SFU

TRIWAVE SYSTEMS

ENSC 440

Akriveia Beacon

Break-Even Analysis

Team 5

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1 Introduction

Over the last couple of decades urban centers around the world have faced substantial population growth. As a result, the number of larger and more complex commercial structures in core urban centers around the world is rapidly increasing. With a large population and massively complex buildings in relatively small areas, the potential impact of damages and casualties in the event of a disaster have greatly increased as well. Due to increased urbanization and complexity of urban structures, search and rescue operations in indoor urban environments face various complications and uncertainties. According to Statistics Canada, an average of 135 fire related deaths occur each year from 2010 to 2014 [1].

As a solution to these major issues the Akriveia Beacon created by TRIWAVE SYSTEMS focuses on improving the locating and rescue process of personnel trapped in buildings during or after small scale disasters such as fires and low magnitude earthquakes, therefore minimizing potential damages and casualties. One great benefit to the Akriveia Beacon product is that it's uniquely placed between two substantially large markets: The Search and Rescue equipment (SAR) market and the Global Indoor Location (GIL) market. SAR equipment is an old existing market and encompasses emergency vehicles such as trucks or helicopters to rescue responders devices such as the Akriveia Beacons. Estimated to be a $113.62 billion dollars industry in 2017, the SAR market is expected to reach $125.66 billion in 2022 [2]. On the other hand, GIL is an emerging market after the proliferation of smartphone users but also the ineffectiveness of GPS for indoor tracking. Currently the GIL market is at $3.43 billion in 2015 and is expected to surpass $29.4 billion in 2022 [3].

Inorder for the Akrivia Beacon to be a viable and economically sustainable product and for TRIWAVE SYSTEMS to become a successful company, it is important to consider engineering and economical cost of the product. This will allow for the company to formulate a revenue plan that will cover the costs of operating a business. This Break-even analysis entails the calculation and examination of the margin of safety for the Akriveia beacon on the revenues collected and associated costs. By analyzing different price levels relating to various levels of demand, break-even analysis can determine the level of sales necessary to cover TRIWAVE SYSTEMS' total fixed costs.

2 Break-Even Analysis

Break-even analysis details the calculation for the margin of safety for the Akriveia Beacon based on the revenues collected and associated costs [4]. By analyzing different price levels relating to various levels of demand, the break-even analysis can determine the level of sales necessary to cover the company's total fixed costs. Break-even analysis depends on the Break-even Point (BEP) which is calculated by dividing the total fixed costs of production by the contribution margin or price difference of a product per individual unit and the variable costs of production as shown in equation (1) [5].

$$\text{BEP} = \text{Fixed Costs} \; / \; (\text{Selling Price} - \text{Variable Cost Per Unit}) \tag{1}$$

There are two phases where the break-even point will be calculated for, first is the gamma prototype which reflects the current product state, the second will be the mass production version which reflects the final version of the Akriveia Beacon at a higher level of optimization with integrated PCB and injection molding casing design. For mass production a quantity of 1000 is used for quoting.

2.1 Gamma Prototype

For Gamma Prototype the fix cost is fairly low as there are no cost associated with tangible or intangible assets, rent, salaries, utilities, and taxes; since the development team is composed of SFU engineering students. To simply calculations the fix cost will be determined by the amount of budget current contributed to the development of the prototype which will be $1000.00 CAD. Component cost for each beacon and ID Tag is shown below in Table 1 and Table 2. These costs reflect the purchase price of each component on the date of purchase and are derived only from material costs, which does not include additional costs such as shipping, import taxes, labour, and miscellaneous materials used such as wires, solder, screws, tape, and etc, since materials were obtained outside of budget. Furthermore, software development cost is considered to be zero.

Item	**Supplier**	**Price [CAD]**
DWM1000 UWB RF TX/RX MODULE [6]	Decawave	$46.13
Arduino Pro Mini 328 - 3.3V/8MHz [7]	Lonten	$1.80
ESP32 Development Board - ESP32-D0WDQ6 Chip [8]	WalFront	$15.59
DC5.0V 10000mAh Rechargeable Li-Polymer Battery	uxcell	$15.99
AMS1117-3.3 DC Voltage Regulator Step Down Module	Icstation	$2.40
Power Hexfet IRFZ44 N-Channel ×2	Infineon	$5.60
Push Button PS-29C On-Off	Daywel	$1.30
8 × 12cm Double Sided Universal PerfBoard [9]	uxcell	$3.47
Beacon Casing 3D Printing [10]	3DHubs	$35.27
	Total:	**$127.55**

Table 1: Gamma Prototype Beacon Component & Price

Item	Supplier	Price [CAD]
DWM1000 UWB RF TX/RX MODULE [6]	Decawave	$46.13
Arduino Pro Mini 328 - 3.3V/8MHz [7]	Lonten	$1.80
DC3.0V 1000mAh Rechargeable Li-Polymer Battery	uxcell	$10.24
Micro USB 5V 1A TP4056 Battery Charger Module	NJTP ASIC Corp.	$1.79
Push Button PS-29C On-Off	Daywel	$1.30
4 × 6cm Double Sided Universal PerfBoard [9]	uxcell	$1.41
Beacon Casing 3D Printing [10]	3DHubs	$11.89
	Total:	**$74.56**

Table 2: Gamma Prototype ID Tag Component & Price

Since the Akriveia Beacon product is meant to be sold as a system and not an individual product, multiple Beacons and ID Tags must be purchased as a package. Assuming each package/unit of purchase contains 3 Beacons and 10 ID tags along with an estimated software lease cost of $250, and a desired return on sales of 25% (excluding taxes); the required sale price is calculated to be $1722.81 for each unit as shown in equation (3). Using the values obtained below the BEP is calculated in equation (3) and plotted in Figure 1. In order for the Akriveia Beacon to break-even at its Gamma prototype state, a minimal sale of **2 units** is required.

$$\text{Variable Cost Per Unit} = \$127.55 \times 3 + \$74.56 \times 10 = \$1128.25 \tag{2}$$

$$\text{Required Sale Price} = \$1128.25 + \$250.00 = \$1378.25 \times 1.25 = \$1722.81 \tag{3}$$

$$\text{BEP} = \$1000.00/(\$1722.81 - \$1128.25) = 1.682 \approx \mathbf{2} \tag{4}$$

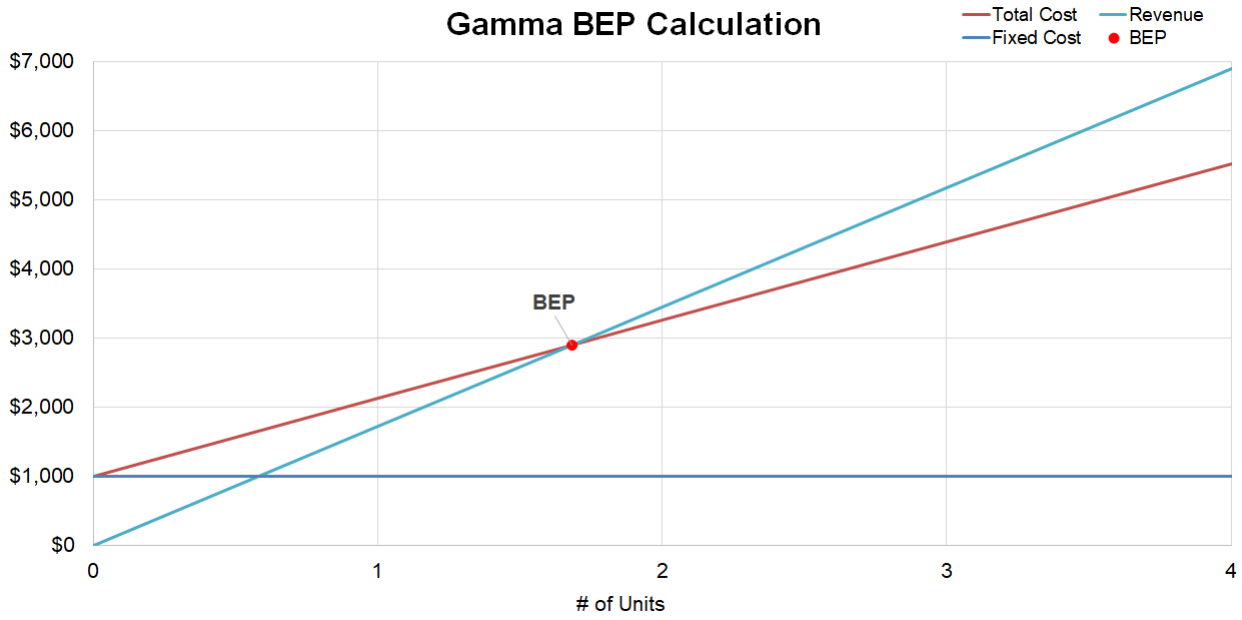

Figure 1: Gamma Prototype Break-Even Point Calculation

2.2 Mass Production

For mass production the Akriveia Beacons system will undergo major design optimization including custom integrated printed circuit board (PCB) containing all hardware components, injection molding for Beacon and Tag casing and improved software deployment processes. The fixed cost is greatly increased due to various factors such as shipping, taxes, rent, utilities, labour, and office expenses. Assuming some expenses can be negated and only tooling, PCB fabrication, assembly and material costs is considered for fixed costs.

Custom integrated PCB for Beacons and ID Tags will be fabricated and assembled with Arduino and ESPRESSIF integrated circuit (IC) chips ordered directly from suppliers as well as any surface mount device (SMD), which lowers the variable cost per unit dramatically. Bittele Electronics Inc. [11] was chosen as the fraborator and assembler for the integrated PCBs since they offer free passive components as part of the assembly and low prices for mass production. However, PCB assembly cost of $3888.30 for Beacons and $2693.32 for ID Tags will be added into fixed cost (see Appendix C).

Although 3D printing is very useful for prototyping, it is not a sufficient or cost effective way for mass production. A few venders has been evaluated based on tooling price, unit cost and materials available, and 3D Hubs [10] has been chosen as the supplier for the Beacon and Tag casing which will be done through injection molding with Polyether Ether Ketone (PEEK). For injection molding there is a fix tooling cost of $10474.79 for beacons and $5181.55 for ID Tags (see Appendix B). Additionally, an estimate of $2000.00 for final assembly is added, this brings the total fixed cost to $24237.96.

Variable cost per unit is dramatically lowered due to bulk prices which are supplied directly from manufacturers, resulting in 71.23% decrease in cost for Beacons and 69.45% decrease for Tags. The mass production variable cost for Beacons and ID Tags can be seen in Table 3 and Table 4.

Item	**Price [CAD]**
DWM1000 UWB RF TX/RX MODULE [6]	$16.88
PM33**	$0.67
ESP32**	$5.72
MOSFET N-Ch. 50V 500mA	$0.06
Linear Voltage Regulator IC 300mA	$0.19
TP4056 Li-ion Battery Charger IC	$0.61
5V 10000mAh Rechargeable Battery	$8.29
30A 250VAC 1E4 Rocker Switch	$0.50
PEEK Injection Molding	$2.30
PCB Fabrication	$1.43
Total:	**$36.70**

Table 3: Mass Production Beacon Component & Price

**Detailed BOM in Appendix A.

Item	Price [CAD]
DWM1000 UWB RF TX/RX MODULE [6]	$16.88
PM33**	$0.67
TP4056 Li-ion Battery Charger IC	$0.61
3.3V 10000mAh Rechargeable Battery	$2.10
30A 250VAC 1E4 Rocker Switch	$0.50
PEEK Injection Molding	$1.25
PCB Fabrication	$0.77
Total:	**$22.78**

Table 4: Mass Production ID Tag Component & Price

**Detailed BOM in Appendix A.

Similar to Gamma Prototype, assuming each package/unit of purchase contains 3 Beacons and 10 ID tags along with an estimated software lease cost of $250.00, with a desired return on sales of 25% (excluding taxes); the required sale price for the mass production product is calculated to be $734.88 for each unit as shown in equation (6). Using the values obtained below the mass production BEP is calculated in equation (7) and plotted in Figure 2. In order for the mass production Akriveia Beacon to break-even, a minimal sale of **62 units** is required.

$$\text{Variable Cost Per Unit} = \$36.70 * 3 + \$22.78 * 10 = \$337.90 \tag{5}$$

$$\text{Required Sale Price} = \$336.56 + \$250.00 = \$587.90 * 1.25 = \$734.88 \tag{6}$$

$$\text{BEP} = \$24237.96/(\$734.88 - \$337.90) = 61.06 \approx \mathbf{62} \tag{7}$$

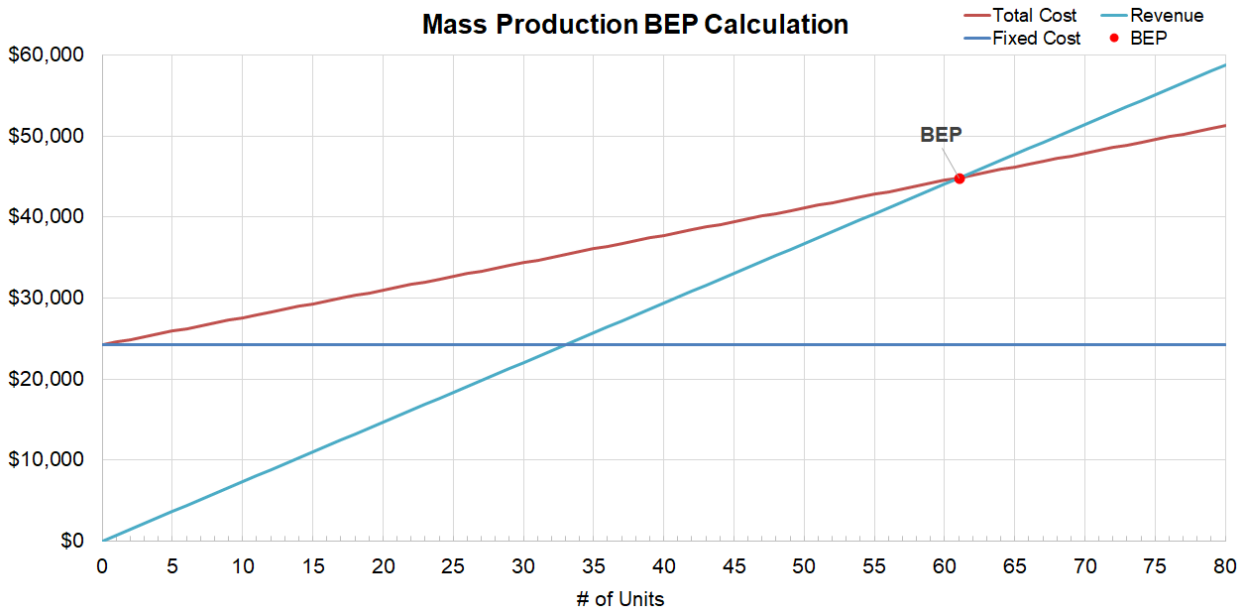

Figure 2: Mass Production Break-Even Point Calculation

3 Conclusion

In order for the Akriveia Beacon system to become a successful and economically sustainable product, a break-even analysis was performed to categorising production costs between those which are variable and those that are fixed. The break-even point is key in determining TRIWAVE SYSTEMS' financial plan; by calculating the fixed and variable costs for the product, the minimum product units needed to be sold at a given price point to break-even can be obtained. This is an integral part of budgeting process which includes any business and operational cost and will be important for the company to continue development and production. From the break-even analysis the break-even point was determined for the gamma prototype to be 2 units and 62 units for mass production.

The Gamma prototype had a very high variable cost with $127.55 for Beacons and $74.56 for ID Tag, since most components were purchased individually from distributors. Furthermore, the prototype had a very low fixed cost since there are no major cost associated with manufacturing, fabrication, or assembly which contributed to a low break-even point. As all hardware components were assembled by the team using available equipment supplied by SFU. However, considering the time and effort allocated for assembly of the gamma prototype which was around two days for three Beacons and two ID Tags, and the inconsistent quality of the final work, it is unreasonable to mass produce using these production methods.

For mass production, the variable cost decreased dramatically to $36.70 for Beacons and $22.78 for Tags. Since the components are ordered in bulk directly from the manufacturer and assembled on custom integrated PCB. However, fixed cost associated with mass production increased greatly taking in considerations for manufacturing, fabrication, assembly, and material cost. But through mass production the assembly process can be streamlined to produce a higher quantity product in much less time with better quality as well. Furthermore, by lowering sale prices higher sale numbers can be achieved, therefore, allowing the company to reach break-even point sooner.

However, it should also be noted that the break-even analysis should not act as a predictor of demand. If the current market does not have high demand or the product goes into the market with the wrong price or wrong target audience, it will be very difficult to ever hit the break-even point. Which is why it is also critical to understand the current markets and to develop a strong Market Entry Strategies. This will allow for TRIWAVE SYSTEMS to become a successful company and is an important factor for investment recognition. As a product that could potentially change the outcome of disaster relief operations for thousands of people, the Akriveia Beacon is designed with the utmost care. As aforementioned, TRIWAVE SYSTEMS is dedicated to create a reliable and robust system design to improve disaster search and rescue operations with human safety as the pivotal focus.

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5 Appendix A - Bill of Material

ESP32						
ID	Name	Manufacturer	Part Number	Quantity	Unit Price	Total Price
1	ESP32-D0WDQ6	ESPRESSIF	C95209	1	$ 2.37	$ 2.37
2	10k	UniOhm	C128781	5	$ -	$ -
3	SKSCLAE010	ALPS Electric	C130445	3	$ 0.13	$ 0.40
4	CP2104-F03-GM	SILICON LABS	C47742	1	$ 1.42	$ 1.42
5	10uF	MuRata	C86277	2	$ -	$ -
6	MMBT2222A	SK	C171740	2	$ 0.01	$ 0.02
7	MCP73831T-2ATI/OT	MICROCHIP	C14879	1	$ 0.56	$ 0.56
8	4.7k	UniOhm	C148464	3	$ -	$ -
9	SMD BUZZERMLT-7525	HNDZ	C95299	1	$ 0.31	$ 0.31
10	1N4148W	PANJIT	C116002	2	$ 0.01	$ 0.03
11	MMBT3904	FMS	C163254	2	$ 0.01	$ 0.02
12	1K	UniOhm	C25585	1	$ -	$ -
13	Micro USB-B 5P-Female-SMT_C40940	ValuePro	C40940	1	$ 0.07	$ 0.07
14	TLV73333PDBVR	TI	C134139	1	$ 0.07	$ 0.07
15	47uF	FH	C178330	2	$ -	$ -
16	1uF	FH	C157684	1	$ -	$ -
17	CONN_PERIPHERAL	BOOMELE	C68234	1	$ 0.05	$ 0.05
18	CONN_ESP	BOOMELE	C68234	1	$ 0.05	$ 0.05
19	LTST-S270KGKT	LITEON	C125113	1	$ 0.03	$ 0.03
20	100k	UniOhm	C133733	7	$ -	$ -
21	K3-1293S-E2	Rectangular Connectors	C145852	1	$ 0.18	$ 0.18
22	Header-Male-2.54_1x4	Ckmtw	C124378	1	$ 0.02	$ 0.02
23	DMG3415U-7	Diodes Incorporated	C96616	1	$ 0.09	$ 0.09
24	MBR120LSF	SK	C130880	1	$ 0.03	$ 0.03
					Total	$ 5.72

Figure 3: ESP32 Bill of Material

DWM1000						
ID	Name	BOM_Manufacturer	Part Number	Quantity	Price	Total Price
1	DWM1000 UWB Module	Decawave	1479-1002-1-N	1	$ 16.880	$ 16.88
2	10k Resistor	Murata Electronics	C89600	3	$ -	$ -
3	22uF Capacitor	Murata Electronics	C76903	1	$ -	$ -
					Total	$ 16.88

Figure 4: DWM1000 UWB Module Bill of Material

MSIC						
ID	Name	BOM_Manufacturer	Part Number	Quantity	Price	Total Price
1	MOSFET N-Ch. 50V 500mA AEC-Q101	Diodes Inc.	DMN53D0LQ-7	2	$ 0.055	$ 0.11
2	Linear Voltage Regulator IC 2 Output 300mA	Microchip Technology	MIC5350-SMYMT-TR	1	$ 0.190	$ 0.19
3	5v 10000mAh lithium polymer battery rechargable	Kingberry	KBPB-E002	1	$ 8.290	$ 8.29
4	30A 250VAC 1E4 kcd4 t120/55 Rocker Switch	Haifei	KCD4	1	$ 0.500	$ 0.50
5	3.7V 103048 1500mah Rechargeable Battery	Wonzer	103048	1	$ 2.100	$ 2.10
6	TP4056 Li-ion Battery Charger IC	TP	SOP-8	1	$ 0.61	$ 0.61

Figure 5: Miscellaneous Component Bill of Material

PM33						
ID	Name	BOM_Manufacturer	Part Number	Quantity	Unit Price	Total Price
1	ATMEGA32U4-AU	ATmega	C44854	1	$ 0.133	$ 0.133
2	1uF(105)	FENGHUA	C108463	2	$ -	$ -
3	100nF(104)	Samsung Electro-Mechanics	C143639	3	$ -	$ -
4	8MHz	Yangxing Tech	C70615	1	$ 0.080	$ 0.080
5	CD1206-S01575	Bourns Inc.	C75465	1	$ 0.028	$ 0.028
6	10KΩ	Murata Electronics	C89600	3	$ -	$ -
7	1K	Walsin Tech Corp	C171210	4	$ 0.009	$ 0.036
8	micro 5P 5.9 M	Jing Extension of the Electronic Co.	C40939	1	$ 0.057	$ 0.057
9	led Green	Foshan NationStar Optoelectronics	C75560	2	$ 0.060	$ 0.120
10	3528 Red LED	Foshan NationStar Optoelectronics	C185806	3	$ 0.060	$ 0.180
12	10nF(103)	Murata Electronics	C17313	1	$ -	$ -
13	8.2nH	Murata Electronics	C136487	1	$ 0.019	$ 0.019
14	2.7nH	Murata Electronics	C136461	1	$ 0.002	$ 0.002
15	3.9nH	Murata Electronics	C87541	1	$ 0.007	$ 0.007
16	1.8pF	Murata Electronics	C258490	1	$ -	$ -
18	1MΩ	Murata Electronics	C258488	1	$ -	$ -
19	22pF	Murata Electronics	C76903	2	$ -	$ -
21	100nF(104)	Murata Electronics	C26087	3	$ -	$ -
22	1K	Murata Electronics	C258503	1	$ -	$ -
23	22uF	Murata Electronics	C49036	1	$ -	$ -
24	FC-A2012BK-470H2	Foshan NationStar Optoelectronics	C253372	1	$ 0.004	$ 0.004
					Total	$ 0.666

Figure 6: Arduino Pro Mini 3.3V 8MHz Bill of Material

6 Appendix B - Injection Molding Quotes

3DHUBS - ABS	
Material	ABS
Beacon Tooling Cost [CAD]	$6360.94
Tag Tooling Cost [CAD]	$4718.34
Beacon Unit Price [CAD]	$1.80
Tag Unit Price [CAD]	$0.73

Table 5: Injection Molding Quote - 3DHUBS (ABS)

3DHUBS - PEEK	
Material	PEEK
Beacon Tooling Cost [CAD]	$10474.79
Tag Tooling Cost [CAD]	$5181.55
Beacon Unit Price [CAD]	$2.30
Tag Unit Price [CAD]	$1.25

Table 6: Injection Molding Quote - 3DHUBS (PEEK)

ICOMolds	
Material	ABS Chimei Pa-757, Natural
Beacon Tooling Cost [CAD]	$6829.00
Tag Tooling Cost [CAD]	$4357.00
Beacon Unit Price [CAD]	$1.97
Tag Unit Price [CAD]	$0.59

Table 7: Injection Molding Quote - ICOMold (ABS)

7 Appendix C - PCB Fabrication and Assembly Quotes

Board Quantity	1000
Board Size	5 × 12 cm
Thickness	0.062 inch
Layers	2
Copper weight	1.0 oz
Routing	Individual
Total Price [CAD]	$1429.72
Unit Price [CAD]	$1.43

Table 8: Beacon PCB Fabrication Quote

Board Quantity	1000
Board Size	4 × 6 cm
Thickness	0.062 inch
Layers	2
Copper weight	1.0 oz
Routing	Individual
Total Price [CAD]	$768.39
Unit Price [CAD]	$0.77

Table 9: ID Tag PCB Fabrication Quote

Board Quantity	1000
BOM Lines	51
N-sided SMT	Single Side
Processing	Leaded
SMT Pads	100
Tru-Holes	0
Fine Pitch Parts	10
BGA/QFN Parts	0
Total Price [CAD]	$3888.30

Table 10: Beacon PCB Assembly Quote

Board Quantity	1000
BOM Lines	27
N-sided SMT	Single Side
Processing	Leaded
SMT Pads	60
Tru-Holes	0
Fine Pitch Parts	5
BGA/QFN Parts	0
Total Price [CAD]	$2693.32

Table 11: ID Tag PCB Assembly Quote