ECG R 4161

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Lectures

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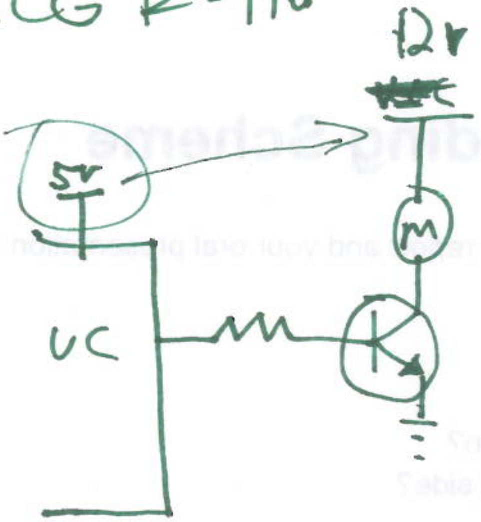

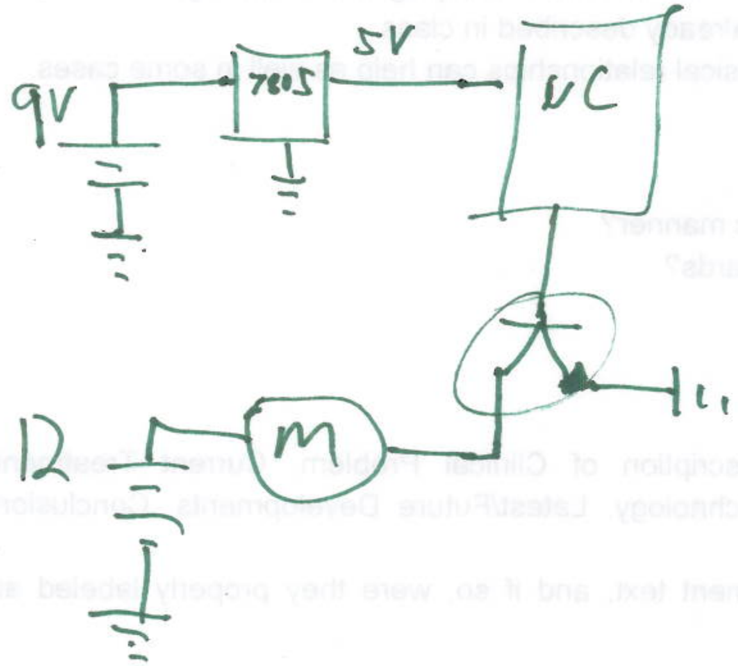

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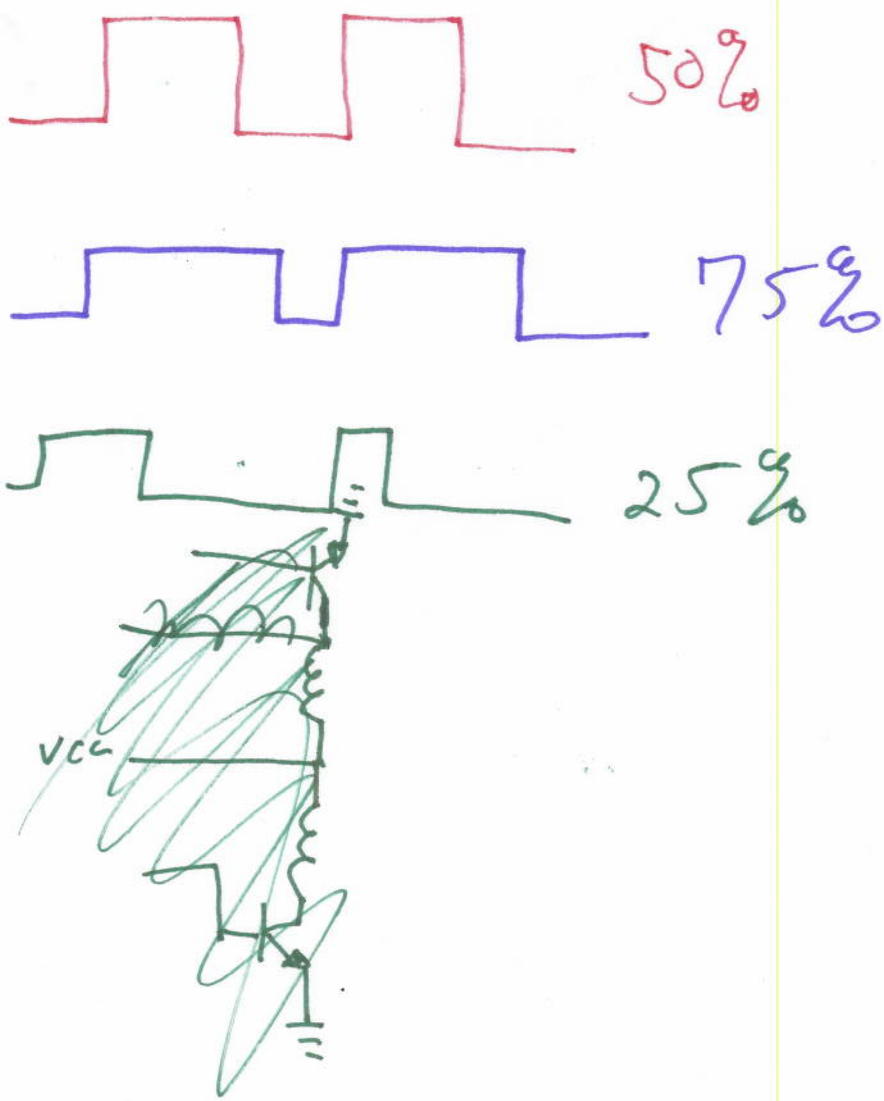

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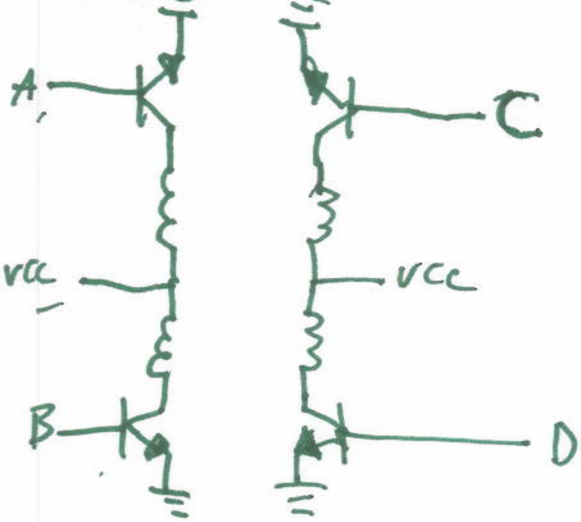

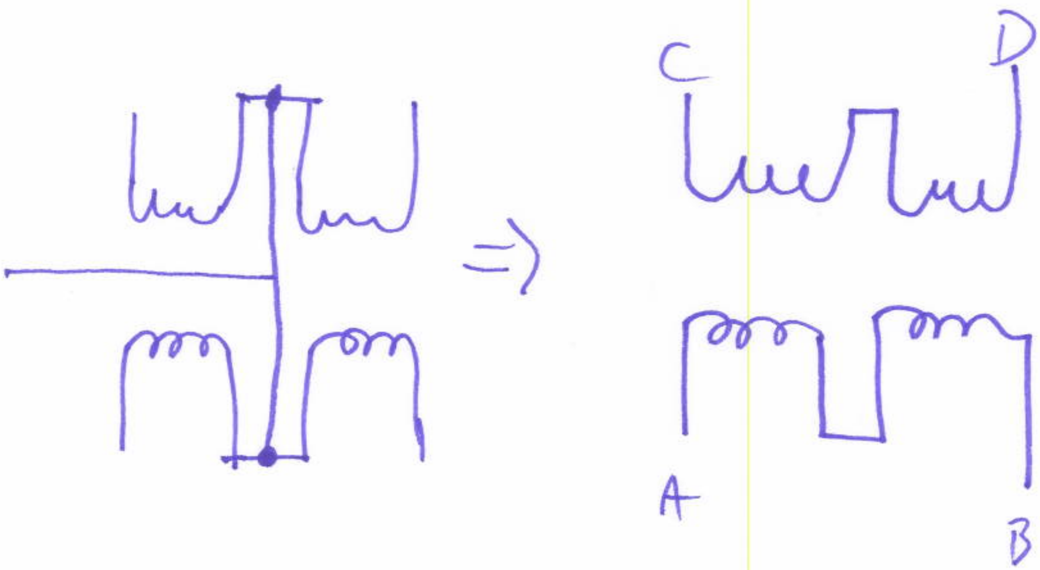

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Wheeled Locomotion:
Half of chapter 2 and chapter 3 in the text.
Take a look at what is involved in wheeled locomotion. Motor (of some kind) usually gears, some method of tracking rotations (Encoder) called feedback.

Different kinds of drive systems: Direct Drive vs. Geared. EXAMPLE
Gearing:
Motor spins at high rate of speed, but very little torque (torque is the measure of turning force). This isn't useful for most robots. You can't simply attach a motor to a wheel and expect it to work. The motor will either spin too fast to be useful, or it won't have the power to move the robot at all.

We use gears to convert Speed to Torque in this case. Speed and Torque are inversely proportional: ie. an increase in speed results in a decrease of torque and vice versa. You can find the gear ratio by simply counting the teeth on each gear: EXAMPLE

Gears that touch one another spin opposite directions: EXAMPLE

How to drive motors: The circuits used to drive motors depends on the type of motor you are using. Why do we need motor driver circuits?

Use a transistor as a switch (or a relay) to turn on and off a motor. Add a flyback diode to eliminate voltage spikes across an inductor. This is because if you use a relay, you have the inductor coil, and in a DC motor, the motor coil. Source: http://en.wikipedia.org/wiki/Flyback_diode

H-briidge allows bi-directional control of a DC motor. It acts as 4 switches:
Use images from here: http://en.wikipedia.org/wiki/H_bridge or draw them by hand.

Of course, again, be sure to use a flyback resistor. TIP: MOSFETS can drive motors more efficiently than BJTs, so use those when possible.
Extra information: (Good tutorial) http://roko.ca/robotics/h-bridge-fundamentals

There are integrated H-bridge chips available. Two of the mots common are the L298 and the 754410 chips for small motors. These both work the same way. (Look up datasheets)

You can control speed of a DC motor using Pule-Width modulation or (PWM). Be aware that PWM is used in different ways. In normal DC motors, PWM can control the **Speed** of a motor. But when PWM drives a servo, it represents the **Position** of the servo. Draw examples of PWM.

Direct Drive: Must have a lot of torque, eg. **Stepper motors**:
Who researched stepper motors? Bring up that slide: Discuss stepper motors. Watch animation here:http://en.wikipedia.org/wiki/Stepper_motor

Stepper motors have a lot of torque and generally won't require gears to move your wheels, etc.

Have a "Degree per step" rating. Common values are 7.5 degrees, 1.8 degrees, and 0.9 degrees. (Divide 360 by the degrees per step to see how many steps per revolution) 360/7.5 = 48 steps per rev.
360 / 1.8 = 200 steps per rev
360 / 0.9 = 400 steps per rev

They move to the next position and stop there, in fact, it is hard to move it from that position when the coils are energized.
Come in a variety of numbers of wires: 4-wire, 5-wire, 6-wire, 8-wire.
Coils draw a **LOT** of current, so you may need to use current-limiting resistor in series with each coil to prevent burning out your controller.

Multi-stepping: Half, quarter, 8^{th}, 16^{th} (increase resolution, but not uniform torque)[stepperworld]
There are two types of stepper motors, **unipolar** and **bipolar**.
BIPOLAR Usually have 4 or 8 wires.
Simple case is a 2 coil bipolar motor (draw it) where each coil can be driven by an H-bridge.
http://arduino.cc/en/Reference/StepperBipolarCircuit
http://en.wikibooks.org/wiki/Practical_Electronics/Stepper_Motors
Draw out Normal wave drive?
Good source for additional information. http://www.stepperworld.com/Tutorials/pgBipolarTutorial.htm

UNIPOLAR
Has 5 or more wires. Similar to Bipolar, except each coil has a center tap which is the common (or power) node.

Can be used as Bipolar.
8-wire is the most versatile as it can be converted to a 6-wire, 5-wire, or a 4-wire motor.
A Simple driver includes Darlington transistor array:
http://arduino.cc/en/Reference/StepperUnipolarCircuit
Good source for additional information.
http://www.stepperworld.com/Tutorials/pgUnipolarTutorial.htm
http://en.wikibooks.org/wiki/Practical_Electronics/Stepper_Motors
http://www.motionking.com/support/unipolar_bipolar.htm
Stepper Motor Driver Interfacing:
Unless you design it yourself, stepper motor drivers are usually designed to accept two inputs: Step and Direction. Direction is binary (0 for one direction, 1 for the other) and the "step" line is pulsed once for each time you wish the motor to step in that particular direction. This simplifies the driver schematic and the driver can be treated as a black box.

Control:
There are Open Loop and Closed Loop control paradigms. Open loop means that you send the signal to the motors, and assume the motors do exactly what you expect. There is no error checking. If the motors get stuck and don't spin correctly, there is no way to check this. Original LEGO robot kit (Mindstorms) used this type of system. You tell the robot to move the motors for a certain amount of time. **What happens when the batteries run low and don't provide the same amount of power to the motors?**

Closed loop uses a sensor to check that the motor actually performed as expected. Newer LEGO robot kits (NXT) use this method to control motors. You can set the number of degrees of rotation, or number of rotations, etc. This also allows you to have better control of the motor's speed. Servos also use a closed-loop control system. You send the servo a signal representing the desired position, and the servo spins the motor until it reaches that position.

Encoders track the position of a motor. There are different types:
Magnetic encoder: Like a bicycle speedometer. Magnets are placed on the wheel and a magnetic sensor can detect this as the wheel turns. Multiple magnets with alternating poles can improve the accuracy of the reading.
Optical encoder: An infrared beam is passed through, or reflected off an encoder wheel. This wheel has slots to allow the light to pass, and spokes that will block the light. By counting the light pulses, you can tell how many degrees the motor has turned. Again, the more spokes on the encoder wheel, the better accuracy.
Quadrature Encoder: Uses two optical encoders per wheel. This allows you to tell which direction the motor is spinning as well as how far it has spun.
http://quantumdevices.wordpress.com/2010/02/22/why-use-an-optical-quadrature-encoder-for-a-motor-encoder/

Robot Position Estimation:
There are many different wheel configurations for mobile robots. Each configuration has its own (sometimes complicated) mathematical methods for calculating how to drive the robot. Chapter 3 in the textbook covers the details of some of the math. Here are some other examples you might find useful: http://www.ikalogic.com/small-robot-drive-trains/

Differential Drive robots:
You control each **side of a robot**. For example, sumo-bots, tanks, DANI bots, GEARS, Roomba. These robots are simple to build because there is no complicated scheme used to turn them, simply spin the motors on each side different directions to spin in place.
http://chess.eecs.berkeley.edu/eecs149/documentation/differentialDrive.pdf

http://rossum.sourceforge.net/papers/DiffSteer/

Swedish Wheel (Omni-directional)
Sidewinder Forklift http://youtu.be/vAiwLRGsNrE
Omni-wheel Robot: http://youtu.be/5vJCucpVdX0
Three-wheeled robot http://youtu.be/mNy09kuIdzs

Spherical Wheel
http://youtu.be/sB9lowB8nx8
LEGO Robot http://youtu.be/OAc1ipVpn3k

Ackerman Steering

Like a car. Two "steerable" wheels must turn at different angles to turn about the same point.

Look at pages in Chapter 2 for more driving configurations.

Robotic Position Estimation:
Every object in 3D space has a reference frame. Lets simplify this to a top-down view of a mobile robot, which will give us only 2 dimensions to work with.
http://processing.org/learning/transform2d/

Rotational Matrices
http://www.youtube.com/watch?feature=player_detailpage&v=QKyDrUonp98#t=1720s

For my lecture Tuesday:
1:45 mins with break in the middle
Go through how to drive robots, wheels, drive types, h-bridges, stepper motors (find old graphics form previous lectures) Get ratios and wheel ration with robot width included

Differential drive
Sweedish Wheel,
Compare to Danny drives (especially mention gears)
open loop/Close loop

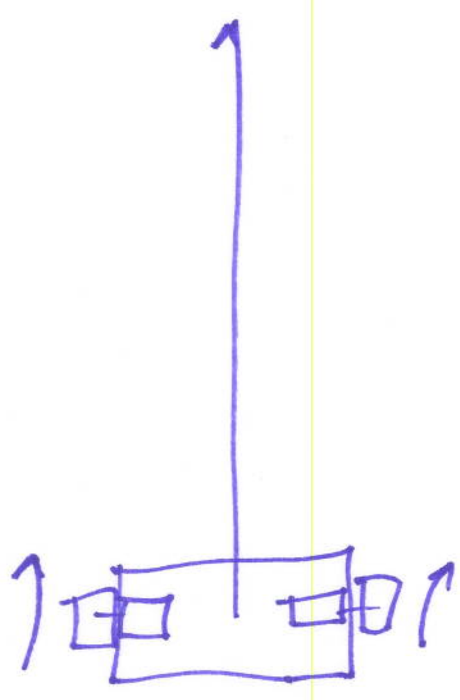
http://webpages.uncc.edu/~jmconrad/ECGR4161-2009-01/notes.html
http://webpages.uncc.edu/~jmconrad/ECGR4161-2010-05/notes.html
http://webpages.uncc.edu/~jmconrad/ECGR4161-2011-05/notes.html
http://webpages.uncc.edu/~jmconrad/ECGR4161-2012-05/notes.html

Chapter 3 in book: pp55-99 Mobile Robot Kinematics

Another: 400 meters
wheel revolutions?

$$400\,m * \frac{1\text{ wheel rev}}{0.44\,m} = \text{wheel revolutions}$$

$= 909.1$ wheel revolutions



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3. Consider a robotic vehicle like the one that is used in Lab 2 and 3. The motor has 53:1 gearing (53 rotations of the motor equals 1 rotation of the wheel) and the wheel radius is 7 cm. How many revolutions of each motor are needed for the vehicle to move 2m in a straight line? Show your work. (10 pts)

Motor → Wheel → Travelled

53 rev → 1 rev = ?.m = 0.44 m

$2\pi r$

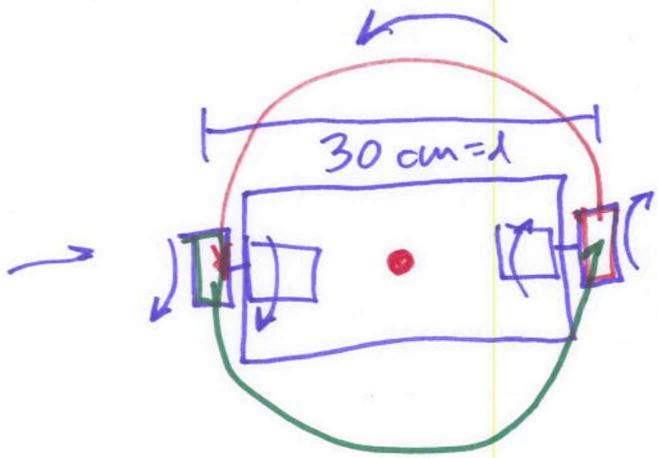
$2\pi .07 m$

$2m * \frac{1 \text{ wheel rev}}{0.44m} * \frac{53 \text{ motor rev}}{1 \text{ wheel rev}} = 240.9$ motor rev

$0.44m = 2 * \pi * 0.07m$

4. Consider a robotic vehicle like the one that is used in Lab 2 & 3. The motor has 53:1 gearing (53 rotations of the motor equals 1 rotation of the wheel) and the wheel radius is 7 cm. The width of the robot is 30cm (from the wheels on each side). If I declare the "center" of the robot to be the point halfway between the wheels, how many revolutions of each motor are needed for the vehicle to turn 180 degrees in place (the center of the robot stays in the same place)? Show your work. Include a drawing to help convey your thought process. (10 pts)

How much distance will the wheel travel



r = 15cm

circumfrence = $2\pi r$

we want 1/2 of circumfrence

$\frac{1}{2} * 2\pi r$ = distance traveled

15π cm

$15\pi \text{ cm} * \frac{1 m}{100 cm} * \frac{1 \text{ wheel rev}}{2*0.07m*\pi} * \frac{53 \text{ motor rev}}{1 \text{ wheel rev}} = 56.8$ motor revs