Proposal for upgrading NuMI horn field-mapping system

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Current longitudinal system

Probe sled:

- Three-axis control
- Stepper motors: Parker Zeta83-135-MO
  - 382 oz-in (Nm) Static Torque
  - frame size 34
  - 10.47 oz-in rotor inertia
  - 3/8" shafts
- Not well documented at all. Unclear what the motor phase current rating is.
- Possibly one LVDT per axis, though connectors appear damaged. Have not yet located signal conditioners/receivers.

Current longitudinal system

Stepper motor electronics:

- ZETA4 stepper motor system from Parker Motion
- Proprietary, uses “Motion Architect” software to talk to controllers
- Motion architect only runs on Windows XP or older
- Requires: legacy Windows OS, PC with serial ports or USB-to-serial adapters
- One controller module (pictured) per motor

Magnetic field probes:

- Single 3D probe
- Probe reading manually recorded

Proposed upgrades

Probe sled:

- Motors are likely re-usable if coil and coil-to-coil resistances are nominal.
- Linear encoders exist and should be usable
- Slip-clutch motor couplings and hard stops with limit switches may be desirable

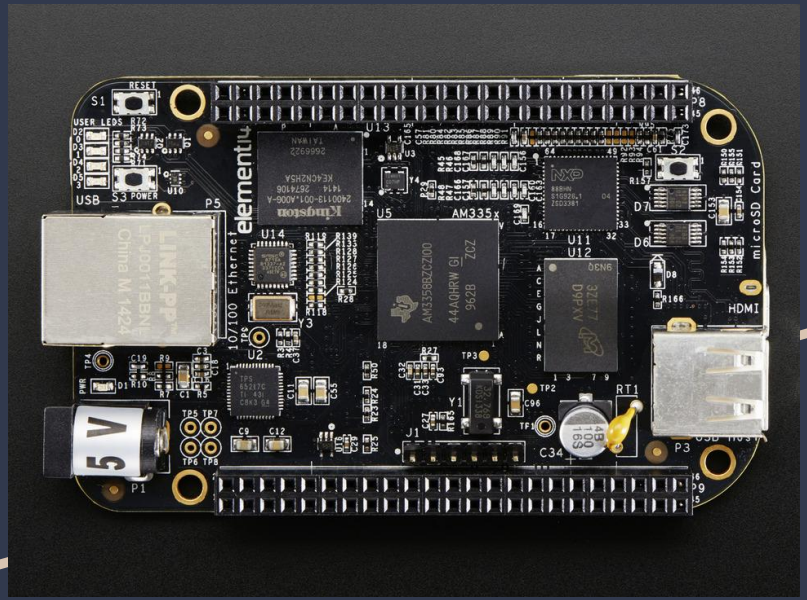
Stepper motor electronics:

- Use single-board Linux computer to interface to modern stepper motor controllers that can be programmed with open-source software.

Magnetic field probes:

- Use probe receiver that can be read out by single-board Linux computer, synchronizing probe placement, horn pulse timing, and probe readout. Katsuya has provided this probe.

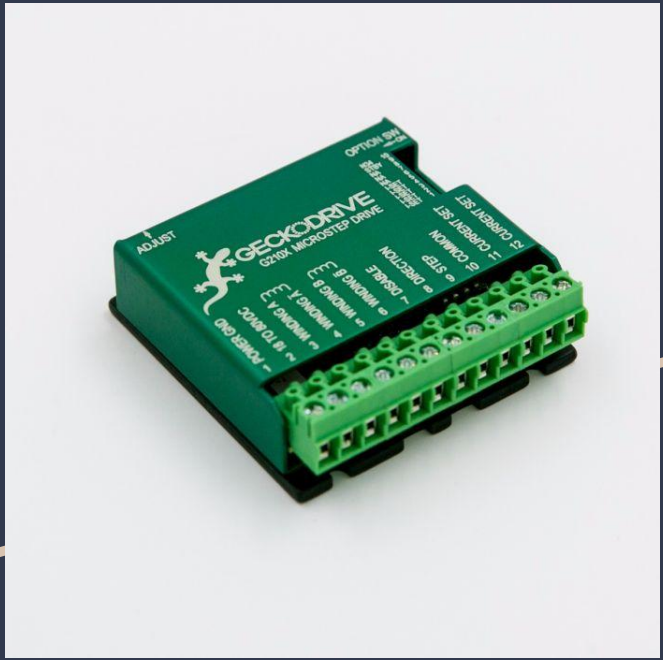
Single-board Linux computer



Beaglebone Black:

- Credit-card-sized single-board Linux computer, open-source hardware with open-source software and OS
- Specs:
  - Debian or Ubuntu Linux
  - 1 GHz ARM Cortex-A8 CPU
  - 512MB DDR3 RAM
  - 4GB 8-bit eMMC on-board flash storage
  - 2x PRU 32-bit microcontrollers
  - Ethernet, micro-HDMI, USB
  - 8 ADC pins, 0-1.8V, 12-bit resolution
  - 62 GPIO pins
- GPIO/ADC open-source Python library freely available and supported
- External storage: microSD or USB flash
- Cost: $55

Stepper motor controllers



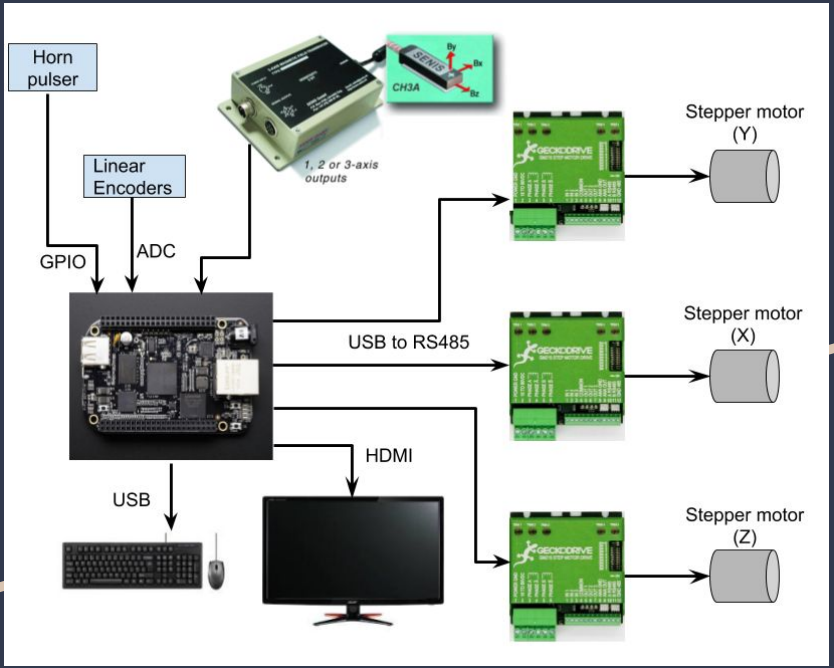
Geckodrive GM210X Step Motor Drive:

- 80VDC, 7A maximum output to motor, one controller per motor
- Can be set to drive lower motor (for transverse) with onboard DIP switches
- Will control with Linux board’s GPIO pins; moves a programmable number of steps per input pulse from the GPIO pin.
- Cost: $127 each

Stepper controller power supplies

- Controllers accept 18-80V input.
- Higher voltage means quicker stepping, probably not necessary for us
- Optimal voltage is 32*sqrt(L), where L is the motor’s inductance in mH.
- Maximum power supply current is 67% of the motor’s rated phase current.
- Difficult to size given challenge in finding specifications for existing motors
- Best guess, something like 36V 7.0A (pictured), cost: $23
- One per motor
- Transverse motor power supply will be smaller (1.65V 4.7A motor rating).

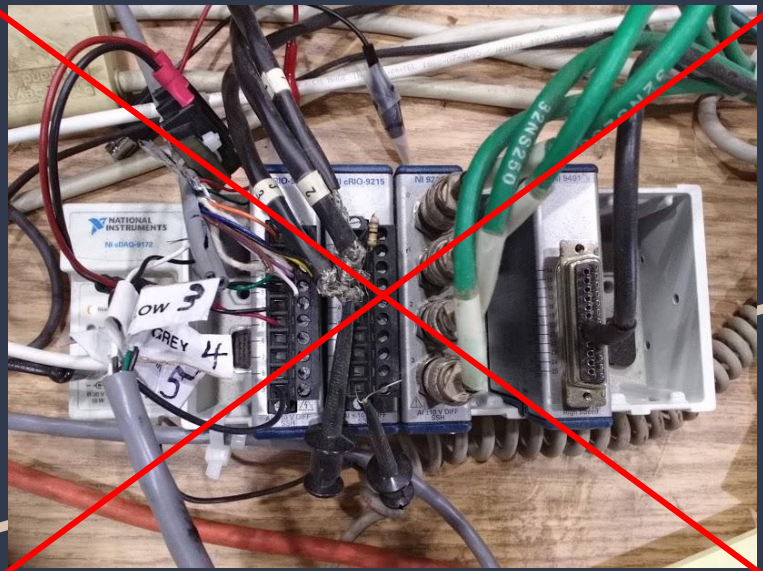
Proposed system overview



Overview:

- Linux board sends move commands to stepper motor controllers
- Horn pulser sends signal to Linux board digital GPIO pin
- Linux board reads linear encoders and magnetic field probe via ADC pins upon GPIO interrupt from horn pulser signal
- Linux board provides user interface (keyboard/mouse and monitor), as well as script to control motors and concatenate data. (GUI?)

Transverse measurement



Transverse field measurement

- Same Linux board can control single stepper motor for transverse measurement
- Same stepper controller, use onboard DIP switches to set current limit and motor size lower
- Existing motor is well-documented
- System is much simpler with just one motor.
- Should follow same controller-motor-encoder-probe topology as one axis of longitudinal system.
- Separate script/GUI for transverse system, but same computer
- Can re-use NMR probe receiver from longitudinal measurement
- No more LabView!

Proposed system overview

Bill of Materials for Longitudinal system:

- Main board **$55**
- Stepper motor controllers **4x $127**
- USB to RS485 cable **4x $30**
- USB hub **$10**
- Power supplies ~**4x$23**
- Replacement motors if necessary, ~$45 ea.
- Monitor and mouse/keyboard

Rough total **$785** w/out new motors

Unknowns

- Deadline for project?
- Emergency stopping
  - Can install limit switches and stop stepper motors when they’re reached. However, should include slip-clutch couplers between motor and axis drive.
- Required precision of measurements
  - Step resolution?
  - Number of averaged data points per step?
- Time between horn pulses?
- Is the longitudinal travel of the current sled+probe long enough?
- Field outside horn: should we shield electronics?
- Transverse probe movement, measurement of displacement
- New motors with well-documented specifications?

New motors

- Since the existing motors are not well-documented (namely, phase current rating not available, I have to guess based on old documentation), may be prudent to use new motors
- Pictured motor has slightly higher static torque than existing motors, but same size, is well-documented and compatible with GM210X drivers
- Available with an optional electromagnetic brake...probably not necessary if we use hard stops, limit switches, and a slip-clutch shaft coupler
- Cost (without brake): **$52.00**