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WIDE DYNAMIC RANGE TRANIMPEDANCE AMPLIFIER USING PEAKING CAPACITANCE TECHNIQUE FOR HIGH SPEED OPTICAL WIRELESS COMMUNICATION SYSTEM

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ABSTRACT

In the high speed optical communication, the requirement of designing the new optical transceivers is quite challenging due to the bandwidth, noise and environmental conditions for designing the optical transceivers. The optical transceivers design is also challenging because of weak optical signal at the frond-end amplifier. In this paper, the optical transceivers via an optical preamplifier for optical wireless communication is designed. The designed system offers the improved performance in terms of bandwidth and gain compared to existing optical transceivers. It is defined that using the designed system, a high bandwidth of 2.114GHz at 29.72dB gain is achieved. The designed optical transceiver provides the bandwidth enhancement utilizing the peaking inductor and capacitor.

Keywords: Bandwidth, Gain, Optical preamplifier, Optical transceivers.

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1. INTRODUCTION

The transmission of free-space propagation is incurred via light for communication in the wireless communication [1]. The optical receiver design provides the wireless data links for end devices to propagate in the free space [2]. In the wireless optical receivers especially infrared (IR) type process the signal currents from photodiodes wireless via sensitive current-input preamplifiers [3]. It is defined IR wireless preamplifier is characterized using three main requirements. These requirements are; wide dynamic range, wide bandwidth, and strong ability to cast-off ambient light [4]. It also discussed that fiber-optic receivers have different bandwidth statues compare to IR wireless receivers [5]. Because of this large photodiodes are needed and also need to take care of the costs issue for compensating the path losses incurred during free-space transmission required in order to make up for the path losses that occur over transmission of free-space [6]. The variable link distances are accommodated using wide range parameter. The wide range also offers the detection of the signals in the incidence of strong ambient light for receiver in different environments [7]. It is discussed in [8] that using preamplifier stage via transimpedance amplifier, the bandwidth of receiver can be enhanced. It is also defined that for an IR wireless receiver the characteristic dynamic range of a transimpedance amplifier is characteristically not adequate [9-10]. The characteristic dynamic range for the wide range can be extended exactly at the preamplifier stage [11] and secondly, using a bipolar differential pair the characteristic dynamic range can be expanded. It is defined that bipolar transistors are suitable for this characteristic dynamic range because their voltage to current characteristic is exponential and regulates the photodiode bias voltage. It is also observed that the bipolar transistors use is not suitable for CMOS [12]. In this concern, transimpedance amplifiers has its own challenged in design the wide range receiver design due to stabilize the output. However, we have demonstrated in this paper that bandwidth of transimpedance amplifier can be controlled for whole gain range and regulatory of bandwidth recovers receiver's sensitivity. This receiver's sensitivity rejects the out-of-band noises without using supplementary filter techniques.

2. METHODOLOGY

In this work, bandwidth enhancement is carried out for IR wireless receiver. The bandwidth enhancement is mainly carried using two techniques shunt peaking and capacitive peaking. The shunt peaking provides the output in terms of amplitude to rolloff at high frequencies. It also enhance the by including an inductor in series along with the output load. This method reduces the capacitive reactance droplets at high frequencies to in order to increase the effective load impedance [13]. The capacitive peaking provides the peaking on terms of capacitance. This action is performed using an explicit capacitor that regulates the pole locations for a feedback amplifier.

In this work, the designed receiver uses the peaking capacitor technique to increase the bandwidth. The bandwidth enhancement for IR wireless receiver using peaking capacitor is demonstrated in Figure 1.

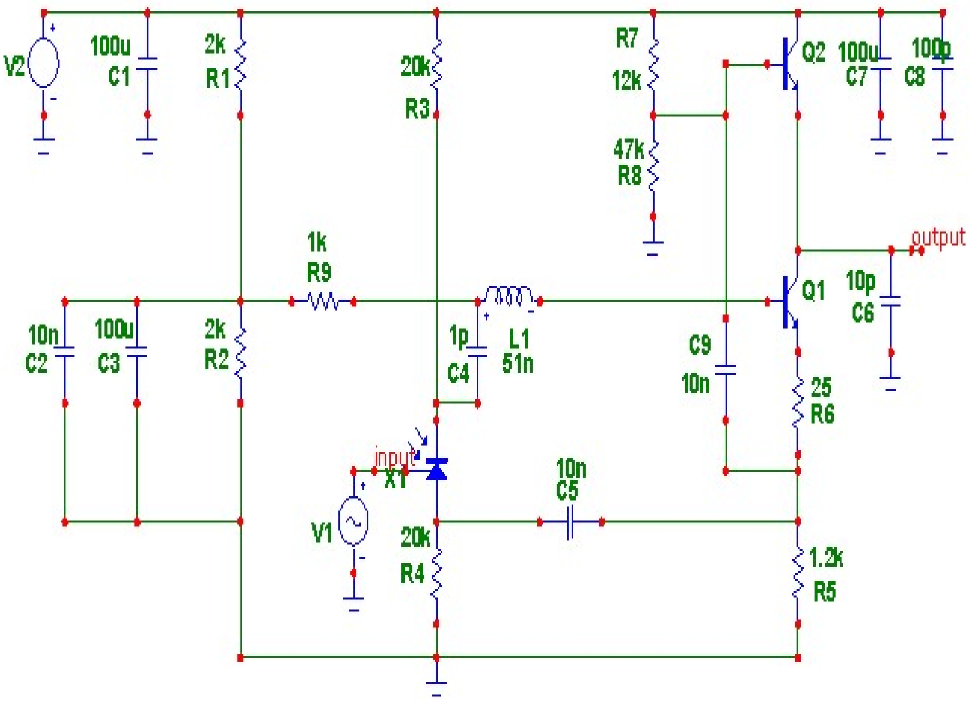

Fig.1. Designed Front End Amplifier

It is defined in Figure 1 that using peaking capacitance technique the circuit is designed for improving the bandwidth and it is defined that in the peaking capacitance the capacitor is connected along with load. It can be observed in Figure 1 that a capacitor *C4* is connected in parallel to photodiode. The RC circuit in the Front End amplifier i.e. *C1 and R1* are utilized for the stabilization of the current. Similarly, *C2, C3,* and *R2* also provided the current stabilization for the designed Front End amplifier. The parameters for the designed Front End amplifier are illustrated in Table 1.

Table 1. Preamplifier characteristics

Parameters	Values
Bandwidth	-3 dB
Gain	29.722dB
Supply voltage	12V
Input capacitance	1.6 pF
Frequency	2.114 GHz

It is defined in Table 1 that bandwidth enhancement using peaking capacitance is achieved for the designed Front End amplifier. The designed Front End amplifier has cut-off bandwidth of -3dB and gain attained for the designed Front End amplifier is 29.7 dB for the frequency of 2.11 GHz. It also defined that the capacitance for the designed Front End amplifier is limited at 1.6pF.

It is also demonstrated in Figure 1 for the designed Front End amplifier that loading of the Front End amplifier is demonstrated using *Q1* and *Q2.* It can be observed that both *Q1* and *Q2* are connected in Darlington configuration and in this condition both *Q1* and *Q2* are always on. The reason for arranging the both *Q1* and *Q2* in Darlington configuration that *Q1* is the input impedance of the *Q2* transistor.

Along with is loading combination of *Q1* and *Q2*, the parallel combination of resistor *R7* and *R8* is also connected. This combination of *R7* and *R8* works as a voltage divider and it stabilize the voltage for the designed Front End amplifier. It can also be seen in Figure 1 that the *C4* and *C5* are the bypass capacitor. The combination of *C4* and *C5* provides the overall stability for the designed Front End amplifier circuit. In addition, *C6* and *R9* are used for coupling and to stabilize the output gain respectively. In the next, the result and discussion is discussed for the designed Front End amplifier to verify the performance of the designed Front End amplifier at different capacitance level. The performance of the designed Front End amplifier is demonstrated for different capacitance values in order to verify the use of peaking capacitance technique for the designed Front End amplifier in order to enhance the bandwidth of the receiver.

3. RESULTS AND DISCUSSION

In this work, the bandwidth for the designed Front End amplifier is enhanced using peaking capacitance to increase the bandwidth for wireless IR receiver. It can be defined that the performance of the designed Front End amplifier is dependent on configuration and arrangement of components used in designed Front End amplifier i.e. *Q1*, *Q2*, *R7*, *R8*, *C4*, *C5*, *C6* and *R9*. It is also important to note that the values of these is parameters for designing the Front End amplifier is also key factor in enhancing the bandwidth of receiver.

It is also defined that arrangement of *Q1* and *Q2* transistors is carried out in Darlington configuration. The main contribution of this work is that this combination *Q1* and *Q2* transistors t in Darlington configuration acts as a single element. It provides the current gain, which is product of the current gains of the discrete transistor either *Q1* or *Q2*. The values of *R1* is fixed to 1 KΩ and with the variation in *R9* the gain stability is controlled. However, *C4* provides the cut-off frequency and gain stability. Because, when *C4* is high in values the cut off frequency is limited to MHz range with high gain. Due to this, in order to achieve the higher bandwidth, *C4* must be kept in the range of pF. The performance of the designed Front End amplifier is observed for variation in *C4*. It is defined that for the designed Front End amplifier different capacitance values are attained as shown in Table 2.

Table 2. Values of capacitance that effect the frequency

Capacitance	Frequency
10 nF	177.17 MHz
100 nF	172.05 MHz
1 pF	2.14 GHz

Table 2 defines the different values of capacitance for *C4* for enhancing the bandwidth of the designed Front End amplifier. It is defined that when *C4* is operated 10nF the frequency attained for the designed Front End amplifier is 177.17 MHz. The frequency response of the designed Front End amplifier with *C4* at 10nF is shown in Figure 2. It can be observed that for *C4* at 10nF the frequency of 177.17 MHz is achieved in frequency response.

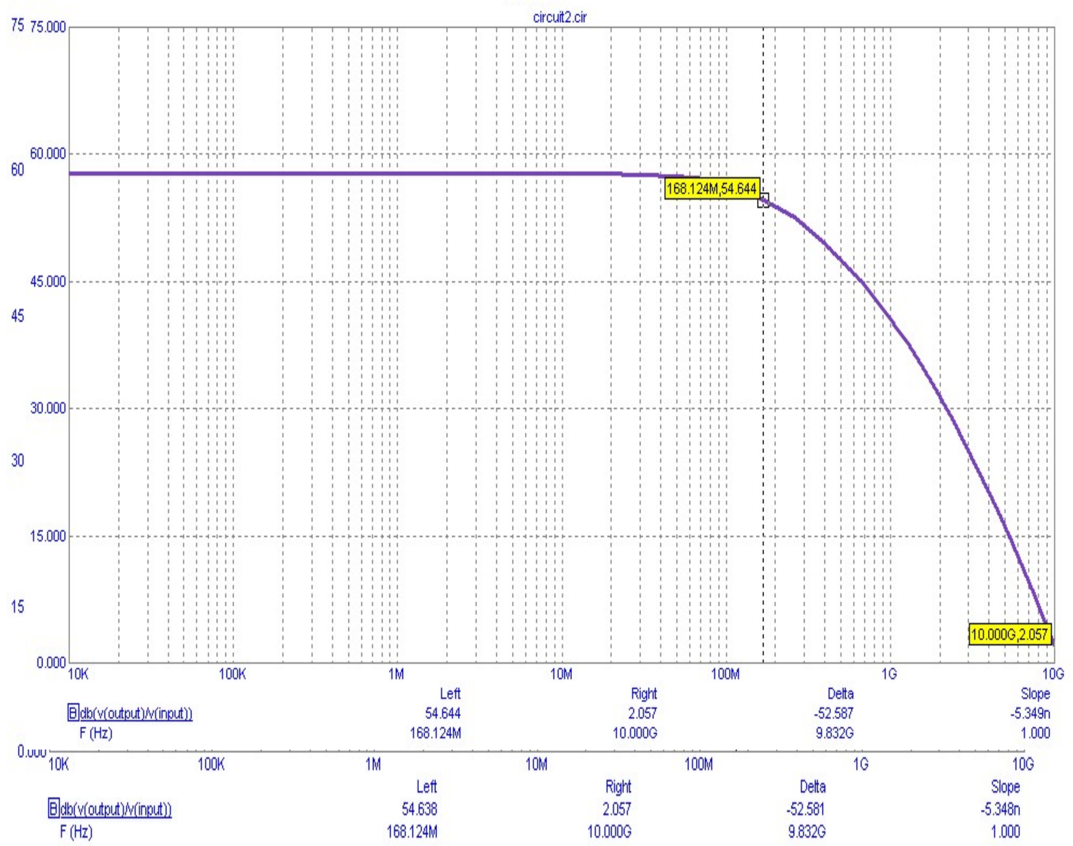

Fig.2. Frequency response of the designed Front End amplifier with at *C4*=10nF

When, *C4* is operated 100nF the frequency attained for the designed Front End amplifier is 172.05 MHz. The frequency response of the designed Front End amplifier at *C4* = 100nF is demonstrated in Figure 3. It is shown that when capacitance is changed from 10nF to 100nF the bandwidth of the designed Front End amplifier is reduced. It is noted that for the designed Front End amplifier using peaking capacitance variation in bandwidth is observed. The response in Figure 3 demonstrates that the bandwidth of 172 MHz is attained for *C4* = 100nF.

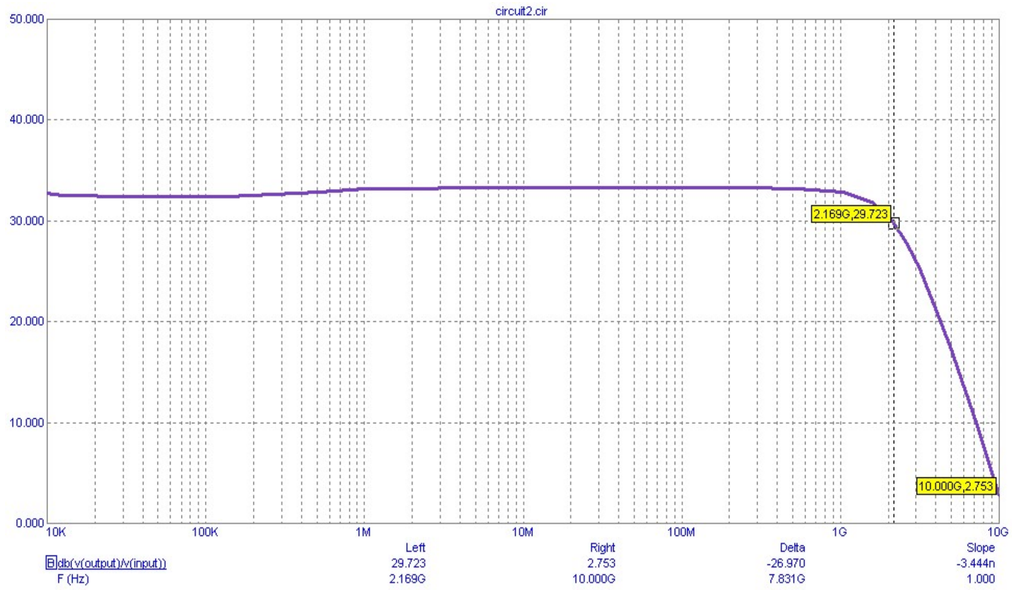

Fig.3. Frequency response of the designed Front End amplifier with at *C4*=100nF

When, *C4* is operated 1pF the frequency attained for the designed Front End amplifier is 2.14 GHz. The frequency response of the designed Front End amplifier at *C4* = 1pF is demonstrated in Figure 4.

It is shown that when capacitance is changed from 100nF to 1pF the significant improvement in the bandwidth of the designed Front End amplifier is recorded. It is noted that for the designed Front End amplifier using peaking capacitance significant variation in bandwidth is observed. The response of the designed Front End amplifier at *C4* = 1pF is depicted in Figure 4 and it is defined that bandwidth of 2.14 GHz is attained for the designed Front End amplifier. The performance of the designed Front End amplifier is verified at *C4* = 1pF at bandwidth of 2.14 GHz and the response of the designed Front End amplifier at *C4* = 1pF is also demonstrated using gain at *R9* = 500Ω and 2kΩ. The response of gain at *R9* = 500Ω and 2kΩ at *C4* = 1pF is shown in Figure 5 and in Figure 6 respectively.

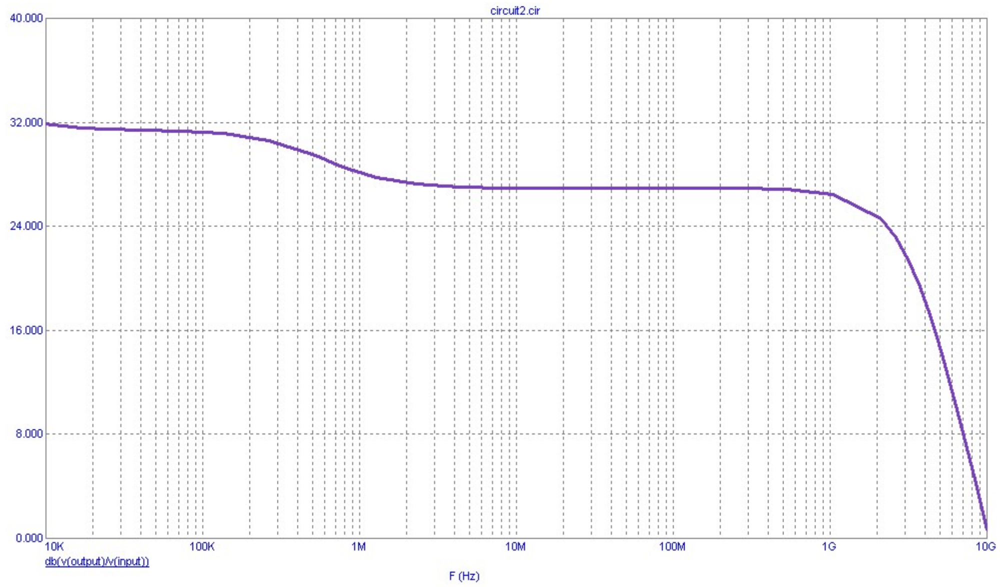

Fig.4. The unstable gain when the resistor, R9=500Ω

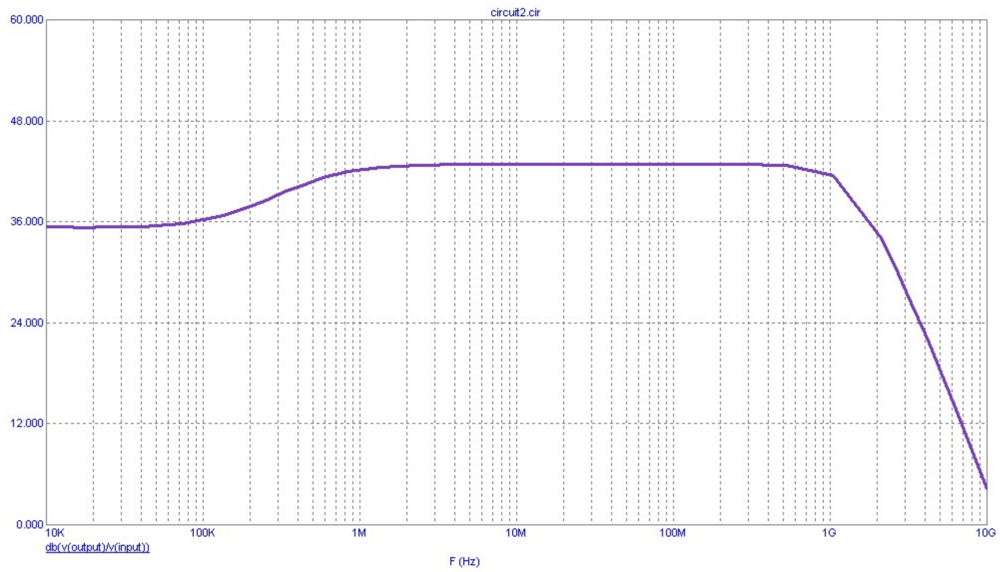

Fig.5. The unstable gain when the resistor, R9=2KΩ

The performance of the designed Front End amplifier is also demonstrated using noise analysis. The reason for discussing analysis for the designed Front End amplifier is that if the designed amplifier is able to minimize of the output noise the performance of the designed Front End amplifier for the selected parameters will yield the proper bandwidth enhancement. Another reason for performing the noise analysis for the designed Front End amplifier is that input transistor provides the tradeoff between noise, gain performance and DC power consumption.

It is defined that for the designed Front End amplifier the output noise level is noise low at the high frequency of GHz. The noise analysis is carried out using a pin photodiode with 91% quantum efficiency at wavelength of 410 nm at differential capacitance *Cd* of 1.6pF [12]. The different output and input noise value between low frequency and high frequency is shown below. The input noise values for low frequency and high frequency are shown Table 3.

Table 3. The difference input noise level at high and low frequency

Frequency	Noise (τnoise) np/A
10 KHz	790.8 p
100 KHz	496.03p
1 GHz	156.1p
10 GHz	12.73n

Table 3 defines the inout noise level at different frequencies. It can be seen in the Table 2 that at 10 KHz, the noise level 790.8 np/A and at 100 KHz, the noise level is 496.03 np/A, at 1 MHz, the noise level is 156.1 np/A and at high frequency of 10 MHz, the noise level is 12.73 np/A.

The response of the input noise level for the designed Front End amplifier is demonstrated in Figure 7. It can be observed from Figure 7 that as frequency is increased the noise level is also increased.

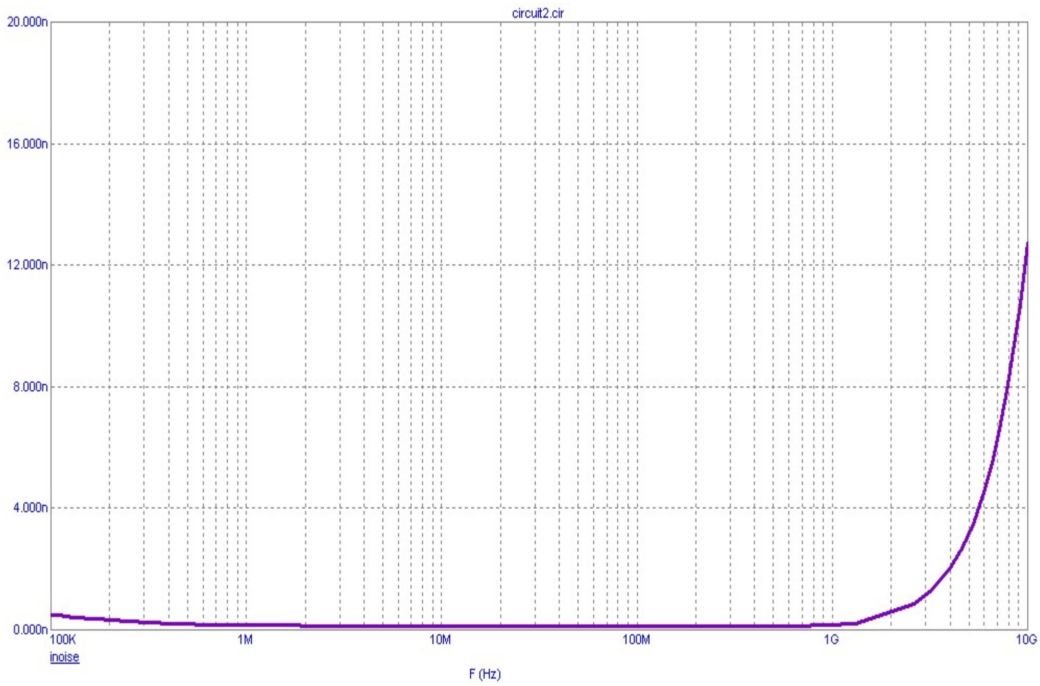

Fig.6. Input Noise of the designed Front End amplifier

The output noise values for low frequency and high frequency are shown Table 4. It can be analyzed from Table 2 that at 10 KHz, the noise level is 1.06 np/A and at 100 KHz, the noise level is 107.3 np/A, at 1 MHz, the noise level is 11.006 np/A and at high frequency of 10 MHz, the noise level is 1.11 np/A.

Table 4. The difference output noise level at high and low frequency

Frequency	Noise (τnoise) np/A
10 KHz	1.064
100 KHz	107.3
1 MHz	11.006
10 MHz	1.11f

From results, it is defined that the designed Front End amplifier provides the bandwidth enhancement using Peaking Capacitance Technique along with reduced output noise for the IR wireless receivers. The designed Front End amplifier can be used in existing communication system to provide the free space transmission with wider bandwidth, high dynamic range and reduced output noise level for the high frequency operation.

4. CONCLUSION

In this work, a wide dynamic range transimpedance amplifier using peaking capacitor technique for high-speed optical wireless communication system is designed. The designed Front End amplifier provides the frequency response of 2.144 GHz. It is concluded that the designed Front End amplifier can be used for adjusting the bandwidth and frequency of the preamplifier.

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