Energy Consumption Rate in a DC Motor

Teachers: Prasad Akavoor and Yancey Quiñones, Mentor: Dr. Joo Kim, Research Collaborator: Henry Clever and Dustyn Roberts

Research

Title: Energy Consumption Rate in a DC Motor

How mechanical work affects the performance of and energy consumption rate in a motor—attached to a robot for example—is an ongoing engineering question. It is well understood that negative mechanical work done on a motor would increase the current through the motor and decrease the voltage across it. As a result, the energy consumption in the motor would increase. To understand this phenomenon, consider a circuit where a motor is connected to a battery of voltage V and draws a certain current I. The power consumed would be the product $V \times I$. The motor draws less current when there is no mechanical load than when a negative mechanical work is done on the motor. This is because the motor runs faster without the load and therefore a significant amount of back electromotive force (EMF) builds up, and this back EMF sends a current opposing the current supplied by the battery, thus reducing the total current going through the motor. However, when a mechanical load is added to the motor or when the motor is forced to slow down by an external force, then the back EMF is smaller and therefore the circuit draws more current. Although the effect described above could easily be demonstrated with a DC motor, an ammeter, and a battery connected in series, a methodical, quantitative study of the power consumed by a motor as a function of time is in order. Our objective in the present work was to investigate in detail energy consumed by a DC motor. Using two different current sensors, Adafruit's INA219 and Sparkfun's ACS712, we have measured the current through and voltage across a DC motor, run without a mechanical load, with a load for a brief period of time, and completely stalled for a brief period of time. With both sensors, we have measured the load voltage using the Arduino Uno microcontroller. We have documented the relevant circuit diagrams, the Arduino code in its entirety, and the correct experimental procedures.

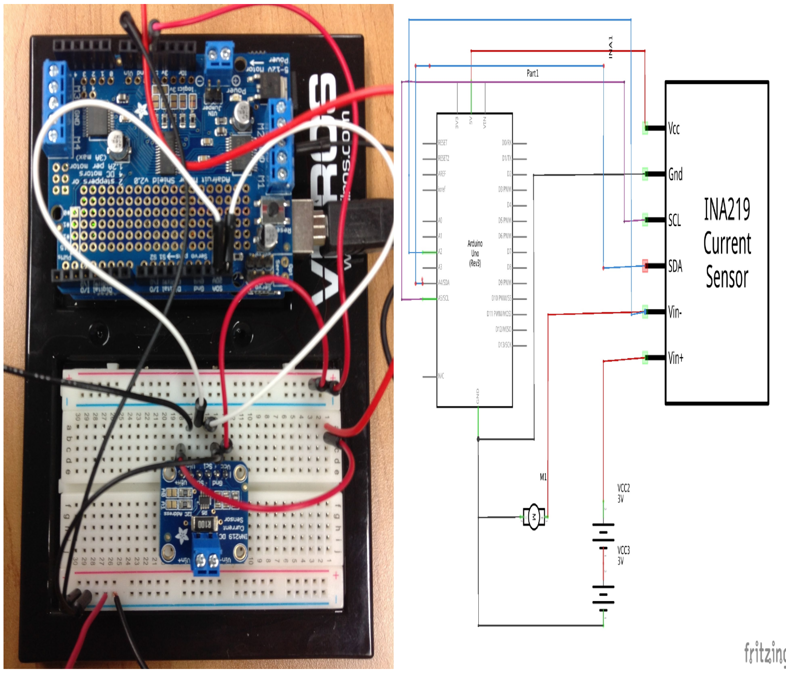

Figure: Experimental set up for current measurement

Lesson Plan

Title: Lenz’s Law and Back EMF in DC Motors

Students will set up a basic DC motor circuit with an ammeter and voltmeter to measure the current through and voltage across a DC motor as shown in Figure A. Students will take voltage and current data as the motor spins freely with no mechanical load on it and then they can apply a mechanical load either by placing an object like a propeller on the motor (Figure B) or by slowing it down with their finger (Figure C). What happens to the voltage and current in each mechanical load situation? These observations motivate a discussion of Lenz’s law and back EMF in DC motors.

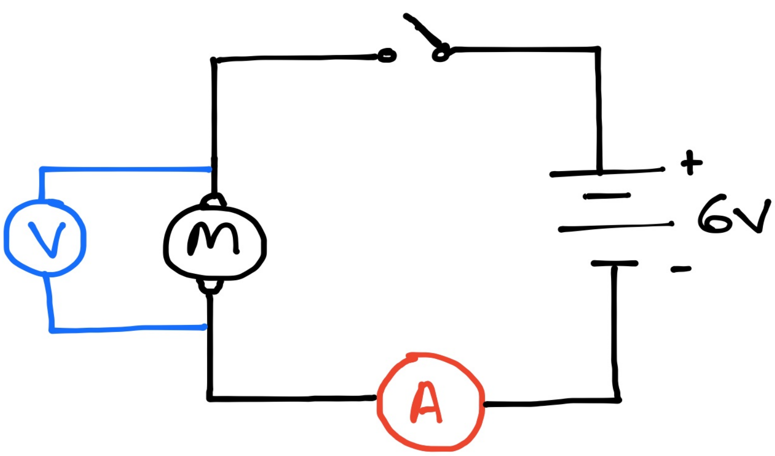

Figure A: Circuit diagram for measuring current through and voltage across a DC motor

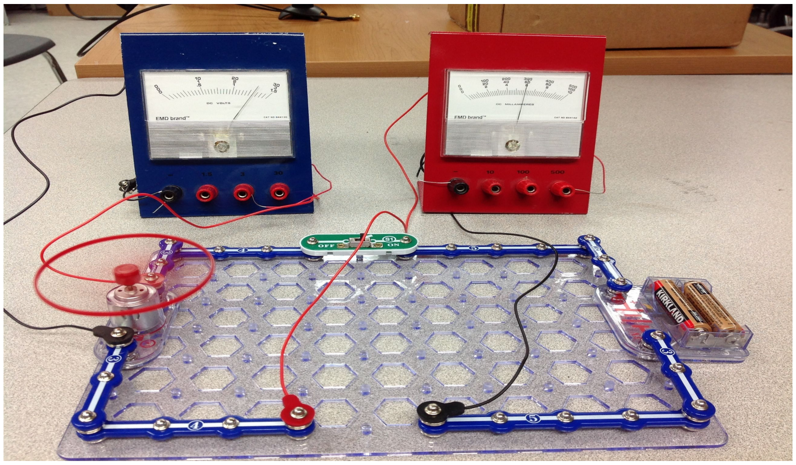

Figure B: DC motor with propeller as mechanical load

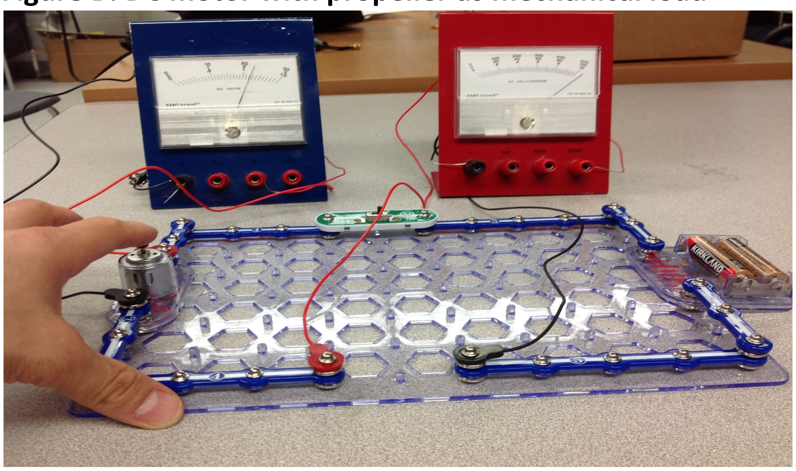

Figure C: DC motor with finger as mechanical load