To-Be-Named Capacitor Kart Project

Design Meeting #1 Notes – 6/21/2008
Recorded By: S.C.

"I'm outta here; you guys are crazy." –Max

Design Objectives

- Convert gas go-kart to fully electric.
- Utilize ultracapacitor for boost/brake modes (regenerative).
- Implement "electronic" transmission (CVT and/or paddle shifter) using a separately excited DC motor.
- Implement full telemetry to collect useful data wirelessly while testing.
- Beat TLB's electric go-kart in Google hits?
- Exhibit at AltWheels (Sept 26/27) in Boston: www.altwheels.org.

Ultracapacitor

- Stores energy as electric field vs. chemical reaction in batteries. See: http://electronics.howstuffworks.com/capacitor.htm.
- "110 Farads?!" –Ed

$$E_{capacitor} = \tfrac{1}{2}CV^2 = \tfrac{1}{2}(110F)(16V)^2 = 14{,}080J$$

- Looks like kinetic energy? Blame calculus. How it compares to the kart moving at about 30mph:

$$E_{kinetic} = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(200kg)(13\,{}^{m}\!/\!{}_{s})^2 = 16{,}900J$$

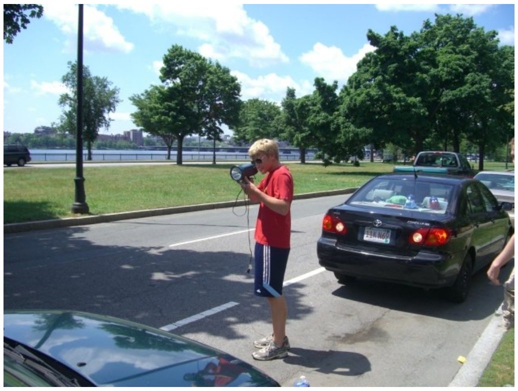
- For comparison/perspective:

AA Battery:	9,000J
FIRST Battery:	780,000J
Tank of Gas:	2×10^9J!

- Clearly a long way to go to replace gas or batteries entirely. Our use: supplemental power and a place to put regenerative braking energy.

Brief DC Motor Theory

- Uses of the strobe gun:

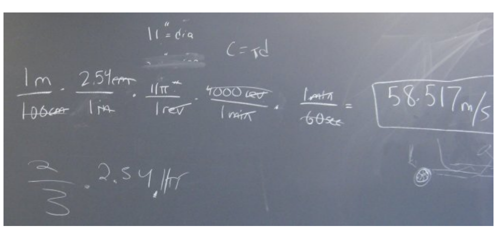

Bad Idea

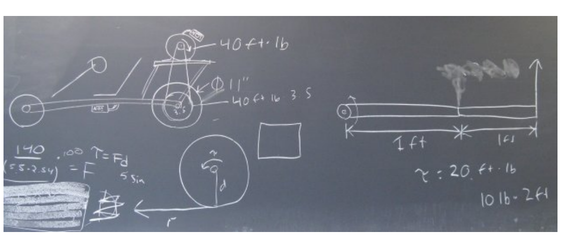

Good Idea

- Strobe experiment to show that in general for a brushed DC motor: *voltage corresponds to speed, current corresponds to torque*.
- Both relationships are *linear*, which gives a linear torque curve. Slope determined by magnetic field strength, which we can vary with our motor.
- Our max voltage: 36V (batteries only), 48V (batteries + capacitor).
- Our max current: 300A?
- Wikipedia article is actually fairly good, but ignore sections 2 and 5: http://en.wikipedia.org/wiki/Brushed_DC_Electric_Motor
  Explanation of back-EMF (important for braking and gearing) and section on speed control (PWM, flywheel diode, and field weakening) all apply.

Gear Ratio Calculation

- Start with nearly illegible fax from motor manufacturer, confirmed with strobe testing:
- About the fastest the motor will ever spin, given 48V, the "highest gear" (weak magnetic field) and a reasonable drag load: **4,000 RPM**.
- About the most torque the motor will ever put out from a dead stop, given 300A and the "lowest gear" (strong magnetic field): **40 lb-ft**.
- I'm sure there was a method to this madness…I will try to decipher what you did:





$$\frac{1}{100}\cdot 2.54\cdot 11\pi\cdot\frac{4000}{60} = 58.517$$

$$58.517\cdot\frac{3600}{1}\cdot\frac{1}{1610} = 130.845$$

$$130.845\cdot\frac{1}{3.5} = 37.384$$

$$40\cdot 3.5\cdot\frac{12}{5.5} = 305.455$$

$$\frac{305.455}{440} = 0.694$$

$$\frac{37.384}{4}\cdot 3 = 28.038$$

1. To calculate ground speed given 4,000 RPM, 11" tire, and a 1:1 gear ratio?

$$\frac{4000\text{rev}}{1\text{min}} \cdot \frac{1\text{min}}{60\text{s}} \cdot \frac{11 \cdot \pi \text{in}}{\text{rev}} \cdot \frac{2.54\text{cm}}{1\text{in}} \cdot \frac{1\text{m}}{100\text{cm}} = 58.517 \frac{\text{m}}{\text{s}} \quad \text{or} \quad \frac{58.517\text{m}}{1\text{s}} \cdot \frac{3600\text{s}}{1\text{hr}} \cdot \frac{1\text{mi}}{1610\text{m}} = 130.845 \frac{\text{mi}}{\text{hr}}$$

2. This is ridiculously fast, so choose a ratio to scale it to something reasonable:

$$130.845\text{mph} \cdot \frac{1}{3.5} = 37.384\,\text{mph}$$

(give or take a few thousandths of a mph…)

3. Gear ratio divides RPM and multiplies torque, so given 40 lb-ft → 140 lb-ft. Torque is just force times distance, so divide by tire radius to get ground force:

$$40\text{lbf} \cdot \text{ft} \cdot 3.5 \cdot \frac{12\text{in}}{1\text{ft}} \cdot \frac{1}{5.5\text{in}} = 305.455\,\text{lbf}$$

4. Get fraction of a 200kg (440lb) kart. This is the same as dividing by mass (F/m = a) and then dividing by g. So this is the "g-force" of max acceleration.

$$\frac{305.455\text{lbf}}{440\text{lbf}} = 0.694$$

5. Sounds like a lot? Will there even be 70% of weight on the rear tires? If not, what happens? Another good analogy: like starting on a 45º hill: sin(45º) = 0.707.
6. Lastly, the speed calc was for 48V (boost mode). At 36V, it scales proportionally:

$$37.384\text{mph} \cdot \frac{3}{4} = 28.038\,\text{mph}$$

Other Thoughts

- Batteries: Deep-cycle or dual-purpose marine/RV batteries (*not* car starting batteries). Too expensive to ship – I will look locally (West Marine?). General consensus seems to be heavier but more range preferable to lighter/less range. Must be sealed. Will try to get before next meeting.
- Shifting: Most like paddle-shifter idea. Limited range for field-weakening, so realistically only two gears. Keep CVT option (very little extra work).
- Instrumentation: paddle shifters fixed (not rotating with wheel), button for cap on wheel, cap voltage + speed + shift light on front panel, start button + mode selections + anything else on side panel.
- Testing: Adequate experimental verification that it is not street legal. Test on private property only. (At MIT? F1 track? Professor Hunter's secret location? Pursue any leads.)

Stuff for Next Meeting

- Anything to be cut on waterjet should be done in CAD. (Motor shelf, paddle shifters, heat sinks for controller, etc.)
- Design battery mounts (if we have batteries).
- Full list of parts to order.
- Talk about how to wire it up / electronic system in general.