

Helmet Temperature Sensor Project – Final Report

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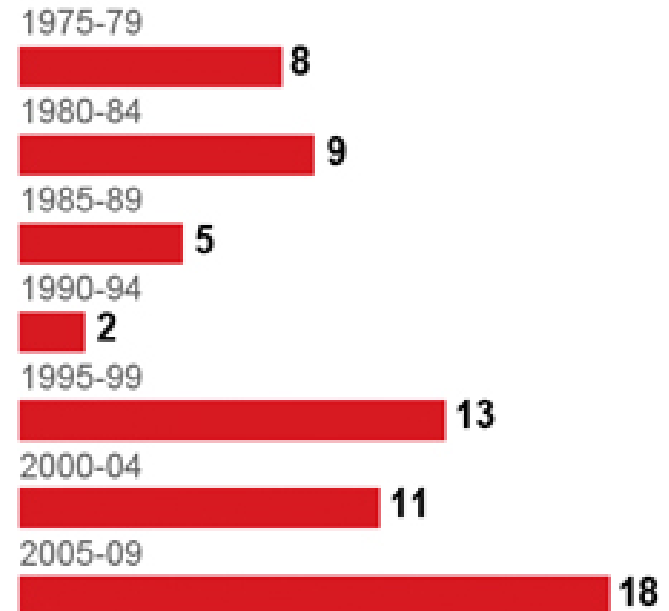
Client: Marc Schmidt, Jarden Team Sports

Background and Need

- 1979-1995: 7000 heat related deaths in the US
- Heat illness - Third leading cause of death in US high school athletes
- Since 1995, 39 football players have died of heatstroke

Heat deaths rising

Heat-related fatalities that occurred during sports have more than doubled since 1975.



Source: Korey Stringer Institute
By Veronica Salazar, USA TODAY

Design Specifications

Specification	Requirement
Size	All components fit in existing equipment
Weight	2-3 ounces
Alarm	The device should be in the audible range of 70-75 dB, visible from 100 yards, or generate 1.2-26.2 G
Accurate	$\pm .1^{\circ} \text{C}$
Reliable	Less than 5 false alarms per season
Durable	Can continue operating after an impact of 250-300G
Cost	No requirement

Pugh Chart

		Location: Mouth Guard								
		Infrared Thermometer			Thermistor			Thermocouple		
Variables	Weight	Sound Alert	Vibration Alert	Light Alert	Sound Alert	Vibration Alert	Light Alert	Sound Alert	Vibration Alert	Light Alert
Client Preference	10	9	9	9	9	9	9	9	9	9
Time	10	7	7	8	7	7	8	7	7	8
Safety	10	7	7	6	7	7	6	7	7	6
Size	9	6	5	6	7	6	7	7	6	7
Accuracy	8	7	7	7	8	8	8	6	6	6
Alert Efficacy	8	5	9	5	5	9	5	5	9	5
Weight	7	6	5	6	7	6	7	7	6	7
Susceptibility to damage	6	6	6	4	7	7	5	7	7	5
Cost	4	7	7	7	8	8	8	8	8	8
Total		486	502	474	520	536	508	504	520	492

Parts

Thermistor – ON-909-44034 OMEGA surface sensing

Battery - CR1225 3V Lithium Cell Battery

Battery Cell Holder - HU1225-LF Through-hole battery holder

Microprocessor - MSP430F2003IPW Mixed Signal Microcontroller

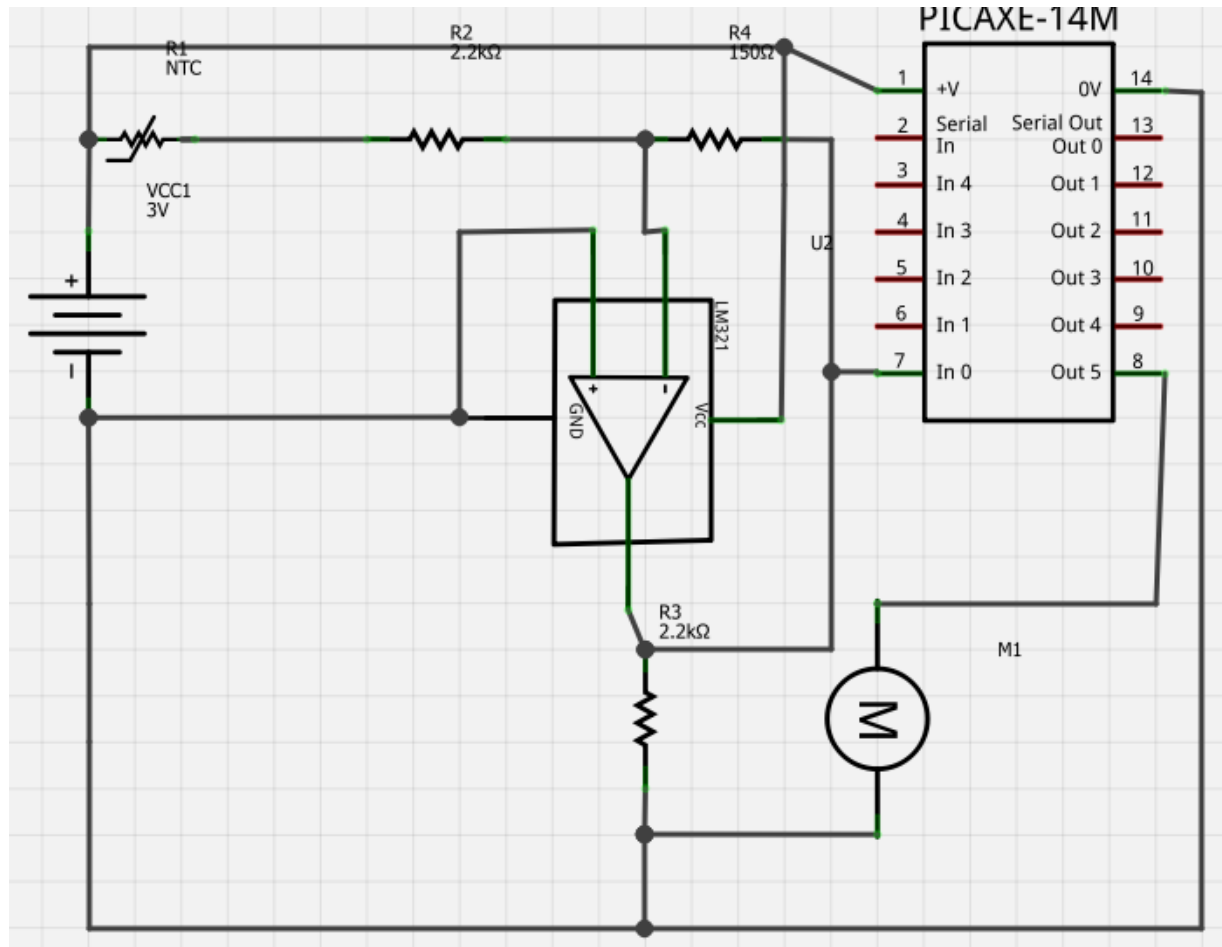
Vibrating Motor – 310-013 Pico Vibe 10mm Vibration Motor

Operational Amplifier - LM321MF Low Power Single Op Amp

Resistor - CH0402-20RJPT, Thin Film Microwave Resistor

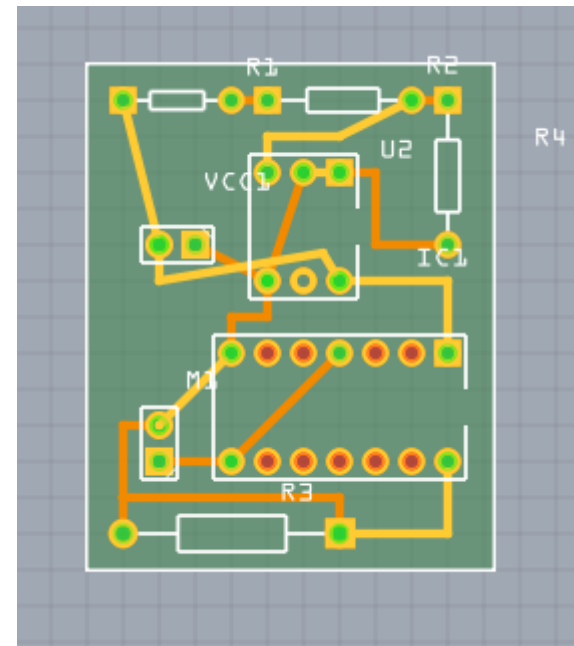
Additional Wires – to connect parts

Circuit Diagram



Printed Circuit Board Option

- 29 mm x 36 mm
- Uses carbon resistor
- Requires larger packages for chips
- Concerned about board being damaged if mouth guard bends



Microprocessor Flow Chart

Active 1

- Take 100 data points in 1 second
- If 75 are above threshold then criteria 1 is met

Inactive 1

- Processor is in low power mode

Active 2

- Takes another 100 data points for 1 second
- If again 75 points are above the threshold then criteria 2 is met
- Motor activates for 10 seconds

Criteria 1: One sampling period has is has 75% of data points above threshold

Criteria 2: Current and previous sampling period each had 75% of data points above threshold

Motor activates: Criteria 1 and 2 are met

Circuit Calculations

Temperature Resolution

$$LSB = \frac{V_{FSR}}{2^n} = \frac{3}{2^{16}} = 0.0000458 \text{ V}$$

$$\Delta R_T = 0.076 \Omega$$

Using a linear approximation $\Delta T = 0.003^\circ\text{C}$

Power Requirements

- Operating currents
 - Thermistor: $15\mu\text{A}$
 - Operational Amplifier: $430\mu\text{A}$
 - Microprocessor Active (1.7%): $720\mu\text{A}$
 - Microprocessor LPM (98.3%): $.9\mu\text{A}$
- Average operating current: $458.05 \mu\text{A}$

Gain Required

Analysis done with 50° C as upper limit

$$I_{in} = \frac{V_{battery}}{R_T} = \frac{3 V}{1801 \Omega} = 1665 \mu A$$

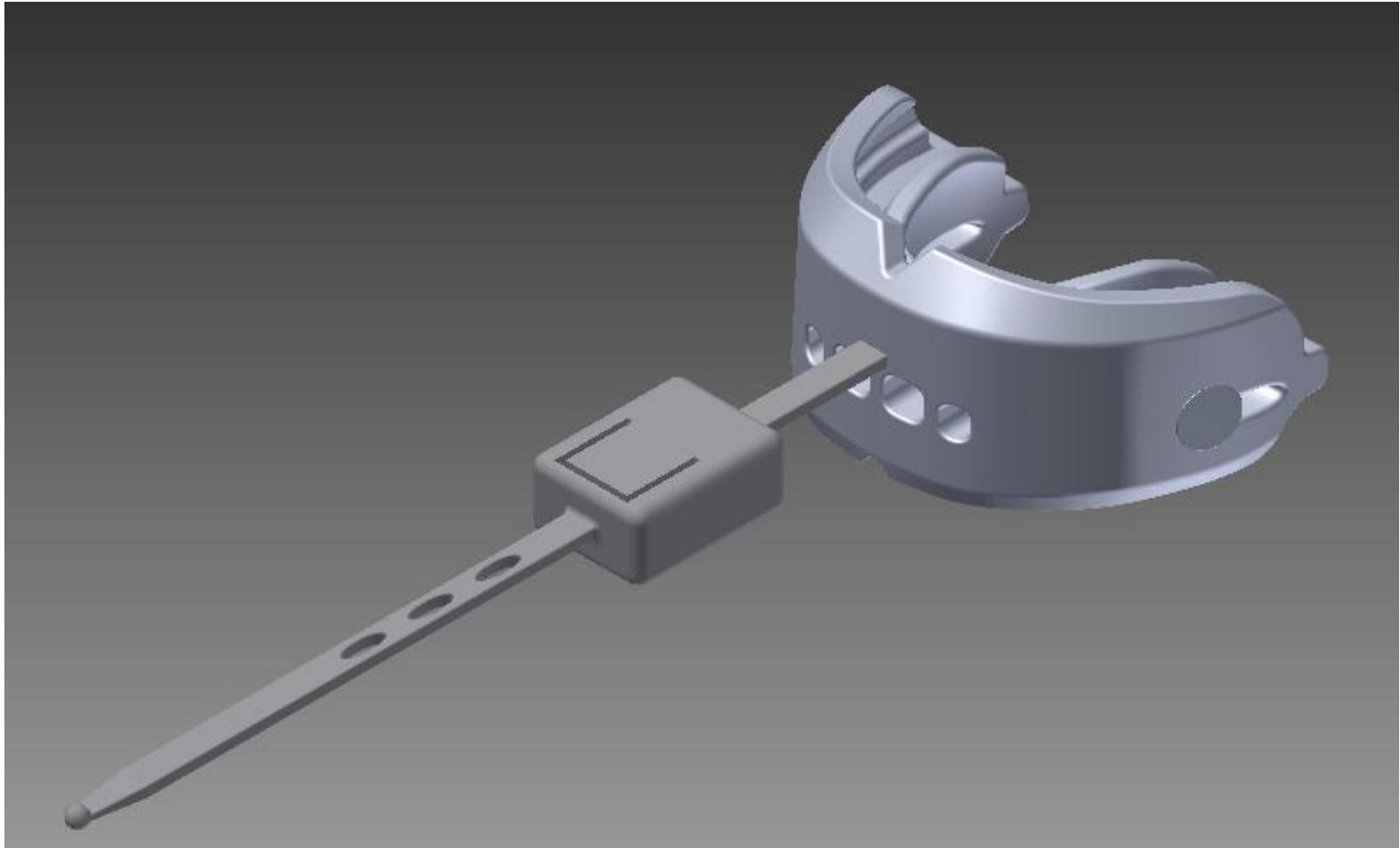
$$I_{out} = \frac{V_{max}}{R_{mp}} = \frac{3 V}{200,000 \Omega} = 15 \mu A$$

Gain: 0.01

$$R_f = 20,000 \Omega$$

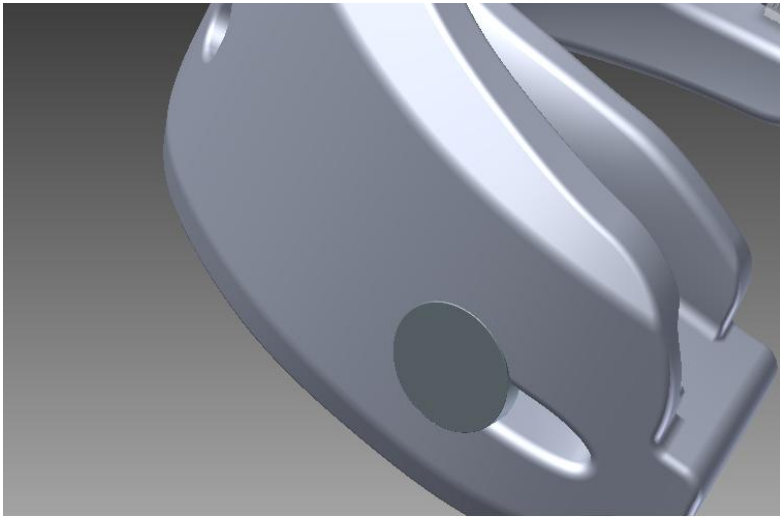
$$R_1 = 200 \Omega$$

Mouth Guard Design

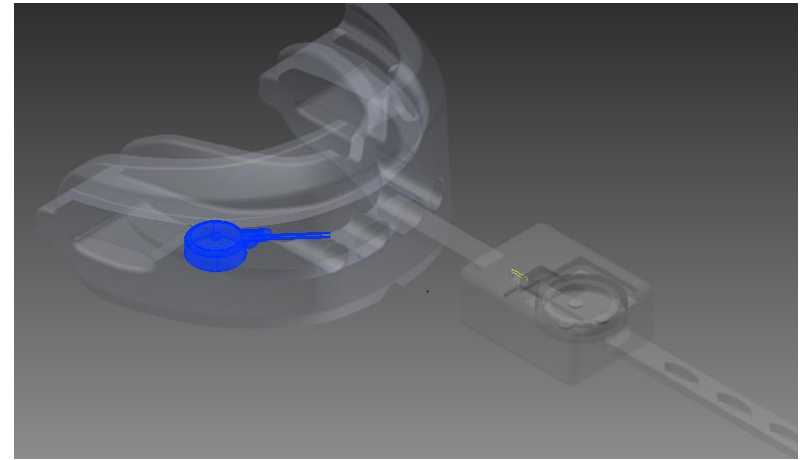


Internal Mouth Guard Components

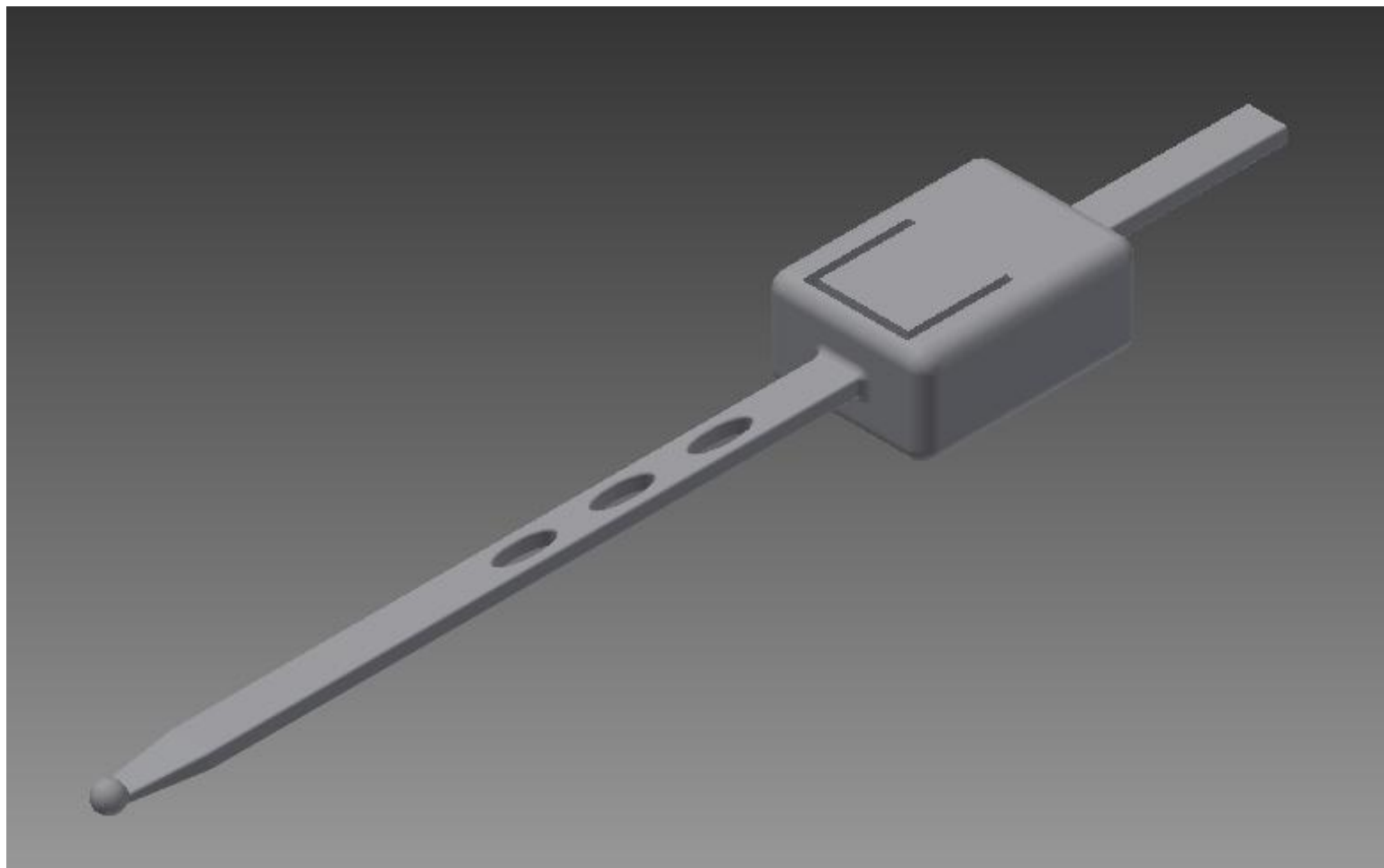
Thermistor



Vibrating Motor

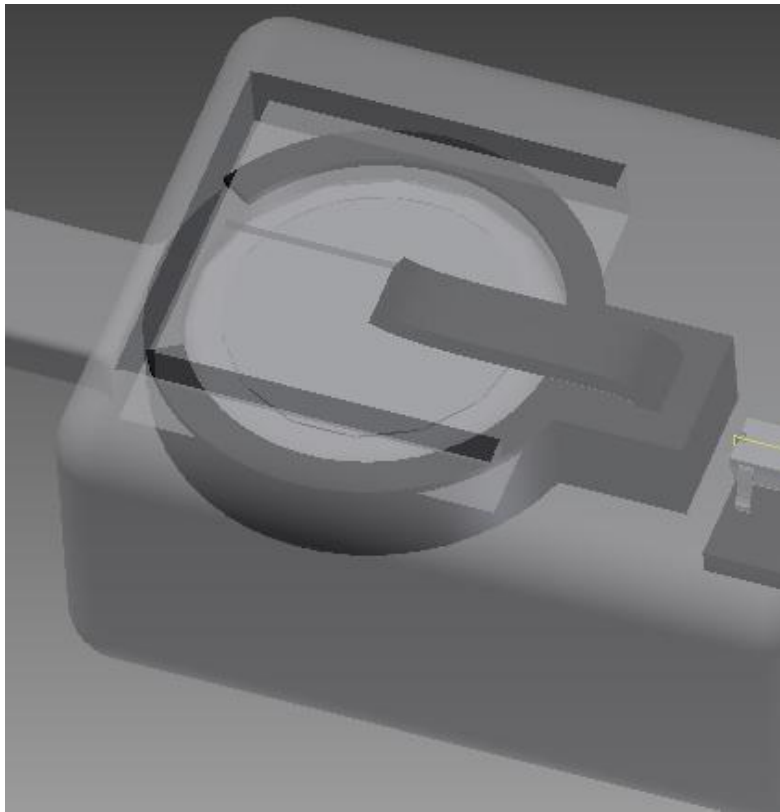


Mouth Guard Extension

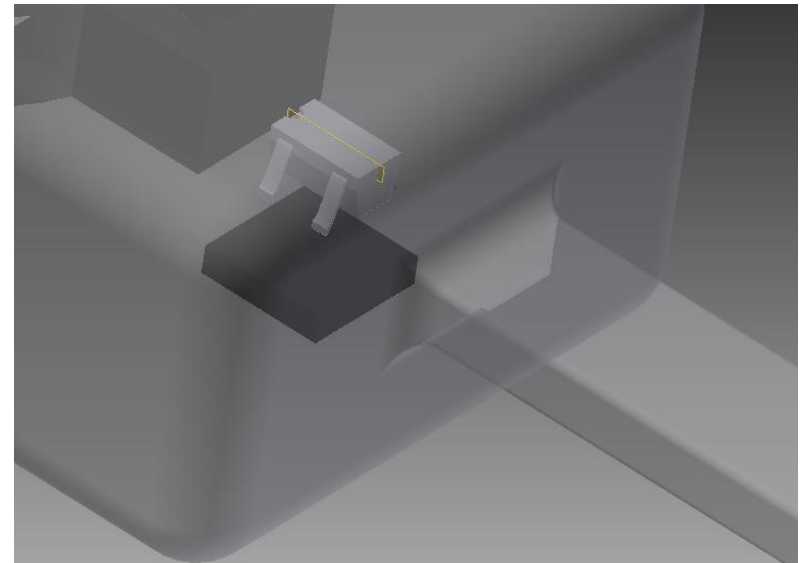


Internal Extension Components

Battery and Holder



Electrical Components



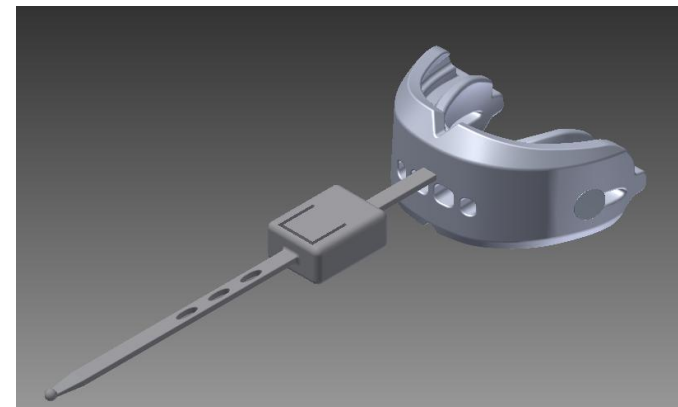
Manufacturing

- Components will be soldered together and placed in an injection mold
- The mold will be filled with Elvax[®] (DuPont), an ethylene-vinyl acetate resin



Source: DuPont

Injection pressure	35-100 MPa
Melt temperature	< 220 °C
Mold coolant temp.	15-40 °C



Pricing

Thermistor Part Number: ON-909-44034	
1 to 9	\$55
10 to 24	\$49.50
25 to 49	\$44
50 to 99	\$38.50
100 and over	\$33
Availability	Now
Lead Time	None

3V Lithium Cell Battery Part Number: CR 1225	
1	\$1.41
10	\$1.33
50	\$1.26
100	\$1.20
200	\$1.12
500	\$1.01
1000	\$0.93
Availability	Now
Lead Time	None

Battery Holder Part Number: HU1225-LF	
1	\$0.85
10	\$0.77
50	\$0.73
100	\$0.69
200	\$0.64
500	\$0.61
1000	\$0.57
2000	\$0.54
Availability	Now
Lead Time	None

Operational Amplifier Part Number: LM321MF	
1	\$0.70
10	\$0.53
100	\$0.28
1000	\$0.25
Availability	Now
Lead Time	2 weeks

Microprocessor Part Number: MSP430F2003IPW	
1	\$2.41
10	\$2.00
25	\$1.78
50	\$1.68
100	\$1.20
250	\$1.18
500	\$1.16
750	\$1.14
1000	\$1.11
Availability	Now
Lead Time	6 weeks

Resistor Part Number: CH0402-20RJPT	
1	\$4.33
25	\$3.66
50	\$2.99
100	\$2.66
200	\$2.40
500	\$2.13
1000	\$2.06
2000	\$2.00
5000	\$1.93
Availability	Stock Low
Lead Time	None

Vibrating Motor Part Number: 310-003	
100	\$5.77
1000	\$1.80
10000	\$1.62
Availability	Now
Lead Time	3 weeks

Safety

- Proper care needed to prevent bacteria and mold
- Limited electronic components in the mouth
- Battery holder has built in safety features for preventing shorts
- Warnings and manuals recommended to mitigate risk

Conclusion

- Did we achieve the goal?
- Future Directions
 - Wireless communication
 - Helmet temperature sensor
 - Integrating system into more mouth guards
- Project Improvements
 - Talk to more football/players coaches
 - No perfect way to measure temperature
- Intellectual Property
 - Combination of all different parts into one
 - Patent
 - Rights given to Jarden Team Sports

References

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Thank you!

Are there any questions?