JAET

Journal homepage: http://jae-tech.com

ISSN : 2523-6032 ISSN-L : 2523-2924

Journal of Applied Engineering & Technology

CMOS Amplifier Receiver with AGC Bandwidth Circuit

Amirrul Aiman din Abdul Rehman[1], M.F.L Abdullah[1, *]

[1]Department of Communication Engineering,
Faculty of Electrical and Electronic Engineering, Universiti Tun Hussein Onn Malaysia.

*Corresponding Author

Abstract: This research work focuses on the concept of wireless optical communication system. A „CMOS Amplifier Receiver with Gain and Bandwidth Adjustment Capabilities" has been designed to detect the gain and bandwidth of the transmitted signal. Configurations of receivers had been designed using LMH6624 as the front-end transimpedance amplifier and the LMH6504 amplifier as the Automatic Gain Control (AGC) circuit. Furthermore, this research work also use LMH6732 amplifier at the output in order to have the capability of controlling the bandwidth. The output frequency response achieved by transimpedance amplifier using LMH6624 is 180.44 MHz and 144.61 MHz cut-off frequency after the AGC circuit while the controllable bandwidth amplifier by using LMH6732 produced is 75.32 MHz.

Keywords: Gain Control; Bandwidth; Frequency Response;

1. Introduction

Nowadays, wireless communication has become an essential part in most of the devices and inventions for many reasons such as security, data transfer and etc. The challenge of creating inexpensive link for wireless is driving into new innovation in the design of amplifier receiver. In order to have a good signal, we need to have a high performance at the receiver. Good receiver depends on the quality of the bandwidth and the gain of the signal. Therefore, the research work concerned about how to have the capabilities of adjusting the signal bandwidth of the receiver according to the transmitted signal. Furthermore, the research work is also concerned with how to have gain control capabilities at the receiver. Hence by combining both concepts a high performance receiver will be produced.

This research work use transimpedance amplifier as the front end of these circuit. Then, an „Automatic Gain Control" amplifier is being used in order to controlling the output gain into several levels. The output level can be controlled by varying a single potentiometer. This receiver amplifier also uses LMH6732 in order to have bandwidth controlling capabilities. The bandwidth can be adjusted by changing a single value of resistor, Rp. The work is proposed to design a CMOS amplifier receiver with bandwidth adjustment capabilities, and create a CMOS amplifier receiver circuit with Automatic Gain Control (AGC). The simulation of proposed CMOS amplifier receiver using any existing electronic Software such as Micro-Cap, PSpice and etc. The fabrication of the proposed CMOS amplifier receiver circuit into Printed Circuit Board (PCB). The work is is focused towards the concept of wireless communication for designing and simulate the circuit using Multisim 9 and Pspice with component CMOS amplifier for bandwidth and gain adjustment.

2. Background and Literature Review

2.1 Photodiodes

A photodiode is a type of photodetector that is capable of converting light into either current or voltage. It could also be either of the visible light type or the type essentially sensitive to infra-red radiation. Semiconductor photodiodes are small, light, and fast and can operate with just a few bias volts. Semiconductor materials commonly used for making photodiodes are Si, Ge, GaAs, InAs, and InGaAs [1]. Indirect bandgap materials, such as Si and Ge, are

*Corresponding author: faiz@uthm.edu.my

preferred over direct bandgap materials. There is several type of photodiode in existence such as P-I-N photodiode, P-N photodiode and Avalanche photodiode.

2.2 Transimpedance Amplifier

Transimpedance amplifier or TIA is a front-end architecture that provides a good compromise between the lownoise characteristics of the high-impedance front-end and the wideband nature of the low-impedance voltage-amplifier frontend {2-3]. TIA is also known as a transresistance amplifier and a current-to-voltage converter. This device will convert an input current into an output voltage. The conversion is linear, so when the input current doubles, so will the output voltage be [4-6].

The transimpedance design uses a feedback to reduce input impedance, where this will permit fast response due to the low effective input RC-time constant and low thermal noise since Rf can be made large. The result is that the RC-time constant limitation is multiplied by the amplifier gain and the signal output is a function of the size of the feedback resistance [7]. The transimpedance amplifier has a wide range but is limited in noise performance or frequency response as shown in Fig. 1 [8].

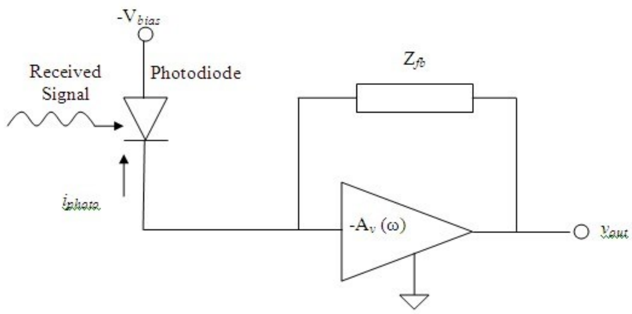

Fig. 1 – Typical circuit configuration of TIA

The transimpedance amplifier comprises of an op-amp of gain, A with feedback resistor, Rf and feedback capacitor, Cf. The gain of the transimpedance amplifier can be expressed as A= 1+ (Ri/R1):

2.3 Automatic Gain Control

Automatic Gain Control (AGC) is an automatic timevarying gain of a signal according to the input signal level. An AGC is typically made up of a signal detector, a gain computer, where the signal detector detects the signal level of the input signal and the gain computer controls the gain or output signal level depending on the output of the signal detector [9-10]. There are two type of AGC circuit. If the AGC is used to reduce the dynamic range of a signal, it is called compression, while if it is used to increase the dynamic range, it is called expansion [11]. Typical applications of an AGC are compressors and limiters. Compressors and limiters perform similar tasks, but one essential point makes them different between one another. Limiters abruptly limit the signal above a certain level, while compressors control the signal more gently over a wide rage. In this receiver circuit, AGC is use to maintain the amplitude of the output accordance to the reference value which is set by the potentiometer [12].

2.4 Adjustable Bandwidth Amplifier

The LMH6732 is used for this amplifier and it is an adjustable supply current, current feedback operational amplifier. Supply current and consequently dynamic performance can be easily adjusted by selecting the value of a single external resistor (Rp) [6].

Table 1 – Device Parameter Related To Supply Current

Specification	Effect as ICC increase
Bandwidth	Increase
Rise time	Decrease
Enable / Disable Speed	Increase
Output Drive	Increase
Input Bias Current	Increase
Input Impedance	Decrease

Table 1 show that the effect of increased the supply current. The operating point is determined by the supply current which in turn is determined by current (Ip) flowing out of pin 8. Calculating the value of RP:

IP = ICC/ 57
= 9mA/57
= 157.89 µA
RP + 5000 = [(V+ -1.6) – V-]/ IP
RP + 5000 = [(5 – 1.6) – (-5)]/157.89µ RP = 48.2kΩ = 50kΩ

3. Research Methodology

In this work, the simulation of the circuit is done by using the „Micro-Cap 9 Spectrum Software" since this software offer all the components needed in this amplifier circuit such as photodiode, LMH6624, LMH6504 and LMH6732 as shown in Fig. 2.

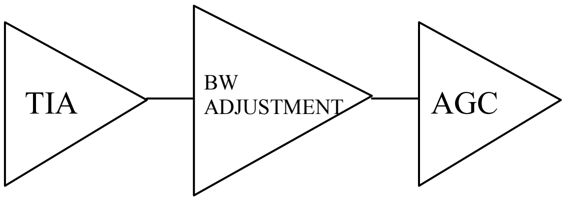

Fig. 2 – Block diagram of Transimpedance Amplifier

3.1 Receiver with Gain and Bandwidth Adjustment Capabilities

CMOS Amplifier Receiver with Gain Bandwidth and adjustment Capabilities consists of four main parts which are a photodiode, a transimpedance amplifier, an automatic gain control and finally a adjustable bandwidth amplifier as show in Fig. 3.

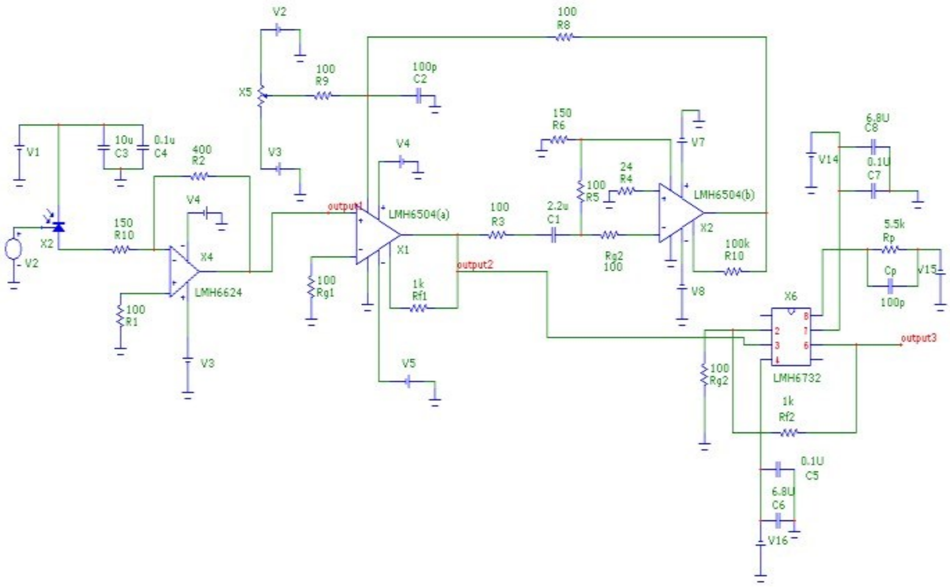

Fig. 3 – Circuit of CMOS Amplifier Receiver with Gain and Bandwidth Adjustment Capabilities.

The photodiode will detect the gain or the amplitude of a signal that is transmitted by a transmitter and change it to voltage source. The transimpedance amplifier will then convert the current input into voltage output. The output is then given to automatic gain control where it will control the gain or the amplitude of the signal. The signal is then will be the input to LMH6732 in order to maintain the bandwidth of this receiver circuit. The automatic gain control (AGC) circuit employs two LMH6504. In the circuit, LMH6504(a) receives the input signal and produces an output signal of constant amplitude. LMH6504(b) is configured to provide negative feedback. LMH6504(b) generates a rectified gain control signal that works against an adjustable bias level which may be set by the potentiometer, X5. C2 integrates the bias and negative feedback. The resultant gain control signal is applied to the LMH6504(a) gain control input. The bias adjustment allows the LMH6504(a) output to be set at an arbitrary level less than the maximum output specification of the amplifier. Rectification is accomplished in LMH6504(b) by driving both the amplifier input and the gain control input with the LMH6504(a) output signal. The voltage divider that is performed by R6 and R5 sets the rectifier gain.

4. Results and Discussion

4.1 Simulation result

The receiver receives a sinusoidal input signal. When the signal passes through the transimpedance amplifier stage, the signal is oscillated at some high frequency above the bandwidth cut-off. The signal from the final stage of the main amplifier in the AGC circuit is compared with a preset reference level and fed back to adjust the high voltage bias supply in order to maintain a constant signal level. The signal is then pass through the adjustable bandwidth using LMH6732 which can be done by adjusting a single value of resistor, Rp through pin 8.

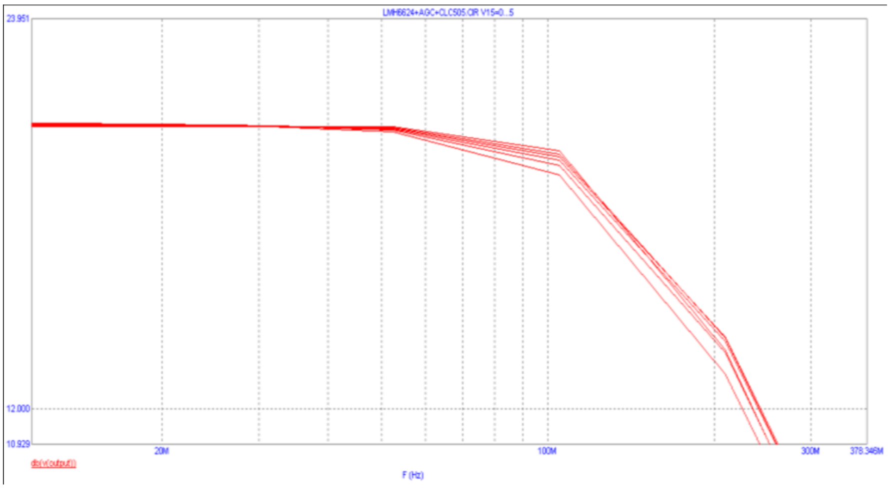

Fig. 4 – Frequency Response When Varying the Voltage at Pin 8.

Fig. 4 show that the effect of varying the voltage at pin 8 of the LMH6732. The voltage is varied from 0V to 5V. From the waveform, we can say that the voltage is directly proportional to the bandwidth where the bandwidth will increased with the increasing of the voltage. Table 2 summarizes the effect on cutoff frequency when varying the voltage at pin 8. The voltage supply to pin 8 is limited until 5V only since LMH6732 will support until this range only. Any voltage higher than 5V or lower that 0V will lead to the damaged of this IC [6].

Table 2 – Cutoff frequency when varying the voltage value at Pin 8

Voltage at Rp	Cutoff Frequency	Gain
5	149.75 MHz	20.60 dB
4	136.67 MHz	20.48 dB
3	133.55 MHz	20.44 dB
2	130.49 MHz	20.36 dB
1	128.99 MHz	20.29 dB
0	121.73 MHz	20.22 dB

Fig. 5 show that the frequency response of the Automatic Gain Control amplifier when varying the value of the potentiometer. The potentiometer is varied from 1kΩ to 50kΩ with the step of 1000. The function of this potentiometer is to set the amplitude level of the output [7]. From the waveform, the gain varied from 1kΩ to 10kΩ but there is no significant different of the gain when the value of the potentiometer is 10kΩ and above. Table 3 summarizes the effect of changing the value of potentiometer to the amplifier gain. The cutoff frequency will be diminished with the raise of the amplifier gain.

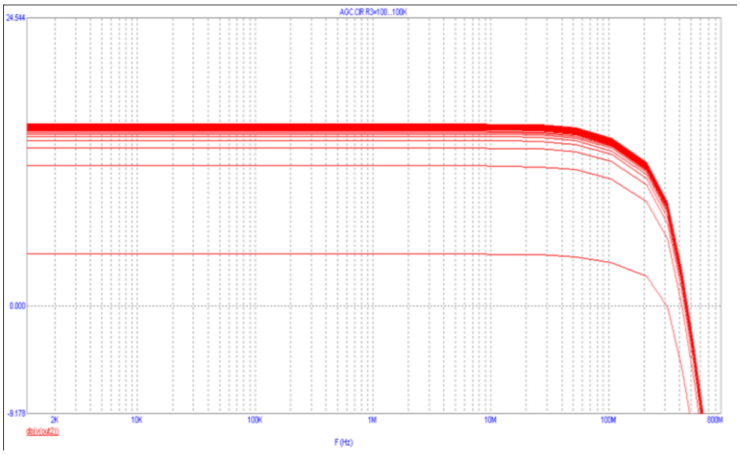

Fig. 5 – Frequency Response When Varying the Potentiometer at the AGC Amplifier.

Table 3 – Summary of the effect of the gain when varying the Potentiometer

Potentiometer X3 (Ω)	Gain	Cutoff frequency
1k	8.70 dB	207.29 MHz
2k	13.15 dB	204.91 MHz
3k	13.93 dB	200.96 MHz
4k	14.37 dB	200.74 MHz
5k	14.61 dB	195.38 MHz

Fig. 6 show that the frequency responses of this full receiver circuit. The first graph show that the frequency responses of output at transimpedance amplifier using LMH6624. It is having cutoff frequency of 179.65 MHz and gain of 46.02 dB. The second graph represents the output at AGC amplifier. The potentiometer at this AGC was set to 2kΩ. Accordance to the graph, AGC amplifier has the cutoff frequency of 164.59 MHz and gain of 50.43 dB. Finally, the last graph represents the bandwidth adjusting amplifier. The voltage at pin 8 is set to 5V which is the best value to get higher frequency. It has cutoff frequency of 77.08 MHz and gain of 76.02 dB.

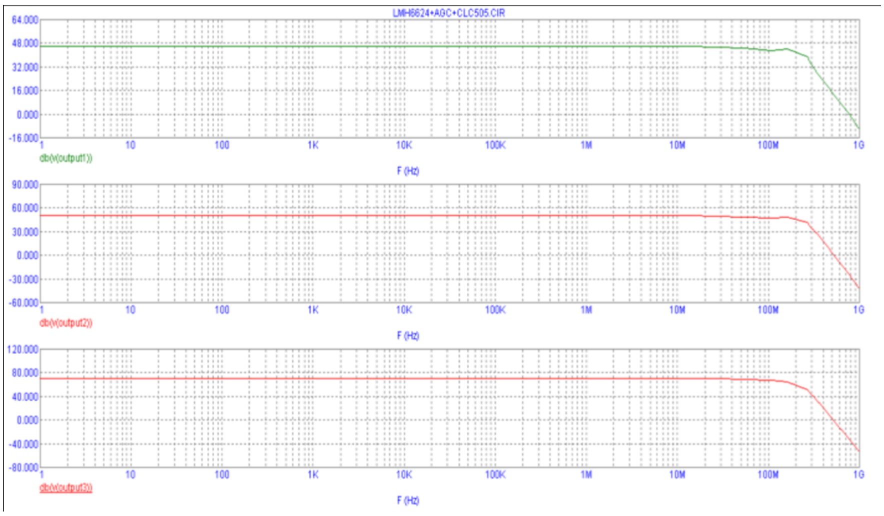

Fig. 6 – AC Analysis Waveform of Transimpedance Amplifier with Gain and Bandwidth Adjustment Capabilities.

Table 4 – Summarized Out-Off Gain and Frequency

Amplifier	Gain	Bandwidth
Transimpedance Amplifier	46.02 dB	179.65 MHz
AGC Amplifier	50.43 dB	164.59 MHz
Adjustable Bandwidth Amplifier	76.02 dB	77.08 MHz

The cut-off frequency for the transimpedance amplifier which is the first stage of this receiver amplifier is higher than cut-off frequency after the AGC stage and adjustable bandwidth stage. This is because at the first stage, the signal is amplified by the transimpedance amplifier but when the signal passes through the AGC, the signal"s dynamic range is reduced and is applied to the preamplifier giving increased optical dynamic range at the receiver input.

4.2 Hardware Result

Fig. 7 below show the output of this receiver amplifier. The first graph represent the waveform of the input supply which having 1V peak to peak and 10MHz of frequency. The second graph represent the output waveform of this amplifier circuit which having 7.28V peak to peak. So, the gain of this amplifier can be calculated using:

Gain (A) = output voltage / input voltage = 7.28 / 1 = 7.28

Gain (AdB) = 10 log 7.28 = 8.62 dB

So, at frequency 10MHz, the gain of this amplifier is 8.62. This research work will collect all the input peak to peak voltage and output peak to peak voltage from several differences frequency. Table 5 show that the collected data of input voltage and output voltage from frequency of 1 kHz to 100MHz.

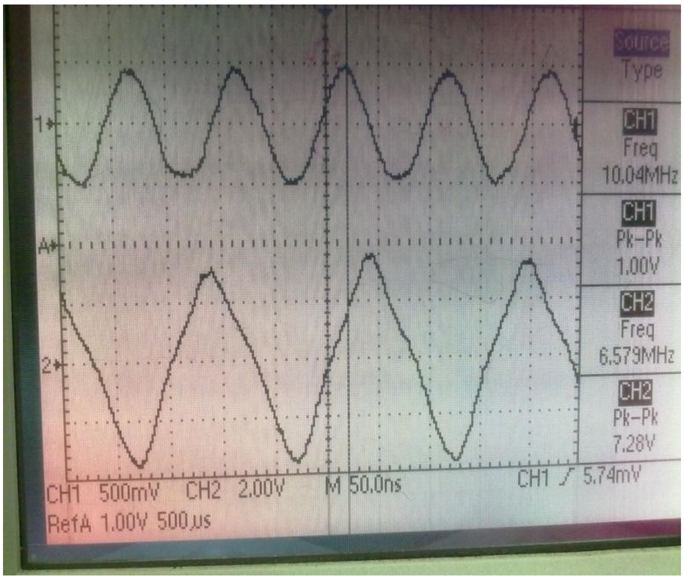

Fig. 7 – Output Result at 10MHz Frequency

Table 5 – Hardware Result

Frequency	VIN	VOUT	Gain	Gain(dB)
100 kHz	1 V	7.80V	7.80	8.92
1 MHz	1V	7.80V	7.80	8.92
10MHz	1V	7.28V	7.28	8.62
20MHz	1V	7.20V	7.20	8.57
30MHz	1V	6.96V	6.96	8.43
40MHz	1V	6.89V	6.89	8.38
50MHz	1V	6.92V	6.92	8.40
60MHz	1V	6.56V	6.56	8.17
70MHz	1V	3.66V	3.56	5.51
80MHz	1V	1.04V	1.04	0.17
90MHz	1V	880mV	880mV	-0.56
100MHz	1V	900mV	900mV	-0.46

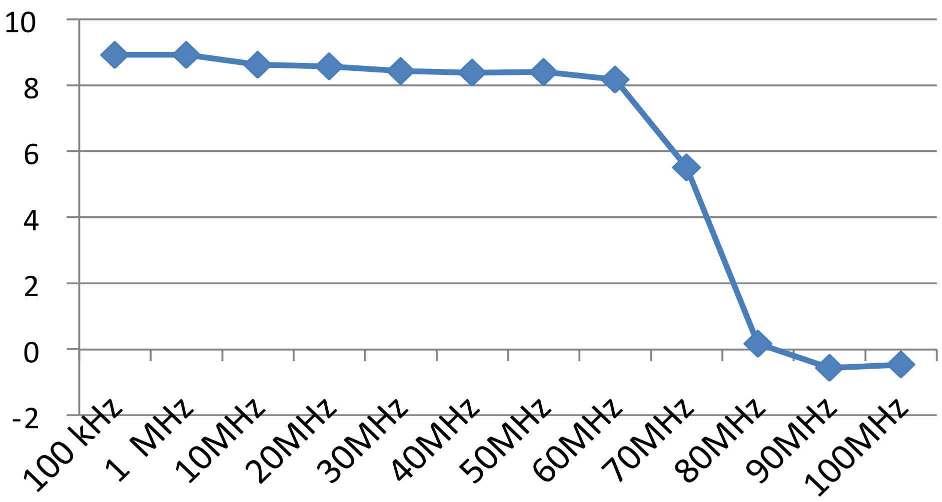

Fig. 8 – Graph Gain versus Frequency

Fig. 8 shows that the plotted graph gain (dB) versus frequency (Hz) of the receiver amplifier. The cutoff frequency of this circuit is at 70MHz and gain of 8.92dB. There is slightly difference between hardware result and simulation result due to error or noise may happen during the hardware testing process. A lot of jumper wire used also may lead to any error or noise occurred.

5. Conclusion

A CMOS Amplifier Receiver with Gain and Bandwidth Adjustment Capabilities" has been designed. It is an optical wireless receiver that is capable of controlling the gain of the incoming signal automatically and maintains the bandwidth of the received signal.

There some improvements that can be done for future work. First of all, the change the AGC IC"s from LMH6504 to LMH6514. The LMH6514 is a high performance, digitally controlled variable gain amplifier (DVGA) [8] which is more precise rather than using LMH6504. In addition, Signal to Noise (SNR) circuit can be place to the pin 8 of the LMH6732. The SNR circuit represent by Gilbert function to detect any noise occurred in the circuit in form of sinusoidal wave. The signal is then should be converted from AC to DC using any converter existed. Then, this DC SNR signal can be supplied to the pin 8 of LMH6732 and will automatically improve the needed bandwidth of the receiver circuit.

Acknowledgement

Merciful to Allah the Al-Mighty for making my final year research work a wonderful experience. I would like to thank my supervisor. A million thanks also to individual that has contributed either directly or indirectly in this research work.

References

[1] Stephen B. Alexander (1997), "Optical Communication Receiver Design", Ciena Corporation, IEE Telecommunication Series, SPIE Optical Engineering Press.

[2] Idrus,S.M, Hafizah, Azis, S.I.A. (2006), Performance Analysis of BootsrtaTransimpedance Amplifier for Lare Window Optical Wireless Receiver.RFM2006: Putrajaya

[3] J.R Smith (1998), "Modern Communication Circuit", McGraw Hill Electrical and Computer Engineering Series, 2nd Edition, New York.

[4] R.G. Bozomitu and V.I. Cehan, "A Differential CMOS Automatic Gain Control Amplifier" Faculty of Electronics and Telecommunications, "Gh. Asachi" Technical University

[5] J.P. Gonzále. (2017). "Adaptive Dynamic Filter using MOSFET Receiver," J. of Applied Engineering & Technology Vol. 1 No. 1 (2017) p. 9-15.

[6] H.R.A. Rahman, Mohammad Faiz. (2017). "Amplitude and Frequency Shift Keying Infrared Transmitter," J. of Applied Engineering & Technology Vol. 1 No. 1 (2017) p. 16-21.

[7] R. G. Bozomitu, VI. Cehan (2007),"A Differential CMOS Automatic Gain Control Amplifier", IEEE 1-4244-0969-1

[8] Steve Hranilovic (2004), “Wireless Optical Communication Systems”, Assistant Professor, Department of Electrical and Computer Engineering, McMaster University, Hamilton, Ontario, Canada, Springer Science+Business Media, Inc.
[9] National Semiconductor Corporation, LMH6732 High SpeedOp Amp with Adjustable Bandwidth, Product Datasheet, Semi Conductor Corporation.
[10] Heller, L., Griffin, W., Davis, J., & Thoma, N. (1984, February). Cascode voltage switch logic: A differential CMOS logic family. In 1984 IEEE International Solid-State Circuits Conference. Digest of Technical Papers (Vol. 27, pp. 16-17). IEEE.
[11] Tiri, K., Akmal, M., & Verbauwhede, I. (2002, September). A dynamic and differential CMOS logic with signal independent power consumption to withstand differential power analysis on smart cards. In Proceedings of the 28th European solid-state circuits conference (pp. 403-406). IEEE.
[12] Ahn, H. T., & Allstot, D. J. (2002). A 0.5-8.5 GHz fully differential CMOS distributed amplifier. IEEE Journal of Solid-State Circuits, 37(8), 985-993.