A&C Build Readiness Review

Data Acquisition (DAQ), Engine Controller (EC), Spark Plug Ignition System

Recap: Targets & Constraints

- Qualities
  - Sufficient amperage to handle pull from all sensors and valves (~11-12 Amps)
  - Enough power for all components with some tolerance
  - Reliable; fast clock speeds
  - Modular - add or take away components
  - Antialiasing - clear signals - noise reduction - biasing
- Quantities
  - ~~14 Valves~~ 6 Valves
  - ~~8 Pressure Transducers~~ 4 Pressure Transducers
  - 3 Thermocouples
  - ~~1 Load Cell~~
  - 5”x5” PCB

Deviations from PDR

- Added a design for Spark Plug Ignition System

General Design Choices

Teensy 4.1

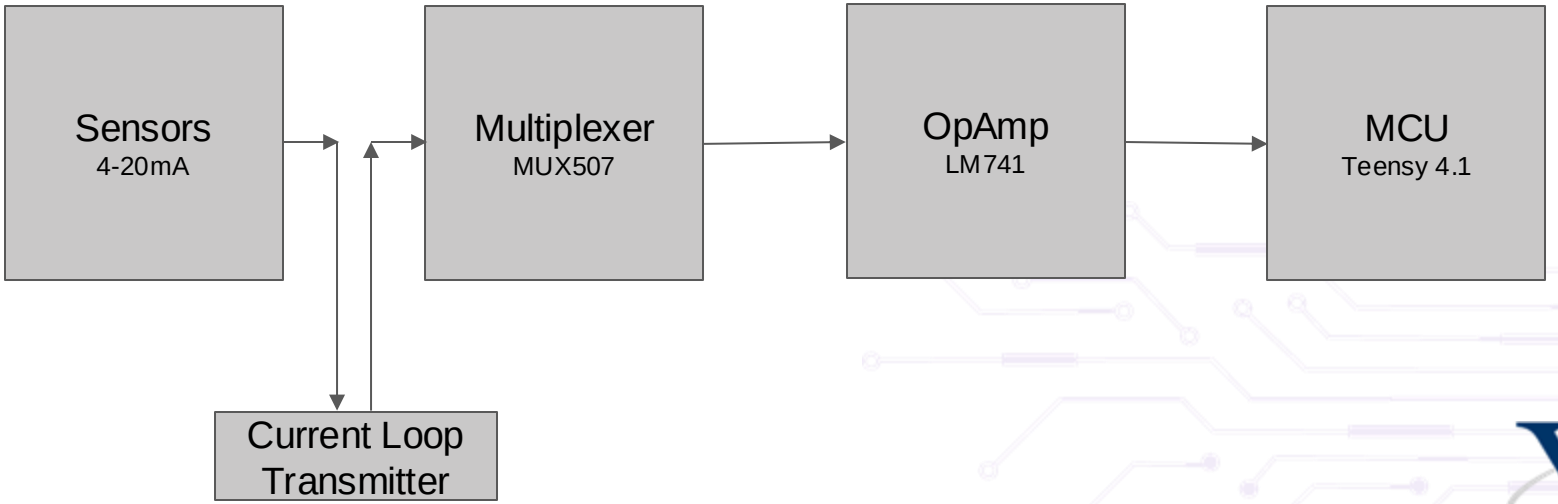
- ARM Cortex-M7 at 600 MHz
- 55 digital input/output pins, 35 PWM output pins
- 18 analog input pins
- 8 serial, 3 SPI, 3 I2C ports
- Ethernet 10/100 Mbit
- 10-12 bit ADC
- Arduino IDE

24VDC Battery

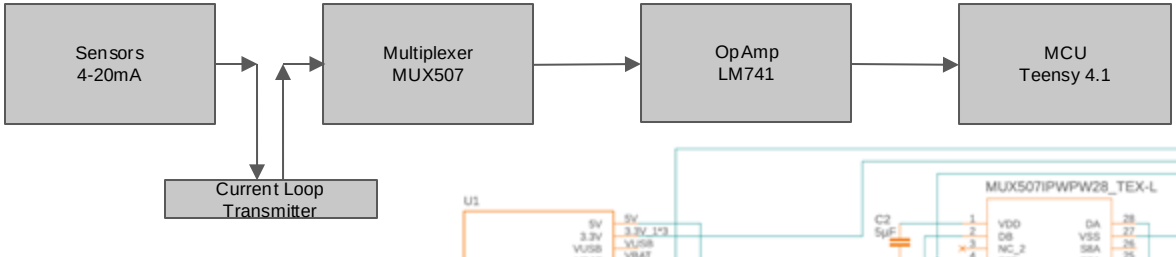
- Rechargeable
- 20A
- Bullet Connectors

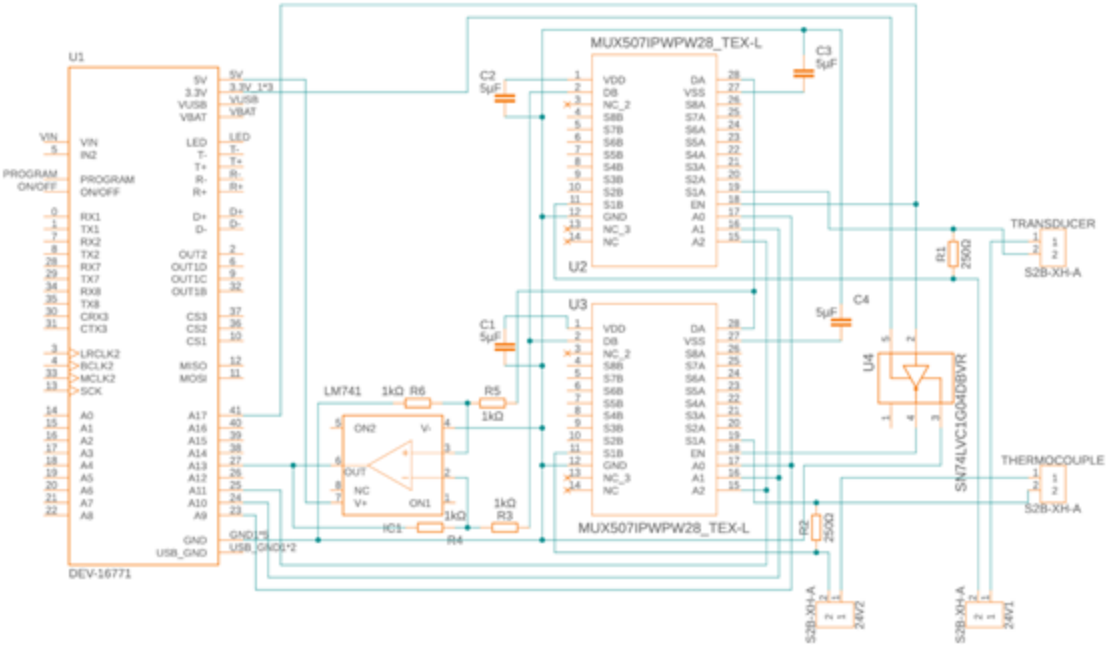
Data Acquisition

Data Acquisition System

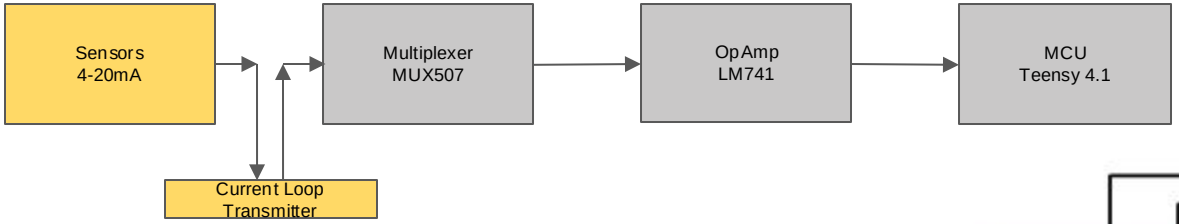


Data Acquisition System

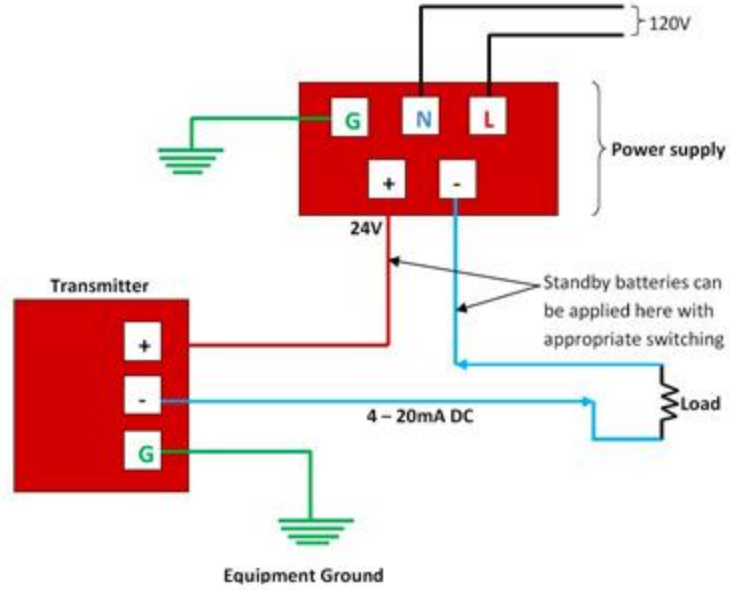




Current Loop Transmitter



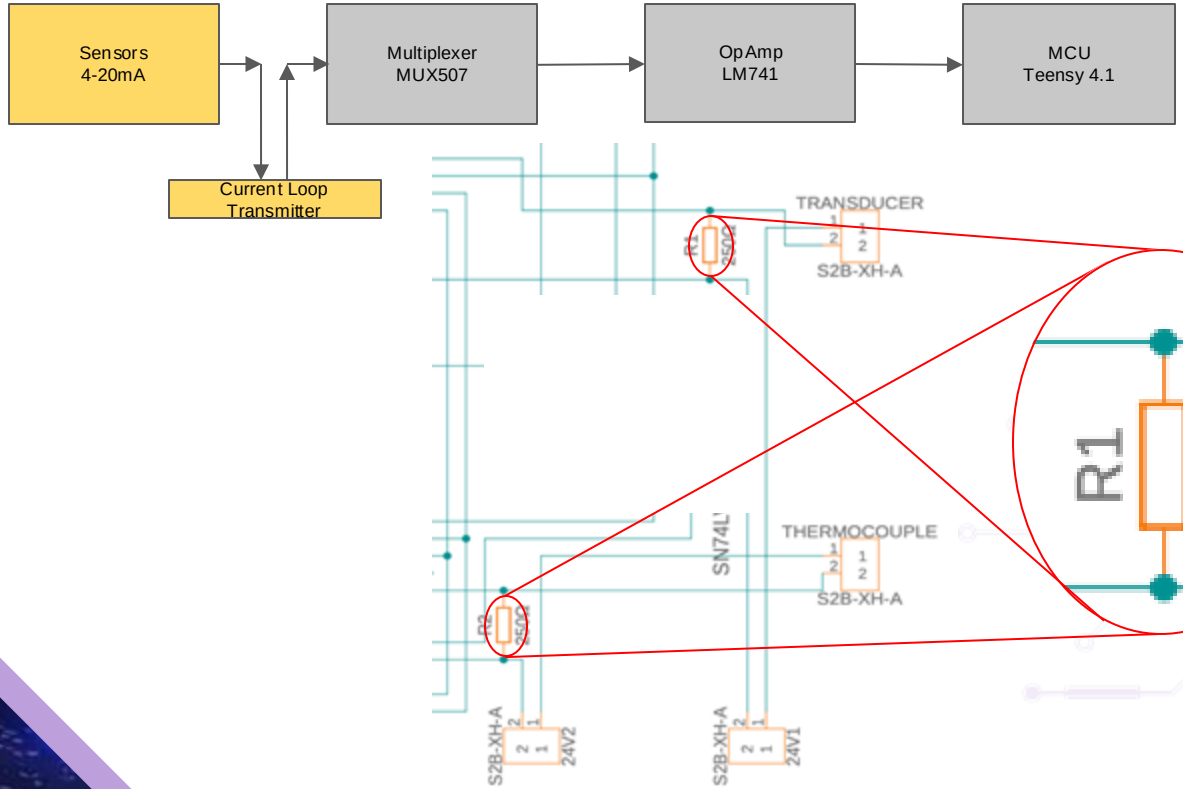
0-5V	4-20mA
Voltage drop as wires are longer	Current is the same along the length of the wire



*not our system, general function of a current loop transmitter

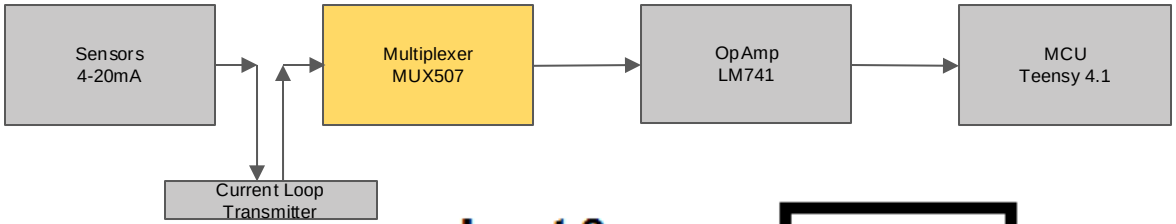
https://www.instrumentationtoolbox.com/2011/02/electronic-transmitters-wire.html

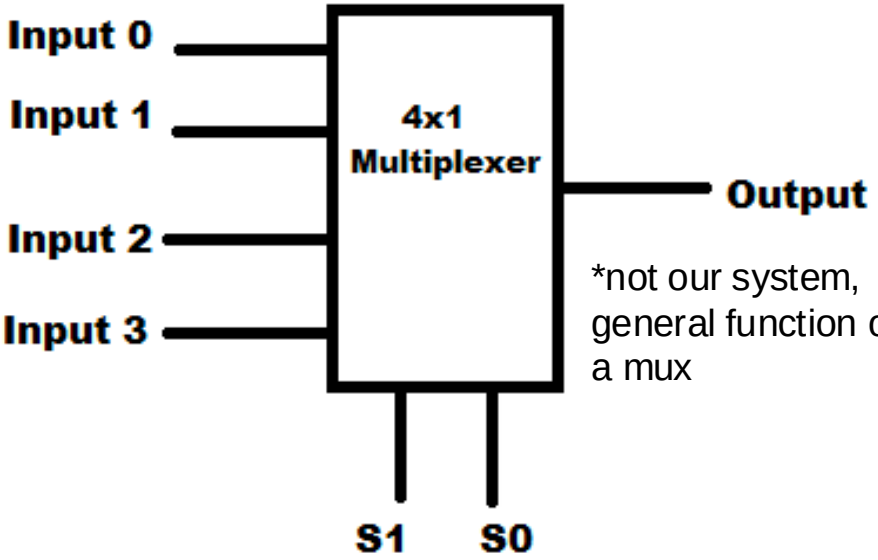
Current Loop Transmitter In Context



4-20mA → 250Ω → 0-5V

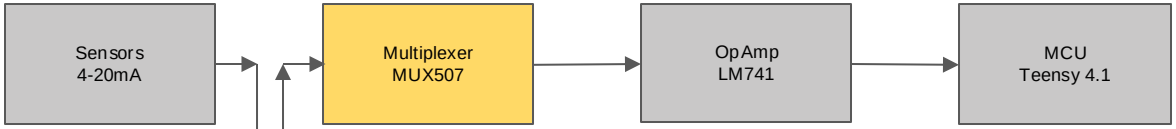
MUX

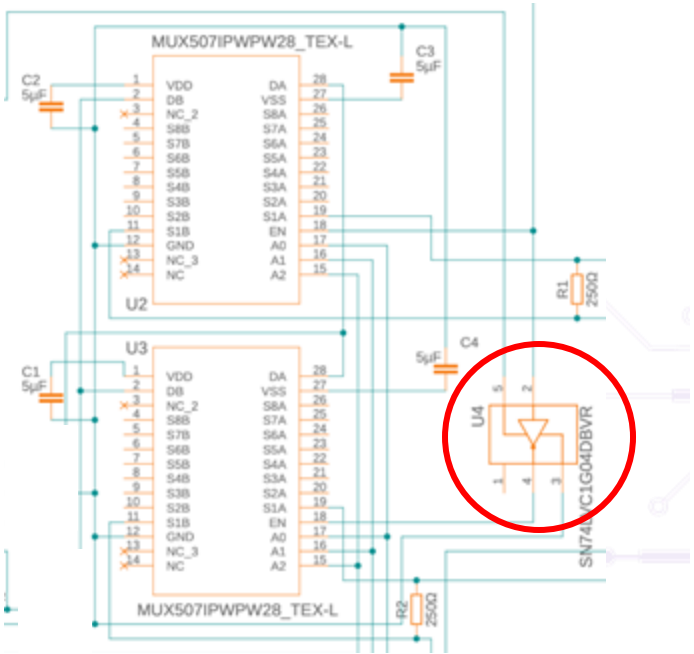


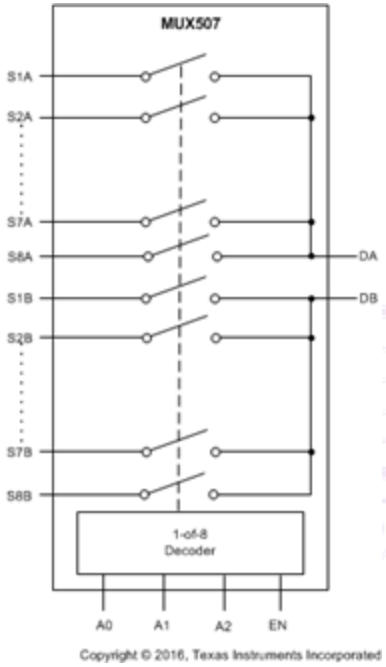


*not our system, general function of a mux

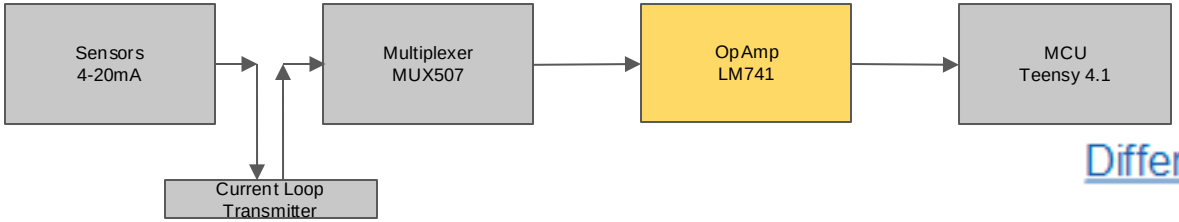
MUX

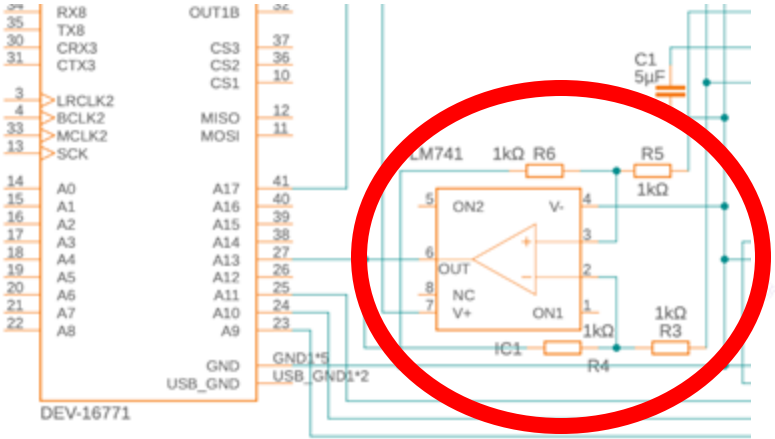


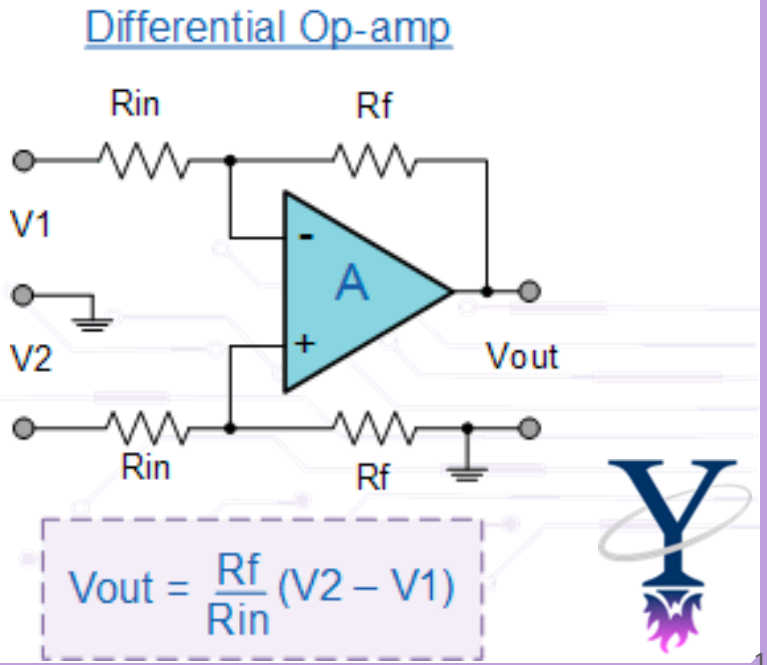




Operational Amplifier



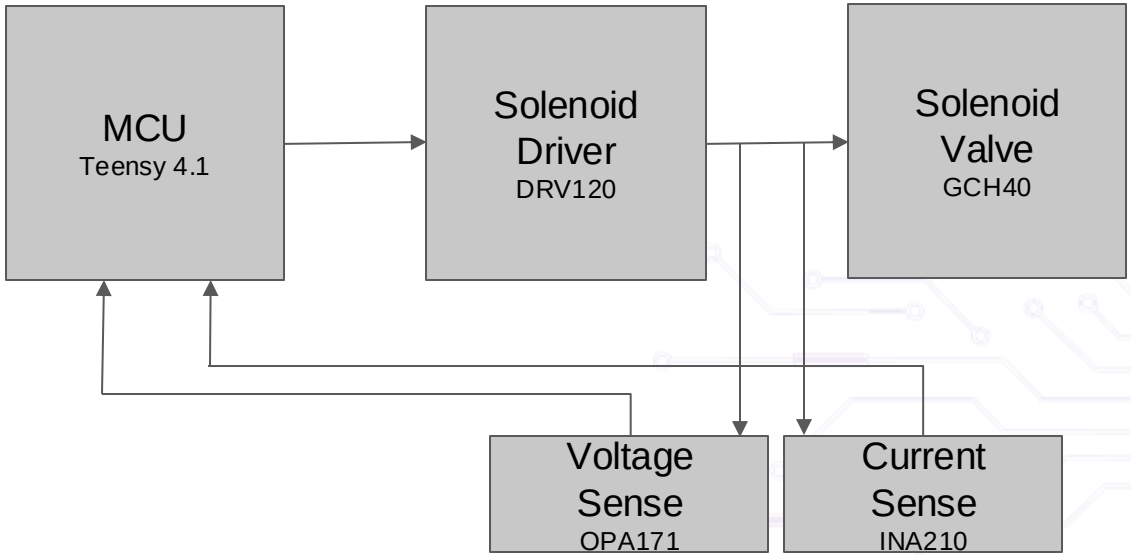




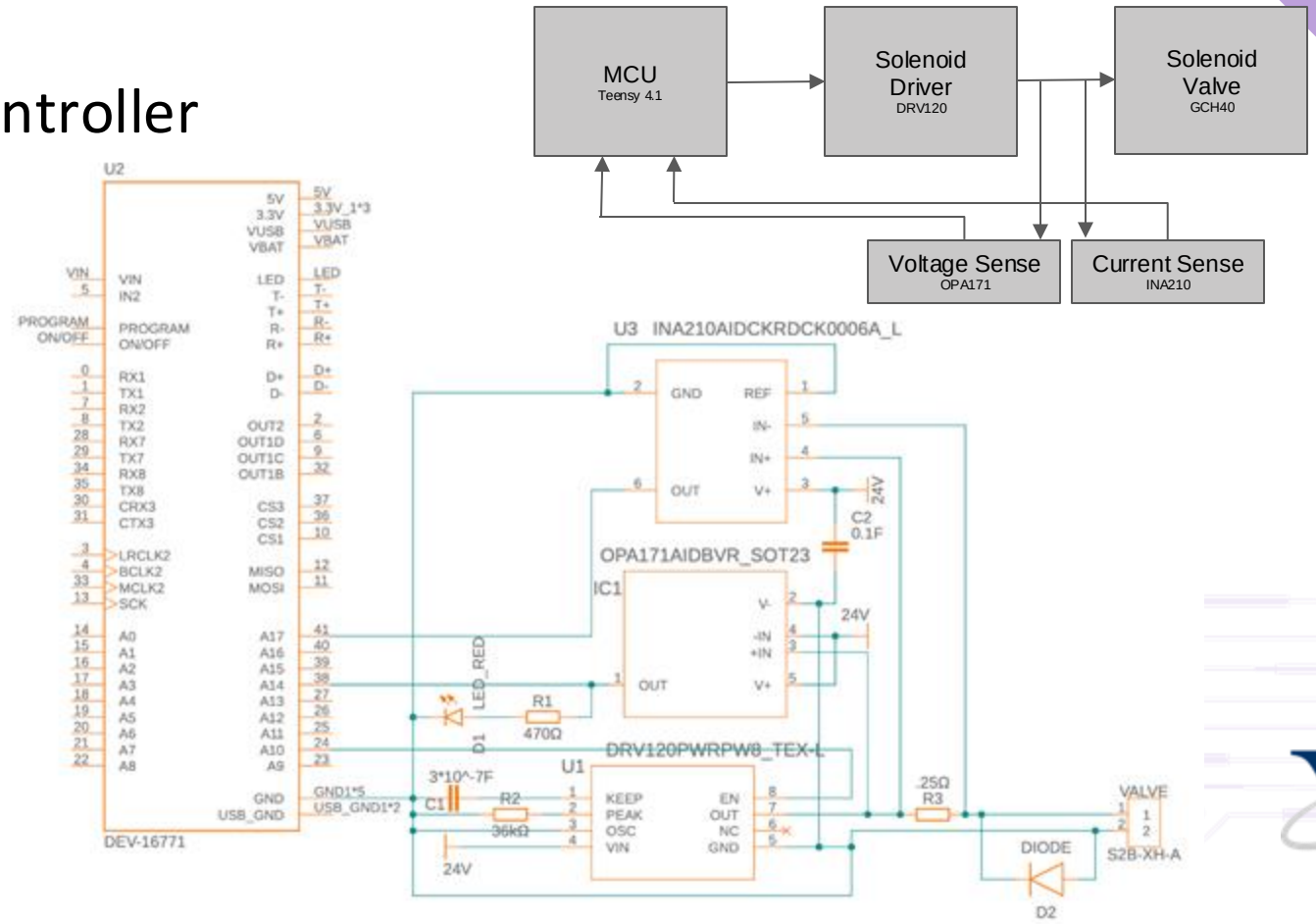
https://www.electronics-tutorials.ws/opamp/opamp_8.html

Engine Controller

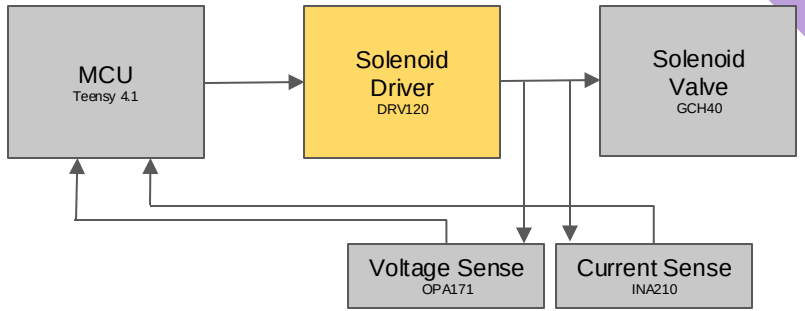
Engine Controller

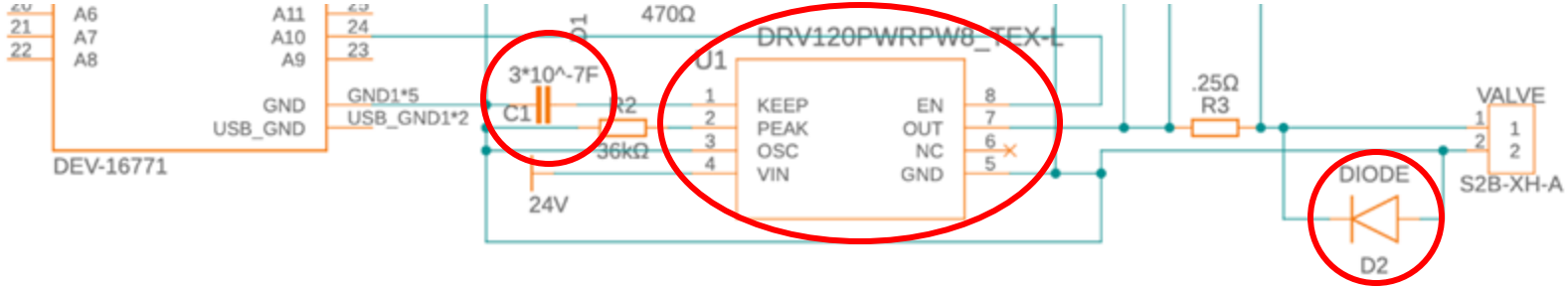


Engine Controller



DRV120





https://www.ti.com/lit/ds/symlink/drv120.pdf?ts=1695829263042

DRV120

I-Peak ~ 2A

I-Hold ~ .86A

t-keep ~ 20-50ms

$$t_{KEEP}\left[s\right] = C_{KEEP}\left[F\right] \cdot 75 \cdot 10^{3}\left[\frac{s}{F}\right]$$

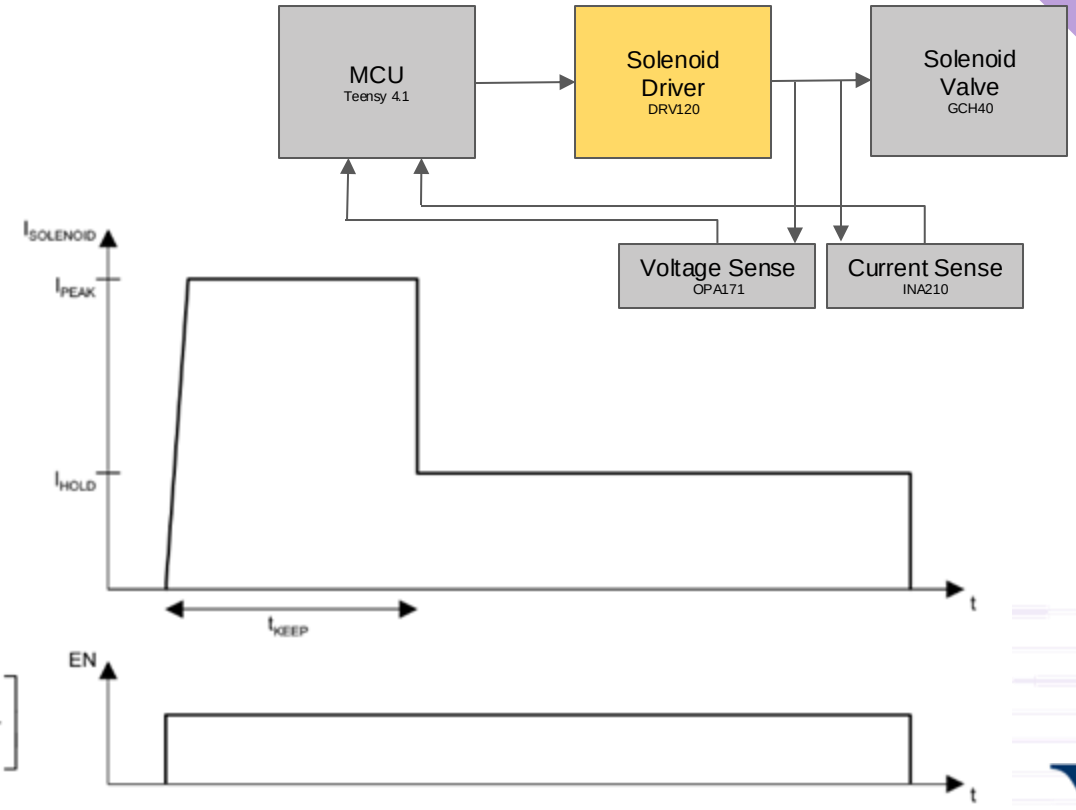
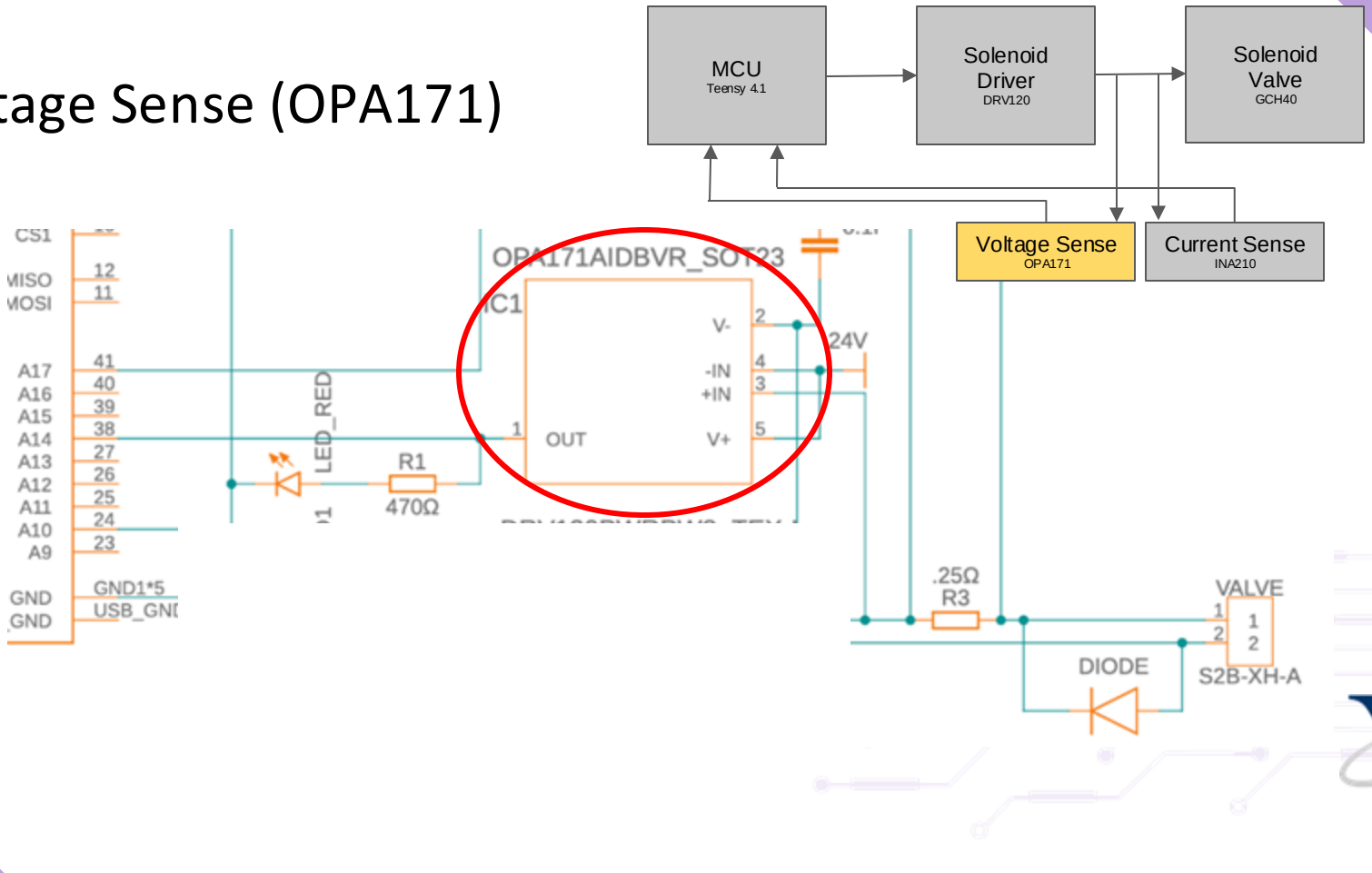


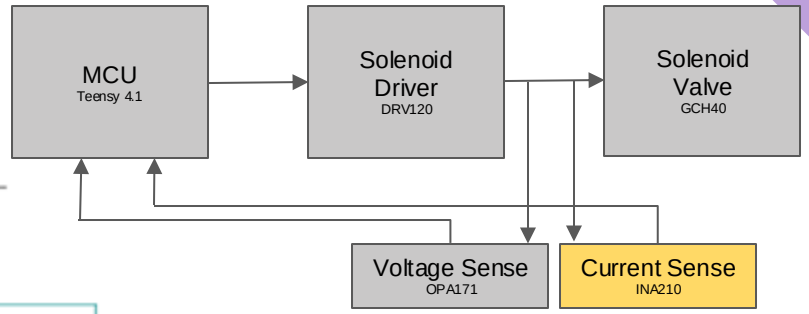
Figure 2. Typical Current Waveform Through the Solenoid

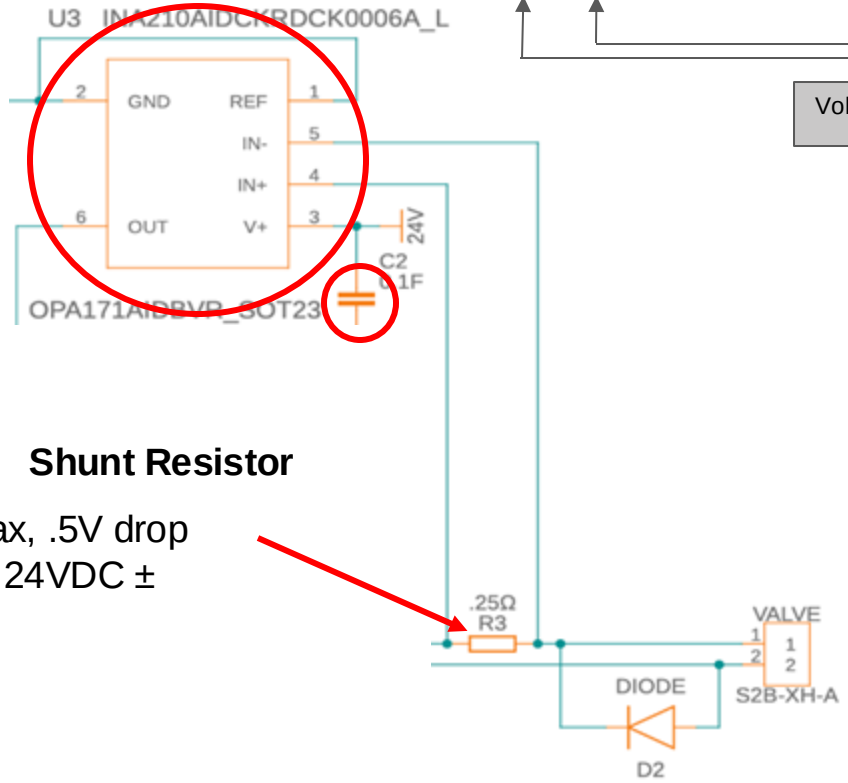
https://www.ti.com/lit/ds/symlink/drv120.pdf?ts=1695829263042

Voltage Sense (OPA171)



Current Sense (INA210)



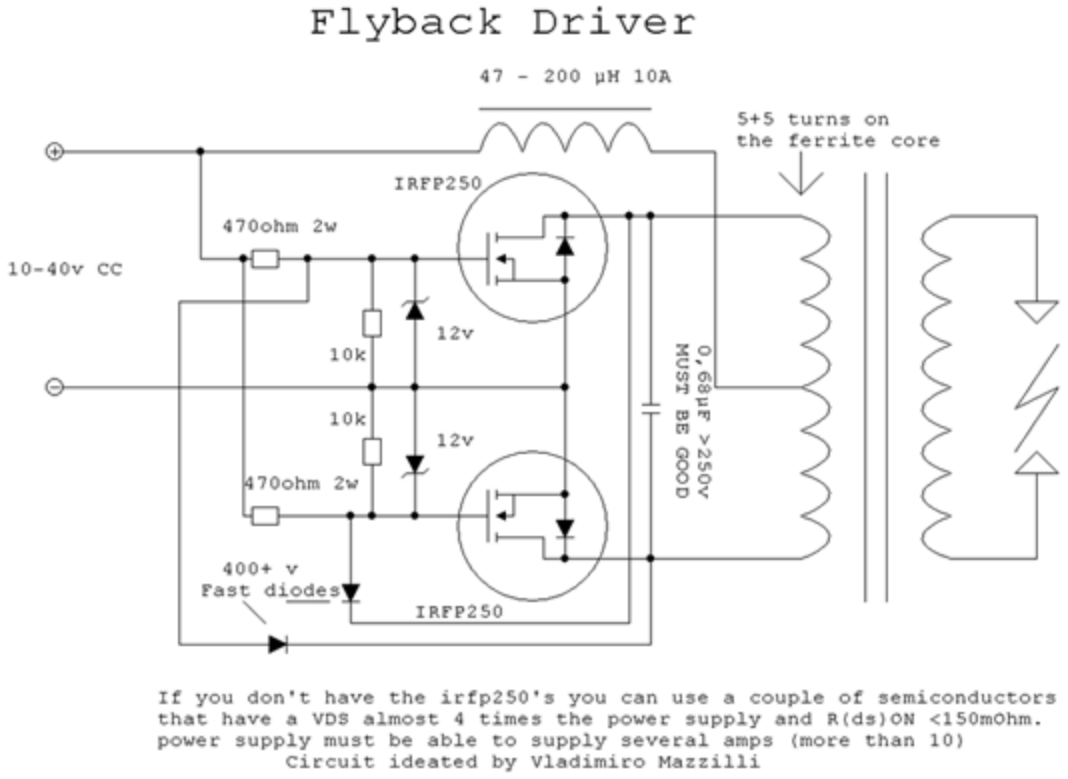


Shunt Resistor

2A max, .5V drop
Valve 24VDC ± 10%

Spark Plug Ignition System

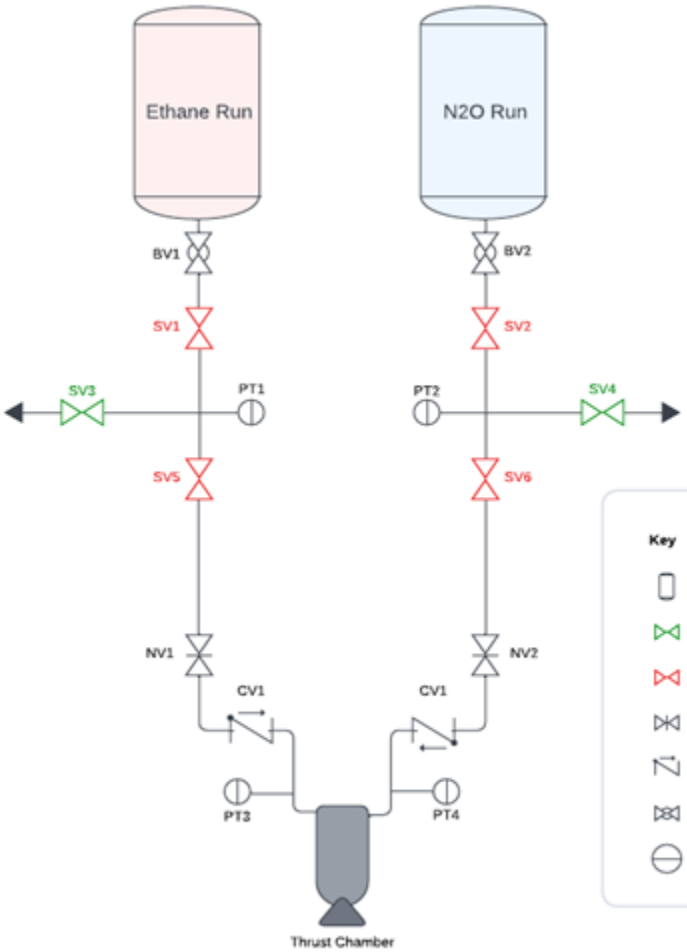
Zero Voltage Switching (ZVS) Driver

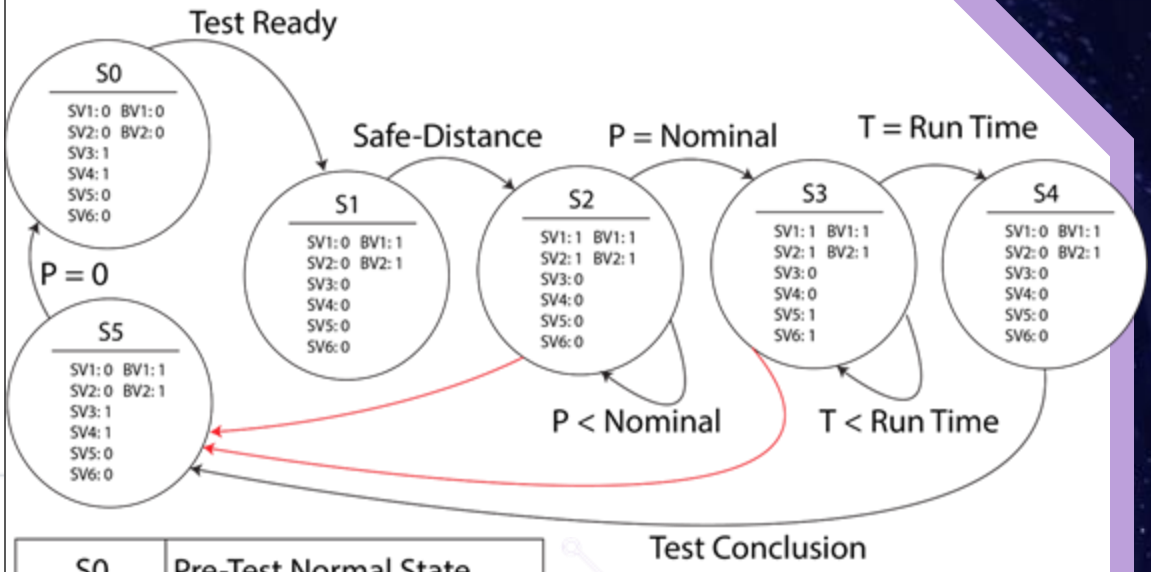


Characteristics:

- 47-200µH inductor can change based on desired output
- MOSFETs generate little heat
- Run the transformer for longer before MOSFETs overheat

Control





S0	Pre-Test Normal State
S1	Test-Ready
S2	Cross Pressurization
S3	Run State
S4	Close Valves
S5	Testing Normal State

Normal Operation

Kill Switch

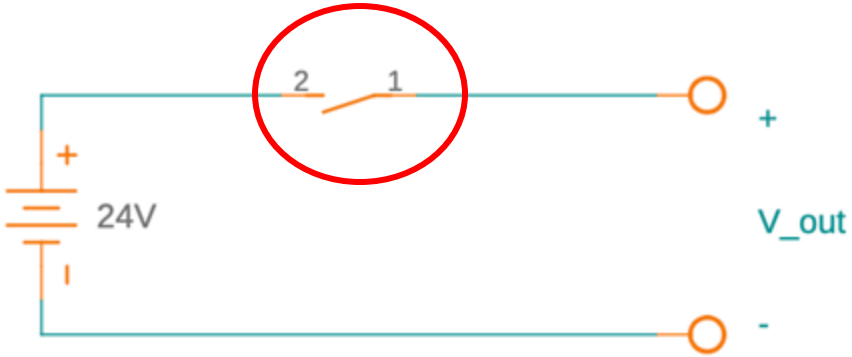
T (Elapsed Time)
P (Pressure)

Safety

Considerations

- ESD
  - PCBs to be made with ample distance between traces
  - Ground plane covering the entire PCB
  - Materials with low dielectric constants (FR-4)
  - In the workspace:
    - ESD Mats
    - Wrist Bands
- High Voltages
  - International Electrotechnical Commission definition: > 1500V
  - Safety goggles, insulated gloves
  - Epoxy any exposed circuitry w/ high voltages

Kill Switch



https://www.amazon.com/IndusTec-Position-Maintained-Latching-Automotive/dp/B0985FPDJC/ref=sr_1_26?crid=54UNZO7977T9&keywords=single+pole+toggle+switch&qid=1696402709&sprefix=single+poletoggle+switch%2Caps%2C71&sr=8-26

Logistics

BOM

Component	Price	Qty	Total Price
Teensy 4.1	$31.50	2	$63.00
24V Battery	$139.99	1	$139.99
MUX507	$2.85	2	$5.70
LM741	$0.224	1	$0.22
SN74LVC1G04	$0.025	1	$0.03
250Ω Resistor		7	$0.00
XT30 Connector	$11.90	2	$23.80
5microF Capacitor		4	$0.00
1kΩ Resistor		4	$0.00
3*10^-7 F Capacitor		6	$0.00
Diode		6	$0.00
OPA171	$0.662	6	$3.97
INA210	$0.25	6	$1.50
470Ω Resistor		6	$0.00
36kΩ Resistor		6	$0.00
Red LED		6	$0.00
.25Ω Resistor		6	$0.00

Testing Plan

Pre-PCB

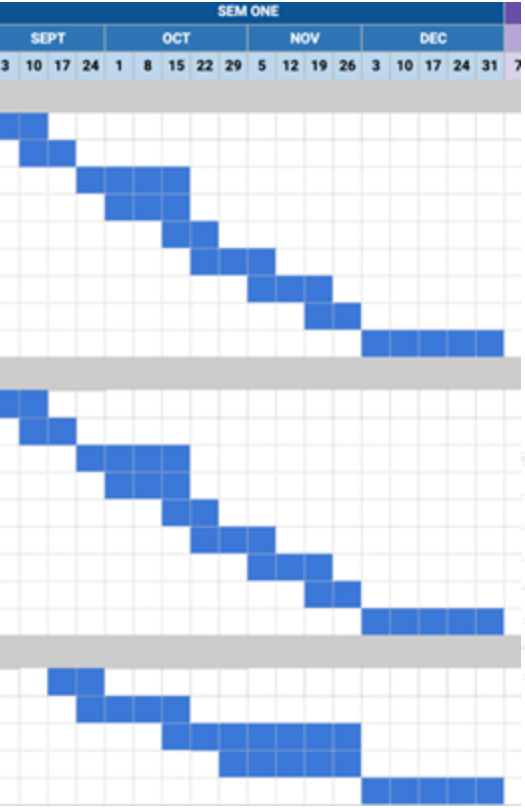
- Order samples parts
- Breadboard/Protoboard testing
- Test with in-house tech (i.e. valves here)
- Revise
- Repeat

Post-PCB

- Ensure valves work as expected using engine controller
- Ensure sensors are reading using DAQ and known pressure source

Timeline

WBS NUMBER	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION	PCT OF TASK COMPLETE
1	**Data Acquisition Board**	**Ollie + Adrian**				
1.1	Research					100%
1.2	Circuit Design					100%
1.3	Prototyping + Testing					10%
1.4	Revisions					0%
1.5	PCB Design					0%
1.6	Design Validation					0%
1.7	PCB Production					0%
1.8	Testing					0%
1.9	Integration					0%
2	**Engine Controller**	**Ollie + Adrian**				
2.1	Research					100%
2.2	Circuit Design					100%
2.3	Prototyping + Testing					10%
2.4	Revisions					0%
2.5	PCB Design					0%
2.6	Design Validation					0%
2.7	PCB Production					0%
2.8	Testing					0%
2.9	Integration					0%
3	**Spark Plug Ignition System**	**Mason**				
3.1	Resarch					100%
3.2	Design					50%
3.3	Prototyping + Testing					0%
3.4	Revisions					0%
3.5	Integration					0%



Challenges

- Ordering parts, waiting for parts
- Debugging (Hardware + Programming)

Wins

- Designed two full prototyped circuits
- Learned about flyback current, voltage/current sense, coupling/decoupling capacitors, power electronics

Questions

- How to change the frequency of the switching in the ZVS driver?
- Best practice for spark plug testing?
- Switching between MUXes and inputs the best way to collect data?

Questions? Comments? Concerns?