

Design and Implementation of Optical Receiving Bipolar ICs for Optical Links

Sang-Yep Nam *, Woo-Young Ohm **, Won-Seok Lee ***, and Sang-Yeoul Yi ****

* Dept of Information & Communication, Kyung Moon College, Kyungki-do, 459-070, Korea

Tel : +82-31-610-8122 Fax ; +82-31-610-8120 E-mail: r13337@unitel.co.kr

**Dept of Digital Electronics & Information, Inha Technical College, Incheon-si, 980-1234, Korea

Tel : +82-32-870-2216 Fax : +82-32-870-2508 E-mail: wyohm@inhac.ac.kr

*** Dept of Electronics, Dongyang Technical College, Seoul, 155-8611, Korea

Tel : +82-2-2610-1781 Fax : +82-2-2610-1854 E-mail: wslee@dongyang.ac.kr

**** ICSUN , Seongnam-shi, Kyeongki,-do, 461-713, Korea

Tel : +82-00-111-2345 Fax : +82-00-111-6789 E-mail: ysy@icsun.co.kr

Abstract A design was done, and all characteristic of photodetector of the web pattern type which a standard process of the Bipolar which Si PIN structure was used in this paper, and was used for the current amplifier design was used, and high-speed, was used as receiving optical area of high altitude, and the module which had a low dark current characteristic was implemented with one chip with a base. Important area decreases an area of IC at the time of this in order to consider an electrical characteristic and economy than the existing receiving IC, and performance of a product and confidence are got done in incense. First of all, the receiving IC which a spec, pattern of a wafer to be satisfied with the following electrical optical characteristic that produced receiving IC of 5V and structure are determined, and did one-chip is made. On the other hand, the time when AR layer of double is $\text{Si}_3\text{N}_4/\text{SiO}_2=1500/1800$ has an optical reflectivity of less than 10% on an incidence optical wavelength of 660 nm, and, in case of photodetector which reverse voltage made with 1.8V runs in 1.65V, an error about a change of thickness is very the thickness that can be improved surely. And, as for the optical current characteristic, about 5 times increases had the optical current with 274nA in 55nA when P_c was -27dBm. A BJT process is used, and receiving IC running electricity suitable for low voltage and an optical characteristic in minimum 1.8V with a base with two phases is made with one chip. IC of low voltage operates in 1.8V and 3.0V at the same time, and optical link receiving IC is going to be implemented

Keyword; Receiver IC, Bipolar process, SPICE, optical link, APF, Web-pattern, photodetector

1. INTRODUCTION

Currently optical use is increased trend in a multimedia field according to industrial altitude, high reliability. It was done an appearance the Optical Link which can be transmitted to between systems with working digital development and progress of related equipment by digital broadcasting, Internet spread. An application field is used by the Home Network, car internal Network(MOST), LAN, WAN back which used AC3 Amp, IEEE 1394B of audio. A solution of Receiving IC gets integrated done by one chip like photodetector, and a circuit design uses SPICE. And a standard element is made, and important area tries confirmation, and level shifter, Latch, HPF, Push full is used, and $2V_{BE}$ is overcome, and layout of an element is arranged with optimum, and optical Noise is minimized. The consumption current which is principal performance of a product and an action frequency and reliability are improved, and the element development that

use is possible is made target by commerce. First of all, an actualization order of Receiving IC implements the photodetector which optimized Pattern and Structure.

A BJT process is used with the receiving IC which element simulation is used before starting a process, and electricity and an optical characteristic are

checked, and operate in minimum 1.8V, and photodetector area and amplifier area are made with a design with one chip

2. PHOTODETECTOR

Configuration of an Optical Link system seems to be Fig. 1, and configuration is transmitting module and receiving module and optical fiber of a transmission track.

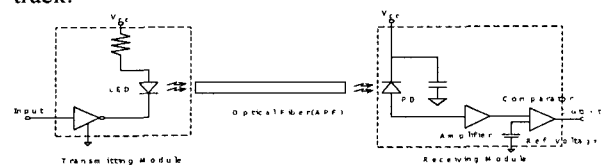


Fig. 1. Optical link A Optical link system

Transmitting module converts an electrical signal into optical signal. Configuration becomes LED or LD and light source driver IC. Receiving module is composed of receiving IC (Rx; photodetector and amplifier IC) and housing. Photodetector of the inside, high reliability and optical link to have a low dark current characteristic is made with a design in this paper.

And IC to amplify exchanged an electric current displayed in photodetector for a voltage, and IC was included, and was made from one chip.

Photodetector of PIN type is having a lot of merit to use for a product of consumer than APD. Therefore, red light is suitable for a search of a wavelength of the 670nm which is used mainly for CD or LD player, and can be seen. It is necessary for coating to do the matter which has suitable refractive index and suitable thickness on the face in order to reduce a reflectivity because AR (antireflection layer) layer has the influence that small, face reflection to occur in air and semiconductor layer does a sensitiveness. It is a AR layer coating, and this coating is played. Reflection prevention layer must be made on the stomach in order parameter field that must be considered when integrate photodetector to have become is designed reduces a reflectivity of the light that incidence does first, and to do a sensitivity greatly.

Various process parameter must be optimized for an action speed and an elevation of a sensitiveness. It is necessary for coating to do a medium to have suitable refractive index and suitable thickness on the face in order to reduce a reflectivity because light reflected in photodetector of PIN type has an influence small, to do responsibility. This coating is classified into an AR coating, double-layer AR coating, multi layer AR coating.

3. A DESIGN OF PHOTODETECTOR AND A SIMULATION.

Simulation was used with Si photodetector, and a general characteristic and inclination were analyzed in order to realize receiving module of optical link with Bipolar IC. This is structural fitness and a process of a process former level to recognize electricity and an optical characteristic of an element of photodetector to make receiving module with one chip.

Table 1. A physical parameter of photodetector for simulation

Joint construction	circle type, web type
Wafer orientation	<111>
Epi th	10 , 12 , 14
Epi Density	3.7×10 ¹⁴ /cm ³ , 1.1×10 ¹⁵ /cm ³ , 1.5×10 ¹⁵ /cm ³
Epi Impurities	P(phosphorus)
p+ Joint depth	0.8
p+ Density	1.6×10 ¹⁹ /cm ³
B/L density	3×10 ¹⁹ /cm ³
B/L Impurities	Arsenic

A reverse direction and a forward current - voltage characteristic can know an almost similar thing regardless of shape an I-V characteristic to have been based on a junction shape of the simulation element which worked. The maximum value shows an almost similar characteristic with a curve to show spectral response based on a junction shape, but a characteristic of time for a wavelength of light to be small can know that red light is distinguished in web type. Web pattern is showing this that optical current streamed very

much in a short wavelength. However, a change happened in 350nm or above is later current is suddenly increased, and a current characteristic is almost same, and is appearing in 700nm neighborhood. Electric field curve and lines to follow perpendicularly show a border of depletion layer in the middle by a electric field distribution to have obeyed a reverse voltage price in unit cell of web structure. Optical current is influenced, and thickness is large, and current streams greatly, and epi thickness can see that approximately 210nA stream down about 700 maximum current in an optical wavelength of nm. This current shows line current value. And number pA flow through a dark current when reverse voltage is 5 V. Therefore, an element designed in this study can know that signal disconnection ability is desirable on digital optical signal. 670nm showing red light is not the maximum value near, but current size is so, and, as for the optical signal current of a designed element, a margin can know a lot of things in 650nm 750nm. Therefore, that high optical signal current can be expected when 670nm neighboring optical signal is received, and thickness of EPi layer is large, and optical seems to be turned into current on absorption, and an increase was done can be known. As the result web type photodetector designed in this study is suitable for bipolar technology, and compare to former circle type photodetector, and red light is distinguished for an electrical characteristic, and red light is appearing. Also, fast change time can be expected when low junction capacitance is owned by decrease of an effective junction area, and According to this a high-speed signal is dealt with.

4. A RECEIVING IC CIRCUIT DESIGN OF LOW VOLTAGE.

An IC standard needs the characteristic that the absolute maximum rating, is electrical, a PIN diode characteristic in order to implement receiving IC. The receiving IC designed photodetector and preamplifier with the target which got integrated done by one chip. If integrated does cell of photodetector of a diameter of 500 , a reverse photocurrent flow the dirt which received light by about 100nA- 500nA, and a dark current of less than 1nA flow time for light not to be.

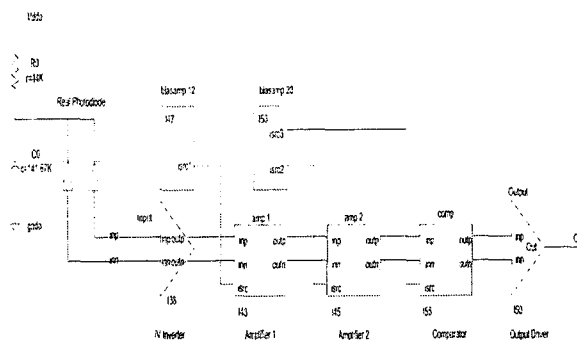


Fig. 2. A receiving IC block

Therefore, a photocurrent of the photodetector which preamplifier was going to amplify was called so

that at least approximately 50nA worked. A block of receiving IC is this in Fig. 2, too. This IC is composed of an input unit, amplifier, comparator, output unit. Input unit lets convert current into a voltage function. It is a device letting amplify a few 10 times in a voltage signal converted in input unit in amplifier unit. Comparator unit lets convert a displayed analog signal of amplifier unit into a digital signal of a logic level. A digital signal of a TTL level is displayed in the last in output unit. The HPF(high pass filter), level shifter and the output drive unit especially carried out a design for problem conquest in particular when was designed with low voltage. Only an AC component of a differential amplifier amplifies HPF, and a capacitor price of this part lets there be a lot of influences by a delay in a total circuit. There is a bias circuit on configuration with start-up and current source as a circuit to supply circuit everyone with constant current. An I-V conversion lets convert current coming in photodetector into a voltage. If the input current 250nA which is replaced with constant current source when a simulation is done because there is not a SPICE library of photodetector, and did typical of photodetector is authorized, an output voltage becomes 5mV because a feedback resistance is 20k Ω . Was set up as very a little capacitor value in this design, and operating transfer rate was improved. A latch circuit was inserted in rear part in order to improve inferiority of an operating characteristic of low frequency scope expected at the time of this. Role of latch is it is held down the maximum, and to be devoted to a noise influence of a low frequency. No problem generated the simulation results in spec like having been reflected on a table 1. However, knew that duty changed a bit by a dispersion change of a low resistance.

Table 2. The simulation results

Parameter	Condition	spec.	Simulation data	Unit
Operation supply voltage	-	1.65~3	1.4~6	V
Output voltage	No input signal V _{cc} =1.8V		1.14	V
Dissipation current	Input high level V _{cc} =1.8V	less 10	5.5	mA
High level output voltage	6Mbps NRZ duty 50% V _{cc} =1.8V	1	1.084	V
Low level output voltage		0.36	0.103	V
Rise time		30	20	nS
Fall time		30	9.5	nS
Propagation delay time		170	75	nS
		170	75	nS
Operating transfer rate		1~15	~more 15	Mbps

A good characteristic of an element is had in perfect contrariety wiring of each element. Layout of this Rx IC considers the following matter. 1) Feedback of a parasitic resistance of V_{CC} and GND line must be minimized. It is made an action of a circuit from

unstable state, and a parasitic feedback resistance causes an oscillation. Power line of early signal process unit and bias unit, output unit to stand in in order to minimize is separated from each pad. 2) All circuit sections which excluded photodiode in order to minimize an influence of light are stopped up with 2nd metal layer. 3) When the sections which are sensitive to a noise are arranged in a circuit, is far-off, and is arranged from photodiode. Passivation is made 2nd metal layer here, and a function of cover about an electromagnetism noise is added with connecting to GND. It is amplified hfe times, and an influence of a parasitic photocurrent appears with collector current in case of PNP TR in particular. 4) Lets minimize the noise component which obeyed a signal change when lets insert capacitor between V_{CC} and GND, and operates, and a PSRR characteristic is improved. PSpice was used, and a circuit was verified with a design. Because there was not parameter of a simulation acid PIN diode, was replaced with constant current source, and it was played. In order to confirm a frequency characteristic and I_c(max) of PNP TR. of an amplifier and output unit partly made a gulf with B/B, and proved. It is Design rule: 10V sum BJT(single Iso), Chip size : 1.55 × 1.55 of a low voltage receiving IC design of Fig. 3 [μ / number cm], mask is 12 sheet, sheets in \pm 0.25 in 1.25 mm², epi spec (TVG) : 6 \pm 0.5 [], (p VG) ..

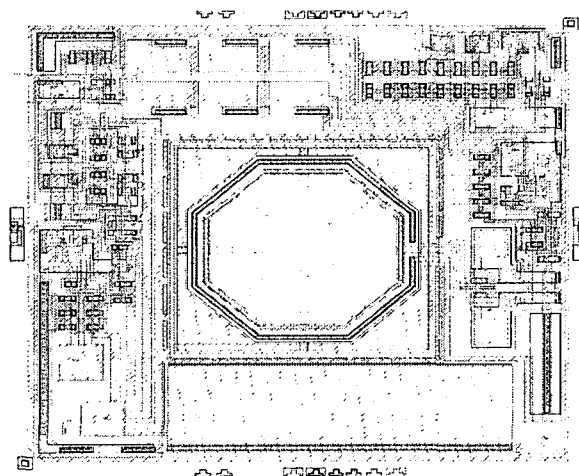
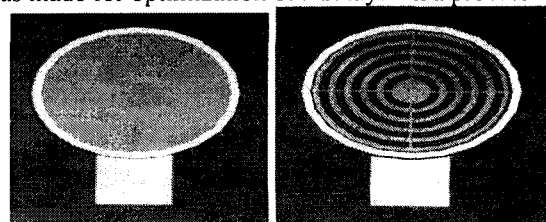


Fig. 3. Layout of low voltage receiving IC

5. EXPERIMENTATION AND THE RESULTS

The first experimentation was confirmed with a sensitivity difference of pattern of photodetector. The pattern which gave a change to length around an receiving optical area joint as below in order to improve a sensitive characteristic of photodetector of low voltage with this base was designed, and a test was made for optimization of AR layer in a process.



(a) Circle type (b) Web-pattern type

Fig. 4. The photodetector which was made.

Fig. 4 is actual made photodetector.

The design regulation that was used when is made is same as a table 3. Length was changed around a junction of pattern of receiving optical area in order to raise a sensitivity of photodetector. As a result of matter of AR layer and thickness were coordinated, and having done production, test, a photodetector characteristic of Rx of 5V was compared with, and similar, the dark current and the capacitance characteristic appeared, and red light was improved clearly in the optical current side. If look into an influence about a variable, did not

have the pattern change and the influence of a photocurrent to have been based on receiving part spread p^+ density, and matter of AR layer and thickness are the largest in a photocurrent characteristic appeared with what influenced. In case of photodetector of 5V, as for the AR layer, Si_3N_4 500 is formed, and reflectivity value of this time reaches 59% (vertical incidence, 660nm). On the other hand, an optical current characteristic is clear, and, in case of made photodetector, what an improvement (55nA 274nA, at $P_c=-27dBm$) became can be known by owning an optical reflectivity of less than 10% on an incidence optical wavelength of 660nm with $Si_3N_4(1500\text{\AA})/SiO_2(1800\text{\AA})$. Even if Pattern B3 is applied, and is applied to 1.8V Rx asking at least receiving optical power of -27dBm, a problem is determined because there is not. The measurement results about the B3 that photodetector and pattern of 5V were same as the following table 4 were summarized.

Table3. All characteristic of Web pattern& 1.8V photodetector

Symbol	Unit	result				condition
		Low voltage		5V		
		AVG	STDEV	AVG	STDEV	
I_{PH}	nA	274	14	55	8	$VR=1.65V, P_c=-27dBm$
I_{dark}	pA	5.7	2.85	1.23		$VR=7V, \text{no light}$
Capacitance	pF	26.37	0.34	26.88	0.87	$VR=1.65V, f=1MHz$
BV	V	46		63		$IR=100nA$

Generally a standardization to stand in Si photodetector in order to realize receiving module of optical link with Bipolar IC in order a simulation technique is used, and to measure all characteristic of optical element before objection needs that worked. However, some every each semiconductor company it is a general way a measurement circuit is provided because there is a difference, and do with a user, and please measure a crack, and to do. Therefore, must be done on certainly following measurement circuit and condition to stand in order to measure the characteristic that spec of this receiving IC covers with me.

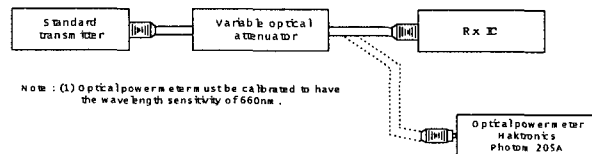


Fig. 5. An optical characteristic measurement circuit

As for the results that tried to be measured, as for the second Rx of low voltage, the problems that were happened in the first were almost improved, but an a little short point is with what is applied to a thing in audio of the still latest way.

An overall characteristic can be seen in a table 4, and Rx of the second low voltage did not do an oscillation when it was no signal, and operated from 1Hz. As for the measurement results, satisfaction got spec done by the I_{cc} , low/high output voltage, rise/fall time, Jitter, and the duty ratio changed according to a frequency, but about 52.63% high duty ratio was had in 6 Mbps. Also, the output wavelength type of Rx was normally said.

Table4. Low voltage Rx spec and measurement data

Parameter	Symbol	Condition	Unit	SPEC.			Measured Data			
				Min.	Typ.	Max.	1st Avg.	Std.	2nd Avg.	Std.
Output Voltage		No Input Signal		No oscillation, Hor L state			oscillation. No oscillation			
Dissipation Current	I_{cc}	Input High Level	mA		7	10	4.27	0.23	4.60	0.21
High Level Output Voltage	V_{OH}		V		1		1.22	0.01	1.14	0.02
Low Level Output Voltage	V_{OL}	$V_{cc}=1.8V$	V		0.2	0.36	-0.01	0.00	0.01	0.01
Rise Time	t_r	$V_{in}=6 Mbps$	ns		25	30	3.01	0.15	9.54	0.68
Fall Time	t_f	NRZ Duty 50%	ns		25	30	4.16	0.15	6.82	0.59
Jitter	Δt_j		ns			30	3.32	0.48	4.33	0.39
Duty Ratio @ Duty of $V_{in}=50\%$	Duty		%	45	50	55	54.64	1.34	52.63	1.36

However, if they a few matter is improved, there is not a problem in utility, and commercial business is enough for the section where a function is low level (a 48k sampling method). When it is no signal, Fig. 6 keeps a proposal and state of low by an oscillation to guild. This is becoming operation of latch added to a circuit smoothly. Or a wavelength type of 10Hz and 1MHz can know normalcy through experimentation an input frequency. As for the second Rx of this experimentation results low voltage, the occurrence problems that worked were improved in the first. Commercial business is enough a function in a low level part (a 48K sampling method).

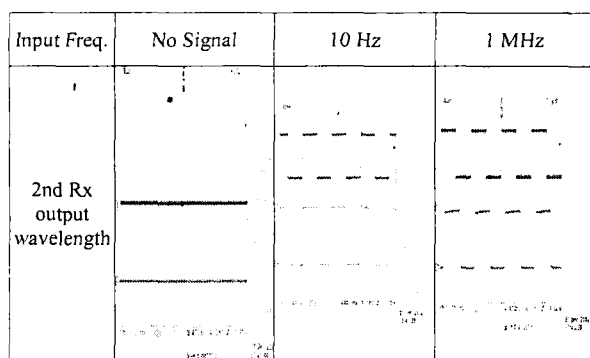


Fig. 6. A change of a Rx output wavelength type about a frequency

From now on, a table 5 is an improvement item.

Table 5. The item which Rx of low voltage must improve

No	2nd Rx problem	Improve item	notes
1.	Delay time of Spec (>160ns)	Less than 120ns improve	Need redesign
2.	Δt_w ; large (<20ns)	Δt_w improve.	Stability for process

6. CONCLUSION

Stand up in order to develop receiving IC of low voltage of high sensitivity, first of all, photodetector development of high sensitivity must be preceded. Si PIN structure to operate in 5V was used with this, and photodetector of APF optical link was made with a design, and the characteristic was analyzed. Optical let a p+-shallow spread of web pattern was executed, and an effective junction area was reduced, and the receiving optical area which incidence became extend space electrical charge scope of intrinsic area with horizontally in photodetector of two structure made at the time of this, and web-pattern compared with circle type, and distinguished electricity and optical characteristic were shown. When low junction capacitance ($C_j \square 4$) and optical signal were transmitted from an operation voltage of -5V, the photodetector of Web-pattern showed a low dark current ($I_d=180$) and high optical signal current (output current: 1.221, sensitivity: 0.55A/W at $V_{in}=5V$ and LAMP=1m). Web structure was applied, and a photocurrent displayed a 10^3 or above difference in digital signal process acid 0($V_{in}=0V$) and 1($V_{in}=5V$) state, and distinguished signal disconnection ability was shown. Also, an output optical spectrum (peak wavelength: 670 ~ 700) characteristic to almost agree with an input optical spectrum (center wavelength, λ , 670,) in a optical signal search plane was shown. Red light let the pattern reduced an error all characteristic was faced, and an element simulation was forecasted, and to occur in development in spring with this proposed structure, and reduce a development period. Receiving IC of low voltage was developed

for development of photodetector of high altitude. Si PIN structure to operate in 5V was used with this, and a design was made and, and the characteristic was analyzed. Was made, and the area reduced 55% than the existing thing a one chip design with 5V receiving IC with a base with this characteristic. All characteristic compared etc to the existing thing, and, as for the ICCQ, the 5mA (with 15mA, 10mA) right way decreased. As for the operating transfer rate, approximately 4 Mbps were increased, and, in case of t_f , t_r , about 3 ns was increased. Remainder characteristic was able to carry enough out a function of audio system optical link with keeping the almost same level. When there is not the input that was a problem in case of 5V, an oscillation problem was solved, and the operation frequency did a design in order to be able to operate by DC. When all general characteristic of this IC tried to be compared, the speed and the delivery delay time dropped than 5V, but it was improved in a function, and was designed. That is, HPF and level shifter were put, and $2V_{BE}$ was overcome, and let add latch, and a low frequency characteristic became stable, and operated. Also, was played in order a push full technique was used in output unit, and to be able to operate enough. And let photodetector and an interval of an active element of each kind be far from the maximum, and the layout got a contrariety done in order to minimize a noise. A technique was put on because capacitor between GND and V_{CC} was inserted, and to improve a characteristic of PSRR was used. Designed in order to become enough spec (1.8V, 10 Mbps, action) because used receiving IC of the low voltage which designed in this paper for commerce (a portable computer and a terminal of a DVD player, PDA, mobile communication). The spec which test results can be used enough for worked. However, performance to have been improved more is asked to the newest audio. Continuously necessary a researcher in order study analyzes a process and structure with the current various the first in order to use with a lot of use in the future, and to become mass products.

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