INTRODUCTION TO DIGIAC 1750
TRANSDUCERS & INSTRUMENTATION TRAINING SYSTEM

The digiac 1750 (D1750) unit is a comprehensive transducer and instrumentation trainer with examples of a full range of input and output transducers, signal conditioning circuits and display devices. Transducer experiments I & II will be performed on this set. The unit is self contained and enables the characteristics of individual devices to be studied and also their interconnection to form complete closed loop systems. The only additional items recommended are an electronic voltmeter and an oscilloscope.

1. BASIC CONTROL SYSTEMS EQUIPMENT

1.1) Open Loop System

![Open Loop System Diagram](image)

Fig. 1. represents a block diagram of an open loop system. A reference input, or command signal, is fed to an actuator which operates on the controlled variable to produce an output. The output magnitude depends on the magnitude of the reference input signal but the actual output magnitude for a particular input may not remain constant but may vary due to changes within or exterior to the system.

For example, in a simple room heating application, a heater set for a certain output will result in a certain room temperature. The actual temperature will depend on the ambient temperature outside the room and also whether the doors and windows are open or closed.

1.2) Closed Loop System

![Closed Loop System Diagram](image)

Fig. 2 shows a block diagram of a practical closed loop system. With this system, the output magnitude is sensed, fed back and compared with the desired value as represented by the reference input. Any error signal is fed to the actuator to vary the controlled variable to reduce this error.

The system thus tends to maintain a constant output magnitude for a fixed magnitude input reference signal. The feedback signal is effectively subtracted from the reference signal input to obtain the error signal and hence the system is referred to as a negative feedback system.

Signal conditioning may consist of signal amplification, attenuation or linearising, waveform filtering or modification, conversion from analogue to digital form or may be a matching circuit,
these being necessary to convert the output from one circuit into a form suitable for the input to the following circuit or to improve the system accuracy.

For a particular industrial process there may be more than one controlled variable and each of the controlled variables will have its own closed loop control system.

The controlled variable may be:
- Position (Angular or linear)
- Temperature
- Pressure
- Flow rate
- Humidity
- Speed
- Acceleration
- Light level
- Sound level

The control system may operate using pneumatic, hydraulic or electric principles and the sensors used for the measurement of the controlled variable must provide an output signal in a form suitable for the system in use. This will normally involve a conversion from one energy system to another and devices used to accomplish this energy conversion are referred to as transducers. Sensors and actuators are both forms of transducer, sensors representing input transducers and actuators representing output transducers.

2. INPUT TRANSDUCERS

2.1) Resistance Transducers:

The unit consists basically of a "track" having a fixed resistance and a variable contact which can be moved along and make continuous contact with the track. With a voltage applied across the ends of the fixed track, a variable voltage can be obtained from the variable contact as it is moved along the track. The output voltage will depend on the position of the variable contact and hence the output voltage indicates the position of the variable contact.

If the track resistance is proportional to the length along the track (i.e., linear track), the output voltage will be proportional to the movement of the variable contact and the unit is suitable for use as a position transducer. These units are referred to as linear types. Another type of unit has a track with the resistance not proportional to the length along the track. These are referred to as logarithmic types and are not suitable for use as positional transducers.

The track may comprise a film of carbon formed on a substrate or may be a length of resistance wire wound on an insulating former. The unit may be constructed in a rotary form or may be straight.

On Digiac 1750, in addition to carbon track and wirewound track resistance transducers, a further rotational resistance transducer is fitted to the motorised shaft assembly. This unit is capable of continuous rotation, the track covering almost the full 360 degrees.

The 10 turn resistor is of value 10 KΩ with a maximum nonlinearity of 0.25 %. The "fine" dial is calibrated 0-100 in steps of 2 and the "coarse" reading is calibrated 0-10 thus enabling readings to be obtained from the dial with a resolution of 1, this representing a resolution of 10Ω.

2.2) Transducers for Temperature Measurement:

On digiac 1750 the active transducers are contained within a clear plastic container which includes as a heater. In the case of the N.T.C. thermistors and the thermocouples, a separate unit is mounted outside the heated enclosure.
2.2.A) The I.C. Temperature Transducer:

This is an integrated circuit containing 16 transistors, 9 resistors and 2 capacitors contained in a transistor type package. The device reference number is LM335 and it provides an output of 10mV/°K. A measurement of the output voltage therefore indicates the temperature directly in °K. A 2-pin socket is provided for the connection of an external LM335 unit if desired. The output from the "int" socket indicates the temperature within the heated enclosure.


The construction of the platinum R.T.D. transducer is shown in fig 3., consisting basically of a thin film of platinum deposited on a ceramic substrate and having gold contact plates at each end that make contact with the film. The resistance of the film increases as the temperature increases, i.e. it has a positive temperature coefficient. The increase in resistance is linear, the relationship between resistance change and temperature rise being 0.385Ω/°C for the unit.

\[
R_t = R_0 + 0.385t
\]

where \( R_t \) = Resistance at temperature \( t \)°C and \( R_0 \) = Resistance at 0°C = 100Ω

Normally, the unit would be connected to a D.C. supply via a series resistor and the voltage drop across the transducer is measured. The current flow through the transducer will then cause some self heating, the temperature rise due to this being of the order of 0.2°C/mW dissipated in the transducer.

2.2.C) The N.T.C.(negative temperature coefficient) Thermistor:

The construction of the N.T.C. thermistor is shown in fig 4., consisting basically of an element made from sintered oxides of metals such as nickel, manganese and cobalt and with contacts made to each side of the element. As the temperature of the element increases, its resistance falls, the resistance/temperature characteristic being nonlinear.

The resistance of the thermistors provided with the digiac 1750 unit is of the order of 5KΩ at an ambient temperature of 20°C(293°C).
The relationship between resistance and temperature is given by the formula:

$$R_2 = R_1 e^{(B/T_2) - (B/T_1)}$$

where
- $R_1$ = Resistance at temperature $T_1$°K
- $R_2$ = Resistance at temperature $T_2$°K
- $e$ = 2.718
- $B$ = Characteristic temperature = 4350°K

Two similar unit are provided, one being mounted inside the heated enclosure, this being connected to the +5V supply and designated A. The other is mounted outside the heated enclosure, is connected to the 0V connection and is designated B.

### 2.2.D) The Type "K" Thermocouple Temperature Transducer:

![Figure 5.](image)

Fig 5. shows the basic construction of a thermocouple, consisting of two wires of different materials joined together at one end. For the type "K" thermocouple the two materials are alumel and chromel.

With this arrangement, when the ends that are joined together are heated, an output voltage is obtained between the other two ends. The ends that are joined together are referred to as the "hot" junction and the other ends are referred to as the "cold" junction. The magnitude of the output voltage depends on the temperature difference between the "hot" and "cold" junctions and on the materials used. For the type "K" thermocouple the output voltage is fairly linear over the temperature range 0-100°C and of magnitude 40.28μV/°C difference between the "hot" and "cold" junctions.

Two thermocouples are provided with the digiac 1750 unit, one being mounted within the heated enclosure, this being the active unit which will have its "hot" and "cold" junctions at different temperatures in operation. The other unit is mounted outside the heated enclosure and is incorporated in a heat sink with an LM335 I.C. temperature transducer so that the temperature of the "cold" junction of the active thermocouple can be measured. This second thermocouple is connected in series with the first with the wires of the same material connected together. The second thermocouple does not contribute to the output voltage because its "hot" and "cold" junctions are maintained at the same temperature.

The output from the "ref" socket can be used as an indication of the ambient temperature outside the heated enclosure.

### 2.3) Transducers For Light Measurement:

The transducers are contained within a clear circular container and are illuminated by a lamp which is placed centrally.
2.3.A) The Photovoltaic Cell:

![Figure 6](image)

Fig 6. shows the basic construction of a semiconductor photovoltaic cell, consisting basically of a two layer silicon device. A thin layer of p-type material is formed on an n-type substrate. When light falls on the junction of the two materials, a voltage is developed with the n-type material positive with respect to the p-type. The output voltage depends on the magnitude of the light falling on the device and is a maximum of the order of 0.6V.

2.3.B) The Phototransistor:

![Figure 7](image)

The basic construction and the circuit used are shown in fig 7. The unit is basically an npn three layer semiconductor device as for a normal transistor, the connections to the n, p and sections being labelled e(emitter), b(base) and c(collector). The collector being connected to the positive of a dc supply via a load resistor R. The base connection is not used in this circuit but is available for use in other circuits if desired. With no light falling on the device there will be a small current flow due to thermally generated hole-electron pairs and the output voltage from the circuit will be slightly less than the supply value due to the voltage drop across the load resistor R. With light falling on the collector-base junction the current flow increases. With the base connection open circuit, the collector-base current must flow in the base-emitter circuit and hence the current flowing is amplified by normal transistor action. The output voltage from the circuit falls as the current increases and hence the output voltage is dependent on the light falling on the device.

2.3.C) The Photoconductive Cell:

![Figure 8](image)
Fig 8. shows the basic construction of a photoconductive cell, consisting of a semiconductor disc base with a gold overlay pattern making contact with the semiconductor material. The resistance of the semiconductor material between the gold contacts varies when light falls on it. With no light on the material, the resistance is high. Light falling on the material produces hole-electron pairs and reduces the resistance.

2.3.D) The P.I.N. Photodiode:

![Diagram of P.I.N. Photodiode]

Fig 9. shows the construction of the P.I.N. photodiode. This differs from the normal pn diode by having a layer of intrinsic or very lightly doped silicon introduced between the p and n sections. This reduces the capacitance of the device and as a result, the response time is reduced. The device can be operated in one of two ways:
1) as a photovoltaic cell, measuring the voltage output
2) by measuring the small output current and converting this to a voltage

2.4) Transducers for Linear Position or Force:

2.4.A) The Linear Variable Differential Transformer (LVDT):

![Diagram of LVDT]

The construction of an LVDT is shown in fig 10., consisting of three coils mounted on a common former and having a magnetic core that is movable within the coils. The center coil is the primary and is supplied from an ac supply and the coils on either side are secondary coils and are labelled A and B. Coils A and B have equal number of turns and are connected in series opposing so that the output voltage is the difference between the voltages induced in the coils. With the core in its central position, there will be equal voltages induced in coils A and B by normal transformer action and the output voltage will be zero. With the core moved to the left, the voltage induced in coil A (Va) will be greater than that induced in coil B (Vb). There will therefore be an output voltage $V_{out} = V_a - V_b$ and this voltage will be in phase with the input voltage. With the core moved to the right, the voltage induced in coil A (Va) will be less than that induced in coil B (Vb) and again there will be an output voltage $V_{out} = V_a - V_b$ but in this case the output voltage will be 180° out phase with the input voltage. Movement of the core from its central position therefore produces an output voltage, this voltage increasing with the movement from the central position to a maximum value and then falling for further movement from this maximum setting.

2.4.B) The Linear Variable Capacitor:
A capacitor consists basically of two conducting plates separated by an insulator which is referred to as the dielectric. The capacitance of the device is directly proportional to the cross sectional area that the plates overlap and is inversely proportional to the separation distance between the plates. A variable capacitor can therefore be constructed by varying either the area of plates overlapping or the separation distance.

![Diagram of capacitor construction](image)

**Figure 11.**

Fig 11. shows the construction of the capacitor fitted in the digiac 1750 unit, this being fitted at the end of the coil former of the LVDT. This uses the magnetic slug core as one plate of the capacitor, the moving plate. The fixed plate consists of a brass sleeve fitted around the coil former. The capacitance magnitude depends on the length (l) of the slug enclosed within the brass sleeve, the capacitance increasing with increase of length l.

### 2.4.C) The Strain Gauge Transducer:

![Strain gauge diagram](image)

**Figure 12.**

Fig 12. shows the construction of a strain gauge, consisting basically of a grid of fine wire or semiconductor material bonded to a backing material. When in use, the unit is glued to the member under test and is arranged so that the variation in length under loaded conditions is along the gauge sensitive axis. Increase in loading then increases the length of the gauge wire and hence increases its resistance.

### 2.5) Transducers for Environmental Measurement:

#### 2.5.A) The Air Flow Transducer:

![Air flow transducer diagram](image)

**Figure 13**

Fig 13. shows the basic construction of an air flow transducer, consisting of two R.T.D.’s mounted in a plastic case. One of the devices has an integral heating element incorporated with it and the
other is unheated. The operation of the device uses the principle that when air flows over the R.T.D.’s, the temperature of the heated unit will fall more than that of the unheated one. The temperature difference will be related to the air flow rate and this in turn will affect the resistance of the R.T.D.’s. With the digiac 1750 unit, the transducer is enclosed in a clear plastic container and provision is made for air to be pumped over the device.

2.5.B) The Air Pressure Transducer:

![Figure 14](image)

Fig 14. shows the basic construction of an air pressure transducer, consisting of an outer plastic case which is open to the atmosphere via two ports. Within this case is an inner container from which the air has been evacuated and on the surface of this, a strain gauge Wheatstone Bridge circuit is fitted.

The air pressure in the outer container will produce an output from the bridge and variation of the pressure will produce a variation of this output.

2.5.C) The Humidity Transducer:

![Figure 15](image)

Fig 15. shows the construction of a humidity transducer, consisting basically of a thin diaphragm disc of a material whose properties vary with humidity. Each side of the disc metallised and the unit forms a capacitor, the capacitance varying with the humidity. The unit is housed in a perforated in a plastic case. The unit is connected in series with a resistor with the output taken from the resistor. With an alternating voltage applied to the input, the output voltage will vary humidity due to the variation of capacitance of the transducer.

2.6) Transducers for Rotational Speed or Position Measurement:
2.6.A) The Slotted Opto Transducer:

![Figure 16.](image1)

Fig 16. shows the construction of a slotted opto transducer, consisting of a gallium arsenide infra red L.E.D. and silicon phototransistor mounted on opposite sides of a slot, each being enclosed in a plastic case which is transparent to infra red illumination. The slot between them allows the infra red beam to be broken when an infra red opaque object is inserted. The collector current of the phototransistor is low when the infra red beam is broken and increases when the beam is admitted. Positive voltage pulses are obtained from the emitter circuit of the phototransistor each time the beam is admitted and hence the device is suitable for counting and speed measurement applications.

2.6.B) The Reflective Opto Transducer:

![Figure 17.](image2)

Fig 17. shows the construction of a reflective opto transducer, consisting of an infra red L.E.D. and phototransistor. The components are arranged so that the beam is reflected correctly if a reflective surface is placed at the correct distance. A non reflective surface breaks the beam. Three separate units are provided with the digiac 1750 unit, these being mounted in line vertically. The reflective surface is a gray-coded disc, this being fixed approximately 4mm from the transducers. The black areas break the beam and produce a low output from the associated transducer and the clear areas reflect the beam and produce a high output. Three L.E.D.’s are provided to indicate when the beam is reflected from the respective transducer unit. The output A is the least significant bit and the output C is the most significant bit. The digiac 1750 unit operates as a rotational angular position transducer.

2.6.C) The Inductive Transducer:
Thick slotted disc
Coil
Ferrite bobin

Figure 18.

Fig 18. shows the basic construction for the device provided with the digiac 1750. This consists of a 1mH inductor and a slotted aluminium disc fitted to the drive shaft which rotates above this. The inductance of the unit varies with the position of the slot and with an aluminium disc the inductance increases with the slot positioned directly above the inductor.

2.6.D) The Hall Effect Transducer:

The Hall effect principle:
When a direct current is passed between two opposite faces of a rectangular section conductor and there is a magnetic field through the material with its axis at 90° to the current flow, then there is a direct voltage developed between the two faces that are mutually at 90° to the current and the magnetic field. The magnitude of the voltage is proportional to the current and the magnetic flux. The polarity of the voltage depends on the directions of the current and flux.

Sensor

Figure 19.

Fig 19. shows the layout of the Hall effect transducer assembly fitted to the digiac 1750 unit. On digiac 1750 unit, two outputs are provided for the Hall effect transducer. The output voltage from one increases with the magnetic field and that from the other decreases with the magnetic field.

2.6.E) The D.C. Permanent Magnet Tachogenerator:

A d.c. permanent magnet tachogenerator consists basically of a set of coils connected to a commutator, these rotating inside a permanent magnet stator. With the coils rotating, an alternating e.m.f is generated in them and the commutator converts this to d.c. The magnitude of the generated e.m.f. is proportional to the rotational speed and the polarity depends on the direction of rotation.

2.7) Transducers for Sound Measurement:

2.7.A) The Dynamic Microphone:
The basic construction of the dynamic microphone is shown in fig 20., consisting of a coil attached to a thin diaphragm, the coil being suspended in the field of a permanent magnet. The diaphragm moves in response to any sound vibration in the air and causes the coil to move in the magnetic field. This induces an e.m.f. in the coil, the magnitude of the e.m.f. being proportional to the sound amplitude.

2.7.B) The Ultrasonic Receiver:

The basic construction of an ultrasonic receiver is shown in fig 21. The device consists of a piece of ceramic material fixed to a small diaphragm inside the case of the unit. The operation of the device relies on the principle that certain ceramic materials produce a voltage when they are stressed. This is referred to as the "piezo-electric" principle. Vibration of the diaphragm stresses the ceramic material and hence produces an output voltage. The dimensions of the components are arranged so that there is resonance at around 40kHz. The device therefore gives an output for frequencies in the region of 40kHz. This is outside the normal audio range (maximum 20kHz) and hence referred to as ultrasonic.

3. OUTPUT TRANSDUCERS

3.1) Transducers for Sound Output:
3.1.A) The Moving Coil Loudspeaker:

The basic construction of a moving coil loudspeaker is shown in Fig. 22. In this device the diaphragm is attached to a large paper cone supported by a frame, the cone being free to move with the coil. An alternating voltage applied to the coil causes it to move forwards and backwards in the magnetic field. With the applied frequency in the audio range (say 50-20000Hz) the cone movement will cause a variation of the air pressure at this frequency and produce a tone that is audible to the human ear.

3.1.B) The Ultrasonic Transmitter:

The construction is basically the same as for the ultrasonic receiver but a transmitter device is arranged to have lower input impedance so that a larger power output is possible for a certain voltage input. The device is fed from 40kHz oscillator and used with the ultrasonic receiver.

3.1.C) The Buzzer:

The basic construction of the buzzer used in the digiac 1750 unit is shown in Fig. 23. This consists of a small transistorised oscillator circuit which feeds an alternating e.m.f. to an iron cored coil. The alternating magnetic field produced by the coil attracts and repels a small permanent magnet attached to a spring. This magnet vibrates against a diaphragm and creates a loud noise. Its output frequency depends on the d.c supply voltage. It produces 350, 400 and 450Hz, at 8, 12, 16V respectively.

3.2) Output Transducers for Linear or Angular Motion:

3.2.A) The D.C. Solenoid:
The basic construction of a d.c. solenoid is shown in fig 24., consisting basically of a soft iron core and actuator shaft which is free to move in a coil.

With the coil not energised, the core is held by a spring in its neutral position against a mechanical stop. When the coil energised with its rated voltage, the soft iron core is attracted into the coil and is held in this position. With the coil de-energised, the core returns to its neutral position under the action of the spring.

The voltage at which the core is pulled in by the coil is referred to as the "pull-in" voltage. With the de-energised and the core attracted, if the coil voltage is now reduced gradually, when the has fallen to a certain value the core will return to its neutral position under the action of the spring. This voltage is referred to as the "drop out" or "release" voltage.

3.2.B) The D.C. Relay:

The basic construction of a d.c. relay is shown in fig 25., consisting of a coil with an iron core and having a soft iron strip attached to a spring which holds the strip just above the core. Changeover contacts are attached to the strip and with the strip in its normal position it makes contact with one of the contacts, this being referred to as the "normally closed" contact. With the coil energised at its rated voltage, the core will be magnetised and attract the soft iron strip. This causes the connection to the normally closed contact to be broken and contact is made to the other contact, this contact being referred to as the "normally open" contact.

3.2.C) The Solenoid Air Valve:
Fig 26. shows the construction of the device fitted to the digiac 1750 unit. The construction is similar to the solenoid, but the soft iron core now operates on two valves, the inlet and the exhaust valves.

With the coil de-energised the core is held, by the return spring, in the position with the inlet valve closed and the exhaust valve open. In this position the cylinder port is connected to the exhaust port outlet. With the coil energised, the core is attracted and is held in the position with the exhaust valve closed and the inlet valve open. In this position the inlet port is connected to the pump and the cylinder port is connected to a pneumatic actuator. With the pump on, the pneumatic actuator will be operated when the coil is energised and illustrates the principle of electrical control of pneumatic devices.

3.2.D) The D.C. Permanent Magnet Motor:

The unit is identical with the tachogenerator unit but for motoring applications, a d.c. supply is fed to the armature coils. Current flowing in the armature coils in the permanent magnet field produces a force which causes the armature to rotate. The force acting on the armature is proportional to the current flowing. When the armature rotates, an e.m.f. is induced in the coils. This e.m.f opposes the applied voltage and is referred to as the "back e.m.f.". The armature will accelerate until the speed is such as to produce a back e.m.f approximately equal to the voltage applied to the armature. When a load is applied to the shaft, the speed will tend to fall, thus reducing the back e.m.f. This allows more current to flow from the supply and the current taken will adjust to the value that produces a torque just sufficient to balance the load torque. The speed will fall slightly with load due to the increase in voltage drop in the armature coils caused by the higher current.

4. DISPLAY DEVICES

4.1) The Timer/Counter:

The output display is provided by three 7-segment l.e.d.'s. The unit as provided can be used in three ways as follows:
1) time measurement, with the controls set to "time" and "free run":
2) counting, with the controls set to "count" and "free run"
3) count rate/sec or frequency, with the controls set to "count" and "1s"

In addition, with some signal conditioning it can be used for voltage measurement.

4.2) The L.E.D. Bargraph Display:

The construction of the bargraph device consists basically of 10 separate L.E.D.'s fitted in a 20-pin package. The light from each diode is collected by a light pipe and emitted from the top surface as a red bar. A dedicated I.C. driver chip controls the device and the provision is made for adjusting the voltage levels required for adjacent L.E.D.'s to light. With the device as fitted to the digiac 1750
unit the voltage level between adjacent L.E.D.’s is 0.5V and hence the minimum voltage for the last L.E.D. to light is 5V.

4.3) The Moving Coil Meter:

The moving coil meter consists of a coil suspended between the poles of a permanent magnet with a pointer attached to the coil, this moving over the meter scale. The coil is held in its center position by two hairsprings and a "set zero" screw is provided for adjustment of the pointer position to zero with no voltage applied to the meter. When current is fed to the coil via the hairsprings, a force is produced by interaction between the current and the magnetic field and the coil rotates. The direction of the rotation depends on the direction of the current flow and the magnitude of the rotation depends on the magnitude of the current flowing. The coil rotates until the force produced by the current is balanced by the force exerted by the hairsprings. Using the connections + and -, the voltage difference between any two points in a circuit can be measured. By connecting the - socket to 0V, the voltage of any point with respect to the 0V can be measured using the + connection.

5. SIGNAL CONDITIONING CIRCUITS

5.1) Amplifiers:

5.1.A) The Characteristics of D.C. Amplifiers:

The device consists of d.c. coupled stages of amplification that are capable of amplifying both d.c. and a.c. signals. The ratio of the output signal amplitude to the input signal amplitude is referred to as the gain of the circuit. Three amplifier circuits provided with the Digiac 1750 are specifically designed for amplification applications:
1) amplifier #1 having a variable preset gain over the range of 0.1 to 100 approximately. This amplifier is provided with an "offset" control.
2) amplifier #2 which is identical to amplifier #1.
3) x100 amplifier which has a fixed gain of 100 approximately and has no "offset" control provided.

5.1.B) The Characteristics of A.C. Amplifiers:

The capacitors in the input and output circuits remove any d.c. level and hence there is no d.c. offset problem with these amplifiers. The a.c. amplifier provided with the digiac 1750 unit has three fixed gain settings 10, 100 and 1000.

5.1.C) The Characteristics of a Power Amplifier:

The main characteristic of a power amplifier is the capability of a large power output. The device provided with the digiac 1750 unit has unity gain and a maximum current output of the order of 1.5A.

5.1.D) The Characteristics of a Current Amplifier:

The amplifier basically converts an input current to an output voltage. The device provided with the digiac 1750 unit is intended for use with the P.I.N. photodiode, giving an output voltage 10000 times the input currents.

5.1.E) The Characteristics of a Buffer Amplifier:
These amplifiers have a high input impedance and a low output impedance and are inserted in the circuit between a device having a high output impedance and one having a low input impedance. The characteristics are basically the same as those of the power amplifier but having a much lower output current capability (of the order of 20 mA max. for the devices provided with the digiac 1750 unit).

5.1.F) The Characteristics of an Inverter:

The inverter amp. reverses the polarity of the voltage applied to the input. The device provided with the digiac 1750 unit has a voltage gain of unity.

5.1.G) The Characteristics of a Differential Amplifier:

The output voltage from the device depends on the difference in voltages applied to the two inputs. For the device provided with the digiac 1750 unit, the output voltage is given by \( V_A - V_B \). Two differential amp. circuits are provided, the second being labelled "instrumentation amp.". This carries out the same basic functions as a differential amp. but has an improved common mode gain and it presents the same input impedance at each input.

5.2) Signal Converting Circuits:

5.2.A) The Characteristics of a Voltage to Current Converter:

The voltage to current converter converts an input voltage to a current output. Transfer ratio is 16mA/V.

5.2.B) The Characteristics of a Current to Voltage Converter:

The current to voltage converter converts an input current to an output voltage. The transfer ratio is 62.5 mA/mV.

5.2.C) The Characteristics of a Voltage to Frequency Converter:

This device converts an input voltage to an output frequency, the frequency being proportional to the input voltage. The output waveform is rectangular. Transfer ratio is 1kHz/V.

5.2.D) The Characteristics of a Frequency to Voltage Converter:

This device converts an input frequency to an output voltage. Transfer ratio is 1V/kHZ.

5.2.E) The Characteristics of a Fullwave Rectifier:

The fullwave rectifier converts an input d.c. signal of either polarity into an output of positive polarity, the magnitude of the output being the same as that of the input signal. The circuit enables measurement of a.c. quantities using d.c. instruments.

5.3) Comparators, Oscillators and Filters:

5.3.A) The Characteristics of a Comparator:
The output voltage has two possible states:
1) with input A voltage more positive than B, the output is approximately +12V
2) with input A voltage more negative than B, the output is approximately -12V.
With the two voltages approximately equal, any slight variation can cause the output voltage to change from one state to the other and the circuit is unstable. To overcome this problem, the circuit is modified so that the voltage at input A must rise to a certain value above B for switching to occur and similarly, with the voltage falling, the voltage at A must fall to a certain value below that of B before the circuit switches back. This is referred to as "hysteresis" and the difference in the voltages is referred to as the hysteresis voltage.

5.3.B) The Characteristics of an Alarm Oscillator:

The alarm oscillator consists basically of two stages, the input circuit being a comparator and this is followed by an oscillator circuit. With the input voltage low, the oscillator does not operate, oscillations only occurring when the input voltage exceeds a certain value that is fixed by the circuit components. With the "latch" switch in the off position, the oscillator will be on or off depending on whether the input voltage is above or below the preset switching value. With the "latch" switch in the on position, when the oscillator has been turned on, by the input voltage exceeding the switching value, it remains on continuously irrespective of the input voltage until the power supply is turned off.

5.3.C) The Characteristics of an Electronic Switch:

This is basically a comparator input circuit controlling a transistor switch output circuit. With the input voltage below the trip value for the comparator circuit, the switch is effectively open and with the input voltage above the trip value, the switch is effectively closed.

5.3.D) The Characteristics of the 40kHz Oscillator:

The 40kHz oscillator produces a sinusoidal output of frequency approximately 40kHz for use with some of the a.c. driven transducers provided with the digiac 1750 unit.

5.3.E) The Characteristics of Filters:

There are basically three types of filter, specified by the range of frequencies passed:
1) high pass filter, passing all frequencies above a certain value
2) band pass filter, passing those frequencies within a certain range
3) low pass filter, passing all frequencies below a certain value
Only a band pass and a low pass filter are provided with the digiac 1750 unit.

5.4) Circuits Performing Mathematical Operations:

5.4.A) The Characteristics of a Summing Amplifier:

The output voltage is the sum of the input voltages applied to the three inputs providing the output voltage is below a certain maximum value. The maximum value is limited by the circuit supply voltage and is approximately 10V for the digiac 1750 unit.

5.4.B) The Characteristics of an Integrator Circuit:

An integrator circuit is one having an input and an output, the output voltage being proportional to the input voltage multiplied by the time. In mathematical terms this is referred to as the "integral" of
voltage x time. With the input voltage constant, the output will increase linearly with the time and the time taken for the output voltage to equal the input voltage is referred to as the "time constant" of the circuit. The maximum possible value of the output voltage is limited by the supply voltage and is approximately 11V for the device provided.

5.4.C) The Characteristics of a Differentiator:

The differentiator circuit has an input and output, the output voltage being proportional to the rate of change of the input voltage. There is a time constant associated with these circuits and the actual output voltage obtained is given by the rate of change of input voltage multiplied by the time constant. The circuit can be used for pulse shaping applications.

5.4.D) The Characteristics of a Sample and Hold:

This circuit allows the value of an input signal to be stored on command and held for further processing. In the "sample" mode, the instantaneous value of the input signal is tracked and on receipt of the "hold" signal, the current value of the input is held as a charge on a capacitor. The capacitor voltage will fall gradually with time as the capacitor discharges through any leakage paths and this fall in voltage is referred to as "droop".