HACETTEPE UNIVERSITY
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING

ELE 356 CONTROL SYSTEMS LABORATORY

2010-2011 SPRING
<u>RULES</u>

1. There will be 4 one-hour experiments and 2 homeworks in the laboratory program.

2. Everyone should attend the lab. on allocated hours.

3. If one does not attend more than one experiment he/she will take the grade F1.

4. Please read the experimental sheets before the experiments and try to solve the problems in the preliminary work session. You do not need to submit the solutions, but it will be assumed that you know the solutions.

5. There will be oral examinations about the experiment and the preliminary work during the lab. session.

6. The experimental reports should be submitted in the following week after the experiment. The experimental reports should include the following items :

   i) TITLE including
      a) Name and number of the student
      b) Name of the experiment
      c) Date of the experiment
      d) Date of submission.
   ii) PURPOSE of the experiment in a few sentences.
   iii) MEASUREMENTS obtained in the experiment (in tabular form).
   iv) GRAPHICS in millimetric papers.
   v) ANSWERS TO QUESTIONS in experimental sheets.
   vi) RESULTS AND CONCLUSION: Comment on experiment, purpose and results.

7. Instead of any midterm examinations, two homeworks related to the computer program MATLAB will be given.

8. If any student does not submit any one of the reports or the homework, he/she will not be able to pass the course.

9. Grading will be as follows :

Oral examination	: 15 %
Experimental report	: 20 %
Homework	: 25 %
Final examination	: 40 %

Res. Ass. Hıdır AŞKAR
Res. Ass. Ömer HALİLOĞLU
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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

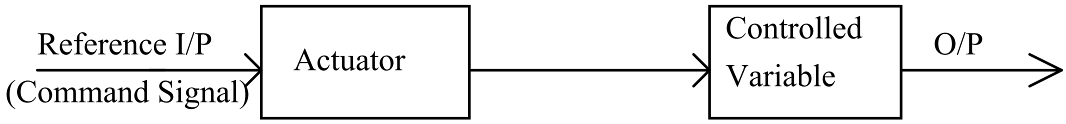

Figure 1.

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

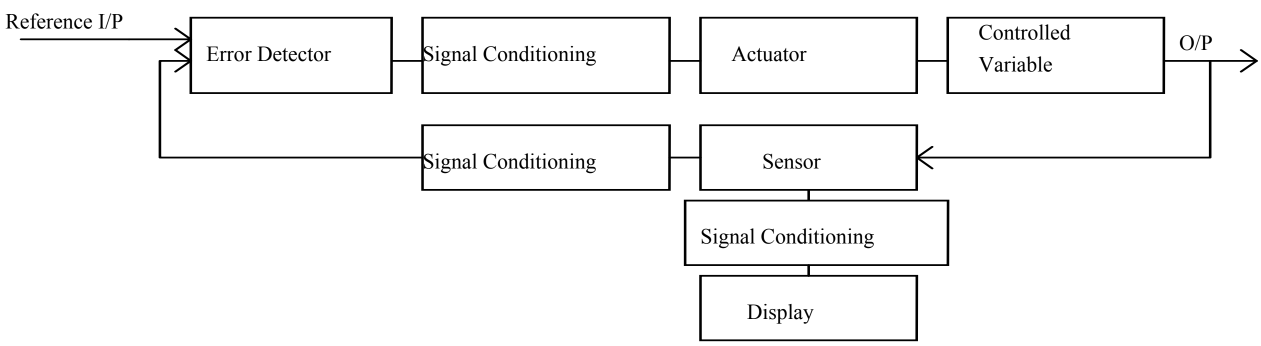

Figure 2.

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 continuos 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 (ie. linear track), the output voltage will be proportional to the movement of the variable contact and the unit is suitable for used 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 continuos 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.

2.2.B) The Platinum R.T.D. (resistance temperature dependent)

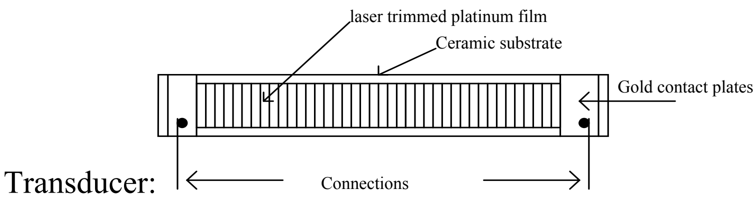

Figure 3

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.

$$R_t = R_o + 0.385t$$

where Rt=Resistance at temperature t°C and Ro=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:

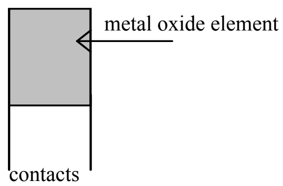

Figure 4

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°K).

The relationship between resistance and temperature is given by the formula:

$$R2=R1e^{((B/T2)-(B/T1))}$$

where R1=Resistance at temperature T1°K

R2=Resistance at temperature T2°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:

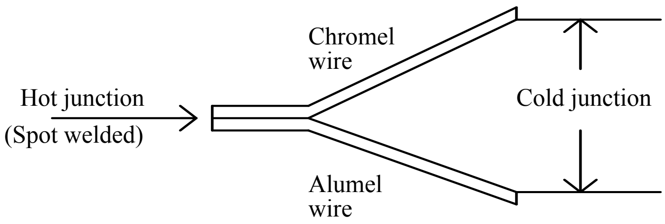

Figure 5.

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:

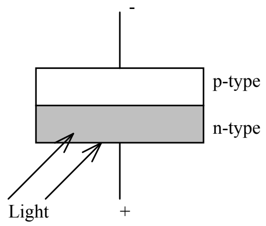

Figure 6

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:

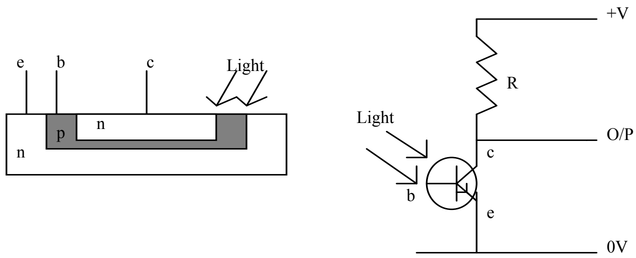

Figure 7

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:

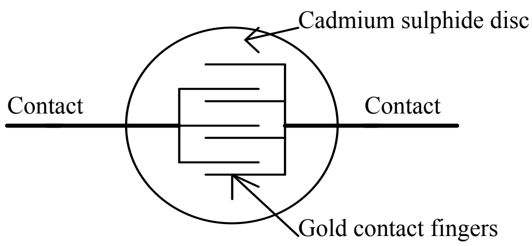

Figure 8.

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:

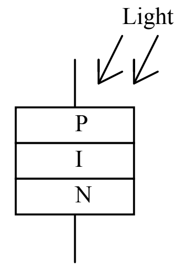

Figure 9

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):

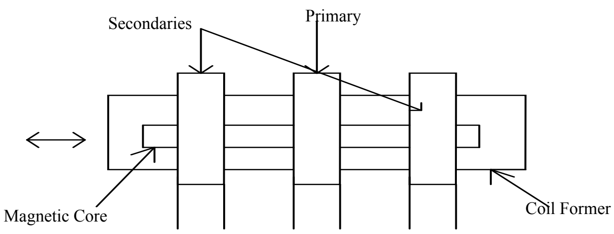

Figure 10

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 Vout=Va-Vb 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 Vout=Va-Vb but in this case the output voltage will be 180º 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.

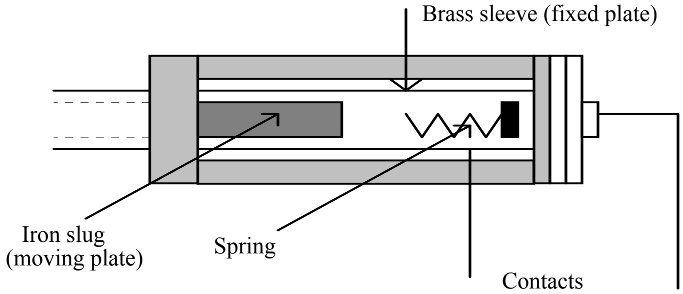

Figure 11.

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:

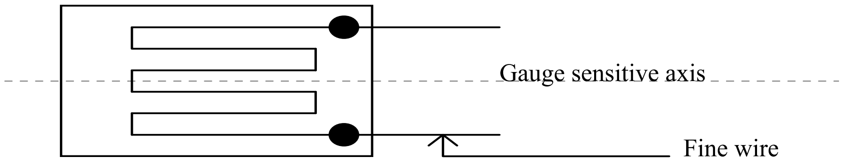

Figure 12.

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:

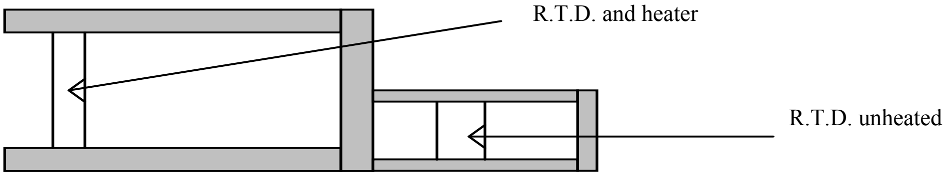

Figure 13

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:

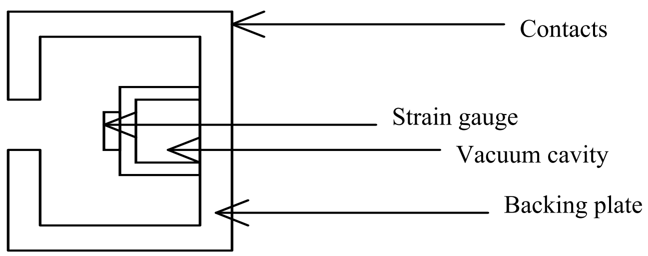

Figure 14

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:

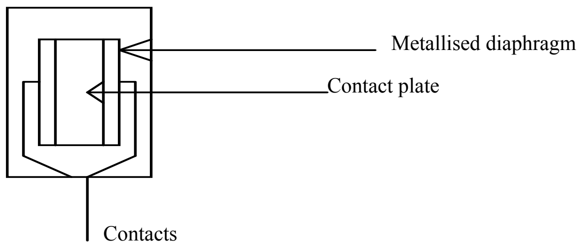

Figure 15.

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:

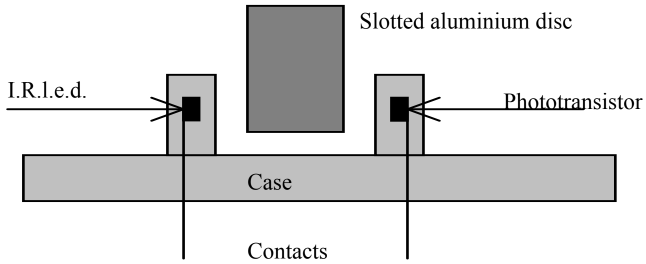

Figure 16.

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:

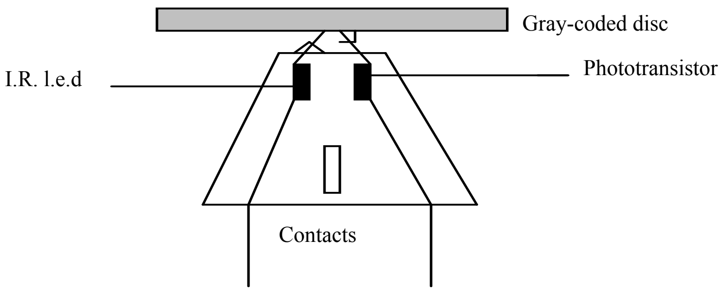

Figure 17.

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:

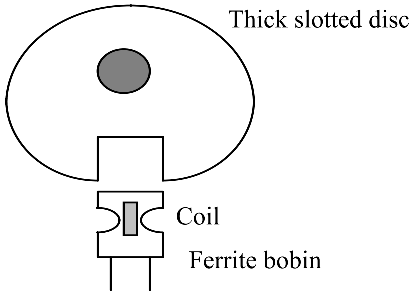

Figure 18.

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.

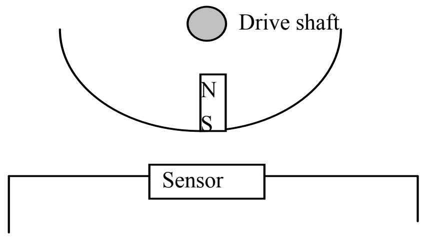

Figure 19.

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:

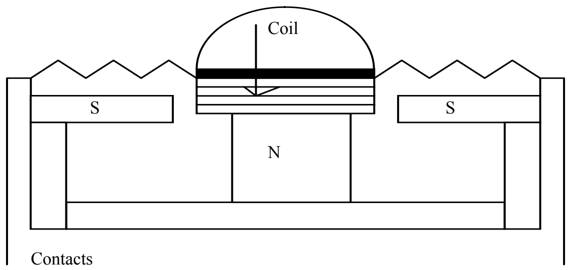

Figure 20.

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:

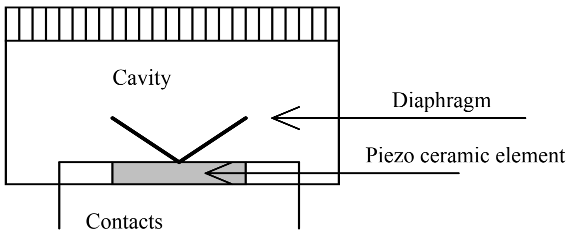

Figure 21.

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 40 kHz. The device therefore gives an output for frequencies in the region of 40 kHz. This is outside the normal audio range (maximum 20 kHz) and hence referred to as ultrasonic.

3. OUTPUT TRANSDUCERS

3.1) Transducers for Sound Output:

3.1.A) The Moving Coil Loudspeaker:

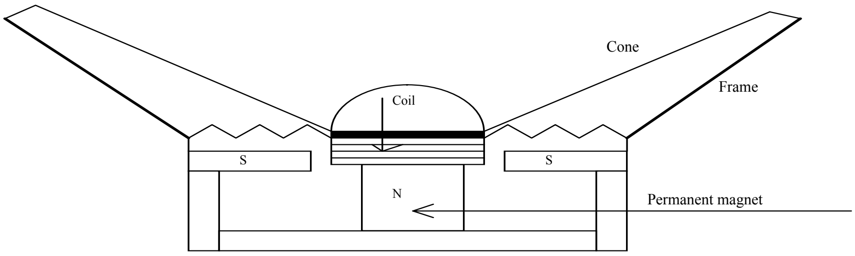

Figure 22.

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 40 kHz oscillator and used with the ultrasonic receiver.

3.1.C) The Buzzer:

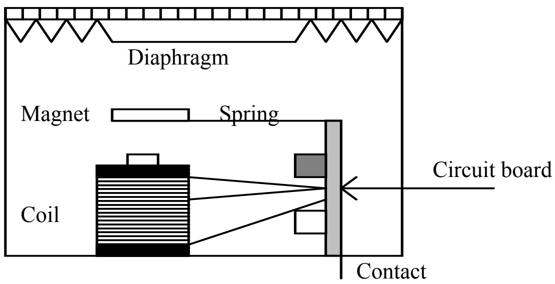

Figure 23.

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:

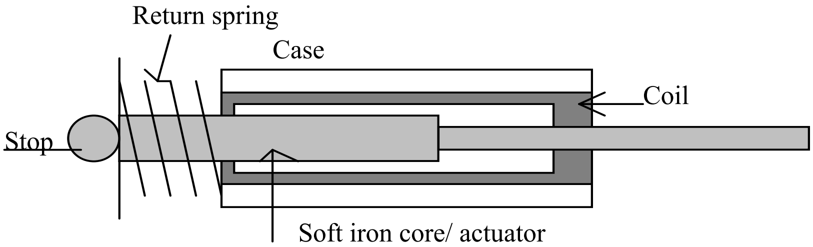

Figure 24.

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 solenoid de-energised and the core attracted, the coil voltage is now reduced gradually. When the voltage 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:

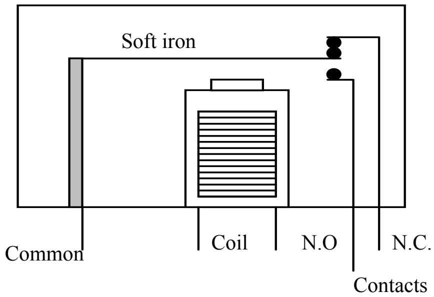

Figure 25.

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:

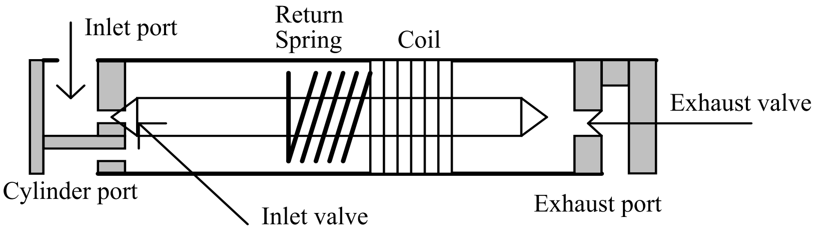

Figure 26.

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 cylinder port. In the digiac 1750 unit, 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 high input impedance and 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 VA- VB. 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 1 kHz/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 40 kHz oscillator produces a sinusoidal output of frequency approximately 40 kHz 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".

POSITION CONTROL SYSTEM

1. INTRODUCTION

In this experiment, it will be shown how the motor can be used to make a simple automatic position control system. The general form of the block diagram of such a system is given in Fig.1.

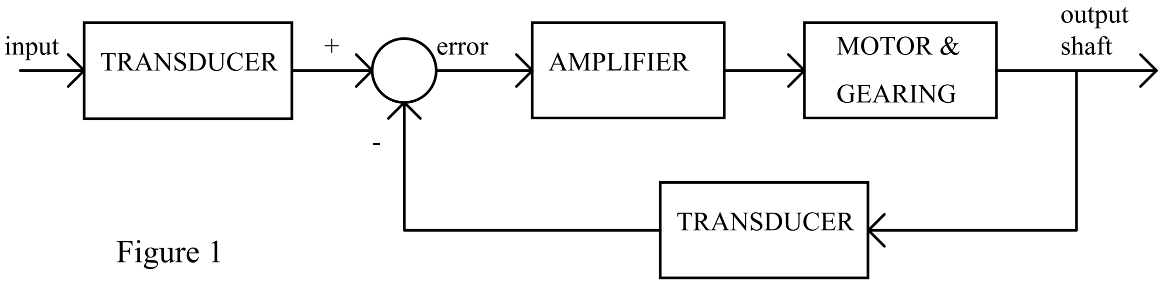

Figure 1

In such a system the input and output "transducers" must measure input and output shaft angles and produce a signal proportional to shaft positions. The difference between input and output positions called "error signal" is used to drive the motor. Experiment will be performed on the set MS 150 consists of following units.

1.1 THE COMPONENTS OF THE MODULAR SERVO SYSTEM MS 150

1.1.1. Power Supply Unit (PS150E)

This unit supplies a 24V dc 2A unregulated supply to the Servo Amplifier that controls the motor. There are two sets of sockets on the front panel to provide ±15V; stabilised dc supplies to operate the smaller amplifiers and provide reference voltages (see fig.3 for layout).

1.1.2. Motor Unit (MT150F)

This unit is made up of three parts:
a) A dc series-wound split-field motor which has an extended shaft, and onto which can be fixed the magnetic brake or inertia disc.
b) Integrated within the unit is a dc tacho-generator with output on the top of the unit.
c) There is a low-speed shaft driven by a 30:1 reduction gearbox. A special push-on coupling can link the output potentiometer to this shaft.
Power is obtained from the Servo Amplifier by an 8-way socket.

1.1.3. Servo Amplifier (SA150D)

Contained in this unit are transistors which drive the motor either direction. Two types of connection are possible to have armature controlled and field controlled motors. To avoid overloading the motor, there is a motor current meter with 2A overload indication (see fig.5).

1.1.4. Attenuator Unit (AU150B)

This unit contains two variable 10kΩ potentiometers. The proportion of the resistance being selected is indicated by a dial graduated from 0 to 10 (see fig.5 for layout).

1.1.5. Input and Output Potentiometers (IP150H & OP150K)

These are rotary potentiometers, used in experiments on position control. The input potentiometer has ±150° of motion while the output potentiometer has no mechanical stops and so can not be damaged by continuous rotation. The input potentiometer is used to set up a reference voltage and the output potentiometer is connected to the motor low-speed shaft to obtain an output voltage proportional to the motion (see fig.3 for layout).

1.1.6. Pre-Amplifier (PA150C)

This provides the correct signals to drive the servo amplifiers in SA150D. A positive signal applied to either input causes the upper output (3) to go positive, the other output (4) staying near zero. A negative input causes the lower output (4) to go positive, the upper one staying near zero. Thus bi-directional motor drive is obtained when these outputs are linked to the SA150D inputs (see fig.5 for layout).

1.1.7. Operational Amplifier (OU150A)

This provides inverting voltage gain and a means of summing two or three signals, as well as facilities for introducing compensation networks (see fig.3 for layout).

1.1.8. Load Unit (LU150L)

An aluminium disc can be mounted on the motor shaft and when rotated between the poles of the magnet of the load unit, the eddy currents generated have the effect of a brake. The strength of the magnetic brake can be controlled by the position of the magnet.

2. PRELIMINARY WORK

2.1. A robot arm is a good example of position control. A feedback control system for a single joint of a robot arm is given in Fig.2. In this diagram θ_c is the desired angle of the robot arm, and θ_L is the actual angle of the arm.

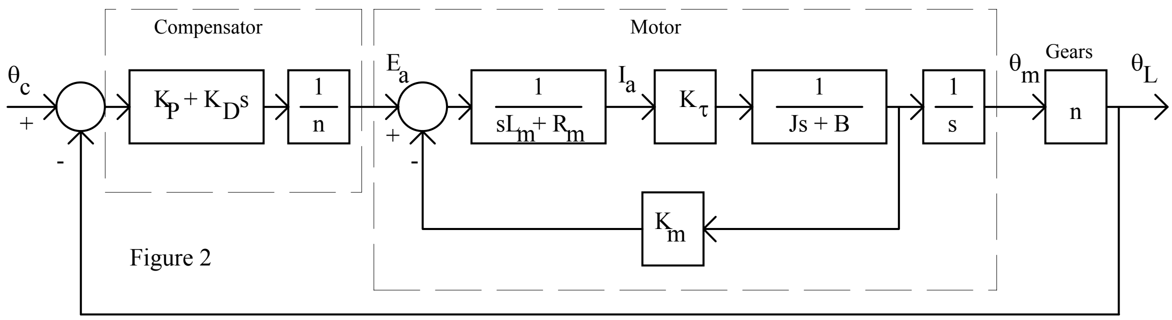

Figure 2

a) Find the plant transfer function $\theta_L(s)/E_a(s)$.

b) Find the closed loop system transfer function $\theta_L(s)/\theta_c(s)$.

c) Find the ranges of compensator gains K_P and K_D such that the closed loop system is stable for the following values of variables : n=1/30, L_m=2, R_m=11, K_τ=18, J=2, B=1, K_m=0.5.

d) Determine the steady state errors due to unit step, unit ramp and unit parabolic inputs in terms of K_P and K_D (n=1/30, L_m=2, R_m=11, K_τ=18, J=2, B=1, K_m=0.5).

2.2. Measurements conducted on a servomechanism show the system response to be

$$y(t) = 1 + 0.2e^{-60t} - 1.2e^{-10t}$$

when subjected to a unit step input.

a) Obtain the expression for the closed loop transfer function.

b) Find the undamped natural frequency and damping ratio of the system. According to damping ratio what would you expect about the unit step response of this system?

c) Determine the delay time t_d, rise time t_r, percentage overshoot PO and settling time t_s according to 2% criterion. Do not use the formula for t_s.

3. EXPERIMENTAL PROCEDURE

3.1. Error Channel Investigation

Set up as in Fig.3 but do not yet connect the two amplifier input leads.

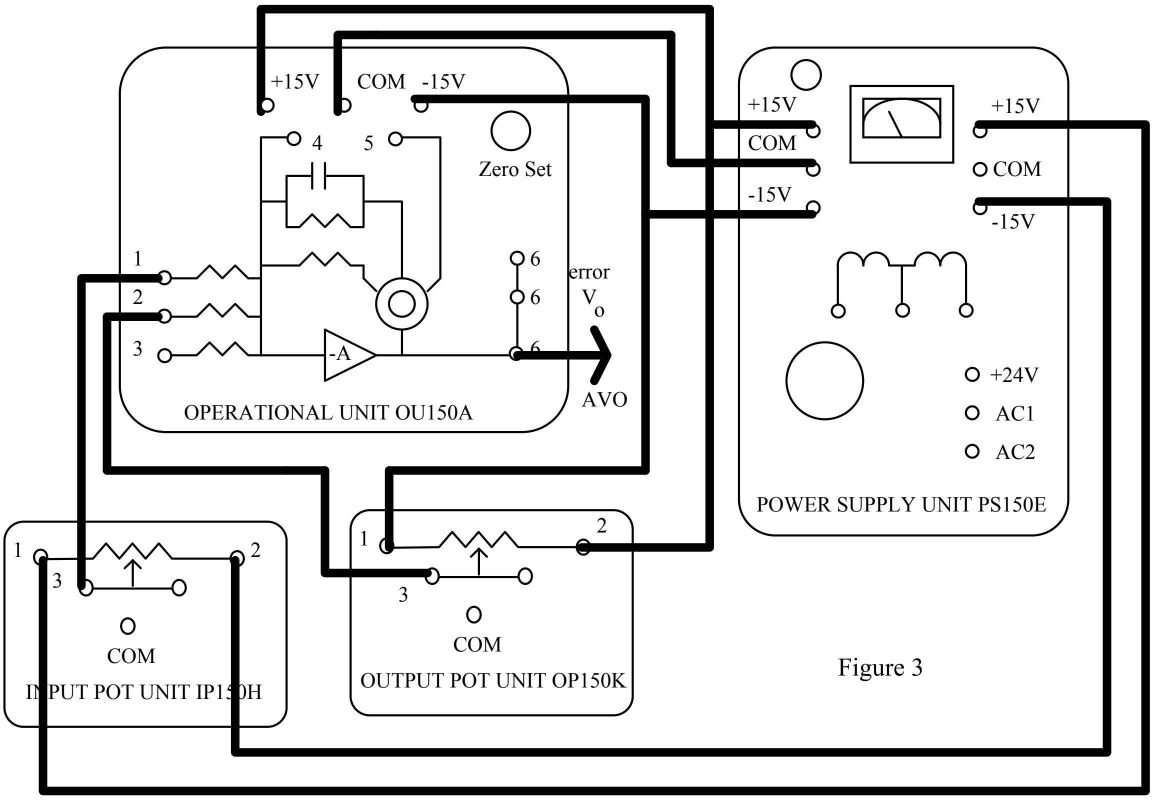

Figure 3

scale reading (degrees)	amplifier output (volts)
0	
30	
60	
90	
120	
140	
-30	
-120	

Table 1

input pot (degrees)	amplifier output(volts) when output pot at 0°	amplifier output (volts) when output pot at -60°
0		
30		
60		
90		
120		
140		
-30		
-120		

Table 2

Be sure that the feedback selector on the operational unit is set to 100KΩ resistor. Connect the voltmeter to the output of the Operational Amplifier, switch on and adjust the zero set to as near zero as possible. Then connect the two sliders into the operational unit inputs.

Measure the potential between each slider (input and output potentiometers) and common, rotating the cursor till the reading is zero. If this does not correspond with the 0° on the angular scale, then record the angle value and taking this value as 0° , readjust the measurements you will make according to this data.

Measure the amplifier output and record it in Table 1. Repeat to measure output voltage for equal values on the angular scales and fill in the Table 1.

Set the output potentiometer to zero and rotate the cursor of the input potentiometer over its range, tabulate your results in Table 2. Repeat your readings setting the output potentiometer to -60°.

3.2. Manual Position Control System

In this part, using the same set up in Fig.3, one student should slowly turn the knob on the input potentiometer and set it at any value in the range ±15V. Let the other student watch only the voltmeter connected to the output V_o and by turning the shaft of the other rotary potentiometer read the zero value on voltmeter. Notice the positions of input and output potentiometers.

Try suddenly changing the position of input cursor, while attempting to keep the error at zero.

3.3. Motor Driven Open Loop Position Control System

Keep the experimental set as in Fig.3 and make the connections shown in Fig.4.
Decide a position you wish the output potentiometer shaft to turn to and stop. Then starting with the attenuator slider at fully counter clockwise position, gradually rotate it untill the motor just rotates. As the cursor nears the required angle, reduce the input signal so that the cursor comes to rest nearly at the required point.

Repeat using increasingly large input signals adjusted by attenuator.

3.4. Closed Loop Automatic Position Control System

This time we shall utilise the error signal output V_o of the Operational Amplifier to drive the output potentiometer via the Pre-Amp and motor. Set up as in Fig.5. With the gain (attenuator) set to zero adjust the Pre-Amplifier zero so that the motor does not rotate.
Now set the input potentiometer to 0° and increase the attenuator setting. The output shaft should rotate to an angle nearly equal to 0°. If the output cursor stops before arriving at the set position, increase the gain and get the correct alignment. Repeating same procedure for different input values fill in the Table 3.

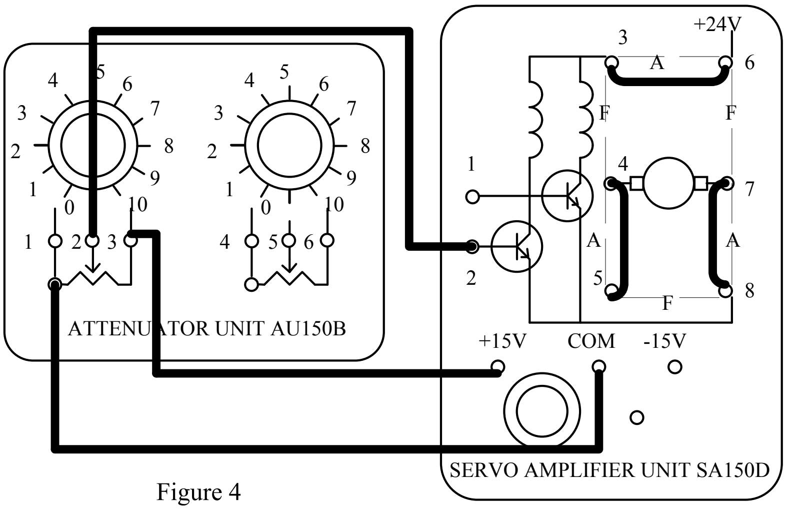

Figure 4

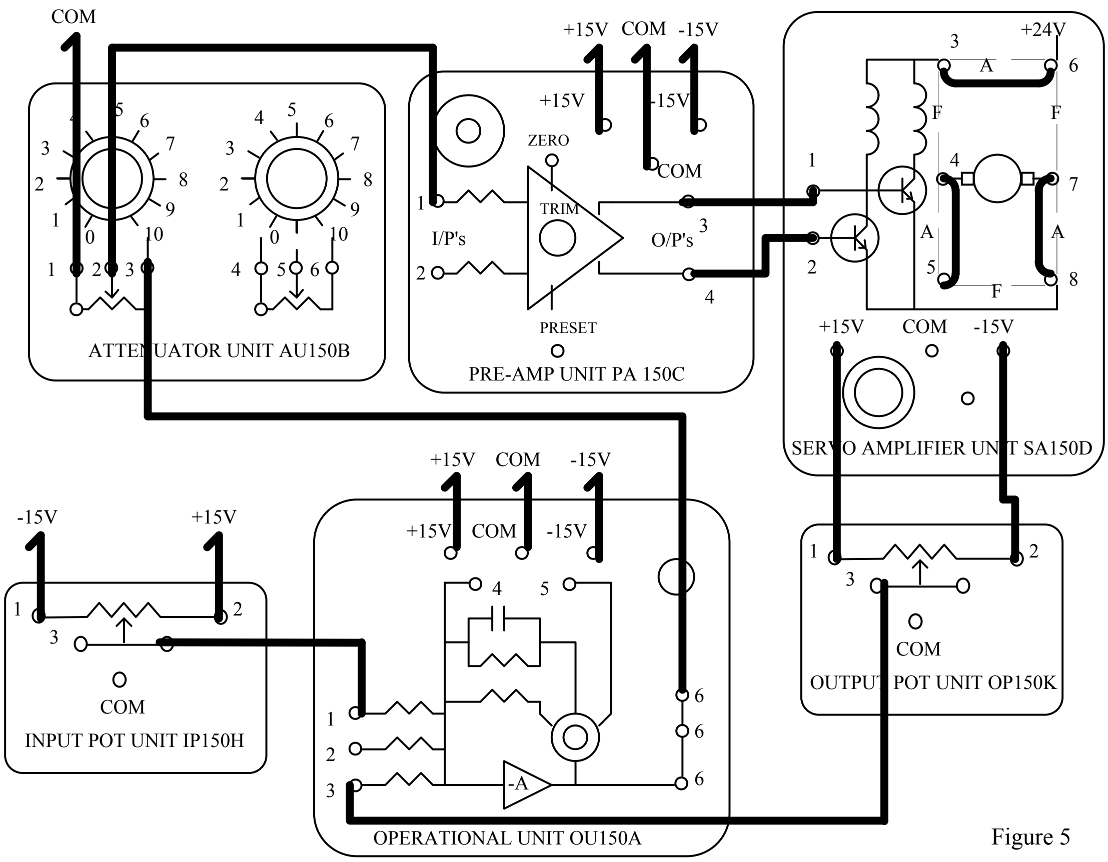

Figure 5

Output Cursor Position in Degrees		
Required	Actual	Misalignment
0		
30		
60		
90		
120		
140		

Table 3

4. RESULTS AND CONCLUSION

4.1. Considering the results in Table 1, what can you say about the linearity of potentiometers?

4.2. Plot the amplifier output voltage (error) versus input potentiometer position for both conditions in Table 2. What do you notice about the two graphs? Calculate the value of error factor K_e in volts/degree.

4.3. Write down your observations on what happened in part 3.2. What sort of control system would this be (open or closed loop)? Why?

4.4. Write down your observations on what happened in part 3.3. Why is this an open loop system?

4.5. Compare the open loop and closed loop systems. Discuss the advantages and disadvantages of these systems giving reasons.

4.6. Give two examples of position control in real life.

4.7. Comment on the experiment and the results.

SPEED CONTROL SYSTEM

1. INTRODUCTION

Speed control for a motor provides a simple example to illustrate some of the general properties of closed loop system. The servo system set MS150 which is also used for position control experiments will be used to investigate the effects of forward gain and disturbances on a speed control system. A simple layout of the experiment is shown in Fig.1.

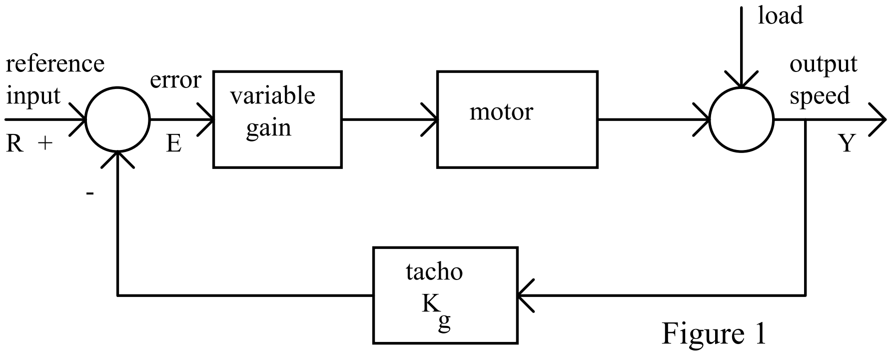

Figure 1

Considering steady state operating conditions of an ideal system it can be said that speed is proportional to the error and

$$Y = KE$$

where K is the forward path gain of the system.
And the relation between Y and R can be expressed as

$$Y = \frac{K}{1 + KK_g} R$$

because $E = R - K_g Y$ where K_g is tacho-generator constant and does not vary significantly.
If the forward path gain is large the relation is satisfactorily approximated as

$$Y = \frac{1}{K_g} R$$

and the speed is directly proportional to the reference voltage.
An alternative relation may be obtained expressing the error as below.

$$E = \frac{1}{1 + KK_g} R$$

That means error decreases as the forward path gain K increases. These, of course, are the advantages of using a feedback system.

It is also possible to have systems which the motor is operated not by an amplifier but by a relay. The error signal operates the relay coil which switches power to the motor. The relay may be 'three-position', in which case the power to the motor can be switched to give forward or reverse rotation as the error changes sign; there is also a central position with the motor power off, which corresponds with the relay coil being unenergised.

2. PRELIMINARY WORK

The automobile cruise system shown in Fig.2 is an application of speed control systems.

2.1. Obtain the Bode plot of the system. Find the gain margin (GM) and phase margin (PM) and indicate them on graph (take K=1 and disturbance torque=0).

2.2. Find the value of K so that the system has a GM of 10 dB.

2.3. To drive a stationary car with a constant velocity of 100 km/h what kind of input should be applied to the above system (i.e. $v(0)=0$ and $v(\infty)=100$ km/h).

2.4. Applying the input you have proposed to the system for the cases a) K=1 and b) GM=10 dB, plot the outputs (v(t)). Compare the responses indicating the effects of the two different gain margins. Hint: You may use any computer program to see the time responses.

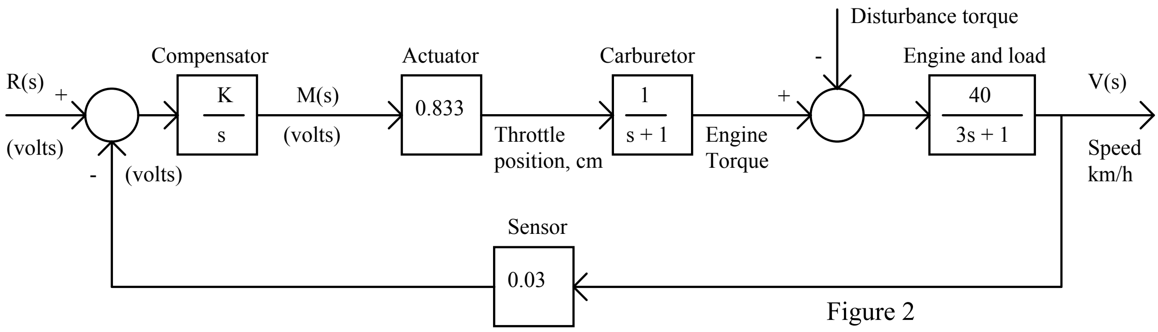

Figure 2

3. EXPERIMENTAL PROCEDURE

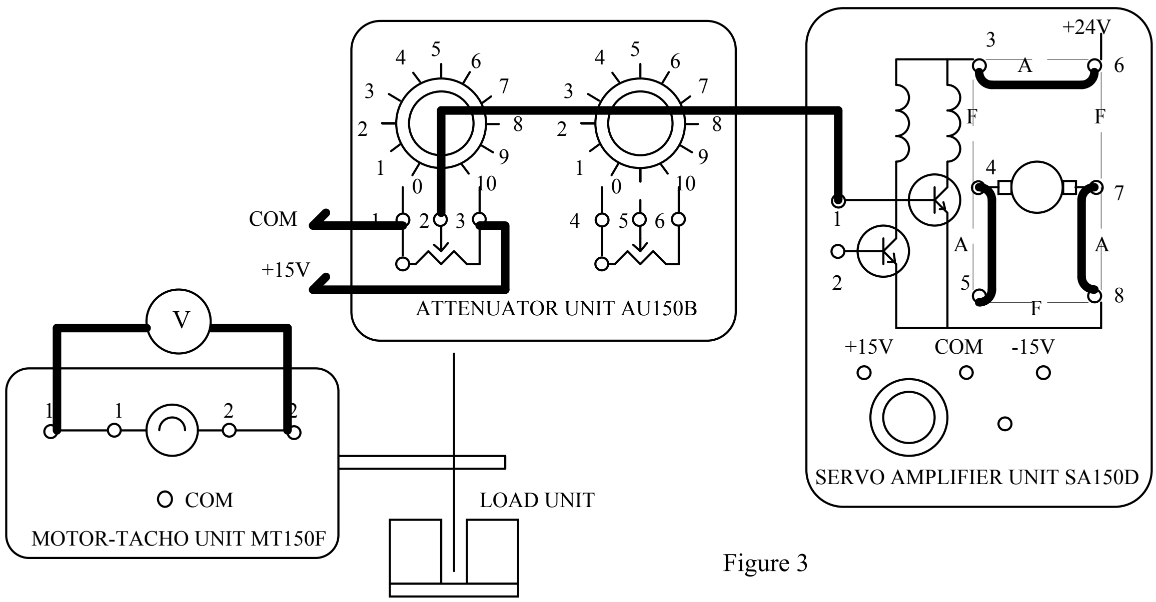

Figure 3

3.1. Motor Characteristics

The first experiment will be to obtain the characteristics of motor connected for armature control. Make the connections as in Fig.3. To obtain voltage values related to speed, it will be necessary to calibrate the tacho generator by finding the factor K_g, which is the volts generated per thousand rev/min of motor shaft.
Set the magnetic brake to the unloaded position and turn the slider on the potentiometer till there is a reading of 1V on the voltmeter. Using a timer, count 3 turns of the geared 30:1 low speed shaft. Tabulate your result as in Table 1. Repeat the procedure for different tacho voltages.

Tacho-generator volts	Number of rotations	Time in seconds	Speed of low speed shaft in rev/min	Speed of high speed shaft in rev/min
1	3		at home	at home
2	5			
3	10			
4	10			
5	10			

Table 1

The relation between the input voltage and the speed: Adjust the input voltage V_{in} using the attenuator to 4V. And read the tachogenerator voltage V_g. Increasing the input voltage, fill in the Table 2.

Vin, (volts)	Vg, (volts)	speed, (rev/min)
4		at home
6		
8		
10		

Table 2

To measure the torque/speed characteristics, fix the brake so that it passes over the disc smoothly while the motor is running. Set the input voltage to have a tacho-generator voltage of 2.7V. For the different positions of brake read the tachogenerator voltage. Tabulate your results as Table 3.
Do not exceed the limit of 2A on power supply. For V_{in} = ? V

Brake position	Vg, (volts)	speed, (rev/min)
0		at home
2		
4		
6		
8		
10		

Table 3

3.2. Effect of Gain on Closed Loop Speed Control.

For a gain control we can use the circuit in Fig.4 which has a gain proportional to $-1/\alpha$.

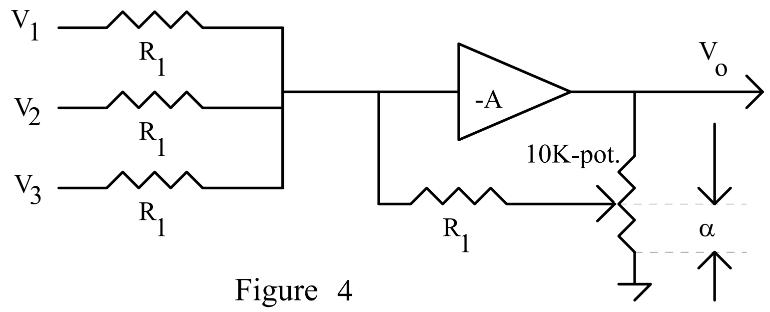

Figure 4

Set up as in Fig.5. Move the feedback selector switch on the Operational Amplifier to the external feedback position. The second potentiometer on the Attenuator unit will be used to adjust the gain. Initially set the gain to unity that is the position 10 on the gain potentiometer scale. Set also the reference volts till the motor runs at 1000 rev/min (approximately 2.7V of tacho voltage).
i) Then take readings of the reference voltage, servo input error voltage and tacho voltage changing the brake position and tabulate as in Table 4.
ii) Repeat the readings for a gain of 10 that is set the gain potentiometer to position 1.

brake	GAIN = 1				GAIN = 10			
position	ref.vol.	error	tacho	speed	ref. vol.	error	tacho	speed
0				at home				at home
2								
4								
6								
8								
10								

Table 4

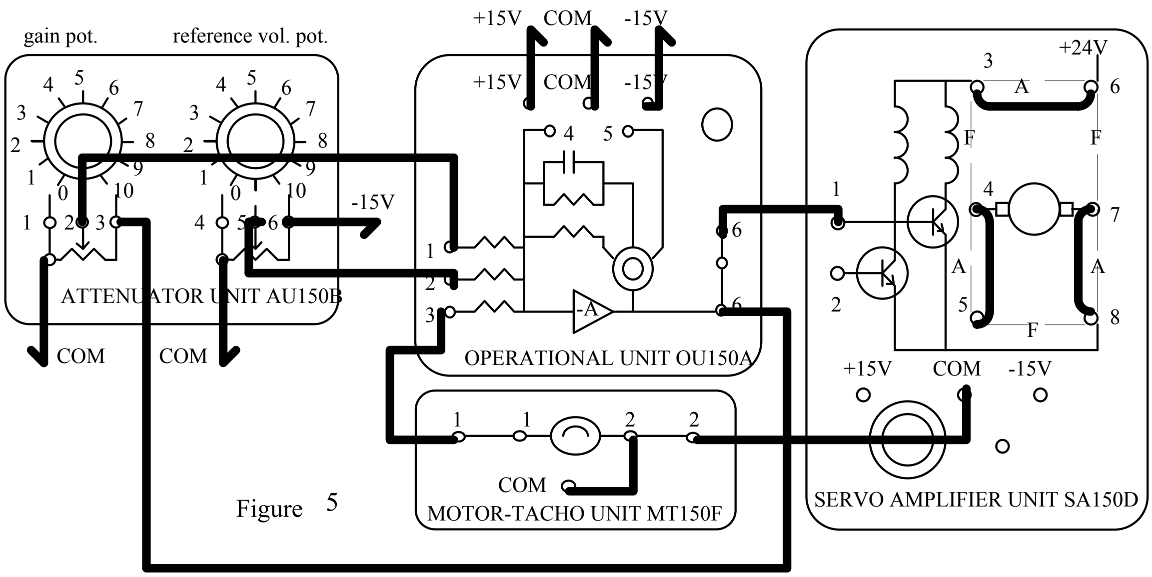

Figure 5

4. RESULTS AND CONCLUSION

4.1. Using the results in Table 1, plot a graph of speed (in rpm) against tachogenerator voltage (in volts). Find the tachogenerator constant K_g. Calculate the tacho. voltage corresponding to 1000 rpm.

4.2. Using the results in Table 2, plot the graph of speed (in rpm) against input voltage (in volts). Calculate the slope (input volts per thousand rev/min). Find the input voltage corresponding to 1000 rpm.

4.3. Using the results in Table 3, plot a graph of speed (in rpm) against torque (brake position).

4.4. Show that the gain can be approximated to $-10K/\alpha$ as stated in part 3.3.

4.5. Using the results in Table 4, plot the graphs of error (in volts) against brake setting and speed (in rpm) against brake setting for gain values of 1 and 10. Compare the graphs.

4.6. Comment on the experiment and the results.

TRANSDUCERS I

1. INTRODUCTION

The properties of several transducers provided by DIGIAC 1750 will be investigated in this experiment. Necessary information about the set is given in separate sheets.

2 . PRELIMINARY WORK

2.1) Write the types of temperature transducers and explain their operations. And state the output voltages you would expect to obtain from LM335 at the following temperatures: 0,50,-20°C.

2.2) A phototransistor is connected to a 10V DC supply via a 2K resistor.
a) For a certain ambient illumination the collector current is 1 mA. What will be the collector voltage?
b) What would you expect the collector current and voltage values to be when the illumination doubled?

2.3) a) For a slotted opto transducer unit with the output taken from emitter connection, state how the output voltage changes when the beam is admitted by the slot.
b) A slotted opto transducer is used with a disc having four slots. For a certain shaft speed the output count is 100 rev/sec. What is the shaft speed in rev/min?

3 . EXPERIMENTAL PROCEDURE

3.1. Digital Thermometer Using The I.C. Temperature Transducer:

LM 335 provides an output of 10 mV/K. A measurement of the output voltage therefore indicates the temperature directly in Kelvin. For example at a temperature of 20 °C the output voltage will be 2.93 V , ie. 293 °K.

i) The offset control of Amp. # 1 must be set correctly. With the power supply switched ON, connect Amp. # 1 input to 0V and connect the output to the M.C. meter. With Amp. # 1 fine gain set 1.0 and coarse gain set 10 adjust the offset for approximate zero output. Make the offset zero again for the coarse gain set to 100. Set amplifier fine and coarse controls to 0.1 and 1 respectively.

ii) Set up the circuit in Fig.1, but do not connect the heater input yet. Set the 10K slider resistor fully to the right, differentiator time constant to 1s and the counter controls to “count " and 1s.

iii) Measure the output voltage of I.C. Temp. sensor and press the reset button of the counter and note the final value displayed. Compare this with voltmeter reading.

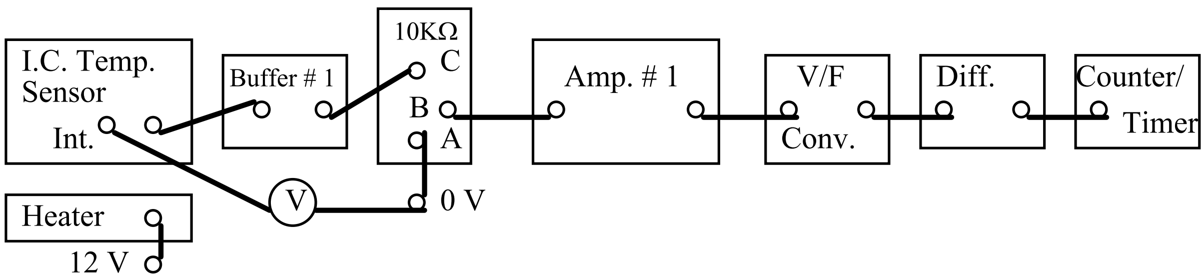

Figure 1.

a) If the displayed value exceeds the voltmeter reading, reduce the setting of the 10K slider slightly and then press the reset button of the counter again and note the revised display. Compare this with the voltmeter reading. Repeat the process if necessary until the display and voltmeter readings are the same.

b) If the displayed value less than the voltmeter reading, increase the " fine " gain setting of amp. # 1 slightly and then press the reset button of the counter, note the revised display. Repeat the process if necessary until the display and voltmeter readings are the same.

iv) Connect the 12 V supply to the heater input, note the time on your watch, note the voltage indicated by the voltmeter, press the counter reset button and note the displayed value. Repeat the reading every minute and enter the values in Table 1.

Time (min)	0	1	2	3	4	5	6	7	8	9	10
Voltage (Volts)											
Temperature (ºK)											
Counter Display											

Table 1.

3.2. The Characteristics Of A Light Controlled On-Off System

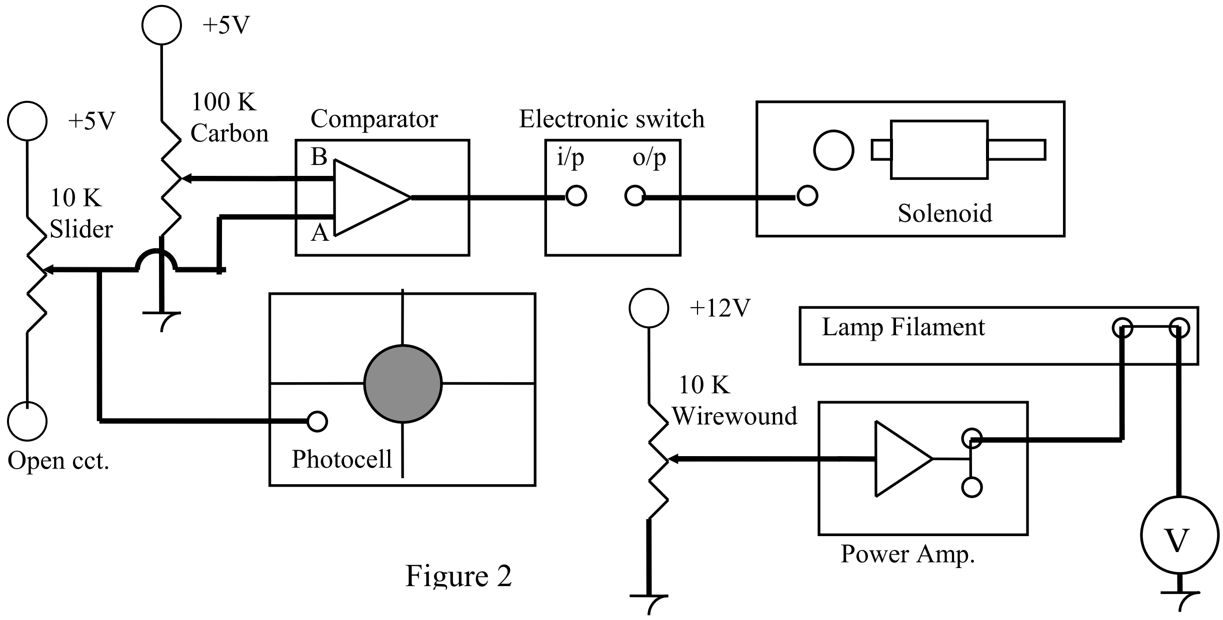

Figure 2

a) Connect the circuit as shown in Fig.2.

b) Set the comparator hysteresis OFF and set all the resistor controls fully counter clockwise or to the left. Switch the supply ON. Adjust the 100 KΩ resistor so that the solenoid is just de-energised. This represents the preset voltage for operating the system with the lightening at the ambient level. Note the output voltage on the 100KΩ resistor.

Ambient Lightening; preset voltage for solenoid change of state =

c) Move your hand over the photoconductive cell. You will note that the solenoid will change its state as the lightening level falls.

d) Add hysteresis to the circuit. Note the change.

e) Make the hysteresis switch OFF. Set the voltage applied to the lamp filament to 10V, and adjust the 100KΩ resistor control until the solenoid changes state. Note the output voltage on the 100K.Ω resistor.

Lamp filament voltage 10V; preset voltage for solenoid change of state =

f) Set the voltage applied to the lamp filament to 2V and with the photoconductive cell covered with hand to remove the ambient lighting. Repeat the procedure.

Lamp filament voltage 2V, covered by hand; preset voltage for solenoid change of state =

3.3. Transducers for Linear Position or Force Applications

Characteristics of a Strain Gauge Transducer :

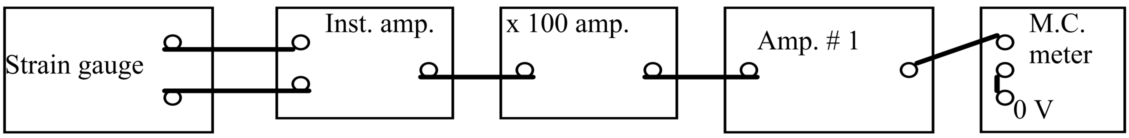

Figure 3.

i) Set up the circuit in Fig.3., and set the amp. # 1 coarse gain to 100 and fine to 0.5 , then with no load on strain gauge adjust the offset of the amp # 1 so that the output voltage is zero.

ii) Place a coin on the beam platform and note the output voltage. Enter the value in Table 3.

iii) Repeat the process, adding further coins one at a time.

Number of coins	0	1	2	3	4	5	6
output voltage							

Table 3.

3.4. Transducers for Speed and Position

Characteristics of a Slotted Opto Transducer and Its Application to Counting and Speed Measurement :

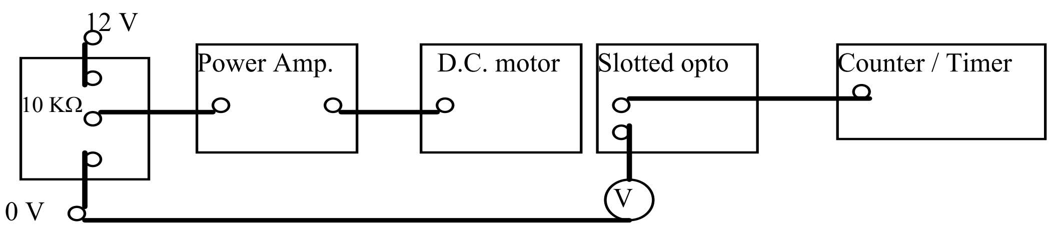

Figure 4

.

i) Set up the circuit in Fig.4, and set the 10 kΩ potentiometer to give 0 V.

ii) Note the output voltage from the slotted opto transducer output socket and also the state of indicating L.E.D ;
a) with the beam broken by aluminium disc, output = , LED is on / off.
b) with the beam admitted trough the slot in the aluminium disc, output = , LED is on / off.

iii) Set the timer/counter to count and free run. The display should show zero, if not , press the reset button. Now rotate the shaft assembly backwards and forwards. How does the counter display change.

iv) Change the state of 10K resistor. The motor should operate and rotate the shaft. Set the speed to a low value. The control setting 2.5 should be suitable for this. The counter value will increment once for each revolution of the shaft and this can be used to measure the speed of the motor.

v) Press the reset button and hold down. With a watch, release the reset button at a suitable time and then note the count value for a minute.
This value represents the shaft speed in revolutions per minute. Note this value, and repeat the process for the resistor control setting is 5. Write this value in the Table 4.

Resistor control setting	2.5	5	7.5	10
Speed (rev/min) by counting				
Speed (rev/sec) by counting				

Table 4

vi) Now set the Free run/1s switch to 1s (1 second). Press the reset button of the counter. The count displayed represents the number of revolutions per second of the shaft. Repeat the process for the resistor control setting is 7.5 and 10. Fill in the Table 4.

4. RESULTS AND CONCLUSIONS

4.1) Plot the temperature obtained by I.C. transducer versus time. Find the time constant of the heating system using this graph..

4.2) Write down the operation of light controlled on/off system. Explain the reason for the voltage drop in preset voltage for solenoid change of state as the lighting increases.

4.3) Plot the graph of output voltage against number of coins using the data in Table 3. Determine a constant representing the characteristics of strain gauge.

4.4) Plot the graph of speed versus input voltage of the motor using Table 4. Derive an approximate expression between speed and input voltage.

4.5) Comment on the experiment and results.

TRANSDUCERS II

1. INTRODUCTION

The properties of several transducers provided by DIGIAC 1750 will be investigated in this experiment. Necessary information about the set is given in separate sheets.

2 . PRELIMINARY WORK

2.1) An ultrasonic transmitter - receiver combination has an operating frequency of 50 KHz. With a moving object in the beam, what would you expect to be the effect on i) the amplitude, ii) the frequency of the received signal if the object is moving:

a) towards the transmitter-receiver
b) away from the transmitter-receiver

2.2) Design a system to observe the characteristic of a moving coil loudspeaker using a 5V source, moving coil speaker, V/F converter, power amplifier and 10 KΩ pot.

2.3) Design a system to observe the characteristics of a buzzer. Use a 12V source, power amplifier, a buzzer and a 10 KΩ pot.

2.4) Design a system to observe the characteristic of a D.C. solenoid using a 12V source, power amplifier, D.C. solenoid, 10 KΩ pot., 10-0-10 M.C. meter.

2.5) What are the differences among a buzzer, a loudspeaker and an ultrasonic transmitter?

3 . EXPERIMENTAL PROCEDURE

3.1. Transducers for Sound Measurement

Characteristics of an Ultrasonic Receiver:

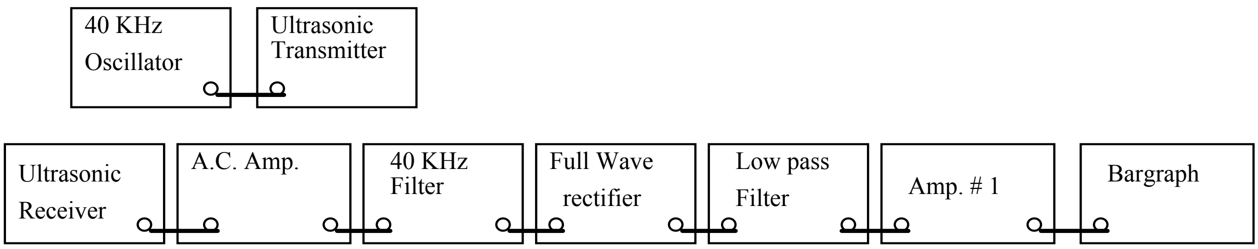

Figure 1.

i) Connect the circuit as shown in Fig.1, set the A.C. Amp. gain to 1000, the low pass filter to 10ms. and Amp. # 1 coarse gain to 10, fine to 0.5.

ii) Note the bargraph display as you hold your hand or other object over the ultrasonic devices and move it towards or away from them. The display should respond, thus indicating the receipt of a signal of frequency 40 KHz by the ultrasonic receiver.

iii) Hold a thin object such as pencil approximately 15 cm over the beam and move it horizontally to left and right , note the distance over which there is any output response, note the value. This indicates the useful direction angle for the device.

iv) Put a sheet of paper over the transmitter unit thus breaking the beam. Is there any output response to movement of the hand over the device now?

3.2. The Characteristics Of A Moving Coil Loudspeaker

i) Setup a system to observe the characteristic of a moving coil loudspeaker using 5V source, 10KΩ pot , moving coil speaker, V/F converter, and power amplifier. Switch the supply on.

ii) Vary the setting of 10 K.Ω resistor over its full range. This will vary the output frequency from the V/F converter from zero to a maximum of 5 KHz and there will be a corresponding tone output from the speaker.

iii) Why is the tone heard not pure ?

3.3.The Characteristics Of A Buzzer

i) Setup a system to observe the characteristics of a buzzer. Use a 12V source, a 10 KΩ pot., power amplifier, and a buzzer. Set the control of the 10 K.Ω resistor for zero output voltage.

ii) Switch the supply on. Increase the voltage applied to the buzzer.

Minimum voltage for buzzer to operate =

iii) Increase the applied voltage to maximum available.
Does the frequency of the sound increase as the voltage is increased?
Does the magnitude of the sound increase as the voltage increases?

3.4. Use the dynamic microphone, the A.C. amplifier, the buffer #1 and the oscilloscope to verify your observations in (3.2.ii) and (3.3.iii).

Plot the typical waveforms of sound signals produced by the loudspeaker and buzzer.

3.5. The Characteristics Of A D.C. Solenoid

i) Setup a system to observe the characteristic of a D.C. solenoid using a 12V source, power amplifier, D.C. solenoid, 10 KΩ pot. and voltmeter.

ii) Set the 10 K.Ω resistor for zero output voltage.

iii) Switch the supply on. Increase the voltage for a full attraction of the solenoid into the coil.

Note the pull-in voltage=

iv) Repeat the process with your finger against the actuator shaft to exert a little load.

Note the pull-in voltage with load=

v) With the coil energized and the coil in its pulled in position, gradually reduce the coil voltage and note the value at which the core returns to its neutral position.

Release voltage with no load =

Release voltage with load =

4. RESULTS AND CONCLUSIONS

4.1) Explain the operation of the circuit in Fig.1.

4.2) Determine the useful direction angle for the ultrasonic receiver approximately.

4.3) Give the block diagram representations of the experiments in 3.2, 3.3 and 3.5

4.4) Explain the functions of the a.c. amplifier and buffer used in 3.4.

4.5) Comment on the experiment and the obtained results.

TABLE F.7 ***Matlab* Functions**

Function Name	Function Description
abs	Computes the absolute value
acos	Computes the arccosine
ans	Variable created for expressions
asin	Computes the arcsine
atan	Computes the arctangent (2 quadrant)
atan2	Computes the arctangent (4 quadrant)
axis	Specifies the manual axis scaling on plots
bode	Generates Bode frequency response plots
c2dm	Converts a continuous-time state variable system representation to a discrete-time system representation
clear	Clears the workspace
clg	Clears the graph window
cloop	Computes the closed-loop system with unity feedback
conj	Computes the complex conjugate
conv	Multiplies two polynomials (convolution)
cos	Computes the cosine
ctrb	Computes the controllability matrix
diary	Saves the session in a disk file
d2cm	Converts a discrete-time state variable system representation to a continuous-time system representation
dstep	Computes the unit step response of a discrete-time system
eig	Computes the eigenvalues and eigenvectors
end	Terminates control structures
exp	Computes the exponential with base e
expm	Computes the matrix exponential with base e
eye	Generates an identity matrix
feedback	Computes the feedback interconnection of two systems
for	Generates a loop
format	Sets the output display format
grid	Adds a grid to the current graph
help	Prints a list of HELP topics
hold	Holds the current graph on the screen
i	$\sqrt{-1}$
imag	Computes the imaginary part of a complex number
impulse	Computes the unit impulse response of a system
inf	Represents infinity
j	$\sqrt{-1}$
linspace	Generates linearly spaced vectors
load	Loads variables saved in a file
log	Computes the natural logarithm
log10	Computes the logarithm base 10
loglog	Generates log-log plots
logspace	Generates logarithmically spaced vectors
lsim	Computes the time response of a system to an arbitrary input and initial conditions
margin	Computes the gain margin, phase margin, and associated crossover frequencies from frequency response data
max	Determines the maximum value
mesh	Creates three-dimensional mesh surfaces
meshdom	Generates arrays for use with the mesh function
min	Determines the minimum value
minreal	Transfer function pole–zero cancellation
NaN	Representation for Not-a-Number
ngrid	Draws grid lines on a Nichols chart
nichols	Computes a Nichols frequency response plot
num2str	Converts numbers to strings
nyquist	Calculates the Nyquist frequency response
obsv	Computes the observability matrix
ones	Generates a matrix of integers where all the integers are 1.
pade	Computes an nth order Padé approximation to a time delay
parallel	Computes a parallel system connection
plot	Generates a linear plot
poly	Computes a polynomial from roots
polyval	Evaluates a polynomial
printsys	Prints state variable and transfer function representations of linear systems in a readable form
pzmap	Plots the pole–zero map of a linear system
rank	Calculates the rank of a matrix
real	Computes the real part of a complex number
residue	Computes a partial fraction expansion
rlocfind	Finds the gain associated with a given set of roots on a root locus plot
rlocus	Computes the root locus
roots	Determines the roots of a polynomial
roots1	Same as the roots function, but gives more accurate answers when there are repeated roots
semilogx	Generates an x-y plot using semilog scales with the x-axis $\log_{10}$ and the y-axis linear
semilogy	Generates an x-y plot using semilog scales with the y-axis $\log_{10}$ and the x-axis linear
series	Computes a series system connection
shg	Shows graph window
sin	Computes the sine
sqrt	Computes the square root
ss2tf	Converts state variable form to transfer function form
step	Calculates the unit step response of a system
subplot	Splits the graph window into subwindows
tan	Computes the tangent
text	Adds text to the current graph
title	Adds a title to the current graph
tf2ss	Converts a transfer function to state variable form
who	Lists the variables currently in memory
whos	Lists the current variables and sizes
xlabel	Adds a label to the x-axis of the current graph
ylabel	Adds a label to the y-axis of the current graph
zeros	Generates a matrix of zeros