Laboratory Environment Monitoring, Safety and Control System

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Northern Kentucky University
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PEOPLE WHO ARE REALLY SERIOUS ABOUT SOFTWARE SHOULD BUILD THEIR OWN HARDWARE.

— Alan Kay; Apple Fellow, Senior Fellow HP Advanced Software Research Team, Fellow of the American Academy of Arts and Sciences

PRESENTATION OUTLINE

- Origin of the Project
- Functional Requirements
- Project Deliverables
- Electronic, Hardware and Software Design
- Financial Analysis
- Project Summary
- Future work
- Acknowledgements

L.M.C.S. ORIGIN

Illustration Credit Courtesy of CINSAM, 2018

- Dr. Morteza Sadat-Hossieny established the development of an electronic control unit for the Kawasaki robot safety cage as a research project with CINSAM (Center for Integrative Natural Science and Mathematics)

- I was honored to be selected as the award candidate for this project and worked with Dr. Sun to expand the project to include a GSM (Global System for Mobile) data interface and environmental monitoring

L.M.C.S. FUNCTIONAL REQUIREMENTS

I. ***Control functions:*** power and control two multi-sensor light curtains to prevent movement of the Kawasaki robot while a person is present within the safety cage of the robotic system.

II. ***Functions to monitor the lab environment:*** sensors monitor temperature, humidity and light levels and compare them against preconfigured parameters.

III. ***Communication and Control functions:*** the lab manager, NKU security and authorized students will have remote access to request reports of the current lab environment, issue arm or disarm commands and receive immediate notification of breaches of the safety cage via GSM plain text messaging.

L.M.C.S. PROJECT DELIVERABLES

MAIN CONTROL UNIT	OPERATING CODE	LIGHT CURTAINS	DOCUMENTATION
• Develop PCB with connections for peripherals: • Speaker • LED indicators • OLED display • PB switches • Key-lock switch • SIM 900 cellular transceiver • Power supply • Enclosure	• Written in “C” and structured according to IEEE best practice. • All functions group matched to the schematic. • Variables name matched to nets. • Auto-error correcting and self-booting. • Well commented.	• Two units consisting of four IR photo-reflective sensors. • Custom PCBs (2) to provide power to the sensors and 4 to 1 logic gates for control signals. • Mounting hardware • Enclosures	• CINSAM poster • Project presentation • Project final report to include: research findings, correlation with coursework, bi-weekly updates, detailed financial analysis and final outcomes summary.

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L.M.C.S. ELECTRONIC DESIGN

- Selected the ATmega 1284 microcontroller
  - 8-bit AVR RISC architecture
  - 16Mhz external crystal
  - 128Kb flash
  - 14Kb EEPROM

Illustration credit Atmel 2018

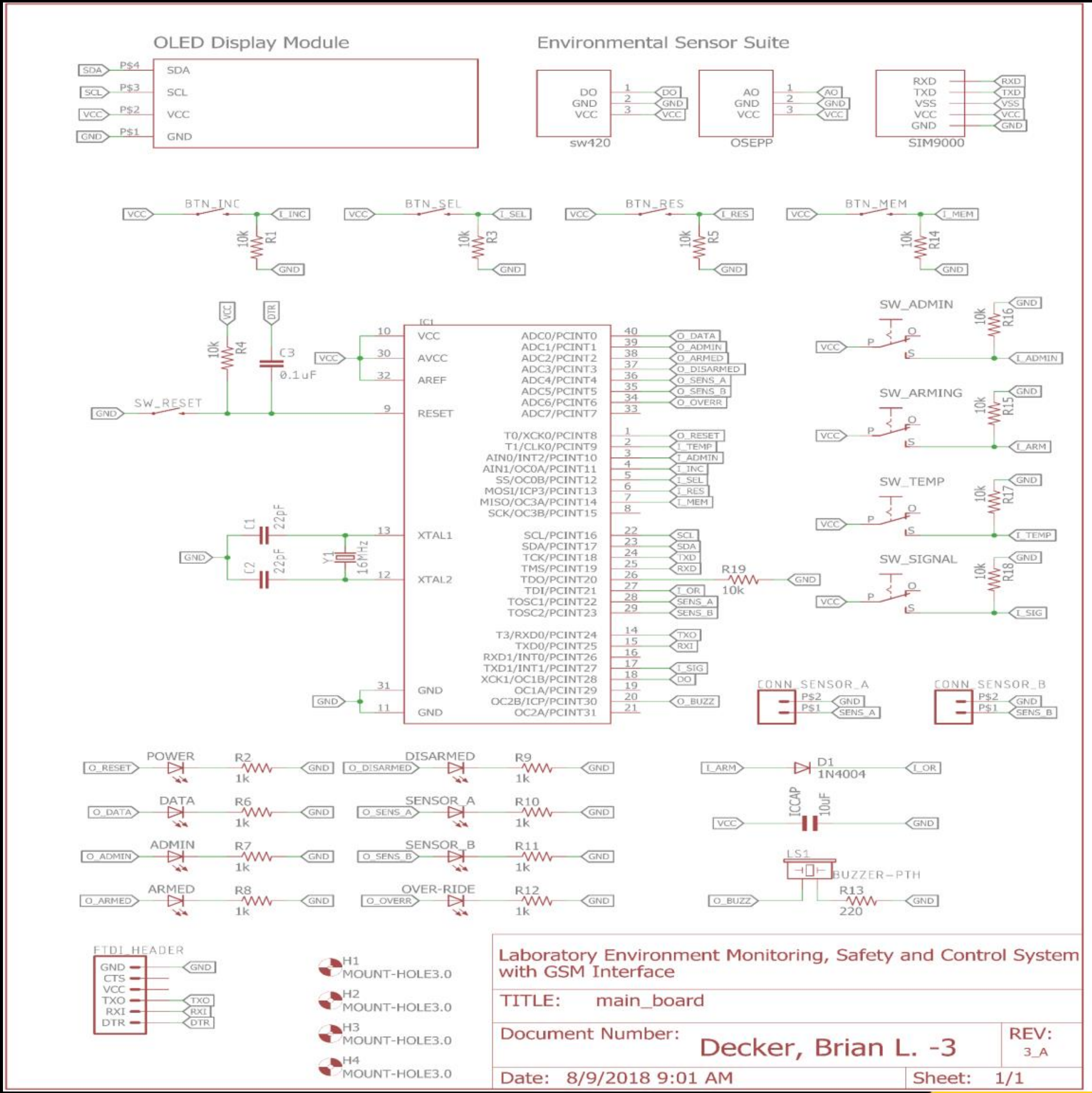
- Considerations
  - Robust microcontroller designed for automotive industry.
  - Large EEPROM allows for storage of multiple phone numbers, text message templates and provisions for data and event logging.
  - **High level of familiarity with this microcontroller and the Visual Micro programming environment.

L.M.C.S. ELECTRONIC DESIGN

- Utilized AutodeskEAGLE for all aspects of PCB design

- Schematic conforms to IEEE standards:
  - Flagged connections
  - Functional grouping
  - Component ID / NET matching
  - Manufacturer footprints

- Final design tested with integrated SPICE simulator



L.M.C.S. ELECTRONIC DESIGN

- Main PCB went through several revisions. Utilizes JST-PH connectors for LED indicators and header pins grouped by function for OLED, SIM900, Input buttons, Key switch and FTDI programming header
- Routing performed manually with angled trace junctions and a poured ground plane to reduce signal noise

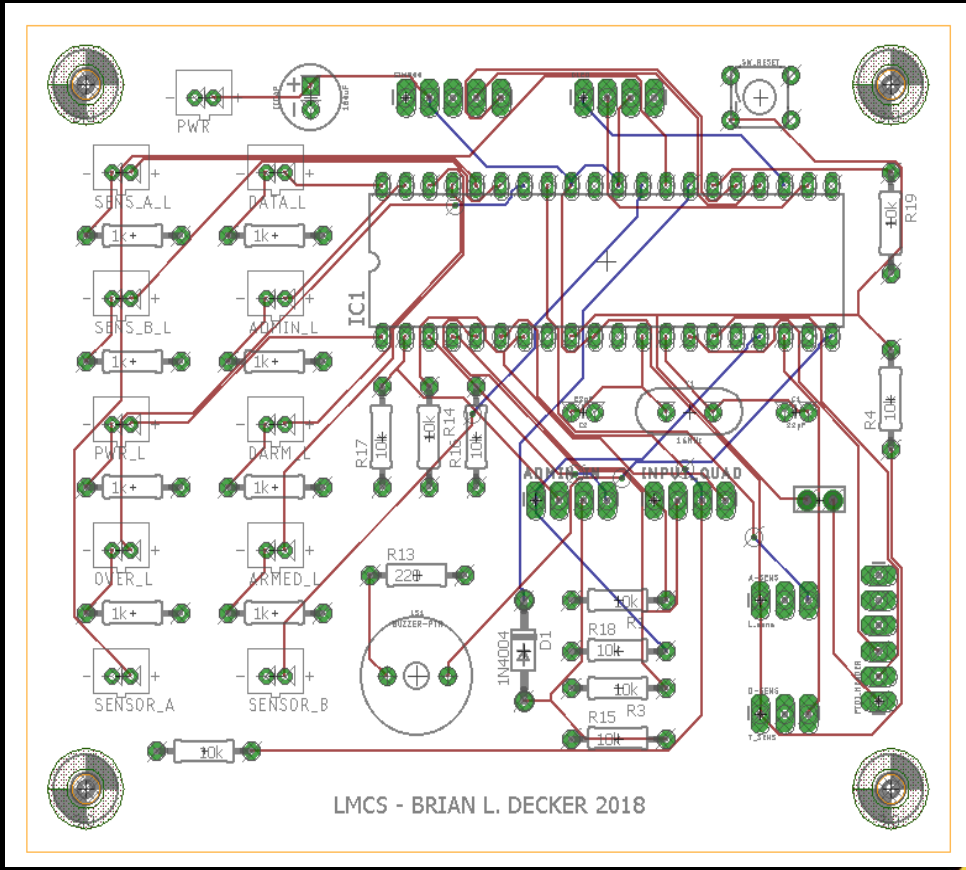
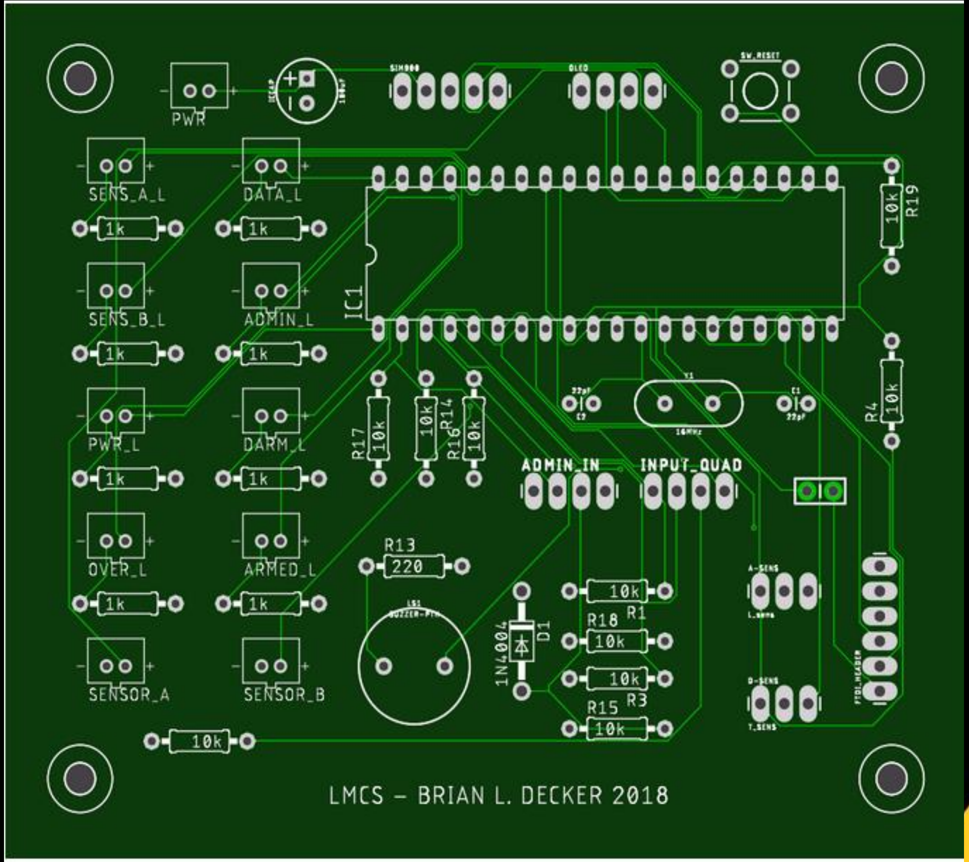


Illustration credit Brian L. Decker,2018

L.M.C.S. ELECTRONIC DESIGN

- Gerber file view for silkscreen verification and footprint dimensioning.
- SEEED Fusion selected as board house due to prototype pricing and quality of final board.
- Component grouping aligned with schematic for ease of test references and debugging.



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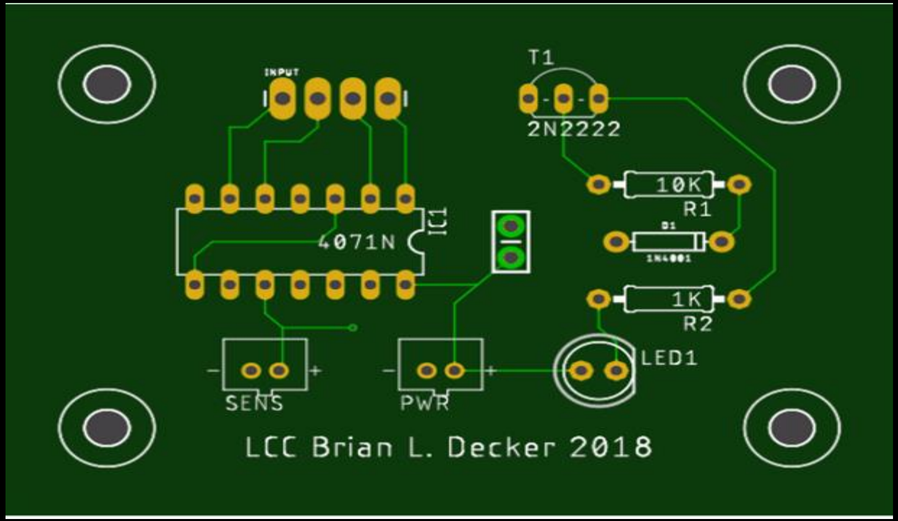
L.M.C.S. ELECTRONIC DESIGN

- Commercial light curtains and their associated controllers were out of the budget scope of this project.

- Designed a simple 4-1 signal condenser utilizing a CMOS 4071N with diode protection and transistor switching. Each light curtain consists of four IR photo reflective sensors



L.M.C.S. ELECTRONIC ASSEMBLY

- All pads and traces verified against the schematic for continuity and proper identification.

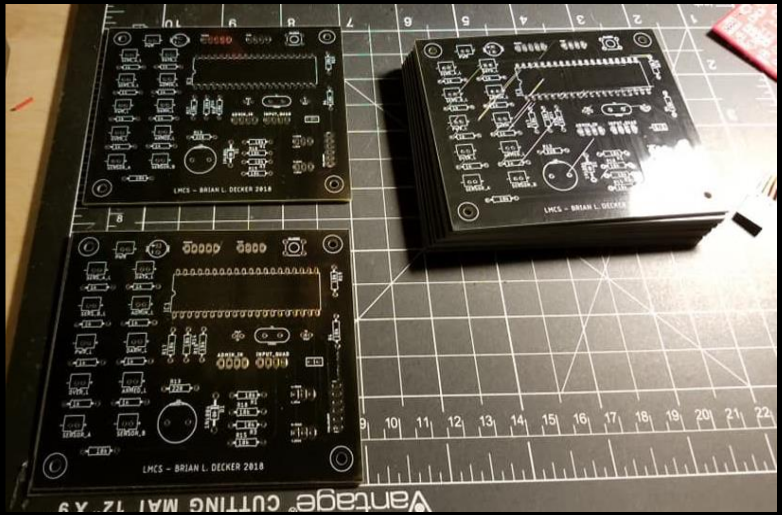


Photo credit Brian L. Decker 2018

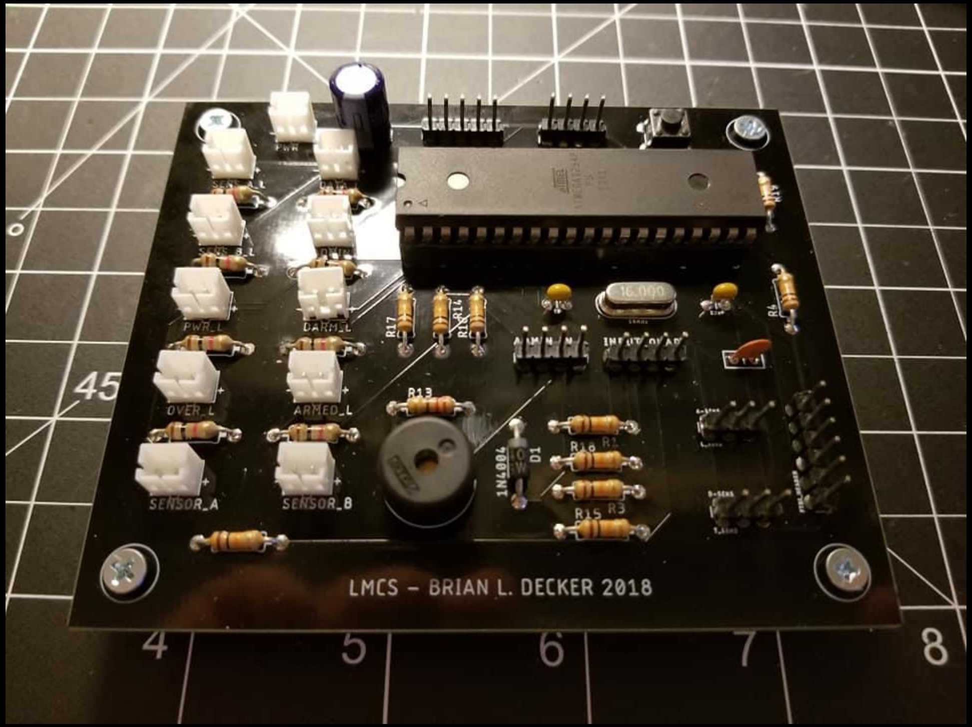


Photo credit Brian L. Decker 2018

- Components assembled using a Hakko FX-888D pen-type iron and Loctite EN 60 0.5mm multi-core solder.

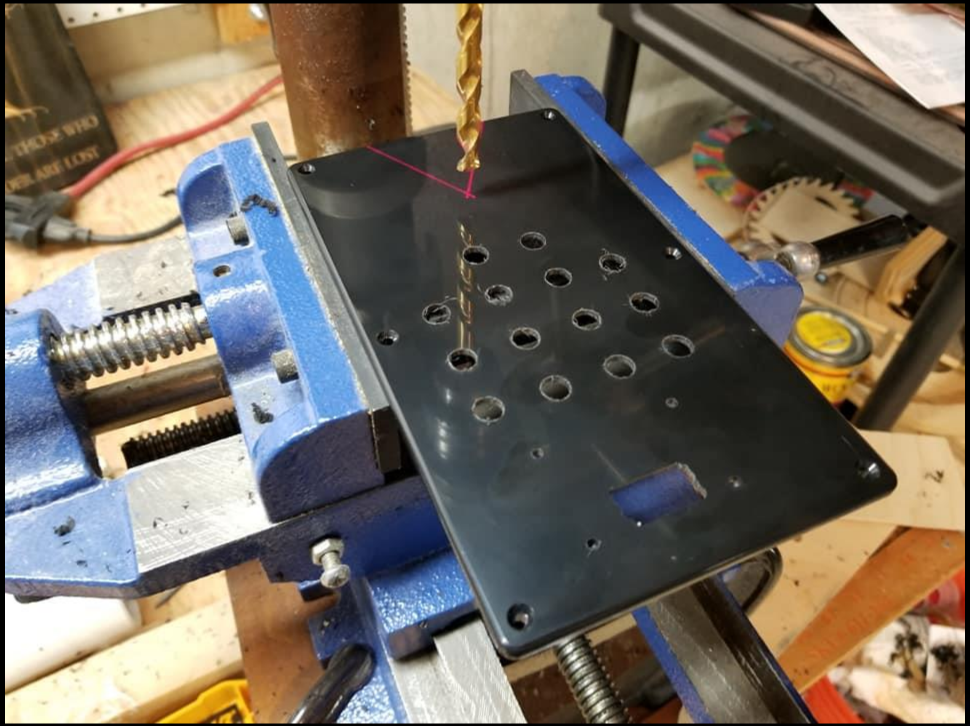
L.M.C.S. HARDWARE DESIGN

- Robust user interface
  - Locking key switch to select operational state
  - OLED display
    - Time, Date, Temp, Humidity, GSM signal strength and operational state
    - Admin functions
  - Four Button I/O
    - Data entry**

L.M.C.S. HARDWARE DESIGN

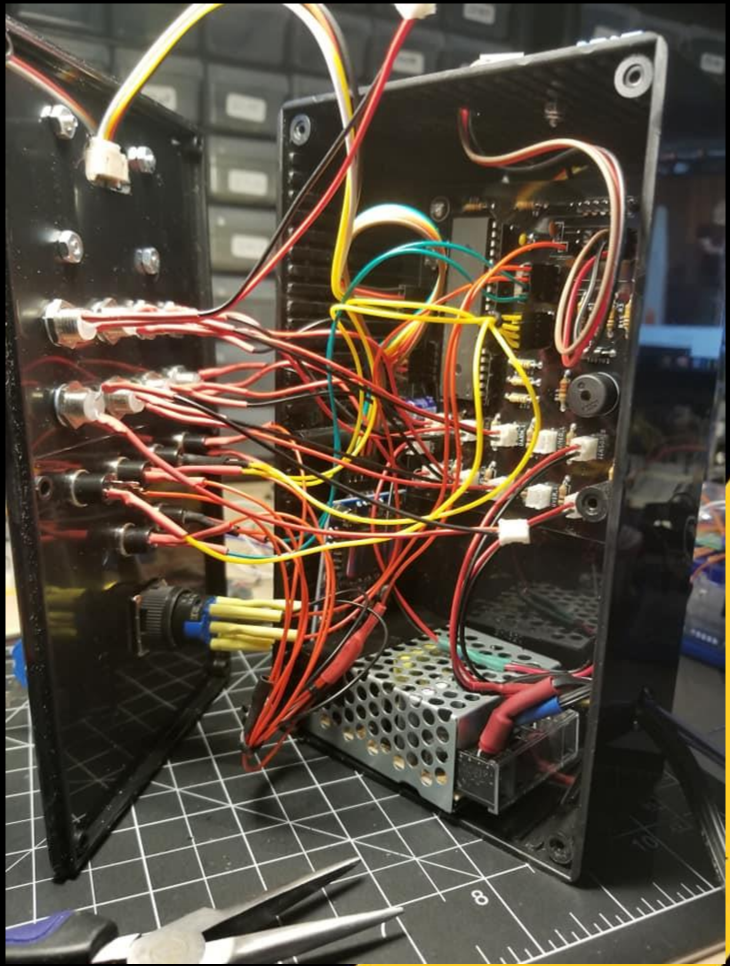
- Main PCB, user interface and power supply integrated into a standard ABS electronics enclosure.

- Used a X/Y translation table and mill/drill to locate and cut cutouts for LED indicators, OLED display, switches and mounting points for PCB standoffs and power supply.



L.M.C.S. HARDWARE ASSEMBLY

- Main PCB, user interface and power supply are integrated into a standard ABS electronics enclosure.
- All wire assemblies, splices and connections soldered using a Hakko FX-888D pen-type iron and Loctite EN 60 0.5mm multi-core solder.
- All lug connections and splices insulated via heat-shrink tubing.



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L.M.C.S. OPERATING SYSTEM DESIGN

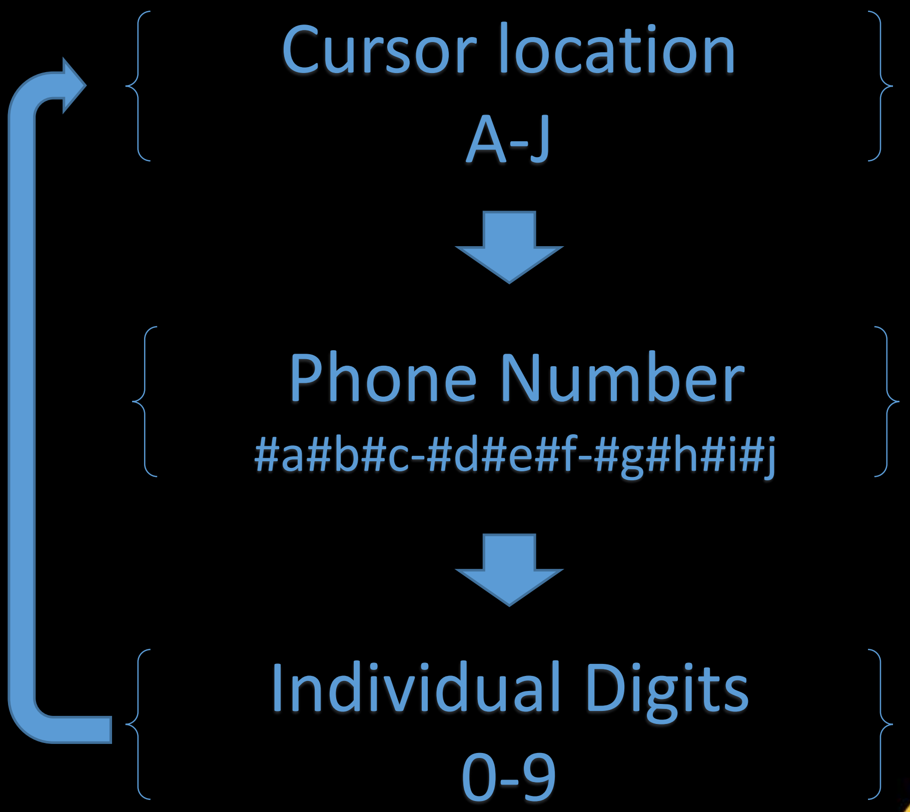
- Code developed using the Visual Micro plugin for VS2017.
- Final code base ~1800 lines “C”
  - Basic operations: UI I/O, light curtain signals, environmental sensor signals, LED indicators, switch debouncing and startup bootstrapping.
  - OLED display: cursor, fonts for text output of operational state, temperature, humidity and GSM signal strength output interpreted to text, phone numbers, date and time.
  - SIM900 tasks: cellular network “handshake”, text message I/O parsing and command execution.

L.M.C.S. OPERATING SYSTEM DESIGN

- Dr. Sun asked how I would allow for users to edit/update phone numbers.
- Shot down my proposal of a standard 4x4 keypad as “too easy”.
- Solved the “4 button input” by writing a set of nested arrays:
  - A *digits array* with decimal 0-9.
  - A *phone number array* to hold the 10 digits of a phone number.
  - A *cursor location array* that defines the pixel location of the OLED cursor.
  - The standard EEPROM address data table.

L.M.C.S. OPERATING SYSTEM DESIGN

- When the key switch is placed in the “admin” position the OLED displays numbers stored in EEPROM or 10 “0” for empty number.
  - Cursor starts under 1st number and phone number array correlates that position to array address 0.
  - Pressing INC increments number from 0 to 9 to 0.
  - Pressing SEL moves cursor beneath 2nd number and increments phone number array to address 1.
  - Pressing MEM once numbers are set calls a EEPROM update function and stores the number.

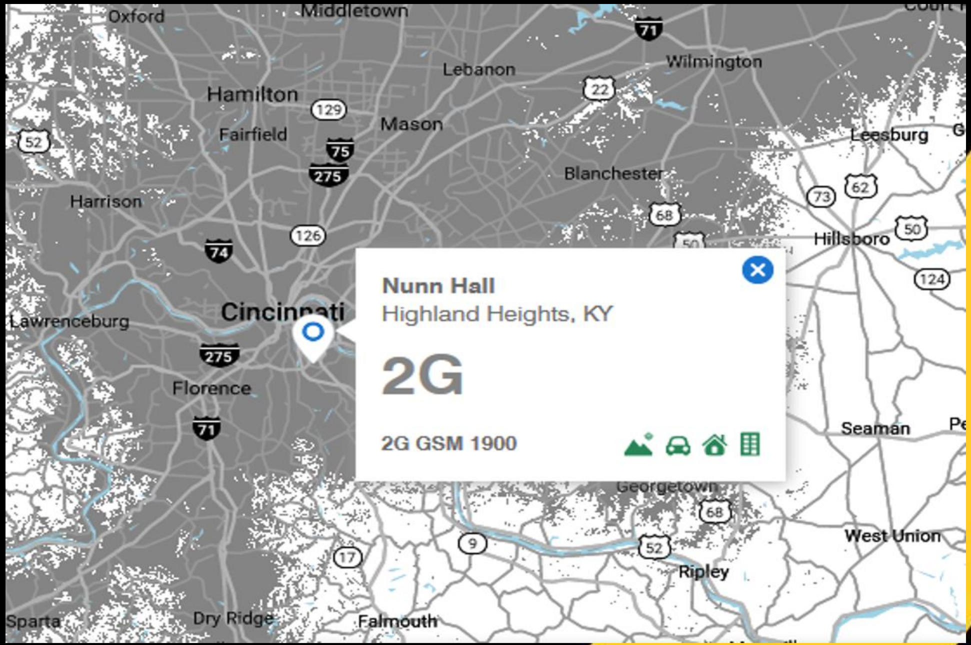


L.M.C.S. OPERATING SYSTEM DESIGN

- Focus of CINSAM research and key feature of the L.M.C.S is the use of parsing plain text GSM messaging for both sending alert notifications and receiving commands.
  - If environmental parameters are exceeded, either light curtain triggered while in a system run state or other alert states messages are immediately sent to designated cell phones.
  - Designated phones may also issue “System Arm” commands and request “Lab Environment” updates via plain text messages.

GSM®
GLOBAL SYSTEM FOR
MOBILE COMMUNICATIONS

Illustration credit GSM Dir 2018



L.M.C.S. COST ANALYSIS

- Overall part cost: $73.24
- Unit Cost: $123.24
- MSRP (Unit Cost*2.75) : ~$350.00
- Ongoing SIM (9*2.75): $24.75/month
- Rev per unit: $225+$189/year
- ROI ($25*480): $12,000/225 = 53
- Units/MM: ~4,500

PART	COST
LED	$1.50
SPST Slide	$3.25
SPST Momentary	$2.00
Capacitors	$3.23
Prog Header	$1.63
FTDI - header	$4.10
1N4004	$0.10
Atmega 1284	$5.13
OLED	$2.83
Buzzer	$0.78
Resistors	$4.25
SW-420	$3.28
16Mhz crystal	$0.49
SIM-900	$20.99
Type 86 Case	$4.68
Shipping	$15.00
parts subtotal	$73.24
assembly (2hrs)	$50.00
Unit Cost	$123.24
MSRP	$338.91
TING Sim (month)	$9.00

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L.M.C.S. PROJECT SUMMARY

- ***Main PCB, Enclosure, Light Curtain Controller and Sensors:***
  - *All delivered on time and within budget. Prototype development led original timelines and allowed for further code refinement and testing.*
  - *Lesson Learned – an additional I/O PCB mounted to the faceplate of the enclosure directly would be a better solution than the use of individual JST-PH plugs.*
- ***Operating System Code:***
  - *Completed on anticipated timeline and meets all functional requirements.*
  - *Lesson Learned – matching functions to the schematic and variables to PCB nets was very helpful during debugging and integration.*
- ***Findings Summary:***
  - *The combination of GSM data transcieving and a plain text parsing algorithm creates a powerful means of extending cellular services beyond voice communication and services currently provided by “apps”.*

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L.M.C.S. FUTURE WORK

REMOTE SENSING	CONSUMER SERVICES	SAFETY SERVICES	BUSINESS SERVICES

• A variety of sensors can be configured for use with the core L.M.C.S. processor:
  • Weather data
  • Environmental hazard detection and warning
  • Tankage leaks or spill basin levels
	• Verification of deliveries to home, office or unoccupied location
	• Security services for remote storage units, off grid farm buildings, gate status or access request
		• Verification of co-location to a transmitting device by children, the elderly, or others whose location and ability to act is needed.
		• Safety alerts in instances of acute incapacitation or emergency
			• Inventory control and communication
			• Security of access and notification of occupation state
			• Notification of trespass
			• Verification of employee colocation to transmitting device

L.M.C.S. ACKNOWLEDGEMENTS

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CINSAM

Digi-Key CORPORATION

seeed studio

Encom Lab

INDIVIDUALS AND FACULTY:

- Dr. Morteza Sadat-Hossieny, Program Director
- Dr. Gang Sun, Faculty Advisor
- Dr. Mark Keshtvarz Faculty Advisor
- Pam Kremer, Administrative Support
- Roger Miller, Laboratory Advisor
- Hadley Decker

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