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A Comparative Analysis of Transimpedance Amplifier in Giga-bit Optical Communication

Dwivedi Praveen, Singh Amit Kumar and R.G. Sangeetha
Dept. of Electrical Engineering, School of Engineering, Shiv Nadar University, Gautam Budh Nagar, INDIA

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Abstract

In this paper a comparative analysis of transimpedance amplifiers in three different technologies, 0.8 µm BICMOS, 2.5 GHz BJT and 0.8 µm CMOS has been presented. Based on their standard device parameters such as gain, bandwidth and noise density the corresponding characteristics such as RF spectrum, Output Power, time domain analysis, Bit error response and Eye diagram were analysed. The core of this analysis has been the receiver part of the optical communication in which the output of the photodiode is applied as an input to the transimpedance amplifier. All the characteristics presented here have thus been measured at the output of the Transimpedance amplifier. All the simulations presented here in this paper have been simulated using OptiSystem 11.0.

Keywords: Optical preamplifier, Transimpedance Amplifier, optical communication, photo diode, BICMOS, CMOS.

Introduction

A transimpedance amplifier finds use in audio applications, ban gap reference circuits, instrumentation systems and various other electronic circuits but it is its use in receivers of optical communication where it leads. The design of an optoelectronic front end which consists of photo detector diode and transimpedance amplifier is a challenging task. High speed transimpedance amplifiers (TIAs) used in optical fiber receivers present design challenges in the form of trade-offs between input noise, current, speed, transimpedance gain, power dissipation, and supply voltage[1]. The function of a transimpedance amplifier is to convert the generated current from photo detector diode into voltage signal with a level that is capable of driving an automatic gain controller post amplifier circuit[2]. Various configurations of transimpedance amplifier were used to compute the performance of transimpedance amplifier in CMOS optical preamplifier design using graphical circuit analysis[3]. Since up gradation of telecommunication services have not taken place in various regions across the world mainly due to the financial and geographical issues. Optical communication continues to be used in several technologies simultaneously. A comparative study will give an insight into the advantages of one technology over the other. Based on these studies, wherever possible telecommunication services can be updated by the service providers.

Analysis

The closed loop gain of transimpedance amplifier is given by the below equation.

$$\frac{V_{out}}{i_{pd}} = -\frac{A}{1+A} R_f \approx -R_f$$

Where A= open loop gain of transimpedance amplifier, R_f = feedback resistance, I_{pd} = photo diode current generated by avalanche photo diode, V_{out} = output voltage of transimpedance amplifier. For Avalanche photodiode the following parameters were used.

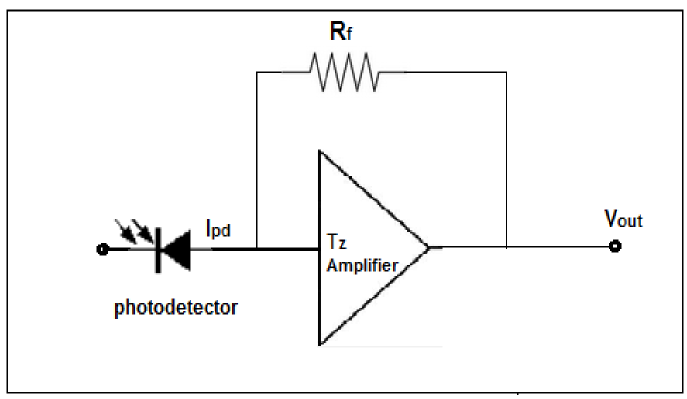

Figure-1
Optical preamplifier based on transimpedance Amplifier

Table- 1
Avalanche photodiode parameters

Name	Value	Units	Mode
Gain	3.0	Unitless	Normal
Responsivity	1.0	A/W	Normal
Ionization ratio	0.9	Unitless	Normal
Dark Current	10.0	nA	Normal

Operation of the Given Simulation Model

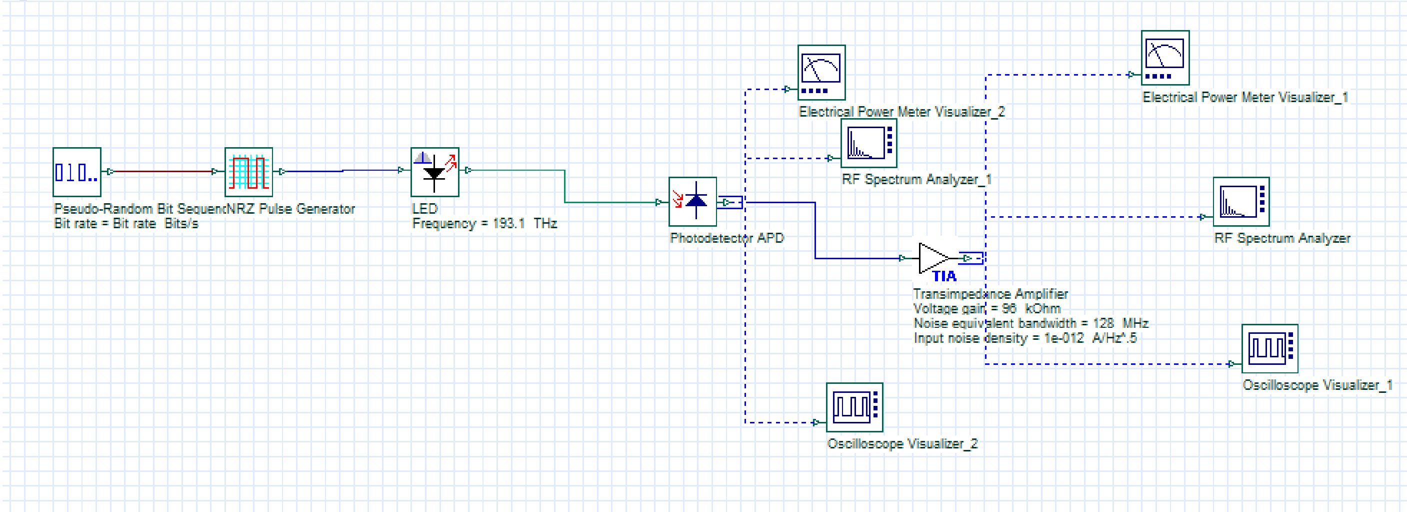

Figure- 2

Snapshot of simulation model for the measurement of RF spectrum, output power and time domain analysis of the transimpedance amplifier

With reference to figure 2, the input binary Pseudo-Random Bit Sequence is applied to the NRZ Pulse Generator. The output of the NRZ Pulse Generator acts as an electrical input to the LED. An Optical signal of frequency 193.1 THz obtained from the LED passes through the optical waveguide and acts as an input to the Avalanche photo diode (photodetector) on the receiver end. The Avalanche Photodiode detects the optical signal and converts it into electrical current signal that acts as an input to the transimpedance amplifier. The transimpedance amplifier converts an input electrical current signal into an output voltage signal. Various parameters such as gain, bandwidth and noise density of the transimpedance amplifiers in three different technologies, 0.8 µm BICMOS, 2.5 GHz BJT and 0.8 µm CMOS were varied. Their corresponding characteristics such as RF spectrum, Output Power and time domain analysis were then measured.

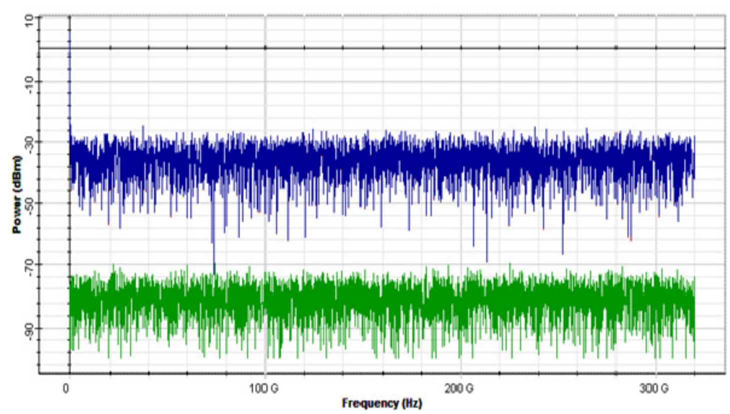

Figure-3

Input power vs. Frequency plot for Transimpedance amplifier

Table-2

Transimpedance Amplifier parameters

Transimpedance Amplifier	Gain (KOhm)	Bandwidth (Mhz)	Noise Density (Pa/$\sqrt{hz}$)
0.8µm BICMOS[3]	98	128	1.17
2.5 GHz BJT[4]	1	220	4
0.8 µm CMOS[5]	150	120	1

Tabulation and Plots: As can be seen from the table-2, we have used parameters such as gain, bandwidth and noise density of transimpedance amplifier in three different technologies namely 0.8 µm BICMOS, 2.5 GHz BJT and 0.8 µm CMOS. The 0.8 µm BICMOS technology has the intermediate values of gain, bandwidth as well as noise density while 2.5 GHz BJT has the least gain and maximum noise density.

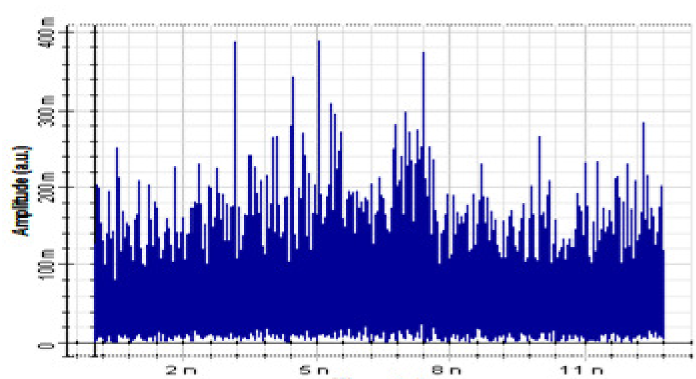

Figure-4

Input amplitude vs. Time plot for Transimpedance amplifier

Figure- 3 and figure- 4 represent the input waveforms that were applied to the transimpedance amplifier. The range of input power is between -70 to -30 dBm and the range of noise power is -70 to -100 dBm. In the time domain plot the range of amplitude of the input electrical signal is 0 to 380mA.

0.8 µm BICMOS – Output Plots: In the case of 0.8 µm BICMOS Transimpedance Amplifier corresponding to the respective input signals the output power range was found in the range 30dBm to 75dBm.The corresponding output amplitude range was found to lie between 0 to 38kV.

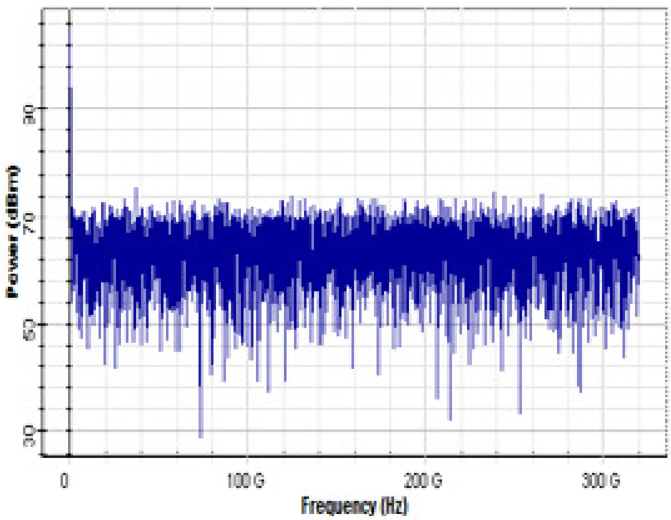

Figure-5
Output power vs. Frequency plot for 0.8 µm BICMOS for Transimpedance Amplifier

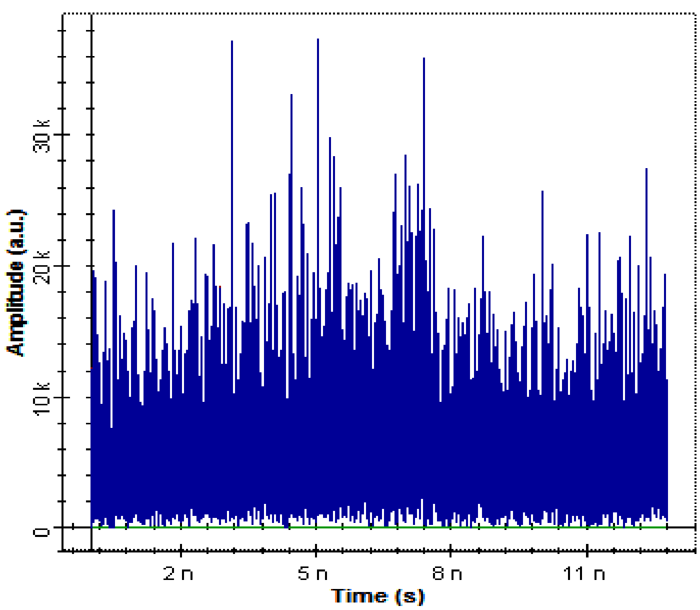

Figure-6
Output Amplitude vs. Time plot for 0.8 µm BICMOS for Transimpedance Amplifier

Ghz Bipolar Transimpedance Amplifier Output Plots: In the case of 2.5Ghz Bipolar tranimpedance amplifier corresponding to the respective input signals applied the output power range was -20dBm to 35dBm. The corresponding output amplitude range was found to lie between 0 to 350V.

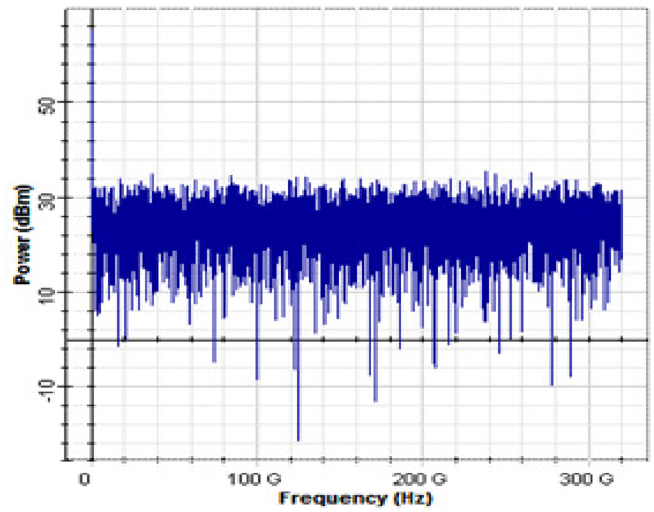

Figure-7
Output power vs. Frequency plot for 2.5Ghz Bipolar transimpedance amplifier

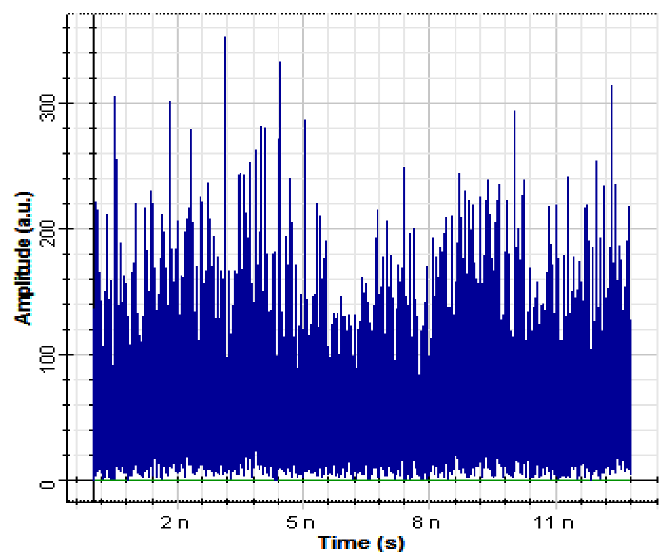

Figure-8
Output Amplitude vs. Time plot for 2.5Ghz Bipolar transimpedance amplifier

0.8 µm CMOS Transimpedance Amplifier Output Plots: In the case of 0.8 µm CMOS transimpedance amplifier corresponding to the respective input signals applied the output power range is 30dBm to 80dBm.the corresponding output amplitude range was found to lie between 0 to 58kV.

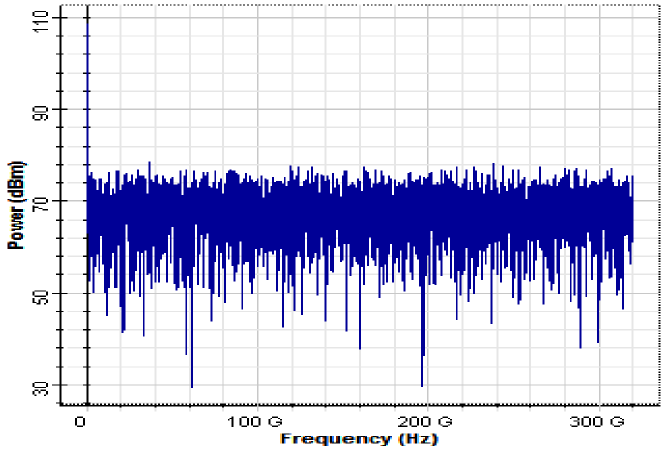

Figure-9
Output power vs. Frequency plot for 0.8µm CMOS transimpedance amplifier.

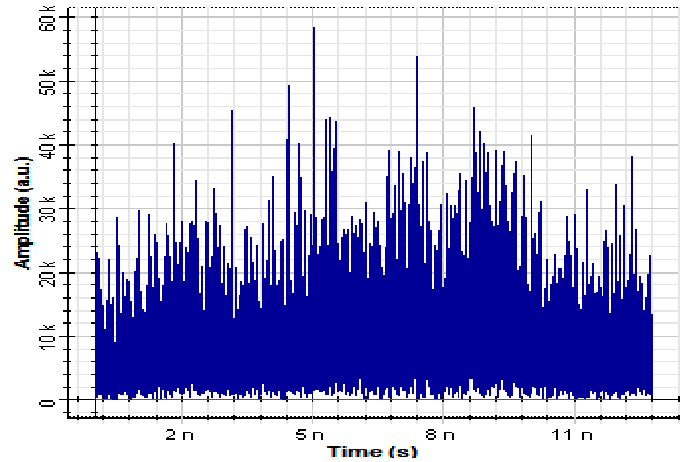

Figure-10
Output Amplitude vs. Time plot for 0.8µm CMOS transimpedance amplifier

Table-3
Transimpedance Amplifier Output results

Input/ output	Electrical power (W)	RF Spectrum (dBm)	Amplitude unit of TIA	BER Measure	Eye Height
Input	5.13e-3	-70 to -30	0-400m	--	--
0.8µm BICMOS	47.6e+6	30 to 75	0-38k	1.905e-33	7230
2.5Ghz BJT	5.17e+3	-20 to 35	0-350m	2.63e-30	79.205
0.8µm CMOS	115.5e+6	30 to 80	0-60k	4.87e-37	11454

Results

Based on on our analysis we found out that 0.8µm CMOS gives better performance as compared to 2.5Ghz BJT and 0.8µm BICMOS technologies. The 0.8µm CMOS technology not only gave higher output electrical power but also better RF Spectrum, BER and eye height. The eye height in case of CMOS technology was much higher as compared to the other two technologies. Thus Optical CMOS technology is a better option for efficient communication.

Conclusion

Based on the standard parameters of transimpedance amplifiers in three different technologies, the electrical power, RF spectrum, amplitude range, BER and eye diagram were comparatively studied in OptiSystem 11.0. According to the Analysis results the 0.8µm CMOS Transimpedance amplifier gives a better result as compared to the other two technologies. The 0.8µm CMOS Transimpedance amplifier gives 115.525e+6 electrical power which is much higher as compared to the other two technologies. The 0.8µm BICMOS transimpedance amplifier gives better noise performance but has a comparatively higher BER and lower eye height.

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