An Introduction to Transducers and Instrumentation

Curriculum Manual IT02

Lesson Module: 17.50 Version 0
Issue: ME706/E

Addendum Sheet

Please note that the following warning label has now been added to the D1750 trainer.

This is to indicate the area of moving parts, and that fingers should be kept clear.

Keep fingers clear of all
moving parts

Technical Publications Department
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Appendices

Introduction

Introduction

This comprehensive course of study is based on a single panel Transducer and Instrumentation Trainer, the DIGIAC 1750.

The D1750 unit provides examples of a full range of input and output transducers, signal conditioning circuits and display devices.

The unit is self-contained and enables the characteristics of many individual devices to be investigated, building to form complete closed loop systems.

As each item is introduced there is a description of the principles of the device, together with practical exercises to illustrate its characteristics and applications.

The treatment is non-mathematical and little previous knowledge is assumed, although it is expected that students will have a basic knowledge of electrical circuits and units, and electronic components and devices.

It is the intention that at the end of this course the student will, with the knowledge gained, be able to select suitable components and interconnect them to form required closed-loop systems.

Although the course has been laid out progressively it is sometimes necessary to make use of a device before a full investigation has been carried out. For instance, in order to investigate any input transducer, an input signal may be needed. This signal may be provided by one of the output transducers not yet covered. Also signal conditioning and display devices will be needed from an early stage. In the event of any difficulty, it is recommended that the student should skip forward to the relevant section to obtain further information.

Test Instruments

It is recommended that a digital multimeter is available for use with this module. The meter must have ranges to cover at least:

DC voltage: 200mV to 20V
DC current: 1mA to 100mA
Resistance: 10Ω to 10MΩ

To complete the exercises you will need to be familiar with connecting, setting the range and obtaining readings from multimeters. If you are not familiar with the use of these instruments please refer first to Appendix A before carrying out any exercises.

Some examinations of voltage waveforms will be called for using a cathode ray oscilloscope. You will be expected to be able to make the necessary adjustments and settings to obtain time related sketches of the waveforms examined. Recommendations for the settings of the various controls will be given where appropriate. Again, if you are not familiar with this instrument or the applications of it, please refer to Appendix B before attempting the relevant exercise.

A function generator will be required to provide sinewave and square wave inputs to some circuits. This should have a range of frequencies covering at least 10Hz - 1MHz, and output of 20Vp-p (with an internal attenuator to allow amplitude settings), and an output impedance of 50Ω. The output lead should be terminated in standard 4mm banana plugs for ease of connection directly to the D1750 Trainer panel.

The Module Power Supplies

The D1750 Transducer and Instrumentation Trainer contains all of the power supplies needed to make it operate. You can switch these power supplies ON and OFF with the Power Supplies switch located on the rear panel.

Making Circuit Connections

During each Practical Exercise in this manual, you will be asked to make circuit connections using the 4mm Patching Cords. Whenever you make (or change) circuit connections, it is good practice to always do so with the Power Supplies switch in the OFF position. You should switch the Power Supplies ON only after you have made, and checked, your connections.

Remember that the Power Supplies switch must be ON in order for you to be able to make the observations and measurements required in the Exercise.

At the end of each Exercise, you should return the 'Power Supplies' switch to the 'OFF' position *before* you dismantle your circuit connections.

Your Workstation

Depending on the laboratory environment in which you are working, your workstation may, or may not, be computer managed. This will affect the way that you use this laboratory manual.

If you are in any doubt about whether your workstation is computer managed, you should consult your instructor.

Using this Manual at a Computer Managed Workstation

In order to use this curriculum manual at a computer managed workstation you will require one of the following items:

- ♦ D3000 Hand-held Data Terminal.
- ♦ A personal computer (PC) that has been installed with computer managed student workstation software.

If you are working in a computer managed environment for the first time, you should first read the operating information that has been provided with your computer managed workstation. This tell you how to:

- ♦ Log onto the management system and request work.
- ♦ Make responses to questions in a computer managed environment.
- ♦ Hand in your work when completed.
- ♦ Log off at the end of your work session.

Whenever you see the symbol  in the left-hand margin of this Curriculum Manual, you are required to respond to questions using your computer managed workstation. You should also record your responses so that you can review them at any time in the future.

The following D3000 Lesson Module is available for use with this Curriculum Manual:

D3000 Lesson Module 17.50

Using this Manual at a Workstation that is *not* Computer Managed

Whenever you see the symbol  in the left-hand margin of this Curriculum Manual, you are required to answer a question. If your workstation is *not* computer managed, you should record your answer so that it can be subsequently marked by your instructor.

Good luck with your Studies.

Chapter 7
Environmental Measurements

Objectives of this Chapter

Having studied this Chapter you will be able to:

- Describe the construction and characteristics of an air flow transducer.
- Describe the construction and characteristics of an air pressure transducer.
- Describe the construction and characteristics of a humidity transducer.

Equipment Required for this Chapter

- DIGIAC 1750 Transducer and Instrumentation Trainer.
- 4mm Connecting Leads.
- Digital Multimeter.

7.1 The Air Flow Transducer

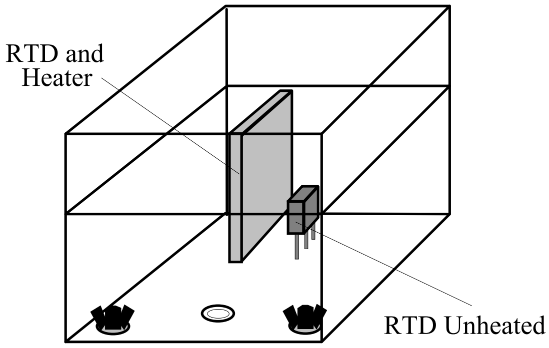

Fig 7.1

Fig 7.1 shows the construction of an Air Flow Transducer, consisting of two RTD's (Resistance Temperature Dependent) 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 RTD's, the temperature of the heated unit will fall more than that of the unheated unit. The temperature difference will be related to the air flow rate which will in turn affect the resistance of the RTD's.

With the DIGIAC 1750 Trainer, the transducers are enclosed in a clear plastic container and provision is made for air to be pumped over the device.

Fig 7.2 shows the electrical circuit arrangement and main characteristics of the device in the DIGIAC 1750 Trainer.

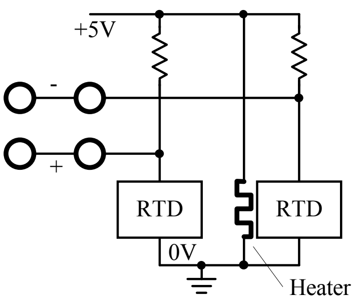

Fig 7.2

Heater power	1W
Output impedance	1.7kΩ
Output voltage (-). Pump OFF	2.1V
Output voltage (+). Pump OFF	1.7V
Voltage change (airflow)	0.06V

Table 7.1

7.2 Practical Exercise
Characteristics of an Air Flow Transducer

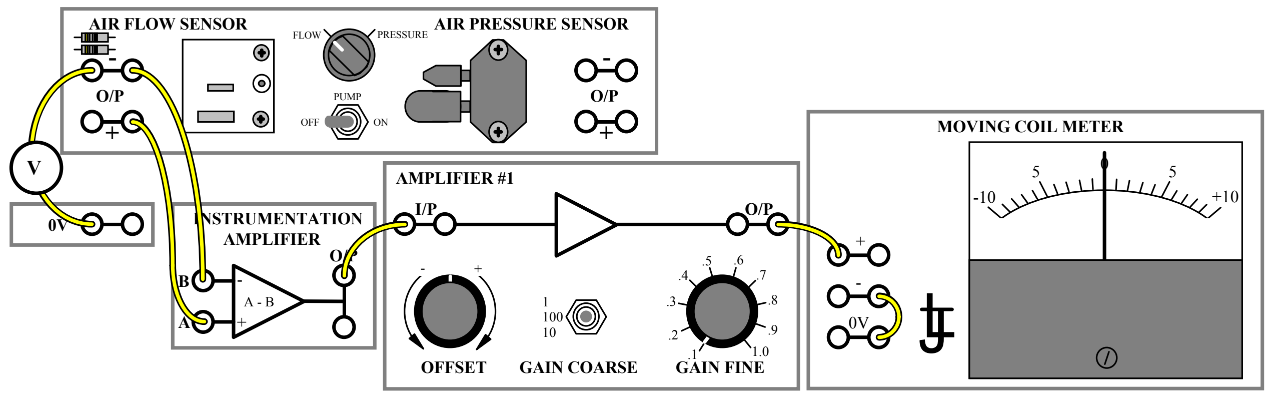

Fig 7.3

- Connect the circuit as shown in Fig 7.3 and set the GAIN COARSE control of Amplifier #1 to 10 and GAIN FINE control to 1.0. Check that the pump control is set to OFF.
- Set the digital multimeter to the 20V range.
- Switch ON the power supply and allow the temperature to stabilize.
- Adjust the OFFSET control of Amplifier #1 for zero output continuously during this time, setting the GAIN COARSE control to 100 when stabilized conditions are approached.
- Set the Flow/Pressure control to FLOW.
- Check that the OFFSET control is set for zero output voltage.
- Use the digital multimeter to note the voltages at the - and + outputs from the transducer and record the values in Table 7.2 overleaf.

- Switch the pump ON and note the voltages again when conditions have stabilized, recording the values in Table 7.2.

	Pump OFF	Pump ON
Transducer - Output Voltage	V	V
Transducer + Output Voltage	V	V
Amplifier #1 Output Voltage	0	V

Table 7.2

The RTD's have a positive temperature coefficient.

7.2a **Which output is connected to the heated RTD, - [a] or + [b] ?**

- Switch OFF the power supply and the pump.

Notes:

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7.3 The Air Pressure Transducer

Fig 7.4 shows the construction of an air pressure transducer and also shows the electric circuit arrangement of the DIGIAC 1750 unit. The device consists 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 a strain gauge Wheatstone bridge circuit is fitted on the surface.

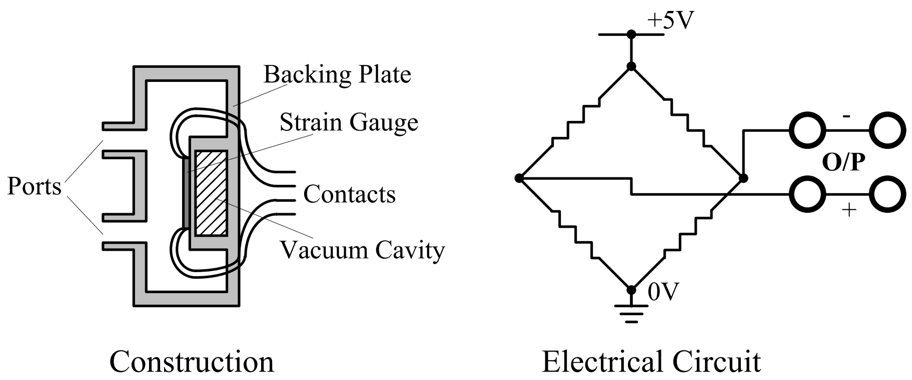

Fig 7.4

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.

The transducer output can be calibrated and may be called an *absolute pressure transducer*.

Provision is made for air to be fed to the unit from the pump.

The main characteristics of the device are:

Type			**SPX200AN**
Sensitivity (typical)	300µV/kPa	Voltage difference Pump OFF	35mV
Temperature coefficient	1350ppm/°C	Voltage difference Pump ON	39mV
Output Voltage (-) Pump OFF	2.48V	Output impedance	1.6kΩ
Output Voltage (+) Pump ON	2.51V		

Table 7.3

7.4 Practical Exercise
Characteristics of an Air Pressure Transducer

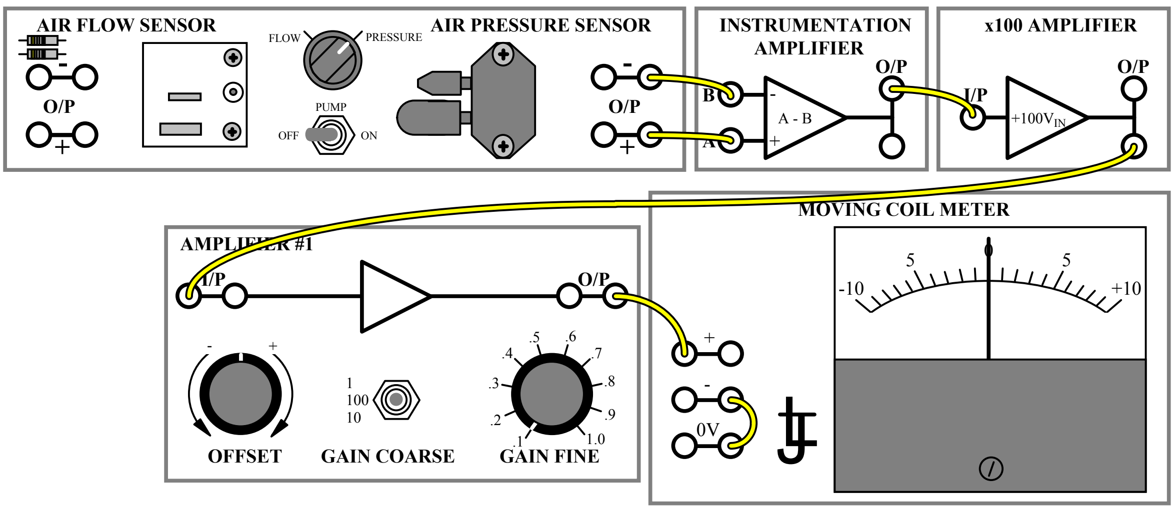

Fig 7.5

- Connect the circuit as shown in Fig 7.5 and set the Amplifier #1 GAIN COARSE control to 10 and GAIN FINE control to 1.0. Ensure that the pump switch is set OFF.

- Switch ON the power supply and adjust the OFFSET control of Amplifier #1 for zero output voltage. The unit is now calibrated zero for the current value of the atmospheric pressure.

- Set the Flow/Pressure control to PRESSURE and then switch the pump ON. The output voltage from the Amplifier #1 will increase. Note the value of this voltage.

Output voltage (Pump ON) = [**V**]

7.4a **Enter your value of output voltage with the Pump ON in V.**

Note that a large amplification is required due to the low magnitude of the device output.

- Switch OFF the power supply and the pump.

7.5 The Humidity Transducer

Fig 7.6(a) shows the construction of a humidity transducer, consisting of a thin disc of a material whose properties vary with humidity. Each side of the disc is metalized to form a capacitor.

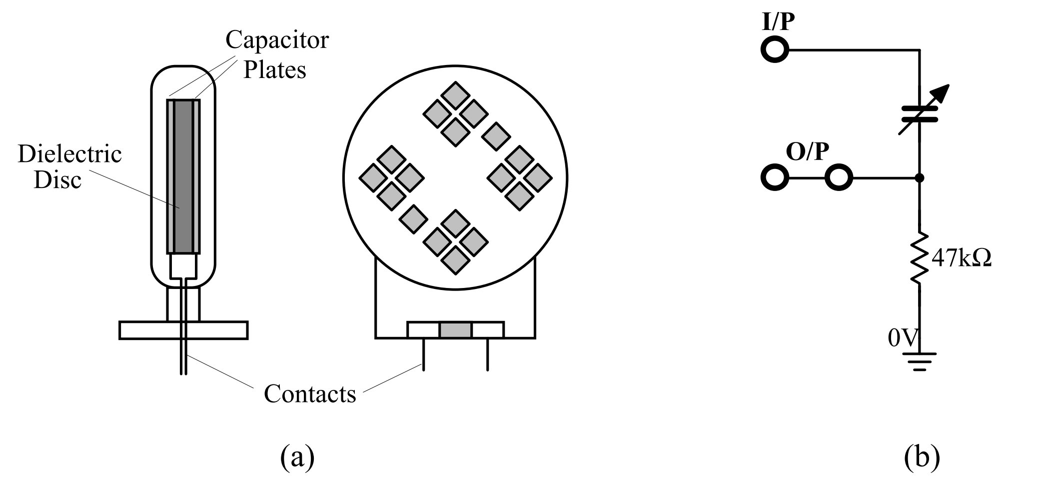

Fig 7.6

Variation of humidity of the surrounding air alters the permittivity and/or thickness of the dielectric material, changing the value of the capacitor. The unit is housed in a perforated plastic case.

Fig 7.6(b) shows the electrical circuit arrangement for the DIGIAC 1750 unit.

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 with humidity due to the variation of capacitance of the transducer.

The main characteristics of the device are:

Type	**90001**
Capacitance (25°C, 45%R/H)	122pF ± 15%
Sensitivity	0.4pF/%RH
Humidity Range	10%-90% RH

Table 7.4

Note: **R/H** is Relative Humidity, $\frac{\text{Ambient Humidity}}{\text{Saturated Air}}$ x 100%.

The device is slow to respond fully to humidity changes, taking in the order of minutes, but this will normally be of no consequence in practice since natural changes in humidity are very slow.

The variation of output voltage from the circuit is only a small percentage of the output and this is difficult to detect.

In the practical exercise you will use signal processing circuits which are available on the DIGIAC 1750 Trainer to convert the output to a DC signal, balance out the standing DC level and thus enable amplification of the small voltage changes.

Notes:

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7.6 Practical Exercise
Characteristics of a Humidity Transducer

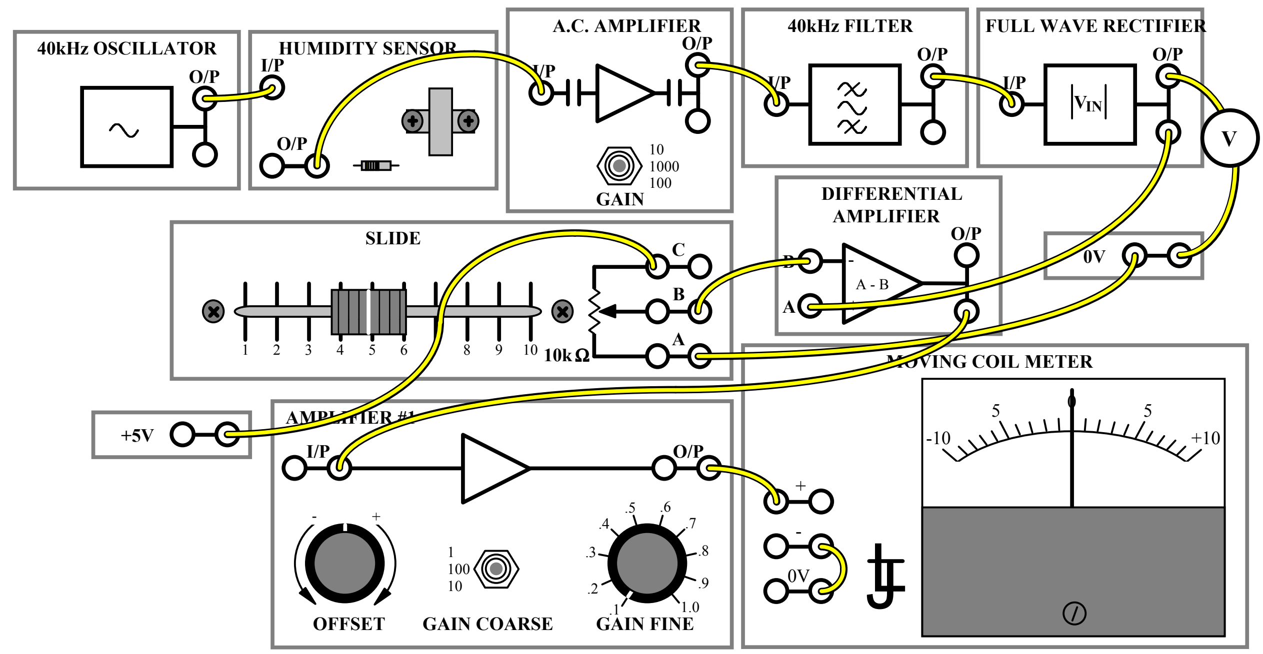


Fig 7.7

- Connect the circuit as shown in Fig 7.7, setting the AC Amplifier gain control to 10 and the Amplifier #1 GAIN COARSE control to 10 and GAIN FINE to 1.0.

- Switch ON the power supply, remove the leads from the Differential Amplifier inputs and connect a short circuit between them. Adjust the OFFSET control of Amplifier #1 for zero output. Switch GAIN COARSE to 100 and make a final adjustment.

- Replace the connections to the inputs of the Differential Amplifier and adjust the control of the 10kΩ carbon resistor for zero output from Amplifier #1. It may be advisable to set the coarse gain to 10 initially and then back to 100 finally during this process.

The bridge circuit is now balanced for the ambient conditions, the Differential Amplifier input from the 10kΩ variable resistor balancing that from the rectifier.

- Note the output voltage from the rectifier circuit as indicated by the digital voltmeter.

Output Voltage	Digital Meter	Moving Coil Meter
Ambient Conditions	V	0 V
After Breathing	V	V

Table 7.5

- Now place your mouth near the humidity transducer and breath on it for a short time. The reading indicated by the Moving Coil Meter will change slowly.

- Note the maximum value of the voltage and also the reading of the digital voltmeter.

Considering the readings obtained. Which meter do you consider gives a better indication of the voltage changes:

[a] the Digital Multimeter, or [b] the Moving Coil Meter?

7.6a Enter your answer, [a] or [b] .

The time taken for the output voltage to return to zero after reaching the maximum voltage illustrates the slow response of the device to humidity changes.

Time taken for output to return to zero = [ ]

Was the time taken for recovery less than 10 minutes [a] , or more [b] ?

7.6b Enter your answer, [a] or [b] .

- Switch OFF the power supply.

Note: It is advisable to check the OFFSET of Amplifier #1 at regular intervals in case there has been any drift. This can be checked by just removing both of the input connections from the Differential Amplifier. The OFFSET control can then be adjusted if necessary.

The ambient humidity conditions should not change during the test, but should a change occur, the bridge output will not return to zero.

Student Assessment 7

1. The operating principle of the Air Flow Transducer relies on the use of:

a strain gauges b RTD's c a capacitor d a pressure pump

2. The Instrumentation Amplifier used in these experiments is a form of:

a differential amplifier b bandpass filter

c AC amplifier d summing amplifier

3. In Practical Exercise 7.2 (Air Flow Transducer Characteristics) the moving coil meter was balanced to zero at the start of the experiment using the:

a 10-turn variable resistor on the Wheatstone Bridge panel

b 10kΩ carbon slider potentiometer

c balancing inputs on the Instrumentation Amplifier

d offset control on Amplifier #1

4. The operating principle of the Air Pressure Transducer relies on the use of:

a strain gauges b RTD's c a capacitor d a pressure pump

5. The output from an Air Pressure Transducer device is derived from a:

a series resistor b series capacitor c bridge circuit d x100 amplifier

6. At the start of the Air Pressure Transducer Characteristic experiment the output of the device is calibrated zero against:

a relative humidity b ambient temperature

c atmospheric pressure d ambient illumination

Continued ...

Student Assessment 7 Continued ...

7. The operating principle of the Humidity Transducer relies on the use of:

- a strain gauges
- b RTD's
- c a capacitor
- d a pressure pump

8. The output from a humidity detector circuit varies between DC values of 3.50V and 3.52V over its full humidity range. Which of the following signal processing circuits would be necessary to provide an output range from 0 - 10V DC?

- a AC amplifier
- b oscillator
- c DC amplifier
- d 40 kHz filter

9. In the Humidity Transducer investigation, the DC component of the full-wave rectifier circuit was balanced out using:

- a 10-turn variable resistor on the Wheatstone Bridge panel
- b 10kΩ carbon slider potentiometer
- c balancing inputs on the Instrumentation Amplifier
- d offset control on Amplifier #1

10. The device investigated in this chapter with the slowest response time was the:

- a Air Flow Sensor
- b Air Pressure Sensor
- c Strain Gauge
- d Humidity Sensor

Chapter 8
Rotational Speed or Position Measurements

Objectives of this Chapter

Having studied this Chapter you will be able to:

- Describe the construction, principles and application of Slotted Opto Transducers for counting and speed measurement.
- Describe the construction, principles and application of Reflective Opto Transducers and Gray Coded Disc for position measurement.
- Describe the construction, principles and application of Inductive Transducers for speed measurement.
- Describe the construction, principles and application of Hall Effect Transducers to speed and positional measurement.
- Describe the construction, principles and application of a Tacho-Generator to speed measurement.

Equipment Required for this Chapter

- DIGIAC 1750 Transducer and Instrumentation Trainer.
- 4mm Connecting Leads.
- Digital Multimeter.

8.1 The Slotted Opto-Transducer

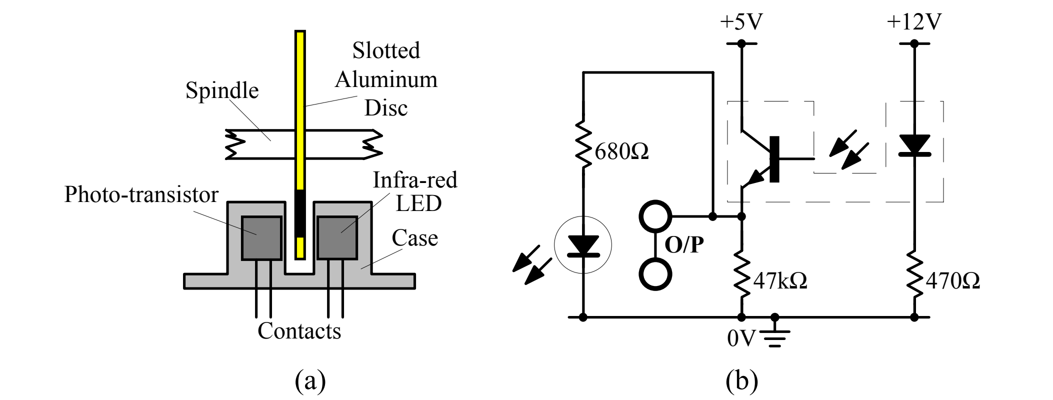


Fig 8.1

Fig 8.1(a) shows the construction of a slotted opto transducer, consisting of a gallium arsenide infra-red LED and silicon phototransistor mounted on opposite sides of a gap in the case, each being enclosed in a plastic case which is transparent to infra-red radiations.

The gap between them allows the infra-red beam to be broken when a solid 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 generates pulses which are suitable for counting rotations.

A slotted aluminum disc connected to the motor shaft assembly rotates in the transducer gap in the DIGIAC 1750 unit and an LED is provided to indicate when the slot position allows the beam to be admitted.

Fig 8.1(b) shows the electrical circuit arrangement for the DIGIAC 1750 unit

The main characteristics of the device are:

Type	**K8102**
Output Voltage (beam broken)	0.1V
Output Voltage (beam admitted)	4.9V

Table 8.1

8.2 Practical Exercise
Characteristics of a Slotted Opto Transducer

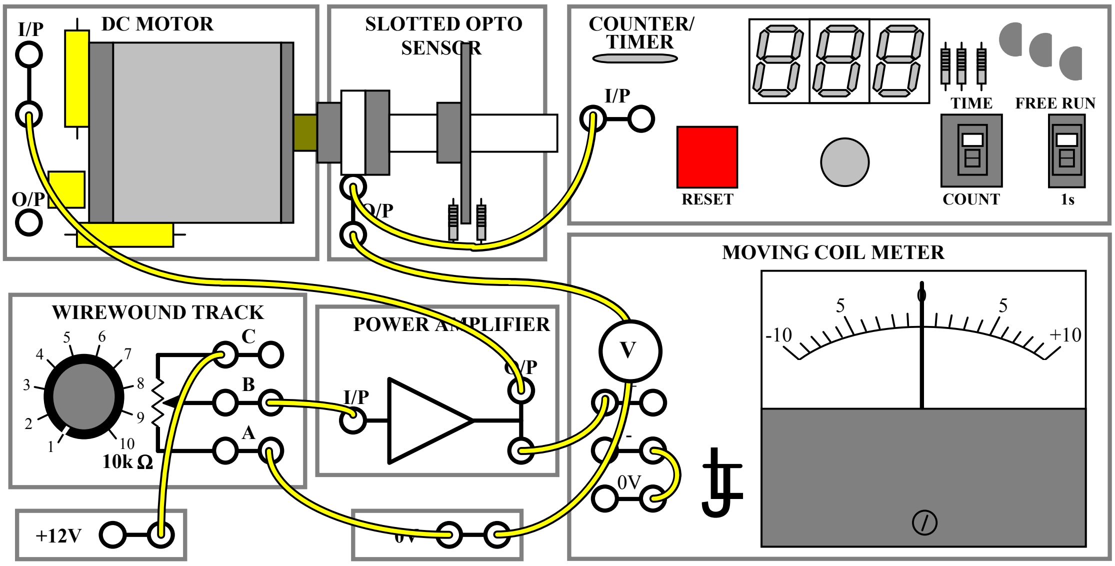


Fig 8.2

- Connect the circuit as shown in Fig 8.2 and set the 10kΩ wirewound resistor control fully counter-clockwise for zero output voltage.

- Switch ON the power supply.

- Rotate the shaft by hand using the large aluminum disc provided with the Hall effect device. Note and record in Table 8.2 the output voltage from the Slotted Opto Transducer output socket and also the state of the indicating LED:
  (a) with the beam broken by the aluminum disc, and
  (b) with the beam admitted through the slot in the aluminum disc.

	Beam Broken	Beam Admitted
Output Voltage	V	V
LED - ON/OFF		

Table 8.2

- Set the Timer/Counter to COUNT and FREE RUN. The display should show zero. If not, press RESET.

- Rotate the shaft backwards and forwards by hand so that the slot in the aluminum disc passes between the opto transducer.

- Note the counter display, this should increment by 1 each time the slot is in line with the transducer beam. This illustrates the use of the opto transducer for counting applications.

- Now adjust the 10kΩ wirewound resistor control to give a drive voltage to the motor of 2V as indicated by the Moving Coil Meter. The motor should operate and rotate the shaft.

  The counter value will increment once for each revolution of the shaft and can be used to measure the shaft speed:

- Press the RESET button and hold down. With a watch, stop watch if available, release the reset button at a suitable time and note the count value after one minute. This value represents the shaft speed in revolutions per minute (rev/min). Record the value in Table 8.3.

Motor Drive Voltage (volts)	2	3	4	5	6	7	8	9	10
Shaft Speed (rev/sec)									
Shaft Speed (rev/min)									

Table 8.3

- Repeat with a motor drive voltage of 3V and add the result to Table 8.3.

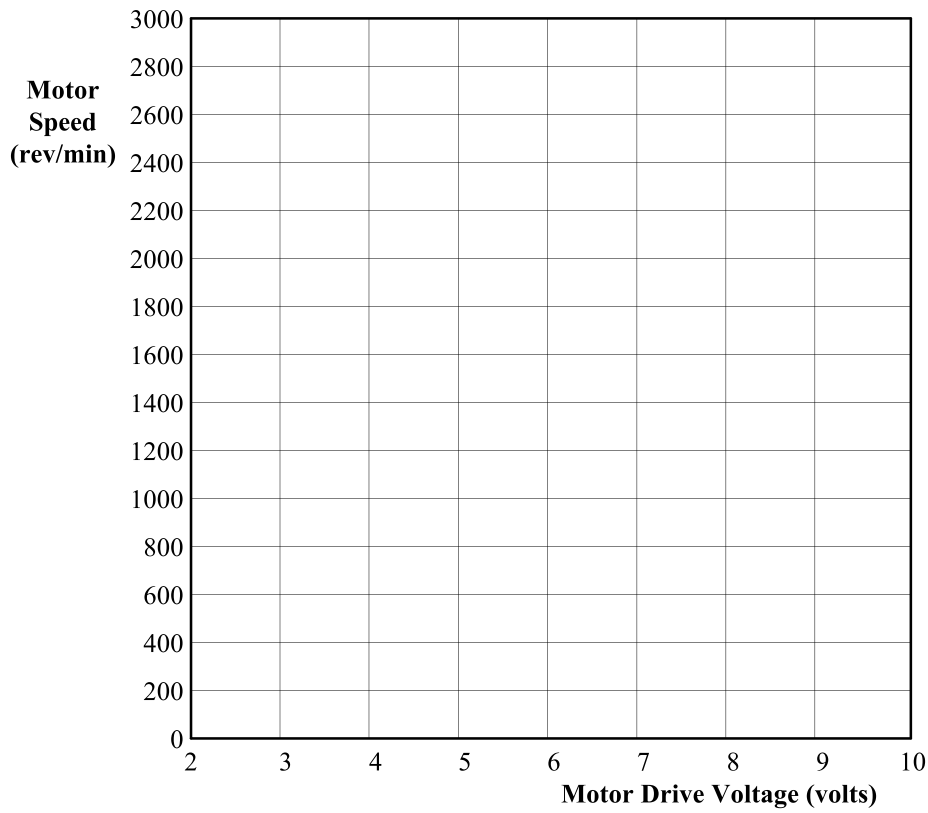
- Set the COUNTER/TIMER FREE RUN/1s switch to 1s (1 second). Set the 10kΩ resistor to give a motor drive voltage of 4V. Press the RESET button of the counter.

  The counter now counts for one second and the count value is "frozen" at the end of this time. The count displayed represents the number of revolutions per second of the shaft Press RESET again. The displayed value should correspond with the previous value. Record the value in Table 8.3 in the relevant row.

- Repeat the procedure with the other motor drive voltages shown in Table 8.3 and for each setting note the shaft speed in rev/sec as displayed by the counter and add to the table. Switch OFF the power supply.

- Multiply each recorded value by 60 to give the shaft speed in revolutions per minute (rev/min or rpm) and add to Table 8.3.

- Plot the graph of motor speed in rev/min against drive voltage on the axes provided:



Graph 8.1

8.2a **From your graph deduce and enter the motor drive voltage needed to give a speed of 1800 rev/min in V.**

Keep the motor drive circuits connected for later experiments.

8.3 The Reflective Opto Transducer

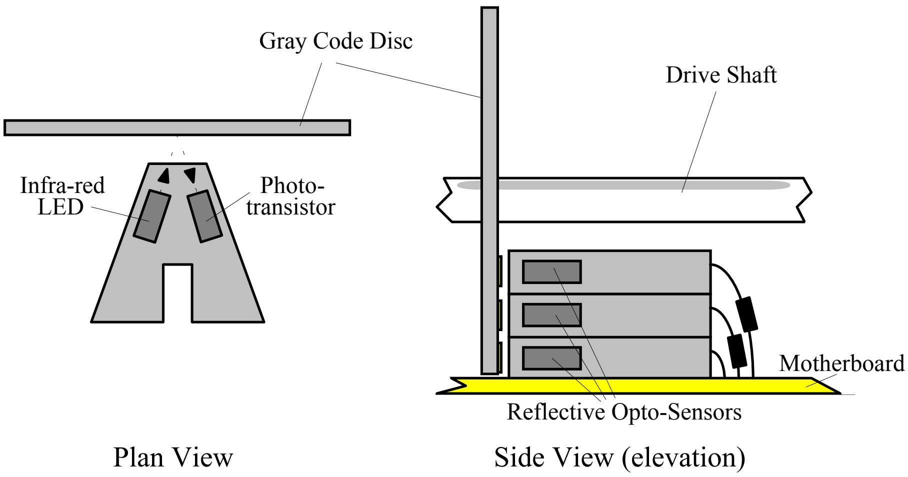


Fig 8.3

Fig 8.3 shows the construction of a *reflective* opto transducer, consisting of an infra-red LED and phototransistor. This is similar to the slotted opto transducer, but in this device the components are arranged so that the beam is reflected back 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, being mounted in line vertically. The reflective surface is a Gray-coded disc, which is fixed approximately 4mm from the transducers.

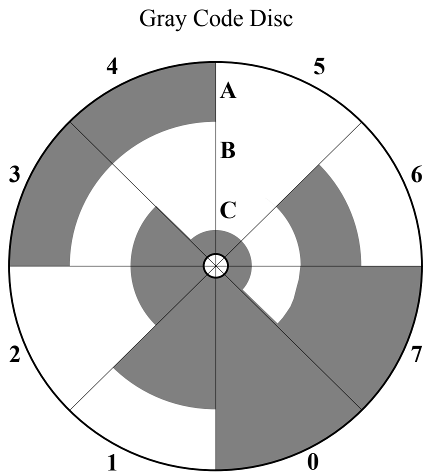
With the beam not reflected the output from the phototransistor emitter is low. When the beam is reflected the output is high.

Three LED's are provided to indicate when the beam is reflected from the respective transducer unit.

The output A is the least significant bit (LSB) and C is the most significant bit (MSB).

The Gray code is used for the encoded disc rather than normal binary because only one digit changes state at any boundary with this code and this minimizes any possibility of error in identifying the actual position when at a segment boundary.

The arrangement of the Gray-coded disc and the respective LED outputs is shown in Fig 8.4.



Position	C	B	A
0	0	0	0
1	0	0	1
2	0	1	1
3	0	1	0
4	1	1	0
5	1	1	1
6	1	0	1
7	1	0	0

Fig 8.4

The dark areas break the beam and produce a low output from the associated transducer and the bright areas reflect the beam and produce a high output.

The DIGIAC 1750 unit operates as a rotational angular position transducer but similar principles can be used for linear position applications.

Slotted opto devices could be used with a transparent disc (transparent where the above disc is reflective).

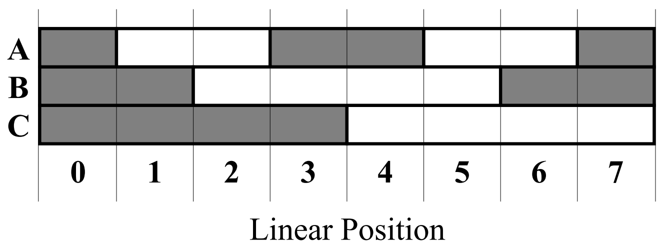


Fig 8.5

Fig 8.5 shows a linear Gray-coded track, the **A** track is the LSB and **C** the MSB.

The resolution provided with a 3-bit code (3 opto devices) is poor but this can be improved by increasing the number of devices and tracks.

Note the Gray code pattern:

		START	REPEATS	
LSB	**A**	**1** unit length '**0**'	**2** unit lengths '**1**'	**2** unit lengths '**0**'
	B	**2** unit length '**0**'	**4** unit lengths '**1**'	**4** unit lengths '**0**'
MSB	**C**	**4** unit length '**0**'	**8** unit lengths '**1**'	**8** unit lengths '**0**'

Table 8.4

The electrical circuit arrangement for the DIGIAC 1750 unit is shown in Fig 8.6:

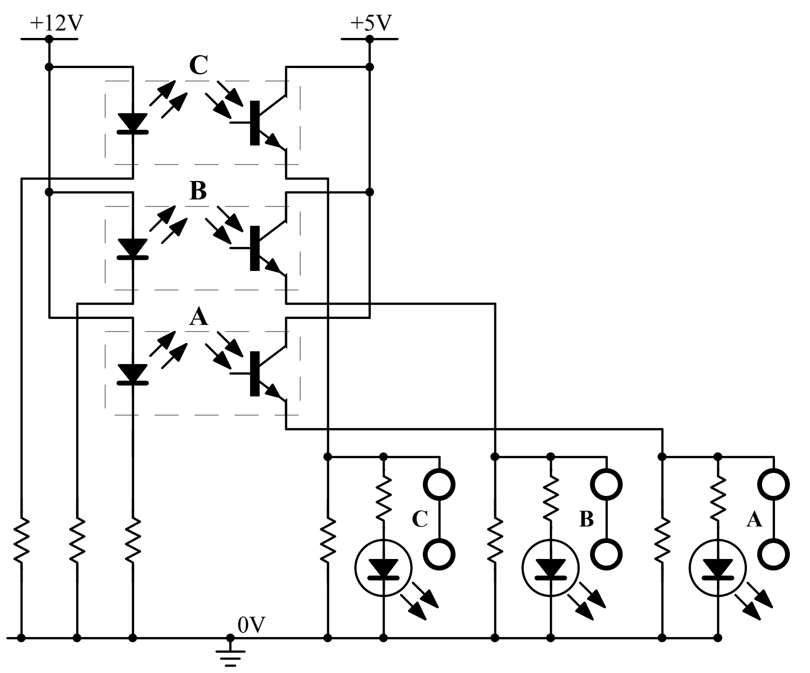


Fig 8.6

The main characteristics of the device are:

Type	**K8711**
Output Voltage (beam broken)	0.5V
Output Voltage (beam admitted)	5V

Table 8.5

8.4 Practical Exercise
Characteristics of Reflective Opto Transducers and Gray Code Disc

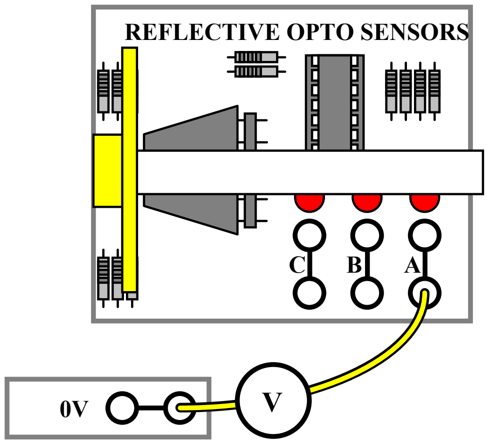


Fig 8.7

- Connect the circuit as shown in Fig 8.7 with the digital multimeter on the 20V DC range.

- Switch ON the power supply and rotate the drive shaft by hand to alter the LED states.

- Rotate the shaft until it is in the position with all LED's OFF. Use the digital multimeter to measure the voltage at each of the outputs and record in Table 8.6.

Output	Output Voltage	
	LED OFF	LED ON
A	V	V
B	V	V
C	V	V

Table 8.6

- Turn the shaft until all LED's are ON and repeat the readings, recording the results again in Table 8.6.

- With the shaft initially in the position with all LED's OFF, rotate the shaft counterclockwise, when looking at the coded side of the disc, and note the state of the LED's at each change of state.

  Denote an LED OFF as logic state 0 and LED ON as logic state 1.

- Record the values in Table 8.7.

Position	C	B	A
0			
1			
2			
3			
4			
5			
6			
7			

Table 8.7

Check the sequence against that shown in the table in Fig 8.4.

8.4a **Enter the voltage at the 'B' output when the LED is ON.**

8.4b **Enter the voltage at the 'B' output when the LED is OFF.**

8.4c **The code which you have recorded for step 6 in the form C B A is:**

[a] 1 1 0 [b] 0 1 1 [c] 1 0 1 [d] none of these

- Switch OFF the power supply.

8.5 The Inductive Transducer

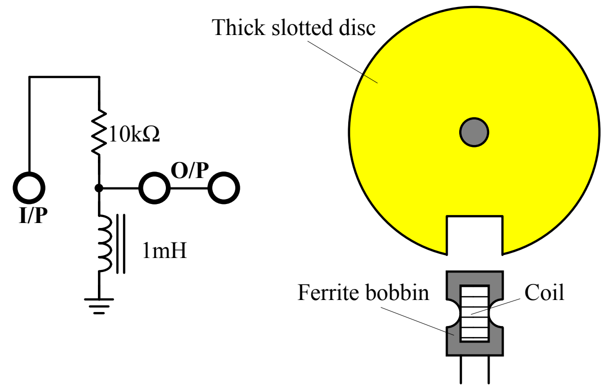


Fig 8.8

Fig 8.8 shows the construction and electrical circuit arrangement for the Inductive Transducer provided with the DIGIAC 1750 unit.

This consists of a 1mH inductor and a slotted aluminum disc fitted to the drive shaft which rotates above the inductor. The inductance of the unit varies with the position of the slot. With an aluminum disc the inductance increases with the slot positioned directly above the inductor.

If a magnetic disc was used, the inductance would decrease for the condition when the slot was above the inductor.

Note that, if unscreened, an inductor will be liable to pick up any stray interference, such as that which may be generated by the motor commutator switching. This can generate spurious short duration output pulses which may need to be suppressed by using a low pass filter.

The main characteristics of the device (in circuit under the disc) are:

Inductance	(under slot)	1mH
Inductance change	(under disc)	7µH
Output voltage	(under slot)	6.9mV
Output voltage change	(under disc)	2mV

Table 8.8

8.6 Practical Exercise
Characteristics of an Inductive Transducer

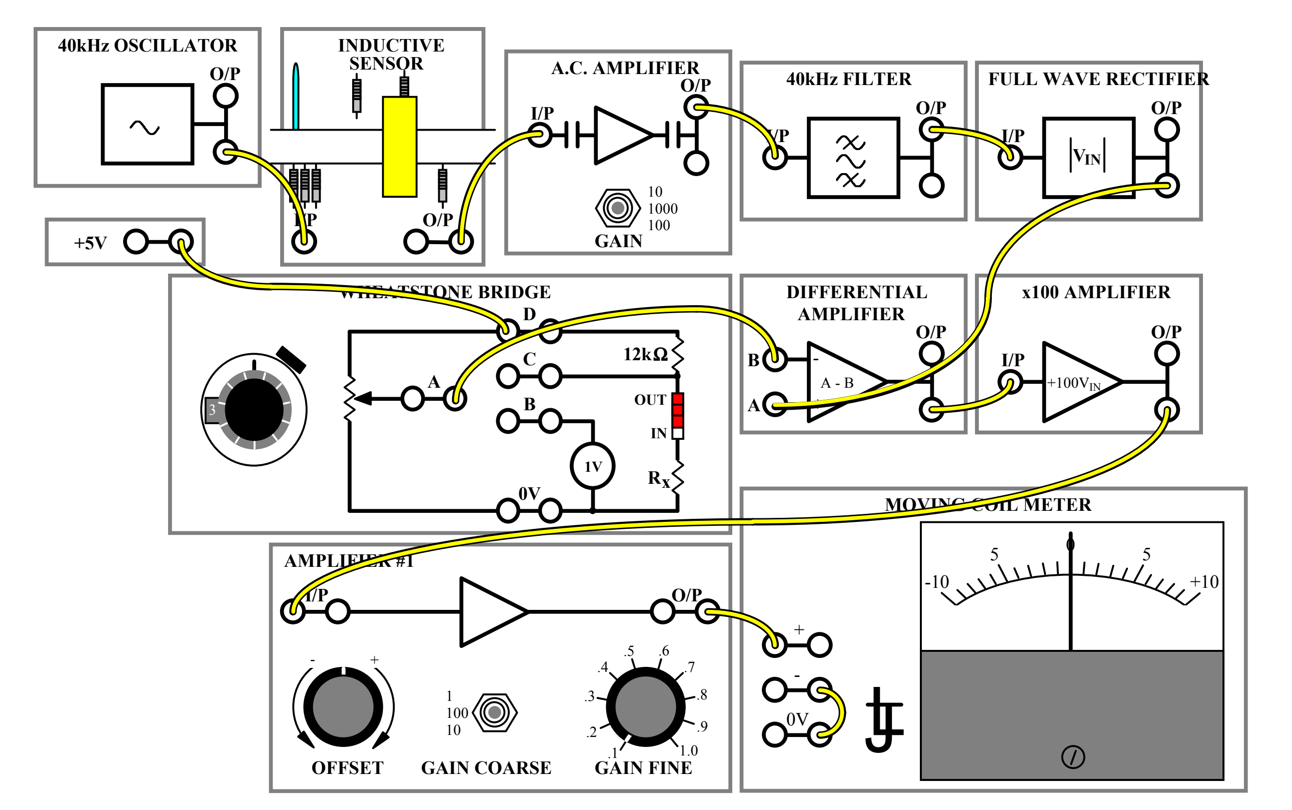


Fig 8.9

- Connect the circuit as shown in Fig 8.9. Set the AC Amplifier gain to 1000 and Amplifier #1 GAIN COARSE to 10 and GAIN FINE to 1.0. Set the drive shaft with the disc slot in the top vertical position.

- Remove the leads from the input to the Differential Amplifier, short the inputs together and switch ON the power supply.

- Adjust the OFFSET control of Amplifier #1 for zero output.

- Replace the leads to the input of the Differential Amplifier and adjust the control of the 10kΩ 10-turn resistor so that the meter reading is again zero. The control setting will be critical with such high overall amplifier gains.

- Check the zero reading and then rotate the motor shaft to obtain the maximum output voltage when the slot is immediately above the Inductive Sensor. Note the value of this voltage:

Output voltage with slot over the inductor = [ ] **V**

8.6a **Enter your maximum value of output voltage in V.**

This indicates an application of inductive transducers to proximity detection of metallic objects. The device can also be used for counting or speed measurement applications.

- Switch OFF the power supply. Retain your circuit, but remove the Moving Coil Meter from the output of Amplifier #1 and then add the circuits of Fig 8.10.

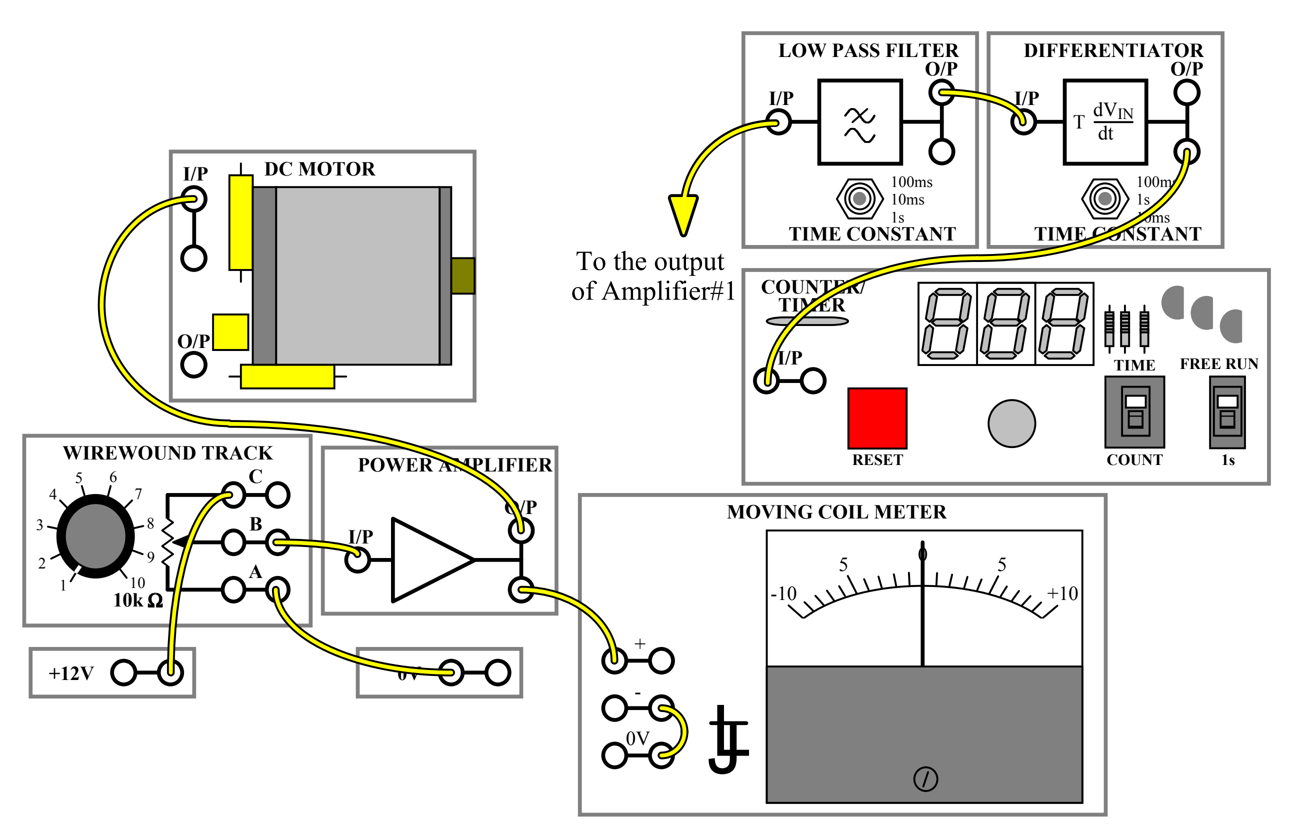


Fig 8.10

- Set the motor speed to zero.
- Set the TIME CONSTANT switches of the Low Pass Filter and the Differentiator to 1s and set the counter to COUNT and 1s.
- Switch on the power supply.
- Apply 2V input to the DC motor so that the shaft rotates slowly. Press the counter reset button several times and note the displayed value, this represents the speed in rev/sec.

Speed of the shaft recorded with the Inductive Sensor = ☐

- Remove the lead from the o/p of the Low Pass Filter to the Differentiator and take the lead from the input of the Low Pass Filter and connect it to the Differentiator input. Press the Counter RESET button several times and observe the result. If the result is zero, then refer to the re-calibration procedure described in the next point and repeat the counts with and without the Low Pass Filter. When a reading has been observed restore the Low Pass Filter back into the circuit by moving the lead back and adding the connection between the Low Pass Filter and Differentiator.

Speed of the shaft recorded without Low Pass Filter = ☐

- Re-calibrate the Inductive Sensor circuit by removing the lead from the MC meter to the Power Amplifier and connecting it between the MC meter and the output of Amplifier #1. Adjust the control of the 10KΩ 10-turn resistor so that the meter reading is zero. Then reconnect the MC meter to the Power Amplifier.
- Remove the Counter input lead from the Differentiator output and connect it to the output from the Slotted Opto Transducer. Press the counter reset button and note the displayed reading which also represents the shaft speed. Compare these value with the value obtained from using the Inductive Sensor.
- Repeat the two measurements for the motor input voltages and complete Table 8.9 on the next page.

Motor Voltage Shaft Speed (rev/sec)	2V	4V	7V	10V
Inductive Transducer				
Slotted Opto Transducer				

Table 8.9

8.6b **When the Low Pass Filter was removed from circuit the effect on the Counter readings was to:**

[a] produce a constant count each time [b] make no change

[c] reduce the count [d] increase the count

You will note that a considerable amount of signal conditioning has been required for the inductive transducer unit due to the small output voltage available and also the problem of the susceptibility of the counter to voltage spikes.

Notes:

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8.7 The Hall Effect Transducer

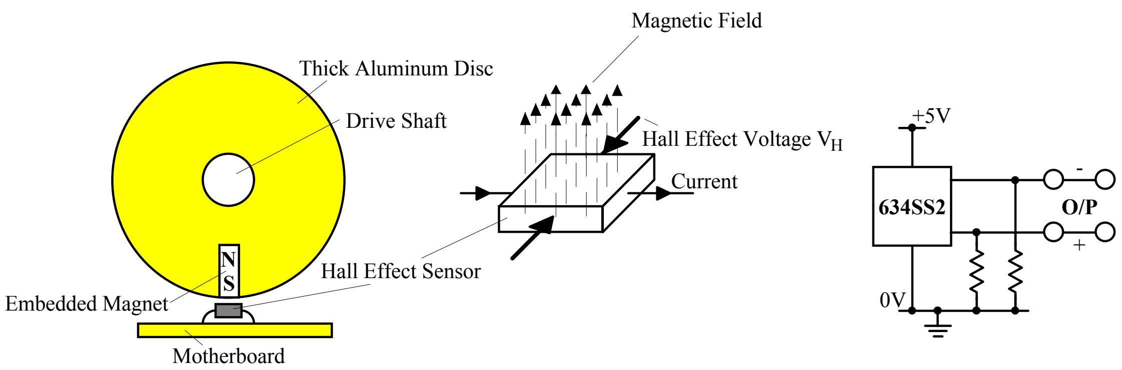


Fig 8.11

Fig 8.11 shows the layout and electrical circuit arrangement of the Hall Effect Transducer assembly fitted to the DIGIAC 1750 Trainer and illustrates the Hall Effect principle.

Hall Effect Principle
When current flows through the flat slice of semiconductor at right-angles to a magnetic field there is a force on each individual electron which tends to move it in one particular direction (the motor principle).

The current is pushed to one side of the slice. The surplus of electrons on one side of the slice means that this side is negatively charged, resulting in an EMF across the slice (the Hall voltage V_H) which is at right-angles to both the current and the magnetic field. The value of this voltage is directly proportional to the strength of the magnetic field.

The transducer provided on the DIGIAC 1750 Trainer also contains an active silicon semiconductor device to increase the output voltage and provide differential outputs, one going more positive and the other more negative (less positive).

The main characteristics of the device are:

Output voltage (+) (no field)	1.75-2.25V
Output voltage (-) (no field)	1.60V
Output voltage change	7.5-10.6mV/mT
Output voltage change (under magnet)	380mV

Table 8.10

8.8 Practical Exercise
The Characteristics of a Hall Effect Transducer

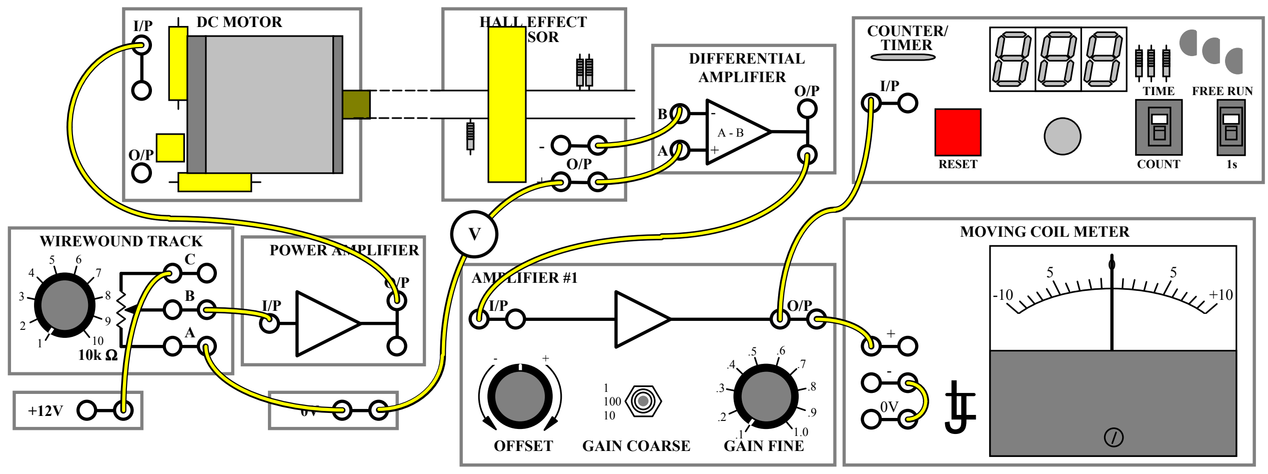


Fig 8.12

- Connect the circuit as shown in Fig 8.12. Set the Amplifier #1 GAIN COARSE control to 10, GAIN FINE to 0.8 and the motor drive voltage to zero. Switch ON the power supply.
- Set the drive shaft position so that the magnet in the Hall effect disc is horizontal (to one side) so that there is *no magnetic field* cutting the Hall effect device.
- Adjust the OFFSET control of Amplifier #1 for zero output indication on the Moving Coil Meter.
- Note the output voltage from the - and + output sockets of the Hall Effect device with the digital voltmeter directly on the Hall Effect Sensor panel and also from the Moving Coil Meter. Record the results in Table 8.11.

Magnetic Field	Digital Multimeter		Moving Coil Meter
	Output Voltage (-)	Output Voltage (+)	
None	V	V	0 V
Maximum	V	V	V

Table 8.11

- Rotate the disc so that the magnet is directly above the Hall effect device. This position will be indicated by the maximum output voltage.

- Note the voltages again and record in Table 8.11.

These readings illustrate the basic characteristics of the Hall Effect device and indicate its application to proximity detection. It is also suitable for speed measurement applications.

- With the output of Amplifier #1 connected to the Counter/Timer input set the controls for COUNT and 1s.

- Transfer the digital multimeter to the output of the Power Amplifier and apply an input voltage of 2V to the motor so that the shaft rotates slowly. Press the Counter RESET button and note the displayed value, this representing the shaft speed in rev/sec. Record the result in Table 8.12

- Remove the input to the counter from Amplifier #1 and connect it to the output of the Slotted Opto Transducer unit. Press the counter "reset" button and note the displayed value, this being the shaft speed for comparison with the previous reading. Add the value to Table 8.12.

Motor Voltage / Shaft Speed (rev/sec)	2V	4V	7V	10V
Hall Effect Transducer				
Slotted Opto Transducer				

Table 8.12

- Repeat the procedure for the other values of motor drive voltage given in Table 8.12 for comparison. Switch OFF the power supply.

8.8a **Enter your value of output voltage from the (+) O/P of the Hall Effect sensor with *no* magnetic field.**

8.8b **Enter your value of output voltage from the (+) O/P of the Hall Effect sensor with *maximum* magnetic field.**

Hall Effect devices are available for proximity detection, linear or angular displacement, multiplier and current or magnetic flux density measurement applications.

8.9 The DC Permanent Magnet Tacho-Generator

Fig 8.13 shows the construction and electrical circuit arrangement of the DC Permanent Magnet Tacho-Generator fitted to the DIGIAC 1750 Trainer. This consists of a set of coils connected to a commutator which rotate inside a permanent magnet stator.

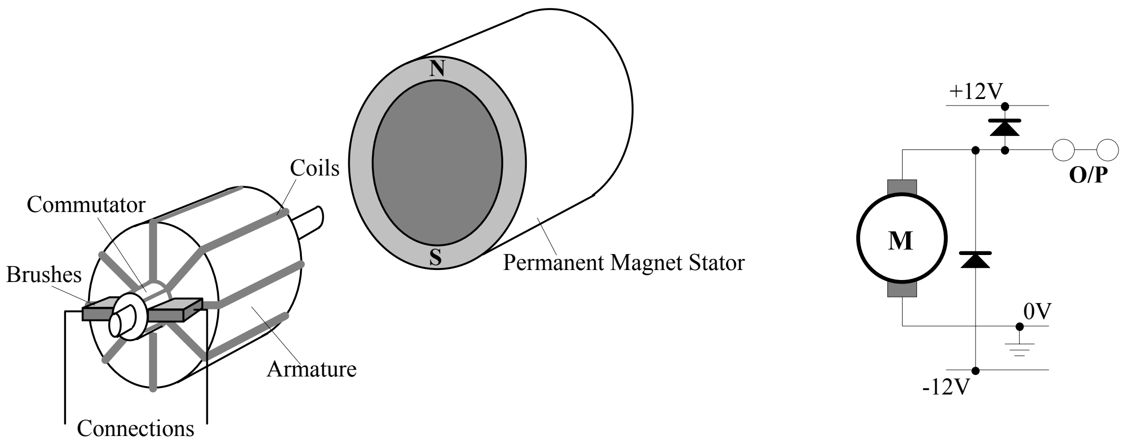


Fig 8.13

The rotating assembly is called the armature. With the coils rotating, an alternating EMF is generated in them. The commutator converts this to DC.

The magnitude of the generated EMF is proportional to the rate of cutting flux and therefore to the rotational speed. The polarity depends on the direction of cutting flux and therefore on the direction of rotation.

The diodes are fitted to limit any voltage spikes that may be generated by the commutation process (i.e. conversion from AC to DC) to a maximum of ±12V.

The main characteristics of the device are:

Open circuit voltage (12V to motor)	10.5V
Short circuit current (12V to motor)	750mA
Output impedance	39Ω
Output noise	200mV p-p

Table 8.13

8.10 Practical Exercise
Characteristics of a Permanent Magnet DC Tacho-Generator

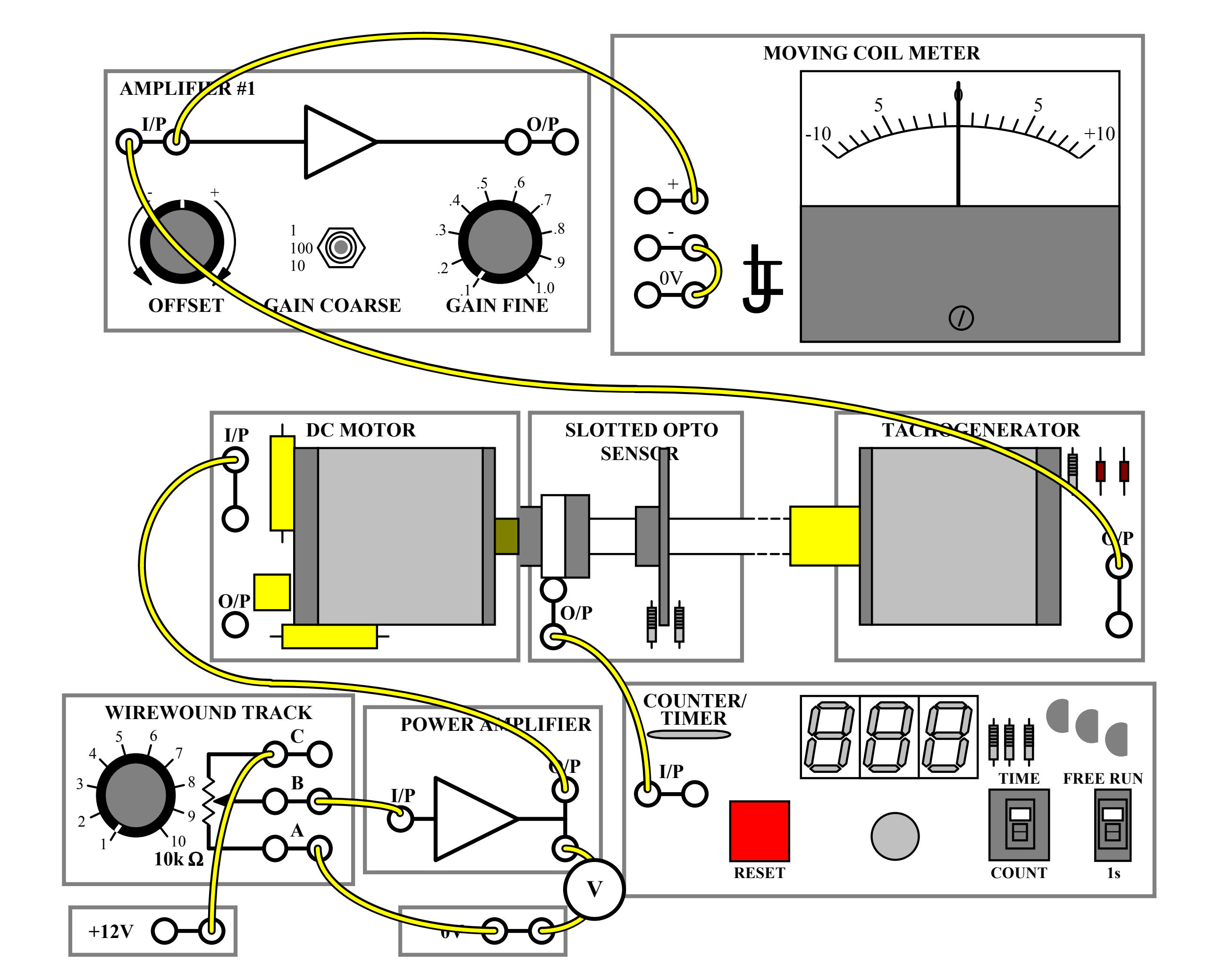


Fig 8.14

- Connect the circuit as shown in Fig 8.14.
- Set the COUNTER/TIMER controls to COUNT and 1s.
  Set Amplifier #1 GAIN COARSE control to 10 and GAIN FINE to 0.1.
- Switch ON the power supply.

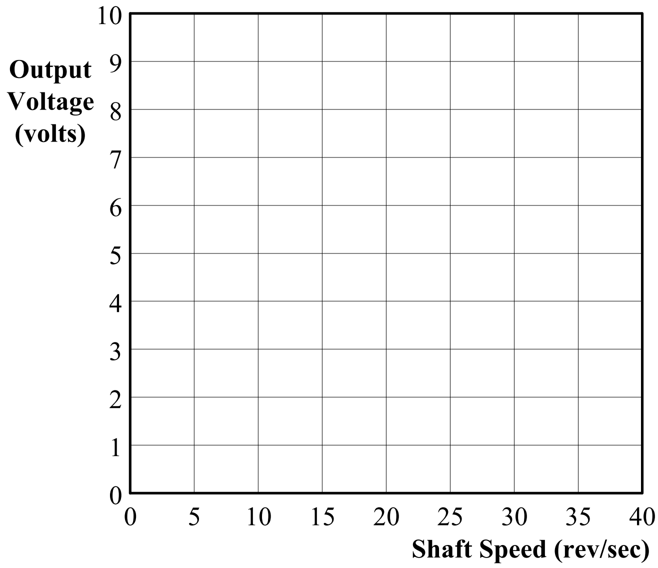
- Apply an input to the motor and set the shaft speed to 5 rev/sec (Note: Table 8.3 and Graph 8.1 may help) as indicated by the counter after pressing the RESET button. Note the output voltages indicated on the Moving Coil Meter and record the values in Table 8.14.

Shaft Speed (rev/sec)	5	10	20	30	40
Output Voltage (Moving Coil Meter)	V	V	V	V	V

Table 8.14

- Repeat the procedure for the other shaft speed settings indicated in Table 8.14.

- Draw the graph of output voltage against shaft speed on the axes provided.



Graph 8.2

8.10a **Is the characteristic linear?**

Yes or No

8.10b **From your graph estimate and enter your recorded output voltage from the digital multimeter when the shaft speed is 25 rev/sec.**

Calibration of the Moving Coil Meter to Indicate Speed Directly.

The scale to be used is 20V represents 2000 rev/min (100 rev/min/V).

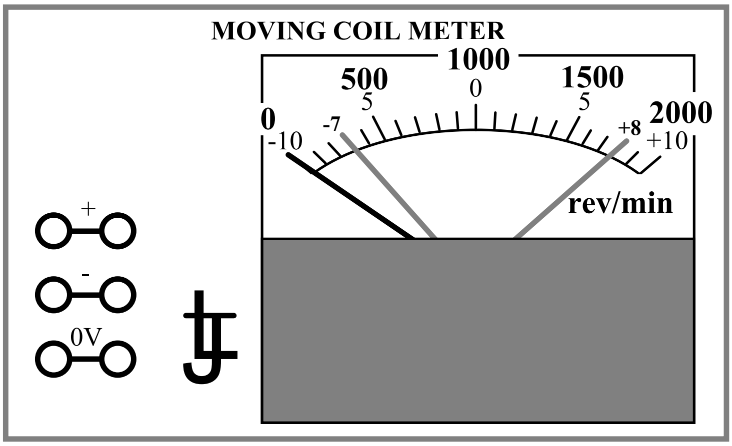


Fig 8.15

- Transfer the connection of the Moving Coil Meter from the input of Amplifier #1 to the output of Amplifier #1. Set the GAIN FINE control to just a little above 0.3.

- Apply a low input to the motor and set the shaft speed to 5 rev/sec (300 rev/min) as shown on the Counter after pressing RESET. Adjust the OFFSET control of Amplifier #1 to set the Moving Coil Meter reading to -7V (Fig 8.15).

- Change the motor drive voltage to set the shaft speed to 30 rev/sec (1800 rev/min) as shown on the Counter after pressing RESET. Adjust the GAIN FINE control of Amplifier #1 so that the Moving Coil Meter indicates +8V (Fig 8.15).

- Repeat both of the above settings and adjustments as often as necessary to make both of them correct (changing one of them will have altered the other. Some anticipation may be helpful). The meter will then be calibrated as shown in Fig 8.15.

- Use the calibrated Moving Coil Meter to set the motor speed as shown in Table 8.15.

- Calculate the corresponding speed in rev/sec and then check at each setting against those obtained from the Opto Transducer and Counter.

Shaft Speed (rev/min)	600	1000	1200	1600
Calculated Shaft Speed (rev/sec)				
Shaft Speed from Counter (rev/sec)				

Table 8.15

8.10c **Which was easier for setting the motor speed, the calibrated Moving Coil Meter [a] , or the Counter [b] ?**

8.10d **Enter your motor speed as indicated on the Counter in rev/sec when the motor speed was set to 1000 rev/min.**

8.10e **Enter your motor speed as indicated on the Counter in rev/sec when the motor speed was set to 1200 rev/min.**

- Switch OFF the power supply

Student Assessment 8

1. For a slotted opto transducer to count revolutions of a shaft it requires a:

[a] slotted disc [b] reflective disc [c] non-magnetic disc [d] magnetic disc

2. The output voltage generated by the slotted opto transducer used in your experiments was in the order of:

[a] 500µV [b] 50mV [c] 5V [d] 12V

3. A shaft speed of 24 rev/sec corresponds to a motor speed in rev/min (rpm) of:

[a] 240 [b] 600 [c] 720 [d] 1440

4. Which of the following could NOT be in sequence (one after the other) for a Gray code output?

[a] 0 1 1, 0 1 0 [b] 0 0 1, 0 1 0 [c] 1 1 0, 1 1 1 [d] 1 1 1, 1 0 1

5. The number of outputs generated by a 3-bit Gray code system is :

[a] 3 [b] 6 [c] 8 [d] 10

6. Comparing a slotted magnetic disc to a slotted aluminum disc, the effect on the inductance of the slot passing over an inductive transducer is to:

[a] increase the inductance in both cases

[b] increase the inductance with a magnetic disc but decrease it with aluminum

[c] decrease the inductance in both cases

[d] decrease the inductance with a magnetic disc but increase it with aluminum

7. The purpose of the low pass filter used with the inductive transducer was to:

[a] remove interference pulses [b] respond to low revolutions only

[c] respond to high revolutions only [d] display only low revolution counts

Student Assessment 8 Continued ...

8. The purpose of the differential amplifier in the inductive transducer experiment was to:

- a respond to both increases or decreases in transducer output voltage
- b balance out the steady DC component of the rectifier output
- c invert the polarity of the signal from the transducer
- d sharpen up the output pulses from the transducer

9. An output voltage is generated by a Hall effect device when:

- a a slot in an aluminum disc passes over it
- b a magnetic field pass through it
- c it is exposed to light radiations
- d an external EMF is applied

10. The expected change in output voltage of an activated Hall effect transducer of the type fitted on the DIGIAC 1750 Trainer is of the order of:

- a ±500μV
- b ±500mV
- c ±5V
- d ±12V

11. The magnitude of the output voltage generated by a permanent magnet tacho-generator is dependent on:

- a rate of cutting flux
- b direction of rotation
- c frequency of interference pulses
- d number of commutator segments

12. The purpose of the commutator in a permanent magnet tacho-generator is to:

- a increase the magnitude of the output voltage
- b increase the frequency of the output voltage
- c stabilize the input voltage
- d convert the output from AC into DC

Notes:

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