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Design and Development of Low-Cost Optical Fiber Transmitter for High frequency Applications

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Abstract: ***Fiber optical technology is rapidly becoming an indispensable part of human life. The purpose of designing a fiber optic transmitter lab kit is to provide hands on experience on the various parameters related to optical communications at a relatively low cost. The kit will be useful in establishing a fiber optic analog link, voice link, to study PAM technique of communication, time division multiplexing and also to observe both propagation losses and bending losses. As an initial part of the design, various circuits' functionality is tested on the bread board. Later the schematics for various circuits are designed using EAGLE layout editor. Further the design is fabricated and implemented on the PCB. This kit is an introduction to Fiber Optic communication technology for instructors .***

***Keywords*: .Fiber Optics, PAM Techniques, Circuit Design, PCB Design.**

I. INTRODUCTION

Fiber Optics technology is rapidly becoming a familiar & indispensable part of human life. You have undoubtedly heard of Fiber Optics. Futurists, science writers and entrepreneurs forecast fantastic growth for Fiber Optics applications. Their enthusiasm is valid. Today medical fiber optic systems allow physicians to peer inside the human body without surgery. Military commanders demand portable battlefield communication systems which use superior fiber optic transmission. Modern fiber-optic communication systems generally include an optical transmitter to convert an electrical signal into an optical signal to send into the optical fiber, a cable containing bundles of multiple optical fibers that is routed through underground conduits and buildings, multiple kinds of amplifiers, and an optical receiver to recover the signal as an electrical signal. The information transmitted is typically digital information generated by computers, telephone systems, and cable television companies. Many science colleges, universities and engineering colleges have included fiber optics in their syllabus. There arises a need that students understand the basic concepts of Fiber Optic Communication system which is enabled by a Fiber - Optic trainer kit. However Fiber optic trainer kits in the market cost a lot and hence prove to be a hindrance for many colleges in imparting the required subject to a student. This low cost fiber optic kit acts as an introduction to the fiber optics communication technology for instructors, students & hobbyist. Every one require an insight into fiber optic communications and therefore the need arises for designing a fiber optic trainer kit which while being cost effective is also compact, sleek and knowledge imparting. Fiber Optics trainer kit allows students to perform study of all concepts used in modern Fiber Optics communication systems. A wide range of experiments can be carried out on the kit ranging from Setting up of Fiber Optic Analog Link, Study of Pulse Amplitude Modulation to Study of Time Division Multiplexing[1], [2].
The research paper is organized as in section II, discussed the Related research work, in section review criteria on fibre optics, in section IV, Results and discussions followed by conclusion.

II. RELATED TO RESEARCH WORK

Fiber optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information. First developed in the 1970s, fiber-optic communication systems have revolutionized the telecommunications industry and have played a major role in the advent of the Information Age. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world. Modern fiber-optic communication systems generally include an optical transmitter to convert an electrical signal into an optical signal to send into the optical fiber, a cable containing bundles of multiple optical fibers that is routed through underground conduits and buildings, multiple kinds of amplifiers, and an optical receiver to recover the signal as an electrical signal. The information transmitted is typically digital information generated by computers, telephone systems, and cable television companies. The most commonly-used optical transmitters are semiconductor devices such as light-emitting diodes (LEDs) and laser diodes. The difference between LEDs and laser diodes is that LEDs produce incoherent light, while laser diodes produce coherent light. For use in optical communications, semiconductor optical transmitters must be designed to be compact, efficient, and reliable, while operating in an optimal wavelength range, and directly modulated at high frequencies.

In its simplest form, an LED is a forward-biased p-n junction, emitting light through spontaneous emission, a phenomenon referred to as electroluminescence. The emitted light is incoherent with a relatively wide spectral width of 30-60 nm. LED light transmission is also inefficient, with only about 1 % of input power, or about 100 microwatts, eventually converted into launched power which has been coupled into the optical fiber. However, due to their relatively simple design, LEDs are very useful for low-cost applications[3], [4], [5]. Communications LEDs are most commonly made from gallium arsenide phosphide (GaAsP) or gallium arsenide (GaAs). Because GaAsP LEDs operate at a longer wavelength than GaAs LEDs (1.3 micrometers vs. 0.81-0.87 micrometers), their output spectrum is wider by a factor of about 1.7. The large spectrum width of LEDs causes higher fiber dispersion, considerably limiting their bit rate-distance product (a common measure of usefulness). LEDs are suitable primarily for local-area-network applications with bit rates of 10-100 Mbit/s and transmission distances of a few kilometers. LEDs have also been developed that use several quantum wells to emit light at different wavelengths over a broad spectrum, and are currently in use for local-area WDM networks[6], [7], [8].

A semiconductor laser emits light through stimulated emission rather than spontaneous emission, which results in high output power (~100 mW) as well as other benefits related to the nature of coherent light. The output of a laser is relatively directional, allowing high coupling efficiency (~50 %) into single-mode fiber. The narrow spectral width also allows for high bit rates since it reduces the effect of chromatic dispersion. Furthermore, semiconductor lasers can be modulated directly at high frequencies because of short recombination time.

Laser diodes are often directly modulated, that is the light output is controlled by a current applied directly to the device. For very high data rates or very long distance *links*, a laser source may be operated continuous wave, and the light modulated by an external device such as an electro absorption modulator or Mach-Zehnder interferometer. External modulation increases the achievable link distance by eliminating laser chirp, which broadens the line width of directly-modulated lasers, increasing the chromatic dispersion in the fiber[9], [10].

Receivers

The main component of an optical receiver is a photodetector, which converts light into electricity using the photoelectric effect. The photodetector is typically a semiconductor-based photodiode. Several types of photodiodes include p-n photodiodes, a p-i-n photodiodes, and avalanche photodiodes.

The optical-electrical converters are typically coupled with a transimpedance amplifier and a limiting amplifier to produce a digital signal in the electrical domain from the incoming optical signal, which may be attenuated and distorted while passing through the channel. Further signal processing such as clock recovery from data (CDR) performed by a phase-locked loop may also be applied before the data is passed on. An optical fiber consists of a core, cladding, and a buffer (a protective outer coating), in which the cladding guides the light along the core by using the method of total internal reflection. The core and the cladding (which has a lower-refractive-index) are usually made of high-quality silica glass, although they can both be made of plastic as well. Connecting two optical fibers is done by fusion splicing or mechanical splicing and requires special skills and interconnection technology due to the microscopic precision required to align the fiber cores.

Two main types of optical fiber used in optic communications. A multi-mode optical fiber has a larger core (≥ 50 micrometers), allowing less precise, cheaper transmitters and receivers to connect to it as well as cheaper connectors. The core of a single-mode fiber is smaller (<10 micrometers) and requires more expensive components and interconnection methods, but allows much longer, higher-performance links[11], [12].

In order to package fiber into a commercially-viable product, it is typically protectively-coated by using ultraviolet (UV), light-cured acrylate polymers, then terminated with optical fiber connectors, and finally assembled into a cable. After that, it can be laid in the ground and then run through the walls of a building and deployed aerially in a manner similar to copper cables. These fibers require less maintenance than common twisted pair wires, once they are deployed. The transmission distance of a fiber-optic communication system has traditionally been limited by fiber attenuation and by fiber distortion. By using opto-electronic repeaters, these problems have been eliminated. These repeaters convert the signal into an electrical signal, and then use a transmitter to send the signal again at a higher intensity than it was before. Because of the high complexity with modern wavelength-division multiplexed signals (including the fact that they had to be installed about once every 20 km), the cost of these repeaters is very high. An alternative approach is to use an optical amplifier, which amplifies the optical signal directly without having to convert the signal into the electrical domain. It is made by doping a length of fiber with the rare-earth mineral erbium, and *pumping* it with light from a laser with a shorter wavelength than the communications signal (typically 980 nm). Amplifiers have largely replaced repeaters in new installations [13], [14], [15]

III. REVIEW CRITERIA ON FIBIRE OPTICS

Fiber-optic communication is a method of transmitting information from one place to another by sending pulses of light through an optical fiber. The light forms an electromagnetic carrier wave that is modulated to carry information. First developed in the 1970s, fiber-optic communication systems have revolutionized the telecommunications industry and have played a major role in the advent of the Information Age. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world.

The process of communicating using fiber-optics involves the following basic steps: Creating the optical signal involving the use of a transmitter, relaying the signal along the fiber, ensuring that the signal does not become too distorted or weak, receiving the optical signal, and converting it into an electrical signal. Fiber optic transmitters are typically composed of a buffer, driver and optical source.

The buffer electronics provides both an electrical connection and isolation between the transmitter and the electrical system supplying the data. The driver electronics provides electrical power to the optical source in a fashion that duplicates the pattern of data being fed to the transmitter. Finally the optical source (LED) converts the electrical current to light energy with the same pattern. The LED SFH450V operates outside the visible light spectrum. Its optical output is centered at near infrared wavelength of 950nm.The emission spectrum is broad, so a faint red glow can usually be seen when the LED is on in a dark room. The LED SFH450V is coupled to the transistor driver in common emitter mode. The driver is preceded by the amplifier buffer. The amplifier in this case is a LM741 operational amplifier configured as voltage follower in the absence of input signal. In the absence of input signal half of the supply voltage appears at the base of the transistor. This biases the transistor near midpoint within the active region for linear applications. Thus LED emits constant intensity of light at this time. When the signal is applied to the amplifier it overrides the DC level at the base of the transistor which causes the Q point of the transistor to oscillate about the midpoint. So the intensity of the LED varies about its previous constant value. This variation in the intensity has linear relation with the input electrical signal. Optical signal is then carried over by the optical fiber.

Various blocks of Fiber Optic Transmitter:

1. Transmitter

2. Pulse amplitude modulation

3. Simple Analog link and voice link

4. Time division multiplexing

It may be observed that all the blocks of Transmitter kit are not necessary to be used simultaneously. For instance when signal which is Pulse Amplitude Modulated is used then it is required that Pulse Amplitude De-Modulation circuit be used after receiver. Similarly when Time Division Multiplexing is used on the Transmitter kit, time division de-multiplexing circuit needs to be used. Fig.1 represents the architecture for the design.

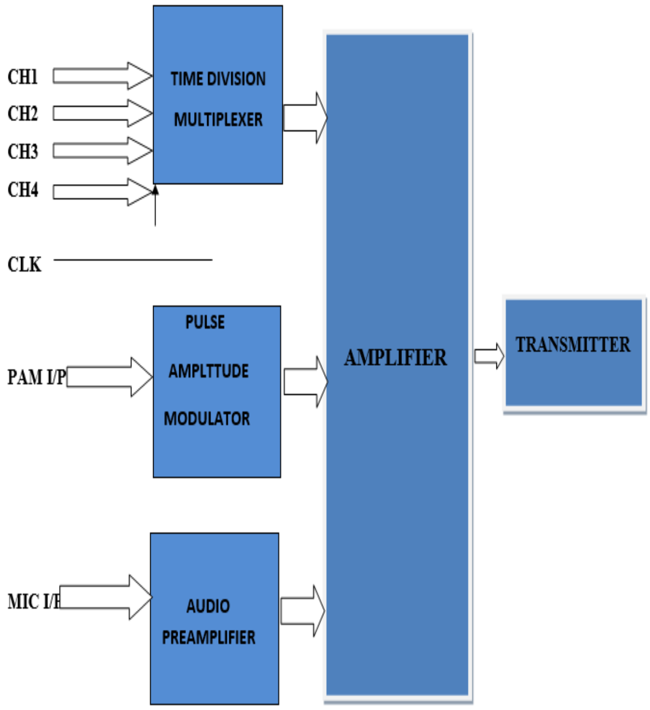

Fig.1 Architecture for the design

IV. RESULTS AND DISCUSSIONS

Testing is the crucial part of the project. A lot of time has been spared in this part of the project to ensure that the circuits are absolutely consistent. While doing the testing on the breadboard it became extremely difficult to connect the entire transmitter circuits with one another from each bread board. As a result we are unable to get the desired results that we are expecting at the initial part of the testing. We later decided to take each individual circuit into consideration and connect it on the bread board. Connect the input and check the output for each and every circuit separately. This has helped us to check the operation of the circuit very precisely and helped us in saving a lot of time.

EXECUTION AND ACCURACY

To ensure the correct operation of our circuits and to modify the circuits in order to get the results more accurately we decided to test the circuits in both hardware and simulated environment. MULTISIM V11.0 software has been used to check the consistency of the circuits. Each and every circuit has been simulated using the MULTISIM software. By changing various parameters of components in the circuits we were able to modify the circuits accordingly and able to get the desired results[15], [16], [17].

All the circuits have been tested on the bread board. The outputs were found to be very satisfactory and consistent with the results obtained by simulating the circuits using MULTISIM software. The schematics and outputs of some of the circuits obtained through simulating using the MULTISIM software are given below. Fig.2 represents the Schematics of the amplifier stage of the transmitter circuit using Multisim software. Fig.3. Output of the amplifier stage of the transmitter circuit. Fig.4 Schematics of the TIMER circuit of the transmitter circuit. Fig.5. Output of the TIMER circuit of the transmitter circuit. Fig.6 represents the schematic of the transmitter circuit and Fig.7 gives the output of the transmitter.

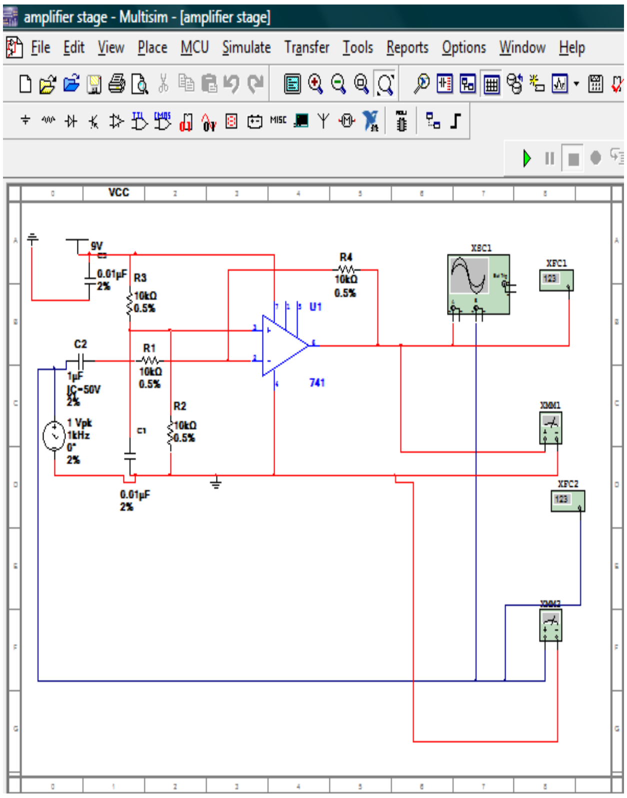

Fig.2 Schematics of the amplifier stage of the transmitter circuit using Multisim software

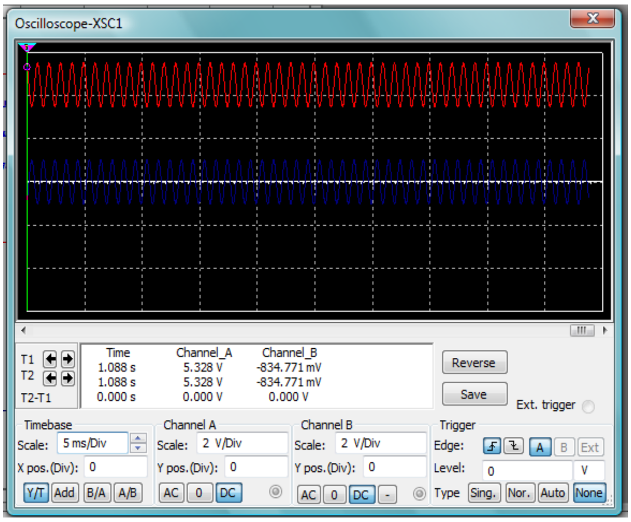

Fig.3 Output of the amplifier stage of the transmitter circuit

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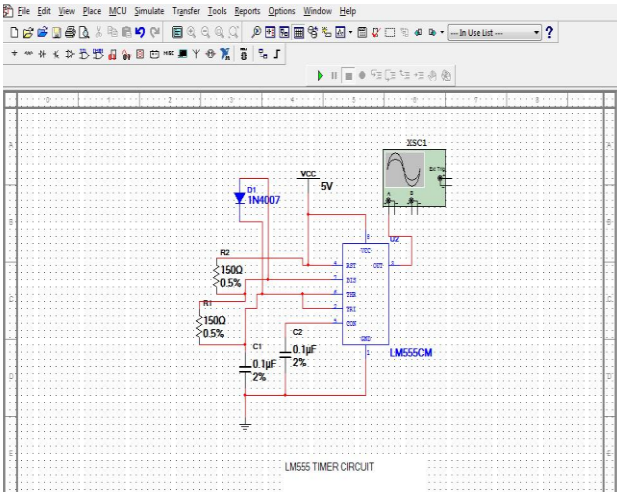

Fig. 4 Schematics of the TIMER circuit of the transmitter circuit

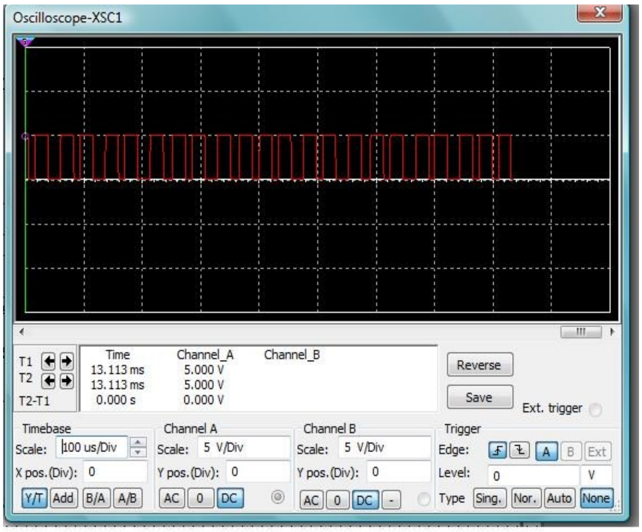

Fig.5 Output of the TIMER circuit of the transmitter circuit

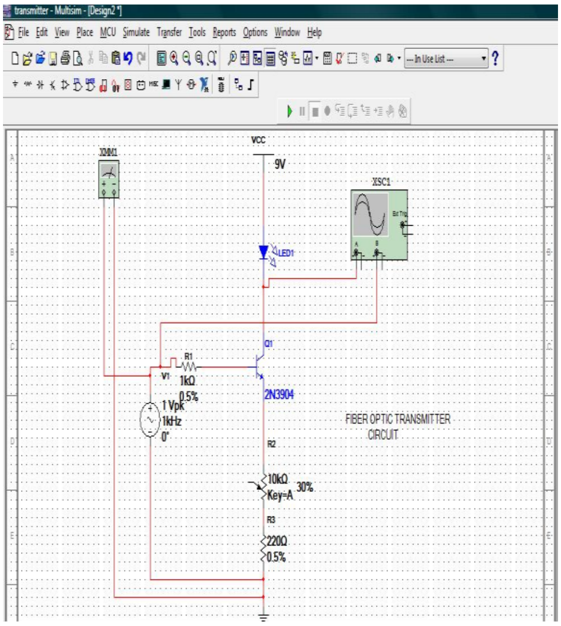

Fig.6 Schematics of the transmitter circuit using

Multisim software.

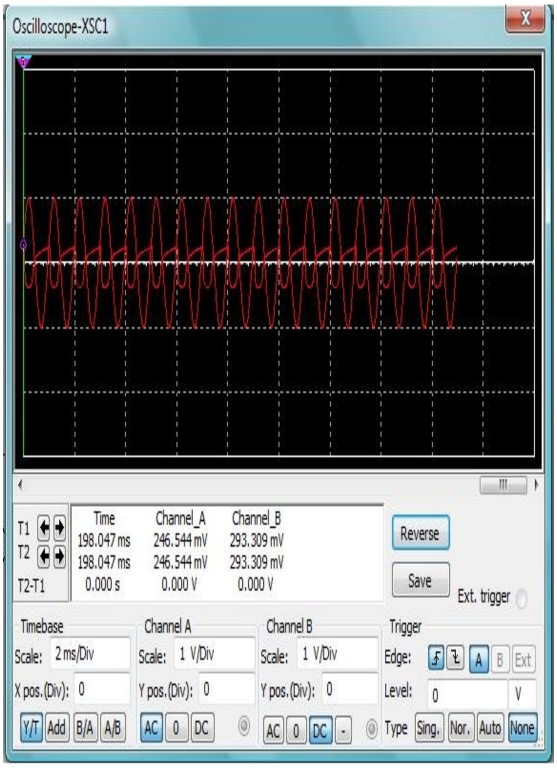

Fig.7 Output of the transmitter circuit

V. CONCLUSION

The project is successfully implemented with all the features mention in fiber optic technology. The project trainer kit acts an introduction to fiber optics communication for instructors, students and hobbyist. The planned project is developed by keeping in view building a powerful, versatile and cost effective experimenter kit usable to train at all levels from beginner to expert. This paper certainly provides the students with hands on experience on various fiber optic and digital communication techniques. The project has enabled to reduce the cost of the trainer kit drastically compared to the markets existing price. The various fiber optic and digital communication experiments in the trainer kit have been tested and the results were satisfactory. The goals that have been achieved are:

i. Low cost trainer kit

ii. Introduction to fiber optic technology and digital communication techniques.

iii. Ready to use kit with accessories

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