THE
FIBRE-OPTICS TRAINER
MANUAL

ELLMAX
ELECTRONICS

THE
FIBRE-OPTICS TRAINER
MANUAL

THE FIBRE-OPTICS TRAINER CONTAINS:

TRANSMITTER UNIT

RECEIVER UNIT

5m. LENGTH OF TERMINATED OPTICAL CABLE

INSTRUCTION MANUAL (THIS BOOK)

CARRYING CASE

2 x BATTERY CLIPS

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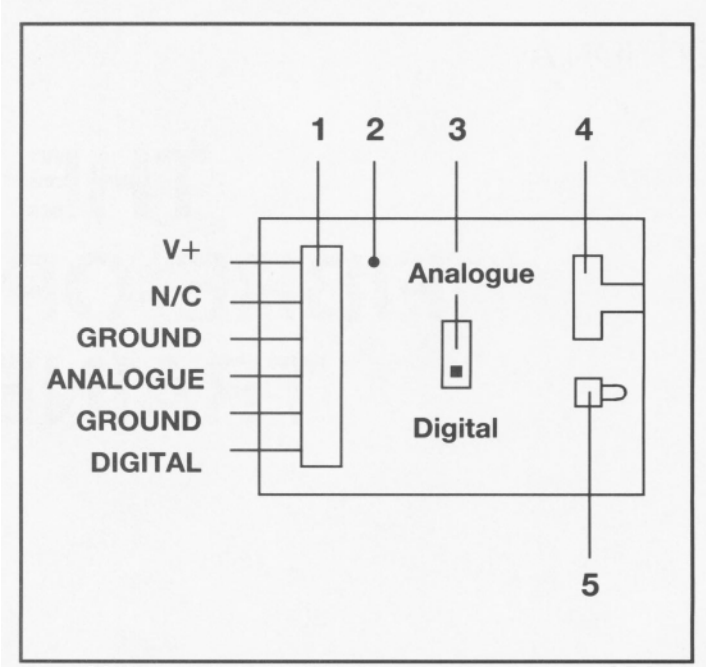
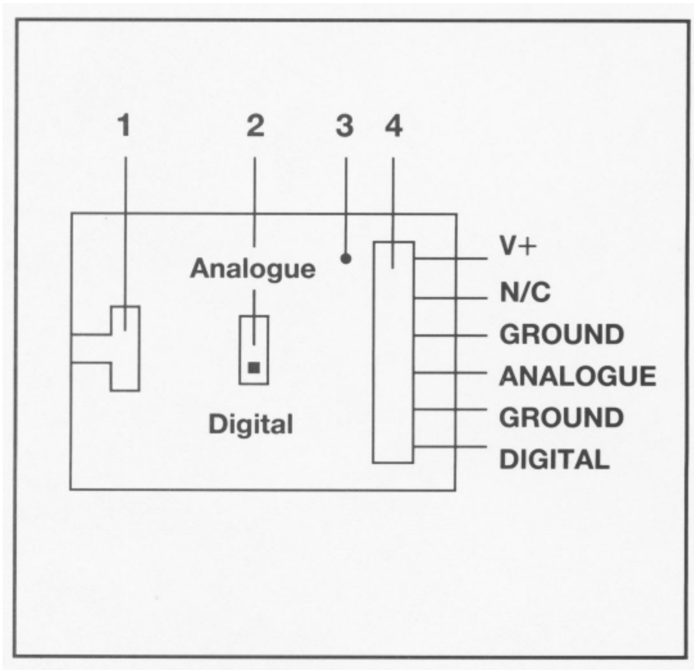


TRANSMITTER UNIT

1. Screw terminal block for power, and analogue and digital inputs.
2. Power indicator l.e.d.
3. Switches between analogue and digital modes.
4. Red l.e.d. in connector housing.
5. Red l.e.d., unhoused, for free-space transmission.

Electrical Interfaces:	Power (V+):	+9V to +12V d.c.
	Analogue input:	40kΩ input impedance, a.c. coupled
	Digital input:	10kΩ input impedance, 1.15V and 1.6V Schmitt levels.



RECEIVER UNIT

1. Receive diode in connector housing.
2. Switches between analogue and digital modes.
3. Power indicator l.e.d.
4. Screw terminal block for power, and analogue and digital outputs.

Electrical Interfaces:	Power (V+):	+9V to +12V d.c.
	Analogue output:	Approx 100Ω output impedance, a.c. coupled
	Digital output:	Voltage levels are ground and [(V+) — 1.5]V

A.1 INTRODUCTION TO THE TRAINER

The Fibre-Optics Trainer has been developed primarily for the teaching in schools of fibre-optics, but the equipment may also be used for general optics, telecommunications, and electronics tuition. Visible light sources have been incorporated into the transmitter, so that the students may more readily visualise the concepts being taught.

In order to minimise the cost of the equipment, only those items which are essential for the various demonstrations, and which are not to be found in the majority of school laboratories, have been included with the product. The following lists give those items of equipment which may be used in conjunction with the Trainer:

(a) Essential equipment:

Loudspeaker amplifier, variable gain

Analogue signal source, e.g. (i) a radio, MP3 player, or CD player with earpiece or headphone socket (ii) a microphone, or (iii) a signal generator

Torch

2 d.c. power sources (+9V to +12V d.c.) [batteries will suffice]

Simple digital electronic input and output equipment.

(b) Optional equipment:

Frequency meter

Optical components, such as a mirror and lenses

Oscilloscope

Variable frequency generator

Tuning fork

Rotating disc.

A.2 CONNECTING POWER SUPPLIES

Both the transmitter and receiver operate from a single supply voltage, connected between the V+ and GROUND terminals on each PCB. The voltage should be in the range +9V to +12V d.c. — IT IS IMPORTANT THAT THE +12V MAXIMUM IS NOT EXCEEDED. A diode is connected in series with the supply input to ensure that reverse polarity will not damage the equipment. Each unit draws less than 40mA current, so power may be conveniently provided by a small battery, an alkaline battery being preferred as it gives a longer life. For this purpose, battery clips are included with the equipment.

A.3 OPTICAL CABLE

A 5m length of polymer optical cable is provided with the Trainer. To demonstrate light transmission through the cable, point one end to a light source, such as room lighting or window light, and pass a finger repeatedly across this end. The interrupted beam may then be viewed at the other end of the cable.

A.4 ANALOGUE TRANSMISSION

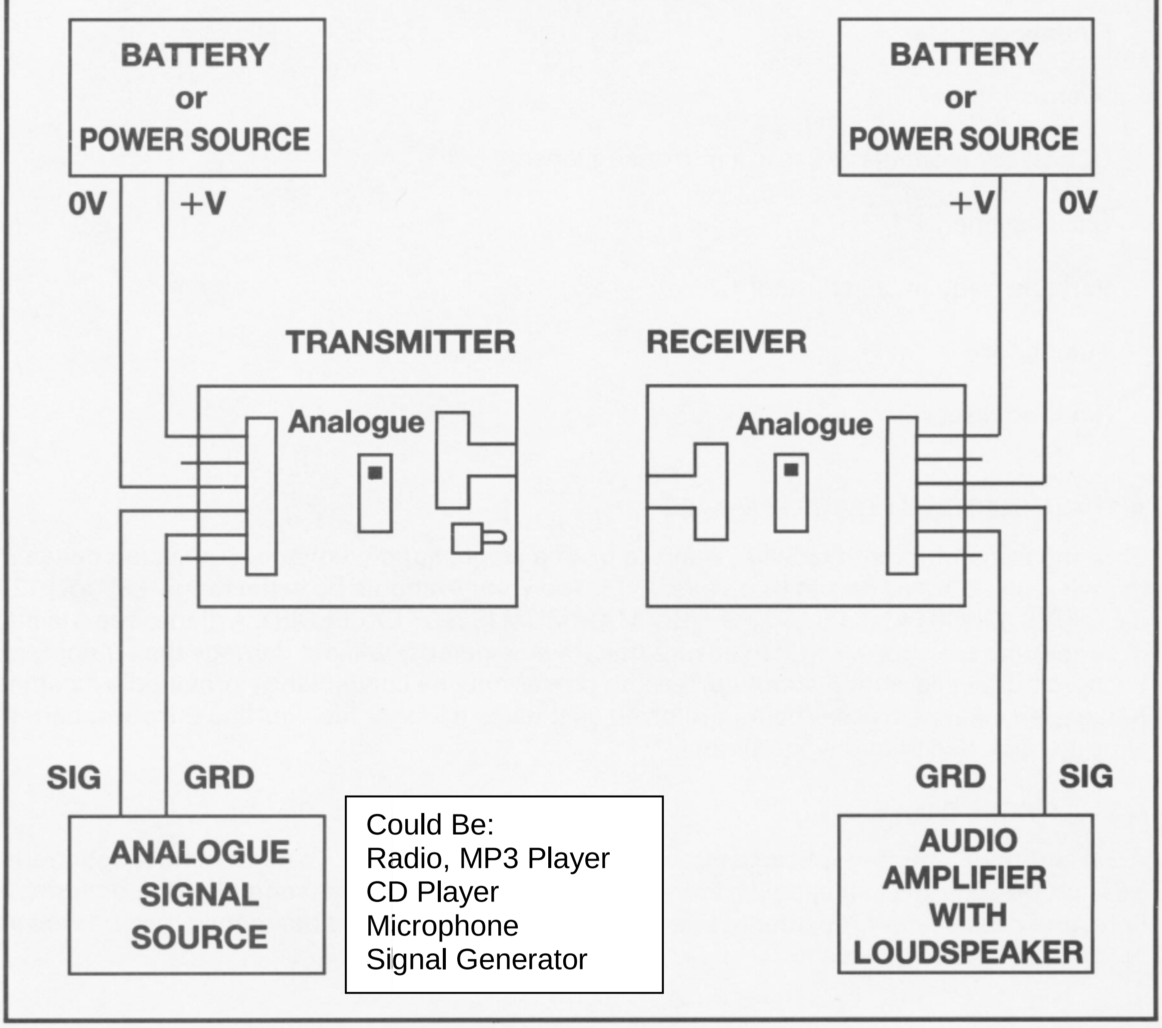
When the Trainer is used in the analogue mode, the output light intensity of the transmitter is directly proportional to the input voltage signal (plus a d.c. bias), while the output voltage at the receiver is directly proportional to the input a.c. optical signal. The fundamental concepts of both free-space and cable transmission may be demonstrated with the Trainer.

A.4.1 AUDIO SIGNAL OVER FREE-SPACE

Connect power supplies to the transmitter and receiver units, and switch both over to analogue. In order to listen directly to the received signal, connect an audio amplifier (with loudspeaker) between the analogue output and ground terminals of the receiver. An audio source must be provided for connection to the transmitter, between the analogue input and ground terminals. This source may be a radio, an MP3 player, a CD player, a microphone, or a signal generator. (For a radio, MP3 player, or CD player, the signal is taken from the earpiece or headphone socket using an appropriate plug). Place the receiver so that the receiving diode socket is facing the emitting diodes of the transmitter, and adjust the audio amplifier's gain until a clear sound is heard at the loudspeaker. If the sound is distorted, then turn down the amplitude of the signal source until the distortion disappears. The receiver and transmitter units may be separated by a distance of a few metres while still maintaining transmission. See figure A.4.1.1 for the equipment set-up.

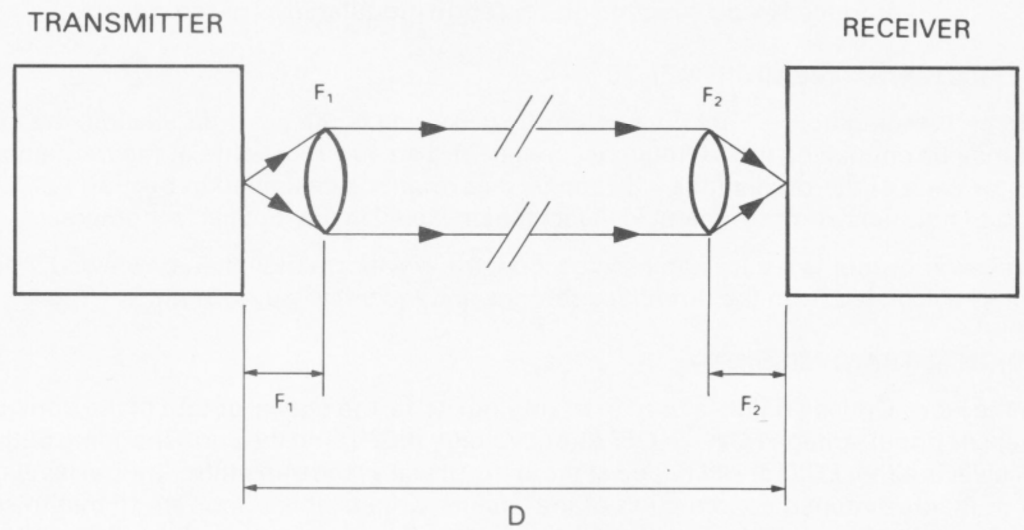
An effective demonstration of the basic properties of light, for example reflection and refraction, may be carried out with the above set-up, by inserting various optical components, such as a mirror and lenses, between the transmitter and receiver.

Fig A.4.1.1 ANALOGUE SIGNAL OVER FREE-SPACE



It is possible to transmit the optical signal over a few hundred metres using a lens system. This is done by positioning a converging lens one focal length away from the unhoused transmitting diode (and thereby producing a parallel beam), and accurately positioning another converging lens some distance along the beam, and focusing the signal down onto the receiving diode (which is similarly one focal length away from the lens.) Figure A.4.1.2 illustrates this arrangement.

Figure A.4.1.2 *Transmission over a long distance using lenses*



D may be many hundreds of metres with accurate lens positioning.

The above demonstrations may also be carried out using the transmitter on digital mode, with a square-wave generator connected between the digital input and ground terminals acting as the signal source, and listening to the resulting tone at the receiver.

A.4.2 AUDIO SIGNAL OVER OPTICAL CABLE

With the equipment set up as in A.4.1, connect the transmitter and receiver units with the optical cable provided, and then fibre-optics transmission may be effectively shown. A good demonstration of the fact that the audio signal is really passing down the fibre is to remove the optical cable at either the transmitter or receiver, and then position this cable end close to the connector — the intensity of the loudspeaker output varies with the relative positions of the cable end and the optical diode.

A.4.3 'LISTENING' TO LIGHT

With the receiver set-up as in Section A.4.1, point the receive diode, or the optical cable connected to the receiver, in the direction of an electric light. The 100Hz mains 'hum' will be heard at the loudspeaker. This effect shows that the light from a light source that is run from the mains supply is in fact varying in intensity at 100Hz, a frequency too fast for the eye to detect. (The frequency is 100Hz rather than the mains frequency of 50Hz, since the power output of a mains source is related to the square of the voltage, which has the effect of frequency doubling).

Other examples of 'listening' to light sources using the receiver/audio amplifier combination are:

a. the 'hiss' that torch light or daylight produces (this is shot noise).

b. a high pitched sound that a torch produces if it is knocked. This is caused by the torch bulb's filament vibrating at a high frequency.

c. the frequencies produced by a variable frequency source connected to the transmitter input. Changing the frequency alters the pitch of the sound heard at the receiver. The higher frequencies cannot be detected by the eye, (at the transmitter), although they are readily detectable by the ear.

d. various sounds may be produced by using a rotating disc with pre-coded markings, and reflecting light off this disc into the receiver.

e. the tone of a tuning fork may be amplified by inserting a vibrating fork between a constant d.c. light source (e.g. a torch) and the receiver, and thereby producing light fluctuations at the receiver which follow the oscillations of the tuning fork.

f. modulated infra-red radiation will also be detected by the receiver circuitry, and so the Trainer may be used for 'viewing' infra-red patterns, such as those produced by a diffraction grating and a modulated infra-red source.

A.4.4 FREQUENCY MEASUREMENTS

Instead of 'listening' to the light fluctuations as described in the previous section, the output signal may be connected into a frequency meter, and an accurate value of the frequency obtained for each of the oscillations, vibrations, and rotations described in Section A.4.3. This method of frequency measurement is in fact the one used in any optical tachometer.

If the receiver output is fed into an oscilloscope, the waveform may then be viewed, and the frequency calculated from the time-base settings and the trace 'wavelength'.

A.5 DIGITAL TRANSMISSION

When the Fibre-Optics Trainer is used in the digital mode, the optical output of the transmitter is either **ON** (input voltage **LOW)** or **OFF** (input voltage **HIGH),** and the corresponding output of the receiver is either **LOW** or **HIGH** (and at the same phase as the transmitter's input levels). Because of the unscreened construction of the Trainer circuits, it is important to minimise the possibility of induced interference into the receiver. Therefore, be careful to keep all wires away from the PCB components in the receiver, and refrain from handling input and output signal connections and the receiver components.

A.5.1 GENERAL DIGITAL SIGNALS

Power up the transmitter and receiver units, and switch both over to digital. Connect the optical cable between the two units.

The signal to be transmitted is connected between the digital input and ground terminals of the transmitter. Both TTL and CMOS levels will drive the transmitter (since the input threshold voltages are 1.6V for input **LOW** to **HIGH** transitions, and 1.15V for input **HIGH** to **LOW** transitions). The input may be connected to the +ve supply **(HIGH** input) and ground **(LOW** input) for manually inputting digital voltage levels.

At the receiver, the digital signal appears between the digital output and ground terminals, where the voltage levels are the supply voltage less 1.5 Volts **(HIGH),** and zero Volts **(LOW).** See Figure A.5.1.1 for the equipment set-up.

(To check that the received optical power level is high enough for digital transmission, the peak to peak signal voltage at the analogue output may be measured on an oscilloscope, with the receiver in analogue mode. This pp voltage, which is **directly proportional** to the a.c. optical input level, should be greater than 150mV, and to ensure an adequate margin, this voltage magnitude needs to be larger than 250mV).*

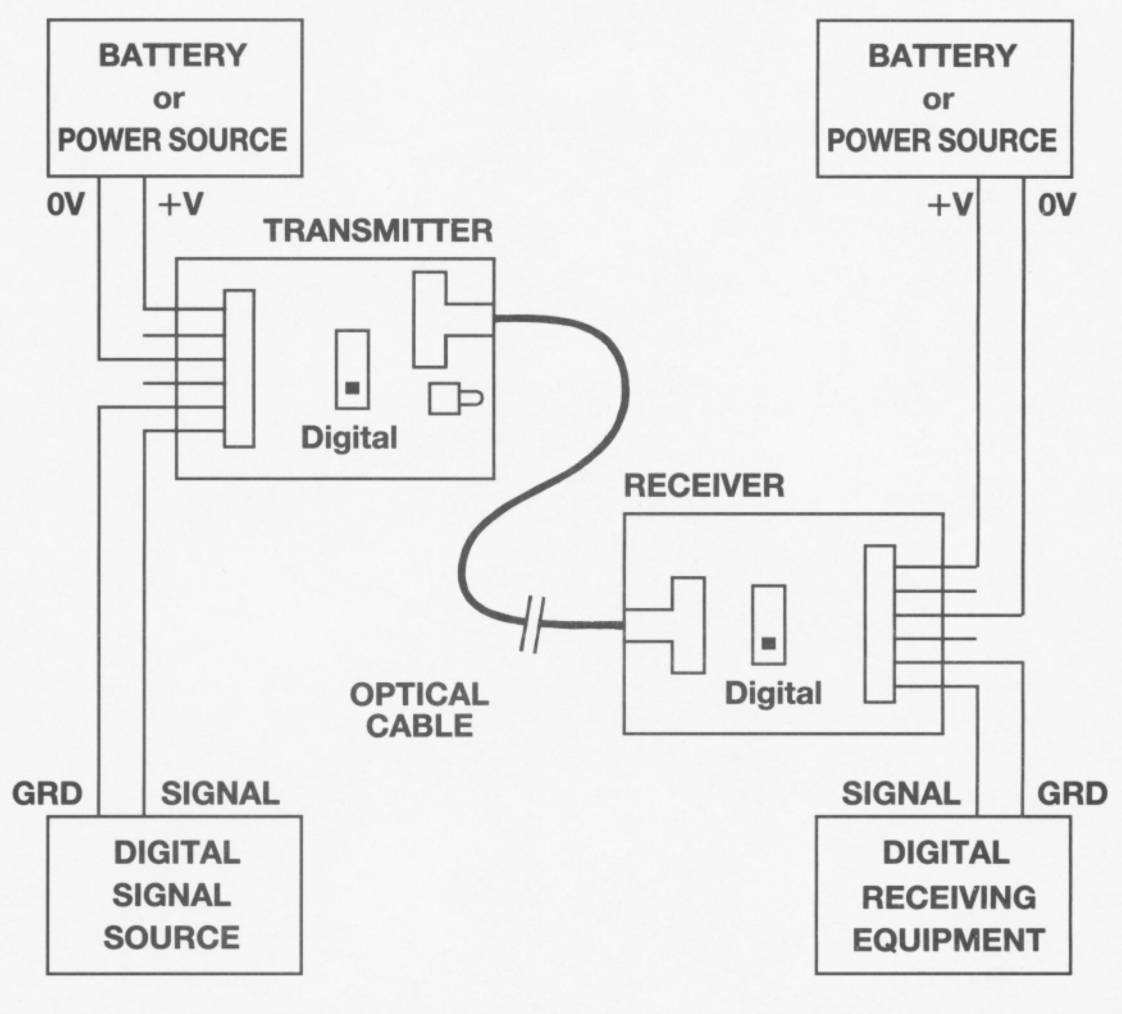
As well as being used for receiving digital data, the digital receiver circuitry may also be activated by room light. Pointing the receive diode, or the fibre connected to the receiver, towards a light source of adequate intensity will be detected by the receiver.

A digital signal may be communicated from the transmitter to receiver a short distance over 'free-space', rather than through an optical cable. This demonstration is carried out by removing the interconnecting fibre, and positioning the units so that the transmitting diodes face the

***Note on OPTICAL-FIBRE ATTENUTATION MEASUREMENTS:** Since the peak-to-peak amplitude or RMS voltage level of the analogue output of the receiver is directly proportional to the a.c. optical input level, the Trainer may be used for accurately comparing the loss or attenuation (see Section B2.1) of different fibre lengths, using a modulated source at the transmitter (preferably on digital mode), and an oscilloscope or a.c. voltmeter at the receiver, which has been set to analogue mode. The difference in loss between two cable lengths measured in dB is equal to 10 $\log_{10}(V_1/V_2)$, where V_1 and V_2 are either the peak-to-peak or RMS voltage levels of the two received signals. To measure the attenuation of a fibre-optics route, first of all connect a short cable length (of 0.5 to 1 metre or so) between the transmitter and receiver, and take the RMS voltmeter reading for this reference length ($=V_{REF}$), then connect up the route to be measured between the transmitter and receiver, in place of the reference length, and take the voltmeter reading ($=V_0$). The attenuation (sometimes called the insertion loss) of the route is equal to 10 $\log_{10}(V_{REF}/V_0)$. See Appendix C for Fibre-Optics Attenuation Calculations.

receiving diode. The transmission distance is however limited to a few cms (point the receiver away from any bright external source to ensure that it is not switched **LOW** by the ambient light).

Fig. A.5.1.1 DIGITAL SIGNAL OVER OPTICAL CABLE



A.5.2 LIGHT DETECTION APPLICATIONS

A number of applications, demonstrations or experiments involving the reception of digital-type signals may be devised by the user. Some examples are:

1. detection of low-level light signals, to trigger off some external system;
2. construction of an alarm based on the presence of a light signal;
3. use of the Trainer as the transmitting and receiving units in an optical pulse counting system for applications such as quality assurance, and scientific and engineering experiments.

APPENDIX A TRAINER TRANSMITTER AND RECEIVER — BRIEF TECHNICAL DESCRIPTION and CIRCUIT DIAGRAMS

APP.A.1 Transmitter

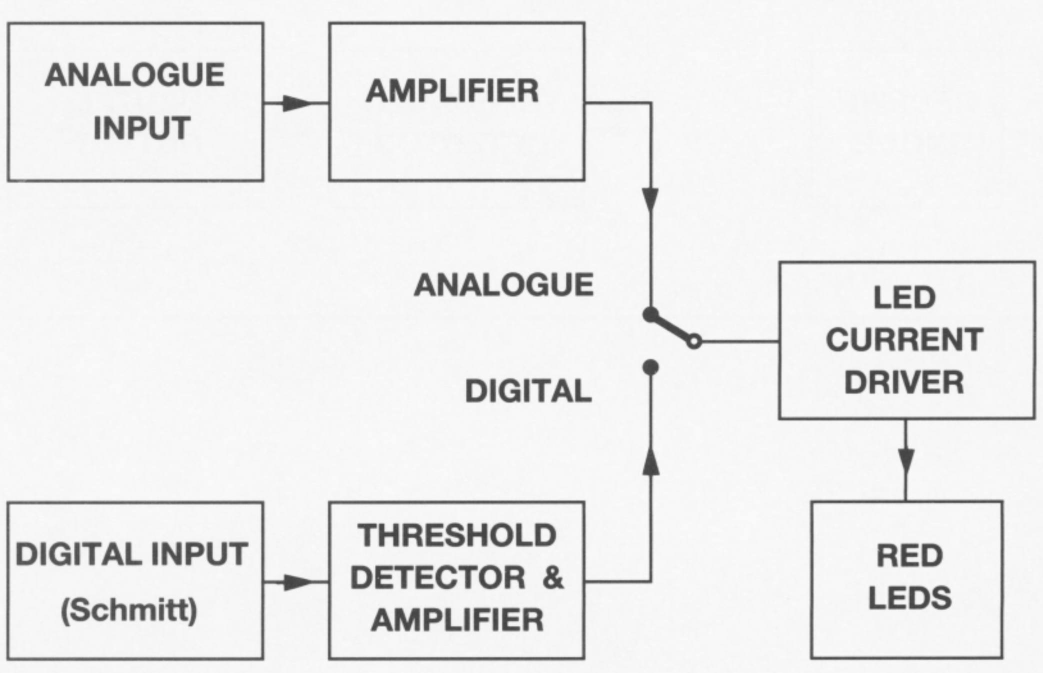
Exhibit APP.A.1 shows a block diagram of the transmitter circuitry of the Fibre-Optics Trainer.

When the transmitter is in the analogue mode, the light intensity of the emitting diodes is directly proportional to the input voltage signal (plus a d.c. bias). In the digital mode, the optical output is either **ON** or **OFF,** corresponding to a **LOW** or **HIGH** input respectively.

The I.e.d. driver section produces a current through the emitting diodes that is proportional to the input voltage. This is achieved using an emitter follower configuration, with the diodes connected in series in the collector of the output transistor.

The threshold detector is a device which has a two state output, dependent on whether the input voltage is above or below a certain threshold value. The Schmitt circuitry changes this threshold voltage slightly for +ve going and —ve going inputs, thereby reducing the possibility of an extraneous output due to noise at the input.

Exhibit APP.A.1 FIBRE-OPTICS TRAINER TRANSMITTER – BLOCK DIAGRAM



APP.A.2 Receiver

A block diagram of the Fibre-Optics Trainer Receiver appears in Exhibit APP.A.2.

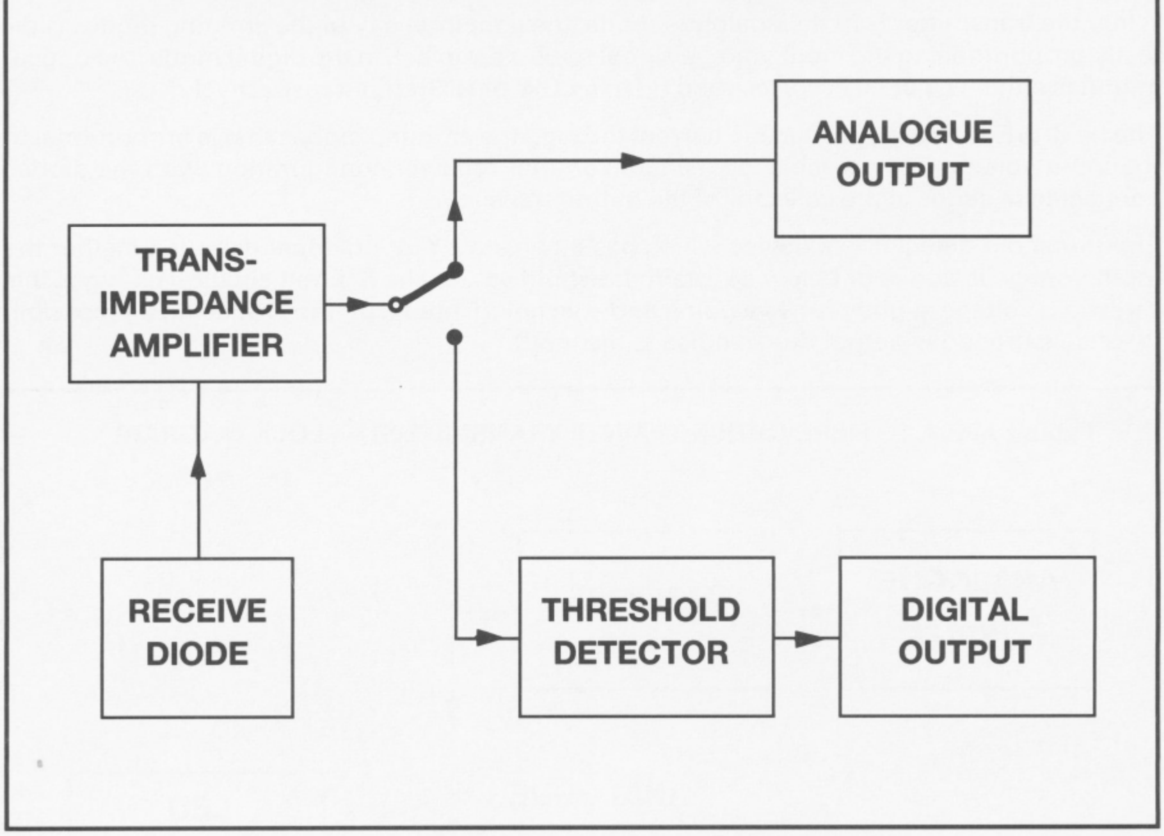
When the receiver is in the analogue mode, the analogue output signal is directly proportional to the received a.c. optical signal. In the digital mode, the digital output is either **HIGH** or **LOW,** depending on the level of the received optical signal.

The transimpedance amplifier circuitry (see Section B.2.4.2) incorporates a switch at its front end, which shuts off d.c. when the receiver is in analogue mode, thus reducing the likelihood of receiver overload.

The electrical noise at the analogue output is due primarily to the thermal noise of the 1MΩ transimpedance resistor. This noise is not, however, a major factor is determining the digital circuitry's sensitivity. Since the digital circuit operates down to d.c. frequency, it is d.c. coupled, and the dominant cause limiting its sensitivity is amplifier d.c. offsets.

In the digital circuitry, the threshold detector is similar to the one included in the transmitter, which is briefly described in Section APP.A.1. The receiver threshold detector also incorporates an automatic threshold control which increases the threshold voltage as the optical signal increases, thus producing better signal characteristics for higher optical input levels.

Exhibit APP.A.2 FIBRE-OPTICS RECEIVER – BLOCK DIAGRAM



APPENDIX B TRAINER SPECIFICATIONS

a) Transmitter/Receiver Combination

Bandwidth:
Analogue: 20Hz to 25kHz
Digital: d.c. to 20kBit/s

Range for analogue transmission (better than 20dB S.N.R.): 20dB
Range for digital transmission (better than 1 in 10^9 error rate): 10dB
(Above transmission ranges are for 1mm diameter polymer fibre)

Operating Temperature Range: 0°C to 50°C

Optical Connectors: AMP DNP

b) Transmitter

Typical power launched into 1mm plastic fibre: 10µW peak at 10V supply

Peak Output Wavelength: 650nm

Schmitt threshold levels: 1.15V and 1.6V

Digital Input Impedance: 10kΩ to ground

Phase of Digital Signal:
Input 'mark' (1) gives **no** light at output
Input 'space' (0) gives light at output

Maximum Transmitted Date Rate for less than 15% pulse width distortion: 0.5MBit/s

Maximum voltage at analogue input for no clipping: 200mV pp

Input impedance at analogue socket: 40kΩ

Analogue frequency response: 7Hz to 80kHz

Phase of Analogue Signal: optical output inverted relative to input

c) Receiver

Photodiode type: Silicon p-i-n

Digital Bandwidth: d.c. to 20kBit/s

Minimum power for better than 1 in 10^9 error rate: 850nW peak at 650nm

Digital Output:
'space' = zero Volts
'mark' = Supply Voltage minus 1.5V

Output impedance:
'space': 47Ω
'mark': 2kΩ

Phase of Digital Signal:
Light at input gives 'space' at output
No light at input gives 'mark' at output

Maximum Pulse Width Distortion: 8µS

Analogue Frequency Response: 15Hz to 30kHz

Minimum Power for 20dB S.N.R: 100nW pp at 650nm

Typical analogue signal response: 0.17V per µW at 650nm

Analogue output impedance: 100Ω typical, a.c. coupled

Phase of Analogue Signal: inverted relative to optical input

Maximum signal at analogue output: 3V pp

Optical overload at 650nm:
a.c. overload on analogue: 30µW pp
d.c. overload on analogue: 100µW

d) Power Supply

1) Transmitter +9V to +12V (current is 25mA typical at 9V)
2) Receiver +9V to +12V (current is 15mA typical at 9V)

While the information is true at the time of printing, small production changes in the course of the company's policy of improvement through research and design might not be indicated in the specifications.

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