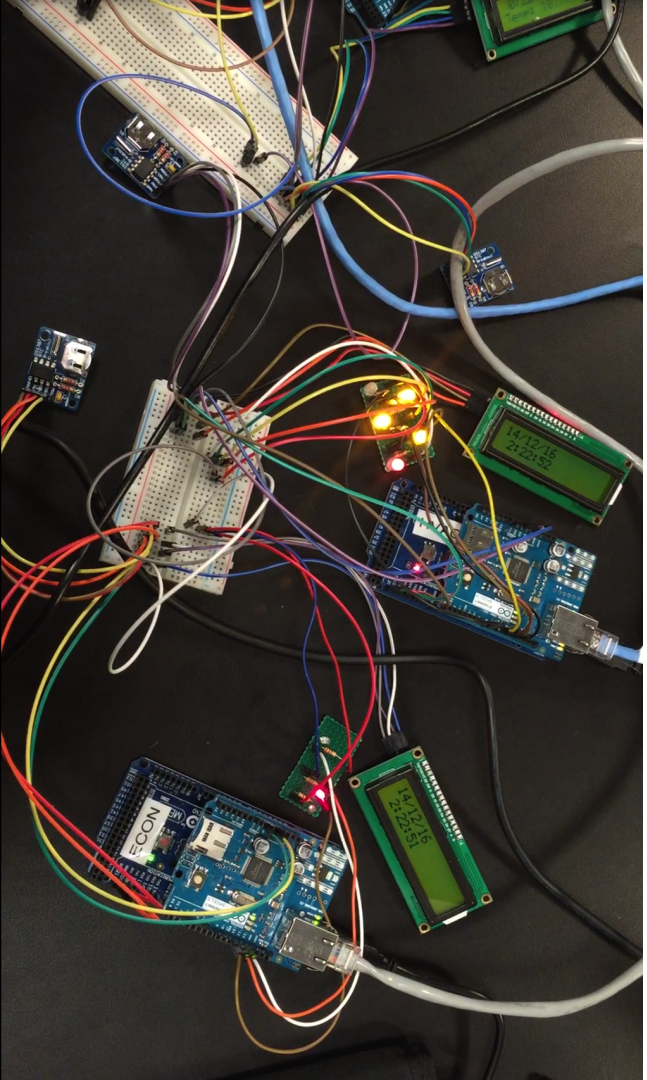


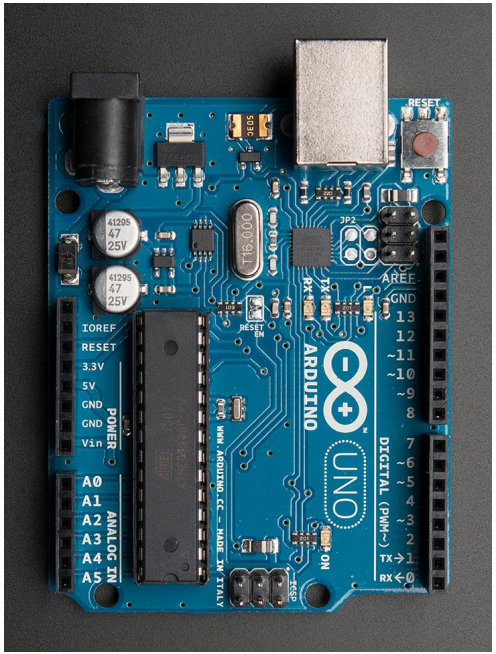
Isochronous Control of Sensor Networks

By Aishwarya Parasuram
Nikhil Goyal
Jack Kolb

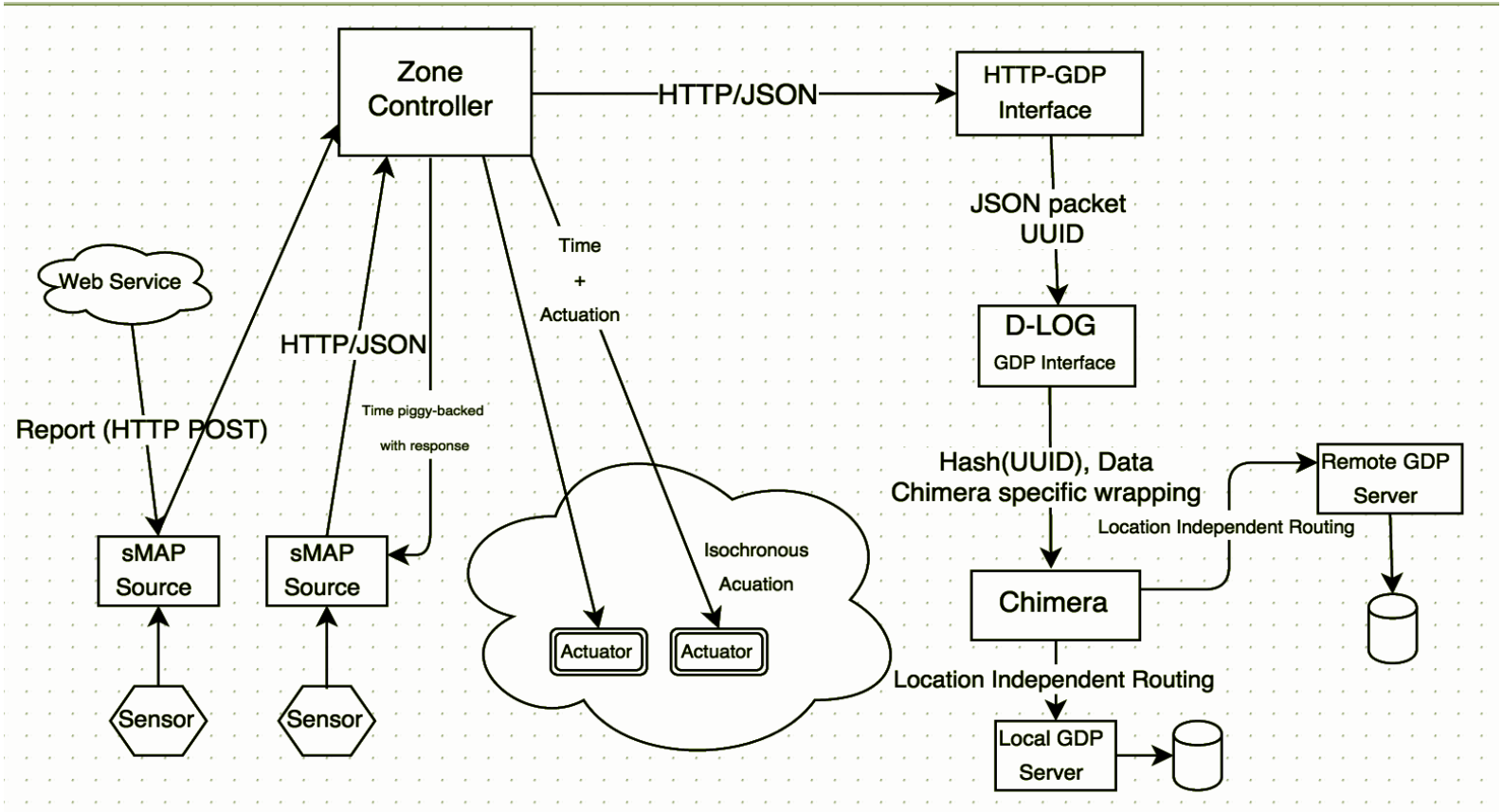
Goals

- Introduce modularity in the existing sMAP architecture by moving sMAP sources to minimal embedded driver
- Collect sensor data in an isochronous manner
- Send intelligent actuation signals from zone controller to actuators
- Achieve isochronous actuation at the actuators
- Achieve global notion of time among all participants in the sensor network

Embedded Driver Optimization



System Level Diagram



Why Isochronous?

- Ensures stability of control loops
  - Feedback Systems
- Real time data loses value as time progresses. Actuation needs to be done in a timely manner.
- Allows appliances to work in a correlated manner

Our Use Case

- Providing thermal comfort and acceptable indoor air quality within a room based on room temperature and the outdoor temperature
- Isochronous Control of
  - Heating, Ventilation, Air Conditioning Conditioning (HVAC)
  - Economiser

Modelling the Use case

- 2 Temperature Sensors
  - TMP36GT9
- 2 Actuators
  - 5 Yellow LEDS on a board (representing HVAC)
  - 3 Red LEDS on another board (representing Economizer)
- Zone Controller
  - HTTP server implemented in Python
  - Bottle Library

Zone Controller

- Ensures that each node subscribes to a common time
- Local time on nodes is regularly corrected
- Performs intelligent analysis on incoming sensor data from a group of sensors corresponding to a physical zone
- Generates appropriate actuation signals on actuators pertaining to that zone
- Actuation signals sent as soon as they are computed, buffered at destination

Implementation of the Actuators

- **HVAC**

  5 Yellow LEDs on board

  - Sig 1: HVAC Off (1 LED on)
  - Sig 2: Partial Cool ON (2 LEDs ON)
  - Sig 3: Partial Heat ON (3 LEDs ON)
  - Sig 4: Cooling ON (4 LEDs ON)
  - Sig 5: Heating ON (5 LEDs ON)
- **Economiser**

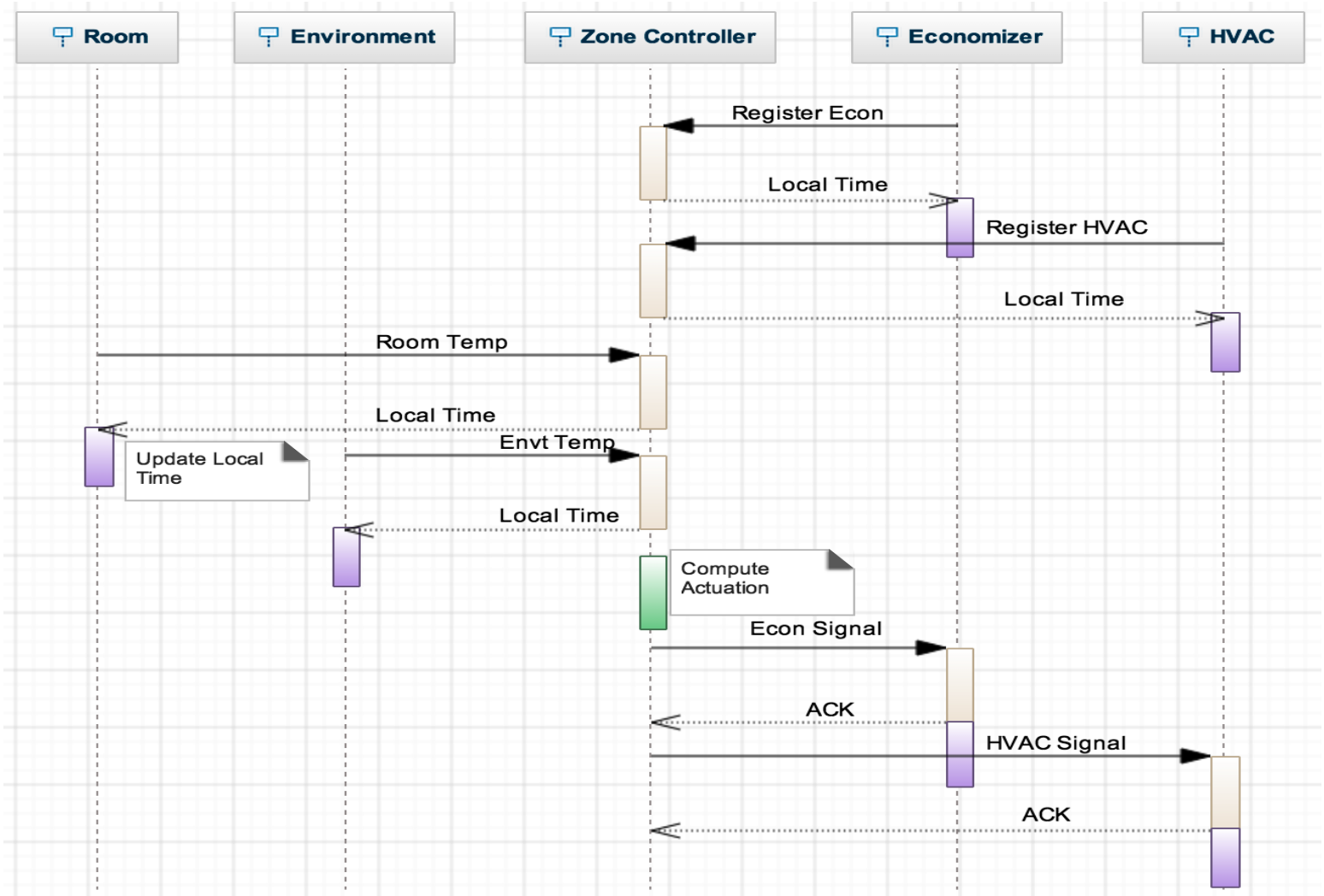
  3 Red LEDs on board

  - Sig 1: Fully Open(1 LED ON)
  - Sig 2: Partially Open (2 LEDs ON)
  - Sig 3: Fully Closed (3 LEDs ON)

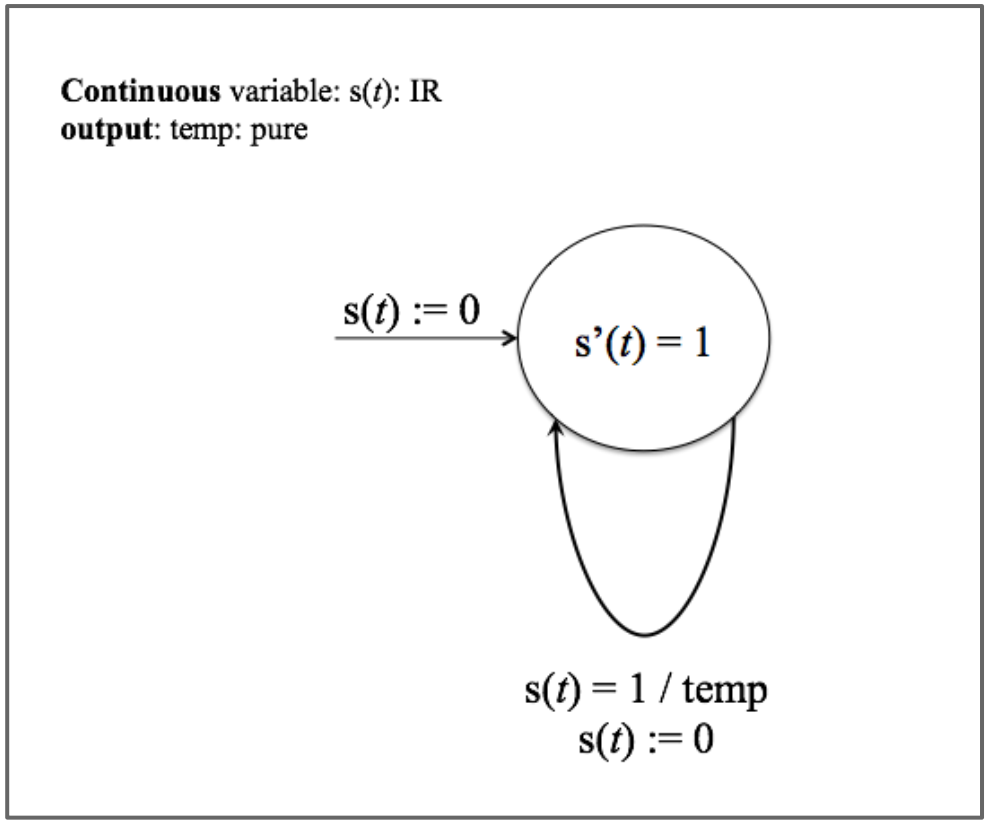
Sequence of Messages Sent

HTTP/JSON

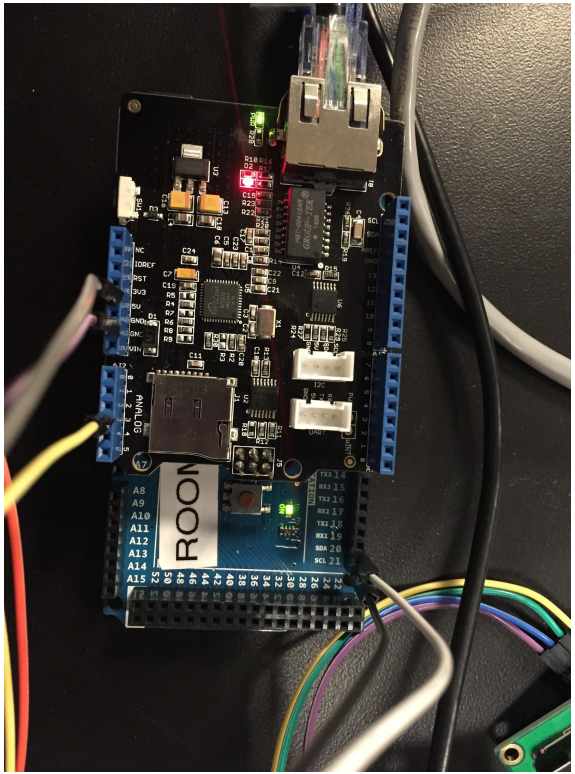
- Actuators register with Z.C
- TMP36 sends UUID, Temperature and Timestamp
- Z.C responds with local time
- Z.C sends Signal and local time to actuator

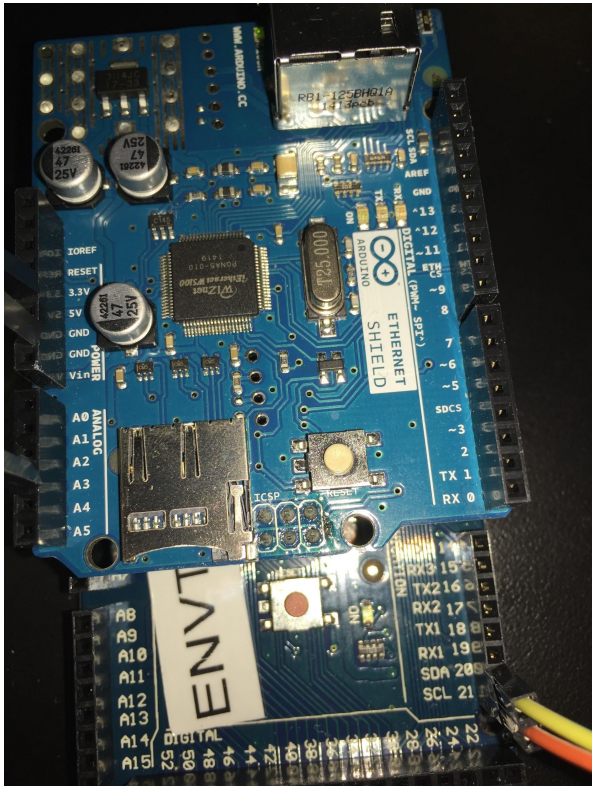

Room
Environment
Zone Controller
Economizer
HVAC
Register Econ
Local Time
Register HVAC
Local Time
Room Temp
Local Time
Update Local Time
Envt Temp
Local Time
Compute Actuation
Econ Signal
ACK
HVAC Signal
ACK

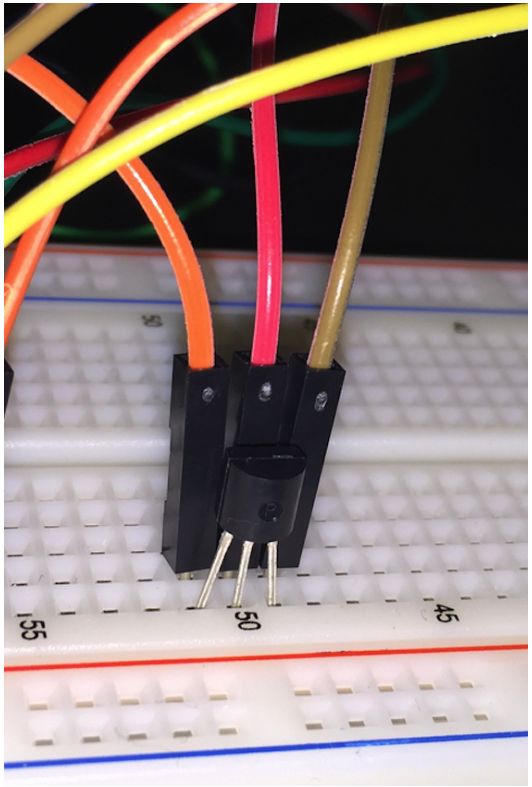
Sensor FSM


Continuous variable: s(*t*): IR
output: temp: pure
s(*t*) := 0
s'(*t*) = 1
s(*t*) = 1 / temp
s(*t*) := 0

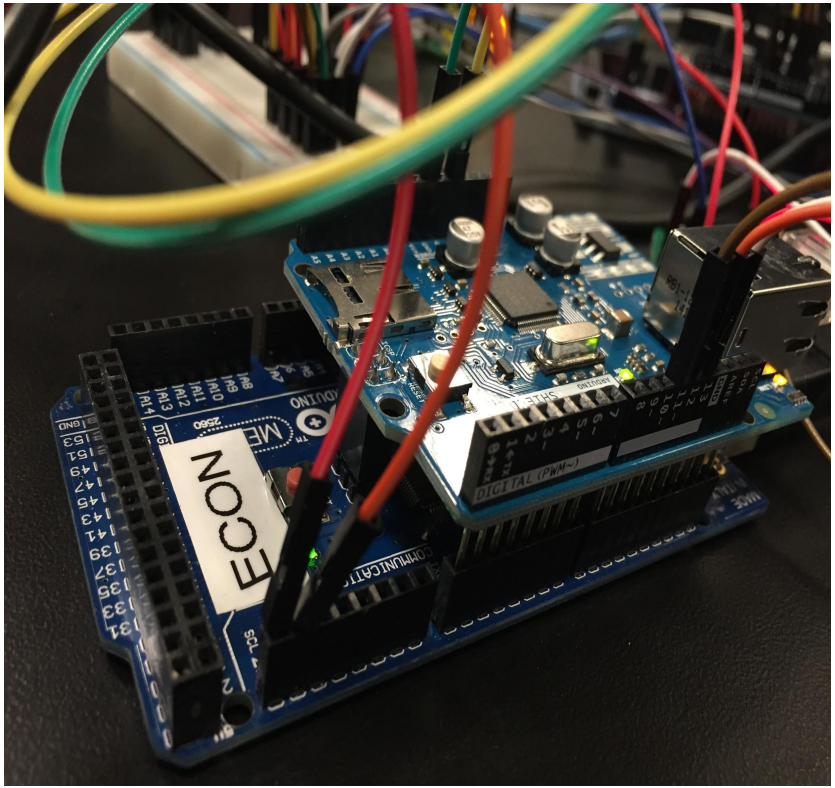
Source of Sensor Data

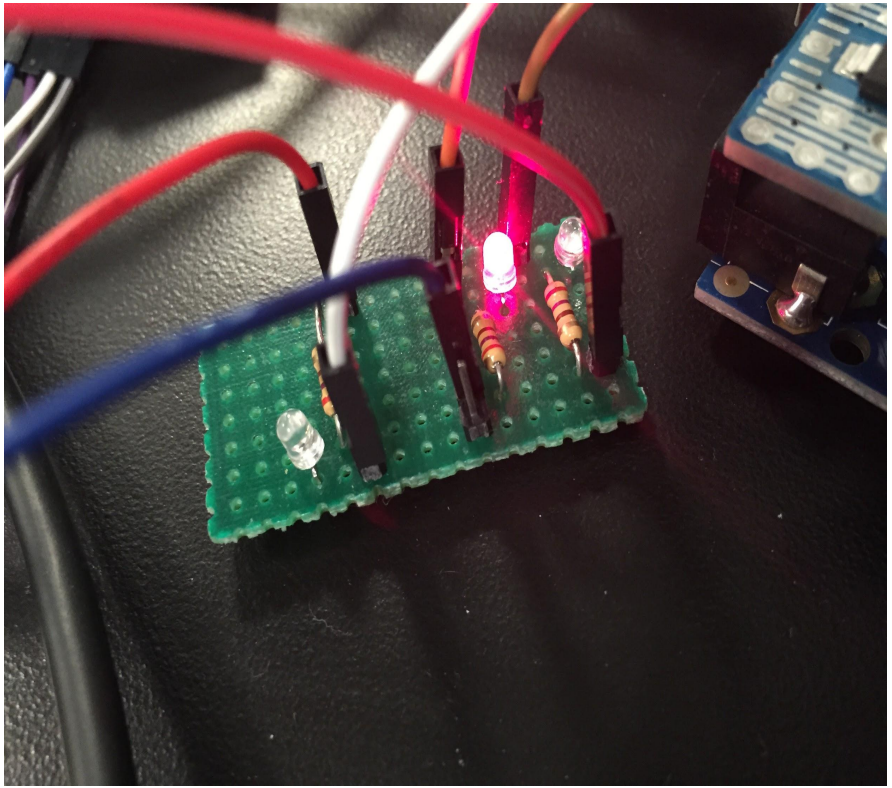




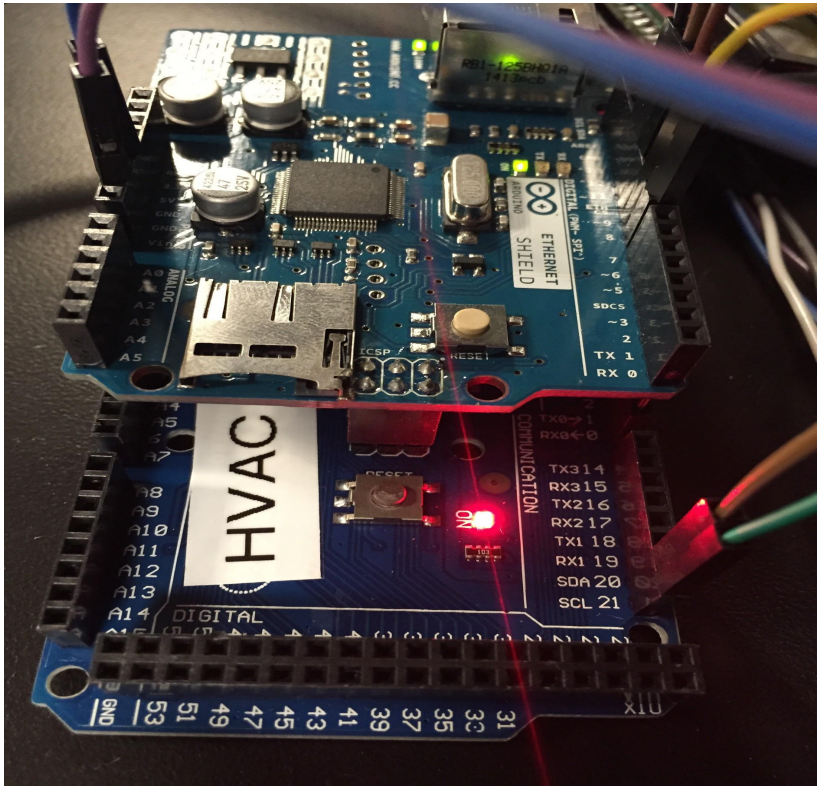


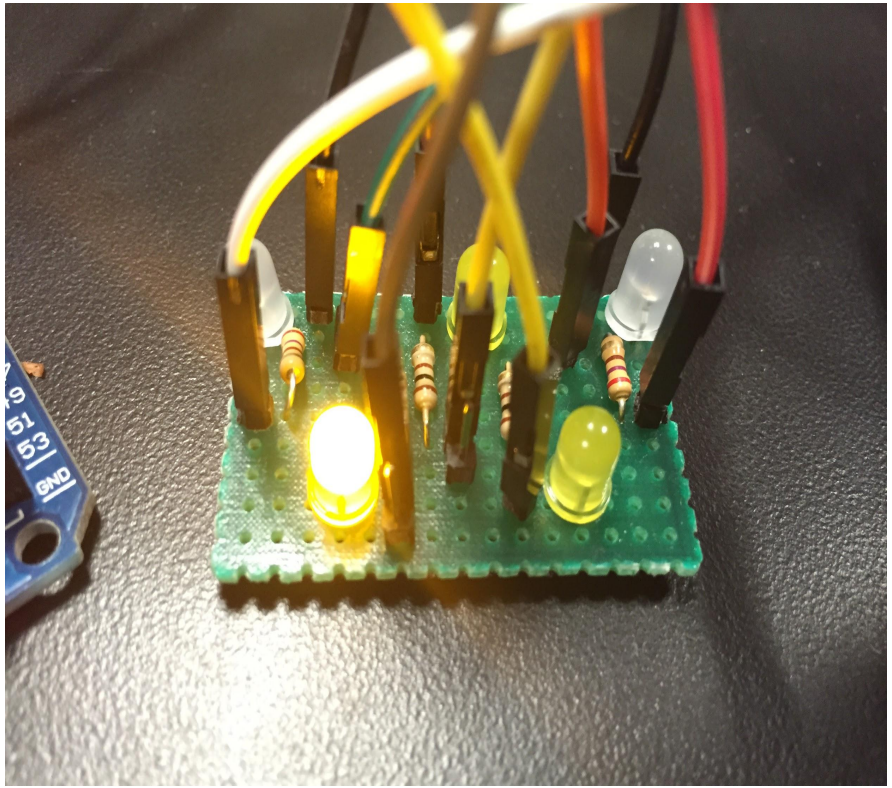
Actuators - Economizer



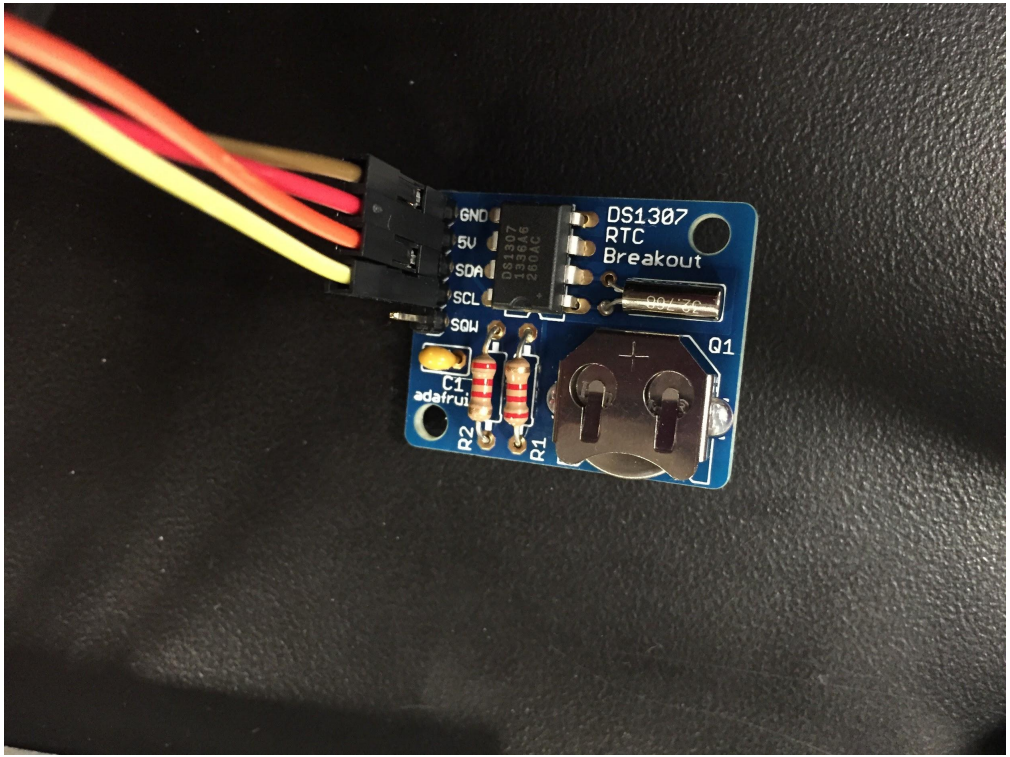


Actuators - HVAC



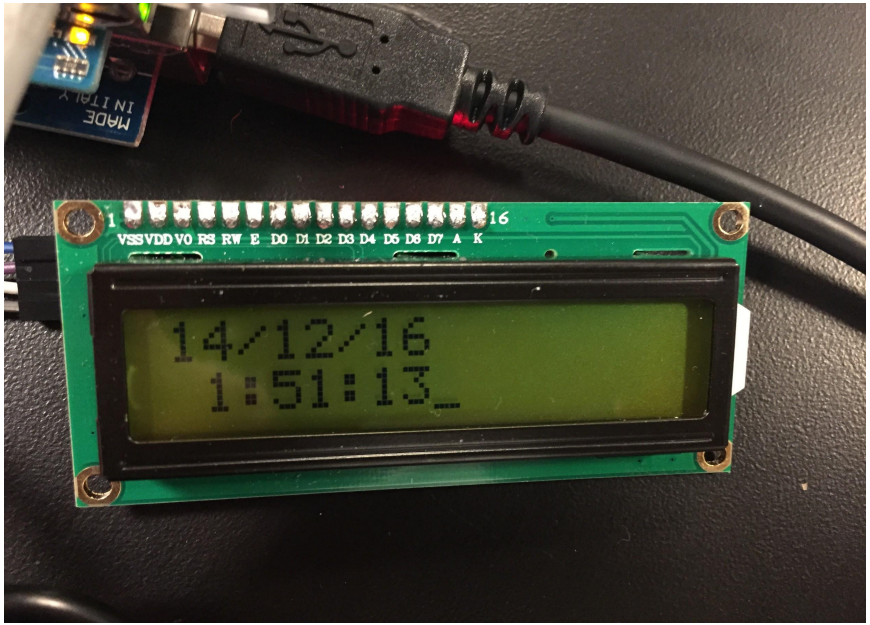


Real Time Clock (DS1307)

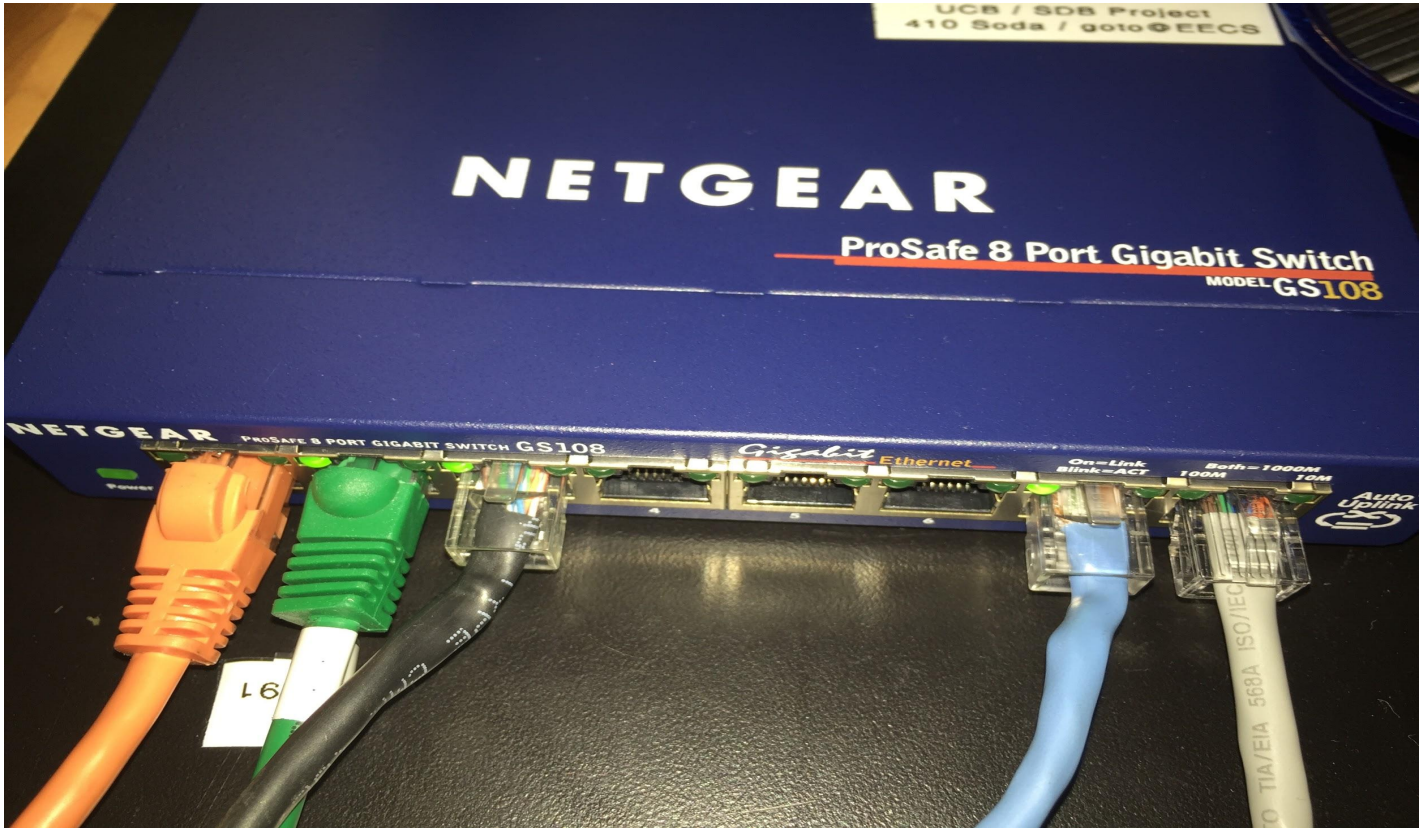


LCD Shield

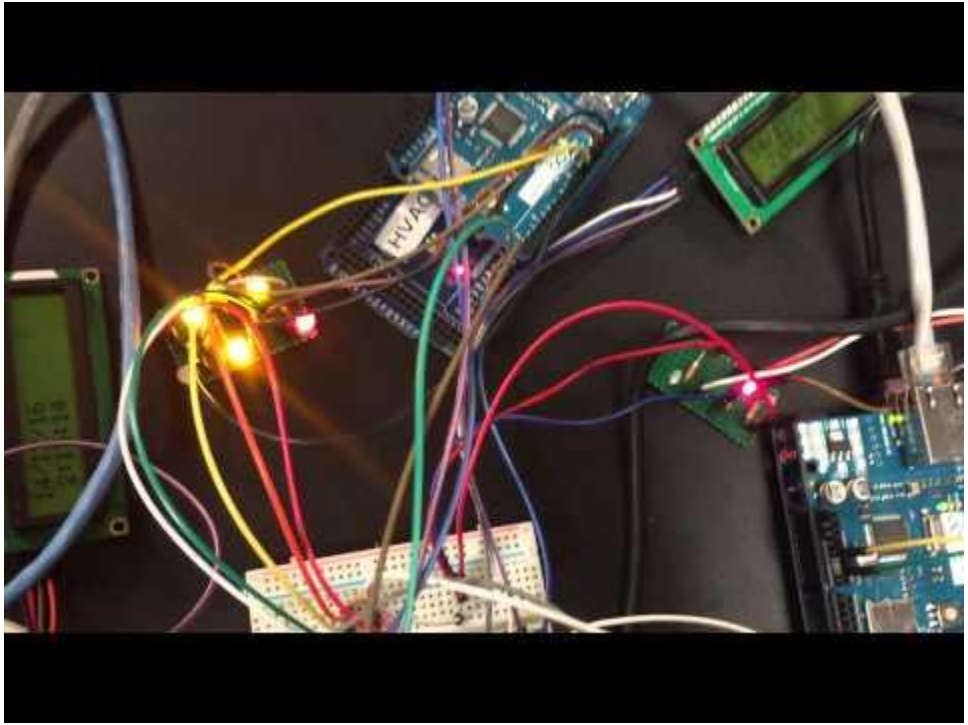

14/12/16
1:50:32


VSSVDDV0 RS RW E D0 D1 D2 D3 D4 D5 D6 D7 A K
14/12/16
1:51:13

Network Switch



Project Video



Challenges

- Actuators sometimes miss a signal
  - Arduino - No support for threads
  - RTC precision - 1 sec
  - Finer control by using Timers on Arduino for extra precision
- Ethernet Libraries were incompatible
  - Seeed Studio (EthernetV2_0)
  - Standard Arduino (Ethernet)

References

1. http://www.arduino.cc/
2. http://www.seeedstudio.com/wiki/Ethernet_Shield_V2.0
3. https://github.com/SoftwareDefinedBuildings/smap/wiki/Zone-Controllers
4. http://bottlepy.org/docs/dev/index.html
5. Dawson-Haggerty, S., Jiang, X., Tolle, G., Ortiz, J., & Culler, D. (2010, November). sMAP: a simple measurement and actuation profile for physical information. In Proceedings of the 8th ACM Conference on Embedded Networked Sensor Systems (pp. 197-210). ACM.