RECEIVER BANDWIDTH ENHANCEMENT DESIGN FOR HIGH SPEED OPTICAL SYSTEM

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ABSTRACT

The technology of optical-fiber systems is advancing rapidly. Parallel to the development of long-haul telecommunication systems in the gigabits per second data rates operating in the long-wavelength region is the wide penetration of optical-fiber systems in local area networks, video trunking and distribution, sensors, etc. These diversified applications impose different and often conflicting constraints on the optical receiver. The weakest signal level determined at the front-end receiver and it should be improved by appropriate design. The optimum receiver performance can be achieved depends on the devices and design techniques used. This project re-examines the optical receiver design using several method which is applying the basic transimpedance amplifier, cascade transimpedance amplifier and multiple gain stage transimpedance amplifier method. The receiver amplifier design will be simulate using existing Software such as P-spice and Micro-Cap, and then the design will be fabricated as a prototype circuit. Cascade Transimpedance Amplifier method achieved 4.568MHz for the cutoff frequency, while the Multiple Stage Gain Transimpedance Amplifier method achieved 4.4956MHz. Transimpedance Amplifier using BJT transistor method with a cascade connection and feedback structure technique achieved the objective of project to enhance the bandwidth for front-end receiver in the range of approximately in Giga Hertz which is 1.189 GHz.

ABSTRAK

Teknologi sistem gentian optik kini semakin berkembang pesat dari hari ke hari. Selaras dengan perkembangan sistem komunikasi jarak jauh yang mencapai kadar data gigabit per saat dalam komunikasi serantau, sistem gentian optik kini telah mula menembusi rangkaian kawasan tempatan, saluran video, pengedaran, pengesan dan beberapa teknologi lain secara meluas. Kepelbagaian aplikasi telah menimbulkan pelbagai masalah teknikal dan konflik dalam penerima optik. Penerimaan aras isyarat yang lemah pada penerima hadapan perlu diperbaiki dengan rekaan teknologi yang lebih jitu dan sesuai. Keupayaan penerima boleh dicapai secara optimum bergantung kepada peralatan dan rekabentuk teknik yang digunakan. Projek ini akan mengkaji semula rekabentuk penerima optik menggunakan beberapa kaedah seperti penguat transimpedan asas, penguat transimpedan lata dan penguat transimpedan pelbagai peringkat. Rekabentuk penerima penguat ini disimulasi melalui perisian seperti *P-Spice* dan *Micro-Cap* sebelum difabrikasi kepada litar prototaip. Kaedah Penguat Lata Transimpedan telah mencapai 4.568MHz untuk ‘cutoff frequency’, manakala kaedah Penguat Pelbagai Peringkat telah mencapai 4.4956MHz untuk ‘cutoff frequency’ . Penguat Transimpedan yang dihasilkan menggunakan transistor BJT dan penyambungan lata (*cascade connection*) serta teknik struktur suapbalik (*feedback structure technique*), berjaya mencapai objektif untuk meningkatkan kadar jalur lebar penerima hadapan supaya mencapai frekuansi Giga Hertz iaitu 1.189 GHz.

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LIST OF ABBREVIATIONS

BW - Bandwidth

FSO Free Space Optic

GBW - Gain Bandwidth Product

BJT - Bipolar Junction Transistor

Hz - Hertz

PCB - Printed Circuit Board

TIA - Transimpedance Amplifier

dB - Decibel

LIST OF SYMBOLS

GHz	-	Giga-Hertz
MHz	-	Mega Hertz
Rf	-	Feedback capacitor
Cf	-	Feedback capacitance
f_{cu}	-	Upper critical frequency
f_{cl}	-	Lower critical frequency
r_o	-	Output resistance
r_e	-	Small-signal input resistance between base and emitter (Looking into the emitter)
r_π	-	Small-signal input resistance between base and emitter (Looking into the base)
g_m	-	Transconductance
v_{be}	-	Total instantaneous base-emitter voltage

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CHAPTER 1

INTRODUCTION

1.1 Project Background

The emergence of fiber optic and free space optics (FSO) technologies nowadays has made it as a base in the communication field, replacing the electrical transmission medium. This is because of the demand for higher speed and wider bandwidth in a data communication network. If the fiber optic and FSO system had a bad configuration of optical receiver, it will cause the system to be slow, noisy and a lot of disturbance. All potential disturbances and noise can be addressed through the appropriate network design and planning. The weakest signal level is determined at the front-end receiver and it should be improved by appropriate design. The optimum receiver performance can be achieved depends on the devices and design techniques used [1].

A good sensitivity and a broad bandwidth will invariably use a small area photodiode where the aperture is small. However, free-space optics requires a large aperture and thus, the receiver is required to have a large collection area, which may be achieved by using a large area photodetector and large filter. However, large area of photodetector produces a high input capacitance that will be reduced the bandwidth. Typical large photodetection area commercial detectors has capacitance are around 100-300pF compared to 50pF in fiber link. Hence, techniques to reduce the effective detector capacitance are required in order to achieve a low noise and wide bandwidth design.

This project aims to use Transimpedance Amplifier using BJT transistor with a cascade connection and feedback structure technique, to enhance the bandwidth for front-end receiver, due to successful storey using this technique by various researcher.

1.1 Problem Statements

The weakest front end means that is too noisy and too slow or both. The performance of the optical front end receiver has a significant impact on the overall optical system performance .In order to reduce shot noise in the detector due to ambient light an optical filter is required, whilst the preamplifier should allow shot-noise limited operation. The signal level in an optical receiver is weakest at the front end of the receiver due to the photodetector capacitance. In addition, there are high path loss and background noise in the environment system.

A fundamental requirement in the design of an optical receiver is the achievement of high sensitivity and broad bandwidth. There are several basic configurations such as low-impedance voltage amplifier, high impedance amplifier and transimpedance amplifier. Any of the configurations can be built using contemporary electronics devices such as operational amplifiers (Op-Amp), bipolar junction transistors (BJT), field effect transistors (FET) or high electron mobility transistor (such as CMOS). The receiver performance that is achieved will depend on the devices and design techniques used. In this project presented several techniques to broaden the bandwidth and maximize the receiver performance.

1.2 Project Objectives

The objectives of this project are as follows:

a) To improve front-end receiver performance and enhance the receiver bandwidth.

b) To design the receiver amplifier with the bandwidth enhancement in the range of approximately in Giga hertz using existing Software such as P-spice and Micro-Cap.

c) To develop and fabricate a prototype of the designed receiver amplifier.

1.3 Project Scopes

This project focused on the concept of fiber and wireless optical receiver amplifier communication. The circuit will be designed to meet the objective of having a receiver with bandwidth enhancement capabilities. There are several scopes for this project:

a) The main scope concentrates on this project towards the front-end receiver in a red box, refer to Figure 1.1 below which contains only preamplifier circuit.

b) There are several methods proposed in designing the front-end receiver for this project to improve receiver performance and bandwidth enhancement to perform high gain-bandwidth which are the basic transimpedance amplifier, cascade transimpedance amplifier and multiple gain stage transimpedance amplifier. The simulation results for each technique will be compared where the best performance receiver for wider bandwidth and high gain is chosen to be fabricated as prototype. The proposed design will used of the BJT transistor (BFR540) and amplifier IC(LMH6642).

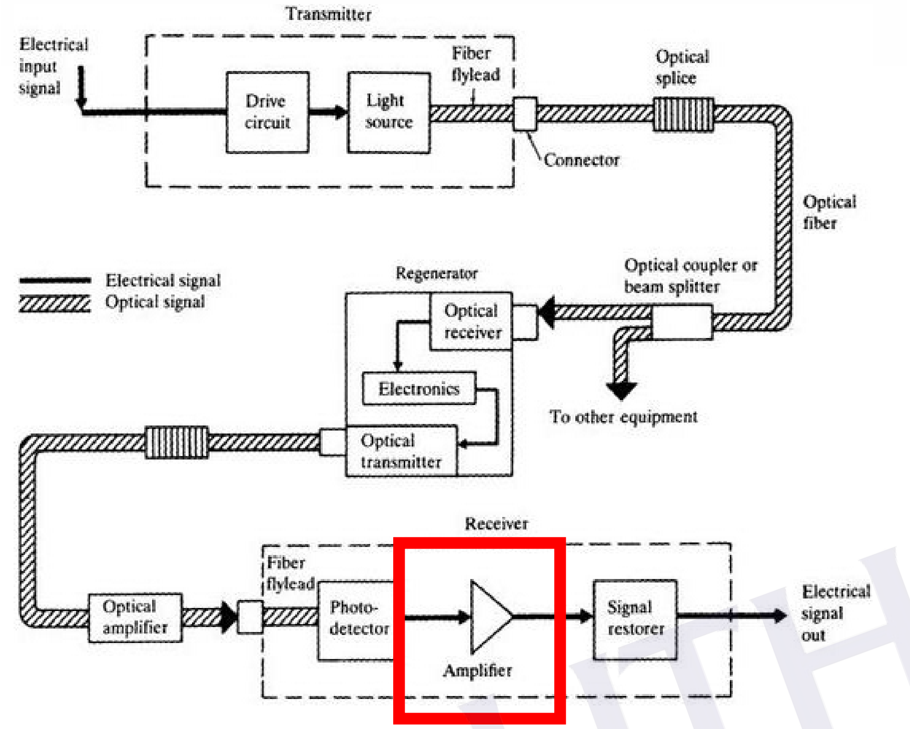


Figure 1.1: Block diagram of fiber optic system [3]

c) The design of receiver amplifier circuit will be simulate using Micro-cap electronic software and Orcad P-spice.

d) The output simulation result using P-spice will be compared with the output prototype circuit to verify the result.

1.5 Thesis Outline

This thesis presents an overview study of several application techniques on designing a front-end optical receiver to improve the receiver performance and bandwidth enhancement in order to obtain high gain-bandwidth. The summaries of each chapter in this project are as follows:

Chapter 1

The objectives and scopes for this project are explained in Chapter1.

Chapter 2

This chapter will present the entire concept or technique that has been used by previous researcher and the theory that will be used in designing this project.

Chapter 3

Chapter 3 will focus on the techniques that will be used in designing this project such as TIA, cascade and multistage technique. This chapter will also present the simulation output of the proposed design circuit using Micro-cap software and Orcad Pspice.

Chapter 4

This chapter will focused on the procedure on how to fabricated the prototype circuit. The fabricated prototype circuit is based on the selected circuit that has been chosen depending on the simulation result which is discussed in Chapter 3. A brief description on the equipments used in experimental work and method used for measurement in this project will be explained in this chapter.

Chapter 5

This chapter discussed the result obtained from experimental test and its practical measurement is presented here.

Chapter 6

All the findings and comparison between software simulation and hardware measurements will be concluded in this Chapter. A summary of this project will be discussed, along with future recommendation for further improvement of this work.

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Concept of Fiber Optic System

A basic optical communication system is well illustrated in Figure 2.1. This system basically same with other communication systems, there is a transmitter, a receiver, and a channel to convey energy from transmitter to receiver. The information to be transmitted to the receiver is assumed to exist initially in an electrical form. The information from the transmitter is combined with the drive signals needed to operate a laser. The laser output is coupled into an optical fiber through which it propagates to the receiver. The receiver may perform optical processing on the incoming signal. The optical processing may correspond to a simple optical filter or it may involve interferometers, the introduction of additional optical fields, or the use of an optical amplifier. Once the received field is optically processed it is detected. The photodetection process generates an electrical signal that varies in response to the modulations present in the received optical field**.** The electrical signal is typically low-level and requires amplification and signal processing for the information to be recovered [4][5].

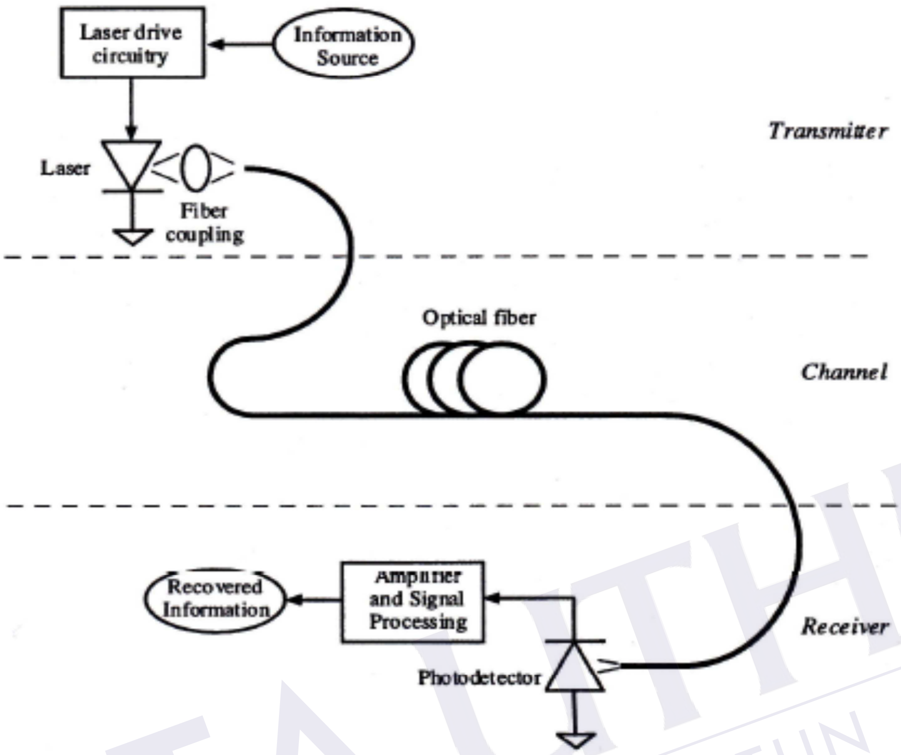


Figure 2.1: Block Diagram of a fiber system [4]

From the previous research, the front-end plays a major role in determining the noise performance of receiver. This research project tends to focus in designing and developing the front end-receiver amplifier.

2.1.1 Architecture of Optical Front-End

Theoretically, the front-end of an optical receiver responds to an optical signal by generating a photocurrent with a photodetector. The photocurrent is then converted into voltage. In order to extract the desired information, the recovered voltage had been process on the electronic signal processing stages. The dimensions of the transfer function associated with the front-end will consequently be volts per amp or ohms. Therefore, the transfer functions of virtually all optical receivers are actually transimpedance in nature.

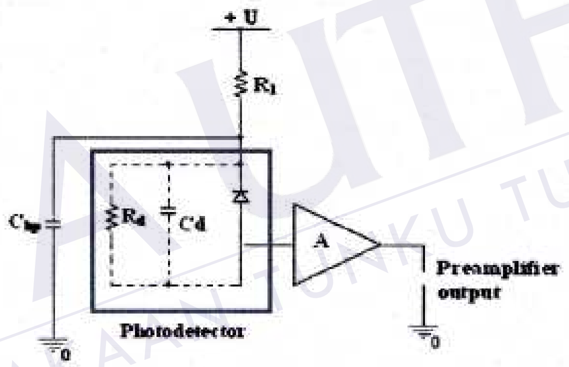


Figure 2.2: Optical Receiver Front-End [2].

The configuration of an optical receiver as shown in Figure 2.2 consists of photodetector which is the fundamental element, followed by amplifiers and signal conditioning circuitry. The optical receiver will convert the optical energy emerging from electrical signal and then to amplify the signal to a large enough value, it will be processed by the electronic circuit following the receiver amplifier.

An optical receiver’s front-end design can usually be grouped into three basic configurations [2]:

a) Low-impedance voltage amplifier
b) High-impedance amplifier
c) Transimpedance amplifier

Any of the configurations can be built using contemporary electronic devices such as operational amplifiers, bipolar junction transistors, field-effect transistors, or high electron mobility transistors. The receiver performance that is achieved will depend on the devices and design techniques used.

2.1.1.1 Low-impedance Voltage Amplifier

A simple optical receiver front-end consists of a photodetector, a load resistor and a low input-impedance voltage amplifier. The photodiode can be either AC coupled or DC coupled to the amplifier as shown in Figure 2.3. In the AC coupled amplifier, a separate load resistor is used to derive a voltage proportional to the photocurrent and to provide a path for the DC photocurrent to flow. The low-frequency components of the photocurrent see a load resistor Rl while the high-frequency see a load resistance that is the parallel combination of Rl and the amplifier input impedance Zin. There are a wide variety of commercially available high gain wideband amplifiers that are AC coupled.

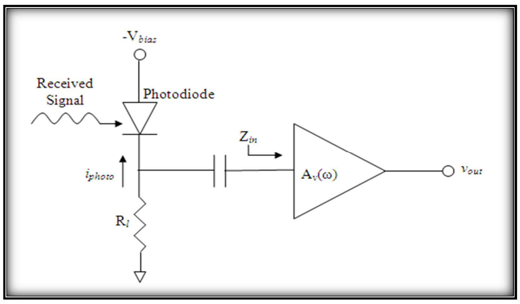


Figure 2.3: AC coupled low-impedance voltage amplifier [4]

2.1.1.2 High-impedance Voltage Amplifier

The high-impedance amplifier is an approach that substantially reduces the effect of the thermal-noise of the load resistor, resulting improved sensitivity. The high-impedance receiver is based on a technique that has been successfully used over other capacitive current sources such as silicon tubes and is descended from vacuum tube amplifiers. Figure 2.4 shows a simple high-impedance amplifier configuration.

The basic design principle is to load the current-source with as large impedance as possible. This will maximize the amount of voltage developed at the input of the amplifier, since the voltage is maximized, the effects of any amplifier noise sources will be reduced. In general, the high-impedance receiver results in the lowest noise baseband front-end that can be realized without extraordinary effort where the low-noise is obtained by making the load resistor as large as possible.

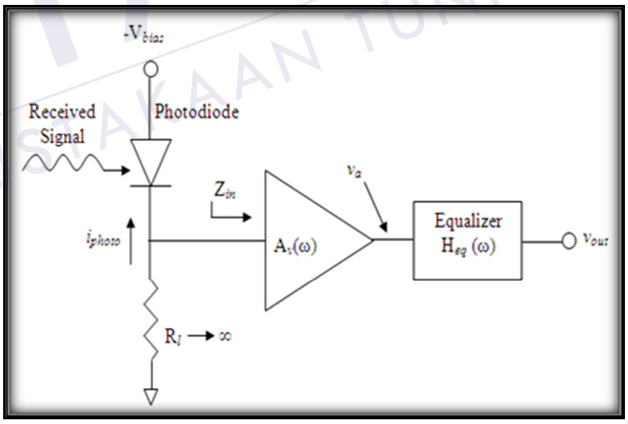


Figure 2.4: High-impedance amplifier [4]

2.1.1.3 Transimpedance Amplifier

Bandwidth is a high priority in transimpedance amplifiers (TIA). Unlike conventional microwave amplifiers, these amplifiers have to maintain an acceptable response down to very low frequencies and still perform satisfactorily at high frequencies. The low frequency response must extend as close as possible to zero Hz. This aspect of the transimpedance amplifiers is usually the primary focus in the design. It is very difficult to maintain a flat gain versus frequency response at low frequencies when the upper frequency goes into the GHz region. Device inadequacies and bias networks commonly limit the lowest achievable frequency.

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. The transimpedance amplifier has a wide range but is limited in noise performance or frequency response.

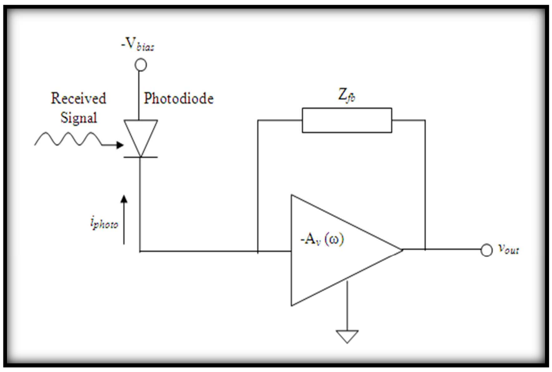


Figure 2.5: Typical circuit configuration of TIA [4].

The standard transimpedance amplifier comprises an op-amp of gain A(s) with feedback resistor, Rf and feedback capacitor, Cf as shown in Figure 2.6. The signal source is represented by a current generator, Id in parallel with a capacitance, Cin and resistance, Rs. The capacitance, Cin, represents both the source capacitance (photodiode capacitance, Cd) and the input capacitance of the op-amp (Cs). Negative feedback causes the op-amp to look at its input terminals and swing its output around so that the external feedback network brings the input differential to zero [6]. The output voltage required to do this is the voltage across the feedback resistor, Rf, this being set by the input current, the majority of which flows through Rf. The advantage of this circuit is that the inverting input is a virtual ground, thus the circuit presents almost zero load impedance to the current source.

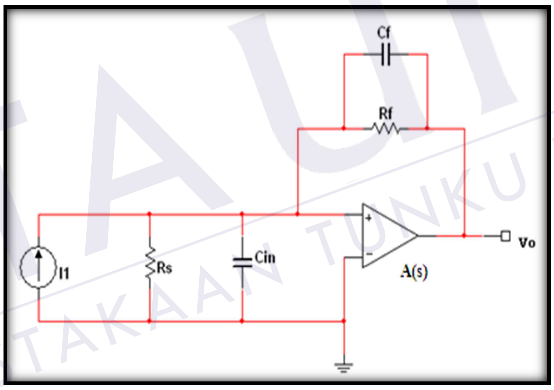


Figure 2.6: The transimpedance feedback amplifier [6]

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 below:

$$A = 1 + \frac{\mathrm{Rf}}{\mathrm{Rs}} \tag{2.1}$$

2.2 Gain Bandwidth Product

One character of amplifier is that the product of the voltage gain and the bandwidth is always constant when the roll- off is -20dB/decade. This characteristic is called the gain-bandwidth product. Let’s assume that the lower critical frequency of a particular amplifier is much less than upper critical frequency, $f_{cl} << f_{cu}$.

The bandwidth can then be approximated as BW $= f_{cu} - f_{cl} \cong f_{\ cu}$

The simplified Bode plot for this condition is shown in Figure 2.7 below.Notice that f_{cl} is neglected because it is so much smaller than f_{cu}, and the bandwidth approximately equal f_{cu}. Beginning at f_{cu}, the gain rolls off until unity gain (0 dB) is reached. The frequency at which amplifier’s gain is 1 is called the unity gain frequency, f_T. The significant of f_T is that it always equal the product of the midrange voltage gain times the bandwidth and is constant for given transistor [7].

$$f_T = \text{Av(mid)BW} \tag{2.2}$$

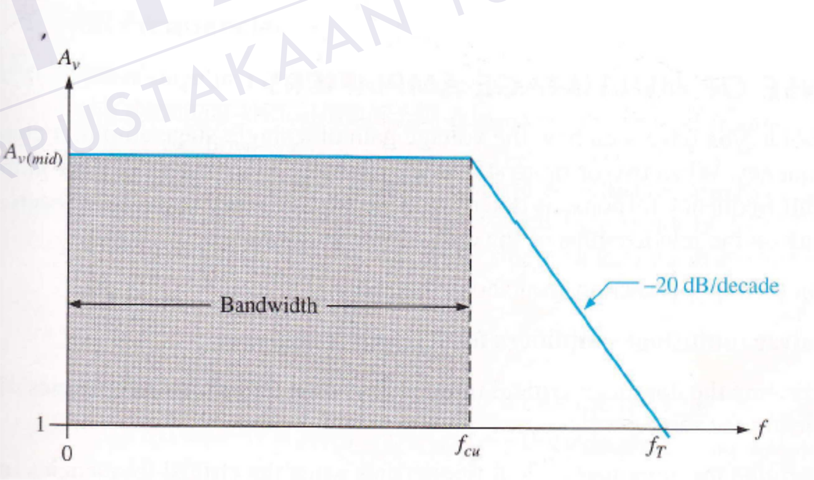


Figure 2.7: Simplified response curve where f_{c1} is negligible(assume to be zero) compare to f_{cu} [7]

2.3 Transistor Amplifier Analysis and Small Signal Model

Small signal model is using to determine the transistor amplifier characteristic such as Gain. The ability of small-signal BJT circuit models makes the analysis of transistor amplifier circuits a systematic process. The process consists of the following steps [8]:

1. Determine the dc operating point of the BJT and in particular the dc collector current Ic.
2. Calculate the values of the small-signal model parameters : $g_m = \frac{Ic}{V_T} = \frac{\beta}{g_m}$ and $r_e \cong \frac{V_T}{I_E} \cong \frac{1}{g_m}$
3. Eliminate the dc source by replacing each dc voltage source with a short circuit and each dc current source with an open circuit.
4. Replace the BJT with one of its small-signal equivalent circuit models. Although any one of the models can be used, one might be more convenient than the others for the particular circuit being analyzed.
5. Analyzed the resulting circuit to determine the required quantities (e.g., voltage gain, input resistance).

There are two type of basic small-signal model which is ‘Hybrid-π Model’ and ‘T Model’.

2.3.1 Hybrid-π Model

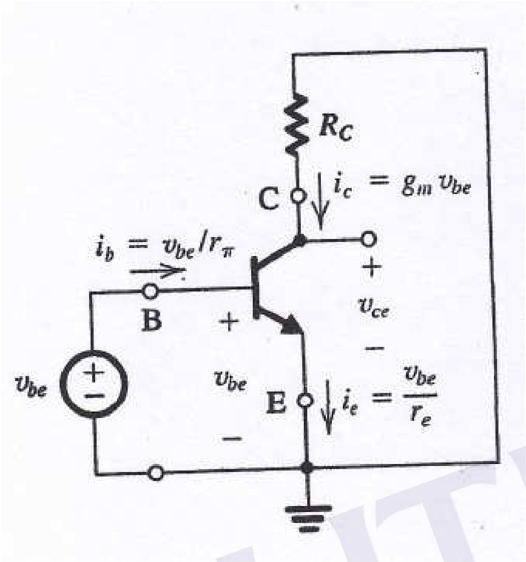


Figure 2.8: The amplifier circuit with dc source V_{BE} and V_{CC} eliminated (short circuit) [8].

An equivalent circuit model for BJT is shown in Figure 2.8. This model represents the BJT as a voltage-controlled current source and explicitly includes the input resistance looking into the base, r_π. The model obviously yields $i_c = g_m\, v_{be}$ and $Ib = \frac{v_{be}}{r_\pi}$. Not so obvious, however, is the fact that the model also yields the correct expression for i_e. This can be shown as follow;

Emitter node:

$$i_e = \frac{v_{be}}{r_\pi} + g_m V_{be} = \frac{v_{be}}{r_\pi}(1 + g_m r_\pi)$$

$$i_e = \frac{v_{be}}{r_\pi}(1 + \beta) = \frac{v_{be}}{\frac{r_\pi}{1+\beta}} \qquad (2.3)$$

A slight different equivalent circuit model can be obtained by expressing the current of the controlled source ($g_m v_{be}$) in terms of the base current i_b as follows:

$$g_m v_{be} = g_m(i_b r_\pi) = (g_m r_\pi) i_b = \beta i_b \qquad (2.4)$$

This results in the alternative equivalent circuit model show in Figure 2.9(b). Here the transistor is represented as current-controlled current source, with the control current being i_b. The two model of Figure 2.9 are simplified version of what is known as the Hybrid-π Model. This is most widely used model for BJT [8].

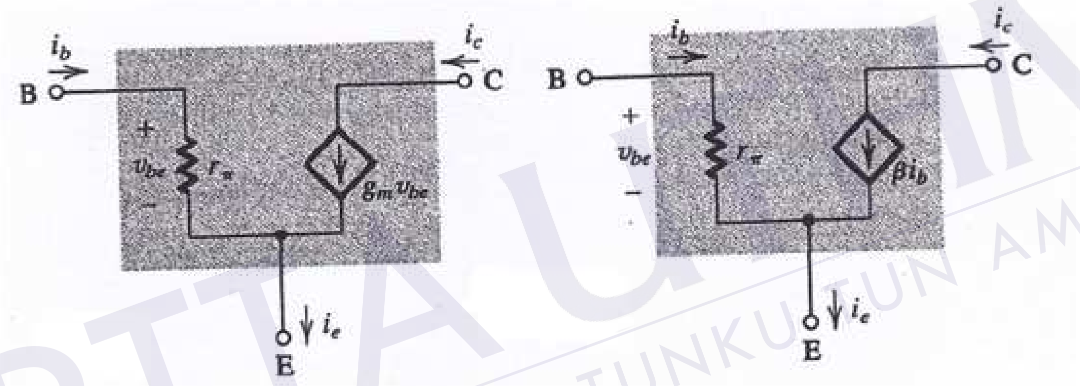


Figure 2.9: (a) BJT as a voltage-controlled current source (a transconductance amplifier) (b) BJT as a current-controlled current source (a current amplifier)[8].

It is important to note that the small-signal equivalent circuits of Figure 9 model the operation of BJT at a given bias point. This should be obvious from the fact that the model parameters g_m and r_π depend on the value of the dc bias current i_c. Finally, although the models have been developed for an npn transistor, they apply equally well to pnp transistor with no change of polarities.

The output resistance r_o should be added if the circuit amplifier is considering the early effect. The early effect causes the collector current to depend not only on VBE but also on VCE. The dependence on VCE can modeled by assigning a finite output resistance to the controlled current-source in the 'Hybrid-π Model' as shown in Figure

2.10 .Its value is given by $r_o \cong V_A/i_c$, where V_A is the early voltage and i_c is the collector dc bias current.

The output voltage becomes;

$$V_o = -g_m v_{be}(R_c//r_0) \tag{2.5}$$

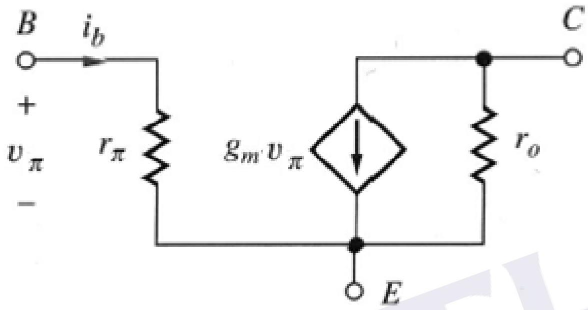


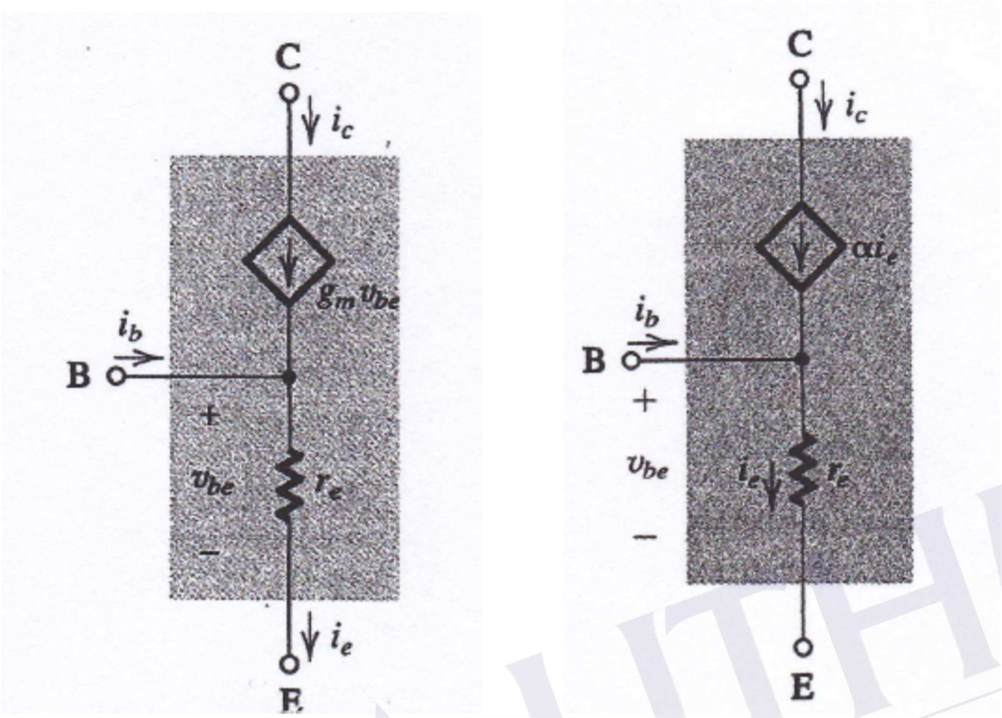
Figure 2.10: Hybrid-π Model with the resistance r_0 included [8].

2.3.2 T Model

Although the hybrid-π model can be used to carry out small-signal analysis of all transistor circuit, there are situations in which an alternative model, shown in Figure 2.11. This model, called the T model. The T model of Figure 2.11 (a) represents the BJTas a voltage-controlled current source with the control voltage being v_{be}. However, the resistance between base and emitter, looking into the emitter, is explicitly shown. From the Figure. 2.11(a) we see clearly that the model yields the correct expressions for i_c and i_e. For i_b we note that at the base node we have;

$$i_b = \frac{v_{be}}{r_e} + g_m v_{be} = \frac{v_{be}}{r_e}(1 - g_m r_e)$$

$$i_b = \frac{v_{be}}{r_e}(1+\alpha) = \frac{v_{be}}{r_e}\left(1 - \frac{\beta}{\beta+1}\right) = \frac{v_{be}}{(\beta+1)r_e} = \frac{v_{be}}{r_\pi} \tag{2.6}$$



(a) (b)

Figure 2.11: T model of BJT (a) BJT as a voltage-controlled current source (b) BJT as a current-controlled current source[8].

If in the model Figure 2.11 (a) the current of the controlled source is expressed in terms of emitter current as follows:

$$g_m v_{be} = g_m(i_e r_e) = (g_m r_e) i_e = \alpha i_e \qquad (2.7)$$

obtained the alternative T-model shown in Figure 2.11(b). Here the BJT is represented as current-controlled current source but with the control signal being i_e [8].

The Hybrid-Π and the T circuit models are equivalent, because they both will result in the same correct answer.

2.4 Previous Research Review

This section present the past research based on bandwidth enhancement. Previous design method and technique have been developed by designer had been compared as a guided to design the front-end receiver and in order to achieved the project objective.

2.4.1 First Review

Author:	Reza Samadi and Aydın Ilker Karsilayan.
Project Title:	Uniform Design of Multi-Peak Bandwidth Enhancement Technique for Multistage Amplifiers
Summary:	This paper introduces a new technique for designing uniform multistage amplifiers (MAs) for high-frequency applications is introduced. The proposed method uses the multi-peak bandwidth enhancement technique while it employs identical, simple and inductorless stages. The intrinsic capacitances within transistors are exploited by the active negative feedbacks to expand the bandwidth. While all stages of the proposed MA topology are identical, the gain-bandwidth product can be extended several times. Using the proposed topology, a six-stage amplifier in TSMC 0.35- m CMOS process was designed. Measurement results show that the gain can be varied between 16 and 44 dB within 0.7–3.2-GHz bandwidth with less than 5.2-nV Hz noise. Die area of the amplifier is 175 m 300 m. Performance of these systems is usually affected by bandwidth and gain limitation of amplifiers. High voltage gain from dc to several gigahertz frequencies is acquired by cascading several gain stages in the form of multistage amplifiers (MAs). A new topology entitled the chained MA (CMA), which uses the peaking technique to expand the bandwidth while the topology

can be implemented uniformly. Due to active feedback, amplifier sections can be designed with low quality factors and with no inductors. In addition, CMA exploits the intrinsic capacitance within the transistors to push output pole of each stage to a higher frequency. The topology of CMA offers several advantages such as improved performance and gain-bandwidth product that make the proposed structure suitable for optical communications.

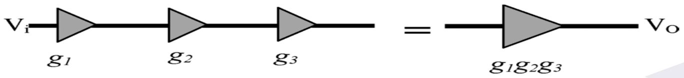


Figure 2.12: Three-stage conventional MA

A typical MA can be designed by cascading simple gain stages. Figure 2.12 above illustrates a three-stage MA consisting of three forward amplifiers with gains of g_1, g_2 and g_3 where the overall gain is $g_1g_2g_3$.

Topology of the proposed amplifier is illustrated in Figure 2.13. The overall structure consists of identical forward amplifiers with identical active feedbacks . The transfer function of the uniform -stage CMA can be obtained as shown as Figure 2.14 where L(s) = g(s)f(s) is the loop gain [9].

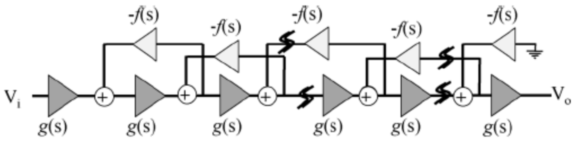


Figure 2.13: Topology of the proposed MA[9].

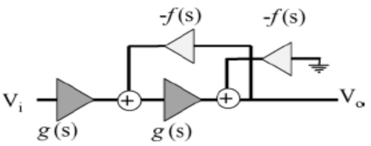
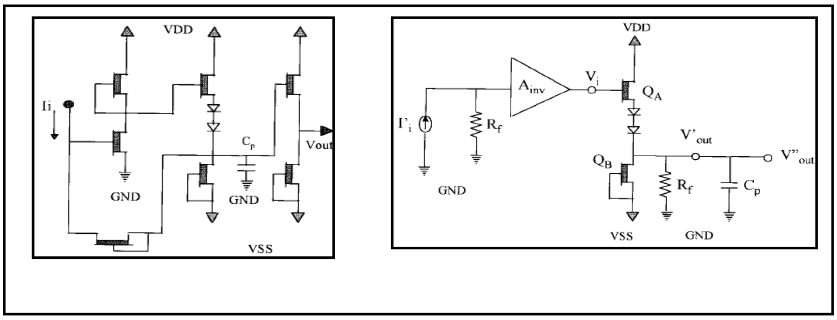


Figure 2.14: Topology of the uniform 2-stage CMA[9].

2.4.2 Second Review

Author:	Feng-Tso Chien and Yi-Jen Chan
Project Title:	Bandwidth Enhancement of Transimpedance Amplifier by a Capacitive-Peaking Design
Summary:	From the research paper the author is proposing a capacitive-peaking (C-peaking) technique, instead of inductive peaking, to increase the bandwidth of a transimpedance amplifier. The reports of a peaking technique using capacitors are very few. Although some different types of the capacitance peaking have been proposed previously. An optoelectronic receiver, which usually consists of a photodetector and a transimpedance amplifier, is used to convert the optical signals into electrical signals in the front end of optical fiber communication. Based on that fact, we can design a larger bandwidth of a transimpedance amplifier. From this paper, they only discuss the idea of capacitor peaking technique and also derive an analytical method to predict the amplifier performance. A TZ amplifier can be represented as a shunt shunt feedback amplifier, and the transfer function of this circuit is given by: $Z_T(s) \equiv \frac{V_{\text{out}}}{I_i}(s) = \frac{A(s)}{1 + A(s)\beta(s)}$ $\left(\beta(s) = -\frac{1}{Z_f(s)} = -\frac{1 + sC_f R_f}{R_f}\right)$ Where A(s) is the open-loop transfer function of the TZ amplifier and β(s) is the feedback transfer function or simply a feedback factor. Rf is the effective feedback resistance and Cf is the parasitic capacitance associated with Rf [9]. Figure. 2.15(a) shows the schematic circuit of this C-peaking TZ amplifier. In order to analyze the peaking effect resulting from this peaking capacitor first, they derive the open-loop

transfer functions before and after adding the respectively. Figure 2.15(b) shows the equivalent open-loop circuit of a TZ amplifier.

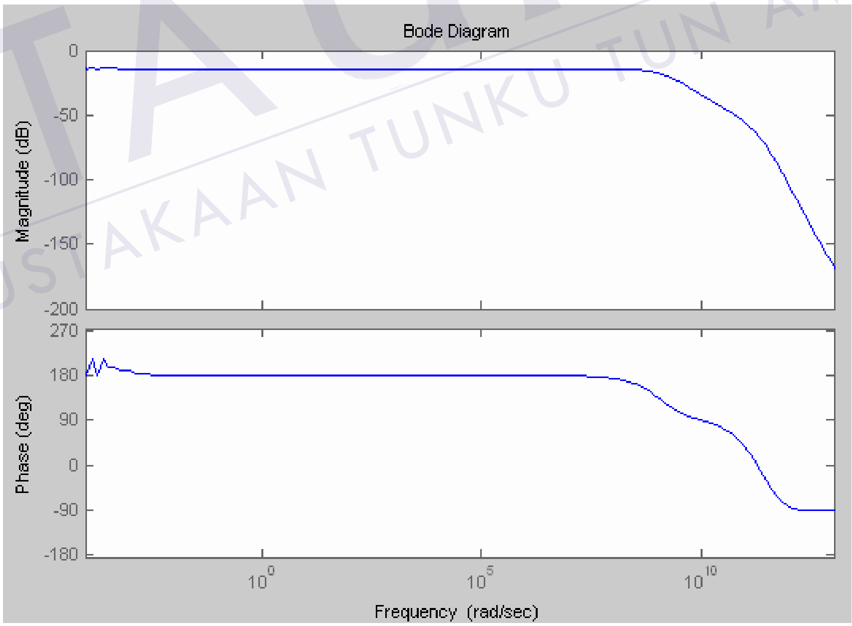


(a) (b)

Figure 2.15: (a) Circuit schematic of C-peaking transimpedance amplifier. (b) Equivalent open-loop circuit of transimpedance amplifier with and without a peaking capacitor [10].

Based on the analytical calculation, a Butterworth-type TZ amplifier can be realized to increase its bandwidth. The measured TZ amplifiers demonstrate a linear gain of 0.95 K with a wide dynamic injected current. The 3-dB bandwidth of the TZ amplifier is enhanced from 1.1 to 2.3 GHz by a C-peaking design without sacrificing its low-frequency gain. This approach provides an easy way to enhance the bandwidth of an optical receiving front end without further investing any sophisticated process equipment [10].

2.4.3 Third Review

Author :	Siti Sara binti Rais, UTM
Project Title:	Optical Receiver Bandwidth Enhancement Using Bootstrap Transimpedance Amplification Technique
Summary:	In this project, modeling and analysis the bootstrap transimpedance amplifier (BTA) of front-end receiver for input capacitance reduction has been simulated. This technique improved TIA bandwidth up to 1000 times with an effective capacitance reduction technique for optical wireless detector. Shunt-series BTA model produced 982MHZ bandwidth for large Cd (100pF).  Figure 2.16: Frequency Response of Series-Shunt Bootstrap [5].

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