

## UNIT 22: PROGRAMMABLE LOGIC CONTROLLERS

Unit code: A/601/1625      QCF level: 4      Credit value: 15

### OUTCOME 1

This tutorial covers all of outcome 1. The material is quite suitable for anyone wishing to study this interesting subject and does not require a lot of mathematical knowledge. Obviously, access to suitable computer software such as Pneusim Pro™ or Bytronics™ simulation software will be a great help. You do need to have a reasonable knowledge of computer technology and a good background understanding of industrial processes.

### SYLLABUS

#### 1. Understand the design and operational characteristics of a PLC system

*Design characteristics:* unitary; modular; rack-mounted

*Input and output devices:* mechanical switches; non-mechanical digital sources; transducers; relays

*Communication links:* twisted pair; coaxial; fibre-optic; networks

Internal architecture: central processor unit (CPU); arithmetic logic unit (ALU); storage devices; memory opto-isolators; input and output units; flags; shift; registers

*Operational characteristics:* scanning; performing logic operations; continuous updating mass input/output (I/O) copying

Learning outcomes On successful completion of this unit a learner will:	Assessment criteria for pass The learner can:
LO1 Understand the design and operational characteristics of a PLC system	1.1 evaluate the design characteristics of typical programmable logic devices 1.2 describe different types of input and output devices 1.3 evaluate the different types of communication link used in programmable logic control systems 1.4 describe the internal architecture and operational characteristics of the CPU of a typical programmable logic device

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  - Testing
  - Programming Methods
3. **STYLES**
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  - Modular
  - Rack Mounting
4. **INPUT SENSORS**
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5. **OUTPUT DEVICES**
  - Relays and Thyristors
6. **COMMUNICATING**
  - Twisted Pair
  - Coaxial Cable
  - Fibre Optic



The next diagram shows a very oversimplified diagram of the structure. The Central processing Unit controls everything according to a programme stored in the memory (RAM or ROM). Everything is interconnected by two busses, the address bus and the data bus (shown as a single red line). The system must be able to communicate with external devices such as programmers, display monitors and Analogue/Digital converters.

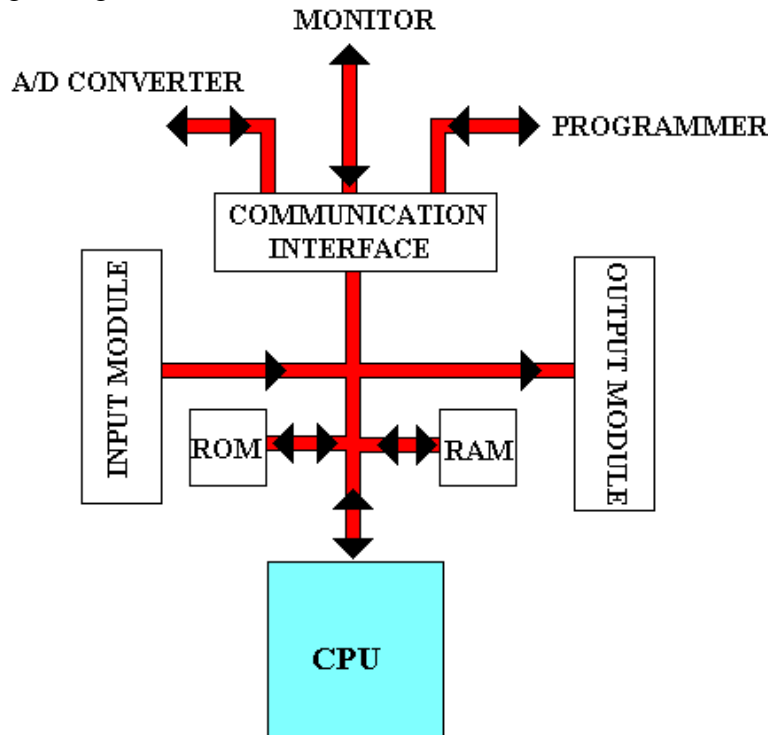


Figure 2

## THE CPU

The next diagram shows the internal structure of the Central Processing Unit in its simplest form. It usually contains (but sometimes it is external and separate) an Arithmetic Logic Unit. This is the part that performs operations such as adding, subtracting, multiplying, dividing and comparing. The Buffers act as switches that isolate the lines on either side if required. A, B and C are latches that pass the data from one side to the other when told to do so.

Digital data is passed around through busses. The busses were originally 4 parallel lines but as technology progressed this became 8, then 16 and now 32. Digital numbers and how they are put onto busses is explained in outcome 2.

The busses are connected to memory chips. In a memory chip, digital numbers are stored in locations. The number is the data and the location is the address. Data can be sent to or brought from memory locations by either writing it or reading. The lines labelled R and W are signal lines that make the CPU read or write.

A REGISTER is a temporary memory location where data is put to be manipulated and then taken away.

The CLOCK line is pulsed at a regular rate to synchronise the operations. Currently this has reached a rate measure in Giga Hertz (1000 million times a second).

The Reset line when activated resets the programme Counter to Zero.

The operations are carried out to a set of instructions (the programme) and these are decoded in the ID (Instruction Decoder)

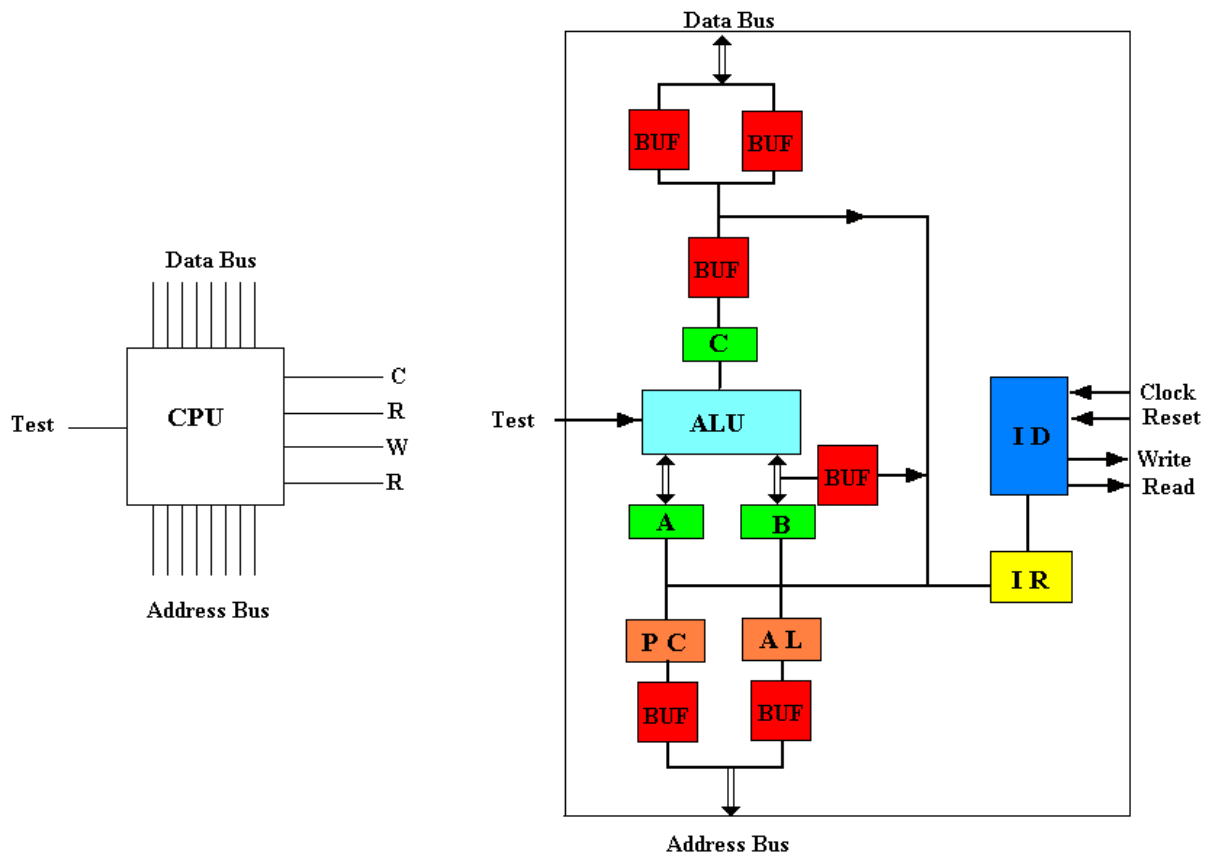


Figure 3

## INPUT MODULE

The input module connects the input terminals to the rest of the system. Each terminal is usually electrically isolated from the internal electronics by OPTO ISOLATORS. This is a way of passing on the status of the input (on or off) by use of a light emitting diode and phototransistor. A typical opto isolator is shown. They have the advantage of reducing the effects of spurious pulses generated from electro magnetic sources. It is also a safety feature to prevent live voltages appearing on the input lines in the event of a fault.

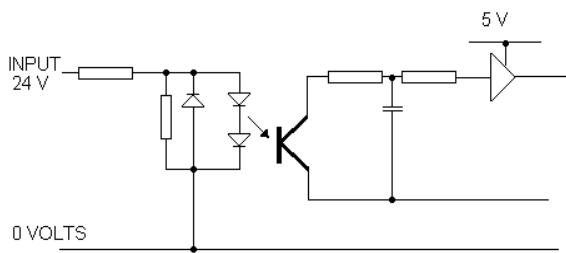


Figure 4

## OUTPUT MODULE

The output module contains switches activated by the CPU in order to connect two terminals and so allow current to flow in the external circuit. This will activate devices such as pneumatic solenoid valves, hydraulic solenoid valves, motors, pipe line valves, heating elements and so on. Care must be taken not to overload the contacts. The switch may be a transistor or a relay. The diagram shows a typical output arrangement. The terminals are numbered and these numbers are used in the programme.



Figure 5

## MEMORY

The PLC has RAM (Random Access Memory) and ROM (Read Only Memory). The programme, when written and entered, is stored in the RAM. The ROM contains permanent programmes such as that required to monitor the status of the inputs and outputs and to run diagnostic tests.

## TESTING

The PLC has certain diagnostic, monitoring and testing facilities within the software. Light Emitting Diodes (LED) shows the status of the inputs and outputs. It is also possible to fix a bank of switches to the input side and test a programme by setting the switches to a certain state and seeing if the appropriate output action is taken. The most advanced method connects the PLC to a computer with appropriate software and runs a complete simulation of the system being controlled showing the status of everything.

## PROGRAMMING METHODS

The P.L.C. is programmed with logical commands. This may be done through a programming panel or by connection to a computer. There are several types of programming panels varying in complexity from a simple key pad to a full blown hand held computer with graphics screen. Computers are able to run programming software with graphics, simulators, diagnostics and monitoring. This could be a laptop carried to the site or a main computer some distance away. Often the programme is developed and tested on the computer and the programme is transferred to the PLC. This could be by a communication link, by a magnetic tape, compact disc or more likely with an EEPROM. The EEPROM is a memory chip to which the programme is written. The chip is then taken to the PLC and simply plugged in. The memory cannot be overwritten but it can be erased by exposure to UV light and reused.



Figure 6 Typical Programming Panel

## 3. STYLES

The main styles are UNITARY, MODULAR and RACK MOUNTING.



Figure 7. A range of styles

## UNITARY

The Unitary PLC contains every feature of a basic system in one box. They are attached to the machine being controlled.



Figure 8 Unitary PLCs

## MODULAR

These use a range of modules that slot together to build up a system. The basic modules are the power supply, the main module containing the CPU, the input module and the output module. Other modules such as A/D converters may be added. The main advantage is that the number of input and output terminals can be expanded to cope with changes to the hardware system.

Modular PLCs may be designed to be fixed direct to a back panel. Usually they are arranged on a rack or rail and mounted inside a large cabinet for protection and security.



Figure 9 Modular PLCs

## RACK MOUNTING

This is a similar concept to the modular design but the modules are on standard cards that slot into a standard rack inside a cabinet. These are flexible and allow expansion of the system.

#### 4. INPUT SENSORS

A range of sensors are needed to provide feed-back to the input terminals of the PLC. These measure or monitor many things such as:

- Position (linear and angular)
- Temperature
- Speed
- Pressure
- Weight
- Quantity
- Flow rate
- Depth
- Density
- Acidity
- Content (e.g. the carbon dioxide in a flue gas)
- Voltage
- Current
- Torque
- Power

Some of the sensors simply determine if something is on or off, such as:

- Simple switches (like start and stop)
- Micro switches
- Proximity switches
- Relays
- Voltage sensing relays
- Outputs of A/D converters



Figure 10 A Range of Sensors

In order to control the position of actuators (electrical, hydraulic or pneumatic), sensors may be placed on them or on the machine that they move. These detect when the correct position has been reached (e.g. a switch to indicate that a guard is in place). If the control valves are electrically (solenoid) operated, simple mechanically operated electric switches may be used (micro switches).

Switches and valves may be normally open (NO) or normally closed (NC).

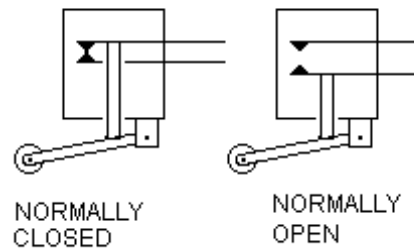


Figure 11

In many cases it is best to fit the sensor to the actuator. Cylinders are often fitted with reed switches, which are activated by a magnet fixed in the piston. These only work if the barrel is made of non-magnetic material such as aluminium.

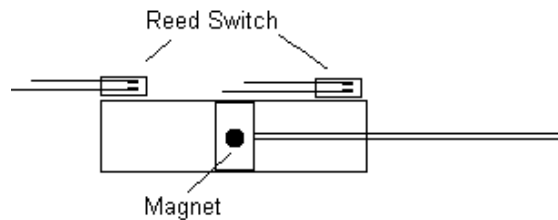


Figure 12

There are ranges of devices, which switch on when something comes close to them. These are called PROXIMITY switches. They work on various electronic principles. The switching signal is turned on or off when the sensor is activated. Some will detect any material, some will only detect iron, and some will only detect metals in general. In this way, for example, it is possible to detect if the object is metal or plastic).

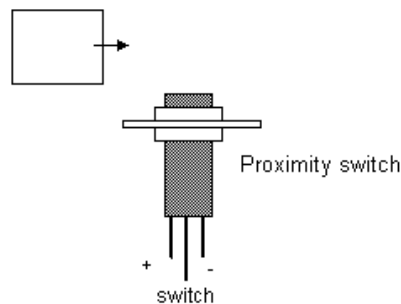


Figure 13

A similar sensor uses light beams and sensors. Often the light used is infrared. These sensors switch on or off when the light beam is interrupted. These might be used for detecting an item passing on a conveyor belt and activate a cylinder accordingly. They are widely used for counting the number of objects passing by.

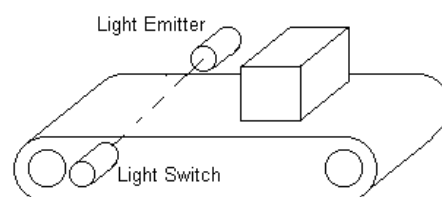


Figure 14



## VOLTAGE SENSING RELAYS

These are used with analogue devices that produce a voltage representing the variable (e.g. a DC tachometer for measuring speed). The unit is adjusted to trip a relay when a certain point is reached (e.g. to indicate a motor has reached its correct speed). Typically 24 V is applied to the PLC input. Another example is a level measuring device that produces a voltage proportional to level and when the level reaches a certain depth, the voltage sensing relay trips and activates the PLC input.

## INPUT VOLTAGES

Typical input voltages are 12V and 24V but sometimes they can be as low as 5V (the normal computer bus voltage) or as high as 110 or 240 V (normal mains a.c. levels). They may accept d.c. or a.c. No two PC's are the same so you must take care to check the input rating.

## 5. OUTPUT DEVICES

Output devices are switched on by the PLC. This can be anything electrical such as the following.

- D.C. motor (e.g. to start a conveyor belt).
- A.C. motor (e.g. to start a pump).
- Linear electric actuator
- Solenoid valve in hydraulic or pneumatic systems.
- Solenoid valves on plant systems (e.g. to open a pipe line valve or allow steam into a heater).
- Lights (e.g. traffic lights)
- Alarms (e.g. fire alarm or oil level alarm).
- Heating elements (e.g. heater in a hydraulic tank)

Typical switching voltages are 12V, 24V, 110 and 240 V. In many cases, the PLC cannot switch the device directly because of the high voltage or current needed. In this case power switching relays or transistors are used.

## RELAYS and THYRISTORS

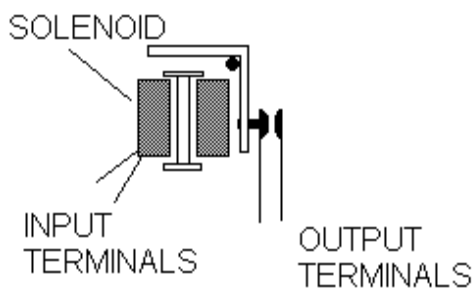


Figure 15 Relay

Modern equipment is likely to use electronic devices such as Thyristors that can switch large electric currents on or off on application of a small current to a control terminal.

Some output switches are not able to switch high currents directly and the module would be damaged by high currents. They have to be interfaced to the hardware by relays. A relay is used to allow a small current to operate devices with high current ratings. The relay is a mechanical switch and the contacts are moved by a solenoid.



Figure 16 Thyristor

## 6. COMMUNICATING

A PLC must communicate with other devices. This is needed to link them to programming devices and to other equipment. Many modern instruments and other equipment send and receive information digitally so they are connected to the PLC by some form of network. The PLC's may form part of a larger system controlled by a mainframe computer. The PLCs must be linked to each other and to the computer by a network. This is covered in Outcome 2. The diagram shows a network connecting a mainframe computer to a series of PLCs. Each PLC controls a different part of the overall process. These may be embedded and dedicated microcontrollers (PICs) covered in outcome 4.

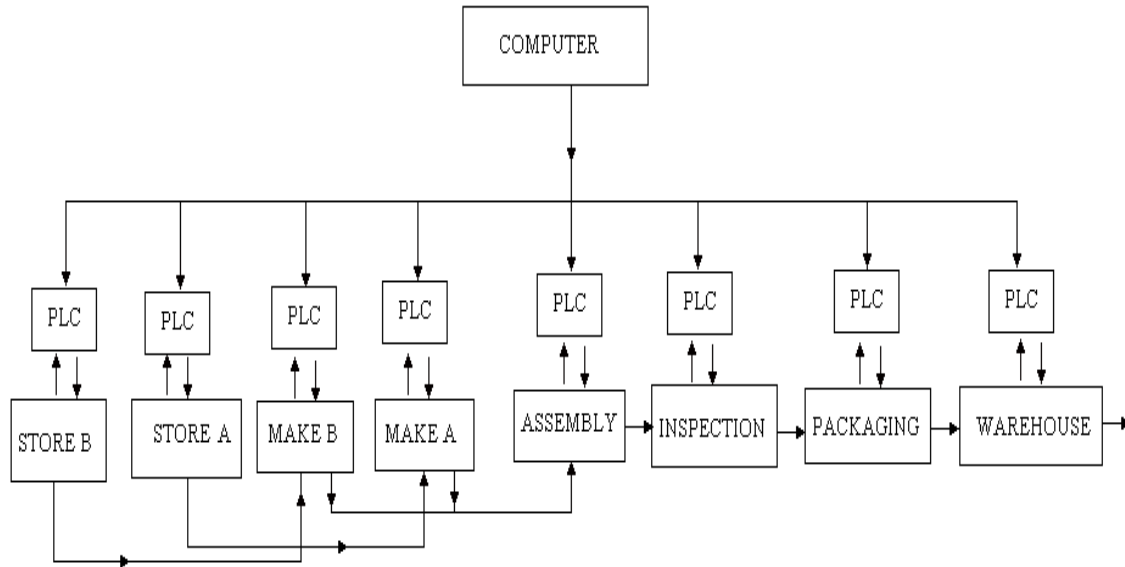


Figure 17

Links may be made through cables using serial data or parallel data. Parallel data may be through a ribbon cable (e.g. the ribbon cable linking a disc drive to a motherboard in a computer) or a screened multi-core cable (e.g. the printer cable on a computer). Serial data only requires two wires (e.g. a modem) although often many more are used (e.g. the Com port on a computer is serial but uses many wires).

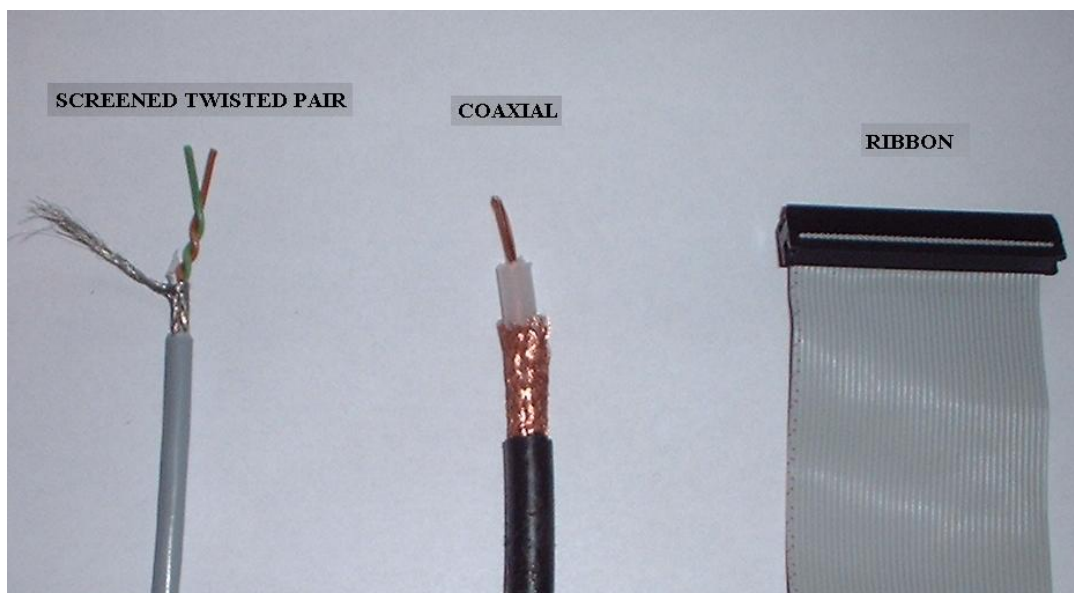


Figure 18

## **TWISTED PAIR**

When information is sent along two wires, often a twisted pair is used. An example of this is the ordinary copper wire that connects your landline telephone to the network. To reduce the chances of picking up stray electro-magnetic signals from other lines running along side it, the two insulated copper wires are twisted around each other. More than one twisted pair may be placed inside an outer insulated layer and sometimes the cable is screened or shielded by a grounded outer layer. Twisted pairs come with each pair uniquely colour coded when it is packaged in multiple pairs. Different uses such as analogue, digital, and Ethernet require different pair multiples. Although the twisted pair is often associated with home use, a higher grade of twisted pair is often used for horizontal wiring in LAN installations because it is less expensive than coaxial cable.

## **COAXIAL CABLES**

Coaxial cable is the kind of cable used to connect a TV set to the aerial. It is also used to connect telephone exchanges to the telephone poles near to users. It is also widely used to connect computers and PLC's with systems such as Ethernet and other types of local area network (LAN).

The cable has an inner conductor surrounded by a concentric conductor (coaxial with it) made from copper mesh and separated by a layer of insulation. The outer layer is usually grounded. They can carry information for a great distance.

## **FIBRE OPTICS**

Fibre optic cables are basically thin glass strands. When light is shone into one end of a strand (e.g. by a laser) it is carried inside the fibre over enormous distances without losing its strength. The light can be pulsed to carry digital information at enormous speeds and rates. Optical fibre carries much more information than conventional copper wire and is in general not subject to electromagnetic interference and the need to retransmit signals. Many strands can be bundled together to give many more channels. Computers needing high speed data transmission usually have fibre optic links to the server.

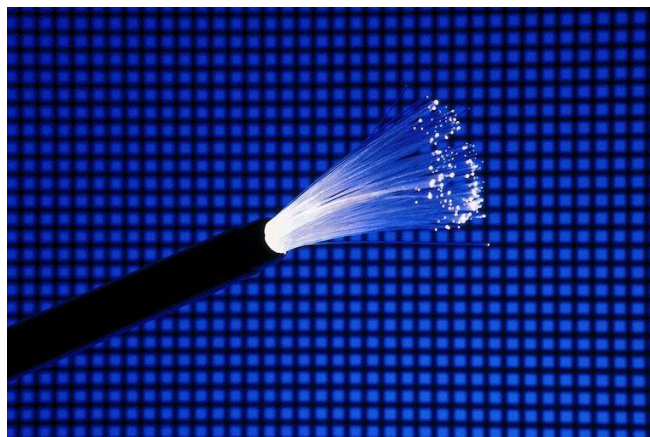


Figure 19 Optic Fibre Cable