University of Utah
Electrical & Computer Engineering Department
ECE 1250 Lab 2

Battery and Source Model

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Rev.

Objectives

1 Introduce the Remote-Control (R/C) car.
2 Make measurements of the battery.
3 Use Matlab plot the data and help create a battery model.
4 Use this model to make predictions and test.

Parts to be supplied by the student:

- Lab notebook for this and all future labs. (This will not be mentioned again.)

Check out from window:

- Remote-Control (R/C) car with the owner's manual
- Elenco Multimeter
- Two 1157 Light bulb with leads

Remote-Control (R/C) car

Two objectives of ECE 1250 are to introduce you to wide range of fields within Electrical and Computer Engineering (ECE) and to do so in an interesting, engaging and hands-on way. The R/C car has a number of systems which can illustrate different ECE fields:

- A battery for power, voltage and current.
- DC motors for drive and steering.
- Power electronics for pulse-width-modulation (PWM) control of the drive motor.
- A feedback control system in the steering servo.
- A radio-frequency (RF) transmitter and receiver pair.
- RF and intermediate-frequency (IF) signal processing and filtering in a superheterodyne receiver.
- Digital circuitry to encode and decode control data on the RF signal.

As for interesting and fun– welllll..., maybe we'll let you watch us drive it....

Operation

Find page 10 of the owner's manual and examine the picture of the transmitter so that you can identify the parts and controls. Pull out the antenna on the transmitter such that you have only one or two of the thickest segments visible. (This may require you to pull it out to full length and then carefully push the thinnest 4 or 5 segments back in.) This shortened antenna will give you plenty of range and doesn't bend, break, or poke someone so easily.

Find page 6 of the owner's manual and examine the picture of the car so that you can identify the motor, the battery connecter (not labeled), and, especially, the Electronic Speed Control (ESC). Keep in mind that the motor and ESC may become quite hot during operation. If the battery hasn't been installed or connected to the ESC, do that now.

Examine page 15 to see how the transmitter controls work. Turn on the transmitter **FIRST**.

Turn on the car by pushing the button on the ESC. The LED will blink green a few times and then change to solid red. Drive carefully and in control. Be especially gentle on the throttle and take some tome to learn the brake/reverse control. Learn control before attempting speed. Problems? See XL-5 Operation on page 17 and LED Codes and Protection Modes on page 19. Have some fun for a few minutes, but **STAY IN CONTROL**, especially don't drive the car where it could be stepped on and **DO NOT RACE**. Try some high-control tasks, like driving into and out of tight spots or parallel parking.

The Annoying Brake/Reverse
Pushing the transmitter trigger forward will cause a braking action if the car is in motion and reverse if the car isn't moving. It is easy to get frustrated by a reverse that doesn't work instantly and end up reversing too hard. Be patient with the reverse.

After some play, and being careful of the parts which could be hot, pick up the car and examine the steering mechanism while fiddling with the steering control. Try to find the source of the steering motion (the steering servo).

When finished running the car (or when asked), turn off the car **FIRST** by pushing the button on the ESC. Test the steering control on the transmitter to be sure the car is indeed off. Turn off the transmitter to conserve its batteries. Outline the on/off procedures in your lab notebook so that I don't have to repeat them later. Make some comments about driving. Could this car be used as a platform for mobile robotics?

Turn off the transmitter to conserve its batteries.

Identify systems
Examine pages 13 and 6 of the owner's manual so that you can identify the battery, the motor, the Electronic Speed Control (ESC), the receiver (probably absent the cover in your case), and the steering servo (you'll have to look in from the side). Make a sketch of the car in your notebook and leave enough room to describe what each of these items do.

The battery provides the power for all the electrical systems in the car. You will examine the battery more closely in this lab. In fact you'll take enough measurements to make a model of the battery and use that model to calculate a charging rate and see how accurate that is.

A powerful permanent-magnet DC motor is located at the rear of the car. This provides the mechanical forward and reverse drive power. It is hooked to the rear wheels through some gears and a differential. You can tell there is a differential because when you manually turn one rear wheel the other turns in the opposite direction. You can tell the motor has permanent magnets because when you turn both rear wheels together you can feel the poles of the motor's rotor pass from one permanent magnet pole to another. The motor current passes through brushes which make contact with the rotating commutator. You can actually see these parts if you look through the opening at the end of the motor. If you need more explanation of these terms and parts of the DC motor, check out these web sites: http://hyperphysics.phy-astr.gsu.edu/hbase/magnetic/motdc.html
http://en.wikipedia.org/wiki/Brushed_DC_electric_motor

When the red lead of the motor is positive with respect to the black lead, the motor turns in a forward direction (makes the car move forward). To go in reverse, the polarity of the leads is reversed. It is not a gear change in the transmission like it is in your automobile. Your automobile engine cannot change directions.

The motor currents are controlled by the Electronic Speed Control (ESC). It controls the direction by polarity and the speed by turning the current on and off in a series of pulses. The pulse rate is nearly 2000 times per second (2000Hz). You probably heard the motor reacting to these pulses as a squeaky sound when operating the car. The width, or duty cycle of the pulses control the speed. The ESC also contains protection circuitry and a power supply for the receiver (BEC). Its specs are pretty impressive and can be found as a sidebar on page 17 in the owner's manual. You will examine the ESC in more detail in a later lab.

The receiver receives the radio (RF) signal from the air, mixes it with a crystal-controlled local oscillator frequency to produce an intermediate frequency (IF) which is amplified and filtered to remove the interference from all other frequencies. It then detects the Amplitude Modulated (AM) signal and splits it up into the speed and steering signals for the ESC and steering servo. You will examine the encoding and decoding of this information in more detail in a later lab.

The steering servo decodes the steering information as an angular position for its output shaft, compares it to the actual shaft position and amplifies the difference (error signal) to control a small DC motor. The DC motor is turned in right direction to eliminate the error. This is a classic feedback loop control system. Yes, another lab.

As you work through these upcoming labs you will get a chance to see which of these subjects interest you. There are classes in the ECE department which continue on each of these subjects.

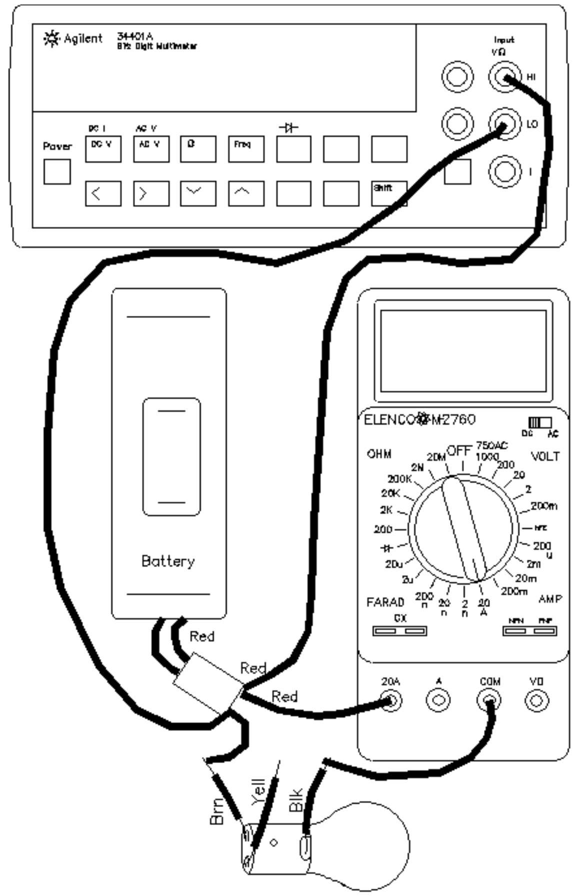
Experiment

WARNING: This section requires you to make connections to the battery and use an ammeter. If you do not make these connections correctly and short the battery in some way– **YOU WILL DO DAMAGE** to the battery and/or the meter and/or the wires and can weld wires together and even start a fire. This battery can supply enough current to **BURN THINGS UP!** Be Careful! Think about what you're doing! Keep track of your wires and don't let them accidentally touch in the wrong way. **DON'T DO ANYTHING DUMB!**

Disconnect the battery from the car. Set up the Agilent multimeter as a DC voltmeter, like you did in the last lab. Make sure the leads are not in the ammeter positions, Measure the battery voltage with no current. This will be the first entry in a table of voltage and current measurements.

Each of the bulbs has two filaments. The black lead is common and is usually grounded. The brown lead is a low-current filament and the yellow is a high-current. You will be hooking these bulb filaments up to the battery, first one and then another in parallel, etc.. If you have one bulb, how many possible different current measurements could you make, including the no-current case you've already done? What if you have two bulbs (consider only parallel connections)?

Connect the ammeter and one bulb as shown. Add these voltage and current measurements to your table. Using the bulb(s) as loads, make several more measurements over as large a range of current as you can (excluding a dead short, of course). Some of the higher current measurements may require you and your lab partner to act quickly and take both readings at the same time. They can change as the battery warms up and discharges. Our model does not account for these time-changes, a more accurate model would.



Matlab

You may wish to refer to the pages attached to lab 1 in order to use Matlab to make a current v.s. voltage plot for the battery and to help you find V_S and R_S of a source model. When you've printed your plot, trim it and tape or glue it in your notebook. Make notes in your notebook. Leave the computer on so you can look something up on the internet later.

Draw model, Predict charge behavior and Test

Draw a source model for the battery and include the values of V_S and R_S. Show how you calculated these by hand or from the "polyfit" results in Matlab. Mark the V_S point on the Matlab plot and indicate the R_S slope.

Use your model to determine what voltage would be necessary to charge the battery with 0.5A of current. Show your calculations. Turn on the Agilent power supply like you did in lab 1 and use the same output connections. Adjust it to supply this voltage using the knob and the "<" and ">" buttons. (Try it, you'll figure it out.) Connect the power supply to the battery, + to red and - to black. Compare the battery charging rate to 0.5A.Carefully, starting with the least significant digit first, adjust the power supply voltage until the charge rate is as close to 0.5A as you can get. Compare the voltage to your calculate voltage.

Google "Charge NMHI" or "NMHI charge", Find technical information about the charging of Nickle-Metal-Hydride batteries. Find some information and facts which could help you design a better, faster, and/or safer charger and include several in your notebook (at least 2 or 3).

Conclude

Call your lab instructor over to check you off. Be prepared to discuss your measurements, calculations, and conclusions and to show off your notebook.

Write a conclusion in your notebook like you did in lab 1. If you have any time left over, you may want to play with the car some more. Before leaving, make sure everything is turned off and return the stuff you checked out.