University of British Columbia
Electrical and Computer Engineering
EECE281/EECE282

Project 2: Electromagnetic Tether Robot.

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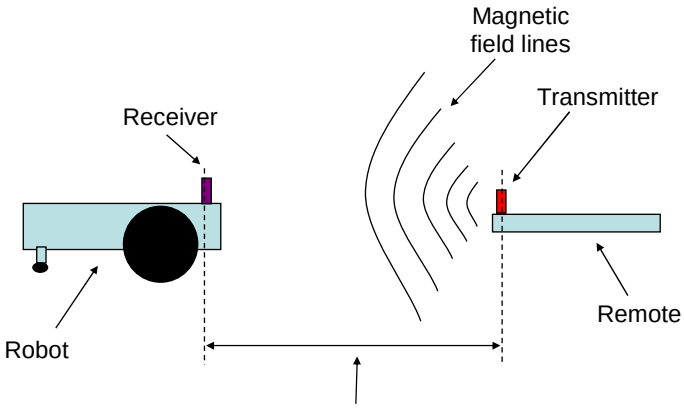
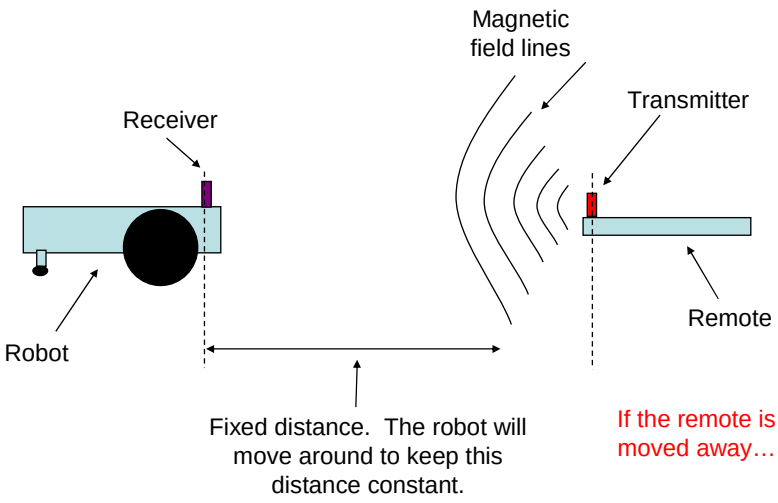
Requirements

- LP51B Microcontrollers (two required!):
  - Robot is the receiver. It keeps a preprogrammed and configurable distance from the remote (transmitter).
  - Remote is the transmitter. It sends the beacon and commands to the Robot.
- Programmed in C.
- Battery powered**.**
- Discrete MOSFET drivers.
- Remote commands:
  - Move farther.
  - Move closer.
  - Rotate 180º.
  - Parallel park.
- Smallest maximum distance of 50 cm or so. An acceptable range would be 20cm (min.) to 50cm (max.).

EM Tether Robot

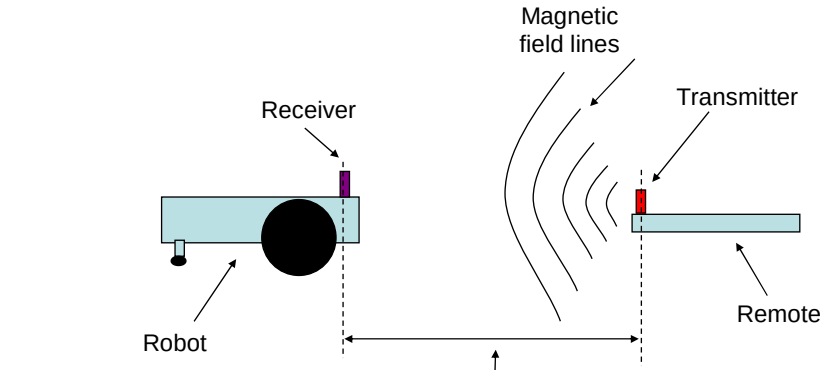


EM Tether Robot



If the remote is moved away…

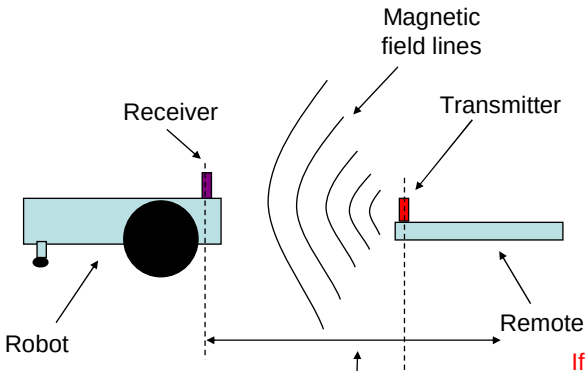
EM Tether Robot



The robot will move closer to keep the distance constant.

Fixed distance. The robot will move around to keep this distance constant.

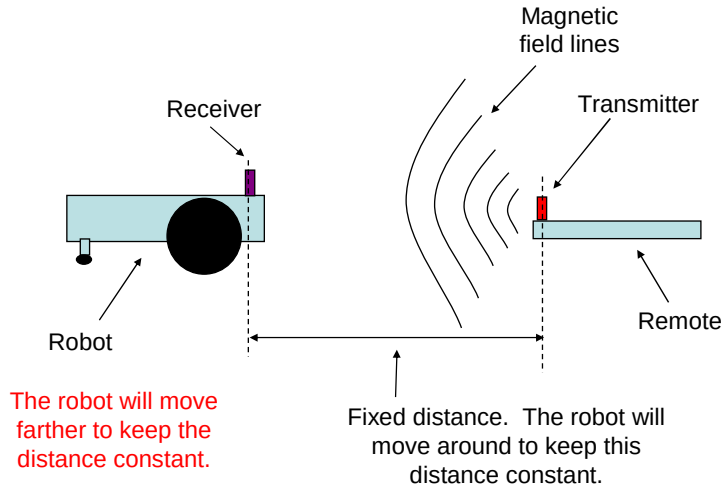
EM Tether Robot



If the remote is moved closer…

Fixed distance. The robot will move around to keep this distance constant.

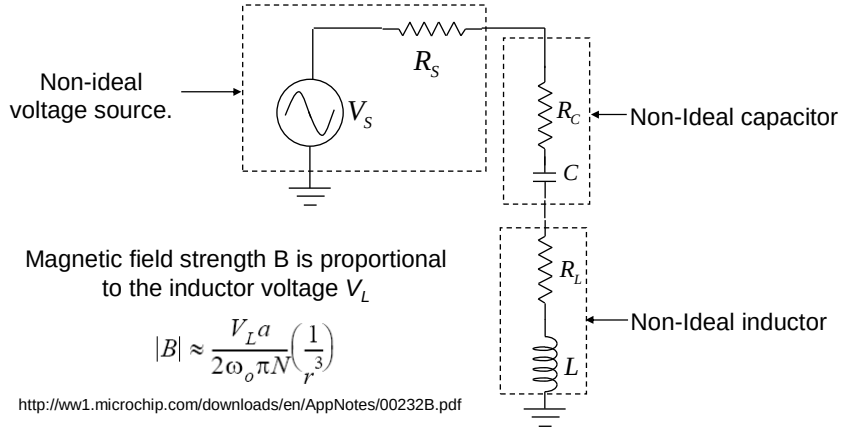
EM Tether Robot



Transmitter

- It is a series RLC circuit some of you know from EECE253.
- The inductor (L) is provided in the robot kit. You can use any inductor you want!
- For the capacitor (C) you can use the capacitors you already have, but they may not work very well. Optionally you can buy a much better capacitor in local electronics parts stores.
- You'll need a safe, stable, and reliable transmitter for your project.

Simplified RLC Transmitter Circuit



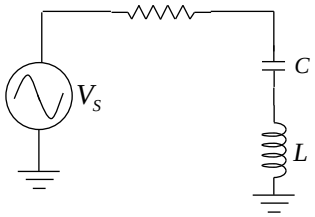
Magnetic field strength B is proportional to the inductor voltage V_L

$$|B| \approx \frac{V_L a}{2\omega_o \pi N}\left(\frac{1}{r^3}\right)$$

http://ww1.microchip.com/downloads/en/AppNotes/00232B.pdf

Simplified RLC Transmitter Circuit

$$R = R_S + R_C + R_L$$

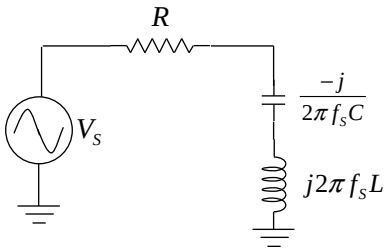


For maximum voltage at the inductor, the circuit must be tuned:

$$f_S = \frac{1}{2\pi\sqrt{LC}}$$

Other factors affect the magnitude of VL. Use phasor analysis!

Simplified RLC Transmitter Circuit



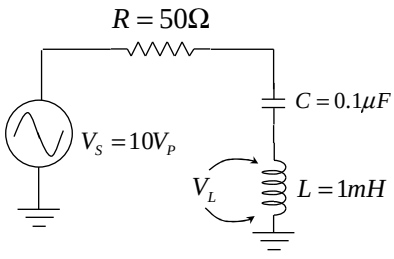
$$i = \frac{V_S}{R - \frac{j}{2\pi f_S C} + j2\pi f_S L} = \frac{Vs}{R}$$

At the tuned frequency this two values are equal!

$$f_S = \frac{1}{2\pi\sqrt{LC}}$$

$$V_L = \frac{jV_S 2\pi f_S L}{R}$$

Simplified RLC Transmitter Circuit



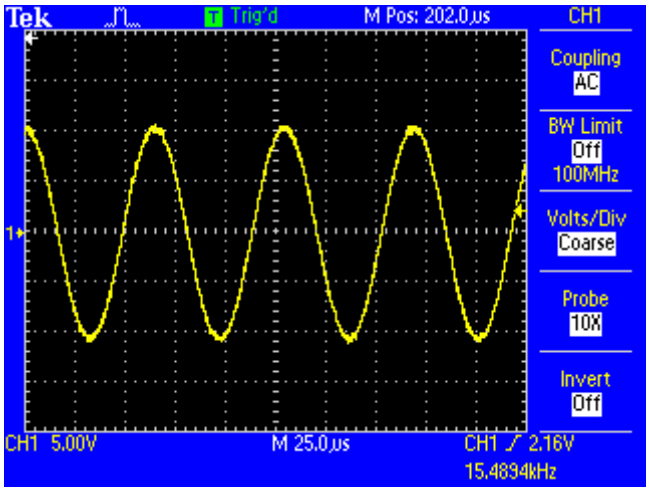
$$f_S = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{1mH \times 0.1\mu F}} = 15.92kHz$$

$$i = \frac{Vs}{R} = \frac{10V_P}{50\Omega} = 0.2A_P$$

$$V_L = j \times 0.2A_P \times 2\pi \times 15.92kHz \times 1mH = 20V_P$$

Not good enough. You'll need 150 to 500 V_p!

V_S Using a Function Generator



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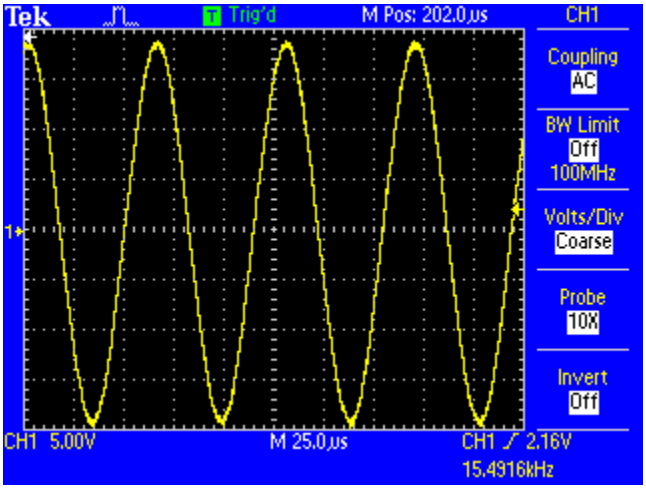
V_L From the Circuit Above



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Maximizing V_L

- Increase V_S.
  - Con: Large source voltages are difficult to handle. Potentially dangerous.
- ~~Increase f_S.~~
  - Con: It ~~won't~~ work because f_s is in the denominator of the magnetic field strength equation. $|B| \approx \frac{V_L a}{2\omega_o \pi N}\left(\frac{1}{r^3}\right)$
- ~~Increase L.~~
  - Con: you'll need to get new inductors. The ones you have are pretty good! Is it also in the magnetic field strength equation?!
- Decrease R.
  - Con: None! Decrease R!

V_S

- It can be an square wave!
- The Fourier Series of a square wave is given by:

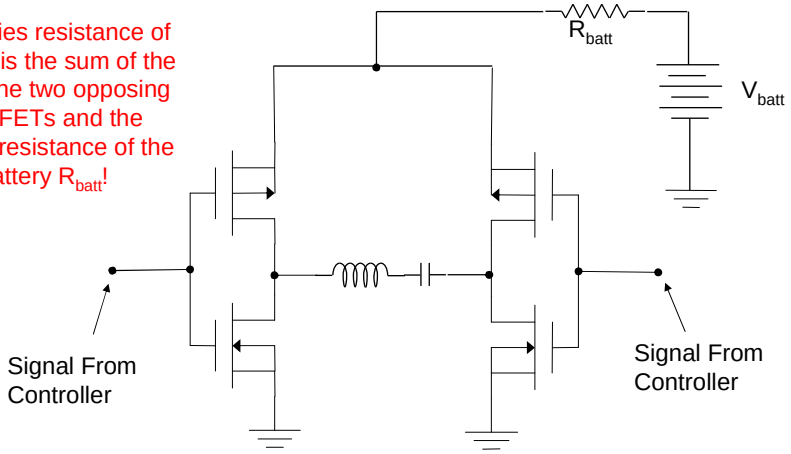
$$x(t) = \frac{4}{\pi}\sum_{k=1}^{\infty}\frac{\sin(2\pi(2k-1)ft)}{2k-1} = \frac{4}{\pi}\left(\sin(2\pi ft) + \frac{1}{3}\sin(6\pi ft) + \frac{1}{5}\sin(10\pi ft) + \ldots\right)$$

Fundamental — 3rd harmonic — 5th harmonic

Bonus: The amplitude of the fundamental is $4/\pi$=1.273 times the amplitude of the square wave!

V_S: you can use an H-bridge!

The series resistance of this 'Vs' is the sum of the R_{DS} of the two opposing MOSFETs and the internal resistance of the battery R_{batt}!



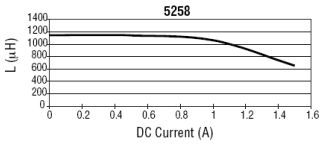
Optocouplers may not be fast enough for transmitter frequency!.

The Inductor

Don't drop the inductor. The core may break!

- DigiKey part number M8275-ND

Type	Wirewound
Material - Core	Ferrite
Inductance	1mH
Tolerance	±20%
Current Rating	1A
DC Resistance	0.55 Ohms

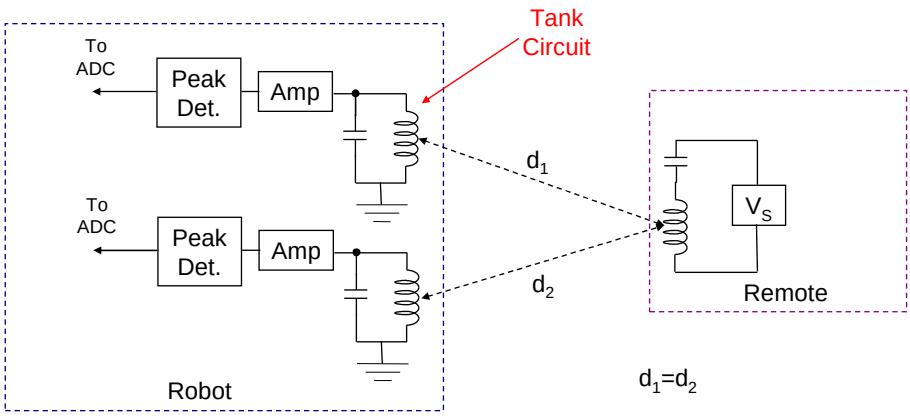


The Capacitor

- The peak value of the voltage across the capacitor is equal to the peak value across the inductor. The capacitor MUST be rated for the operating voltage! If not:
  - The capacitor may over heat and explode.
  - The capacitor may short circuit and catch fire.
  - The capacitor may introduce too much series resistance.
- Go to RP, Main, or Lee's and buy some good capacitors!

The Receiver

- It requires two inductors to determine which way to move:



Robot Logic

- If (d1>d) move motor 1 back.
- If (d2>d) move motor 2 back.
- If (d1<d) move motor 1 forward.
- If (d2<d) move motor 2 forward.
- d is preset after reset, but it can be changed by receiving a command from the remote.

Robot Construction

Part #	**Description**
Solarbotics GM4	Gear Motor 4 - Clear Servo
Lynxmotion Servo Wheel	2.63" x 0.35" (pair) wheels
Tamiya 70144	Ball Caster
4 x AA	Battery holder
1 x 9V cable	9V battery clip
Unfolded chassis	Aluminum chassis made using the water jet cutter.

Fitting the Wheels to the Motors

Question:

"*We're finally assembling our rover and the wheels seem to not have the same spline pattern as the motor shaft. I'd rather not force these to mate. Is this unusual? Can you suggest a solution?*"

Answer:

The wheels pressure fit into the motor shafts. The wheels are flexible so they will expand a bit making an excellent and tight fit to the shaft. It is hard to press the wheels into the shafts, but if you used the provided screws, you can fit them very easily by screwing them in.

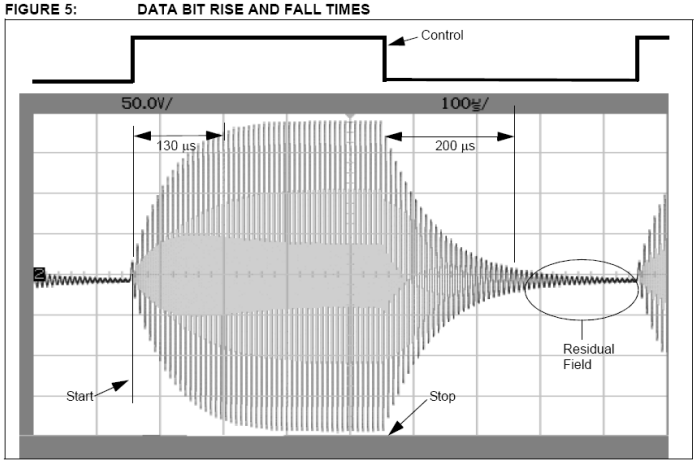
Sending Commands From the Remote to the Robot

- Check application note from Microchip. It describes On-Off Keying for data transmission:
  http://ww1.microchip.com/downloads/en/AppNotes/00232B.pdf
- A minimum of four commands required:
  - **Move closer.** When the user presses a button in the transmitter, it commands the robot to move closer.
  - **Move farther.** When the user presses a button in the transmitter, it commands the robot to move farther.
  - **Rotate 180º.** When the user presses a button in the transmitter, it commands the robot to rotate 180o.
  - **Parallel park.** When the user presses a button in the transmitter, it commands the robot to parallel park in a space that is 1.5 times the length of the robot.

Data Bit Rise and Fall Times

From Microchip's application note AN232 "Low-Frequency Magnetic Transmitter Design"

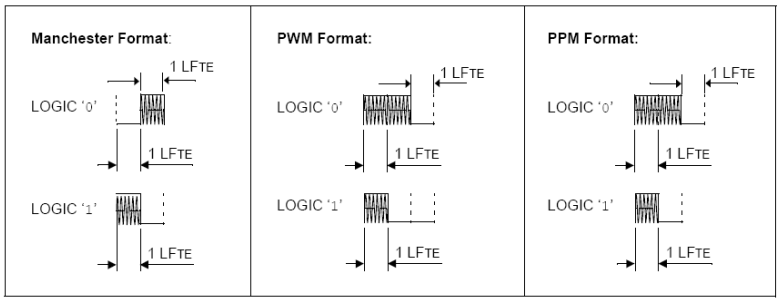
FIGURE 5: DATA BIT RISE AND FALL TIMES



Data Modulation Formats

From Microchip's application note AN232 "Low-Frequency Magnetic Transmitter Design"

FIGURE 6: DATA MODULATION FORMATS



Since you'll need to transmit only a few data bits, it is not a problem to assume 'field present' equal 'logic one' and 'field not present' equal 'logic zero'. The baud rate has to be very low. You can bit bang the transmission and reception as shown in the next slide.

Bit-bang Transmission/Reception

The 'wait_bit_time()' function must be exactly the same!

```
void tx_byte ( unsigned char val )
{
    unsigned char j;

    //Send the start bit
    txon=0;
    wait_bit_time();
    for (j=0; j<8; j++)
    {
        txon=val&(0x01<<j)?1:0;
        wait_bit_time();
    }
    txon=1;
    //Send the stop bits
    wait_bit_time();
    wait_bit_time();
}
```

Bit-bang transmission in the remote

```
unsigned char rx_byte ( int min )
{
    unsigned char j, val;
    int v;

    //Skip the start bit
    val=0;
    wait_one_and_half_bit_time();
    for(j=0; j<8; j++)
    {
        v=GetADC(0);
        val|=(v>min)?(0x01<<j):0x00;
        wait_bit_time();
    }
    //Wait for stop bits
    wait_one_and_half_bit_time();
    return val;
}
```

Bit-bang reception in the robot

C programmed.

- Both the robot and the remote must be programmed using the C programming language.
- You may 'inline' small portions of assembly code, but the bulk of your code must be C.
- Newer version of "at89lp51rd2.h" must replace older version in folder:

  Crosside\Call51\Include\mcs51

Battery powered.

- Your project must be battery powered. This includes the electronics and motors of both the transmitter and receiver
- A 9 volt battery strap and a 4 x AA battery holder are included in the parts kit for this project.
- You can use any kind of batteries you want, provided that you acquire the batteries and the holders yourself.
- WARNING: batteries are neither included in the parts kits nor they will be provided in the lab. You must buy your own batteries.

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Project 2 Due Dates

Function demo: April 3 and 4

Report: April 7

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