Design Review

EGR 314

Team 10

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Mechanical Design

Physical Prototype

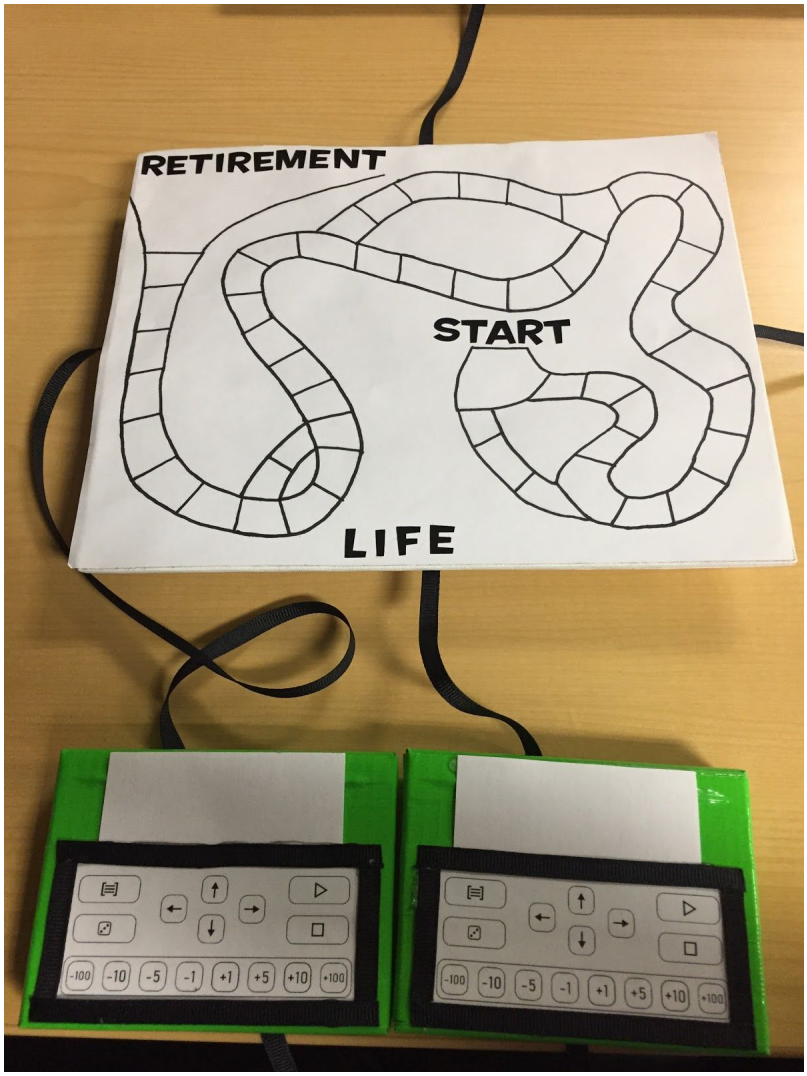


Figure 1: Physical prototype of scorepads with an electronic game of life

Product Use in Context

Figure 2: Product in use with a non-electronic board game

Problem Definition

Problem Statement

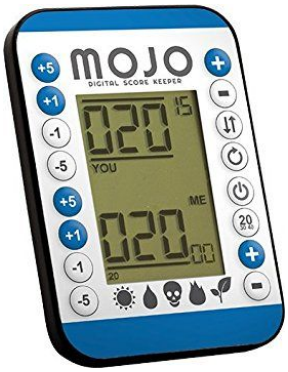
The purpose of our project is to create an electronic scorepad accessory, showcased with an electronic game board. This will help players enjoy a more personalized and relevant game experience, be able to change difficulty settings, and cut-down on long turn times.

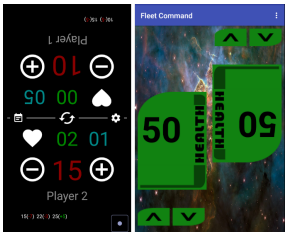
Customer Impact Statement

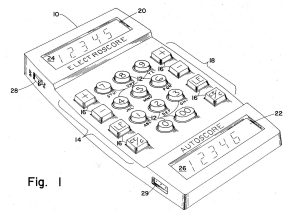
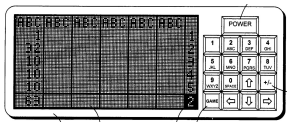
At the Customer Discovery Dinner, we learned that board gamers are frustrated with long turn times and would like a way to change the difficulty of games. The electronic game board and scorepad will help people play board games in a more convenient manner. The scorepad can be used without the gameboard to enhance the experience of playing traditional, non-electronic games. The optional game board is just one example of how our technology can be integrated into board games, and the scorepad will be expandable in order to allow the addition of new games. This device will increase enjoyability and take the guesswork out of tallying points, keeping time and counting money while playing board games. The electric game board and scorepad may not work with every game and requires a power source.

Benchmarking

Table 1: Benchmarking of related solutions

Solution (1 point each)	Description (1 point each)	Pros (2 points each)	Cons (2 points each)
Mojo Digital Life Counter ($13)  www.amazon.com	The Mojo Digital Life Counter makes it easy to calculate scores and prevents your score from being lost if your scoring cards/dice fall off the table by using a digital counter.	• Works with many games • Small size - fits in a card deck box • Two counters for each player • Two month battery life	• Only supports two players • No timer feature
Legion Lifecalc ($12)  www.amazon.com	The Legion Lifecalc makes it easy to calculate scores and prevents your score from being lost if your scoring cards/dice fall off the table by using a digital counter.	• Works with many games • Small size • Long battery life	• Only supports two players • No timer feature • Battery cannot be changed • Low quality
Robolife Digital Chess Clock ($19)  www.amazon.com	The Robolife digital chess clock keeps track of two players' turns using a pair of digital timers.	• Delay/Bonus Time Function • Stores user settings • Portable • Alarm Feature	• Only meant for Chess • Only acts as timer • Batteries have to be replaced
Scrabble Electronic Scoring ($25)	The Scrabble electronic scoring edition eliminates scoring on paper by	• Supports up to four players • Dial makes it easy to enter large numbers	• Only meant for Scrabble • Only available as part of a complete scrabble set

 www.amazon.com	using an electronic calculator.	• Built in timer feature	• Batteries must be replaced
Hasbro “Flash” Games - Scrabble, Yahtzee, and Boggle ($30 - $40)  www.amazon.com	The Hasbro “Flash” game line reduces the number of components in games and eliminates manual scoring by using smart game pieces.	• Automatically calculates scores • Can be used with a large number of players • Built in timer feature	• Individual sets must be purchased for each game • Batteries must be replaced in each of five separate devices
Monopoly: Ultimate Banking Edition ($35)  www.amazon.com	The Monopoly Ultimate Banking Edition keeps track of wealth, property value, and auction bids by using a digital banking device.	• Supports up to four players • Bank cards keep track of player wealth • Effects of chance cards are automatically applied • Shorter gameplay (30min.)	• Only meant for Monopoly • Batteries must be replaced • Rule changes may decrease market demand for game
Phone Apps (Free)  play.google.com (1), play.google.com (2)	Game scoring phone apps provide score counters that are tuned for specific games by using a device that you already own.	• Uses a device the user already owns • Can be tailored specifically to each game • Timer available	• Separate apps must be downloaded for different games • Requires phone to be unlocked • Uses your phone’s battery life

Electronic Scoring Device (US4286323 A)  Fig. 1 Patent	The electronic scoring device makes it easier to score games with a complex scoring system by using game-specific programs.	• Numeric keypad allows for fast number entry • External memory port allows different scoring programs to be loaded	• No timer feature • Only supports two players
Electronic Scorepad (US20060091603 A1)  Patent	The electronic scorepad prevents calculation mistakes in games with multiple rounds by automatically adding up scores.	• Supports 4+ players • Numeric keypad allows for fast number entry • Saves scores for each round as well as the current total • Allows for custom player/team names	• No timer feature • Display can be cluttered if scores for each round are not needed

Criteria and Constraints

Table 2: Project criteria

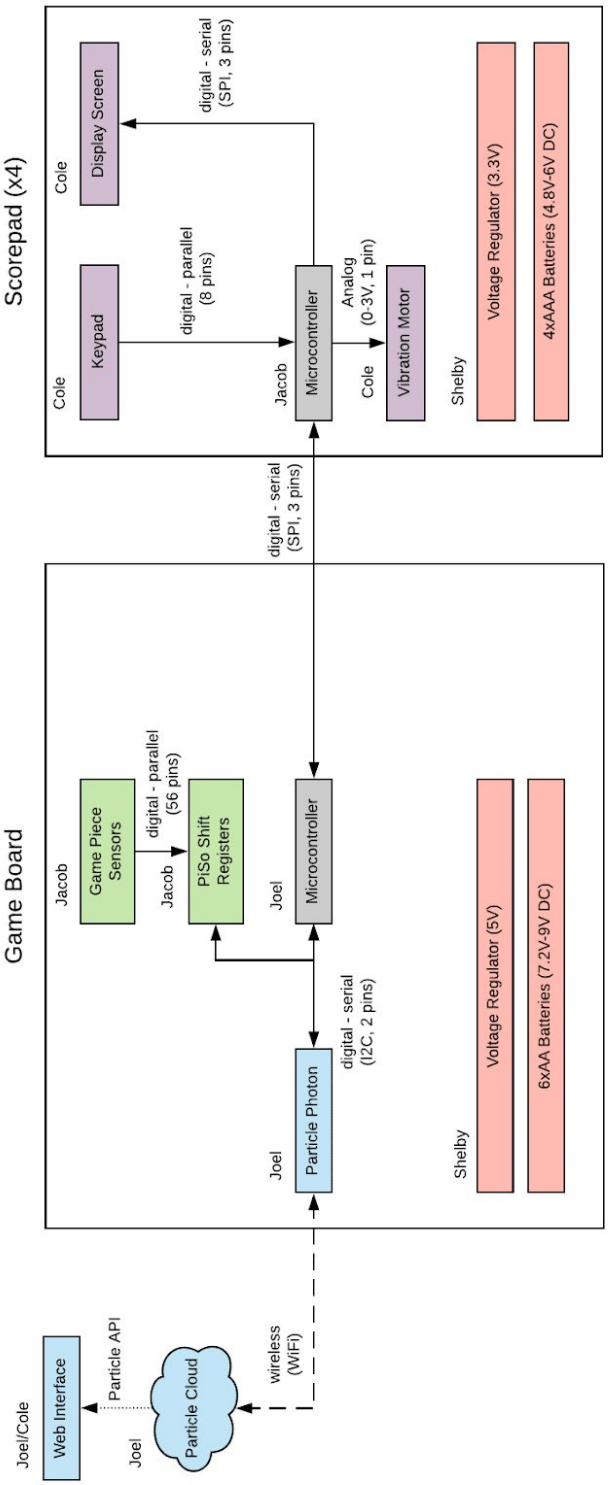
Criteria	**Threshold** ***(Halt & Review)***	**Target Goal** ***(Plan of Record)***	**Stretch Goal** ***(Design Stop)***	**Rationale**	**Current Status**
CR-1: Online scoreboard	Top 5 scores in 1 game	All scores in 1 game	All scores for 10 games	Users can compare their scores with those of others around the world	All scores in 1 game
CR-2: Scorepad Size	Less than 8”x8”x4”	Less than 6”x4”x1”	Less than 5.5”x3”x0.5”	It needs to be portable and stowable	3.7”x3.7”x1.25”
CR-3: Turn timer	00:01:00.00 resolution	00:00:01.00 resolution	00:00:01.00 resolution	Users can limit the length of turns	1 second resolution
CR-4: Reduce the number of game components	Replace the score counter	Replace the score counter and money	Replace the score counter, money, and dice	Setup time and the chance of losing pieces will be reduced	Replace all 3 components
CR-5: Long battery life	> 1 month	> 3 months	> 6 months	Device should work for people who play games infrequently	Testing Required

Table 3: Project constraints

Constraints	**Threshold *(Halt & Review)***	**Target Goal *(Plan of Record)***	**Stretch Goal *(Design Stop)***	**Rationale**	**Current Status**
CO-1: Keep track of score/other quantities	Count 1 value	Count 3 values	Count 7 values	Allow game and players to know current stats	3 values
CO-2: Track players' positions	Track positions in software	Sense positions of players' game pieces with hardware	Control positions of players' game pieces with hardware and software	Allow game and players to know current positions	Sense positions with hardware
CO-3: Generate random events	10 different events	100 events	1000 events	Allow for changeable gameplay of varying difficulty	100 events
CO-4: Prototype budget	$280	$200	$150	Defined by professors	$150.66
CO-5: Estimated production cost (in quantity)	< market value	50% of market value	10% of market value	Defined by professors	Full set: $147 One scorepad: $30.35
CO-6: Power supply and voltage regulator circuit	1	2	3	Defined by professors	2 power rails
CO-7: Microcontroller (8- or 16-bit, bare IC)	1	2	4	Defined by professors	8-bit PIC
CO-8: Sensor(s) read by a microcontroller	1	10	40	Defined by professors	64 sensors
CO-9: Actuator(s) controlled by a microcontroller	1	1	5	Defined by professors	3 Actuators

CO-10: Wireless communications	1	2	4	Defined by professors	1 Photon
CO-11: Serial communications to communicate with another chip or device	1 (e.g., I2C, SPI, UART)	1	4	Defined by professors	4 serial devices
CO-12: Functioning custom printed circuit board	1	2	4	Defined by professors	Subsystem PCBs designed and manufactured
CO-13: Surface mount components	1	10	40	Defined by professors	All surface mount components
CO-14: Programmed in C or C++	Programmed in C	Programmed in C++	Programmed in C/C++	Defined by professors	Software designed
CO-15: Hardware and/or software-driven interrupts	1	2	40	Defined by professors	Sleep/Wake Switch Interrupt

Block Diagram



Microcontroller Selection Rationale

Considerations	**My Project Requirement** (9 points)	**Microchip AVR (formerly Atmel)** (16 points)	**Cypress** (16 points)	**Microchip PIC** (16 points)	**NXP Semiconductors** (16 points)f	**Texas Instruments** (16 points)
URL to product page		www.microchip.com	cypress.com	microchip.com	nxp.com	www.mouser.com
Part Number		ATXMEGA32D4-AU	CY8C29466-24SXI	PIC18F47K40	S9S08RN32W1CLF	TM4C1231D5PMT7
Unit Cost		$2.75	$4.86	$1.37	$1.39	$7.46
# of GPIO Pins	>=20	34	24	40	39	43
Architecture	8 bit	8/16 bit AVR	8-bit	8-bit	8 bit	32-bit ARM
Power Consumption	3.3V - relatively low current b/c battery-powered	1.6-3.6V	3.0-5.25V	1.8-5.5V	2.7-5.5V	1.08-3.63V
Internal Features Required	>= 1 I2C, >= 2 SPI, (UART and 3 I2C would be nice)	2 I2C, 4 SPI, 2 UART	1 I2C, 4 SPI, 4 UART	2 SPI / I2C 2 UART	2 SPI, 1 I2C	6 I2C, 4 SPI, 8 UART
IDE Name, Cost, and URL		Atmel Studio 7 (free) www.microchip.com	PSoC Creator (free) cypress.com	MPLAB X IDE/MPLAB Code Configurator (free) microchip.com	CodeWarrior (Eclipse) (free) nxp.com	GNU C/C++ Compiler (Eclipse) (free) https://developer.arm.com
Compiler Availability	C or C++	C/C++	C/C++	C/C++	C	C/C++
Programming Hardware Cost and URL	Cheaper is better Hopefully cheap enough to get more than 1	USB ISP 3.3V / 5V AVR Programmer ($3.95) www.oddwires.com	ICE-Cube ($99) cypress.com	PICkit 3 ($47.95) microchip.com	UMultilink ($200) nxp.com	ST-Link v2 Programmer ($12.50) www.adafruit.com
ISP Capability and Type		AVR067: JTAGICE mkII Communication Protocol	Emulator, debugging, programming	PICkit 3 In-Circuit Debugger/Programmer	Emulator, debugging, programming	eTM4C1231D5PM JTAG
Available IC Packages		AU, AUR, CU, CUR, M7, MH, M7R, MHR (surface mount)	SOIC	PDIP & TQFP	LQFP	SMD/SMT

Link(s) to Data Sheets		microchip.com	cypress.com	microchip.com	nxp.com	www.ti.com
Link(s) to Application Notes		microchip.com	cypress.com	microchip.com	nxp.com	www.ti.com
Link(s) to Code Examples		microchip.com microchip.com	cypress.com	microchip.com	nxp.com	www.ti.com
Link(s) to Additional Documentation		microchip.com	cypress.com	microchip.com	nxp.com	www.ti.com
Additional Considerations *(optional)*	Program Flash Memory	16kB	32kB	128kB	32kB	2kB
Overall Pros		Meets wire requirements, low operating voltage, 8-bit control (simple programming)	Meets internal features required, Built in FPGA	Good website, plenty of pins and UART, cheap, free samples in 1 week, wide operating voltage range, available in both surface mount and through-hole packages	Meets internal features required, low price point, can run 3.3V and 5V, 8-bit control for simple programming	Contains more of the needed features than required.
Overall Cons		Small size (10mmx10mmx 1mm)	Expensive programmer, higher cost, higher operating voltage (>3V)	More expensive programmer	Expensive programmer, only available in small package	32-bit and MCU is more expensive than competitors.
Ranking (1 low - 5 high)		4	3	5	2	1

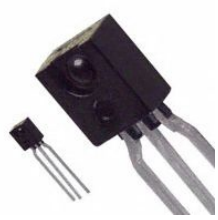
Final Microcontroller Choice *(10 points)*: PIC18F47K40

Rationale *(11 points)*: The PIC is the best because it has a wide input voltage range, adequate serial communication interfaces, plenty of I/O pins, and it uses 8-bit architecture. Additionally, it is the cheapest of the five options and Microchip provides plenty of documentation as well as a nice IDE and programmer/debugger. The PIC also has the most program storage space of the 5 options in addition to a large amount of RAM and EEPROM.

Major Component Selection Rationale

Game Piece Sensor Subsystem

Table 4: Game Piece Sensors

Solution	Pros	Cons
Option 1: Logic Output Photo-Detector ON Semiconductor QSE159 ($1.03)  digikey.com	• Does not require additional hardware in pieces • Larger package, easier to work with	• Light unreliable • 5V only • $1.03
Option 2: Magnetic Sensor Switch Toshiba Semiconductor and Storage TCS40DPR,LF ($0.40)  digikey.com	• $0.40 • Less susceptible to interference • 3.3-5V	• Requires putting magnets in game pieces • Very small package

Choice: Option 2: TCS40DPR,LF
Rationale: Although it requires adding additional mechanical components, it improves the reliability and reduces the cost of the system.

Table 5: Shift Registers

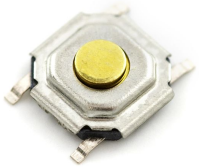
Solution	Pros	Cons
Option 1: 74HC597D,653 ($0.60)  digikey.com	• $0.60 • 3.3-5V	• 8 bit • Limited documentation

Option 2: MCP23017 ($1.27)  digikey.com	• 16 bits (ie more output channels) • I2C interface • Example code and better documentation {-Max Voltage: 3.3-5V -Max Current: 93.75mA into Vdd; 112.5mA out Vss (25% safety margin)}	• $1.27 • More pins, smaller traces
Option 3: Counter Shift Registers ($1.70)  mouser.com	• 12-bits • Automotive product qualification • ESD protection: HBM AEC-Q100-002 revision D class H2 exceeds 2500 V CDM AEC-Q100-011 revision C1 class C6 exceeds 1000 V {-Max Voltage: 33V -Max Current: 187.5mA (25% safety margin)}	• MCU is 16-bit, but shift register is 12-bit • Recommended Supply Voltage is 4.5-5.5V, but MCU is ~3.0V • More expensive than competitors

Choice: Option 2: MCP23017
Rationale: Although this chip is more expensive, it includes twice as many outputs, so it's price is not as bad given that consideration. Its I2C interface will make interfacing with the PIC easier, and we will require fewer devices since option 2 is a 16 bit device.

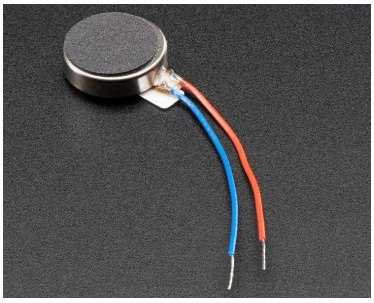
Scorepad User Interface Subsystem

Table 6: Keypad Switches

Solution	Pros	Cons
Option 1: Capacitive pads (Free)  microchip.com	• Free • Can be etched into PCB design • No actuation limit • Supports slider inputs • Easier to design case	• Uses a larger number of pins • Lack of tactile feedback
Option 2: TL3305 Series Ultraminiature SMT Tact Switch ($0.19)  mouser.com	• Low cost • Small size (4.5mmx4.5mm) • Surface mount • Simple to program	• Greater thickness than other options (3.8mm) • Projected lifetime of switch is 200,000 uses • Requires soldering to PCB
Option 3: Mini Pushbutton Switch - SMD ($0.95)  sparkfun.com	• Small size (5.2mmx5.2mm) • Flat design makes it fit easier into casings • Surface mount • Simple to program	• Projected lifetime of switch is 100,000 uses • Requires soldering to PCB • More expensive than other options

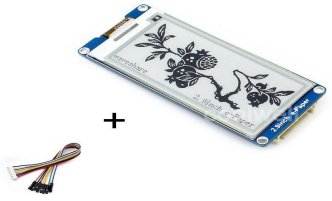
Choice: Option 1: Capacitive pads
Rationale: Capacitive touch is built into MCU and capacitive pads would allow for a sleek design, eliminate the need to 3D print buttons, and allow for easier fitting into controller casing. A low-cost vibrator motor can be used to provide tactile feedback.

Table 7: Vibrator Motor

Solution	Pros	Cons
Option 1: Flat Coin Vibration Motor ($3.99)  mouser.com	• 2.7-3.3V • Small size	• Higher current draw (90mA) • Higher cost • May require a transistor to drive
Option 2: Mini Disc Vibration Motor ($1.08)  amazon.com	• 2-5v • Small size • Lower current draw (60mA)	• May require a transistor to drive • No detailed datasheet available

Choice: Option 2: Mini Disc Vibration Motor
Rationale: This motor is lower cost, has a larger voltage range, and has low current draw. This component is very simple to use, so the lack of a detailed datasheet should not be a problem.

Table 8: Display

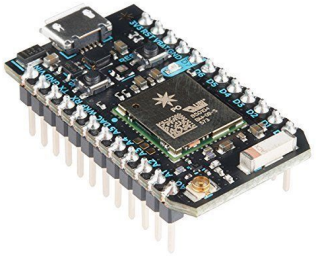
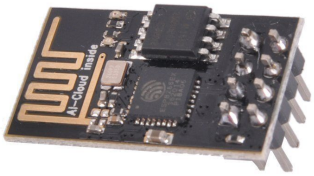
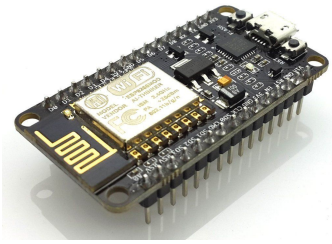
Solution	Pros	Cons
Option 1: 2.9 Inch E-Paper Display ($24.99) 	• Low power consumption • Very visible in bright lighting • High pixel count • 3.3V • SPI control	• Not visible in dark environments • Higher cost

amazon.com		
Option 2: MikroElektronika MIKROE-2659 ($59.99)  mouser.com	• Low power consumption • Very visible in bright lighting • High pixel count • 3.3V • SPI control • Premade drivers are available for our microcontroller	• Not visible in dark environments • Higher cost
Option 3: 20x4 Character LCD ($7.99)  amazon.com	• Lower cost • Visible at night	• Higher power consumption • Character-based display • 5V Only • Parallel control
Option 4: 2.8 Inch TFT Touch Screen ($14.99)  amazon.com	• High pixel count • Includes touch screen sensor • Visible at night	• Higher power consumption • 5V Only • Parallel control

Choice: Option 1: 2.9 Inch E-Paper Display
Rationale: A non-character-based display is better suited to our project and our system would ideally have a display that works with 3.3V and has low power consumption. Cost is also an important factor since we will have multiple displays, making option 2 impractical.

Online Leaderboard Subsystem

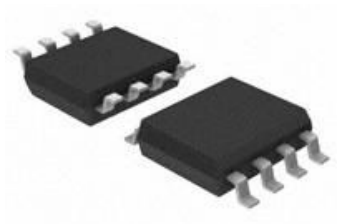
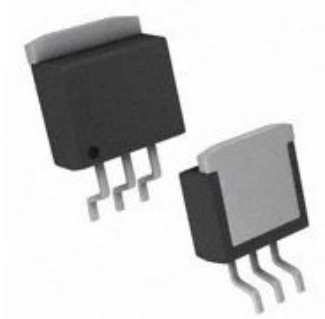
Table 9: WiFi Chip

Solution	Pros	Cons
Option 1: Particle Photon ($28.33, free from lab)  amazon.com	• Good documentation • Integrated programmer • Available from the lab (free)	• Larger board size - more pins than necessary • Higher production cost
Option 2: ESP8266 (~$4.00)  amazon.com	• Low cost • Small size	• May be difficult to program • Limited documentation
Option 3: ESP8266 Development Board ($8.79)  amazon.com	• Integrated programmer • Low cost	• Larger board size - more pins than necessary • Limited documentation

Choice: Option 1: Particle Photon
Rationale: This board is available to check out for free from the lab. Also, cloud storage is readily available from the manufacturer free of cost with extensive documentation which will make it easier to work with for our project.

Game Board Power Supply Selection - 5V

Table 10: 5V Regulator

Solution	Pros	Cons
Option 1: TPS5405DR ($1.60)  digikey.com	• Wide input voltage range (6.5-28V) • Switching regulator - more efficient • 2A current output	• More complicated supporting circuitry • Not low-dropout
Option 2: MIC29310-5.0WU ($2.63)  digikey.com	• Wide input voltage range (6-16V) • Low-dropout • Supports an external heatsink pad • 3A current output	• Linear regulator - less efficient • Higher Cost

Choice: Option 2: MIC29310-5.0WU
Rationale: Option 2 can accommodate our battery input voltage range, will supply ample current with a safety margin, is a low-dropout regulator, and requires little supporting circuitry. The price should not be an issue, since we only need one for the board and it is still very cheap compared to our budget.

Table 11: Power Supply

Solution	Pros	Cons
Option 1: 6x Rechargeable AA Batteries (~$11.25)  amazon.com	• Rechargeable • Easily replaceable • Would allow alkaline batteries to be used if desired	• Low capacity for size • Requires an external charger
Option 2: 2S (7.4V) 2000mAh Lipo Battery ($14.99)  amazon.com	• Rechargeable • High capacity for size	• Requires a specialized charger or charging circuit • May pose a safety hazard

Choice: Option 1: 6x Rechargeable AA Batteries
Rationale: AA batteries are commonly used, easily replaced, and can be charged with common battery chargers.

Scorepad Power Supply Selection - 3.3V

Table 12: 3.3V Regulator

Solution	Pros	Cons
Option 1: TPS768 ($3.31)  ti.com	• Wide input voltage range (2.7-10V) • Low-dropout • Large package • Free sample	• High cost • 1 A current output • Confusing output voltage options • Linear regulator - less efficient
Option 2: AP1509-33SG-13 ($1.63)  digikey.com	• High maximum input voltage (4.5V - 22V) • Fixed 3.3V output • High output current (2A) • Switching regulator - more efficient	• $1.63 • Not low-dropout
Option 3: LD29150DT33R ($1.51)  digikey.com	• Wide input voltage range (4.0V-14V) • Low-dropout • 1.5 A output current	• $1.51 • Small package • Linear regulator - less efficient

Choice: Option 3: LD29150DT33R
Rationale: Option 3 can accommodate our battery input voltage range, will supply ample current with a safety margin, and is a low-dropout regulator. The price should not be an issue, since we only need one per scorepad and it is still very cheap compared to our budget.

Table 13: Power Supply

Solution	Pros	Cons
Option 1: 4x Rechargeable AAA Batteries (~$6.00)  amazon.com	• Rechargeable • Easily replaceable • Would allow alkaline batteries to be used if desired	• Low capacity for size • Requires an external charger
Option 2: 2S (7.4V) 800mAh Lipo Battery ($6.50)  amazon.com	• Rechargeable • High capacity for size	• Higher voltage than necessary due to available Lipo size options • Requires a specialized charger or charging circuit • May pose a safety hazard

Choice: Option 1: 4x Rechargeable AAA Batteries
Rationale: AAA batteries are commonly used, easily replaced, and can be charged with common battery chargers.

Hardware Design

Schematics

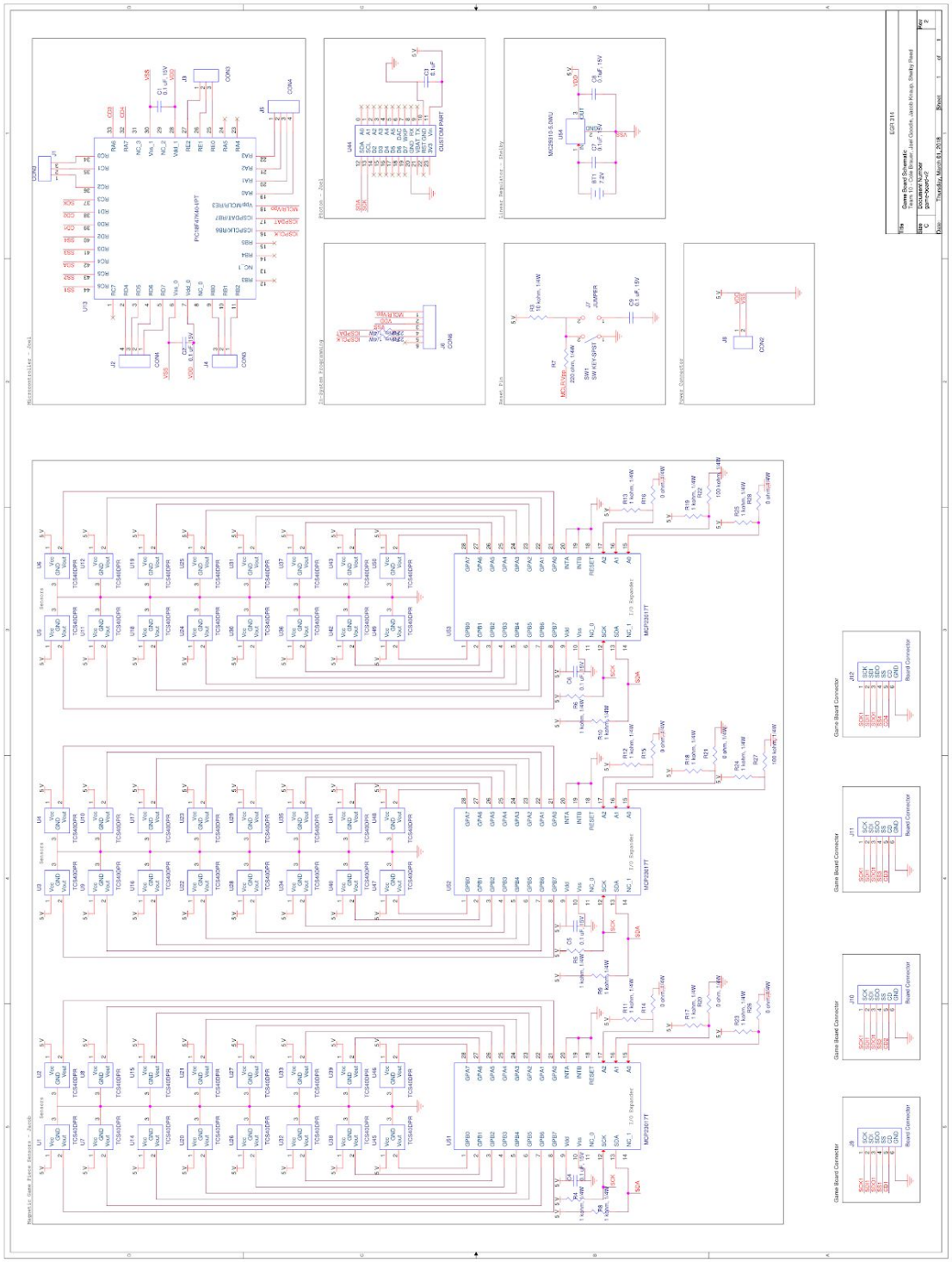


Figure 3: Game Board Schematic

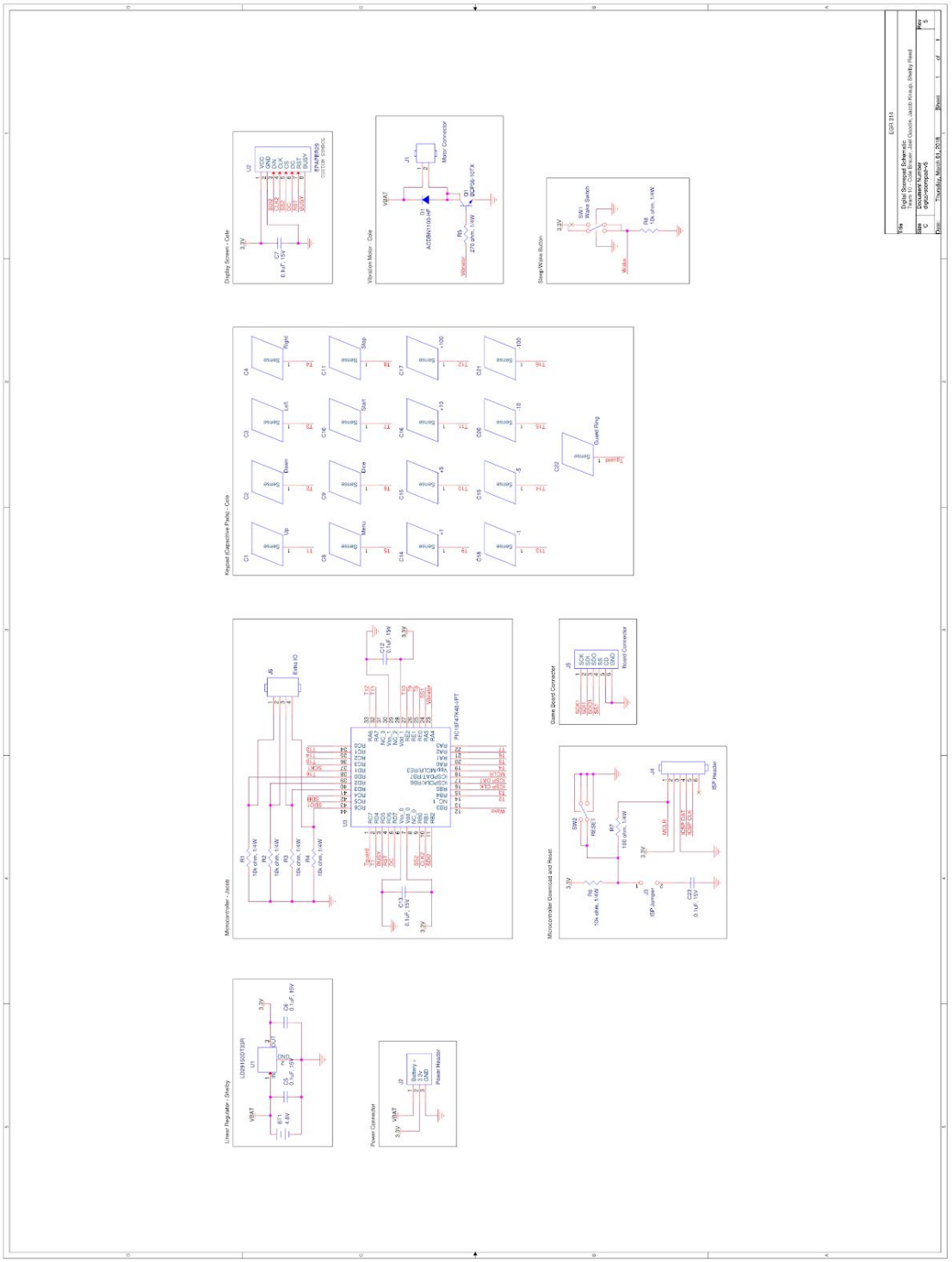


Figure 4: Scorepad Schematic

Bill of Materials

Part Name/Description	Unit Quantity	Unit Prototype Cost	Total Prototype Cost	Unit Production Cost	Total Production Cost	Manufacturer
PIC Microcontroller	5	$0.00	$0.00	$1.37	$6.85	Microchip
Magnetic Sensor Switch	48	$0.40	$19.20	$0.16	$7.60	Toshiba
I/O Expander	3	$1.27	$3.81	$0.84	$2.52	Microchip
Magnets	4	$0.27	$1.08	$0.10	$0.39	Radial Magnet Inc
3.3V Regulator	4	$1.51	$6.04	$0.68	$2.74	STMicroelectronics
5V Regulator	1	$2.63	$2.63	$1.99	$1.99	Microchip
Pushbutton	10	$0.47	$4.70	$0.38	$3.82	Wurth Electronics Inc.
Diode	4	$0.34	$1.36	$0.10	$0.41	Comchip Technology
PNP Transistor	4	$0.26	$1.04	$0.10	$0.39	Nexperia USA Inc.
0.1 uF Capacitor	13	$0.08	$0.99	$0.02	$0.25	Samsung Electro-Mechanics
0 ohm resistor	7	$0.03	$0.18	$0.01	$0.04	Yageo
22 ohm resistor	2	$0.03	$0.05	$0.01	$0.01	Yageo
100 ohm resistor	6	$0.03	$0.15	$0.01	$0.03	Yageo
220 ohm resistor	2	$0.03	$0.05	$0.01	$0.01	Yageo
1k ohm resistor	21	$0.03	$0.53	$0.01	$0.11	Yageo
10k ohm resistor	7	$0.03	$0.18	$0.01	$0.04	Yageo
Mini Disc Vibration Motor	4	$1.08	$4.32	$1.08	$4.32	uxcell
2.9 Inch E-Paper Display Panel Module	4	$24.99	$99.96	$24.99	$99.96	Waveshare
AAA Battery Holder	4	$0.80	$3.20	$0.80	$3.20	TrendBox
Rechargeable AA Battery	6	$0.00	$0.00	$1.88	$11.25	AmazonBasics
Rechargeable AAA Battery	16	$0.00	$0.00	$1.50	$24.00	AmazonBasics
AA Battery Holder	1	$1.16	$1.16	$1.16	$1.16	Ajax Scientific
Particle Photon	1	$0.00	$0.00	$19.00	$19.00	Particle
Header pin	40	$0.00	$0.00	$0.06	$2.52	Harwin Inc.

Manufacturer Part #	Supplier	Supplier Part #	# Ordered	Date Ordered	# Received	Surplus	Schematic Reference Designators
PIC18F47K40	Microchip Direct	PIC18F47K40	3	1/29/2018	3	-2	Board U13 Scorepad U3
TCS40DPR,LF	Digikey	TCS40DPRLFCT-ND	8	2/7/2018	0	-48	Board U1-U12, U14-U43, U45-U50
MCP23017	Digikey	MCP23017T-E/ SOCT-ND	4	2/7/2018	0	-3	Board U51-U53
8005	Digikey	469-1031-ND	4	2/7/2018	0	-4	
LD29150DT33R	Digikey	497-1496-1-ND	6	2/7/2018	0	-4	Scorepad U1
MIC29310-5.0WU	Digikey	576-2230-ND	2	2/7/2018	0	-1	Board U53
431151015826	Digikey	732-7029-1-ND	12	2/7/2018	0	-10	Board SW1 Scorepad SW1-SW2
ACDBN1100-HF	Digikey	641-1614-1-ND	10	2/26/2018	0	-4	Scorepad D1
BCP56-10TX	Digikey	1727-2537-1-ND	10	2/26/2018	0	-4	Scorepad Q1
CL31B104KACNNNC	Digikey	1276-2742-1-ND	30	2/26/2018	0	-13	Board C1-C8 Scorepad C5-C7, C12-C13, C23
RC1206FR-070RL	Digikey	YAG3367CT-ND	20	2/26/2018	0	-7	Board R14-R16, R20-R21, R26, R28
RC1206FR-0720RL	Digikey	311-22.0FRCT-ND	10	2/26/2018	0	-2	Board R1-R2
RC1206FR-07100RL	Digikey	311-100FRCT-ND	10	2/26/2018	0	-6	Board R22, R27 Scorepad R7
RC1206FR-07220RL	Digikey	311-220FRCT-ND	10	2/26/2018	0	-2	Board R7 Scorepad R5
RC1206FR-071K02L	Digikey	311-1.02KFRCT-ND	60	2/26/2018	0	-21	Board R4-R6, R8-R13
RC1206JR-0710KL	Digikey	311-10KERCT-ND	20	2/26/2018	0	-7	Board R3 Scorepad R1-R4, R6, R8
a14061100ux0057	Amazon	B00PZYMCT8	5	2/11/2018	5	1	Scorepad J1
2.9inch-e-paper	Amazon	B071JFRV2S	1	2/7/2018	0	-4	Scorepad U2
B071RW2MK5	Amazon	B071RW2MK5	10		0	-4	Scorepad BT1
HR-3UTG-AMZN (8P)	Team Members	B00CWNMV4G	6	2/7/2018	6	0	Board BT1
HR-4UTG-AMZN (8P)	Team Members	B00CWNMXQW	16	2/7/2018	16	0	Scorepad BT1
EL032-0004	Peralta	B00EPQKBTU	10	2/26/2018	1	0	Board BT1
PHOTONH	Peralta	117	1	1/31/2018	1	0	Board U44
M20-9990345	Peralta	952-2263-ND	40	2/7/2018	40	0	Board J1-J12, Scorepad J1-J5

Power Budget

Table 14: Game Board Power Budget

1. List major components					
Component Name	**Part Number**	**Supply Voltage Range**	**Quantity**	**Absolute Maximum Current (mA)**	**Total Current (mA)**
Microcontroller	PIC18F47K40	1.8-5.5	1	350	350mA
I/O Expander	MCP23017	1.8-5.5V	4	125	500mA
Magnet Sensor	TCS40DPR	3.3-5V	50	1.6	80mA
Photon	PHOTONH	3.0-5.5V	1	430	430mA
2. Assign major components to power rails. Try to minimize the number of power rails necessary. Add additional voltage rails if needed.					
5V Power Rail					
Component Name	**Part Number**	**Supply Voltage Range**	**Quantity**	**Absolute Maximum Current (mA)**	**Total Current (mA)**
Microcontroller	PIC18F47K40	1.8-5.5	1	350	350mA
I/O Expander	MCP23017	1.8-5.5V	4	125	500mA
Magnet Sensor	TCS40DPR	3.3-5.0V	50	1.6	80mA
Photon	PHOTONH	3.0-5.5V	1	430	430mA
				Subtotal	1360mA
				Safety Margin	25%
5V Regulator				***Total Current Required on 5V Rail***	1700mA
5V Regulator	MIC29310-5.0WU	6.0V-16.0V	1	3000	3000mA
3. Calculate Power Supply Requirements					
Component Name	**Part Number**	**Supply Voltage Range**	**Quantity**	**Absolute Maximum Current (mA)**	**Total Current (mA)**
5V Regulator	MIC29310-5.0WU	6.0V-16.0V	1	3000	3000mA
External Supply				***Total Current Required of External Supply***	3000mA
Rechargeable Battery	6xAA	7.2V	1	2000	2000mA
4. Calculate Battery Life					
Component Name	**Part Number**	**Supply Voltage Range**	**Quantity**	**Absolute Maximum Current (mAh)**	**Total Current (mAh)**
Rechargeable Battery	6xAA	7.2V	1	2000	2000mAh
				Battery Life	0.67hours

Table 15: Scorepad Power Budget

1. List major components					
Component Name	**Part Number**	**Supply Voltage Range**	**Quantity**	**Absolute Maximum Current (mA)**	**Total Current (mA)**
Microcontroller	PIC18F47K40	1.8-5.5V	1	350	350mA
E-Paper Display	B071JFRV2S	2.4-3.7V	1	12.12	12.12mA
Vibrator Motor	1201	2-5V	1	100	100mA
2. Assign major components to power rails. Try to minimize the number of power rails necessary. Add additional voltage rails if needed.					
3.3V Power Rail					
Component Name	**Part Number**	**Supply Voltage Range**	**Quantity**	**Absolute Maximum Current (mA)**	**Total Current (mA)**
Microcontroller	PIC18F47K40	1.8-5.5V	1	350	350mA
E-Paper Display	B071JFRV2S	2.4-3.7V	1	12.12	12.12mA
Vibrator Motor	1201	2.0-5.0V	1	100	100mA
				Subtotal	462.12mA
				Safety Margin	25%
3.3V Regulator				***Total Current Required on 3.3V Rail***	577.65mA
3.3V low-dropout regulator	LD29150DT33R	4.0-14.0V	1	1500	1500mA
3. Calculate Power Supply Requirements					
Component Name	**Part Number**	**Supply Voltage Range**	**Quantity**	**Absolute Maximum Current (mA)**	**Total Current (mA)**
3.3V low-dropout regulator	LD29150DT33R	4.0-14.0V	1	1500	1500mA
External Supply				***Total Current Required of External Supply***	1500mA
Rechargeable Battery Pack	4xAAA	4.8V	1	800	800mA
4. Calculate Battery Life					
Component Name	**Part Number**	**Supply Voltage Range**	**Quantity**	**Absolute Maximum Current (mAh)**	**Total Current (mAh)**
Rechargeable Battery Pack	4xAAA	4.8V	1	800	800mAh
				Battery Life	0.53hours

Software Design

Activity Diagrams

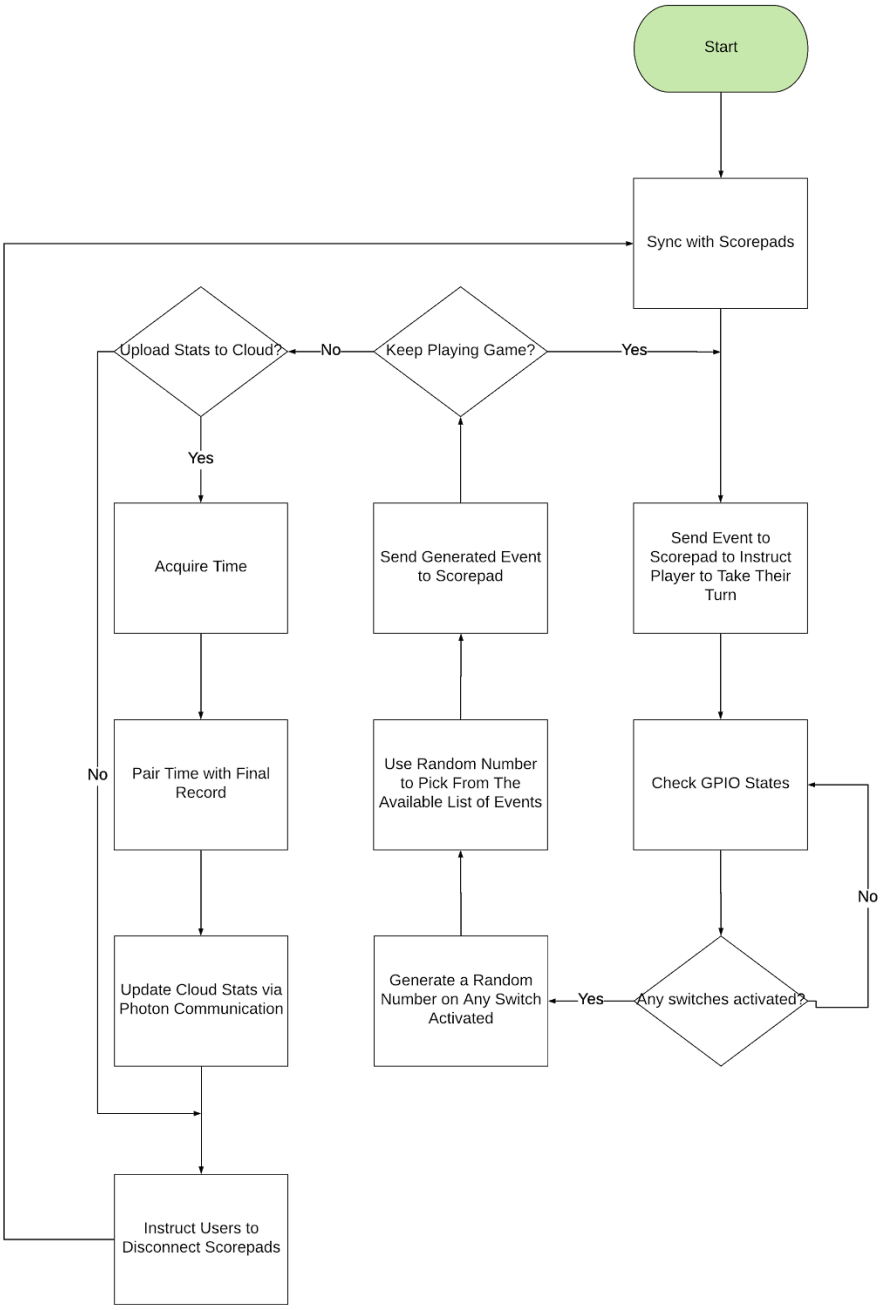


Figure 5: Game Board Activity Diagram

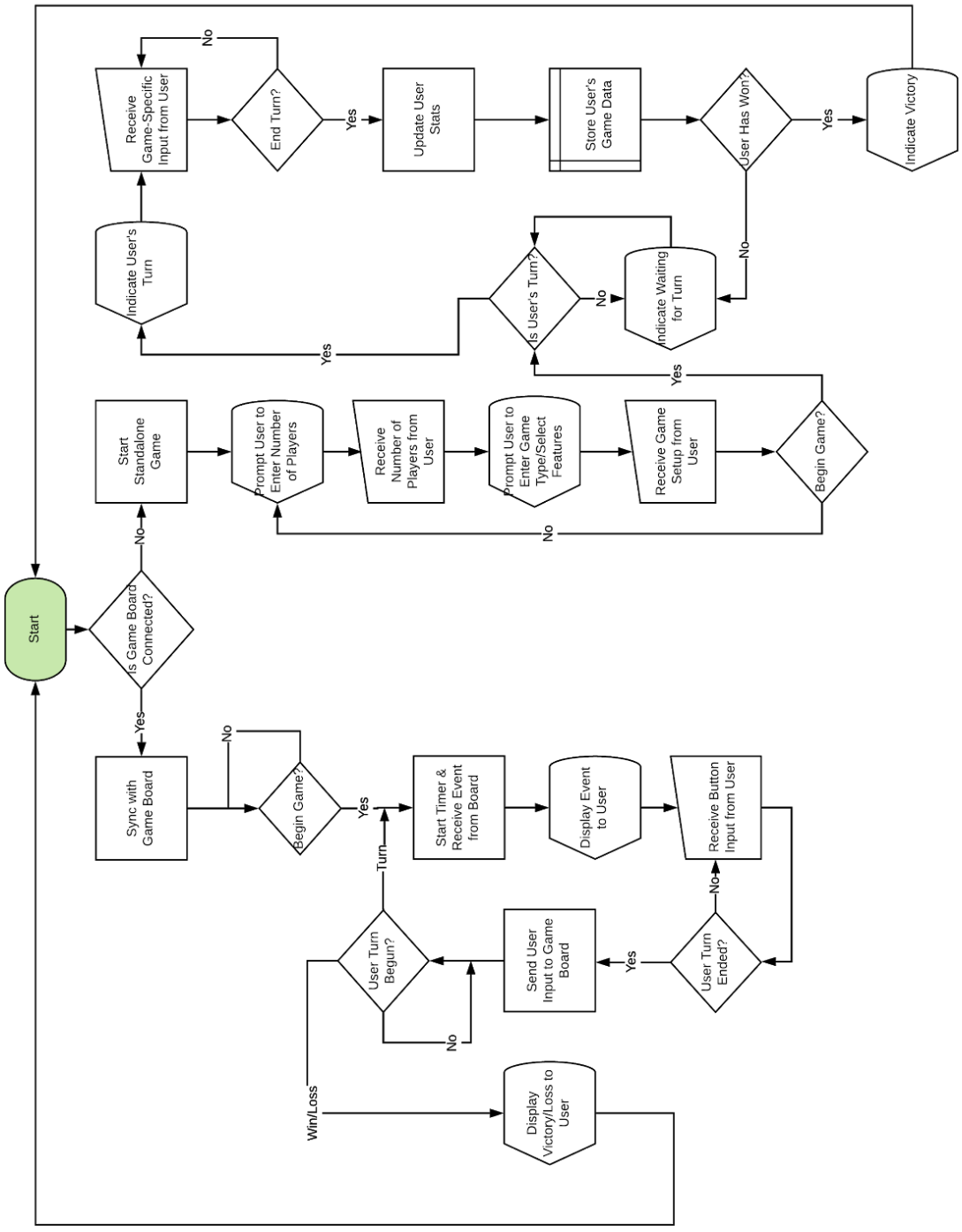


Figure 6: Scorepad Activity Diagram