NFPA Fluid Power Vehicle Challenge

NFPA Education and Technology Foundation

FINAL PRESENTATION
FLUID POWER CLUB AT
SOUTH DAKOTA STATE
DOUG PRAIRIE
4/24/2024

Team Introductions: ABE

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Team Introductions: ABE

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Design Objectives

- New Frame
  - "Pallet" concept for mounting hydraulic circuit
- New Components
  - Pump, Motor, Manifold, Reservoir
- Simplify hydraulic circuit
- Adding 6-Speed Transmission
- New Electronic System

Progress Since Midway Review

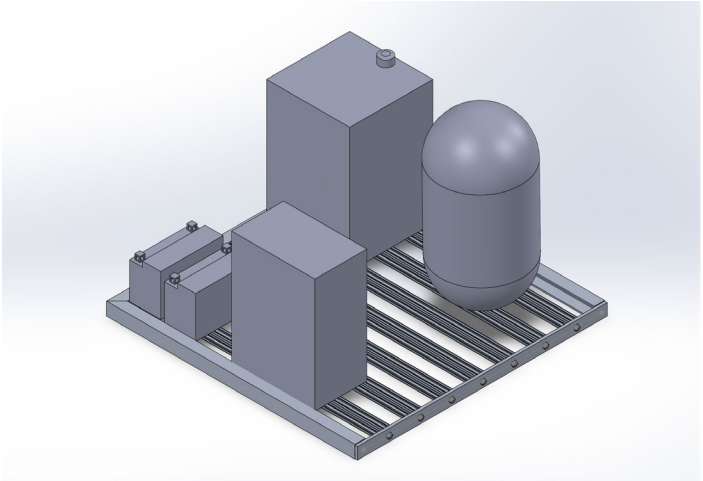
- New Frame Construction
  - Routed Plumbing
  - Attached Components
  - Shifter and Brake Cable
- Test New Bike: 3/18/24-4/19/24
  - Collect Data
  - Analyze Data
  - Make Improvements
- Finishing Touches: 4/21/24-4/24/24

Design Choices

- Simplified manifold; size and circuit
  - Simplify lines to reservoir, Accumulator valve nominally closed
- Transmission
  - Pinion 6-speed transmission
- Pump / Motor
  - Changed from gear to piston pump for efficiency
  - Increased motor displacement from 4.1 to 5 cc/rev
- Brand new electronics

Pallet Concept

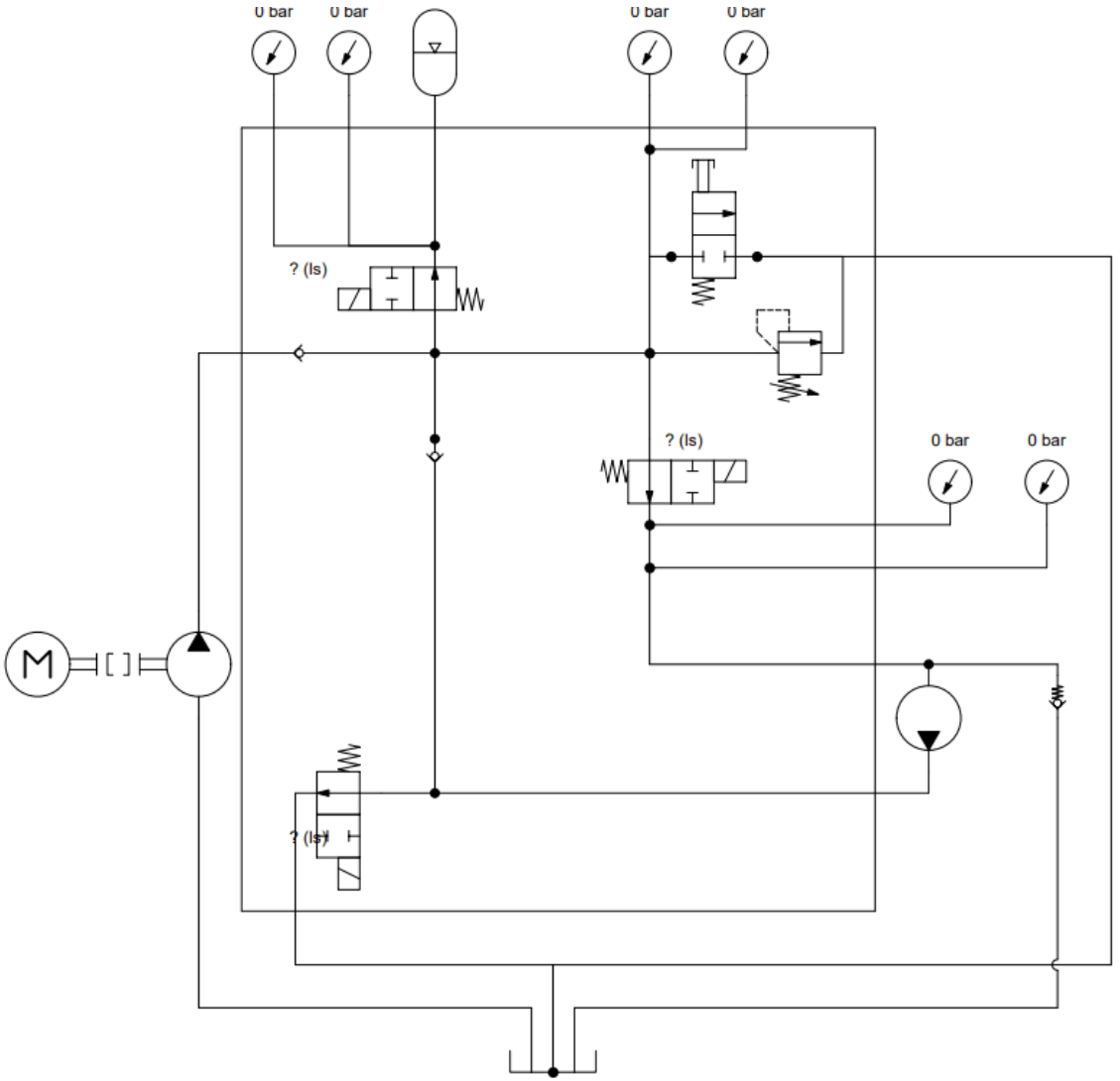
- Package components above rear axle on the new "pallet"
  - Improved Serviceability (repairs, monitoring, etc.)
  - Improved Manufacturability (hydraulic system testing)
  - Simplicity
  - Safety
- Minimize conduit lengths – all elements placed next to each other
- Creates "Cleaner" look to bike
- Improve rider experience



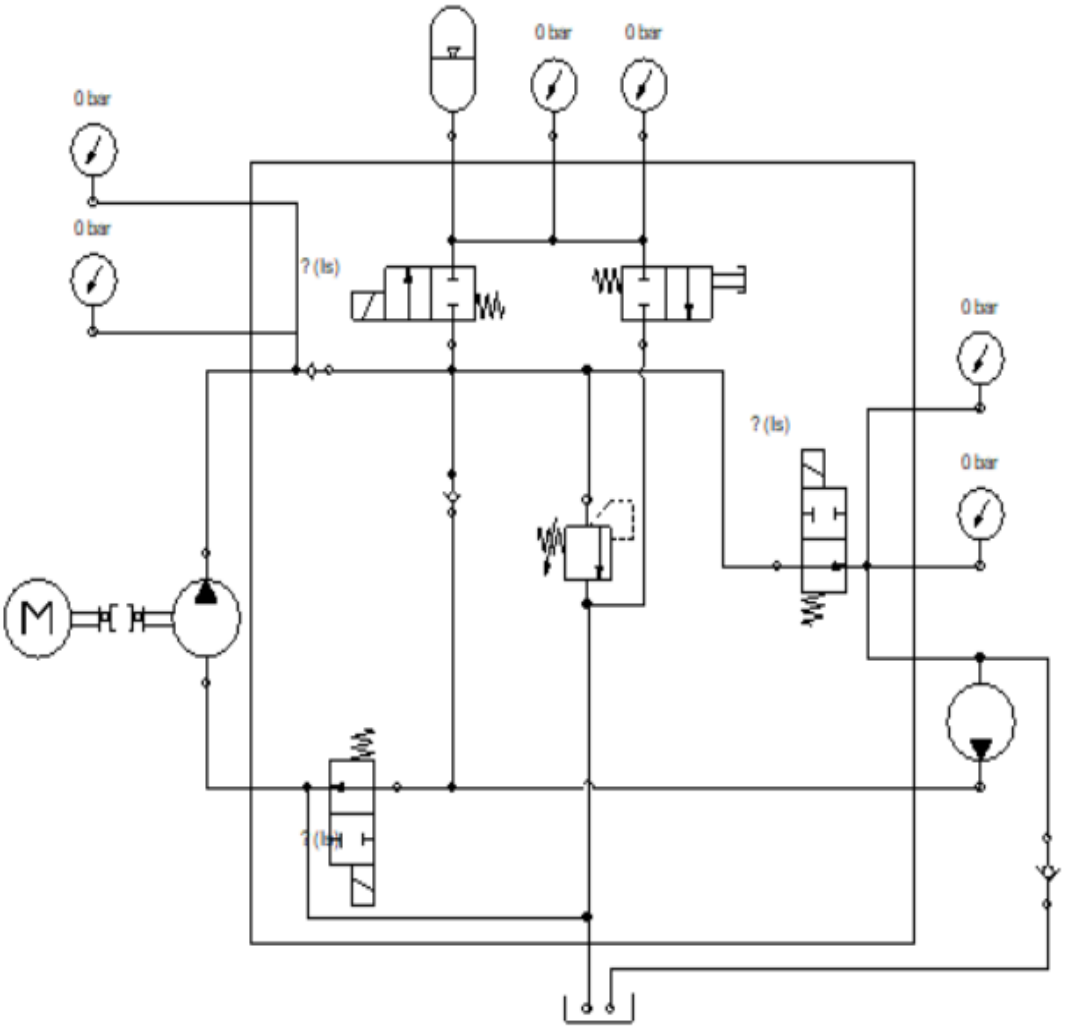
New Components

- Simplified manifold
  - Designed to have "coast" mode
  - Valve nominally open for accumulator
  - Easy access manual pressure relief valve
- New Reservoir
- Pinion 6-Speed Transmission
- Pump
- Motor

Hydraulics: Old Circuit

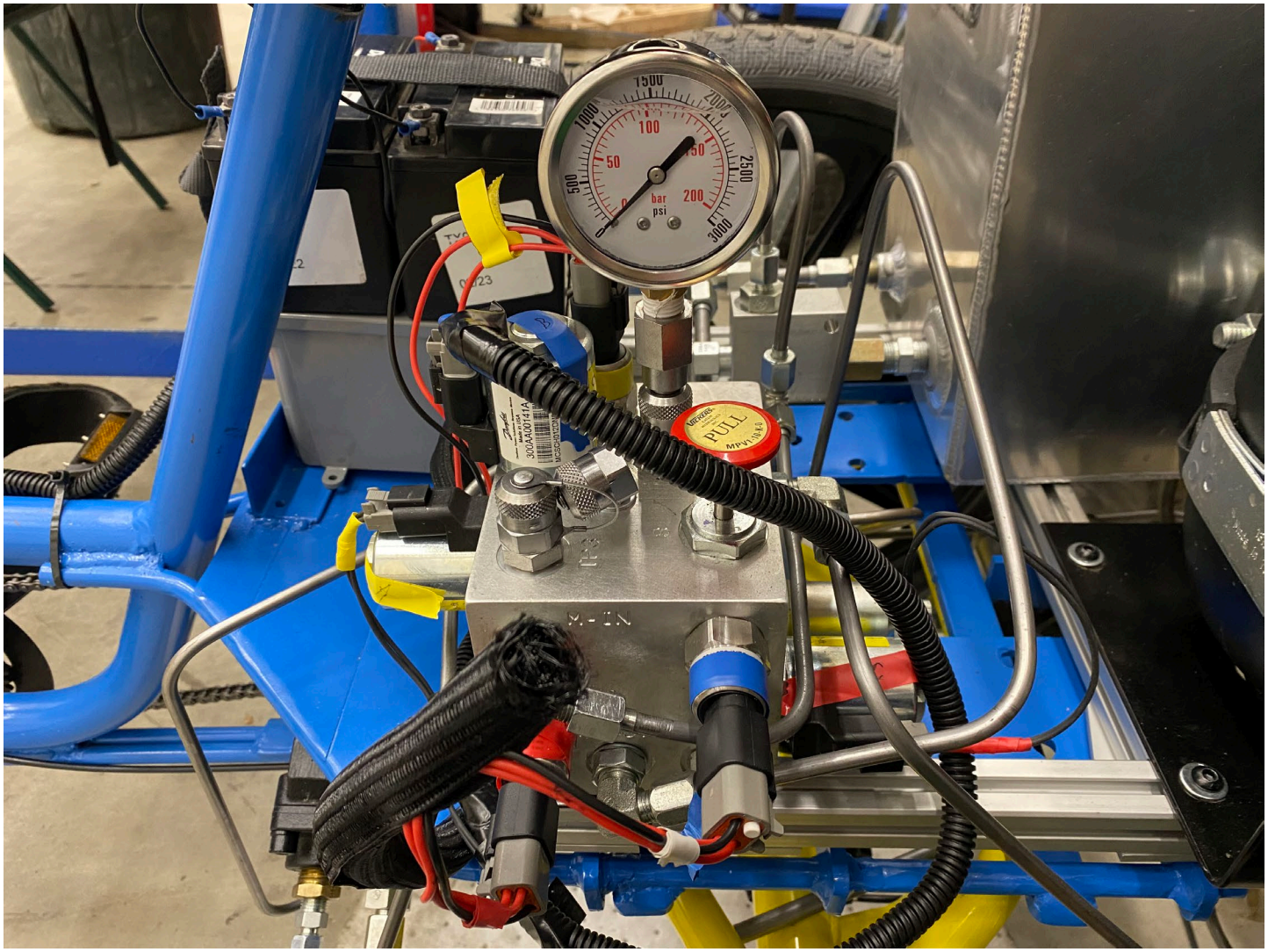


Hydraulics: New Circuit

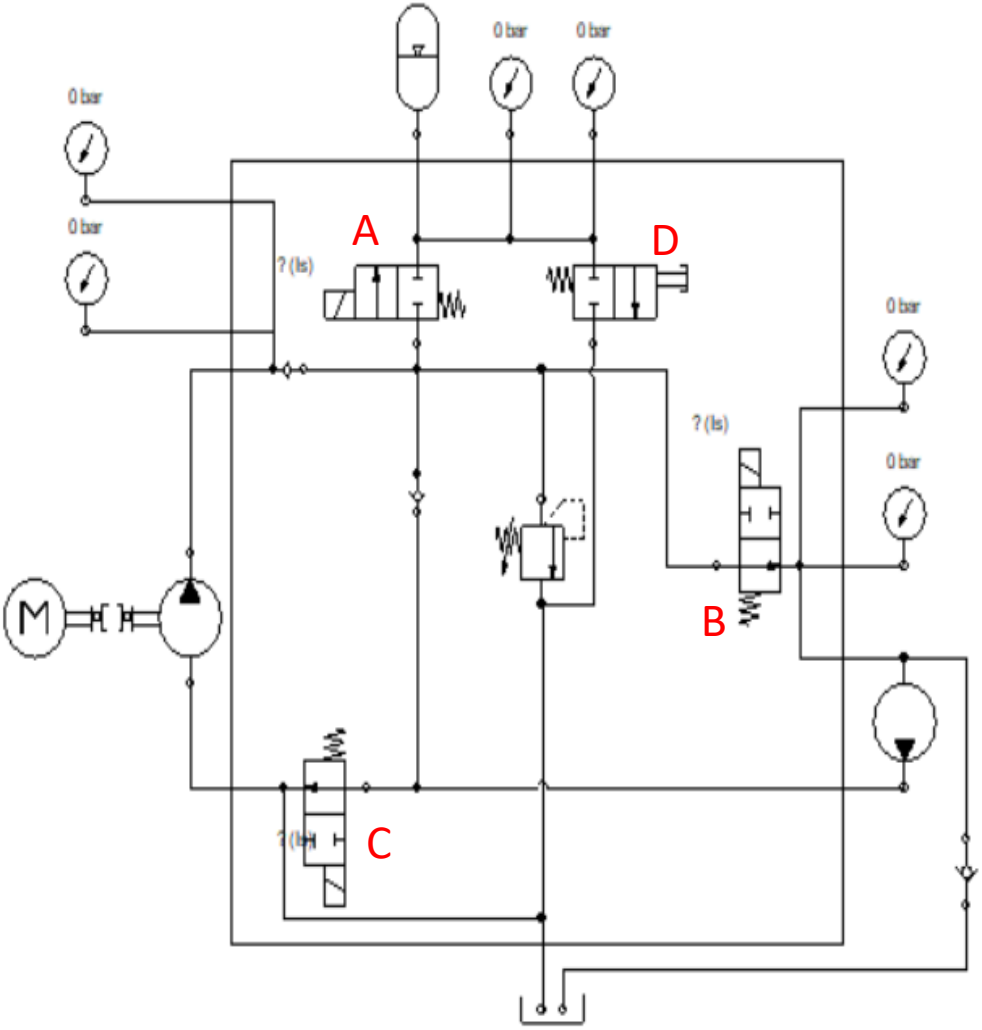


- Test Ports
  - Located at every component
  - Pressure transducers
  - Manual test ports
- "Coast Mode"
- Pedal to Power mode when no battery power
- Accumulator valve nominally closed
- Manual relief valve in case of power loss
- External check valve for regen suction

Hydraulics: New Manifold



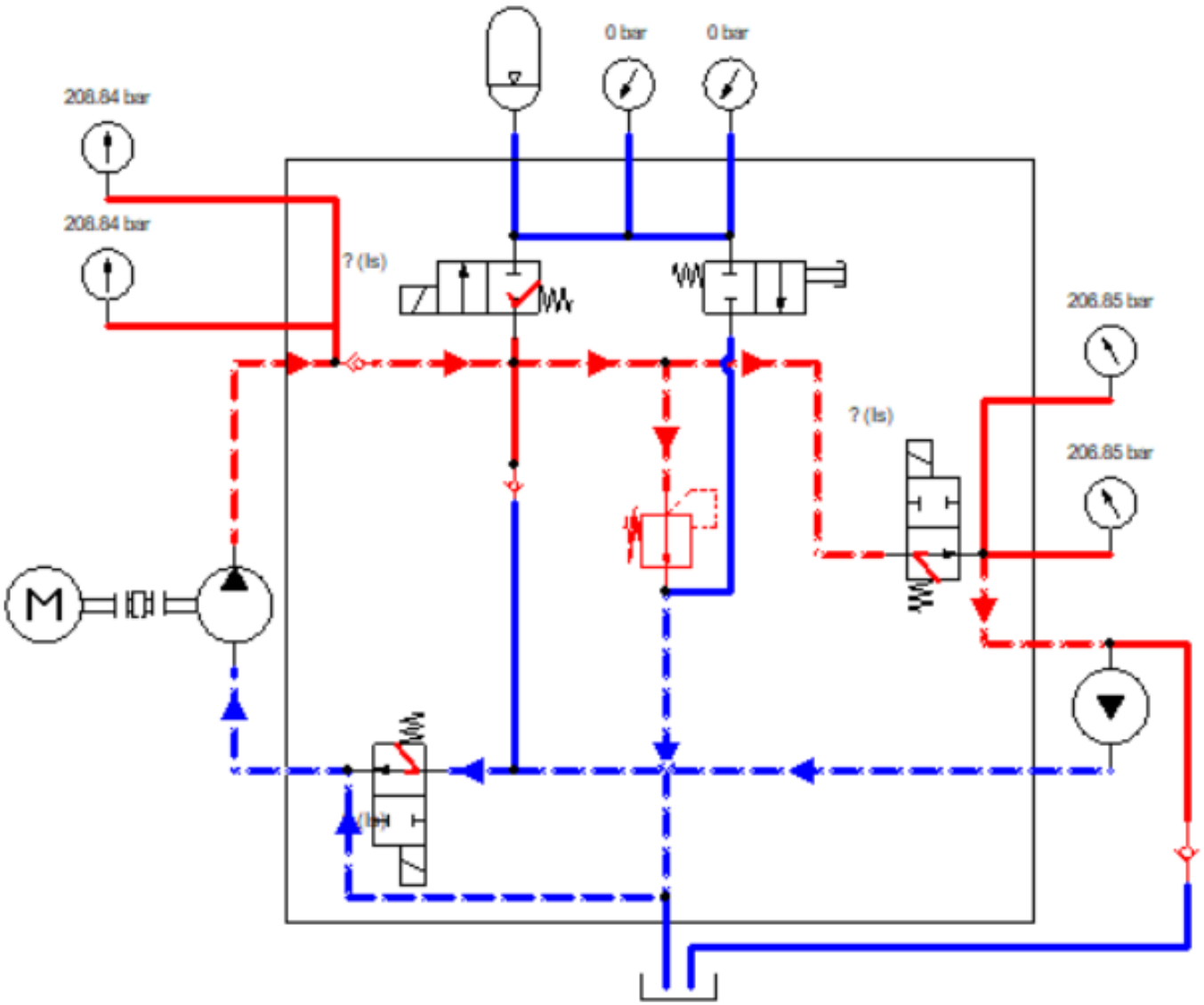
Hydraulics: Valve Positions



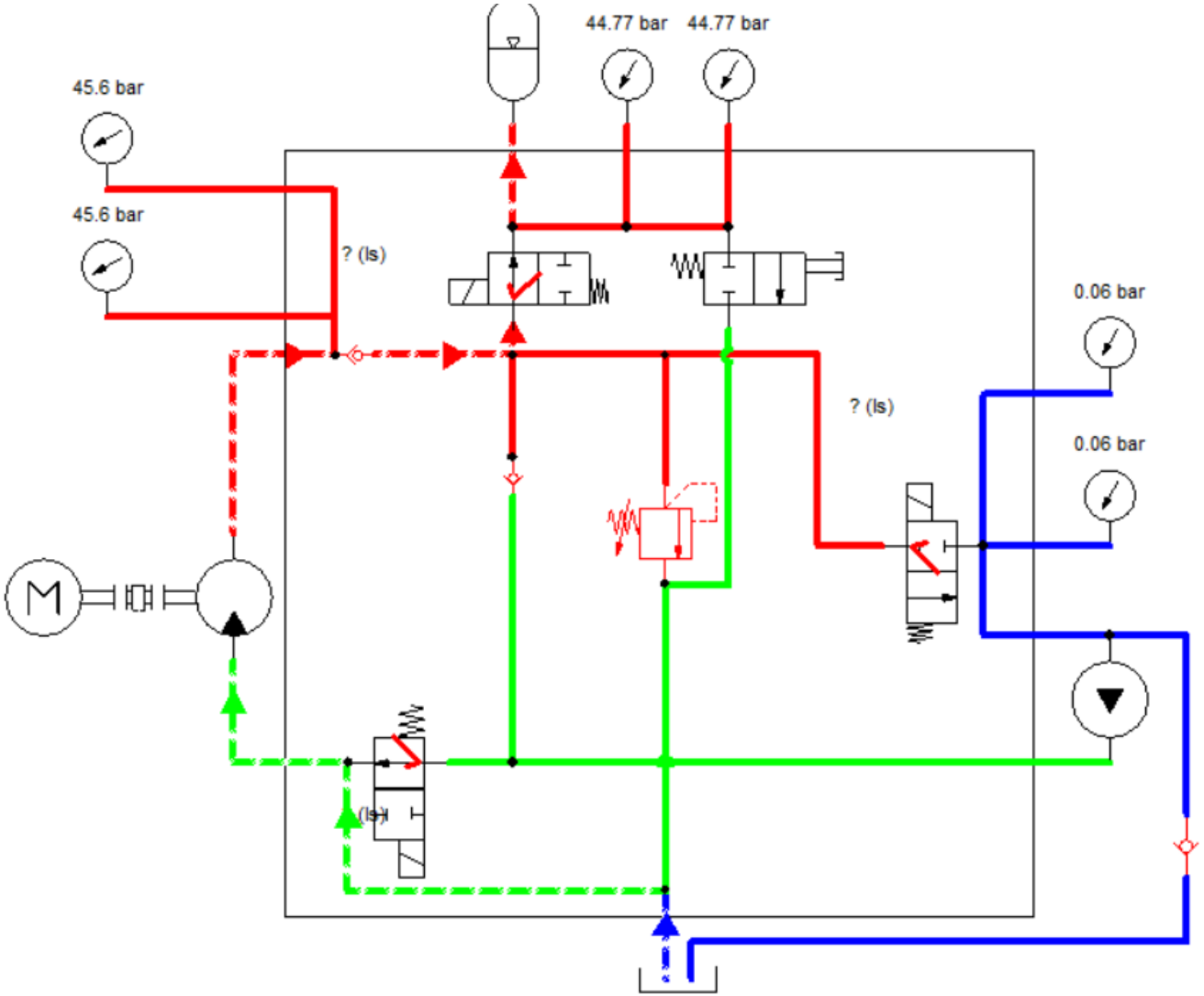
Mode	Valve			
	A	B	C	D
Pedal to Power	0	0	0	0
Accumulator Charge	1	1	0	0
Regenerative Charge	1	1	1	0
Accumulator Discharge	1	0	0	0
System Dump	0	0	0	1

* Valve D is for manual discharge

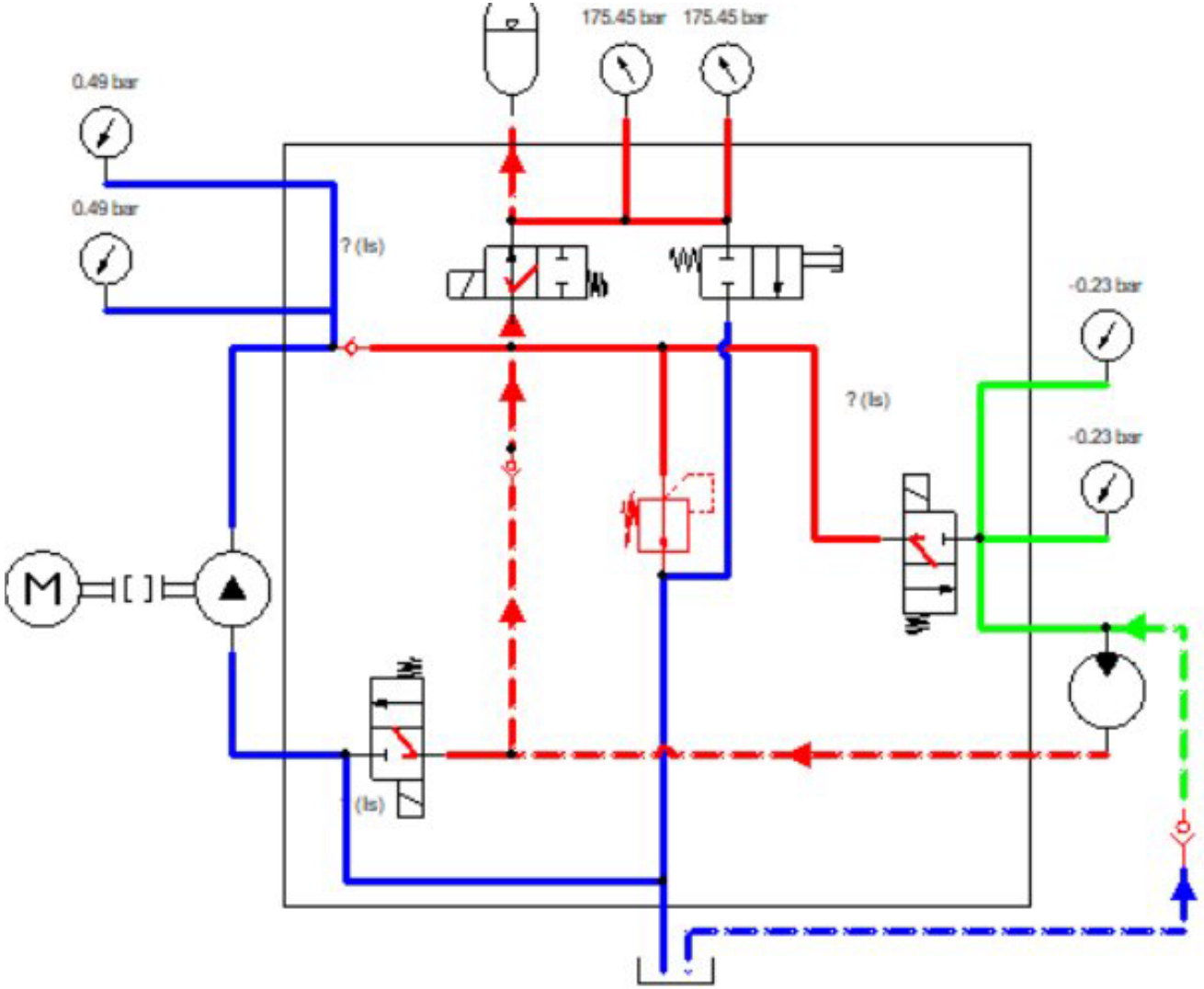
Hydraulics: Pedal to Power



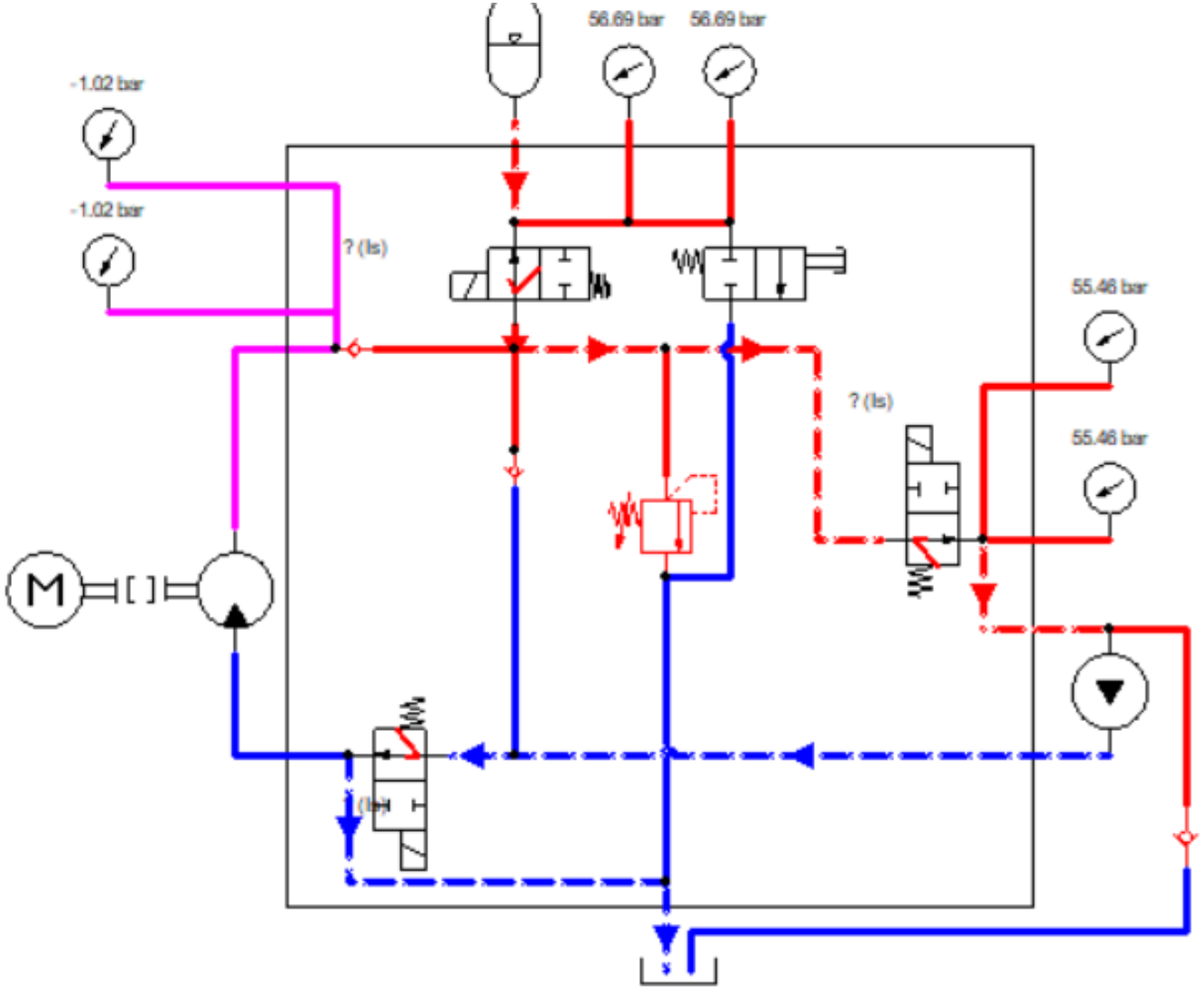
Hydraulics: Accumulator Charge



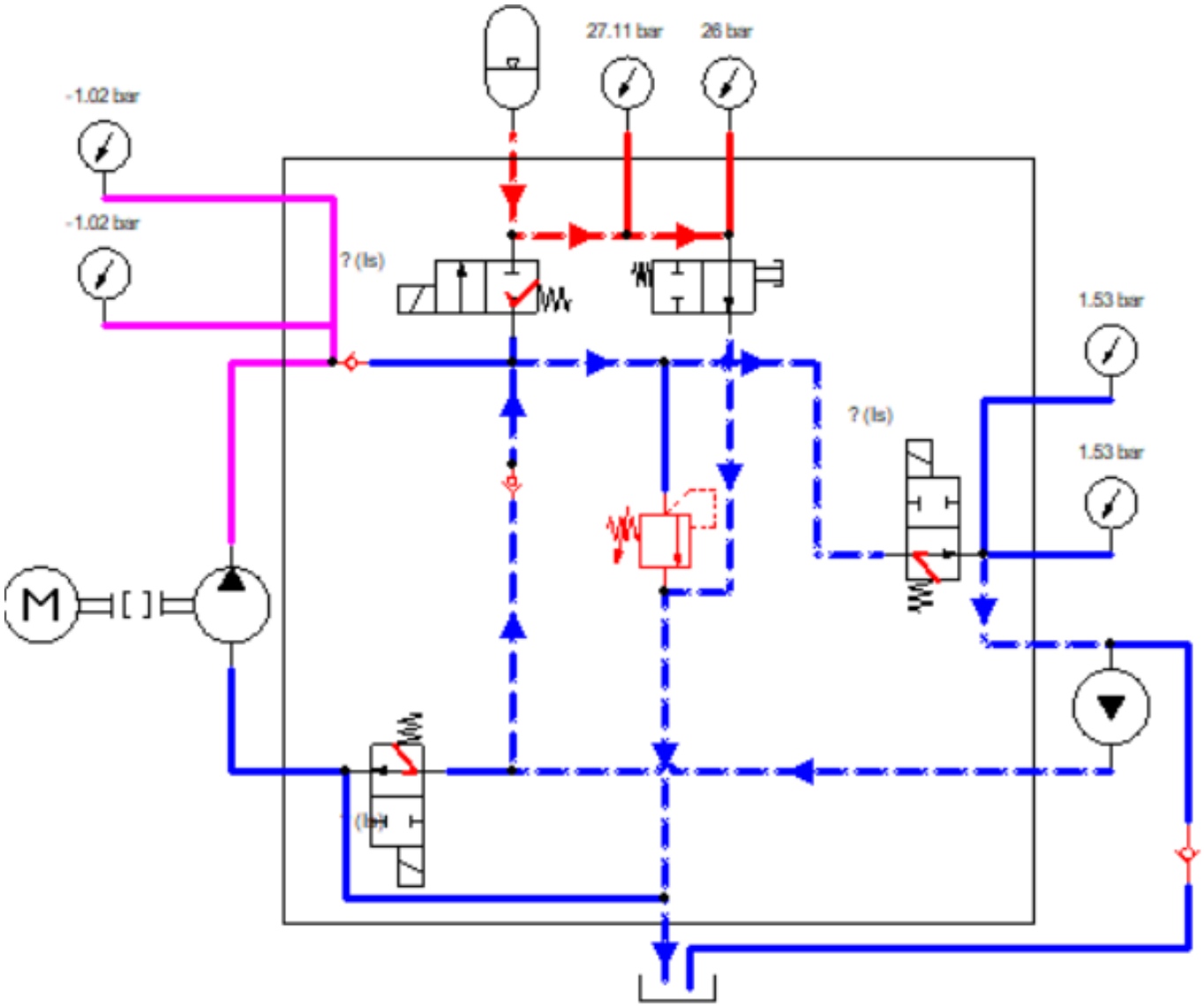
Hydraulics: Regenerative Charge



Hydraulics: Accumulator Discharge



Hydraulics: System Dump



Hardware Selection

Pinion 6-speed Transmission

Current bike has low speed gear
- Good for take off
- Difficult to reach high speeds

New Transmission
- Bike will have 6 gears
- Later information about gear ratios

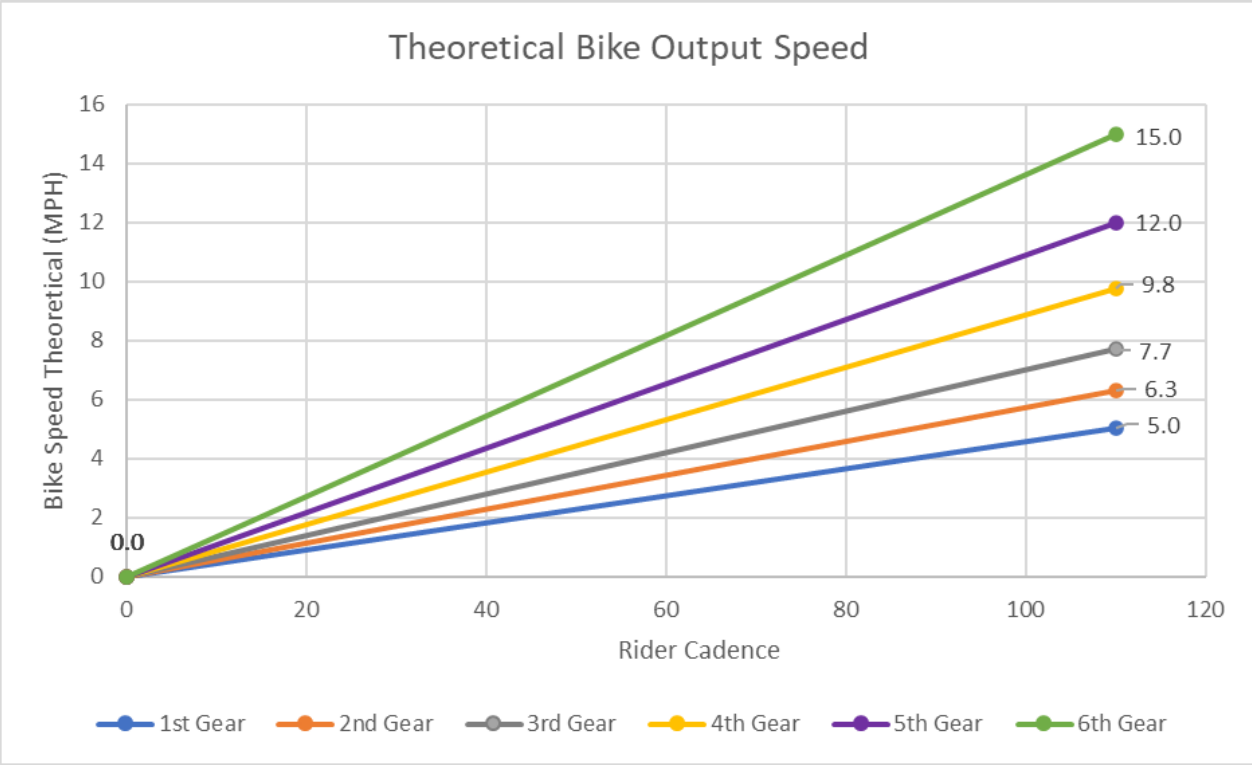
Number of gears	6
Total range	295 %
Step size	24.3 %
Easiest gear	0.95
Fastest Gear	0.32
Gearbox weight	ca. 1800 g

Rider Cadence 80RPM

Gear	Internal Ratio	RPM Out	4:1 gear to pump
1	1.05	84	336
2	1.32	105.6	422.4
3	1.61	128.8	515.2
4	2.04	163.2	652.8
5	2.5	200	800
6	3.13	250.4	1001.6

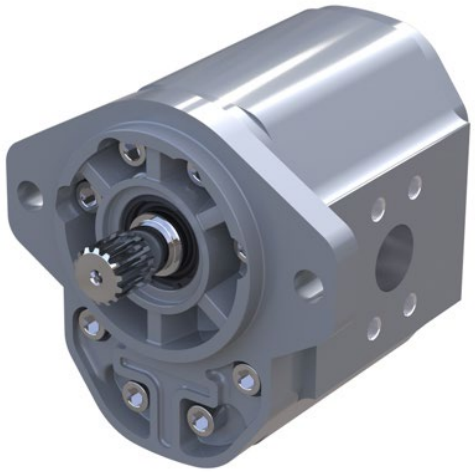
New Hardware Improvements

- Reduced Operator Felt Impulse (Hydro Leduc minimum speed 200RPM, Danfoss 700RPM)
- Efficiency Increase (92% Bent Axis) Closer to operational Speed
- Torque Increase
- Increased Momentum

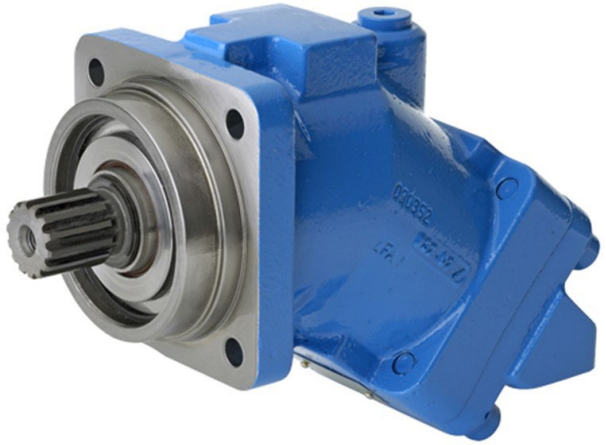


New Pump and Motor

Type: Gear Motor
Manufacturer: Danfoss
Weight: 5.5lb
Bi-Directional
Displacement: 8.4 cm^3



Type: Bent Axis Piston Pump
Manufacturer: Hydro Leduc
Weight: 9.7lbs
Clockwise Rotation
Displacement: 5 cm^3
Flow Rate:3.67 GPM

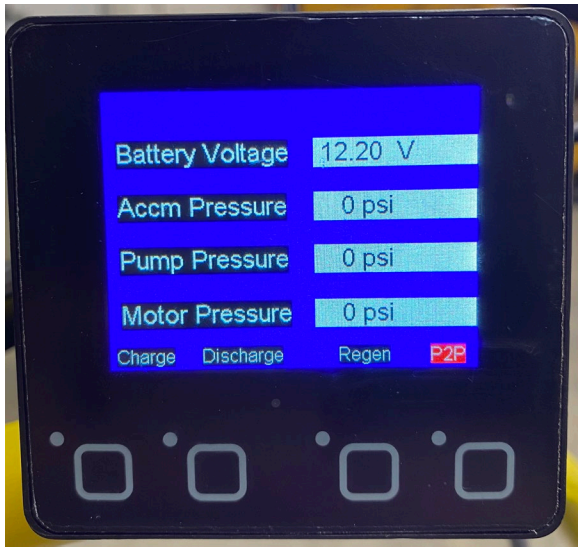


New Display

- MRS MConn Mini
  - Series Smallest HMI-Display
  - 2.4-inch Colored Display
  - Customizable, Waterproof, Flexible

Last year's controller display

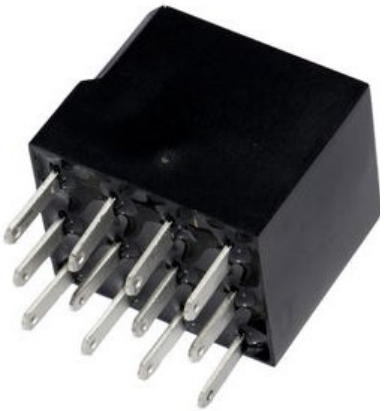
MRS ELECTRONIC



Focus on simplicity, functionality, and easily accessible support

Electronic Controller

- MicroPlex 7X – CAN Controller with High Integration
  - 7 inputs/outputs & 3 configurable analog or digital inputs
- Cody adds code?
- Microcontroller things?



Splitting Data

```
// We need this because we are sending data values that are larger than 256   We need up to 5000

//Return value of most signigicant hex bit of an int between the value 256 - 65535
int user_return_hex_MSB(int value)
{
    int MSB = (value >> 8) & 0xFF;
    return MSB;
}

//Return value of least signigicant hex bit of an int between the value 256 - 65535

int user_return_hex_LSB(int value)
{
    int LSB = (value & 0xFF);
    return LSB;
}
```

Micro Plex Programming


```
// 3 Input/Output for the 3 coils.
user_Coil1 = can_db_get_value(0, Coil_1);          //Read CAN Message
os_pin_write(Coil1, user_Coil1);                   //set a Digital Output

user_Coil2 = can_db_get_value(0, Coil_2);          //Read CAN Message
os_pin_write(Coil2, user_Coil2);                   //set a Digital Output

user_Coil3 = can_db_get_value(0, Coil_3);          //Read CAN Message
os_pin_write(Coil3, user_Coil3);                   //set a Digital Output

os_can_send_message(0x720, 0, 8, user_heartbeat, 0, 0, 0, 0, 0, 0, 0, 0);                  //Sending CAN Heartbeat Message
// os_can_send_message(0x101, 0, 8, user_Coil1, user_Coil2, user_Coil3, 0, 0, 0, 0, 0);     //Sending CAN Message for 3 coils..... They can be sent individually in PCAN View  //101 = Coil_Messag
//Andrew said to comment out line above

// 3 Gauge Readings and the Battery Voltage.

user_BattVolt =  os_algin_mv(Batt_Volt);             // Reading Battery Voltage          (Read Analog Input)   (Name of Pin)      Battery Voltage =       Pin 2
user_AccmPress = os_algin_mv(Accm_Press);            // Reading Accumulator Presssure    (Read Analog Input)   (Name of Pin)   Accumulator Pressure =  Pin 8
user_PumpPress = os_algin_mv(Pump_Press);            // Reading Pump Presssure           (Read Analog Input)   (Name of Pin)   Pump Pressure =         Pin 7
user_MotorPress = os_algin_mv(Motor_Press);          // Reading Motor Presssure          (Read Analog Input)   (Name of Pin)  Motor Pressure =        Pin 9

tmpbyte_batt_volt_MSB = user_return_hex_MSB(user_BattVolt);
tmpbyte_batt_volt_LSB = user_return_hex_LSB(user_BattVolt);

tmpbyte_accm_press_MSB = user_return_hex_MSB(user_AccmPress);
tmpbyte_accm_press_LSB = user_return_hex_LSB(user_AccmPress);

tmpbyte_pump_press_MSB = user_return_hex_MSB(user_PumpPress);
tmpbyte_pump_press_LSB = user_return_hex_LSB(user_PumpPress);

tmpbyte_motor_press_MSB = user_return_hex_MSB(user_MotorPress);
tmpbyte_motor_press_LSB = user_return_hex_LSB(user_MotorPress);
```

Display Static Code

```
// clear display once and prepare the static content of the display page and
if(flag_clear_do_once == 0)
{
    flag_clear_do_once = 1;
    // Prepare background, clear old content
    board_set_lcd_background_color(LCD_COLOR_BLUE );

    // print the gauge reading information Titles
    board_lcd_print_text( 10  , 40    , "Battery Voltage", LCD_FONT_ARIAL_22, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 10  , 86    , "Accm Pressure", LCD_FONT_ARIAL_22, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 10  , 132   , "Pump Pressure", LCD_FONT_ARIAL_22, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 10  , 180   , "Motor Pressure", LCD_FONT_ARIAL_22, LCD_COLOR_WHITE, LCD_COLOR_BLACK);

}
```

Display Status Code

```
//Mode Determination for 4 Buttons
//Pedal to Power
if ((user_Coil1_State == 0) && (user_Coil2_State == 0) && (user_Coil3_State == 0))
{
    board_lcd_print_text( 280 , 220, "P2P", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_RED);
    board_lcd_print_text( 5 , 220, "Charge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 200   , 220, "Regen", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 80   , 220, "Discharge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
}
//Accumulator Charge
else if((user_Coil1_State == 1) && (user_Coil2_State == 1) && (user_Coil3_State == 0))
{
    board_lcd_print_text( 280 , 220, "P2P", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 5 , 220, "Charge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_RED);
    board_lcd_print_text( 200   , 220, "Regen", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 80   , 220, "Discharge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
}
//Mode Determination for Regen
else if((user_Coil1_State == 1) && (user_Coil2_State == 1) && (user_Coil3_State == 1))
{
    board_lcd_print_text( 280 , 220, "P2P", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 5 , 220, "Charge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 200   , 220, "Regen", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_RED);
    board_lcd_print_text( 80   , 220, "Discharge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
}
//Accumulator Discharge
else if((user_Coil1_State == 1) && (user_Coil2_State == 0) && (user_Coil3_State == 0))
{
    board_lcd_print_text( 280 , 220, "P2P", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 5 , 220, "Charge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 200   , 220, "Regen", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_BLACK);
    board_lcd_print_text( 80   , 220, "Discharge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_RED);
}
else
{
    board_lcd_print_text( 280 , 220, "P2P", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_RED);
    board_lcd_print_text( 5   , 220, "Charge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_RED);
    board_lcd_print_text( 200 , 220, "Regen", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_RED);
    board_lcd_print_text( 80  , 220, "Discharge", LCD_FONT_ARIAL_16, LCD_COLOR_WHITE, LCD_COLOR_RED);
}
```

Testing:

- Accumulator pre-charged to 800psi
- Pulsing discharge for increased distance
- Adjusting pressure relief valve to just under 3,000 psi limit
- 50-yard speed testing (old vs new)

OLD BIKE	
Person A Time (sec)	Person B Time (sec)
12.91	12.86
13.83	13.05
15.26	13.26

NEW BIKE		
Person A Time (sec)	Person B Time (sec)	Strategy
15.77	17.46	Shifting
16.45	17.34	Shifting
15.37	14.46	3rd Gear
26.64	16.84	Acc. Dump

Analysis: Transmission

- Pedal speed: 110 RPM MAX
- Wheel speed: 266 RPM, 20 mph
- Built a max of 400 psi in Pedal to Power
- Accumulator can be built to ~2600 psi

Gearbox Output Speed * (Input Gear/Output Gear)= Output Gear RPM (26" Tires)

P1.6	Gearbox Ratio	gearbox output speed RPM	Pump Rpm	motor rpm	rear axle rpm	ground speed ft/min	rider input rpm	mph
1	1.05	115.5	462	222.49	89.48	608.50	110.00	6.91
2	1.32	145.2	580.8	279.70	112.50	764.97	110.00	8.69
3	1.61	177.1	708.4	341.15	137.21	933.03	110.00	10.60
4	2.04	224.4	897.6	432.27	173.86	1182.22	110.00	13.43
5	2.5	275	1100	529.74	213.06	1448.80	110.00	16.46
6	3.13	344.3	1377.2	663.23	266.75	1813.90	110.00	20.61

Lessons Learned

- Accumulator – charging, valve, etc.
- Plumbing – Need to design for backing up
- Transmission design
- Gear ratios and free wheel
- Time management
- Basic teamwork skills
- Communication skills
- Troubleshooting
- Basic Electronic Coding

Questions?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