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# Energy Efficient Solar Charge Sensor Design Using Spartan-6 FPGA

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***Abstract-*** **Over charging of batteries as well as not charging discharged batteries in time spoils battery life. Human life is becoming very busy and many people do not care about how to do with batteries. Solar Charge Sensor Design is introduced to sense the voltage level of battery. It gives indication according to the voltage level to user. This will increase the life span of battery and make them work efficiently .Low Voltage Complementary metal oxide semiconductor i.e. LVCMOS25 standard on Spartan6 FPGA is used for making Solar Charge Sensor energy efficient and precise.**

Keywords- *Battery, Solar Charge Sensor, Field Programmable Gate Array, Charging.*

## I. INTRODUCTION

This paper is about making a sensor efficient which makes batteries to work n efficient manner by increasing their performance. Solar Charger Sensor senses the voltage level of the battery and tells user that it is time to charge battery now or battery is sufficiently charged as per the requirement. The charging of battery will automatically stop when sensor will indicate that battery is charged sufficiently. So there is no fear of overcharging. To make Solar Charge Sensor to use low power the research is done for Low Voltage Complementary Metal Oxide LVCMOS25 standard based on Spatan6 Field Programmable array using capacitance scaling. The value of different parameters and total power used by solar charge sensor is noted down over a range of output Load. The data is collected for 1GHz, 10GHz and 100GHz. To what extent power consumption is reduced is noted down and calculated as percentage reduction. The reductions in all the factors are analyzed and then plotted for easy understanding. Solar Charge Sensor has many Properties. It not only checks for voltage level and indicates the need but also helps to achieve better performance in many ways. Some of the features of Sensor that makes the battery life long are shown in figure1.

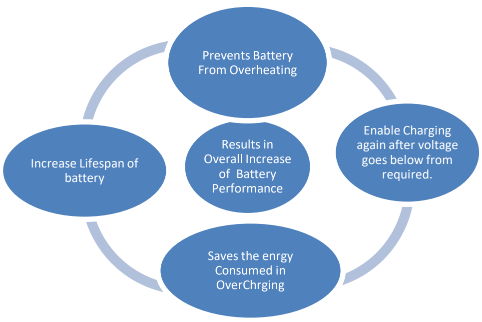


**Figure 1:** Factors Result in Better Performance

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## II. RELATED WORK

The research needs to be done in this field. Very less work has already done in this field. A paper i.e. LVCMOS based energy efficient solar charge sensor design on FPGA **[1]** has done some work .This paper is similar to our paper as the approaches are similar to attain the low power solar charge sensor. The software used is also Xilinx for the interpretation of Data .The technique used is however different. We have used Capacitance Scaling for LVCMOS25 at three different frequencies. Where as in this paper frequency scaling is done based on LVCMOS15, LVCMOS18, LVCMOS25 and LVCMOS33. The frequency considered is 900MHz, 5GHz and 60GHz. Field Programmable Array used in our paper is Spartan-6 instead of 28nm Artix-7 FPGA. Except this there is some work which is done for efficient charging of capacitors [2] for extended lifespan. For making systems energy efficient the work is done for ALU on 40nm FPGA [3] , signal process using FPGA[4] etc. But the idea of making sensors for indication of battery charging is still not that touched and work should be necessarily done for this.

## III. RESEARCH TECHNIQUE

Xilinx Integrated Synthesis Environment Design Suite 12.1 used analyzing the design which is based on Spartan-6 FPGA for LVCMOS25 standard. Xilinx is tool for analyzing designs for various factors. The Capacitance is scaled from 10pF to 100pF for 1GHz, 10GHz and 100GHz. Overall downturn in power consumption for the sensor is studied. Top Level RTL schematic for Solar Charge Sensor obtained using Xilinx is shown in Fig. 2.

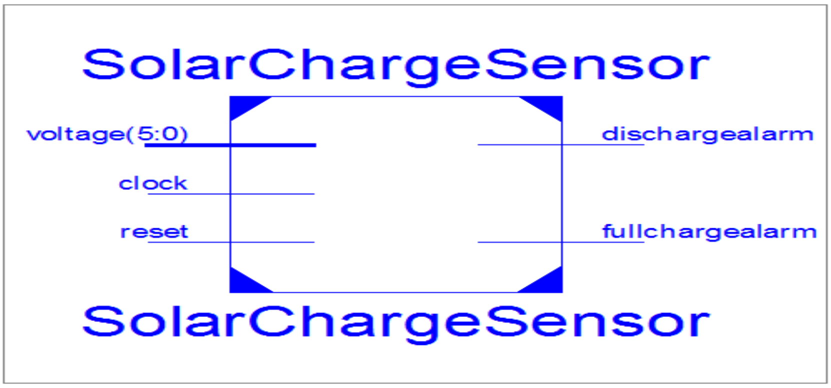


**Figure 2:** RTL Schematic of Solar Charger Sensor

## IV. DATA ANALYSIS AND INTERPRETATION

### A. Readings at Frequency 1GHz

Values for Junction Temperature, Ambient Temperature, IOs and Total Power are shown in Table1.

Table 1: Readings for Temperature, I/O and Total Power at 1GHz for 10pF-50pF Capacitance

| Output Load (pF) | 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|
| Junction Temperature($^0$C) | 26.3 | 26.3 | 26.4 | 26.5 | 26.5 |
| Ambient Temperature($^0$C) | 83.7 | 83.7 | 83.6 | 83.5 | 83.5 |
| IOs | 0.007 | 0.009 | 0.010 | 0.012 | 0.013 |
| Total Power | 0.030 | 0.031 | 0.033 | 0.035 | 0.036 |

Percentage downturn in Junction Temperature is 0%, 0.37%, 0.75% and 0.75% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively. Percentage downturn in Ambient Temperature is 0%, 0.37%, 0.75% and 0.75% when we upturn output load from 10pF to 20pF, 30pF, 40pF and 50pF respectively. Percentage downturn in I/Os is 7.69%, 23.07%, 30.76% and 46.15% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively. Percentage downturn in Total Power is 2.7%, 8.33%, 13.88% and 16.66% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively which is shown graphically in Fig. 3.

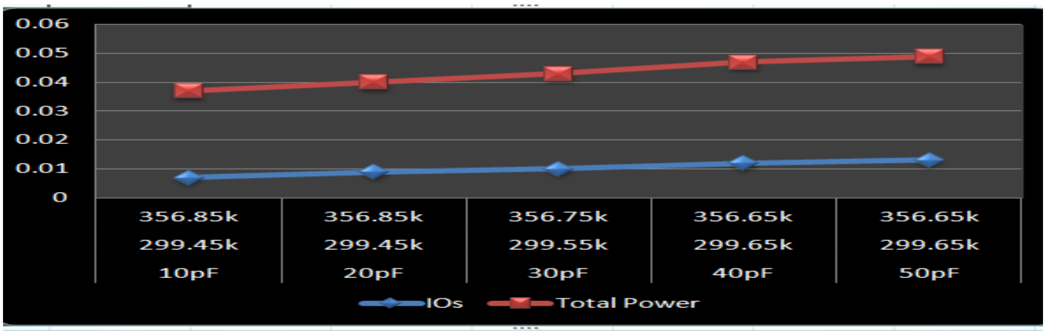


**Figure3:** Graphical Representation 0f Temperature, I/O and Total Power at 1GHz for 10pF-50pF Capacitance

Values for Junction Temperature, Ambient Temperature, IOs and Total Power are shown in Table2.

Table2: Readings for Temperature, I/O and Total Power at 1GHz for 60pF-100pF Capacitance

| Output Load (pF) | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|
| Junction Temperature($^0$C) | 26.6 | 26.6 | 26.7 | 26.8 | 26.9 |
| Ambient Temperature ($^0$C) | 83.4 | 83.4 | 83.3 | 83.2 | 83.1 |
| IOs | 0.015 | 0.015 | 0.018 | 0.020 | 0.021 |
| Total Power | 0.038 | 0.038 | 0.041 | 0.043 | 0.044 |

Percentage downturn in Junction Temperature is 0.37%, 0.74%, 1.11% and 1.11% when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively. Percentage downturn in Ambient Temperature is 0.11%, 0.11%, 0.23% and 0.35% when we upturn output load from 60pF to 70pF, 80pF, 90pF and 100pF respectively. Percentage downturn in I/Os is 4.76%, 14.28%, 28.57% and 28.57% when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively. Percentage downturn in Total Power is 2.27%, 9.09%, 13.63% and 13.63% when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively as shown in Fig. 4.

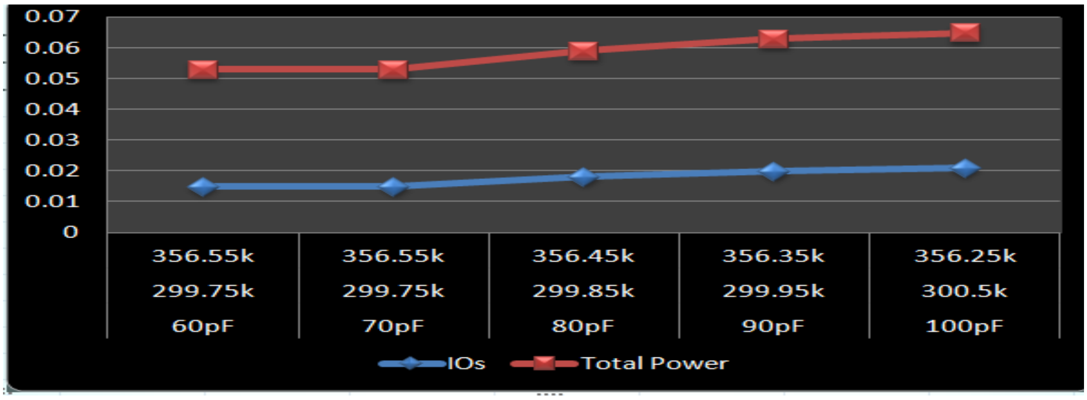


**Figure4:** Graphical Representation 0f Temperature, I/O and Total Power at 1GHz for 60pF-100pF Capacitance

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## B. Readings at Frequency 10GHz

Values for Junction Temperature, Ambient Temperature, IOs and Total Power are shown in Table3.

Table 3: Readings for Temperature, I/O and Total Power at 10GHz for 10pF-50pF Capacitance

| Output Load (pF) | 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|
| Junction Temperature($^0$C) | 32.4 | 33.1 | 33.8 | 34.5 | 35.2 |
| Ambient Temperature ($^0$C) | 77.6 | 76.9 | 76.2 | 75.5 | 74.8 |
| IOs | 0.069 | 0.085 | 0.102 | 0.118 | 0.134 |
| Total Power | 0.174 | 0.191 | 0.207 | 0.223 | 0.240 |

Percentage downturn in Junction Temperature is 1.98%, 3.977%, 5.96% and 7.95% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively. Percentage downturn in Ambient Temperature is 0.90%, 1.80%, 2.70% and 3.60% when we upturn output load from 10pF to 20pF, 30pF, 40pF and 50pF respectively. Percentage downturn in I/Os is 11.94%, 23.88%, 36.56% and 48.50% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively. Percentage downturn in Total Power is 7.08%, 13.75%, 20.4% and 27.5% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively as shown in Fig. 5.

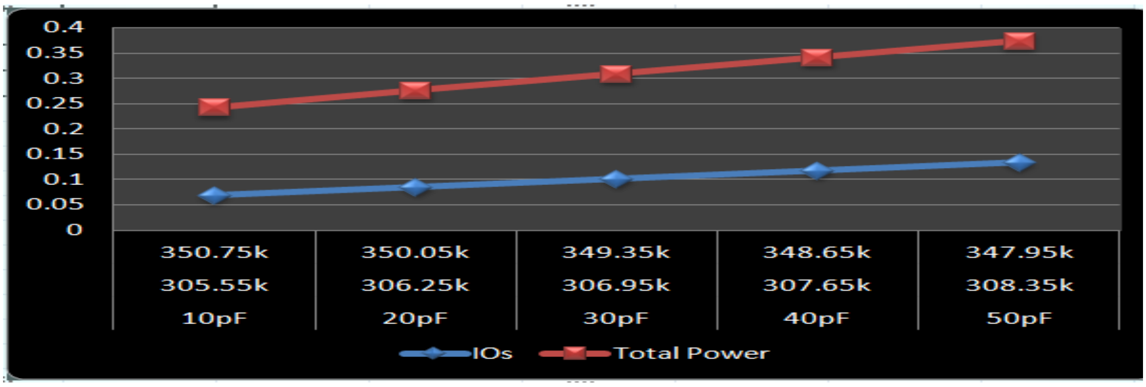


**Figure5:** Graphical Representation 0f Temperature, I/O and Total Power at 10GHz for 10pF-50pF Capacitance

Values for Junction Temperature, Ambient Temperature, IOs and Total Power are shown in Table4.

Table 4: Readings for Temperature, I/O and Total Power at 10GHz for 60pF-100pF Capacitance

| Output Load (pF) | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|
| Junction Temperature ($^0$C) | 35.9 | 36.6 | 37.2 | 37.9 | 38.6 |
| Ambient Temperature ($^0$C) | 74.1 | 73.4 | 72.8 | 72.1 | 71.4 |
| IOs | 0.150 | 0.166 | 0.182 | 0.198 | 0.214 |
| Total Power | 0.256 | 0.272 | 0.289 | 0.305 | 0.321 |

Percentage downturn in Junction Temperature is 1.81%, 3.626%, 5.18% and 6.99% when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively. Percentage downturn in Ambient Temperature is 0.94%, 1.75%, 2.69% and 3.64% when we upturn output load from 60pF to 70pF, 80pF, 90pF and 100pF respectively. Percentage downturn in I/Os is 7.47%, 14.95%, 22.42% and 29.90% when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively. Percentage downturn in Total Power is 4.984%, 9.96%, 15.26% and 20.24% when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively as shown in Fig. 6.

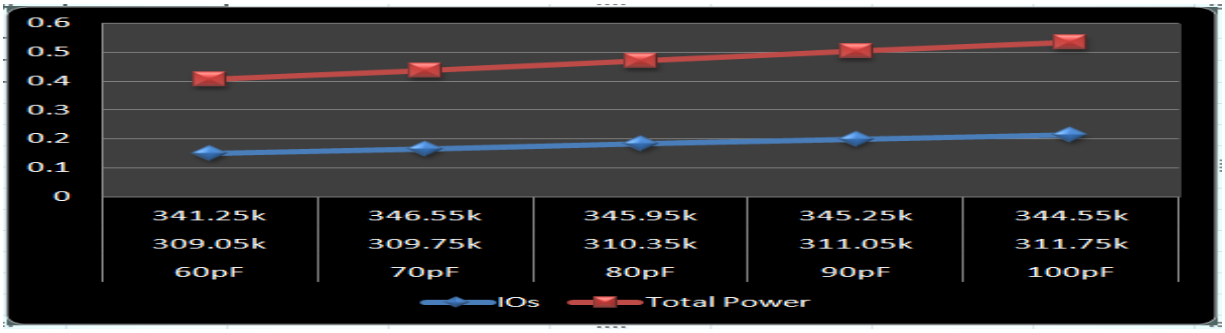


**Figure 6:** Graphical Representation 0f Temperature, I/O and Total Power at 10GHz for 60pF-100pF Capacitance

## C. **Readings at Frequency 100GHz**

Values for Junction Temperature, Ambient Temperature, IOs and Total Power are shown in Table5.

Table 5: Readings for Temperature, I/O and Total Power at 100GHz for 10pF-50pF Capacitance

| Output Load (pF) | 10 | 20 | 30 | 40 | 50 |
|---|---|---|---|---|---|
| Junction Temperature( $^0$C) | 93.6 | 100.4 | 107.2 | 114.1 | 120.9 |
| Ambient Temperature( $^0$C) | 16.4 | 9.6 | 2.8 | -4.1 | -10.9 |
| IOs | 0.693 | 0.854 | 1.015 | 1.177 | 1.338 |
| Total Power | 1.617 | 1.778 | 1.939 | 2.101 | 2.262 |

Percentage downturn in Junction Temperature is 5.62%, 11.33%, 16.95% and 22.58% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively. Percentage downturn in Ambient Temperature is 41.46%, 82.92%, 125% and 166% when we upturn output load from 10pF to 20pF, 30pF, 40pF and 50pF respectively. Percentage downturn in I/Os is 12.03%, 24.14%, 36.17% and 48.20% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively. Percentage downturn in Total Power is 7.11%, 14.27%, 21.39% and 16.66% when we downturn output load from 50pF to 40pF, 30pF, 20pF and 10pF respectively as shown in Fig. 7.

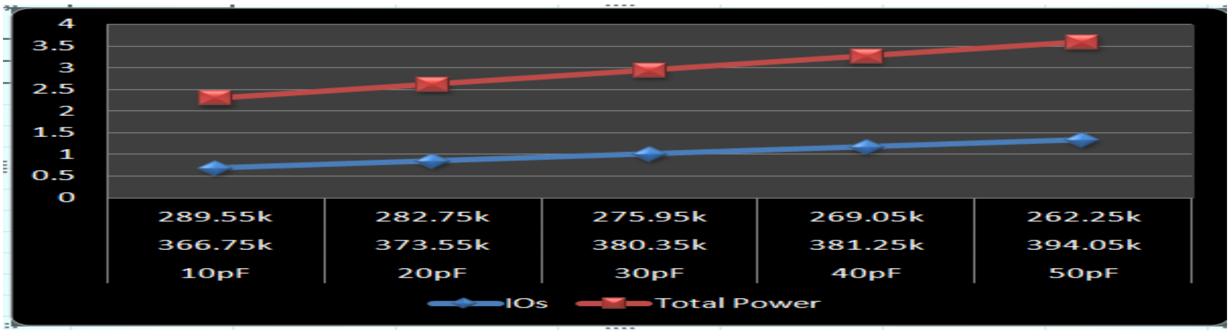


**Figure 7:** Graphical Representation 0f Temperature, I/O and Total Power at 100GHz for 10pF-50pF Capacitance

Values for Junction Temperature, Ambient Temperature, IOs and Total Power are shown in Table6.

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Table 6: Readings for Temperature, I/O and Total Power at 1GHz for 60pF-100pF Capacitance

| Output Load ( pF) | 60 | 70 | 80 | 90 | 100 |
|---|---|---|---|---|---|
| Junction Temperature ($^0$C) | 125 | 125 | 125 | 125 | 125 |
| Ambient Temperature ($^0$C) | -17.7 | -24.6 | -31.4 | -38.3 | -45.1 |
| IOs | 1.499 | 1.660 | 1.822 | 1.983 | 2.144 |
| Total Power | 2.423 | 2.584 | 2.746 | 2.907 | 3.068 |

Junction Temperature remains constant when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively. Percentage downturn in Ambient Temperature is -38.98%, -77.40%, -116.9% and -154.80% when we upturn output load from 60pF to 70pF, 80pF, 90pF and 100pF respectively. Percentage downturn in I/Os is 7.50%, 15.01%, 22.57% and 30.08% when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively. Percentage downturn in Total Power is 5.24%, 10.49%, 15.77% and 21.02% when we downturn output load from 100pF to 90pF, 80pF, 70pF and 60pF respectively as shown in Fig. 8.

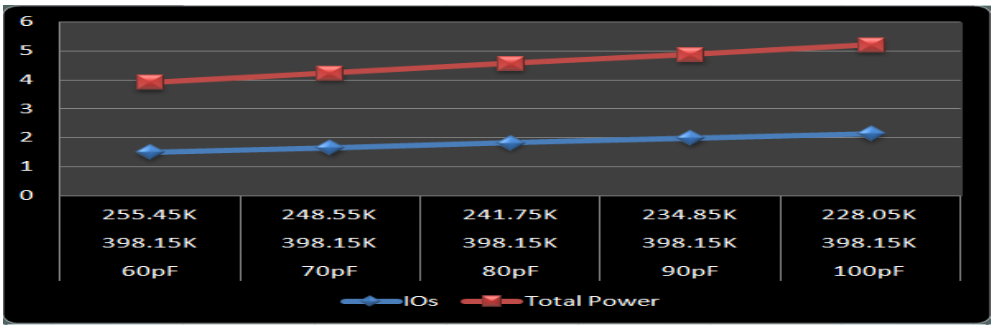


**Figure 8:** Graphical Representation 0f Temperature, I/O and Total Power at 100GHz for 60pF-100pF Capacitance

## V. CONCLUSION

The data is obtained and plotted graphically. The power reductions are obtained at three frequencies. The maximum reduction in power is 16.66%, 20.24% and 27.2% for 1GHz, 10GHz and 100GHz respectively. Also it is obtained that ambient temperature goes below 00C as shown in Table 7 and Table 8. The Junction temperature varies with output load at different frequencies but when frequency is 100GHz the Junction temperature attains a constant value i.e. 1250C even capacitance is changed from 60pF to 70pF, 80pF, 90pF and 100pF. For easy understanding and plotting temperatures properly junction temperature and ambient temperature are converted to Kelvin scale.

## VI. FUTURE SCOPE

Solar Charger Sensor is a concept that can save the life of batteries and hence have a lot of scope for future. The study needs to be done in this concept and work should be done to make this sensor energy efficient. In future the work can be done for HSTL, SSTL, Mobile DDR [5] and many more. Different field programmable gate arrays can be considered for further research. Voltage Scaling can be done. The design can also be modified so that battery performance can be made as much better as possible. Many factors such as heating, current leakage etc can be reduced by further modifications in design for future.

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