Group 12
Shenmin Lo, EE
Joseph Lunder, CpE
Siarhei Traskouski, EE
Robert Wadsworth II, EE

Motivation

- To allow players separated across great distances to play Chess together
- To streamline the process of practicing Chess against an AI
- To create an elegant physical and virtual environment that is easy to use
- To put a spin on traditional gameplay and create a new way to play a classic game

Deep RGB?

- Automated Chess Board
  - Use magnets to move pieces
  - Take input physically from user
  - Correct user errors
  - Visually assists gameplay
  - Multiple playing modes
  - Sends data wirelessly to off-site server
- Web Interface
  - Allow gameplay from any web-enabled device
  - Allow for environment customization
  - Store saved games and other user data

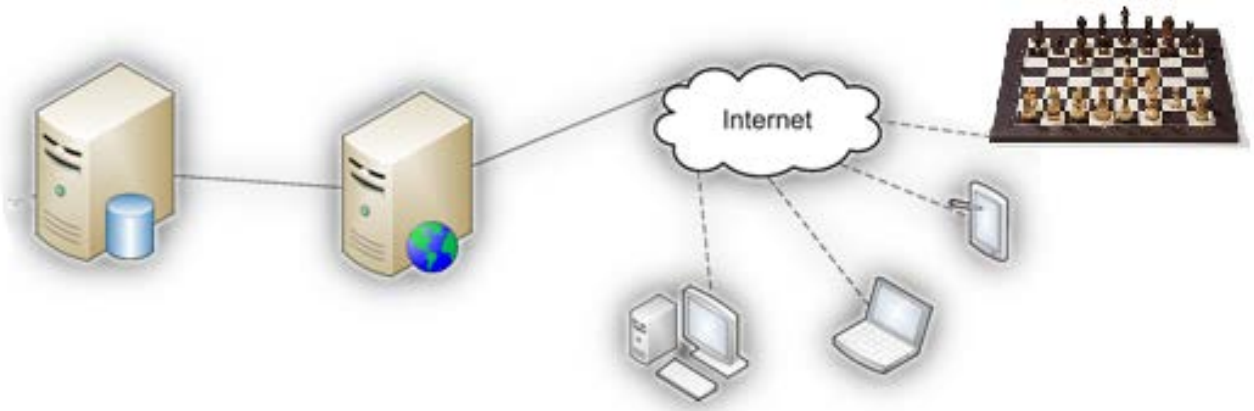
Goals

- Allow for play between human and computer, human and remote human, or two computers
- Connect to server over any available wireless network
- Detect pieces using a Hall-Effect sensor grid
- Make required moves with under-board magnet
- Show available moves via in-board LEDs
- Play selected sound effects depending on game state

Requirements

- Weight of entire unit no more than 10kg
- Dimensions of playing field no larger than 40cm by 40cm
- Dimensions of whole unit no larger than 70cm by 55cm by 20 cm
- Operates under 110-220V 50/60Hz AC
- Pieces positioned with less than 5% error

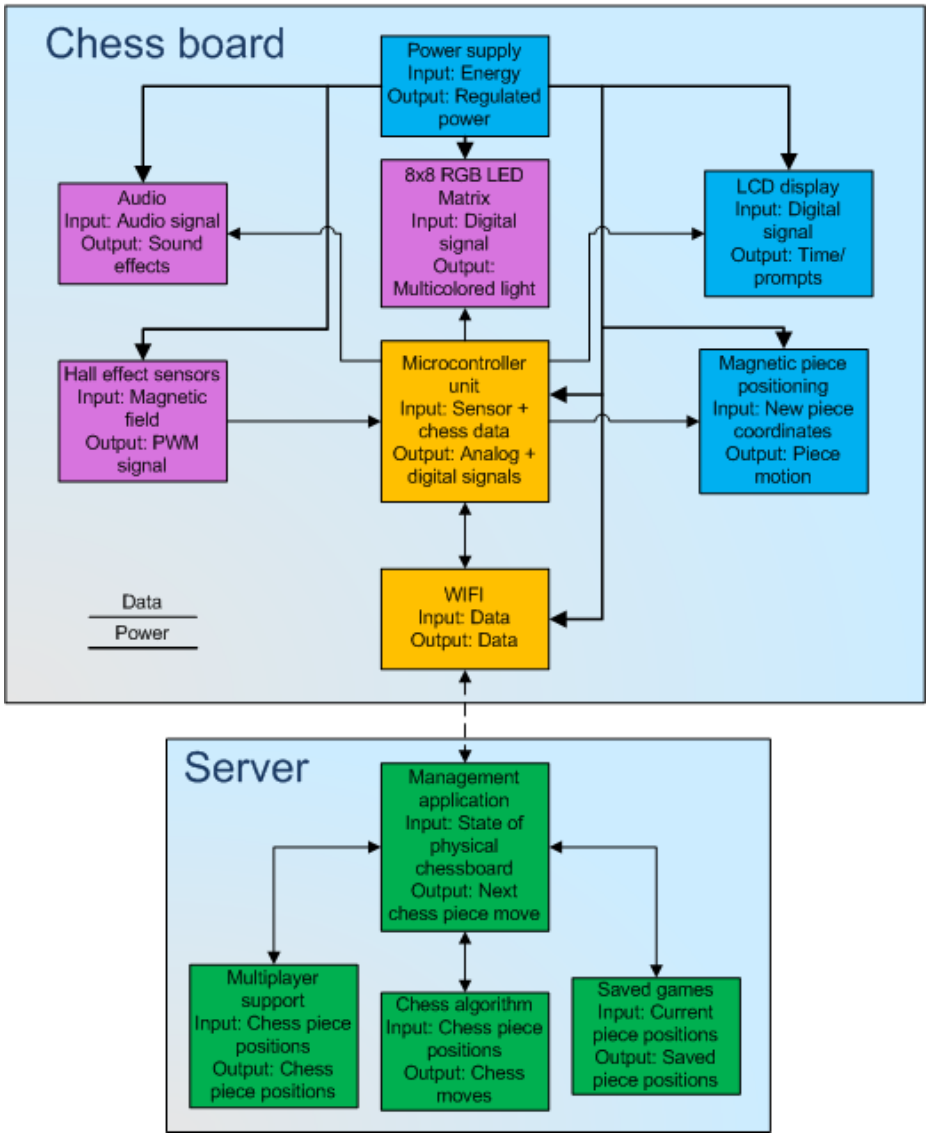
Subsystem Layout

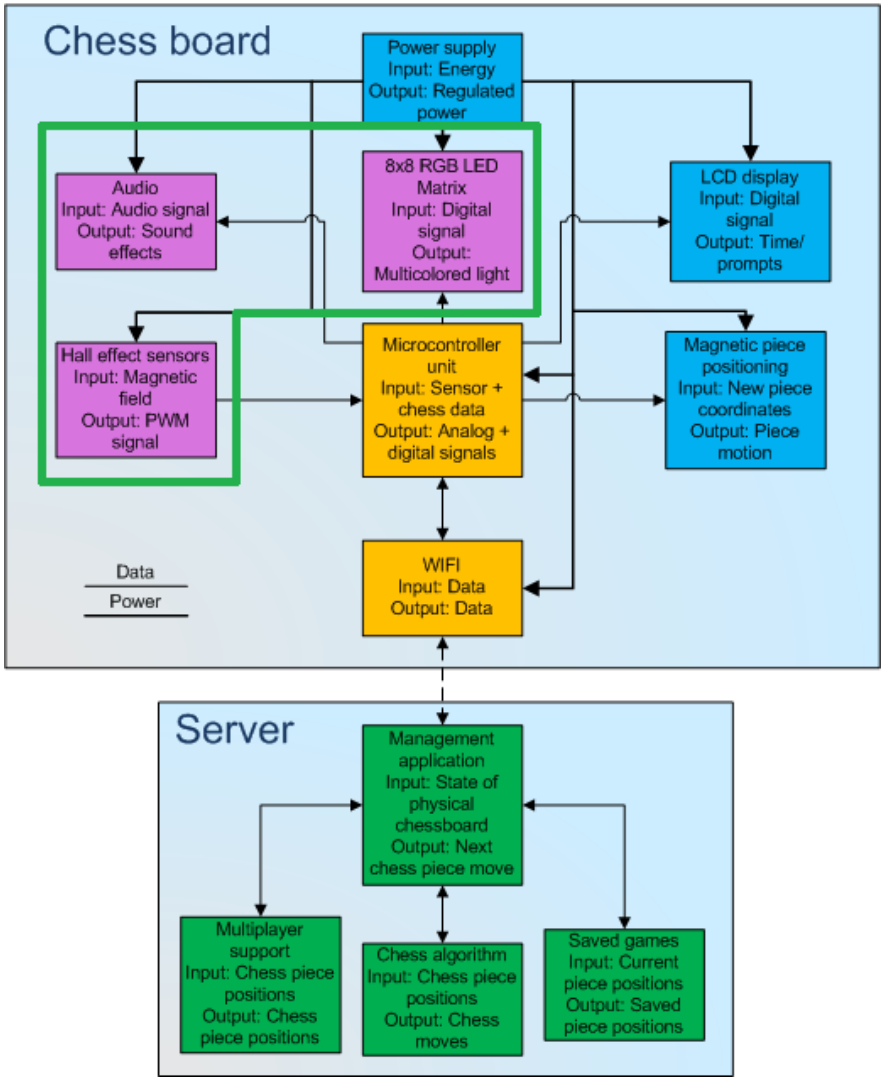


Full System

Labor is divided into hardware and software

- Hardware subsystems
  - Shenmin in yellow
  - Robert in pink
  - Siarhei in blue
- Software subsystems
  - Joseph in green



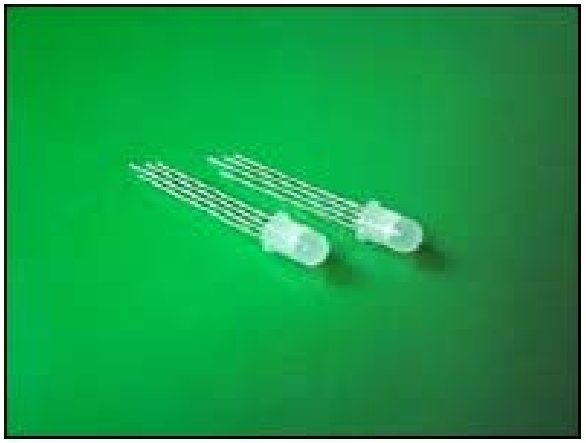

Chess board
Power supply
Input: Energy
Output: Regulated power
Audio
Input: Audio signal
Output: Sound effects
8x8 RGB LED Matrix
Input: Digital signal
Output: Multicolored light
LCD display
Input: Digital signal
Output: Time/ prompts
Hall effect sensors
Input: Magnetic field
Output: PWM signal
Microcontroller unit
Input: Sensor + chess data
Output: Analog + digital signals
Magnetic piece positioning
Input: New piece coordinates
Output: Piece motion
Data
Power
WIFI
Input: Data
Output: Data
Server
Management application
Input: State of physical chessboard
Output: Next chess piece move
Multiplayer support
Input: Chess piece positions
Output: Chess piece positions
Chess algorithm
Input: Chess piece positions
Output: Chess moves
Saved games
Input: Current piece positions
Output: Saved piece positions

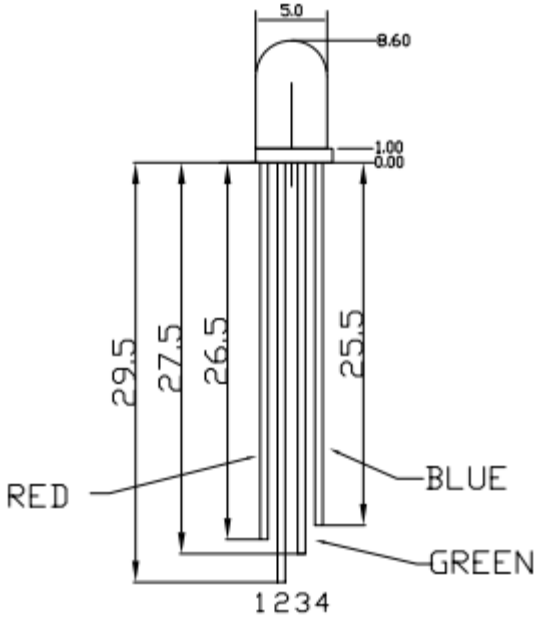
RGB Light Emitting Diodes

	RL5-RGB-C-2	R596CR3G4B5C-C10	R596CR3G4B5W-F12
Operating Voltage (R,G,B)	2.6,4.0,4.0 V	2.2, 3.4, 3.4 V	2.2,3.4,3.4 V
I(Peak)	50mA	30mA	30mA
Viewing Angle	15°	40°	40°
Luminosity	1K-5K mcd	800-4000 mcd	1200-6500 mcd
Diameter	5mm	5mm	5mm
Package	SIP	SIP	SIP
Pins	4	4	4
Price per Unit	$1.59	$0.60	$0.60

R596CR3G4B5W-F12

- Super bright RGB LED
- High Viewing angle
- Compact design
- Capable of creating a wide array of colors
- Low cost when bought in bulk





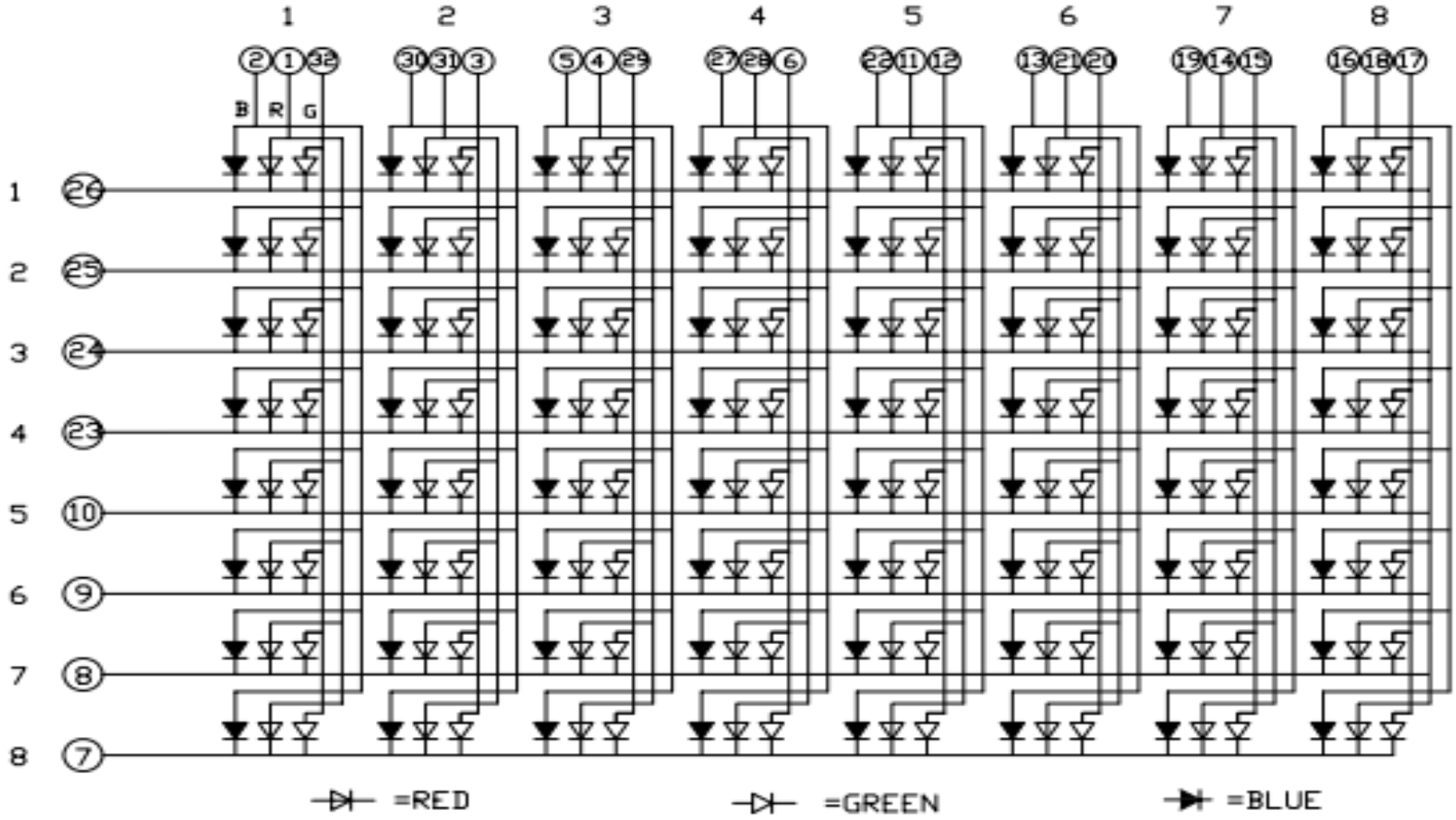
LED Array Functionality

- Display available moves when a piece is picked up
- Draw a line from piece to piece when in check
- Visual queues for errors
- Personalization and user customization

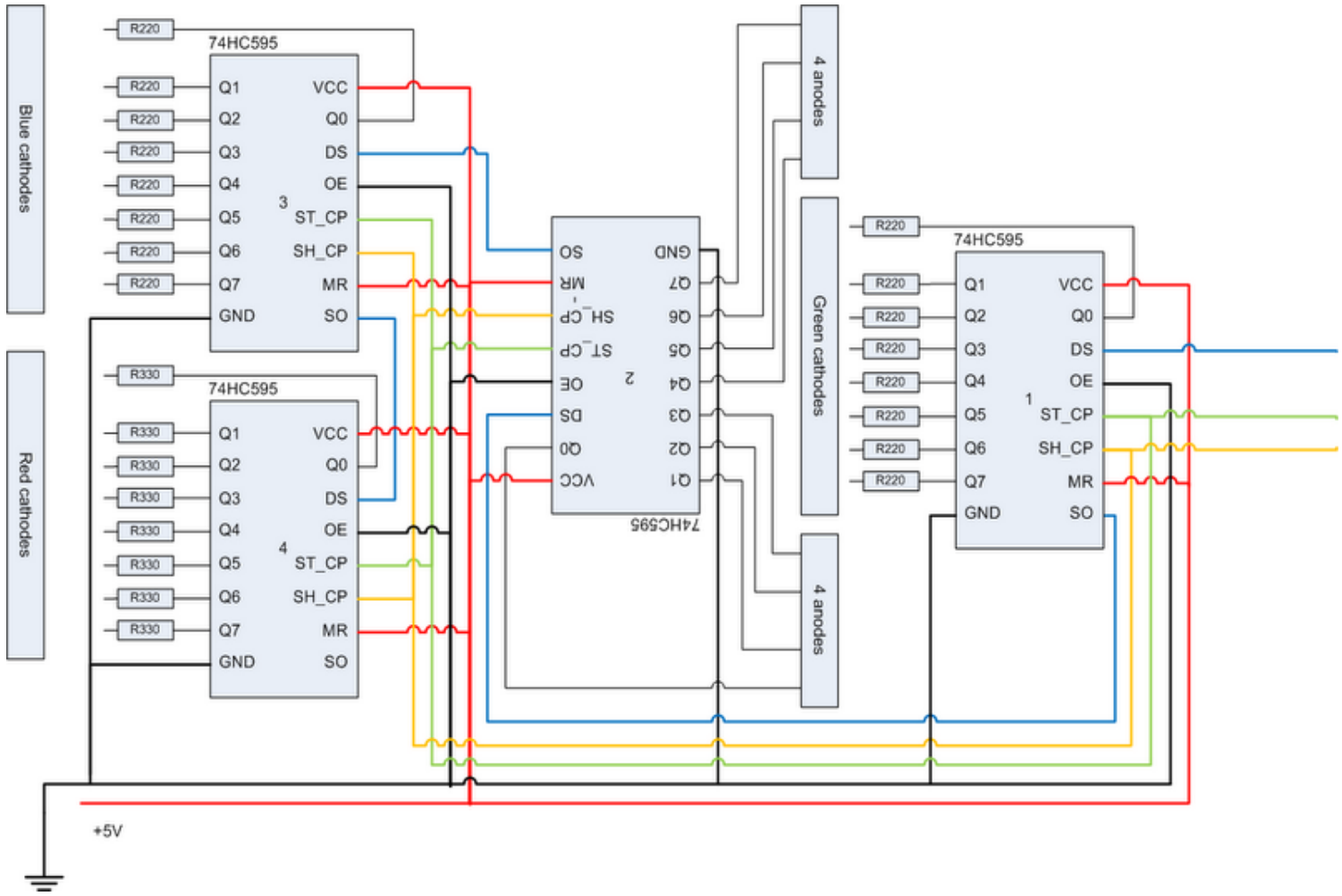
LED Array Implementation

- Each pin is connected to a specific bus running horizontally and vertically
- Each LED is activated one at a time by activating two or more busses
- Busses are controlled using four shift registers connected in series
- Each register controls one group of busses; red, green, blue and anode

LED Array Schematic



Shift Register Configuration

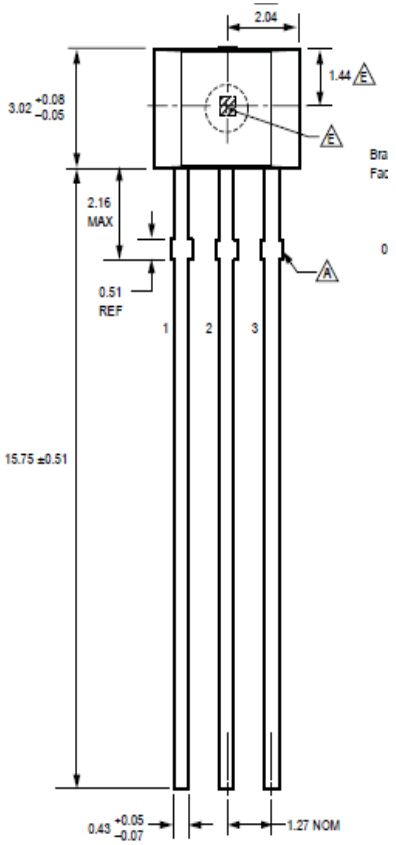


Hall-Effect Sensor

	MLX 90215	A1384	A1302
VCC(recommended)	5V	5V	4.5 – 6V
VCC(max)	5.5V	5.5V	8V
I(max)	6.5mA	8mA	11mA
Package	SIP	SIP	SIP
Pins	4	3	3
Sensitivity	5-140 mV/G	1.4 mV/G	0.85 – 1.75 mV/G
Price per Unit	$2.38	$3.16	$1.54

Allegro A1302

- Linear ratiometric Hall-effect sensor
- Capable of determining range and polarity
- Simple, small and reliable
- Low cost per unit



Hall-effect Grid

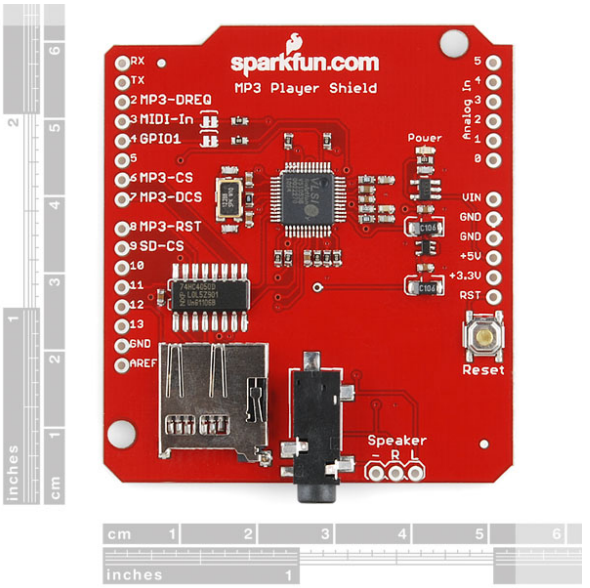
- 2D 9X13 array (117 sensors)
- One sensor in the corner of each tile
- Powered through two 1:16 multiplexers
- Multiplexers controlled by one 8bit shift register
- Output pipelined into one input on the MCU
- Controlled in similar way to the LED array

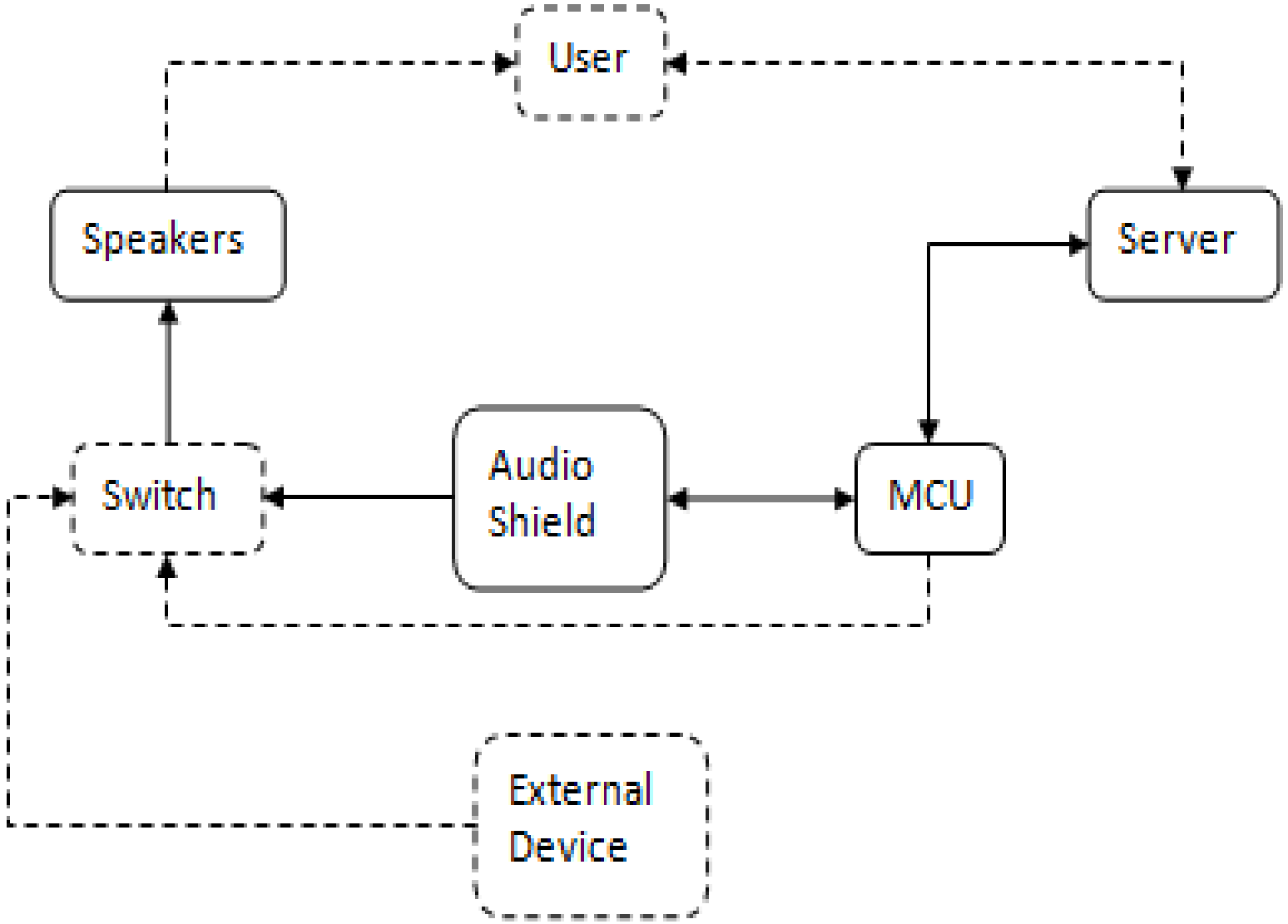
Audio Module

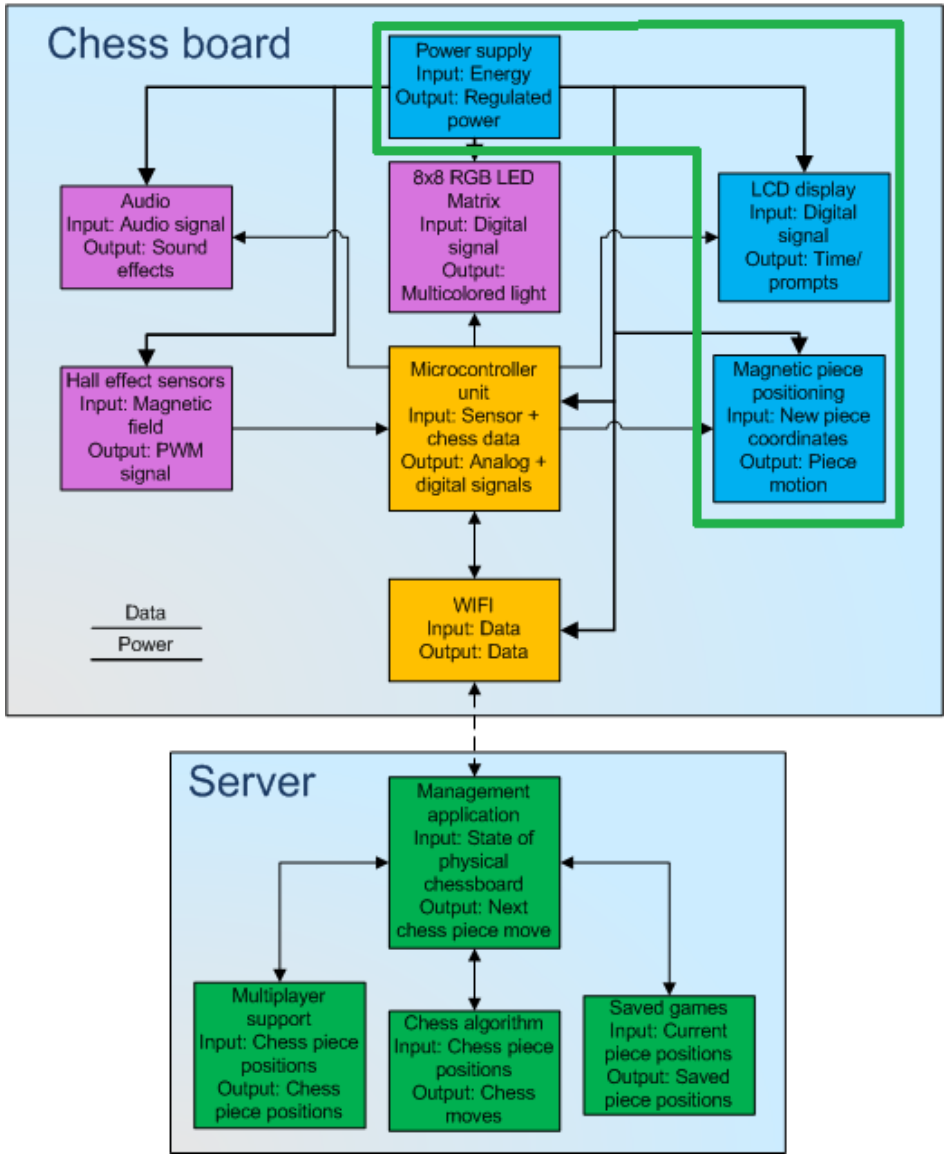
	Arduino-019	rMP3	DEV-10628
Operating voltage	5V	5V	5V
Current	Unspecified	60mA	Unspecified
Input	SPI	SPI	SPI
Outputs	3.5mm jack, line out	3.5mm jack	3.5mm jack , line out
Data Storage	Micro SD up to 2GB	Micro SD up to 32GB	Micro SD
Interrupt Capable	Unspecified	Yes	Yes
Decoding Capabilities	Mp3, Ogg Vorbis	Mp3	Mp3, Ogg Vorbis
Price	$27.50	$64.99	$39.95

DEV-10628

- Low cost audio shield
- Designed for use with Arduino boards
- Capable of decoding most popular audio formats
- Onboard data storage
- Interrupt capable through buffer
- Multiple outputs




User
Speakers
Server
Switch
Audio
Shield
MCU
External
Device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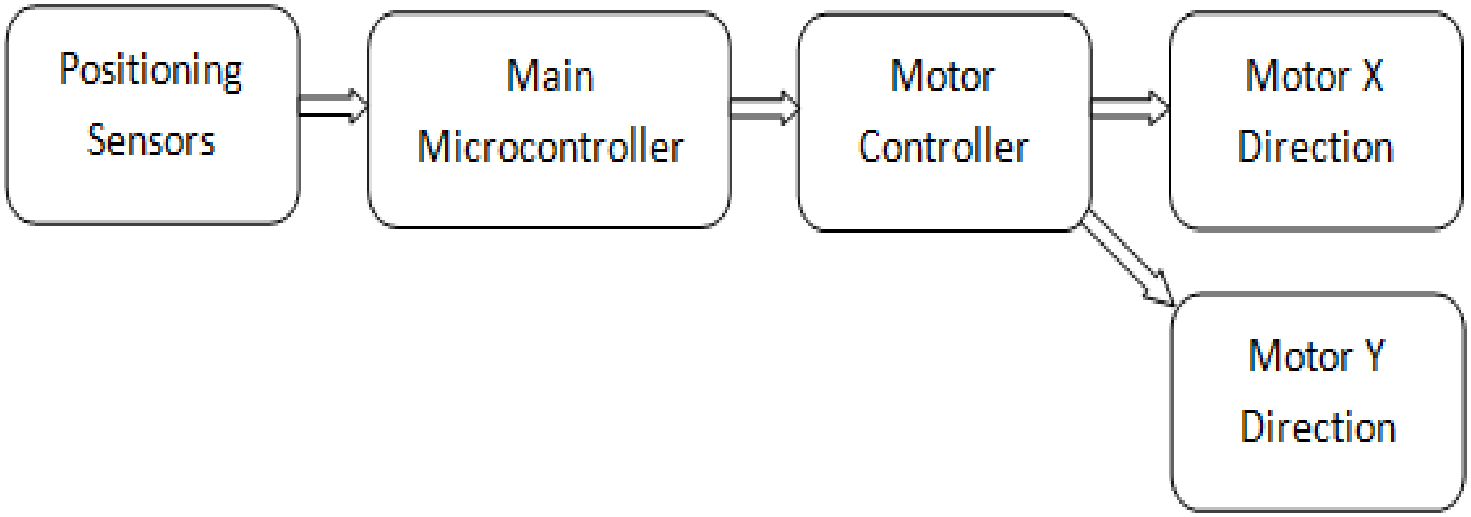
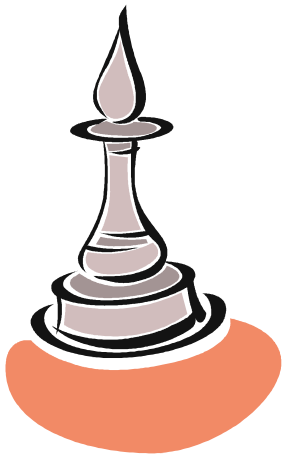
Moving System Block Diagram



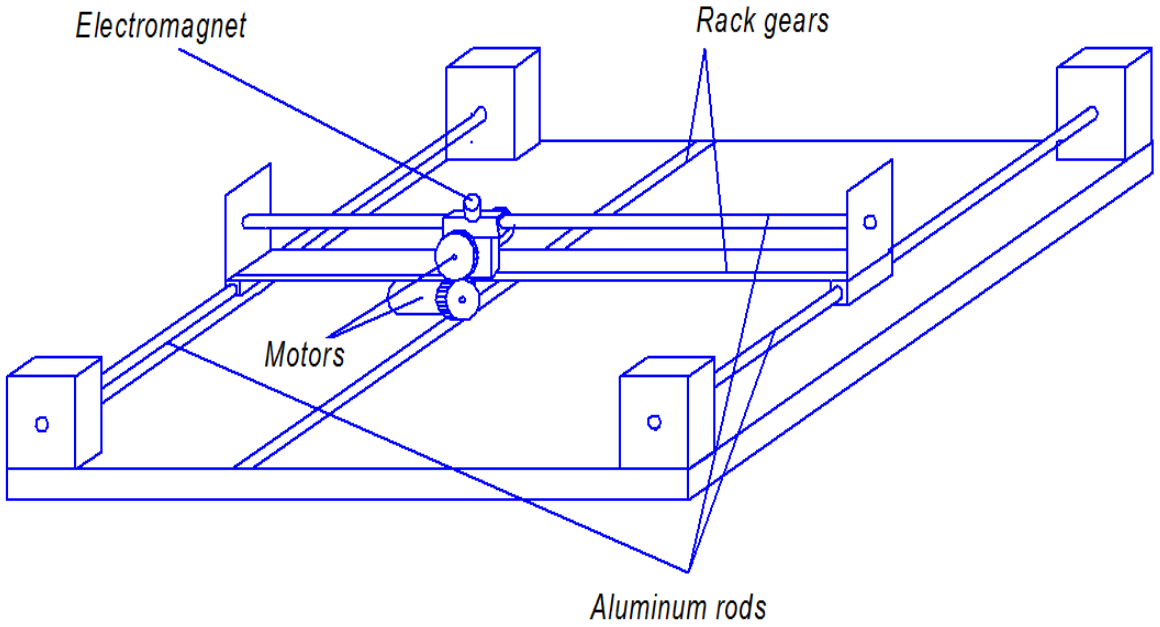
Magnetic Piece Moving System

- Main parts of the moving system are the X and Y positioning tables.
- The XY rails will be located underneath the chess board
- It will be capable of moving from one X-Y coordinate to another smoothly in order to move certain chess pieces



Moving system

	Noise level	Difficulty of installation	Reliability	Cost of the system
Internal gear	High	Medium	Low	Medium
Worm gear	Low	High	High	High
Rack gear	Medium	Low	Medium	Low



Magnets

- Each chess piece will have a magnet attached to the bottom of it
- Under the board we will have one strong magnet installed on the moving positioning system

Chess figures' neodymium magnets

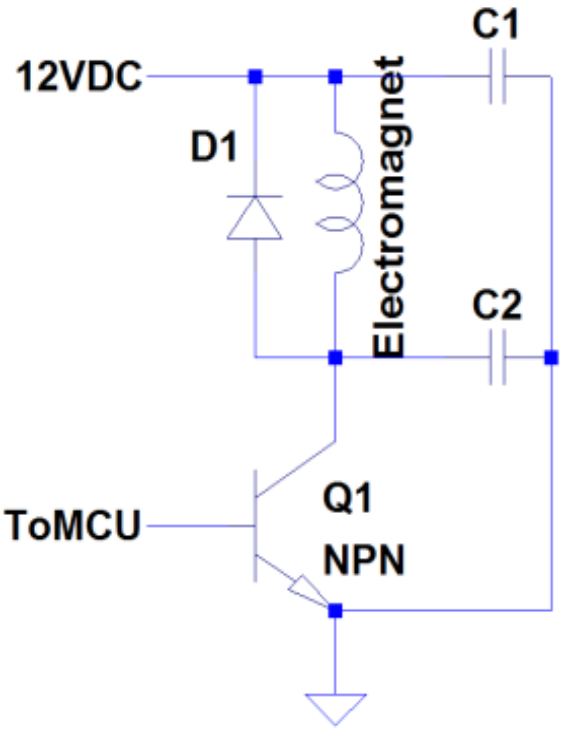
- Disk 1/2" x 1/8"
- N42-class
- Over 6.6 lbs pulling force

Electromagnet

Model of electromagnet	R-1207-12	EM 137	ER2-103
Voltage, V	12	12	24
Duty	Continuous	Continuous	Continuous
Watts	3.3	5	4.2
Amps	0.28	0.41	n/a
Holding Force, Lbs	45	33	22
Weight, Lbs	0.24	0.24	0.4
Diameter, cm	3.175	3.493	3.175
Height, cm	1.905	2.06	n/a
Price, $	40	29.24	76.06

Electromagnet control

- EM 137
  - Inexpensive and lightweight
- We used NPN-transistor as a switch
- Diode used to protect the transistor from back voltage
- Capacitors reduced signal noise from electromagnet.
- Optional adjustable pulling force via potentiometer



Stepper motors

Motor Model #	Stepper Motor -200 steps/rev	Unipolar/Bipolar, 200 steps/rev	Applied Motion – 5017–009 Bipolar Stepper Motor	Mercury ROB-09238 Bipolar Stepper Motor
Motor type	Bipolar	Unipolar/Bipolar	Unipolar/Bipolar	Bipolar
Step Angle, degree	1.8	1.8	1.8	1.8
# of Wire Leads	4	6	6	4
Leads length, mm	230	300	305	1200
Drive Shaft Diameter, mm	5	5	5	5
Rated Voltage, V	12	4	6	12
Rated Current, mA	350	1200	570	330
Holding Torque, oz-in	28	44	31.4	31.9
Winding Resistance, Ohm	34	3.3	15	34
Frame Size, mm	42.3 x 42.3	42.3 x 42.3	42.3 x 42.3	42.3 x 42.3
Weights, g	200	350	n/a	200
Price, $	14.00	19.95	12.95	14.95

Mercury ROB-09238 Bipolar Stepper Motor

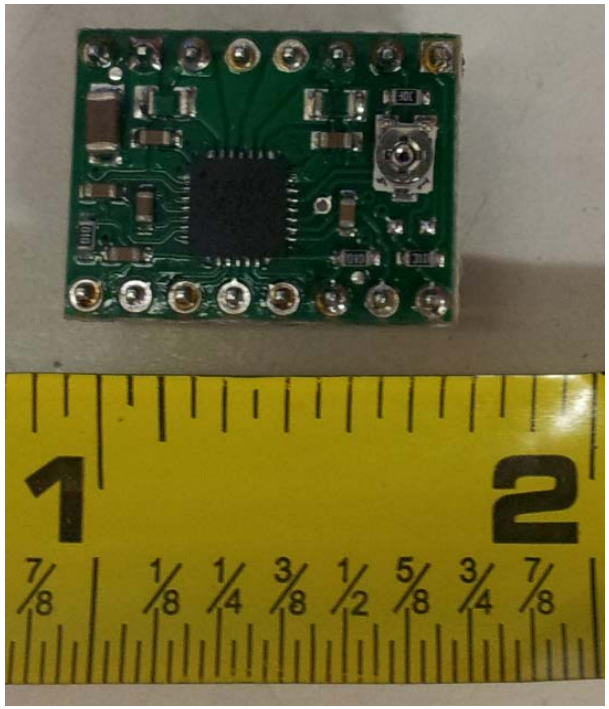
- Bipolar Motor
- 5mm shaft diameter
- 12V at 330 mA
- 0.166 foot pounds of torque

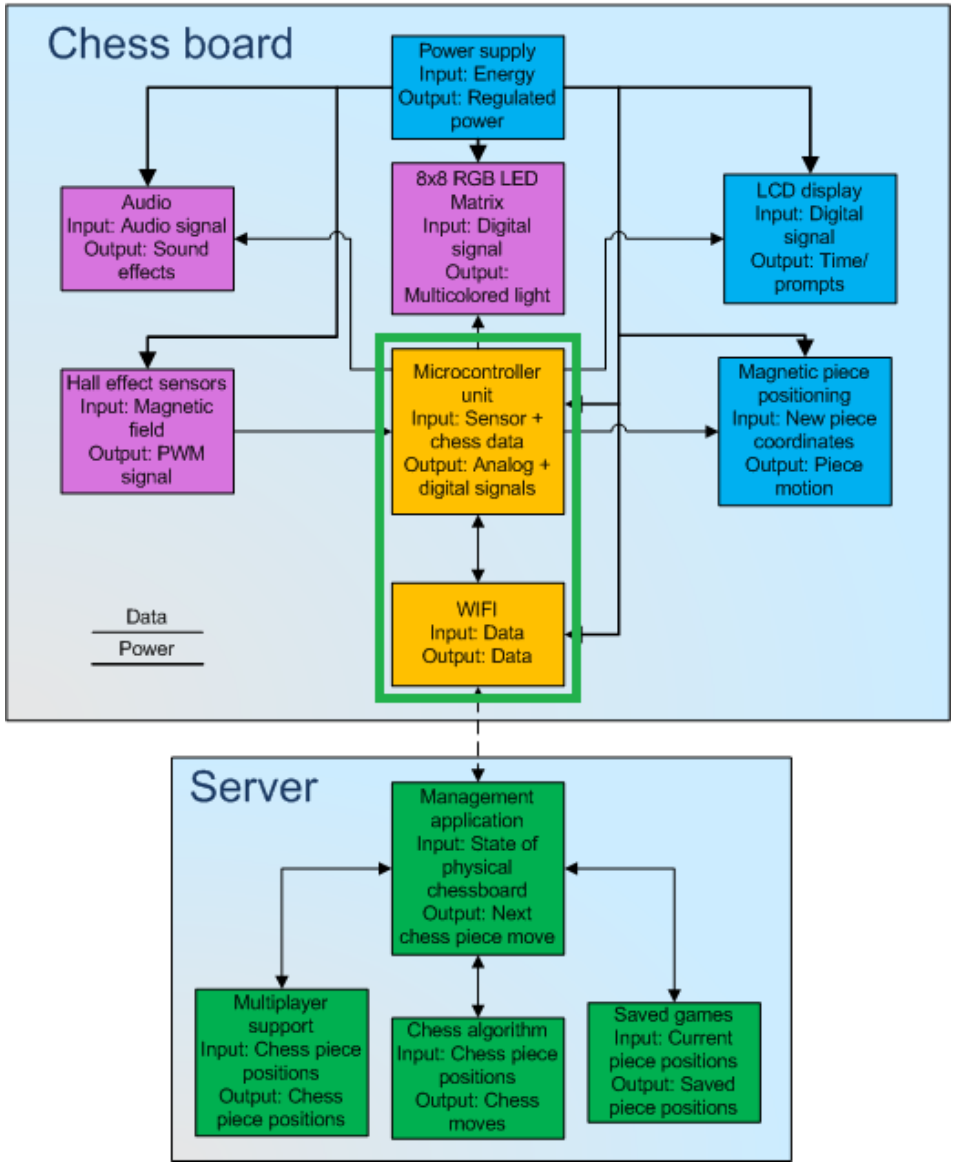
Motor Driver

	Easy Driver	Big Easy Driver	A4988 Stepper Motor Driver
Power supply range, V	From 7 to 30	From 8 to 35	From 8 to 35
Output power, V	3.3/5	3.3/5	3.3/5
Microsteps	1/2; 1/4; 1/8	1/2; 1/4; 1/8; 1/16	1/2; 1/4; 1/8; 1/16
Chip	A3967	A4983	A4988
Current control per phase, mA	Up to 750	Up to 2000	Up to 2000
Board size, in	0.6 x 1.9	1.25 x 1.75	0.7 x 1.4
Source	Open	Open	n/a
Price, $	14.95	22.95	14.95

A4988 Stepper Motor Driver

- 8 to 35V stepper voltage range
- Capable of 1/2; 1/4; 1/8; 1/16 steps
- Tiny board size
- Inexpensive

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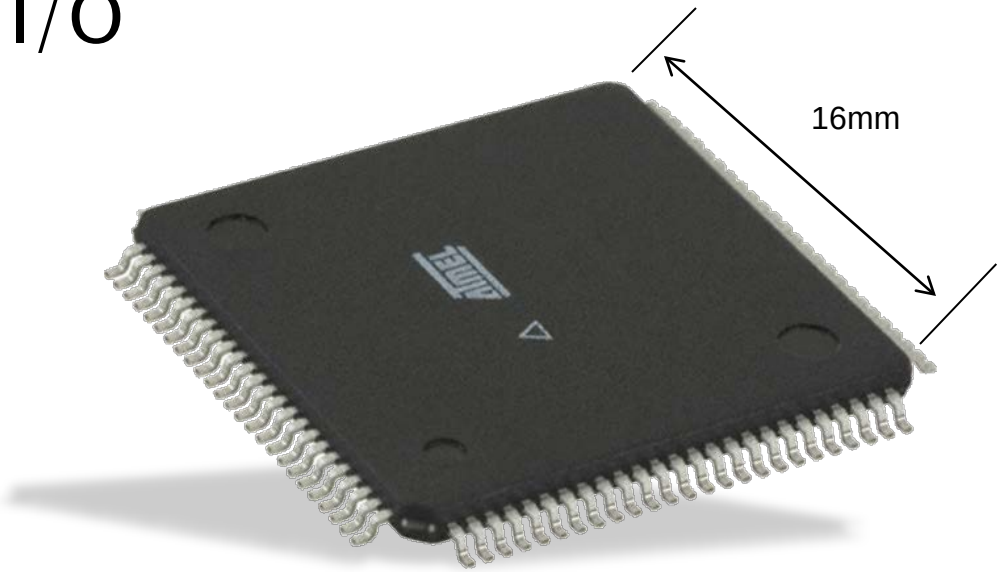
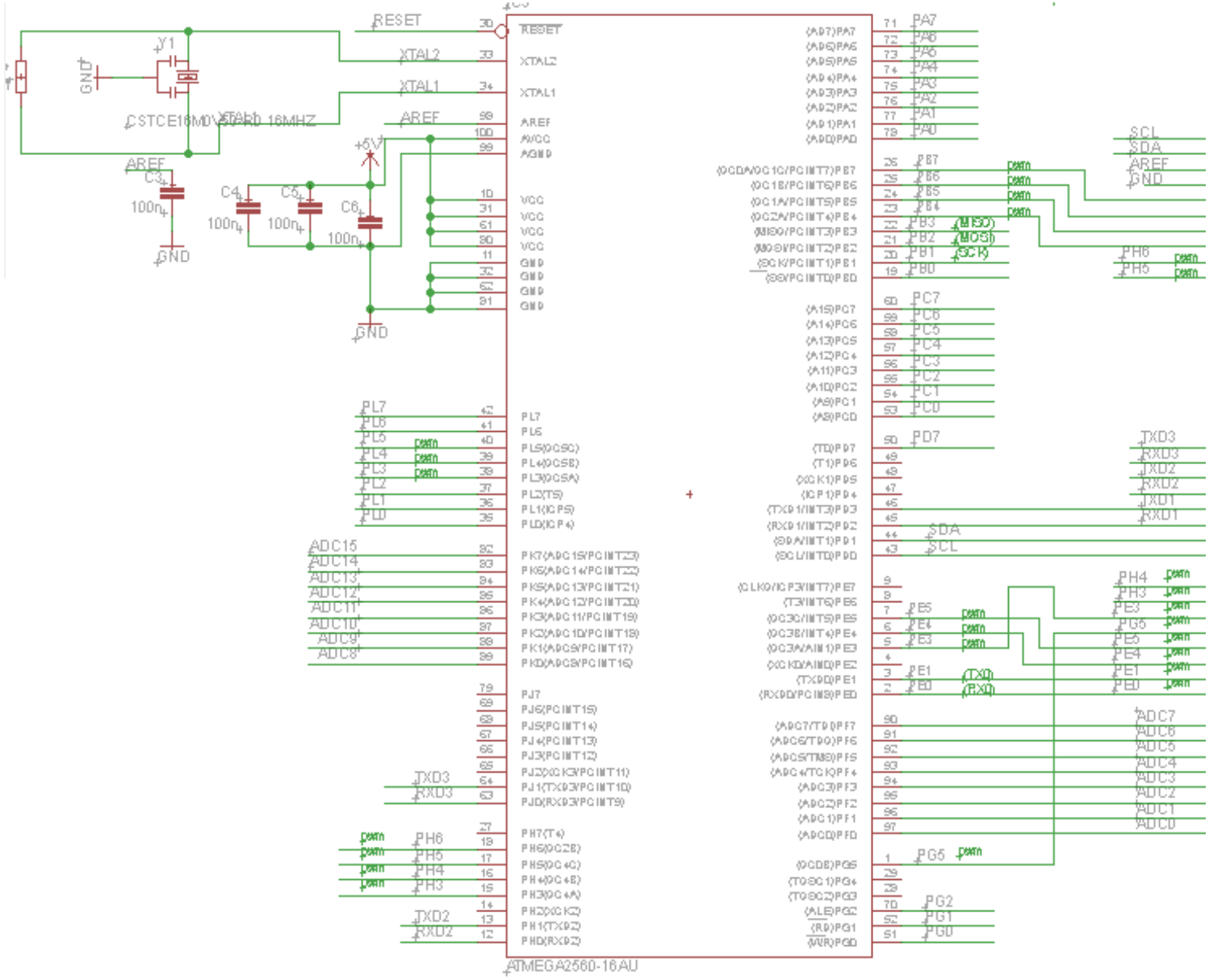
Microcontroller Unit (MCU)

	PIC18F46K80	MSP430FR5739	Atmel Corporation ATmega 2560
Operating voltage	1.8 – 5.5 V	2 – 3.6 V	2.7 – 5.5 V
Digital I/O pins	35	33	54
Analog input pins	11	14	16
UART & SPI busses	3	3	4
Program memory	64 KB	16 KB	256KB
Clock speed	64 MHz	24 MHz	16 MHz
Experience with product	None	None	Very experienced
Price per microcontroller	$4.30	$6.35	$17.97
Price per development board	$165.00	$29.00	$58.95

Atmel ATMega 2560

- Low power 8-bit microcontroller
- Clock Rate of 16MHz
- 4 serial I/O
- Has analog to digital converter
- 70 General Purpose I/O




RESET
XTAL2
XTAL1
AREF
+5V
GND
Y1
CSTCE16M0V53-R0
16MHZ
C3
C4
C5
C6
100n
ATMEGA2560-16AU
PA7
PA6
PA5
PA4
PA3
PA2
PA1
PA0
PB7
PB6
PB5
PB4
PB3
PB2
PB1
PB0
PC7
PC6
PC5
PC4
PC3
PC2
PC1
PC0
PD7
PL7
PL6
PL5
PL4
PL3
PL2
PL1
PL0
PK7
PK6
PK5
PK4
PK3
PK2
PK1
PK0
PJ7
PJ6
PJ5
PJ4
PJ3
PJ2
PJ1
PJ0
PH7
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PE1
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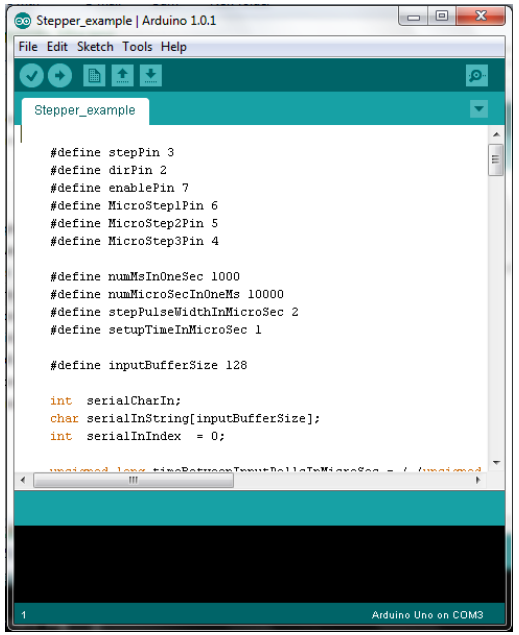
PF7
PF6
PF5
PF4
PF3
PF2
PF1
PF0
PG5
PG4
PG3
PG2
PG1
PG0
SCL
SDA
TXD3
RXD3
TXD2
RXD2
ADC15
ADC14
ADC13
ADC12
ADC11
ADC10
ADC9
ADC8
ADC7
ADC6
ADC5
ADC4
ADC3
ADC2
ADC1
ADC0

Development Environment

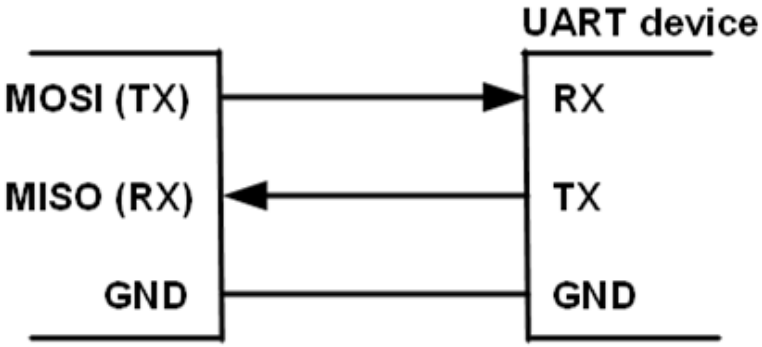
- Hardware
  - Arduino Mega 2560 R3
    - Open source schematic
    - Low cost

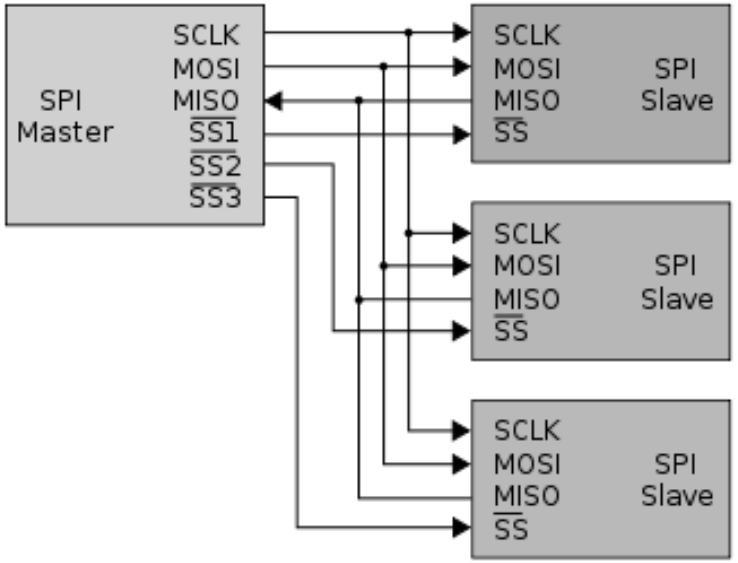
- Software
  - Multiplatform capability
  - Community supported
  - C-esque programming language



Distribution of I/O

- Wireless networking
  - UART bus
- LCD/Stepper motors/Electromagnet
  - General purpose I/O pins
- LED, Sensor matrix/Audio module
  - SPI bus



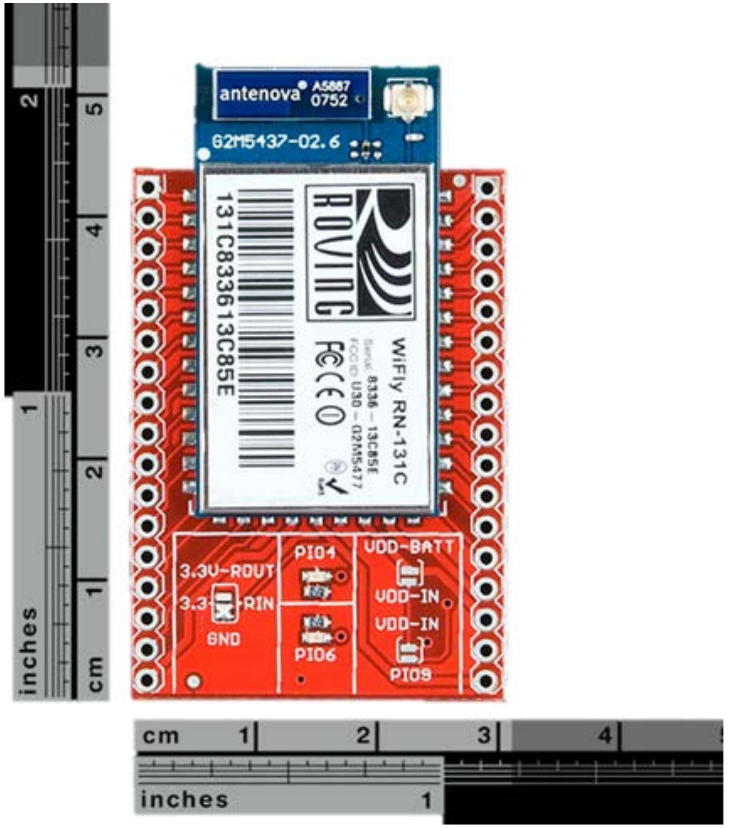


Wireless Networking

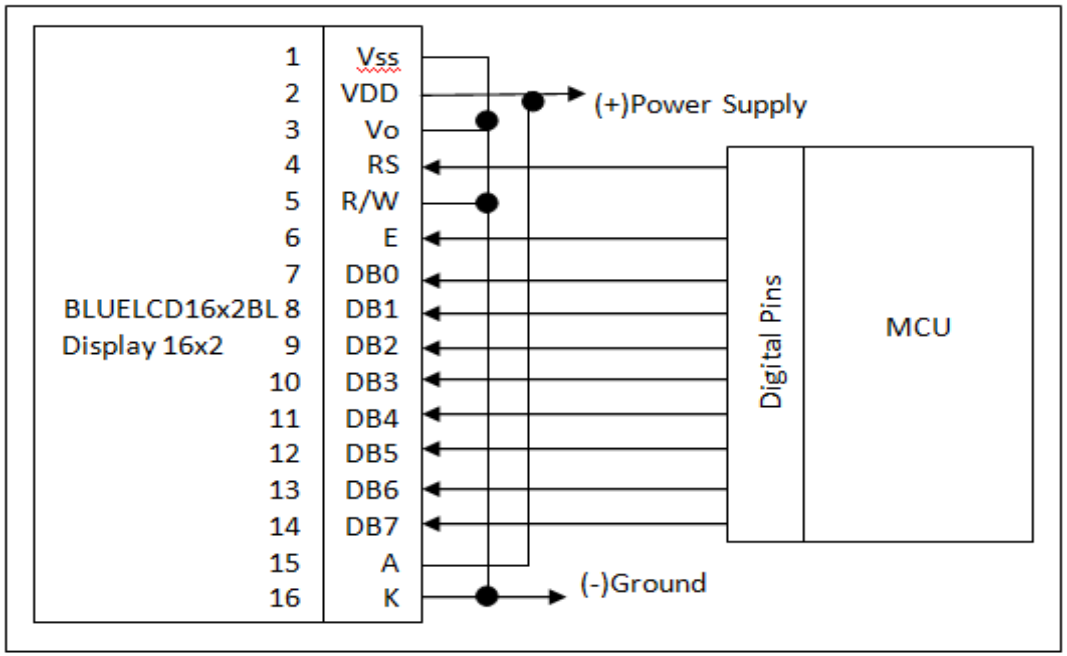
Device Name	WiFly GSX	XBee Series 1	BlueSMiRf Silver
Data transfer rate	1Mbps	0.24Mbps	0.1Mbps
Range	100m	100m	18m
Required input voltage	3.3V	3.3V	3.3V
Required input current	210mA	50mA	45mA
Microcontroller interface	UART	UART	UART
Price	$84.95	$22.95	$39.95

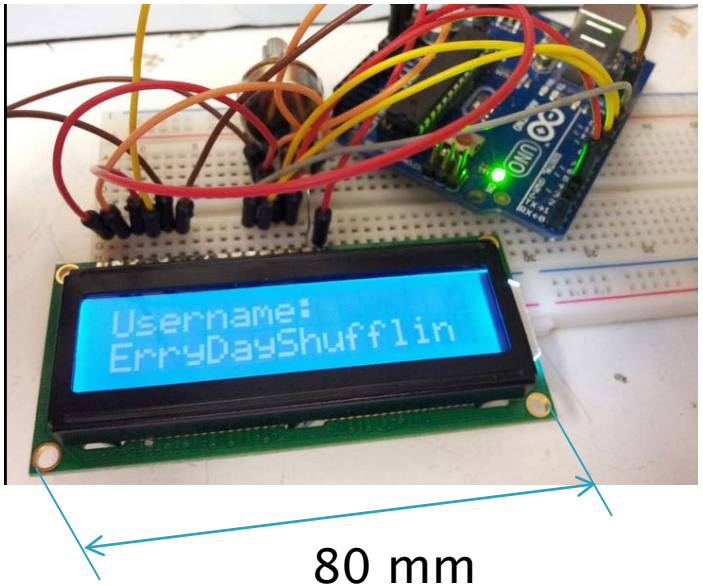
WiFly GSX

- 2.4GHz IEEE 802.11b/g transceiver
- 1Mbps data rate with TCP/IP and WPA2
- Up to 100m range
- UART hardware interface
- WEP-128, WPA-PSK (TKIP), WPA2-PSK (AES)
- FCC / CE/ ICS certified and RoHS compliant.



BLUELCD16x2BL LCD Display





- 5V DC supply voltage
- Hitachi HD 44780 display driver
- Temperature range from 5 C to 40 C

Power supply

N82E16817103064

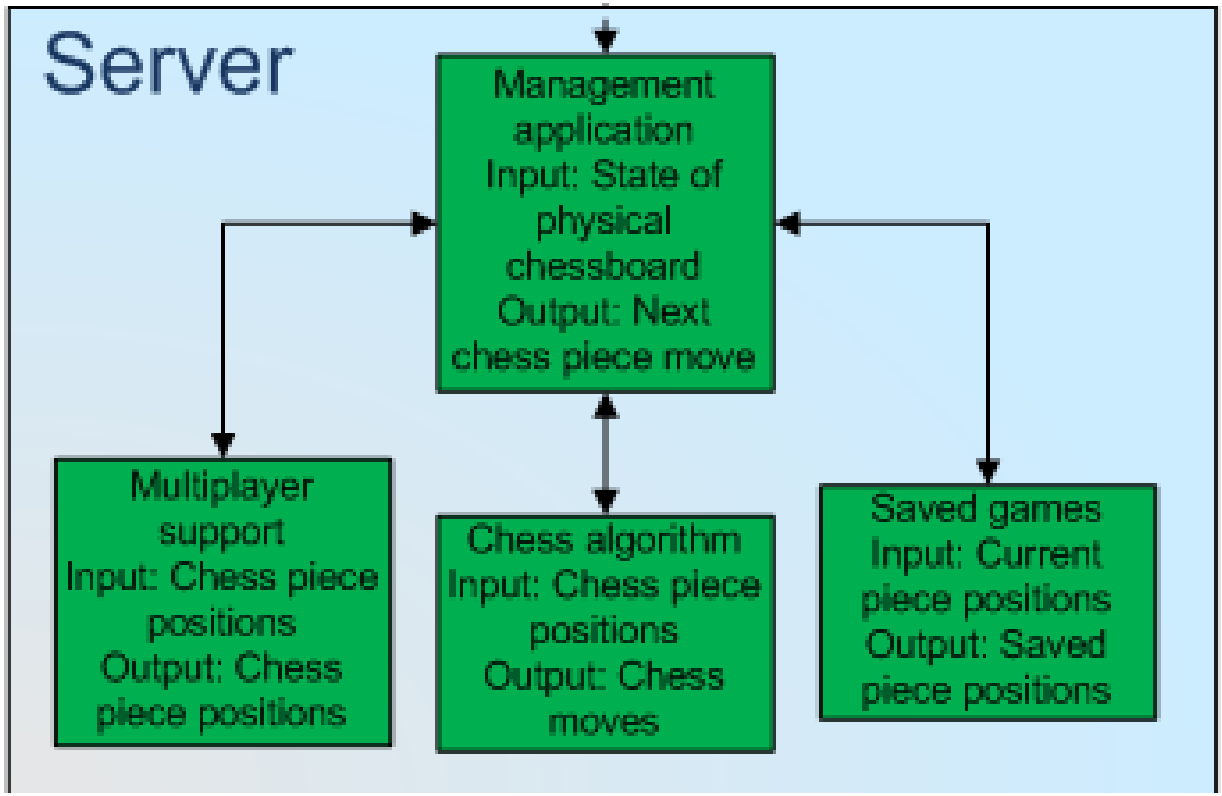
- Flex ATX /TX12VSingle/
- Power150W
- Output Current+3.3V@10A, +5V@13A, +12V1@10A, -12V@0.5A, +5Vsb@2A
- Cost: $30

Power AC Adapter from laptop

- Power 90W
- Output Voltage 19 V
- Output Current 4.74A
- Cost: $10

Arduino Code

- Wifi
  - Utilize the WiFly library to connect to a secure hotspot and transmit and receive piece positions to and from the website
- Sensor matrix
  - Loop through the matrix of sensors and obtain the positions as they arise
- Piece positioning
  - Position the electromagnet to the correct location
  - Turn the electromagnet on and travel a clear path to the new location
- LED matrix
  - Assign an 8 bit number to control the color of the LED
- Audio
  - Will be run on an interrupt and only request new data when necessary
- LCD
  - Utilizes the LiquidCrystal library to write to the LCD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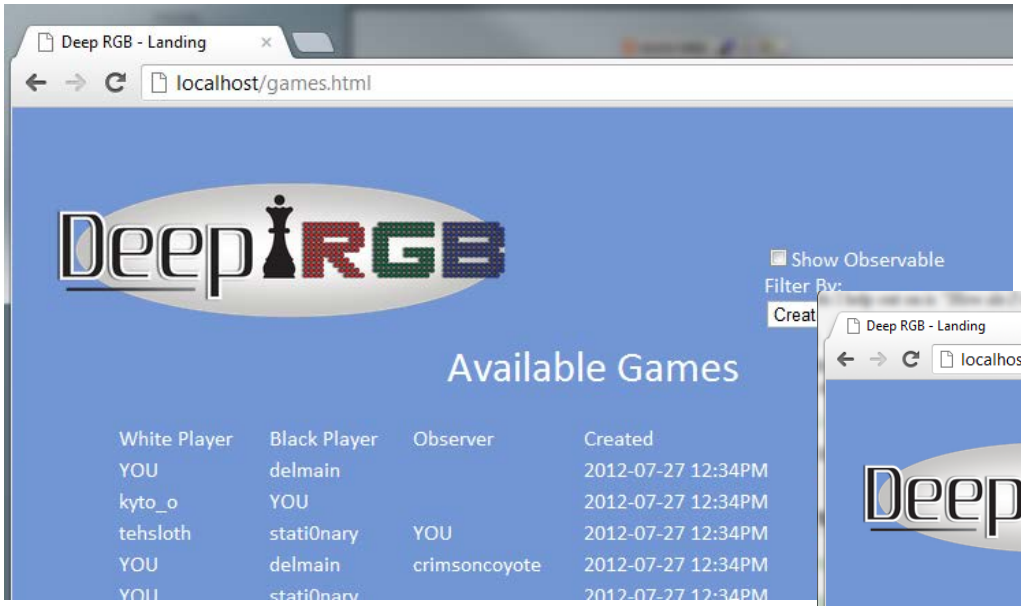
Management Pages

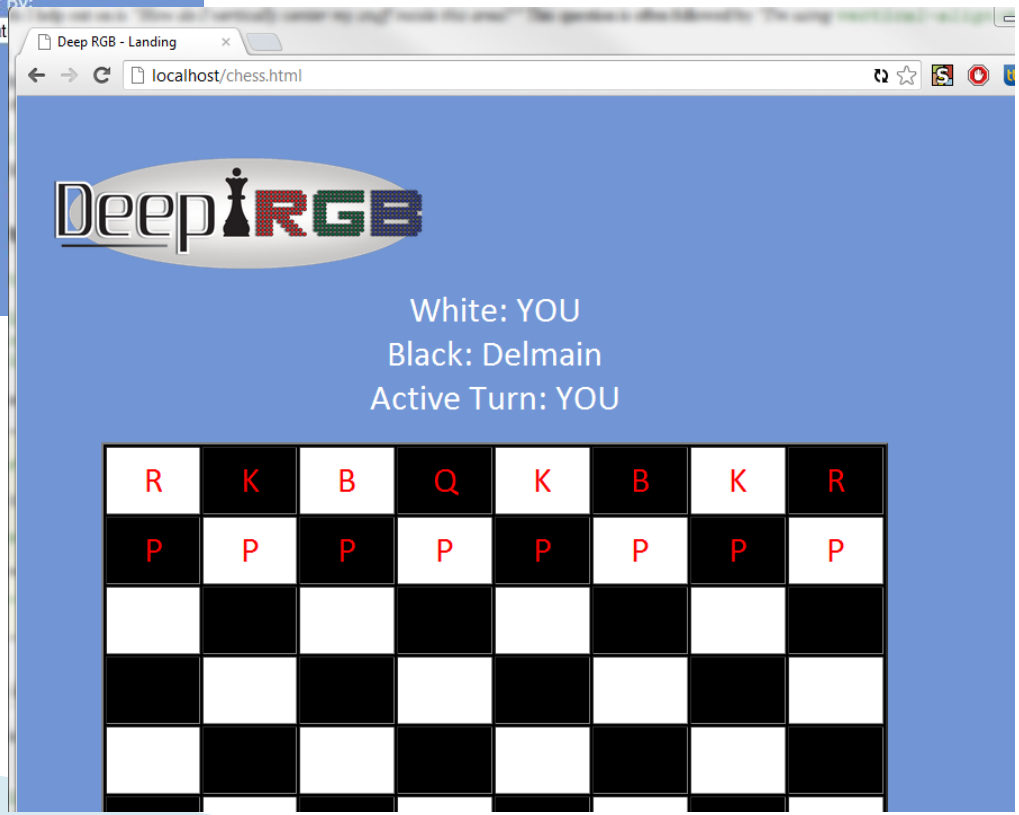
Page Name	Required Input	Optional Input	Output	Description
Log In	• Username • Password (SHA-1 hashed)		• Authentication Key • User ID	Logs in a user and creates a session on the server
User Info	• Authentication Key • User ID		• Username • LED Color • Audio Theme	Get information about the currently logged in user.
Games List	• Authentication Key • User ID	• *showObserver* • *page_count* • *page_number*	• Games IDs • Player usernames	Get a list of all games the user can interact with.
Game Info	• Authentication Key • User ID • Game ID	• *moves* • *move_limit*	• Game ID • Players • Board State • Turn Number • Active Player • Turns (Optional)	Get the full state of a game, given its ID.
Create Game	• Authentication Key • User ID • Opponent Username	• *allowObserver*	• (Success) o Game ID o Players o Board State o Turn Number o Active Player	Make a new game, given a logged in user and an opponent.

Management Pages

Page Name	Required Input	Optional Input	Output	Description
Update Move	• Authentication Key • User ID • Game ID • Board State • Move Made		• (Success) o Game ID o Players o Board State o Turn Number o Active Player	Submit a move in an ongoing game.
New Account	• Username • Real Name • Email Address	• LED Color • Audio Theme	• (Success) o Success Code	Create a new account using the information provided.
Pass Lost	• Username		• Email containing reset key	Request a reset key for a user who has lost their password
Pass Reset	• UserID • Reset Key		• (Success) o Success Code	Choose a new password for the user
Add Observer	• UserID • Authentication Key • GameID		• (Success) o Success Code	Add a user to a game as an observer.

Web Interface

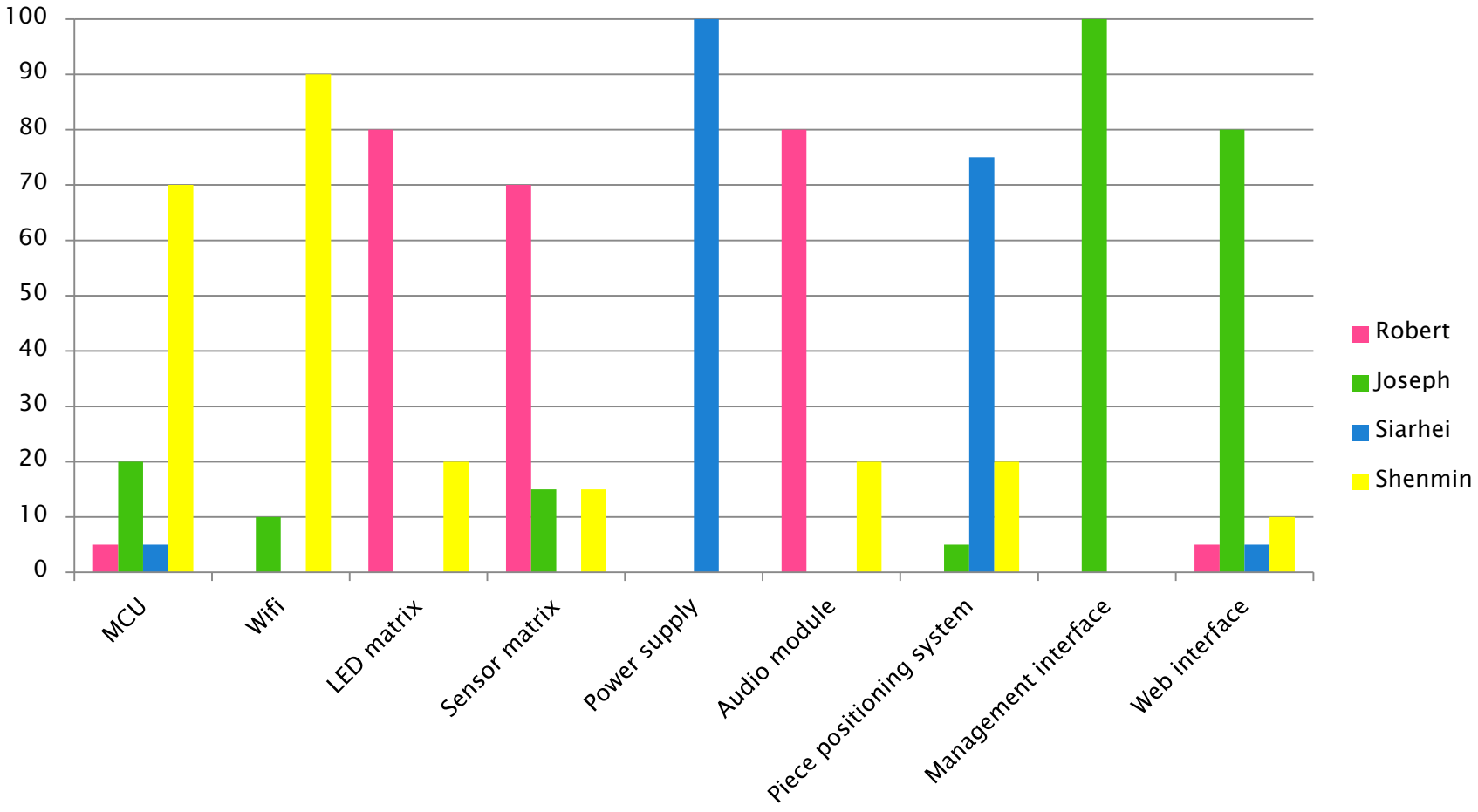




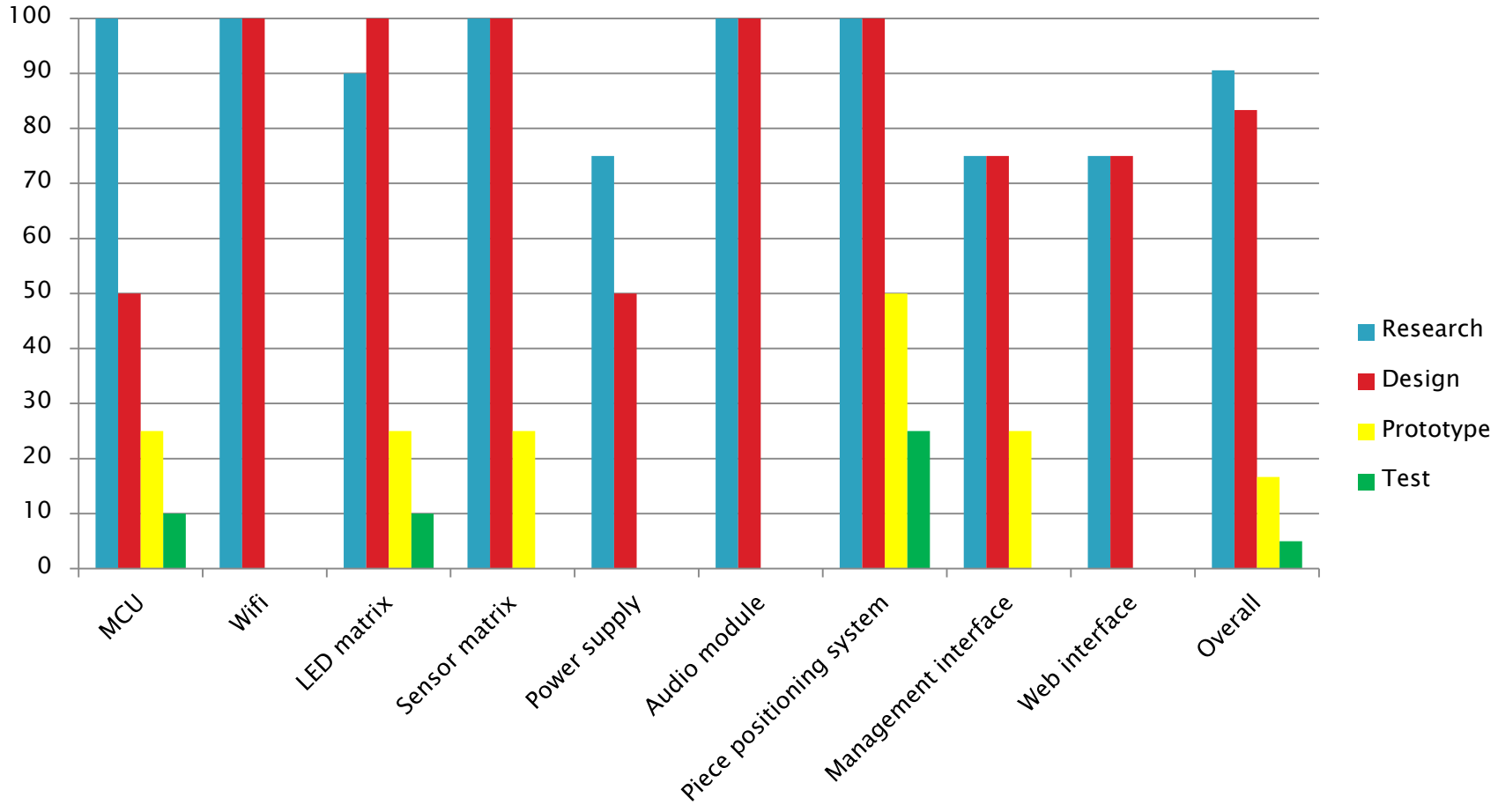
Bill of Materials

Item	Source	Part Num.	Quantity	Projected cost	Total Cost
Arduino Atmega 2560	Sparkfun	DEV-11061	1	$58.95	$58.95
WiFly GSX	Sparkfun	WRL-10050	1	$84.95	$84.95
Neodymium magnets	Amazon	B001ANVAHI	1 (pack of 100)	$4.59	$4.59
16x2 LCD display	Donated	LM1602C	1	$10.00	$0.00
Stepper motors	Sparkfun	ROB-09238	2	$29.90	$29.90
Rack Gearbox Bracket (2-pack)	Vexrobotics	275-1188	1	$9.99	$9.99
Advanced Gear Kit	Vexrobotics	276-2184	1	$19.99	$19.99
Amico Electromagnet	Amazon	B005F79TIW	1	$6.82	$6.82
Sparkle power supply	Newegg	N82E16817103064	1	$37.99	$37.99
MP3 Player shield	Sparkfun	DEV-10628	1	$39.95	$39.95
Stepper motor driver	Pololu	1183	2	$39.90	$39.90
Analog multiplexer	Analog	ADG406BNZ	4	$6.60	$6.60
Allegro Hall Effect Sensor	Digikey	A1360LKTTN-T	117	$281.43	$281.43
Shift registers	Digikey	296-14857-1-ND	10	$4.94	$4.94
RGB LEDs	Sparkfun	YSL-R596CR3G4B5W-F12	1 (pack of 100)	$59.95	$59.95
Custom PC functioning as server	Donated	None	1	$300.00	$0.00
Server OS	Donated	None	1	$0.00	$0.00
Visual Studio 10	Donated	None	1	$180.00	$0.00
SQL Server Browser	Donated	None	1	$200.00	$0.00
Chrome Developer Toold	Google Inc.	None	1	$0.00	$0.00
Total price without tax or shipping				$1,375.95	$692.36

Distribution of Labor

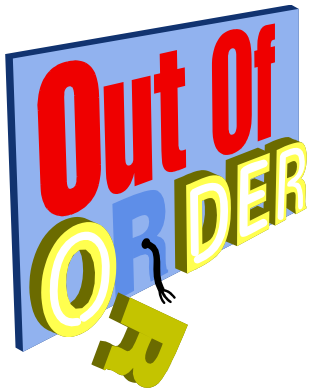


Progress


100
90
80
70
60
50
40
30
20
10
0
MCU
Wifi
LED matrix
Sensor matrix
Power supply
Audio module
Piece positioning system
Management interface
Web interface
Overall
Research
Design
Prototype
Test

Problems

- Low Hall-Effect sensor sensitivity
- Finding low cost matching gear and rack systems
- Stable power for the electromagnet



Questions?