Bakeout and Environmental Monitoring with Raspberry Pis

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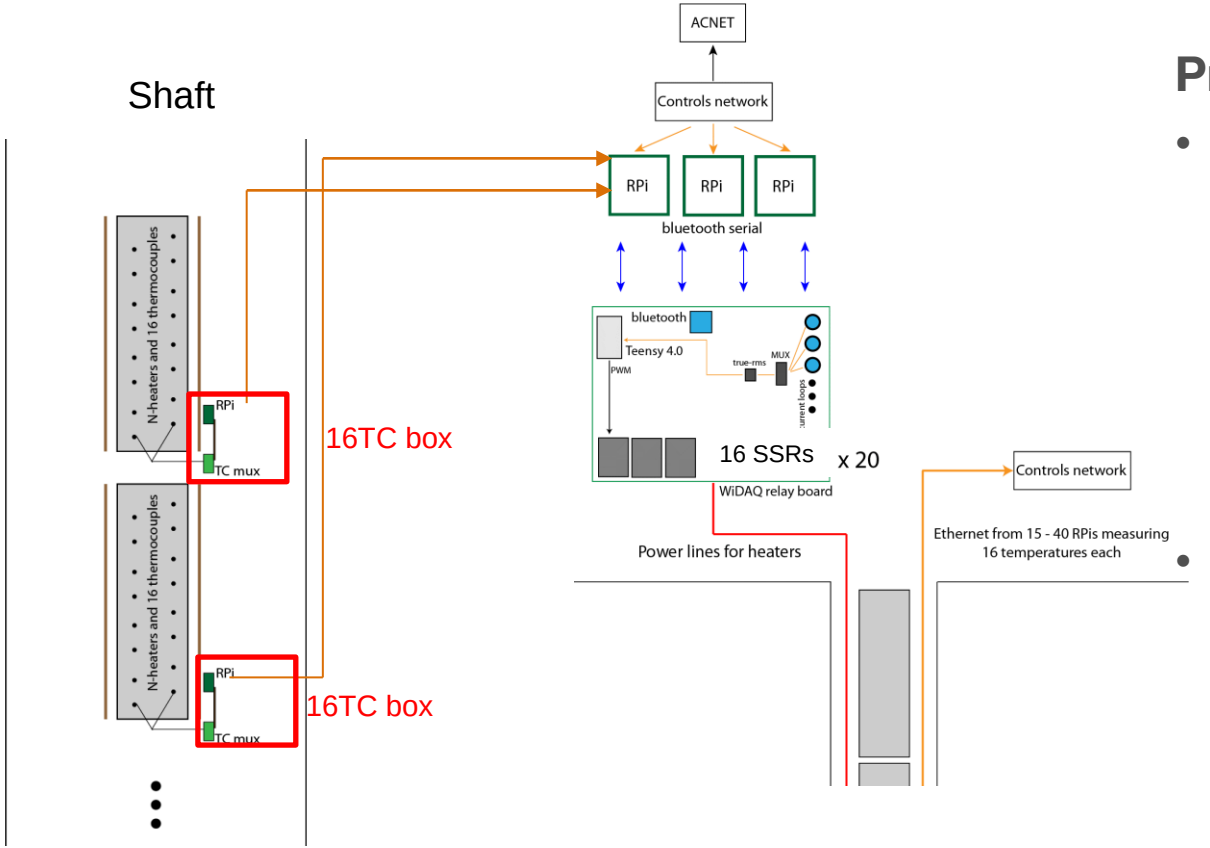
MAGIS-100 Simulation & Analysis Workshop

2 February 2022

Diagram of shaft and surface devices



Proposed hardware:

- Temperature module (shaft):
  - One Raspberry Pi 4B per vacuum module
  - 16-channel multiplexer board via an SPI interface
  - 16 T-type TC's
  - Extra diagnostics and cameras (not related to bakeout)
- Heater power controls module (upstairs)
  - RPi 3B+ (or 4B)
  - Teensy 4.0 with a 5Hz PWM capability
  - 16 channel 10-A SSRs with output current transformers
  - …

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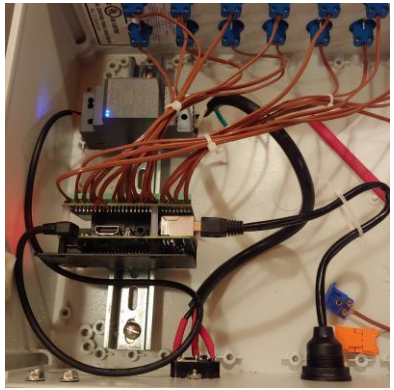
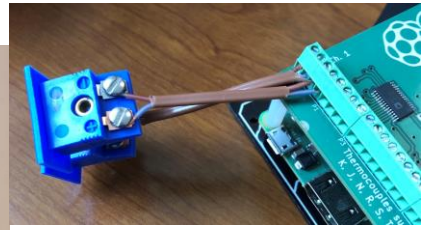
Temperature module (a.k.a. the 16TC box)





- The existing Fermilab ACNET accelerator controls system (user interface with data logging, alarms, plotting, etc)
- ACNET uses the so-called “controls network”, behind the Fermilab Firewall. The Controls network presently does not allow wifi devices.
- We are proposing to use “wired” RPi’s on the Fermilab controls network with static IP addresses.
- Each RPi is running a webserver based on Node.js

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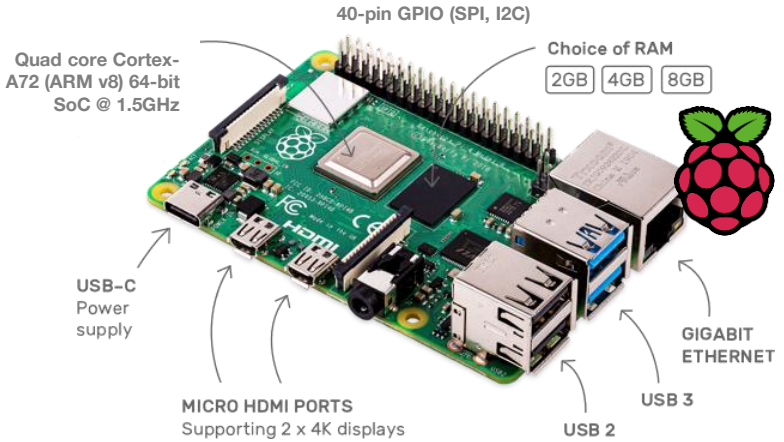
Environmental Monitoring

- Temperature
- Humidity
- Barometric pressure
- Vibrations
  - Seismometers
  - Fast & slow accelerometers
- Magnetic field
  - Inside (& outside?) shield
- Facilities
  - Elevator function
  - Roll-up door function
  - Motion in the bay



Bake system: ~1 Raspberry pi per modular section

Capitalize on existing:

- Physical, electrical infrastructure
- Software development
- Computing power

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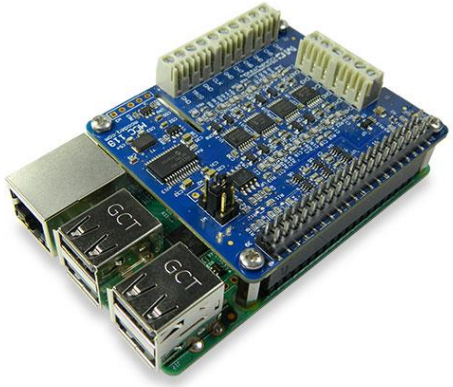
Controller Electronics

TC-MUX Board

- SPI + GPIO
- 16 inputs

RPi



MCC-118 ADC

- 8 analog inputs
- Stackable: expand to 64 channels

Three enclosure styles

Bake enclosure (~15)

- RPi + TCMUX + MCC118
- Every modular section

Dedicated enclosure (2)

- RPi + MCC118
- USB + LAN connections
  - Seismometers, accelerometers
- Top and bottom sections

Facilities (~3)

- Individual design

Sensors

IC sensors deployed on connectorized PCBs

- Temperature -- already deployed thermocouples
- Humidity [AI] (SHT31)
- Barometric pressure [I2C] (MS5607)
- 3-axis magnetoresistive devices [AI] (HMC1053/2003)

Power sourced from enclosure (aiming for all 5V devices)

Seismometers and accelerometers: dedicated digitizers (USB or LAN)

- Trimble 151B and Trimble 147A (REF-TEK 130)
- PCB 393B12 (USB signal conditioner)

Facilities: Current monitoring circuit breaker? Clamp-on meter digitized by RPi?

RPi as a data server

- Node.js is an open-source, cross-platform, back-end JavaScript runtime environment that runs on the Chrome V8 engine and executes JavaScript code outside a web browser.
  - https://nodejs.org/en/

- Node-RED is a flow-based development tool for visual programming developed originally by IBM for wiring together hardware devices, APIs and online services as part of the Internet of Things.
  - https://nodered.org/

  - Node-RED provides a user interface for each RPi, accessible through by a browser on port 1880.
  - Node-RED provides connectivity to Fermilab ACNET

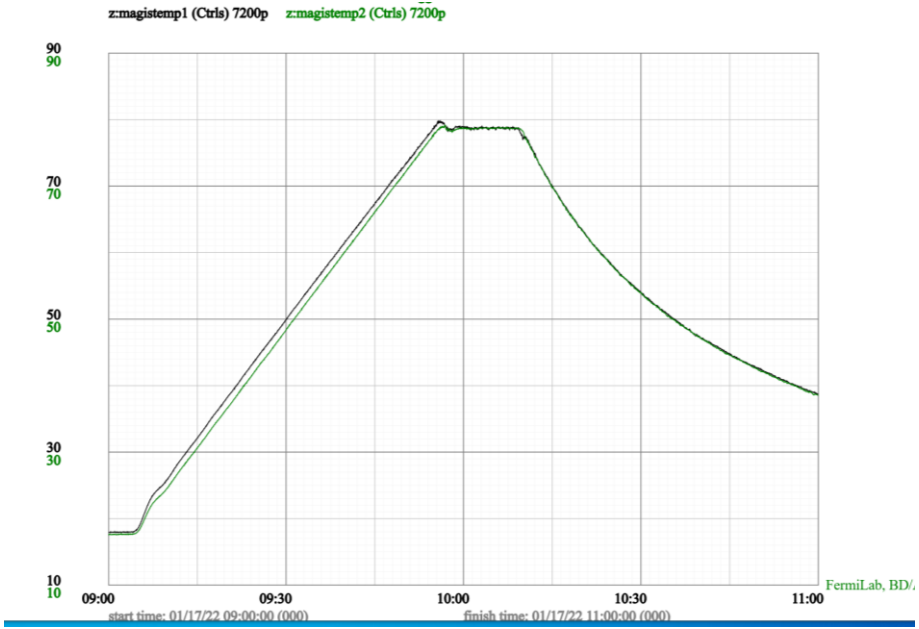
ACNET interface (example)

GoTo MONITOR Application | Find devices | ACNET Name Strainer

magisTCtemps --- 18 Devices

Z:MAGISTEMP1 **MAGIS Temperature 1** 25.73 25.73 C	**Z:MAGISTEMP2** **MAGIS Temperature 2** 25.62 25.62 C
E:MAGIST1 **MAGIS temperature #1** 23.93 23.93 C	**E:MAGIST2** **MAGIS temperature #2** 25.477 25.477 C *.. D
E:MAGIST3 **MAGIS temperature #3** 25.281 25.281 C *.. D	**E:MAGIST4** **MAGIS temperature #4** 23.953 23.953 C *.. D
E:MAGIST5 **MAGIS temperature #5** 24.281 24.281 C *.. D	**E:MAGIST6** **MAGIS temperature #6** 25.875 25.875 C *.. D
E:MAGIST7 **MAGIS temperature #7** 24.805 24.805 C *.. D	**E:MAGIST8** **MAGIS temperature #8** 24.805 24.805 C *.. D
E:MAGIST9 **MAGIS temperature #9** 25.078 25.078 C *.. D	**E:MAGIST10** **MAGIS temperature #10** 25.859 25.859 C *.. D

ACNET datalogging (example)
Devices logged at 1Hz rate



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Data Storage

Acquire data using bake system Node-RED where feasible

Each RPi manages posting its own data (also hosted on a web server)

Through bake out:	Temperature (x16 each) data → ACNET
	Environmental data → MAGIS DB @ FNAL
Commissioning and operation:	Temperature (x1 each) data → MAGIS DB @ FNAL
	Environmental data → MAGIS DB @ FNAL

Data rate ~ 10 GB/day

Discussion

- Primary interfaces: run control (time sync & data storage), network
- Any other useful sensors/peripherals to deploy along baseline?
  - USB 2.0, USB 3.0 (1x reserved for diagnostic camera), AI,
- Diagnostic cameras: image processing or compression on distributed RPis?
- Non-invasive methods for monitoring elevator and roll-up function?
- How often to shuttle buffered data to DB/LTS?