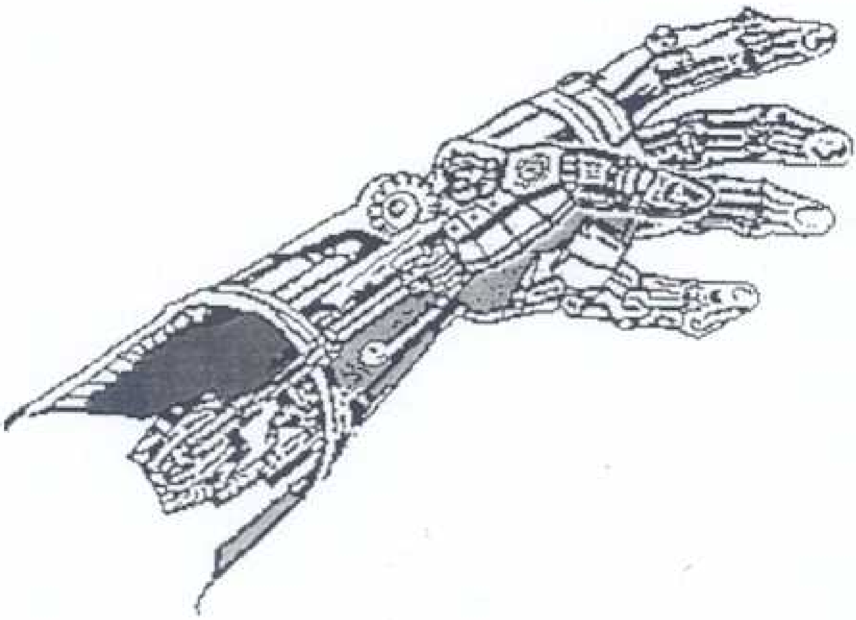
Hand Force Reflection using Pneumatic Muscle Actuators



Quarterly Report – No.4

Contract F61708-98-W00134

Date 23-03-99

C. Favède and D.G.Caldwell
University of Salford
Manchester, M5 4WT
UK

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
23 MAR 1999	**N/A**	**-**

4. TITLE AND SUBTITLE **Hand Force Reflection using Pneumatic Muscle Actuators - Quarterly Report - No.4**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of Salford Manchester, M5 4WT, UK**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001765 Hand Force Reflection Using Pneumatic Muscle Actuators.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**50**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

CONTENTS

INTRODUCTION

The aim of this project has been the development of a light weight, user friendly hand force reflection device using pneumatic Muscle Actuators (pMAs) as the primary drive source.

The project was divided into four parts. During the first period of this project a detailed study of the key motions of the human hand and the background technology was undertaken in order to determine the requirements of the system. As a second milestone a prototype showing the physical structure of the hand master was designed [1]. This prototype is actuated by two pMAs, and reflects force into the middle finger and the thumb. It also exhibits the characteristics mentioned in the original proposal, i.e. a low mass (<200g), high force at the finger tips (>15N) and, full unencumbered motion of the user's fingers. In addition, a finger position detecting glove instrumented using strain gauges was designed [2]. The third milestone of the project was to control the hand master. The system air supply is regulated using JOUCOMATIC proportional solenoid valves, which are digitally controlled using a computer and a PID controller implemented in C language. This controller allows fast and accurate control of the pMAs that constrain the user's finger motions and provide realistic sensations when a virtual object is grasped [3]. The final milestone of the work programme involves the use of the exoskeleton glove to control and reflect sensations in a telepresence and virtual environment. The virtual environment test consists of movements within a constrained area studying the ability to manoeuvre, detect collisions between fingers and objects, 'feel' shapes and reflect the forces. These features are modelled within a virtual world developed using Sense8's WorldToolKit VR software.

The completion of this fourth milestone forms the basis of this report. Appendices consisting of the hardware description and all the PCB layouts have been added to the report together with software for the AutoCAD and 3Dstudio virtual environment models.

1- HARDWARE CONFIGURATION

During the first three phases of this project an exoskeleton hand master was developed [1-3]. This hand master monitors finger positions using strain gauges, while the pMAs provide force reflection on the middle finger and the thumb when a virtual object is grasped. Detailed hardware description of each of the electronic boards, and sensors designed during the first three stages of this project are given in the appendices.

The final aspect of this project will consider the development of a virtual world in which the effectiveness of the feedback glove can be tested. A schematic of the system hardware used in the implementation is shown in Figure 1-1.

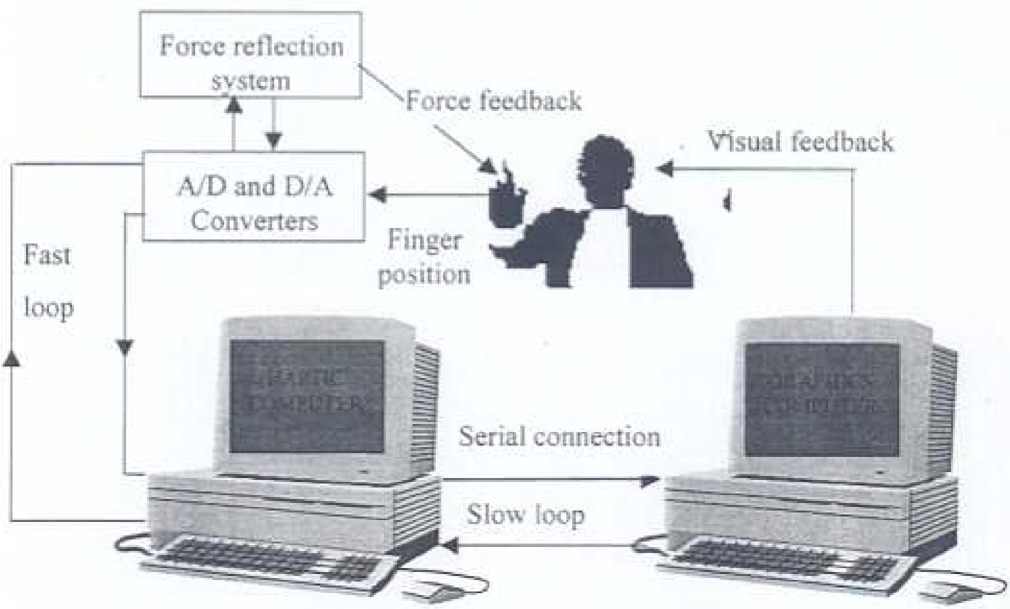


Fig. 1-1. Schematic of the system hardware.

One computer, termed the HAPTIC computer (Pentium 166 MHz), controls the operation of inputs from the exoskeleton glove. This provides data on the position of the fingers and is measured by the strain gauge sensors mounted on the glove at the finger joint sites [2]. This HAPTIC computer also outputs signals to the pMAs in order to constrain the finger motion when contact with an object is to be simulated. To achieve this force reflection function a PID controller was implemented [3]. The information on the user's finger positions is then transmitted from the input glove via the HAPTIC computer to a second computer, the GRAPHICS computer (Pentium 350 MHz with 64 MB RAM and an Evans and Sutherland Freedom open GL graphics board). This GRAPHICS computer is the host site for the models of the virtual world and incorporates both objects and physical based motions.

2- SOFTWARE CONFIGURATION

2.1- SOFTWARE STRUCTURE

The distributed nature of the hardware configuration necessitated the use of a similarly distributed software system. The Graphics computer software is responsible for the construction of the virtual world, graphics updating, and collision detection. The HAPTIC software is responsible for monitoring the motion tracking system, calculating the reactions and sending this data to the force reflection hardware, as shown in Figure 2-1.

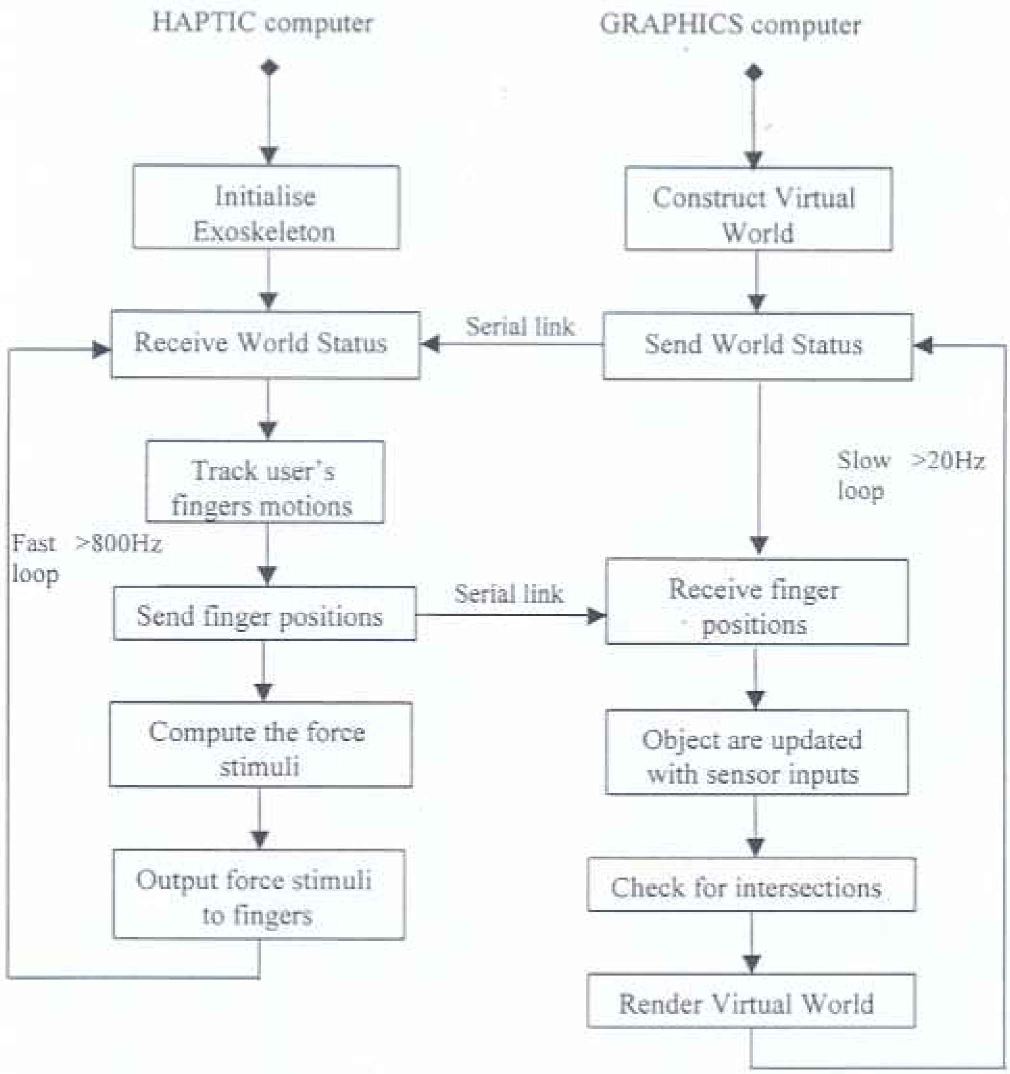


Figure. 2-1. Software data flow diagram.

The data exchange between the computers involves the transfer of the World status to the Haptics computer from the Graphics computer and the return of the position of the user's fingers back to the Graphics computer. Communications between the two computer are achieved using a serial link with a baud rate of 9600. Should the virtual hand be touching an object, the world status attributes (which fingers are in contact with a virtual object) are transmitted by the Graphics computer and the resulting sensations are calculated by the Haptics machine and used to control the pMAs.

This two computer setup results in a similar division of software load. The HAPTIC computer program runs under DOS because of the requirements of the PC30 board which is used to perform A/D and D/A conversions [2]. This program was developed using C with a flowchart is represented in Figure 2-2. A listing of this program is contained on disc in the Appendix.

2.2- THE HAPTIC PROGRAM

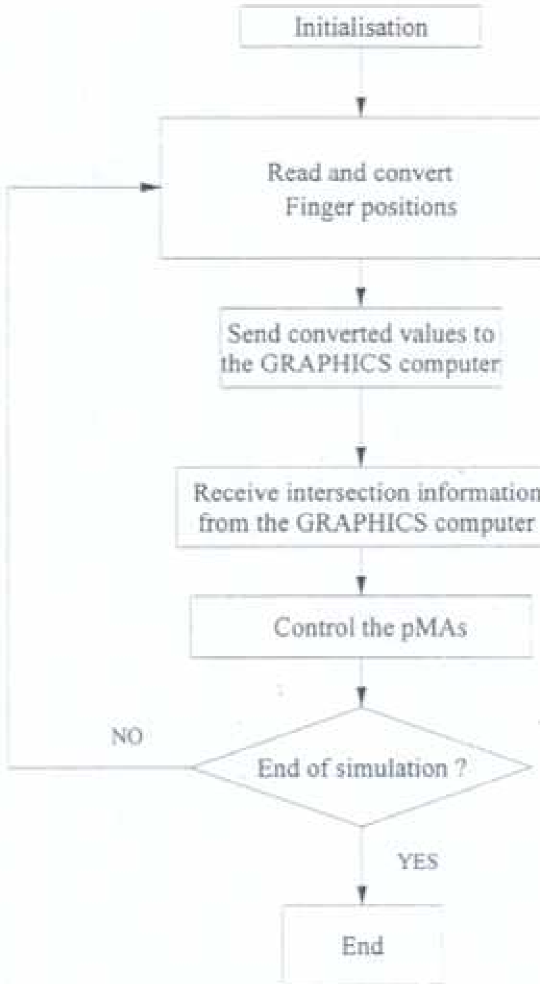


Figure. 2-2. Flowchart of the HAPTIC program.

2.2.1- Initialisation

The first requirement of the program is system initialisation, and this occurs in three steps as described in Figure 2-3.
Firstly, the PC30 board needs to be initialised to convert the analogue values given by the strain gauge position sensors of the hand exoskeleton structure into digital values that can be sent to the Graphics computer. The PC30 board also needs to be initialised in order to use its digital outputs. These digital outputs are used to inflate or deflate the pMAs providing the force that constrains the user's fingers [3].
The second aspect of the initialisation involves setting up the serial communications between the two PCs. Subsequently information can be exchanged between HAPTIC

PC to the GRAPHICS systems and vice versa.

Finally, the calibration positions of the finger angles need to be saved. To initialise these values the user needs to put his hand in a known initial position, which is hand open, with the palm and the fingers resting flat on the desk. The computer reads and converts these values via the PC30 board, and then stores them as the initial set values.

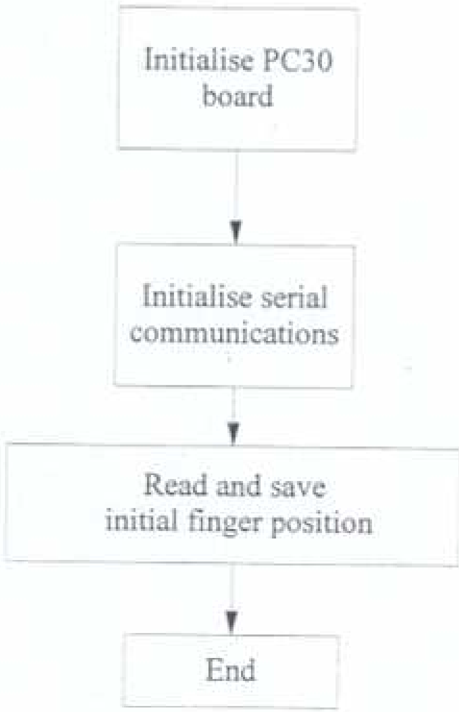


Figure. 2-3. The initialisation process.

2.2.2- Read and convert finger positions

This function first reads and then converts the voltages returned by the strain gauges in order to obtain the angles of rotation of each joint of the user's fingers. It then subtracts the converted value from the set up value stored during the initialisation process, Figure 2-4.

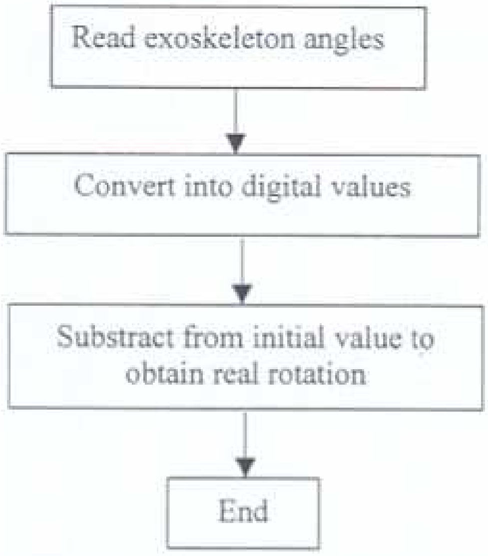


Figure. 2-4. Read finger positions.

2.2.3- Send finger positions to the GRAPHICS computer

The architecture of the hand is illustrated in Figure 2-5. Strain gauge sensors have been placed in the glove in order to monitor the metacarpo-phalangeal joint and proximal interphalangeal joint of the four fingers. The input sensors also monitor the metacarpo-phalangeal joint and the interphalangeal joint of the thumb.

Once all the position data from these joints has been collected and converted, the HAPTICS communications program can send the joint angle information to the GRAPHICS computer which uses this information to carry out the simulation on the screen. This data is continuously sent, however, this initially caused a problem ensuring that the GRAPHICS computer knew which joint the received angles should be attributed too. To remove this confusion a simple communication protocol was designed in which the data is sent in packets of 12 numbers. The first and last numbers of the packet are always the same and have the hexadecimal value #ff and #fe respectively (255 and 254 in decimal base). The second and third numbers of the packet correspond to the metacarpo-phalangeal joint and the proximal interphalangeal joint of the index finger, while the fourth and fifth values belong to the middle finger.

Subsequent numbers in the sequence refer to two joints in the ring finger, and the two angles of the little finger. The tenth and eleventh numbers are the joint positions for the thumb. The GRAPHICS computer reads a data sequence until it finds the number #ff (packet start value), the subsequent data sequence can then be related to the relevant joint. The last number of the packet which is #fe, allows the computer to check if all the data was sent and if the transmission was correct. As the maximum angle for any joint is 180°, #ff and #fe are outside the acceptable angle values and therefore there can be no confusion between the start data and angle data. A relatively low baud rate of 9600 is used for all communication and has been found to be acceptable in all circumstances. This will be considered in more detail later in the report.

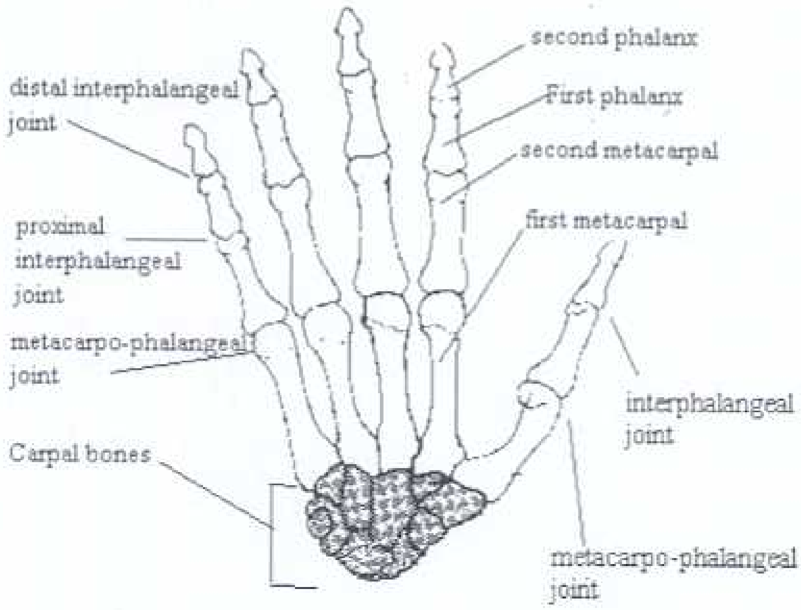


Figure. 2-5. The architecture of the human hand

As an example of a typical communication sequence, consider the case where a user is executing a precision grasp as illustrated in Figure 2-6. In this instance the metacarpo-phalangeal joint and the proximal interphalangeal joint of the index finger are 45° and 90°, the two angles of the middle finger are 20° and 60°, the ring finger angles are 0° and 20°, because the little finger is fully extended the two angles of the little finger have the same value of 0°. The two thumb angles sensed by the strain gauges position device are 20° and 40°. The HAPTIC computer will send the packet 255, 45, 90, 20, 60, 0, 20, 0, 0, 20, 40, 254 to the GRAPHICS computer.

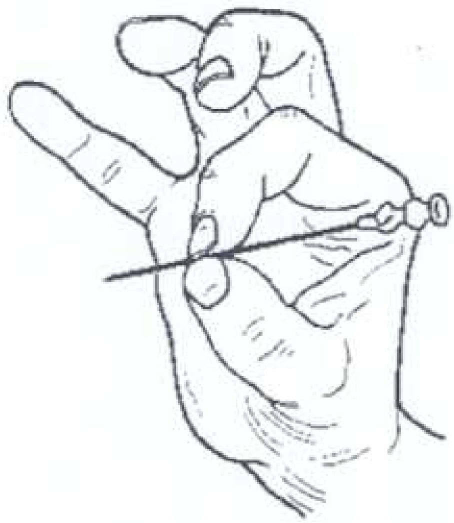


Figure. 2-6. Example of precision grasp.

2.2.4- Receive data.

The HAPTIC computer receives information on object/finger collisions or intersections from the GRAPHIC computer. When there is an intersection, the current angle of the finger is saved as the maximum value that the finger is allowed to reach. The HAPTIC computer running a PID controller program activates the pMAs in order to constrain the user's fingers preventing motion (hand closure) beyond this finger intersection limit. The GRAPHICS computer sends only a 2 bit binary number, each bit corresponding to an active joint. At this stage in the development active force feedback is only available on the thumb and the middle finger hence the requirement for only a two bit binary signal. The first bit corresponds to the middle finger and the second bit to the thumb. If the GRAPHICS computer has detected an intersection of one of these fingers with an object in the simulation a 1 is sent and then the previous angle value of the finger is saved as the maximum value for the PID controller [3]. If the value is 0 there is no intersection, therefore no control of the pMAs is needed.

2.3- THE GRAPHICS ROUTINE

This program is the heart of the system, running the simulation and controlling all the graphics activities. It was written using WorldToolKit (WKT) which is a C library function based program, while the objects in the virtual environment are designed using AutoCAD. The flowchart of the WKT program is illustrated in Figure 2-7, while the listing is contained on disc in the Appendix.

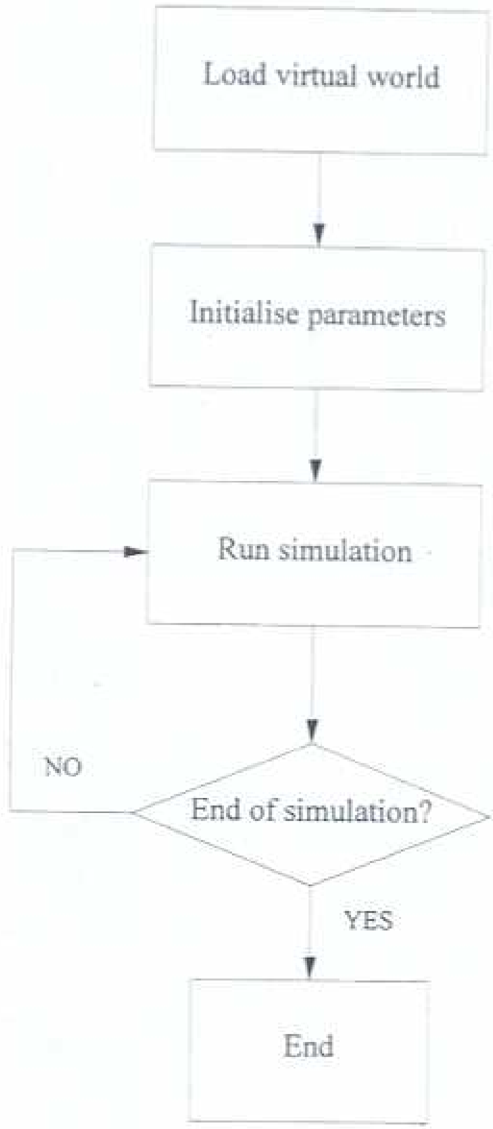


Figure 2-7. The GRAPHICS program.

2.3.1- Load the virtual world

Initially, the program loads the test environment in which the simulation takes place. For these test sequences this consisted of a simple room, designed using the Sense8 neutral file format (NFF). This is a generic representation for polygonal geometry [4]. The room is shown in Figure 2-8. The NFF file is listing is on the disc in the Appendix.

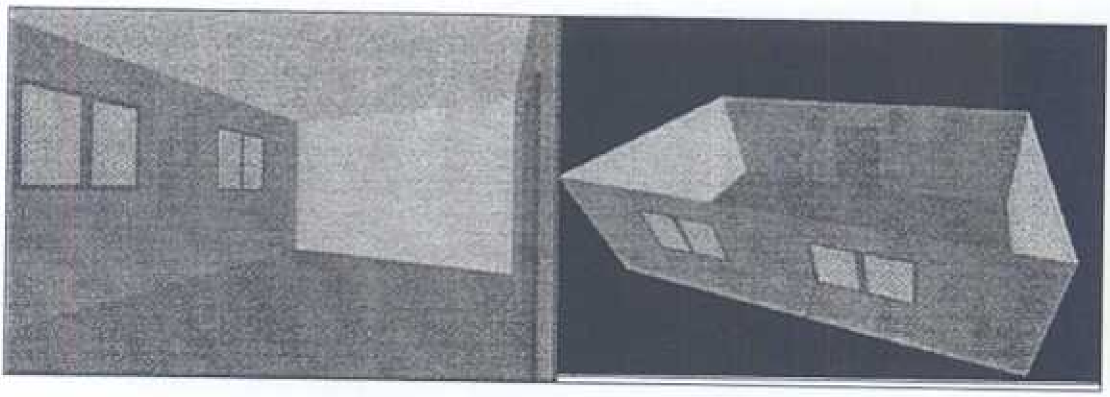


Figure. 2-8. The virtual environment.

In NFF, objects are represented as sets of polygons, and these polygons are ordered collections of vertices. The format specifies polygon, colour and texture applications, backface rejection, vertex normals, object names, polygon IDs (which are all set to zero for the room), and portals [4].

Once the environment is loaded, the program continues by loading the virtual hand designed to replicate the motions of the operator's hand, Figure 2-9. The file hand.3ds which is the representation of the hand is again listed in the disc in the Appendix.

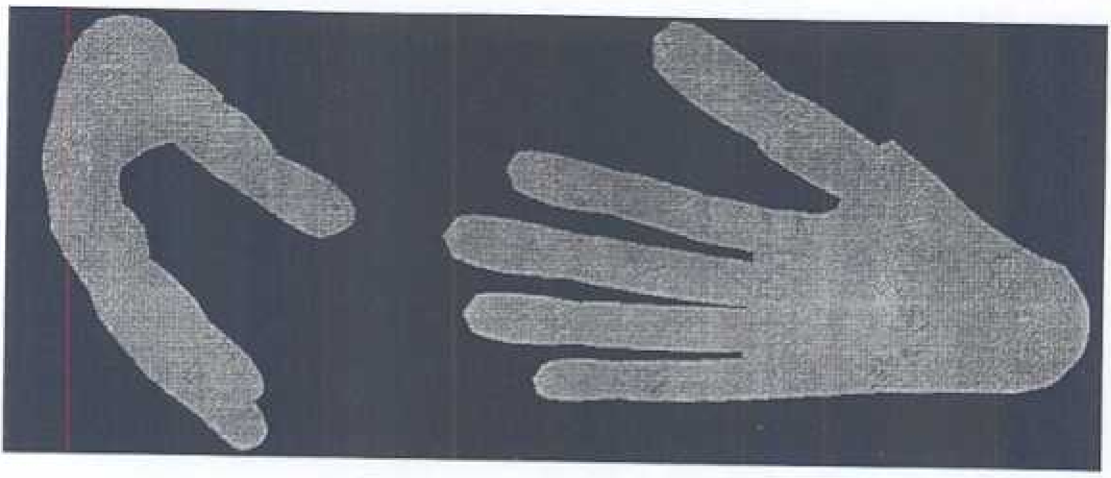


Figure. 2-9. The virtual hand.

The hand was designed using 3D Studio which is modelling, rendering, and animation software developed by Autodesk [5]. The three dimensional file designed with 3D studio has the extension 3DS which is compatible with WKT, therefore the file can be loaded very simply inside the virtual environment simulation.

Lights are also added to the simulation to create a real life situation. As in the real world if there is no light the user is unable to see where he is, and what is in front of him.

Finally, the program loads into the virtual environment the other objects of the simulation. In this instance this includes a desk and a joystick. These objects were designed using AutoCAD. AutoCAD is the worlds' most popular Computer Aided Design (CAD) software [6], and as with 3D Studio files, the .DXF files created using AutoCAD are directly compatible with WKT and are easily imported into the virtual environment. The virtual environment which consists of the room, the hand, the desk and the joystick on the top of the desk are illustrated in Fig. 2-10. The table and joystick object files are list in the Appendix disc.

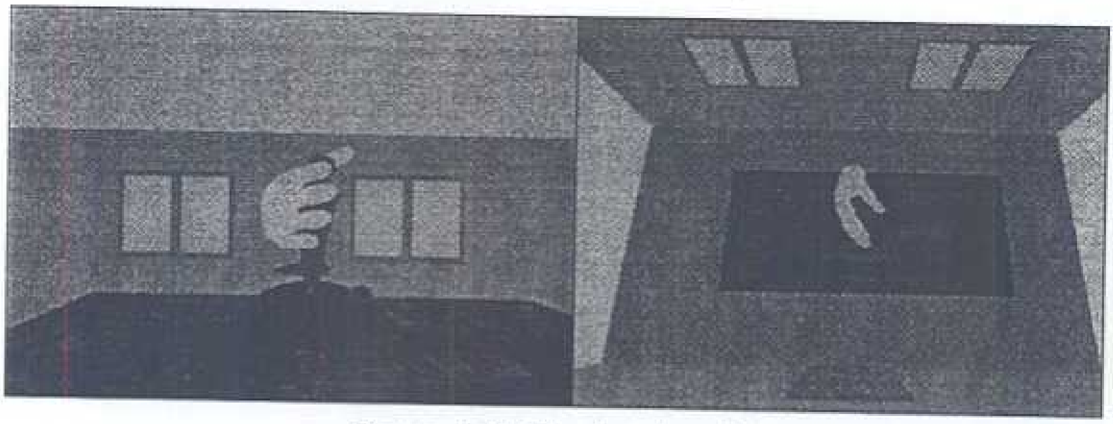


Figure. 2-10. The virtual world.

These latter two objects were simply added to the virtual world by using a function of WKT called WTobject_new. This function allows scaling of the object, which can be useful if objects are designed on different scales. WKT also allows texture mapping, which was used on the desk where a wooden texture was applied. Each object added to the simulation has a different ID number.

2.3.2- The simulation

After loading the virtual world and initialising the computer for serial communications, the program is ready to run the simulation. The flowchart of the simulation routine is given in Figure 2-11.

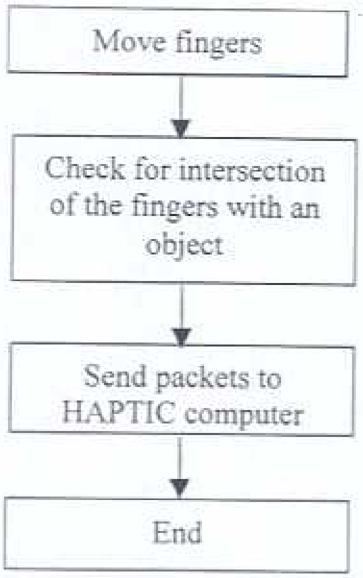


Figure. 2-11. The simulation flowchart.

As shown, this function consists of four subsets which are described below.

2.3.2.1- Move the fingers

This consists of reading the data coming from the HAPTIC computer, and then rotating each joint to the desired angle. The detailed flowchart of this function is given in Figure 2-12. During the initialisation process the initial value of each angle was reset to 0.

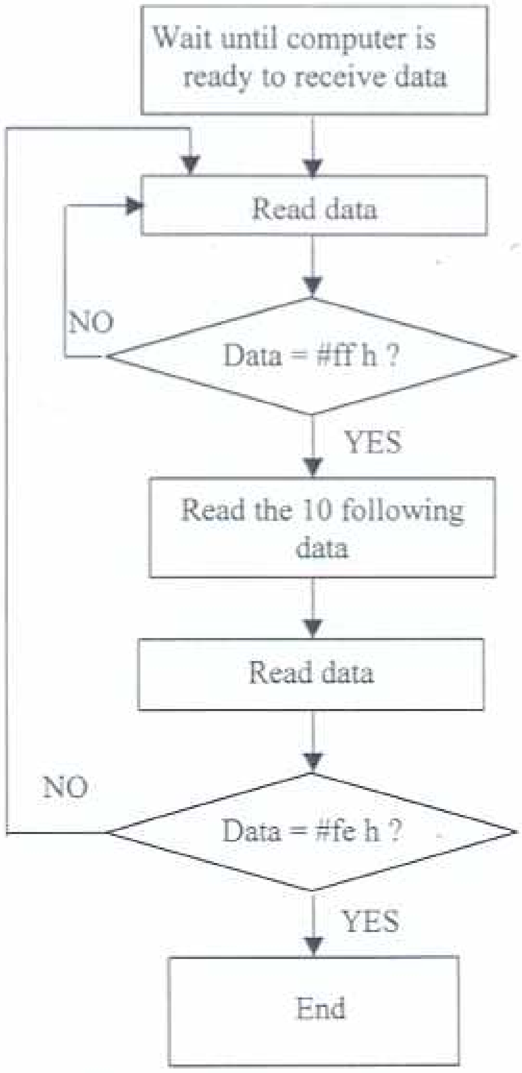


Figure. 2-12. Move the fingers.

2.3.2.2- Check for intersection of the fingers

This function checks if a part of a finger is touching an object. If an intersection is detected a command is sent to the HAPTIC computer controlling the action of the pMA. This function of the program has the highest computational overhead and may slow down the simulation if the world model is overly complex. Therefore, a trade off has to be made between the number of polygons used to design the hand and the speed of the simulation (time between an action in the real world and the same action in the virtual world).

Since the present hand master gives force feedback for only the middle finger and the thumb the program only checks for intersection of these two fingers with object in the simulation. These fingers are composed of hundreds of polygons, as illustrated in Figure 2-13. The program has to test for the intersection of each polygon of the middle finger and the thumb with each polygon of the objects in the virtual world. This requires intensive computer calculations that would drastically slow down the simulation, therefore another solution was implemented. To reduce this computational overhead a bounding box based solution was adopted. Using this technique a six sided box closely overlaps the finger model, as shown for the first phalanx of the ring finger in Figure 2-13. Since the bounding box consists of only six polygons, it requires fewer computer calculations to test, than for the hundreds of polygons of a finger.

The function first tests for intersections of the fingers bounding boxes with the other graphical entities in the simulation, and returns a list of exactly which polygons are intersected by the fingers bounding box. As a bounding box is slightly bigger than a finger, when an intersection with a polygon is registered this polygon has to be tested to ascertain if it intersects with any of the polygons of the finger.

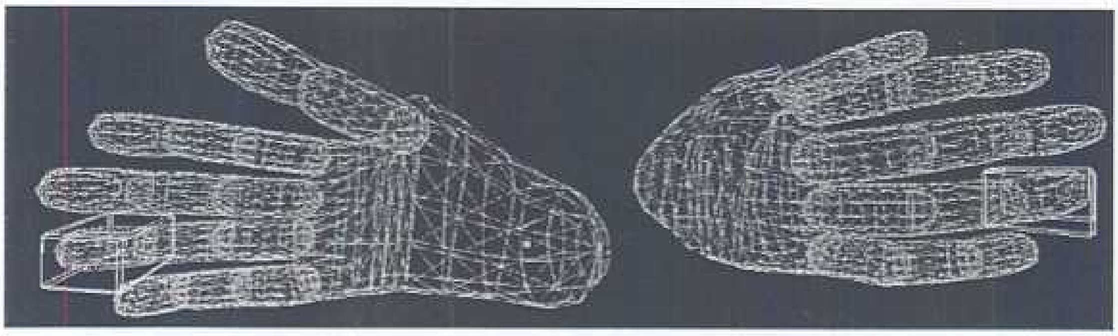


Figure. 2-13. Polygonal representation of the hand.

2.2.2.3- The send packet function

This function is very simple, and sends only a two bit binary number (needed for the thumb and middle finger) to the HAPTIC computer. If the first bit is 0 then the middle finger is not intersecting an object, if it is a 1 it is intersecting an object. Subsequently the HAPTIC computer can retrieve the value of the angle and activate the PID controller in order to control the pMA and produce a restrained finger motion in line with the detected intersection. The second bit of the number works in the same way but for the thumb.

CONCLUSION

During this fourth phase of the project virtual reality software was developed to model the motions of a hand using inputs from the tactile glove, and to feedback contact information to constrain the motions of the thumb and middle finger, thereby presenting a grasp sensation to the user. This virtual environment will be used to test the system, and measure the performances of the user to use the exoskeleton glove to control and reflect sensations.

This project has advanced as planed in the proposal document, and the different deliverables mentioned in the document were achieved.

i). A sensorised lightweight input exoskeleton with 11 degrees of freedom operating efficiently, safely and comfortably over 90% of the normal human work volume.

ii). A feedback exoskeleton using Pneumatic Muscle Actuators for the middle finger and the thumb, providing a low mass, safe, force/restraint replicating sensation during complex anthropomorphic manipulations

iii). Demonstration of the control motions and feedback of the hand exoskeleton using a VR simulation

iv). Adaptation of the present Pneumatic Muscle Actuators and actuator control techniques to permit force and position control of operator's limbs (fingers).

At this stage a first prototype has been designed, but future work has already be planed:

i). Development of a second prototype to improve the aesthetic appeal of the exoskeleton structure and reduce the bulkiness of the system. This involves a new development of the pMAs attachment on the user' fingers and on the exoskeleton.

ii). Add force sensors on to the exoskeleton structures to monitor the force exerted by the system on the user's fingers.

iii). Test the exoskeleton in a more complex virtual environment and in real life situations i.e. controlling a robot dextrous hand. To ascertain that the force feedback will allow the operator to use the minimum necessary grasp force which will reduce the danger of damage to the slave or the environment, shorten task completion times, and reduce errors.

REFERENCES

[1]- C. Favède and D. G. Caldwell, "Hand force reflection using Pneumatic Muscle Actuators", Quarterly report – No. 1, EOARD contract F61708-98-W00134, Mars 1998.

[2]- C. Favède and D. G. Caldwell, "Hand force reflection using Pneumatic Muscle Actuators", Quarterly report – No. 2, EOARD contract F61708-98-W00134, July 1998.

[3]- C. Favède and D. G. Caldwell, "Hand force reflection using Pneumatic Muscle Actuators", Quarterly report – No. 3, EOARD contract F61708-98-W00134, October 1998.

[4]- "WorldToolKit ™ version 2.1", reference manual, Sense'8™ corporation,1995.

[5]- M. T. Peterson, "3D STUDIO MAX Fundamentals", New Riders, Indianapolis, 1996.

[6]- J. H. Zirbel and S. B. Combs, "Special edition using AutoCAD Release 13 for Windows", Que Corporation, Indianapolis, 1995.

APPENDIX

THE VALVE DRIVER

Valve Driver

The operation of the valve driver forms an essential requirement for actuator control. The full development of this has been outlined in a previous report [3].

Each valve uses a voltage varying between 0 - 24 V with a current requirement of 1.2A, but the output provided by the digital output of the PC30 card is only between 0 and 5V at only a few mA. To solve this problem a drive circuit has been designed, figure A.1, that can drive up to four valves.

This driver consists of two distinctive parts :

- The first section which includes the operational amplifier is an adaptation of a conventional impedance circuit and functions as a buffer to protect the PC30 card.

The second section, the bipolar transistor circuit provides the current needed the drive the valve's coil.

The electronic circuit for a board which can drive up to 4 valves is given in figure A1.

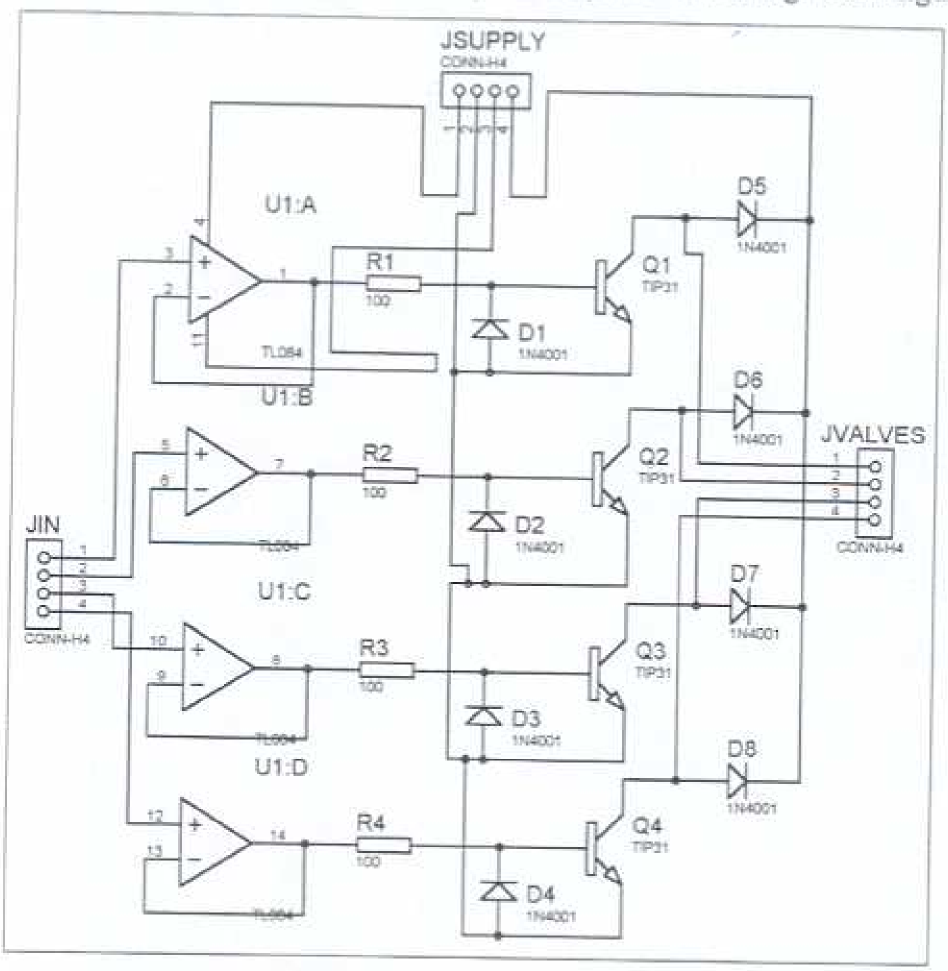


Figure. A.1. Electrical power driver.

The overall drive behaviour of circuit is illustrated in figure A.2.

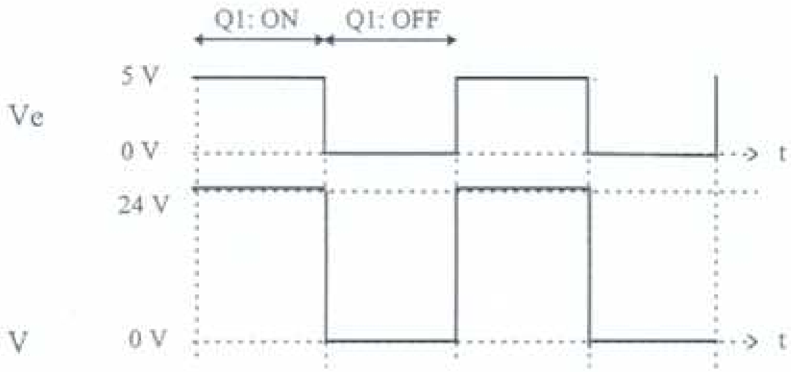
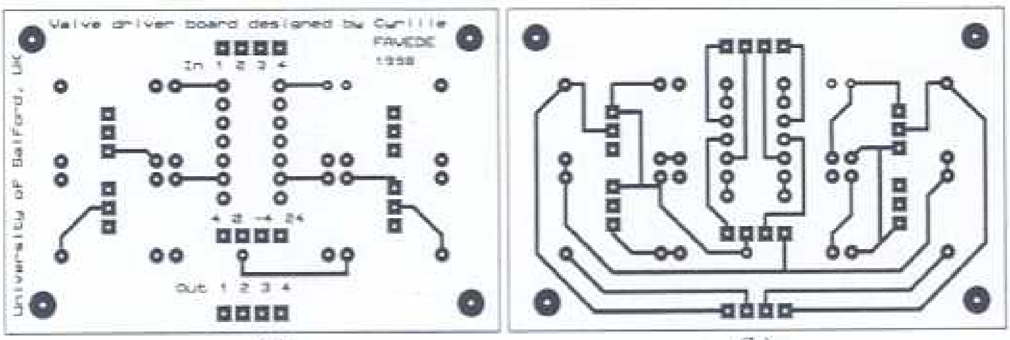


Figure. A.2. Characteristics of the drive circuit.

When Ve = 5V, the transistor Q1 is not saturated. Current can go through the transistor Q1, and the potential voltage in B (transistor collector) is 0. The input voltage of the valve is therefore 24V.

When Ve changes from 5V to 0, transistor Q1 switches from the on-state to the off-state and becomes saturated. The voltage in B is equal to the power voltage, 24V and the input voltage of the valve is therefore 0V.

A printed circuit board has been designed to control four valves. The layout of the circuit is given in figure A.3, figure A.3(a) is for the component side and figure A.3(b) for the soldering side.



(a) (b)

Figure A.3. Valves driver board layout

Figure A.4 shows the component layout.

Component values:

R1, R2, R3, R4 : 100 Ω ¼W 1%

D1, D2, D3, D4, D5, D6, D7, D8 : Diode 1N4001

Q1, Q2, Q3, Q4 : NPN power transistor BD241C

U1 : quad JFET TL084CAN

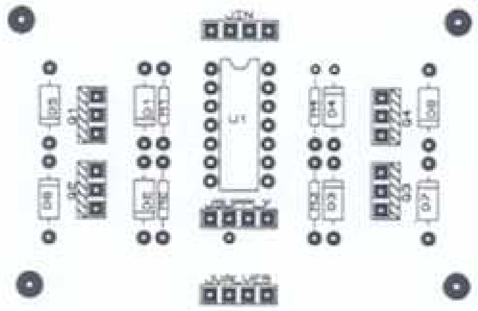


Figure A.4. Valves drivers board components layout

The connector JIN receives inputs from the PC30 portA (A0, A1).

The connector JVALVES is connected to the two valves (at present only two valves are used).

The connector JSUPPLY is connected to the +4V, GROUND, -4V, and 24V.

The board as been labelled correctly in order to the user to connect everything as required.

The valves used are JOUCOMATIC electro-pneumatic 3 ports servovalves (SENTRONIC 602 series).

APPENDIX

THE STRAIN GAUGES AMPLIFIER

STRAIN GAUGES AMPLIFIER

Strain gauges sensors are used to measure the fingers positions. A sensor consists of two gauges bound to opposite sides of a thin plastic beam which is attached on the glove at each of the finger joints. Strain gauges are resistive tranducers, wherein resistance varies as a consequence of strain changes within the gauge. The strain gauge resistance is expressed in the form of R+ΔR, where R is the resistance of the gauge in the absence of the strain (reference value) and ΔR represents the deviation from this reference value as a consequence of a change in the strain.

To measure resistance deviation, a method to convert ΔR to the voltage variation ΔV is to make the strain gauge part of a strain gauge bridge.

The strain gauge resistance changes when the device is lengthened or shortened according to:

$$\Delta R = 2R\frac{\Delta l}{l}$$

Where R is the unstrained resistance and $\frac{\Delta l}{l}$ is the fractional elongation experienced by the gauge.

The deviation ΔR is extremely small in comparison to R, thus a fairly high gain amplification is required to achieve an acceptable sensitivity. Furthermore precautions must be taken to prevent temperature variations from overshadowing the variations induced by strain.

A solution is to use pairs of strain gauges so that the temperature variations of one gauge compensate for the temperature variations of the other, thus leaving the ratios between their reference values constant. Also to avoid cancelling out the variation due to strain, one of the two gauges must be of the R+ΔR type and the other of R-ΔR type. An additional advantage of using strain gauges in pairs is a doubling in bridge sensitivity. This is achieved by attaching the two gauges to opposite sides of the thin plastic beam mounted over each finger joint. When the finger is bent, the beam is then put under strain, causing one of the gauges to lengthen with a resultant resistance, while the other gauge will be shortened and its resistance will decrease.

The circuit illustrated in figure B.1 has been designed to measure finger positions for two sensors. This circuit is duplicated six times to cover all the active joints in the hand.

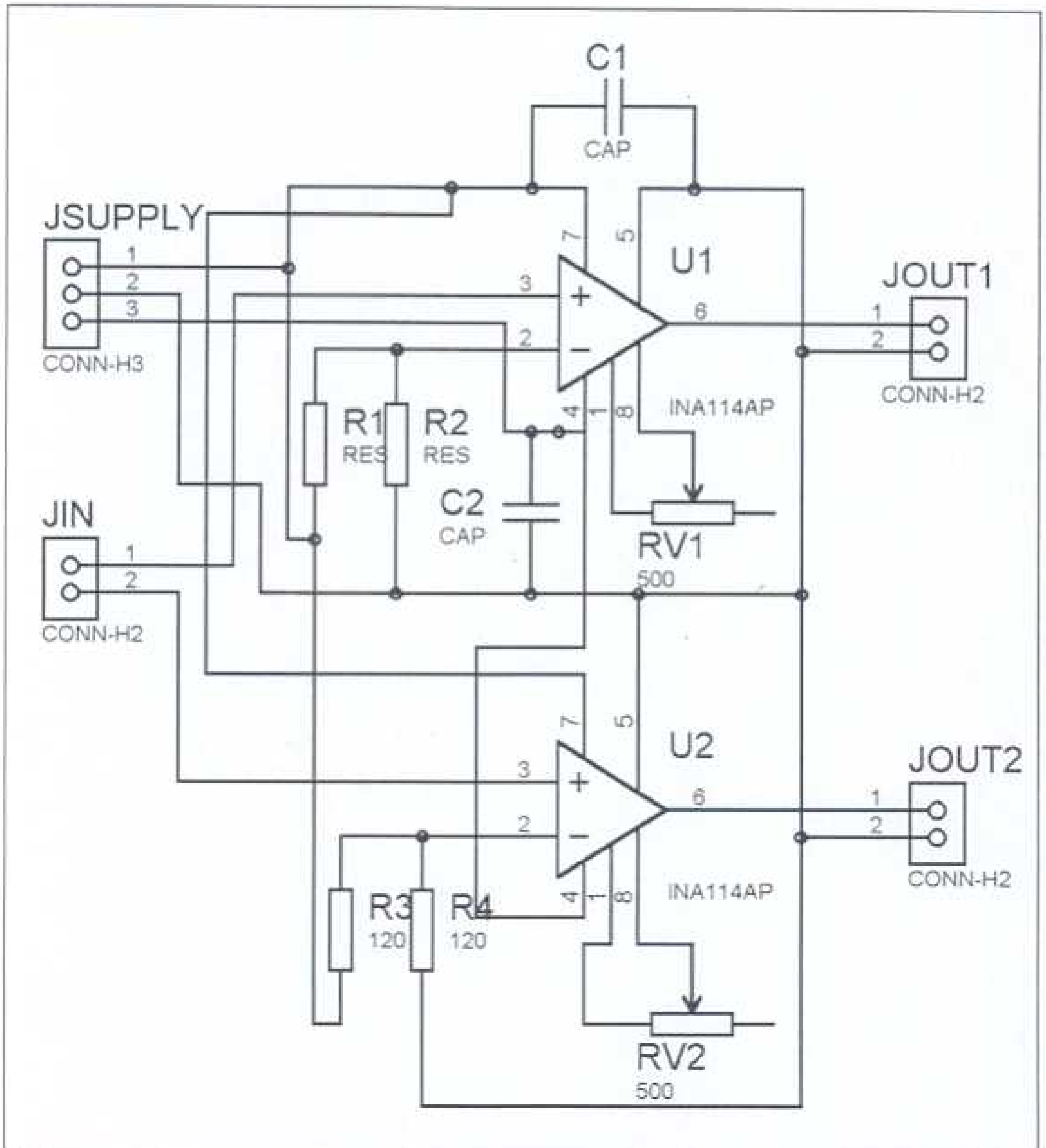


Figure.B.1. The strain gauge circuit to measure the finger position.

To achieve the desired amplification, a INA114AP (Burr-Brown) operational amplifier has been used. This operational amplifier is a general purpose operational amplifier offering excellent accuracy. The gain of this operational amplifier can be set from 1 to 10000 with only a single resistor.

Gain for this system is given as : $G = 1 + \frac{50k\Omega}{R_G}$.

This circuit converts the finger position into a voltage which is then sent to the computer via the PC30 board. The latter uses its A/D function to display the position of the finger on the computer screen. Tests on the resolution of this input glove found that it was better than 0.3°.

The PCB designed for this circuit is double sided as illustrated in figure B.2 where the layout for the solder side and the component side are given.

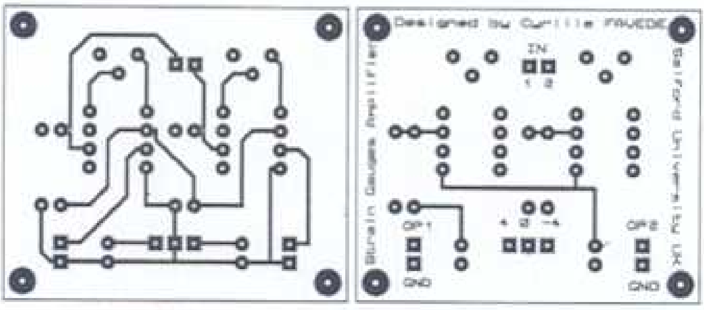


Figure.B.2. Strain gauges amplifier layout

Figure B.3 shows the components layout.

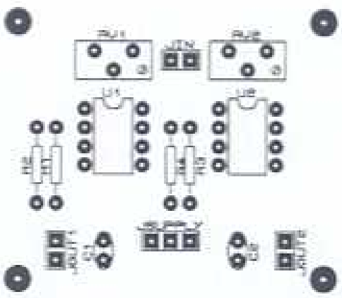


Figure.B.3. Components layout

Components values :

R1, R2, R3, R4 :	120Ω ¼W 1%
U1, U2 :	INA114AP Instrumentation amplifiers
C1, C2 :	0.1μF capacitors
RV1, RV2 :	500Ω 500mW ±10% multi turn potentiometer

The connector JIN is connected to the two sensors, JOUT1 and JOUT2 are connected to the A/D input (channel) of the PC30 board. The connector JSUPPLY is connected to 4V, ground and –4V.

Construction and connection of the strain gauge sensor

The sensor consists of two strain gauges bound to opposite sides of a thin plastic beam, which is attached to the glove at a finger joint.

Pin 1 of the first strain gauge is connected to +4V, pin 2 is connected to pin 1 of the second strain gauge. This is also connected to the input of the strain gauges amplifier board. Pin 2 of the second strain gauge is connected to ground.

The strain gauges used are general purpose foil type, polyester backed strain gauges. The gauge length is 8mm, and the gauge resistance is 120Ω ±0.5%. The data sheets for the strain gauges are given in this appendix.

APPENDIX

THE 24V POWER SUPPLY

THE 24V POWER SUPPLY

The two JOUCOMATIC servo valves used are powered using a 24V supply voltage, with each valve having a current requirement of 1.2A. A 24V 5A power supply has been designed, its electronic circuit is given in figure C.1. This will drive the valves needed to drive the pMAs currently on the thumb and middle finger.

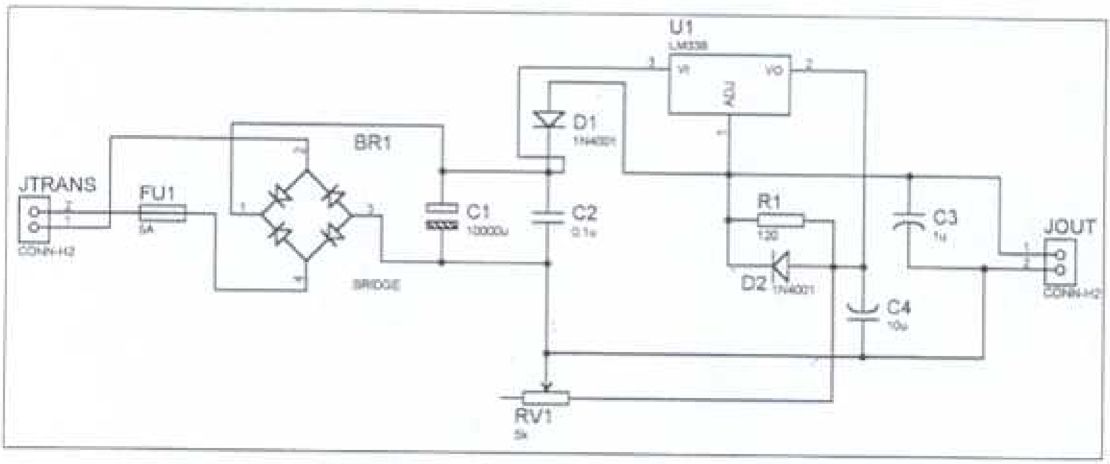


Figure.C.1. Electrical power supply.

The PCB layout of this power supply is given in figure C.2, the PCB is single sided.

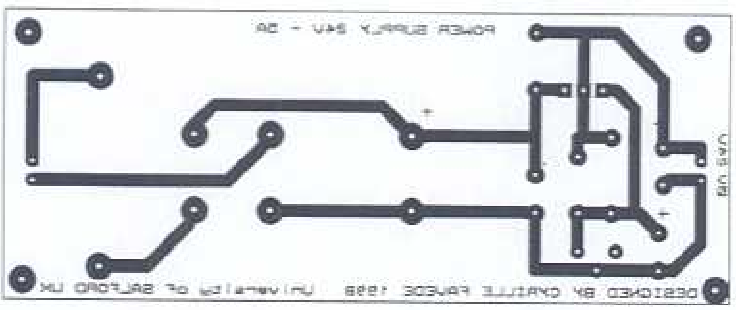


Figure.C.2. Power supply layout

The component layout is given in figure C.3.

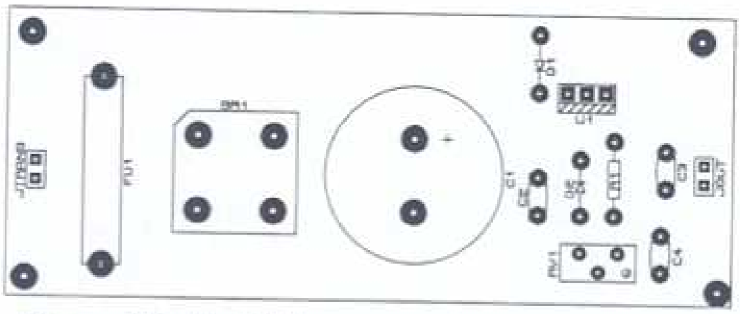


Figure.C.3. The 24V power supply component layout

Components values :

R1 :	120 Ω ¼W 1%
RV1 :	5kΩ 500mW ±10% multi turn potentiometer
C1 :	35V 10000µF radial electrolytic
C2 :	0.1µF
C3 :	1µF tantalum radial
C4 :	10µF tantalum radial
FU1 :	5A fuse 5x20mm
BR1 :	6A rectifier bridge KBPC6005 $V_{RRM} = 50V$
D1, D2 :	1N4001 diodes
U1 :	LM338 voltage regulator 0-32V 5A

J_{TRANS} is connected to a 2 * 20V, 5A transformer (100 VA per secondary binding).

APPENDIX

THE ±4V POWER SUPPLY

THE ±4V POWER SUPPLY

The strain gauges sensors are powered using a ±4V voltage supply, which also powers all the electronics of the system (except the valves which are powered by a 24V power supply). A 1A power supply will be sufficient to power all the circuits.

The electronic circuit of the power supply is given in figure D.1.

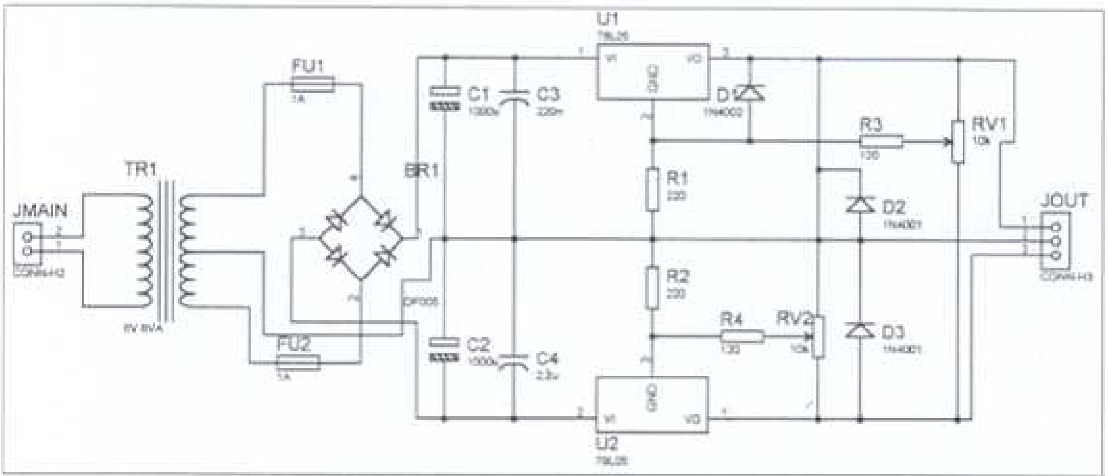


Figure.D.1. Electrical power supply.

The PCB layout of this power supply is given in figure D.2. The PCB is single sided.

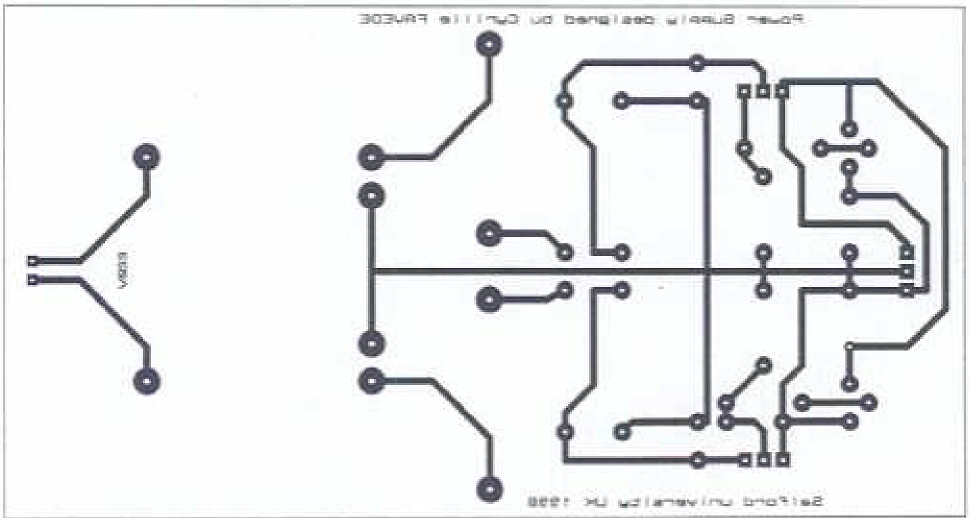


Figure.D.2. Power supply layout

The component layout is given in figure D.3.

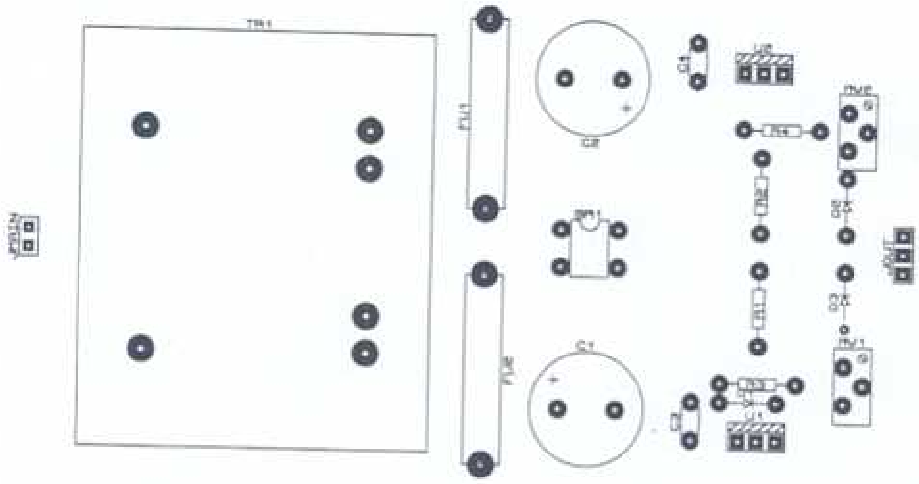


Figure.D.3. The ±4V power supply component layout

Components values :

R1, R2 : 220 Ω ¼W 1%

R3, R4 : 120Ω ¼W 1%

RV1, RV2 : 10kΩ 500mW ±10% multi turn potentiometer

C1, C2 : 16V 1000μF radial electrolytic

C3 : 220nF tantalum radial

C4 : 2.2μF tantalum radial

FU1, FU2 : 1A fuse 5x20mm

BR1 : 1A DIL bridge rectifier DF005 $V_{RRM} = 50V$

D1 : 1N4002 diode

D2, D3 : 1N4001 diode

U1 : LM7805C voltage regulator 5V 1A

U2 : LM7905CT voltage regulator –5V 1A

TR1 : Transformer 2*0-6V 1.33A (8VA per secondary winding, 230Va.c. primary).

APPENDIX

THE VALVES

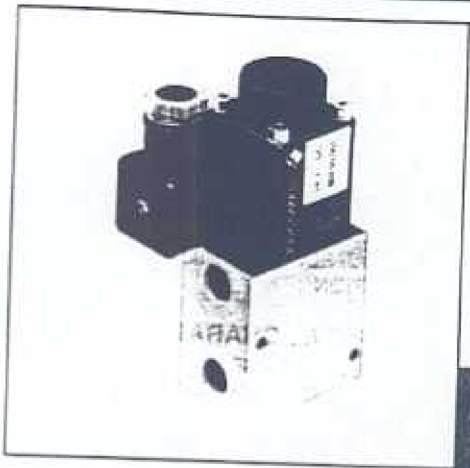
DATA SHEETS

PROPORTIONAL 3 PORTS SOLENOID VALVE

Series 602

GENERALITES

Together with an electronic PI card and separate pressure detector, this solenoid valve is the equivalent to a servo valve SENTRONIC.
This modular arrangement allows the components to be built into specific regulation systems.
Installation of the proportional valve allows a higher ambient temperature range than the SENTRONIC valve.



SPECIFICATIONS

FLUIDS : Air or neutral gas filtered 50 µm, lubricated or dry
MAXIMUM PRESSURE (MAP) : 8 or 16 bar (G 1/4 - see table below)
12 bar (G1/2 - G1)
BAND OF REGULATION (PMR) : 6 or 16 bar (G 1/4 - see table below)
12 bar (G 1/2 - G 1)
FLUID TEMPERATURE : -10°C, +60°C
AMBIENT TEMPERATURE : -10°C, +60°C

CONSTRUCTION

Direct operated poppet valve
Body : anodised aluminium
Internal parts : stainless steel and brass
Sealing : nitrile (NBR)

INSTALLATION

Assembly position : any
Comply with required air quality
Comply with electrical supply specifications

3

ELECTRICAL CHARACTERISTICS

Nominal diameter (mm)	Stabilized voltage (1) (DC)	Max. power (W)	Max. current (mA)	Insulation class	Degree of protection	Electrical connection
6 12 20	24 V = +-10%	20 27 35	800 1100 1400	F	IP 65	Connector ISO 4400 rotatable in 90° steps CM 10 (Pg11P)

(1) Maximum ripple : 10 %

CHOICE OF EQUIPMENT

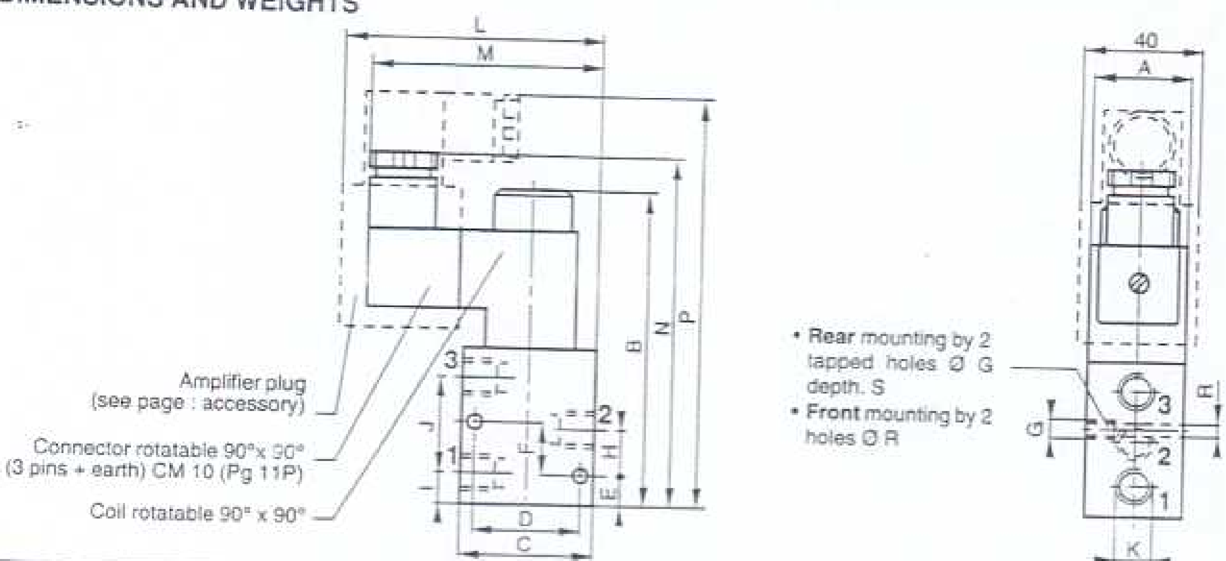
Ø Ports	Ø Orifice (mm)	Flow Coefficient KV	Flow at 6 bar l/min (ANR)	PMR (bar)	MAP (bar)	CODES
G 1/4	6	10	700	6 (2) 16	8 16	602 00 002 (2) 602 00 001
G 1/2	12	20	1400	12	12	602 00 004
G 1	20	80	5600	12	12	602 00 007

(2) Low hysteresis version

OPTION : Sealing FPM - code : **460 594**

[ ] : The codes in the grey shaded areas correspond to commonly used products which can be supplied rapidly

DIMENSIONS AND WEIGHTS



Ø nominal	A	B	C	D	E	F	G	H	I	J	K	L	M	N	P	R	S	Weights (Kg)
6	35	115	52	43	10	20	M5	16	11	34	G1/4	107	82	123	153	4	10	0.700
12	45	151	70	57.5	12	28	M6	22.5	15	48.5	G1/2	119	96	151	190	4.5	10	1.500
20	60	188	96	79	15	33	M8	30.5	20	60	G1	-	116	184	-	6.5	15	3.300

APPENDIX

THE STRAIN GAUGES DATA SHEETS

Data Sheet

Strain gauges and load cells

Strain gauges

Two ranges of foil strain gauges to cover general engineering requirements for strain analysis. All gauges have 30mm integral leads to alleviate damage to the gauges due to excessive heat being applied during soldering and installation.

Miniature gauges can be used for precise point measurement of instrumentation of small components. The polyimide backing of the gauges can withstand temperatures up to 180°C making them ideal for higher temperature applications.

The larger size of the standard gauges will not only make these gauges suitable for larger components, but is useful to assess the average strain over the area covered by the gauge thus reducing the possibility of incorrect readings due to stress concentrations.

Gauges temperature compensated for aluminium match materials with a coefficient of thermal expansion of 23.4 x 10^{-6}/°C and are indicated by blue colour coding of the backing material.

Gauges temperature compensated for mild steel match materials with a coefficient of thermal expansion of 10.8 x 19^{-6}/°C and are indicated by red colour coding of the backing material.

All gauges are intended for uniaxial strain measurements only.

General specification (all types)

Measurable strain		2 to 4% max.
Thermal output	20 to 160°C	±2 micro strain/°C*
	160°C to 180°C	±5 micro strain/°C*
Gauge factor change with temperature		± 0.015%/°C max.
Gauge resistance		120Ω
Gauge resistance tolerance		±0.5%
Fatigue life		>10^5 reversals @ 100 micro strain*
Foil material		copper nickel alloy

* 1 micro strain is equivalent to an extension of 0.0001%

Specification (Standard polyester backed types)

Temperature range	-30°C to +80°C
Gauge length	8 mm
Gauge width	2 mm
Gauge factor	2.1
Base length (single types)	13.0 mm
Base width (single types)	4.0 mm
Base diameter (rosettes)	21.0 mm

Specification (Miniature polyimide backed type)

Temperature range	-30°C to +180°C	
Gauge length	2 mm	5mm
Gauge width	1.6 mm	1.8mm
Gauge factor	2.0	2.1
Base length (single types)	6.0 mm	9.0 mm
Base width (single types)	2.5 mm	3.5 mm
Base diameter (rosettes)	7.5 x 7.5 mm	12 x 12mm

Construction and principle of operation

The strain gauge measuring grid is manufactured from a copper nickel alloy which has a low and controllable temperature coefficient. The actual form of the grid is accurately produced by photo-etching techniques. Thermoplastic film is used to encapsulate the grid, which helps to protect the gauge from mechanical and environmental damage and also acts as a medium to transmit the strain from the test object to the gauge material.

The principle of operation of the device is based on the fact that the resistance of an electrical conductor changes with a ratio of ΔR/R is a stress is applied such that its length changes by a factor ΔL/L. Where ΔR is change resistance from unstressed value, and ΔL is change in length from original unstressed length.

The change in resistance is brought about mainly by the physical size of the conductor changing and an alteration of the conductivity of the material, due to changes in the materials structure.

Copper nickel alloy is commonly used in strain gauge construction because the resistance change of the foil is virtually proportional to the applied strain i.e.

$\Delta R/R = K.E.$

where K is a constant known as a gauge factor,

$= \frac{\Delta R/R}{\Delta L/L}$

And $E = \text{strain} = \Delta L/L \therefore K = \frac{\Delta R/R}{E}$

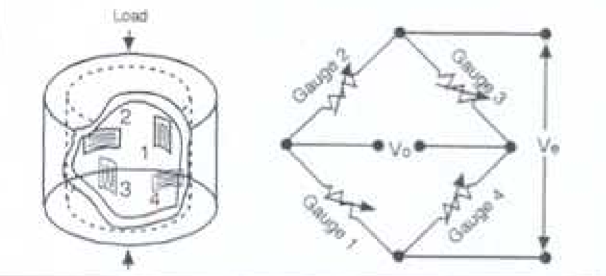
The change in resistance of the strain gauge can therefore be utilised to measure strain accurately when connected to an appropriate measuring and indicating circuit e.g. Strain gain amplifier **RS** stock no. 846-171 detailed later in this data sheet.

Applications

When strain gauges are used in compressive load transducer applications, which normally require more stringent accuracy requirements, a full bridge circuit is used with active gauges in all four arms of the bridge, (Figure 1).

The load transducer shown in Figure 1 utilises four strain gauges attached to the cylinder. The gauges are connected into the bridge circuitry in such a manner as to make use of Poisons ratio i.e. the ratio between the relative expansion in the direction of force applied and the relative contraction perpendicular to the force, to increase the effective gauge factor and thus the sensitivity.

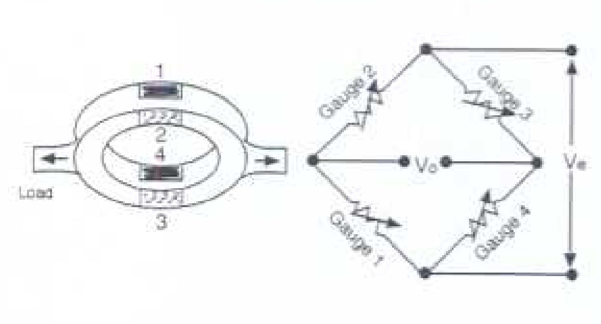
Figure 1 **Compressive load transducer**



To measure tensile loads, a ring with gauges attached as shown in Figure 2 may be used.

Under the action of a tensile load, the curvature of the ring in Figure 2 is deformed such that the inner gauges undergo tension while the outer gauges experience compressive forces.

Figure 2 **Tensile load transducer**



Instructions for mounting of strain gauges

In order to obtain the best possible results from a strain gauge, it is important to thoroughly prepare the gauge and the surface of the specimen to which the gauge is to be attached, prior to bonding with the adhesives recommended in paragraph 3 below.

1. Specimen surface preparation

An area larger than the installation should be cleared of all paint, rust etc., and finally smoothed with a fine grade emery paper or fine sand blasting to provide a sound bonding surface.

The area should now be degreased with a solvent such as **RS** PCB solvent cleaner, **RS** stock no. 496-883, and finally neutralised with a weak detergent solution. Tissues or lint free cloth should be used for this operation, wetting the surface and wiping off the clean tissues or cloth until the final tissue used is stain free. Care must be taken not to wipe grease from a surround-ing area onto the prepared area or to touch the surface with the fingers.

This final cleaning should take place immediately prior to installation of the gauge.

2. Strain gauge preparation

By sticking a short length of adhesive tape along the upper face of the gauge it may be picked up from a flat clean surface. Holding both ends of the tape, orientate the gauge in the desired location and stick the end of the tape furthermost from the tags to the specimen. Bend the other end of the tape back on itself thereby exposing the back of the gauge.

3. Adhesives and strain gauge installation

Two basic types of adhesive are recommended:

a) **RS** cyanoacrylate

b) **RS** 'quick-set' epoxy.

When using epoxy adhesive coat the back of the gauge with adhesive and gently push down into position, wiping excess adhesive to the two outside edges of the gauge, to leave a thin film of adhesive between gauge and sample. Stick the whole length of tape to hold the gauge in position. Care should be taken that there is an even layer of adhesive and no air bubbles are left under the grid. Cover the gauge with cellophane or polyethylene etc., and apply a light weight or clamp as required until adhesive has set. Remove tape by slowly and very carefully pulling it back over itself, staring at the end furthermost from the tags. Do not pull upwards.

If cyanoacrylate adhesive is to be used stick one end of the tape down to the specimen completely up to the gauge. Drop a fillit of adhesive in the 'hinge' point formed by the gauge and the specimen. Starting at the fixed end, with one finger push the gauge down at the same time pushing the adhesive along the gauge in a single wiping motion until the whole gauge is stuck down. Apply pressure with one finger over the whole length of the gauge for approximately one minute. Leave for a further three minutes before removing tape.

4. Wiring

The **RS** strain gauges are fitted with 30 mm leads to enable the gauge to be soldered. The lead out wires are fragile and should be handled with care.

Installation protection

RS strain gauges are encapsulated and therefore are protected from dust and draughts etc. If however, additional protection from humidity, moisture, and mechanical damage is required **RS** silicone rubber compound, **RS** stock no. 555-588, may be used. This should be carefully spread over the installation using a spatula.

Connecting to strain gauges

The following bridge circuits are shown with connection referring to the basic amplifier circuit, Figure 7. All resistors, precision wire wound 0.1% 5 ppm. (For precision resistors see current **RS** Catalogue).

Note: The expressions are assuming that all gauges are subjected to the same strain. Some configurations produce different strain in different gauges, and allowance must be made.

Figure 3 **Full bridge**

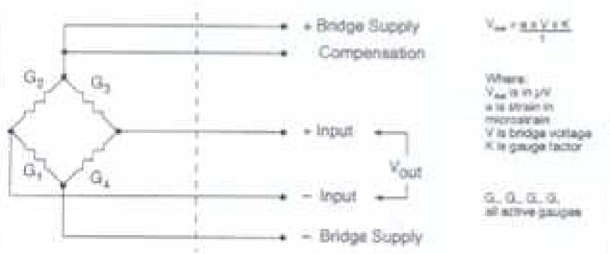


Figure 4 **Half bridge**

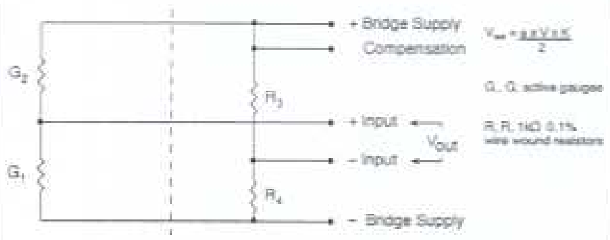
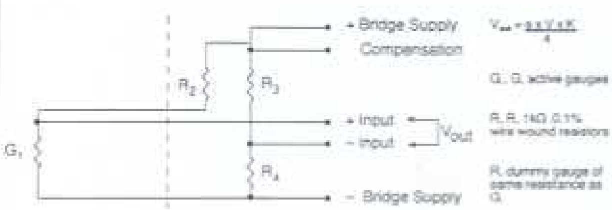


Figure 5 **Quarter bridge (3 wire)**



Strain gauge amplifier (**RS** stock no. 846-171) and printed circuit board (**RS** stock no. 435-692)

Description and operation

The strain gauge amplifier is a purpose designed hybrid, low noise, low drift, linear dc amplifier in a 24 pin DIL package, specifically configured for resistive bridge measurement and in particular the strain gauges detailed earlier in this data sheet.

Foil strain gauges when attached to a specimen, produce very small changes in resistance (typically 0.2Ω in 120Ω per microstrain), and are thus normally connected in a Wheatstone bridge. Overall outputs of less than 1mV on a common mode voltage of 5 volts may be encountered, requiring exceptional common mode rejection which cannot be provided by conventional means.

The strain gauge amplifier overcomes the problem of common mode rejection by removing the common mode voltages. This is achieved by controlling the negative bridge supply voltage in such a manner that the voltage at the negative input terminal is always zero. Thus for a symmetrical bridge, a negative bridge supply is generated equal and opposite to the positive bridge supply, hence zero common mode voltage.

The advantages of such a system are:

- No floating power supply needed.
- Bridge supply easily varied with remote sense if necessary.
- Wire remote sense system.
- Freedom from common mode effects.
- Very high stability dc amplifier enables numerous configurations to be assembled.
- Low noise.
- High speed (at low gains).

Figure 6 **Pin connections**

+ Bridge Voltage	1	24	+ V_S
N/C	2	23	N/C
Compensation	3	22	-Vs
N/C	4	21	N/C
N/C	5	20	Bridge Ref Input
+ Input	6	19	N/C
N/C	7	18	Feedback
N/C	8	17	N/C
N/C	9	16	Output
- Input	10	15	N/C
N/C	11	14	N/C
- Bridge Voltage	12	13	Zero Adjust

Top view

Specification

(At 25°C ambient and ±12V supply unless otherwise stated.)

Supply voltage	±2 to ±20Vdc
Input offset voltage	200μV max.
Input offset voltage/temperature	0.5μV/°C max.
Input offset voltage/supply	3μV/V max.
Input offset voltage/time	0.3μV/month max.
Input impedance	>5MΩ min.
Input noise voltage	0.9μVp.p max.
Band width (unity gain)	450kHz
Output current	5mA
Output voltage span	±(V_s-2)V
Closed loop gain (adjustable)	3 to 60,000
Open loop gain	>120dB
Common mode rejection ratio	>120dB
Bridge supply voltage/temperature	20μV/°C
Maximum bridge supply current	12mA
Power dissipation	0.5W
Warm up time	5 mins
Operating temperature range	-25°C to + 85°C

Figure 7 **Basic circuit for printed circuit board RS stock no. 435-692 (gain approx. 1000)**

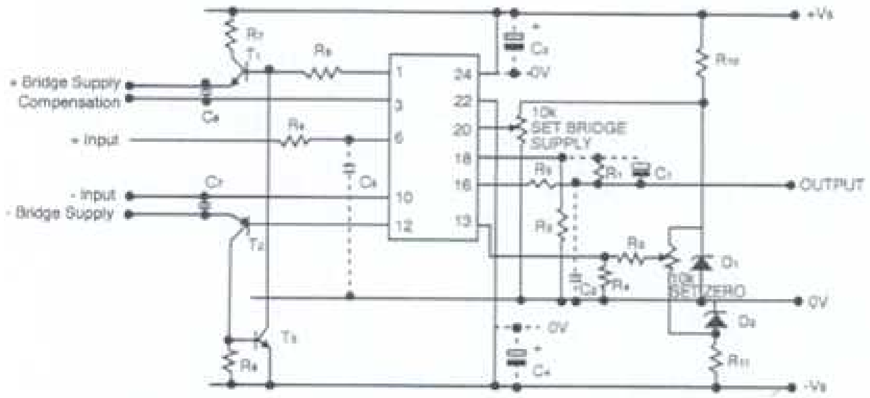
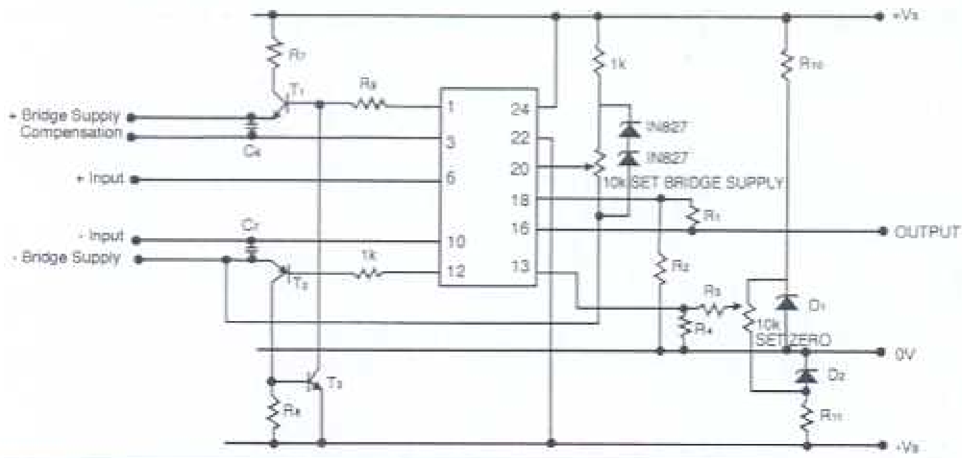


Figure 8 **Circuit for semiconductor gauges and transducers**



Component values (Figures 7 and 8)

R_1 100k	R_7 47R	C_2, C_3 10n (typ.)
R_2 100R	R_8 10R	C_5, C_4 10μ (tant.)
R_3 100k*	R_9 1k0	T_1 BD 135
R_4 68R*	R_{10} 680R	T_2 BD 136
R_5 10R	R_{11} 680R	T_3 BC 108
R_6 100R(typ.)	C_1, C_6, C_7 100n (typ.)	D_1, D_2 1N827

A glass fibre printed circuit boar, **RS** stock no. 435-692 is available for the basic circuit as given in Figure 7.

The board is 46 × 98 mm in size and is complete with screen printed component identification and a solder mask.

Only typical values are given for certain components as adjustment of these values may be necessary in specifics applications to obtain optimum noise reduction (see Minimisation of Noise later in this data sheet).

*R_3 and R_4 values may be adjusted to alter the zero adjustment range when compensating for bridge imbalance.

Notes: 1. Gain is defined as $1 + \frac{R_1}{R_2}$

2. Zero adjustment range $\pm 6.2 \times \frac{R_4}{R_3 + R_4}$ Volts

Total bridge supply = 2 x bridge ref input (pin 20)

C_7 may be omitted for input lead lengths of less than 10 metres

T_1 and T_2 provide bridge currents up to 60mA and should be kept away from amplifier.

T_3 and T_5 provide stability power supplies are being used zero and bridge supply reference may be taken direct from the power rails.

The high output of some semiconductor strain gauges may cause large amounts of asymmetry to the bridge. In correcting for the common mode change, the negative bridge voltage will change, causing a span error. This may be calibrated out or the arrangement above used to eliminate the cause of the error. Some semiconductor strain gauge transducers are temperature compensated by the use of series arm compensation. Thus the common mode voltage changes the with temperature, and hence the arrangement above should be used. This operates by referencing the positive bridge supply to the negative supply, thus varying the common mode but not the overall bridge supply.

Minimisation of noise

1. Inherent white/flicker noise in amplifier.
To keep this to a minimum use high quality (metal film) resistors and protect the amplifier from excessively high temperatures. The inherent noise level may be further reduced from its already low value by fitting C_1 and C_2 to reduce the operating bandwidth.

2. Supply frequency (or harmonics) inference.
If at 100Hz then the cause is almost likely to be from power supply rails, so use stabilised lines. If at 50Hz then it is generally caused by the location of the supply transformer, and/or the wiring. Relocate the supply transformer, screen and input leads to the amplifier, and if possible reduce the operating bandwidth by fitting C_1 and C_2.

3. Power supply transient interference.
It is good practice to decouple the supply lines to the amplifier, by fitting C_3 and C_4, as close to it as possible. If a particular nuisance then fit a mains suppressor.

4. Electromagnetic interference
This may be picked up by input leads, output leads, supply leads or direct into the circuit. Minimisation involves a combination of screening, decoupling and reducing operating bandwidth. Screening. The shield should be connected to only one earth potential at the receiving monitoring equipment end. Try not to earth any of the dc power lines (e.g. 0V). If the shield at the sensor end is earthed then earth the shield at the receiving end and if possible connect this earth potential to the strain gauge amplifier circuit shield. Decouple the power supply leads by fitting C_3 and C_4, decouple the input leads with R_5 and C_5 (note a similar action on the input is not possible). Remove any pickup from the output leads by fitting R_5 and C_2. Fit C_5 if input leads are more than 10m long and fit C_6 if remote sense is longer than 10m. Reduce the operating bandwidth by fitting C_1 and C_2.

Load cells

Introduction

Load cells are basically a beam or other shaped member arranged so that an applied load will cause a proportional strain at certain fixed points on the device.

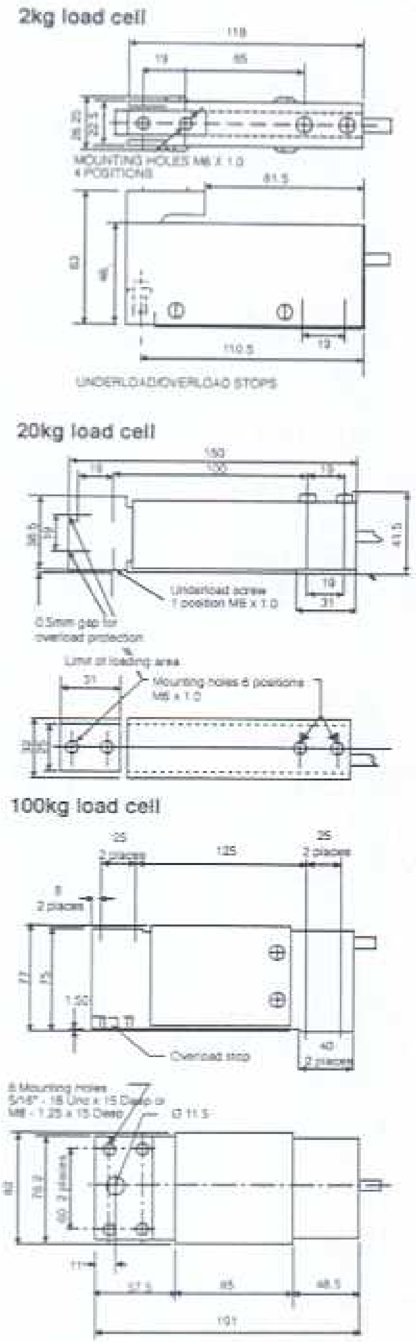
The strain can be detected in several ways, the most common being an arrangement of strain gauges. These gauges convert the strain into an electrical signal which can then be displayed, used as a control signal, etc.

Single point load cells

This **RS** range of load cells comprise of centre type (2kg, 20k & 10kg oil damped) in which a double beam is used. Also in this range is a 100kg low profile off-centred load cell designed for direct mounting of the weighing platform. They are supplied complete with a full bridge of four strain gauges fitted and calibrated ready to connect to any suitable amplifier.

Three sizes of standard units are available for weighing up to 2kg, 20kg and 100kg. Although physically different, the cells are 100kg similar in method of operation and construction.

Figure 9 **Dimensions**



When used in weighing scales a platform up to the maximum size given in the specification can be used without loss of performance.

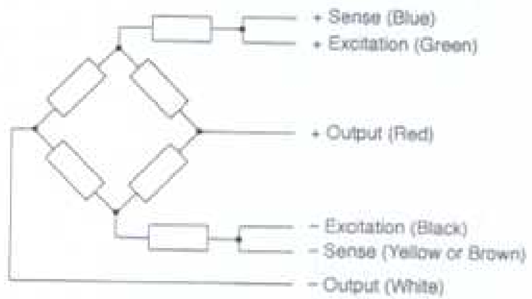
Electrical connections

The cells use a six wire full bridge system for the most accurate results. The lead to the cell is screened and the cores are colour coded as shown in Figure 10.

The **RS** strain gauge amplifier **RS** stock no. 846-171 can be used with these load cells. Use the circuit shown in Figure 7, connecting bridge supply to excitation and compensation to sense (Figure 10). In this circuit a five wire system is employed so that the -ve sense wire shown in Figure 10 is not used and should be connected to the -ve supply.

Other amplifiers can be used but to achieve good results an accurate low drift amplifier is required.

Figure 10 **Internal wiring single point types**



Mechanical fixings

The 2 and 2kg cells are fixed by M6 x 1 set screws and the bodies of the cells are drilled and tapped to a depth of 10mm. The 100kg cell is fixed by M8 x 1.25 set screws with the body drilled and tapped 15mm deep.

Care must be exercised when handling these devices - do not pull the lead or drop the device and ensure that the cell is not subjected to excessive vibration.

A platform, hopper, or any other fixture can be attached to the top or front face of these cells but it must be noted that the weight of these attachments must be taken into account. For example if a 1kg hopper is attached to the 2kg load cell for weighing out polystyrene granuals for injection moulding the cell will only weigh 1kg of the material because of the weight of the hopper.

These load cells must be mounted on a flat rigid base which is level and will not deflect under loading.

The fixing bolts must be tightened to the correct torque of 7Nm. Do not use a ratchet of 'click stop' torque spanner on the 2kg cells as this may damage it.

Overload stops

It is vital that overload protection is provided and it is recommended that under load protection is incorporated where possible.

While these load cells can be subjected to overloads of 150% (200% for 100kg unit) without permanent damage the use of this safety factor cannot be recommended. An overload in excess of 150% (200% for 100kg unit) will cause permanent damage to the cell.

An underload is simply a load which raises rather than depresses the load face. The RS cells are capable of measuring these types of load.

On the 2kg load cell both over and under load stops are built into the device and therefore the cell will be protected if correctly mounted on a flat and rigid base.

With the 20kg cell the base of the beam is machined so that it will deflect and touch any flat base used at rated load. Using a flat rigid base will, therefore, automatically provide overload protection.

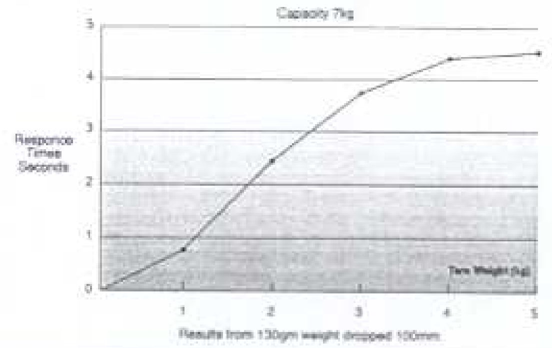
An extra M6 x 1 tapped hole is provided in the base for an underload stop. A mechanical stop should be provided with a no load clearance of 0.5mm so that the load face of the load cell can be only be raised by 0.5mm which is equivalent to the full rated load of the unit.

Single point - oil damped

Principles of operation

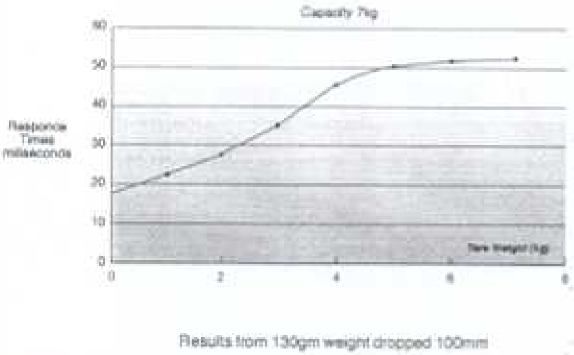
An undamped cantilever load cell can behave like a very stiff spring. Consequently when pre-loaded with a weight and shock excited by another weight, the unit "rings" for an appreciable time. A settling time of several seconds may be acceptable in platform scale applications but it is not acceptable for high speed repetitive weighing (Figure 11).

Figure 11 **Typical response times (undamped)**



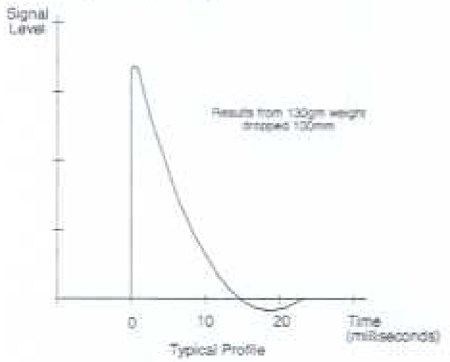
As can be seen tare weight increases settling time and should be kept at a minimum.

Figure 12 **Typical response times (damped)**



With the damped load cell it can be that the settling time is drastically reduced from more than 1 second to less than 100ms. (Figure 12 and 13).

Figure 13 **Capacity 7Kg**



Mounting

The precision obtainable from the unit can only be realised by careful attention to the mechanical mounting. It will be appreciated that if the full scale deflection of the Cell is 0.4mm and the scale is divided into 4000 divisions, one division on the scale is the result of a deflection of 0.0001mm. So, any, force, from whatever source, which brings about such a deflection will introduce an error into the system.

It is for this reason that the baseplate is solid and has a machined surface for mounting. Ensure, therefore that the mounting support is correspondingly flat and rigid. Holding down bolts must be equally torqued to 35-40 Nm (or 25-30 lb ft). Also it is important that the Load Cell be level and that the level should not change significantly when the system is loaded. The initial level should be within 1 degree of the horizontal (check with spirit level) and the deflection under load should not exceed 0.1 degrees.

Vibration

It is sometimes assumed that because the Load Cell is damped it is impervious to external vibration. This is not so. It is damped against its own natural vibration when loaded. If however, the Load Cell is oscillated by external forces, such as adjacent vibrating machinery, it may provide output signals corresponding to these forces because heavy structures tend to oscillate at around 0.1 to 10Hz. It is impossible to damp the Load Cell adequately to eliminate these effects and maintain coherent performance. The design aim must therefore be to attach the unit to a firm flat, level base and to ensure that this base is free from vibration. The main sources of vibration are likely to be rotating machinery on the weigh structure, vibration from the floor etc. Each of these must be nullified, preferably by physical separation, but if that is not possible, by shock absorbers, anti-vibration mounts or similar devices.

Applying the load

The load must be applied via the bearing surface which is uppermost on the load applicator (Figure 14). Both holes must be used, evenly torqued to 7 Nm (5lb/ft) so that the load is evenly distributed.

It is usual to use a flat bar or other load spreading member between the applicator and the weigh platform, table or live superstructure. The mating section and the substructure, must be rigid, otherwise the latter will oscillate and superimpose on the Load Cell output, depending on the frequency and amplitude generated. The supporting member must be flat. The load should be transported on to the weigh platform in such a way that it creates the minimum disturbance. If the load traverses across the platform, it should, if possible, avoid knocking the platform edge (i.e. no step). If the load is lowered on to the platform it should be controlled placement, not a dropped load, if possible. For optimum performance the line of action of the applied load should act as near as possible to the centre line of the Load Cell - in both horizontal planes-to minimise eccentricity effects.

Effect of temperature

Variations in temperature will affect the viscosity of the damping fluid and consequently the settling time of the Load Cell. The standard unit is damped for ambient working temperatures (around 20°C).

It is recommended that the Load Cell temperature be within 10°C of the specified working temperature if the settling time is to be within 50 milliseconds.

Unstable reading

If the repeated application of a load gives a steady but inconsistent reading, or the readings steady at around, but not quite, zero between weighings, then the Load Cell is probably reflecting some form of mechanical interference or "stiction". Check that the platter is not fouling and that dirt etc. has not accumulated somewhere in the scale mechanism. Remove the source of interference and normal weighing should result. Inspect the Load Cell load applicator: this should not be binding on the cover of the unit. Do not unbolt the base unless absolutely necessary. If this has to be done, be sure to follow the bolting down procedure described earlier.

Outline dimensions

Figure 14

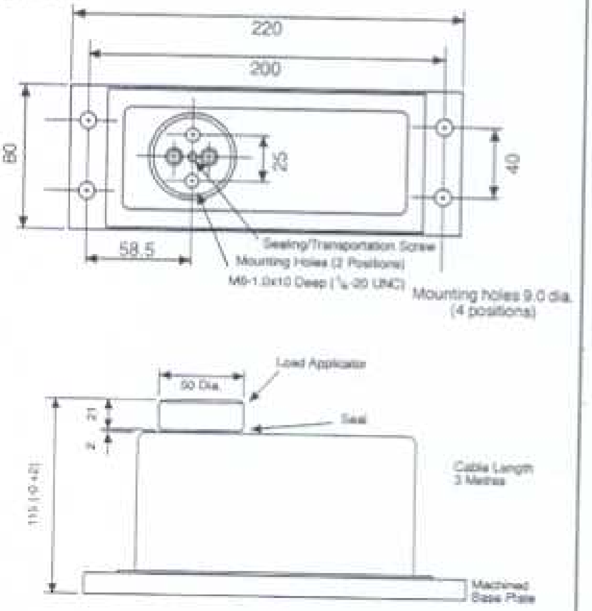


Figure 15 **Mounting**

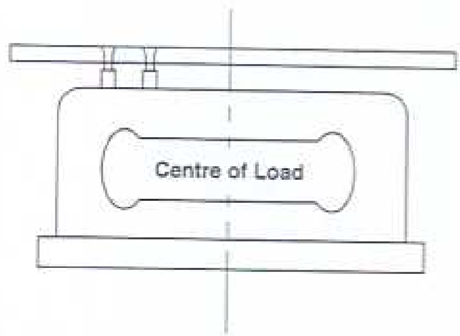
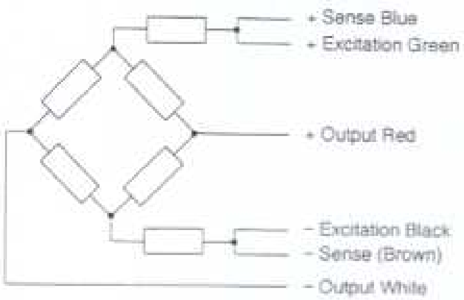


Figure 16 **Wiring schematic**



Tension/compression load cells

These general purpose load cells are for force measurement with loads up to 500kg. Mechanical connections are by M12 x 1.75 threads in the body of the device (½ x 20 UNF on 500kg unit) and electrical connections are via a 3m 5-core screened cable.

These cells can be used for weighing but are ideally suited for the measurement of tensile, or compressive forces by using the cell to replace the structural member under investigation. The 500kg unit is constructed using stainless steel & the 250kg utilises aluminium.

Other applications include, e.g. determining the power output of a motor be replacing the mounting with the cell and measuring the torque reaction produced.

Figure 17 **250kg load cell dimensions**

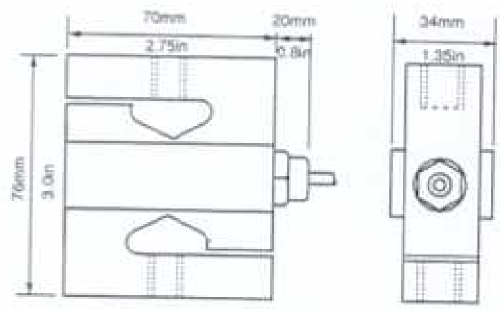


Figure 18 **500kg load cell dimensions**

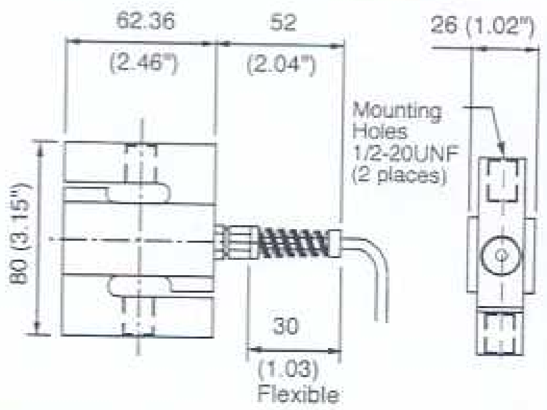
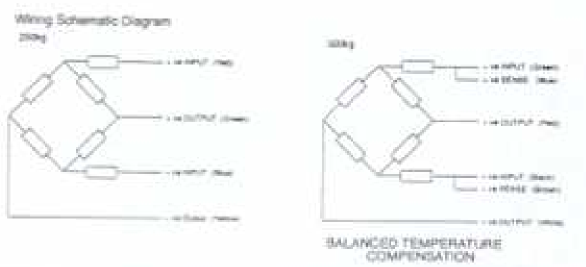


Figure 19



Shear beam load cells

These shear beam load cells are available in stainless steel (500kg & 1000kg) construction or in aluminium (500kg only) construction. All are low profile units providing a high level of environmental protection whilst featuring 6 wire output for temperature compensation. Both types of unit are of rugged construction but the stainless steel products are hermetically sealed to enable the cells to function in harsh environments whilst maintaining its operating specifications.

Typical applications for these products would be in low profile platforms, pallet truck weighers, tanks and silos etc.

Figure 20 **Outline dimensions, stainless steel**

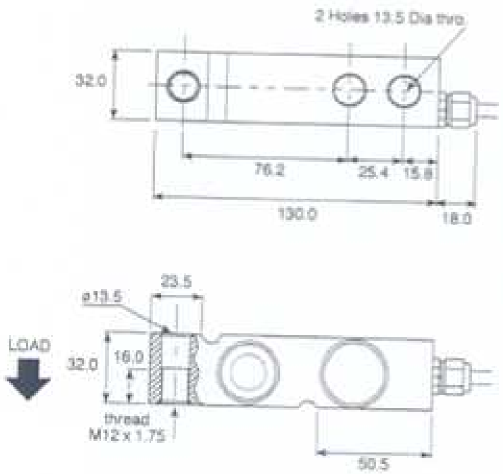
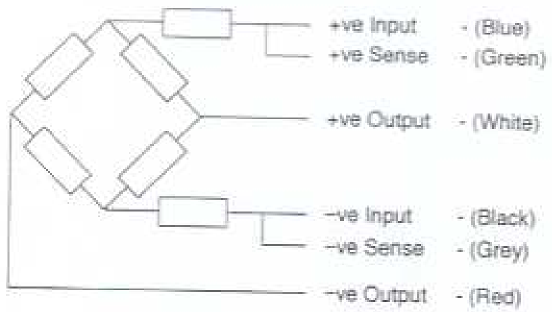


Figure 21 **Wiring schematic diagram**



Balanced temperature compensation

Figure 22 **Outline dimensions, aluminium**

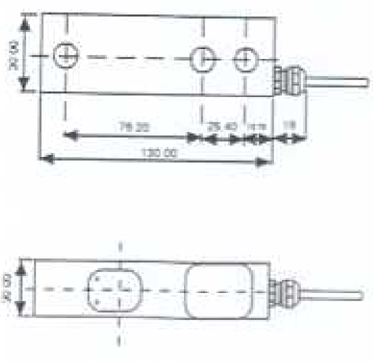
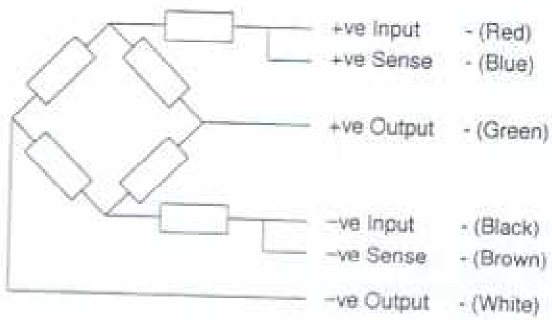


Figure 23 **Wiring schematic diagram**



Balanced temperature compensation

Contilever load cells

These load cells are available in 100kg and 250kg options. They are of welded, bending beam, stainless steel construction and hermetically sealed to enable functionally in harsh environments.

The low profile construction and high accuracy of these products make them ideal for applications such as platform scales, weighing and packing machines and for mechanical scale conversions.

Figure 24 **Outline dimensions**

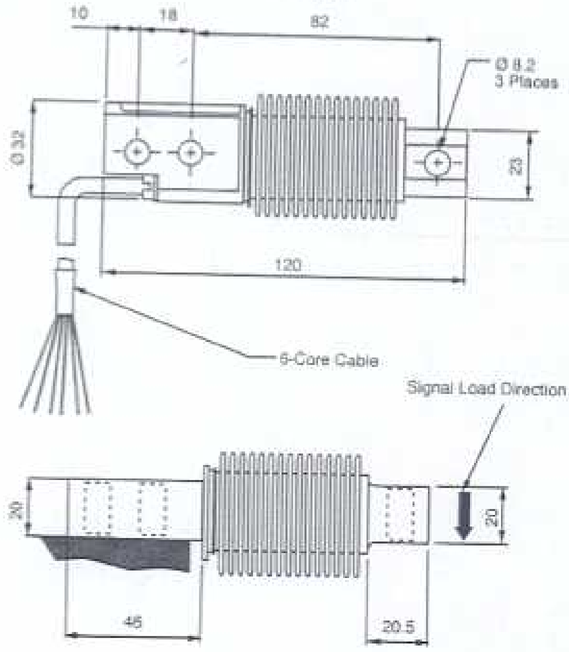
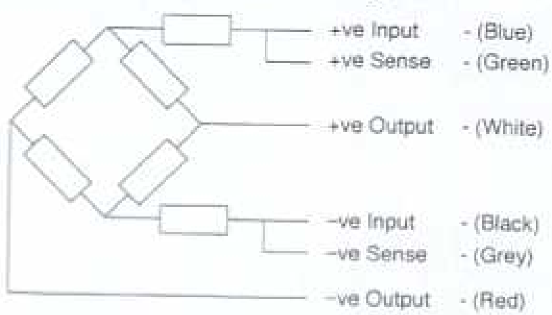


Figure 25 **Wiring schematic diagram**



Balanced temperature compensation