

OPTICAL FIBER COMMUNICATION

LABORATORY MANUAL

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EXPERIMENT 1

FIBER OPTIC DATA LINKS

OBJECT:

To observe and analyze various fiber optic data links when used for both digital and analog data transmission.

EQUIPMENT:

Function generators (Wavetek 186, Tektronix 115, HP 222A)

HP Digital Oscilloscope

2 Fluke 8050A multimeters

Variable D.C. power supply

Fiber optic data links

- 1) 3 Motorola links
- 2) Honeywell link
- 3) Hewlett Packard link
- 4) 20 MBaud link

THEORY:

The fiber optic data link consists of a transmitter which converts an electrical signal to a light signal, an optical fiber to guide the light and a receiver which detects the light signal and converts it to an electrical signal.

Light sources are either light emitting diodes (LED's) or laser diodes and detectors are phototransistors or photodiodes.

The Motorola data links all use the same transmitter with a GaAlAs LED emitting light at a wavelength of 820 nm. The Motorola 1 receiver has a PIN photodiode detector. The Motorola 2 receiver uses a phototransistor detector. The phototransistor is configured such that when light is incident on the base region a current flows from the collector to the emitter. The Motorola 3 receiver uses a photodarlington detector which consists of a second transistor incorporated into the same substrate as the transistor detector. The Motorola links are all noninverting data links.

The Honeywell link uses a GaAlAs LED as emitter at a wavelength of 820 nm and a photodiode detector. This is a noninverting link.

The HP link uses a GaAlAs LED in the transmitter and an integrated photodetector and DC amplifier in the receiver. This is an inverting data link.

The 20 MBaud data link uses a GaAlAs LED as the emitter and an integrated detector/preamplifier in the receiver. This link is noninverting.

All links employ TTL input and have TTL compatible output.

Table 1.1 lists the various links and their optoelectronic components. Specifications for all optoelectronic components are in Appendix 1 along with circuit diagrams for the Motorola, HP and 20 MBaud links. The different values of collector resistance in the Motorola transmitter are used to regulate the current in the LED.

Data Link	Emitter	Detector	Fiber
Motorola 1	MFOE71	MFOD71	ESKA SH 4001
Motorola 2	MFOE71	MFOD72	ESKA SH 4001
Motorola 3	MFOE71	MFOD73	ESKA SH 4001
Honeywell HF4102	SE3352	HFD4000	Belden 226101
HP HFBR-0200	HFBR1201	HFBR2201	HFBR-3001
20 MBaud	MFOE1200F	MFOD2405	Belden 227201

Table 1.1 Data Link Components

The Honeywell system was purchased as an assembled link and the schematic was not supplied. A unipolar square wave will be used as input to the data links to simulate digital data.

For experimental purposes maximum bandwidth will be defined as the frequency at which the output (see Figure 1.1) duty cycle becomes greater than 60/40 (or less than 40/60) or the frequency at which the output signal no longer resembles the input signal.

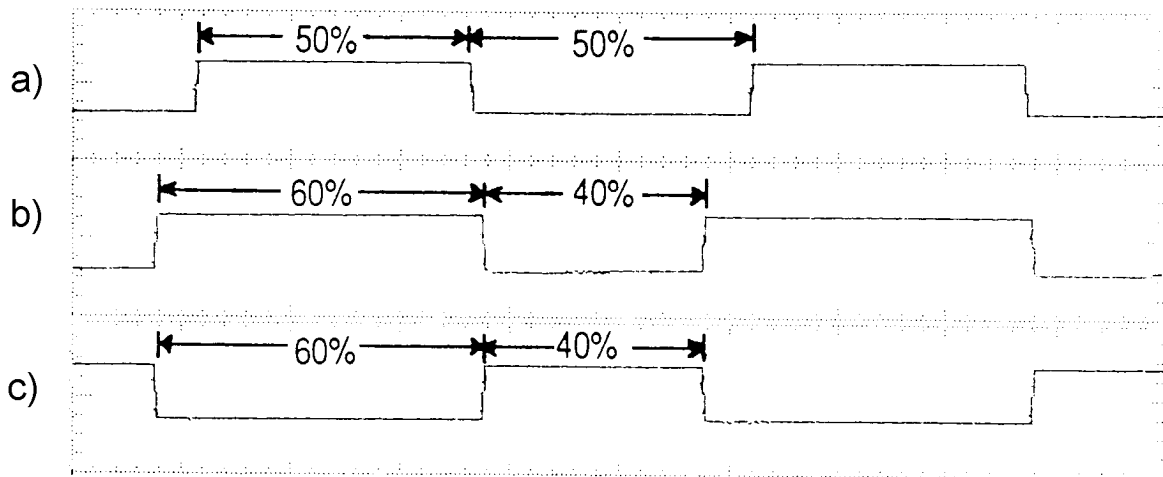


Figure 1.1 a) 50/50 duty cycle b) 60/40 duty cycle c) 40/60 duty cycle

The delay time (t_d) and storage time (t_s) will be measured for various data links as defined in Figure 1.2 for inverting or noninverting links.

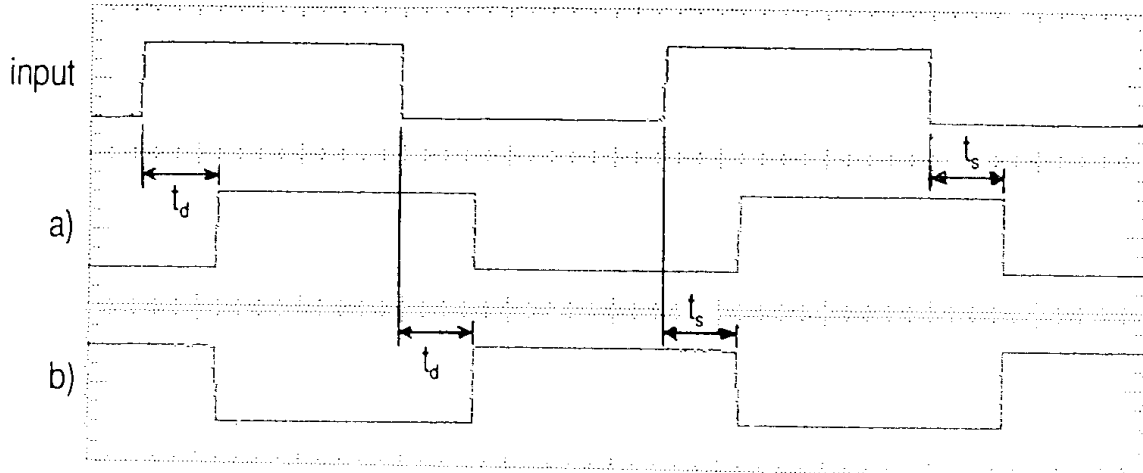


Figure 1.2 a) non-inverting link b) inverting link

The rise time (t_r) and fall time (t_f) will also be measured as defined in Figure 1.3.

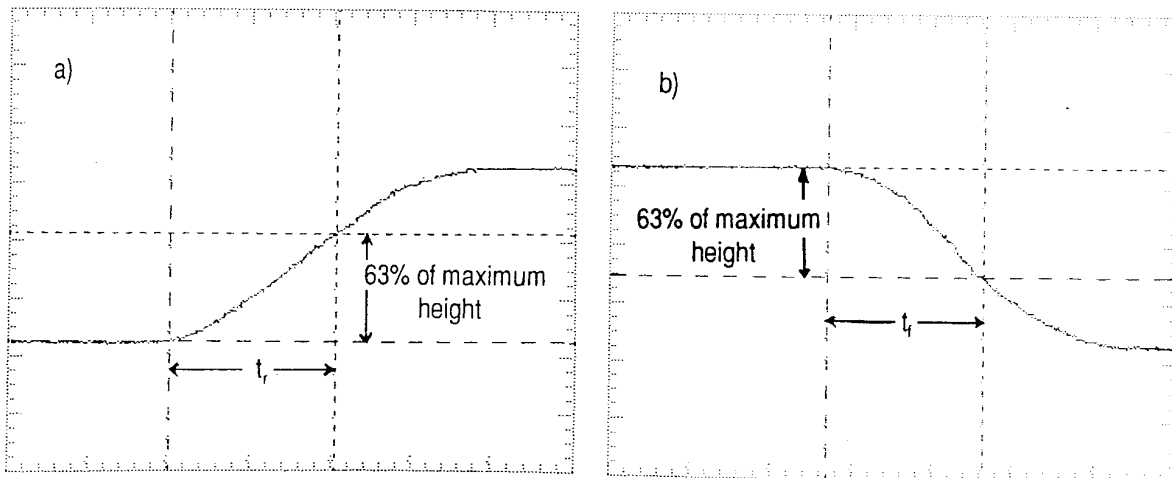


Figure 1.3 a) rise time b) fall time

PROCEDURE:**1. Time Measurements and Bandwidth**

Using a 5 V square wave with a 2.5 V DC offset set at the suggested frequencies, measure the output voltage (V_{out}), delay time (t_d), storage time (t_s), rise time (t_r), fall time (t_f), duty cycle and bandwidth for the specified links. Be careful using the 'measure risetime' function- the oscilloscope does not necessarily measure the 63 % risetime but defaults to a 90/10 risetime. For the Motorola 2 link use the TTL output and for the HP link, ensure that the switch is closed. Some time parameters may be difficult to measure. It may help to trigger the scope on whatever edge you are measuring (rising or falling). The duty cycle can be used to measure the Motorola 2 bandwidth but for the other links determine the bandwidth from the frequency at which the output signal no longer resembles the input signal.

Suggested	Link	V_{out}	t_d	t_s	t_r	t_f	duty cycle	bandwidth
4 KHz	Motorola 2							
140 KHz	Honeywell							
10 KHz	HP							
140 KHz	20 MBaud							

Comment on the delay time, storage time and bandwidth for the various links and compare to any theoretical values available.

For the Motorola 2 (TTL output), vary the transmitter collector resistance and measure the bandwidth.

Collector Resistance	Bandwidth
330 G	
68 G	
33 G	

Comment on the effect that changing the collector resistance has on the bandwidth.

2. Observation of Analog Transmission Capability

Analog transmission will be observed using the Motorola transmitter collector resistance set at 68 ohms. Observing the analog (A) output of the Motorola 1 receiver, begin with a 500 Hz, 830 mV_{p,p}, 1.1 V DC offset sine wave input and adjust the amplitude and DC offset until a sinusoid output of greatest attainable amplitude is observed (not clipped or deformed). Measure the output amplitude (this will be the reference value.) Increase the frequency of the input sine wave until the output amplitude drops 3 dB from the reference value (1/# 2 of the reference value since 20 log 1/# 2 = - 3 dB). The frequency at which the signal has dropped 3 dB is the cutoff frequency. Record the cutoff frequency once it is determined.

Follow the same procedure to find the cutoff frequency for the Motorola 3 detector. Start with a 500 Hz, 210 mV_{p,p}, 1 V DC offset sine wave input.

Comment on the cutoff frequencies and the usefulness of these data links for analog signal transmission.

3. Observation of Currents

3.1 Motorola Transmitter

Place an ammeter in series with the +5 V supply and the +5 V input on the Motorola transmitter. Measure the LED current of the transmitter for each value of collector resistance for both logic one (5 V DC input) and logic zero (0 V DC input) inputs.

Input	330 G	68 G	33 G
+5 V			
0 V			

Calculate the average power consumption of the transmitter for each value of resistance.

$$P_{avg} = \frac{V_{cc} (I_{5V} + I_{0V})}{2} \quad \text{where } V_{cc} = +5V$$

3.2 Motorola Receivers

Measure the detector currents (ammeter in series with the +5 V supply and the D input on the receiver) for both levels of input (+5 V and 0 V), for each of the Motorola receivers at each of the three values of transmitter collector resistance.

Detector	Input Voltage	330 G	68 G	33 G
M1	+5 V			
	0 V			
M2	+5 V			
	0v			
M3	+5 V			
	0 V			

Calculate the average power consumption of each receiver. Comment on the effect of collector resistance value on link performance and power consumption.

3.3 HP Transmitter and Receiver

Measure the supply current (ammeter in series with +5 V supply and +5 V input to transmitter) and LED current (ammeter connected to ammeter inputs and switch opened) of the HP transmitter for logic one and logic zero inputs. Measure the supply current of the receiver for both levels of input (ammeter in series with +5 V receiver input and +5 V supply).

Input	Transmitter Supply Current	Transmitter LED Current	Receiver Supply Current
+5 V			
0 V			

Compare the LED Current measured to the expected value.

$$I_F = \frac{V_{cc} - V_F}{R_1}$$

where

$$\begin{aligned} V_{cc} &= +5V \\ V_F &= 1.7V \\ R_1 &= 200\Omega \end{aligned}$$

Use the supply current values to calculate the average power consumption of the transmitter and receiver.

EXPERIMENT 2

FIBER TO FIBER JOINTS AND OTDR

OBJECT:

To learn proper fiber splicing techniques and to become familiar with the use of optical time domain reflectometry in characterizing optical fibers.

EQUIPMENT:

Oscilloscope (>50 MHz)
 50 G in line termination
 Orionics OTDR-102 or OTDR-103A
 Orionics FW-301 or Northern Telecom QSBE1A fusion set
 2 Fibers
 Tosco cutter
 Fiber strippers

THEORY:

1. Fiber to Fiber Joints

The interconnection of fibers in a low-loss manner is of particular importance in fiber optic systems. The particular technique used for joining the fibers depends on whether a permanent bond or a demountable connection is desired. Permanent bonds are referred to as splices and demountable connections as a connector.

One splicing method is fusion splicing. In this method the fiber ends are cleaved so that they are flat, perpendicular to the fiber axis and smooth. Proper end preparation will minimize losses due to light being deflected and scattered at the joint. The fibers are then aligned, usually with the aid of a microscope, and heated with an electric arc so the fiber ends are momentarily melted and bonded together. Fusion splices can be produced with losses of less than 0.25 dB for identical fibers with these splicers.

A popular method for demountable connections is the channel-based connector. The fibers are permanently fixed in plastic or metal plugs with the use of retaining clips or springs. The fiber end face is then cleaved and made flush with the plug end face. The two plugs may then be inserted in a connector which accurately aligns the fiber end faces and allows them to be butt jointed. Losses of 1-2 dB can be achieved with this method.

2. Optical Time Domain Reflectometry (OTDR)

The OTDR unit operates by periodically launching narrow laser pulses (10-100 ns) into one end of an optical fiber. The back scattered signal can then be analysed to determine the position of splices and breaks. The length, L , to a given reflection in the fiber is

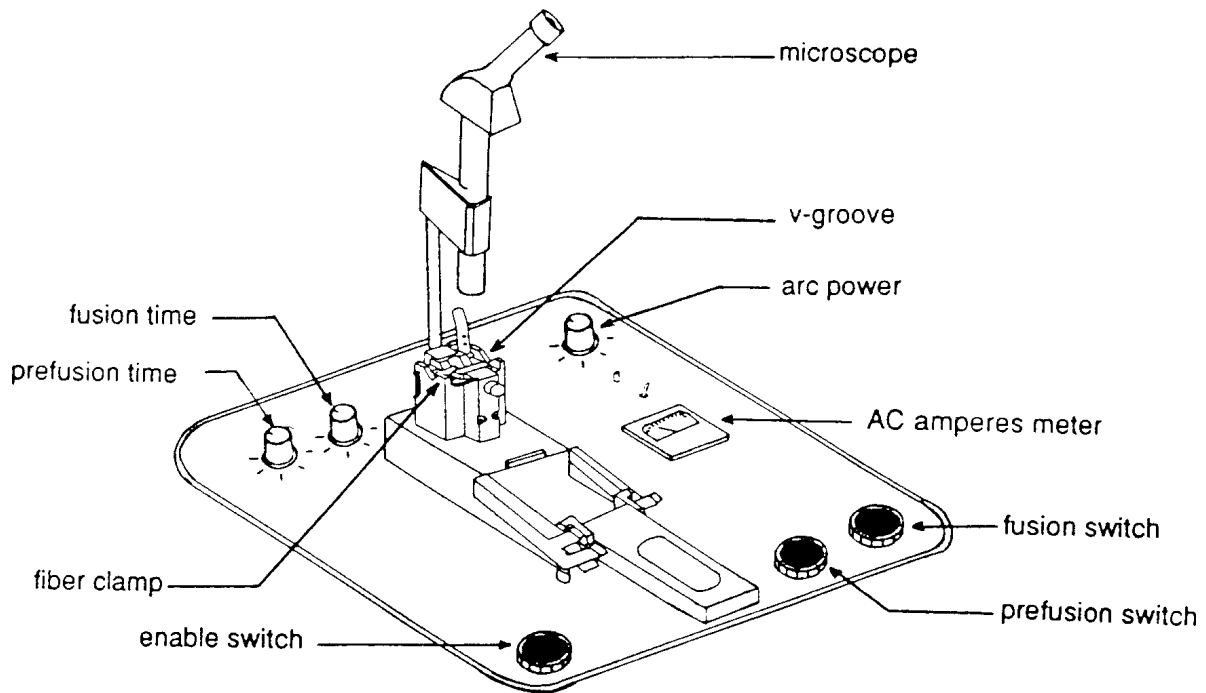
$$L = \frac{c}{2n} (t_r - t_0) \quad (\text{m})$$

where

c = speed of light in m/sec
 n = index of refraction of fiber core (1.47)
 t_0 = zero seconds
 t_r = time to reflection in seconds

PROCEDURE:**1. Fusion Sets**

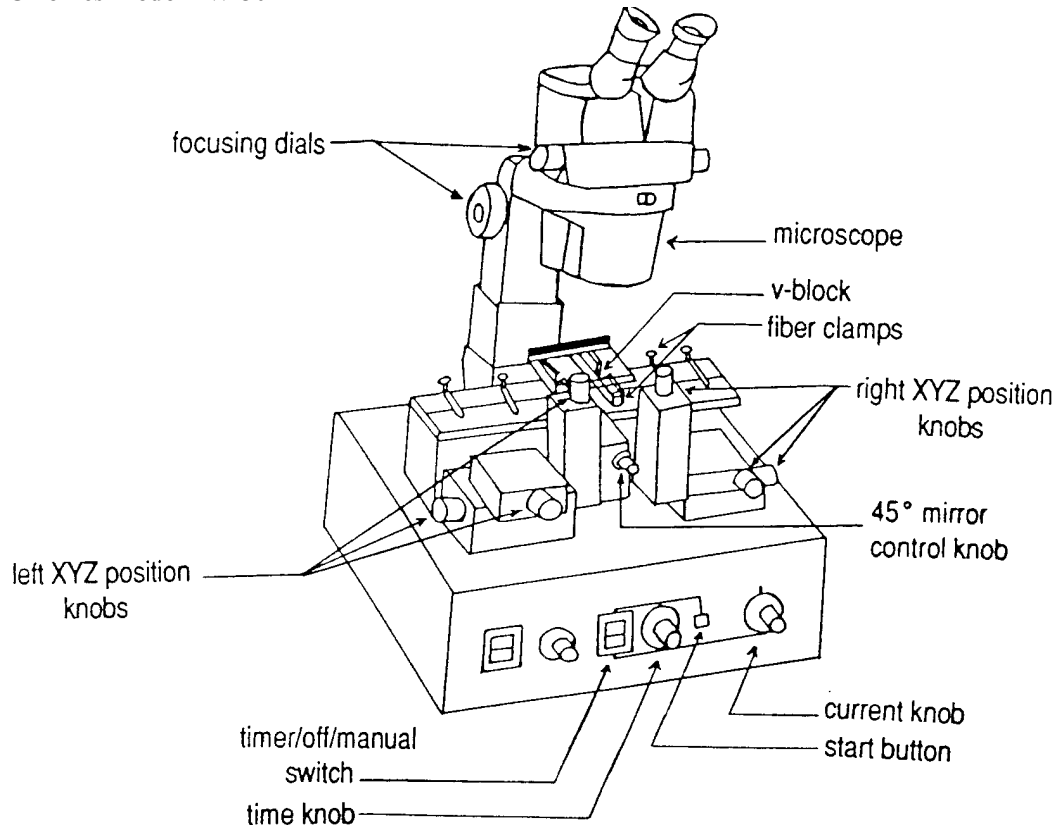
Identify the type of fusion set you have and read the instructions pertaining to that set.

Set #1 Northern Telecom QSBE1A Fusion Set

Microscope :	40x focused by sliding up and down its mast or sliding the eye piece in and out.
Fusion Head:	V-grooved with fiber clamps to hold fiber
Prefusion Time:	Controls the duration of the prefusion cycle
Fusion Time:	Controls the duration of the fusion cycle
Arc Power:	Controls arc intensity
Enable Switch:	Engages the prefusion and fusion switches
Prefusion Switch:	Engages the prefusion arc.
Fusion Switch:	Engages the fusion arc.
AC Amperes Meter:	Indicates current levels.

To place a fiber in the set for viewing, lift the fiber clamp, lay the fiber in the groove and lower the clamp. The fusion set should be focused so that the fiber can clearly be seen. To prefuse and fuse, the enable button must be held down while the prefuse or fuse button is used. Fibers must be aligned by hand with this set.

Set #2 Orionics Model FW-301



Microscope:	17.5x to 105x , focused with focusing dials
Fusion Head:	V-blocks with fiber clamps to hold fiber
Left XYZ Position Knobs:	Move the electrodes and mirror along three mutually perpendicular axes.
Right XYZ Position Knobs:	Move the fiber on the right side along three mutually perpendicular axes.
45° Mirror Control Knob:	Positions a 45° mirror to provide two perpendicular views of the held fibers.
Timer/OFF/Manual Switch:	Chooses between a timed arc or manually controlled arc.
Time Knob:	Controls arc time from 0.1 to 3 seconds.
Start Button:	Initiates the arc when in timer mode
Current Knob:	Sets the arc current level.
AC Amperes Meter:	Indicates the current through the primary of the high voltage arc transformer.

To place a fiber in the set for viewing, lift the fiber clamps, lay the fiber in the groove and lower the fiber clamps. Each side of the fusion head is also equipped with two cable clamps that can be used to secure the fiber. The fusion set should be focused so the fiber can clearly be seen. Once the fibers are in place the right XYZ knobs can be used to move the right fiber. The 45° mirror can be used to aid in lining up the fibers in all directions. To prefuse or fuse the safety shield must be lowered and the mirror must be removed from the electrode area by turning the mirror control knob. Once everything is in place an arc can be applied to prefuse or fuse using the timed controls or manual controls.

2. Cleaving the Fiber End

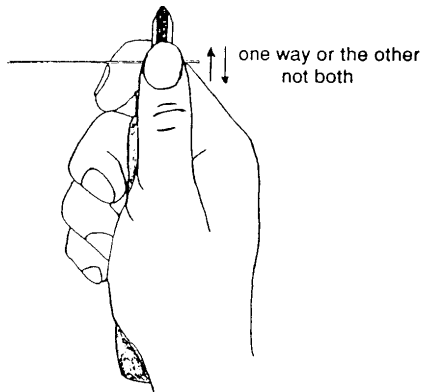
Use whichever method works best for you. Safety glasses should be worn while cleaving.

Method 1: Use the Tosco cutter, on a hard flat surface, to remove approximately 0.5 cm of fiber.



Use the fiber strippers to remove approximately 5-8 mm of coating from the fiber.

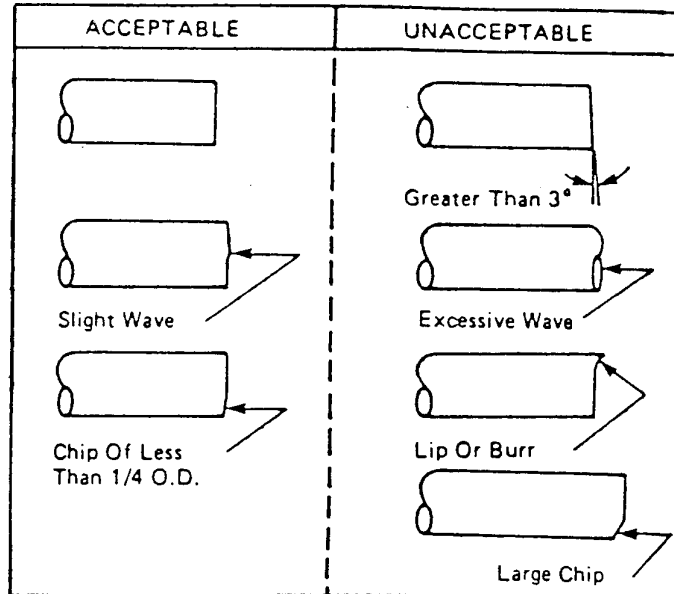
Method 2: Using the fiber strippers, remove approximately 1.5 cm of coating off the end of the fiber. Place the exposed fiber perpendicularly across the edge of the Tosco tool. VERY gently scratch the fiber on the tool in ONE direction only.



Once the fiber has been etched use your finger to flick the end of the fiber off.

3. Inspecting the Cleaved End

Place the cleaved fiber in the fusion set to inspect the end. Once the fiber is placed in the set and is in focus, rotate it to ensure that an acceptable cleave has been achieved.



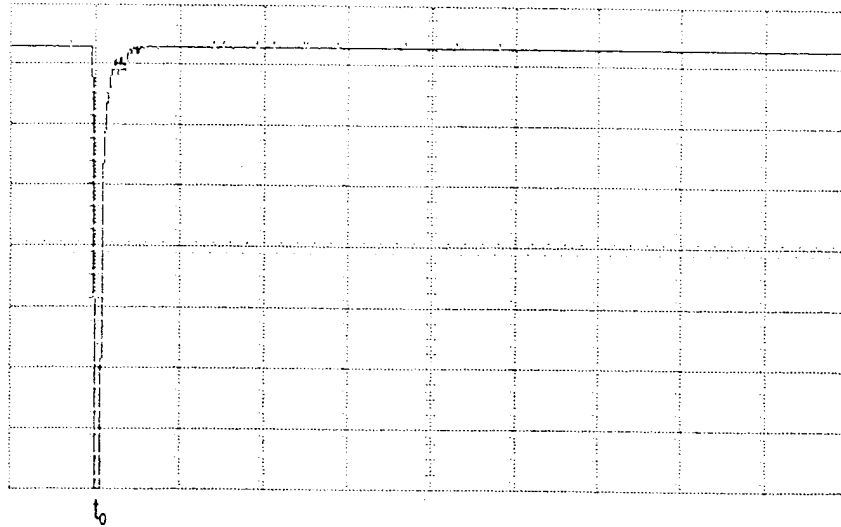
If the end is not acceptable, repeat the cleaving procedure.

4. Setting up the OTDR Unit.

Once the fiber end is prepared, place it in the OTDR XYZ positioner. There is a small dot on the OTDR that the fiber must be aligned with. This is NOT a hole, do not try to put the fiber end in it. Either by hand, or by using a positioning knob, move the fiber in as close as possible to the surface the dot is on. The OTDR should have the pulser ON, the pulse width set at 10 ns and the signal beamwidth set to 5 MHz.

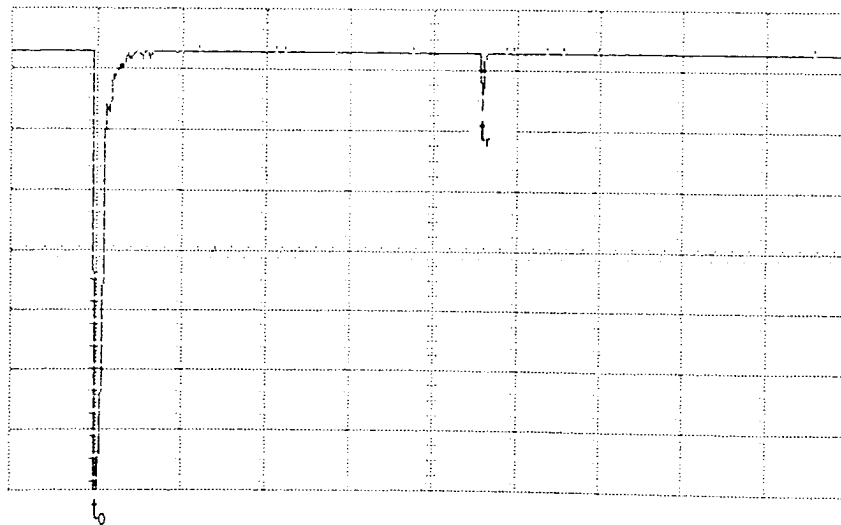
Connect the signal output to one channel of the oscilloscope via a 50 G in line termination. This channel should be set for as low a volts/div as possible (typically around 5 mV/div). If the scope has a x5 or x10 magnification option, this can also be used. Connect the pretrig output to another channel on the oscilloscope that can be used as the triggering source. A time base of 0.5-2 μ sec/div should typically be used (depending on the fiber length).

Once the scope is set up the OTDR signal power amplitude control should be turned up as high as possible without causing excessive noise on the oscilloscope. The display should look like:



Note that the OTDR amplifier is an inverting amplifier, and that the large dip is actually a large spike due to Fresnel reflection at the air-fiber interface.

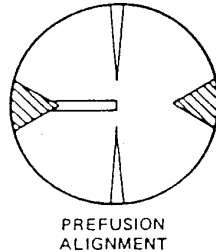
The fiber needs to be aligned with the dot on the OTDR unit. The display on the oscilloscope will waver once you are close. If you are adjusting in one direction and are seeing a waver, you may want to switch adjustment directions. Adjust the fiber until it is aligned and a peak from the reflection at the other end of the fiber can be seen on the oscilloscope. Both ends of the fiber may need to be cleaved to obtain an end reflection.



From the oscilloscope, measure the time between the peaks and using the formula given previously, calculate the length of the fiber.

5. Splicing the Fiber

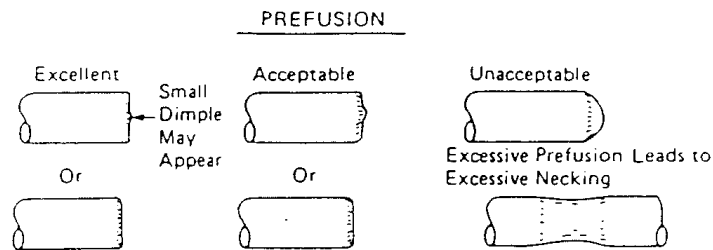
Once both fibers have been prepared and the lengths of both fibers have been established, one fiber must be prefused. To prefuse, align one fiber end between the fusion set electrodes.



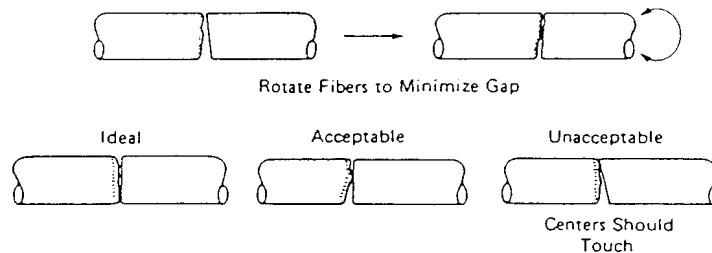
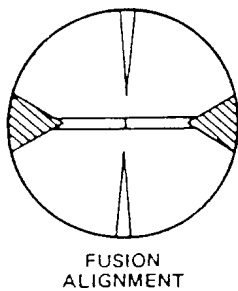
Once the fiber is aligned between the electrodes:

Set #1 Northern Telecom	Set #2 Orionics
With the prefusion time set around 4 seconds and the arc power at about 4, hold down the enable button and then hold down the prefusion button.	Ensure the mirror is removed and the safety shield is lowered. Set the time knob to about 1.2 seconds, put Timer/OFF/Manual switch on Timer, set the current knob to the marked level and push the start button.

Examine the prefused end to ensure that it is acceptable. If it is not, prefuse again, or re-cleave and prefuse again, as necessary.



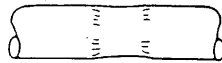
Once the fiber end is acceptably prefused, the fibers can be aligned for fusing. (The Orionics set (Set #2) has a 45° mirror to aid in alignment).



Once the fibers are aligned they can be fused. Look at the fibers to ensure fusion is taking place as you follow the suggested instructions below:

Set #1 Northern Telecom	Set #2 Orionics
With the fusion time set around 1.5 seconds and the arc power at about 5, hold down the enable button and press and hold down the fusion button 5 times to supply 5 continuous pulses.	Ensure the mirror is removed and the safety shield is lowered. Set the time knob to about 1.2 seconds, put Timer/OFF/Manual switch on Timer, set the current knob to the marked level and push the start button 5 times to supply 5 continuous pulses.

Once the fusion is complete, the joint should be rotated and inspected to ensure that there is not excessive necking, trapped bubbles, cracks or gaps. Slight necking is normal but entrapped bubbles are not acceptable.



Slight Necking is Normal

If it seems as though more fusion is needed, do so as seems necessary until you have an acceptable joint.

Once a successful splice has been achieved, place the spliced fiber in the OTDR unit and measure the length. The spliced length should be the sum of the previous two lengths. If it is not, the splice was not successful. If this is the case, the splice needs to be broken, the fiber ends re-cleaved and the splicing procedure repeated.

EXPERIMENT 3

NUMERICAL APERTURE

OBJECT:

Tracing the angular radiation (or reception) pattern of an optical fiber to determine its numerical aperture.

EQUIPMENT:

KOP-100 fiber optics kit
X-Y recorder
2 Fluke 8050A multimeters

THEORY:

The numerical aperture of a step-index fiber is the sine of the maximum acceptance angle of the fiber. Numerical aperture is also defined as the solid angle which encloses 90 % of the total emitted power of the fiber.

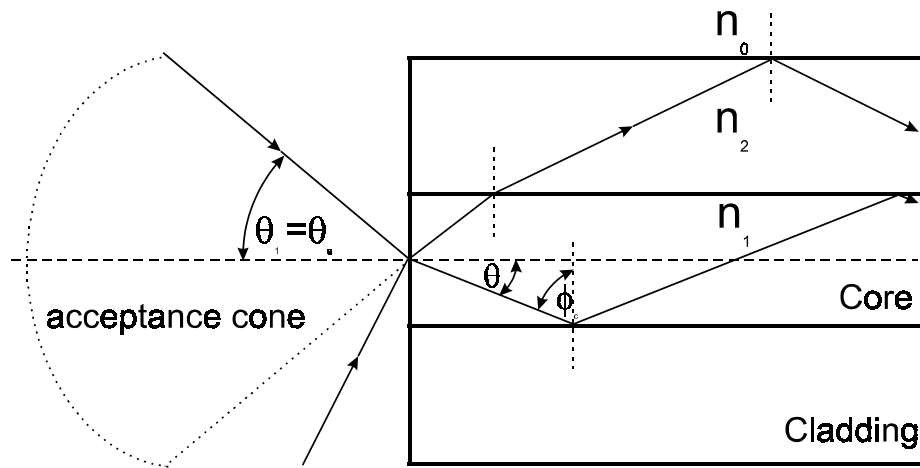


Figure 3.1 acceptance angle and light propagation

Figure 3.1 illustrates light propagation in an ideal step index fiber. From ray optics theory numerical aperture is defined as

$$\text{N.A.} \triangleq \sin \theta_a = \sqrt{n_1^2 - n_2^2}$$

Since a fiber's acceptance and emission patterns are the same, the numerical aperture of a fiber can be experimentally determined by measurement of the emission pattern of the fiber. The radiation pattern can be expressed as

$$I(\theta) = I_0 \cos^m \theta \quad (\text{W/sr})$$

where I_0 is the energy intensity on the symmetry axis and $I(\theta)$ the energy intensity measured at an angle θ from the axis.

The total power intercepted within a cone of half angle θ_1 is

$$P_\theta = I_0 \int_0^{2\pi} \int_0^{\theta_1} \cos^m \theta \sin \theta \, d\theta \, d\phi \quad (\text{W})$$

$$= \frac{2\pi I_0}{m+1} [1 - \cos^{m+1} \theta_1] \quad (\text{W})$$

The total power emitted within a solid angle $2\theta_1$ (i.e. $\theta_1 = \theta/2$) is

$$P_T = \frac{2\pi I_0}{m+1}$$

By definition N.A. is equal to the solid angle enclosing 90 % of the emitted power so

$$0.9 = \frac{P_{\theta_1}}{P_T} = 1 - \cos^{m+1} \theta_1$$

$$\text{so } \cos^{m+1} \theta_1 = 0.1$$

and in general $m \gg 1$ so that

$$\cos^m \theta_1 \approx 0.1$$

and

$$I(\theta_1) = 0.1 I_0 \quad (\text{W/sr})$$

where θ_1 is the angle associated with intensity equal to 10 % of the maximum. Therefore by definition.

$$\text{N.A.} = \sin \theta_1$$

In practice the launch N.A. in a multimode fiber tends to be greater than the equilibrium numerical aperture, N.A._{eq} . The N.A._{eq} is attained after the launched modes have reached equilibrium. The value of N.A._{eq} , therefore, is the important characteristic when considering launched optical power.

The method of determining N.A. will be to inject light into fibers of increasing length and measure their radiation patterns. The value of θ_1 can be determined from the radiation pattern since the ratio of the angle at $I(\theta_1)$ to the angle between the endpoints in degrees is proportional to the same ratio in centimeters (see Figure 3.2).

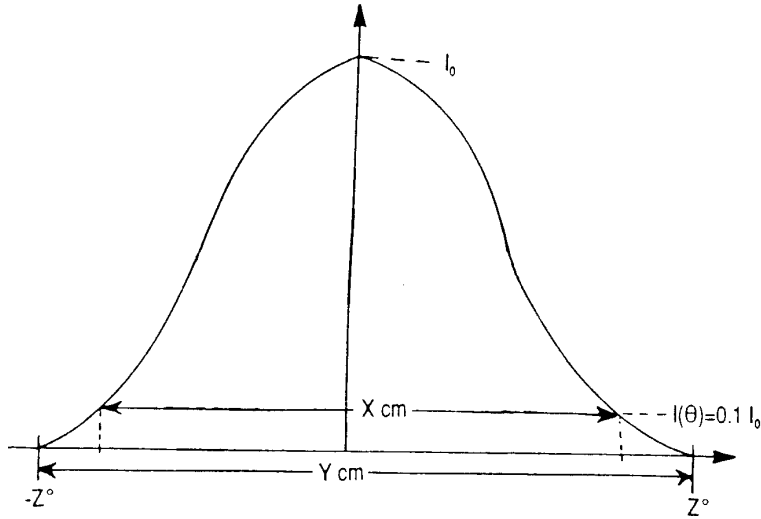


Figure 3.2 analysis of a radiation pattern

$$\frac{2\theta_1}{2Z} = \frac{X}{Y}$$

Once the value of θ_1 is determined, the N.A. can easily be found. A graph of N.A. versus fiber length will be used to determine N.A. eq.

PROCEDURE:

Set the MOD-DIR switch at DIR at GAIN at X10. Connect the TIL24 LED(12) to the TRANSMISSION output and the PIN photodiode (14) to the PIN input.

Install the PIN photodiode on the X-Y mechanical stage and screw the TIL24 LED to the L bracket (18) mounted on the turntable. The L bracket should be mounted so the LED faces the PIN detector. Adjust the X-Y stage for a 5 cm separation between the LED and the detector. Set the variable DC power supply to 4 V and connect it to the TRANSMISSION input. Turn the electronics module on. Connect the ROTATION and PREAMP outputs to voltmeters. The ROTATION output is proportional to the angular rotation of the turntable (10 mV/degree). Adjust the height of the X-Y stage to get maximum PREAMP signal at zero degrees rotation angle. Connect the ROTATION and PREAMP outputs to the X and Y inputs of the recorder respectively (see Figure 3.3). Record the angular radiation pattern of the TIL24 LED from -90 to +90 degrees ($Z=90^\circ$), or as close to -90 to +90 degrees as possible.

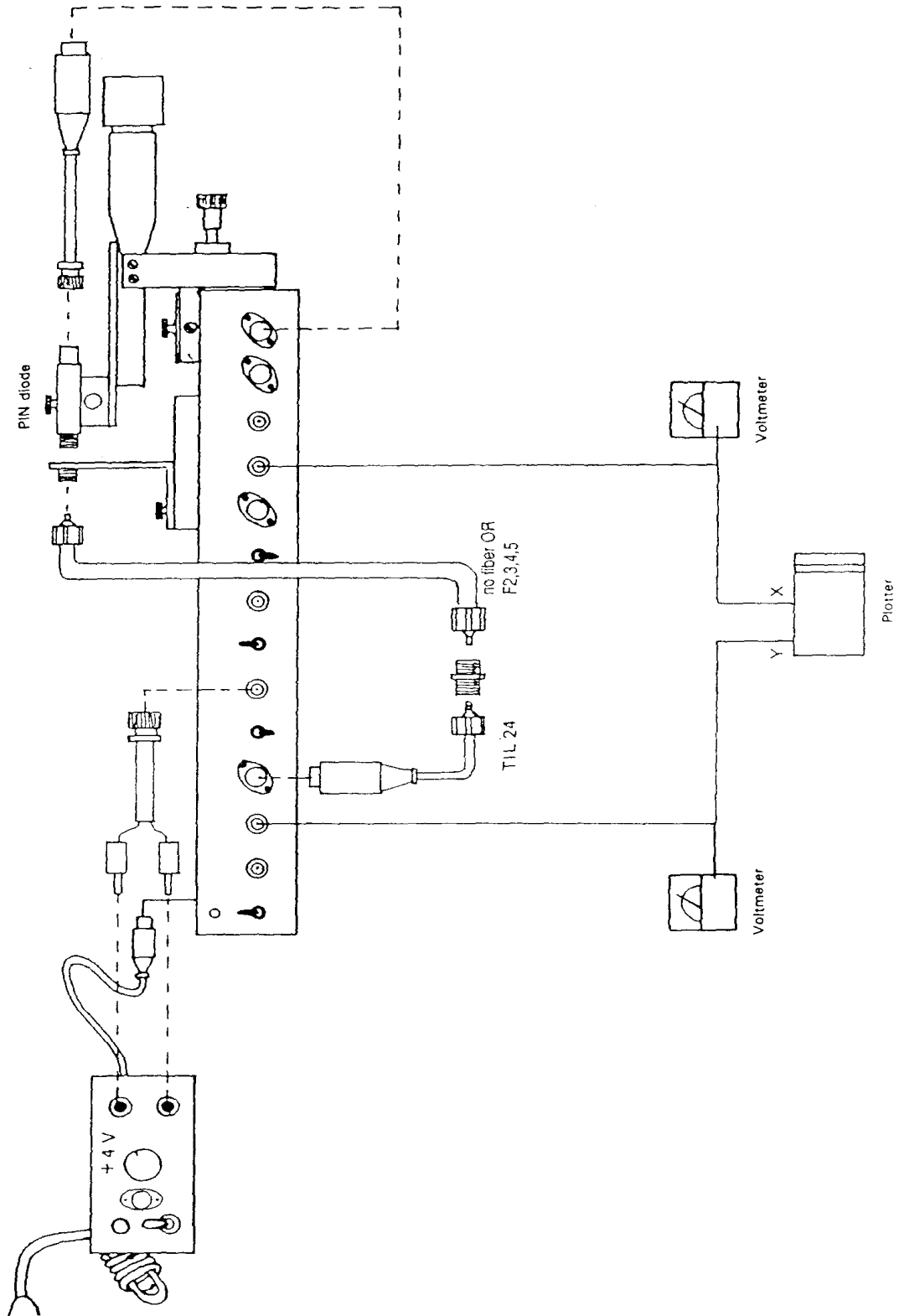


Figure 3.3 equipment connections

Remove the LED from the L bracket. Connect one end of the 0.5 m F2 fiber to the LED and the other to the bracket. Maximize the PREAMP output as before. Record the angular radiation pattern of the fiber from -90 to +90 degrees. Determine the fiber numerical aperture using the method described in the theory. Repeat the above procedure for the 1.0 m F3 fiber.

Adjust the X-Y stage for a 3 cm separation between the LED and detector. Maximize the PREAMP output. Connect the 2.0 m F4 fiber to the LED and bracket. Record the angular radiation pattern of the fiber from -60 to +60 degrees and determine its numerical aperture.

Adjust the X-Y stage for a 2 cm separation. Maximize the PREAMP output. Record the angular radiation pattern of the 4.0 m F5 fiber from -60 to +60 degrees and determine its numerical aperture.

Draw a graph of numerical aperture vs. fiber length.

Questions:

1. For a core refractive index of 1.6 and cladding refractive index of 1.526 calculate the fiber N.A.
2. Compare the value calculated above with the graphical results obtained in the experiment.

EXPERIMENT 4

MISALIGNMENT LOSSES

OBJECT:

Determination of connecting losses due to lateral misalignment, longitudinal displacement, and angular misalignment of fiber cores.

EQUIPMENT:

KOP-100 fiber optics kit
2 Fluke 8050A multimeters

THEORY:

When joining two fibers, either with a splice or a connector, losses due to misalignment will occur. The three types of misalignment are: lateral misalignment (also called radial or axial misalignment), longitudinal (end) displacement, and angular misalignment.

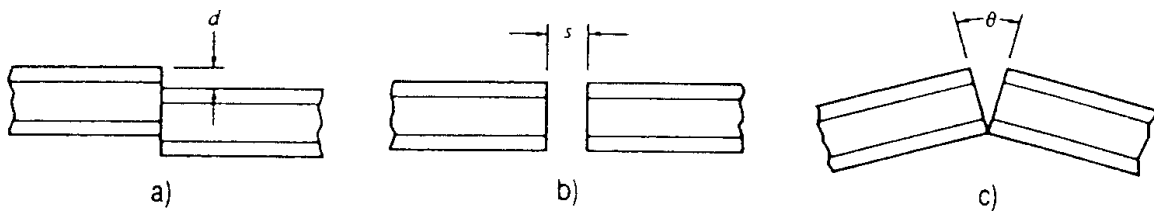


Figure 4.1 a) lateral (axial) b) longitudinal (end separation) c) angular

1. Lateral Misalignment

Lateral misalignment is the separation of the axes of the fibers by a distance d as shown in Figure 4.2.

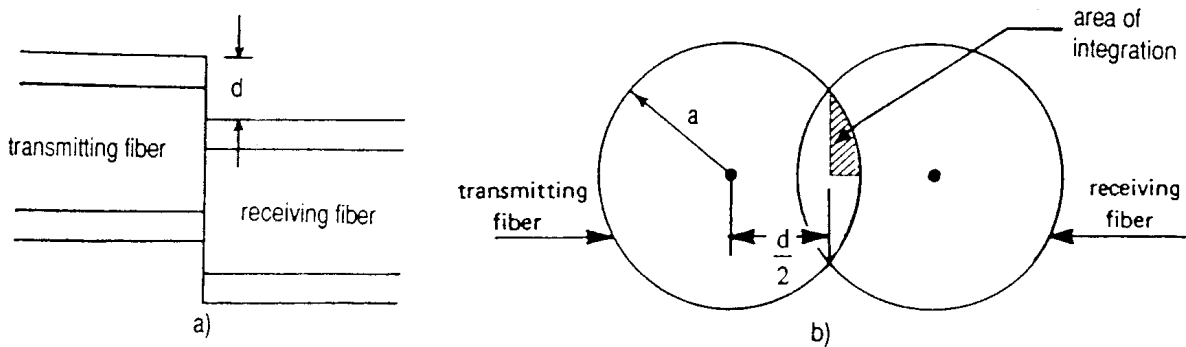


Figure 4.2 lateral misalignment: a) side view b) end view

This displacement reduces the amount of overlap of the two fiber end faces and therefore the amount of power coupled from one fiber to the other. For multimode, step-index fibers of identical numerical aperture and radius a , a reasonable approximation is that the optical power coupled from one fiber to the other is proportional to the core area common to both fibers.

The common area can be calculated as

$$A_{\text{com}} = 4 \int_{\theta=0}^{\cos^{-1} \frac{d}{2a}} \int_{r=\frac{d}{2\cos\theta}}^a r \, dr \, d\theta \quad (m^2)$$

$$= 2a^2 \cos^{-1} \frac{d}{2a} - d \left(a^2 - \frac{d^2}{4} \right)^{\frac{1}{2}} \quad (m^2)$$

and the total area of an end face is $A_t = \pi a^2$ (m²)

so that coupling efficiency (η_{LAT}) is

$$\eta_{\text{LAT}} = \frac{A_{\text{com}}}{A_t} = \frac{2}{\pi} \cos^{-1} \frac{d}{2a} - \frac{d}{\pi a} \left[1 - \left(\frac{d}{2a} \right)^2 \right]^{\frac{1}{2}}$$

and losses due to lateral misalignment are

$$L_{\text{LAT}} = 10 \log \eta_{\text{LAT}} \quad (\text{dB})$$

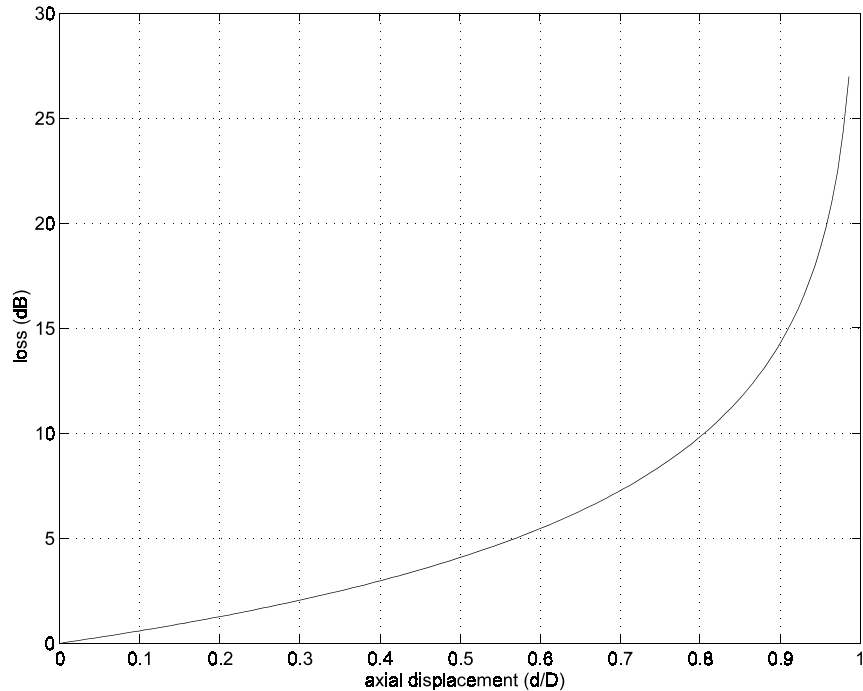


Figure 4.3 connecting losses vs ratio d/D

2. Longitudinal Displacement

Longitudinal displacement is the separation of the two end faces of the fibers by a gap s . The emitting fiber radiates in a solid angle of which only a portion is intercepted by the receiving fiber. The amount of light received is dependent on both the fiber's acceptance angle (θ_a) and on the length of the gap, s . See Figure 4.4.

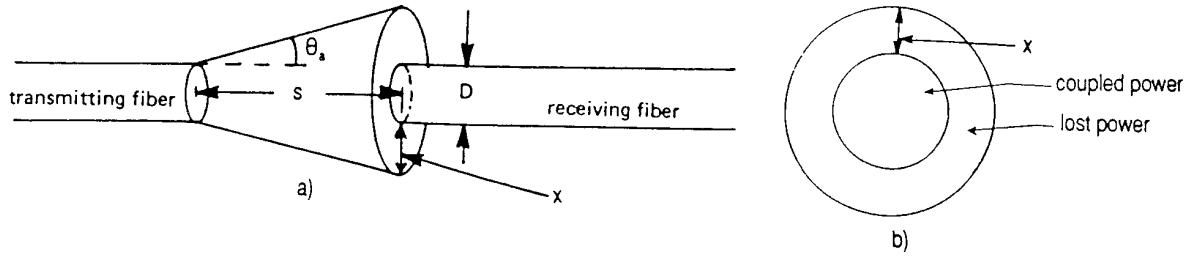


Figure 4.4 longitudinal displacement: (a) side view (b) end view

Assuming, as in the previous case, the fibers are multimode step-index type, and ignoring Fresnel reflections, a reasonable approximation is that the optical power coupled is a ratio of areas.

$$\eta_{\text{LON}} = \frac{\pi a^2}{\pi (a + s \tan \theta_a)^2}$$

$$= \left(\frac{a}{a + s \tan \theta_a} \right)^2$$

The loss due to longitudinal displacement is

$$L_{\text{LON}} = 10 \log \eta_{\text{LON}} \quad (\text{dB})$$

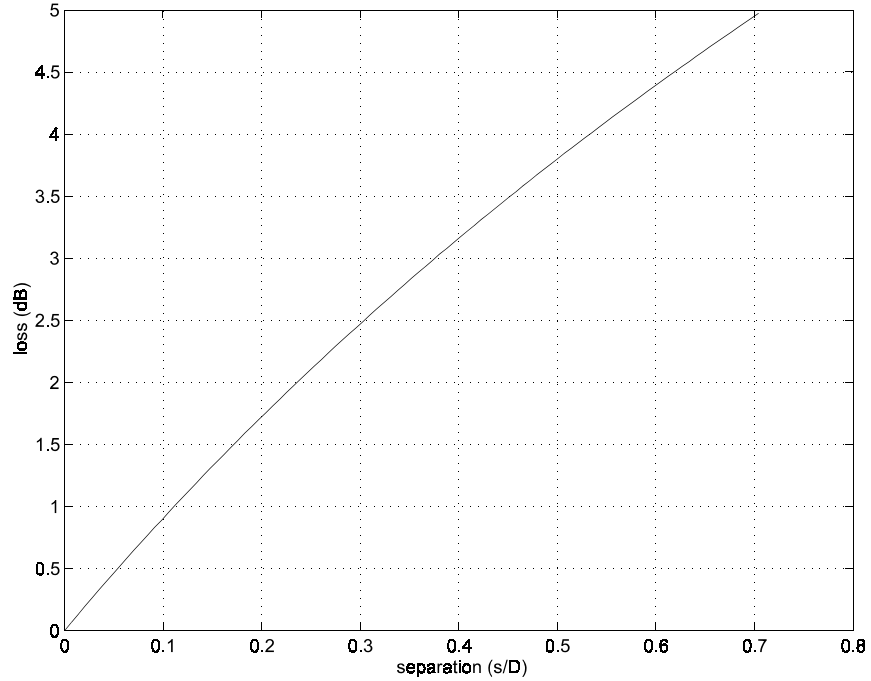


Figure 4.5 connecting losses due to core separation vs ratio s/D

Longitudinal displacement losses can be greatly reduced with the use of an index adaptation liquid as observed in experiment 5.

3. Angular Misalignment

The third type of mechanical misalignment is angular misalignment.

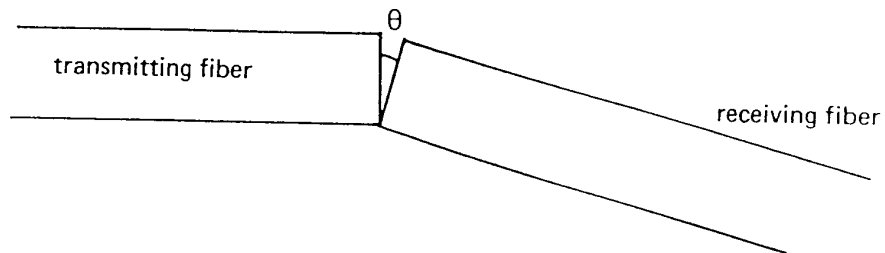


Figure 4.6 angular misalignment

Using the same assumptions as in the previous cases the loss due to angular misalignment has been shown to be

$$L_{\text{ANG}} = -10 \log \frac{16 (n_1/n)^2}{[1+(n_1/n)]^4} \left[1 - \frac{n\theta}{\pi n_1 (2\Delta)^{\frac{1}{2}}} \right] \text{ dB}$$

where θ = angular displacement in radians

n_1 = core refractive index

n = surrounding medium refractive index

Δ = refractive index difference

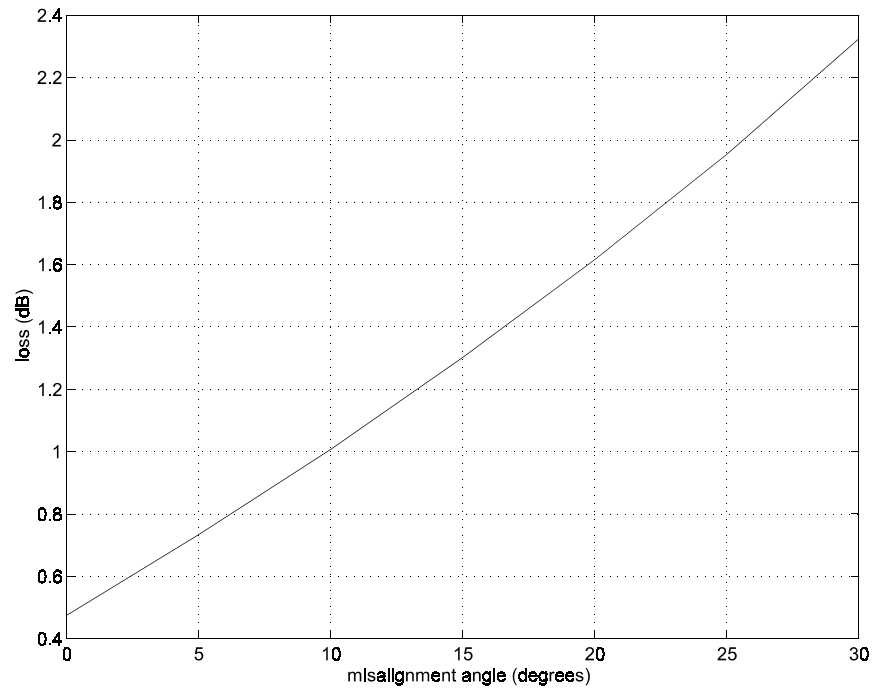


Figure 4.7 connecting losses vs alignment angle

PREPARATION:

1. Calculate the theoretical loss due to lateral misalignment of 0 to 1.4 mm. Graph this as loss, in dB, versus the ratio d/D , where d is the lateral offset and D is the core diameter (1.42 mm).
2. Calculate the theoretical loss due to angular misalignments of 0 to 30 degrees. Graph this as loss, in dB, versus angle of misalignment.

PROCEDURE:

1. Losses due to Longitudinal Displacement

Set the MOD-DIR switch at DIR and GAIN at X1. Connect the TIL24 LED to the TRANSMISSION output and the PIN photodiode (14) to the PIN input. Connect the 0.5 m F2 fiber (2) to the LED and the pigtail fiber (8) to the photodiode. Install the L shaped bracket (18) on the turntable such that at zero degrees rotation the connector is on the edge of the turntable. Connect the F2 fiber to the L bracket. Insert the pigtail fiber (8) into the mounting block (16) on the X-Y mechanical stage and secure it with a set screw. Adjust the X-Y stage to bring the two fiber end faces together. Set the DC power supply at 4 Volts and connect it to the TRANSMISSION input. Turn the KOP-100 electronics module on. Connect the PREAMP output to the multimeter and adjust the X-Y stage to obtain maximum output as close to zero degrees rotation as is possible. Connect the TRANSLATION output to the other multimeter (see Figure 4.9). This voltage is proportional (1V/cm) to the horizontal position of the X-Y stage. Record the PREAMP output for a 0-7 mm range of fiber separation. Plot the loss in dB versus fiber separation (s/D) where D is the fiber diameter (1.42 mm).

Since the detector output voltage is directly proportional to optical power, the use of the following equation is appropriate, where V_o is the voltage measured at 0 separation and V_i is the new voltage reading at each subsequent measurement:

$$loss = -10 \log_{10} \left(\frac{V_o}{V_i} \right)$$

2. Losses due to Lateral Misalignment

Adjust the X-Y stage for 0.5 mm separation between the fibers. Connect the ROTATION output to the multimeter (see Figure 4.10). This output voltage is proportional (10 mV/degree) to the angular rotation of the turntable. Record PREAMP output for angular rotations of 0.3, 0.6, 0.9, 1.2, 1.5 and 1.8 degrees in the positive (clockwise) direction. Rotate the turntable approximately 0.3 degrees past the desired point and then return to the desired point before recording the PREAMP output. For this part of the experiment the following method of approximating the lateral misalignment, d , will be used:

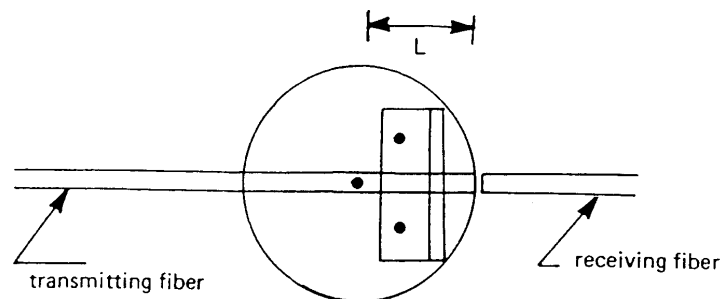


Figure 4.8 lateral misalignment approximation

The distance L (4 cm) from the rotation axis to the transmitting fiber end is large relative to the lateral displacement, d , so

$$d = L \tan \alpha \approx L \alpha \quad (\text{cm})$$

where α , in radians, is the angular displacement of the turntable.

Calculate the lateral displacement, d , for the degree of rotation in each case above. Plot loss in dB versus d/D , where D is the fiber diameter (1.42 mm). Compare these results to theory.

3. Losses Due to Angular Misalignment

Remove the L bracket from its position and reinstall it so the connector is above the center of the turntable (see Figure 4.11). Adjust the X-Y stage for 0.5 mm separation between the fibers. Adjust the stage as in part 1 for maximum PREAMP output at zero degrees rotation. Record the PREAMP output for rotation of 0 to 30 degrees. Calculate the losses due to angular misalignment. Plot loss, in dB, versus angle and compare with the theoretical values.

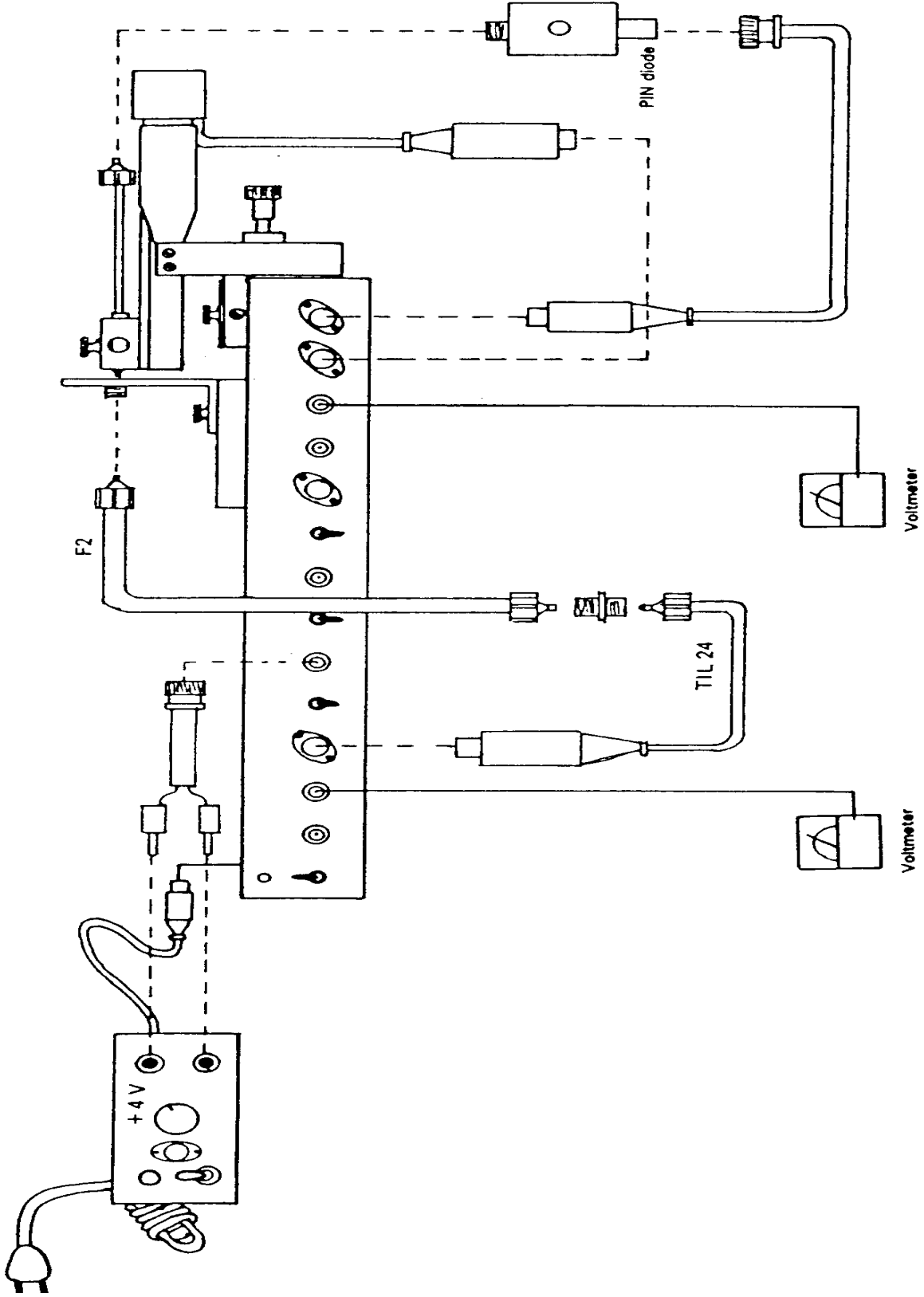


Figure 4.9 equipment connections for part 1

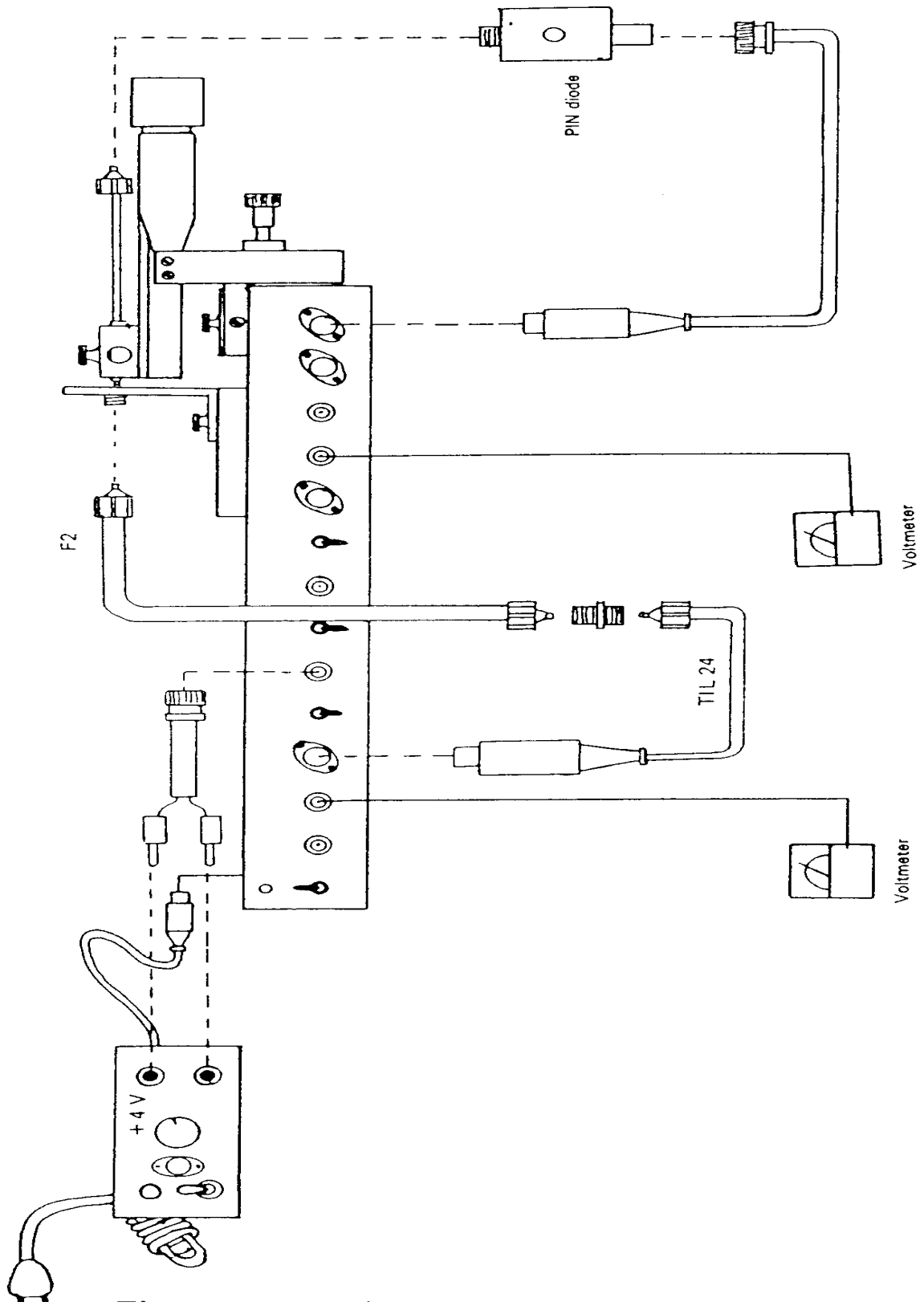


Figure 4.10 equipment connections for part 2

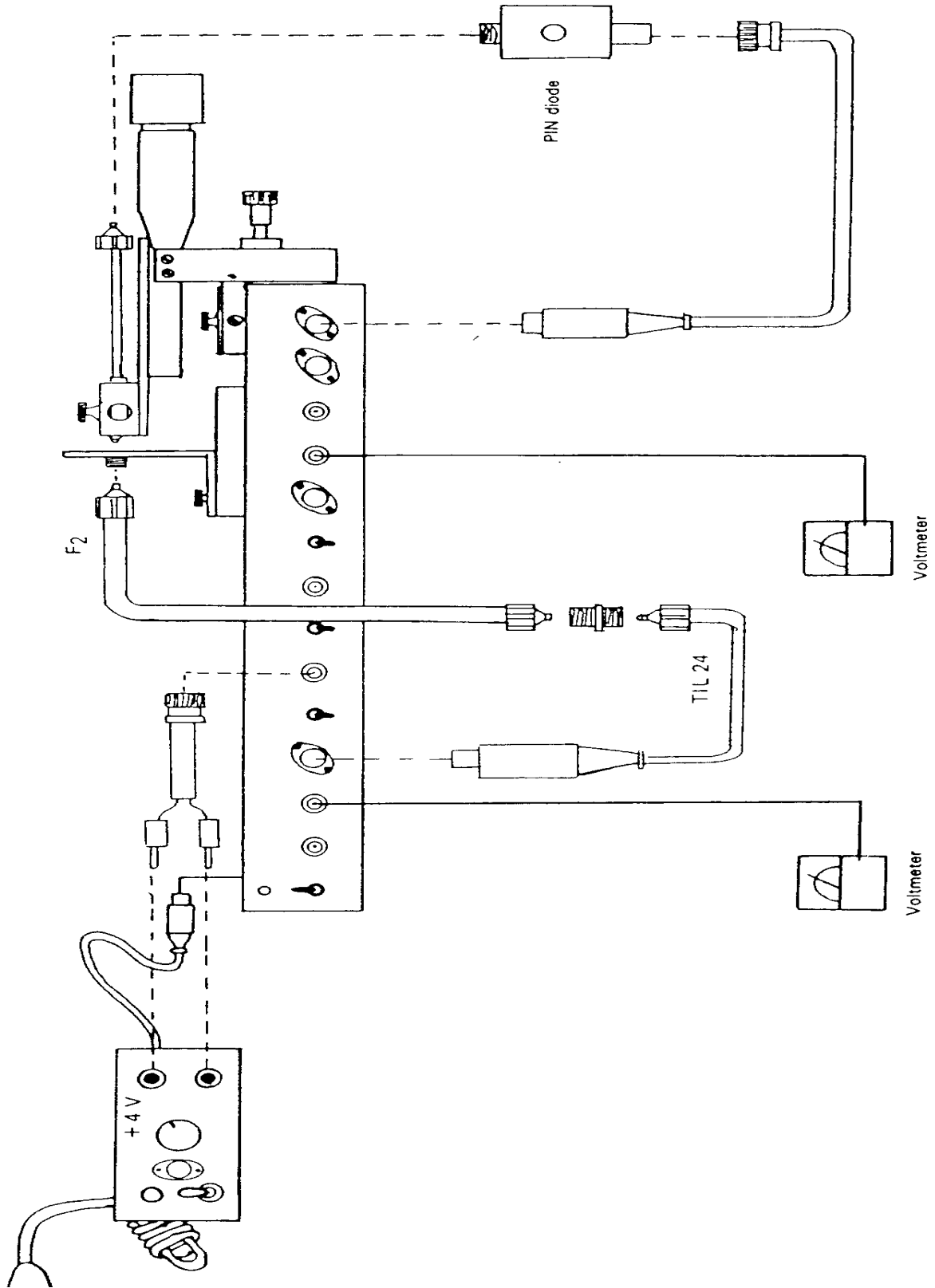


Figure 4.11 equipment connections for part 3

EXPERIMENT 5

LINEAR ATTENUATION

OBJECT:

To determine the linear attenuation of an optical fiber at wavelengths of 650 nm and 940 nm.

EQUIPMENT:

KOP-100 fiber optics kit
1 Fluke 8050A multimeter

THEORY:

The fibers in the KOP -100 kit are of the step index type. The core refractive index is 1.6 and the core diameter 1.42 mm. These are multimode fibers. Multimode fibers have several advantages for the laboratory set-up; the ease with which power can be launched into them, ease of interconnection, and the fact they can be excited using a LED which is the type of emitter used in the KOP kit.

One of the most important characteristics of the optical fiber is the attenuation of the optical signal as a function of distance traveled in the fiber. The basic mechanisms of attenuation are absorption, scattering and radiative losses. Both absorption and scattering are wavelength dependent and therefore the fiber attenuation will be also.

The excitation of a multimode fiber causes the energy to be distributed in several modes. Several hundred modes can be set up in the fiber immediately adjacent the optical source. However, not all of the modes will travel the entire length of the fiber. The input of the fiber plus a coupling length (L_c) can be thought of as a transition region up to where the mode distribution comes to a steady state. In this region, attenuation will be a function of length, and, beyond this region, attenuation per meter will be a constant. See Figure 5.1.

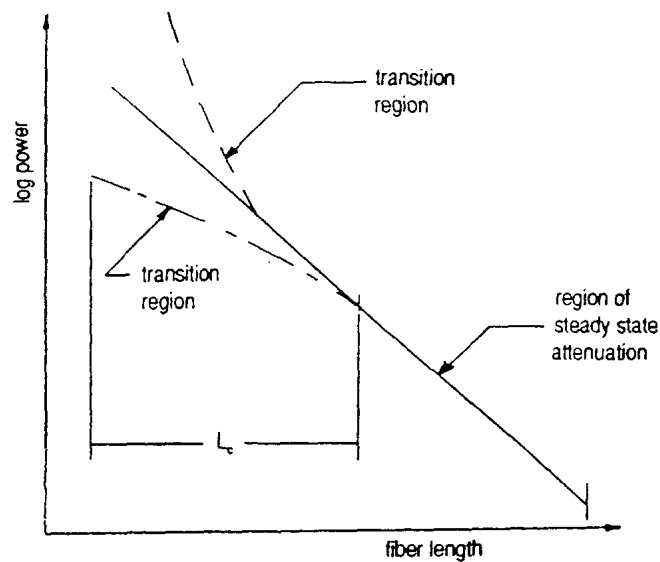


Figure 5.1 coupling length (unconstant ")

The attenuation coefficient (α) will be used to express the rate of diminishment of average power with respect to distance along the fiber.

The differential method will be used in this experiment to determine the total fiber attenuation per unit length.

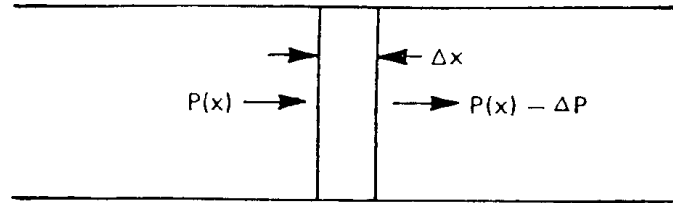


Figure 5.2 power incident on incremental length of fiber

Suppose that an amount of optical power $P(x)$ is incident on the incremental portion of length Δx . The amount of energy diffused and absorbed is statistical and is proportional to $P(x)$ and Δx so

$$\Delta P = -\alpha P(x) \Delta x$$

where α is the attenuation coefficient. This can be written as

$$\frac{\Delta P}{P(x)} = -\alpha \Delta x$$

Solving for $P(x)$ gives

$$P(x) = P(0) e^{-\alpha x} \quad (\text{W})$$

assuming that measurement takes place beyond coupling length (L_c) and therefore α becomes a constant.

Solving for α we obtain

$$\alpha = \frac{\log (P(x_2) / P(x_1))}{0.434 [x_1 - x_2]} \quad (\text{nepers})$$

where x_1, x_2 are in meters, and the power attenuation per meter is

$$\alpha = \frac{10}{[x_1 - x_2]} \log (P(x_2) / P(x_1)) \quad (\text{dB/m})$$

The PREAMP output on the KOP-100 module is a voltage proportional to the optical power incident on the PIN diode and therefore may be substituted for $P(x)$ in order to determine α .

PROCEDURE:

1. Linear Attenuation at 940 nm.

Connect the variable DC power supply to the electronics module. Set the MOD-DIR switch on the electronics module to DIR. Set GAIN at X1. Connect the TIL24 LED (12) to the transmission output and the PIN photodiode (14) to the PIN input. Connect the F1 fiber (1), to the TIL24 LED using a male-male fiber connector. Connect the 1.0 meter long F3 fiber (3) between the F1 fiber (using a connector) and the photodiode. Set the variable DC power supply at 3 Volts and connect it to the transmission input. This voltage is the LED intensity modulation signal. Turn the KOP-100 electronics module on. Measure the PREAMP output with the multimeter. Replace F3 with the 2, 4 and 6 m fibers (F4(4), F5(5), F6(6)) respectively and record the PREAMP output for each (see Figure 5.3). Plot the results on semi-log graph paper: normalized amplitude (for the semilog axis) vs fiber length (linear axis). Calculate linear attenuation, α , in dB/m for both the transition region and the steady state region as determined graphically. Compare these values and comment on any differences between them.

2. Linear Attenuation at 650 nm.

Set GAIN at X10. Set the DC supply at 4 Volts. Connect the TIL221 LED(13) to the power supply. Note the proper polarity for the LED connection (red +, black -). Connect the F1 fiber to the TIL221. Proceed as in Part 1 to measure the PREAMP output for the 1, 2, 4, and 6 m fibers (see Figure 5.4). Plot the results as in Part 1 to determine the two regions and calculate values for α for each range. Comment on any differences.

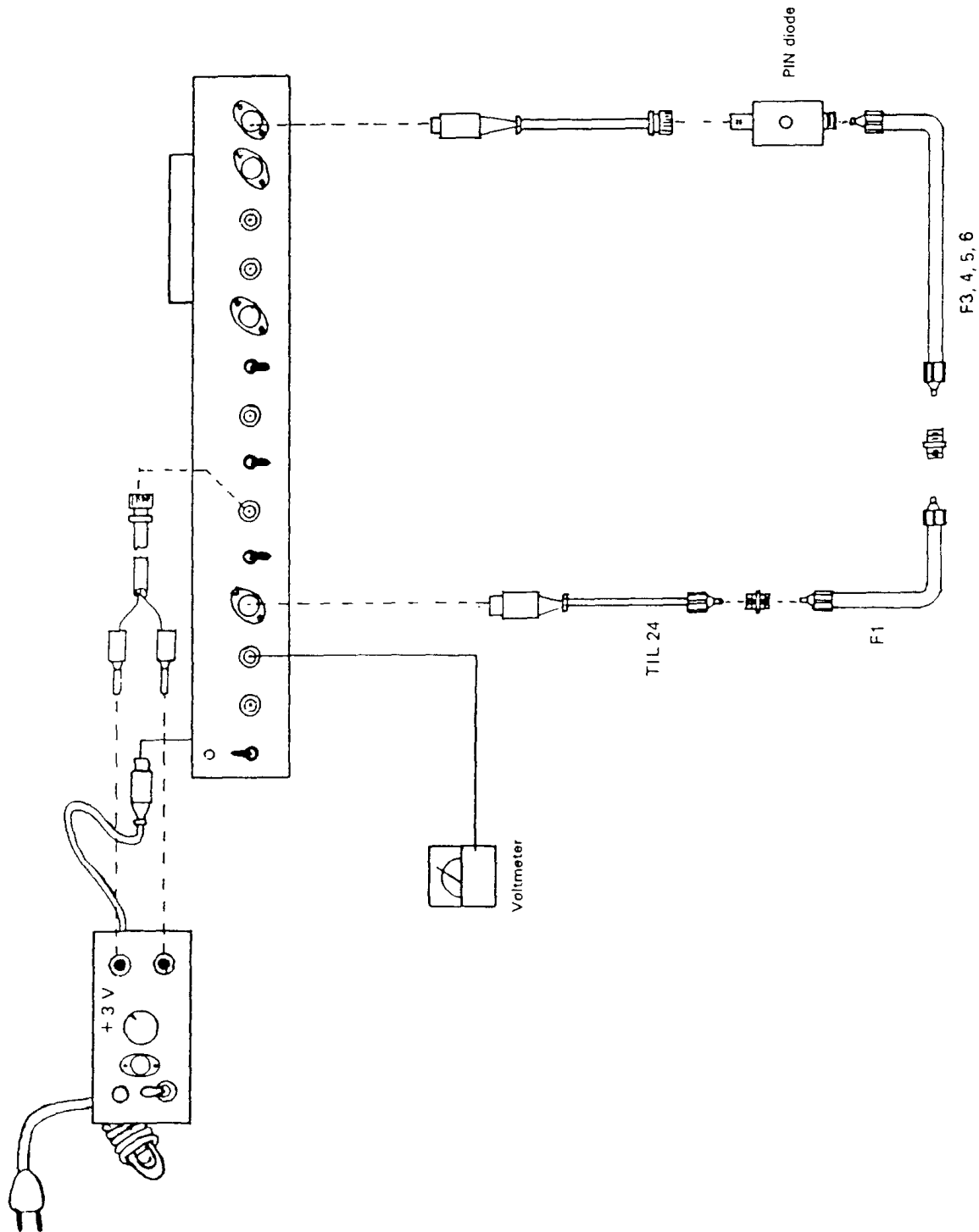


Figure 5.3 equipment connections for part 1

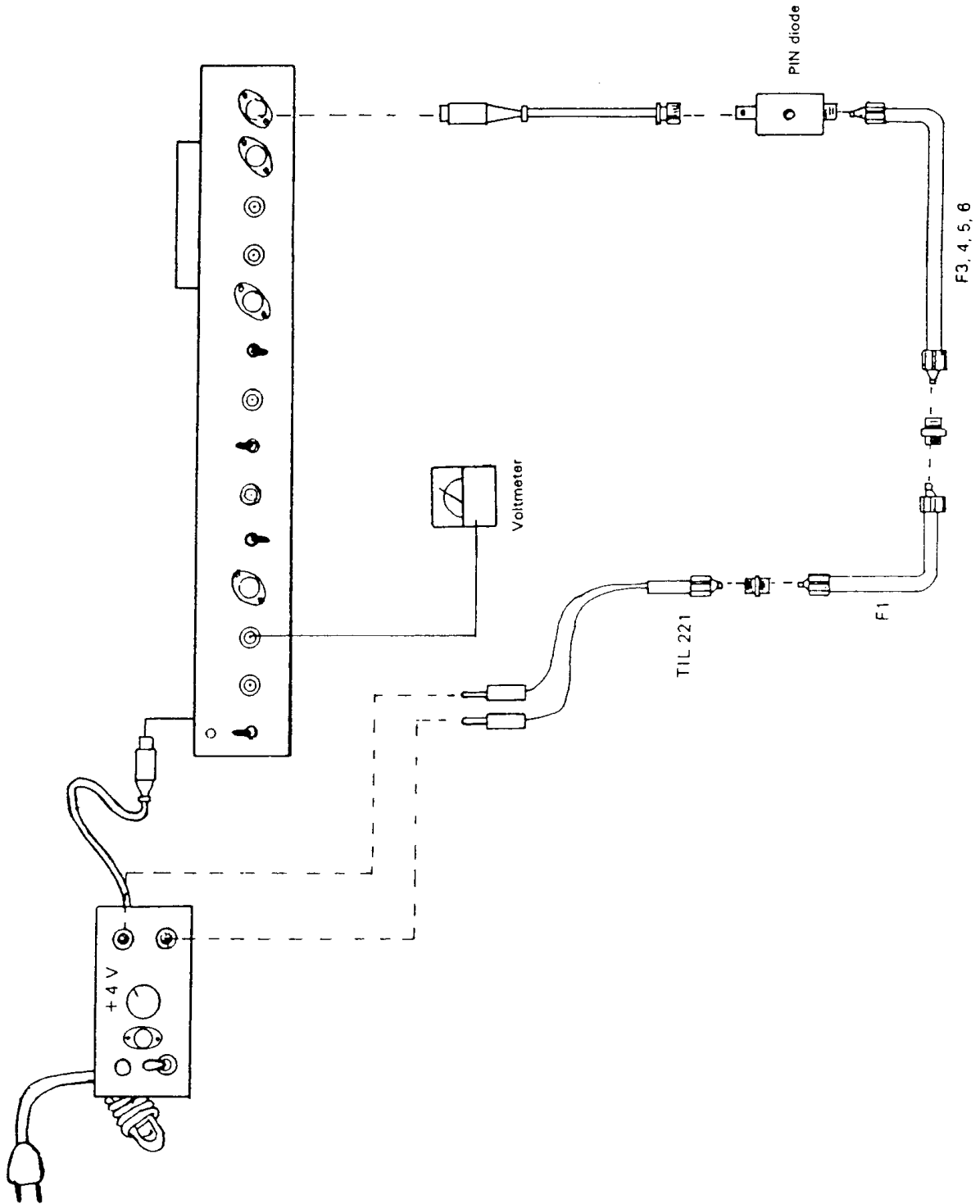


Figure 5.4 equipment connections for part 2

EXPERIMENT 6

INJECTION LOSSES

OBJECT:

To determine the coupling efficiency between an emitter and an optical fiber. To determine the half power beamwidth for the TIL24 LED.

EQUIPMENT:

KOP-100 fiber optics kit
 HP 7045A X-Y recorder
 2 Fluke 8050A multimeters

THEORY:

Injection losses occur at the coupling of an emitter and an optical fiber. Injection losses are due to the loss of optical power which radiates outside of the fiber's acceptance cone.

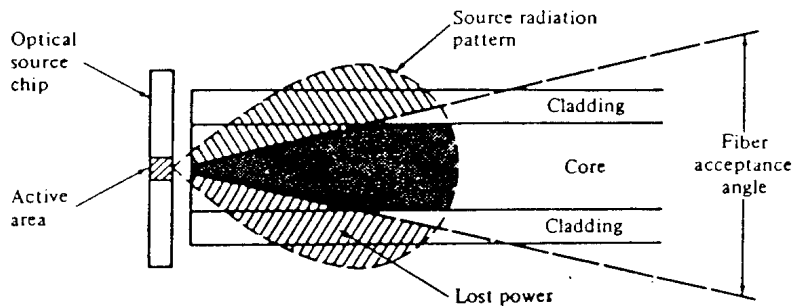


Figure 6.1 Emission and acceptance angle differences

The radiation pattern of a LED can be expressed as

$$B(\theta) = B_0 \cos^m \theta \quad (\text{W /sr}/\text{cm}^2)$$

where B_0 is the radiance on the symmetry axis and $B(\theta)$ the radiance at an angle θ from the axis.

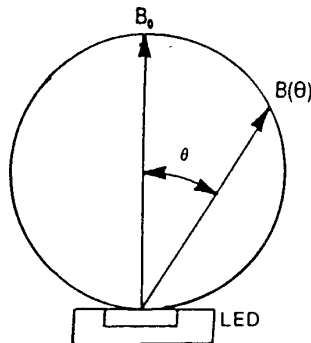


Figure 6.2 emission pattern

For the step-index fiber, assuming perfect coupling, the coupled power (P_F) can be found by integrating the radiance from a point source over the solid acceptance angle of the fiber and then integrating over the emitting area. For a Lambertian emitter

$$P_F = \int_0^{r_s} \int_0^{2\pi} \int_0^{2\pi} \int_0^{\theta_a} B_o \cos \theta \sin \theta \, d\theta \, d\phi \, d\theta_s \, dr \quad (W)$$

$$= \pi^2 B_o r_s^2 NA^2 \quad (W)$$

where r_s = source radius ($r_s < a$)

a = fiber core radius

θ_a = fiber acceptance angle $(\sin \theta_a = \sqrt{n_1^2 - n_2^2})$

θ_s = source angle

The total emitted power (P_s) is

$$P_s = \pi r_s^2 \int_0^{2\pi} \int_0^{\pi/2} B_o \cos \theta \sin \theta \, d\theta \, d\phi \quad (W)$$

$$= \pi^2 r_s^2 B_o \quad (W)$$

and coupling efficiency (η_c) is found to be

$$\eta_c = \frac{P_F}{P_s} NA^2 \quad (\text{Lambertian source})$$

For a non-Lambertian source (mX1) using the same method as above

$$\eta_c = \frac{P_F}{P_s} = 1 - \cos^{m+1} \theta_a \quad (\text{non-Lambertian source})$$

The method to be used in the experiment consists of plotting the angular emission pattern of a LED and of a short length of fiber (to minimize attenuation). The two patterns can then be used to calculate coupling efficiency.

The half power beam width (full width at half maximum) of a light source is the total angle subtended between the two points where light intensity is one half the maximum intensity (i.e. on the symmetry axis, $\theta = 0^\circ$).

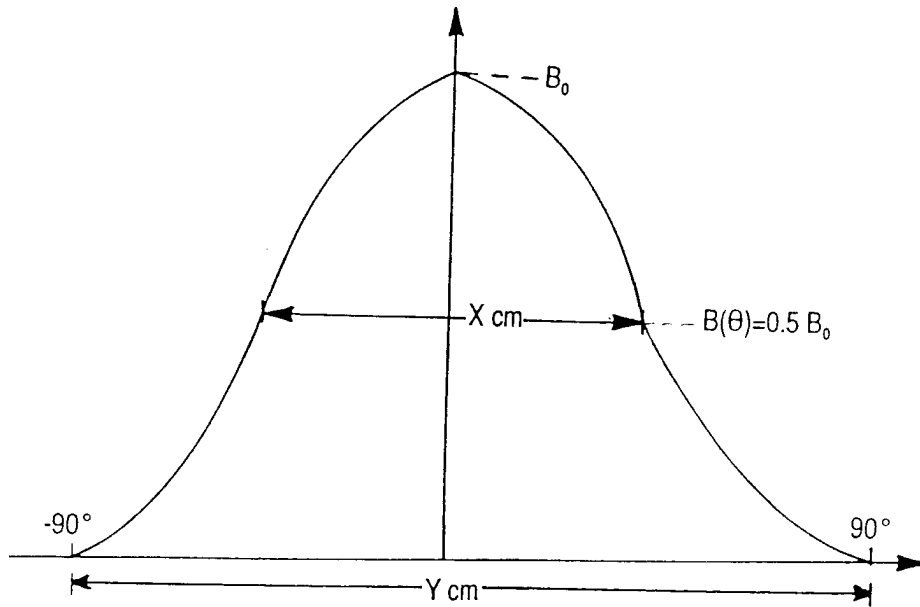


Figure 6.3 radiation pattern of emitted optical power

$$\frac{2\theta_{1/2}}{2Z^\circ} = \frac{X}{Y}$$

$\theta_{1/2}$ is the half-angle at half power: the half power beamwidth is thus $2\theta_{1/2}$. Once $\theta_{1/2}$ is known, m can be found from:

$$B(\theta) = B_0 \cos^m \theta_{1/2}$$

Following the analysis of Lab 3, θ_a can be obtained from the fiber radiation pattern as before.

Once m and θ_a are known the coupling efficiency, ξ_c can be calculated.

PROCEDURE:

1. Set the MOD-DIR switch at DIR and GAIN at X10. Connect the TIL24 LED (12) to the TRANSMISSION output and the PIN photodiode (14) to the PIN input. Install the TIL24 LED on the L bracket (18) mounted on the turntable. Fasten the PIN photodiode to the mounting block (16) mounted on the X-Y mechanism. Set the variable DC power supply at 3 volts and connect it to the TRANSMISSION input. Turn the KOP-100 module on. Position the DETECTOR approximately 4 cm from the LED. Observe the PREAMP and ROTATION outputs with the multimeters. The ROTATION output is proportional to the angular rotation of the turntable (10 mV/degree). Adjust the height of the X-Y mechanism so that maximum PREAMP signal is measured as close as possible to zero degrees. Connect the ROTATION output and the PREAMP output respectively to the X and Y inputs of the recorder (see Figure 6.4). Record the angular emission pattern of the LED from -90 to +90 degrees. Determine the LED half power beam width, $2\theta_{1/2}$.
2. Connect the F1 Fiber (1) to the LED and to the L bracket (see Figure 6.5). Record the angular emission pattern of the fiber. Use the two patterns to calculate coupling efficiency, ξ_c .

Questions:

1. Given that the half-power beam width of the TIL24 LED is 35 degrees ($\theta_{1/2} = 35^\circ/2$) calculate the "m" value which characterizes the LED emission pattern.
2. Use the "m" value to calculate the theoretical coupling efficiency of the LED and fiber and compare this to the value found in the experiment ($n_1 = 1.6$, $n_2 = 1.526$).

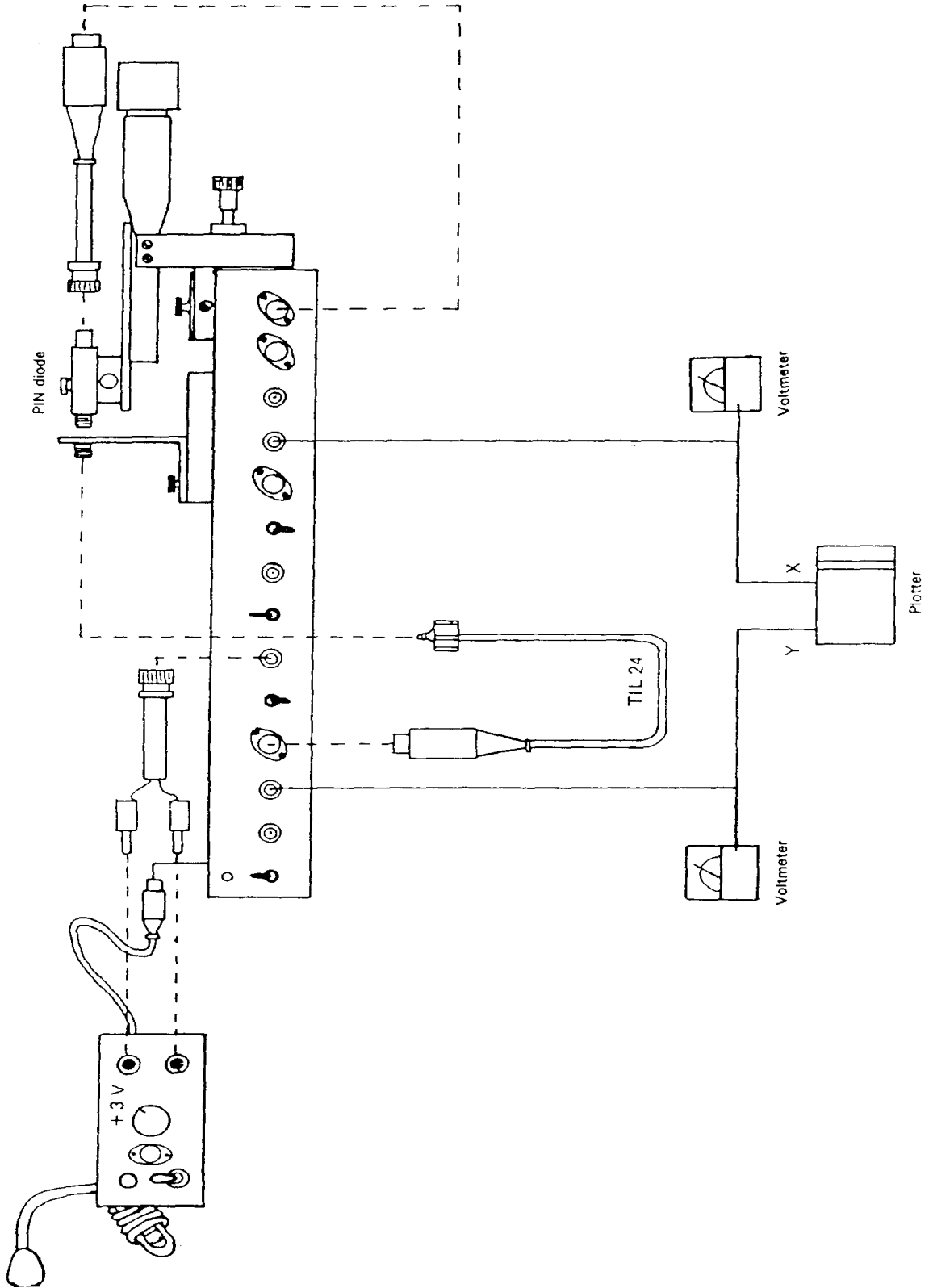


Figure 6.4 equipment connections for part 1

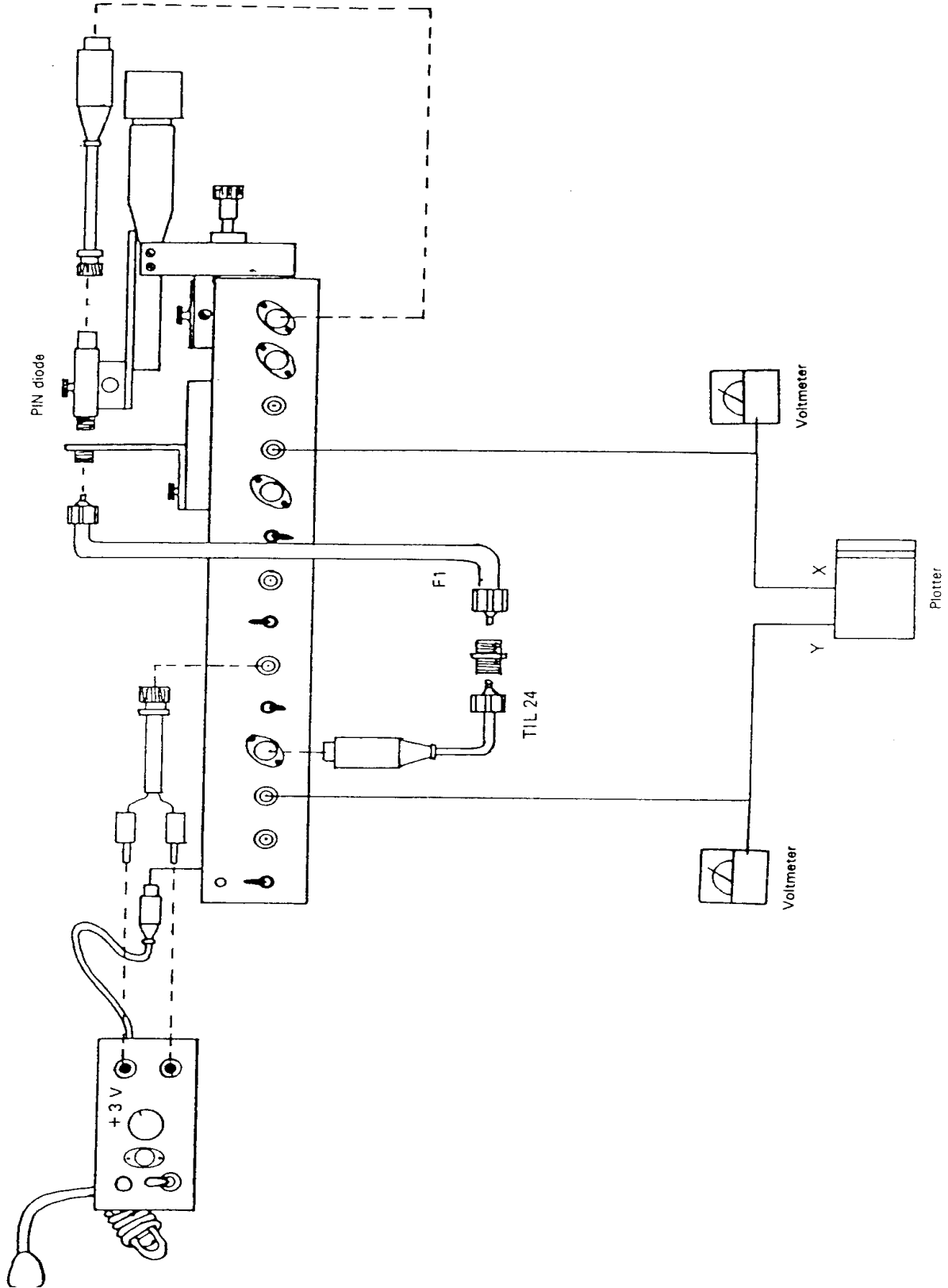


Figure 6.5 equipment connections for part 2

EXPERIMENT 7

CONNECTOR LOSSES

OBJECT:

Measurement of the losses associated with a coupling connector. Also to verify the influence of the condition of fiber end surfaces, and index adaptation liquid, on connector losses.

EQUIPMENT:

KOP-100 fiber optics kit
Index adaptation liquid (glycerine)
Fluke 8050A multimeter

THEORY:

1. Connector Losses

The connector is a temporary mechanical means of joining two optical fibers. An understanding of the losses in a connector is necessary as connectors are widely used in optical communication links. Losses in a connector are due to many factors. Losses due to reflection at a dielectric interface will be examined in this experiment.

From previous transmission theory and with reference to Figure 7.1 reflection and transmission coefficients, ρ and τ , respectively can be found.

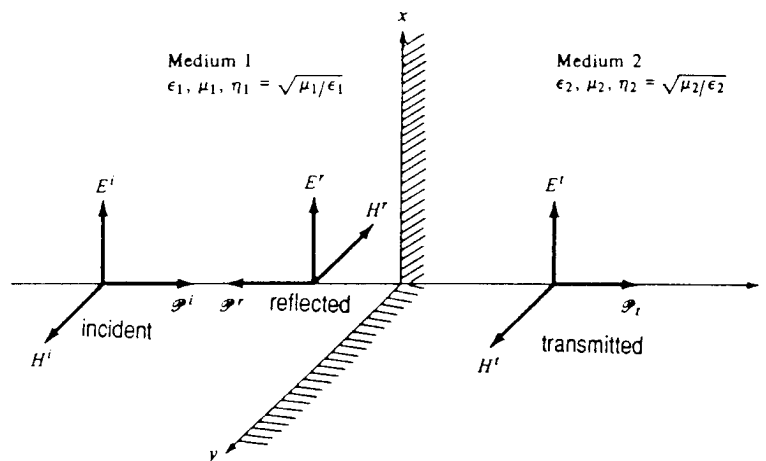


Figure 7.1 the dielectric interface

Solving for the boundary conditions it is found that

$$\rho = \frac{E_r}{E_i} = (\eta_2 - \eta_1) / (\eta_2 + \eta_1) \quad (1)$$

where η = intrinsic impedance of the medium.

In fiber optics the index of refraction, n , is the defining characteristic of a medium and is related to the intrinsic impedance as follows

$$\eta = \frac{\eta_0}{n} \quad (2)$$

Substituting equation (2) into equation (1) gives

$$\rho = (n_1 - n_2) / (n_1 + n_2)$$

Relating this to power

$$\frac{P_r}{P_i} = [(n_1 - n_2) / (n_1 + n_2)]^2 \quad (3)$$

and the power loss at one interface is defined as

$$L = 10 \log (P_t / P_i) \quad (\text{dB}) \quad (4)$$

and since

$$P_i = P_t + P_r$$

then

$$L = 10 \log \{1 - [(n_1 - n_2) / (n_1 + n_2)]^2\} \quad (\text{dB}) \quad (5)$$

2. Effects of Polishing and Index Adaptation Liquid

Polishing ensures a clean flat surface free of residual particles at a fiber end and increases the amount of power coupled at a connector. The use of an index adaptation liquid reduces fiber separation loss by reducing the beam divergence.

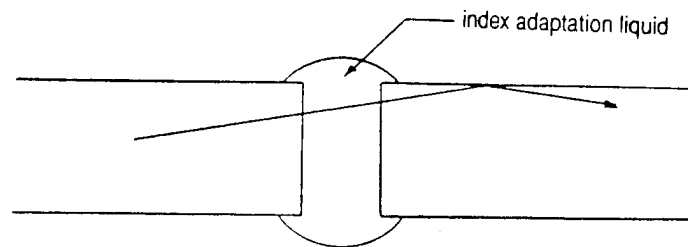


Figure 7.2 effect of index adaptation liquid

PROCEDURE:

1. Influence of Polishing

Set the MOD-DIR switch to DIR and GAIN at X1. Connect the TIL24 LED(12) to the transmission output and the PIN photodiode (14) to the PIN input. Connect the F1 fiber to the TIL24 LED. Connect the 10 cm unpolished fiber F7(7) between the F1 fiber and the PIN photodiode. Use only two turns of the retaining cap on the PIN receptacle. Set the variable DC supply at -1 Volt and connect it to the TRANSMISSION input. This is the bias voltage for the LED. Turn the electronics module on. Measure the PREAMP output with the multimeter (see Figure 7.4) and record. This voltage is proportional to the optical flux at the detector. Disconnect the unpolished fiber F7 and polish both endfaces.

Fiber Polishing

Place the #400 silicon carbide medium grade finishing paper on a firm flat surface. Hold the fiber firmly and upright. Trace circular figures on the #400 paper with the fiber end face approximately 25 times. Clean the fiber end. Repeat the above procedure with #600 paper. Place a small quantity of polishing powder on the felt polishing fabric. Add a drop of distilled water and polish as above until the fiber end has a glossy finish.

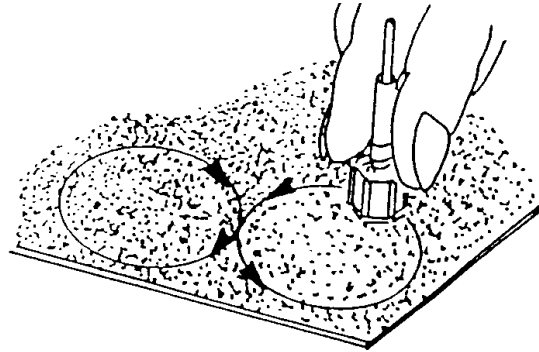


Figure 7.3 polishing techniques

Reconnect the F7 fiber and measure the PREAMP output. Calculate the gain, in dB, due to polishing.

2. Loss due to the Optical Connector

Remove the F1 fiber and connect the F7 fiber directly to the LED. Record the PREAMP output. Calculate the loss, in dB, due to the connector.

3. Gain Due to Index Adaptation Liquid

Reconnect the F1 fiber to the LED and the F7 fiber. Measure the PREAMP output. Place a small amount of glycerine into the connector between fibers F7 and F1. Reconnect the fibers and measure the PREAMP output. Calculate the gain, in dB, due to the use of the index adaptation liquid.

Questions:

1. Calculate the expected loss due to one fiber to fiber connector. The refractive index of the fiber core is 1.6. Compare this to the result found in part 2 above. Comment on any discrepancy.
2. Calculate the expected connector loss when index adaptation liquid is used. The refractive index of glycerine is 1.47. Compare this to the experimental result.

Note: When the experiment is completed both ends of fiber F7 should be rubbed with #400 paper to restore them to their original state. The connector and fiber ends should be cleaned of index adaptation liquid.

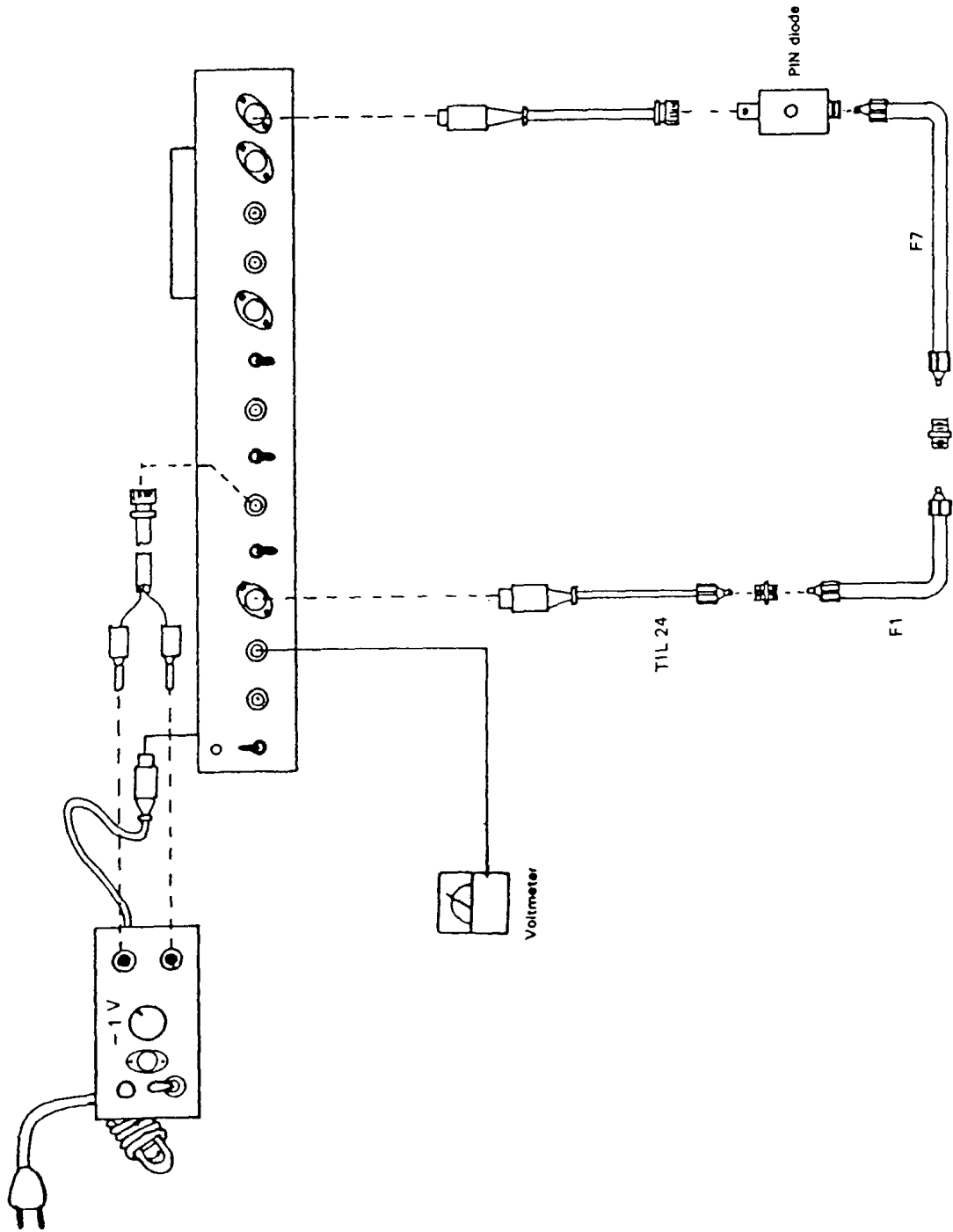


Figure 7.4 equipment connections

EXPERIMENT 8

CHARACTERISTICS OF A LED

OBJECT:

Determination of the characteristic curve of a LED. Measurement of the LED electro-optic response time and of the junction and case thermal time constants.

EQUIPMENT:

KOP-100 Fiber Optics Kit
Function generator
Oscilloscope
2 Fluke 8050A multimeters
HP 7045A X-Y recorder

THEORY:

1. Characteristic Curve of the TIL24 LED

The characteristic curve of output power versus input current for a LED is linear over a suitable range of current for a particular LED. This range generally extends from a few milliamperes up to approximately 50 milliamperes for a LED without a heatsink, or up to 150 milliamperes for a LED with a heatsink. At lower currents the electron-photon conversion efficiency is low while at higher currents a saturation phenomenon occurs due to the heating of the semiconductor.

Experimentally the optical power emitted from the LED will be measured with the PIN photodiode, the current of which is proportional to the incident optical power. This current is then fed to a current-to-voltage converter. The converter output is thus proportional to the optical power. The biasing circuit for the LED, internal to the KOP-100 module is configured such that the LED current, I_{LED} , can be expressed as

$$I_{LED} = 14V_T + 42 \quad (\text{mA})$$

where V_T is the TRANSMISSION input voltage.

2. Electro-optic Time Constant

The electro-optic time constant, τ , of a LED is the time for the LED current, and thus the optical power emitted, to reach 63 percent of its maximum value. This response time is very important when determining the maximum bandwidth for which the LED is modifiable. The cutoff frequency of a LED is expressed as

$$f_c = 1/2\pi\tau \quad (\text{Hz})$$

Experimentally the method used to measure the electro-optic time constant will be to apply a 3 V pulse to the LED bias circuit and measure the time constant of the signal from the detection circuit. This value is a very close approximation of the LED time constant since the time constant of the photodetector is much smaller (≈ 5 ns).

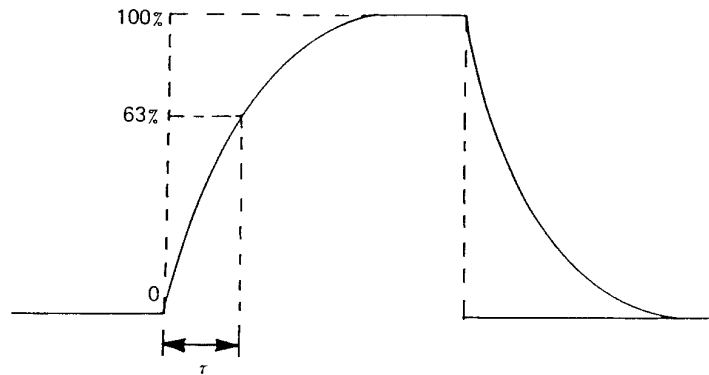


Figure 8.1 electro-optic time constant

3. Thermal Time Constants

The LED external efficiency is dependent upon temperature. Therefore it is important to know the thermal characteristic of the LED. If a high level square current pulse is applied to the diode the emitted optical power will vary with time as a result of the temperature rise caused by the power dissipated in the junction. This temperature rise subsequently lowers the electron-hole pair recombination efficiency. Therefore the junction takes a certain amount of time to reach its equilibrium temperature and recombination efficiency.

The measurement method shall consist of applying a square wave of low frequency to the LED bias circuit and measuring the time for the output pulse of the detector to diminish by 63 % of the difference between the peak value and the equilibrium value. This time is τ_j the junction thermal time constant.

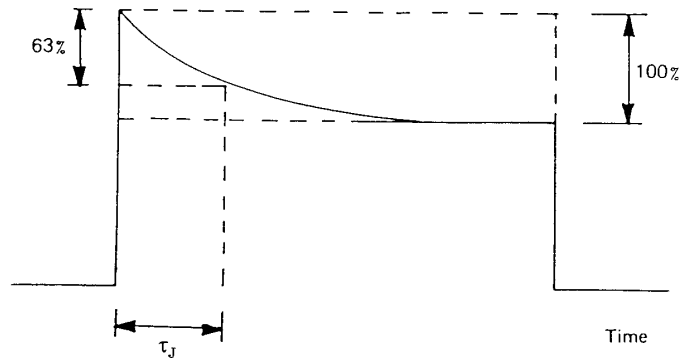


Figure 8.2 junction thermal time constant

The LED case and mounting also take a relatively long time after the application of a current step to reach their thermal equilibrium. To determine the case time constant a current step will be applied to the LED bias circuit and the case thermal time constant, τ_c , is measured in the same manner as the junction thermal time constant above.

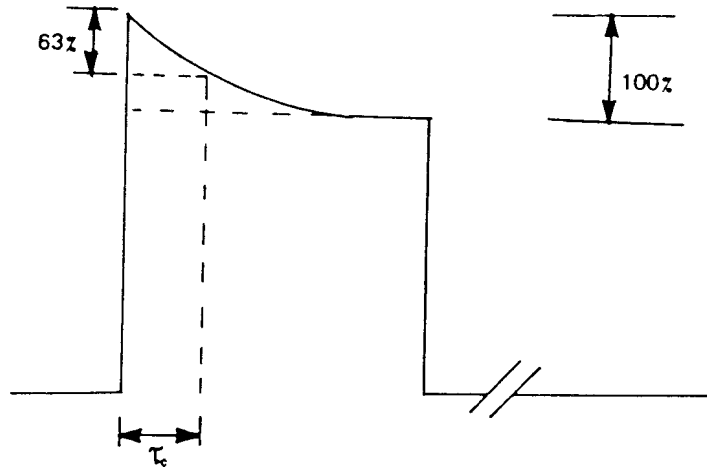


Figure 8.3 case and mounting thermal time constants

PROCEDURE:

1. Characteristic Curve of the TIL24 LED

Set the MOD-DIR switch at DIR and GAIN at X1. Connect the TIL24 LED (12) connector to the TRANSMISSION output and the PIN photodiode connector (29) to the PIN input. Connect the 1 m F3 fiber (3) between the LED and the PIN photodiode. Connect the variable DC supply to the TRANSMISSION input. Monitor the PREAMP output voltage, V_s , with the multimeter. Vary the input voltage, V_T from -3 V to +3 V while recording V_s (see Figure 8.4). Using the equation given in part 1 of the theory to calculate I_{LED} plot results as V_s versus LED current, I_{LED} . Comment on the linearity of the LED output power versus input current.

2. TIL24 Electro-optic Time Constant

Connect the PIN photodiode connector to the DETECTOR input. Set the Transistor-Diode switch at Diode and connect the LED directly to the PIN photodiode. Apply a 1 kHz, 3 V pulse at the TRANSMISSION input. Observe the DETECTOR output with the oscilloscope (see Figure 8.5). Measure the electro-optic time constant, τ_e . Calculate the LED cutoff frequency, f_c . Adjust the function generator to provide a 3 V peak-peak, 1 kHz sinewave and use this as the TRANSMISSION input. Measure the DETECTOR output at 1 kHz. This will be the reference value (0 dB maximum value). Increase the frequency until the DETECTOR output has dropped by 3 dB ($1/\sqrt{2}$ of the maximum value since $20 \log 1/\sqrt{2} = -3$ dB). Record the cutoff frequency, f_c . Compare the cutoff frequency measured with that calculated above.

3.1 Junction thermal time constant

Connect a 10 Hz, 6 V peak-peak square wave to the TRANSMISSION input. Observe the DETECTOR output on the oscilloscope and measure the junction thermal time constant, τ_j (see Figure 8.6a).

3.2 Case and Mounting Thermal Time Constant

Connect the DETECTOR output to the y input of the X-Y recorder. Use the recorder's X time base option of about 5 sec/inch or whatever seems suitable. Just after starting the recorder a 4 V step input should be applied to the transmission input. To do this, the variable DC supply should be set to 4 V and quickly plugged in after the recorder has started (see Figure 8.6b). The recorder may jump back to the start of the page but it must be left running until it reaches an equilibrium value. From the plot measure τ_c , the LED case and mounting thermal time constant.

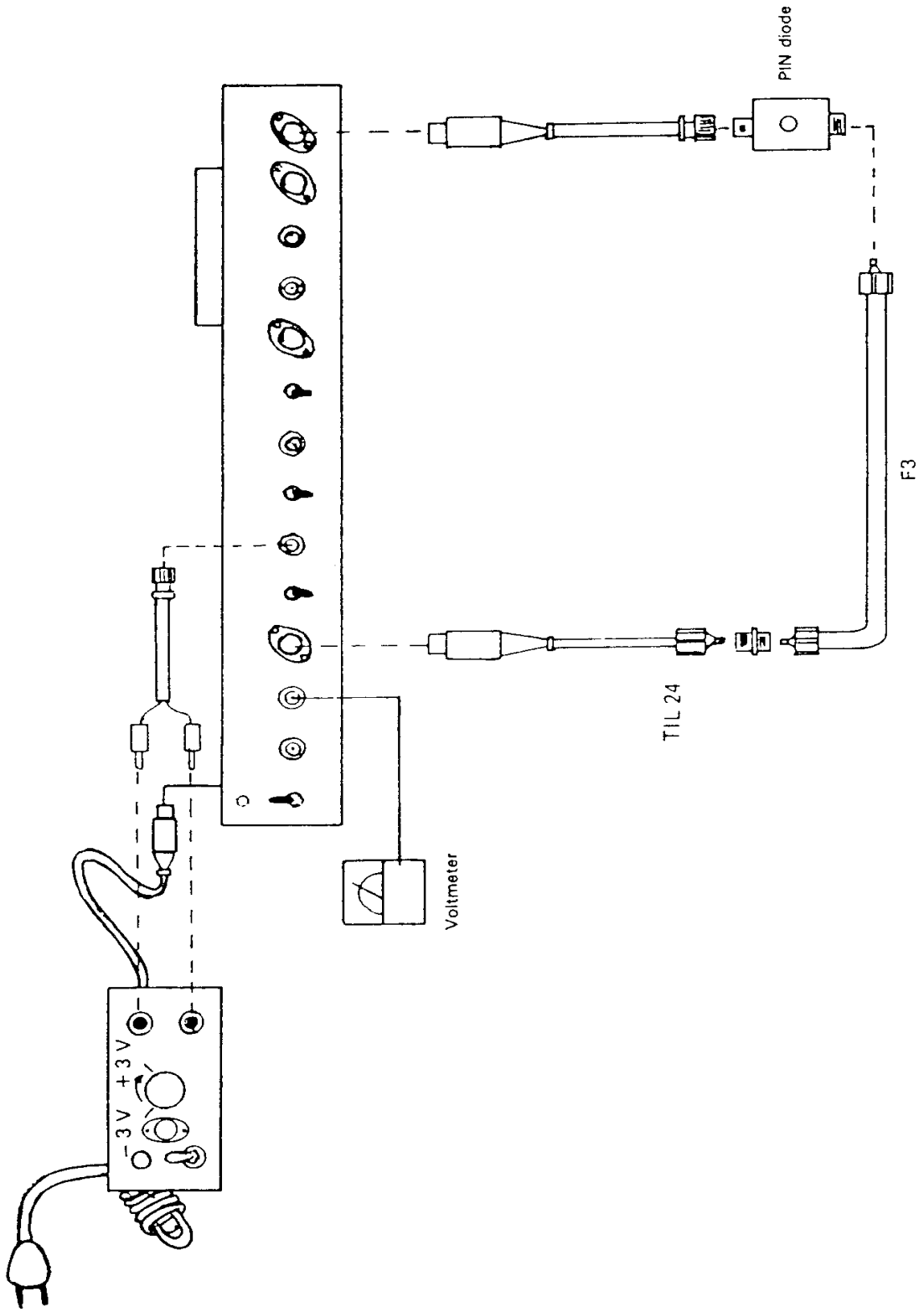


Figure 8.4 equipment connections for part 1

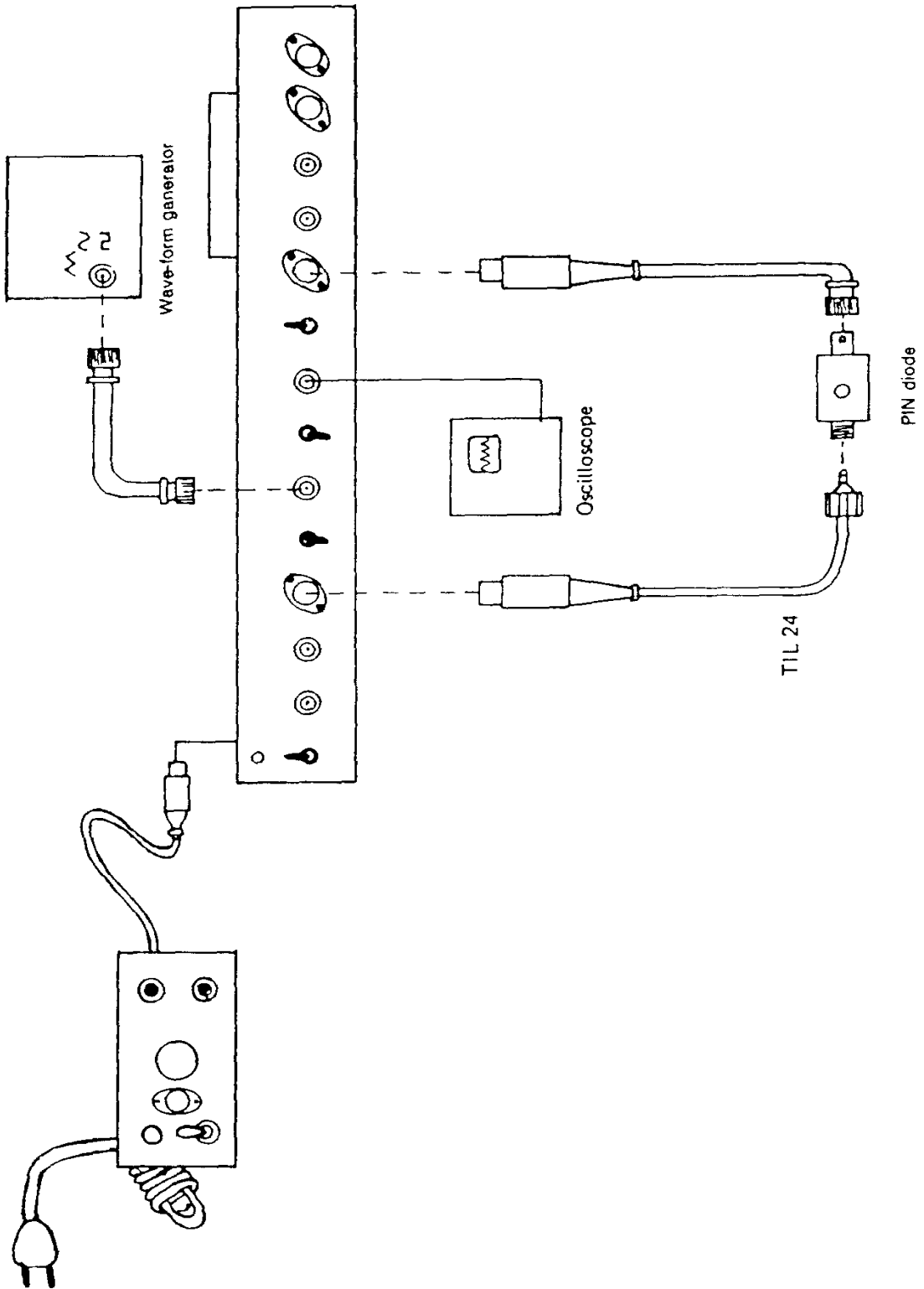


Figure 8.5 equipment connections for part 2

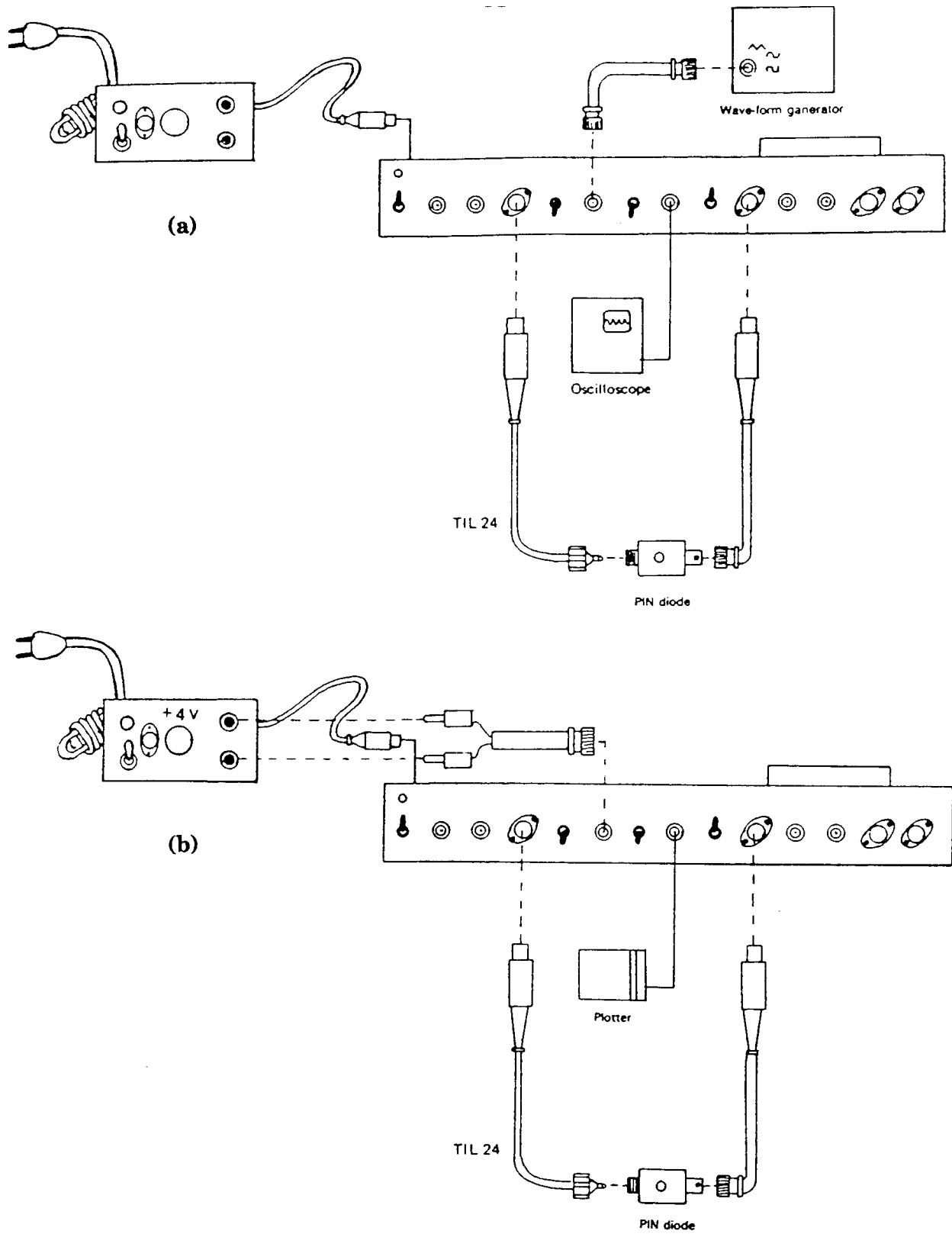


Figure 8.6 equipment connections for a) part 3.1 b) part 3.2

EXPERIMENT 9

PHOTODETECTOR CHARACTERISTICS

OBJECT:

Measurement of the time constants and relative sensitivities of a phototransistor and a photodiode. Measurement of the linearity of a photodetector.

EQUIPMENT:

KOP-100 Fiber Optics Kit
Function generator
Oscilloscope
Fluke 8050A multimeter

THEORY:

Photodetectors are devices which sense incident optical power and convert this varying signal into a correspondingly varying electric current, by means of electron-hole pair generation. The photodetector time constant is a function of the carrier travel time within the depletion region. It depends upon the depletion zone thickness and carrier velocity.

The two main classes of photodetectors are photodiodes and phototransistors. The photodiode is configured such that only the reverse-biased collector-base junction is used, the emitter lead is left open. When light is incident upon the base region a current is generated in the diode. In the phototransistor the emitter forms part of the circuit and thus the photocurrent generated by the collector-base junction is amplified by the transistor current gain β . Thus the sensitivity of the phototransistor is much higher than that of the photodiode due to the forward current gain. However, the addition of the second junction (base-emitter) increases carrier transit time and therefore the phototransistor has a much longer time constant than the photodiode.

Another important characteristic of the photodetector is linearity. The photodetector must have a wide range over which the photocurrent generated varies linearly as a function of the incident optical power.

Experimentally, a step input of light will be applied to the photodetector and its time constant (0-63 %) measured at the detector output using the oscilloscope.

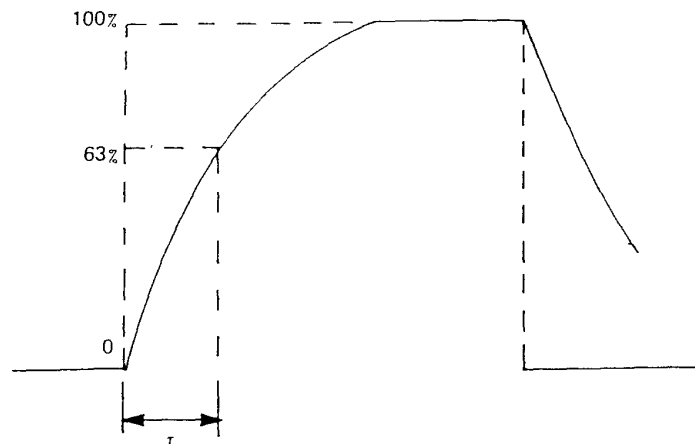


Figure 9.1 photodetector time constant

The relative sensitivities of the phototransistor and the photodiode will be compared by applying a constant voltage to the input of the transmission module and observing the magnitude of the output signal.

The linearity of the PIN photodiode will be determined by measuring the output signal for the photodiode as a function of its separation from a light source. Since the light source used approximates a point source its illumination varies in an inverse square law. Photodiode linearity can then be evaluated by graphing the measurements on a log-log chart. Theoretically, the results should then be a straight line of slope -2.

PROCEDURE:

1. Relative Time Constants of a Phototransistor and a Photodiode.

Set the MOD-DIR switch at DIR. Connect the TIL24 LED (12) to the TRANSMISSION output. Connect the TIL99 photodetector (15) to the DETECTOR input. Set the TRANSISTOR-DIODE switch at TRANSISTOR to use the detector as a phototransistor. Interconnect the LED and detector using the 1 m long F3 fiber (3). Turn the KOP-100 module on. Set the function generator for a 3 V peak-peak square wave a 1 kHz. Connect it to the TRANSMISSION input. Observe the DETECTOR output on the oscilloscope (see Figure 9.2). Measure the detector time constant, τ . Set the TRANSISTOR-DIODE switch at DIODE to use the detector as a photodiode. Connect the LED directly to the detector (remove the F3 fiber). Measure the photodiode time constant. Compare the two time constants relative to those given in the data sheets.

2. Relative Sensitivities of a Photodiode and a Phototransistor

Set the DC supply at 2 V and connect it to the TRANSMISSION input (see Figure 9.3). Note the DETECTOR output amplitude (V_{OD}). Change the switch setting from DIODE to TRANSISTOR. Note the new value of the output signal (V_{OT}). Comment on the relative sensitivities of the two configurations.

3. Determining the Linearity of a PIN Photodiode

Set the GAIN at X10. Connect the PIN connector (29) to the PIN input. Connect one end of the F3 fiber to the LED and connect the other end to the L bracket (18) mounted on the turntable. Install the PIN photodiode (14) on the mounting block installed on the XY mechanism. Apply a 3 V signal at the TRANSMISSION input (see Figure 9.4). Adjust the turntable and the XY mechanism to have a maximum output signal for 0° angle of rotation, while fiber to detector separation is 2 cm. Vary the separation, s , from 2 cm to 11 cm (in 1 cm increments, the TRANSLATION output is proportional (1 V/cm) to the position of the X-Y stage) and record the output signal amplitude, V_{OUT} . Graph the results as $\log V_{OUT}$ versus $\log s$. Comment on the linearity of the PIN photodiode.

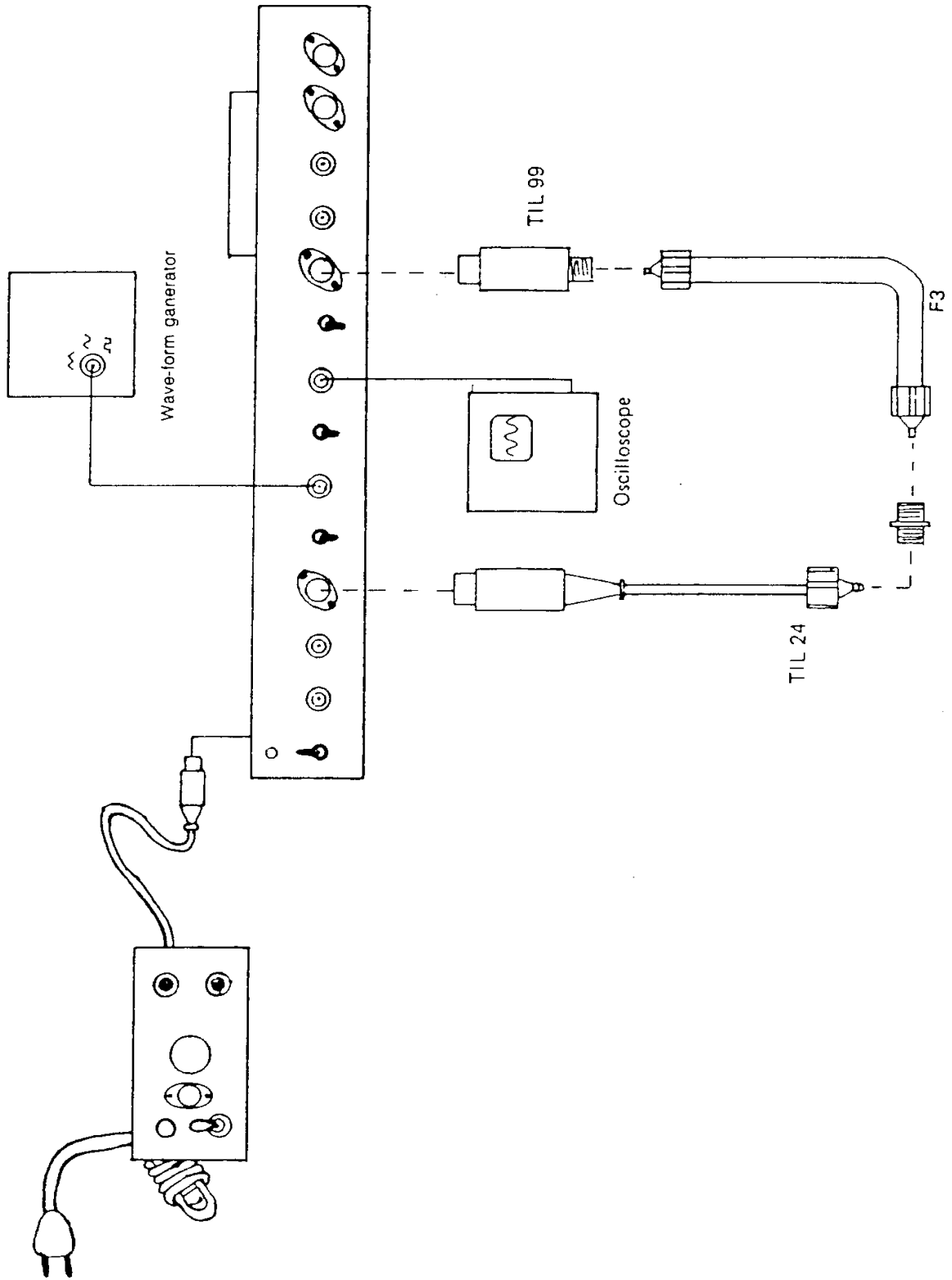


Figure 9.2 equipment connections for part 1

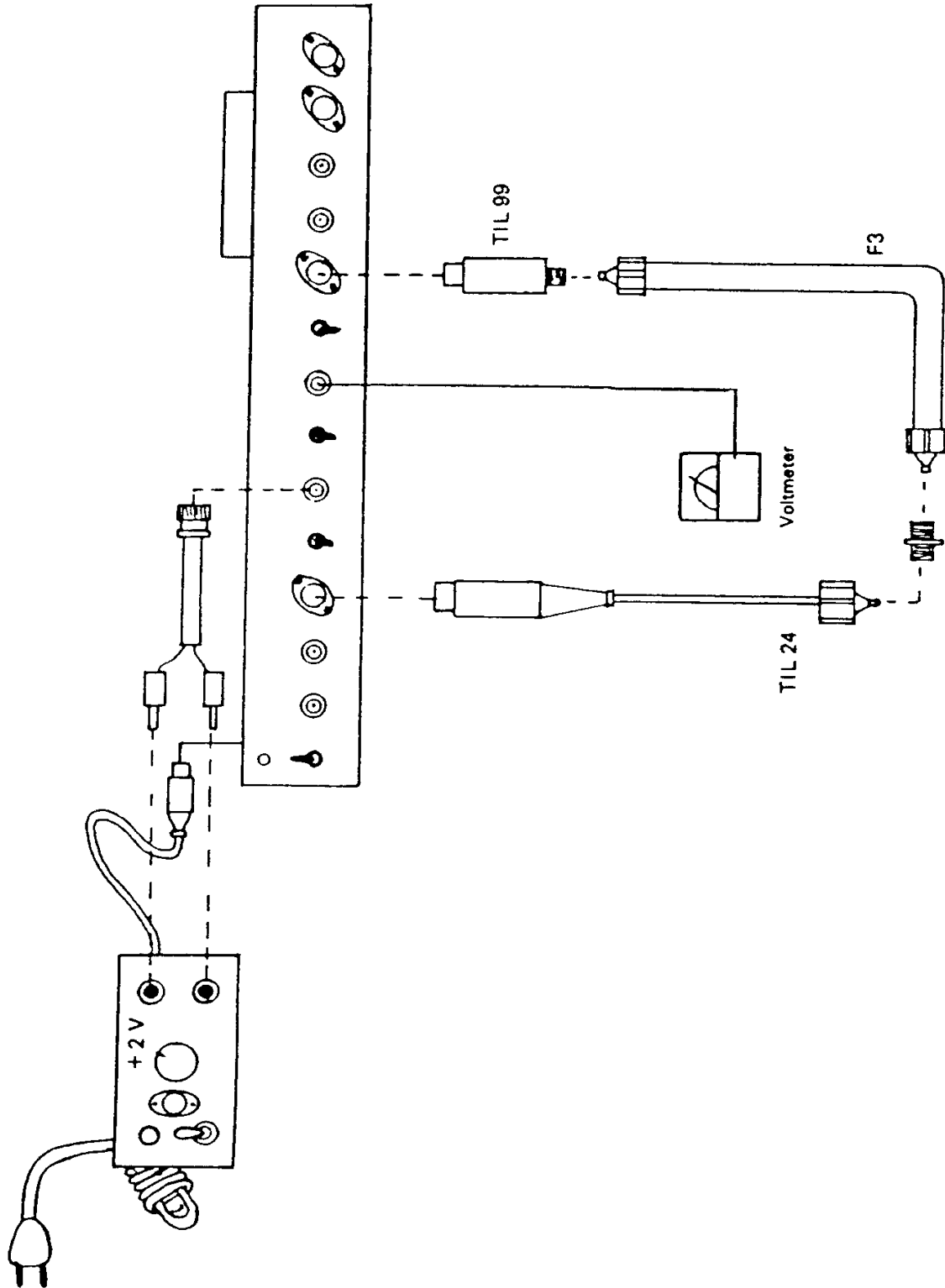


Figure 9.3 equipment connections for part 2

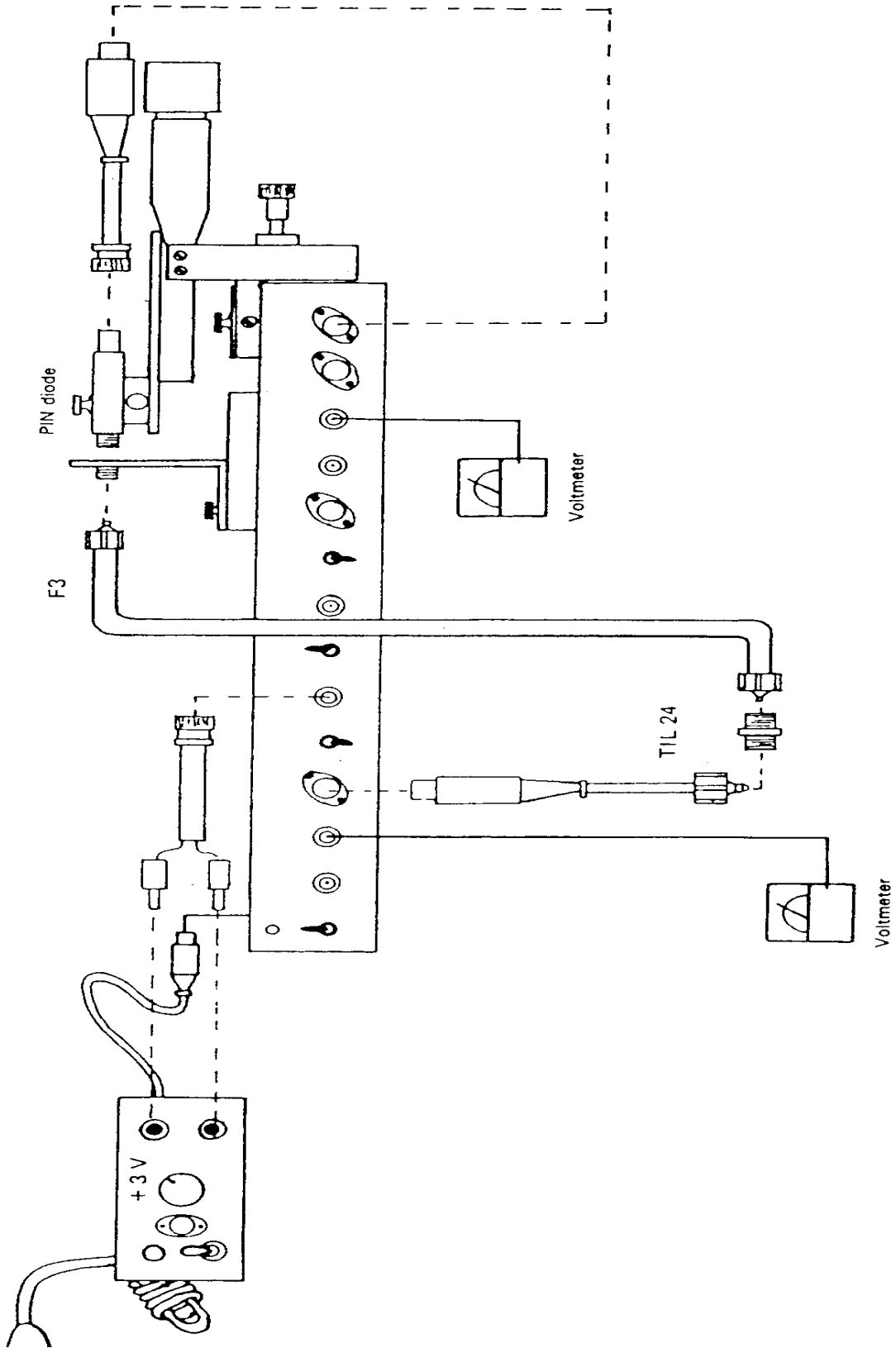


Figure 9.4 equipment connections for part 3

EXPERIMENT 10

TRANSMISSION OF INFORMATION

OBJECT:

To compare the operation and dynamic range of a pulse-width modulated and an amplitude modulated data transmission system.

EQUIPMENT:

KOP-100 Fiber Optics Kit
Oscilloscope
Function Generator
Fluke 8050A multimeter

THEORY

Two methods of data transmission using the KOP-100 module will be observed, pulse-width modulation (PWM) and intensity modulation (IM).

For PWM data transmission the input signal (V_{in}) is fed to a modulator which generates a train of constant frequency, constant amplitude, duty-cycle modulated rectangular pulses. These pulses are converted to light pulses by a LED and transmitted along a fiber. The photodetector signal is fed into a current to voltage converter, the output of which feeds a demodulator. The demodulator output signal's amplitude (V_{out}) and pulse width are proportional to the input signal. Because of its characteristics a constant strong output signal is obtained but is abruptly cut off if the input signal becomes too weak.

For IM transmission the input signal (V_{in}) directly modulates the LED current and therefore the optical signal. The photodetector then converts the optical signal to a current which is fed into a current to voltage converter. This output drives a loudspeaker. The key difference between the two systems is that the amplitude of the electrical signal driving the LED is constant in the case of PWM but is variable for the direct (IM) transmission.

PROCEDURE:

1. Pulse width and Amplitude Modulation of the Input Signal.

Set the MOD-DIR switch at MOD and gain at X1. Connect the TIL24 LED (12) to the transmission output and the PIN photodiode (14) to the PIN input. Connect the 1 m long fiber F3 (3) between the LED and the detector. Set the variable DC supply at 2 Volts and connect it to the TRANSMISSION input. Turn the KOP-100 module on. Measure the pulse width (W) at the PREAMP using the oscilloscope and signal amplitude (A) using the multimeter (see Figure 10.1). Vary the voltage from +2 to -2 Volts in 0.5 V increments. Plot pulse width and demodulated signal amplitude vs input voltage. Comment on the linearity of the PWM system.

2. Comparison of the Dynamic Ranges of the Pulse-Width Modulated Transmission System and of the Intensity Modulated Transmission System.

Connect the earphone to the AMP output. Adjust the function generator for a 200 mV peak-peak sinewave at 1kHz. Disconnect the fiber from the photodetector and mount it on the L bracket on the turntable. Mount the PIN photodiode on the X-Y mechanical stage (see Figure 10.2). Align the fiber and the PIN photodiode. Measure the maximum fiber to detector separation for which the signal is still audible. Also monitor the AMP output on the oscilloscope. Set the MOD-DIR switch at DIR. Measure the maximum fiber to detector separation for which the signal is still audible. Monitor the AMP output as above. Comment on the dynamic ranges of the two transmission systems. Which is the preferred system?

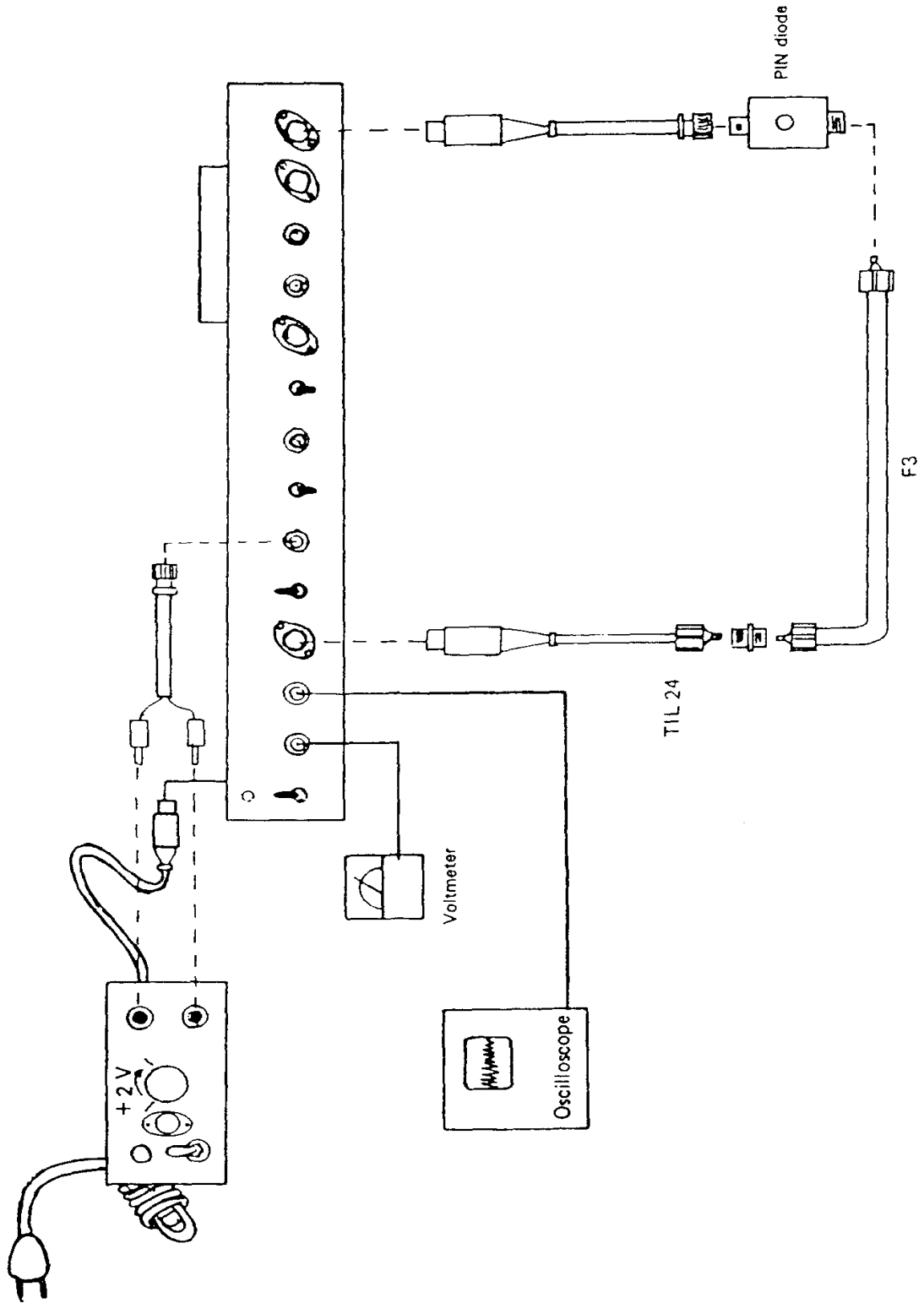


Figure 10.1 equipment connections for part 1

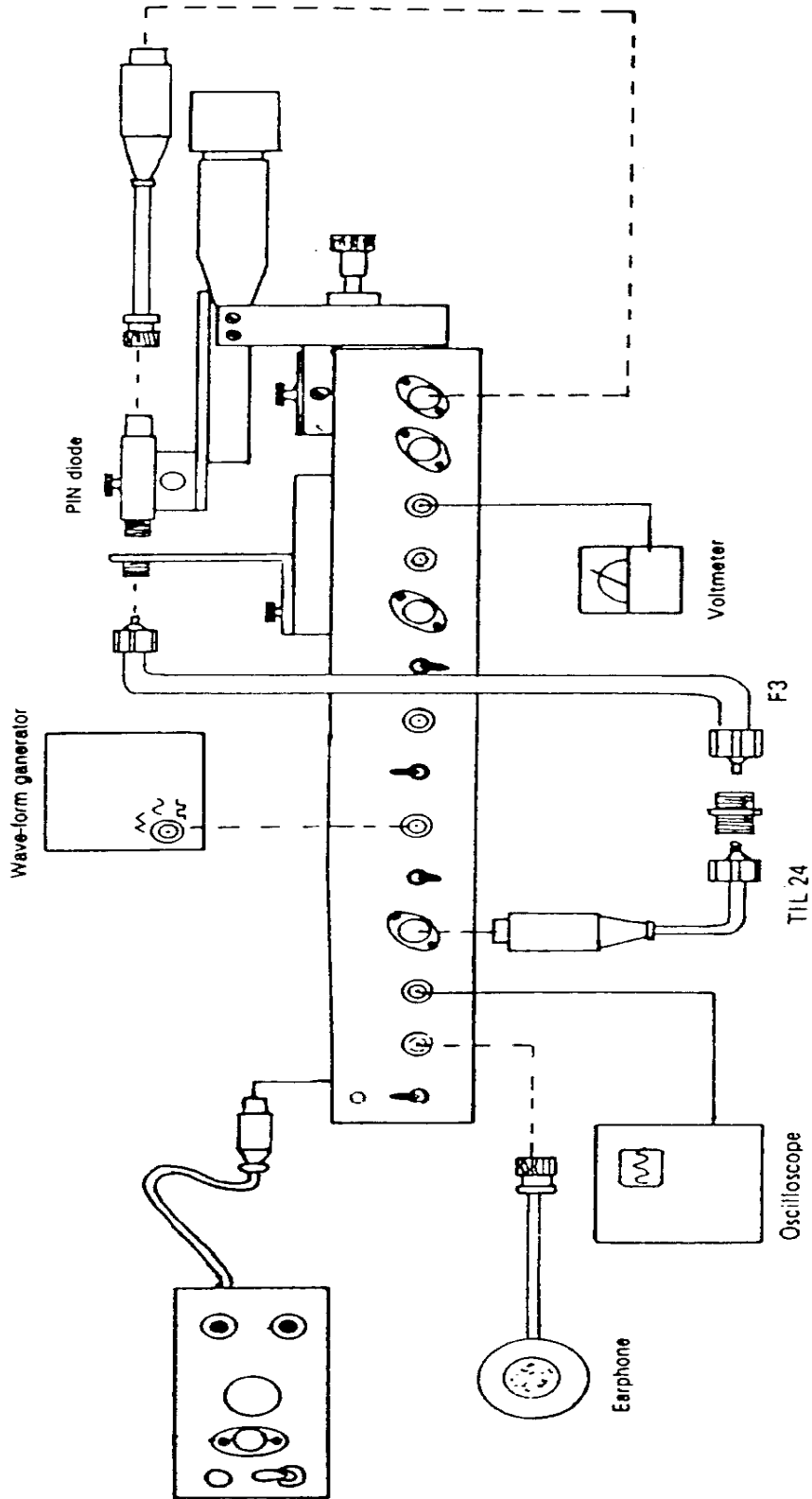
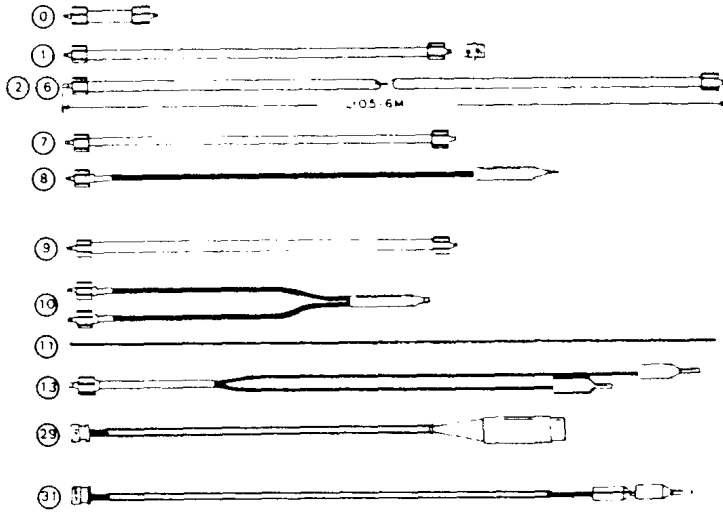


Figure 10.2 equipment connections for part 2

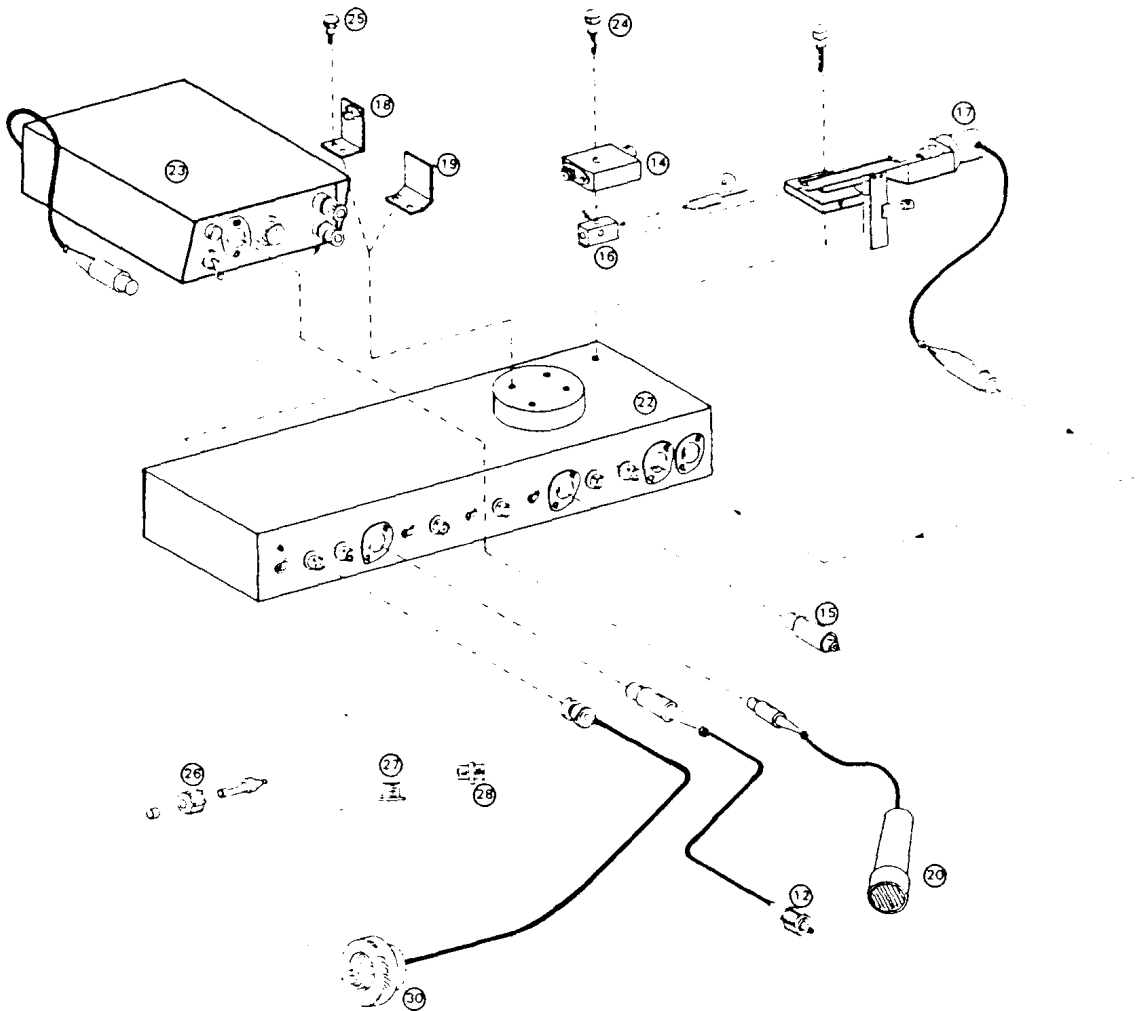
KOP-100 Fiber Optics Module

Important Characteristics of the Principle Elements

1. Fiber
 - plastic core and cladding
 - step index type
 - NA: 0.48
 - core refractive index: 1.6
 - cladding refractive index: 1.526
 - core diameter: 1.42 mm
 - cladding diameter: 1.52 mm
2. TIL24 LED
 - peak emitting wavelength: 940 nm
 - spectral bandwidth: 50 nm
 - half power angle: 35°
 - output flux at 50 mA: 7 mW/sr
 - maximum current: 100 mA
3. TIL 221 LED
 - peak emitting wavelength: 650 nm
 - maximum current: 50 mA
4. C 30808 PIN Photodiode
 - photosensitive surface area: 5 mm²
 - spectral response (10 %): 400 to 1100 nm
 - sensitivity: 0.6 A/W at 900 nm
 - dark current: 30 nA
 - quantum efficiency: 80 % at 900 nm
 - risetime: 5 ns at 900 nm
5. TIL Phototransistor
 - 5.1 Phototransistor configuration
 - photocurrent: 5 mA at 20 mW/cm²
 - risetime: 8 μs
 - falltime: 6 μs
 - hfe: 200
 - 5.2 Photodiode configuration
 - photocurrent: 40 μA at 20 mW/cm²
 - risetime: 350 ns
 - falltime: 500 ns



- 0 Fiber F0 (5 cm)
- 1 Fiber F1 with connector
- 2 to 6: Fibers F2 to F6 (0.5 to 6 m)
- 7: Fiber F7 (10 cm) unpolished both ends
- 8: Pigtail fiber
- 9: Fiber F9 (1 m) unpolished one end
- 10: Fibers F1 and F2
- 11: 5 m loose fiber (no connector)
- 12: TIL 24 LED (transmitter)
- 13: TIL 221 LED (transmitter)
- 14: PIN photodiode (detector)
- 15: TIL99 phototransistor (detector)
- 16: Mounting block
- 17: X-Y mechanical stage
- 18: L bracket with connector
- 19: Diffusion reflector
- 20: Microphone
- 21: Polishing kit (not shown)
- 22: Electronic module
- 23: Electronic module and - 10 V to 10 V power supply
- 24: 6-32 x 1" thumbscrew
- 25: 6-32 x 1/4" thumbscrew
- 26: Optical connector parts
- 27: Polishing bushing
- 28: Male-male connector
- 29: PIN photodiode connector cable
- 30: Earphone
- 31: BNC to bananas plug cable



KOP-100 parts list



MOTOROLA
SEMICONDUCTORS
 PO BOX 20912 • PHOENIX ARIZONA 85036

FIBER OPTIC LOW COST SYSTEM
FLCS INFRARED-EMITTING DIODE

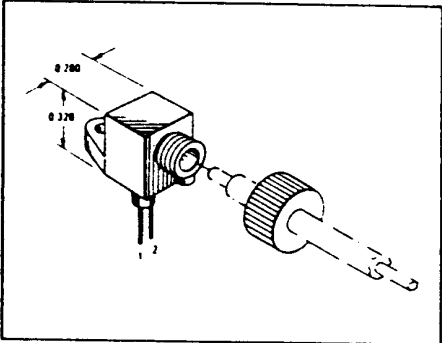
... designed for low cost, medium frequency, short distance Fiber Optic Systems using 1000 micron core plastic fiber.

Typical applications include: high isolation interconnects, disposable medical electronics, consumer products, and microprocessor controlled systems such as coin operated machines, copy machines, electronic games, industrial clothes dryers, etc.

- Fast Response — > 10 MHz
- Spectral Response Matched to FLCS Detectors: MFOD71, 72, 73
- FLCS Package
 - Low Cost
 - Includes Connector
 - Simple Fiber Termination and Connection
 - Easy Board Mounting
 - Molded Lens for Efficient Coupling
 - Mates with 1000 Micron Core Plastic Fiber (DuPont OE1040, Eska SH4001)

MFOE71

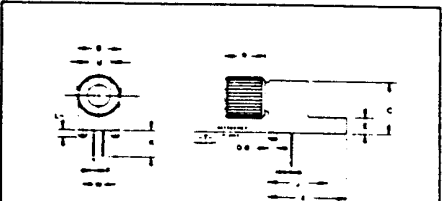
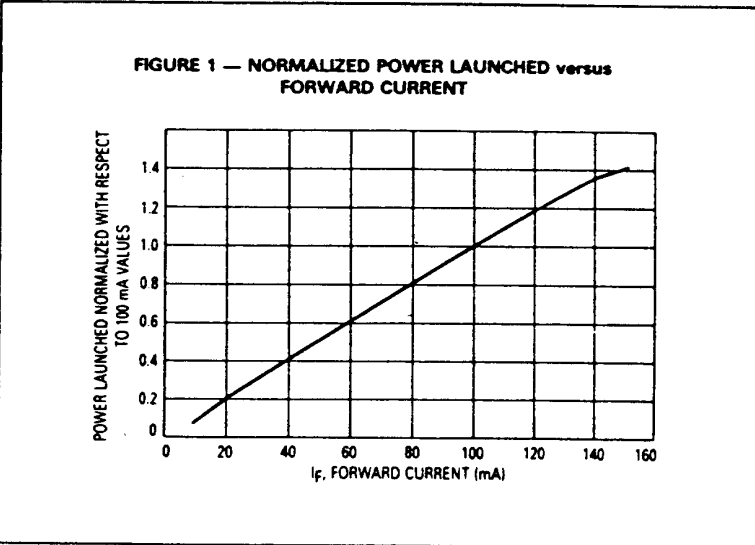
FLCS LINE
FIBER OPTICS
INFRARED-EMITTING DIODE
GALLIUM ALUMINUM ARSENIDE
820 nm



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Reverse Voltage	V _R	6.0	Volts
Forward Current	I _F	150	mA
Total Power Dissipation @ T _A = 25°C Derate above 25°C	P _D (1)	150 2.5	mW mW/°C
Operating and Storage Junction Temperature Range	T _J , T _{stg}	-40 to +85	°C

(1) Measured with the device soldered into a typical printed circuit board.



NOTES

1. DIMENSIONS V AND X ARE DATUMS AND \square IS A DATUM SURFACE
2. POSITIONAL TOLERANCE FOR ϕ (Z PL) $\phi \pm 0.25$ (0.010) (M, T, V, W) (X)
3. POSITIONAL TOLERANCE FOR V DIMENSION (Z PL) $\phi \pm 0.25$ (0.010) (F, Y, W) (X)
4. POSITIONAL TOLERANCE FOR H DIMENSION (Z PL) $\phi \pm 0.25$ (0.010) (T, V, W) (X)
5. DIMENSIONING AND TOLERANCING PER ANSI Y14.5-1982
6. CONTROLLING DIMENSION: INCH

STYLE 1
 PIN 1 ANODE
 PIN 2 CATHODE

MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN
A	18.67	19.05	0.735
B	9.14	9.39	0.360
C	7.75	8.12	0.305
D	1.52	1.72	0.060
E	2.41	2.66	0.095
F	0.43	0.60	0.024
G	2.54	BSC	0.100
H	0.23	0.55	0.009
J	7.87	8.25	0.310
K	10.79	11.14	0.425
L	1.27	1.52	0.050
M	1.94	2.08	0.076
N	3.05	3.30	0.120
R	7.49	8.20	0.295
W	3.50	3.81	0.138
V	6.88	7.11	0.270
X	5.33	BSC	0.210
Y	10.67	11.17	0.420

MFOE71

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage ($I_R = 100 \mu\text{A}$)	—	$V_{(BR)R}$	2.0	4.0	—	Volts
Forward Voltage ($I_F = 100 \text{ mA}$)	—	V_F	—	1.5	2.0	Volts

OPTICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Typ	Max	Unit
Power Launched	2, 4	P_L	110	165	—	μW
Optical Rise and Fall Time	3	t_r, t_f	—	25	35	ns
Peak Wavelength ($I_F = 100 \text{ mA}$)	1	λ_p	—	820	—	nm

For simple fiber termination instructions, see the MFOD71, 72 and 73 data sheet.

FIGURE 2 — POWER LAUNCHED TEST SET

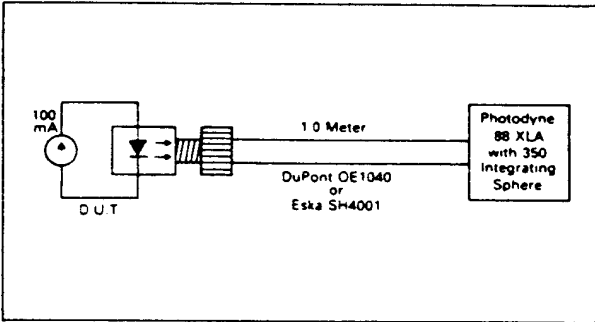


FIGURE 3 — POWER LAUNCHED (P_L) versus FIBER LENGTH

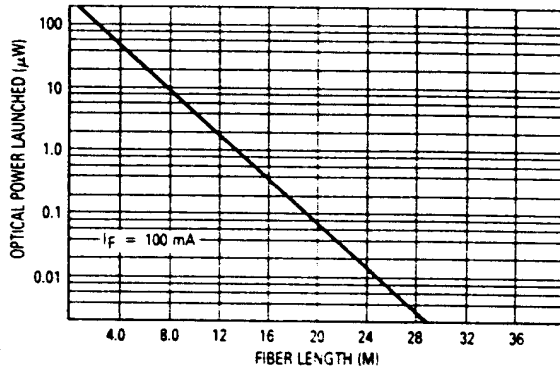


FIGURE 4 — OPTICAL RISE AND FALL TIME TEST SET (10%–90%)

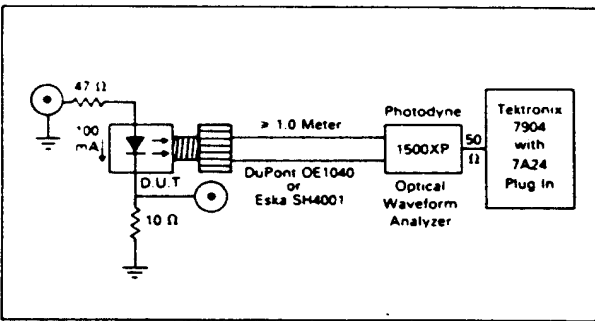
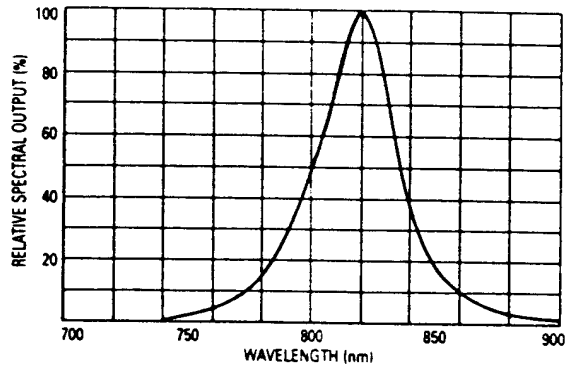


FIGURE 5 — TYPICAL SPECTRAL OUTPUT versus WAVELENGTH



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MOTOROLA Semiconductor Products Inc.

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**MFOD71
MFOD72
MFOD73**

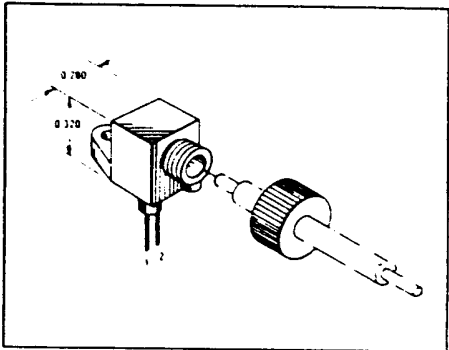
**FIBER OPTIC LOW COST SYSTEM
FLCS DETECTORS**

... designed for low cost, short distance Fiber Optic Systems using 1000 micron core plastic fiber.

Typical applications include: high isolation interconnects, disposable medical electronics, consumer products, and microprocessor controlled systems such as coin operated machines, copy machines, electronic games, industrial clothes dryers, etc.

- Fast PIN Photodiode: Response Time <5.0 ns
- Standard Phototransistor
- High Sensitivity Photodarlington
- Spectral Response Matched to MFOE71 LED
- Annular Passivated Structure for Stability and Reliability
- FLCS Package
 - Includes Connector
 - Simple Fiber Termination and Connection (Figure 4)
 - Easy Board Mounting
 - Molded Lens for Efficient Coupling
 - Mates with 1000 Micron Core Plastic Fiber (DuPont OE1040, Eska SH4001)

**FLCS LINE
FIBER OPTICS
DETECTORS**



MAXIMUM RATINGS (T_A = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V _R	100	Volts
Collector-Emitter Voltage	V _{CEO}	30	Volts
Total Power Dissipation @ T _A = 25°C	P _D	100	mW
Derate above 25°C		1.67	mW/°C
Derate above 25°C		150	mW
Derate above 25°C		2.5	mW/°C
Operating and Storage Junction Temperature Range	T _J , T _{stg}	-40 to +85	°C

NOTES

- DIMENSIONS V AND X ARE DATUMS AND IS A DATUM SURFACE
- POSITIONAL TOLERANCE FOR L, Z, PL
- POSITIONAL TOLERANCE FOR F DIMENSION, 2 PL
- POSITIONAL TOLERANCE FOR N DIMENSION, 2 PL
- DIMENSIONING AND TOLERANCING PER ANSI #45-1982
- CONTROLLING DIMENSION INCH

STYLE 2
PIN 1 EMITTER
2 COLLECTOR

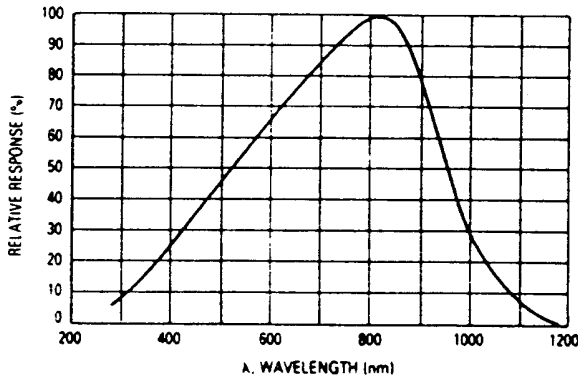
(MFOD71 ONLY)

STYLE 3
PIN 1 CATHODE
2 ANODE

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	78.5	19.25	0.735	0.750
B	9.4	3.35	0.360	0.370
C	7.5	8.12	0.295	0.320
D	1.52	1.72	0.060	0.068
E	2.41	2.66	0.095	0.105
F	0.43	0.60	0.017	0.024
G	2.54 BSC 0.100 BSC			
H	0.13	0.35	0.009	0.027
J	7.67	8.25	0.310	0.325
K	10.29	17.14	0.405	0.675
L	1.27	1.52	0.050	0.060
M	3.25	3.30	0.128	0.129
N	3.25	3.30	0.128	0.130
R	7.49	8.30	0.295	0.315
U	3.56	3.81	0.140	0.150
V	6.86	7.11	0.270	0.280
W	5.33 BSC 0.210 BSC			
X	19.57	17.17	0.420	0.440

CASE 363-01

FIGURE 1 — RELATIVE SPECTRAL RESPONSE



MFOD71 • MFOD72 • MFOD73

MFOD71

STATIC ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Dark Current ($V_R = 20\text{ V}$, $R_L = 10\text{ M}\Omega$) $T_A = 25^\circ\text{C}$ $T_A = 85^\circ\text{C}$	I_D	—	0.06 10	10	nA
Reverse Breakdown Voltage ($I_R = 10\ \mu\text{A}$)	$V_{(BR)R}$	50	100	—	Volts
Forward Voltage ($I_F = 50\text{ mA}$)	V_F	—	—	1.1	Volts
Series Resistance ($I_F = 50\text{ mA}$)	R_s	—	8.0	—	ohms
Total Capacitance ($V_R = 20\text{ V}$; $f = 1.0\text{ MHz}$)	C_T	—	3.0	—	pF

OPTICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$)

Responsivity ($V_R = 5.0\text{ V}$, Figure 2)	R	0.15	0.2	—	$\mu\text{A}/\mu\text{W}$
Response Time ($V_R = 5.0\text{ V}$, $R_L = 50\ \Omega$)	$t_{(resp)}$	—	5.0	—	ns

MFOD72/MFOD73

STATIC ELECTRICAL CHARACTERISTICS

Collector Dark Current ($V_{CE} = 10\text{ V}$)	I_D	—	—	100	nA
Collector-Emitter Breakdown Voltage ($I_C = 10\text{ mA}$)	MFOD72 MFOD73	$V_{(BR)CEO}$	30 60	— —	Volts

OPTICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

Responsivity ($V_{CC} = 5.0\text{ V}$, Figure 2)	MFOD72 MFOD73	R	80 1,000	125 1,500	— —	$\mu\text{A}/\mu\text{W}$	
Saturation Voltage ($\lambda = 820\text{ nm}$, $V_{CC} = 5.0\text{ V}$) ($P_{in} = 10\ \mu\text{W}$, $I_C = 1.0\text{ mA}$) ($P_{in} = 1.0\ \mu\text{W}$, $I_C = 2.0\text{ mA}$)	MFOD72 MFOD73	$V_{CE(sat)}$	— —	0.25 0.75	0.4 1.0	Volts	
Turn-On Time Turn-Off Time	$R_L = 2.4\text{ k}\Omega$, $P_{in} = 10\ \mu\text{W}$, $\lambda = 820\text{ nm}$, $V_{CC} = 5.0\text{ V}$	MFOD72	t_{on} t_{off}	— —	10 60	— —	μs μs
Turn-On Time Turn-Off Time	$R_L = 100\ \Omega$, $P_{in} = 1.0\ \mu\text{W}$, $\lambda = 820\text{ nm}$, $V_{CC} = 5.0\text{ V}$	MFOD73	t_{on} t_{off}	— —	125 150	— —	μs μs

TYPICAL COUPLED CHARACTERISTICS

FIGURE 2 — RESPONSIVITY TEST CONFIGURATION

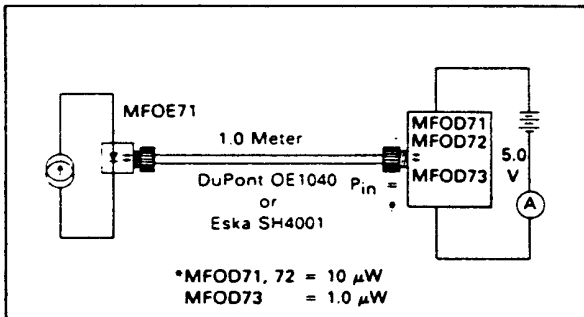
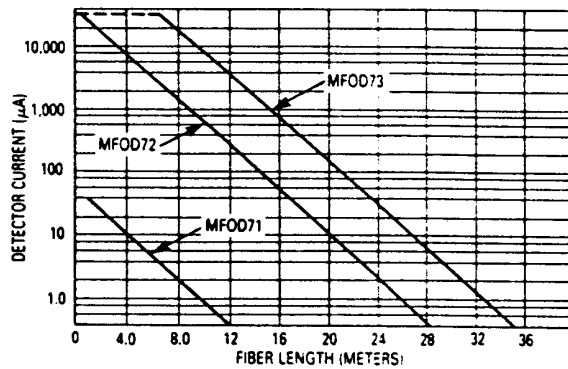


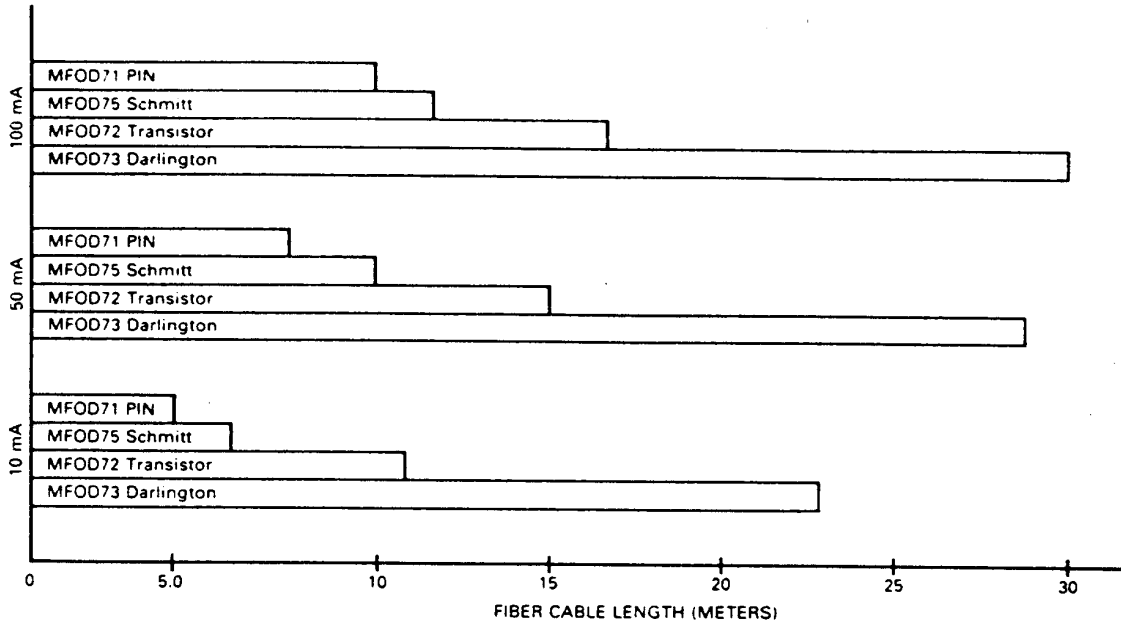
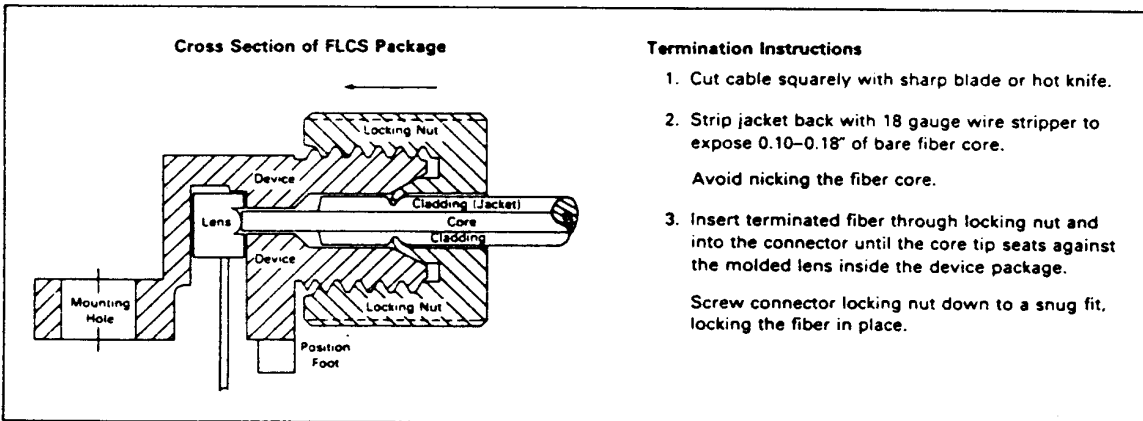
FIGURE 3 — DETECTOR CURRENT versus FIBER LENGTH



MFOD71 • MFOD72 • MFOD73
FLCS WORKING DISTANCES

The system length achieved with a FLCS emitter and detector using the 1000 micron core fiber optic cable depends upon the forward current through the LED and

the Responsivity of the detector chosen. Each emitter/detector combination will work at any cable length up to the maximum length shown.


FIGURE 4 — FO CABLE TERMINATION AND ASSEMBLY


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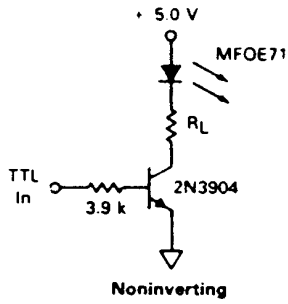

MOTOROLA Semiconductor Products Inc.

MFOD71 • MFOD72 • MFOD73

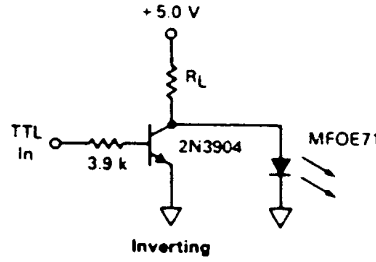
Input Signal Conditioning

The following circuits are suggested to provide the desired forward current through the emitter.

TTL TRANSMITTERS



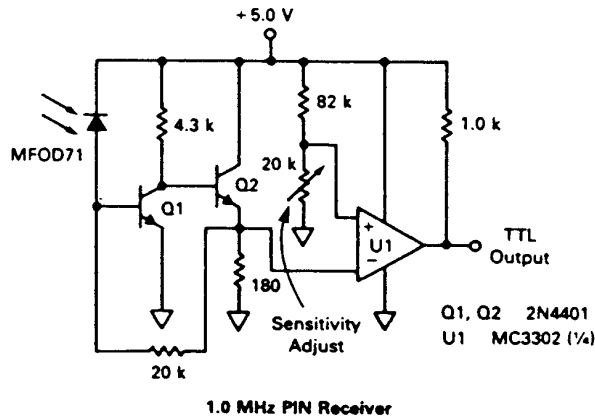
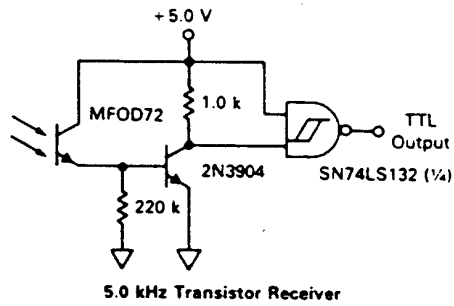
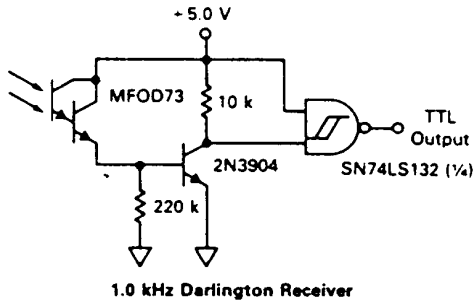
I _F	R _L
10 mA	330
50 mA	68
100 mA	33



Output Signal Conditioning

The following circuits are suggested to take the FLCs detector output and condition it to drive TTL with an acceptable bit error rate.

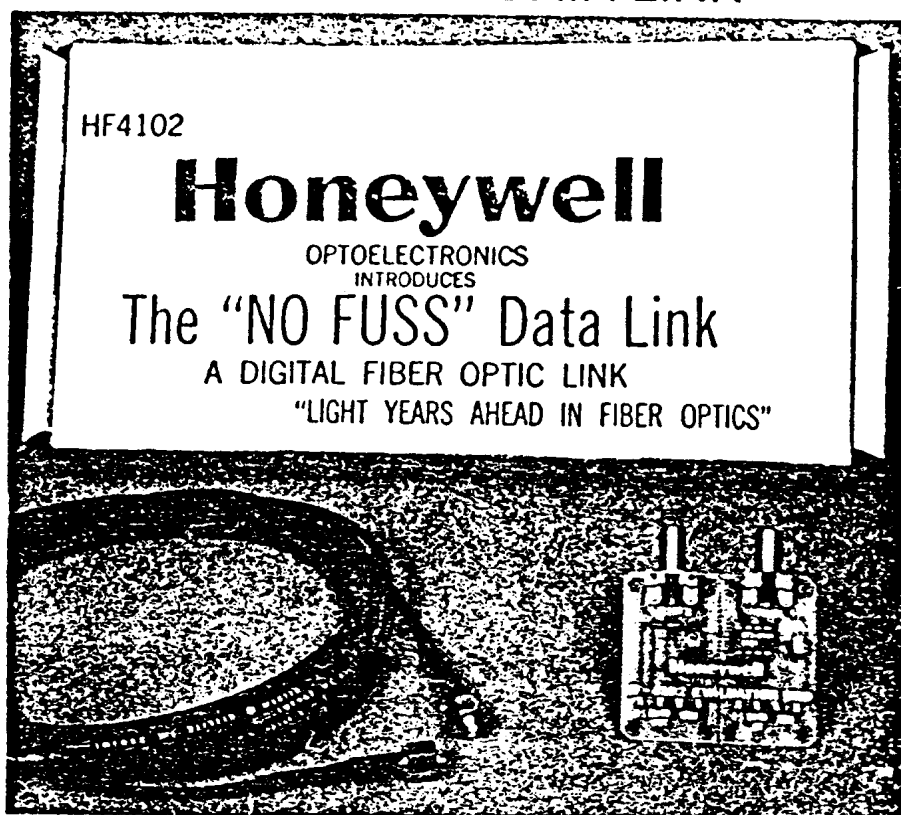
TTL RECEIVERS



MOTOROLA Semiconductor Products Inc.

BOX 20912 • PHOENIX, ARIZONA 85036 • A SUBSIDIARY OF MOTOROLA INC

ASSEMBLED DATA LINK



Honeywell presents the most advanced and complete line of fiber optics in the industry.

That means you can design at the component level with our Sweet Spot LEDs, Pigtail LEDs and PIN Photodiodes.

Or choose assemblies like our Fiber Optic Modules for maximum transmission distances and fast data rates with multiple cable options.

And you can round out your fiber optic needs with our total systems design capability.

So, for a full line of superior fiber optic products, call Honeywell Inc. We could be your brightest light source.

ORDERING INFORMATION

The "No Fuss" Data Link is available through Honeywell Optoelectronics or your local authorized distributor. For order information, call us at: (214) 234-4271

Honeywell

OPTOELECTRONICS

830 EAST ARAPAHO ROAD
RICHARDSON, TEXAS 75081
(214) 234 4271 TELEX 73-0890

Honeywell

OPTOELECTRONICS

Introduces

The "NO FUSS" Data Link

HF 4102

DIGITAL FIBER OPTIC LINK

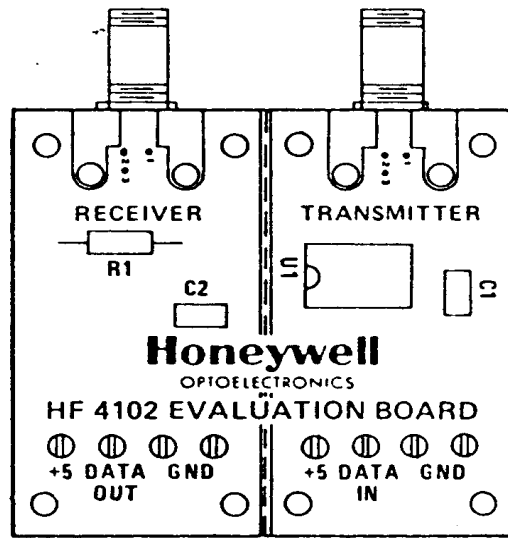
Featuring

- Data Rates to 5 Mb/s
- TTL Compatible inputs and outputs
- Code Transparent Digital Data Transmission
- Temperature and voltage compensated LED Driver in 8 Pin Dip Package
- Hermetic LED and Receiver packages
- Adjustment Free Operation to 2 km
- Operates over wide temperature range

The "NO FUSS" fiber optic link has been designed for computer and process control applications. It requires no knowledge of optics nor adjustment of any components or communication protocols.

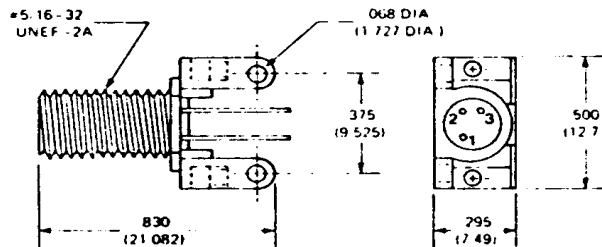
HF 4102 TECHNICAL INFORMATION

The "No Fuss" kit has been designed to allow the construction of a completely TTL compatible serial digital data-link. Unlike most fiber optic kits, there are no extra components to buy or calculations to perform to get your link into operation. During construction and operation standard TTL practice is sufficient. The evaluation board can be snapped in half to assemble a 5 meter simplex (unidirectional) data link, or two kits can be used to complete a full duplex (bi-directional) communications link. Both the transmitter and receiver have been designed to accept standard +4.5V to +5.5V TTL power supplies with 250 mV of power supply noise. Sufficient power supply regulation is made possible by internal regulators as well as an external RC network on the receiver and a decoupling capacitor on the transmitter LED driver. The transmitter IC provides symmetrical rise and fall times, each less than 20ns and free of optical overshoot and ringing.



Note:
Do not short board runs to the connector with mounting screws.

C1, C2 Capacitor, CK05, .1 μ f
R1 Resistor, 1/4 W, 5%, 27 Ω
U1 Integrated Circuit HFI 6000
Recv'r. Receiver HFD 4800
Trans. Transmitter SPX 4689



SPX 4689 Series

1 Anode
2 Cathode
3 Case

HFD 4800

1 VCC
2 Output
3 Case

SE 3352 LED mounted in Amp SFR Connector (SPX4689 Series)

ELECTRO-OPTICAL CHARACTERISTICS (T_{case} = 25°C)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN	TYP	MAX	UNITS
Forward Drop	I _f = 100mA	V _f		1.6	2.0	volts
Series Resistance	DC	R _s		1.6		Ω
Device Capacitance	V _R = 1V	C _T		400		pF
Power Output	I _f = 100mA Aperture 300μm NA = 25 See Note		150 400 1000 150 400	250 700 1100 250 600	— 1000 — — —	— — — — —
Response Time	10 90% 1V Bias 200mA Peak	t _r				
	See Note			12 7	20 10	ns ns
Peak Output Wavelength	I _f = 100mA	λ _p	800	820	850	nm
Spectral Bandwidth	I _f = 100mA	Δλ		35		nm
V _f Temperature Coefficient		ΔV _f /ΔT		-1.70		mV/°C
P _o Temperature Coefficient	I _f = 100mA			-0.12		dB/°C
λ Temperature Coefficient		Δλ/ΔT		0.25		nm/°C
Thermal Resistance		θ		100		°C/W

NOTE: Three digit dash numbers specify hermeticity, rise-time, and power output respectively. First digit is zero for standard devices, one for hermetically tested devices. Second digit is zero for standard devices, one for high speed devices. Third digit specifies power output range.

Example — Hermetic device with maximum rise-time of 20 ns and 400 μW minimum output is numbered SE3352-103

LED Operating temperature range -55°C to +125°C

HFD 4000 Receiver mounted in Amp SFR Connector (HFD 4800 Series)

ELECTRO-OPTICAL CHARACTERISTICS

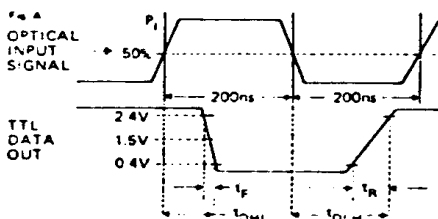
Values shown apply over range given in recommended operating conditions unless otherwise specified

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Input Sensitivity P _i	λ _p = 820nm V _{CC} = 4.5V		1.0	2.0	μW
Output Fall Time t _f	2μs signal V _{CC} = 4.5V		5	15	ns
Output Rise Time t _r	2μs signal V _{CC} = 4.5V		10	30	ns
Propagation Delay t _{DHL}	2μs signal V _{CC} = 4.5V			165	ns
Propagation Delay t _{DLH}	2μs signal V _{CC} = 4.5V			165	ns
Pulsewidth Distortion	2.200μs input V _{CC} = 4.5-5.5V			+35 -25	ns

PARAMETERS	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Supply Current I _{CC}	V _{CC} = 5.5 Volts	6	12	20	mA
Low Level Out Voltage V _{OL}	V _{CC} = 4.5 to 5.5 Volts, I _{OL} = 5mA			0.4	Volts
High Level Out Voltage V _{OH}	V _{CC} = 4.5 to 5.5 Volts, I _{OH} = 100μA	2.4			Volts
Intermessage Recovery Time*	High Level message = 200 microwatts Low Level message = 2 microwatts		500	800	nsec

Note 1 Rise and fall times on optical signal are equal and ≤ 20nseconds

TYPICAL CHARACTERISTICS



ABSOLUTE MAXIMUM RATING

Storage Temperature -65°C to 150°C
Case Operating Temperature -55°C to 85°C
Lead Solder Temperature 260°C, 10 sec
Supply Voltage, V_{CC} -0.5 to 7V

RECOMMENDED OPERATING CONDITIONS

Case Operating Temperature -55° to 85°C
Supply Voltage 4.5 to 5.5V
Distance between signal edges ≥ 200 nseconds
See Figure A

* Intermessage recovery time is a useful parameter when using the HFD 4000 in a distributed application where one signal may be arriving from a transmitter 3 meters away and a different 2 km away. This is the time required for the receiver to recover from a 200μW signal source and detect a 2μW signal (ignoring the time between messages).

The receiver chip contains an on-chip photodiode with a "Sweet Spot" microlens to collect the light from the optical fiber. The receiver is edge triggered so there is no data distortion caused by changes in optical power received. The NRZ data input is reproduced on the output of the receiver over worst case conditions to within 35ns of each transition for optical power inputs of less than 200 microwatts.

TERMINATED 5 METER EVALUATION CABLE

- Cable is Belden type #226101
- Core Diameter 100 microns
- Loss 7 dB/Km
- Fiber Bandwidth 20 MHz per Km
- Meets UL VW-1 flame test

Standard and custom length optical cables are available through Honeywell Optoelectronics for a wide variety of applications.

HFI 6000 LED Driver

ELECTRICAL CHARACTERISTICS

Values shown apply over ranges given in recommended operating conditions unless otherwise specified

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Output Drive Current I_O	$V_{CC} = 5.5$ Volts, $V_I = 0.4$ Volts	43	59	77	mA
Output Drive Current I_{OL}	$V_{CC} = 4.5$ Volts, $V_I = 2.4$ Volts	0	0	3	mA
Supply Current	$V_{CC} = 5.5$ Volts, $V_I = 2.4$ Volts		13	26	mA
Low Level Input Current	$V_{CC} = 5.5$ Volts, $V_I = 0.8$ Volts	0.5	0.85	1.2	mA
High Level Input Current	$V_{CC} = 5.5$ Volts, $V_I = 2.4$ Volts	0		20	μ A
Output Current Rise Time, t_R	$V_{CC} = 5.0$ Volts	4	16	22	nsec
Output Current Fall Time, t_F	$V_{CC} = 5.0$ Volts	1	8	12	nsec
Delay to Rising Edge, t_{DR}	$V_{CC} = 5.0$ Volts	5	12	18	nsec
Delay to Falling Edge, t_{DF}	$V_{CC} = 5.0$ Volts	0	3	10	nsec

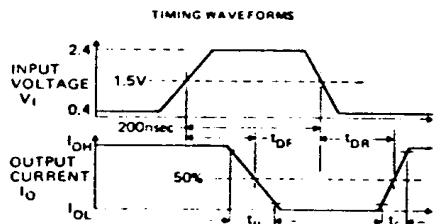
ABSOLUTE MAXIMUM RATINGS

Storage Temperature Range	-65° to 150°C
Operating Free-Air Temperature Range	0°C to 70°C
Lead Solder Temperature	260°C, 10 sec
Supply Voltage (V_{CC})	-0.5V to 7.0V
Input Voltage	-0.5 to 5.5V

RECOMMENDED OPERATING CONDITIONS

Supply Voltage (V_{CC})	4.5V to 5.5V
High Level Input Voltage, V_{IH}	2.4V to V_{CC}
Low Level Input Voltage, V_{IL}	0V to 0.4V

Pin #	Function
1	TTL Input
2	Not Used
3	Ground
4	Ground
5	Not Used
6	Not Used
7	Current Output
8	Supply Voltage



Note 1 All units tested with 20 ohm load.
Recommended LED is SL3352 XX.

Typical Applications

Use basic kit for:

- Intra-Cabinet clock distribution
- Card to card digital data transmission
- EMI immune switching
- High voltage isolation

Use kit with simple modifications for:

- RS232C, RS422, RS423 Interconnects; synchronous and asynchronous
- Parallel to parallel ribbon cable replacement (using time division multiplexing or frequency multiplexing)
- High fidelity audio transmission (using commercial V/F and F/V chips for narrow band FM over noise free link)
- High linearity analog instrumentation links using FM technique.

FOR ADDITIONAL INFORMATION:

CABLES

Belden Corporation
Fiber Optic Group
2000 S. Batavia Ave.
Geneva, IL 60134
(312) 232-8900

CONNECTORS

AMP, Incorporated
Contact your local
sales office



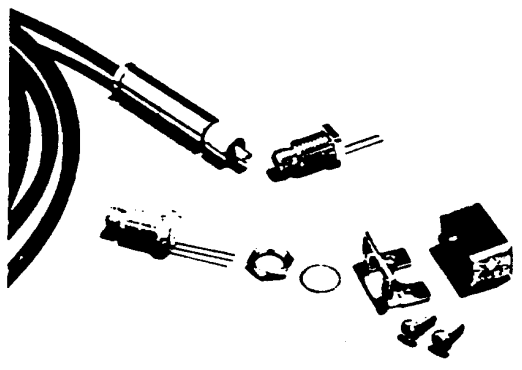
Miniature Fiber Optic Logic Link

**HFBR-0200
SERIES**

TENTATIVE DATA DECEMBER 1981

Features

- DC TO 5 MBAUD DATA RATE
- MAXIMUM LINK LENGTH
500 Metres (Guaranteed)
1200 Metres (Typical)
- TTL/CMOS COMPATIBLE OUTPUT
- MINIATURE, RUGGED METAL PACKAGE
- SINGLE -5V RECEIVER POWER SUPPLY
- INTERNALLY SHIELDED RECEIVER FOR EMI/RFI IMMUNITY
- PCB AND PANEL MOUNTABLE
- HIGH EFFICIENCY GaAIAs EMITTER



Applications

- EMC REGULATED SYSTEMS
- EXPLOSION PROOF SYSTEMS IN OIL INDUSTRY/CHEMICAL PROCESS CONTROL INDUSTRY
- SECURE DATA COMMUNICATIONS
- WEIGHT SENSITIVE SYSTEMS (e.g. Avionics, Mobile Stations)
- HIGH VOLTAGE ISOLATION IN POWER GENERATION

and HFBR-2201 Receiver are housed in miniature, rugged packages compatible with the HFBR-4000 connector and HFBR-3000 series glass fiber optic cable. The HFBR-3000 series fiber optic cable can be ordered with or without installed connectors. The HFBR-0100 connector assembly kit is available if field installation of connectors is desired.

The HFBR-1201 Transmitter contains a high efficiency GaAIAs emitter operating at a wavelength of 820 nm. The transmitter is easily identified by the white epoxy backfill!

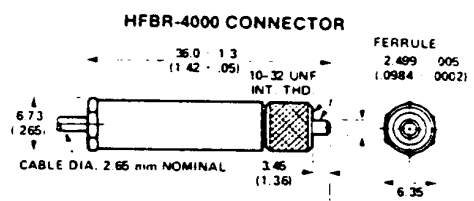
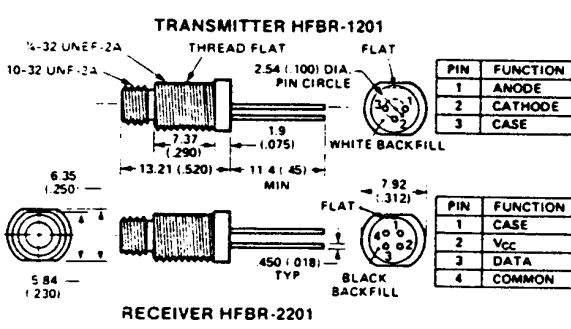
The HFBR-2201 Receiver contains an integrated photodetector and dc amplifier. An open collector Schottky transistor provides logic compatibility. The combination of an internal EMI shield, the metal package, and an isolated case ground provides excellent immunity to EMI/RFI. For unusually severe EMI/ESD environments a metal shield is provided which snaps directly onto the mounting bracket. The receiver is easily identified by the black epoxy backfill.

Description

The HFBR-0200 Series is a dc to 5 MBaud fiber optic data link capable of transmission over distances of 500 metres or more.

A complete evaluation kit is available, HFBR-0200, containing a transmitter, receiver, mounting hardware, 10m of cable and technical literature. The HFBR-1201 Transmitter

Mechanical Dimensions



- NOTES**
1. Dimensions are in mm (inches)
 2. Unless otherwise specified, the tolerances are
X .51mm (.02 in)
XX .13mm (.005 in)
 3. Fiber end is rocket flush with ferrule face

Electrical Description

The HFBR-1201 Transmitter contains a GaAlAs infrared emitter. Both the anode and cathode of the emitter are insulated from the case. This configuration permits the use of a variety of drive circuitry such as series switching, shunt-switching and high frequency peaking. There is no internal drive circuit or current limiter.

The HFBR-2201 Receiver incorporates an integrated photo IC containing a photodetector and dc amplifier driving an open-collector Schottky output transistor. The HFBR-2201 is designed for direct interfacing to popular logic families. The absence of an internal pull-up resistor allows the open-collector output to be used with logic families such as CMOS requiring voltage excursions much higher than V_{CC} . Both the open-collector "Data" output (Pin 3) and V_{CC} (Pin 2) are referenced to "Com" (Pin 4). The "Data" output allows bussing, strobing and wired "OR" circuit configurations. Both the transmitter and receiver are designed to operate from a single -5V supply. Note that the "Com" and "Case" pins are not connected internally.

The HFBR-1201 and HFBR-2201 optical receptacles contain a lens to optimize the coupling between the fiber and the active optical device.

Mechanical Description

The HFBR-1201 fiber optic transmitter and HFBR-2201 receiver are housed in rugged metal packages intended for use with the HFBR-3000 fiber optic cable/connector assemblies. The low profile package is designed for direct mounting on printed circuit boards or through panels without additional heat sinking. A flat on the mounting threads of the device is provided to prevent rotation in all mounting configurations and to provide an orientation reference for the pin-out. Hardware is available for horizontal mounting applications on printed circuit boards. The hardware consists of a stainless steel mounting bracket fastened directly to the printed circuit board with two stainless steel self-tapping screws and a nut and washer for fastening the device in the bracket. A metal shield which snaps directly on the mounting bracket is also available for unusually severe EMI/ESD environments. When mounted in the horizontal configuration, the overall height of the component conforms with guidelines allowing printed circuit board spacing on 12.7 mm (500 centers). A thorough environmental characterization has been performed on these products. The test data as well as information regarding operation beyond the specified limits is available from any Hewlett-Packard sales office.

System Design Considerations

The Miniature Fiber Optic Logic Link is guaranteed to work over the entire range of 0 to 500 metres at a data rate of dc -5 MBd, with arbitrary data format and typically less than 25% pulse width distortion, if the Transmitter is driven with $I_F = 40 \text{ mA}$, $R_1 = 82 \Omega$. If it is desired to economize on power or achieve lower pulse distortion, then a lower drive current I_F may be used. The following example will illustrate the technique for optimizing I_F .

EXAMPLE: Maximum distance required = 200 metres. From Fig. 3, the worst case drive current = 20 mA. From the Transmitter data — $V_F = 1.7 \text{ V} \cdot \text{max.}$

$$R_1 = \frac{V_{CC} - V_F}{I_F} = \frac{5 - 1.7 \text{ V}}{20 \text{ mA}} = 165 \Omega$$

The optical power margin between the typical and worst case curves (Fig. 3) at 200 metres is 4 dB. To calculate the worst case pulse width distortion at 200 metres, see Fig. 9. The power into the Receiver is $P_{RL} - 4 \text{ dB} = -20 \text{ dBm}$. Therefore, the typical distortion is 40 ns or 20% at 5 MBd.

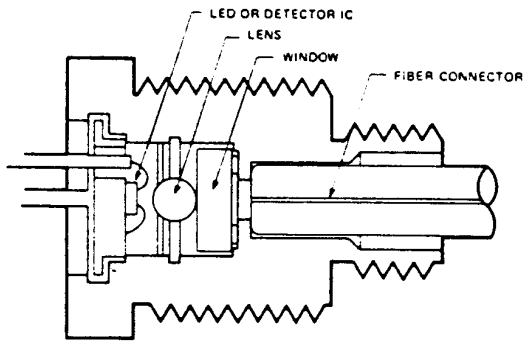


Figure 1. Cross Sectional View

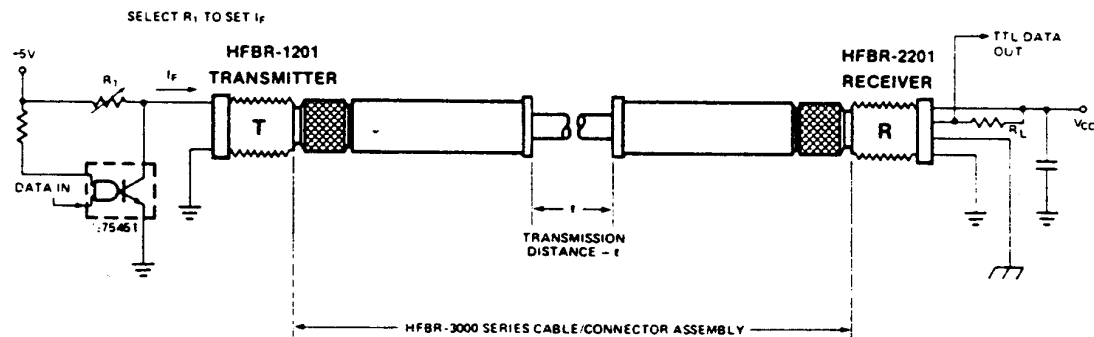


Figure 2.

Recommended Operating Conditions

Parameter	Symbol	Min.	Max.	Units	Reference
TRANSMITTER					
Ambient Temperature	T _A	-20	+85	°C	
Peak Forward Input Current	I _{F PK}		40	mA	Note 7
Average Forward Input Current	I _{F AV}		40	mA	Note 7
RECEIVER					
Ambient Temperature	T _A	-20	+85	°C	
Supply Voltage	V _{CC}	4.75	5.25	V	
Fan Out TTL	N		5		Note 3, Fig. 2
CABLE see HFBR-3000 to 3300 data sheets					

System Performance -20°C to +85°C unless otherwise specified

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions	Reference
Transmission Distance	ℓ	500	1200		Metres		Fig. 3
Data Rate							
Synchronous		dc		5	MBaud		Note 10
Asynchronous		dc		2.5	MBaud		Note 10, Fig. 9
Propagation Delay LOW to HIGH	t _{PLH}		82		nsec	T _A = 25°C P _R = -21 dBm I _{F PK} = 15 mA	Fig. 8, 9, 10
Propagation Delay HIGH to LOW	t _{PHL}		55		nsec		
System Pulse Width Distortion	t _D		27		nsec	ℓ = 1 metre	
Bit Error Rate	BER			10 ⁻⁹		Data Rate ≤ 5 MBaud P _R > -24 dBm 4μW	

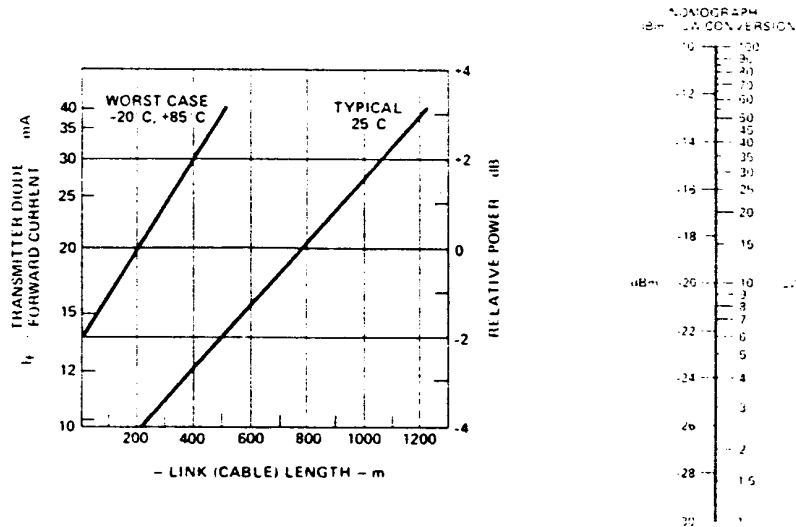


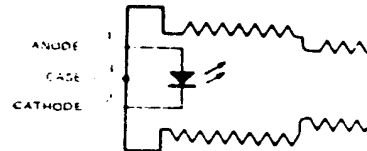
Figure 3. System Performance: HFBR-1201/-2201 with -3000 Series Cable

HFBR-1201 TRANSMITTER

Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Unit	Reference
Storage Temperature	T _S	-55	+85	°C	
Operating Temperature	T _A	-20	+85	°C	
Lead Soldering Cycle	Temp		+260	°C	Note 2
	Time		10	sec	
Forward Input Current	Peak	I _{F PK}	40	mA	Note 7
	Average	I _{F AV}	40	mA	
Reverse Input Voltage	V _{BR}		2.5	V	

HFBR-1201 TRANSMITTER



Electrical/Optical Characteristics

-20°C to +85°C unless otherwise specified

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions	Reference
Forward Voltage	V _F		1.44	1.7	V	I _F = 20 mA	Fig. 6
Forward Voltage Temperature Coefficient	ΔV _F /ΔT		-0.91		mV/°C	I _F = 20 mA	Fig. 6
Reverse Input Voltage	V _{BR}	2.5	4.0		V	I _R = 100 μA	
Numerical Aperture	NA		.35				
Optical Port Diameter	D _T		180		μm		
Peak Emission Wavelength	λ _P		820		nm		Fig. 7

Dynamic Characteristics

-20°C to +85°C unless otherwise specified

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions	Reference
Output Optical Power	P _T	-20	-19		dBm	I _F = 20 mA T _A = 25°C	Fig. 4 Note 4
		10	12		μW		
		-21			dBm	I _F = 20 mA -20°C < T _A < 85°C	
		8			μW		
Optical Power Temperature Coefficient	ΔP _T /ΔT		-0.17		dB/°C		Fig. 5
Propagation Delay LOW to HIGH	t _{PLHT}		17		nsec	I _{F PK} = 10 mA	Note 8 Fig. 8
Propagation Delay HIGH to LOW	t _{PHLT}		6		nsec		

WARNING: OBSERVING THE TRANSMITTER OUTPUT POWER UNDER MAGNIFICATION MAY CAUSE INJURY TO THE EYE. When viewed with the unaided eye, the infrared output is radiologically safe however, when

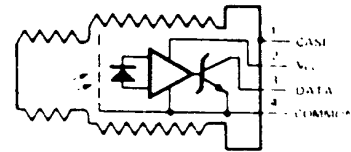
viewed under magnification, precaution should be taken to avoid exceeding the limits recommended in ANSI Z136.1-1976.

HFBR-2201 RECEIVER

Absolute Maximum Ratings

Parameter	Symbol	Min.	Max.	Units	Reference
Storage Temperature	T _S	-55	+85	°C	
Operating Temperature	T _A	-20	+85	°C	
Lead Soldering Cycle	Temp.		+260	°C	Fig. 2
	Time		10	sec	
Supply Voltage	V _{CC}	-0.5	+7.0	V	
Output Current	I _O		25	mA	
Output Voltage	V _O	-0.5	+18.0	V	
Output Collector Power Dissipation	P _{O AV}		40	mW	

HFBR-2201 RECEIVER



Electrical/Optical Characteristics -20°C to +85°C unless otherwise specified

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions	Reference
High Level Output Current	I _{OH}		5	250	μA	V _O = 18V P _R < -40 dBm	
Low Level Output Voltage	V _{OL}		0.4	0.5	V	I _O = 8 mA P _R > -24 dBm	
High Level Supply Current	I _{CCH}		3.5	6.3	mA	V _{CC} = 5.25 V P _R < -40 dBm	
Low Level Supply Current	I _{CCL}		6.2	10	mA	V _{CC} = 5.25 V P _R > -24 dBm	
Optical Port Diameter	D _R		900		μm		
Numerical Aperture	NA		.5				

Dynamic Characteristics -20°C to +85°C unless otherwise specified

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions	Reference
Input Power Level Logic HIGH	P _{RH}			-40	dBm	λ _P = 820 nm	Note 5
				0.1	μW		
Input Power Level Logic LOW	P _{RL}		-25		dBm	T _A = -25°C	Fig. 5, Note 5
			-24		dBm		
			3.2		μW		
			4.0		μW		
Propagation Delay LOW to HIGH	t _{PLHR}		65		nsec	T _A = 25°C, P _R = -21 dBm	Note 8, Fig. 8
Propagation Delay HIGH to LOW	t _{PHLR}		49		nsec		

Notes:

- Typical data at T_A = 25°C, V_{CC} = 5.0V dc
- 2.0mm from where leads enter case
- 8 mA load, 5 x 1.6 mA, R_L = 50Ω
- Measured at the end of 1.0 metre HFBR-3000 Fiber Optic Cable with large area detector
- Measured at the end of HFBR-3000 Fiber Optic Cable with large area detector
- When changing microwatts to dBm, the optical flux is referenced to one milliwatt: 1000 μW
Optical Flux P, dBm = 10 log $\frac{P_{\mu W}}{P_0}$ P₀ = 1000 μW
- I_{FAV} should not be less than 10 mA in the "ON" state. This is to avoid the long turn-on time that occurs at low input current. I_{FAV} may be arbitrarily low as there is no duty factor restriction.
- Propagation delay through the system is the result of several sequentially-occurring phenomena. Consequently it is a combination of data-rate-limiting effects and of transmission-time effects. Because of this, the data-rate limit of the system must be described in terms of time

differentials between delays imposed on falling and rising edges.

As the cable length is increased, the propagation delays increase at 5 ns per metre of length increase. Data rate, as limited by pulse width distortion, is not affected by increasing cable length if the optical power level at the Receiver is maintained.

- Worst case system performance is based on worst case performance of individual components: transmitter at +85°C, receiver and cable at -20°C.

- Synchronous data rate limit is based on these assumptions: a) 50% duty factor modulation (e.g. Manchester I or BiPhase Manchester II); b) continuous data; c) PLL Phase Lock Loop demodulation; d) TTL threshold.

Asynchronous data rate limit is based on these assumptions: a) NRZ data; b) arbitrary timing; c) no duty factor restriction; d) TTL threshold. The EYE pattern describes the timing range within which there is no uncertainty of the light state relative to a specific threshold due to either noise or intersymbol propagation delay effects.

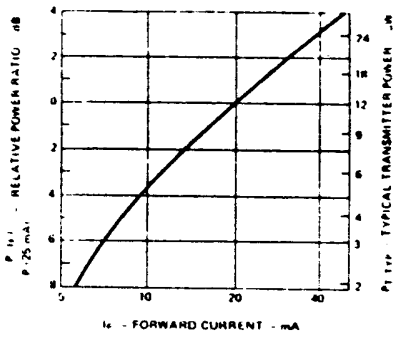


Figure 4. Normalized Transmitter Output vs. Forward Current

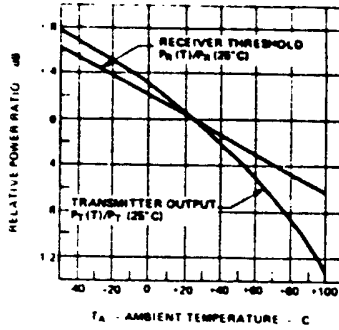


Figure 5. Normalized Thermal Effects in Transmitter Output, Receiver Threshold, and Link Performance (Relative Threshold)

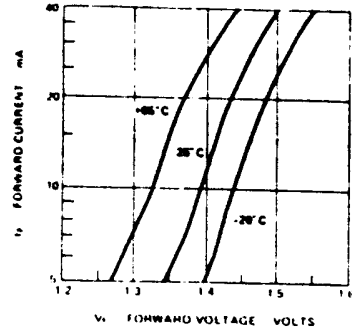


Figure 6. Forward Voltage and Current Characteristics for the Transmitter IRED

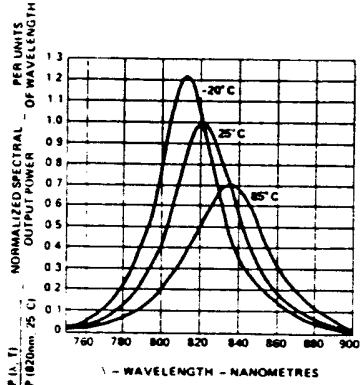


Figure 7. Transmitter Spectrum Normalized to the Peak at 25°C

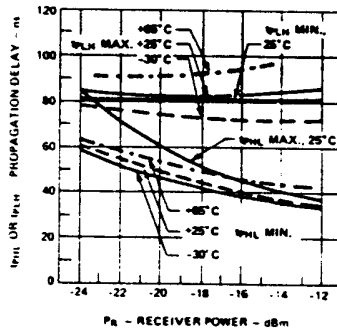


Figure 8. Propagation Delay through System with One Metre of Cable

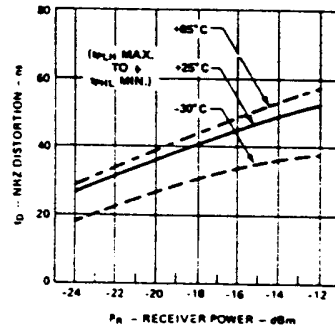


Figure 9. Worst-Case Distortion of NRZ EYE-pattern with Pseudo Random Data at 10 Mb/s. (see note 10).

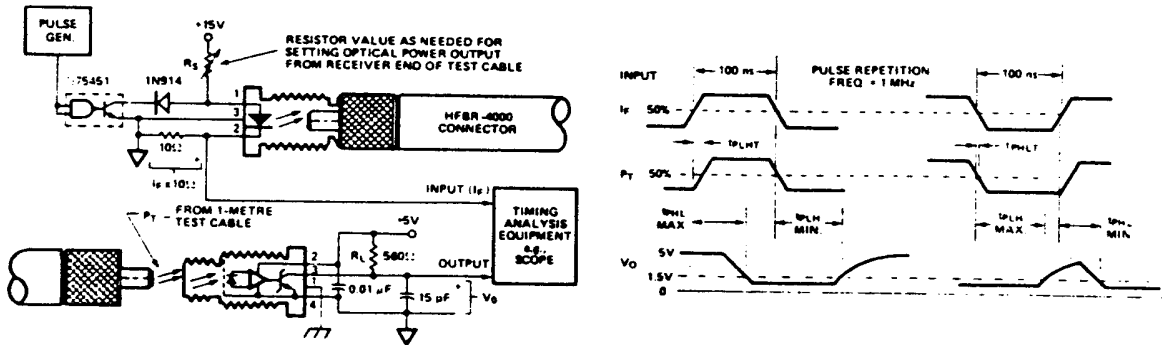
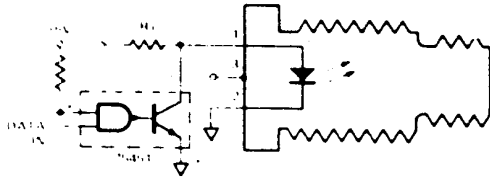
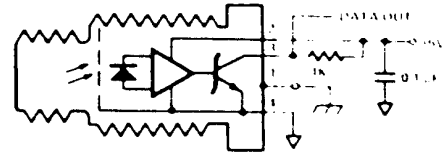


Figure 10. System Propagation Delay Test Circuit and Waveform Timing Definitions

Typical Circuit Configuration



HFBR-1201 TRANSMITTER



HFBR-2201 RECEIVER

Good system performance requires clean port optics and cable ferrules to avoid obstructing the optical path. Clean compressed air often is sufficient to remove particles of dirt; methanol or Freon™ on a cotton swab also works well.

It is essential that a bypass capacitor (0.01 μF to 0.1 μF ceramic) be connected from pin 2 to pin 4 of the receiver. Total lead length between both ends of the capacitor and the pins should not exceed 20 mm.

Horizontal PCB Mounting

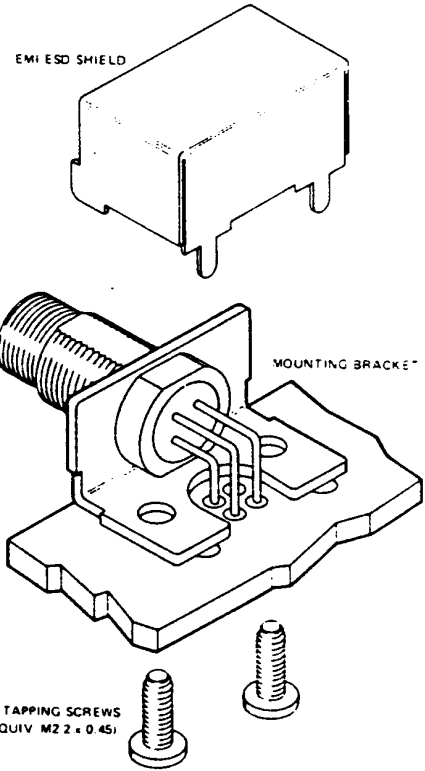
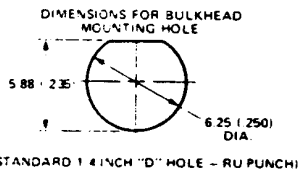
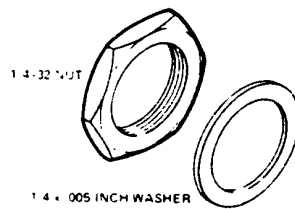
Mounting at the edge of a printed circuit board with the lock nut overhanging the edge is recommended.

When bending the leads, avoid sharp bends right where the lead enters the backfill. Use needle nose pliers to support

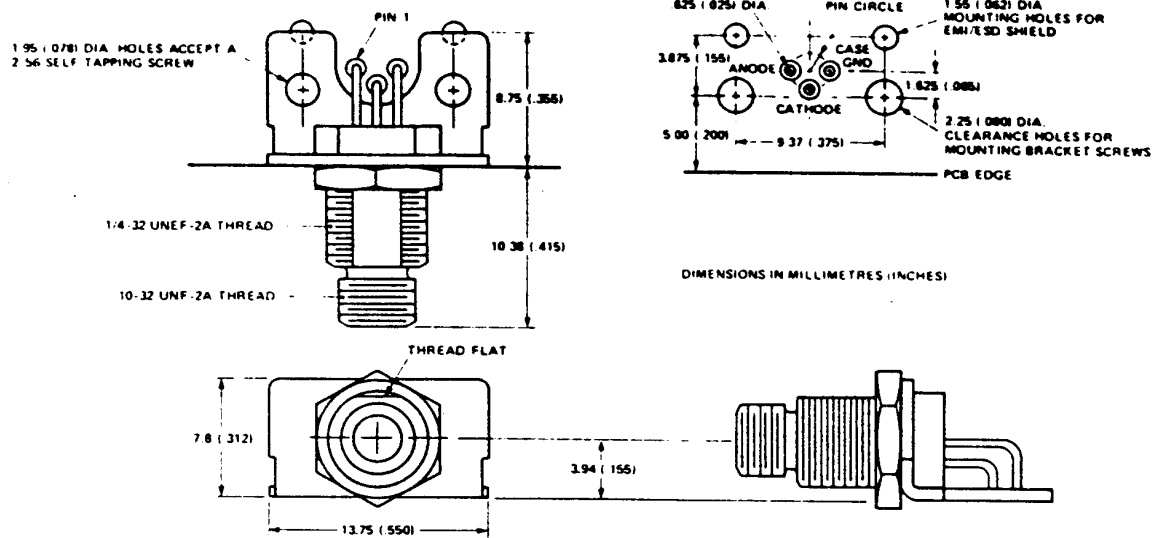
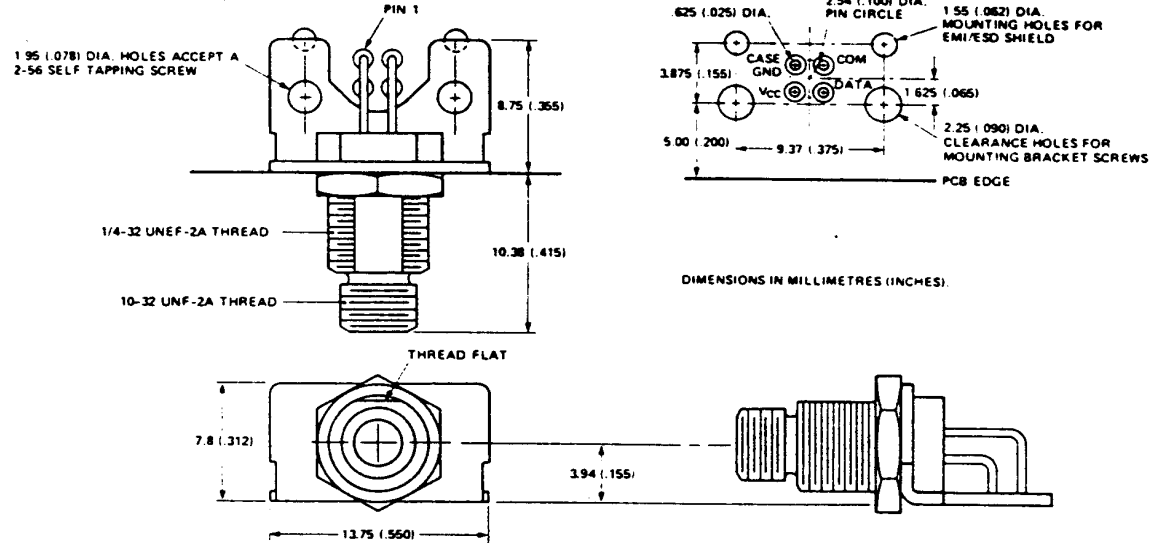
the leads at the base of the package and bend the leads as desired.

When soldering, it is advisable to leave the protective cap on the unit to keep the optics clean.

- MOUNTING HARDWARE - HFBR 4201
- 1 EMI ESD SHIELD
 - 1 1/4-32 NUT
 - 1 1/4 x .005 INCH WASHER
 - 2 2-56 SELF TAPPING SCREWS
 - 1 MOUNTING BRACKET



2-56 SELF TAPPING SCREWS
(METRIC EQUIV. M2.2 x 0.45)

HFBR-1201 TRANSMITTER**HFBR-2201 RECEIVER****Ordering Guide****HFBR-0200 Kit:**

- HFBR-1201 Transmitter
- HFBR-2201 Receiver
- HFBR-4201 Mounting Hardware - 2 sets
- HFBR-3000 10 Metre Cable/Connector Assembly
- Technical Literature

Modules:

HFBR-1201 — Transmitter
 HFBR-2201 — Receiver

Connector HFBR-4000

See data sheet.

Fiber Optic Cable - See data sheet

- HFBR-3000 Simplex Connected
- HFBR-3200 Simplex Unconnected
- HFBR-3100 Duplex Connected
- HFBR-3300 Duplex Unconnected

Mounting Hardware: HFBR-4201

- 1 EMI/ESD shield
- 1 1/4-32 nut
- 1 1/4 x .005" washer
- 2 2-56 self tapping screws
- 1 mounting bracket

Connector Assembly Tooling Kit HFBR-0100

See data sheet



LM139, A
LM239, A **LM2901**
LM339, A **MC3302**

QUAD SINGLE-SUPPLY COMPARATORS

These comparators are designed for use in level detection, low-level sensing and memory applications in Consumer Automotive and Industrial electronic applications.

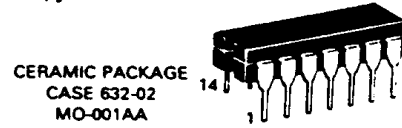
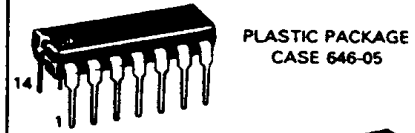
- Single or Split Supply Operation
- Low Input Bias Current — 25 nA (Typ)
- Low Input Offset Current — ±5.0 nA (Typ)
- Low Input Offset Voltage — ±1.0 mV (Typ LM139A Series)
- Input Common-Mode Voltage Range to Gnd
- Low Output Saturation Voltage — 130 mV (Typ) @ 4.0 mA
- TTL and CMOS Compatible

MAXIMUM RATINGS

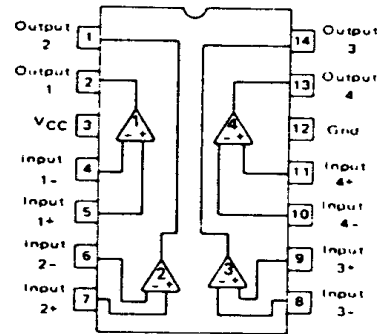
Rating	Symbol	Value	Unit
Power Supply Voltage LM139, A/LM239, A/ LM339A/LM2901 MC3302	V _{CC}	+36 or ±18 +30 or ±15	Vdc
Input Differential Voltage Range LM139, A/LM239, A/LM339, A/LM2901 MC3302	V _{IDR}	36 30	Vdc
Input Common Mode Voltage Range	V _{ICR}	-0.3 to V _{CC}	Vdc
Output Short-Circuit to Gnd (Note 1)	I _{SC}	Continuous	
Input Current (V _{in} < -0.3 Vdc) (Note 2)	I _{in}	50	mA
Power Dissipation @ T _A = 25°C Ceramic Package Derate above 25°C Plastic Package Derate above 25°C	P _D	1.0 8.0 1.0 8.0	Watts mW/°C Watts mW/°C
Operating Ambient Temperature Range LM139, A LM239, A LM2901/MC3302 LM339, A	T _A	-55 to +125 -25 to +85 -40 to +85 0 to +70	°C
Storage Temperature Range	T _{stg}	-65 to +150	°C

QUAD COMPARATORS

**SILICON MONOLITHIC
 INTEGRATED CIRCUIT**

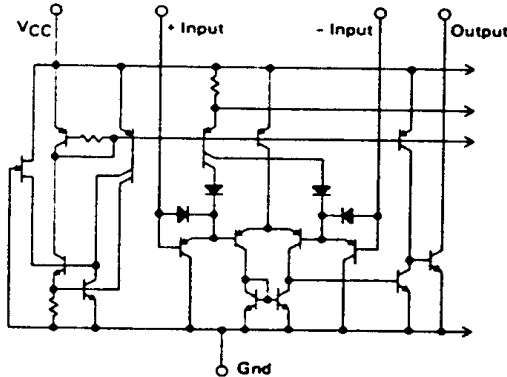


PIN CONNECTIONS



(Top View)

FIGURE 1 — CIRCUIT SCHEMATIC (Diagram shown is for 1 comparator)



ORDERING INFORMATION

Device	Temperature Range	Package
LM139J, AJ	-55°C to +125°C	Ceramic DIP
LM239J, AJ LM239N, AN	-25°C to +85°C	Ceramic DIP Plastic DIP
LM339J, AJ LM339N, AN	0°C to +70°C	Ceramic DIP Plastic DIP
LM2901N MC3302L MC3302P	-40°C to +85°C	Plastic DIP Ceramic DIP Plastic DIP

LM139,A, LM239,A, LM339,A, LM2901, MC3302

ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0 Vdc, I_A = 25 μ C unless otherwise noted)

Characteristic	LM139A		LM239A/339A		LM139		LM239/339		LM2901		MC3302	
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Input Offset Voltage (Note 4)												
V _{IO}	-1.0	-2.0	-1.0	-2.0	-2.0	-5.0	-2.0	-5.0	-2.0	-7.0	-3.0	-20
Input Bias Current (Notes 4, 5)												
I _{IB} (Output in Linear Range)	25	100	25	250	25	100	25	250	25	250	25	500
Input Offset Current (Note 4)												
I _{IO}	-3.0	-25	-5.0	-50	-3.0	-25	-5.0	-50	-5.0	-50	-3.0	-100
Input Common-Mode Voltage Range (Note 7)												
V _{ICR}	0	V _{CC}	0	V _{CC}	0	V _{CC}	0	V _{CC}	0	V _{CC}	0	V _{CC}
Supply Current												
I _{CC}	0	1.5	0	1.5	0	1.5	0	1.5	0	1.5	0	1.5
R _L = ∞ (for All Comparators)												
R _L = V _{CC} = 30 Vdc	0.8	2.0	0.8	2.0	0.8	2.0	0.8	2.0	0.8	2.0	0.8	2.0
Voltage Gain												
A _V	50	200	50	200	200	200	200	200	200	200	200	200
R _L \geq 15 k Ω , V _{CC} = 15 Vdc												
Large Signal Response Time												
V _I = TTL Logic Swing												
V _{OH} = 1.4 Vdc, V _{OL} = 5.0 Vdc												
R _L = 5.1 k Ω												
Response Time (Note 6)												
V _{IL} = 5.0 Vdc, R _L = 5.1 k Ω	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Output Sink Current												
I _{OSink}	6.0	16	6.0	16	6.0	16	6.0	16	6.0	16	6.0	16
V _I (1) \geq 1.0 Vdc, V _I (2) = 0, V _O = 1.5 Vdc												
Saturation Voltage												
V _I (1) \geq 1.0 Vdc, V _I (2) = 0, I _{OSink} = 4.0 mA	130	400	130	400	130	400	130	400	130	400	130	400
Output Leakage Current												
I _{OL}	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
V _I (1) \geq 1.0 Vdc, V _I (2) = 0, V _O = -5.0 Vdc												

PERFORMANCE CHARACTERISTICS (V_{CC} = 5.0 Vdc, I_A = I_{IO} to I_{OSink}, Note 3)

Characteristic	LM139A		LM239A/339A		LM139		LM239/339		LM2901		MC3302	
	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	Min	Typ	Max
Input Offset Voltage (Note 4)												
V _{IO}	-4.0	-300	-4.0	-400	-9.0	-300	-9.0	-400	-15	-500	-40	-1000
Input Bias Current (Notes 4, 5)												
I _{IB} (Output in Linear Range)	100	100	100	100	100	100	100	100	100	100	100	100
Input Offset Current (Note 4)												
I _{IO}	0	0	0	0	0	0	0	0	0	0	0	0
Input Common-Mode Voltage Range												
V _{ICR}	0	V _{CC}	0	V _{CC}	0	V _{CC}	0	V _{CC}	0	V _{CC}	0	V _{CC}
Saturation Voltage												
V _I (1) = 1.0 Vdc, V _I (2) = 0, I _{OSink} = 4.0 mA	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Output Leakage Current												
I _{OL}	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Differential Input Voltage												
All V _I \geq 0 Vdc (Note 7)	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}	V _{CC}

NOTES

- The maximum output current may be as high as 20 mA, independent of the magnitude of V_{CC}. Output short circuits to V_{CC} can cause excessive heating and eventual destruction.
- This magnitude of input current will only occur if the leads are driven more negative than ground or the negative supply voltage. This is due to the input PNP collector-base junction becoming forward biased, acting as an input clamp diode. There is also a lateral PNP parasitic transistor action which can cause the output voltage of the comparators to go to the V_{CC} voltage level (or ground) if overdrive is large during the time that an input is driven negative. This will not destroy the device when limited to the max rating and normal output states will recover when the inputs become ground or negative supply.
- LM139/139A — T_{low} = -55°C, T_{high} = +125°C
LM239/239A — T_{low} = -25°C, T_{high} = +85°C
LM339/339A — T_{low} = 0°C, T_{high} = +70°C
LM2901, MC3302 — T_{low} = -40°C, T_{high} = +85°C
- At the output switch point, V_O = 1.4 Vdc, R_S = 100 Ω , 5.0 Vdc, V_{CC} = 30 Vdc, with the inputs over the full common-mode range (0 Vdc to V_{CC} - 1.5 Vdc)
- The bias current flows out of the inputs due to the PNP input stage. This current is virtually constant, independent of the output state.
- The response time specified is for a 100 mV input step with 5.0 mV overdrive. For larger signals, 300 ns is typical.
- Positive excursions of input voltage may exceed the power supply level. As long as one of the inputs remain within the common-mode range, the comparator will provide the proper output state. With V_{CC} = 5.0 Vdc, V_I should be limited to 25 volts max. Limiting resistors should be used on all inputs that might exceed V_{CC}.

LM139,A, LM239,A, LM339,A, LM2901, MC3302

FIGURE 7 — DRIVING LOGIC

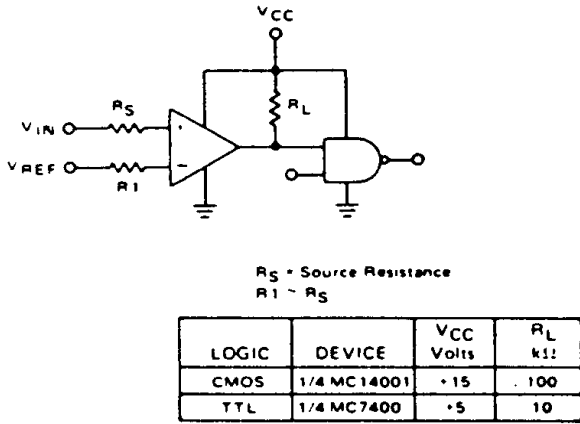
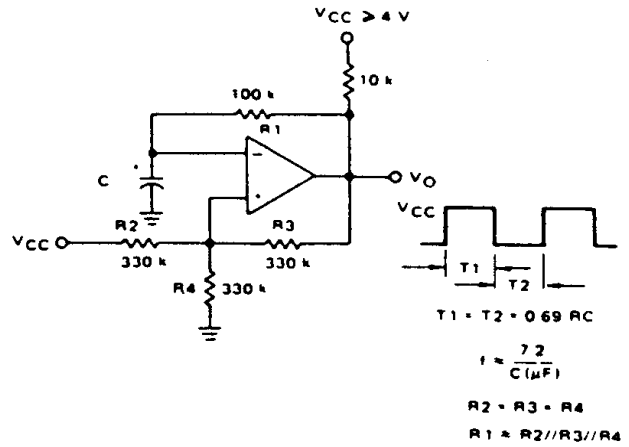


FIGURE 8 — SQUAREWAVE OSCILLATOR



APPLICATIONS INFORMATION

These quad comparators feature high gain, wide bandwidth characteristics. This gives the device oscillation tendencies if the outputs are capacitively coupled to the inputs via stray capacitance. This oscillation manifests itself during output transitions (VOL to VOH). To alleviate this situation input resistors <10 kΩ should be used. The addi-

tion of positive feedback (<10 mV) is also recommended. It is good design practice to ground all unused input pins. Differential input voltages may be larger than supply voltage without damaging the comparator's input voltages. More negative than -300 mV should not be used.

FIGURE 9 — ZERO CROSSING DETECTOR (Single Supply)

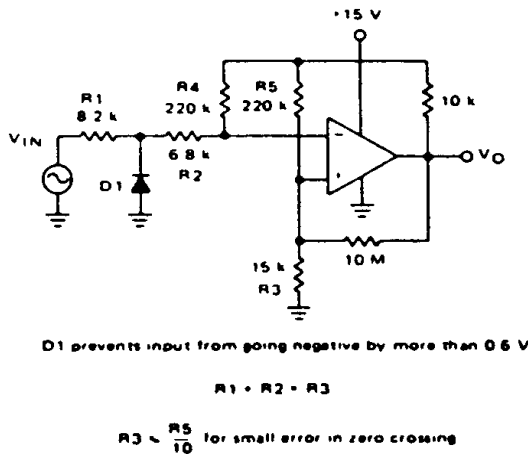
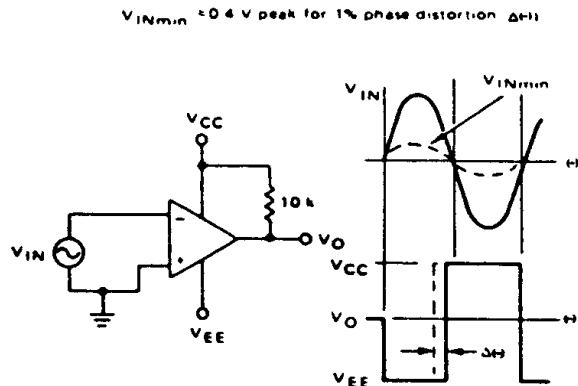


FIGURE 10 — ZERO CROSSING DETECTOR (Split Supplies)



LM139,A, LM239,A, LM339,A, LM2901, MC3302

FIGURE 2 – INVERTING COMPARATOR WITH HYSTERESIS

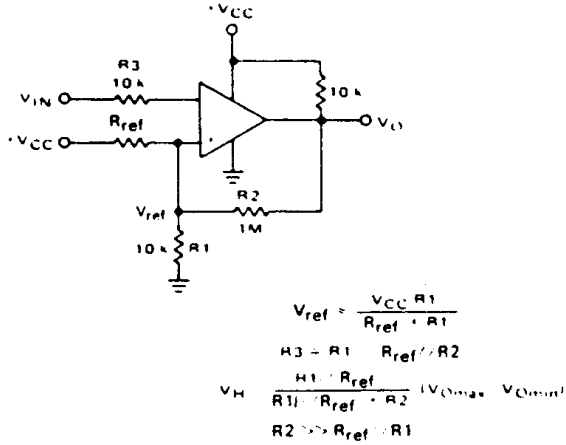
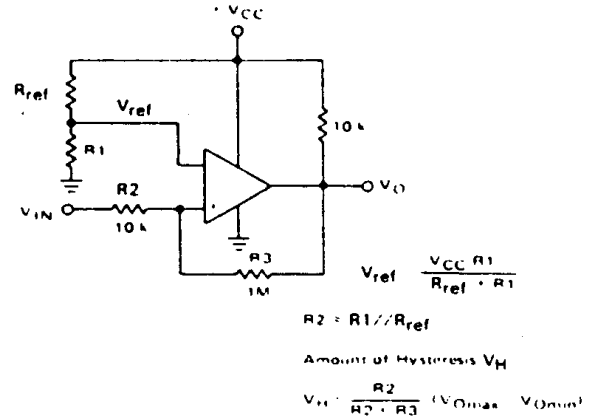


FIGURE 3 – NON-INVERTING COMPARATOR WITH HYSTERESIS



TYPICAL CHARACTERISTICS

($V_{CC} = +15$ Vdc, $T_A = +25^\circ\text{C}$ (each comparator) unless otherwise noted)

FIGURE 4 – NORMALIZED INPUT OFFSET VOLTAGE

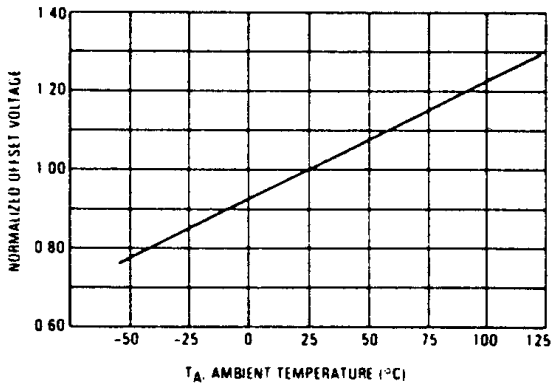


FIGURE 5 – INPUT BIAS CURRENT

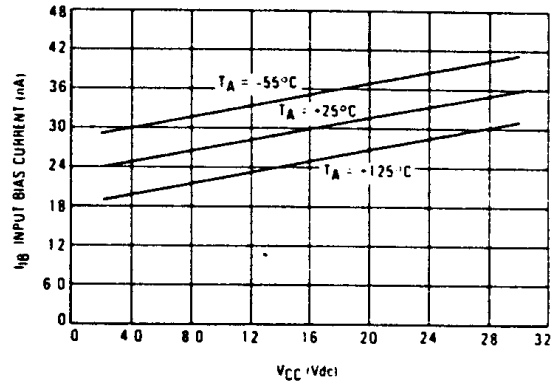
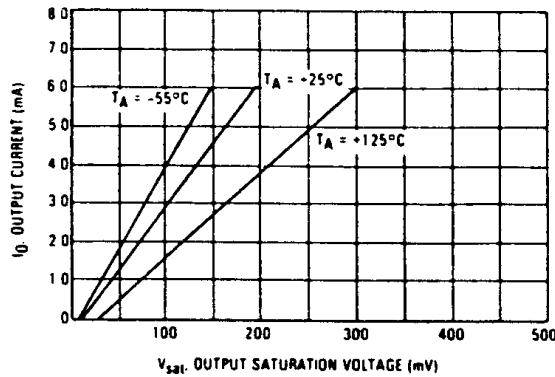


FIGURE 6 – OUTPUT SINK CURRENT versus OUTPUT SATURATION VOLTAGE



MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CE0}	40	Vdc
Collector-Base Voltage	V_{CBO}	60	Vdc
Emitter-Base Voltage	V_{EBO}	6.0	Vdc
Collector Current — Continuous	I_C	200	mAdc
Total Device Dissipation (at $T_A = 25^\circ\text{C}$ Derate above 25°C)	P_D	625 50	mW mW/°C
*Total Device Dissipation (at $T_C = 25^\circ\text{C}$ Derate above 25°C)	P_D	1.5 12	Watts mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

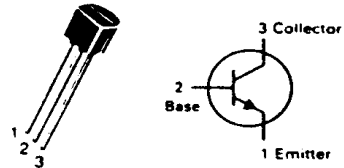
*THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

*Indicates Data in addition to JEDEC Requirements.

2N3903 2N3904*

CASE 29-04, STYLE 1
TO-92 (TO-226AA)



GENERAL PURPOSE TRANSISTORS

NPN SILICON

★This is a Motorola
designated preferred device.

ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted.)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage(1) ($I_C = 1.0 \text{ mAdc}, I_B = 0$)	$V_{(BR)CEO}$	40	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 10 \mu\text{Adc}, I_E = 0$)	$V_{(BR)CBO}$	60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 10 \mu\text{Adc}, I_C = 0$)	$V_{(BR)EBO}$	6.0	—	Vdc
Base Cutoff Current ($V_{CE} = 30 \text{ Vdc}, V_{EB} = 3.0 \text{ Vdc}$)	I_{BL}	—	50	nAdc
Collector Cutoff Current ($V_{CE} = 30 \text{ Vdc}, V_{EB} = 3.0 \text{ Vdc}$)	I_{CEX}	—	50	nAdc
ON CHARACTERISTICS				
DC Current Gain(1) ($I_C = 0.1 \text{ mAdc}, V_{CE} = 1.0 \text{ Vdc}$)	h_{FE}	20	—	—
		40	—	
($I_C = 1.0 \text{ mAdc}, V_{CE} = 1.0 \text{ Vdc}$)		35	—	
		70	—	
($I_C = 10 \text{ mAdc}, V_{CE} = 1.0 \text{ Vdc}$)		50	150	
		100	300	
($I_C = 50 \text{ mAdc}, V_{CE} = 1.0 \text{ Vdc}$)		30	—	
		60	—	
($I_C = 100 \text{ mAdc}, V_{CE} = 1.0 \text{ Vdc}$)		15	—	
		30	—	
Collector-Emitter Saturation Voltage(1) ($I_C = 10 \text{ mAdc}, I_B = 1.0 \text{ mAdc}$) ($I_C = 50 \text{ mAdc}, I_B = 5.0 \text{ mAdc}$)	$V_{CE(sat)}$	—	0.2 0.3	Vdc
Base-Emitter Saturation Voltage(1) ($I_C = 10 \text{ mAdc}, I_B = 1.0 \text{ mAdc}$) ($I_C = 50 \text{ mAdc}, I_B = 5.0 \text{ mAdc}$)	$V_{BE(sat)}$	0.65 —	0.85 0.95	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product ($I_C = 10 \text{ mAdc}, V_{CE} = 20 \text{ Vdc}, f = 100 \text{ MHz}$)	f_T	250 300	— —	MHz

2N3903, 2N3904

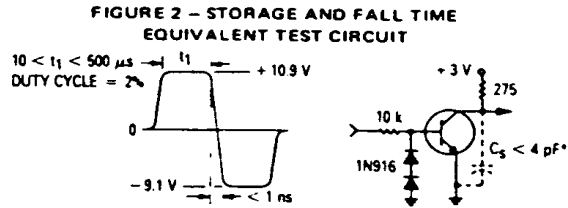
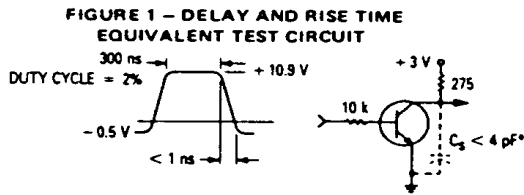
ELECTRICAL CHARACTERISTICS (continued) (T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Max	Unit
Output Capacitance (V _{CB} = 5.0 Vdc, I _E = 0, f = 1.0 MHz)	C _{obo}	—	4.0	pF
Input Capacitance (V _{EB} = 0.5 Vdc, I _C = 0, f = 1.0 MHz)	C _{ibo}	—	8.0	pF
Input Impedance (I _C = 1.0 mAac, V _{CE} = 10 Vdc, f = 1.0 kHz)	h _{ie}	1.0 1.0	8.0 10	k ohms
Voltage Feedback Ratio (I _C = 1.0 mAac, V _{CE} = 10 Vdc, f = 1.0 kHz)	h _{re}	0.1 0.5	5.0 8.0	X 10 ⁻⁴
Small-Signal Current Gain (I _C = 1.0 mAac, V _{CE} = 10 Vdc, f = 1.0 kHz)	h _{fe}	50 100	200 400	—
Output Admittance (I _C = 1.0 mAac, V _{CE} = 10 Vdc, f = 1.0 kHz)	h _{oe}	1.0	40	μmhos
Noise Figure (I _C = 100 μAac, V _{CE} = 5.0 Vdc, R _S = 1.0 k ohms, f = 1.0 kHz)	NF	—	6.0 5.0	dB

SWITCHING CHARACTERISTICS

Delay Time	(V _{CC} = 3.0 Vdc, V _{BE} = 0.5 Vdc, I _C = 10 mAac, I _{B1} = 1.0 mAac)	t _d	—	35	ns
Rise Time		t _r	—	35	ns
Storage Time	(V _{CC} = 3.0 Vdc, I _C = 10 mAac, I _{B1} = I _{B2} = 1.0 mAac)	t _s	—	175 200	ns
Fall Time		t _f	—	50	ns

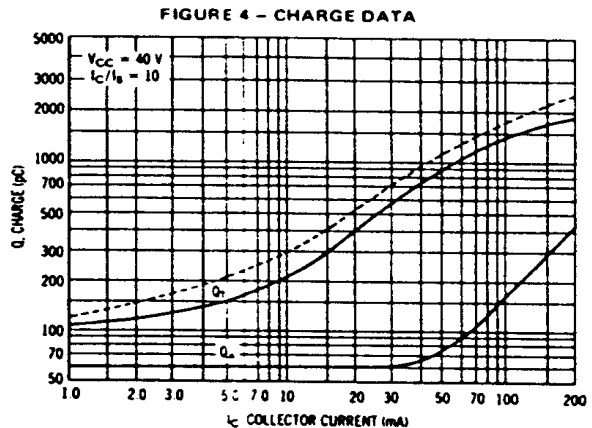
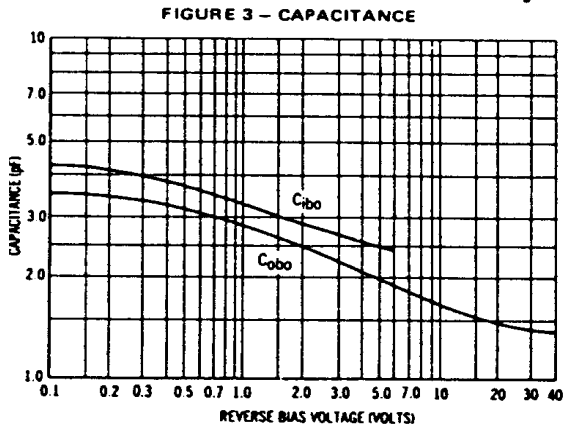
(1) Pulse Test: Pulse Width ≤ 300 μs, Duty Cycle ≤ 2.0%.



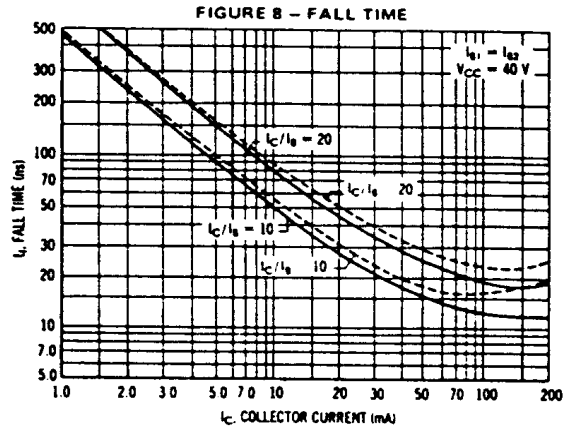
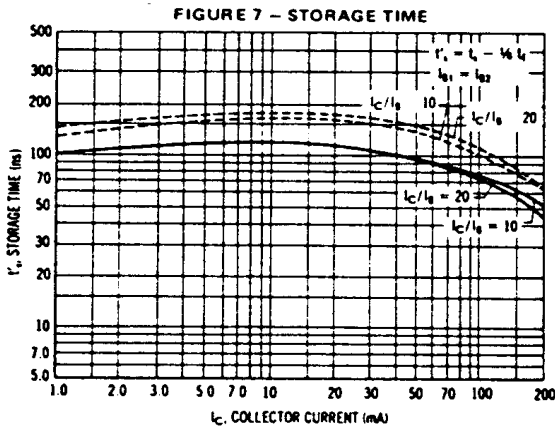
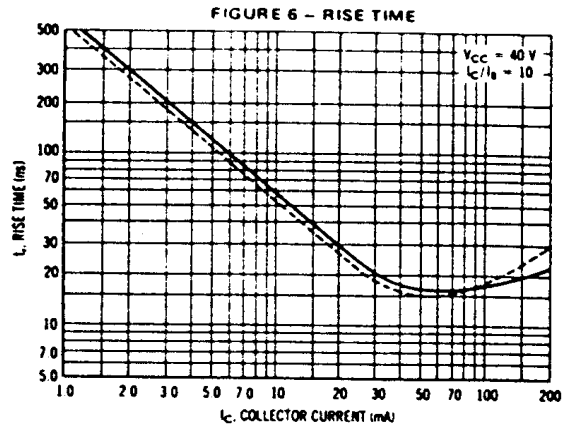
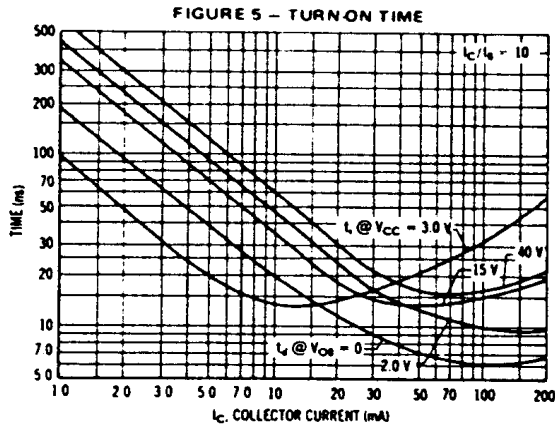
*Total shunt capacitance of test jig and connectors

TYPICAL TRANSIENT CHARACTERISTICS

— T_J = 25°C --- T_J = 125°C



2N3903, 2N3904

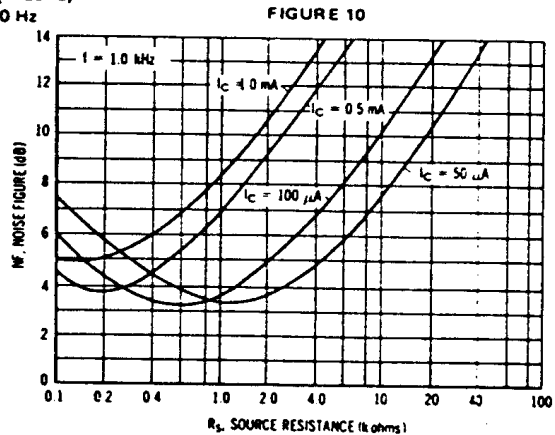
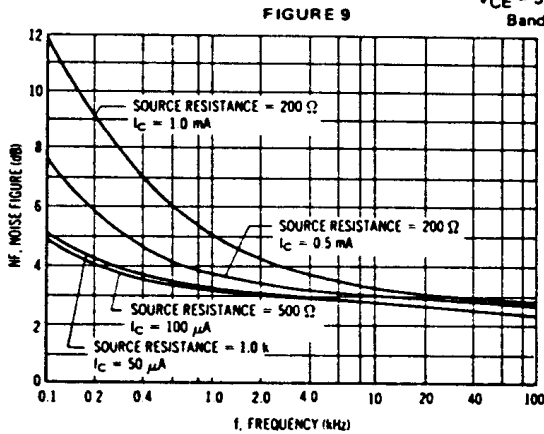


TYPICAL AUDIO SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE VARIATIONS

$V_{CE} = 5.0 V_{dc}$, $T_A = 25^\circ C$,

Bandwidth = 1.0 Hz

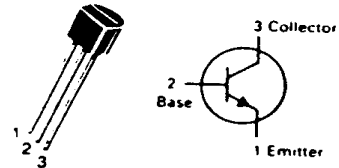


MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Collector-Emitter Voltage	V_{CE0}	40	Vdc
Collector-Base Voltage	V_{CB0}	60	Vdc
Emitter-Base Voltage	V_{EB0}	6.0	Vdc
Collector Current — Continuous	I_C	600	mAdc
Total Device Dissipation ($\theta_A = 25^\circ\text{C}$ Derate above 25°C)	P_D	625 5.0	mW mW/°C
Total Device Dissipation ($\theta_C = 25^\circ\text{C}$ Derate above 25°C)	P_D	1.5 12	Watt mW/°C
Operating and Storage Junction Temperature Range	T_J, T_{stg}	-55 to +150	°C

THERMAL CHARACTERISTICS

Characteristic	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	200	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83.3	°C/W

2N4400
2N4401*
CASE 29-04, STYLE 1
TO-92 (TO-226AA)

GENERAL PURPOSE
TRANSISTORS
NPN SILICON
**This is a Motorola
designated preferred device.*
ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted.)

Characteristic	Symbol	Min	Max	Unit
OFF CHARACTERISTICS				
Collector-Emitter Breakdown Voltage(1) ($I_C = 1.0$ mAdc, $I_B = 0$)	$V_{(BR)CEO}$	40	—	Vdc
Collector-Base Breakdown Voltage ($I_C = 0.1$ mAdc, $I_E = 0$)	$V_{(BR)CBO}$	60	—	Vdc
Emitter-Base Breakdown Voltage ($I_E = 0.1$ mAdc, $I_C = 0$)	$V_{(BR)EBO}$	6.0	—	Vdc
Base Cutoff Current ($V_{CE} = 35$ Vdc, $V_{EB} = 0.4$ Vdc)	I_{BEV}	—	0.1	μAdc
Collector Cutoff Current ($V_{CE} = 35$ Vdc, $V_{EB} = 0.4$ Vdc)	I_{CEX}	—	0.1	μAdc
ON CHARACTERISTICS(1)				
DC Current Gain ($I_C = 0.1$ mAdc, $V_{CE} = 1.0$ Vdc)	h_{FE}	2N4401		—
($I_C = 1.0$ mAdc, $V_{CE} = 1.0$ Vdc)		2N4400 2N4401		—
($I_C = 10$ mAdc, $V_{CE} = 1.0$ Vdc)		2N4400 2N4401		—
($I_C = 150$ mAdc, $V_{CE} = 1.0$ Vdc)		2N4400 2N4401		150 300
($I_C = 500$ mAdc, $V_{CE} = 2.0$ Vdc)		2N4400 2N4401		—
($I_C = 500$ mAdc, $V_{CE} = 2.0$ Vdc)		2N4400 2N4401		—
Collector-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc) ($I_C = 500$ mAdc, $I_B = 50$ mAdc)	$V_{CE(sat)}$	—	0.4 0.75	Vdc
Base-Emitter Saturation Voltage ($I_C = 150$ mAdc, $I_B = 15$ mAdc) ($I_C = 500$ mAdc, $I_B = 50$ mAdc)	$V_{BE(sat)}$	0.75	0.95 1.2	Vdc
SMALL-SIGNAL CHARACTERISTICS				
Current-Gain — Bandwidth Product ($I_C = 20$ mAdc, $V_{CE} = 10$ Vdc, $f = 100$ MHz)	f_T	200 250	—	MHz
Collector-Base Capacitance ($V_{CB} = 5.0$ Vdc, $I_E = 0$, $f = 1.0$ MHz)	C_{cb}	—	6.5	pF

2N4400, 2N4401

ELECTRICAL CHARACTERISTICS (continued) ($T_A = 25^\circ\text{C}$ unless otherwise noted.)

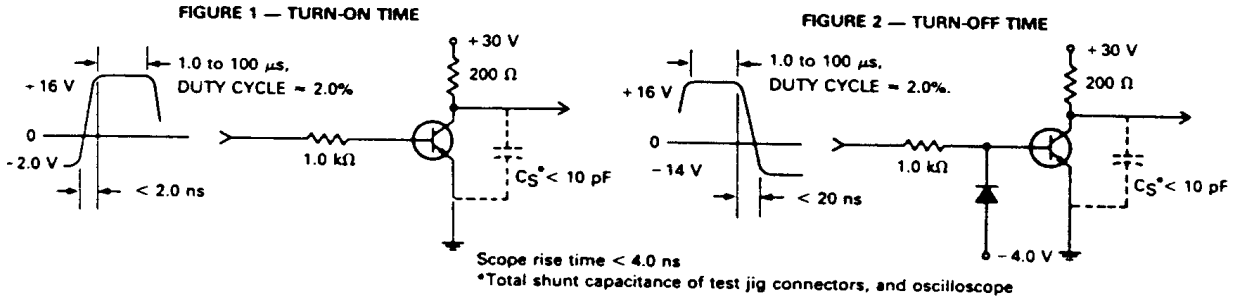
Characteristic	Symbol	Min	Max	Unit
Emitter-Base Capacitance ($V_{EB} = 0.5\text{ Vdc}$, $I_C = 0$, $f = 1.0\text{ MHz}$)	C_{eb}	—	30	μF
Input Impedance ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{ie}	0.5 1.0	7.5 15	k ohms
Voltage Feedback Ratio ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{re}	0.1	8.0	$\times 10^{-4}$
Small-Signal Current Gain ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{fe}	20 40	250 500	—
Output Admittance ($I_C = 1.0\text{ mAdc}$, $V_{CE} = 10\text{ Vdc}$, $f = 1.0\text{ kHz}$)	h_{oe}	1.0	30	μmhos

SWITCHING CHARACTERISTICS

Delay Time	($V_{CC} = 30\text{ Vdc}$, $V_{BE} = 2.0\text{ Vdc}$, $I_C = 150\text{ mAdc}$, $I_{B1} = 15\text{ mAdc}$)	t_d	—	15	ns
Rise Time		t_r	—	20	ns
Storage Time	($V_{CC} = 30\text{ Vdc}$, $I_C = 150\text{ mAdc}$, $I_{B1} = I_{B2} = 15\text{ mAdc}$)	t_s	—	225	ns
Fall Time		t_f	—	30	ns

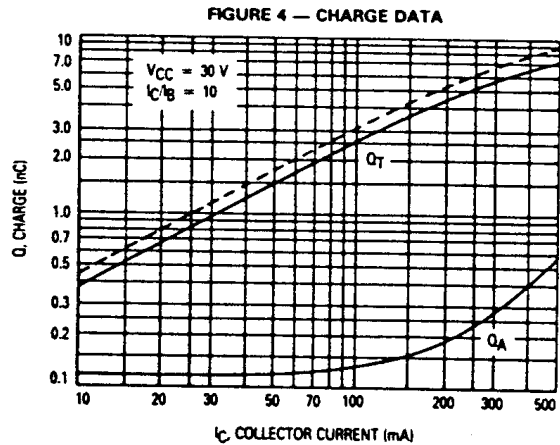
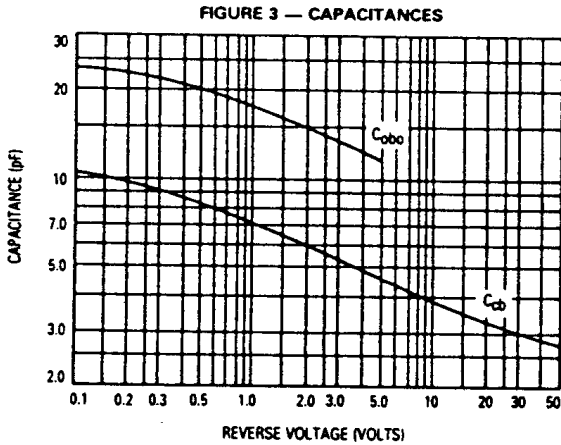
(1) Pulse Test: Pulse Width $\leq 300\ \mu\text{s}$, Duty Cycle $\leq 2.0\%$.

SWITCHING TIME EQUIVALENT TEST CIRCUITS



TRANSIENT CHARACTERISTICS

— 25°C - - - 100°C



2N4400, 2N4401

FIGURE 5 — TURN-ON TIME

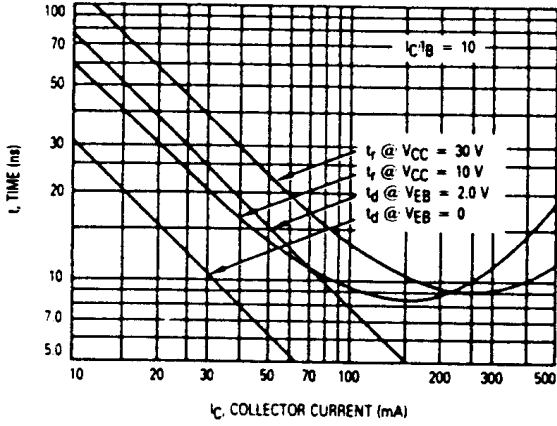


FIGURE 6 — RISE AND FALL TIMES

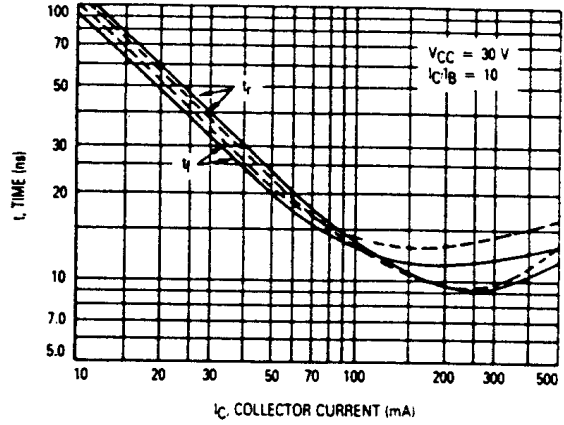


FIGURE 7 — STORAGE TIME

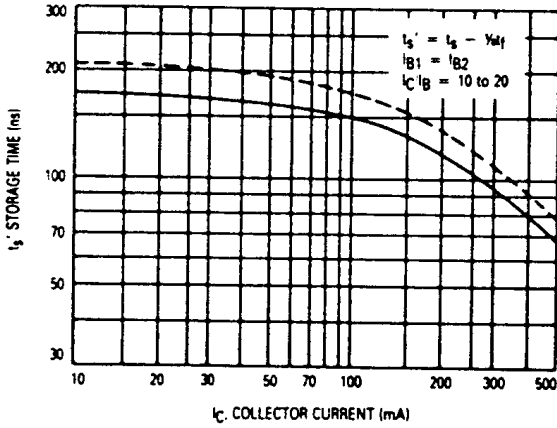
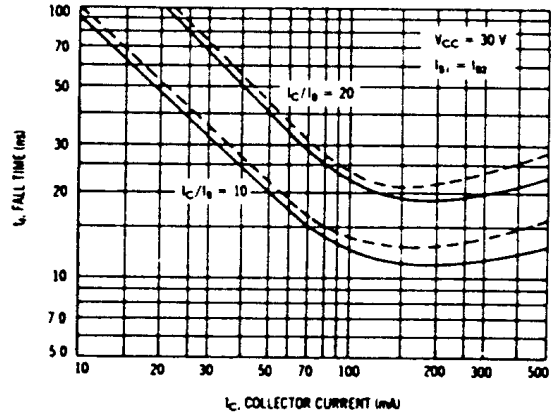


FIGURE 8 — FALL TIME



SMALL-SIGNAL CHARACTERISTICS

NOISE FIGURE
 $V_{CE} = 10\text{ Vdc}$, $T_A = 25^\circ\text{C}$
 Bandwidth = 1.0 Hz

FIGURE 9 — FREQUENCY EFFECTS

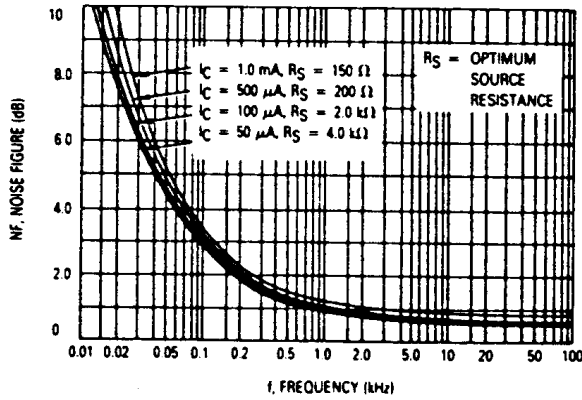
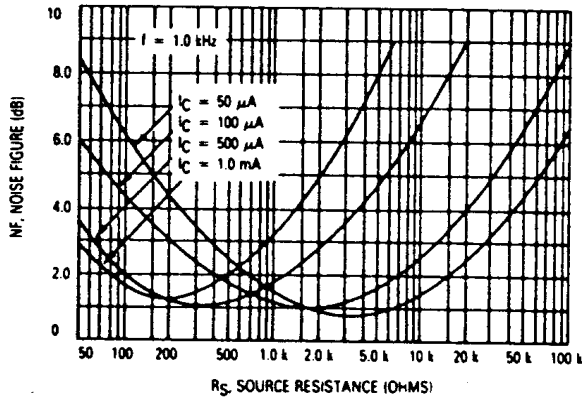


FIGURE 10 — SOURCE RESISTANCE EFFECTS



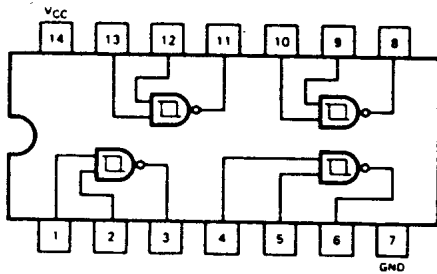
SN54LS132/SN74LS132

QUAD 2-INPUT SCHMITT TRIGGER NAND GATE

DESCRIPTION – The SN54LS132/SN74LS132 contains four 2-Input NAND Gates which accept standard TTL input signals and provide standard TTL output levels. They are capable of transforming slowly changing input signals into sharply defined, jitter-free output signals. Additionally, they have greater noise margin than conventional NAND Gates.

Each circuit contains a 2-input Schmitt trigger followed by a Darlington level shifter and a phase splitter driving a TTL totem pole output. The Schmitt trigger uses positive feedback to effectively speed-up slow input transitions, and provide different input threshold voltages for positive and negative-going transitions. This hysteresis between the positive-going and negative-going input thresholds (typically 800 mV) is determined internally by resistor ratios and is essentially insensitive to temperature and supply voltage variations. As long as one input remains at a more positive voltage than V_{T+} (MAX), the gate will respond to the transitions of the other input as shown in Figure 1.

LOGIC AND CONNECTION DIAGRAM
DIP (TOP VIEW)



V_{IN} VERSUS V_{OUT}
TRANSFER FUNCTION

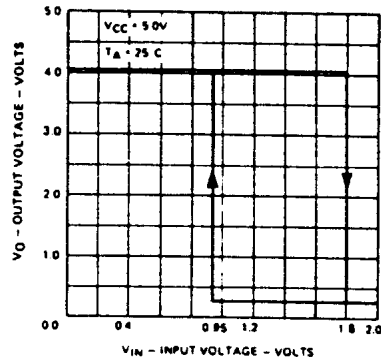


Fig. 1

THRESHOLD VOLTAGE AND HYSTERESIS
VERSUS
POWER SUPPLY VOLTAGE

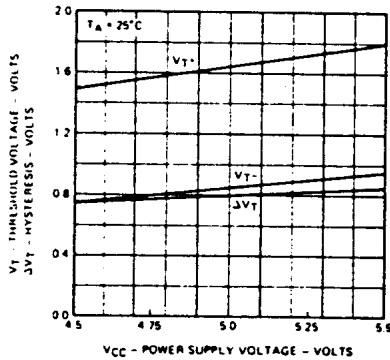


Fig. 2

THRESHOLD VOLTAGE AND HYSTERESIS
VERSUS
TEMPERATURE

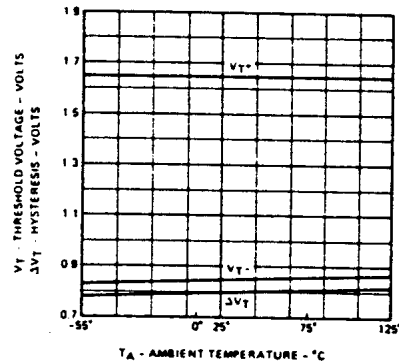


Fig. 3

SN54LS132/SN74LS132

GUARANTEED OPERATING RANGES

PART NUMBERS	SUPPLY VOLTAGE			TEMPERATURE
	MIN	TYP	MAX	
SN54LS132X	4.5 V	5.0 V	5.5 V	-55°C to 125°C
SN74LS132X	4.75 V	5.0 V	5.25 V	0°C to 70°C

X = package type, W for Flatpak, J for Ceramic Dip, N for Plastic Dip. See Packaging Information Section for packages available on this product.

DC CHARACTERISTICS OVER OPERATING TEMPERATURE RANGE (unless otherwise specified)

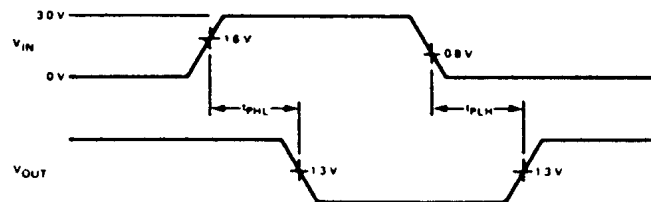
SYMBOL	PARAMETER	LIMITS			UNITS	TEST CONDITIONS (Note 1)
		MIN	TYP	MAX		
V_{T+}	Positive-Going Threshold Voltage	1.5	1.8	2.0	V	$V_{CC} = 5.0 \text{ V}$
V_{T-}	Negative-Going Threshold Voltage	0.6	0.95	1.1	V	$V_{CC} = 5.0 \text{ V}$
$V_{T+} - V_{T-}$	Hysteresis	0.4	0.8		V	$V_{CC} = 5.0 \text{ V}$
V_{CD}	Input Clamp Diode Voltage		-0.65	-1.5	V	$V_{CC} = \text{MIN.}, I_{IN} = -18 \text{ mA}$
V_{OH}	Output HIGH Voltage	54	2.5	3.4	V	$V_{CC} = \text{MIN.}, I_{OH} = -400 \mu\text{A}, V_{IN} = V_{IL}$
		74	2.7	3.4		
V_{OL}	Output LOW Voltage	54,74	0.25	0.4	V	$V_{CC} = \text{MIN.}, I_{OL} = 4.0 \text{ mA}, V_{IN} = 2.0 \text{ V}$
		74	0.35	0.5	V	$V_{CC} = \text{MIN.}, I_{OL} = 8.0 \text{ mA}, V_{IN} = 2.0 \text{ V}$
I_{T+}	Input Current at Positive-Going Threshold		-0.14		mA	$V_{CC} = 5.0 \text{ V}, V_{IN} = V_{T+}$
I_{T-}	Input Current at Negative-Going Threshold		-0.18		mA	$V_{CC} = 5.0 \text{ V}, V_{IN} = V_{T-}$
I_{IH}	Input HIGH Current		1.0	20	μA	$V_{CC} = \text{MAX.}, V_{IN} = 2.7 \text{ V}$
				0.1	mA	$V_{CC} = \text{MAX.}, V_{IN} = 10 \text{ V}$
I_{IL}	Input LOW Current			-0.4	mA	$V_{CC} = \text{MAX.}, V_{IN} = 0.4 \text{ V}$
I_{OS}	Output Short Circuit Current (Note 3)	-15		-100	mA	$V_{CC} = \text{MAX.}, V_{OUT} = 0 \text{ V}$
I_{CCH}	Supply Current HIGH		5.9	11	mA	$V_{CC} = \text{MAX.}, V_{IN} = 0 \text{ V}$
I_{CCL}	Supply Current LOW		8.2	14	mA	$V_{CC} = \text{MAX.}, V_{IN} = 4.5 \text{ V}$

AC CHARACTERISTICS: $T_A = 25^\circ\text{C}$

SYMBOL	PARAMETER	LIMITS			UNITS	TEST CONDITIONS
		MIN	TYP	MAX		
t_{PLH}	Turn Off Delay, Input to Output			20	ns	$V_{CC} = 5.0 \text{ V}$
t_{PHL}	Turn On Delay, Input to Output			20	ns	$C_L = 15 \text{ pF}$

NOTES:

- For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions for the applicable device type.
- Typical limits are at $V_{CC} = 5.0 \text{ V}, T_A = 25^\circ\text{C}$.
- Not more than one output should be shorted at a time.



20 Megabaud Fiber Optic Data Link Parts List

The Materially Optoelectronics Device Data Book (1983) provided a list of most components, although some parts, notably the emitter and detector, had been discontinued. Replacements for these parts have been made.

Figure 3.1 Parts List

Symbol (see schematic)	Description	No. Used
Capacitors		
C1,C2,C3,C6,C7,C8,C9,C12 C13,C14,C15,C18,C21,C22 C27,C28,C29,C30,C31	- 0.1 μ F - >50v Ceramic Capacitors, 0.25" lead spacing Mallory C25C104M101CA	(20)
C5	- 0.01 μ F - 50v Ceramic Capacitor, 0.250" lead spacing, 0.290" OD, Sprague UK50-103	(2)
C10,C11	- 62pF, 5% Dipped Mica Capacitor	(2)
C16,C23	- 2.0 μ F, 25 WVdc - 0.250"OD x 9/16", Sprague TE-1201, electrolytic	(2)
C4,C17,C19,C20,C24, C25	- 25 μ F, 25 WVdc, 0.25"od x 0.625" Mallory TT25X25B, electrolytic	(6)
C26	- 100Pf, 5% dipped mica capacitor	(1)
C32	- 100 Pf, ceramic disk capacitor	(1)
Diodes		
D1	- MF0E1200 Near Infrared LED (replaces MF0E103F Infrared LED)	(1)
D2,D3,D4	- 1N914, High Speed Switching Diode	(3)
Chokes		
L1,L2,L3,L4,L5,L6,L7	- Ferroxcube VK200-09/3B	(7)
Transistors		
Q1,Q2,Q3,Q5,Q6	- MPS6515 general-purpose high-gain NPN Transistor	(5)
Q4	- SN4400, Low $V_{CE(sat)}$ switching transistor	(1)

Parts List Con't

Symbol (see schematic)	Description	No. Used
Resistors (1/4W, 5% carbon composition) - color code		
R1,R3	510 Ω - Grn Br Br	(2)
R2	51 Ω - Grn Br Bl	(1)
R4,R5,R8,R12,R16	1 k Ω - Br Bl R	(5)
R6	680 Ω - Bl Grn Br	(1)
R7	750 Ω - V Grn Br	(1)
R9,R10,R15	100 Ω - Br Bl Br	(3)
R11	2.4 k Ω - R Y R	(1)
R13	47 k Ω - Y V O	(1)
R17	2.2 k Ω - R R R	(2)
R18,R19	75 Ω - V Grn Bl	(2)
R20,R25	180 Ω - Br Gry Br	(1)
R21	330 Ω - OO Br	(1)
R22	8.2 Ω - Gry R Gld	(1)
R23	39 Ω - O W Bl	(1)
R24	270 Ω - R V Br	(1)
R26	240 Ω - R Y Br	(1)
R27	12 Ω - Br R Bl	(1)
Integrated Circuits		
U1	- SN74LS40B, Dual 4-input buffered NAND gate	(1)
U2	- MFOD2405 Integrated Detector Preamplifier (IDP) (replaces MFOD402F IDP)	(1)
U3	- MC1733, Wide Band Linear Video Amplifier	(1)
U4	- MC75107, Dual TTL Line Receiver	(1)
Non-Referenced Items		
	- Low Profile IC Socket AMP# 530177-1	(3)
	- BNC Bulkhead Connector, UG1094/U Female	(2)
	- RFI Shielded Amphenol 905-138-5001 Receptacles (replaces Active Device Mounting Kit No. 227240-1)	(2)
	- BELDEN Fiberoptic Cable CAT# 227201	(10 m)
	- Amphenol Fiberoptic Cable CAT# 906-110-5005 (replaces optimate single position resilient ferrule connector)	(2)

Figure 10 is the logic interface. Its purpose is to generate a standard logic level and provide sufficient drive capability for simple interfacing. The TTL logic level in this receiver is actually generated by the amplitude detector. However, in order to buffer the amplitude detector's output, another line receiver section is used for isolation and the interface to the TTL world. In addition, an emitter follower provides the needed drive for a 75 Ω coaxial line to the external test equipment.

Receiver Schematic Diagram and Circuit Implementation

Figure 17 shows the receiver schematic and indicates which portions perform each of the functions outlined in the functional block diagram description.

The first active component in the receiver schematic is the MFOD402F integrated detector preamp (IDP). It performs both the optical detector and current to voltage converter functions described earlier. It also affords all the isolation advantages of the integrated structure that were outlined in a previous section. Its transfer function is typically 1.0 mV of output amplitude per μ W of optical input power. Output impedance is specified as 200 Ω typical and although its maximum real and reactive loads are also specified, it was found that these loads caused excessive ringing of the IDP output. There-

fore, in this circuit, the real load was kept above 500 Ω and the capacitive load was minimized by careful printed circuit layout. The output rise time of the MFOD402F is specified as typically 20 ns and that is about what appears at the output of the linear amplifier where the signal is sufficiently large in amplitude to measure. The supply voltage of +15 V was chosen so that operation on the flat portion of the IDP's $\frac{\Delta t_R}{\Delta V_{CC}}$

the IDP's rise time begins to degrade rapidly.

The shield over the optical connector and IDP is required for isolation from the receivers own TTL output and the crosstalk of the transmitter. Its contribution to performance may only be measurable in terms of improved bit error rate.

The noise out of the IDP is specified as 300 μ V rms typical, and is a good number to use in calculating the amplitude detector hysteresis required.

Linear Amplifier

The MC1733 was chosen as the linear amplifier primarily because of its wide gain bandwidth and its reasonably low noise. It was used at a gain of 100 because that provides sufficient gain to amplify the IDP noise up to minimum amplitude detector threshold, as will be seen later, and it also allows the simple strapping of Pins 3 and 12 together using a

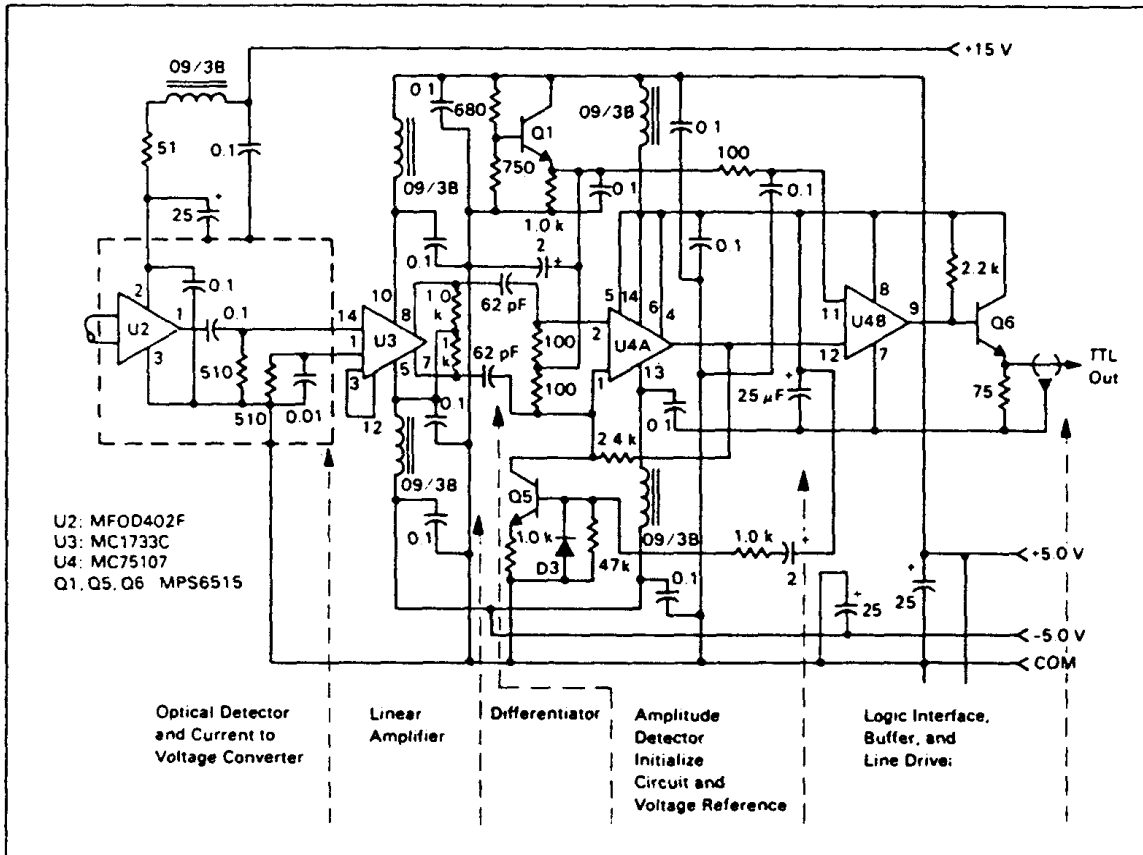


FIGURE 17 — Receiver Schematic

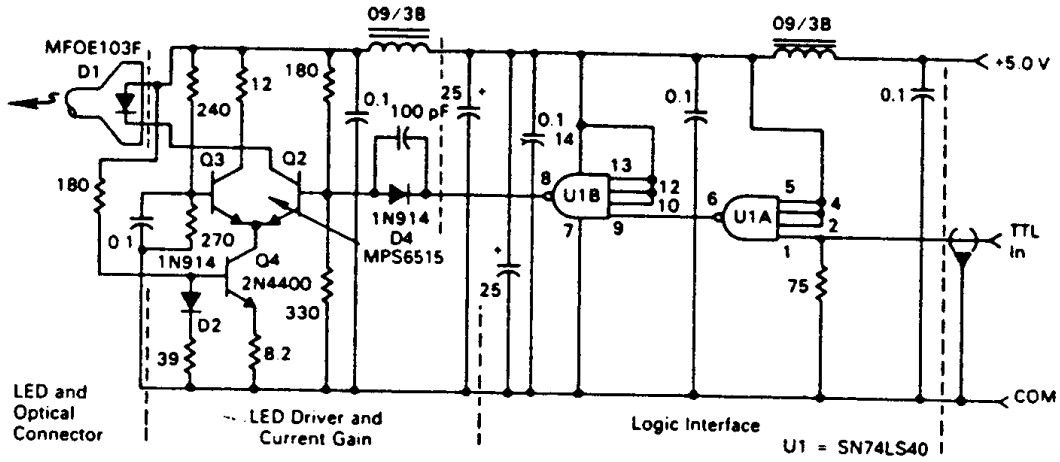


FIGURE 3 — Transmitter Schematic

The effect of a 10 ns longer propagation delay for high to low transitions on a 20 Mbaud squarewave is shown in Figure 4. It will be noted that processing the distorted signal through a second gate having prop delays equal to those of the first gate corrects the duty cycle distortion at the expense of a little higher absolute prop delay. The distorted waveform is delayed by t_{PHL} only whereas the undistorted waveform is delayed by $t_{PHL} + t_{PLH}$. This slight increase in absolute prop delay is usually insignificant compared to the absolute prop delay through the transmission medium. It will also be noted that if the distortion is not corrected, then the waveform applied to the LED driver is of a higher baud rate, thus requiring wider system bandwidth.

The cascading of two identical inverting gates also provides a way of balancing their power supply currents and avoids putting transients on the +5.0 V power line. The schematic shows different loads on

the two NAND gate sections so that the currents are not equal for the two logic input levels. However, if additional power supply decoupling were needed to further reduce transmitter and receiver crosstalk, putting a 430 Ω pull-up resistor from Pin 6 of U1A to +5.0 V would improve the balance of transmitter power supply current between the two logic states at the expense of another 10 mA or so in transmitter current drain.

The gating function mentioned earlier is also not shown in the schematic but can be easily implemented by tying one of Pins 2, 4, or 5 of U1A to +5.0 V through a suitable pull-up resistor and then providing this pin to the outside world for a logic low to gate off the data. This data off condition would also produce an LED off condition.

The 75 Ω termination across the data input is to terminate an expected 75 Ω coaxial cable. If data rates significantly lower than 20 Mbaud are transmitted

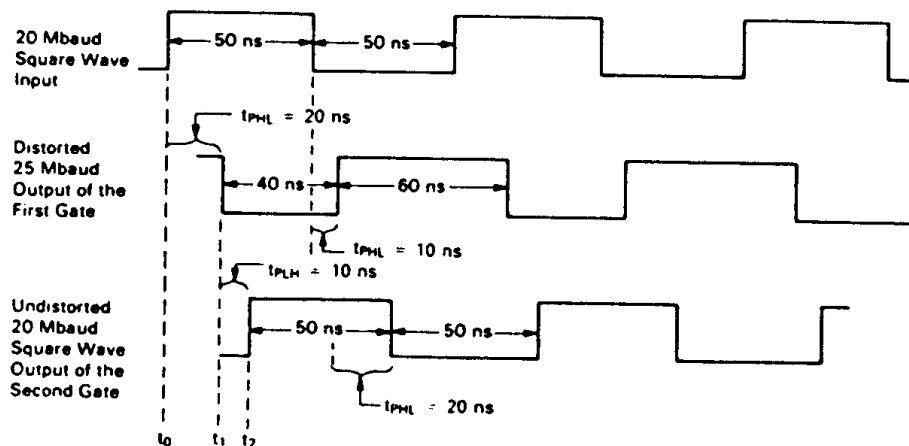


FIGURE 4 — Correction of Duty Cycle Distortion Caused by Gate Differential Prop Delay



MFOD2405

INTEGRATED DETECTOR/PREAMPLIFIER FOR FIBER OPTIC SYSTEMS

... designed as a monolithic integrated circuit containing both detector and preamplifier for use in computer, industrial control, and other communications systems.

Packaged in Motorola's hermetic TO-52 type case, the device fits directly into standard fiber optic connectors which also provide excellent RFI immunity. The output of the device is low impedance to provide even less sensitivity to stray interference. The MFOD2405 has a 300 μm (12 mil) fiber input with a high numerical aperture.

- Usable for Data Systems Through 40 Megabaud
- Dynamic Range Greater than 100:1
- RFI Shielded in AMP #227846-1 and Amphenol 905-138-5001 Receptacles.
- May be used with MFOExxx Emitters
- Hermetic Package
- 300 μm (12 mil) Diameter Optical Spot

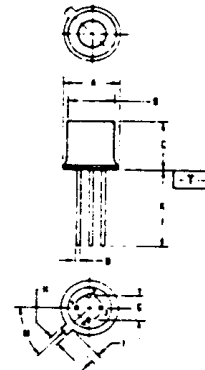
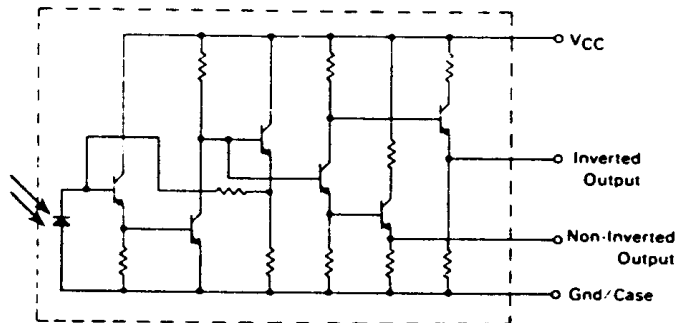
FIBER OPTICS INTEGRATED DETECTOR PREAMPLIFIER



MAXIMUM RATINGS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

Rating	Symbol	Value	Unit
Supply Voltage	VCC	7.5	Volts
Operating Temperature Range	T_A	-65 to +125	$^\circ\text{C}$
Storage Temperature Range	T_{stg}	-65 to +150	$^\circ\text{C}$

FIGURE 1 — EQUIVALENT SCHEMATIC



STYLE 1
 PIN 1 -VOUT
 2 -VOUT
 3. GROUND CASE
 4. +VCC

- NOTES
1. DIMENSIONS A AND H ARE DATUMS AND T IS A DATUM SURFACE.
 2. LEAD POSITIONAL TOLERANCE AT SEATING PLANE ± 0.036 (0.014) mm T A H mm
 3. DIMENSIONING AND TOLERANCING PER Y14.5, 1973

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	5.30	5.38	0.209	0.212
B	4.64	4.69	0.183	0.185
C	3.42	3.60	0.135	0.142
D	0.40	0.48	0.016	0.019
G	2.54 BSC		0.100 BSC	
H	0.91	1.16	0.036	0.046
J	0.83	1.21	0.033	0.048
K	12.70	-	0.500	-
M	45° BSC		45° BSC	

CASE 2100-01

MFOD2405

ELECTRICAL CHARACTERISTICS ($V_{CC} = 5.0\text{ V}$, $T_A = 25^\circ\text{C}$)

Characteristics	Symbol	Conditions	Min	Typ	Max	Units
Power Supply Current	I_{CC}	Circuit A	3.0	4.5	6.0	mA
Quiescent dc Output Voltage (Non-Inverting Output)	V_{q+}	Circuit A	0.6	0.7	0.8	Volts
Quiescent dc Output Voltage (Inverting Output)	V_{q-}	Circuit A	2.7	3.0	3.3	Volts
Output Impedance	Z_o		—	200	—	Ohms
RMS Noise Output	V_{NO}	Circuit A	—	0.5	1.0	mV

OPTICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$)

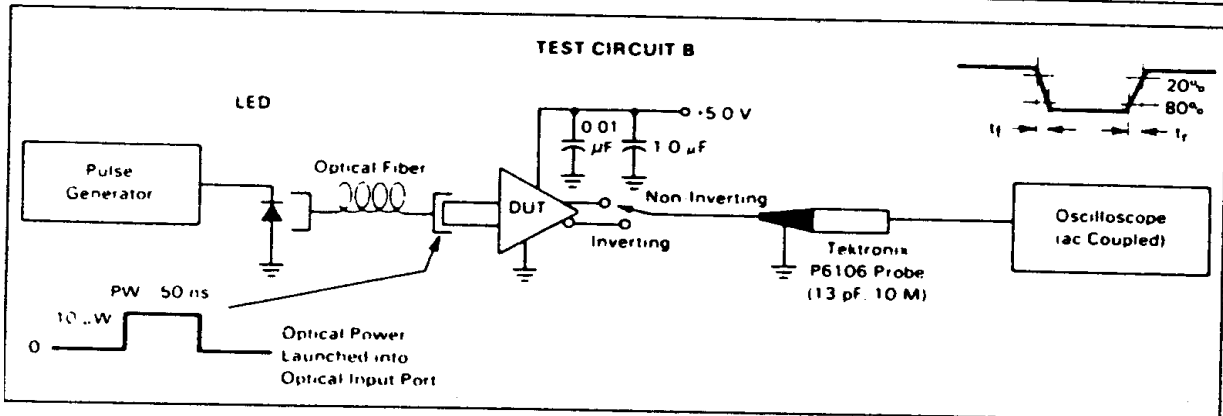
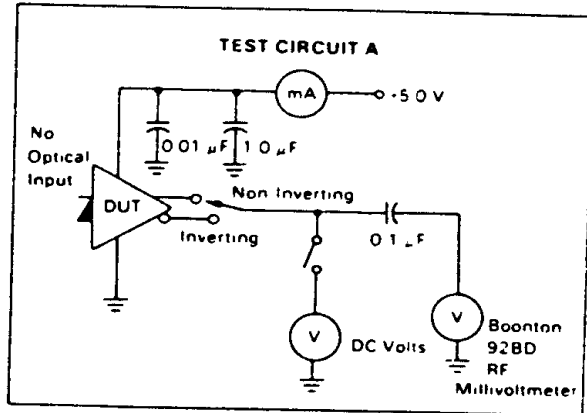
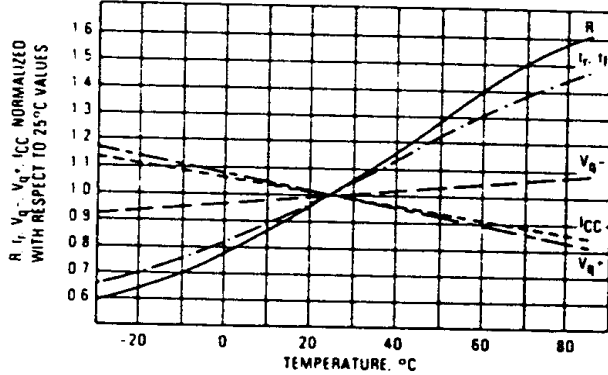
Responsivity ($V_{CC} = 5.0\text{ V}$, $\lambda = 820\text{ nm}$, $P = 10\ \mu\text{W}^*$)	R	Circuit B	3.0	4.5	7.0	$\text{mV}/\mu\text{W}$
Sensitivity (40 Mb/s NRZ, BER = 10^{-9})	S		0.8	—	—	μW
Pulse Response	t_r , t_f	Circuit B	—	10	15	ns
Numerical Aperture of Input Port (300 μm [12 mil] diameter spot)	NA		—	0.70	—	—
Signal-to-Noise Ratio @ $P_{in} = 2.0\ \mu\text{W peak}^*$	S/N		—	24	—	dB
Maximum Input Power for Negligible Distortion in Output Pulse*		Circuit B	—	—	120	μW

RECOMMENDED OPERATING CONDITIONS

Supply Voltage	V_{CC}		4.0	5.0	6.0	Volts
Capacitive Load (Either Output)	C_L		—	—	100	pF
Input Wavelength	λ		—	820	—	nm

*Power launched into Optical input Port. The designer must account for interface coupling losses

FIGURE 2 — TYPICAL PERFORMANCE OVER OPERATING TEMPERATURE RANGE





MFOE1200

AIGaAs FIBER OPTIC EMITTER

... designed for fiber optic applications requiring high power and fast response time. It is spectrally matched to the minimum attenuation region of most fiber optic cables. Motorola's package fits directly into standard OPTIMATE and SMA fiber optic connector systems. Applications are broad, and include industrial controls, computer systems, CATV, military and others.

- Fast Response - >70 MHz Bandwidth
- 250 μm Diameter Spot Size
- Hermetic Package
- Internal Lensing Enhances Coupling Efficiency
- Complements All Motorola FO Detectors
- Compatible With AMP #227846-1 and Amphenol #905-138-5001 Receptacles

FIBER OPTICS HIGH-POWER AIGaAs LED



MAXIMUM RATINGS

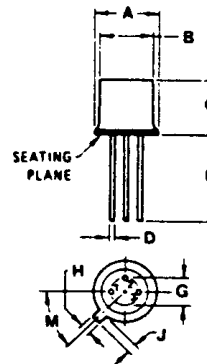
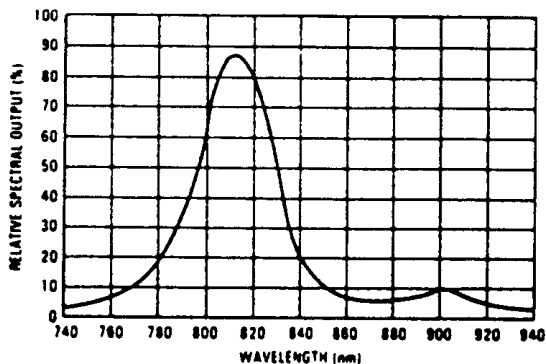
Rating	Symbol	Value	Unit
Reverse Voltage	V _R	3.0	Volts
Forward Current-Continuous	I _F	200	mA
Total Device Dissipation @ T _A = 25°C Derate above 25°C	P _D	400	mW mW/°C
Operating Temperature Range	T _A	-65 to +125	°C
Storage Temperature Range	T _{stg}	-65 to +150	°C

THERMAL CHARACTERISTICS

Characteristics	Symbol	Max	Unit
Thermal Resistance, Junction to Ambient	θ _{JA}	250	C/W
		175°	

*Installed in compatible metal connector housing.

FIGURE 1 — SPECTRAL OUTPUT versus WAVELENGTH



STYLE 1:
PIN 1: ANODE
2: CATHODE
3: CASE

NOTES

1. PIN 3 INTERNALLY CONNECTED TO CASE.
2. LEAD POSITIONAL TOLERANCE AT SEATING PLANE:
⌀ 0.36 (0.014) Ⓜ T A Ⓜ H Ⓜ
3. DIMENSIONS A AND H ARE DATUMS AND T IS A DATUM PLANE.

DIM	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	5.31	5.84	0.209	0.230
B	4.65	4.70	0.183	0.185
C	3.12	3.28	0.123	0.129
D	0.41	0.48	0.016	0.019
G	2.54 BSC		0.100 BSC	
H	0.98	1.17	0.039	0.046
J	0.84	1.22	0.033	0.048
K	12.70	-	0.500	-
M	4.57 BSC		0.180 BSC	

CASE 210A-01
TO-206AC
(TO-52)

MFOE1200

ELECTRICAL CHARACTERISTICS (T_A = 25°C)

Characteristics	Symbol	Min	Typ	Max	Unit
Forward Voltage (I _F = 100 mA)	V _F	—	1.8	2.5	Volts
Total Capacitance (V _R = 0 V, f = 1.0 MHz)	C _T	—	70	—	pF

OPTICAL CHARACTERISTICS (T_A = 25°C)

Total Power Output From 250 μm Optical Spot (I _F = 100 mA, λ = 820 nm)	P _O	900	—	—	μW
Numerical Aperture of Output Port (at -10 dB) (250 μm [10 mil] diameter spot)	NA	—	0.30	—	—
Wavelength of Peak Emission (I _F = 100 mAdc)	—	—	820	—	nm
Spectral Line Half Width	—	—	50	—	nm
Electrical Bandwidth (I _F = 100 mAdc)	BWE	70	—	—	MHz

TYPICAL CHARACTERISTICS

FIGURE 2 — POWER OUTPUT versus JUNCTION TEMPERATURE

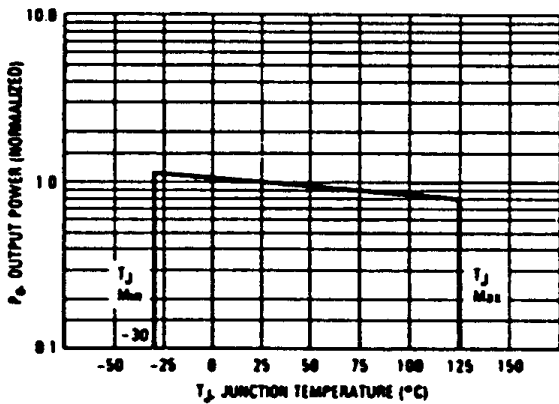


FIGURE 3 — POWER OUTPUT versus FORWARD CURRENT

