



**UNIVERSITI PUTRA MALAYSIA**

**DESIGN OF AN OPTICAL RECEIVER FOR THE FIBER TO THE  
HOME (FTTH) SWITCH**

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**DESIGN OF AN OPTICAL RECEIVER FOR THE FIBER TO THE HOME  
(FTTH) SWITCH**

**By**

**MOHD HANIF BIN YAACOB**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,  
in Partial Fulfillment of the Requirement for the Degree of Master of Science**

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**DESIGN OF AN OPTICAL RECEIVER FOR THE FIBER TO THE HOME (FTTH) SWITCH**

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**Chairman: Associate Professor Borhanuddin Mohd Ali, Ph.D.**

**Faculty: Engineering**

Fiber to the home (FTTH) architecture provides the full set optical telecommunication services (narrowband and broadband) up to customer premises across the local access services. The main challenge to the realization of FTTH is the cost. However, as the installation cost of the optical fiber technology decreases, FTTH started to gain its reputation as the future communication infrastructure. Once implemented, FTTH architecture needs to maintain its reliability and connectivity. These responsibilities are given to FTTH switch; a network device in the FTTH network that provides very fast inter-connectivity and excellent backup features. One main component of the switch is the optical receiver to receive the optical signal from any locations, either from the central office or the premises and convert the signal to its electrical form to be processed by the switch. Therefore, the objective of the research is to design the optical receiver for the FTTH switch.

In this thesis, the intended bandwidth by the receiver is specified at 155 MHz. The other performance parameters concerned are signal to noise ratio (SNR) and sensitivity. The main components of the receiver are PIN photodetector, transimpedance



amplifier and post amplifier. PIN photodetector is used as the optical detector to convert the optical signal into its electrical form. Meanwhile, transimpedance amplifier is the photocurrent to voltage converter. The function of the post amplifier is to amplify the electrical signal. Besides that, additional circuit configuration and topology are applied to improve the performance of the receiver.

The optical receiver design was broken into a few modules. Each of them was developed step by step based on two approaches. They are software simulation and hardware implementation (experiment). The receiver performance was analysed based on the results produced by each approach.

The final results on the optical receiver system show that the performance standard (155 MHz bandwidth) was achieved by the simulation approach. However the experiment only manage to support the bandwidth around 126 MHz. The SNR and sensitivity measured from the experimental circuit also give a lower performance compared to the simulation.

Based on the experimental results, a few solutions are suggested to increase the optical receiver performance. Meanwhile, the application of the designed optical receiver in the other area is also investigated.



Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains

**REKABENTUK PENERIMA OPTIK UNTUK SUIS “FIBER KE RUMAH”  
(FTTH)**

Oleh

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Senibina fiber ke rumah (FTTH) menyediakan satu set lengkap perkhidmatan telekomunikasi optik (jalur sempit dan jalur luas) sehingga ke premis pelanggan melalui perkhidmatan capaian tempatan. Cabaran utama untuk menjalankan FTTH ialah kos. Walau bagaimanapun, disebabkan kos prasarana teknologi fiber optik semakin menurun, FTTH mulai mendapat tempat sebagai infrastruktur komunikasi masa hadapan. Apabila diimplementasi, senibina FTTH perlu mempertahankan kebolehpercayaan dan kesalinghubungannya. Tugas-tugas ini diserahkan kepada suis FTTH; satu peranti rangkaian di dalam rangkaian FTTH yang menyediakan kesalinghubungan yang pantas dan ciri sandaran yang cemerlang. Salah satu komponen suis ini ialah penerima optik yang menerima isyarat optik dari mana-mana lokasi, tidak kira dari pejabat pusat atau premis dan menukarkan isyarat optik tersebut kepada bentuk elektrik untuk diproses oleh suis. Oleh itu, objektif penyelidikan ini adalah untuk merekabentuk satu penerima optik untuk suis FTTH.

Di dalam tesis ini, lebar jalur yang diinginkan oleh penerima optik ditetapkan pada 155 MHz. Parameter prestasi lain yang diambil berat adalah nisbah isyarat ke



hingar (SNR) dan kepekaan. Komponen utama penerima adalah pengesan cahaya PIN, penguat antara-galangan dan penguat pasca. Pengesan cahaya PIN digunakan sebagai pengesan optik untuk menukarkan isyarat optik kepada bentuk elektrik. Sementara, penguat antara-galangan ialah penukar arus cahaya kepada volt. Fungsi penguat pasca pula adalah untuk menguatkan isyarat elektrik tersebut. Selain itu, konfigurasi litar dan topologi tambahan juga digunakan untuk meningkatkan prestasi penerima.

Rekabentuk penerima optik dipecahkan kepada beberapa modul. Setiap satu daripadanya dimajukan langkah demi langkah berdasarkan dua pendekatan. Pendekatan tersebut adalah simulasi perisian dan implementasi perkakasan (eksperimen). Prestasi penerima dianalisa berdasarkan keputusan yang dihasilkan oleh setiap pendekatan.

Keputusan akhir sistem penerima optik menunjukkan piawai prestasi (lebarjalur 155 MHz) telah dicapai oleh pendekatan simulasi. Walau bagaimanapun, eksperimen hanya mampu menyokong lebarjalur sekitar 126 MHz. SNR dan kepekaan yang diukur dari litar eksperimen juga menunjukkan prestasi yang lemah berbanding simulasi.

Berdasarkan keputusan eksperimen, beberapa penyelesaian dicadangkan untuk meningkatkan prestasi penerima optik. Pada masa yang sama, aplikasi penerima optik yang dicipta di dalam bidang lain juga diteroka.

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I certify that an Examination Committee met on 5<sup>th</sup> August 2002 to conduct the final examination of Mohd Hanif bin Yaacob on his Master of Science thesis entitled "Design of an Optical Receiver for the Fiber to the Home (FTTH) Switch" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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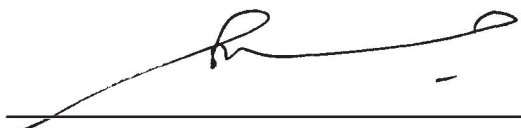
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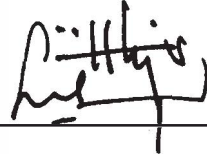
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## DECLARATION

I hereby declare that the thesis is based on my original work except for the quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.



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**MOHD HANIF BIN YAACOB**

Date: 14/10/02

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## LIST OF ABBREVIATIONS

AC	-	Alternating Current
APD	-	Avalanche Photodiode
ATM	-	Asynchronous Transfer Mode
BNC	-	Bayonet Neil-Concelman/British Naval Connector
DC	-	Direct Current
EMI	-	Electromagnetic Interference
ESD	-	Electrostatic Discharge
FDDI	-	Fiber Distributed Data Interface
FTTH	-	Fiber To The Home
GBWP	-	Gain Bandwidth Product
LSBW	-	Large Signal Bandwidth
NEB	-	Noise Equivalent Bandwidth
NEP	-	Noise Equivalent Power
OLT	-	Optical Line Termination
ONU	-	Optical Network Unit
OOK	-	On-Off Keying
Op amp	-	Operational Amplifier
PBX	-	Private Branch Exchange
PCB	-	Printed Circuit Board
PD	-	Photodiode
PIN	-	$p$ - $n$ junction with intrinsic region, $i$
PN	-	$p$ - $n$ junction
POTS	-	Plain Old Telephone Service
RJ11	-	Registered Jack 11



- RJ45 - Registered Jack 45
- SMC - Simple Miller Compensation
- SNR - Signal to Noise Ratio
- STM-1 - Synchronous Transfer Mode 1



## LIST OF NOTATIONS

$\eta$	-	Quantum Efficiency
$\omega$	-	Operating Frequency (Radian)
$\lambda$	-	Operating Wavelength
$A_v$	-	Voltage Gain
$B$	-	Bandwidth
$B_n$	-	Noise Bandwidth
$C_a$	-	Amplifier Capacitance
$C_d$	-	Detector Capacitance
$C_D$	-	Detector Capacitance
$C_{EL2075}$	-	Elantec Amplifier Capacitance
$C_f$	-	Feedback Capacitor
$C_{in(CM)}$	-	Common Mode Input Capacitance
$C_{in(Diff)}$	-	Differential Input Capacitance
$C_T$	-	Total Capacitance
$e$	-	Electronic Charge ( $1.6 \times 10^{-19}$ )
$f$	-	Varied Input Frequency
$G$	-	Open Loop Gain
$h$	-	Planck's Constant ( $6.626 \times 10^{-34}$ )
$H_{CL}$	-	Closed Loop Transfer Function
$i_a$	-	Total Amplifier Noise
$i_{amp}$	-	Amplifier Input Leakage Current
$I_d$	-	Dark Current
$i_D$	-	Dark Current Noise
$i_{det}$	-	Photodetector Current



$i_f$	-	Feedback Current
$i_n$	-	Total Noise
$I_p$	-	Output Photocurrent
$i_s$	-	Shot/Quantum Noise
$i_t$	-	Thermal Noise
$K$	-	Boltzmann's Constant
$P_{ES}$	-	Electrical Output Signal Power
$P_N$	-	Total Noise Power
$P_o$	-	Incident Optical Power
Q factor	-	Quality Factor
$R$	-	Responsivity
$R_o$	-	Output Resistance
$R_a$	-	Amplifier Input Resistance
$R_b$	-	Detector Bias Load
$R_f$		Feedback Resistor
$R_L$	-	Load Resistor
$R_M$	-	Nulling Resistor
$R_T$	-	Total Resistance
$R_{TL}$	-	Total Parallel Resistances (Bias And Amplifier Resistances)
$T$	-	Absolute Temperature
$v$		Velocity of light ( $2.998 \times 10^8 \text{ ms}^{-1}$ )
$V_{amp}$	-	Amplifier Input Noise Voltage
$V_{bias}$	-	Bias Input Voltage
$V_{in}$	-	Input Voltage
$V_{out}$	-	Output Voltage
$V_p$	-	Peak Output Voltage



$V_{p-p}$	-	Peak-To-Peak Output Voltage
$V_{rms}$	-	Root Mean Square Output Voltage
$Z$	-	Impedance
$Z_c$	-	Capacitor Impedance



# CHAPTER 1

## INTRODUCTION

In this chapter, the background of fiber optics communications are given to provide the motivation that leads to the research area. It also provides the overview of the research area and its accomplishment.

### 1.1 Future Media in Telecommunication Network

The period of 21<sup>st</sup> century promise a further shift in the telecommunication technology from the conventional electrical copper-based system to the increasingly popular optical fiber-based system. An important breakthrough in the making of the commercialised fiber optic cable by the scientists at Corning Glass Work in 1970 had lead to an optimistic future of optical fiber telecommunication system (Hecht, 1999). Since then, optical fibers gained its popularity and started to be used widely by the telecommunication companies especially as the backbone for the intercity communication network. The Internet had pushed further the popularity of the optical telecommunication. The explosive growth of the Internet has had a dramatic impact on the communication network. The popularity of networking together with the increase in demand for multimedia over the Internet are forcing the network to deliver more bandwidth to the users with more reliable and secure connections. The bandwidth will always be a scarce resource in the future, as new services will emerge and more and more people shift from using traditional communication equipment to Internetworking facilities (Rantanen, 1998). Optical fiber technology is without doubt the media that can fulfil all the demands.

