Epic Dice Roller

Designed and created by: Braden Harwood, Michael Weston, Stephen Short, Drew Seidel (Team 2 - ECE 411 - Fall 2021)

Problem

Some common problems of ordinary dice…

- They are easy to lose
- Geometrical problems cause many sided dice to be very difficult to make and read
- They lack an interactive and dynamic way of revealing your roll and its implications on the game (i.e green flashing on a good roll, red on a bad)
- They lack history of dies rolled in case of forgetfulness
- They lack the ability to change the number of sides on a whim, leading one to need to own many dice sets

A positive attributes of dice that we don’t want to lose in our design:

- Hands on, the ability to physically feel, and roll dice by shaking
- Random result generation

Vision and Motivation

The goal of our end product is to provide a fun, unique, and engaging way to roll dice for the majority of games that require dice, without eliminating the iconically unique feel of rolling the dice by means of shaking. The product is meant to serve as:

- An efficient and effective means of rolling a variety die sizes, as well as well as the number of die rolled, such that the device can be interchanged for traditional die on the vast majority of common games
- A novelty product. The Epic Dice Roller intends to enhance the dice rolling experience, giving the user fun and innovative feedback, methods for rolling, and methods for changing die size and number of die
- Provides a retro visual aesthetic, feel, and means of interacting with the device, without detracting from the positive features of traditional dice that we all know and love

Objectives

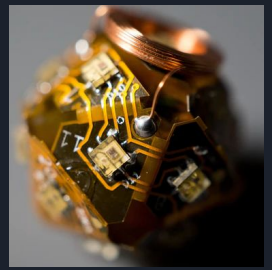
By the end of this project, the goal was to have a not only functional, but nearing ready to move to production product design with a corresponding prototype to demonstrate that this is the case. The product we will unveil today has met the following objectives:

- Electrical design, functionality, and layout is functional and sound
- Power supply to device (9V battery) is simple, and accessible, and replaceable
- Device prototype is user friendly
- Demonstrates the ability to roll up to 9 dice at once
- Demonstrates an ability to be programmed via ICSP for firmware updates
- Demonstrates the ability to have the user change number of die rolled
- Demonstrates the ability to have the user change the dice size (d4, d6, d8, d10, d20, d100)
- Demonstrates that the user can roll dice using three different methods

Alternatives

eDice 2 on Kickstarter and already delivered.

$45 per unit. Rechargeable batteries. Similar features but fewer mechanical inputs.



Pixels Electronic Dice on Kickstarter. No deliveries yet, but many updates.

$39 for once die, or $199 for a set of 7 dice.

Wireless Charging, Open Source, Bluetooth, App, Website Integrations.

No

Requirements

In designing this products, we set out the following goals:

Must:

- Simulate up to 9 dice at once
- Display total of dice
- Be able to preview size of dice and number of dice the user will be rolling
- Be powered from a batter
- Use a microprocessor

Should:

- Mount our microprocessor on our own PCB rather than a daughter board
- Have one compact PCB for the entire design
- Be programmable via on-board ICSP circuitry
- Provide users with at least three methods of dice rolling

May:

- Provide user with the individual result of each dice after a rol
- Allow the user to roll ‘fudge’ dice
- Display previous rolls.
- Have an enclosure.

We are two years ahead of schedule...

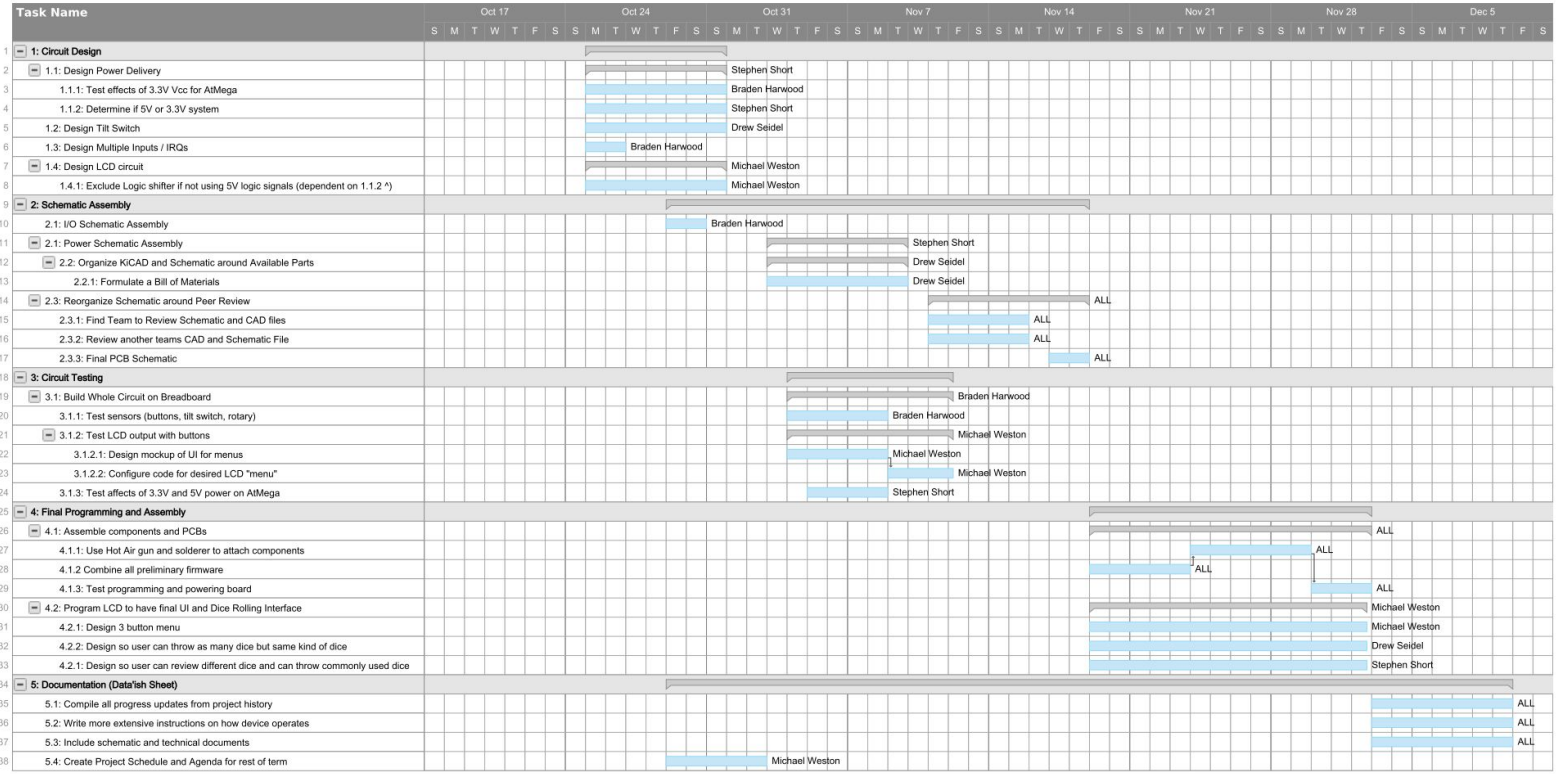
- Implement bluetooth to phone application to reveal roll
- Flashing LEDs on PCB
- Speaker on PCB for noise
- Voice activated

Team #2 - Epic Dice Roller

smartsheet

Michael Weston
Braden Harwood
Drew Seidel
Stephen Short

Our Approach



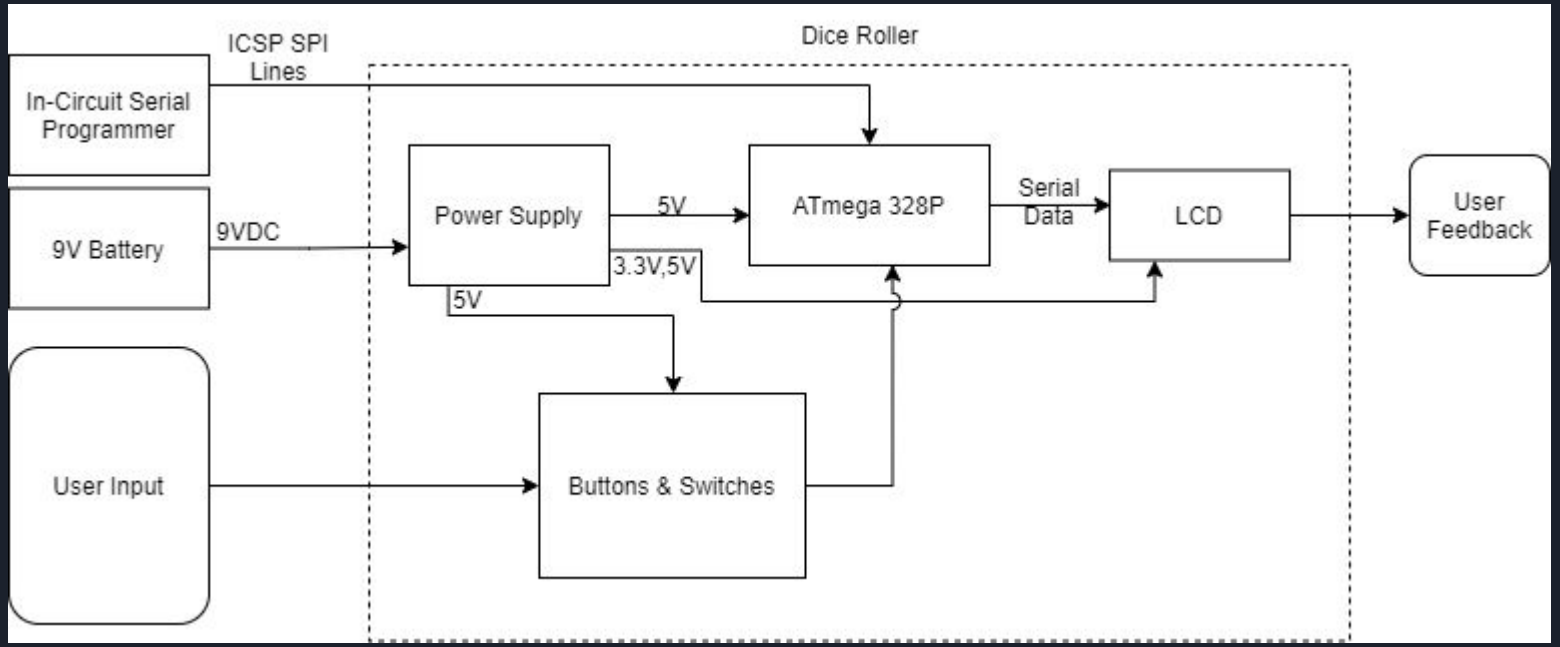
Divide and Conquer

Collaborate Often

Meet twice a week

L0 Block Diagram

L1 Block Diagram



Design - I/O and Chip Selection

Given the I/O components we selected, we elected to use the ATmega328P, given its cost, number of I/O pins, number of interrupt pins, and voltage specifications.

Our I/O circuits can be broken down into the following components/subsections.

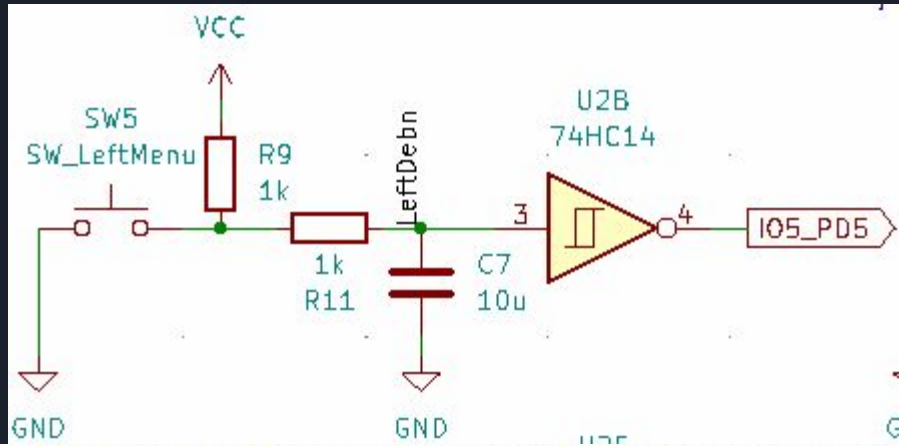
Sensors:

- A toggle switch
- A single pole single throw power switch
- A single pole double throw toggle switch
- Four pushbuttons
- A rotary encoder with a top pushbutton
- A tilt switch

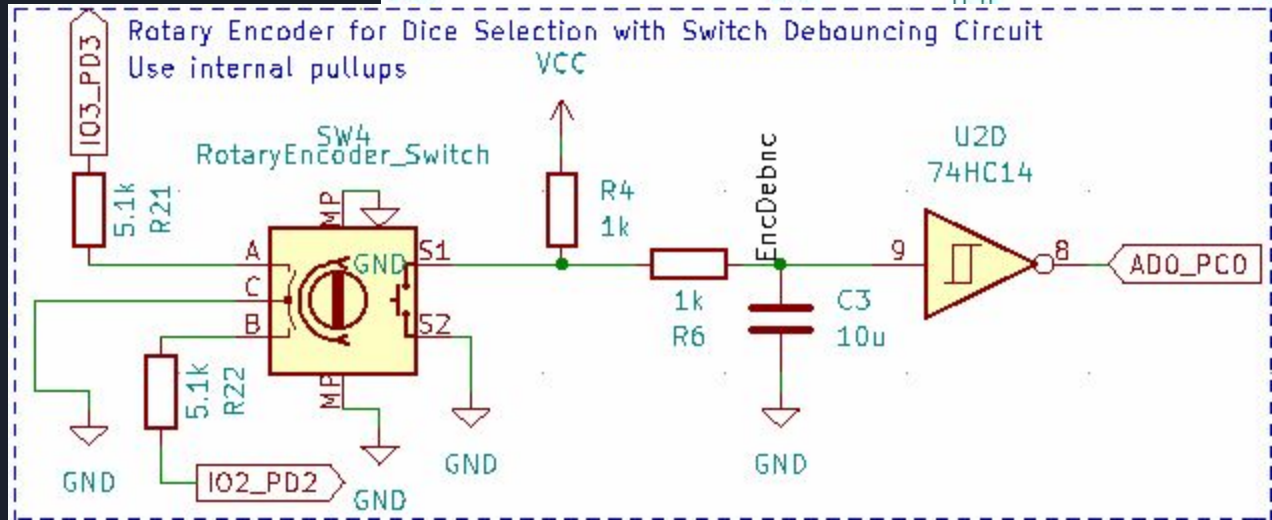
Actuator:

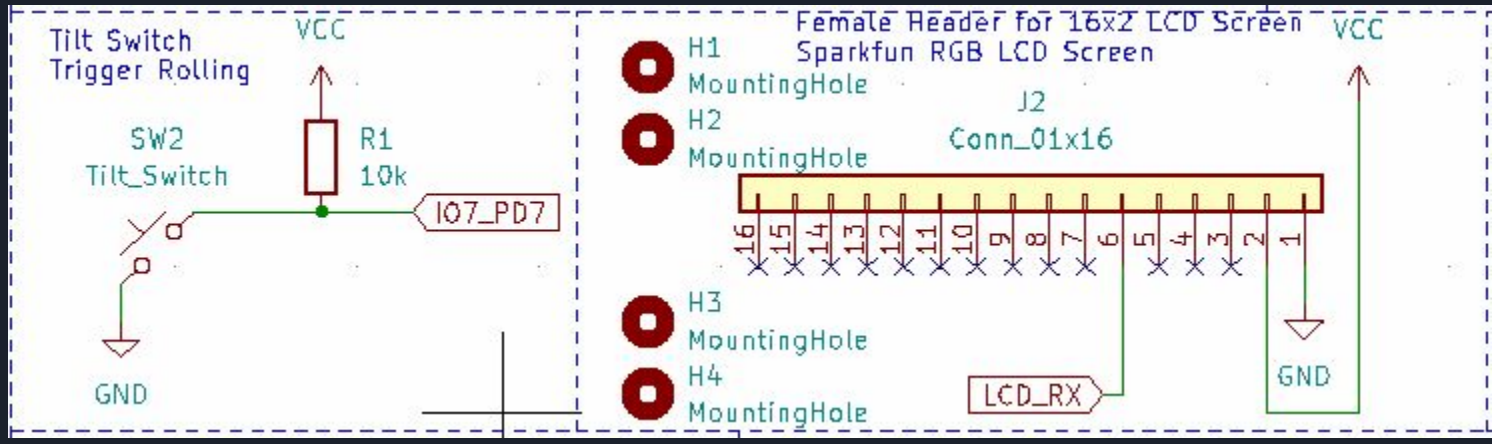
- An LCD screen

Push Button
w/ Schmitt trigger

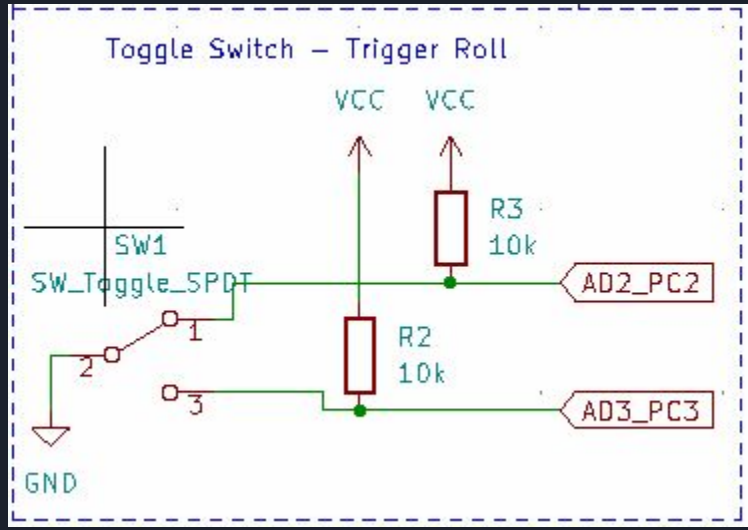


Rotary Encoder
w/ Schmitt trigger



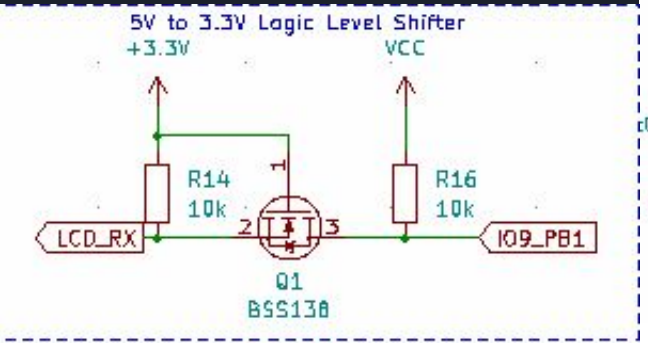


- Tilt Switch
- SerLCD Connector
- Toggle Switch



ATMega328P

5V to 3.3V Logic Level Shifter



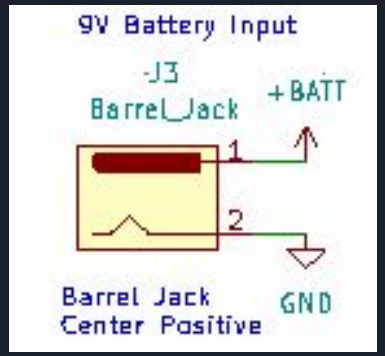
ATMEGA32BP Controller Circuit

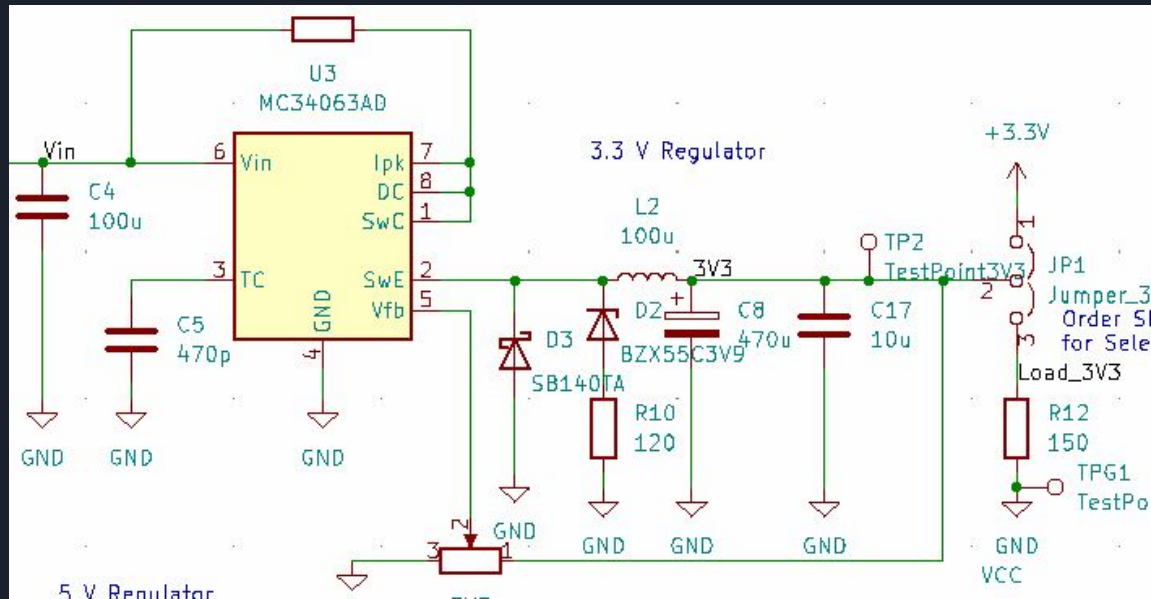
VCC
VCC
20
7
AVCC
VCC
AREF
21
C13
100n
C14
100n
C15
100n
GND
GND
GND
IO8_PB0
IO9_PB1
IO10_SS_PB2
IO11_MOSI_PB3
IO12_MISO_PB4
IO13_SCK_PB5
14
15
16
17
18
19
PB0
PB1
PB2
PB3
PB4
PB5
9
10
XTAL1/PB6
XTAL2/PB7
30p
Crystal for Clock
Y1
Crystal_16MHz
30p
C10
GND
ADO_PC0
AD1_PC1
AD2_PC2
AD3_PC3
AD4_PC4
AD5_PC5
23
24
25
26
27
28
PC0
PC1
PC2
PC3
PC4
PC5
1
RESET/PC6
U4
ATmega328P-P
VCC
SW7
SW_Reset
R18
10k
RESET#
Reset Switch
GND
GND
IO0_RX_PD0
IO1_TX_PD1
IO2_PD2
IO3_PD3
IO4_PD4
IO5_PD5
IO6_PD6
IO7_PD7
2
3
4
5
6
11
12
13
PD0
PD1
PD2
PD3
PD4
PD5
PD6
PD7
GND
8

Design - Power Supply

The power supply was designed to:

- Take one 9V battery, and provide 5V Vcc to the circuit, and a 3.3V line to a logic shifter for the LCD, while maintaining the current requirements of the system

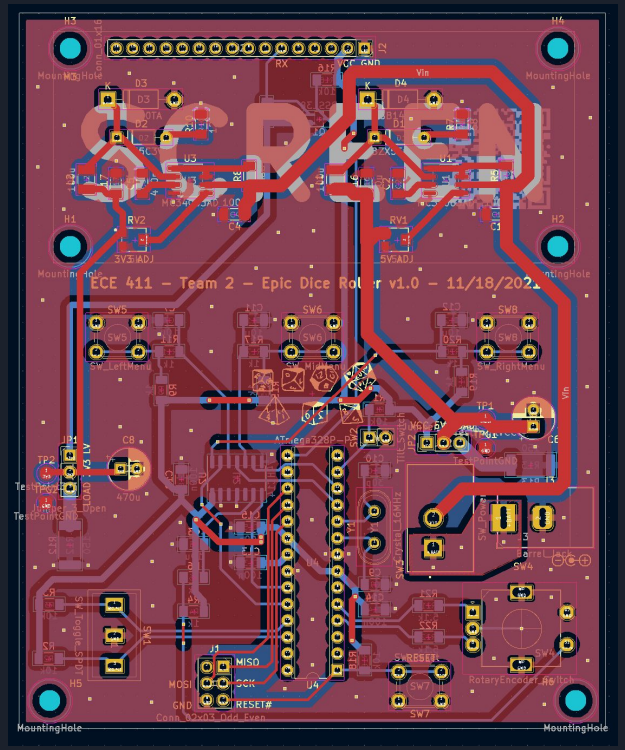


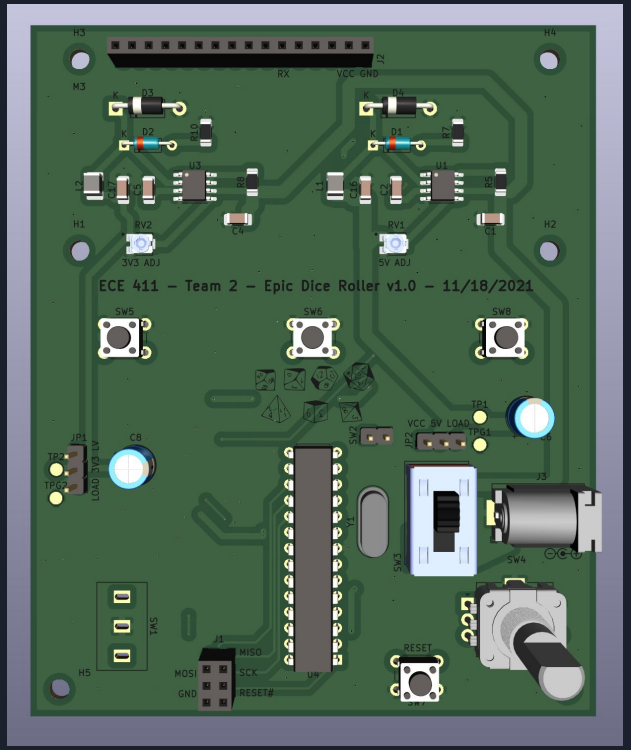


Implementation and Integration

- Used LTSpice to simulate power supply
- Built sub circuits on breadboards for testing.
  - Power supply
  - Buttons & Schmitt trigger
  - Rotary Encoder
  - Tilt Switch
  - Logic Level Shifter and SerLCD screen

Layout


ECE 411 – Team 2 – Epic Dice Roller v1.0 – 11/18/2021
MISO
SCK
RESET#
MOSI
GND


ECE 411 – Team 2 – Epic Dice Roller v1.0 – 11/18/2021
MISO
SCK
RESET#
MOSI
GND

Bill of Materials

Total Cost for 4 Boards

$169.77

Total Cost for 1 Board

$42.44

PCB Manufacturing Cost:

$76.70 for 4 PCBs

$19.18 each

Total Cost of Assembled Board

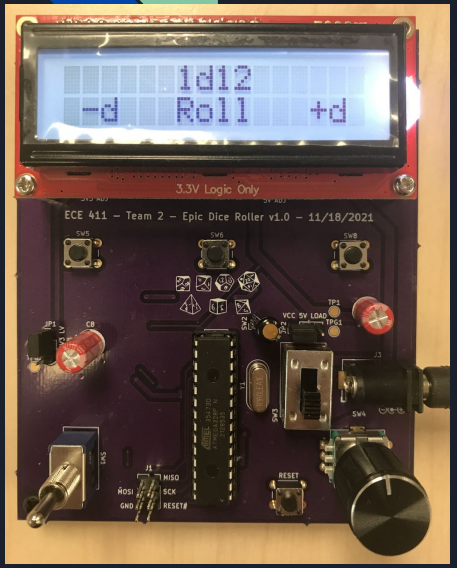
$61.22

Bill Of Materials for: Team 2 Epic Dice Roller
Last modified: 11/10/2021
PCB version: 1.1
BOM revision: 1.1

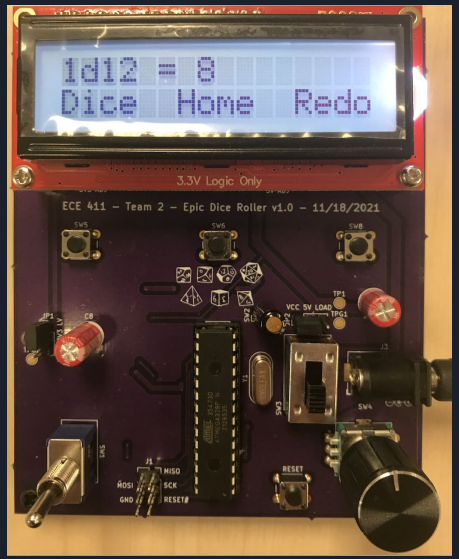
P/NP = Place/Not Place (components marked NP are not stuffed on the board)

Quanity Needed	Part References	P/NP	In Cart	Manufacturer	Manufacturer PN	Description	Distributor	Distributor PN	Cost Each	Cost Total
0	NA	NP		Sparkfun	PGM-09825	POCKET AVR PROGRAMMER	Digikey	PGM-09825	$16.95	$0.00
4	NA	NP		Sparkfun	LCD-16397	16x2 RGB LCD Screen	Digikey	LCD-16397	$20.00	$80.00
8	C1,C4	P	y	TDK Corporation	C3216X6S0G107M160AC	100uF SMD 1206 Capacitors	Digikey	C3216XS0G107M160AC	$1.09	$8.72
8	C2,C5	P	y	TDK Corporation	C3216C0G2J471J085AA	470pF SMD 1206 Capacitors	Digikey	C3216C0G2J471J085AA	$0.28	$2.24
24	C3,C7,C11,C12, C16, C17	P	y	Samsung Electro-Mechanics	CL31A106KQHNNNE	10uF SMD 1206 Capacitors	Digikey	CL31A106KQHNNE	$0.22	$5.28
8	C9,C10	P	y	Kemet	C1206C300F1HAC7800	30pF SMD 1206 Capacitors	Digikey	C1206C300F1HAC7800	$0.39	$3.12
16	C13,C14,C15,C18	P	y	Samsung Electro-Mechanics	CL31A106KQHNNNE	100nF SMD 1206 Capacitors	Digikey	CL31B104KBCNNNC	$0.13	$2.08
8	C6, C8	P	y	Würth Elektronik	860010273011	470uF TH 6.3mmDx2.5mmL Capacitors	Digikey	860010273011	$0.17	$1.36
4	D1	P	y	Vishay General Semiconductor - Diodes Di	BZX55C5V1-TAP	BZX55C5V1: 5.1V Zener Diode	Digikey	BZX55C5V1-TAP	$0.21	$0.84
4	D2	P	y	Vishay General Semiconductor - Diodes Di	BZX55C3V9-TR	BZX55C3V9: 3.9V Zener Diode	Digikey	BZX55C3V9 -TRGICT-ND	$0.21	$0.84
4	J1	P	y	Adam Tech	PH2-06-UA	02x03 Connector - ISP Male Header	Digikey	PH2-06-UA	$0.13	$0.52
4	J2	P	y	Sullins Connector Solutions	PPTC161LFBN-RC	01x16 Connector LCD Screen Female Header	Digikey	PPTC161LFBN-RC	$0.98	$3.92
8	Standoff					Standoffs for LCD Screen WIP				
4	J3	P	y	CUI Devices	PJ-037A	9V barrell jack connector	Digikey	PJ-037A	$0.58	$2.32
8	JP1, JP2	P	y	Sullins Connector Solutions	PREC003SAAN-RC	01x03 Connector - Jumper for 5V and 3.3V PSU Testing	Digikey	PREC003SAAN-RC	$0.09	$0.72
8	Shunt1, Shunt2	P	y	Sullins Connector Solutions	SPC02SYAN	Closed 2 Pin Shunt	Digikey	SPC02SYAN	$0.10	$0.80
8	L1,L2	P	y	Taiyo Yuden	CBC3225T101KR	100u Inductor 1210	Digikey	CBC3225T101KR	$0.30	$2.40
4	Q1	P	y	Nexperia USA Inc.	BSS138BKW,115	BSS138	Digikey	BSS138BKW-115	$0.36	$1.44
24	R1,R2,R3,R14,R16,R18	P	y	YAGEO	RE1206FRE0710KL	10k SMD 1206 Resistor	Digikey	RE1206FRE0710KL	$0.10	$2.40
32	R4, R6, R9, R10, R11, R15, R17, R19	P	y	Panasonic Electronic Components	ERJ-8GEYJ102V	1k SMD 1206 Resistor	Digikey	ERJ-8GEYJ102V	$0.14	$4.48
8	R5,R8	P	y	Panasonic Electronic Components	ERJ-8BQJR33V	0.33 SMD 1206 Resistor	Digikey	ERJ-8BQJR33V	$0.43	$3.44
4	R7	P	y	Stackpole Electronics Inc	RMCF1206JT68R0	68 SMD 1206 Resistor	Digikey	RMCF1206JT68R0	$0.03	$0.11
4	R20	P	y	Stackpole Electronics Inc	RMCF1206JT120R	120 SMD 1206 Resistor	Digikey	RMCF1206JT120R	$0.03	$0.11
8	R21, R22	P	y	Stackpole Electronics Inc	RMCF1206JT5K10	5.1k SMD 1206 Resistor	Digikey	RMCF1206JT5K10	$0.03	$0.22
8	R12, R13	P	y	Stackpole Electronics Inc	RMCF2512FT150R	**150 SMD 2512 Resistor 1W**	Digikey	RMCF2512FT150R	$0.37	$2.96
8	RV1,RV2	P	y	Bourns Inc.	TC33X-2-502E	5k SMD Potentiometer	Digikey	TC33X-2-502E	$0.26	$2.08
4	SW1	P		HiLetgo	MTS-103	Miniature Toggle Switch MTS-103	Amazon	MTS-103	$0.55	$2.20
4	SW2	P		Gilkfun	SW-520D	Tilt Switch	Amazon	SW-520D	$0.38	$1.54
4	SW3	P	y	CW Industries	GF-123-0054	Slide Switch SPST Through Hole	Digikey	GF-123-0054	$1.29	$5.16
4	SW3	P		Cylewet	NA	RotaryEncoder_Alps_EC11E-Switch_Vertical_H20mm	Amazon	EC11 CYT1100	$1.70	$6.79
16	SW5, SW6, SW7, SW8	P		NA	NA	Button_Switch_THT:SW_PUSH_6mm_H5mm	NA	NA	$0.00	$0.00
8	TP1, TP2, TP3	NP		NA	NA	Testpoint	NA	NA	$0.00	$0.00
8	U1,U3	P	y	Texas Instruments	MC34063ADR	MC34063AD	Digikey	MC34063ADR	$0.78	$6.24
4	U2	P	y	Onsemi	MC74HC14ADR2G	74HC14	Digikey	MC74HC14ADR2GOSCT-I	$0.49	$1.96
4	Y1	P	y	Raltron Electronics	AS-16.000-20-EXT	Crystal_16MHz	Digikey	2151-AS-16.000-20-EXT-N	$0.18	$0.72
4	U4	P	y	Microchip Technology	ATMEGA328P-PU	ATmega328P-P	Digikey	ATMEGA328P-PU	$2.82	$11.28
4		P	y	On Shore Technology Inc.	ED281DT	28 pin dip socket	Digikey	ED281DT	$0.37	$1.48
4		NP		DZS Elec	NA	9V Battery to Barrel Jack Cable	Amazon	DZS Elec	$1.00	$4.00
									Total	$169.77

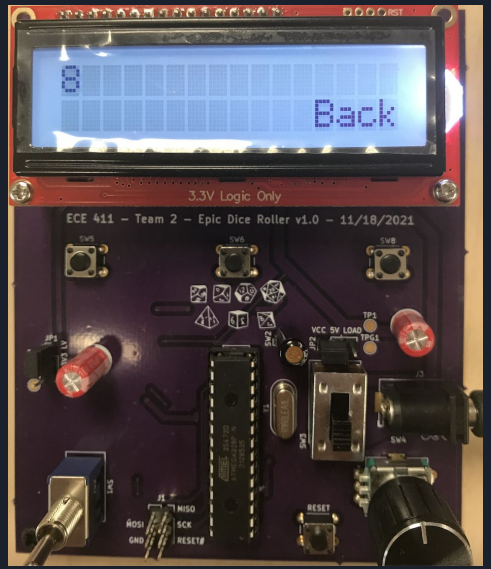
Firmware - Code Overview



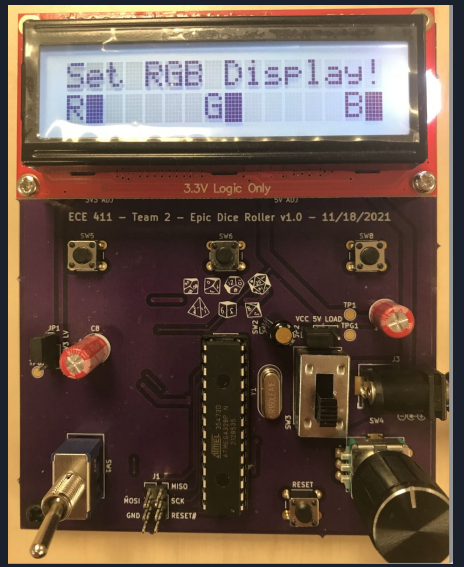
Home Screen
-Main Screen to Roll Dice



Display Dice Total
-Displays total of dice after roll



Display Each Dice Rolled
-Display each individual dice



Set Custom Backlight
-Set custom backlight.

IP and Prior Work

Braden's Dice Roller v0

Arduino Bootloader and IDE

Software Libraries: Entropy, AltSoftSerial, RotaryEncoder, EnableInterrupt

Sparkfun Logic Level Converter

Andrew Greenberg's atmega328p Circuit Example

Reference Design from MC34063ADR Datasheet

KiCAD v5.99

LTSpice XVII

Testing

We tested during each phase of the design process to ensure that the steps we were taking would yield a successful prototype:

Pre-PCB Development Stage:

- Tested the power supply design on breadboard
- Tested tilt switch, other I/O components on breadboard
- Developed a fully working breadboard prototype

During PCB Schematic and Layout Development:

- Multiple iterations, layouts by group members
- ERC tests
- DRC tests
- Design reviews

During PCB Bringup

- Soldered power supply first and tested to ensure success on each board
- Soldered I/O and tested electrical continuity, and validity of input/output functionality from sensors
- Tested electrical functionality of Rx line to LCD pins and it's voltage level

Post PCB Bringup (Firmware Testing)

- Tested all modes to ensure functionality was as expected
- Interrogation of bugs
- Ensured that the random numbers were being generated, and die numbers were within range

Results - Power Supply - 3.3V Output

Test Author: Braden Harwood, Michael Weston, Stephen Short, Drew Seidel						
	Test Case Name:	Epic Dice Roller Power Supply Test 2				**Test ID #:** 2
	Description:	*This test checks the output of the power supply portion of the circuit dividing output to 5V*				**Type:** ✓ white box □ black box □ _____
Tester Information						
	Name of Tester:	Stephen Short and Group				**Date:** 11/30/2021
	HW/SW Version:	1.0				**Time:** 1:15 PM
	Setup:	*Will need the PCB with the 3.3 V supply parts soldered on, 5V supply parts, and soldering and test equipment. Use either a 9V battery or benchtop power supply for input voltage.*				
STEP	**Action**	**Expected Result**	**PASS**	**FAIL**	**N/A**	**Comments**
1	Solder all of the 3.3 V Supply	All components making up the 5 V Supply should be soldered.	Y			Successfully soldered parts.
2	Test for continuity	All connections that should be made are made	Y			Successfully tested connections.
3	Test for shorts	No shorts should be found.	Y			Successfully tested connections.
4	Power up board	Power up the 5V supply for the first time and get an output voltage generated by the supply.	Y			2.7V recorded on power up.
5	Adjust potentiometer to generate 5 V	After adjusting the potentiometer, the output voltage should measure as 5 V.	Y			5.002 V recorded after adjustment.
6	Attach shunt to load resistor.	Measuring output voltage and confirming that it is still near the 5 V expected while the output is connected to a 150 ohm load resistor.	Y			5 V was still measured after shunting it across the load resistor.
7	Confirm 5 V connection to VCC points on PCB	When the shunt is now attached to the VCC, measure all VCC points to make sure they read 5 V	Y			5 V is successfully read at all VCC points.
8	Test 3.3 V Supply Again after finishing the 5 V supply.	After soldering the 5 V supply, make sure the 3.3 V supply still works.	Y			3.3 V is still read on LV test points.
	Overall test result:		Y			5 V power block functional.

Results - Power Supply - 5V Output

Test Author: Braden Harwood, Michael Weston, Stephen Short, Drew Seidel						
	Test Case Name:	Epic Dice Roller Power Supply Test 1			**Test ID #:**	1
	Description:	*This test checks the output of the power supply portion of the circuit dividing output to 3.3V.*			**Type:**	✓ white box □ black box □ _____
Tester Information						
	Name of Tester:	Stephen Short and Group			**Date:**	11/30/2021
	HW/SW Version:	1.0			**Time:**	11:30 AM
	Setup:	*Will need the bare PCBs, parts, soldering and test equipment. Use either a 9V battery or benchtop power supply for input voltage.*				

STEP	**Action**	**Expected Result**	**PASS**	**FAIL**	**N/A**	**Comments**
1	Solder all of the 3.3 V Supply	All components making up the 3.3 V Supply should be soldered.	Y			Successfully soldered parts.
2	Test for continuity	All connections that should be made are made	Y			Successfully tested connections.
3	Test for shorts	No shorts should be found.	Y			Successfully tested connections.
4	Power up board	Power up the 3.3 V supply for the first time and get an output voltage generated by the supply.	Y			2.49V recorded on power up.
5	Adjust potentiometer to generate 3.3 V	After adjusting the potentiometer, the output voltage should measure 3.3 V.	Y			3.3084 V recorded after adjustments.
6	Attach shunt to load resistor.	Measuring output voltage and confirming that it is still near the 3.3 V expected while the output is connected to a 150 ohm load resistor.	Y			Slight increase in voltage to around 3.31 V, voltage remained stable.
7	Confirm 3.3 V connections to level shifter.	When IO9 which will be connected to the software serial port on the arduino controls the LCD screen.	Y			RX pin on the LCD receives 3.3 V logic.
	Overall test result:		Y			3.3 V Power Block Functional

Results - I/O Electrical Functionality

Test Author: Braden Harwood, Michael Weston, Stephen Short, Drew Seidel						
	Test Case Name:	Epic Dice Roller Test 4			**Test ID #:**	4
	Description:	*Attach ATMega328P and LCD screen to dip sockets, attach ISP pins, burn bootloader and write firmware to the Epic Dice Roller. Test functionality of code.*			**Type:**	✓white box ▫ black box ▫ _____
Tester Information						
	Name of Tester:	Group (Test in Progress)			**Date:**	12/1/21 - 12/9/21
	HW/SW Version:				**Time:**	3:00PM
	Setup:	*All PCB components attached, ready for firmware to upload to device*				
STEP	**Action**	**Expected Result**	**PASS**	**FAIL**	**N/A**	**Comments**
1	With the board powered down, put ATMega328P and LCD into their dip sockets Attach ISP pins	Chips should fit firmly into position	Y			ATMega328P and LCD successfully attached.
2	Check VCC and GNDconnections once more	Adding to ATMega328P and LCD should not alter priorly tested VCC and GND pins. Check once more.	Y			Electrical connections are still sound.
3	Power on device, burn bootloader	Bootloader should be able to be successfully uploaded.	Y			Burned bootloader successfully.
4	Upload firmware using the programmer (Pocket AVR, AVR Dragon, Arduino...etc)	Firmware should be successfully uploaded	Y			Firmware uploaded successfully.
5	Observe LCD Output	LCD output should be formatted as designed. Die choice should be on the top row, in the second row, an option for less die, more die, and roll die.	Y			LCD startup output yields expected result.
6	Observe button functionality in non-rolling mode	I/O should behave as expected for non-rolling mode. User ability to change number of die, side of die count, reset, and to roll.	Y			I/O is responding accordingly.
7	Test rolling mode (many cases)	Should produce random numbers for dice, add correctly, and display results to user.	Y			Effective
	Overall test result:		**Y**			**User interface functional**

Results - Firmware Testing and User Interface

Test Author: Braden Harwood, Michael Weston, Stephen Short, Drew Seidel						
	Test Case Name:	Epic Dice Roller Test 4			**Test ID #:**	4
	Description:	*Attach ATMega328P and LCD screen to dip sockets, attach ISP pins, burn bootloader and write firmware to the Epic Dice Roller. Test functionality of code.*			**Type:**	✓white box □ black box □ _____
Tester Information						
	Name of Tester:	Group (Test in Progress)			**Date:**	12/1/21 - 12/9/21
	HW/SW Version:				**Time:**	3:00PM
	Setup:	*All PCB components attached, ready for firmware to upload to device*				
STEP	**Action**	**Expected Result**	**PASS**	**FAIL**	**N/A**	**Comments**
1	With the board powered down, put ATMega328P and LCD into their dip sockets Attach ISP pins	Chips should fit firmly into position	Y			ATMega328P and LCD successfully attached.
2	Check VCC and GNDconnections once more	Adding to ATMega328P and LCD should not alter priorly tested VCC and GND pins. Check once more.	Y			Electrical connections are still sound.
3	Power on device, burn bootloader	Bootloader should be able to be successfully uploaded.	Y			Burned bootloader successfully.
4	Upload firmware using the programmer (Pocket AVR, AVR Dragon, Arduino...etc)	Firmware should be successfully uploaded	Y			Firmware uploaded successfully.
5	Observe LCD Output	LCD output should be formatted as designed. Die choice should be on the top row, in the second row, an option for less die, more die, and roll die.	Y			LCD startup output yields expected result.
6	Observe button functionality in non-rolling mode	I/O should behave as expected for non-rolling mode. User ability to change number of die, side of die count, reset, and to roll.	Y			I/O is responding accordingly.
7	Test rolling mode (many cases)	Should produce random numbers for dice, add correctly, and display results to the user.	Y			Effective
	Overall test result:		**Y**			**User interface functional**

Results and Issues

Fun Features:

- Color splashes when rolling really well or really poorly
- Tilt switch used to initiate a roll
- Several methods of rolling so user can pick their favorite method:
  - Shake detection, button, pressing the rotary encoder
- User can customize the display color and even randomize the color utilizing the shake feature

Issues:

- Using software serial interface occasionally results in transmission being interrupted. Resulting in unexpected characters displayed to the LCD
- Lack of on board LEDs and serial output make it hard to debug during design.
- External pull ups for rotary encoder switch would’ve made testing easier.
- Power switch is would feel more natural if ‘ON’ was up
- Toggle switch footprint is slightly off.

Contributions

Braden - I/O Testing and Breadboarding, Schematic Capture and Layout, Hot Air Soldering Tutorial

Drew - BOM/Part Sourcing, Test Documentation, Tilt Switch Design/Testing

Michael - UI/UX Design, Firmware Development, and Scheduling

Stephen - P/S design (and redesign). PCB testing.

What We Learned

Braden - KiCAD, PCB Layout

Drew -Hot air soldering with solder paste, PCB testing

Michael - Soldering / using solder paste, programing LCD for user, designing PCBs

Stephen - Buck regulator operation, hot air soldering with solder paste

If We Could Turn Back Time...

- Debounce the tilt switch
- Smaller form factor
- Use a rechargeable LiPo battery
- Use ATMega328P hardware for serial communication (either USART or SPI)
- Mount battery to board itself (on back or under screen)
- On board LEDs
- RickRoll QR Code...you know...for science!
- Sound effects
- Accessibility options
- Test point for SerLCD Rx signal
- Route reset button to reset SerLCD as well