Temperature Control of Pseudo Noise Generator Based Optical Transmitter using Airflow and Heat Sink Profile at High Speed Transceiver Logic IO Standard

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***Abstract*—Junction temperature is the final temperature of any device, after that device became dead. In this paper, junction temperature of target device i.e. Pseudo Noise sequence random generator based optical transmitter is controlled using heat sink profile and airflow. Heat sink and airflow are the cooling techniques for thermal efficient design on FPGA. We operated target device at high speed transceiver logic (HSTL) on FPGA at 1, 10,100 and 1000 (GHz) operating frequency. Each IO standard is examined with two airflow values (250 MFL and 500MFL) and Heat sink values (Low profile, Medium profile and high profile). For HSTL_I the reduction in junction temperature is (4%, 5%, 16% and 20%), HSTL_III (2%, 4%, 40%, and 67%), HSTL_I_18 (2%, 15%, 59%, and 68%), HSTL_III_18 (2.4%, 19%, 62%, and 74%) is recorded at respective frequencies. Significant reduction of 74% in junction temperature is observed at 1000GHz using HSTL_III_18. We conclude that for frequencies above 10GHz the heat sink profile and air flow significantly reduces the junction temperature using HSTL_III_18. This design makes the target device, energy efficient, 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.**

***Index Terms*—junction temperature, heat sink profile, airflow, IO standards, Field programming Gate arrays, Pseudo Noise Generator, optical transmitter.**

I. Introduction

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) [1]-[3]. 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 [4]. In optical communication systems PN sequences is interrupted by many parameters such as chromatic dispersion [5], chromatic dispersion in time domain [5], chromatic dispersion in frequency domain [6]. Fig. 1 shows, the design for our PN generator for optical transmitter using SSRG method which is less temperature sensitive then Fibonacci generator. Designed PN generator for optical transmitter using SSRG method is implemented on FPGA. In FPGAs the Vertex™ series-6 is use to configure 16-bit shift register with one Look up Table to generate the PN sequence [7].

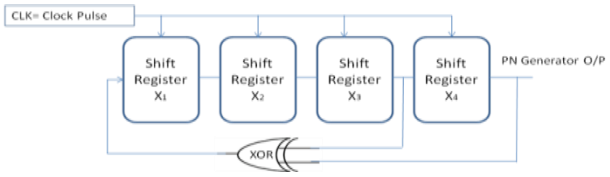

Figure 1. Our design for pseudo noise generator for optical transmitter using SSRG method

II. Junction and Ambient Temperature

Ambient temperature of the electronic device is the temperature at which device usually operates. The Junction temperature is the temperature at which electronic devices become dead. Junction temperature tells about the life of a device [8]. Mostly it is recommended that junction temperature should be less than 125°C. The ambient temperature is directly proportional to junction temperature [9], [10]. Heat will continue to flow from device to surrounding environment (ambience). The estimation of the chip-junction temperature is shown in (1) [10]:

$$T_J = T_A + (R_j \times P_D) \quad (1)$$

where

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- T_A is ambient temperature for the package (℃)
- R_J is junction to ambient thermal resistance (℃ / W)
- P_D is power dissipation in package (W)
- T_J is Junction temperature for the package (℃)

The uncertain change in junction temperature may destroy device or may cause issue like unreliability [11], [12]. In order to design an efficient flow of the system, we are controlling T_J by calculating T_J values for different values of airflow and heat sink profile [13].

A. Heat Sink Profile

A heat sink keeps a device at a temperature below the specified recommended operating temperature [14]. 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 [15]. The goal is to reduce thermal resistance [16], [17].

B. Airflow

An airflow pulse ionization chamber system supported with FPGA-based electronic technique for measurement of alpha-radioactivity in atmosphere [1]-[3]. The unit of airflow is MFL stands for Linear Feet per Minute.

III. Methodology

In this work, we are controlling the Junction temperature of Pseudo noise generator based optical transmitter using heat sink profile and air flow, because when values of these both parameters is increased the junction temperature is decreased. The PN generator based optical transmitter is operated under different IO standards of HSTL family. 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 as shown in Fig. 2. This proposed system is fully integrated with other optical components to make PN generator green or energy efficient. The best value will be selected so for to make PN generator based optical transmitter energy efficient.

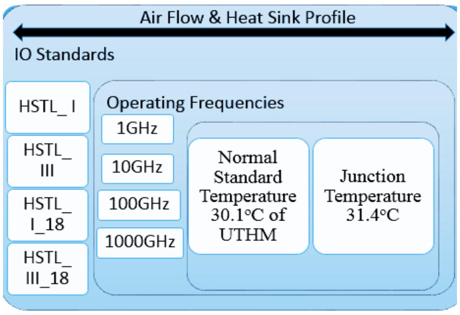

Figure 2. Compatibility test conditions for energy efficient PN generator for optical transmitter.

A. HSTL (High-Speed Transceiver Logic)

The High-Speed Transceiver Logic (HSTL) standard is a general purpose high-speed bus standard sponsored by IBM (EIA/JESD8-6. To support clocking high speed memory interfaces, a differential version of this standard was added. Virtex-6 FPGA I/O supports all four classes HSTL_ I, HSTL_ III, HSTL_ I_18, HSTL_ III_18.

B. Junction Temperature for IO Standard HSTL_I

The Table I contains the different values of junction temperature for operating frequencies 1GHz, 10GHz, 100GHz and 1000GHz with different values of Airflow and heat sink profile. We analyzed that by selecting the heat sink at high profile with maximum and airflow of 500MFL, we have maximum reduction of 4%, 5%, 16% and 20% in junction temperature in comparison with heat sink at low profile and airflow of 250MFL for respective frequencies.

TABLE I. Junction Temperature in {°C}of HSTL_I for Heat Sink and Airflow

Air Flow	Heat Sink Profile	Operating Frequencies			
		1.0GHz	10GHz	100GHz	1000GHz
250LMF	Low Profile	33	34.1	45.6	125
	Medium Profile	32.5	33.5	43.1	125
	High Profile	32.3	33.2	41.9	125
500LMF	Low Profile	32.2	33.1	41.5	125
	Medium Profile	31.8	32.5	39.3	108.1
	High Profile	31.6	32.2	38.3	99.1

C. Junction Temperature for IO Standard HSTL_ III

Table II shows the junction temperature values at frequencies of 1GHz, 10GHz, 100GHz and 1000GHz there is reduction in junction temperature of 2%, 4%, 40% and 67%.

TABLE II. Junction Temperature in {°C } of HSTL_ III for Heat Sink and Airflow

Air Flow	Heat Sink Profile	Operating Frequencies			
		1.0GHz	10GHz	100GHz	1000GHz
250LMF	Low Profile	32.4	33.9	56.1	125
	Medium Profile	32.2	33.5	46.4	125
	High Profile	32	33.1	44.5	125
500LMF	Low Profile	31.9	33.1	40.3	108.1
	Medium Profile	31.7	32.7	39.6	68
	High Profile	31.5	32.4	33.1	41

D. Junction Temperature for IO Standard HSTL_ I_18

Table III describes the junction temperature values at operating frequencies 1GHz, 10GHz, 100GHz and 1000GHz the reduction in junction temperature is of 2%, 15%, 59% and 68% respectively.

TABLE III. JUNCTION TEMPERATURE IN {^{o}C } OF HSTL_ I_18 FOR HEAT SINK AND AIRFLOW

Air Flow	heat sink profile	Operating Frequencies			
		1.0GHz	10GHz	100GHz	1000GHz
250LMF	low profile	32	37.3	79	125
	medium profile	31.8	36.1	63.1	108.1
	high profile	31.4	34.2	55.9	68
500LMF	Low Profile	31.4	32.2	47.3	58.2
	Medium Profile	31.4	31.9	36.3	47.1
	High Profile	31.4	31.4	32.2	40.1

E. Junction Temperature for IO Standard HSTL_ III_18

Table IV shows, that the junction temperature values for two values of air flow (250 and 500MFL) and heat sink profile (Low, Medium and High). At frequencies of 1GHz, 10GHz, 100GHz and 1000GHz the junction temperature reduces 2.4%, 19%, 62% and 74% respectively.

TABLE IV. JUNCTION TEMPERATURE IN {^{o}C } OF HSTL_ III_18 FOR HEAT SINK AND AIRFLOW

Air Flow	Heat Sink Profile	Operating Frequencies			
		1.0GHz	10GHz	100GHz	1000GHz
250LMF	Low Profile	32.3	40.1	85	125
	Medium Profile	31.8	38.3	72.3	90.1
	High Profile	31.6	36.2	63.9	75
500LMF	Low Profile	31.3	34.2	42.3	59.3
	Medium Profile	31.4	33.9	38.3	42.1
	High Profile	31.4	32.4	31.9	32.1

IV. RESULTS AND DISCUSSION

PN generator based optical transmitter is integrated with high speed transceiver logic devices on FPGA vertex-6 at 1GHz, 10GHz, 100GHz, and 1000GHz frequencies. The device is performed under room temperature of 30.1^{o}C with junction temperature 31.4^{o}C. When frequencies is increased the junction temperatures almost reaches to its dead value. Junction temperature is controlled by heat sink and airflow for different IO standard of High speed logic.

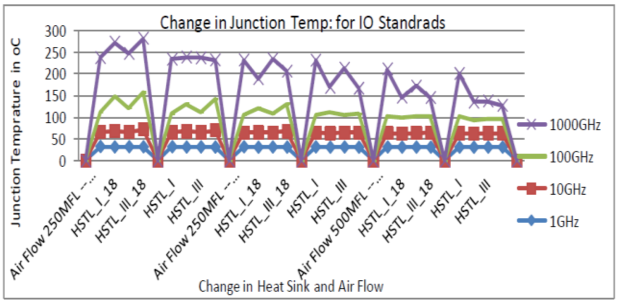

Figure 3. Change in junction temperature for different heat sink and airflow with IO standards

As shown in Fig. 3, HSTL_ I has the peak junction temperature and slope is constant for different heat sink and airflow values for different frequencies. While for HSTL_ III_18, there is a significant change in junction temperature for different values of heat sink and airflow values at different frequencies. The change in slope is negligible in case of HSTL_I and change in slope of junction temperature for HSTL_ III_18 is quite appreciated for reducing the junction temperature of target device.

V. CONCLUSION

We conclude that for high speed transceiver logic interface of PN based optical transmitter the HSTL_ III_18 IO standard gives optimum performance in reduction of junction temperature, when operating at higher frequencies of 100GHz and 1000GHz. The results conclude that Energy-Efficient PN generator based optical transmitter is achieved for high frequency operation for 10GHz to 1000GHz by changing the heat sink profile and airflow. 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.

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