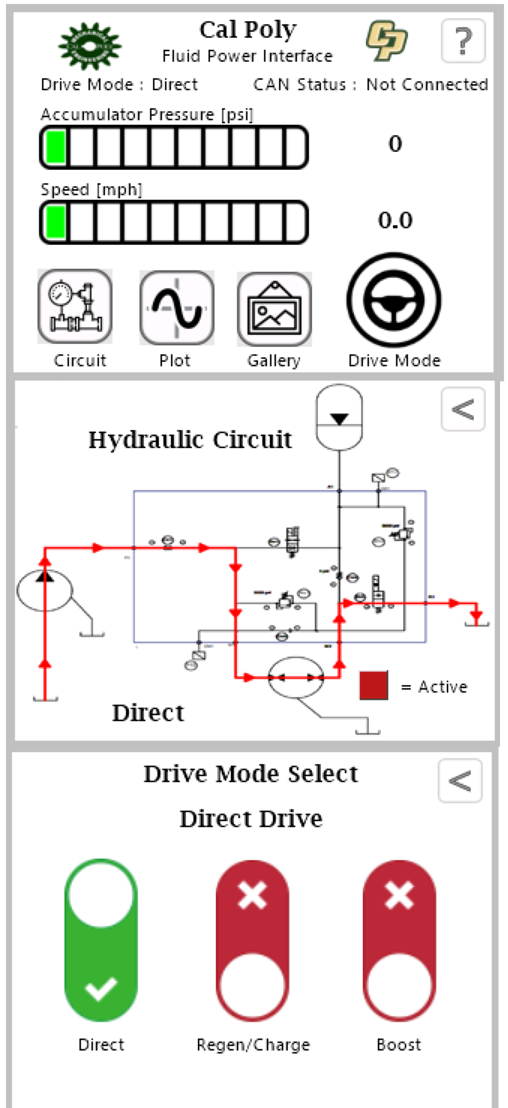
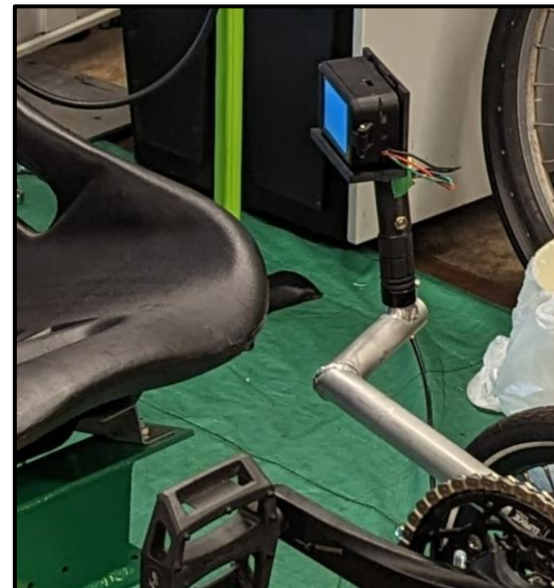
Pneumatic Shifting



Electronics





Problems and Solutions

Problems encounter during manufacturing and testing and how they were addressed.

Testing


- Simulated each of the events
- Experimented with pre-charge variation
- Experienced numerous problems while testing

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Front Legs Weld Yield

- Front legs yielded (V-shape)
  - Insufficient penetration when welding materials
- Needed a quick and non-invasive solution
  - Added additional beam below frame
  - Attached and bent back to shape using plates and bolts

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Aluminum Welding

- TIG welding Aluminum proved to be more difficult than expected
  - Careful amperage calibration to avoid burnout
  - Thin walls
- Motor bracket required fillet welds
  - Difficult to keep oxide layer off before welding
- Solution: Asked an experienced welder on campus to weld the most difficult joints
  - Special thanks to Bryan Lutz for doing this for us

Before:

After:

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Rear Wheel Spokes

Hydraulics

PROBLEM: MOTOR FAILED UNDER LOADING

SOLUTION: CYCLING MOTOR

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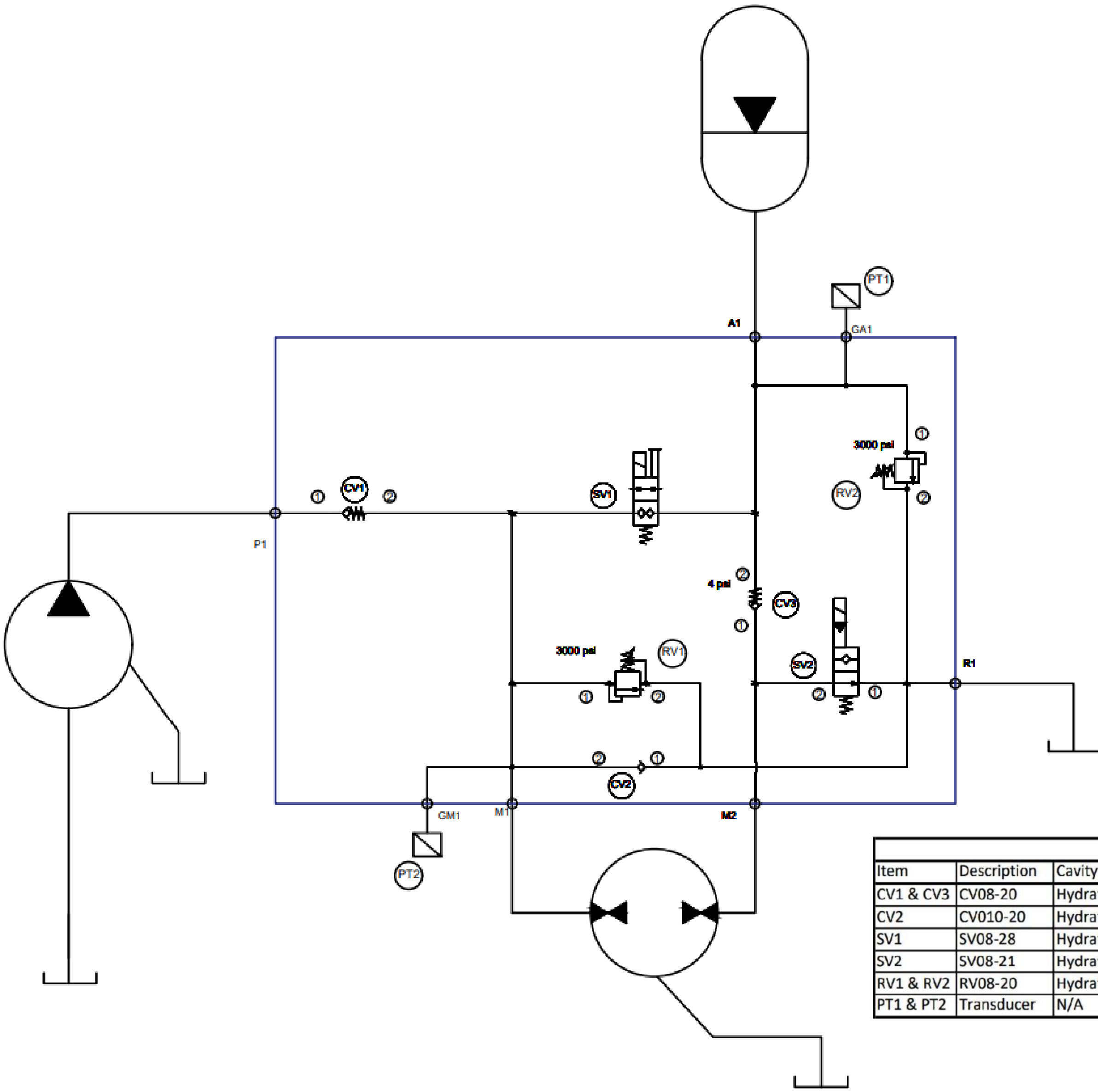

Cal Poly FPVC Valves			
Item	Description	Cavity	Note
CV1 & CV3	CV08-20	Hydraforce VC-08-20 or Equivalent	Cavity Only, Using cartridge from previous year
CV2	CV010-20	Hydraforce VC-08-20 or Equivalent	Cavity Only, Using cartridge from previous year
SV1	SV08-28	Hydraforce VC-08-20 or Equivalent	Cavity Only, Using cartridge from previous year
SV2	SV08-21	Hydraforce VC-08-20 or Equivalent	Cavity Only, Using cartridge from previous year
RV1 & RV2	RV08-20	Hydraforce VC-08-20 or Equivalent	Cavity Only, Using cartridge from previous year
PT1 & PT2	Transducer	N/A	Attaches to a SAE-6 port

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Final Circuit

Pneumatic Consistency

- Replace Regulator
- Permanent connection from actuators to paddles
- Mechatronic control system

Shifting Limitations

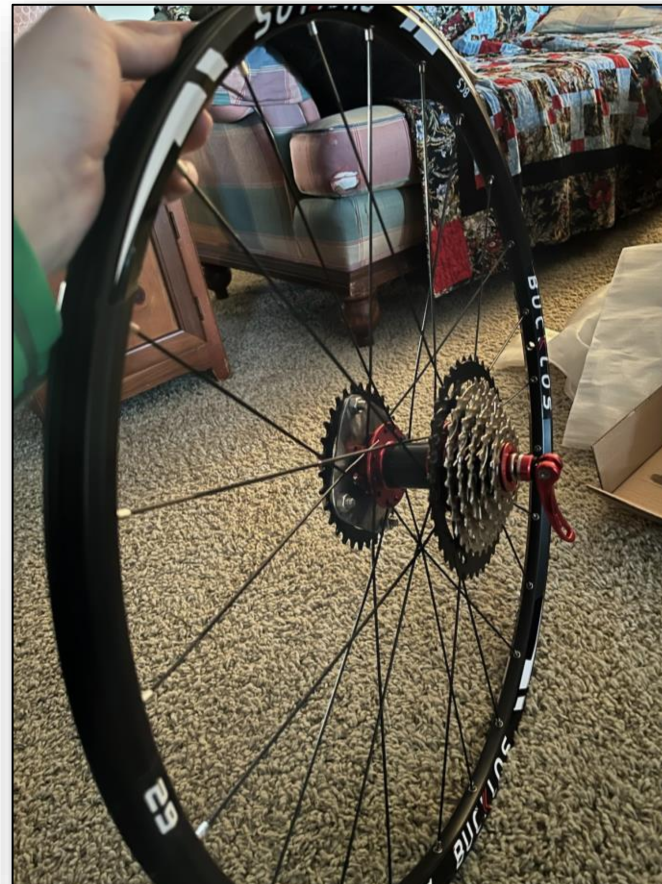
- 7-speed system was too ambitious
  - Difficulty up-shifting
  - Chain angle
- Derailleur positioning

Gearing

Problem: Gear ratios prevented uphill motion.

Solution: Implementation of new gears

Gearing Cont.



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Reflection

Improvements and lessons

Hydraulics

- Improvements:
  - Nitrogen Pre-charge tuning
  - Hardlines and Routing
- Lessons:
  - Assembly takes time
  - Understanding Circuit logic and how careful design contributes to operation and testing
  - The importance of careful planning

Chassis

- Identify potential hang-ups early
  - Isolate aspects of design/manufacturing processes that are unclear, then investigate as soon as possible
    - Ex: welding aluminum or manufacturing space constraints
- Don't be afraid to ask for help
  - Asking shop techs, experienced welders, and faculty for assistance can greatly improve overall quality of chassis and reduce time spent designing/manufacturing
- Rule of Pi
  - Time taken for completion = initial time estimated * π
  - Anticipate that design/manufacturing processes will take longer than initially expected

Front Power Train Improvements

- Improvements:
  - Fewer ratios
  - Better derailleur positioning
- Lessons:
  - Chain angle
  - Huge variety of bike components
  - Importance of early testing

Rear Power Train Improvements

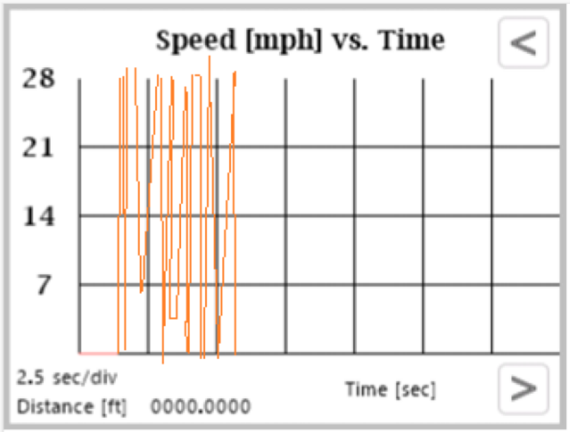
- Improvements:
  - Bolted connection for fixed sprocket
  - Stronger wheel construction
- Lessons:
  - Early stress testing
  - Consulting industry experts

Pneumatic Improvements

- Improvements:
  - Replace Regulator
  - Permanent actuator connections
- Lessons:
  - Scope creep

Electronic Improvements

- Simultaneous pressure readings
- Local averaging on speed sensor
- Integration of Pneumatics



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Sponsors

Questions?

Slide Bank Start

Gearing Analysis

- Original Ratio (OR): .6
- New Ratio (NR): .375
- Motor pressure drop ~700psi
- OR flat: 1522psi
- NR flat: 1214psi
- OR Competition Grade: 2298psi
- NR Competition Grade: 1662psi
- Testing indicates operator can generate ~1800psi at motor inlet.

Start up Torque (Old Gear)

```
M_vehicle = 9.31; %slug bike and rider
r = 1.208; %wheel radius in ft
a_start = 1; %ft/s/s target acceleration
F_load = M_vehicle*a_start; %Force to move bike

%flat ground
T_Start = N_2*F_load*r %Torque on the motor
```

```
T_Start = 6.7479
```

```
P_motor = T_Start/T_psi %Pressure to turn motor in psi
```

```
P_motor = 822.9132
```

```
% 1% Grade (.5729 theta)
F_load2 = M_vehicle*a_start + M_vehicle*32*sind(.5729);
T_Start2 = N_2*F_load2*r; %Torque on the motor
P_motor2 = T_Start2/T_psi %Pressure to turn motor in psi
```

```
P_motor2 = 1.0862e+03
```

```
% 2.7% Grade (1.56 theta)
F_load3 = M_vehicle*a_start + M_vehicle*32*sind(1.56);
T_Start3 = N_2*F_load3*r %Torque on the motor
```

```
T_Start3 = 12.6264
```

```
P_motor3 = T_Start3/T_psi %Pressure to turn motor in psi
```

```
P_motor3 = 1.5398e+03
```

```
% 4% Grade (2.3 theta)
F_load4 = M_vehicle*a_start + M_vehicle*32*sind(2.3);
T_Start4 = N_2*F_load4*r; %Torque on the motor
P_motor4 = T_Start4/T_psi %Pressure to turn motor in psi
```

```
P_motor4 = 1.8797e+03
```

```
%Pressure increase from 0% to 2.7%
P_increase = P_motor3-P_motor
```

```
P_increase = 716.8896
```

Start up Torque (New Gear)

```
M_vehicle = 9.31; %slug bike and rider
r = 1.208; %wheel radius in ft
a_start = 1; %ft/s/s target acceleration
F_load = M_vehicle*a_start; %Force to move bike

%flat ground
T_Start = N_2*F_load*r %Torque on the motor
```

```
T_Start = 4.2174
```

```
P_motor = T_Start/T_psi %Pressure to turn motor in psi
```

```
P_motor = 514.3207
```

```
% 1% Grade (.5729 theta)
F_load2 = M_vehicle*a_start + M_vehicle*32*sind(.5729);
T_Start2 = N_2*F_load2*r; %Torque on the motor
P_motor2 = T_Start2/T_psi %Pressure to turn motor in psi
```

```
P_motor2 = 678.8840
```

```
% 2.7% Grade (1.56 theta)
F_load3 = M_vehicle*a_start + M_vehicle*32*sind(1.56);
T_Start3 = N_2*F_load3*r %Torque on the motor
```

```
T_Start3 = 7.8915
```

```
P_motor3 = T_Start3/T_psi %Pressure to turn motor in psi
```

```
P_motor3 = 962.3768
```

```
% 4% Grade (2.3 theta)
F_load4 = M_vehicle*a_start + M_vehicle*32*sind(2.3);
T_Start4 = N_2*F_load4*r; %Torque on the motor
P_motor4 = T_Start4/T_psi %Pressure to turn motor in psi
```

```
P_motor4 = 1.1748e+03
```

```
%Pressure increase from 0% to 2.7%
P_increase = P_motor3-P_motor
```

```
P_increase = 448.0560
```

Manifold Pictures

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Hydraulic Attachments

- Accumulator/Reservoir Column was reused
- Pump bracket was reused
- New Motor bracket
- New Manifold mounting plate

Complete Display HMI

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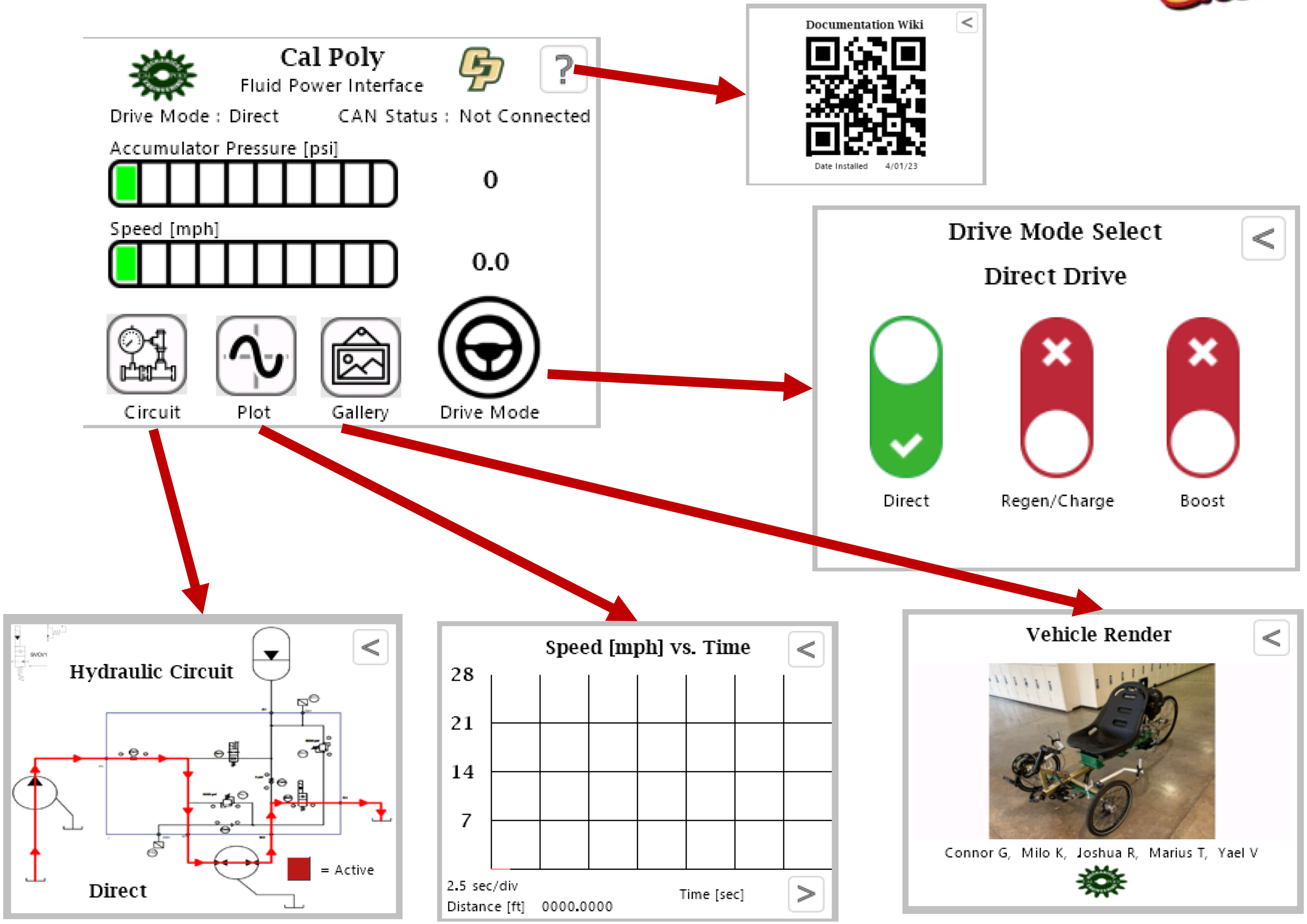
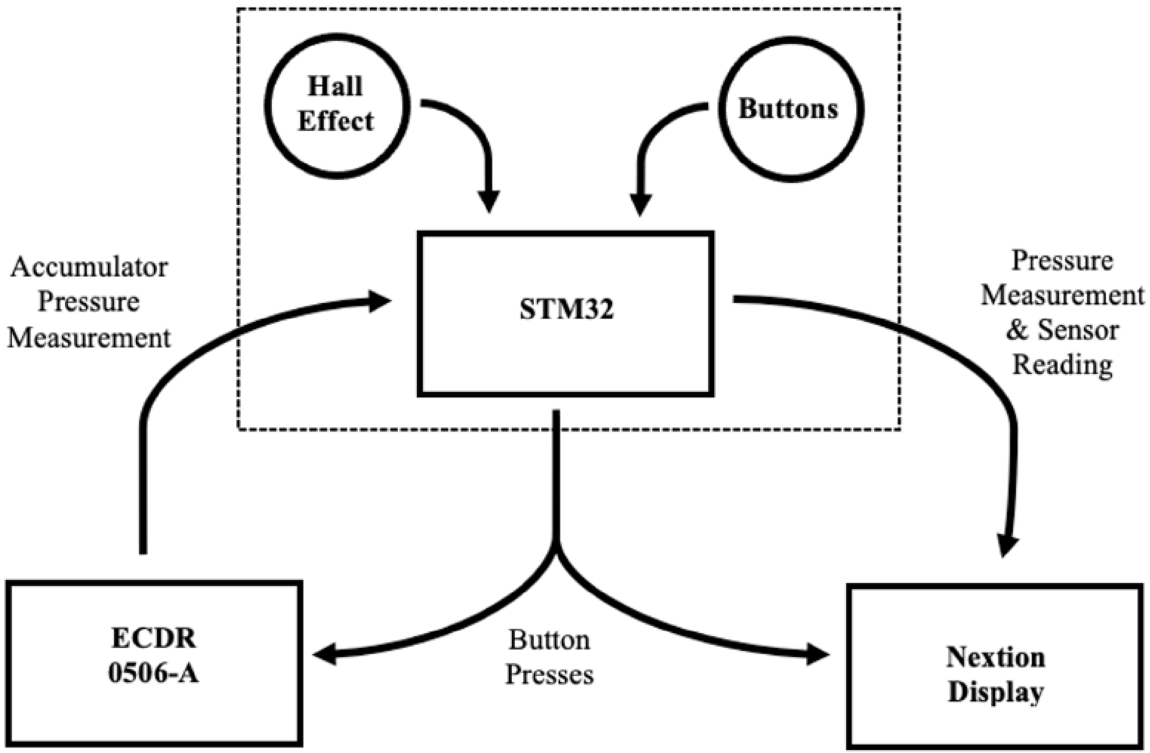


3 Adapters For Interfacing

Component Interfacing



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