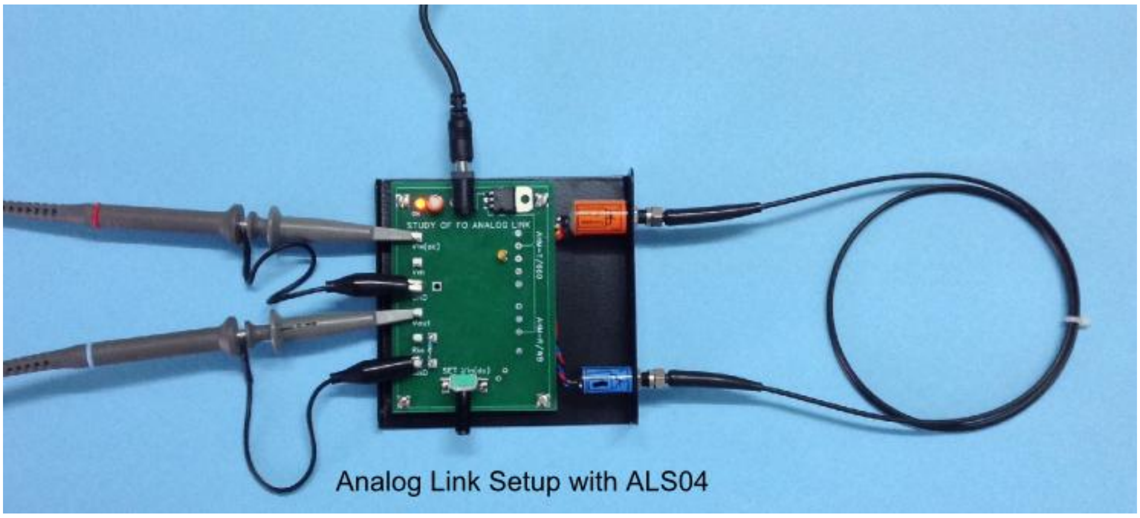
Study of Optical Fiber Analog Links

LABORATORY MANUAL: TESTER ALS04



Analog Link Setup with ALS04

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1. Optical Fiber Analog Link Tester ALS04

1.1 Introduction to Tester ALS04

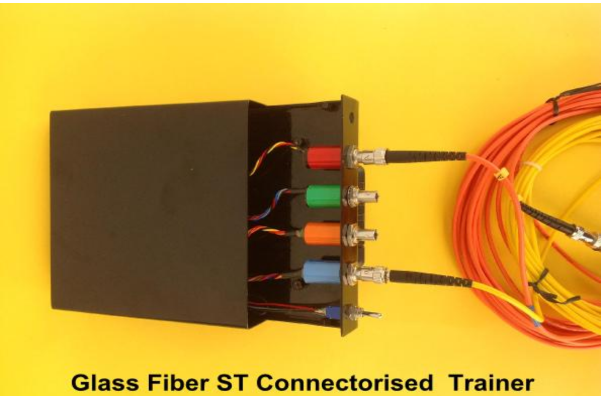
Tester ALS04 is an optimized set-up to conduct a comprehensive study of all parameters relating to transmission of analog signals through an optical fiber linear intensity modulation system. The tester is centred around two popular and proven functional modules that have been in use for 20 years. These modules designated AHM-T/660 and AHM-R/WB are described at length in **Annexure I.** The modules are terminated with industry standard SMA receptacles that facilitate coupling with SMA-SMA connectorised PMMA (plastic) optical fiber (POF) cables. For interconnectivity, industry grade teflon insulated electrical wires are employed in the modules for reliability and durability. The wavelength of operation for Tester ALS04 is 660nm. The tester includes a 1-metre SMA-SMA connectorised PMMA cable. Other T&M equipment comprising a digital multi-meter, a 1 MHz function generator, a 9Vdc power source and a dual channel 20 MHz oscilloscope are required to conduct experiments described in the Lab Manual.

The optoelectronic components employed in ALS04 are identical to the devices that were characterised by another Tester LPS04, designed to study dc characheristics of fiber optic LEDs, PIN photodiodes and phototransistors. While the experiments in LPS04 were limited to studying only dc parameters, ALS04 has been developed to complete the study of ac performances of the basic optoelectronic devices by employing them in practical functional modules. This Lab Manual refers to various dc parameters of the optoelectronic devices during discussions on design and performance evaluation.

In addition to the experiments described in this Lab Manual, many more interesting experiments may be designed and conducted by the user of Tester ALS04.

It may be mentioned that we also manufacture a *650nm laser diode-based fiber optic tester* to study analog links. The tester employs SMA connectorised POF and glass cables. It is supported by a detailed Lab Manual to conduct a variety of experiments, unique to the non-linear laser diode.

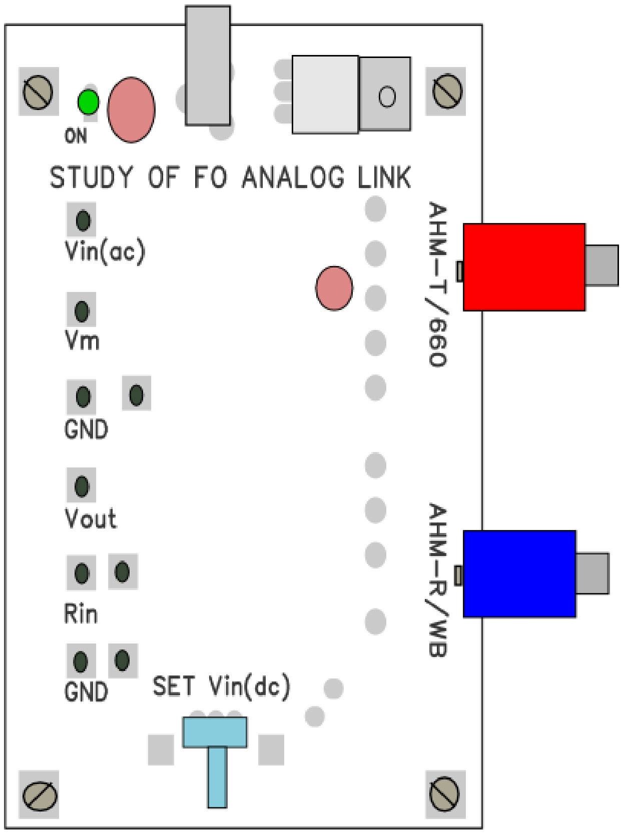
Apart from the range of *PMMA based, SMA connectorised 660nm testers*, we also offer a complete range of *glass fiber based (multimode/ graded index & single mode) trainers* operating at 850nm with industry standard ST connectors.



Glass Fiber ST Connectorised Trainer

1.2 Description of Tester ALS04

Tester ALS04 is described here with reference to the schematic diagram of the PCB.



Schematic of Tester PCB

1.2.1 Power Supply Section

The power supply circuit located at the top requires an external 9 Vdc/500ma power source. An onboard 5Vdc regulator provides for the functioning of AHM-T/660 and AHM-R/WB.

1.2.2 FO Analog Transmitter Section

The transmitter unit converts input electrical signals (ac and dc) to optical signals for transmission through an optical fibre**.** Micromodule, AHM-T/660, converts the input electrical signal to an optical output, P_O, by driving the FO LED linearly, using negative feedback operational amplifier circuitry. The optical power coupled to the optical fiberthrough an SMA connector is directly proportional to Vin (ac+dc)

P_O This is the SMA connectorised optical output port.

SET Vin(dc) This potentiometer facilitates setting the quiescent P_O(dc) by biasing the FO LED with a forward current If(dc) {equal to Vin(dc) / 50}. Vin(dc) is measured on Vm with a digital multi-meter. Vin(dc) is settable in the range 0 to 2000 mV.

Vin(ac) This is a capacitance coupled input for ac signals. Vin(ac) accepts sine, square or triangle waveforms in the voltage range of 0 to 2000 $mV_{p\text{-}p}$ and in the frequency range of 10 Hz to 500 KHz.

GND This is the common ground.

Vm This <u>output</u> facilitates measurement of the LED forward current and hence the output optical power P_O. DC measurements are done with a DMM while the ac measurements require an oscilloscope. Signal distortions due to overdriving or due to cut-off are tested on this terminal. Voltage on Vm is a reflection of the Vin(dc) + Vin(ac).

1.2.3 FO Analog Receiver Section

The signal at the far end of the optical fiber cable is coupled to the receiver through an SMA connector. Micromodule AHM-R/WB converts the input optical signal into a proportional electrical signal. The magnitude and bandwidth of the received signal are determined by the input resistance Rin

P_I This is the <u>optical input</u> port, terminated with an SMA receptacle that mates with the SMA connetorised PMMA cable.

Vout This is the demodulated electrical signal <u>output</u>. Both dc and ac voltages will be present. These are proportional to the incident optical power. The dc component is measured with a DMM and the ac component with an oscilloscope. Any distortions in the waveform due to the transmitter or due to the medium of transmission will be shown on the oscilloscope. The overall system gain is given by Vout/Vin. It is to be noted that the dc gain is higher than the ac gain at high frequencies.

GND This is the common <u>ground.</u>

Rin Provides for setting system gain and bandwidth. The system gain is directly proportional to the value of Rin (gain is given by G_{Rin} = k.Vout / Rin). Rin may be set in the range 50 ohms to 400 ohms through fixed metal film resistors

2. Experiments with ALS04

2.0 General Information on Fiber Optic Analog Links

Intensity modulation is the most commonly employed technique in optical communication, whether the input signal is in the analog or digital form. In a number of optical communication systems, the signal that is to be transmitted through the optical medium is first modulated, using one of the several electronic methods available. The electronically modulated signal is next used as the modulating signal for the light source. While non-linear intensity modulation will be acceptable for digital or frequency modulated signals, linear intensity modulation is essential if a baseband signal is to be used for direct intensity modulation of a light source.
An ideal linear intensity modulation/demodulation system would employ optoelectronic components and circuitry which will have linear characteristics in a specified range of operation. The optical output from the modulator, **P_O**, will be directly proportional to **Vin** (modulating signal). The electrical output **Vout**, from the demodulator will be directly proportional to the incident optical power **P_I**. With the loss in the optical path (optical fiber cable etc) being a constant, we will obtain **Vout** directly proportional to **Vin**.

The experiments deal with five variable parameters of a linear intensity modulation system and their inter-relationships. These are:

Optical Carrier Power, **Po**(dc): This corresponds to the FOLED optical output Po(dc) for a dc quiescent current through the LED which in turn is determined by **Vin(dc). Vin(dc)** is set for linear region of operation, with minimum distortion. All future reference to optical carrier power will be in terms of the corresponding **Vin(dc). Vin(dc)** is settable in the range 0 to 2000 mV

AC Input Voltage, Vin(ac) is settable in the range 0 to 2000 mVp-p.

Frequency is settable in the range 10 Hz to 500 KHz. Measurements may be taken at specified intervals.

OF Cable Loss: This is taken as a constant as only one cable at a fixed wavelength of 660 nm is employed.

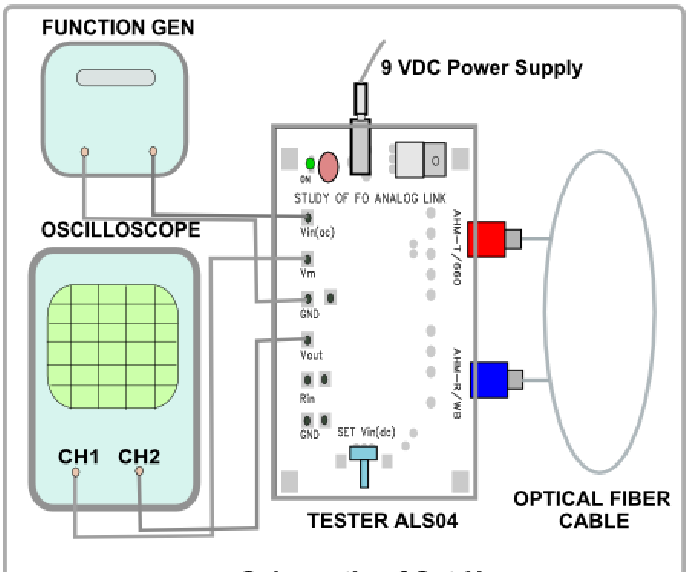
Receiver Gain, G_{Rin} The receiver gain is determined by the Rin of the receiver phototransistor and is directly proportional to it. The system gain G_{100} is approximately unity for Rin=100 ohms. We recommend fixed resistance of 50, 100, 200, and 400 ohms to be used.

The experiments covered in the Lab Manual are:

Gain Characteristics of a FO Linear Intensity Modulation System:
Frequency Response of a FO Linear Intensity Modulation System
Waveform Distortion in a FO Linear Intensity Modulation System
Step Response of a FO Linear Intensity Modulation System

2.1 Experimental Set-Up for FO Linear Intensity Modulation System

The experimental set-up for studying a linear intensity modulation system is shown in the diagram below and is self explanatory.



Schematic of Set-Up

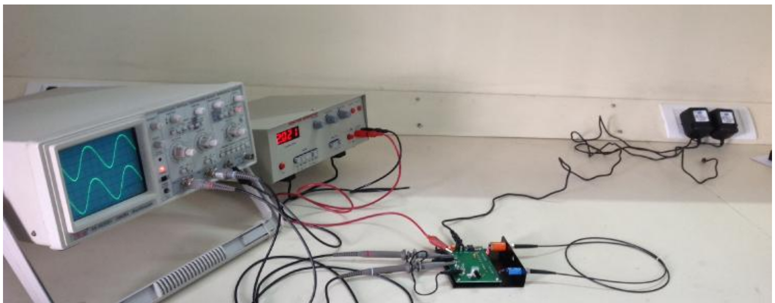
Optical Fiber Cable The optical fiber cable links the transmitter to the receiver. The SMA connectors are threaded. While connecting the cable, ensure the threads are in place. Do not apply excessive force on the cup nut.

9Vdc Power Source When connected, the ON LED glows up. No separate switch is provided for the power.

Digital Multimeter A 31/2 digit DMM will be used as a dc voltmeter in the full scale ranges of 200mV or 2000mV to measure voltages Vm and Vout. .

Function Generator A sine/square wave function generator with Vp-p voltage settable from 10mV to 2000 mV in the frequency range of dc to 500 KHz will suffice. The output of the function generator will be connected to Vin

Dual Channel Oscilloscope with a bandwidth of 20 MHz and matching probes is employed. A DSO will facilitate accurate measurements of amplitudes and timings. CH1 will be used to monitor composite waveforms (dc and ac) on Vm (which also represents Vin). CH2 will be employed to study the received voltage signal on Vout.


Experimental Setup with ALS04

2.2 Experiments and Analysis

2.2.1 Gain Characteristics of a Linear FO Intensity Modulation System:

The response of the linear intensity modulation system to varying input ac levels is studied here. For linear systems Vout(ac) should be proportional to all values of Vin (ac) in a specified region. In other words, the system gain should be a constant for fixed values of Rin, Vin(dc) and frequency in this region.

Step1: Turn on the power of Tester ALS04. Connect the OF cable as shown.

Step2: Set Vin(dc) to 600 mV using a DMM across Vm and Gnd. Connect the function generator sine wave output to Vin(ac) and set the frequency to 2 KHz. Connect a 50 ohm resistor across the Rin terminals.

Step3: Connect CH1 of the oscilloscope to Vm and CH2 to Vout. Set Vin(ac) to 500 mVp-p by adjusting the function generator output level. Note the Vp-p reading on CH2. Record the reading as shown in **Table 2.2.1**

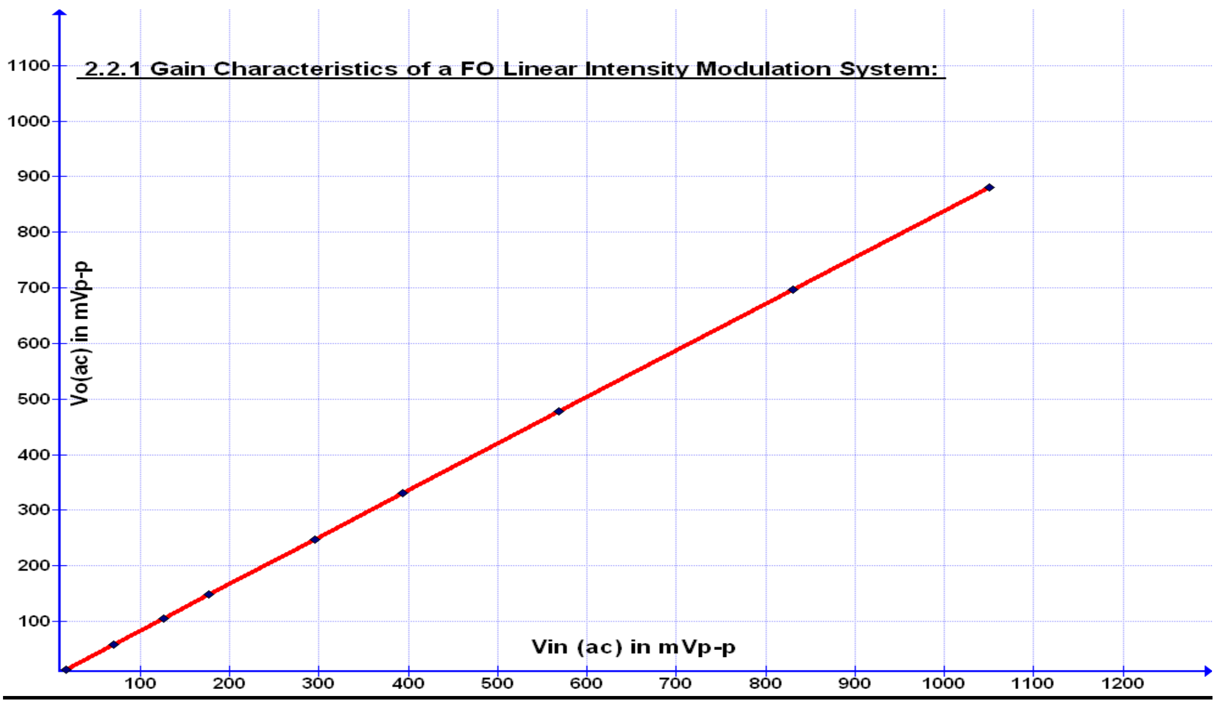
Step:4 Repeat Step3 for Vin(ac) in the range 10mVp-p to 1200mVp-p. You may extend to higher readings if the input/ output is still undistorted.

Table 2.2.1

Vin(dc) = 600 mV ; Freq= 2000Hz Rin= 50 Ohms

Sl No	$V_{in(ac)}$ p-p	$V_{o(ac)}$ p-p	G_{100}
1	10		
	1200		

The typical set of readings from ALS04 was used for plotting the response curve, employing a simple graph plotting software. As can be seen, the Vin (ac) vs Vout(ac) plot is a straight line. The slope of the line is the Gain for Rin=50 ohms and is 0.85 in this case.



2.2.2 Frequency Response of a FO Linear Intensity Modulation System

The frequency response of the linear modulation system is studied here and the bandwidth for a given gain is measured / computed. Over the pass band, the gain should be flat for an ideal system. The bandwidth is inversely proportional to the gain G_{Rin}. The measurements are repeated for 4 values of gain over the frequency range 10 Hz to 500 KHz.

Step1: Repeat Step1 to Step3 of Experiment 2.2.1. Record reading in Table 2.2.2

Step2: Repeat Step1 for other frequencies in the range 10 Hz to 500 KHz with suitable spacing of frequencies.

Step3: Repeat experiment for Rin = 50, 200 and 400 ohms recording in Table2.2.2. Reduce Vin(ac) in case Vout is distorted.

Table 2.2.2

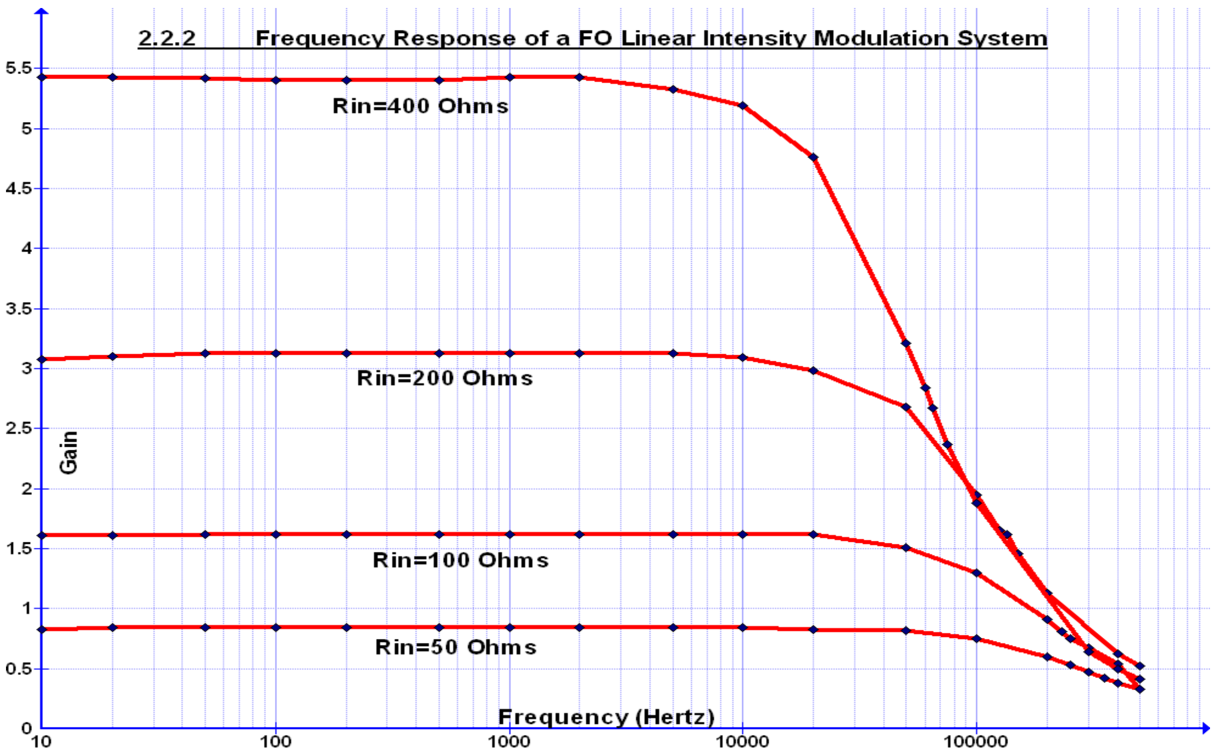
Vin(dc) = 600 mV ; Vin(ac)= 500mV

Sl	Freq	R=50		R=100		R=200		R=400	
		$V_{o(ac)}$ mVp-p	G_{50}	$V_{o(ac)}$ mVp-p	G_{100}	$V_{o(ac)}$ mVp-p	G_{200}	$V_{o(ac)}$ p-p	G_{400}
1	10								
	500000								

Typical sets of readings from ALS04 are plotted in the graph shown below. A simple graph software was employed for this. Frequency is plotted on a logarithmic scale on the X-axis whereas the gain is plotted on a linear Y-axis.

The gain in all the cases of Rin (50,100,200 and 400 ohms) in the pass band is constant. The measured readings are 0.84, 1.62, 3.13 and 5.4 respectively

In the pass band the system gain is also directly proportional to Rin for Rin=50, 100 and 200 ohms. For Rin equal to 50, 100, 200 and 400 ohms the bandwidths measured are 350 KHz, 230 KHz, 133 kHz and 65 KHz respectively.



2.2.3 Waveform Distortion in a FO Linear Intensity Modulation System

In this experiment, we determine the maximum Vin(ac) for distortion free transmission of signal for different settings of Vin(dc), the frequency and gain remaining constant. At low values of Vin(dc), the transmitted signal gets distorted at the lower end due cuf-off and clipping of the bottom. At higher Vin(dc) values the transmitter signal gets distorted because of clipping at the top. The distortion may also result from saturation on the receiver side due to high gain and non linearity of the FO PT at high photocurrents. Clipping of top and bottom will occur both on the transmission side and the receiver side, when Vin(ac) is too high. Selection of proper Vin(dc) and Vin(ac) is essential for distortion free transmission.

Step1: Repeat Step1 to Step3 of Experiment 1.2.1

Step2: Gradually increase Vin(ac). Notice closely Ch1 and Ch2 for distortion of waveform. Stop increasing Vin(ac) when distortion takes place and gradually decrease it to obtain distortion free wave forms on both channels. Record Vin(ac) max for distortion free transmission along with Vo(ac) in Table 1.2.3.

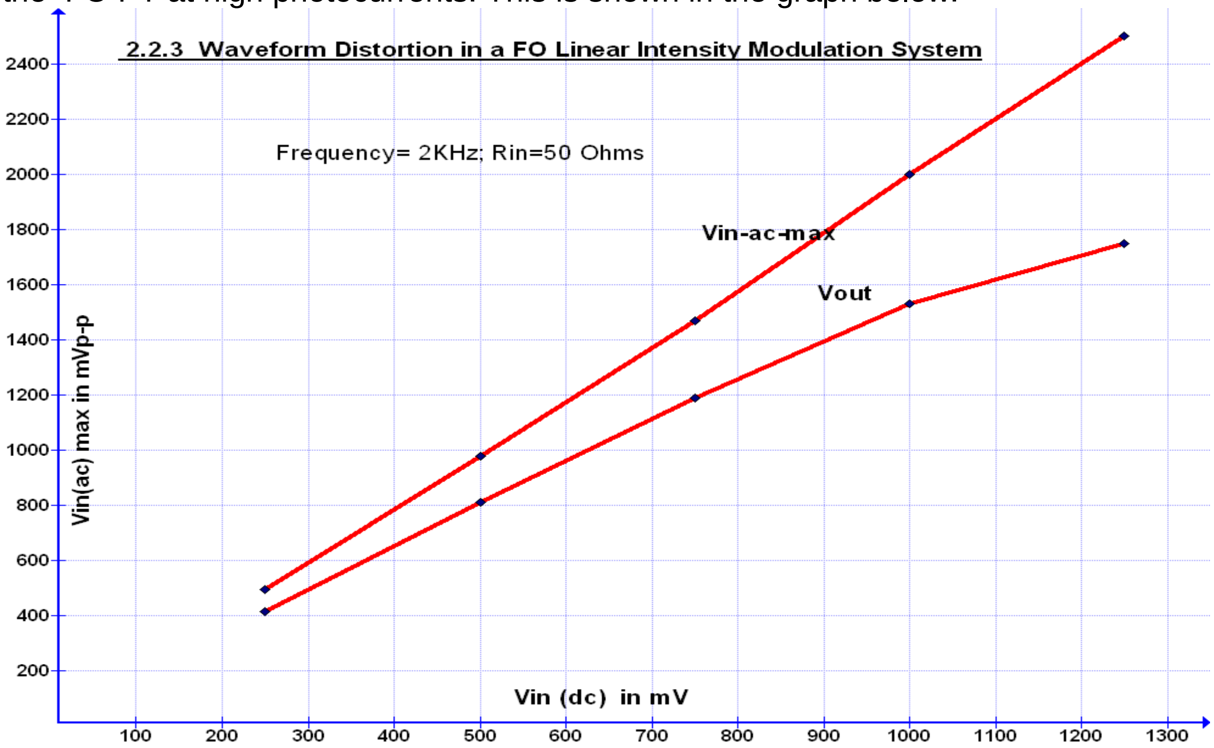
Step3: Repeat Step 3 for Vin(dc) = 250, 500, 750, 1000 and 1250mV.

Table 2.2.3

Freq= 2000Hz Rin= 100 Ohms;

Sl No	$V_{in(dc)}$	$V_{in(ac)}$ p-p (max)	$V_{o(ac)}$ p-p	G_{100}
1	250			
	1250			

Typical sets of readings from ALS04 are plotted in the graph shown above. d for this. It may be observed that the for Vdc(in) of 250 – 750 mV the peak to peak value of Vin(ac) is twice this value. This indicates that the Vin swings from 0 to 2 X Vdc(in). The clipping of Vin(ac) when it is over 2X Vdc(in) is due to signal going into the cut off region. Non linearity sets in at higher Vin (dc) and Vin (ac) due to nonlinearity of the FO PT at high photocurrents. This is shown in the graph below.



2.2.4 Step Response of a FO Linear Intensity Modulation Systems

In this experiment we study the response of the linear intensity modulation system to a step voltage, without driving it to cut-off or saturation conditions. The rise times are recorded for different gains.

Step1: Turn on the Transmitter & Receiver Sections. Connect the OF cable..

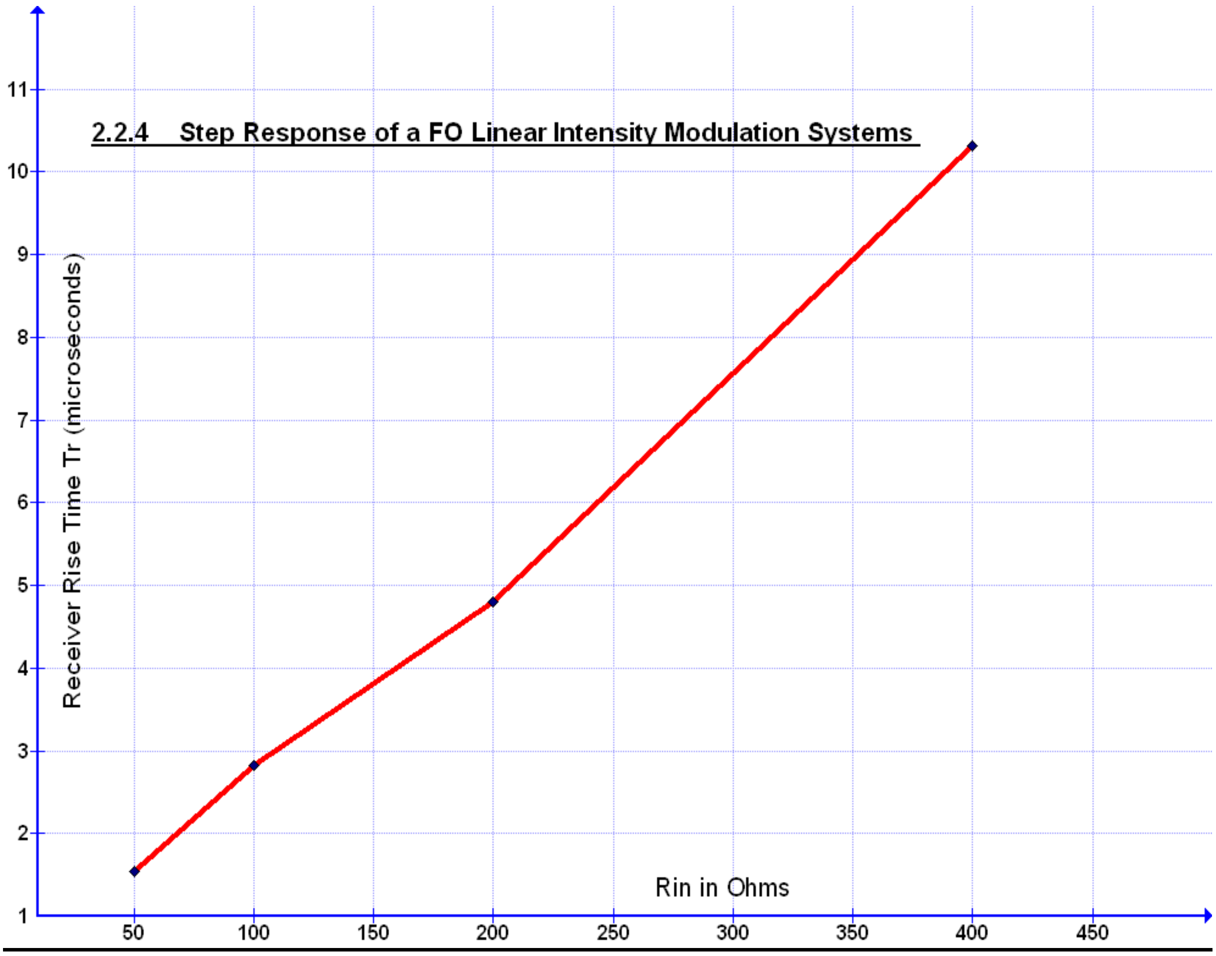
Step2: Set Vin(dc) to 600 mV using a DMM across Vm and Gnd. Connect the function generator square wave output to Vin(ac) and set the frequency to 10 KHz and the amplitude to 200mV p-p. Connect a 50 ohm resistor to Rin terminals.

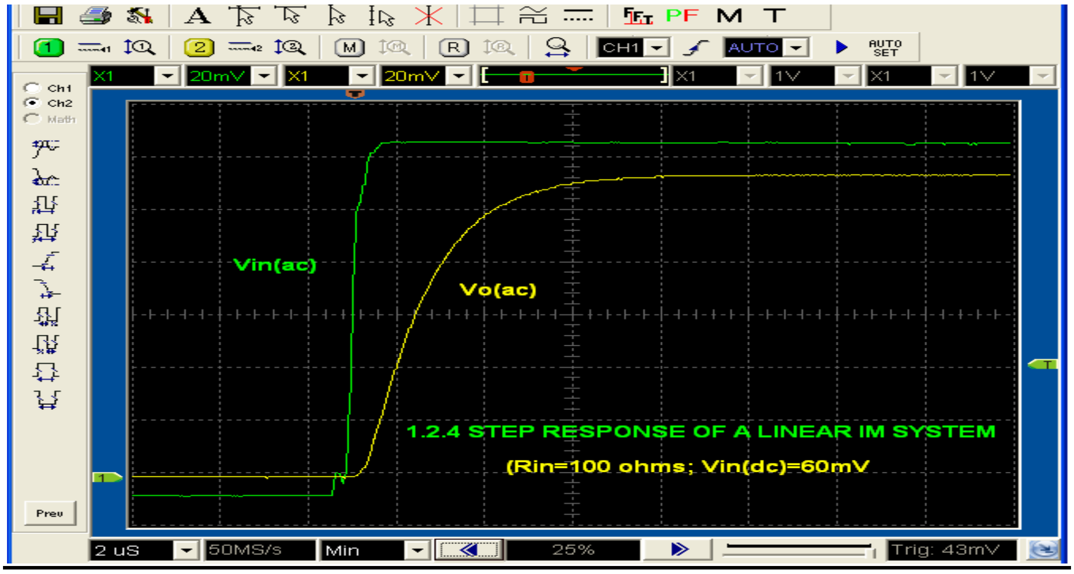
Stpe3: Connect Ch1 of ‘scope to Vm and Ch2 to Vo and record readings for all values of Rin. Lower Vinac if the transmitter of receiver goes to saturation.

Table 2.2.4

Vin(dc)= 600mV Frequency 10KHz (square); Vin(ac) = 500 p-p

Sl No	Rin	Vin(ac)	$V_{o(ac)}$ p-p	G_{Rin}	T_r (ns)
1	50				
	100				
	200				
	400				



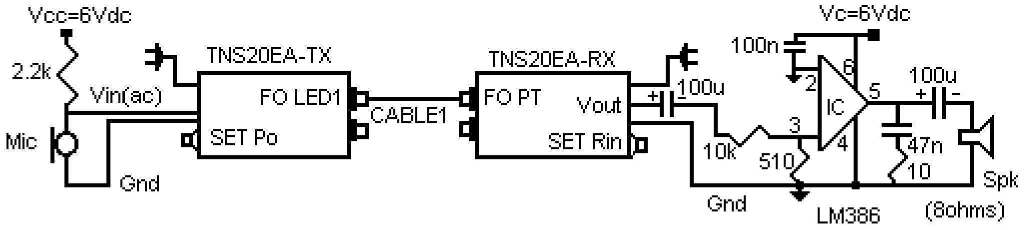


It may be noted that the pulse rise time Tr is directly proportional to Rin. In applications where speed is not a criteria, the linear modulation system may be used for digital transmission, in conjunction with a comparator.

2.3Transmission of an Audio Signal through an Optical Fiber

The necessary hardware is not included in ALS04. However the experimenter may build his/her own audio transmission system with ALS04

We employ the linear intensity modulation system designed to demonstrate transmission of an audio voice signal through the optical fiber. We need a condenser microphone, an 8-ohm loudspeaker and a few other electronic components for the audio driver stage. We base our audio driver on the popular integrated circuit LM386. The output from the microphone is coupled to the **Vin(ac)** lead of ALS04. **Vout** is ac coupled to the audio driver stage input through a 100uf electrolytic capacitor. The speaker is also connected to the output through a 100uf capacitor.
The audio power amplifier LM386 is configured with minimum number of components. The voltage gain is 20 if the input is not attenuated. However we may attenuate the input by the voltage divider comprising 510 ohms and 10kohms to get a unity voltage gain.



ANNEXURE I

FIBER OPTIC MICROMODULES FOR ANALOG TRANSMISSION, Models AHM-T/660 and AHM-R/WD

General Information:

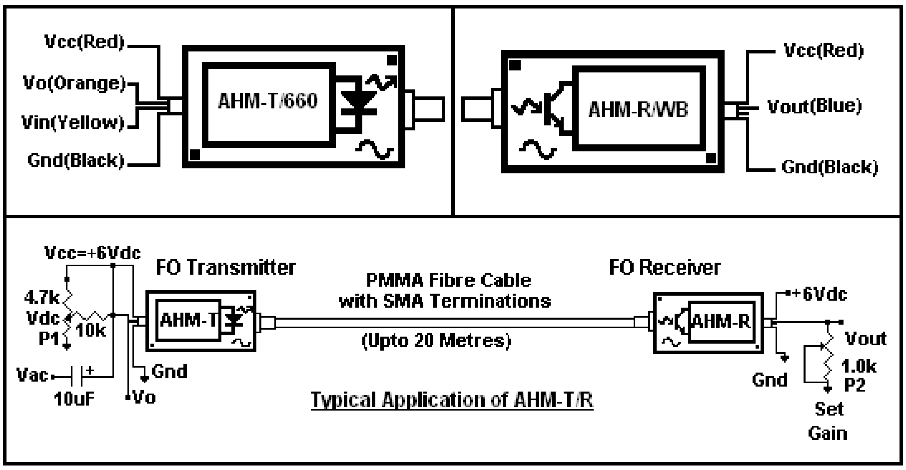
Fiber optic hybrid micro-modules, AHM-T/660 and AHM-R/WB comprise a pair of encapsulated devices (with teflon insulated wire terminals) that facilitate transmission of analog signals (audio range) through a multimode step index plastic optical fiber at a wavelength of 660nm (visible red) employing the linear intensity modulation techniques. SMD technology is employed to achieve a high degree of reliability and compactness. The devices require very few external components to realise a variety of functions. Industry standard SMA optical fiber connectors provide for rugged and consistently repeatable operations.

Applications:

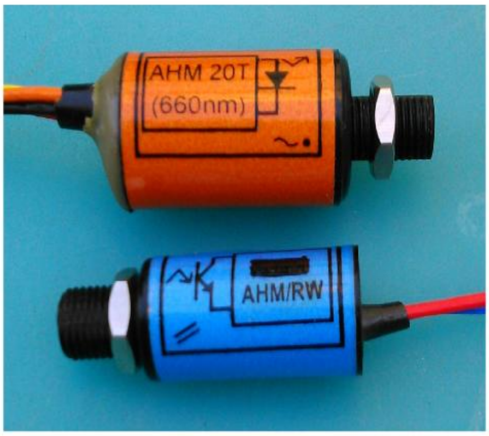
The AHM-T/660 and AHM-R/WB are a rugged and proven set of components that have been in use for 20 years. They find application in lab and educational trainers (eg ALS04, TNS20EA, TNS20AA) to study properties of optical fibers such as numerical aperture, attenuation and signal transmission using intensity modulation techniques. In addition, their other professional applications extend to realisation of low-priced, reliable and easy to use analog/audio links.

Specifications of AHM-T/R

Wavelength:	660 nm
Fibre:	PMMA/Step Index/Multimode NA of 0.5/1mm (dia)/2.2mm
Connector:	SMA (905)
Cable Length:	1 to 5 metres (standard)
Rx Gain:	Settable as shown in diagram
TX Optical Power:	100 uw (maximum)
Tx DC Bias:	Settable as shown in diagram
Power Supply	+6Vdc or 5Vdc (Regulated)/50mA
Vin & Vout:	Analog 10 to 2000 $mV_{(p-p)}$
BandWidth:	Dc to 200 khz (min)
Lead Material:	Tinned copper/teflon insulated



Design with AHM-T/660 and AHM-R/WB
This pair of devices has been the cornerstone in a number of Lab Trainers supplied by Telenet Systems, spread over two decades. These components remain popular with over 50 OEMs in India, who have customized their trainers around them. With technical resources from us, many new applications have been evolved by our clients, over the years.



AHM-T/660 and AHM-R/WB

Power Supply
A single 6Vdc or 5Vdc regulated power supply with a current rating of 50 mA is adequate for optimum operation of the two modules. Where optical isolation is required between the transmitter and the receiver, two independent power supplies may be employed.

AHM-T/660 : Transmitter
The fiber optic analog transmitter is centered around a high intensity directional light emitting diode operating at a wavelength of 660nm whose optical power is directly proportional to its forward current. The internal circuitry facilitates linear intensity modulation of the optical output that is key to analog transmission.
A typical wiring diagram of AHM-T/660 is shown in the previous page. The quiescent dc current through the 660nm LED is set up by the potentiometer, P1. The optical intensity of the LED is directly proportional to the current flowing through it. The ac input given to Vin through the coupling capacitor C1, results in the light intensity of the LED being modulated linearly. The LED current (dc+ac) is monitored on Vm. This may be used to monitor the optical power output.

$$I_{led}(ma)=Vm(mv)/100(ohms).$$

For optimum linearity the dc current may be set to 10+/-2ma(dc) typically, ie Vo=400mv to 600 mV) Distortion in ac modulation will result when the dc quiescent current is set too low or too high. Typical optical output power coupled into a 1-mm PMMA optical fiber for an LED current of 10 mA is -10dbm. The typical maximum peak-peak input ac voltage for undistorted intensity modulation under these conditions is 1

000mVp-p.

AHM-R/WB : Receiver

The fibre optic receiver AHM-R/WB is centered around a high gain wideband (wavelength range of 400 to 1100nm) phototransistor. P2 (refer diagram) sets the gain of receiver as shown:

Vout(mv) = Ip(ma)X P_2(ohms).

For most applications setting for P2 would be in the range 50 to 200 ohms. Typical Vout will be in the range 1500-2000mv for P2=50 ohms and optical power at 660nm equal to -10dbm.

One may note that the bandwidth of the receiver is inversely proportional to the gain of the receiver. Vout will contain both dc and ac components depending on the optical modulation.

AHM-T at Other Wavelengths

Telenet Systems provide AHM-T at other wavelengths with SMA terminations and suited for PMMA cables. The other popular wavelength is 850nm. The transmission properties will however be different for this in comparison with the transmitters at 660nm as the quantum efficiencies of LEDS and losses in optical fibers vary with the wavelength employed. The receiver module is however common for transmitters at other wavelengths.

SMA-SMA Connectorised PMMA Cables

The SMA-SMA connectorised cable or patchcord with PMMA fiber finds application in short distance analog and digital signal transmission. The step-index fiber has a large area of cross section and a high numerical aperture, facilitating easy coupling with transmitting and receiving devices. The light is guided along a fiber core of one millimeter approximately to distances of a few tens of metres.

Specifications of PMMA Cable:

Core Material:	polymethyl methacylate
Cladding Material:	Fluorinated polymer
FiberStructure:	Step index type
Core/Cladding Diameter	960u/1000u
Core Refractive Index	1.492
Cadding Refractive Index	1.405 to 1.417
Numerical Aperture	0.5 (typical)
Acceptance Angle	55 to 60 degrees
Attenuation at 660nm:	Typical 0.2-0.3dB/m
Jacket Material:	Polythene (black);2.2mm OD

Spectral Attenuation of a PMMA Fibre