Temperature Regulations of Pseudo Noise Generator Based Optical Transmitter using Airflow and Heat Sink Profile

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Abstract. For any electronic device, junction temperature is the final temperature after that device became dead. In this paper the temperature of PN based optical transmitter is regulated using heat sink and airflow. Target device is operated at different operating frequencies for LVCMOS IO standard (LVCMOS12, LVCMOS15, LVCMOS18 and LVCMOS25) with two airflow values (250 MFL and 500MFL) and Heat sink values (Low profile, Medium profile and high profile). There is overall 20% reduction at 1000GHz the reduction for LVCMOS12 and for LVCMOS25 71% reduction is recorded for junction temperature. At all frequencies the heat sink profile and airflow significantly reduces the junction temperatures for target devices using LVCMOS25 IO standard. This design makes the target device, energy efficient. Finally this system will be integrated with other optical components to make optical communication system green. Xilinx ISE14.7.1.2 design tool is used to perform the experiment.

Introduction

Today's FPGA provides the facilities for the communication systems to mount system on chip (SoC). This configuration help the electronic circuits to be energy efficient in terms of voltage, frequency and thermal efficient [1]. Ambient temperature scaling technique has been used to design thermal aware frame buffer [2,3,4]. In our designed devices,PN generator produces the sequence of pseudorandom binary numbers. This sequence is used in optical transmitter when the data is modulated at speed of light. The sequence is mainly generated by two configurations (SSRG or Fibonacci) [6,7, 8, 9]. In telecommunication system the PN sequence is used to generate the input bit stream for digital communication, spread spectrum in CDMA and the bit pattern for laser source for optical communications [10]. Figure 1 shows the design for our PN generator for optical transmitter using SSRG method, which is less temperature sensitive then Fibonacci generator. In FPGAs the Vertex™ series-6 is use to configure 16-bit shift register with one Look up Table to generate the PN sequence.

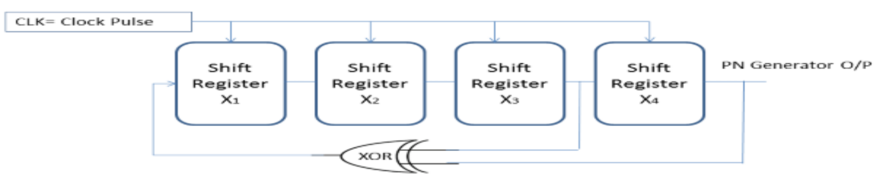

Figure 1.Our design for Pseudo Noise generator for optical Transmitter using SSRG method

Temperatures of Electronic Devices. The temperature at which electronic device operates usually is ambient temperature. The Junction temperature is the temperature at which electronic devices become dead. Junction temperature tells about the life of a device [11,12]. In order to drive electronic device in safe mode, junctiontemperature should be less than 125^{o}C. The normal operating temperature is directly proportional to junction temperature [13,14]. Heat will continue to flow from device to surrounding environment (ambience). The estimation of the chip-junction temperature is shown in Eq.1:

$$T_{i=}T + (R \, * \, P) \qquad (1)$$

Where

─ Tis ambient temperature for the package and T_i is Junction temperature for the package (℃)

─ Ris junction to ambient thermal resistance (℃ / W)

─ Pis power dissipation in package (W)

The undefined change in junction temperature may extinguish device or may cause issue like unreliability [2, 3]. In order to design an efficient flow of the system, the junction temperature is regulated, by calculating junction temperature values for different values of airflow and heat sink profile [4,5].

Heat Sink Profile. A heat sink keeps a device at a temperature below the definiteendorsed operating temperature [12]. With a heat sink, heat from a device flows from the junction to the case, then from the case to the heat sink, and lastly from the heat sink to ambient air [6]. The goal is to reduce thermal resistance.

Airflow. An airflow pulse ionization chamber system supported with FPGA-based electronic technique for measurement of alpha-radioactivity in atmosphere [7]. The FPGA can heat the air in its local area, thereby decreasing the dependency of thermal [8]. MFL stands for Linear Feet per Minute.

Relationship between Junction Temperature, Airflow and Heat Sink Profile. Figure 2 shows, that a certain device is operated at room temperature with junction temperature, when airflow and heat sink profile is increase the junction temperature decreases. Using this relation, the junction temperature of target device is regulated.

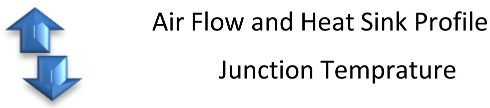

Figure 2. Relationship between Heat Sink, Airflow and Junction temperature

Methodology

In this work, junction temperature of Pseudo noise generator based optical transmitter is regulated using different IO standards of LVCMOS family. The value of junction temperature has taken for each IO standard (LVCMOS12, LVCMOS15, LVCMOS18 and LVCMOS25. The junction temperature is changing with different values of heat sink profile and airflow led two different IO standards available on FPGA by changing the airflow and heat sink profile using different operating frequencies. Airflow of the device Virtex-6 is changing with two values (250 LMF and second is 500LMF), while heat sink profile is changing with three profiles low profile, medium profile and high profile. The effects of these two parameters (Airflow and heat sink profile) on junction temperature is analysed. In order to regulate the junction temperature of our PN generator based optical transmitter is operated using designedPN generator at 1GHz, 10GHz, 100GHz and 100GHZ with different air flow and heat sink values for LVCMOS I/O standard available on FPGA.This proposed system is fully integrated with other optical components to make PN generator green or energy efficient [9, 10,11, 13].

Low Voltage Complementary Metal oxide Semiconductor (LVCMOS). LVCMOS is a widely used switching standard implemented in CMOS transistors. This standard is defined by

JEDEC (JESD 8-5). The LVCMOS standards supported in Virtex-6 FPGAs are: LVCMOS12, LVCMOS15, LVCMOS18, and LVCMOS25.

Junction Temperature in °C for IO standard LVCMOS12. The Table 1contains the different values of junction temperature for operating frequencies (1GHz, 10GHz, 100GHz and 1000GHz) with different values of Airflow and heat sink profile. Selecting the heat sink at high profile with maximum and airflow of 500MFL, maximum reduction of 20% in comparison with heat sink at low profile and airflow of 250MFL for 1000GHz. At 1GHz maximum reduction of 4%. We observed that heat sink and airflow significantly reduces the junction temperature at high frequency.

Table 1: Junction temperature of LVCMOS12 for heat sink and airflow

Air Flow	Heat Sink Profile	Operating Frequencies			
		1.0GHz	10GHz	100GHz	1000GHz
250LMF	Low Profile	32.9	34.1	45.5	125
	Medium Profile	32.5	33.4	43	125
	High Profile	32.3	33.1	41.8	125
500LMF	Low Profile	32.2	33	41.4	125
	Medium Profile	31.8	32.5	39.3	108
	High Profile	31.6	32.2	38.2	99

Table 2: Junction temperature of LVCMOS15 for heat sink and airflow

Air Flow	Heat Sink Profile	Operating Frequencies			
		1.0GHz	10GHz	100GHz	1000GHz
250LMF	Low Profile	32.8	34	45.4	125
	Medium Profile	32.4	33.3	42.9	125
	High Profile	32.2	33	41.7	125
500LMF	Low Profile	32.1	32.9	41.3	125
	Medium Profile	31.7	32.4	39.2	108
	High Profile	31.5	32.1	38.1	98

Junction Temperature in °Cfor IO standard LVCMOS15. Table 2 shows, the junction temperature values for two values of air flow (250 and 500MFL) and heat sink profile (Low, Medium and High). At different frequencies of 1GHz, 10GHz, 100GHz and 1000GHz the reduction in junction temperature is 4%, 5%, 16% and 21% respectively in comparison with Airflow 250MFL and low heat sink profile with Airflow 500MFL and high profile heat sink.

Junction Temperature in °C for IO standard LVCMOS18. The Table 3 describes, the junction temperature values for two values of air flow (250 and 500MFL) and heat sink profile (Low, Medium and High). At different frequencies of 1GHz, 10GHz, 100GHz and 1000GHz the reduction in junction temperature is investigated as; 3%, 6%, 35% and 63% respectively in comparison with Airflow 250MFL and low heat sink profile with Airflow 500MFL and high profile heat sink.

Table 3: Junction temperature of LVCMOS18 for heat sink and airflow

Air Flow	Heat Sink Profile	Operating Frequencies			
		1.0GHz	10GHz	100GHz	1000GHz
250LMF	Low Profile	31.9	33.1	49.5	125
	Medium Profile	31.5	33	41	78.7
	High Profile	31.3	32.7	40.6	65.1
500LMF	Low Profile	31.2	32	39	61.4
	Medium Profile	31	31.6	33.6	50.1
	High Profile	30.8	31	32	46

Junction Temperature in °C for IO standard LVCMOS25. The Table 4, shows that the junction temperature values for two values of air flow (250 and 500MFL) and heat sink profile

(Low, Medium and High). At different frequencies of 1GHz, 10GHz, 100GHz and 1000GHz the reduction in junction temperature is 8%, 12%, 15% and 71% respectively in comparison with Airflow 250MFL and low heat sink profile with Airflow 500MFL and high profile heat sink.

Table 4: Junction temperature of LVCMOS25 for heat sink and airflow

Air Flow	Heat Sink Profile	Operating Frequencies			
		1.0GHz	10GHz	100GHz	1000GHz
250LMF	Low Profile	35.7	35.4	47	125
	Medium Profile	34.8	34.4	45.2	90
	High Profile	34.3	33.9	43.1	83.2
500LMF	Low Profile	34.2	33.3	42	81.9
	Medium Profile	33.4	32	41.3	75.3
	High Profile	33	31	40	36

Results and Discussion

PN generator based optical transmitter is demonstrated on FPGA vertex-6 at different operating frequencies (1GHz, 10GHz, 100GHz, and 1000GHz). Initially the junction temperature is 31.4^{o}C. When device is operated for different IO standard by the increase in frequency the junction temperature raised beyond the dead value of device. The heat sink and airflow regulates the junction temperature even when the devices are working on high frequency of 1000GHz. When device is operated at 1GHz using LVCMOS12 there is reduction in 2% in comparison with airflow 250MFL for heat sink low profile with airflow 500MFL for heat sink high profile.Similarly for LVCMOS12 at 1GHz there is reduction in 3.5% in comparison with airflow 250MFL for heat sink low profile with airflow 5000MFL for heat sink high profile. The reduction is 4% and 3.5% when device is operated at 1GHz using LVCMOS25. At 1000GHz the reduction for LVCMOS12, the reduction in junction temperature is 0% and 20% in comparison with airflow 250MFL for heat sink low profile with airflow 500MFL for heat sink high profile. The reduction is 33% and 56% when device is operated at 1000GHz using LVCMOS25. Therefore at 1000GHz operating frequency, LVCMOS25 is the best choice to use for PN generator based optical transmitter with heat sink profile high and airflow 500MFL. As shown in figure 3,LVCMOS12 has the peak junction temperature and slope is constant for different heat sink and airflow values for different frequencies. While the LVCMOS25 has significant changes in junction temperature for different values of heat sink and airflow values at different frequencies. The change in slope is negligible in case of LVCMOS12 and change in slope of junction temperature for LVCMOS25 is quite appreciated for reducing the junction temperature of target device.

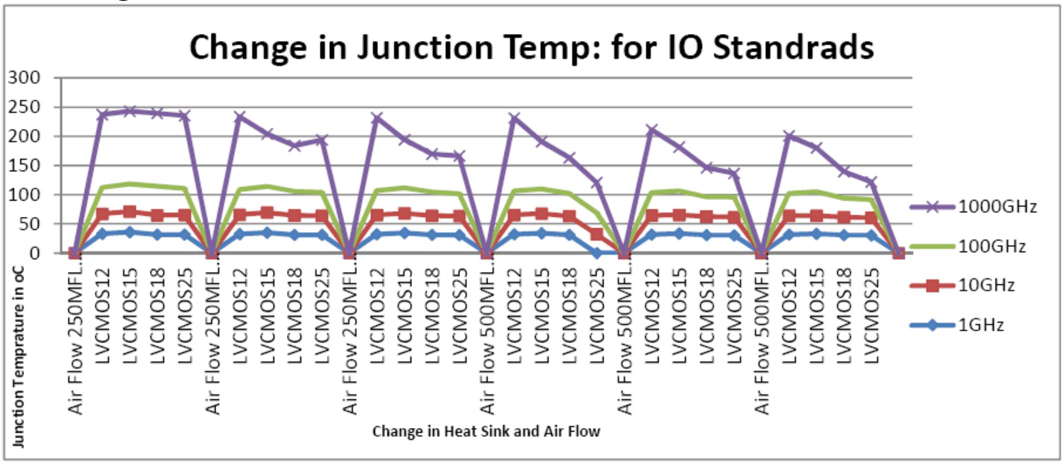

Figure 3. Change in Junction Temperature for different heat sink and airflow with IO standards

Conclusion

Significant reduction in junction temperature of target device using LVCMOS25 is achieved, with 71% using airflow 500MFL and high profile heat sink value at 1THz frequency. Therefore, LVCMOS25 is energy efficient design for PN generator for optical transmitter in the final design when operating at high frequency of 1THz.Finally this energy efficient PN generator for optical communication is integrated with other optical components such as optical modulators, receiver for green optical communication. Here only one component of optical communication is enabled for green communication. In future, we can redesign all optical communication components to make the optical communications system green.

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