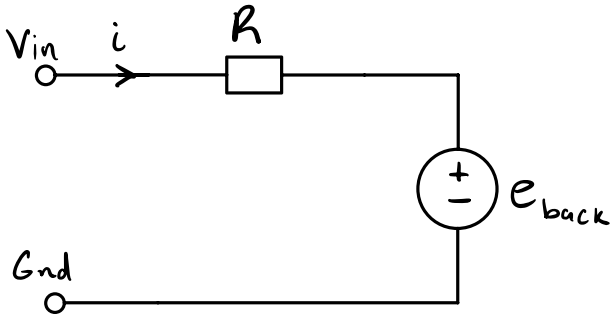
LTSPICE MODEL

3V DC motor

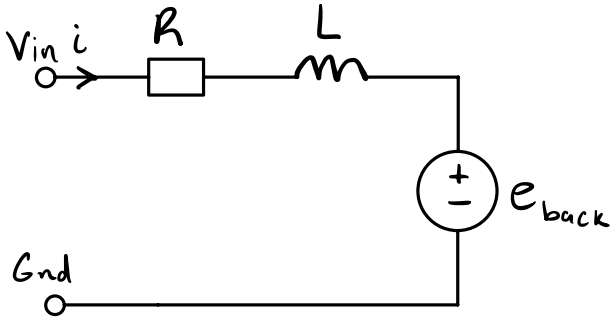
First, we define the voltage drop across a steady state DC motor as:

$$V = e_{back} + iR$$

where e_{back} is the opposing electromotive force and iR is the resistive voltage drop. This gives us a model 1:



But this model only works at steady state. We must also account for the inductence of the motor due to the loops within it:



where L is the inductance of the motor. This gives us a new equation:

$$V = e_{back} + iR + L \cdot \frac{di}{dt}$$

For the model, we need values. We can find R and L by measuring the current at $t>0$ for:

$$x(t) = 3u(t)$$

For e_{back}:

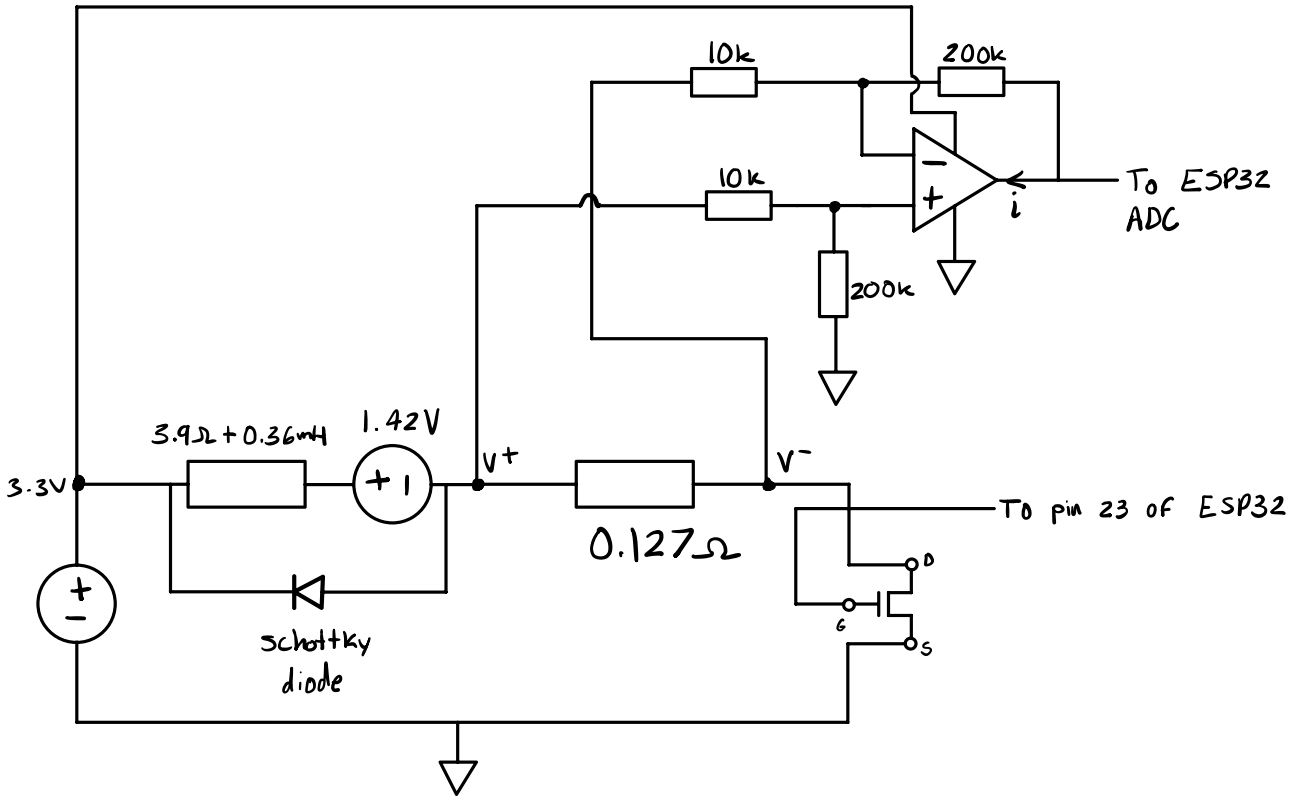
$$e_{back} = k_v \cdot w$$

Where k_v is a constant with units $\frac{V}{rad/s}$ and w is the angular speed in rad/s. Right now, we are only simulating for testing, so we can set e_{back} to a measured constant of 1.42V.

Current Sensor with Op-Amp

We will use an operational amplifier and the voltage across a shunt resistor (0.127Ω), in series with the DC motor, to find current $\left(\frac{V}{\Omega}\right)$. To model this, we will measure the load resistance value to find 3.9Ω and guess the inductance as 0.36mH. The full circuit with inductance protection becomes:

COMPLETE MODEL



RESULTS

The results matched the simulated graph perfectly in terms of shape. The time constant was found as $\tau = 20.3\mu s$. This makes the inductance of the motor

$R \cdot \tau = L \rightarrow 20.3\mu s \cdot 3.9\Omega = 79.17\mu H$.

CONCLUSION

Overall, results matched the simulation. This system can be used to find the inductance of any motor rated $\leq 12V$.

CHALLENGES & SOLUTIONS

1) ESP32 Sampling Rate

The sampling rate of the ESP32 is only about 100kSls. This means it can sample properly once every ten microseconds. The problem here is that the time constant for a motor can range from six microseconds to 100. Due to this, I decided to sample in discrete time intervals (0μs, 2μs, 4μs) per run. After 126 runs, I was able to get a matching graph.

2) Heating

The motor draws a lot of current, which heats up the wires and coils. To solve this, we wait two seconds before each new sample.