Nashua Robot Builders
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Nashua NH

Acoustic Position Tracking

Progress Report

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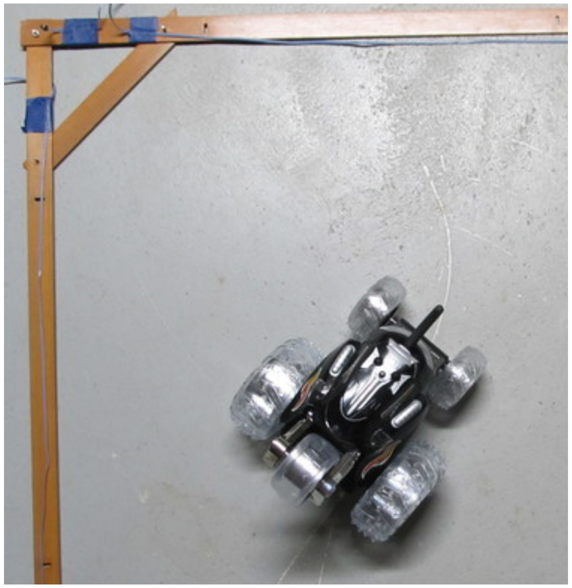


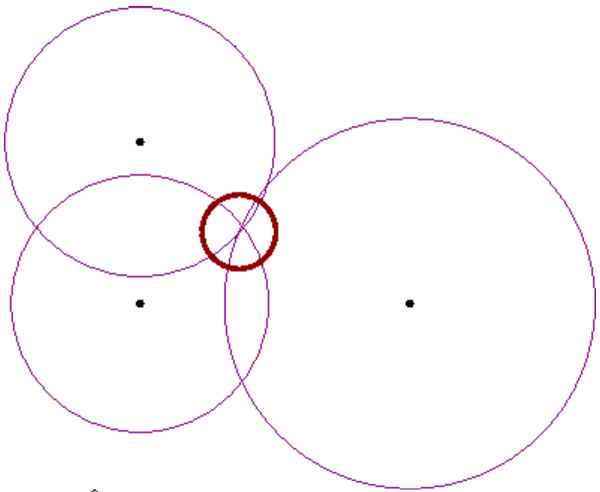
Rev. Jul. 14, 2018

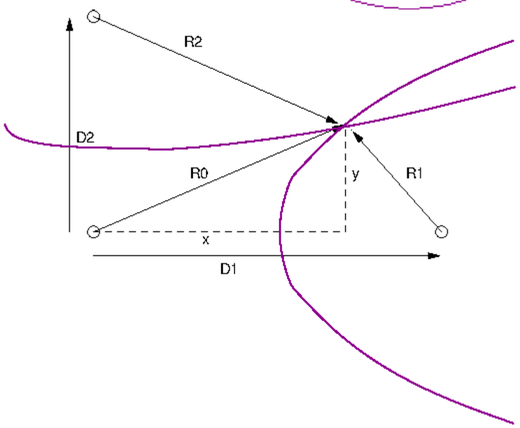
The Eventual Goal

- Track position relative to known aids.
  - Sub-inch resolution.
  - Hobby-level cost.
- For repeatable path tracking.
  - Follow a specific path (eg, writing)
  - Go to a specific point (charging station)
- Limited range (for now)
  - Tabletop, room.
  - 10x10ft sort of range.

Propagation Time Navigation

- **If we know transmit and receive times, we know distance.**
  - **Distance is radius of circle around beacon.**
  - **2 beacons: robot is where the circles intersect.**
  - **Transmit and Receive must both know accurate time.**
- **If we only know receive times**
  - **i.e., beacons use same clock, robot not sync'ed to it.**
  - **We know difference in arrival time of pulses, so difference in distances.**
  - **Solution of $r_0 - r_1 = \delta$ is a hyperbola.**
  - **With 3 or more beacons, we look for the intersections of multiple hyperbolas.**

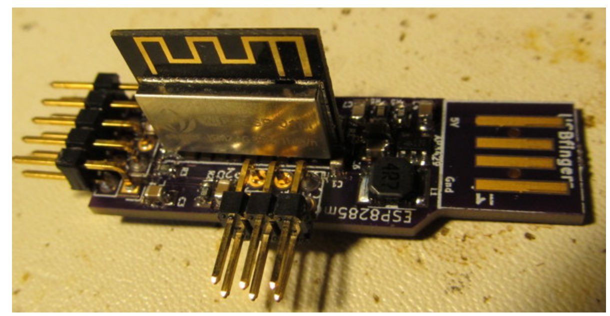




How to Build It?

- **RF:**
  - **Speed of light is 1ft/nanosecond, so need resolution corresponding to 10GHz clock.**
  - **Phase techniques (interferometry) can do it, but not simple.**
  - **Also, FCC sometimes gets upset about intentional emitters.**
- **Acoustic:**
  - **Speed of sound 1125 ft/s: simple hardware, reasonable clock resolutions.**
- **Timekeeping**
  - **Crystal oscillators (10-100ppm) dirft out of sync in a few seconds.**
  - **Atomic (Rubidium) clocks are good for days. Available from Digikey for only $1000 or so.**
  - **I plan to use hyperbola method or WiFi time sync.**
- **WiFi**
  - **Planning to use ESP8255 (little brother of ESP8266/ESP32).**
  - **$3.01 from Digikey.**
  - **Carrier board fabbed and assembled.**

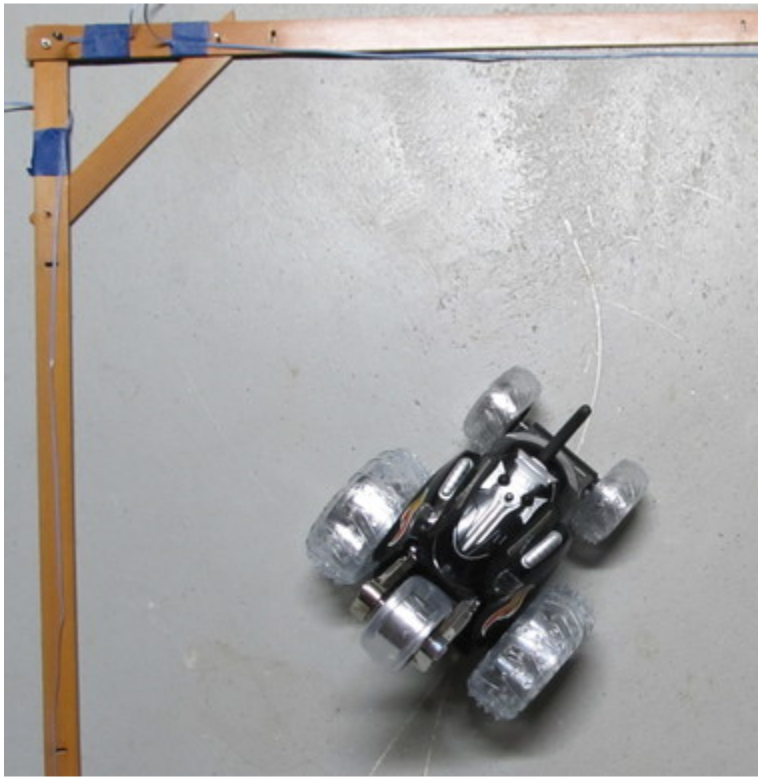
LFRBXO059244 Atomic Clock
$1844 from Digikey.



First setup

- **Speaker to be on robot.**
- **Multiple microphones in known locations, wired to common controller.**
- **Use RF (WiFi) to sync clocks and communicate location.**

- **Using**
  - **STM32F4Discovery board for data capture, USB transfer to host.**
  - **PC for data analysis (for now).**
- **Microchip MCP3913 data acquisition chip.**
  - **6 channel, simultaneous sampling (simplifies time comparisons).**
  - **Delta-Sigma converter (good for audio).**
  - **1x-32x programmable gain (can interface direct to cheap electret mics - barely).**
  - **24-bit conversion (15 or so good bits with my settings).**
  - **Sampling to 32kHz or so (only 8k working now).**

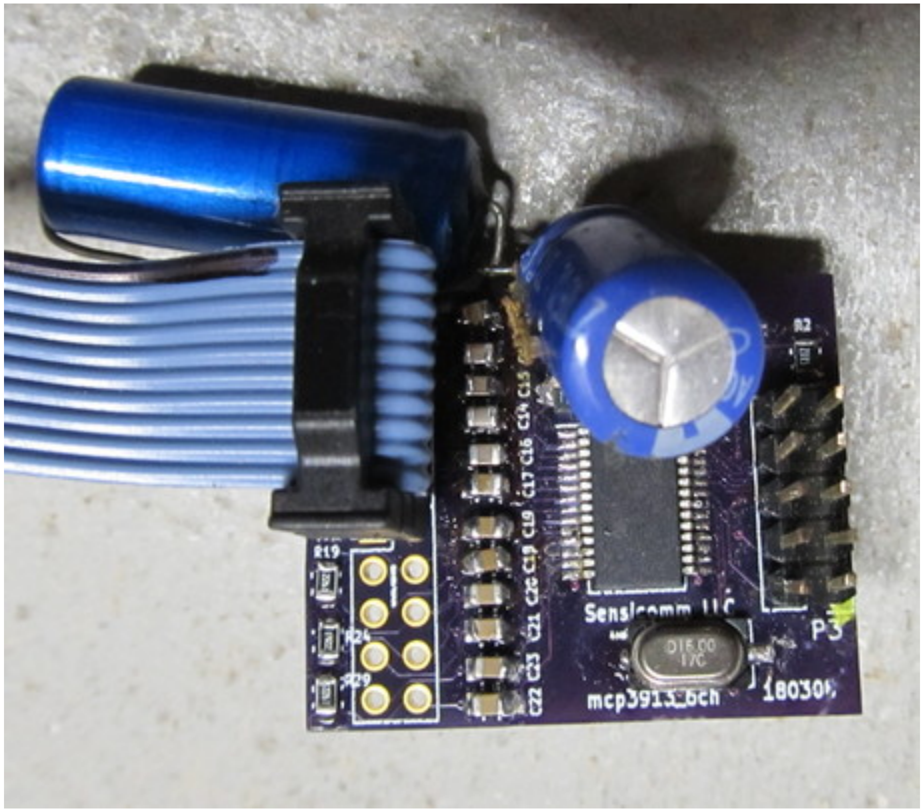


Signals

- **Using regular audio speakers and microphones.**
  - **Cheaper and easier than ultrasonic.**
  - **Readily available.**
- **Transmitting a Pseudorandom (PN) sequence.**
  - **E.G., en.wikipedia.org/wiki/Pseudorandom_noise**
  - **Sounds like white noise, so not too annoying.**
  - **Allows more precise time alignment than a single pulse.**

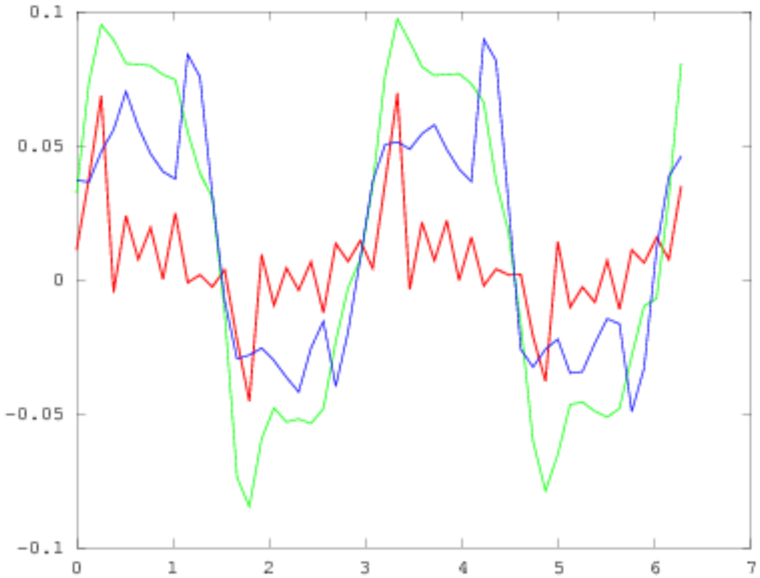
Progress: ADC Noise

- **MCP3913 spec sheet says ADC noise should be 85-90dB below full scale with my settings.**
- **Initially measured around 35-40dB down.**
- **Solution: lots more capacitance on analog section's power pin, and electret mic bias.**
- **Now in the 65-70 range. Good enough for now.**



Progress: Speakers

- **An unenclosed speaker cannot generate much low frequency response.**
- **www.eminence.com/sealed-vs-ported-enclosures**
- **Square wave test signal at ≈ 500 Hz.**
  - **Freestanding speaker mostly reproduces the edges.**
  - **Hi Fi bookshelf speaker looks reasonable.**
  - **Simple cardboard box enclosure helps a lot.**
- **To do:**
  - **Better speaker enclosure.**
  - **or, shift the signal to higher frequencies.**



Speaker driven by square wave RED Bare speaker. GREENBookshelf speaker. BLUESpeaker in cardboard box.

Status

- **Peaks looking reasonable.**
  - **May need padding around microphones to attenuate reflections.**
- **Next step is to implement some location algorithms.**