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Solar Powered Smartwatch using FSTN LCD A PROJECT REPORT

Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology

in

Mechanical Engineering

by

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ABSTRACT

Smart watches are nowadays one of the most integral parts of our lifestyle but battery backup on a daily basis creates a lot of inconvenience due to excessive use of the watch. This project focuses on increasing the battery backup of smartwatch by integrating PV cells under the display of the watch. Also integrating voltage step up IC to match the charging voltage of the battery.

FSTN (Film Compensated Super Twisted Nematic) is essentially a black and white display which can be operated in 3 ways, reflective, transflective and transmissive. In our project we will be using FSTN LCD in transmissive mode which is transparent when not in use.

Using a transparent FSTN LCD for the display tends to pass light through it so that PV cells can work with at least 80-90% solar efficiency.

Performed calculations for the power output of the PV cells, approximate power usage of the watch under everyday usage, power usage of the display, net power gain/loss per day along with approximate efficiencies of all the components and at last approximating the battery life of our smartwatch.

1. INTRODUCTION AND LITERATURE REVIEWS

A smartwatch is like a small mobile phone on your wrist. Initially smartwatches were designed with the intention of showing your smartphone notifications so that one doesn't have to use their phone quite often, over the years smartwatches have been upgraded to perform many more tasks than just showing notifications such as monitoring vital health data, using them as remotes for controlling media, sleep tracking, and much more.

Comparing to its older sibling a normal wrist watch which could go years on a single battery before having to replace the battery which costed just a few rupees and two mins, smart watches have to be charged very frequently. A conventional smartwatch goes from anywhere between a day to a week before needing to be charged which takes around an hour or two to fully charge.

As per many surveys this is the biggest problem that smartwatch users face today, that the battery life is too short and almost 50% of the survey participants wants better battery life in their next smartwatch.

Our project aims to counter this problem, we are aiming to integrate PV cells in our watch which will provide continuous power to the watch to extend its battery life at the same time we will also be replacing the display from being amoled/oled on a conventional smartwatch to FSTN LCD on our watch which consumes very less power to operate, at the same time we won't be compromising on the number of features that our watch would have, our essential aim is to extend the battery life of our watch as much as possible.

1.2 OBJECTIVES

- To increase the battery life of a conventional smart watch with the use of solar cells and FSTN LCD.
- To introduce a sustainable mode in the watch wherein it would disable all the features except just show time and date essentially letting the watch go on without the need of any charging.
- Maintaining minimum cost of the product with market and cost analysis
- 3D printing of the prototype.

1.3 LITERATURE REVIEW

Design of ultra-low power circuit using quantum dots that can capture power input of PV sources more efficiently with integration of flexible solar cells in the strap of smartwatch. But by the time there is possibility of wearing off of those solar cells due to friction with wrist (Lee et.al, 2019).

Wearable device for health and fitness monitoring especially sweat glucose monitoring where the smartwatch is being self-powered using PV cells and Zn-MnO2 batteries serves as an energy storage (Zhaoet.al, 2019).

A wearable device which uses sunlight to harvest energy to measure various metabolic biomarkers containing flexible PV cells in the band harvesting enough to work for 8 days with 14 min of charging enough for power consumption of 176 µW (Songkakul et.al, 2021).

Derived an analytical formula to calculate the parameters of display cell using 3X3 matrix method. Transmission spectrum as the function of twisted angle of STN has been done (Yang et.al,2006)

Talks about the upcoming possibilities of using PV cells instead of hard batteries and their growing market in the field of IoT and have answered various research-based questions such as its history, expected market, usage, performance etc (Mathews et.al, 2019).

The research is done on the usage of organic PV cells for indoor conditions comprising of 3 major sources 1. poly (3-hexylthiophene-2,5-diyl), The research is done on the usage of organic PV cells for indoor conditions comprising of 3 major sources **1.** Poly (3-hexylthiophene-2,5-diyl), **2.** Poly [N-9′-heptadecanyl-2,7-carbazole-alt-5,5-(4′,7′-di-2-thienyl-2′,1′,3′-benzothiadiazole)], **3.** poly[[4,8-bis[(2-ethylhexyl)oxy]benzo[1,2-b:4,5-b′]dithiophene-2,6-diyl][3-fluoro-2-[(2-ethylhexyl)carbonyl]thieno[3,4-b]thiophenediyl]], where PCDTBT devices are most likely to be used due to high performance and PTB7 shows high efficiency under sun (Lee et.al. 2016).

Talks about an LCD based touch pad providing the capacitive touch and other haptic features on it. There has been use of ⅛ - VGA (240 X 160 pixels) FSTN LCD display (Leeper, 2002).

Talks about smartwatch battery usage, user satisfaction, concerns and recharging patterns and compared it to a smartphone. 35% were satisfied, 36% were neutral and 31% were dissatisfied with the battery life (Min et.al, 2015).

This paper talks about optimizing android smartwatch energy consumption. Smartwatch battery consumption is much different from smartphones. Display on a smartwatch uses more than 30% of the total battery capacity. Proposed solutions for improving the energy efficiency of smartwatches, such as energy-efficient watch face display, smart display dimming, and adding delay-tolerant support to push notification delivery (lu and Qian, 2016).

The smartwatches have multiple functions so the consumers can derive great enjoyment and will promote to purchase more smartwatches. This article is one of the first attempt to get the prediction of smartwatches usage for the future.(hong et.al. 2016)

This research article talks about the acceptance level of a smartwatch and also the price acceptance of the people associated with the same in comparison to a traditional watch which still a lot of people prefer and has a lot more value to it at times.(Bolen 2020)

This paper displays the future of STN displays i.e. holographical reflective LCDs which enhance the brightness and contrast of the display 2x to 3x without consuming additional battery power and also provides backlit experience. (Chen et.al 1995)

From this paper we found out the daily battery consumption of accelerometer, screen, bluetooth and heart rate monitor. (Aras et.al 2015)

1.4 GAPS IN LITERATURE

- The design used in papers read till now are not very optimized. Flexible PV cells were installed on the straps of some watches which can deteriorate by the time and can reduce the efficiency. There are very fewer smart watches in the market which are solar powered and with transparent FSTN display, where the available ones are very expensive.
- There are very less or no papers which focuses on general smartwatches with PV cells and FSTN together.

1.5 CRITICAL REVIEW

- Researchers have been focusing on integrating PV cells in various wearable devices for measuring mostly health parameters of a human body by usage of methods such as low power circuit design using quantum dots (which can carry power input of PV sources); organic PV cells (PCDTBT, PTB7). Flexible PV cells are also being used by them to integrate in the straps of the watch but the drawback is that by the period of time the effectiveness of the PV cells may reduce due to it.
- Use of Zn-MnO2 batteries instead of usually used Lithium-ion is also been seen for energy storage which is abundantly available and cheaper than Lithium Ion making it more sustainable and environment friendly. Though they have the tendency to lose the rechargeability earlier than lithium ion but in the long run it is possible to increase its capacity. Even they are resistant to exploding or catching fire.
- FSTN are being used in various devices such as calculators, old video games, digital watches, being cheaper and more sustainable than OLED. The energy consumption is way less than an OLED screen but the quality which we get is significantly mediocre.

1.6 MOTIVATION

We felt that the battery backup for the watches is not sufficient enough for our Army officers, trekking people, nomads etc as battery backup is quite low and hence, they cannot make the most of it. In order to enhance battery backup, and to move towards the era of sustainability we incorporate PV panels just before the display and to further raise the battery backup, we also provide FSTN display technology. Apart from this, we also experience low battery backup and high cost of our smartwatches and these are the reasons why we come up with this project.

1.7 PROBLEM DEFINITION

Smartwatches have become a very integral gadget for us in recent times, allowing us access to our notifications as well as vital health data are one of the biggest uses of a smart watch but when it comes to its biggest con, as per some survey findings too, majority of the people were dissatisfied with its battery life (Fig 1.1) and approximate 50% of the people expect better battery life in their next smart watch purchase (Fig 1.2) . Some data is presented below:

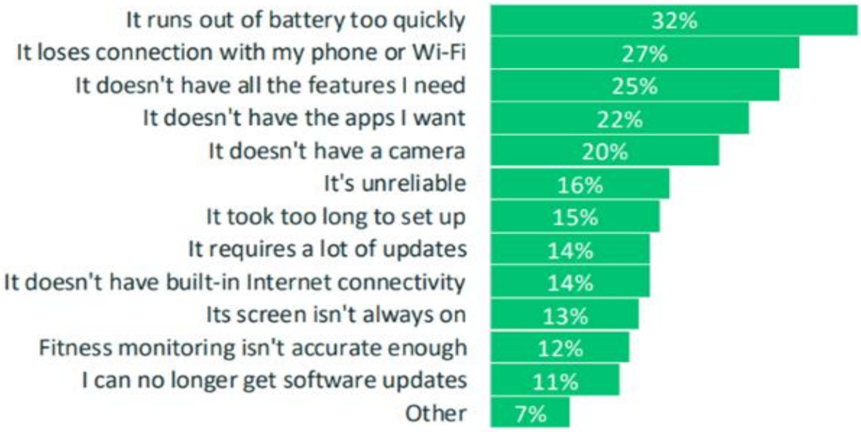


Fig. 1.1. Bar chart on Reasons for dissatisfaction in smartwatches **(User Survey, 2018)** **(**https://www.ccsinsight.com/wpcontent/uploads/2019/02/CCS_Insight_User_Survey_Smartwatches_2018_Sample.pdf)

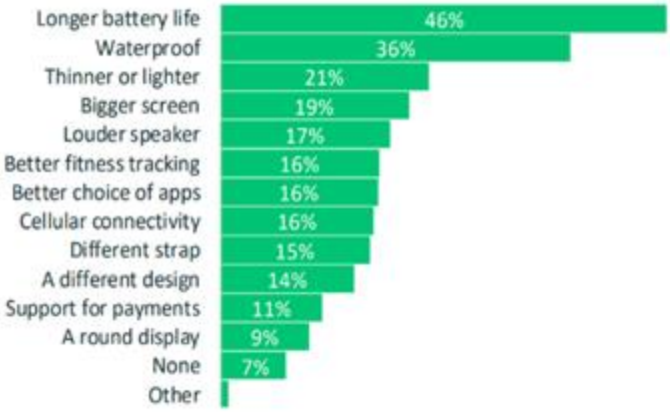


Fig. 1.2. Bar chart representing Improvements in a Smart Watch. **(User Survey, 2018)** **(**https://www.ccsinsight.com/wpcontent/uploads/2019/02/CCS_Insight_User_Survey_Smartwatches_2018_Sample.pdf)

1.8 THEORY

Why FSTN LCD (Film compensated Super Twisted Nematic):

FSTN LCD is a monochrome display that is made by adding a retardation film to a STN display to give a black and white display. This results in producing a display which has higher contrast as well as wider viewing angle than a STN or TN panel. When the display is in positive configuration it is opaque when the pixel is "ON", and transparent when the pixel is "OFF". Usually, the image background is larger than the image, so when the ambient light is high positive mode of operation is favored and so that it will help with the contrast of the display, especially while utilizing a reflective rear polarizer.

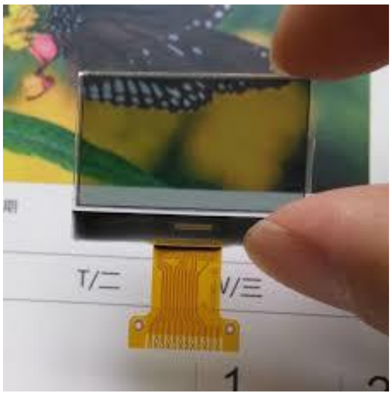


Fig 1.3. Photo FSTN Display

Choosing the right Solar Cell

Solar cells make the most integral part of the solar panels, so choosing which solar panels to use is critical. Some of the different types of solar cells available are mentioned below for comparison.

Crystalline Silicon Solar Cell (Mono vs. Poly)

Mono solar cell efficiency and price is higher than polycrystalline silicon solar cells but polycrystalline silicon solar cells are currently the most widely used solar cell. At the moment, the efficiency of monocrystalline silicon solar cells lies between 19% - 21%, whereas the efficiency of polycrystalline silicon solar cells lies between 17% - 19%. Therefore, the efficiency of monocrystalline silicon solar cell is higher than that of polycrystalline silicon solar cells but it also comes at a higher cost. However, as the technology of monocrystalline silicon solar cells is further improved and the production cost is further reduced, also the price difference between monocrystalline solar panels and polycrystalline solar panels is not significant for small solar panels.

For crystalline silicon solar panels, the encapsulation method can be glass lamination, PET lamination, or epoxy.

Sunpower Solar Cell vs Crystalline Silicon

Sunpower solar cells are a high-efficiency solar cell produced by Sunpower Corporation of the United States. They have the highest efficiency and price. It is currently the most efficient solar cell on the market with an efficiency of over 21% and thus cost much more than crystalline silicon solar cells. For these solar panels, the encapsulation method can be PET lamination, or ETFE lamination.

2. METHODOLOGY AND EXPERIMENTAL WORK

2.1 Project Execution Stages

Step 1: - Deciding the need for the PV panel in the smart watches.

Step 2: - Review the literature and identify various methods to implement into our solar watch.

Step 3: - We will incorporate conventional watch battery which is rechargeable along with the PV panel.

Step 4: - Designing the solar watch in Fusion 360.

Step 5: - Need of already available PV panel of our dimensions.

Step 6: - Step up transformer will be in use in order to raise the voltage output of pv panel in accordance with the battery.

Step 7: - FSTN LCD display will be used of our dimensions.

Step 8: - Experimental check by finding FSTN LCD and PV panel from the market.

Step 9: - Calculations of overall battery life with the usage of FSTN and PV cell.

Step 10: - Power consumption/battery usage of various watch modes.

Step 11: - Market surveys and analysis.

Step 12: - Cost analysis of overall product.

Step 13: - Prototyping of the product to give the overall working.

Step 14: - Documentation and thesis work.

2.2 Market Survey

According to Fig 2.1 survey 65.4% of the people already own a smartwatch while 35% of the people don't use a smartwatch.

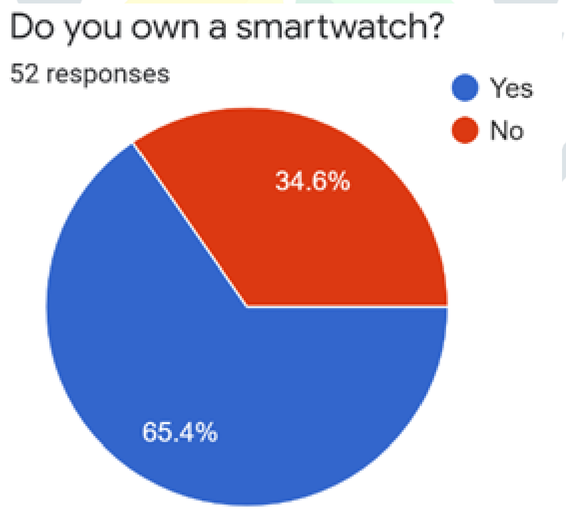


Fig 2.1 Pie chart depicting proportion of people who own a smartwatch vs who doesn't own one.

According to Fig 2.2 34.6% people suffer from low battery backup, 25% from less features, 32.7% people don't own a smartwatch whereas rest are dissatisfied with no water resistance.

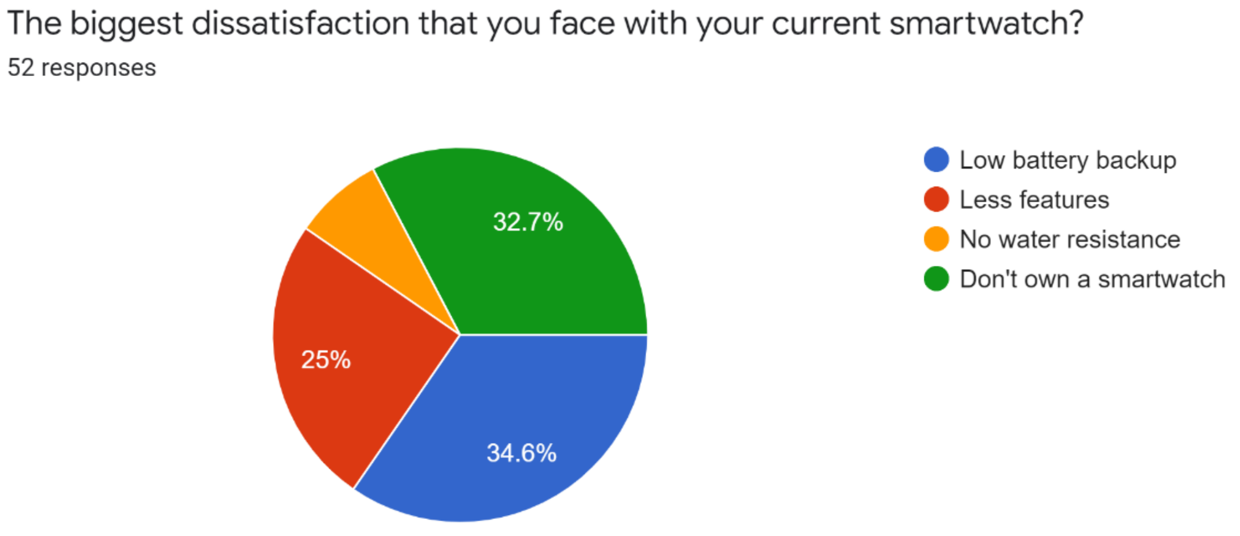


Fig – 2.2 Pie chart depicting the biggest dissatisfaction that people have with their current smartwatch.

According to Fig 2.3 bar chart 53.8% people use smartwatch for measuring workout data, 42.3% for measuring heart rate and SpO2, 32.7% for receiving calls and replying notifications and 34.6% people don't own a smartwatch.

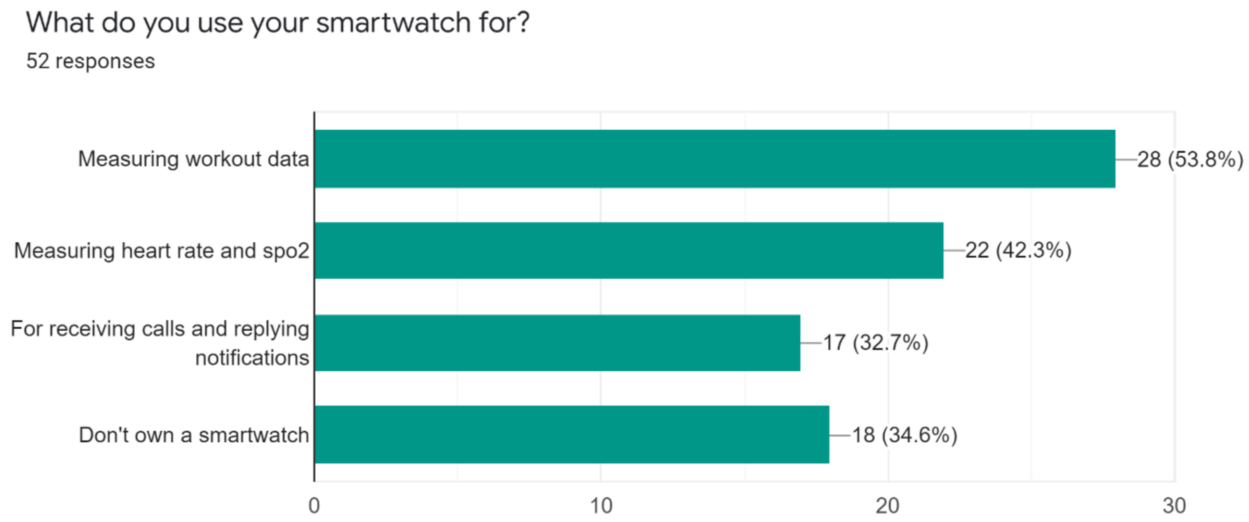
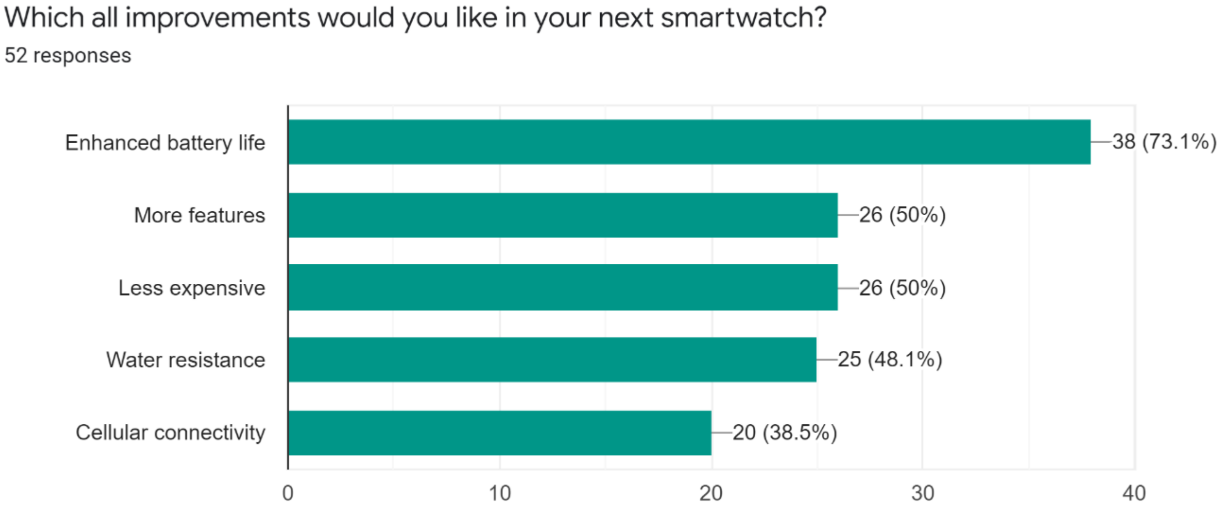


Fig 2.3 – Survey findings showing the major use cases for a smartwatch.

According to Fig 2.4 bar chart majority of the people wants enhanced battery life in a smartwatch followed by more features, cost effective and water resistant.

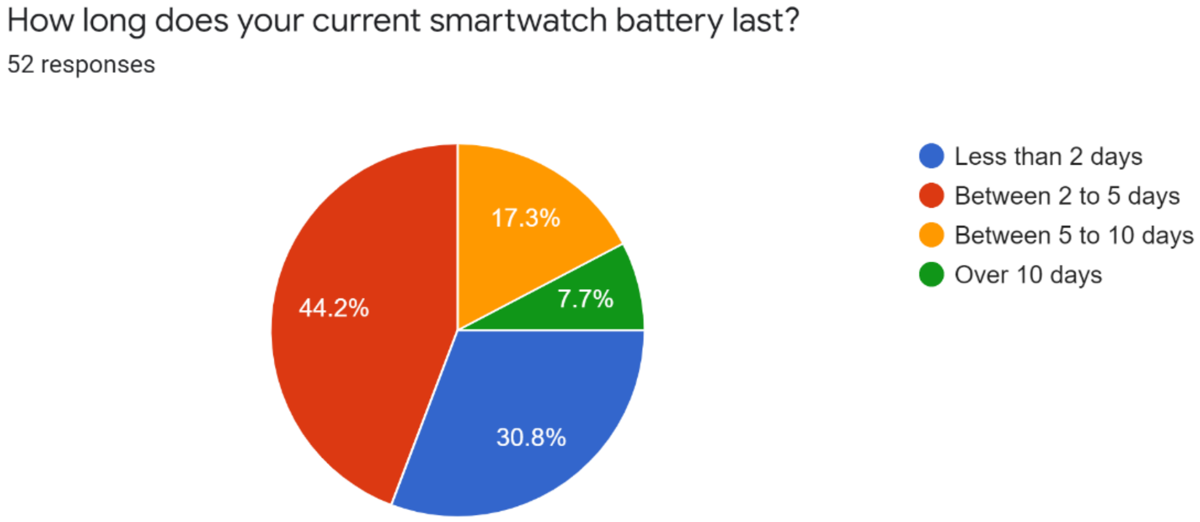
Fig 2.4 –



Survey findings showing improvements people ask for in their next smartwatch.

According to Fig 2.5 pie chart 44.2% of people’s smartwatch battery last for only 2 to 5 days and 30.8% for less than 2 days.

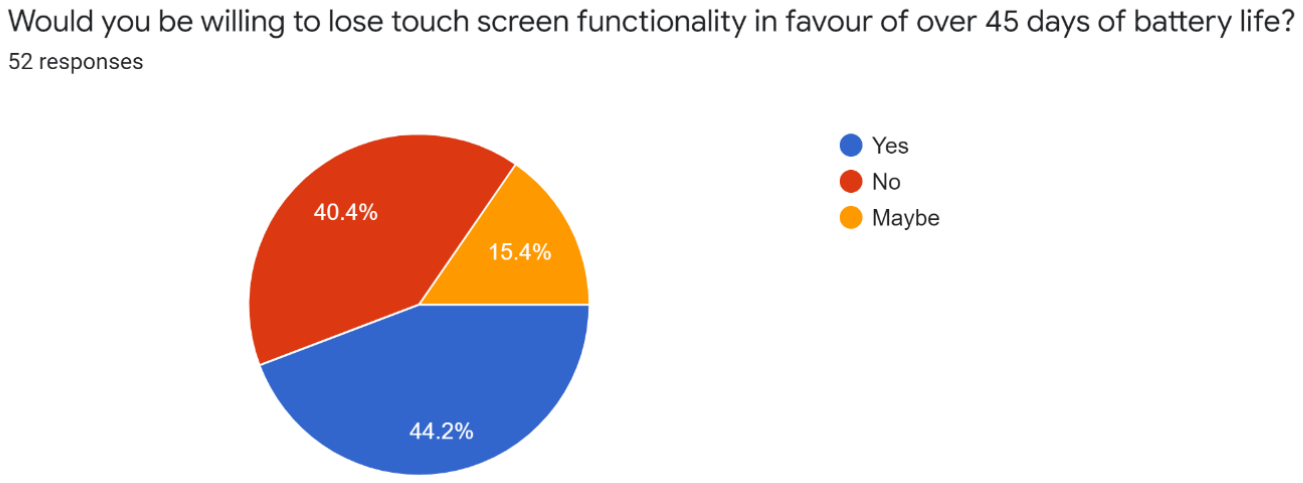
Fig



2.5 – Pie chart depicting the average battery life of smartwatches that people currently own.

According to Fig 2.6 pie chart 44.2% of people are willing to lose touchscreen functionality in favor of over 45 days of battery life, 40.4% are not in favor while 15.4% are unsure about it.

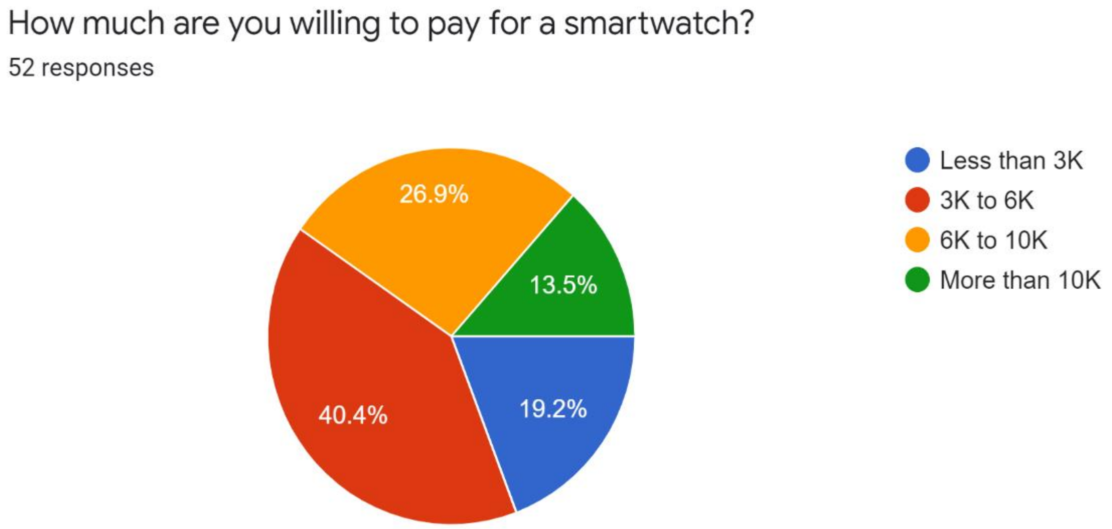
Fig



2.6 – Pie chart depicting the number of people willing to lose touchscreen functionality in favour of better battery life.

According to Fig 2.7 pie chart 40.4% of the people are willing to pay between 3k to 6k for a smartwatch, followed by 26.9% who are willing to pay between 6k to 10k.

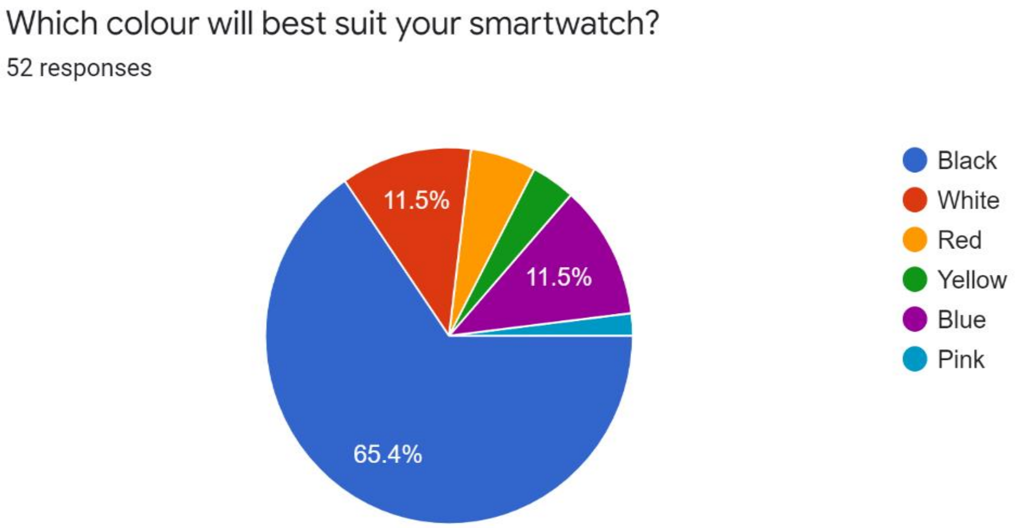
Fig 2.7 – Pie chart



depicting the price people are willing to pay for a smartwatch

According to Fig 2.8 pie chart black is the most preferred color for a smartwatch followed by white and blue.

Fig



2.8 – Pie chart depicting the colour preference of people.

2.3 Theoretical power Consumption

1. Battery capacity as well as expected battery life data is collected for most popular smartwatches in India from their respective brand websites and e-commerce platforms.

2. Per-day consumption is calculated by dividing battery capacity by claimed number of active days.

3. Average daily consumption of a general smartwatch is calculated.

4. Average daily power consumption is calculated by the formula P = V*I, for a smartwatch battery of 3.7 volts and average daily consumption of 45 mAh, the average daily power consumption is 3.7*45 = 166.5 mWh.

Table 2.1 – Theoretical power consumption of the most popular smartwatches available in the market.

S.No	Name	Battery Capacity(mAh)	Battery Life(Days)	Daily Consumption(mAh)
1	Huami Amazfit GTS 2	246	5	49
2	Amazefit Bip U Pro	230	7	32
3	BoAt Watch Xtend	300	5	60
4	BoAt Watch Flash	200	5	40
5	Garmin Venu Square	350	4	87
6	Fire-Boltt Ring	270	8	33
7	Noise Colorfit Pro 3	210	8	26
8	Realme Watch Pro 2	390	10	39
			Sum	366
			Average	45
			Daily power consumption(mWh)	166.5

NOTE: Thus, if we can counter any percentage of this consumption with the use of PV panel, we are essentially increasing the battery life.

2.4 Technical Specifications (Watch Specifications)

- Display Type: FSTN
- Display Dimensions: 30mm x 33mm x 1.5mm
- Battery Type: Li-Po
- Battery Capacity: 450 mAh
- Body Material: Plastic
- Strap Size: 20mm
- Strap Material: Silicon
- Watch Dimensions: 41mm x 36mm x 13mm
- IC Specifications: TPS61322 6.5-µA Quiescent current, 1.8-A switch current boost converter by Texas Instruments

2.5 Design Approach Details (Watch Design)

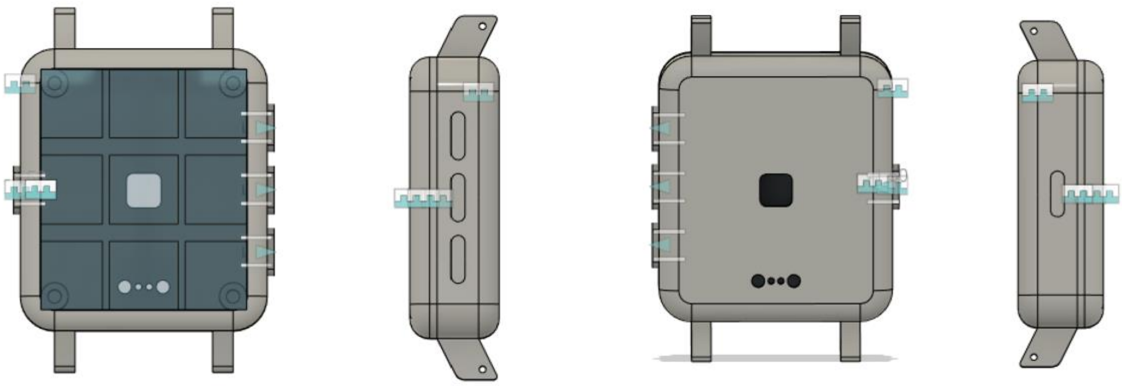


Fig 2.9 – Final design of the watch as per component dimensions

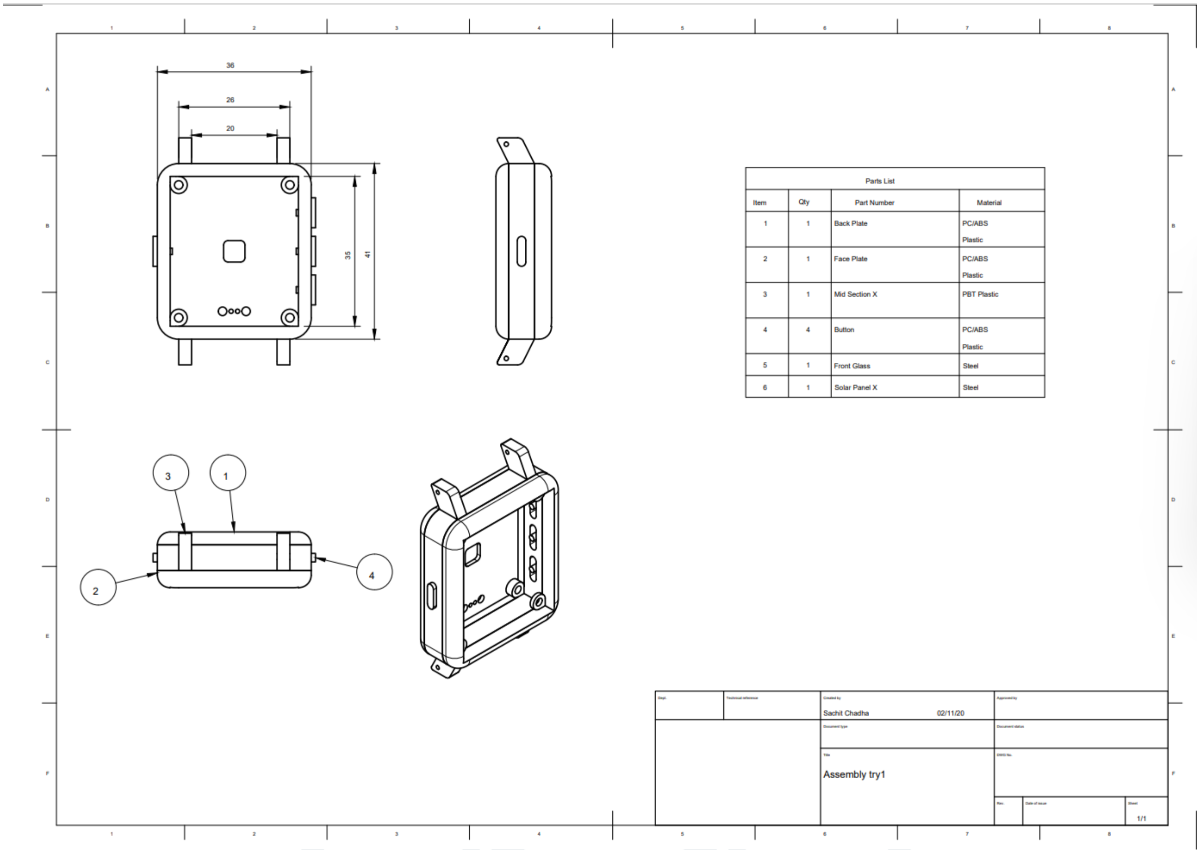


Fig 2.10 – Final 2D design of the watch as per component dimensions

2.6 Lab Experimentation – Procedure

In order to proceed the experimental work we took FSTN display (Fig 2.11) in working condition with 3 panels of size 30mm X 10mm each (Fig 2.12), along with a multimeter and a big solar panel of size 233mm X 130mm.

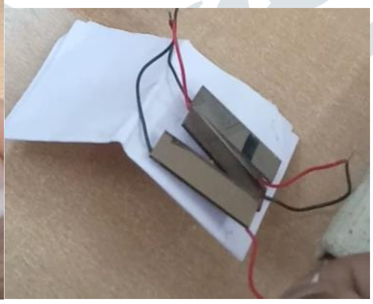


Fig 2.11 FSTN Display **Fig 2.12** 3 small PV panels

- Lab experimentation is done to find the power output of the solar panels, we had taken 3 solar panels of dimension 30mm x 10mm each, and connected them in series.
- These solar panels were connected to a multimeter to calculate the voltage as well as current output.
- Solar panels provide DC current.

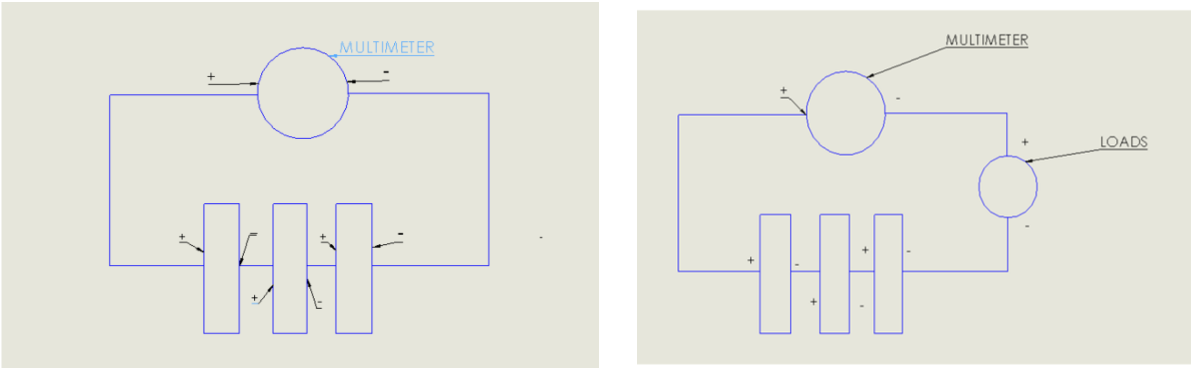


Fig 2.13 – Schematic diagrams of the experimental setup for measuring voltage and current

2.7 Lab Experimentation – Results

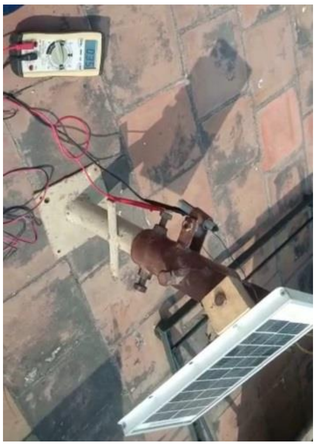


Fig 2.14 Big Solar Panel

Fig 2.15 Current Value

Fig 2.16 Voltage value

Table 2.2 – Power output for big solar panel of dimension 233mm x 130mm under bright sunlight

S.No.	Voltage (V)	Current (mA)	Power Output (mW)
1	10	350	3500
2	10	370	3700
3	10	360	3600
		Av. Power	3600
	Dimensions : 233mm x 130mm		

- Under bright sunlight a solar panel of dimensions 233mm x 130mm was kept and connected to a multimeter and voltage as well as current was measured as mentioned in the table above.
- Power output was calculated using the formula P=V*I.
- Experiment was conducted 3 times with the gap of 15 mins and average power was calculated.
- Using proportionality, we can estimate the power output of a 30mm x 30mm panel as solar output is directly based on the area available. Thus power output should be (900/(233*130))*3600 = 106.9 mW.

Fig 2.17 Voltage value of small panel

Fig 2.18 Amp value of small panel under direct sun

Table 2.3 – Power output for 3 solar panel of dimension 30mm x 10mm each connected in parallel under direct bright sunlight

S.No.	Voltage (V)	Current (mA)	Power Output (mW)
1	3.1	20	62
2	3.1	20	62
3	3.1	20	62
		Av. Power	62
	Connection Type : Parallel		
	Dimensions : 30mm x 30mm		

- Under bright sunlight (under FSTN LCD) 3 solar panel of dimensions 30mm x 10mm connected in parallel were kept and connected to a multimeter and voltage as well as current was measured as mentioned in the table above.
- Power output was calculated using the formula P=V*I.
- Experiment was conducted 3 times with the gap of 15 mins and average power was calculated.
- As the PV panels we used were of very bad quality extracted from calculators the power output is about 1/3 of the output expected, still it is able to compensate for the energy required for running the watch.

Fig 2.19 Small Panel setup under FSTN

Fig 2.20 Amp value of small panels under FSTN

Table 2.4 – Power output for 3 solar panel of dimension 30mm x 10mm each connected in parallel under FSTN display under bright sunlight

S.No.	Voltage (V)	Current (mA)	Power Output (mW)
1	3.1	10	31
2	3.1	10	31
3	3.1	10	31
		Av. Power	31
	Connection Type : Parallel		
	Dimensions : 30mm x 30mm		

- Under bright sunlight (under FSTN LCD) 3 solar panel of dimensions 30mm x 10mm connected in parallel were kept and connected to a multimeter and voltage as well as current was measured as mentioned in the table above.
- Power output was calculated using the formula P=V*I.
- Experiment was conducted 3 times with the gap of 15 mins and average power was calculated.
- As the PV panels we used were of very bad quality extracted from calculators the power output is about 1/3 of the output expected, still it is able to compensate for the energy required for running the watch.

2.8 Lab Experimentation- Calculation

- Power consumption of an average smartwatch is measured theoretically to be 166.5 mWh per day. Considering we will provide all the features exactly the same as any conventional smartwatch with one minor change of using an FSTN LCD instead of an OLED or AMOLED display, which uses 4 times the power an FSTN LCD consumes, we need to compensate for the same.
- Through the study of research articles we got to know that an OLED or AMOLED display uses more than 30% of the whole power consumption.
- Thus the final theoretical power consumption per day comes out to be (166.5-

166.5*0.3)+(166.5*0.3*0.25) = 129 mWh.

- Thus we need to counter this daily consumption with the use of our PV panels, considering our panels receive 4 hours of effective sunlight throughout the day, thus the total power output through our solar panels comes out to be 31*4 = 124 mWh.
- Through experimentation we figured out that FSTN allows 80% of the light to pass through it thus the power output becomes 124*0.8 = 99.2 mWh.
- To step up the voltage to 4.2 volts which is the charging voltage for our battery, we need to use a boost step-up IC which converts the voltage with 90% efficiency.
- Now the net power output through our solar panel comes out to be 99.2*0.90 = 89.28 mWh.
- Thus, the net power consumption per day = 129-89.29 = 39.72 mWh.
- Thus, battery life = (450 mAh * 3.7 V)/39.72 mWh/day = 42 days.

2.9 SWOT Analysis

STRENGTH:

- Over 42 days of battery life.
- Reparability of the watch.
- Button interface reduces the risk of touch screen damage.
- Heart rate sensor integration for heart rate abnormalities detection as well as other heath related calculations.
- Other features like step tracking and calorie count are also available.
- The cost of the watch is a lot less when compared to the competition producing similar products.
- Made out of Aluminum which helps in heat dissipation as well as adds to the durability of the watch.
- SpO2 sensor available as per the current needs of the people.
- Equipped with all features available in a conventional smartwatch such as notification alerts, sleep tracking and much more.

WEAKNESS:

- The solar panel provides very less power when compared to conventional sources of power like plugging in the watch to an adapter.
- The display of the watch is not a touch screen.
- Display is not very bright under indoor lighting conditions.

- No calling facility.
- No GPS facility.

OPPORTUNITIES:

- The massive battery life will reduce the people's anxiety of having these devices fail at them.
- The watch has the ability and hardware to support a lot more features than it does right now which we may enable with an OTA update.
- May add features such as fall detection and irregular heart beat detection for elderly as well as needy people.
- With new technologies emerging such as holographic FSTN display, we may further enhance the display quality of our watch.

THREATS:

- It is difficult to establish a new brand when a lot of already established brands already exist.
- The watch may look bulky which a lot of people might dislike.
- A lot of people prefer OLED display in their smartwatches due to better display quality, vibrant colors as well as more brightness.
- Our watch lacks a touch screen which maybe a deal breaker for a lot of people.
- It is difficult to convince the usefulness of our product to new customers.

2.10 Codes and Standards

Our watch is IP68 certified, i.e., fit enough to withstand dust, dirt and sand, and are resistant to submersion up to a maximum depth of 1.5m underwater for up to thirty minutes. This is achieved by gluing the front panel of the watch with air tight adhesive and also there is a gap in back panel for a rubber gasket which sits to provide water resistance for the back panel. All the buttons are backed by water proofing around them.

2.11 Cost Analysis

Table 2.5 Cost analysis of the smartwatch

Component	Price	Description
PCB (Assembly)	Rs.500 - Rs.1000	
FSTN LCD	Rs.100 - Rs.500	Transmissive, 30 mm x 33 mm x 1.5 mm
Straps	Rs.100 - 200	Silicon
Charger	Rs.100 - 200	Magnet Based
IC	Rs.10 - 20	Texas Instruments TPS61322
PV Cells	Rs.100 - 300	Polycrystalline Cells
Battery	Rs.150 - 200	450 mAh
Casing (Aluminium)	Rs.500 - Rs.800	Injection Moulding
Manufacturing Cost (Production)	Rs.150 - Rs.300	
Average cost (assumed)	Min: Rs 1710 Max: Rs 3520	Production cost (avg): Rs 2600
Retail Price	Approx. 40% profit	Rs 3599

3. RESULTS AND DISCUSSIONS

- After performing all the calculations, we were able to achieve a battery life of 42 days.
- As per our cost estimation the price of our watch should fall between Min: 1710 rupees Max: 3520 rupees, with retail price of approximate 3599 rupees after keeping profit margin of around 40%.
- The main USP of our watch is high battery backup which can be used by people going for long treks where there is now power supply or by our army officials.
- With the usage of PV cells, we are moving towards an era of sustainability.
- The approximate retail price of our watch also matches the competitive world of smartwatches where our watch is giving every other feature a smartwatch should have.

4. CONCLUSIONS

4.1 Contributions to the literature

- Initiated the idea of incorporating PV Panels under smartwatch
- Initiation of experimentation and calculation work for the same.
- Using transparent FSTN Display instead of opaque OLED so as to improve costing as well as the efficiency of PV panels.

4.2 Scope for future work

- Improvement in design aspects of the watch with better PV cells so as to include OLED instead of FSTN
- Usage of new FSTN technology such as Holographic FSTN to improve the contrast and the brightness of the panel.
- Reaching to a stage where the watch is getting charged with the help of sunlight for indefinite number of days even for high watch usage.

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