Travis Crumley
Final Project
ENGR 355 Winter Quarter 2014

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Introduction

This project is the final project for ENGR 355 Winter Quarter 2014 Embedded Systems Design. The project included both hardware and software elements which in combination resulted in a working board that could participate in a game known as J.S. Joust.

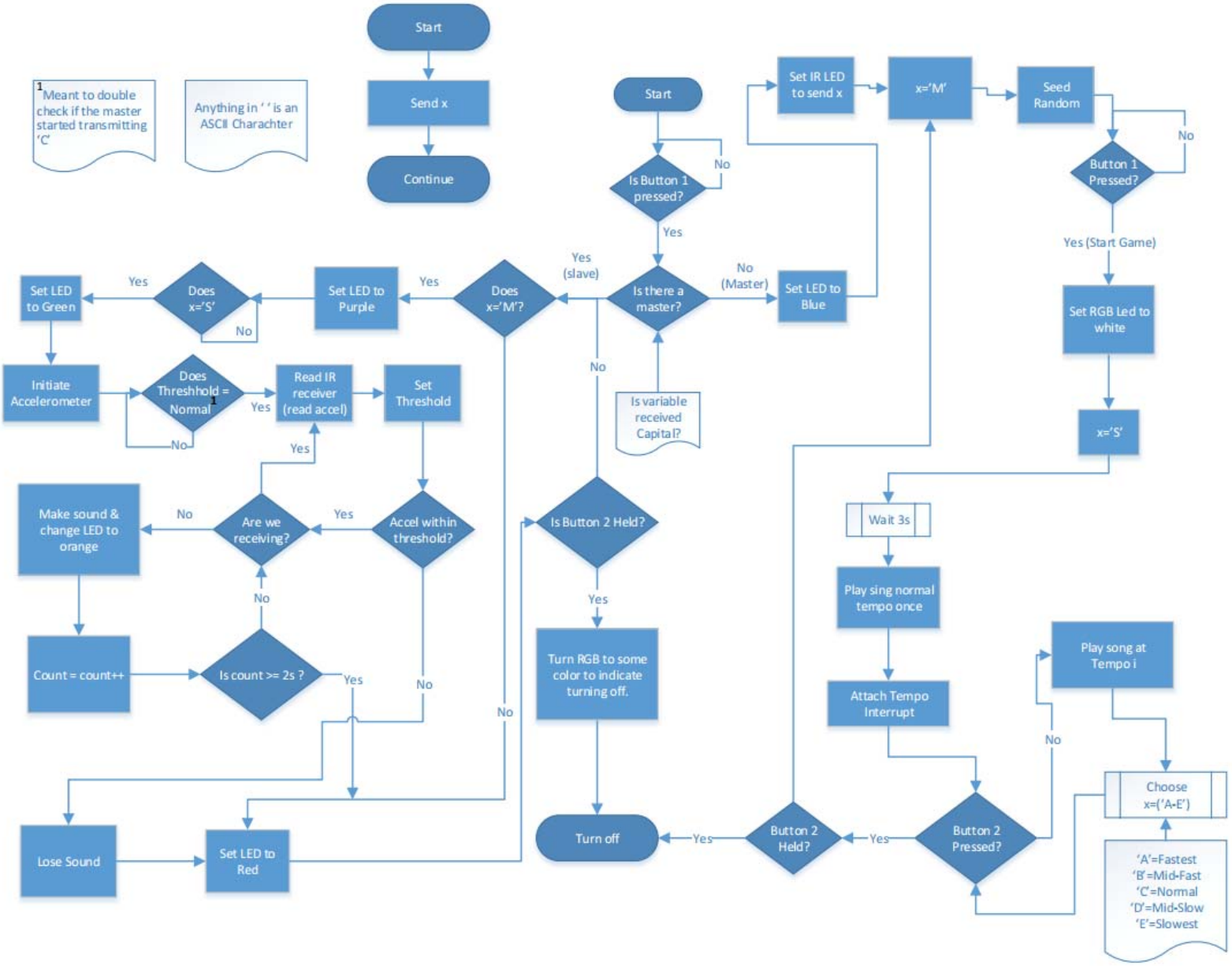
J.S. Joust is a relatively simple game where some music is played at a varying tempo, and depending on that tempo the players can move their game pieces faster or slower. The goal of the game is to cause the other players to move their game pieces faster than the tempo allows, causing them to lose and drop out of the game for that round.

Procedure

The project first started with an overall schematic that was built on many elements that we had been working on in labs and classwork over the course of the quarter. We then used Mentor Graphics to create an actual circuit board to carry the required parts for the schematic, using the same processor as we used in labs on a breadboard.

Once we got the circuit boards we then spent time manually placing the parts and soldering them on. As might be expected for a project with newcomers many boards did not work properly, and extensive troubleshooting was required. Some boards, such as mine, never did become fully functional and I instead partnered up to use another student's board. This process if further documented in the troubleshooting section.

The last step was to create code to actually play the game . Using the flow chart shown below, I created a master and slave portion of code that will either play music and send appropriate tempos or receive those tempos and act as a game piece – failing when the device is moved more quickly than the tempo allows.


Start
Send x
Continue
[1]Meant to double check if the master started transmitting 'C'
Anything in ' ' is an ASCII Charachter
Start
Is Button 1 pressed?
No
Yes
Is there a master?
Yes (slave)
No (Master)
Is variable received Capital?
No
Does x='M'?
Yes
Set LED to Purple
Yes
Does x='S'
Yes
No
Set LED to Green
Initiate Accelerometer
Does Threshhold = Normal[1]
No
Yes
Read IR receiver (read accel)
Set Threshold
Yes
Accel within threshold?
Yes
Are we receiving?
No
Make sound & change LED to orange
Count = count++
Is count >= 2s ?
Yes
No
No
Lose Sound
Set LED to Red
Set LED to Blue
Set IR LED to send x
x='M'
Seed Random
Button 1 Pressed?
No
Yes (Start Game)
Set RGB Led to white
x='S'
Wait 3s
Play sing normal tempo once
Attach Tempo Interrupt
Button 2 Pressed?
Yes
No
Play song at Tempo i
Choose x=('A-E')
'A'=Fastest
'B'=Mid-Fast
'C'=Normal
'D'=Mid-Slow
'E'=Slowest
Button 2 Held?
Yes
Turn off
Is Button 2 Held?
Yes
No
Turn RGB to some color to indicate turning off.

Troubleshooting

I had several minor issues getting the initial parts and soldering many of them on by hand, but the real issues started when I plugged it into my computer. I was briefly ecstatic, as it was recognized by my computer and came up with a pop-up that said installing Generic USB Hub Driver but as nothing happened for a moment I grabbed the board and immediately yanked my hand back – the voltage regulator was extremely hot. I quickly unplugged the board and began the debug process.

The problem seemed to be related to some 3.3V connection so we first guessed that the accelerometer had a short. I used the more hardcore version of a soldering iron (with air compression) to remove it, but the pins seemed fine and that probably wasn't actually my issue. I next removed some further issues with bridging on the processor and a random wire that found its way onto my board. Testing it further I found that the jumper was also hot, and as I was testing for resistance between nodes I realized that my PMOSFET had fallen off sometime and I couldn't find it.

I soldered on another part but realized it was the wrong one (had 1-P on it) and was starting to lose hope until Greg and Professor Tim managed to find another in the projects lab. I soldered that on after some minor issues removing the other (who knew how hard it would be to get that little thing off – ended up removing one of its legs) and tested it again with the same overheating results. I then returned to trying to figure out some sort of solution testing for resistance.

We seemed to trace the resistance issue to the 3.3V line, and proceeded to take off all of my transistors in an effort to find the source of a short. Unfortunately even with that effort the short was still causing my board to heat up and I went back to the PCP Layout to see where an error might lie. I had to do quite a bit of soldering on and around the processor (and a great deal of solder-wicking) and when I saw that there were a large number of vias under the processor placed very close to the edges (and each other) the professor and I agreed that it would be wiser to work with someone else's board instead of trying to hand-solder all the tiny pins of the processor. Though it was disappointing to not get the board working I learned a great deal and since I prefer working with software it was not as frustrating as it might have been.

Since I enjoy programming the code was a relatively painless process and overall went quite well. Some challenges I had early on were solved by the group at large (namely changing 26us modulation to 2us) and the issues I did have with my code were rather quickly resolved by discussing the code and flow chart with Howie, Carlos, and Hillary in particular (as well as most of the rest of the class from time to time).

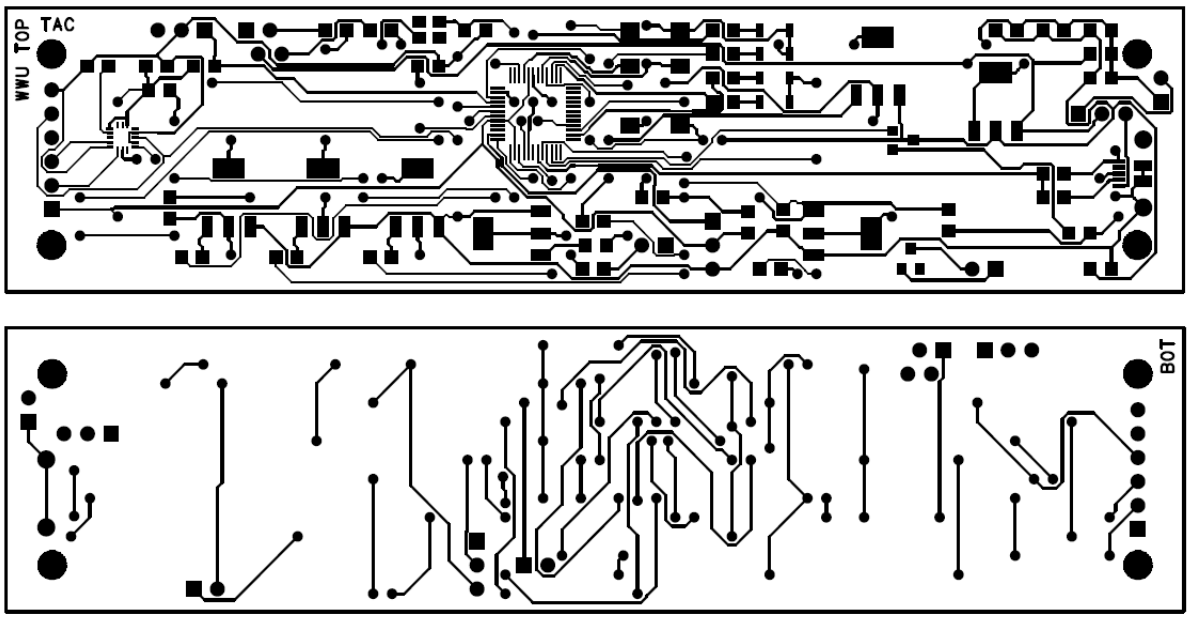
Note: Most of the "I"s in this troubleshooting process included help from the professor.

Bill of Materials

Ref	PN	Value	Geom
C1	DK-PCC2225CT	10u	0805
C10	DK-PCC180CNCT	18p	0805
C11	DK-PCC180CNCT	18p	0805
C12	DK-PCC180CNCT	18p	0805
C13	DK-PCC180CNCT	18p	0805
C2	DK-PCC2225CT	10u	0805
C3	DK-PCC2225CT	10u	0805
C4	DK-PCC1840CT	0.1u	0805
C5	DK-PCC1840CT	0.1u	0805
C6	DK-PCC1840CT	0.1u	0805
C7	DK-PCC1840CT	0.1u	0805
C8	DK-PCC1840CT	0.1u	0805
C9	DK-PCC1840CT	0.1u	0805
D1	DK-MMBD4148FSCT	SOT23	
DS1	PN-4300H1LC-T-1.75	LED_T1.75	
DS10	DK-160-1169-1	led_1206	
DS6	DK-000-0000	LED_T1.75_4lead	
DS7	DK-160-1169-1	led_1206	
DS8	DK-160-1169-1	led_1206	
DS9	DK-160-1169-1	led_1206	
J1	DK-H11610CT	conn_musb_t	
J2	DK-WM6406	conn1x6-std100	
J3	DK-S1012-03	conn1x3-std100	
J4	DK-S1012-03	conn1x3-std100	
J5	DK-S1012-03	conn1x3-std100	
J6	DK-S2012-01	conn2x1-std100	
J7	DK-S2012-01	conn2x1-std100	
Q1	MI-CZT2907A	SOT223	
Q2	MI-CZT2222A	SOT223	
Q3	MI-CZT2222A	SOT223	
Q4	MI-CZT2222A	SOT223	
Q5	MI-CZT2222A	SOT223	
Q6	MI-CZT2222A	SOT223	
Q7	DK-BS250FCT	SOT23	

R1	DK-P10KACT	10K	0805
R10	DK-P1KACT	1K	0805
R11	DK-P1KACT	1K	0805
R12	DK-P1KACT	1K	0805
R13	DK-P1KACT	1K	0805
R14	DK-P1KACT	1K	0805
R15	DK-P220ACT	220	0805
R16	DK-P220ACT	220	0805
R17	DK-P150ACT	150	0805
R18	DK-P33ACT	33	0805
R19	DK-P33ACT	33	0805
R2	DK-P10KACT	10K	0805
R20	DK-P20ACT	20	0805
R3	DK-P10KACT	10K	0805
R4	DK-P10KACT	10K	0805
R5	DK-P2.2KACT	2.2K	0805
R6	DK-P1KACT	1K	0805
R7	DK-P1KACT	1K	0805
R8	DK-P1KACT	1K	0805
R9	DK-P1KACT	1K	0805
S1	MO-101-0134-EV	switch_35X60mm	
S2	MO-652-STSM-31-N	switch_35X60mm	
S3	MO-652-STSM-31-N	switch_35X60mm	
U1	DK-MMA8452QR1CT	qfn_16_mma	
U2	DK-568-8521		sqfp_7x7_48
U3	DK-LM1117MP-3.3CT	3.3	rlp230
X1	DK-887-1121-1	12.0MHz	xtal_smd_7m

PCP Layout



C1 to C3 - 10u Capacitor
Part #: PCC2225CT
Purchasing Source: Digikey
Price: Similar Items Cost $0.1
Function:
C1 is used as a decoupling capacitor.
C2 and C3 are used to support the voltage regulator
Datasheet Name: Capacitor

Package: 0805 (2012 Metric)
Mentor Graphics Location: Capacitor -> 0805 Cer SMD

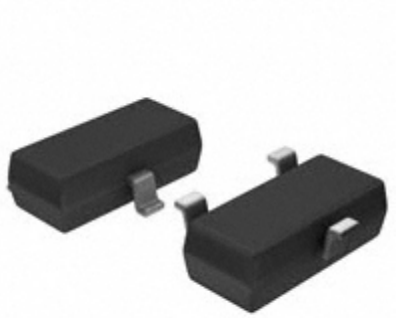
C4 to C9 - 0.1u Capacitor
Part #: PCC1840CT
Purchasing Source: Digikey
Price: Similar Items Cost $0.1
Function: C4 and C5 are used as decoupling capacitors
C6 is connected from 3.3V to ground to help the IR Reciever
C7 and C8 assist the Accelerometer
C9 with R2 forms a debounce circuit for the Reset function
Datasheet Name: Capacitor

Package: 0805 (2012 Metric)
Mentor Graphics Location: Capacitor -> 0805 Cer SMD

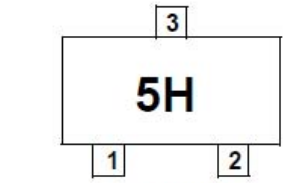
C10 to C13 - 18pF Capacitor
Part #: PCC180CNCT
Purchasing Source: Digikey
Price: Similar Items Cost $0.1
Function:
C10 and C11 filter the input/output of the crystal
C12 and C13 with R18 and R19 form a low pass filter to remove noise on the USB data wires
Datasheet Name: Capacitor

Package: 0805 (2012 Metric)
Mentor Graphics Location: Capacitor -> 0805 Cer SMD

D1 - Diode
Part #: MMBD4148FSCT-ND
Purchasing Source: Digikey
Price: $0.19
Function: Diode used to support the Speaker
Datasheet Name: Diode

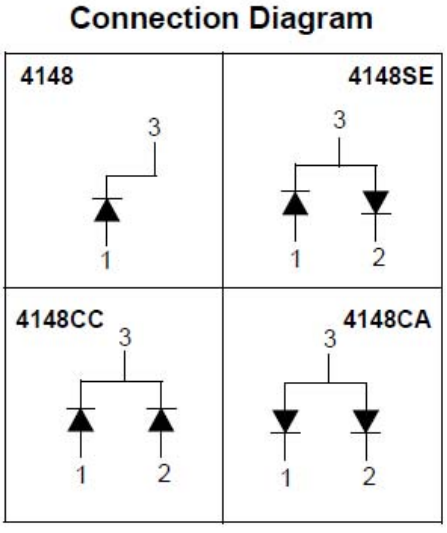


Package: TO-236-3, SC-59, SOT-23-3
Mentor Graphics Location:
Active Discrete -> WWU Diode -> Diode MMBD4148 -> SOT23



MARKING

MMBD4148	5H	MMBD4148CA	D6
MMBD4148CC	D5	MMBD4148SE	D4



DS1 - IR LED

For more Information, see IR LED near the end of the part information section

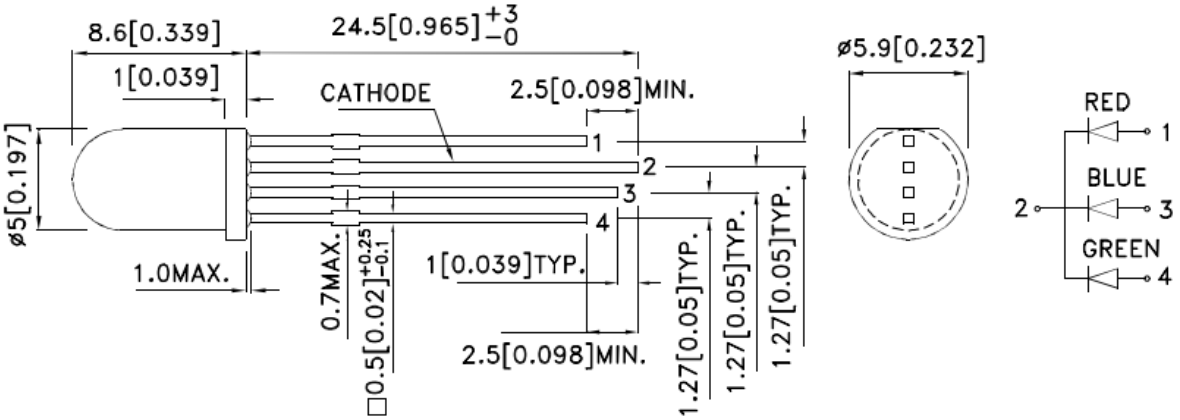
Mentor Graphics Location:

Active Discrete -> WWU Diode -> Diode MMBD4148 -> SOT23

DS6 - RGB LED
Part #: 754-1615-ND
Purchasing Source: Digikey
Price: $1.89
Function: We use this RGB LED to tell the player if the device is ready and game results
Datasheet Name: RGB LED

Package: Radial - 4 Leads
Mentor Graphics Location:

Active Discrete -> WWU LED -> Common Anode -> RGB Led refine

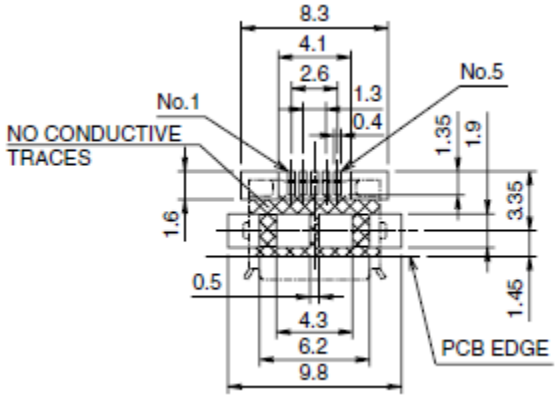


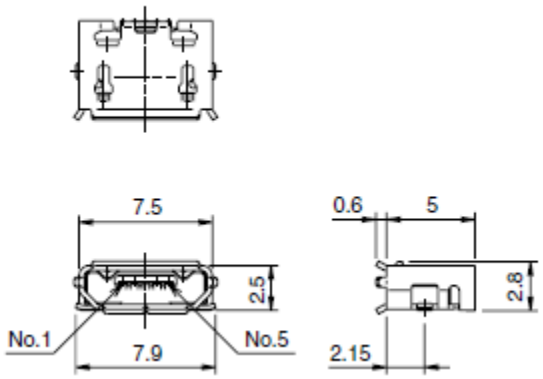
DS7 to DS10 - Indicator LEDs
Part #: 160-1169-1
Purchasing Source: Digikey
Price: $0.34
Function: An Indicator LED for debugging and other uses
Datasheet Name: Indicator LED

Package: 1206 (3216 Metric)
Mentor Graphics Location: N/A

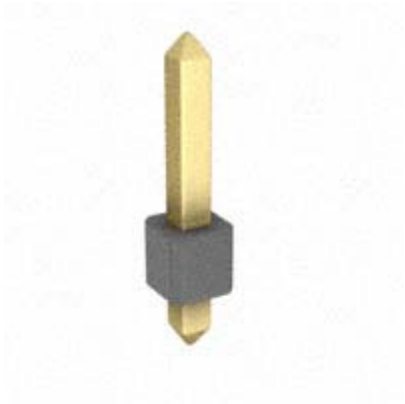
J1 - Micro USB Connector
Part #: H11610CT
Purchasing Source: Digikey
Price: $1.18
Function: This allows the circuit to be programmed/powered by a computer
Datasheet Name: Micro USB

Package: ZX62D-B-5P8
Mentor Graphics Location: Other -> Connector:Micro USB -> Only Refine option





J2 - 1x6 Header Pins
Part #: WM6406
Purchasing Source: Digikey
Price: $0.29
Function: Header Pins for Input/Output (not actually used in circuit) here for possible need for debugging/fixing errors
Datasheet Name: 1x6 Header

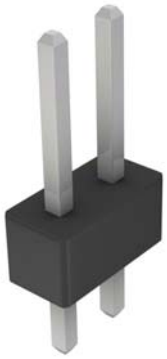


Package: 0022284060
Mentor Graphics Location: N/A

J3 to J5 - 1x3 Header Pins
Part #: S1012-03
Purchasing Source: Digikey
Price: $0.29
Function: Header Pins for connecting lines with jumpers
Datasheet Name: 1x3 Header

Package: PTC03SAAN
Mentor Graphics Location: N/A

J6 to J7 - 2x1 Header Pins
Part #: S2012-01
Purchasing Source: Digikey
Price: $0.54
Function: Header Pins for attaching the battery
Datasheet Name: 2x1 Header

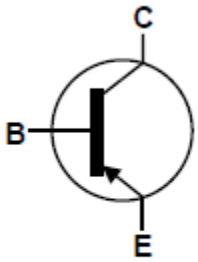


Package: PTC01DAAN
Mentor Graphics Location: N/A

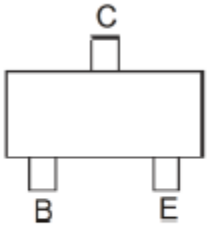
Q1 - PNP Transistor
Part #: CZT2907A from Mouser, MMBT2907A-FDITR-ND from Digikey
Purchasing Source: Digikey or Mouser
Price: $0.02295
Function: A PNP BJT Transistor used with the IR LED of the circuit
Datasheet Name: PNP Transistor

Package: TO-236-3, SC-59, SOT-23-3
Mentor Graphics Location:
Active Discrete -> WWU PNP -> Big 2097 -> SOT223 -> Default

Top View



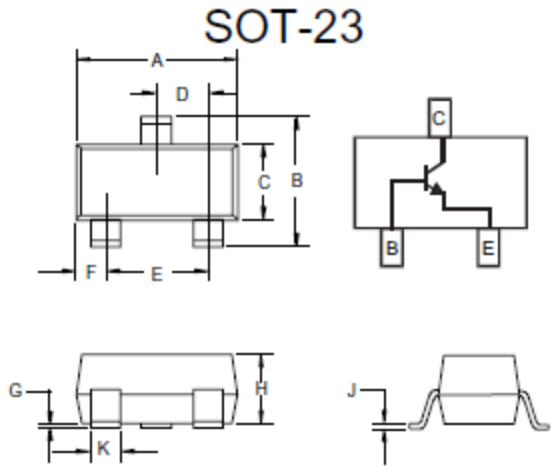
Device Symbol



Top View
Pin-Out

Q2 to Q6 - NPN Transistor
Part #: CZT2222A from Mouser, MMBT2222ATPMSTR-ND from Digikey
Purchasing Source: Digikey or Mouser
Price: $0.02295
Function: A NPN BJT Transistor used with the speaker, IR LED, and RGB LED
Datasheet Name: NPN Transistor

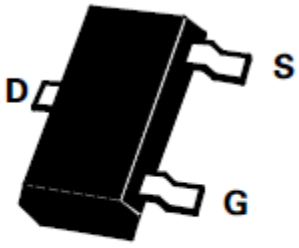
Package: TO-236-3, SC-59, SOT-23-3
Mentor Graphics Location: Active Discrete -> WWU NPN -> Big 2222A



Q7 - P Channel MOSFET
Part #: BS250FCT-ND
Purchasing Source: Digikey
Price: $0.7
Function: A P Channel Mosfet
Datasheet Name: PMosfet

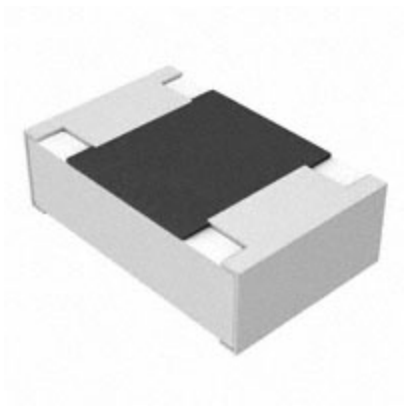
Package: TO-236-3, SC-59, SOT-23-3
Mentor Graphics Location:

Active Discrete -> WWC PMOSFET -> BS250P -> SOT-23(SMD)



SOT23

R1 to R4 - 10k Resistor
Part #: P10KACT
Purchasing Source: Digikey
Price: $0.1
Function:
R1 pulls the SA pin on the accelerometer high. This isn't strictly needed, it could just be a wire to Vcc. But if an external accelerometer was installed backwards, this limits the current to prevent frying it.
R2 and C9 form a debounce circuit for the Reset function on the processor.
R3 pulls Enable function high. This function is used to enable USB programming.
R4 is a pullup for the USB Data Plus Pin.
Datasheet Name: Resistor Datasheets

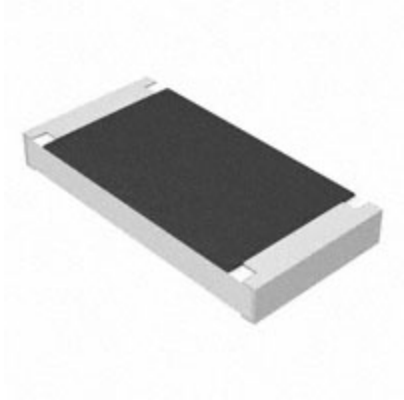


Package: 0805 (2012 Metric)
Mentor Graphics Location: Resistor -> SMD 805

R5 - 2.2k Resistor
Part #: P2.2KACT
Purchasing Source: Digikey
Price: $0.1
Function:
R5 limits the current on the microprocessor pin driving the speaker to the 4mA spec.
Datasheet Name: Resistor Datasheets

Package: 0805 (2012 Metric)
Mentor Graphics Location: Resistor -> SMD 805

R6 to R14 - 1k Resistor
Part #: P1KACT (But only one found is P1KACCT on Website)
Purchasing Source: Digikey
Price: $0.68
Function:
R6 and R7 Limit the current for the microprocessor pins PIO1_24 and PIO0_21 the IR LED DS1.
R8, R9, R10, R11 limit the current through the test LEDs.
R12, R13, R14 limit the current for the microprocessor pins to less than the 4mA spec. These pins drive the RGB LED.
Datasheet Name: Resistor Datasheets



Package: 2010 (5025 Metric)
Mentor Graphics Location: Resistor -> SMD 805

R15 to R16 - 200 Ohm Resistor
Part #: P220ACT
Purchasing Source: Digikey
Price: $0.1
Function:
R15, R16, R17 limit the current through the RGB sections of the RGB LED.
Datasheet Name: Resistor Datasheets

Package: 0805 (2012 Metric)
Mentor Graphics Location: Resistor -> SMD 805

R17 - 150 Ohm Resistor
Part #: P150ACT
Purchasing Source: Digikey
Price: $0.1
Function:
R15, R16, R17 limit the current through the RGB sections of the RGB LED.
Datasheet Name: Resistor Datasheets

Package: 0805 (2012 Metric)
Mentor Graphics Location: Resistor -> SMD 805

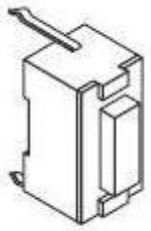
R18 to R19 - 33 Ohm Resistor
Part #: P33ACT
Purchasing Source: Digikey
Price: $0.1
Function:
R18 & R19 with their associated capacitors C12 and C13 form a low pass filter to remove noise on the USB data wires.
Datasheet Name: Resistor Datasheets

Package: 0805 (2012 Metric)
Mentor Graphics Location: Resistor -> SMD 805

R20 - 20 Ohm Resistor
Part #: P20ACT
Purchasing Source: Digikey
Price: $0.1
Function:
R20 limits the current through IR LED DS1.
Datasheet Name: Resistor Datasheets

Package: 0805 (2012 Metric)
Mentor Graphics Location: Resistor -> SMD 805

S1 - Tactile Switch
Part #: 101-0134-EV
Purchasing Source: Mouser
Price: $0.27
Function: Tactile Switch for Input. Note: Must be used in pull-up mode.
Datasheet Name: S1 Switch



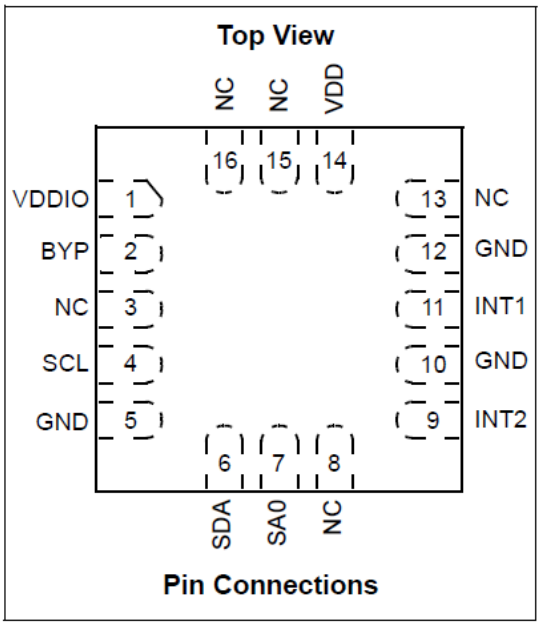
Package: N/A
Mentor Graphics Location: Other -> Switch:Pushbutton 2-pin -> MO-101

S2 to S3 - Tactile Switch
Part #: 652-STSM-31-N
Purchasing Source: Mouser
Price: $0.27
Function: Tactile Switch for Input. Note: Must be used in pull-up mode
Datasheet Name: S2 to S3 Switch

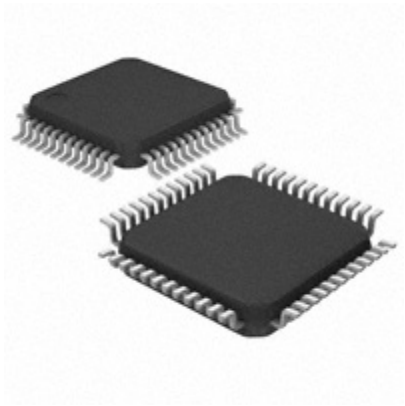
Package: STS Series - Ultraminiature Tactile Switch
Mentor Graphics Location: Other -> Switch:Pushbutton 2-pin -> MO-101

U1 - Accelerometer
Part #: MMA8452QR1CT
Purchasing Source: Digikey
Price: $1.43
Function: This is a 3 axis accelerometer that allows the circuit to detect the orientation and degree of motion of the device.
Datasheet Name: Accelerometer

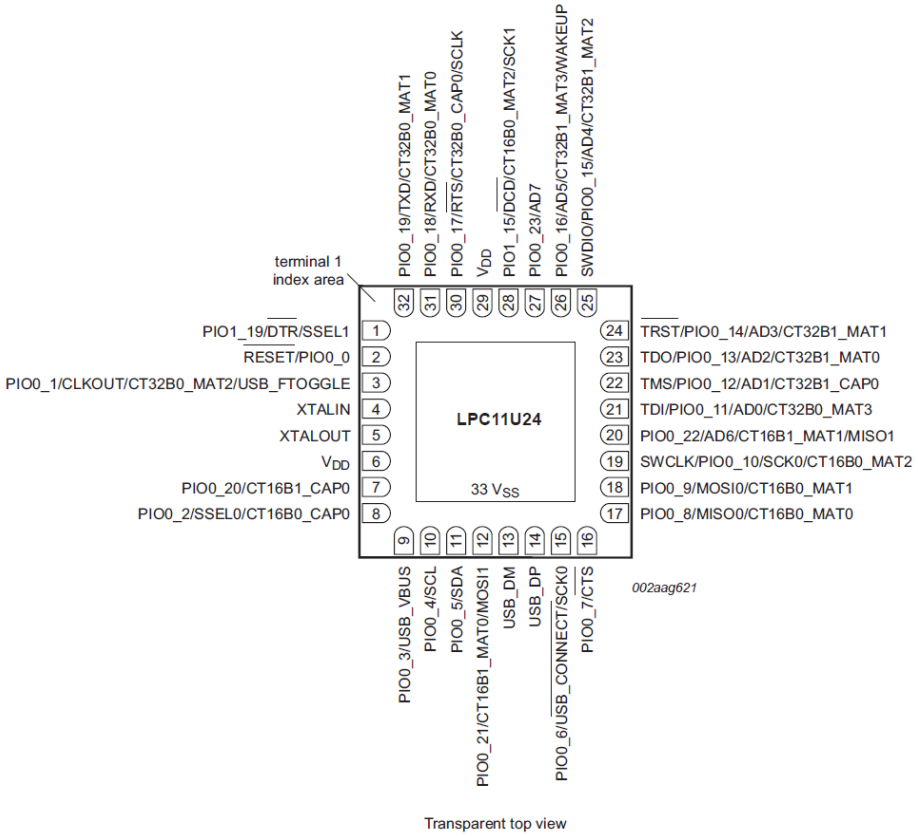
Package: 16-VFQFN
Mentor Graphics Location: Other Digital -> 12 Bit Dig Accelerometer -> Only option



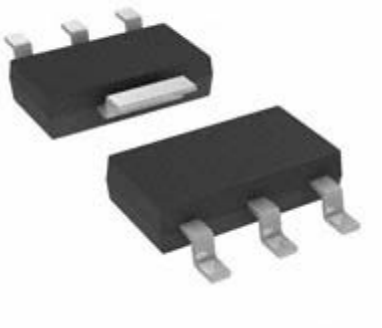
U2 - LPC11U24 Processor
Part #: 568-8521-ND
Purchasing Source: Digikey
Price: $3.67
Function: The Main Control and Processing Unit for the circuit
Datasheet Name: Processor



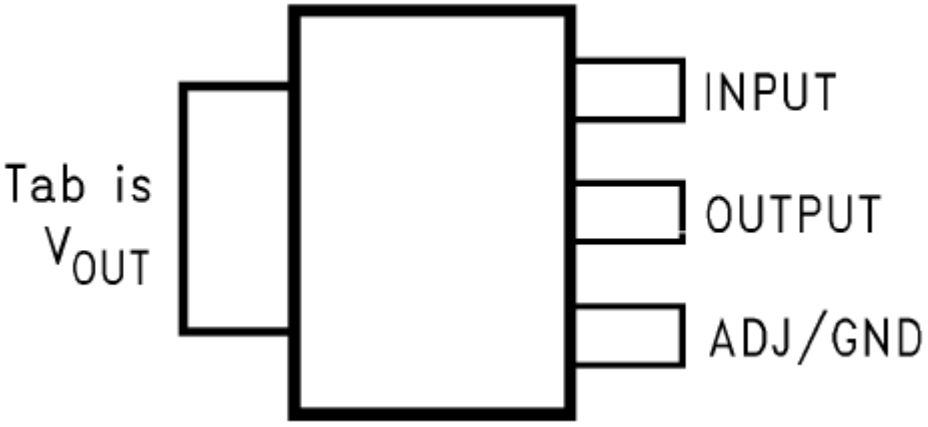
Package: 48-LQFP
Mentor Graphics Location: It's the base you start with, N/A



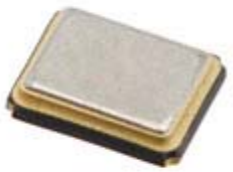
U3 - Voltage Regulator
Part #: LM1117MP - 3.3CT
Purchasing Source: Digikey
Price: $1.1
Function: This regulates the voltage, giving 3.3V from the a 5V source
Datasheet Name: Voltage Regulator



Package: TO-261-4, TO-261AA
Mentor Graphics Location:
Analog IC -> WWC Voltage Regulator -> List part LM 1117 -> Refine 3.3V



X1 - 12 MHz Quartz Crystal
Part #: 887-1121-1
Purchasing Source: Digikey
Price: $0.96000
Function: This crystal serves as a clock for the circuit to base its timings off of, keeps everything in sync as von Neumann architecture requires.
Datasheet Name: 12MHz Crystal



Package: 4-SMD, No Lead (DFN, LCC)
Mentor Graphics Location: Active Discrete -> 3.2x2.5 SMD -> 12.0 MHz

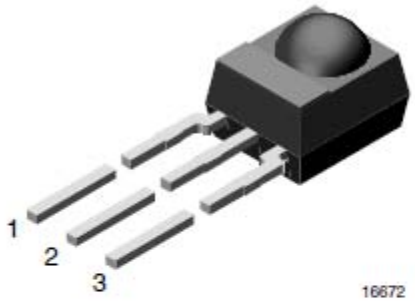
IR LED
Part #: SFH4550
Purchasing Source: Digikey
Price: $0.53
Function: This IR LED allows me to output IR signals
Datasheet Name: IR LED

Package: T 1 3/4
Mentor Graphics Location: Represented with the following generic LED:

Active Discrete -> WWU LED -> Generic LED -> 2nd option for first then only option

IR Reciever
Part #: 751-1384-5-ND
Purchasing Source: Digikey
Price: $1.12
Function: This IR Reciever allows me to receive and interpret IR signals
Datasheet Name: IR Reciever

Package: TSOP32338 IR Reciever Module
Mentor Graphics Location: Represented with the following connector:
Other -> Connector 2-Pin -> .1 Header
Pin1 for Output, 2 for Vcc, 3 for Ground



MECHANICAL DATA

Pinning for TSOP341.., TSOP343.., TSOP345..:

1 = OUT, 2 = GND, 3 = V_S

Pinning for TSOP321.., TSOP323.., TSOP325..:

1 = OUT, 2 = V_S, 3 = GND

.1” Jumper
Part #: 3M9580-ND
Purchasing Source: Digikey
Price: $0.1
Function: This is a simple .1” Shunt Jumper
Datasheet Name: Jumper .1

Package: 3M Shunt 969 Series
Mentor Graphics Location: Other -> Connector:2x1

AAA Battery Case
Part #: BH24AAAW-ND
Purchasing Source: Digikey
Price: $1.45
Function: Holds the mobile power source (in this case AAA batteries)
Datasheet Name: Battery Case

Package: Memory Protection Devices Inc BH24AAAW
Mentor Graphics Location: Battery is represented as a jumper

Speaker
Part #: 668-1231-ND
Purchasing Source: Digikey
Price: $3.85
Function: The Speaker to output music if the device is a master
Datasheet Name: Speaker

Package: SPEAKER 8OHM 1W 80DB28MM
Mentor Graphics Location:
Represented with: Other -> Connector 2-Pin -> .1 Header

SPST Switch
Part #: 450-2038-1-ND
Purchasing Source: Digikey
Price: $0.16
Function: A tactile switch for input purposes
Datasheet Name: SPST Switch

Package: SWITCH TACTILE SPST-NO 0.05A 12V
Mentor Graphics Location: Other -> Switch:Pushbutton 2-pin -> MO-101