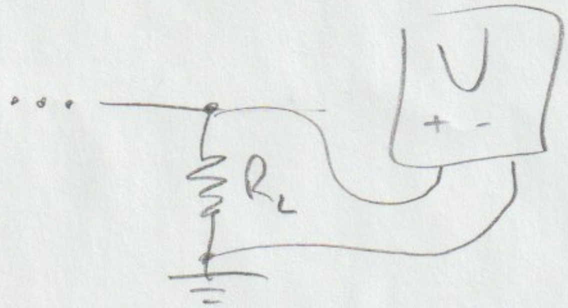
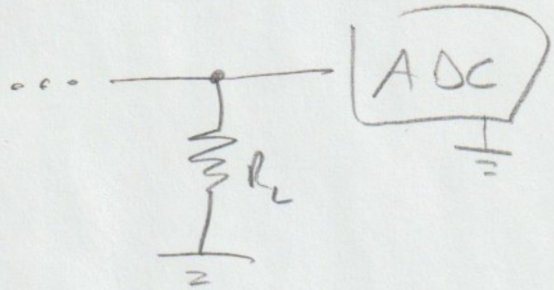
Measuring Voltage

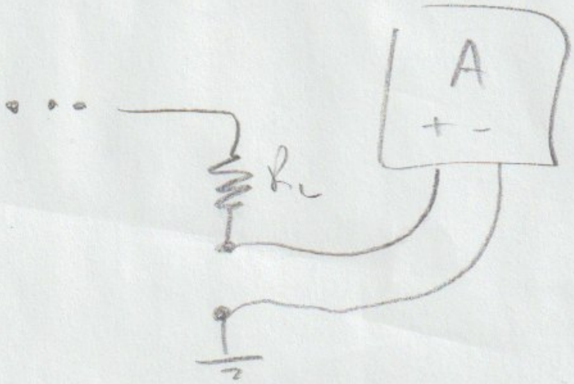


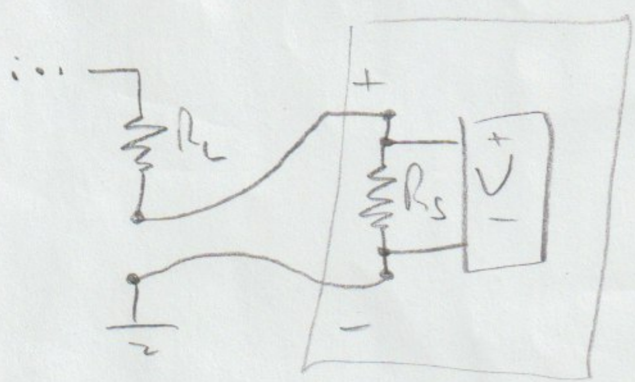


ADC Resolution

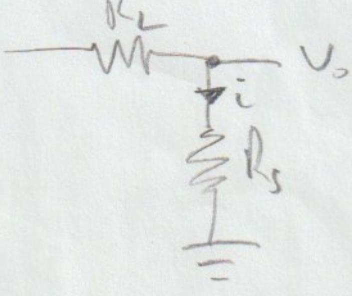
- 10-bit on the Arduino Mega $[0, 1023]$
- 5V Maximum
  - $\frac{5V}{1024} \approx 5mV$ increments

Measuring Current

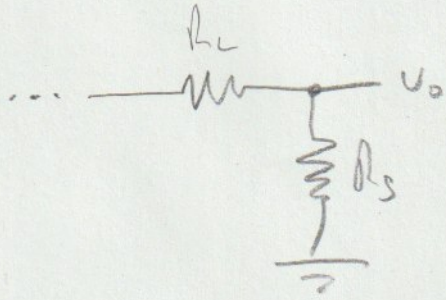




Effectively



$$i = \frac{V_o}{R_s}$$



For accurate current,

$R_S \ll R_L$

$R_S \approx 1 \times 10^{-3}\ \Omega$

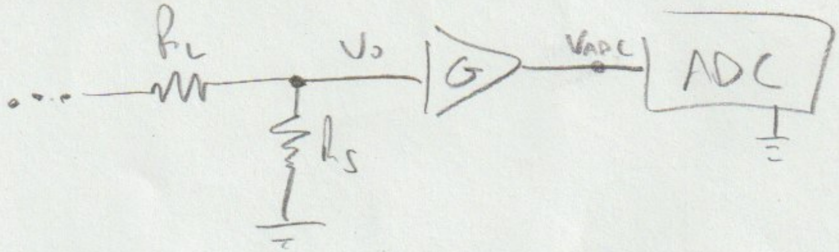
ADC Resolution

- Keep $0 \le V_0 \le 5V$
- What current corresponds to $5V$ for $R_S = 5m\Omega$?

$$I = \frac{5V}{0.005\Omega} = 1000\ A$$

$$P = IV = 1000A \cdot 5V = 5000\ W$$

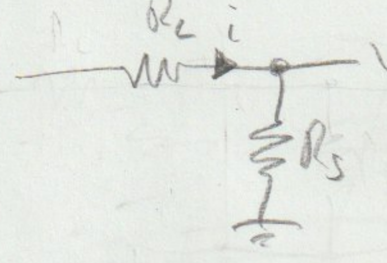
- Problem 1: 5000W shunt resistors
  - we don't actually need to measure 1000 A
- Problem 2: Poor current resolution at 5mV per step
  - $I = \dfrac{0.005\ V}{0.005\ \Omega} = 1\ A$
- Solution: Amplify the voltage V_0



- Using 1A max current, $V_0 = 1A \cdot 0.005\Omega = 0.005V$
- For $V_{ADC} = 5V$ @ 1A, $G = \dfrac{5V}{0.005V} = 1000$

Demo

Using $R_S = 0.1\,\Omega$, $I_{max} = 0.5A$

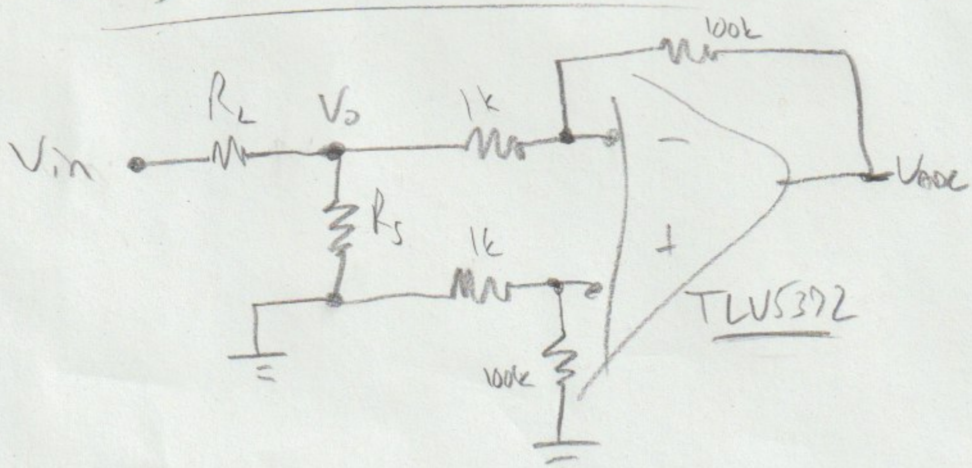


$V_o = 0.5A \cdot 0.1\Omega$
$= 0.05V$

- Need $V_{ADC} = 5V$ when $V_o = 50mV$

$$G = \frac{5}{0.05} = 100$$

Using Differential Amplifier



$$G = \frac{100k}{1k} = 100$$

Testing w/ $V_{in} = 5V$, $R_L \in \{10k, 1k, 100, 10\}$

Assuming $R_S \ll R_L$ $\therefore R_S \approx 0$ $\Rightarrow I = \frac{V_{in}}{R_L} \Rightarrow I \in \{0.5mA, 5mA, 50mA, 500mA\}$

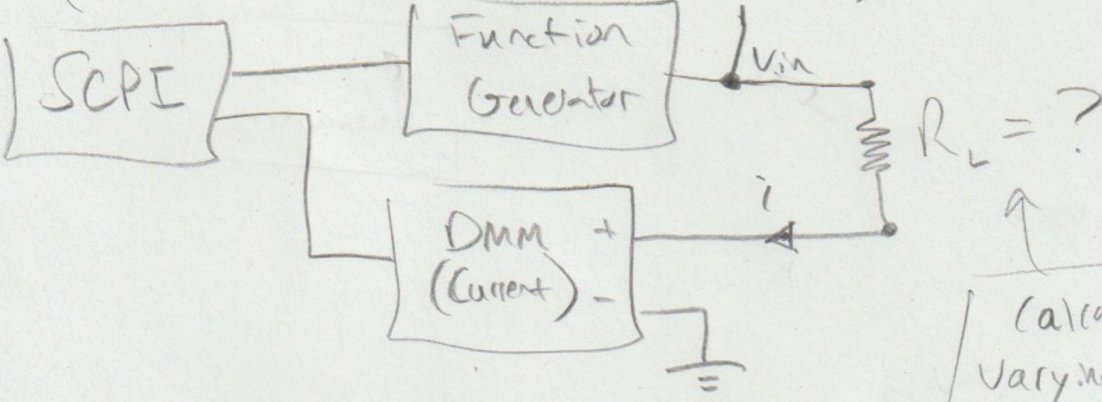
Expect $V_{ADC} = 100 \cdot I \cdot R_S$

$V_{ADC} \in \{5mV, 50mV, 500mV, 5V\}$

Week 1 Deliverable

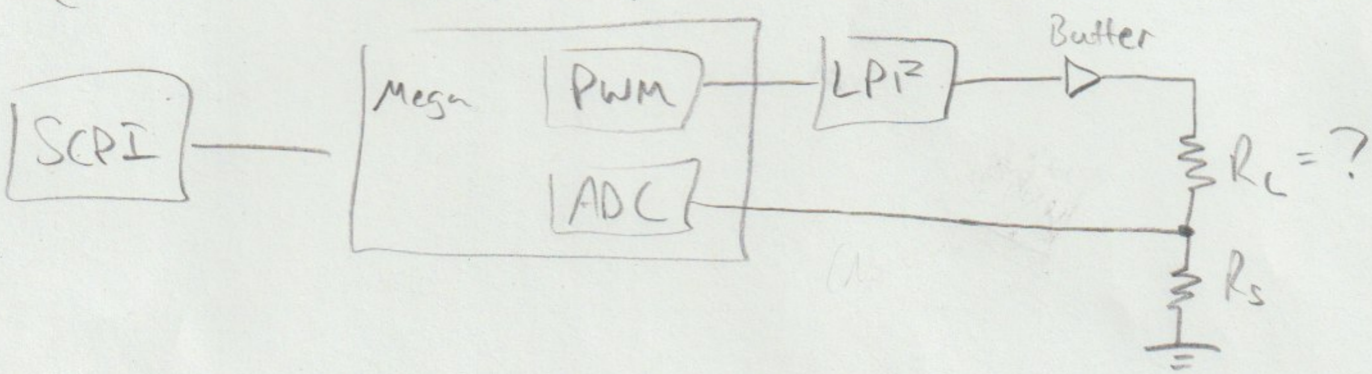
(With Lab equipment)

Vin is
DC offset
in (0, 5) V



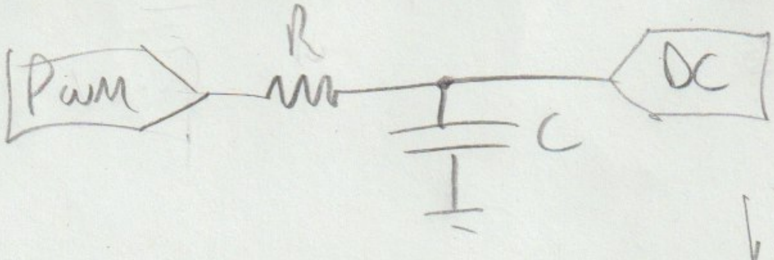
Calculate R_L by varying Vin and measuring i

(without Lab equipment)



Low Pass Filter

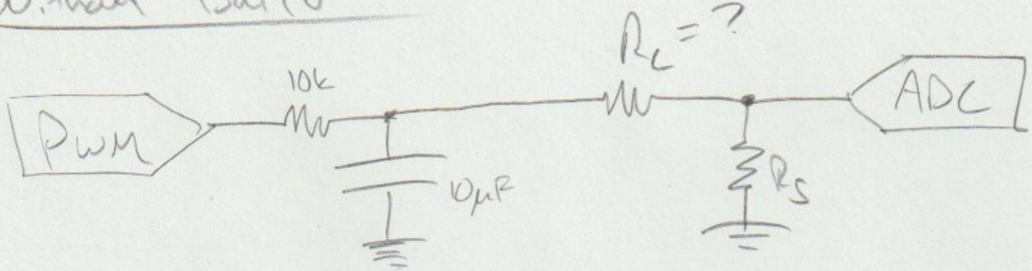
- Converts PWM to DC voltage
- First order LPF



$$f_c = \frac{1}{2\pi RC}$$

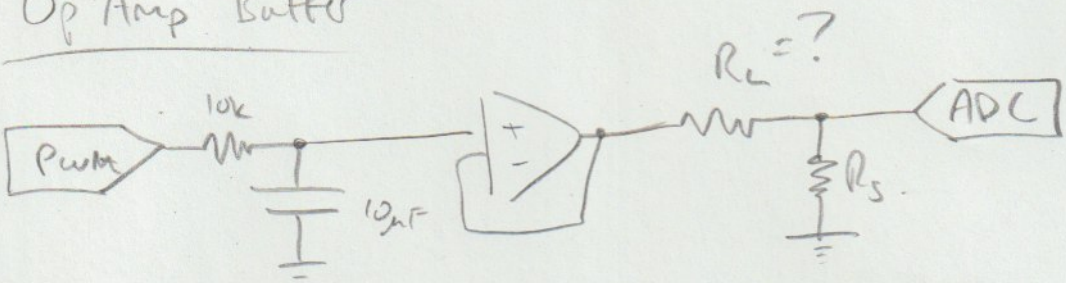
use $R = 10k$
$C = 10\mu F$
for $f_c = 1.6$ Hz

Without Buffer



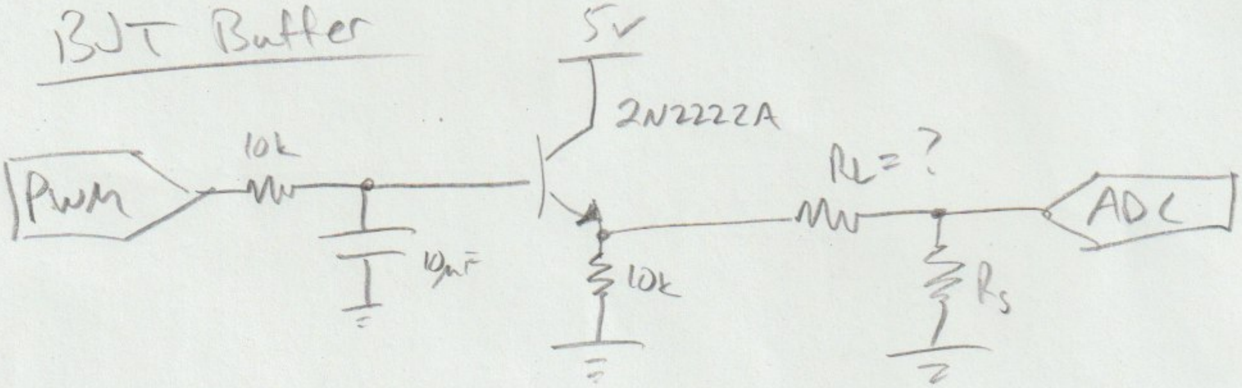
- Too many voltage dividers!
- R_L/R_S divider "loaded" by LPF's output resistance ≈ 10k

Op Amp Buffer



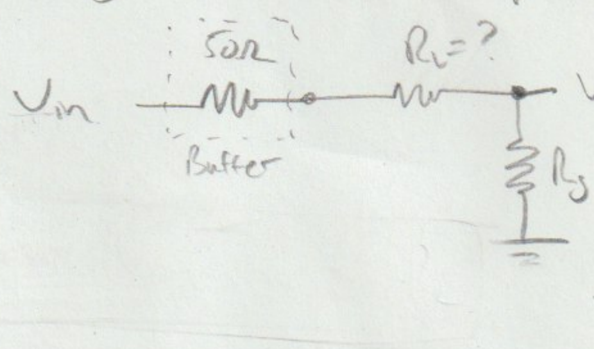
- Op Amp buffer has $G=1$ and output resistance ≈ 0 Ω

BJT Buffer



- BJT buffer has $G \approx 1$ and output resistance ≈ 50Ω

Effectively:



$$V_o = V_i \frac{R_S}{50 + R_L + R_S}$$

Week 1 Deliverable Summary

1. Build lowpass filter (LPF) to convert PWM into DC voltage **Vin**
   - More info: https://www.electronics-tutorials.ws/filter/filter_2.html
2. Build BJT Emitter Follower to buffer the LPF output voltage
   - More info: https://www.electronics-tutorials.ws/amplifier/common-collector-amplifier.html
3. Choose an appropriate shunt resistor **Rs** from your kit's resistors (**justify your decision**)
4. Comment on your resistance meter's expected accuracy for different values of **RL,** given your choice of **Rs**
5. Upload the provided SCPI Arduino code to your Arduino Mega. You should not need to modify this code. Use pin 3 for PWM and A0 for the ADC reading **Vadc**
6. Modify the provided MATLAB code to
   A. Use measured **Vadc** and **Rs** to compute the current through **Rs** (same as through **RL**)
   B. Use Vin and current through **RL** to compute **RL** via linear regression
   - More info: https://www.mathworks.com/help/matlab/data_analysis/linear-regression.html
7. Repeat part 6 for 10 test points and 100 test points. Discuss any differences between the two results.
8. Your report should include your two final plots (10 and 100 data points) exported from MATLAB, and a photo of your Arduino and breadboarded circuit.