THE
FIBRE-OPTICS EDUCATOR
MANUAL

ELLMAX
ELECTRONICS

The

FIBRE-OPTICS EDUCATOR

contains the following items:

FIBRE-OPTICS EDUCATOR TRANSMITTER UNIT

FIBRE-OPTICS EDUCATOR RECEIVER UNIT

5m. LENGTH OF POLYMER OPTICAL CABLE
1 m. LENGTH OF POLYMER OPTICAL CABLE
MICROPHONE
TORCH
RADIO
EARPIECE
EARPIECE WITH DIAPHRAGM EXPOSED
OPTICAL THROUGH CONNECTOR (AMP DNP)
MIRROR
3.5mm FREE CONNECTOR
CABLE WITH 3.5mm AUDIO CONNECTORS
CABLE WITH 3.5mm CONNECTOR TO CROC. CLIPS
BATTERIES FOR TX, RX, RADIO AND TORCH
INSTRUCTION MANUAL (THIS BOOK)
TELECOMMUNICATIONS BOOK
CARRYING CASE

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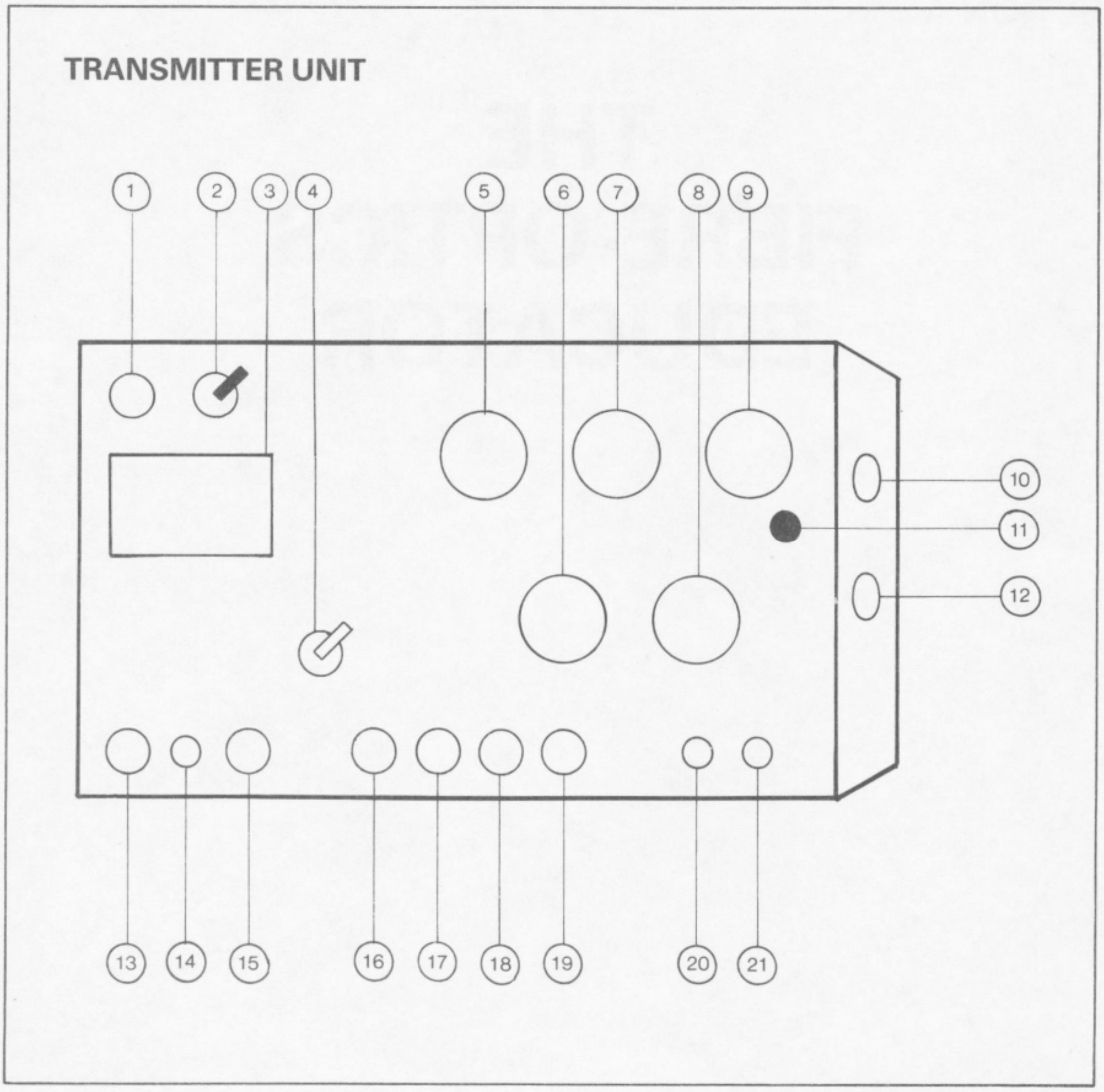
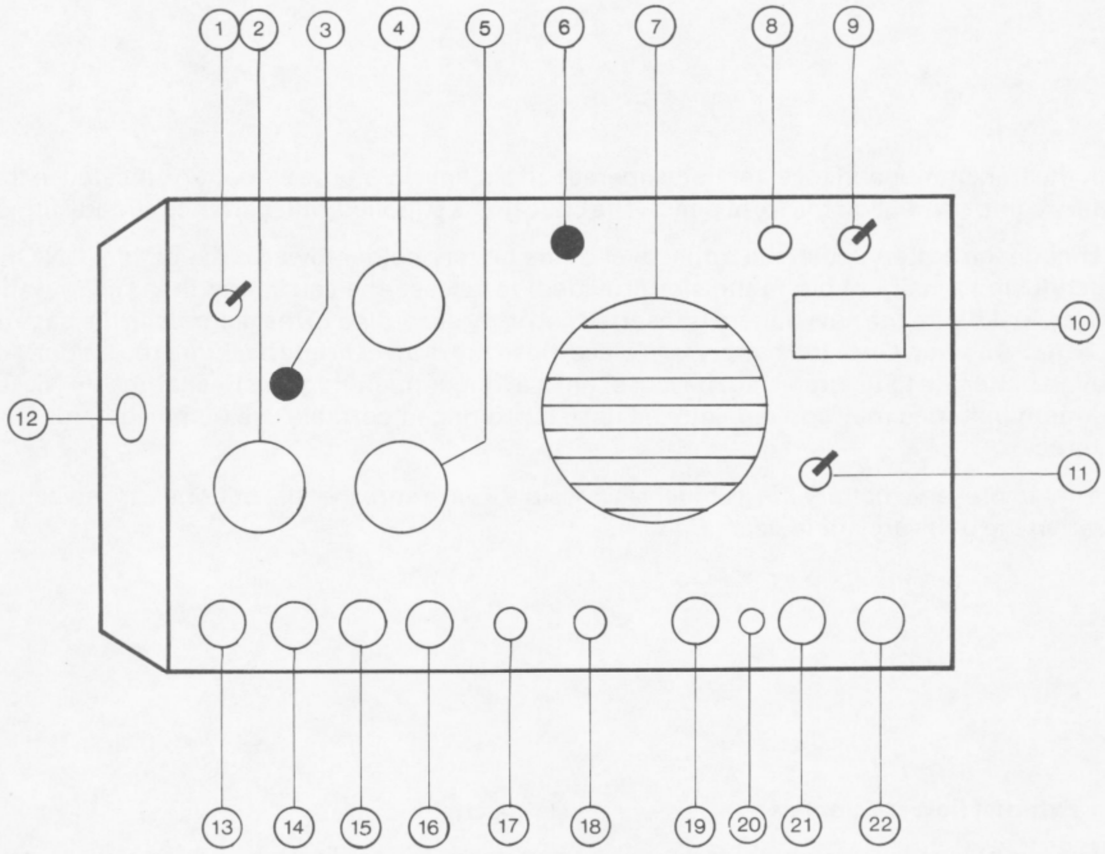
A. THE FIBRE-OPTICS EDUCATOR

FIBRE-OPTICS EDUCATOR — APPLICATIONS AND DEMONSTRATIONS:



1. Shows state of power supply.
2. ON/OFF switch for battery. Does not control optional external supply.
3. Battery holder for PP3-type battery.
4. Morse key for manually inputting digital data. Overrides all other digital inputs.
5. Controls the frequency of the pseudo-random and square wave signal generator (20Hz to 4.5kHz).
6. Selection switch for type of digital input.
7. Switches the transmitter between digital and analogue modes.
8. Controls gain of analogue amplifier (28dB range).
9. Controls output intensity of high-radiance l.e.d., infra-red l.e.d. and output indicator. (Approx 20dB range).
10. High-radiance red l.e.d. socket.
11. Gives a visible indication of the output of the transmitting diodes.
12. Infra-red l.e.d. window.
13. Terminal for optional external supply of +9V to +15V d.c., to be used with supply ground terminal.
14. 2.5mm socket for optional external power supply of +9V to +15V d.c., which can be used as an alternative to supply terminals.
15. Supply ground.
16. TTL logic level input.
17. CMOS logic level input.
18. RS232 voltage level input. Also acts as output monitor for signal generator.
19. Common ground for all digital inputs.
20. Analogue input, high impedance (20kΩ), a.c. coupled.
21. Analogue input, low impedance (8Ω). Same phase as high impedance input.

RECEIVER UNIT



1. Switches the buzzer in or out of circuit. The buzzer gives an audible indication of the state of the digital signal.
2. Controls the sensitivity of the digital comparator (32.4dB range).
3. Gives a visible indication of the state of the digital signal.
4. Switches the receiver between digital and analogue modes.
5. Controls the gain of analogue amplifier (30dB range).
6. Gives a visible output proportional to the amplitude of the analogue signal.
7. Loudspeaker output of analogue circuit.
8. Shows state of power supply.
9. ON/OFF switch for battery. Does not control external supplies.
10. Battery holder for PP3-type battery.
11. ON/OFF switch for low impedance analogue output and loudspeaker.
12. Receive diode socket.
13. TTL logic level output.
14. CMOS logic level output.
15. RS232 voltage level output.
16. Common ground for all digital outputs.
17. Analogue output, high impedance (1kΩ).
18. Analogue output, low impedance (less than 1Ω). Connection to this socket automatically disconnects the loudspeaker.
19. Optional external supply of +9V to +15V d.c., to be used with supply ground terminal.
20. 2.5mm socket for optional external power supply of+9V to +15V d.c., can be used as an alternative to positive supply terminals.
21. Supply ground.
22. Negative supply voltage of -9V to -15V for RS232 voltage level output, to be used with supply ground terminal.

CONNECTING POWER SUPPLIES TO EDUCATOR

(a) Batteries

Both the transmitter and receiver units operate off a single PP3-type 9V battery, located in the battery compartment on the front panel. The Educator is supplied with batteries already fitted.

To change the battery, push the front cover of the battery holder towards the battery ON/OFF switch (using a nail or coin in the slot provided) to release the catch, and then pull out the drawer. Make sure the new battery is inserted correctly according to the diagram in the base of the battery drawer. Once the battery is in place, push the drawer firmly back into the holder. An alkaline battery is to be preferred, because it has a longer operating life. Rechargeable batteries may conveniently be used if prolonged portable use of the equipment is required.

In order to preserve battery life as much as possible, make sure that the batteries are switched off when the units are not in use.

(b) External Power Supplies

Power supply sockets are provided on the front panel for applications which require prolonged use of the units. An external supply may be connected across the terminal posts (between the ground and the +ve supply posts), or by using the 2.5mm socket. The supply voltage should be in the range +9V to +15V d.c. — IT IS IMPORTANT THAT THE +15V MAXIMUM IS NOT EXCEEDED. Diodes are connected in series from each of the supply sockets (and also from the battery supply) to the circuitry, ensuring that reverse polarity will not damage the equipment. These diodes also ensure that current cannot flow between power sources, and that the equipment draws current from the source with the maximum supply voltage if more than one supply is connected up. The battery ON/OFF switch only controls the connection to the battery, and not to the external supply sockets.

In order to use the RS232 voltage level output in the receiver, a negative supply must be connected between the -ve terminal and ground. This supply should be in the range -9V to -15V d.c. — IT IS IMPORTANT THAT THE MAGNITUDE OF THIS NEGATIVE VOLTAGE DOES NOT EXCEED -15V.

FIBRE-OPTICS EDUCATOR — APPLICATIONS AND DEMONSTRATIONS

A.1 OPTICAL CABLES AND CONNECTORS

Point one end of the fibre-optic cable to a light source, such as room lighting or window light. Notice that the light passes through the cable and can be seen at the other end. The effect is heightened by passing a finger repeatedly across the end of the fibre where the light is entering, and viewing the interrupted beam coming from the fibre.

Turn on the torch provided, and place the bulb close to one end of the longer length of cable. The light coming from the fibre is yellow. This is because the fibre absorbs some colours more than others, and the yellow light is absorbed least out of all the colours present in the white torch light. The way the cable is coiled or wound has very little effect on the transmission of light through its length. Using the through-connector provided, join together the two optical cables by pushing the two ends into this connector. Again shine the torch light into one fibre end, and notice that this light, although slightly reduced in intensity by the connector, still passes through the connected fibres.

If the fibre ends become dirty, they should be cleaned to minimise optical losses. This is easily done by wiping them lightly with a damp cloth.

A.2 ANALOGUE TRANSMISSION

When the Educator is used in the analogue mode, the output light intensity at the transmitter is directly proportional to the input voltage signal (plus a d.c. bias).

A.2.1 Radio Signal Over 'Free-Space'

Switch on both the transmitter and receiver, and switch both over to analogue. (The transmitter's output indicator and high radiance red diode, and also the receiver's analogue indicator should now be on).

Turn on the FM radio, and tune in to a clear signal (the FM band normally gives the best reception within a building). Using one of the electrical leads provided, connect the earphone output socket of the radio to the 'low Z' socket of the transmitter. Set the transmitter analogue gain control to minimum (by turning it fully anti-clockwise). Put the transmitter output power onto maximum by turning the output power control fully clockwise. Adjust the radio volume control until the transmitter's output indicator begins to flicker in intensity, and then reduce this volume control to the point where this intensity just becomes constant. (This procedure ensures that the transmitter is giving out a signal with very little distortion).

Turn on the loudspeaker/low Z switch. Place the receiver so that the receive diode socket is facing the emitting diode socket of the transmitter, and adjust the analogue gain of the receiver until an adequate output is heard from the loudspeaker. If the sound is distorted, then turn down the radio's volume control until the distortion disappears. The receiver and transmitter units may be separated by a distance of a few metres while still maintaining transmission.

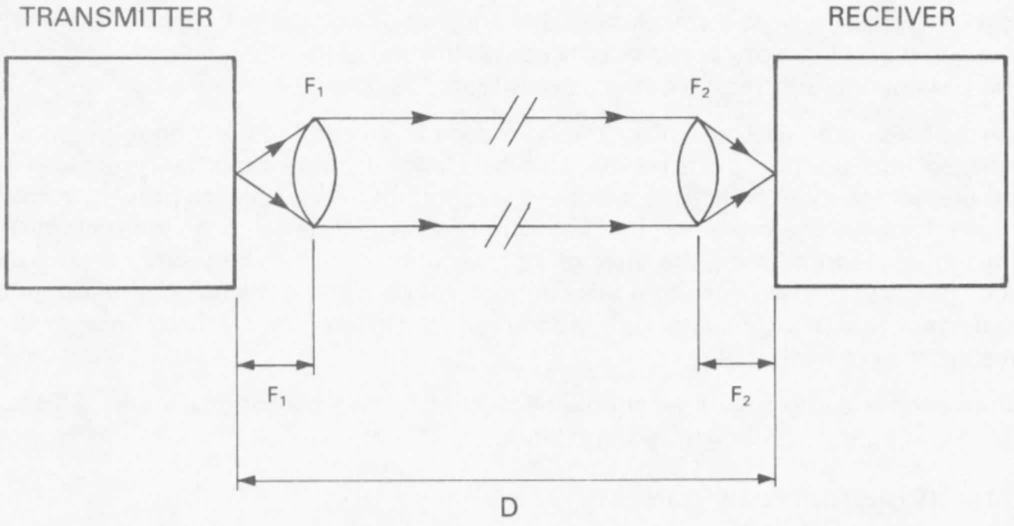
In this demonstration, the signal being transmitted comes mainly from the infra-red light emitting diode. This can be shown by placing a finger over the high radiance red diode and noting that the level of the received signal is hardly affected. (The output power of the infra-red diode is higher than that of the high radiance red diode).

To show that infra-red radiation behaves in a very similar way to visible light, place the transmitter and receiver at right-angles, and position a mirror or any reflecting material to reflect the radiation into the receiving diode when sound will again be produced at the loudspeaker.

It is possible to transmit the optical signal over many hundreds of metres using a lens system. This is done by positioning a converging lens one focal length away from the transmitting diode (and thereby producing a parallel light beam), and accurately positioning another converging lens some distance along the light beam, and focussing the signal down onto the receiving diode (which is similarly one focal length away from the lens). Figure A.2.1.1 illustrates this arrangement.

The above demonstrations may be carried out using the output from the digital square wave generator as the transmitted signal.

Fig A.2.1.1 *Transmission over a long distance using lenses*



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

A.2.2 Radio Signal Over Optical Fibre

Connect the radio to the transmitter, and set up the signal levels as in the first two paragraphs of Section A.2.1. Turn the loudspeaker on. Take a length of optical cable, and push-fit the connectors into the sockets at both the transmitter and receiver. Reduce the output power of the transmitter (by turning the output power knob anti-clockwise) until the received signal sounds clear and undistorted. (This operation is carried out to ensure that the intensity of the light coming out of the fibre is not high enough to overload the receiver). Then adjust the analogue gain of the receiver for the most suitable loudspeaker sound level.

A good demonstration of the fact that the audio signal is really passing down the fibre is as follows: using the set-up described in the above paragraph, turn both the transmitter output power and the receiver analogue gain to maximum (fully clockwise), connect the shorter optical cable to the transmitter, and the longer one to the receiver, and position the free cable ends close to each other — the intensity of the loudspeaker output varies with the positioning of these two ends.

A.2.3 Using the Output Indicator as the Transmitting Device

The output indicator diode at the transmitter emits the same signal as the main emitting diodes, although at lower intensity. This can be demonstrated by setting up the transmitter and receiver for analogue transmission of the radio signal. Turn the transmitter output power to maximum, and the receiver analogue gain to maximum. Connect the smaller length of fibre to the receiver input socket, and position the other end of this fibre close to the transmitter output indicator. The radio signal will be heard at the loudspeaker.

A.2.4 Voice Signal Over System

Demonstrations A.2.1 and A.2.2 can be carried out using the microphone connected into the 'high Z' socket of the transmitter, with the radio disconnected. In order to prevent the high-pitched whistle caused by feedback from loudspeaker to microphone, separate the loudspeaker and microphone by as much as the optical and electrical cables permit, and reduce the analogue gain in the receiver and/or the transmitter's output power until the whistling stops. The transmitter analogue gain should be at maximum in these demonstrations.

A.2.5 General Analogue Signals Over System

Any analogue signal in the bandwidth of 25Hz to 25kHz may be passed through the system. There are choices of high and low impedance sockets at both the transmitter and receiver.

Care must always be taken when transmitting analogue signals to ensure that:

1. The analogue gain in the transmitter must be adjusted to ensure that the signal at the emitting diodes is not high enough to distort the optical output through 'clipping'. If this signal is too high, the transmitter indicator diode will fluctuate in intensity. The highest suitable gain of the analogue signal is at a position just less than when this intensity fluctuation begins to occur. (A more exact determination may be carried out by calculating levels using the figures given in the transmitter specification in Appendix B). Distortion of the optical signal due to the l.e.d. response not being exactly linear may be decreased by further reducing the analogue gain.

2. The received optical power must not be high enough to overload the receiver circuitry. To set an acceptable level, carry out the following procedure:

   a. Connect up the optical route, set the transmitter to analogue and turn the output power to maximum (control fully clockwise).

   b. Switch the receiver to **digital**, and turn the threshold sensitivity control fully anti-clockwise (lowest sensitivity).

   If the digital indicator light is OFF, follow instruction C1, and if it is ON, follow C2. If the receiver's digital indicator light is **OFF**:

   Cl Leave the transmitted power at its maximum position, and switch the receiver to analogue. The system is now set up for the transmission of analogue signals, and the receiver analogue gain may be adjusted to the required level.

   If the receiver's digital indicator light is **ON**:

   C2 Turn the transmitter output power control anti-clockwise until the indicator **just** goes OFF, and switch the receiver back to analogue operation. The system is now set up for the transmission of analogue signals, and the receiver analogue gain may be adjusted to the required level.

   Throughout the above setting-up procedure, the buzzer may be switched on and used as the indicator instead of the digital indicator light.

   (Special design features in the receiver circuitry to reduce the likelihood of signal overload do in fact permit the d.c. component of the input signal to be at a higher level than that allowed for by the above setting-up procedure).

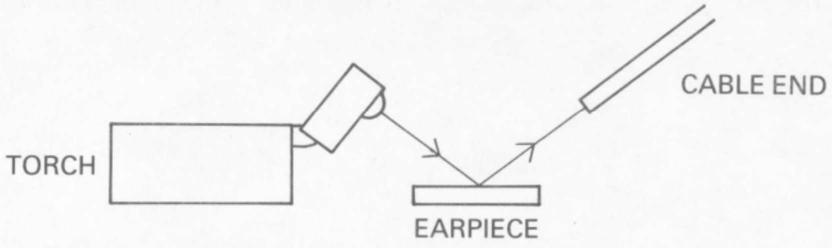
A.2.6 Using a Reflecting Diaphragm as a Transmitter

Connect the earphone with the top removed (this is provided with the Educator) into the earphone socket of the radio. Turn the radio volume control up to a high level. Turn the loudspeaker on, switch the receiver to analogue and turn its analogue gain up to maximum. Connect the shorter optical cable to the receiver, and position the torch, earpiece and cable end as in Figure A.2.6.1.

Do not place the torch bulb and the cable end too close to the earpiece, or the receiver may be overloaded by the signal. Adjust the positions of the torch and cable until a strong sound is produced by the loudspeaker.

The effect is caused by the metal diaphragm of the earpiece modulating the reflected light, and so producing a light beam at the fibre which varies in intensity with the original audio signal.

Figure A.2.6.1 *Reflecting Diaphragm Transmitter*



A.2.7 'Listening to Light'

With the receiver set up as in A.2.6, point the optical cable that is 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).

A.2.8 Optical Feedback

With the receiver set up as in A.2.6, position the free end of the optical cable close to the analogue indicator diode of the receiver. A noise will be heard at the loudspeaker, and the frequency and intensity of this sound may be changed by adjusting the position of the cable end or altering the receiver analogue gain. This effect is due to optical feedback, since the analogue indicator is driven by a voltage signal that is produced by the receiver amplifier. Directing the light of this indicator into the input fibre completes the loop. The effect is similar to the 'whistling' that can occur in a microphone/amplifier/loudspeaker system, where the feedback is from the loudspeaker to the microphone.

A similar positive feedback effect may be demonstrated by connecting the 'high Z' input of the transmitter to the 'high Z' output of the receiver, with both units on analogue and the loudspeaker switched on, and lining up the transmitting and receiving diodes.

A.2.9 Other Analogue Signals

A variety of demonstrations, applications or experiments involving the reception of analogue light signals may be devised by the user. Possibilities include:

1. using a rotating disc with pre-coded markings and a light source to provide a modulated light signal at the receiver;
2. measuring the frequency of a rotating disc or a vibrating object using light reflection or transmission;
3. using the fibre as an 'optical wand' to detect a pre-prepared 'bar-code'.

It is possible to 'listen' to a number of different light sources by using the receiver/loudspeaker arrangement. Detecting the 100Hz hum of mains lighting has already been mentioned. Another example is the 'hiss' that torch light or daylight produces (but be careful not to overload the receiver by pointing the receive diode directly at a very bright light source). If the torch is knocked, a high pitched sound is heard at the loudspeaker—this is caused by the torch bulb's filament vibrating at a high frequency. It is possible to 'listen' to light intensity variations caused by nature, such as the high frequency produced by reflecting sunlight off a fly's wings in motion.

Another effective demonstration of 'listening to light' is to use the variable frequency square wave generator in the transmitter as the source. Changing the frequency alters the pitch of the sound heard at the receiver. The higher frequencies cannot be detected by the eye, although they are readily detectable by the ear. Turning the transmitter onto 'pseudo-random signal' produces a sound with which players of computer games will be familiar.

Demonstrations of the presence of infra-red radiation may be convincingly carried out with the Educator. For example, a diffraction pattern produced by the transmitter's infra-red source together with a diffraction grating may be detected using an audio transmission procedure similar to those described in Sections A.2.1 and A.2.2, with the square wave as the transmitted signal.

If the HIGH Z output of the receiver is used, then the LOUDSPEAKER/LOW Z switch may be turned off in order to reduce power consumption as well as to disconnect the loudspeaker.

A.3 DIGITAL TRANSMISSION

When the Educator is used in the digital mode, the optical output of the transmitter is either ON or OFF, depending on the state of the input voltage signal.

A.3.1 Morse Communications

Set the transmitter to digital operation, turn the rotary switch to the TTL/CONTACT/MORSE position, and set the output power at maximum (fully clockwise).

At the receiver, set the analogue/digital switch to digital, put the digital threshold sensitivity control at a midway position, and turn the buzzer switch on. Connect an optical cable between the transmitter and receiver.

Depressing the morse key will cause the transmitter to emit radiation (the output indicator will go on), and the receiver's buzzer and digital indicator will also be turned on. (The buzzer may be switched off, if desired, leaving the digital indicator diode to show when the receiver detects a light signal). A morse message may be communicated through the system. A proper morse key may be used by connecting it between the TTL/CONTACT and GROUND terminals.

The digital receiver circuitry may also be activated by room light. Pointing the receiving diode, or the fibre connected to the receiver, towards a light source of adequate intensity will be detected by the receiver. In order to detect a light signal in the presence of background (ambient) light, it is necessary to reduce the digital threshold sensitivity (turn control anti-clockwise) to a level at which the background light does not activate the receiver. (When the threshold sensitivity is set at maximum, the receiver is extremely sensitive, and will trigger off an optical level of just 50nW, that is fifty thousandths of a micro-Watt).

A morse signal may be communicated from transmitter to receiver 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 diode faces the receiving diode. (See Section A.2.1 for the similar demonstration of an analogue signal over 'free-space'). The transmission distance is limited to about half a metre even with the output power on maximum and with the digital threshold sensitivity as high as the ambient light allows (point receiver away from any bright external source for best results). This distance is shorter than that achievable in the analogue demonstration described in A.2.1, due to the fact that the receiver's digital sensitivity is not as high as its analogue sensitivity.

A.3.2 Communications Using Internal Digital Signal Generator

Instead of transmitting a morse signal, the internal pseudo-random signal source (which may be viewed as an 'automatic morse code generator') may be used.

Turn the transmitter's rotary switch onto 'Pseudo-random Signal' and turn down the 'Signal Generator Frequency' control to a minimum. Otherwise, maintain the same set-up as described in the first two paragraphs of Section A.3.1. The Frequency of the internal signal source may be increased by turning the 'Signal Generator Frequency' control in a clockwise direction.

A.3.3 General Digital Signals Over System

Both the transmitter and receiver must be set to 'digital' for digital operation.

The digital bandwidth of the system is D.C. to 20kBit/s. A number of digital interfaces are provided:

- TTL
- CMOS
- RS232 Signal Voltage
- Contact Switch
- Morse

At the transmitter, only one of the TTL, CMOS or RS232 can be used at any one time. Selection is carried out by means of the multi-position rotary switch together with the corresponding input socket. (The signal is connected between the relevant socket and the 'ground' terminal). In the receiver, any or all of the TTL, CMOS and RS232 interfaces may be used simultaneously, by making connections to the corresponding output terminals.

A 'contact' interface may be used at the transmitter. This is selected by turning the rotary switch to TTL/CONTACT/MORSE, and connecting wires to the TTL/CONTACT and ground terminals. The transmitting l.e.d. is turned on by making contact between these two wires, thus shorting the sockets.

The morse interface is described in Section A.3.1. The morse key may be pressed when any other interface is being used, **as the morse key overrides all other signals.** This feature is useful for checking the integrity of the link between the transmitter and the receiver.

At the receiver, the digital indicator (and also the buzzer, if switched on) goes ON if the signal is a 'space' (corresponding to light at the input) and goes OFF if the signal is a 'mark' (corresponding to no light at the input).

In order to obtain the necessary signal characteristics at the receiver, the following procedure, which sets up the best values of output power and threshold sensitivity, must be carried out before transmitting digital data in order to minimise pulse width distortion:

a. Connect up the optical route, set the controls to digital, and turn the transmitting diode to a continuous ON state. (This may be done by turning the transmitter's rotary switch to CMOS, and leaving the CMOS terminal unconnected).
b. Turn the transmitter 'output power' control onto maximum (fully clockwise).
c. Turn the receiver 'digital threshold sensitivity' control to minimum sensitivity (fully anti-clockwise).

If the digital indicator light is OFF, follow instruction d1, and if it is ON, follow d2.

If the receiver's digital indicator light is **OFF:**

d1 Increase the digital threshold sensitivity at the receiver (by turning the control clockwise) until the indicator light just goes on. Note this position of the threshold control. Now turn the threshold control clockwise to the point mid-way between the noted position and the fully clockwise (i.e. maximum sensitivity) position. (The indicator light should now be ON). The system is now set up for the transmission of digital data.

Instead of carrying out the above step the threshold sensitivity may be set at maximum (fully clockwise). However, this results in up to typically 7.5µsec. pulse width distortion (equivalent to 15% at 20kBit/s data rate, with the percentage distortion reducing in proportion to the data rate). Setting the threshold at maximum sensitivity enables a wide range of input power levels to be used if the 7.5µsec. distortion is not critical to the application.

If the indicator light remains off when the sensitivity is increased to its maximum position, and steps, a, b, c and d1 have been carried out correctly, then the optical signal at the receiver is too weak for a digital link to be established. If this is the case, check that all the optical connections are good, and that the fibre ends are clean. The route attentuation may then be measured (See Section A.4) to ensure that it falls within the system specification.

If the receiver's digital indicator light is **ON:**

d2. Reduce the transmitter's output power (turn control anti-clockwise) until the indicator light just goes OFF (to ensure the optical intensity is not high enough to overload the receiver). Then follow instructions d1 above.

Throughout the above setting-up procedure the buzzer may be switched on and used as the indicator instead of the digital indicator light.

A.3.4 Other Digital Signals

A large 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 very small signal levels by the receiver;
2. construction of an alarm system based upon the presence of a light signal;
3. use of the Educator as the transmitting and receiving units in an optical pulse counting system for applications such as quality assurance, and scientific and engineering experiments.

A.4 OPTICAL-FIBRE ATTENUATION MEASUREMENTS

A.4.1 Standard Measurement 1

The Fibre-Optics Educator, in conjunction with a digital voltmeter set to read a.c. voltage, can be used to measure the attenuation (see Section B2.1) of a fibre-optics route. The standard measuring procedure is given in the rest of this Section, and it is advisable for the user to familiarise himself with this first method before attempting the others.

Steps a and b must be carried out initially to ensure that there is no optical overload at the receiver.

a. Set the receiver to digital operation, and reduce the threshold sensitivity to a minimum (control fully anti-clockwise).

b. Set the transmitter to digital operation, and set the emitting diode to a continuous ON by switching onto CMOS and leaving the CMOS terminal unconnected. Set the output power onto maximum (control fully clockwise). Connect a short length (about a metre) of optical cable between the transmitter and receiver. This short length of cable must have flat, clean ends in order to achieve a good measurement accuracy. Reduce the transmitted output power level (turn the control anticlockwise) until the receiver's digital indicator light **just** goes OFF. **Do not alter the output power level throughout the remainder of the measurement.**

c. Turn the transmitter onto Square Wave and set the Signal Generator Frequency control to maximum (fully clockwise).

d. Switch the receiver onto analogue, and turn the receiver's analogue gain down to the MINIMUM (fully anti-clockwise), and turn the loudspeaker off. Connect a digital voltmeter, which can measure a.c. values down to a tenth of a milli-Volt, to the 'high Z' socket of the receiver. A 3½ digit DVM with a 200mV a.c. scale is ideal for this purpose.

e. Take the voltmeter reading (=V_{REF}), with the short cable length connected between the transmitter and receiver.

f. Connect up the route to be measured between the transmitter and receiver, in place of the short length, and take the voltmeter reading (=V_0). (Do NOT alter any controls during Step f).

   Check the electrical noise level by switching off the transmitter and noting the voltmeter reading (=V_A). V_A will be zero if the DVM specified in Step d is used.

g. The attenuation (or insertion loss) of the route is calculated using the following formula:

$$\text{attenuation} = 10\log_{10}\frac{V_{REF}}{\sqrt{(V_o^2 - V_A^2)}}\ \text{dB},$$

which approximates to $10\log_{10}\frac{V_{REF}}{V_o}$ dB

when V_A is small compared to V_o

(V_A is zero for Standard Measurement 1 if a 0.1 mV sensitivity DVM is used).

(See Appendix C for derivation of basic attenuation formula)

For measurement of a number of routes, only the final two steps f and g need be repeated. If the output power level of the transmitter is altered, however, steps a to e must be carried out to re-set a suitable level. After measuring a number of routes, check that V_{REF} is essentially the same as the original value.

The attenuation range using the above procedure is 25dB, and the accuracy is within ±1dB. This accuracy figure is predominantly determined by the inconsistency of connector losses.

A.4.2 Standard Measurement 2

If the complete measurement procedure (including Steps d and e) described in Section A.4.1 is carried out with the DVM connected to the 'low Z' socket of the receiver (and with the loudspeaker/low Z switch on), the attenuation range is increased to 30dB. However, V_A, the voltage contribution from noise, may not be zero and so its value must be taken into account in the attenuation formula of A.4.1.g. if a relatively high loss route is being measured. The accuracy is again within ±1dB.

A.4.3 High Loss Methods 1 and 2

In order to increase the attenuation range capability of the Educator, steps f and g of the procedure described in Section A.4.1 are replaced by the following (which may be used to measure losses of greater than 15dB):

> Connect up the route to be measured between the transmitter and receiver, in place of the short reference length. Then, increase the receiver analogue gain to maximum by turning the control fully clockwise. Take the voltmeter reading (= V_1).
>
> Measure the electrical noise level by switching off the transmitter, and noting the voltmeter reading (= V_B).
>
> The attenuation of the route is given by the formula:
>
> $$\text{attenuation} = 10 \log_{10} \frac{V_{REF}}{\sqrt{(V_1^{\,2} - V_B^{\,2})}} + k \quad \text{dB},$$
>
> where the approximate value of k = 15
>
> (k is derived from the ratio of the maximum to minimum gain of the receiver).

Remember to turn the receiver analogue gain back down to minimum if re-measurement of V_{REF} is required.

The range of the instrument using this method (i.e. High Loss Method 1) is 40dB, while the accuracy is ±2.5dB.

If the above method (including Steps d and e) is carried out with the DVM connected to the 'low Z' socket (and with the loudspeaker/low Z switch ON), the range is increased to 50dB, and the measurement accuracy is ±3dB. This method is High Loss Method 2.

In order to increase the dB accuracy of the High Loss Methods, the constant k may be accurately determined by equating the measurement results of a route with a loss between 15 and 25dB, using the Standard and High Loss Methods. A precise value of k leads to accuracies of ±1.5dB and ±2dB for the High Loss Methods 1 and 2 respectively.

A.4.4 Measurement with non AMP DNP-terminated cable

The attenuation of a cable route with end connectors other than AMP DNP may also be measured with the Fibre-Optics Educator. Identical methods to those described in Sections A.4.1 to A.4.3 are used, but with short (one metre or less) interface cables connecting the Educator units to the cable to be measured. Steps a to e of Section A.4.1 must be carried out with a short length of cable terminated with the same type of connectors as in the route to be measured, and this short reference cable is also connected to the transmitter and receiver via the two interface cables.

Although device/connector/cable mis-match is compensated to some extent by the setting of the transmitted power level in Steps a and b of Section A.4.1, a large mis-match will result in a reduced measurement range of the equipment (although the accuracy will not be affected).

A.5 Test Equipment Applications of the Educator

The Educator transmitter and receiver units form useful pieces of test equipment in a fibre-optics and general optics laboratory, production facility or at an installation site, and may be used for many other test applications besides the measurement of fibre attenuation as described in the previous sections.

The transmitter may be used as a versatile optical source for testing out optical receivers. Possible test configurations include:

1. utilising the internal pseudo-random and square wave generators to provide a realistic data format (the signal generator output may be monitored at the RS232/Sig. Gen. Monitor socket);
2. connecting an external signal generator to the TTL input to produce data trains up to a rate of 0.5 MBit/s;
3. using an analogue signal generator in conjunction with the transmitter in analogue mode, to produce optical signals that correspond to those formed by a dispersive medium, for testing digital receivers. This analogue set-up may also be used to test analogue optical receivers.

In all of the above configurations, the output power control, which has a range of approximately 20dB, provides a useful feature for receiver sensitivity testing.

Equipment terminated with connectors other than AMP DNP may also be tested by using an appropriate interface cable between the Educator and the equipment under test, or by utilising the infra-red l.e.d.

The Educator receiver may be used in the digital or analogue mode to test out optical transmitters. Also, it may be used in the analogue mode for giving an audible indication of the presence of infra-red radiation at locations such as the remote ends of optical links, cable breaks, bad joints and "lossy" optical coupling arrangements, if the transmitted signal contains audio frequency components. The receiver's digital circuitry with buzzer output also provides a convenient method for detecting infra-red radiation. A short length of optical cable may be used as a probe for optical radiation detection purposes.

It is also possible to measure the optical absorption or reflection properties of various materials at the wavelengths of the emitting devices by detecting the level of radiation at the receiver (in analogue mode), with the transmitter set on 'square wave' acting as the source. The material to be tested is inserted between the transmitter and receiver units (or between the ends of the cable attached to these) for transmission experiments, and at a suitable angle for reflection measurements. A DVM set to a.c. may be used to accurately measure the signal at either the 'high Z' or 'low Z' analogue outputs. For accurate measurements over free-space, it is important to minimise the contribution to the signal of ambient light from mains lighting. Also, when very small signal levels are being measured, the effect of electrical noise of the receiver may be taken into account by using the square root of the difference of the squares formula, which has been used in Steps f and g of section A.4.1, i.e., Signal Voltage = $[(\text{Total Voltage})^2 — (\text{Noise Voltage})^2]^{1/2}$.

APPENDIX A — EDUCATOR TRANSMITTER AND RECEIVER — BRIEF TECHNICAL DESCRIPTION

APP.A.1. Transmitter

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

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, depending on the state of the input voltage signal.

Analogue amplification is provided by MOS operational amplifiers, powered by a single supply voltage. Both analogue inputs are at the same phase.

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.

In the digital section, each input has a Schmitt trigger, and the RS232 voltage input is opposite in phase to both the TTL and CMOS inputs. The pseudo-random generator contains a 7-bit shift register tapped at the output of the sixth and seventh stages. These taps are connected to an exclusive OR gate, whose output is fed into the first stage of the register.

The threshold detector is a device which has a two state output, dependent on the input voltage. When the input voltage is below a threshold, then the output is LOW, and when the input is higher than this threshold voltage, the output becomes HIGH.

APP.A.2. Receiver

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

When the receiver is in the analogue mode, the analogue output signals are directly proportional to the received a.c. optical signal. In the digital mode, the digital output signals are either ON or OFF, depending on the level of the received optical signal and also the setting of the digital threshold sensitivity control.

The transimpedance amplifier (see Section B.2.4.2) incorporates a CMOS switch in the feedback path, which shuts off d.c. when the receiver is in analogue mode, thus reducing the likelihood of receiver overload.

A class B power amplifier is used to drive the loudspeaker and also the low impedance output. When this output is connected up, the loudspeaker is automatically switched off.

The RS232 voltage output is opposite in phase to both the CMOS and TTL outputs. In order for the RS232 voltage levels to function, the negative voltage supply must be connected. If this extra supply is not present, the voltage at the RS232 socket will correspond to an inverted CMOS output signal.

Variable sensitivity in the digital part of the circuitry is achieved by a voltage threshold control on the digital comparator. (The comparator is very similar to the transmitter's threshold detector, which is briefly described in Section APP.A.1).

The electrical noise at the analogue outputs (resulting in a low level hiss at the loudspeaker at high analogue gain) is due primarily to the thermal noise of the 5MΩ transimpedance resistor. This noise is not, however, a major factor in determining the digital circuitry's sensitivity. Since the digital circuit operates down to d.c. frequency, it is d.c. coupled, and the dominant causes limiting its sensitivity are amplifier d.c. offsets and the receiver diode's dark current.

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

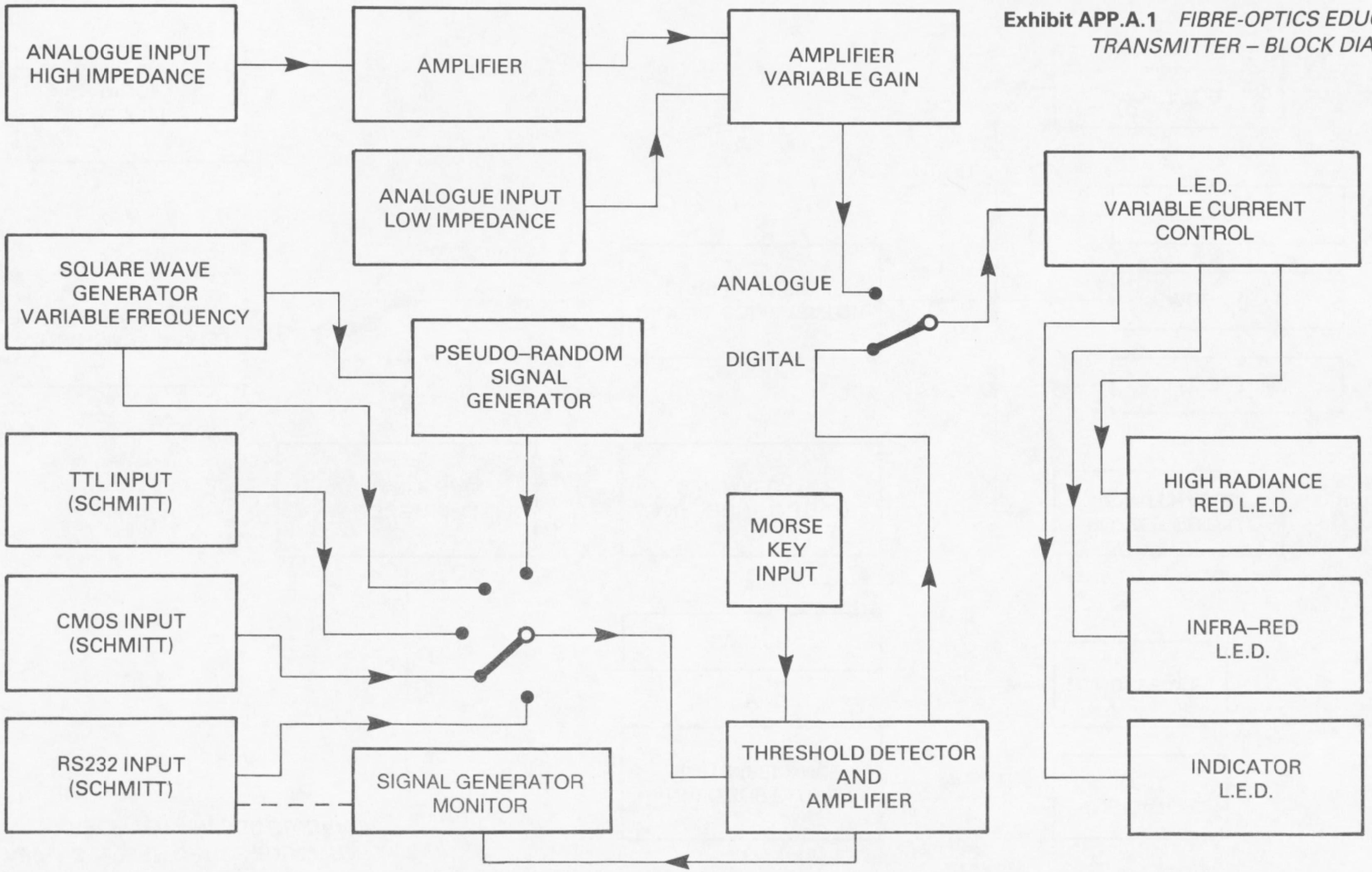
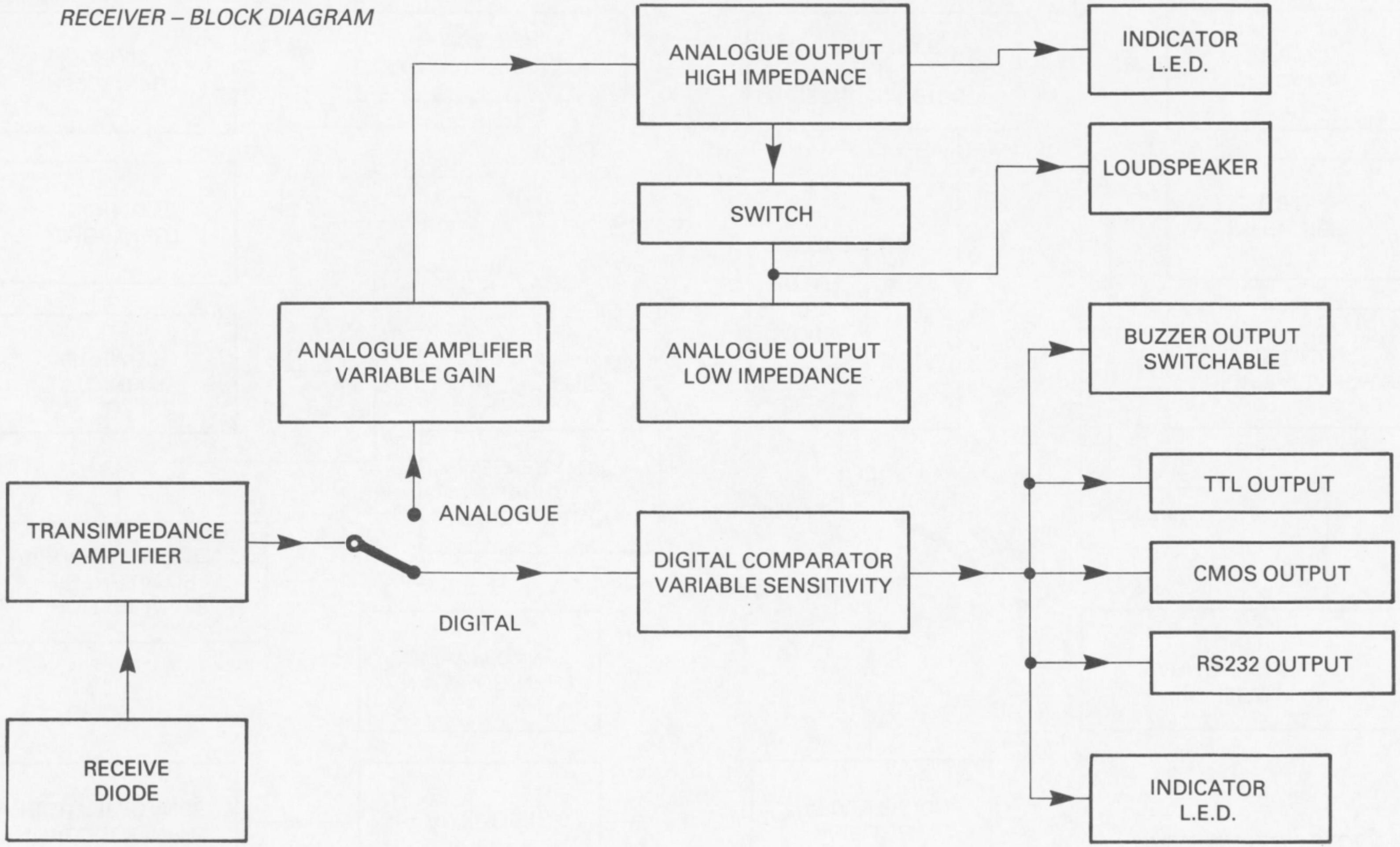


Exhibit APP.A.2 *FIBRE-OPTICS EDUCATOR RECEIVER – BLOCK DIAGRAM*



APPENDIX B - EDUCATOR SPECIFICATIONS

a) Transmitter/Receiver Combination

Bandwidth:
Analogue: 25Hz to 25kHz (3dB points)
Digital: d.c. to 20kBit/s

Range for analogue transmission (better than 40dB S.N.R.): 25dB
Range for digital transmission (better than 1 in 10^9error rate): 25dB

(The above transmission ranges are for a fibre link, with the high radiance red l.e.d. being used to launch light into a 1mm plastic fibre).

Attenuation measurement range:
Standard Method 1: 25dB
Standard Method 2: 30dB
High Loss Method 1: 40dB
High Loss Method 2: 50dB

Operating Temperature Range: 0°C to 50°C

Optical Connectors: AMP OPTIMATE* DNP

b) Transmitter

Typical power launched into 1mm plastic fibre from high radiance red l.e.d: 20µW peak (at maximum setting) at 9V supply.

Typical output power from infra-red l.e.d: 2mW (at maximum setting) at 9V supply.

Variable l.e.d drive control: 20dB range (±3dB), for high radiance red l.e.d.

Peak Output Wavelength:
High Radiance red l.e.d: 660nm
Infra-red l.e.d: 940nm

Schmitt Threshold Levels:
TTL: 1.2V and 1.6V
CMOS: 2.8V and 3.8V
RS232: 0.35V and 0.8V (optical output phase opposite to TTL and CMOS)

Input Impedance:
TTL: 47kΩ to +3V
CMOS: 52kΩ to ground
RS232: 4kΩ to ground

Phase of Digital Signal:
Input 'mark' gives **no** light at output
Input 'space' gives light at output

Signal Generator:
— 127 bit length pseudo-random generator
— Variable clock rate: 20Hz to 4.5kHz (for square wave and pseudo-random signal)

Maximum Transmitted Data Rate for less that 10% pulse width distortion:
TTL: 0.5 MBit/s
CMOS: 100kBit/s
RS232: 0.5 MBit/s

Optical Rise and Fall times:
High Radiance Red l.e.d: Less than 200ns
Infra-red l.e.d: Less than 1µs

Signal Generator Monitor:
— Voltage level of approx. 200mVpp
— Inverted signal
— Output impedance 6kΩ. (The monitor may be terminated with 1nF capacitance to minimise clock breakthrough)

Analogue Voltage Gain:
Low impedance input: 1 to 25
High impedance input: 4 to 100

Maximum Voltage at l.e.d. for no clipping: 1Vpp

Input impedance at analogue sockets:
Low Z: 8Ω to ground
High Z: 20kΩ, capacatively coupled
High Z and Low Z inputs are at the same phase, and are inverted relative to optical output.

Analogue Frequency Response: 15Hz to 35kHz

*OPTIMATE is a trademark of AMP Incorporated

c) Receiver

Front-end transimpedance amplifier response (typical):
1V per µW at 660nm
2V per µW at 940nm

Photodiode type: Silicon p-i-n

Digital Bandwidth: d.c. to 20kBit/s (upper rate can be extended to 100kBit/s at the expense of more critical threshold adjustments)

Minimum power for better than 1 in 10^9 error rate: 50nW peak at 660nm

Variable Digital Threshold Voltage: 30mV to 1.25V (corresponding to 30nW and 1.2µW respectively at 660nm)

Digital Outputs:
- — TTL
- — CMOS (Positive level determined by supply voltage)
- — RS232 (Positive and Negative levels determined by supply voltages). Phase of RS232 is opposite to TTL and CMOS.

Fan Out:
TTL: Source 1.5mA, Sink 5mA
CMOS: Source 0.5mA, Sink 5mA
RS232: 470Ω output impedance

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

Analogue Frequency Response:
High Z output: 15Hz to 35kHz
Low Z output into greater than 36Ω: 25Hz to 30kHz
Low Z output into 8Ω: 90Hz to 30kHz

Minimum Power for 40dB Signal to Noise Ratio:
50nWpp at 660nm
25nWpp at 940nm

Typical analogue response at 660nm wavelength at minimum gain:
High Z: 0.2V/µW, non-inverted signal relative to transmitter input
Low Z: 1.1 V/µW, inverted signal relative to transmitter input

Analogue Voltage gain: 30dB range

Analogue Output Impedance:
High Z: 1kΩ
Low Z: less than 1Ω

Phase of Analogue Signal:
High Z output is inverted relative to optical input
Low Z output is non-inverted relative to optical input

Maximum power into 8Ω (and at loudspeaker) from Low Z output: 0.25W with 15V power supply

Maximum signal at Low Z output at zero load current: 2.5Vpp

Maximum signal at High Z output: 400mVpp

Optical Overload at 660nm:
overload on digital: 1.5µW
a.c. overload on analogue: 3µWpp
d.c. overload on analogue: 30µW with 9V power supply
55µW with 15V power supply
(at overload on analogue mode, the noise level increases significantly)

d) Power Supply:

9V PP3-type battery
Optional external d.c. supply:
1) Transmitter +9V to +15V (current is 25mA typical at 9V)
2) Receiver +9V to +15V (current is 25mA typical at 9V)
and -9V to -15V (5mA) for RS232 Interface

e) Physical Characteristics

Dimensions: 200 x 130 x 90mm approx. for each unit

Weight:
Transmitter: 750gm approx.
Receiver: 900gm approx.

While the information given 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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