Design of Energy Efficient Receiver and Transmitter for Optical Communication

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Abstract

In the past, the modes of communication were wired, wireless and then came optical fiber communication into scenario. Nowadays, a new technology have been introduced known as Free Space Optics (FSO) that uses line of sight technology which uses lasers and photo detectors to provide optical connection. In this paper, the main aim of the author is to design an energy efficient transceiver for wireless optical communication. This paper consists of a transceiver design that is implemented on Xilinx ISE Design Suite 14.2 and results were tested on 28nm FPGA platform that is Kintex-7. Our design is based on 28nm FPGA and the device used is XC7K160T, package used is FBG676 and it is working on -3 speed grade. The advantages of FSO over fibre are it provides unlimited bandwidth, freedom from licensing, speed is very high, and high bit rate. Nowadays, bit rate is 2.5Gbps and in future it is expected to be 10Gbps. In this paper frequency scaling technique is used and frequency is varied to obtain power consumption of the Transceiver. Airflow has been kept 250 LFM and medium Heat sink. Power has been analyzed at different temperature range. At the end it can conclude that the maximum power consumption is at 2.2 GHz frequency and minimum power consumption is at 1.2 GHz. In terms of temperature maximum power is consumed at 56.7oC and minimum is consumed at 21oC.

Keywords: Energy Efficient, Free Space Optical Communication, FPGA, Transmitter, Receiver

1. Introduction

Communication requires any media to exchange information. Earlier the modes of communication were wired, wireless and then came optical fiber communication into scenario. Nowadays, a new technology have been introduced known as Free Space Optics (FSO) that uses line of sight technology which uses lasers and photo detectors to provide optical connection. Bit rate is very high that's why it is in demand these days. The approximate value of bit rate is 2.5Gbps. Nowadays dual communication is in new trend and many corporations are using this technology to enhance its capability [1]. Dual communication involves both wired as well as wireless communication [1]. Wireless communication is one of the medium of communication that involves transfer of information without using electrical signals. Wireless communication can also be called as "Unguided Media". Other technologies are also emerging day-by-day Optical-Wireless known as "FiWi" access network is a newly emerged access network

architecture that uses passive optical networks (PONs) with wireless mesh networks (WMNs) to provide low cost, high bandwidth Internet access [2]. Wireless Optical communication technology is being used to design an eco-system that comprises of wireless communication, navigation, natural user interfaces and many more [3]. Other technology that is underwater optical wireless communication uses visible light for communication purpose because of the high data rate compared to other technologies and has low path attenuation compared to radio frequency (RF) technology [4]. In this paper, the main aim of the author is to design an energy efficient [11-14] transceiver for wireless optical communication. Figure 1 represents the different modes of communication. Earlier wired communication was in trend and now due to users demand for high bit rate, low error rate and high speed wireless optical communication (FSO) is preferred over all.
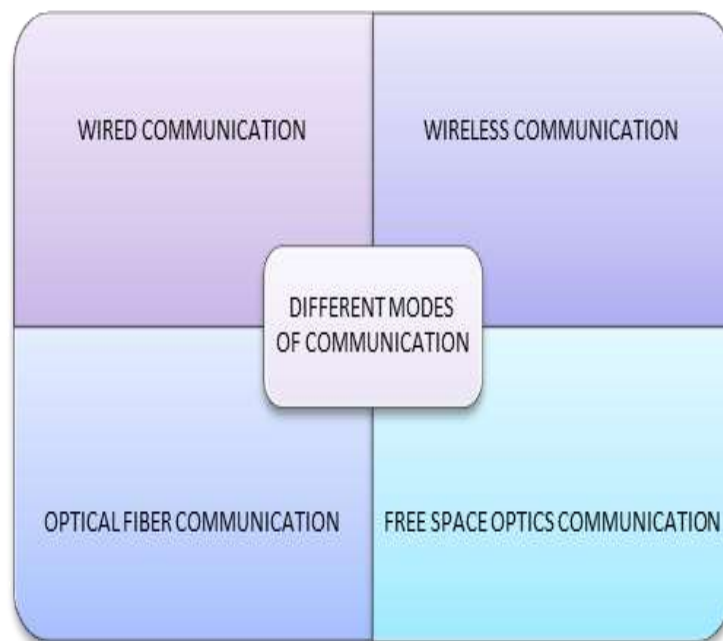

Figure 1. Different Modes of Communication

This paper consists of a transceiver design that is implemented on Xilinx ISE Design Suite 14.2 and results were tested on 28nm FPGA platform that is Kintex-7. Our design is based on 28nm FPGA and the device used is XC7K160T, package used is FBG676 and it is working on -3 speed grade. Table 1 shows different parameters in kintex-7 FPGA. Our main aim of this paper is to design a low power design for this we have taken different frequencies and calculated its power. Today's demand forces us to design the low power energy efficient device which takes lesser time for its execution.

Table 1. Different Parameters in Kintex-7 FPGA

IO pins	676
LUT Elements	101400
Flip Flop	202800
DSPS	600
Available IOBS	400
Gb transceiver	8
Block RAM	325
GTXE2 Transceiver	8
PCI Buses	1.1

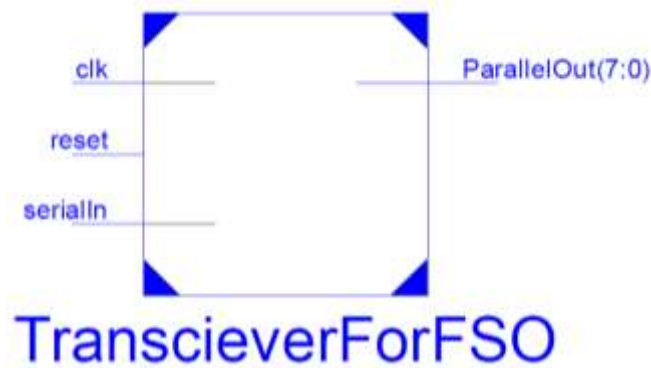| MMCMS	8
Min operating temperature	0 degree Celsius
Reference operating temperature	85 degree Celsius
Maximum operating Temperature	85 degree Celsius
Minimum operating voltage	0.97V
Reference operating Voltage	0.97V
Maximum operating Voltage	1.03V
Temperature Grade Letter	C

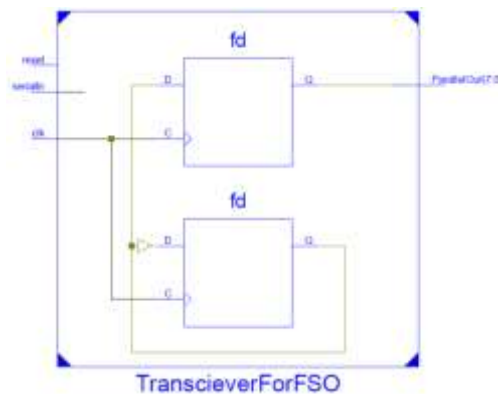**Figure 2. Symbol of Transceiver for FSO**

Figure 3. Schematic Diagram of Transceiver for FSO

Transceiver symbol as shown in Figure 2 consists of three inputs and one output. The design is clocked and works according to the clock input. The data or signal is given to the transceiver using serialIn and in taken out using parallelOut. Figure 3 shows the schematic diagram of transceiver for Free Space Optics (FSO). Free Space Optics (FSO) is a line of sight technology that does not use fibres but uses lasers and photo detectors to provide optical connections between the 2 points for communication purpose. Nowadays Free Space Optics (FSO) has become a high bandwidth alternative to fibre optic cabling [4]. The advantages of FSO over fibre are it provides unlimited bandwidth, freedom from licensing, speed is very high, and high bit rate. Nowadays, bit rate is 2.5Gbps and in future it is expected to be 10Gbps. The disadvantage of FSO over fibre is that laser power attenuation through the atmosphere, beam dispersion occurs, fog and rain affects the

radiations. FSO is also called "Free Space Photonics". Free space here means air, outer space and vacuum. The only essential requirement for Free Space Optics (FSO) or optical wireless transmission is line of sight between the two ends of the link. This technology uses two telescopes for transmission and reception. Light beams travels from one telescope to another using low power infrared lasers. Receivers are telescopic lenses that are able to collect the photon stream coming from the transmitter. Figure 4 shows the mechanism of free space optical communication. This technology is gaining popularity because it can function over distance of several kilometres. Free space optics is much more secure than other modes of communication as it cannot be detected by spectrum analyser or RF meters and interception is also very difficult.
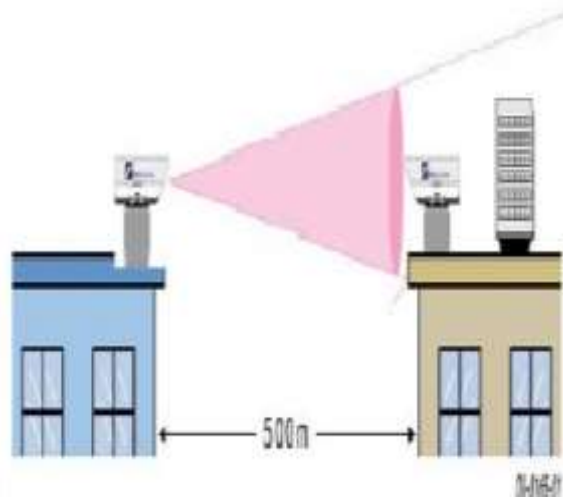

Figure 4. Free Space Optics Mechanism

Table 2. Set of Frequencies Taken in Consideration

Frequency	Mobile Set
1400 MHz	Nokia Lumia 710
1.2 GHz	Samsung Galaxy Core
2100 MHz	I phone6
1700 MHz	HTC/T
1800 MHz	Micromax X091
2.2 GHz	Sony Xperia Z1

In this paper frequency scaling technique is used and frequency is varied to obtain power consumption of the Transceiver. The frequencies taken under consideration are shown in Table 2. Different sets of mobile phones operate at different frequencies and these frequencies are considered for designing an energy efficient device. There are many other types of techniques like capacitance scaling technique [5], thermal scaling [6], clock gating [7], various design goals [8], impedance matching with different logic family, scalable implementation scheme [9] and mapping. Airflow and heat sink are main parameters while analyzing the thermal dissipation in the circuit [10]. In this work we have taken constant value of air flow and heat sink. Airflow has been kept 250 LFM and medium Heat sink. Power has been analyzed at different temperature range. Four different regions have been considered having different temperature like Furnace Creek Ranch (329.85K), Mohenjo-Daro (326.65K), median temperature of Delhi (313.15K) and standard normal temperature (294.15K).

2. POWER ANALYSIS

2.1 Power Analysis at 56.7 degree Celsius

Table 3. Power Analysis at 56.7ºCelsius

Frequency	Total Power Dissipated
1400MHz	0.159
1.2GHz	0.152
2100MHz	0.186
1700MHz	0.171
1800MHz	0.174
2.2GHz	0.188

There is 19.14% saving in total power dissipation with 1.2 GHz when compared with 2.2 GHz at 56.7 Degree Celsius as shown in Figure 5 and Table 3 .
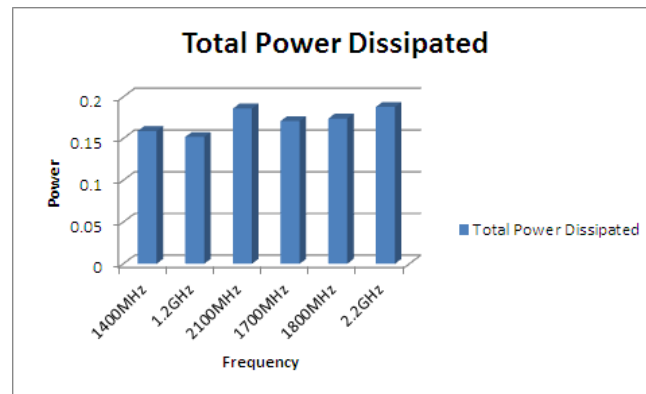

Figure 5. Power Dissipation at 56.7ºCelsius Temperature

2.2. Power Analysis at 53.5 Degree Celsius

Table 4. Power Analysis at 53.5ºCelsius

Frequency	Total Power Dissipated
1400MHz	0.148
1.2GHz	0.141
2100MHz	0.175
1700MHz	0.160
1800MHz	0.163
2.2GHz	0.177

There is 20.33% saving in total power dissipation with 1.2 GHz when compared with 2.2 GHz at 56.7 Degree Celsius as shown in Figure 6 and Table 4 .

Figure 6. Power Dissipation at 53.5ºCelsius Temperature

2.3. Power Analysis at 40 Degree Celsius

Table 5. Power Analysis at 40ºCelsius

Frequency	Total Power Dissipated
1400MHz	0.114
1.2GHz	0.107
2100MHz	0.141
1700MHz	0.126
1800MHz	0.129
2.2GHz	0.143

There is 25.17% saving in total power dissipation with 1.2 GHz when compared with 2.2 GHz at 56.7 Degree Celsius as shown in Figure 7 and Table 5.
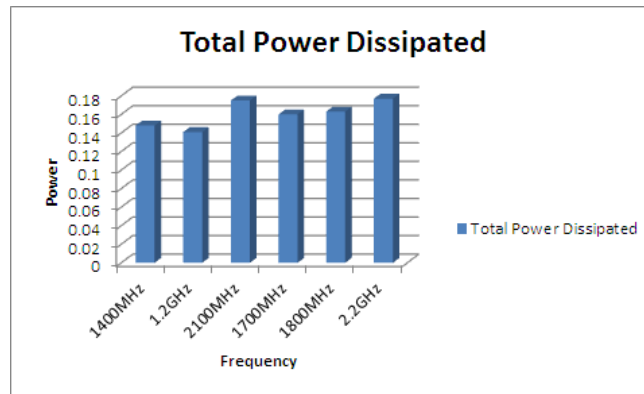

Figure 7. Power Dissipation at 40ºCelsius Temperature

2.4. Power Analysis at 21 Degree Celsius

Table 6. Power Analysis at 21°Celsius

Frequency	Total Power Dissipated
1400MHz	0.090
1.2GHz	0.083
2100MHz	0.118
1700MHz	0.102
1800MHz	0.105
2.2GHz	0.119

There is 30.25% saving in total power dissipation with 1.2 GHz when compared with 2.2 GHz at 56.7 Degree Celsius as shown in Figure 8 and Table 6.
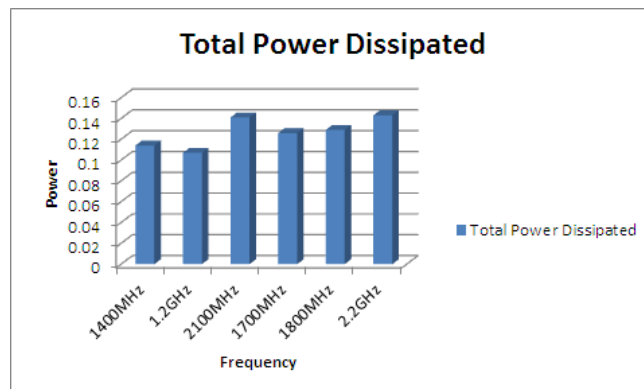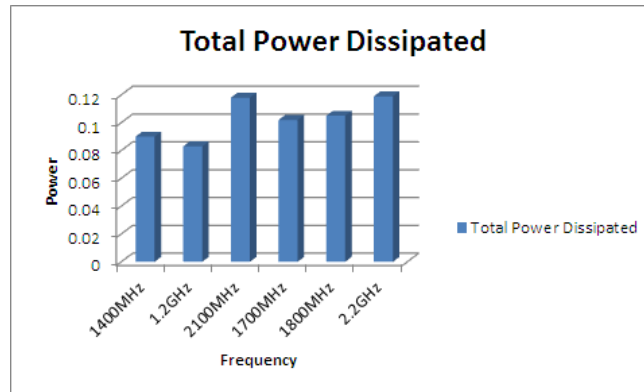

Figure 8. Power Dissipation at 21°Celsius Temperature

2.5. Power Consumption at Different Frequencies at Different Temperatures

Table 7. IO Power Analysis for Different Frequencies at Different Temperatures

Frequency	56.7°C	53.5°C	40°C	21°C
1400MHz	0.159	0.148	0.114	0.090
1.2GHz	0.152	0.141	0.107	0.083
2100MHz	0.186	0.175	0.141	0.118
1700MHz	0.171	0.160	0.126	0.102
1800MHz	0.174	0.163	0.129	0.105
2.2GHz	0.188	0.177	0.143	0.119

From Table 7 and Figure 9 it can conclude that the maximum power consumption is at 2.2 GHz frequency and minimum power consumption is at 1.2 GHz. In terms of temperature maximum power is consumed at 56.7°C and minimum is consumed at 21°C.
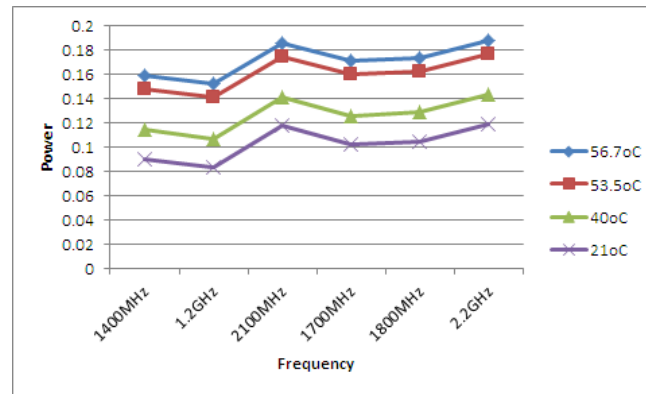
Figure 9. IO Power Analysis for Different Frequencies at Different Temperatures

3. Conclusion

The design is low power energy efficient and the code has been implemented in Xilinx ISE Design Suite 14.2 and results were tested on 28nm FPGA platform. This transceiver design consists of three inputs and one output. The device has been clocked and tested at different frequency levels at different temperature ranges. In this paper thermal analysis has been done to make our device energy efficient device. Four different values of temperature of four different regions have been considered like Furnace Creek Ranch (329.85K), Mohenjo-Daro (326.65K), median temperature of Delhi (313.15K) and standard normal temperature (294.15K). At the end it can conclude that the maximum power consumption is at 2.2 GHz frequency and minimum power consumption is at 1.2 GHz. In terms of temperature maximum power is consumed at 56.7oC and minimum is consumed at 21oC.

4. Future Scope

The future scope of "Energy Efficient Receiver and Transmitter Design for Free Space Optical Communication" on 28nm FPGA is that we can also implement this design on 22nm or 18 nm FPGA. The FPGA family used in this paper is Kintex7. Different FPGA families like automotive Artix7, automotive Coolrunner2, automotive Spartan, automotive Spartan-3A DSP, automotive Spartan 3A, automotive Spartan 3E, automotive Spartan6, Spartan3, Spartan3E can also be used. Here, Thermal Aware and frequency scaling technique has been implemented by varying the value of temperature at different frequency. The design can be redesigned with other energy efficient technique like capacitance scaling, clock gating, and impedance matching with different logic family, and mapping. The analysis in this paper is done only at 1400 MHz, 1.2 GHz, 1700 MHz, 1800 MHz, 2100 MHz and 2.2 GHz. Frequency range can be varied to make the design more energy efficient. IO Standards can be introduced to enhance the capability of the device or to make it more efficient. IO standards like LVCMOS, SSTL, HSTL MOBILE_DDR and many more can be used.

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